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Original article

Acoustic and economic valuation of soundscape: An application to the 'Retiro' Urban Forest Park

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ABSTRACT

Urban parks play an outstanding role in cities in protecting their inhabitants from the stress of daily life. However, these green areas might be affected by noise pollution, thus reducing their social function. The aim of this study was twofold: (i) to characterize the soundscape of the Retiro Park, an urban forest park located in Madrid (Spain), and (ii) to estimate the willingness to pay for a noise reduction program. For that purpose, sound levels were measured in different areas in the park, and an on-site survey was conducted to monitor the visitor's sound perception. The noise pollution in the park was not perceived as being high by the majority of the visitors, even though the measurements indicate values of $L_{Aeq} > 55$ dB(A) in 6 out of the 9 studied areas. Finally, visitors would be willing to pay 6.36€ once in a lifetime towards a noise reduction program.

1. Introduction

A large number of human activities generate noise pollution in cities. This anthropogenic type of environmental pollution can affect city dwellers, causing different diseases, ranging from slight feelings of discomfort to more serious health problems like hormonal stress and cardiovascular disorders (WHO, 2011). To underline the importance of health issues related to noise pollution, Tobías et al. (2015) reported that this type of pollution is related to the mortality of people exposed to it in large crowded cities like Madrid (Spain), where more than 400 deaths annually could be prevented if road traffic noise levels were slightly reduced. It is estimated that, in Europe, exposure to noise contributes toward 910,000 preventable hypertension cases, 43,000 hospital admissions, and 10,000 premature deaths per year from heart disease (Houthuijs et al., 2014).

Urban forest parks or green areas are of enormous benefit to citizens both mentally and physically (Konijnendijk et al., 2013; Liu et al., 2017; Ulmer et al., 2016). Moreover, urban parks not only have a positive effect on the citizens' health but also generate ecosystem services like air cleaning, rainwater drainage, micro climate regulation, among others (Bolund and Hunhammar, 1999). In addition, these green spaces help to pinpoint the negative perception of noise in the cities (Dzhambov and Dimitrova, 2015). These areas are so important that many actions have been taken to identify and protect them (EEA, 2014a).

Noise pollution and its impacts can be measured and assessed in different ways, i.e. using in-situ measurements, noise modeling, indicators, etc. Despite these methods undoubtedly being useful, it is also of interest to note how noise pollution can be characterized by its monetary value. That characterization helps to find out the economic impact of noise on society, and it can be used as an argument to set up new policies and legislation to reduce it. There are many different methods for assessing the economic value of noise by means of revealed and stated preferences (Navrud, 2002). As an example of how costly this type of pollution is, it is estimated that the cost derived from rail and road traffic noise pollution in the European Union reaches forty thousand million euros yearly (EEA, 2014b). On a smaller scale, some research has reported that noise polluted areas show a reduction in property prices compared to those with the same characteristics, but with lower noise levels (Blanco and Flindell, 2011; Łowicki and Piotrowska, 2015).

The presence of an urban park or green area can increase the economic value of the houses and buildings close to it (Latinopoulos et al., 2016; Weigher and Zerbst, 1973). However, those parks located in the middle of cities, and surrounded by avenues and streets with a large number of motor vehicles, might be affected by noise, thus diminishing

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their effectiveness for their inhabitants' leisure and recreation. Some studies have been conducted to estimate the monetary value of noise inside cities (Barreiro et al., 2005; Bjørner, 2004), and also in more natural environments like National Parks (Iglesias Merchan et al., 2014). Nevertheless, the economic value of noise in an urban park inside a city is unknown in Spain.

Considering how beneficial urban parks are to cities and citizens, and the importance of their preservation and protection from noise pollution, it is vital to find out both the physical and economic impacts of this kind of pollution. Therefore, the aim of this study was twofold: to characterize the soundscape of an urban forest park; and to assess the willingness of its visitors to pay (WTP) for a noise reduction program inside the park.

2. Material and methods

2.1. The study area

The Retiro Park is a historic and touristic urban park located in the city center of the municipality of Madrid (Spain). This park covers 114 ha and is recognized as being one of the largest green areas in the city due to its amount of vegetation, which is characterized by more than 7900 ornamental shrubs and 19,000 trees from 168 different species. This green area was selected for the study because it is surrounded by important streets in the city of Madrid, all of them with an annual average daily traffic of more than 70,000 vehicles according to municipal data (Ayuntamiento de Madrid, 2012). Another reason for selecting this area was the fact that, being a national heritage site, the Retiro Park is visited daily not only by Madrid's citizens but also by many tourists. However, though this park is of great importance for both tourists and local inhabitants, no statistics are available on its visitors.

For this study, the Retiro Park has been divided into 7 different zones, and 2 additional ones corresponding to the two main paths inside the park (Fig. 1). Each zone is configured in accordance with the park's geometry and its different uses. Thus, varied soundscapes can be found along these areas; for instance, there are sports facilities, museums, children's playgrounds, music, exhibitions, fountains etc. This heterogeneous matrix of elements causes an unequal visitor distribution in the park, with notably more people congregating in those zones with tourist attractions, thus increasing the sound pressure levels in them.

2.2. Acoustic data

In order to characterize the Retiro Park acoustically, sound pressure levels were collected in the 7 zones and in the two main paths during the second half of August 2015. For this acoustical characterization, 14 sampling points were selected in considering these criteria: one sampling point for each internal zone and in the main paths, and two sampling points in the external zones. One of these points was located close to the external streets and the other one in the innermost area of the zone to observe the sound pressure level differences caused by road traffic noise propagation. In zones 1 and 4, two sampling points were allocated because of their rectangular shape and in considering the interest of achieving a homogeneous sound characterization. The number of points measured is in accordance with other studies conducted in urban parks of approximately the same size (Szeremeta and Zannin, 2009). To avoid annoyance to the visitors or municipal workers, the measurement points were located at the sides of the paths.

At each sampling point, 4 sound pressure measurements were taken: two in morning-early afternoon periods (between 9:00 a.m. and 2:00 p.m.) and two in the evening (between 2:00 p.m. and 9:00 p.m.). Sound-pressure levels were measured with a type II professional sound level meter (SLM) using "A" frequency weighting and the "SLOW" mode for data recording, i.e., one sound pressure level datum per second measured in dB(A). The duration of each measurement was 30 min, yielding data in 1800 measurements at each point and each period, from which indicators were obtained. The duration of 30 min was chosen due to the lack of consensus on the measuring times in urban parks in the literature, though some recommendations suggest that, depending on the indicators, 10–20 min are the optimal ones (Brocolini et al., 2013). However, in some cases, only 5, 10, 20, 30 min of continuous monitoring methods are used (Brambilla et al., 2013b; Carvalho and Dias, 2012; Filipan et al., 2014; Lafon and Lavandier, 2015; Szeremeta and Zannin, 2009). In accordance with the International Organization for Standardization (ISO), the SLM was placed at 1.5 ± 0.1 m above the ground and calibrated before and after each measurement (ISO 1996-2, 2007). No data were collected during rainy days, or on ones with a wind speed faster than 5 m/s. For each sample, five of the noise indicators most used according to other urban park studies were measured: L_{Aeq} (equivalent continuous sound level), L_{Amax} (maximum sound level), L_{Amin} (minimum sound level), *SEL* (sound exposure level; this normalizes sound events of different durations and intensities into a sound event of 1 s), and L_{90} (the sound pressure level exceeded during 90% of the measurement period, background sound level) (Brambilla et al., 2013b; Iglesias Merchan et al., 2014; Sakieh et al., 2017; Szeremeta and Zannin, 2009).

2.3. Questionnaire and interviews

For the evaluation of the visitors' perception of the environmental noise and different sounds inside the park, a personal survey was conducted. The survey[1] consisted of 26 questions divided into five different categories. The first one consisted of questions to locate the individuals surveyed inside the park. The second contained questions on the visitors' general perception of the park (congestion level, ecosystem services provided, among others). The third one asked questions about environmental noise and sound perception; in this part of the survey, the respondent was asked to classify some sound sources (road traffic noise, twittering of birds, maintenance vehicles, etc.) as annoying or pleasant. They were also asked to express their environmental noise perception both inside the park and in their daily environment on a scale of annoyance from 0 to 5. The fourth category prompted questions on the economic value of noise pollution in the park, in which visitors were asked about their willingness to pay for a noise reduction program inside it and their reasons for making (or not) that payment. Finally, the fifth and last category was based on personal questions to make an anonymous statistical profile of the respondent.

The visitors were interviewed in the different zones of the park during August, September, and October, 2015. The interviews were conducted in random locations inside the different zones previously configured, and it was aimed to survey the same number of people in each zone. The respondents were selected using a walking routine, i.e. the interviewer walked along the different zones of the Park and randomly chose one individual, although neither non-national citizens nor individuals of under 18 years old were surveyed; nor were people with headphones or visitors who were doing high intensity activities such as cycling or running.

2.4. Economic valuation of noise

To estimate the economic value of the environmental noise inside the park, a contingent valuation (Alberini and Kahn, 2006) exercise was implemented. In the fourth part of the questionnaire, visitors were asked about their willingness to pay (WTP) for a noise reduction program inside the park. The payment proposed was a 'once in a lifetime donation' and the money raised would be exclusively used for that program. Respondents were presented with a payment card (ranging from €1 to €80) for them to select their maximum willingness to make

[1] The questionnaire is presented as supplementary material.