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Soundscape Optimization Strategies Based on Landscape Elements in Urban Parks: A Case Study of Greenlake Park in Kunming

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Abstract: The soundscape quality of urban parks can influence the mental and physical health of park visitors. This paper proposes strategies for optimizing soundscape quality by correlating the physical parameters to the human perception. The data has been gathered through a case study of Greenlake Park located in Kunming, China. The objective physical acoustic indexes and the subjective soundscape perception were analyzed using a combination of GIS spatial statistical analysis from 1224 pieces of environmental sound pressure level data and questionnaire data of human perception collected through soundwalks. The conclusions are as follows: (1) Compared with water bodies, lands perform better in absorbing and reducing the environmental sound pressure level with a decrease of 2.0 dB every 15 m in the terrestrial landscape of rich plant layers and high degree of enclosure, compared to a decrease of 1.5 dB every 15 m in the water landscape with lotus leaves, cruise ships or structures; (2) Sound pressure level and types of sound sources profoundly affect our soundscape perception. Acoustic environment evaluation, soundscape suitability, visual preferences, pleasure perception and relaxation perception are positively correlated with natural sound perception ($p < 0.01$), while significantly negatively correlated with sound pressure level, human activity and mechanical sound perception. In the end, the correlation between landscape elements and sound pressure level, sound sources and soundscape perception are discussed, and a soundscape optimization strategy for urban parks supported by research data is proposed.

Keywords: soundscape; soundwalk; city park; soundscape perception; sound pressure level

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1. Introduction

The term "soundscape" first appeared in The Tuning of the World published in 1977 by Murray Schafer [1]. The International Organization for Standardization (ISO) in 2014 defined it as an "acoustic environment as perceived or experienced and/or understood by people, in context" [2] A soundscape contains three elements: environment, humans and sounds. In urban settings, sounds like traffic and construction can have negative physical and mental health impacts [3]. The benefits of health and wellbeing by visiting the green and blue spaces in parks have been proved [4,5]. Since urban parks are places where people can escape from unwanted noises to rest and relax, the soundscape quality of such parks is closely linked to people's well-being and health [6]. According to ISO 12913-2 [7], soundscape quality can be evaluated with objective physical acoustic indexes and subjective soundscape perception. It is found that soundscape quality is primarily shaped by environmental sound pressure level (SPL) [8,9]. However, there are several papers argue that a decrease in environmental SPL may not necessarily contribute to an increase in the level of urban acoustic comfort [10,11]. This is because specific sound sources and soundscape perceptions can affect soundscape quality [12–15]. In addition, landscape elements, including plants [16], structures, [17] and water bodies [18,19], can

affect soundscape quality. Hence, exploring the relationships between landscape elements and environmental SPL, types of sound sources and soundscape perception serves as a key starting point for the study of optimizing soundscape quality.

Researchers conclude that environmental SPL is affected by landscape elements. Studies on the relationship between vegetated landscapes and acoustic environments show that plants can attenuate noise annoyance [20]. The results showed that the noise reduction effects of the plant community were related to its structure. The effect of noise reduction of the plant community was more distinct than that of open space [21]. Water in the form of fountains can buffer unwanted noises [22]. Terrain such as earth forms can also attenuate environmental noise. For example, the Beijing Olympic Forest Park used grading of fluctuating earth to reduce environmental noises [23].

Several studies have demonstrated that the subjective evaluation of the quality of soundscapes is influenced by two elements, types of sound sources [24], and soundscape perception [25–27]. In terms of the former, Hong and Jeon discovered that the sounds of birds chirping are the most popular among various types of sound sources [28]. Hong and Liu observed that in urban parks, bird chirping and the sounds of waterfalls can "mask unpleasant noise" [29,30]. Moreover, Alvarsson and Wiens found that nature sounds, including birds chirping and sounds of water flowing, can contribute to a calming and pleasant state of mind and relieve mental stressors [31]. Bahali and other scholars concluded that the addition of positive sound sources increases acoustic comfort. They analyzed soundwalks to understand which elements most affected the participants and created a soundscape classification and identified the positive characteristics based on responses at four spots along the Gezi Park-Tunel Square route [32].

Soundscape perception is considered subjective and is affected by many complex factors. Soundscape perception is not only related to physical acoustic indexes (environmental SPL in particular) [33] but is also linked to other perceptual factors including demographic [8,34,35] and visual preferences [36–38]. Ma and Axelsson discovered that SPL, types of sound sources and tourist behavior influence visitors' soundscape perceptions [39,40]. Interestingly, Ma Hui et al. found that visual landscape also affects soundscape perception and that increasing overall visual satisfaction with the environment can reduce people's subjective annoyance when it is not possible to reduce the ambient sound pressure level [41].

Greenlake Park in Kunming is the site of the case study discussed in this paper. Altogether 1224 environmental SPL data were obtained using a sound level meter during three-time slots. GIS spatial statistical analysis was conducted to analyze the impacts of the water bodies and earth forms on environmental SPL. The participants subjective landscape perceptions were also collected through soundwalks. Following the field data collection, the objective physical acoustic indexes were combined with the subjective sound landscape perception. Based on the correlations between humans, sounds and environment, the internal relationships between landscape elements and environmental SPL, and those between sound sources and soundscape perception were analyzed to develop strategies for optimizing soundscape quality in the park.

2. Research Approach

2.1. Case Study

Greenlake Park is located in the central urban core of Kunming City, Yunnan Province. It encompasses an area of 21.6 km^2 and 15 km^2, and 69.4% of the total is made up of water bodies. As a beautiful urban park, it is defined by tranquil water bodies and has a large volume of visitor ship. Built in the late Yuan Dynasty, it was originally called Cai Haizi (literal translation: sea of vegetables), it has a long history of passive recreational use. Greenlake Park used to be a shallow arm of Dianchi Lake, but due to the lowering water level became a landform. In the early period of the Republic of China (ROC), the lake was turned into a park and given the name "Cuihu Lake" (the literal translation of Cuihu is a green lake), renowned for its emerald lake embankment and beautiful spring dawn.

Soundscape ecology divides sounds into three categories: geophonies, anthrophonies, and biophonies [42]. This paper, based on the literature [43], classifies the sound sources of Greenlake Park into three categories: natural, human activity and mechanical sounds (see Table 1). The layout of the park features two long willow tree-lined footpaths crossing at the park center dividing the lake into four functional areas. The landscape elements of the park include lake banks, bridges, water surfaces, vegetation, squares, roads, sculptures, pavilions, promenades, fountains, etc. (Figure 1).

Table 1. Greenlake Park Sound Source Classification.

Type	Source
Natural sounds	Birds chirping, insects chirping, wind, leaves rustling in the wind, water flowing, and duck calling
Human activity sounds	Talking, footsteps, and children playing
Mechanical sounds	Electronic equipment sounds, traffic sounds (e.g., cars, buses, and air planes), and construction sounds

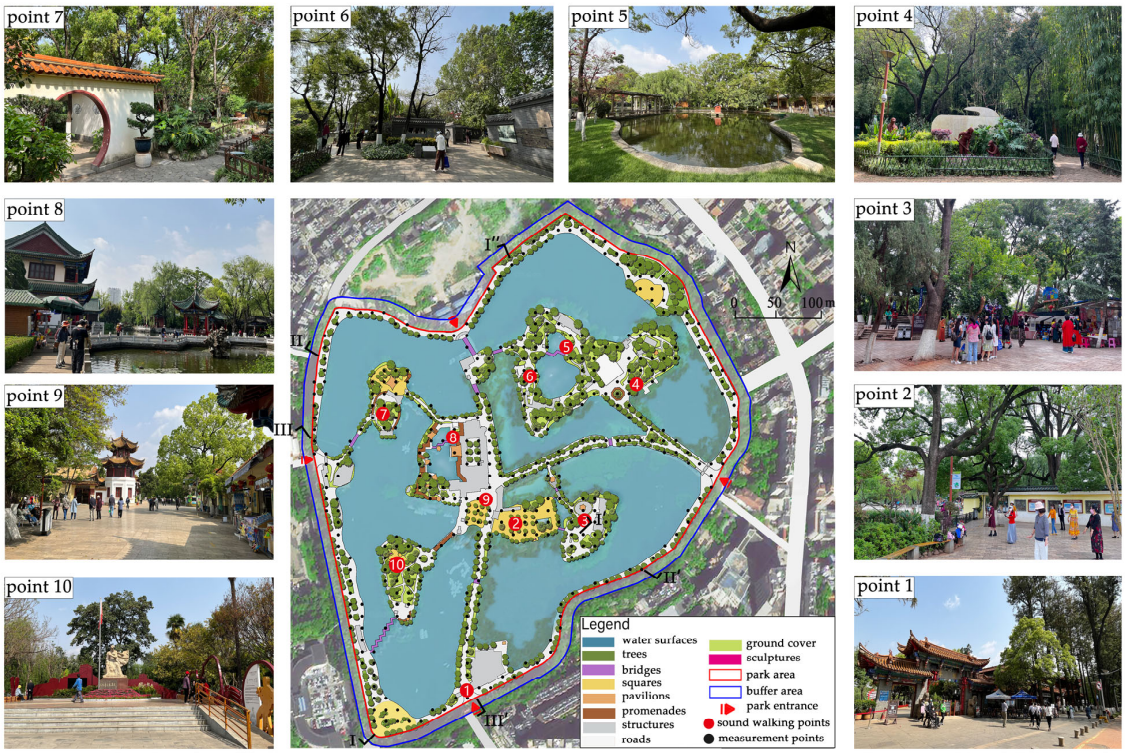


Figure 1. Point landscape elements and section lines of soundwalks.

2.2. Research Method

2.2.1. SPL Measurement in Greenlake Park

The case study employed model AWA6228+multi-function sound level meter to measure and collect data on the environmental SPL of Greenlake Park. "Environmental quality standard for noise (GB3096-2008) [44]" and "Technical specifications for environmental noise monitoring (HJ640-2012) [45]" were followed for SPL data collection and A-weighting network (A-weighted SPL) was used.

The study adopted a grid measurement system in accordance with the provisions of ISO [7] to divide the site into grids of 15 × 15 m with a total of 408 measurement points, all on land. SPL was measured on working days from early September to mid-October in 2021. Based on the park traffic, measurements were taken from 8:00–10:00, 12:00–14:00, and 16:00–18:00, as shown in Figure 1. To obtain optimal results, the sound level meter was placed at the intersection of

the grids at a height of 1.5 m, the average height of Chinese men and women and the standard ear position [46]. Each point was measured for 3 min. To keep an accurate record of acoustic measurements, windshields [34] were adopted and the sound level meter used was calibrated with a sound level calibrator before measurements were taken. The weather conditions during the measurement were stable, with no rain, snow, thunder or lightning.

2.2.2. Soundwalk

The soundwalk is a research method that is frequently used in environmental acoustics research [47]. This study utilizes the soundwalk approach to record real-time sounds and evaluate the corresponding soundscape in the park area, thereby elaborating and evaluating the park's soundscape from multiple perspectives based on both qualitative and quantitative analysis [48].

Ten sound walking points were selected (Figure 1) considering the characteristics of park landscape elements and surrounding sound sources. Twenty subjects (10 male and 10 female) were students majoring in landscape architecture were invited. They all have normal hearing and are familiar with the spatial layout and various landscape elements of the park. Before the soundwalk, training on experiment procedure, evaluation methods and points for attention were given. During the soundwalk, the subjects stayed for three minutes at each point and used a questionnaire (Appendix A) which adopts the data collection protocols Method A and Method B provided by ISO 12913-2 [7] and the sound level meter for background sound measurement. The soundwalks were conducted from 10:00–12:00 on weekdays when rich sound sources were prevalent in the park. Narrative interviews were also conducted with each subject after the soundwalk [34].

2.3. Data Processing

2.3.1. Analysis of Environmental SPL of the Park

Studies have shown that soundscape mapping can intuitively demonstrate the characteristics of environmental SPL. In this case study, the park boundary was extended by 15 m as a buffer area, and GIS was used to visualize the data. After 1224 pieces of SPL data were collected and inputted into ArcGIS10.2, the Kriging interpolation was adopted to obtain the spatial distribution map (Figure 2) of the average environmental SPL and the level during the three-time slots. The highest and lowest SPLs of each time slot were marked on the map. Moreover, three sections were drawn to show the internal relations between the change of SPL and the landscape elements (Figure 3).

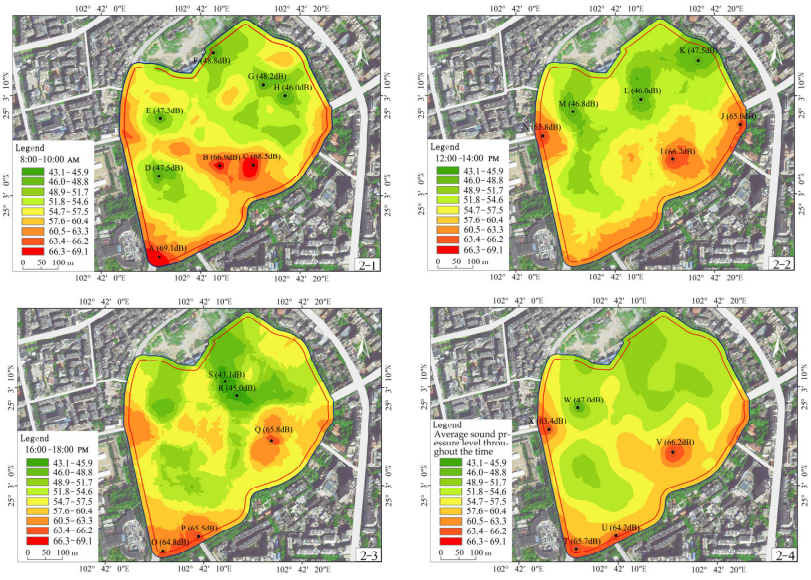


Figure 2. SPL distribution map of Greenlake Park.

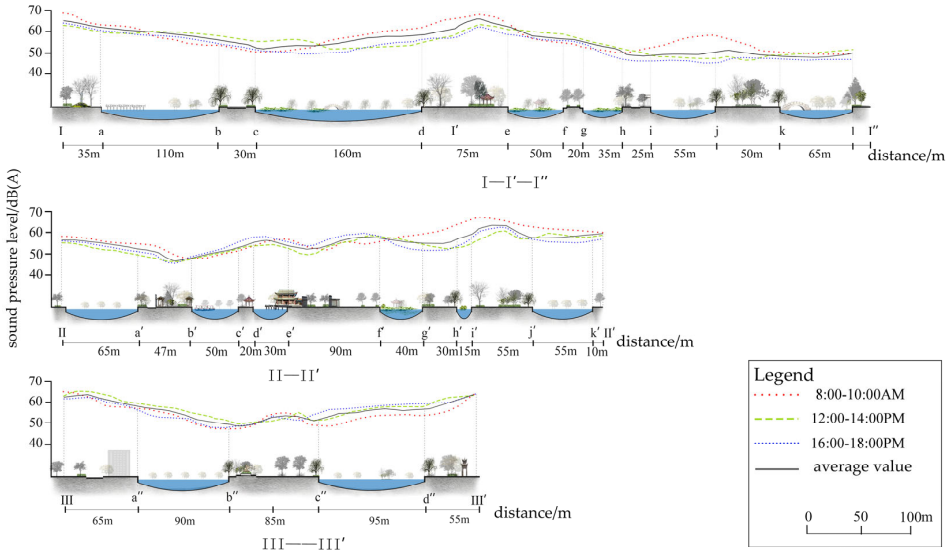


Figure 3. Sectional view of change in SPL during different time slots.

2.3.2. Analysis of Soundscape Perception of the Park

At each soundwalk point, the subject was required to fill out a questionnaire that included the questions under Method A and Method B of ISO 12913-2 [7]. Subjects were asked to grade the Perceived Occurrences (POS), Perceived Preference of Sound Source (PFS), and the Acceptability and Coordination of people's environment perceptions. For the convenience of statistical analysis, the questionnaire data was collected according to the five-point Likert scale, and Microsoft Excel and SPSS Statistics 24.0 were used for data processing, and Pearson for correlation analysis.

3. Results

3.1. Environmental SPL of the Park

3.1.1. Spatial-Temporal Changes of Environmental SPL of the Park

1. The SPL distribution from 8:00 to 10:00: As shown in 2-1 of Figure 2, the highest SPLs are distributed at points A (69.1 dB), B (66.9 dB), and C (68.5 dB), and primarily composed of traffic sounds, equipment sounds from public square dancing, people talking, and construction sounds; while the lowest SPLs are distributed at points D (47.5 dB), E (47.3 dB), F (48.8 dB), G (48.2 dB), H (46.0 dB), and mainly consist of sounds of the wind, chirping birds and insects, and leaves rustling. It can be seen from Figure 3 that the SPL of section I-I′-I″ drops significantly by 19.1 dB from the maximum of 68.9 dB to the minimum of 49.8 dB; the SPL of II-II′ shows a decline of 18.4 dB from 67.2 dB to 48.8 dB; the SPL of section III-III′ goes down from 65.0 dB to 47.5 dB, showing a decrease of 17.5 dB.
2. The SPL distribution from 12:00 to 14:00: According to 2-2 of Figure 2, the highest SPLs in the area are distributed at points I (66.2 dB), J (65.0 dB), and N (65.8 dB), and primarily composed of traffic sounds, people talking, children playing, and sounds of entertainment facilities; while the lowest SPLs are distributed at points K (47.5 dB), L (46.0 dB), and M (46.8 dB), and primarily composed of birds chirping and leaves rustling. As illustrated in Figure 3 the SPL of section I-I′-I″ drops from a maximum of 64.0 dB to a minimum of 46.5 dB, with a decrease of 17.5 dB; the SPL of section II-II′ goes down from 61.5 dB to 47 dB, with a decrease of 14.5 dB; the SPL of III-III′ drops by 14.5 dB from 64.5 dB to 50.0 dB.
3. The SPL distribution from 16:00 to 18:00: As shown in 2-3 of Figure 2 the highest SPLs in the area are distributed at point O (64.8 dB) and P (65.5 dB), mainly made up of traffic sounds, people talking, and equipment sounds; while the lowest SPLs are distributed at point R (43.1 dB) and S (45.0 dB), primarily composed of the sounds of

wind, chirping insects, and rustling leaves. According to Figure 3, the SPL of section I-I′-I″ drops from a maximum of 64.0 dB to the minimum 45.2 dB, with a decrease of 18.8 dB; the SPL of II-II′ shows a decline of 16 dB from 62.5 dB to 46.5 dB; the SPL of section III-III′ falls by 15.5 dB from 64.5 dB to 49 dB.

4. The distribution of average SPL throughout the measurement period (means the average of the data of three time periods). According to 2-4 of Figure 2, the highest SPLs in the area are distributed at point T (65.7 dB), U (64.2 dB), V (66.2 dB) and X (63.4 dB); and the lowest SPL is distributed at point W (47.0 dB). As shown in Figure 3, the SPL of section I-I′-I″ shows the largest decline of 17.5 dB from a maximum of 65.5 dB to a minimum of 48 dB when compared with sections II-II′ and III-III′ whose SPLs go down by 17 dB and 15 dB, from 63.5 dB to 46.5 dB and from 64 dB to 49 dB accordingly.

3.1.2. The Influence of Water Body and Land on the Change of SPL

With the water body and land form encompassing 69.4% and 30.6% of the area respectively, Greenlake Park is an urban park with a small land area and large flows of visitors. It is an ideal place for studying the effects of water body and landform on noise attenuation. The figure below shows three sections and the actual area cover of all types of small islands and banks in the park and includes all types of acoustic environments, such as the entrance square, lake bank, entertainment area, recreation area, central activity area, park entrance, and perimeter roads of the park.

In general, section I-I′-I″ has an average decrease in SPL of 0.9 dB per every 15 m of distance increase from a sound source. As illustrated in Figure 3, this section spans six water bodies. The 50 m-wide subsection e-f, with a water body and lotus leaves as the primary landscape elements, produces the best result with a resulting SPL of 1.5 dB per measuring unit. On the contrary, the 65 m-wide subsection k-l, having a single water body as its major landscape element, generates the least decrease in SPL of 0.5 dB per measuring unit. This section also spans six blocks of land and the average SPL on land drops by 1.4 dB of every 15 m distance from a sound source. The 70 m-wide subsection d-e, with rich plants, roads, and pavilions as major landscape elements witnesses the best performance on SPL reduction with a 1.7 dB decline per measuring unit. By comparison, the 20 m-wide subsection f–g, with a single type of street trees and shrubs as the dominant landscape elements produces the worst reduction effect with only an SPL decrease of 1.2 dB for the same measuring unit.

In terms of section II-II′, its SPL drops by 1.0 dB on an average of15 m distance from a sound source. It can be seen from Figure 3 that this section stretches across six water bodies. The 50 m-wide subsection b′–c′ outperforms others in SPL reduction with a water body and tourist boats as the dominant landscape elements: a decrease of 1.4 dB per measuring unit. By contrast, subsection j′–k′, with 65 m in width and being dominated by a single water body produces the worst performance on reducing SPL: a decrease of 0.7 dB per measuring unit. This section also contains six subsections of land and their SPL drops by 1.4 dB every 15 m distance from a sound source on average. Specifically, the 47 m-wide subsection a′–b′, featuring rich plants, roads, promenades, and enclosed spaces as the major landscape elements offers the best performance on SPL reduction with a drop of 2.0 dB per measuring unit. In contrast, the 90 m-wide subsection e′–f′, with buildings, roads, and a single type of arbors as the major landscape elements results in a relatively worse result on SPL reduction with only a decrease of 1.0 dB per measuring unit. Moreover, subsection k′–II′ performs the worst with SPL drops of only 0.8 dB per measuring unit. This section is 10 m wide and contains a single type of street tree as its dominant landscape element.

3.2. Soundscape Perception of the Park

3.2.1. The Perception of Types of Sound Sources of the Park

It is demonstrated in Figure 4 that among three types of sound sources, natural sounds produce the highest score regarding preference, acceptability, and coordination of people's

sound environment perceptions while mechanical sounds receive the lowest. Human activity sounds elicited the highest score on perception.

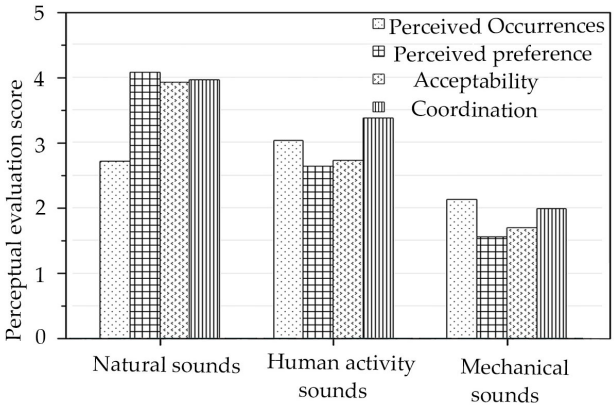


Figure 4. The average perceived occurrences, preference, acceptance, and coordination of three types of sound sources.

Figure 5 illustrates that in terms of perceived occurrences of natural sounds, points 4, 5 and 7 produced the highest scores. These points are in the areas with less mechanical and human activity sounds but richer in natural sound elements, such as birds and insects chirping, leaves rustling, and the sound of water flowing. By contrast, points 1, 2, and 3 have the lowest perceived occurrences of natural sounds. They are dominated by sounds of traffic, people talking and equipment, forming a relatively boisterous condition. With regards to the acceptability and coordination of human activity sounds perceptions, points 8 and 9 in the areas with high foot traffic show comparably higher scores. Point 7 which is in a quiet resting area receives much lower scores. Hence, it can be argued that people tend to show different acceptability towards the same sound source when the surrounding environment changes.

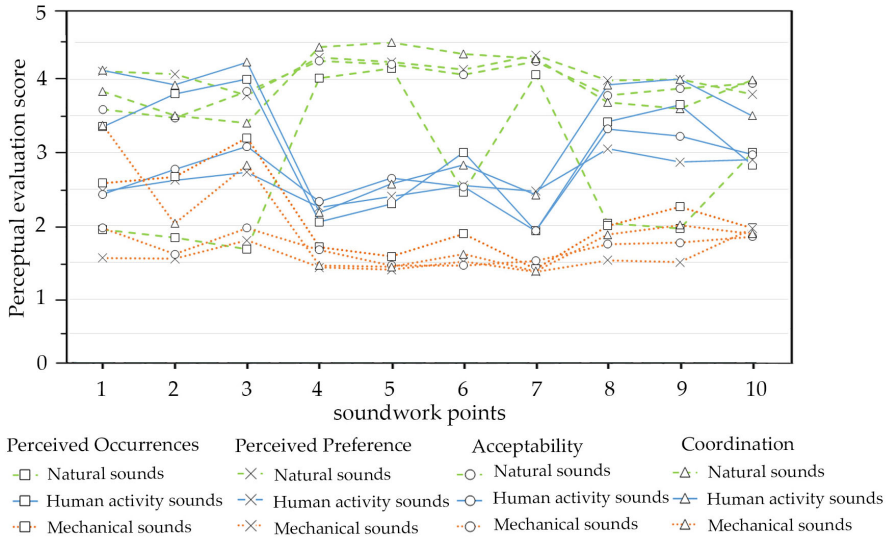


Figure 5. The Perceived Occurrences (POS), Perceived Preference (PFS), and Acceptability and Coordination of three types of sound sources at ten sound walking points.

3.2.2. SPL and Soundscape Perception

Studies have pointed out that SPL plays an important role in subjective perception evaluation [48]. People tend to give a better score on the acoustic environment at a SPL of around 46 dB. In the case study, the SPLs of ten sound walking points are between 47.3 dB to 68.5 dB.

It can be concluded from Figure 6 and Table 2 that SPL is positively correlated with perceived occurrences of human activity and mechanical sounds, and significantly negatively correlated with acoustic environment evaluation, appropriateness of soundscape, visual preferences, pleasure, relaxation, and natural sound perception. While point 3 has the highest SPL at 68.5 dB and the lowest score on soundscape perception, point 7 reaches the lowest SPL at 47.3 dB with the highest score on acoustic environment evaluation. It can be concluded that SPL is an important factor influencing soundscape perception. Point 5 has a relatively high SPL at 55 dB, and high scores for perceived occurrences of natural sounds, relaxation, pleasure, and visual preferences, indicating that the types of sound sources and visual preferences may have a considerable influence on soundscape perception.

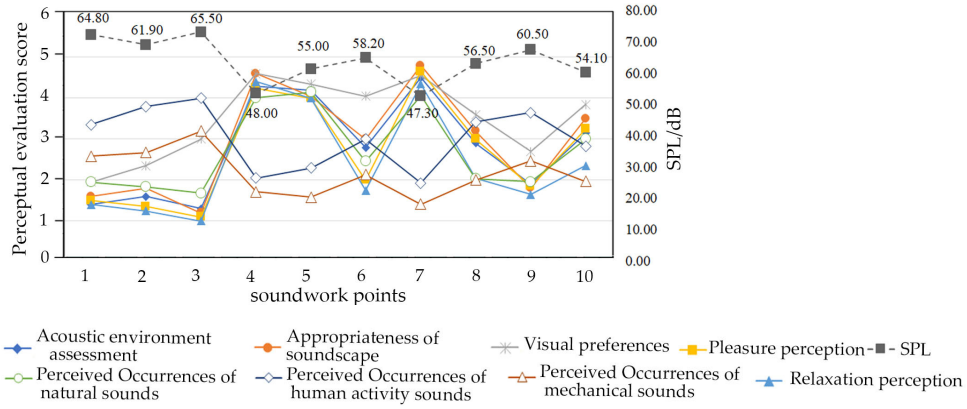


Figure 6. Diagram analysis of SPL and soundscape perception.

Table 2. Correlation analysis of SPL and various elements of soundscape perception.

	Acoustic Environment Evaluation	Appropriateness of Soundscape	Visual Preferences	Pleasure Perception	Relaxation Perception	Perceived Occurrences of Natural Sounds	Perceived Occurrences of Human Activity Sounds	Perceived Occurrences of Mechanical Sounds
Appropriateness of soundscape	0.982 **							
Visual preferences	0.925 **	0.886 **						
Pleasure perception	0.977 **	0.964 **	0.873 **					
Relaxation perception	0.957 **	0.933 **	0.858 **	0.963 **				
Perceived occurrences of natural sounds	0.953 **	0.927 **	0.883 **	0.938 **	0.975 **			
Perceived occurrences of human activity sounds	−0.948 **	−0.935 **	−0.900 **	−0.932 **	−0.957 **	−0.978 **		
Perceived occurrences of Mechanical sounds	−0.964 **	−0.960 **	−0.835 **	−0.936 **	−0.875 **	−0.866 **	0.868 **	
SPL	−0.972 **	−0.959 **	−0.891 **	−0.973 **	−0.934 **	−0.916 **	0.937 **	0.951 **

Note: ** indicates significant correlation at the level of 0.01 (two-tailed). Sample size of 20.

3.2.3. Types of Sound Sources and Soundscape Perception

It is demonstrated in Table 2 that perceived occurrences of natural sounds is significantly positively correlated with acoustic environment evaluation, appropriateness of soundscape, visual preferences, pleasure and relaxation perception and is significantly negatively correlated with perceived occurrences of human-activity perceived occurrences of mechanical sounds and SPL. It can be concluded that when the natural sound perception frequency is higher, the perceptual influence on people is biased towards positive influence, such as nodes 4, 5 and 7 achieve higher scores on perceived occurrences of natural sounds, their scores on relaxation

and pleasure perception also rank high. This result echoes other studies which claim that soundscape plays a crucial role in shaping human perception, especially the finding that natural sound sources like bird chirping and water flowing can generate a sense of pleasure for humans [49]. It can be reflected that increasing the frequency of natural sound perception is one of the important factors to be considered in park soundscape design.

In addition, perceived occurrences of human-activity and mechanical sounds are notably negatively correlated with acoustic environment evaluation, appropriateness of soundscape, visual preferences, pleasure, relaxation, and perceived occurrences of natural sounds and are significantly positively correlated with SPL. For example, points 1, 2, and 3 are mainly located at the entrance of the park as well as adjacent to the main road, with more continuous traffic sound, construction sound and recreational facilities sound, resulting in lower perception of pleasure and relaxation, indicating that effective control of sound pressure level of sound sources can provide people's recreation satisfaction.

4. Discussion

4.1. Evidence for Using Landscape Elements to Optimize Soundscapes

4.1.1. Evidence 1: Landscape Elements Can Reduce Environmental SPL

In general, lands with rich plant layers and a high degree of enclosure are more effective than water bodies in reducing environmental SPL. However, water bodies containing aquatic plants or structures show a stronger influence on reducing SPL.

On land, for every increase of 15 m distancing from a sound source, the SPL reduces by an average of 1.4 dB. Richly layered trees and shrubs, as well as promenades, roads, and enclosed landscape combinations achieve better results on sound reduction with a SPL drop of 2.0 dB per measuring unit. In contrast, areas with buildings, roads and single type of arbors as the main landscape elements have poorer performance on sound reduction with only a decrease of 1.0 dB per measuring unit.

From the perspective of water bodies, the SPL drops by an average of 1.0 dB for every 15 m distancing from a sound source. Water bodies with lotus leaves, tourist boats or structures perform better in sound reduction with a decrease in SPL of 1.5 dB per measuring unit. However, a single water body, whose SPL only drops by 0.5 dB per measuring unit, produced the worst performance on sound reduction.

4.1.2. Evidence 2: Environmental SPL Can Significantly Influence Soundscape Perception Assessment of Water Body Parks

The higher the SPL of a point, the lower the score on acoustic environment evaluation, appropriateness of soundscape, visual preferences, pleasure, relaxation, and perceived occurrences of natural sounds.

4.1.3. Evidence 3: The Perception of Natural Sounds Can Improve Soundscape Perception Evaluation of the Park

Natural sound effects are the most popular type of sources. Points 4, 5, and 7 show relatively higher perceived occurrences of natural sounds as well as higher scores on relaxation and pleasure perception, appropriateness of soundscape, and acoustic environment evaluation. These points featured landscape elements of rich plants, which are also habitats for insects and birds and produce natural sounds from leaves, wind and rain.

4.1.4. Evidence 4: The Quality of Visual Landscape Can Significantly Influence Soundscape Perception Assessment of the Park

It is often the case that the higher the SPL, the lower the score on soundscape perception evaluation. However, points with good scores on visual preference still receive excellent scores on acoustic environment evaluation despite a high SPL. This indicates that an enjoyable visual landscape can contribute to a reduction in the negative impact of undesired sounds such as traffic and construction sounds. This point is also reflected in the case study that, despite large flows of visitors and noises at point 5, the beautiful Greenlake Park is still popular among residents.

4.2. Soundscape Optimization Strategy of Urban Park with Water Bodies Based on Landscape Elements

4.2.1. Strategy 1: Reduce Environmental Noise by Optimizing Landscape Elements

According to Environmental Quality Standard for Noise (GB 3096-2008) [44] of China, the limit of daytime noise in a Class I environmental functional area is 55 dB. In urban parks, noise mainly comes from sources such as traffic and construction. To improve the acoustic environment of urban parks, it is necessary to mask, reduce or directly eliminate unpleasant noises. In the landscape, the commonly used methods are plantings and the use of new materials to reduce noise. On land, noise can be mitigated by growing appropriate plants, transforming micro-topography, and setting up rockery walls and structures. When it comes to water bodies, noise can be reduced by planting aquatic plants, building lake banks, and constructing artificial islands and structures, that utilize sound absorption and reflection, consistent with the results of Hong et al. [50].

4.2.2. Strategy 2: Increase Natural Sounds by Creating Biological Habitats

Introducing pleasant natural sounds, such as water flowing and bird chirping, into parks to buffer or diminish urban park noises like traffic and construction sounds can improve human acoustic comfort, consistent with the findings of Ong et al. [51]. Taking Greenlake Park as an example, appropriate water drops or fountains can be set up to mask negative sound sources at locations adjacent to park roads where traffic and construction noises are most impactful (such as point 1). Plants with rich, diverse layers and textures can be introduced to provide habitats for animals at spots for resting and viewing (such as points 4, 5, and 7) Growing bird-attracting plants (such as camphor and willow), fruit trees (such as tangerine trees, persimmon trees, and cherry trees) and bee-attracting flowers (such as golden chrysanthemum, Chinese rose, and forsythia) can increase the frequency of natural sounds. Accordingly, the biodiversity of the park can be improved.

4.2.3. Strategy 3: Lower the Perception Level of Undesired Sounds by Improving the Visual Quality of Landscapes

The resting areas of urban parks can be renovated into semi-open spaces to establish a degree of sound insulation. For example, applying sound insulation materials to build cultural referencing walls and decorative or landscape walls. In areas where undesired sounds appear at a relatively high frequency, multi-layered arbors, shrubs, and ornamental grasses can be placed. It is not only the ornamental value of the arbors, shrubs, and other ground cover plants, but also the ecological value. The relationship of the plant growth to the surrounding space, condition of plantings and sight lines should be taken into consideration. Only in this way can a comfortable soundscape space be created to realize "psychological noise reduction" through the interplay between the visual sense and auditory sense.

5. Conclusions

Optimizing the soundscape of urban parks is an important component of a healthy urban lifestyle, especially in high-density urban areas with harsh acoustic environments. As an interdisciplinary subject featuring acoustic experts, landscape architects and environmental psychologists, soundscape involves three elements: sounds, environment, and humans. Only by combining objective acoustic indexes with human subjective soundscape perception, can the relationships and strategies of soundscape optimization be explored more comprehensively. Considering SPL is the most concerned acoustic characteristics in current research on soundscapes, this study obtains the data of the high-density environmental SPL's of Greenlake Park using a sound level meter, and a spatial statistical analysis using GIS to summarize the pattern of how SPL decreases in terrestrial and water landscapes. This study also provides reference data and strategies for soundscape optimization in combination with data of soundscape perception. It is suggested that future studies can analyze other acoustic indexes, such as frequency, and consider soundscape perception of various populations to further supplement the theory and data for the study of soundscape optimization.

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Appendix A

The following questionnaire was distributed to participants of the soundwalk in the park Reported below.

Sex: Age:
Time of survey: site:

Questionnaire part 1 :Sound environment perception and preference

（1）How would you describe the present sound environment?（Please tick off one response alternative per type of sound “√”）

Category	Types of sound sources	Perceived Occurrences					Perceived Preference				
		Not at all	A little	Moderately	A lot	completely	Very unpreferred	Unpreferred	Moderately	Preferred	Very preferred
Natural sounds	wind										
	water flowing										
	leaves rustling in the wind										
	insects chirping										
	duck calling										
	birds chirping										
Human activity sounds	talking										
	footsteps										
	Children playing										
Mechanical sounds	electronic equipment										
	entertainment facilities										
	Airplane sound										
	Vehicle Sound										
	construction sounds										

Category	Types of sound sources	Acceptability					Coordination				
		Not at all	A little	Moderately	A lot	completely	Not at all	A little	Moderately	A lot	completely
Natural sounds	wind										
	water flowing										

	leaves rustling in the wind										
	insects chirping										
	duck calling										
	birds chirping										
Human activity sounds	talking										
	footsteps										
	Children playing										
Mechanical sounds	electronic equipment										
	entertainment facilities										
	Airplane sound										
	Vehicle Sound										
	construction sounds										

Questionnaire part 2: Perceived affective quality

For each of the 8 scales below, to what extend do you agree or disagree that the present surrounding sound environment is...

Please tick off one reponse alternative per scale

	Strongly agree	agree	Neither agree nor disagree	disagree	Strongly disagree
Pleasant					
Chaotic					
Vibrant					
Uneventful					
Calm					
Annoying					
Eventful					
Monotonous					

Questionnaire part 3: assessment of the surrounding sound environment

（1）Overall, how would you describe the present surrounding sound environment?

Very good	Good	Neither good ,nor bad	Bad	Very bad

（2）Overall, to what extent is the present surrounding sound environment appropriate to the present place?

Not at all	Slightly	Moderately	Very	Perfectly

(3) Do you have any feelings and suggestions about the current sound environment in your area?

_____

_____

Questionnaire part 4: visual environment preference

（1）Overall, to what extent is the present surrounding visual environment preference appropriate to the present place?

Very good	Good	Neither good ,nor bad	Bad	Very bad

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