Soundscape Evaluation and Influence Factors in Lanzhou Yintan Wetland Park

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Abstract Soundscape has been attracting more attention as a key landscape component, its effect on environmental perception relies not only on the physical attributes of sounds, but also the co-influence and interaction of sound sources and surroundings. To systematically identify the objective soundscape characteristics in the wetland park and the influence factors, this paper applied sound walk method to investigate the sound source types, sound pressure level (SPL), and objects and subjects' soundscape perception. The results showed that artificial sounds accounted for the most of soundscapes in the park (60%), natural sounds accounted for 25%, life sounds about 15%. Among the natural sounds, bird chirping and frog croaking were the favorite of users; the mean equivalent continuous A sound level of each measure point in the park was 50.2 dB, complying with the national standard limit value. Optimization of the sound environment in the wetland park should comprehensively consider the landscape layout, current characteristics and users' requirements, relevant designs and management strategies are of great practical significance for improving the quality of soundscape and the comfort degree of overall environment.

Keywords Wetland park, Sound walk, Soundscape evaluation, Sound pressure level
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Landscape design research has long focused on visual dimension, but neglected the essential role of hearing in leisure and sightseeing. The ideal park experience should be established on the basis of "coordination of five senses"[1]. Since the Canadian composer Schafer proposed the concept of "Soundscape" in the 1960s[2], the role of hearing in environmental perception and research has been gradually improved[3]. Soundscape referred to the sounds that could be perceived and mutually interacted in a specific environment[4], the research focused on not only the acoustic physical parameters, but more on human perception and evaluation of the sounds[5], and moreover, sound source types, landscape attributes and individual differences were all considered[6]. Therefore, soundscape evaluation has already become one of the hottest topic of the research.

Current soundscape evaluation methods mainly include sound walk[7], semantic differential method[8], Analytic Hierarchy Process (AHP) [9], subjective and objective evaluation method[10] and etc.. Among which sound walk has already become an essential research method for its integrated capacity in quantitative measurement and qualitative analysis[11]. Zhang Qinying et al.[12] applied this method to explore the soundscape mechanism of urban green spaces and proposed the optimization suggestions; Yorukoglu et al.[13] investigated soundscapes in an area in Italy, and discovered the impact of cultural background and behavioral habits on soundscape perception; Hong Xinchen et al.[14] built the soundscape preference evaluation model by combining sound walk and semantic analysis. Hu Jun et al.[15] introduced GIS to draw soundscape map, and disclosed its spatio-temporal variation rules. The above researches contributed to the soundscape research theories and methods, but empirical researches on soundscape characteristics and influencing mechanism in wetland parks have been less reported. Soundscape as an important quality component of a scenic area plays a key role in shaping the landscape atmosphere and visitors' experience.

Taking Lanzhou Yintan Wetland Park for an example, this paper used sound walk method to investigate the study area systematically from multiple dimensions of sound source type, sound pressure level, subjective and objective perception, quantitatively analyze objective soundscape parameters and subjective soundscape evaluation, so as to comprehensively assess the soundscape quality of the park. Using spatial analysis and statistics, this study identified the relationship between soundscape satisfaction and sound environment composition, quietness degree and visual spatial characteristics, in order to provide scientific basis and practical strategies for optimizing the park soundscapes.

1 Research area

Lanzhou Yintan Wetland Park was located at the both sides of north end of Yintan Yellow River Bridge (103° E, 36° N), lying adjacent to North Binhe Road in the north, the Yellow River in the south, and natural beaches of the Yellow River in both east and west (Fig.1). This study selected the wetland park on the western side of the bridge as the sample area for the following consideration: (i) the park is next to the main artery of the city, North Binhe Road (two-way six-lane express way), causing obvious traffic noise; (ii) the park has rich terrain variations, clear functional division, diversified user groups and activities, which is suitable for conducting spatial differential analysis of sound environment; (iii) there are complicate sound source types, sound pressure levels change drastically in different functional areas, so it is typical and representative for soundscape researches.

2 Research method

2.1 Sound walk method

Sound walk is a soundscape investigation method centering on the hearing experience in site[16], stressing the capture and recording of soundscape elements and perceptual characteristics in a dynamic environment[17]. This study was conducted on sunny Saturdays during April and May of 2024, lasting from 08:00 to 20:00 each day, and the temperature varied from 15 to 20 °C. According to the main touring routes and representativeness visual landscapes, 10 sampling points were set as Fig.2. During the sound walk, participants were required to record the source source types and their preferences they perceived, and finished the 7-score scale covering satisfaction with soundscape and visual landscape, and richness of soundscape and visual landscapes, also marked the sound source types they liked or disliked.

2.2 Sound level measurement

High-fidelity recording devices and TES1350A

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noise analyzer were used to test the sound pressure level and record the sound level inside and outside the park for the comparative analysis. For each sampling point, a 60-second audio was recorded for the consequent analysis, sound level meter was used for the A-weighted instantaneous measurement (closest to hearing characteristics of human ears). Before the measurement, the sound level meter was calibrated to control the deviation within ±0.5 dB. At each point, the test was conducted for 10 times continually, 2 min each time, and 20 min in total for each. Sound level meter was fixed on the tripod, 1.2 m high above the ground, 1 m at least away from the surrounding obstacles. The test conditions were maintained as the same.

3 Research results and analysis

3.1 Soundscape composition and sound preference analysis

Sound sources in the park can be classified into 3 categories by attribute, i.e. natural sound, life sound and artificial sound. Natural sound mainly contains chirping, water fowls' sound, croaking, rustling and so on. Life sound includes mainly people talking, children's playing, musical instrument sound, and sounds of mobile phones. Artificial sound is represented by traffic noise (vehicle driving and honking). Sound source analysis showed that artificial sound accounted for the prominent ratio (60%), natural sound 25%, and life sound only 15%. Among the natural sounds, chirping was the most common type, and life sound was dominated by talking.

Sound preference investigation showed (Table 1) that chirping and leaves rustling were the most favorite sound types, because their definite natural attributes, stable sound mode and high integration with the environment could easily trigger the pleasant experience of users. Evaluation of life sound showed distinctive variations for the individual differences, musical instrument sound such as pianica and trumpet appeared nearby sampling point 1, 60% of the participants liked it, 10% disliked, and 30% took a neutral attitude. Influenced by urban express road and the Yintan Yellow Bridge, traffic noise was the most disliked sound type in the park.

3.2 Sound environment characteristics of sampling points and their influence factors

Through comprehensive analysis of sound environment and subjective evaluation of each sampling point (Fig.3), it was found that soundscape characteristics was greatly influenced by its spatial layout, vegetation sheltering and human activities. For the main entrance next to the urban express road, traffic noise was obvious with a LAeq of 52.7 dBA; however, for the entrance square also close to the roads, its elevation differences reduced the noise impact, its LAeq degraded to 46.3 dBA with the accompany of musical instrument sound. The sampling point 2 was in the pavilion surrounded by vegetation, the high-degree enclosure greatly reduced the background noise (LAeq=42.3 dBA), it got the highest quietness score (6.5), the best natural degree of soundscape and visual landscape (5.6/5.4). The sampling point 3 (Viewing Platform) and 4 (Lake-center Pavilion) had excellent visuall landscapes and water soundscape, their LAeq was 45.1 dBA and 44.5 dBA, the former had clear chirping and strong natural atmosphere, the latter had broad visual field and varied water fowl sounds, the visual satisfaction degree was up to 6.3. The sampling point 5 (Central Square) had large visitor flow and more children's activities, thus it has obvious noise and the lowest score of naturalness (2.8/2.6), its LAeq was 45.5 dBA. The sampling point 6 (Waterfront Path) had the richest soundscape components, covering chirping, water fowl and frog croaking, soundscape and visual landscape richness were both up to 6.2, and LAeq was 44.1 dBA. Being close to the Yintan Bridge, the sampling point 7 and 8 experienced stronger traffic noise, with a LAeq of 49.5 dBA and 54.9 dBA, and the latter had a quietness degree of only 2.5 for lacking in vegetation sheltering, being next to the express road, and the strong human noises. The sampling point 9 was co-influenced by traffic on the bridge and "no vegetation sheltering", so it had the highest noise (LAeq=55.9 dBA), the lowest quietness degree and visual satisfaction degree (2.1/3.0). The sampling point 10 (Sunken Square) had complex human noises, but its LAeq was below 50.0 dBA for being sheltered by vegetation. Overall, quality of sound environment was closely related to vegetation coverage, terrain sheltering and distance to sound source.

3.3 Correlation analysis between soundscape and environment comfort

This study further analyzed the correlation between soundscape elements and environment comfort, to clarify the key acoustic and environment factors that influence the comfort degree of users. The results showed that sound pressure level (LAeq) was negatively correlated with environment comfort, i.e. the increase of noise intensity would greatly reduce the users' comfort degree, particularly on the sampling points next to main arteries (8 and 9), high noise would cause the drastic decline of comfort score. In addition, quietness evaluation of soundscape showed high positive correlation with the overall comfort degree. For instance, the sampling point 2, due to its excellent vegetation coverage and low noise interference, achieved the highest scores in both quietness and comfort.

In terms of the composition of sound sources, the proportion of natural sounds was positively correlated with the comfort evaluation, especially natural elements such as birds' chirping and water

Table 1 Evaluation of soundscapes and visual landscapes, and sound preferences in measure points

Measure point	Soundscape evaluation			Visual landscape evaluation				Sound preference		
	Satisfaction	Quietness	Abundance	Type	Spatial scale	Abundance	Satisfaction	Type	Like	Dislike
Outside of the main entrance	2.5	3.3	2.5	2.3	4.5	2.6	3.5	3.4	Chirping	Traffic noise
R1	3.5	3.8	3.4	3.4	4.7	3.5	3.8	4.2	Musical instrument playing	Traffic noise
R2	6.2	6.5	4.5	6.1	3.2	4.4	4.2	5.6	Leaves rustling	Talking
R3	4.1	4.8	4	5.4	4.6	3.9	4.3	4.4	Chirping	Talking
R4	5.8	4.9	5.6	5.1	6.4	5.4	6.3	5.4	Waterfowl call	Children playing and laughing
R5	3.7	3.6	3.4	2.6	6.2	3.3	4.2	2.8	Chirping	Sounds of mobile phones
R6	5.1	4.8	6.2	5.2	3.5	6.2	4.5	5.3	Frog croaking	Talking
R7	4.4	4	4.7	4.6	4.3	4.6	4.6	4.7	Chirping	Traffic noise
R8	4.5	2.5	4.1	3.5	5.4	4.2	4.1	4.5	Chirping	Traffic noise
R9	3.2	2.1	4.2	3.4	4.0	4.1	3.0	4.6	Chirping	Traffic noise
R10	3.7	4.2	3.6	3.8	4.3	3.7	3.5	4.5	Chirping	Traffic noise

flow significantly enhanced the pleasantness of the environment. In contrast, the increase of artificial sounds (especially traffic noise) significantly reduced the comfort of users. The satisfaction of visual landscape also showed a synergistic enhancement relationship with the comfort of soundscapes, indicating that the combined effect of audio-visual perception had a comprehensive impact on environmental comfort. The above results suggested that reducing noise intensity, increasing the proportion of natural sound sources, and enhancing the sense of tranquility of the space through landscape design were effective ways to improve the comfort of the sound environment in wetland parks.

Fig.1 Location of Lanzhou Yintan Wetland Park

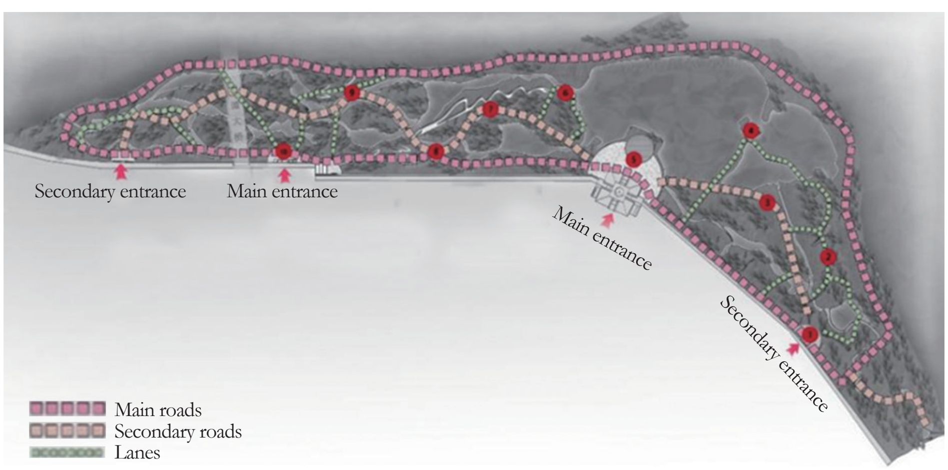

Fig.2 Measure points in Lanzhou Yintan Wetland Park

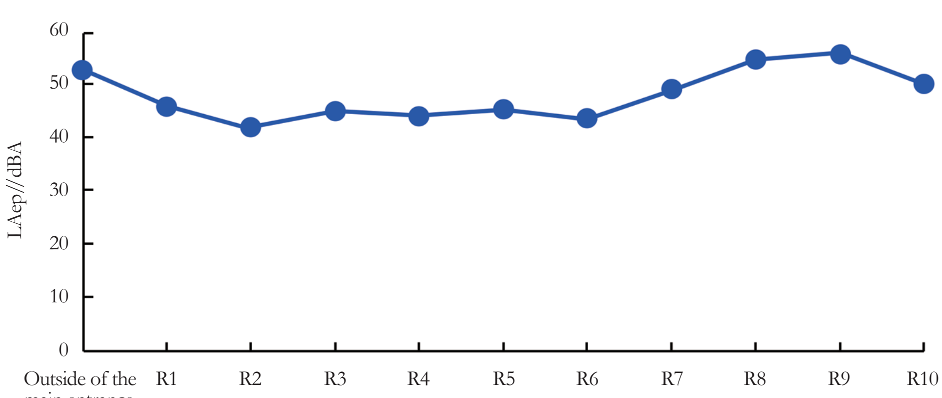

Fig.3 Comparison of continuous equivalent sound pressure level at each measure point

3.4 Correlation analysis between soundscape elements and landscape composition

In the correlation analysis of soundscapes and visual landscape composition, this study revealed a significant coupling relationship between different types of landscape spaces and their soundscape characteristics. Areas with high naturalness (e.g., waters, dense forests) typically exhibited a higher proportion of natural sounds and greater soundscape richness. For instance, the sampling point 4 (Lake-Center Pavilion) and the sampling point 6 (Waterfront Path)—featuring open water, diverse vegetation, and abundant animal vocalizations (waterfowl calls, frog croaking)—achieved high ratings in both visual landscape and soundscape evaluations.

The degree of spatial enclosure also exerted a critical influence on soundscapes: highly enclosed areas (e.g., the sampling point 2) maintain a quieter soundscape with a prominent sense of naturalness, as vegetation effectively shields external noise. In contrast, open areas (e.g., the sampling points 5 and 8) lack sound barriers, making them vulnerable to traffic and human noise, thus leading to a significant increase in the proportion of artificial sounds.

Visual landscape satisfaction showed a positive correlation with both the naturalness and richness of soundscapes, indicating that visual aesthetics and ecological diversity could enhance positive perceptions of soundscapes. Additionally, the intensity of human activities was significantly positively correlated with the proportion of living sounds and artificial sounds. For example, the main square and entrance areas—characterized by high foot traffic and diverse activities—had more complex sound source compositions, resulting in polarized soundscape evaluations.

Overall, landscape composition elements such as vegetation coverage, water distribution, the degree of spatial openness/enclosure, and the intensity of human activities collectively shaped the structure and perceptual effects of soundscapes. This suggested that in landscape planning, the overall coordination of visual and auditory elements should be comprehensively considered to create a more immersive and comfortable soundscape environment.

4 Results and suggestions for the optimization

4.1 Results

A systematic investigation of the soundscape of Lanzhou Yintan Wetland Park was conducted via the sound walk methodology, integrating objective acoustic measurements with subjective perceptual assessments. The primary conclusions are as follows:

(1) The wetland park exhibited a relatively rich diversity of soundscape types, with artificial sounds dominating (accounting for 60%), exceeding natural sounds (25%) and daily-life sounds (15%). Among various sound sources, natural sounds such as "bird chirping" and "frog croaking" were the most preferred due to their favorable coherence and high likability; traffic noise ranked as the least favorably evaluated sound type by respondents. In terms of sound pressure level (SPL), the average equivalent continuous A-weighted sound level (Leq,A) across all measurement points in the park was 50.2 dB(A), which met relevant national standards. Notably, the sampling point R9, adjacent to the North Binhe Expressway and the Yintan Bridge, was significantly disturbed by traffic noise, with an SPL approximately 8 dB(A) higher than other areas; in contrast, the sampling point R2—far from main roads and characterized by dense vegetation—had the lowest SPL and the quietest acoustic environment.

(2) Evaluations of soundscapes and visual landscapes revealed distinct disparities among different spaces in the wetland park regarding enclosure degree, soundscape satisfaction, and richness. Overall, respondents expressed relatively high satisfaction with the park's soundscape. Statistical analyses indicated that soundscape satisfaction was significantly correlated with spatial scale, quietness level, and sound source types. Therefore, effectively mitigating traffic noise, reducing the overall SPL, and increasing the proportion of natural sound sources constituted the key approaches to further enhancing the soundscape quality of the park.

4.2 Suggestions for the soundscape optimization

The results indicated that the enhancement of soundscape quality could effectively promote the overall environmental comfort of wetland parks. The auditory comfort of Yintan Wetland Park was primarily disturbed by human activity sounds and traffic noise, which to a certain extent masked the natural soundscape and impaired visitors' perceptual experience. From the perspective of landscape pattern, the wetland park was dominated by open spaces; the soundscape characteristics corresponding to different landscape elements were not distinctly differentiated, and there was a lack of effective guidance and control over artificial sounds. Therefore, it is necessary to systematically carry out soundscape design and management optimization based on landscape patterns, current sound source conditions, and users' needs, so as to improve soundscape quality and enhance overall comfort.

Based on the above research findings, the following optimization strategies were proposed from the dimensions of sound source control, spatial design, and public participation to improve the soundscape quality and overall environmental comfort of the wetland park:

(1) Strengthen traffic noise prevention and control. To address the significant noise interference in areas adjacent to urban arterial roads, it is recommended to implement comprehensive management by combining ecological sound barriers (such as dense arbor belts and micro-topography construction) with physical sound insulation facilities (such as soundproof walls). Priority should be given to noise reduction projects in high-noise-sensitive areas (e.g., points 8 and 9).

(2) Increase the proportion of natural soundscapes. In vegetation design, it is recommended to consciously introduce plant species that attract birds and other animals to create habitats with rich biodiversity. Meanwhile, dynamic water features such as fountains and cascades can be appropriately installed in open water areas or waterfront zones, using natural water sounds to enhance the layering and appeal of the soundscape.

(3) Implement zonal soundscape management. Soundscape control zones can be specified according to the park's functions and spatial characteristics: for example, rest areas and bird-watching areas can be designed as "quiet zones" where artificial noise and the external playback of electronic devices are restricted; activity squares and children's play areas as "vibrant zones" where a certain level of daily-life sounds is permitted, but design-based guidance and sound source direction should be adopted to prevent interference with quiet zones.

(4) Enhance public awareness of soundscapes. Visitors' attention to and awareness of protecting the sound environment can be further improved by setting up soundscape interpretation signs and organizing natural sound experience activities, guiding them to become active co-builders of positive soundscapes.

(5) Integrate soundscape into coordinated design. In future landscape planning and renovation, soundscape thinking should be incorporated at an early stage, with emphasis on the consistency of visual and auditory perception. Through the organic integration of spatial form, vegetation configuration, and water design, a recreational environment can be created to integrate visual and auditory experiences and bring physical and mental pleasure.

5 Conclusions

By integrating subjective and objective approaches, this study revealed the soundscape characteristics and their influencing mechanisms of Lanzhou Yintan Wetland Park, confirming the pivotal role of the acoustic environment in the overall landscape experience. The findings indicated that the auditory comfort score falls between the visual comfort score and the overall comfort score, suggesting that the degradation of soundscape quality could exert a significant disruptive effect on environmental experience. In the future, soundscapes should not merely be regarded as negative factors to be avoided; instead, they should be transformed into positive elements that enhance landscape perception quality through systematic planning, design, and management. The optimization strategies proposed in this paper are not only applicable to Yintan Wetland Park but also provide a reference for soundscape construction in similar urban wetland spaces, promoting the shift of soundscape research from evaluation to practice and ultimately realizing the harmonious coexistence of humans and the environment.

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(To be continued in P19)

period. However, the implementation of measures such as vegetation restoration and color coordination effectively mitigated these impacts, thereby controlling the interference effects. The evaluation index system developed by the research institute, encompassing five primary dimensions (natural landscape and aesthetic vakue, geological landforms, biodiversity, etc.) with 38 specific indicators, not only satisfies the visual protection requirements outlined in the *Operational Guidelines for the Implementation of the World Heritage Convention* but also effectively aligns with the landscape characteristics of ecologically sensitive karst areas. Consequently, it offers targeted index support for assessing the impact of linear engineering projects within the buffer zone of the heritage sites.

This study presents an innovative integration of the AHP and FCE methods, effectively addressing the limitations associated with the "predominance of subjective experience" and the "lack of sufficient quantification" in traditional landscape impact assessments. Specifically, AHP facilitates the scientific allocation of index weights by incorporating input from multidisciplinary experts, thereby resolving the challenge of ranking the relative importance of various inpact factors. Concurrently, FCE manages the fuzziness and uncertainty inherent in "visual landscape interference" through membership degree analysis, enabling the conversion of qualitative descriptions into quantitative data. The evaluation model, developed through the integration of two approaches, can accurately assess the degree and extent of engineering interference while also offering clear guidance for the formulation of mitigation measures. This research outcome not only provides a scientific foundation for landscape maintenance during the follow-up operational phase of the Guiyang–Nanning High–Speed Railway but also establishes an operational technical framework and methodological reference for visual landscape impact assessments of other linear infrastructure projects, such as high-speed railways and expressways, within the buffer zones of World Heritage Sites. Consequently, it holds significant practical value in balancing heritage site preservation with the sustainable development of regional infrastructure.

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