Research Article

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Sonic environment of Singapore Botanic Gardens and benchmarking with various urban gardens of the world

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Abstract: The urban parks and gardens are usually surrounded by busy streets, commercial buildings and areas of high noise levels due to human activities and heavy traffic. These parks and gardens therefore have a unique function of providing relatively quiet areas to get away from the hustle and bustle of city lives. In this study, the sonic environment of the Singapore Botanic Gardens, which was the first UNESCO Heritage site in Singapore, was measured on various occasions and benchmarked with various urban gardens and parks around the world, namely the Luxembourg Gardens in Paris, Real Jardín Botánico in Madrid, St James's Park in London, Old Botanical Gardens Hamburg, and Carlton Gardens in Melbourne. The *Leq* noise level was found to be compatible with the respective *Leq* noise level of the other urban parks and gardens. The sonic environment of the Singapore Botanic gardens was found to be dominated by cicada sound, human activities and water features. The sound level of various water features such as mini waterfalls and water fountains were also measured and analysed.

Keywords: Sonic environment, noise level, water features, botanical gardens

1 Introduction

According to research by global engineering firm Arup, green cities are healthier, more prosperous and safer [1]. White *et al.* [2] based on a study of panel data collected from over 10,000 individuals to explore the relationship between urban green space and well-being concluded that

individuals had both lower mental distress and higher well-being when living in urban areas with more green space. Stott *et al.* [3] reported that land sparing, intensive and extremely compact urbanization alongside separate, large, contiguous green space was crucial for sustaining many ecosystem services. Virtudes [4] reported that the need for green spaces had been present at city level since ancient times and that greenery had a strategic importance in the contemporary urban fabric as most of the people lived in cities. There are indeed many examples of greenery, gardens and parks in major cities of the world. Notable examples are the central park in New York City, Luxembourg Gardens in Paris, St James's Park in London, and Real Jardín Botánico in Madrid. The parks and gardens in the cities and urban areas are usually surrounded by busy streets and commercial buildings which are usually areas of high noise levels due to human activities and heavy traffic. These parks and gardens therefore have a unique function of providing relatively quiet areas or oasis to get away from the hustle and bustle of city lives. This is the reason for the establishment of the soundscape and aural environment of urban parks and gardens in several reported studies [5–11]. Most of these reported studies focused on the average noise level for the parks or gardens and there were few reported studies on the frequency content or the spatial variation of the soundscape within the parks or gardens.

Singapore is well known as a Garden City and the Singapore Botanic Gardens is the country's first UNESCO Heritage Site [12]. The Botanic Gardens was established in 1859 by the Agri-Horticultural Society at that time. The Botanic Gardens has been ranked Asia's top park attraction since 2013 by TripAdvisor Travellers' Choice Awards. It was declared the inaugural Garden of the Year by the International Garden Tourism Awards in 2012. The Botanic Gardens opens from 5 a.m. to 12 midnight every day of the year. More than 10,000 species of flora can be found over its 82-hectares area. The longest distance between the northern and southern two extreme ends is 2.5 km. The Botanic Gardens get about 4.5 million visitors every year. In a small country like Singapore, a relatively large garden is espe-

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cially treasured for its role in improving the soundscape of the area and quality of life for the people.

The term soundscape refers to the acoustic or sonic environment as perceived by humans. Soundscape consists of a set of audio recordings of an environment together with the perception of a group of people captured with the help of a questionnaire. In this study, the sonic environment of the Singapore Botanic Gardens was conducted based on a series of sound walks on different occasions using smartphones with the microphones calibrated against a type 1 sound level meter. One of the main objectives of this study is to evaluate the readiness of the methods developed for using smartphones to record sonic environment as well as their use in crowdsourcing the recording of sonic environments. Crowdsourcing can be a very useful tool to gather large amount of data in a short period of time using citizen scientists. Hence, in this study we recorded only the sonic environment and did not used a questionnaire to capture people's perception. The smartphone was able to provide the respective GPS location during the process of sound measurement. The variation of the sound levels and frequency spectrum for different parts of the gardens were then analysed and presented. The effects of environmental noise such as human voice from the visitors, chattering sound from insects such as cicadas and sound from water features such as fountains and water features on the overall sonic environment were also studied and presented. Finally, the sonic environment of the Singapore Botanic Gardens was benchmarked against five other well-known gardens and parks around the world, namely the Luxembourg Gardens in Paris, Real Jardín Botánico de Madrid, St James's Park in London, the Old Botanical Gardens in Hamburg, and the Carlton's Gardens in Melbourne.

2 Methods

The sound walk of the Singapore Botanic Gardens was carried out on several occasions spreading over a span of nearly a year using a smartphone with the built-in microphone calibrated using our in-house developed apps. We have developed a novel statistical method for accurately calibrating a typical smartphone microphone against a reference type 1 microphone [13]. As detailed in the paper, we showed that for over 7-hours of environmental noise data, the proposed method had an accuracy of ± 0.7 dB for 99.7% of the measurements. This range of accuracy has allowed the smartphone for the measurement of sonic environment.

The smartphone was hand-held at a comfortable distance away from the body with its microphone facing outwards. The smartphone was put on the silent mode so that notification sounds will not disturb measurements. The sound was recorded while a researcher walked at comfortable pace. Water features were recorded while standing still in one place.

We had developed an app named as *NoiseExplorer* for measuring Sound Pressure Level (SPL) using smartphones. Besides the instantaneous sound pressure level, the app also keeps track of the minimum SPL, the maximum SPL, and the continuous equivalent SPL for the current session. This information along with GPS location of the smartphone is also written to log files which are then used to generate noise maps. The users can choose to show either a live frequency spectrum or the current location of the smartphone on Google Maps using Google Maps Android API. Moreover, the user can optionally choose to record the audio as uncompressed WAV files which can be used for further analysis. The app has been developed for both the Android and the iOS platforms.

Water features such as waterfalls, water streams, and water fountains have been known to improve the soundscape of a park [14–17]. The sonic environment of the various water features such as water fountains, mini waterfalls and water streams in the Singapore Botanic Gardens were also measured and analysed.

3 Results and discussion

The overall sound map of the Singapore Botanic Gardens is shown in Figure 1. The enlarged view of a specific area can be carried out with the weblink [18]. A total of 18 hours of sound was recorded in 27 trips over a period of 2.5 years. The overall *Leq* SPL is 67.8 dBA with the maximum SPL of 95.8 dBA. It is probably the only reported sound map of the Singapore Botanic Gardens and probably the most comprehensive and extensive sound maps that have been reported for all urban gardens and parks around the world.

There are several noisy areas within the Singapore Botanic Gardens going from the northern to the southern end of the gardens. The top right-hand corner of the gardens is the Jacob Ballas Children's Garden as shown in Figure 2. The noise is due to the children's activities. The other noisy area is at the central portion of the park near the Nassim Gate of the Gardens (Figure 3). There is a restaurant at that area and also there are several water features and the sonic environment in that area is dominated by the water sound. To the lower left of this area is the entrance of the

Figure 1: The overall noise map of the Singapore Botanic Gardens

National Orchid Centre (Figure 4) where there is a clock tower and visitors to the park, in particular visitors and tourists like to congregate at this spot to take group photos. The last noisy spot is the lower right-hand corner near the main entrance, namely the Tanglin Gate to the Gardens at the junction of Cluny Road and Holland Road. The sonic

environment just outside the main gate is dominated by the traffic noise (Figure 5).

The sonic environment of the Singapore Botanic Gardens is dominated by three different type of sounds: human activities and conversations, cicadas, and many water features located at various parts of the gardens. A typical spectrogram and the corresponding average frequency

Figure 2: The noise map of the Jacob Ballas Children's Garden (enlarged view of the top right-hand corner of Figure 1)

Figure 3: The noise map of the centre portion of the Singapore Botanic Gardens near the Nassim Gate (enlarged view of the middle portion of Figure 1)

Figure 4: The noise map of the entrance to the National Orchid Centre (enlarged view of the middle portion of Figure 1)

Figure 5: The noise map of the bottom right hand corner of the Singapore Botanic Gardens near the Tanglin Gate (enlarged view of the middle portion of Figure 1)

Figure 6: The average frequency spectrum and spectrogram in dBA for the north eastern portion of the gardens with dominant cicada sound

Figure 7: Two water features at the central region near Nassim Gate and their average frequency spectrums in dBA

Figure 8: Two water fountains at the Orchid Gardens and their average frequency spectrums in dBA

spectrum is dominated by cicada sound is shown in Figure 6. Cicada sound typically consists of frequencies at several bands above 1000 Hz. The overall noise level caused by cicadas was not high.

There are various water features in the Singapore Botanic Gardens from water streams to various designs of water falls and water fountains. There are several water features at the central portion (Figure 3) next to the Nassim gate. One of them is a small water feature surrounding the trees and the other is a cascading low level water fall as shown in Figure 7. The corresponding average spectrums in dBA are presented in Figure 7.

There are also several water features at the Orchid Gardens. Two of the water fountains with the corresponding average frequency spectrums in dBA is shown in Figure 8.

There are another two mini water falls next to the entrance of the Orchid Gardens. The two water falls with the corresponding average frequency spectrums in dBA is

shown in Figure 9. The overall SPL for all water features is presented in Table 1.

Table 1: The sound pressure levels in dBA for various water features in the Singapore Botanic Gardens. Water features are located next to Nassim gate, water fountains are located at the Orchid Gardens, and mini waterfalls are located next to the entrance of the Orchid Gardens

Water features	Duration (seconds)	LASeq (dBA)	LASmax (dBA)
Water feature 1	25.1	70.6	74.8
Water feature 2	22.1	74.9	75.3
Water fountain 1	23.8	69.3	71.2
Water fountain 2	31.0	71.6	72.7
Mini waterfall 1	21.0	73.0	75.5
Mini waterfall 2	21.9	75.2	77.0

Figure 9: Two mini waterfalls next to the entrance of Orchid Gardens and their average frequency spectrums in dBA

Table 2: The sound pressure levels in dBA of various gardens of the world

Park	Duration (hh:mm:ss)	LASeq (dBA)	LASmax (dBA)
Singapore Botanic Gardens	18:02:11	67.8	95.8
Carlton Gardens, Melbourne	00:38:43	81.6	101.1
Luxembourg Gardens, Paris	00:17:47	69.4	86.4
Old Botanical Gardens, Hamburg	00:14:04	76.1	95.9
Real Jardin Botánico, Madrid	00:27:50	73.9	88.9
St. James Park, London	00:18:12	63.1	75.3

Figure 10: Sonic environment of five gardens. (a) Carlton Gardens Melbourne, (b) Luxembourg Gardens Paris, (c) Old Botanical Gardens Hamburg, (d) Real Jardin Botánico Madrid, and (e) St. James Park London

To benchmark the sonic environment of the Singapore Botanic Gardens, the sonic environment of five other well-known urban parks and gardens were recorded on various occasions. It should be noted that the duration of the sound recordings for the other urban parks and gardens were not as long as the one performed for the Singapore Botanic Gardens and might not be representative of the respective sonic environment due to the changing seasons and weather patterns that might affect the activities of birds and insects and nature of human activities. The traffic conditions surrounding the various urban parks and gardens are also different for different times. The sonic environment of the gardens next to the major roads were dominated by the traffic noise. A potential approach to mask the traffic noise at the boundary, besides the use of physical road barriers which may reduce the natural ventilation and also affect the aesthetics of the gardens in the surrounding areas is the inclusion of water features to mask the surrounding traffic noise. The respective duration of measurement, the *Leq* SPL, and the maximum SPL in dBA is tabulated in Table 2.

The sonic environment of these five urban gardens and parks are shown in Figure 10. In general, the sound levels at the urban parks and gardens are lower than the surrounding busy roads mainly dominated by traffic noise. Similar to the Singapore Botanic Gardens, the noisiest location of each park is usually due to human activities or next to the busy streets with heavy traffic. For example, the location within the Real Jardin Botánico in Madrid with the highest sound level is near the Palacio de Cristal at the centre of the park, a well-known landmark of the garden [19].

4 Conclusions

In this study, the sonic environment of the Singapore Botanic Gardens, which was Singapore's first UNESCO Heritage site, was measured on various occasions and benchmarked with the sonic environment of various urban gardens and parks of the world, namely the Luxembourg Gardens in Paris, Real Jardin Botánico in Madrid, St James's Park in London, the Old Botanical Gardens in Hamburg, and the Carlton's Gardens in Melbourne. The present study has demonstrated the viability for the use of calibrated smartphones to acquire the sonic environment of various gardens. It is the first step towards the possibility of crowd sourcing of such data. The day of presenting the sound map of the world similar to the noise map of US [20] may not be too far away.

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References

- [1] Frost J., Cities Alive - Arup, 2016, <https://www.arup.com/perspectives/cities-alive>
- [2] White M.P., Alcock I., Wheeler B.W., Depledge M.H., Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data, *Psychol. Sci.*, 2013, 24(6), 920-928.
- [3] Stott I., Soga M., Inger R., Gaston K.J., Land sparing is crucial for urban ecosystem services, *Frontiers in Ecology and the Environment*, 2015, 13(7), 387-393.
- [4] Virtudes A., Benefits of Greenery in Contemporary City, In: IOP Conference Series: Earth and Environmental Science, 2016.
- [5] Zannin P.H.T., Ferreira A.M.C., Szeremetta B., Evaluation of Noise Pollution in Urban Parks, *Environmental Monitoring and Assessment*, 2006, 18(1), 423-433.
- [6] Carvalho A.P., Cleto R.A., Sound and noise in urban parks, *Proc. Meetings on Acoustics*, 2012, 18(1), 040001.
- [7] Brambilla G., Gallo V., Zambon G., The Soundscape Quality in Some Urban Parks in Milan, Italy, *Int. J. Environ. Res. Public Health*, 2013, 10(6), 2348-2369.
- [8] Brambilla G., Gallo V., Asdrubali F., D'Alessandro F., The perceived quality of soundscape in three urban parks in Rome, *J. Acoust. Soc. Amer.*, 2013, 134, 808-815.
- [9] Lafon J., Lavandier C., Soundscape quality of urban parks and gardens, In: *EuroNoise*, Maastricht, 2015.
- [10] Asdrubali F., Guattari C., Evangelisti L., Marrone P., Orsini F., Grazieschi G., Urban soundscape analysis: The case study of the department of human arts of Roma tre university, In: 24th Int. Congress on Sound and Vibration, London, 2017.
- [11] Soares A.C.L., Coelho J.L.B., Urban park soundscape in distinct sociocultural and geographical contexts, *Noise Mapp.*, 2019, 3(1), 232-246.
- [12] N.P.B. Singapore Botanic Gardens, 2019, <https://www.nparks.gov.sg/gardens-parks-and-nature/singapore-botanic-garden>
- [13] Garg S., Lim K.M., Lee H.P., An averaging method for accurately calibrating smartphone microphones for environmental noise measurement, *Appl. Acoust.*, 2019, 143, 222-228.
- [14] Galbrun L., Ali T.T., Acoustical and perceptual assessment of water sounds and their use over road traffic noise, *J. Acoust. Soc. Amer.*, 2013, 133(1), 227-237.
- [15] Jeon J.Y., Lee P.J., You J., Kang J., Acoustical characteristics of water sounds for soundscape enhancement in urban open spaces, *J. Acoust. Soc. Amer.*, 2012, 131(3), 2101-2109.
- [16] Skoda S., Steffens J., Becker-Schweitzer J., Road traffic noise annoyance in domestic environments can be reduced by water sounds, In: *Proc. 7th Forum Acusticum (Europ. Congress on Acoustics)*, Krakow, Poland, 2014.

- [17] Coensel B.D., Vanwetswinkel S., Botteldooren D., Effects of natural sounds on the perception of road traffic noise, *J. Acoust. Soc. Amer.*, 2011, 129(4), EL148-EL153.
- [18] Garg S., Lee H.P., Lim K.M., Singapore Botanical Gardens, Singapore, 2019, <http://worldnoisemap.com/papers/gardens/sg-botanicgardens.html>
- [19] W. C. Palacio de Cristal del Retiro, Wikipedia, 2019, https://en.wikipedia.org/w/index.php?title=Palacio_de_Cristal_del_Retiro&oldid=892476663
- [20] Maxwell R., The Sound of Silence: A Noise Map of the U.S., 2015, <https://www.gislounge.com/the-sound-of-silence-a-noise-map-of-the-u-s>