



# A METHODOLOGY FOR SOUNDSCAPE MANAGEMENT OF MONUMENTAL SPACES

Germán Pérez-Martínez<sup>1</sup>, Antonio J. Torija<sup>2</sup>, Diego P. Ruiz<sup>1</sup>

<sup>1</sup>Applied Physics Department, Faculty of Sciences, University of Granada, Spain.  
(gperez@ugr.es, druiz@ugr.es)

<sup>2</sup>ISVR, University of Southampton, Highfield Campus, SO17 1BJ Southampton, UK  
ajtorija@ugr.es

## Abstract

This work proposes a two-step methodology for the evaluation and management of the sound quality in historic buildings based on the subjective perception of dominant sounds in these areas. As part of this methodology, an index (named *CD* index) is defined to perform a categorization of the study area, based on soundscape quality areas. To apply the developed methodology, we chose the Alhambra of Granada as case study. The application of this methodology in this historic site shows that different soundscape quality areas can be found in the Alhambra and an area categorization is proposed based on the *CD* index values. It was found that while the presence of agglomerations of people has a very negative impact on the quality of the soundscape, natural sounds are evaluated in a very positive way, being the sounds of water the main contributor for improving the overall sound quality of the Alhambra of Granada.

**Keywords:** soundscape, sound quality assessment, historical buildings, area categorization

**PACS:** 43.50.Rq 43.50.Sr

## 1 Introduction

In monumental spaces occurs a tourist experience where the main activity of the visitors is contemplating, walking, resting and even relaxing along the visit. The beauty is the main attractive of the monumental spaces. In [1] the aesthetic quality was identified as an important dimension in the perception of the surroundings, where the pleasure and beauty represent the most influential dimension in the environmental assessment. However, sound is also one of the essential ways by which we perceive the environment, and may affect the assessment of the general perception. The perception of the environment is multisensory and the soundscape is a part of the sensory aesthetic that is related to how nice the environment is perceived [2]. Consequently, a good quality of the soundscape could achieve a more pleasant sightseeing and improve the overall impression of a complex monumental space.

The context is an important factor in the evaluation of the soundscape, since the preferences of the people toward a particular attribute of the soundscape can vary significantly depending on it [3]. There are many research on soundscapes which have been made in urban areas (parks, squares, etc.) [4], rural spaces [5], natural spaces [6], etc. However, few research has been carried out on the quality of the soundscape in the context of historic buildings. Although they are very specific spaces and



sometimes reduced, they host millions of people a year and it would be a good practice its study and management for the conservation or improvement of their sound aspects.

One of the most characteristic sounds of the historic buildings is the generated by the visitors themselves. On many occasions, due to overcrowding and the crowds that generally occur in these tourist areas, human voices tend to dominate on the other sounds present in that place. In the majority of the researches, human sounds have been evaluated as neutral, for example in [7], and only in some ones are evaluated as pleasant [8]. However, these investigations have been carried out in urban environments and no research has referred to the evaluation of the human sounds in areas with these features where overcrowding of people is generated.

The underlying hypothesis of this work is that the dominant sounds play an important role in the evaluation of the soundscape and they are closely related to the quality of the soundscape. The main objective of this study is to develop a methodology based on the perception of the dominant sounds for the evaluation of the sound quality of monumental sites. As a case study we chose the Alhambra of Granada for its great variety of sounds and spaces.

## 2 Methodology

### 2.1 Description of the study area

The Alhambra in Granada is a monumental complex of great extension with different types of spaces (outdoor, indoor and courtyards) and with different types of sounds that can be included in three categories; natural sounds, human voices and technology sounds. The first two are present in most of the monumental complex, while the third one is present, directly, in a few locations, as is the case of the walled perimeter and some of its towers. The geographical situation and the morphology of the monumental complex make natural barrier for the unwanted sounds from the city, such as the traffic noise in and work noise, etc. The sounds of water are the main feature of the Alhambra, being present in a large part of its extension and in all its forms. The human sounds are also characteristic, since it is one of the most visited tourist destination in Spain.

### 2.2 Selection of locations

By way of a pre-study, several experts conducted exploratory walks around the monument complex and took notes on its sound aspects (individual sounds and temporal evolution) and its spatial aspects (outdoor, courtyards and interiors). These tours had the main objective of collecting the total variety of spatial and sound aspects of the monument complex for the subsequent assessment by visitors. Finally, a total of 19 locations (see table 1) was selected. Then we determined the exact point of the locations where there would make both sound recordings and subjective evaluations, taking into account the following considerations:

- They must be located in the tourist tour and closely located to banks that people could use to sit down to rest and contemplate the sounds in the environment.
- Each point represents the overall sound of its location, i.e. people can heard in a clear way the existing sounds taking care that any sound could not mask completely the other.

Table 1 shows the 19 selected locations and sound and space considerations for selection criteria. In addition, images and a detailed description of the locations can be found on the web page: <http://www.alhambraGranada.info> and <http://www.alhambraGranada.org>.



Table 1 – Locations and considerations for selecting them.

No.	Locations	Area	Type of Space	Traffic	Birds	Water	People
1	Courtyard de la Reja	Nasrid Palaces	Courtyard	Yes	Yes	Fountain	Yes
2	Courtyard de los Leones	Nasrid Palaces	Courtyard	No	Yes	Fountain	Yes
3	Torre del Cubo	Alcazaba	Outdoor Space	Yes	Yes	Water Flowing	No
4	Jardín de los Adarves	Alcazaba	Courtyard	Yes	Yes	Fountain	No
5	Courtyard de Lindaraja	Nasrid Palaces	Courtyard	No	No	Fountain	Yes
6	Partal	Alhambra Alta	Outdoor Space	No	Yes	Water Flowing	Yes
7	Courtyard de la Acequia	Generalife	Courtyard	No	No	Fountain	Yes
8	Jardines de la Medina	Alhambra Alta	Outdoor Space	No	Yes	No	No
9	Jardines Bajos	Generalife	Outdoor Space	No	Yes	Fountain	No
10	Salón de Embajadores	Nasrid Palaces	Indoor Space	No	No	No	Yes
11	Torre de la Vela	Alcazaba	Outdoor Space	Yes	Yes	No	No
12	Entrance to Generalife	Generalife	Outdoor Space	No	Yes	Waterfalls	No
13	Courtyard de la Sultana	Generalife	Courtyard	No	Yes	Fountain	No
14	Cuarto Dorado	Nasrid Palaces	Courtyard	No	No	No	Yes
15	Entrance to la Medina	Alhambra Alta	Outdoor Space	Yes	Yes	No	No
16	Torre de las Infantas	Alhambra Alta	Outdoor Space	No	Yes	Waterfalls	No
17	Jardines Altos	Generalife	Outdoor Space	No	No	Fountain	Yes
18	Sala de Dos Hermanas	Nasrid Palaces	Indoor Space	No	No	Fountain	Yes
19	Las Placetras	Carlos V	Outdoor Space	No	Yes	No	Yes

### 2.3 Evaluation of the soundscapes

A total of 385 people take part in the evaluation of the soundscape of the monumental complex, with a minimum of 20 participants by location. They were all tourists visiting the complex monumental at that time, 171 men and 214 women between 16 and 66 years (mean = 31 years). It was given to them a questionnaire, and they were led to the point where they had to fill it out and were asked to listen the ambient sounds for 30 seconds before starting. Visitors participated on a voluntary basis and received no monetary compensation.

The questionnaire consisted of 4 different parts:

- The first part was referred to the identification of sounds and their individual assessment, where each participant wrote in an open question those sounds they identified at that time and they answered, in an ordinal scale of 5 points, how nice it was each of the sounds identified at the time and current context. In the scale "1" was unpleasant and "5" was nice. They were also asked a question about the dominant sounds: do you consider that there are some dominant sounds in this place? If your answer is "yes", they were asked to say what it was.
- The second part was to assess the quality of the soundscape, the visual environment, the intensity of the perceived sound and the overall impression through a continuous flowsheet scale assessment where the left end was "0" (nothing) and the right end was "10" (a lot).
- The third part consisted in the evaluation of a number of attributes of the soundscape.
- The fourth part was referring to the socio/demographics.

The time slot of the interviews was 10:00 to 12:00, due the flow of visitors in this period can be considered as average. Figure 1 shows the different areas of the Alhambra and the assessment points.

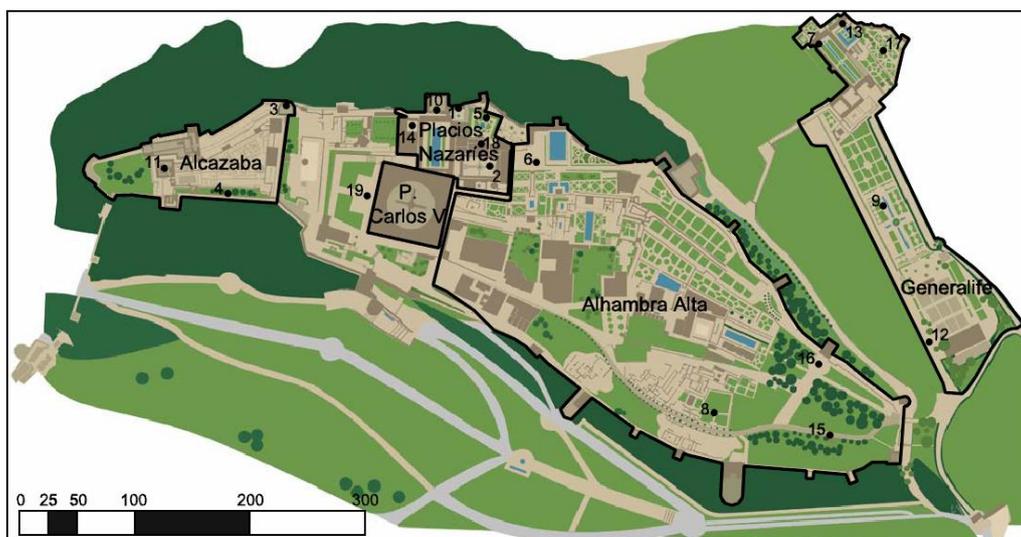


Figure 1 – Areas of the Alhambra and assessment points.

### 3 Results and Discussion

#### 3.1 Identification and sound assesment

Each participant identified the sounds of each place and they assess them. Table 2 show the percentage of surveyed people that identify a particular type of sound in each one of the 19 places and their evaluation. It has been omitted the sounds identified with a relative frequency below than 0.01. For a better understanding, the answers were grouped into: "1 and 2" unpleasant, "3" neutral and "4 and 5" pleasant. It is noted that the human voices, the sounds of the birds and the sounds of water are the most identified sounds, well above the others. The human voices are the most frequently identified, this is due to the cultural nature of the Alhambra, which hosts a lot of visitors each day. The sound of the birds was the second more identified sound, since the forest of the Alhambra that surrounds the walled monument complex and the extensions of landscaped areas are a refuge for many species of birds. The sound of the water takes the third place, due to the richness of water that exists in great part of its extension in all its forms.

The technological sounds such as the urban traffic, air traffic, noise from works, walkie-talkies or photo cameras, were evaluated by a high percentage of respondents as "nasty". The sounds of the people, as the voices and steps were also evaluated by the majority as "nasty", although a high percentage also evaluated them as "neutral". In the case of the natural sounds, all were evaluated as "nice", with the exception of sounds coming from the dogs and the frogs, which were mostly assessed as "nasty" (although the sample size is not considered sufficient to make a categorical affirmation). The sound of water was the best valued of all sounds.

Table 2 – Identification and evaluation of individual sounds in the 19 selected locations.

Type of sound	% participants identifying the sounds	% participants assessing each sound as unpleasant	% participants assessing each sound as neutral	% participants assessing each sound as pleasant
People talking	71.9	52.3	43.7	4.0
Birds	69.6	3.4	30.6	66.0
Water	58.7	3.1	13.3	83.6
Wind	15.1	15.5	19.0	65.5
Steps	14.0	50.0	33.3	16.7
Traffic	10.1	84.6	15.4	0.0
Photo Cameras	7.5	65.5	27.6	6.9
Leaves on the trees	5.5	9.5	28.6	61.9
Cicadas	3.6	14.3	50.0	35.7
Campaigns	3.6	14.3	21.4	64.3
Works	3.1	75.0	25.0	0.0
Aircraft	2.3	77.8	22.2	0.0
Walkie-Talkies	2.1	100.0	0.0	0.0
Frogs	1.8	71.4	14.3	14.3
Dogs	1.8	57.1	42.9	0.0

### 3.2 Dominant sounds.

The participants also identified the dominant sounds of the place, i.e. the sounds that could be heard above the other sounds in that place. Table 3 shows the type of dominant sound and the frequency it is identified. The number of sounds is reduced to 6 types: the wind, the city (traffic and works), cicadas, birds, people and water. "No ident" stands for the frequency with which people did not choose a particular sound as dominant in a given place. This may be due to the difficulty with which some people have to choose a sound dominant when the sound composition is complex. It is noted that, as in table 2, the sounds identified as the most frequently dominant were those coming from water, people and birds.

Table 3 – Percentage of participants identifying each particular sound as dominant for the 19 locations.

Type of sound	% participants identifying each sound as dominant
Water	38.2
People talking	26.2
Birds	24.4
No ident	6.0
Cicadas	2.3
City	1.8
Wind	1.0

In spite of the fact that the sound of people was the most frequently identified by the participants (table 2), the sound of water was identified as dominant (table 3) by a larger number of participants. This suggests that, in general, although the sounds of the people were more present in the whole monument, the sound of water acquired greater importance, becoming noticeable over the other sounds of the place on many occasions, and therefore in the evaluation of the participants. This result opens the hypothesis that the evaluation of the dominant sounds can give reliable results with regard to the evaluation of the quality of the soundscape.



Table 4 – Classification of the dominant sounds by locations

Group	Sound	Locations	N	Quality
A	People	10, 15, 18, 19	80	5,56
B	Water	4, 5, 6, 7, 9, 13, 16, 17	163	7,35
C	Birds	2, 3, 11, 12, 14	101	6,63

With the aim of analyzing the influence of the dominant sounds with regard to the quality of the soundscape, we have classified the different locations according to their percentage of dominant sounds. The classification criterion is selected according to when the percentage in which sounds are identified as dominant by participants is equal to or greater than 50%. Table 4 shows the three groups of dominant sounds (people, water, birds), the locations in which dominate these sounds, the number of the sample and the evaluation of the quality of the soundscape for each group. The locations 1 and 8 had not been able to classify in any group as it did not reach the 50% of dominance in any of its sounds.

### 3.3 Quality of the soundscape as a function of the dominant sounds

A Mann-Whitney U test was used to compare the evaluations of the quality of the soundscape between the dominant groups of sounds (according to table 4). In group A (locations dominated by the sound of the people) score was significantly lower ( $p$ -value  $< 0.001$ ) than in groups B and C (locations dominated by the sound of water and birds respectively), which indicates that the quality of the soundscape worsened in the locations where the sound of the people dominated. Group B had a statistically significant score greater than both Group A ( $p$ -value  $< 0.001$ ) and Group C ( $p$ -value  $< 0.01$ ), which suggests that the quality of the soundscape significantly improved when dominated the sound of the water compared to the other sounds in that place. With regard to Group C, it obtained a statistically significant higher score ( $p$ -value  $< 0.001$ ) than the Group A but a statistically significantly lower score ( $p$ -value  $< 0.01$ ) than Group B, which suggests that when dominated the sound of the birds the score of the quality of the soundscape was acceptable but not better than when the sound of water dominates.

Table 5 – Classification of the locations according to the group of dominant sounds and the type of space.

Group	Space	Location	N	Quality
A	Interior	10, 18	40	5,66
	Outside	15, 19	40	5,46
B	Courtyard	4, 5, 7, 13	81	7,41
	Outside	6, 9, 16, 17	82	7,26
C	Courtyard	2, 14	40	6,10
	Outside	3, 11, 12	61	6,96

Since the evaluation was carried out in three types of spaces (outdoor, courtyards and interiors), we also analyze the quality of the soundscape depending on the type of space, to explore whether or not the type of space affected the perception of the soundscape. To this goal, the different types of space were grouped depending on the type of dominant sound (see table 5). We then perform a Mann-Whitney U test to compare the evaluations of the quality of the soundscapes with the types of spaces



and the type of dominant sound. Results show that when the sound of people dominated there were no statistically significant differences (p-value=0.70) between the type of space (inside and outside), as well as when the sound of water dominated (p-value= 0.64) between the type of space (foreign and courtyard). However, when the sound of birds dominated there were statistically significant differences (p-value = 0.04) between different spaces (exterior and courtyard). This difference could be due to the own typology of birds that lived in this spaces. While the birds with tuneful and soft songs dominated in the outsides, courtyards were dominated by birds (common swift) with a scratchier and high level songs. An example is location 2 (Courtyard of the Lions) that despite its great source of water which is often considered one of the most characteristic and emblematic ornaments, their sound only was identified as dominant by the 5 % of the surveyed, compared to the 95% that considered the sound of swifts dominant. These results suggest that the quality of the soundscape did not depend on the type of space, but only on the type of sound that dominated in each location.

### 3.4 Relationship between the quality of the soundscape and the dominant sounds

The above results suggest that we can establish a relationship between the quality of the perceived soundscape and the dominant sounds. To this goal, an index is created (called *CD*) based on the percentage of the dominant sounds, the subjective evaluation of their pleasantness and the reported loudness. This index was applied to the 19 locations of the Alhambra, thus obtaining a value for each one of them, which it were highly correlated with the assessment of the quality of the soundscape (Pearson  $r = 0.911$ ), which indicates the high reliability of this index. This index is defined as follows:

$$CD = \sum_{i=1}^n \frac{\%d_i}{100} A_i + (M - L) \quad (1)$$

Where  $n$  is the number of pleasant sounds identified as dominant;  $\%d$  is the percentage of identification of each dominant sounds perceived as pleasant (see Table 2);  $A$  is the average rating of the pleasantness for dominant sounds (perceived pleasantness > 3);  $M$  is the central value of the scale used (in this case  $M = 3$ ); and  $L$  is the average reported loudness of the soundscape.

This index will allow us to reduce the number of items from the surveys and reduce the number of participants in future evaluations. Furthermore, it will give us valuable information about the sounds that affect the sound quality in a particular place for their management and conservation.

## 4 Proposal for evaluating the soundscape in historic buildings.

On the basis of the preceding study case of the Alhambra, where the quality of the soundscape depended primarily on the type of sound subjectively dominant, we propose the following methodology for the evaluation and management of the soundscapes in historical environments:

- 1) Exploratory phase: exploratory sound walks by a group of experts to select a representative sample of the monumental complex. It shall select the points of assessment and determine the time of evaluation in terms of the temporal variation of the sounds.
- 2) Evaluation of the locations: a group of experts or trained people identify the individual and dominant sounds in the place, and evaluated them in a scale of pleasantness ( $A$ ) ranging from 1 to 5. It also evaluates the overall perceived loudness ( $L$ ) on a scale of 1 to 5. This will be repeated throughout the sampling period selected, as many times as you get a representative

sample. The evaluation of the pleasantness and reported loudness may be learned from previous assessments, if any.

- 3) Calculation of the percentage of dominant sounds: for each location we should get the percentage of participants that identify a type of dominant sound ( $%d$ ) during the representative period selected.
- 4) Calculate the proposed index, eq. (1): using the parameters obtained in the previous steps ( $A$ ,  $L$  and  $%d$ ) the score of  $CD$  is calculated for each location. The score for this index is between -2 and 7. As an alternative we also propose an abacus for a quick use (see figure 2) for an approximate in-situ assessment. In case of using the abacus,  $%d$  must be rounded to the nearest percentage value and  $A$  must be weighted by the percentage of each dominant sound. Abacus would only be applicable if there is only one type of pleasant sound, or several pleasant sounds with a similar  $A$  score. The use of the abacus will be as follows. Imagine you has done a sampling measure in a preset time and place, and you has obtained that a 78% of the dominant sounds belong to natural sounds (e.g. water and birds), both with a score of  $A=4$ , and the 22% belong to unnatural sounds (e.g. people and traffic) with a score of  $A=2.5$  and  $2.2$  respectively. The overall perceived loudness is  $L = 3.2$ . To use the abacus, round up the percentage of pleasant sounds (with  $A > 3$ ) to the nearest integer, i.e.  $%d = 80$  and with the corresponding line in the abacus we look for the point that cuts  $A = 4$  with  $L = 3.2$ . The result obtained with the abacus is  $CD = 3$ , and the result applying the formula would be  $CD = 2.94$ .
- 5) Once the  $CD$  index is calculated, we propose the following categorization: locations are considered with a sound quality acceptable when they are between category 1 and 2. Category 1:  $CD > 4$ . High quality soundscape. Category 2:  $2.5 < CD < 4$ . Medium soundscape quality. Category 3:  $1 < CD < 2.5$ . Category 4:  $-2 < CD < 1$ .

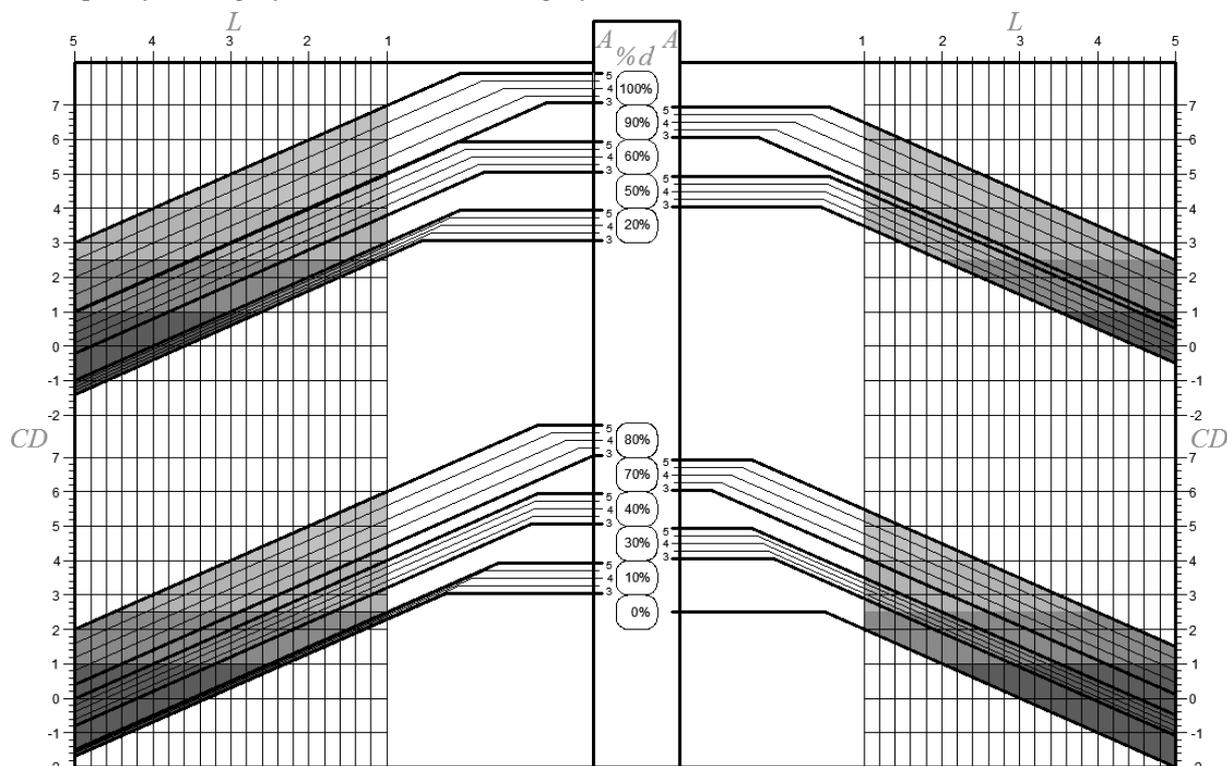


Figure 2 – Abacus for quick assessment of the quality of the soundscape



## 5 Conclusions

In this paper we have chosen the Alhambra of Granada as a case study representative of the great diversity of sound sources and spaces (outsides, courtyards and interiors) existing in historic buildings. After an exploratory phase, we selected 19 locations and carried out an analysis of the individual and dominant sounds. Results show that the dominant sounds were decisive items in the assessment of the soundscape and they are closely related to the quality of the soundscape. Based on these results, we propose an index (named *CD*) that allows us to reduce the field work in the subjective assessments (lowering the number of evaluated sounds, the number of questionnaires and the number of participants needed), thus providing a more quick assessment for future evaluations. Based on the proposed index, this work suggests a methodology for the evaluation of the quality of the soundscape of historic buildings. This methodology also provides important information about the sounds that affect the soundscape and gives a technical guidance for the management of the soundscape of historic buildings with the aid of their enhancement and conservation.

In relation to the results obtained from the analysis in the Alhambra in Granada, we determine the following:

- The presence of crowds of people had a negative impact. When the sound of the people was identified as dominant by more than 50 per cent of surveyed person, the quality of soundscape declined significantly.
- Natural sounds were evaluated in a very positive way, being the sounds of water those which most notably improved the overall quality of the soundscape.
- It cannot be said that the spatial characteristics have a direct influence on the assessment of the soundscape. The assessment of each space is given by their own sound characteristics, essentially determined by the type of sound that dominates in that space.

## Acknowledgements

This work was supported by the "Ministerio de Economía y Competitividad" of Spain under projects TEC2012-38883-C02-02 and TIN2015-64776-C3-1-R and by the BioTic Granada Campus under project P\_CP\_27. It is also acknowledged the financial support of the "Ministerio de Educación" of Spain for the PFU grant awarded to Germán Pérez Martínez.

## References

- [1] R. Kaplan, S. Kaplan, *The Experience of Nature. A Psychological Perspective*, 1989.
- [2] J. Lang, Symbolic aesthetics in architecture: toward a research agenda, *Environ. Aesthet. Theory, Res. Appl.* (1988) 45–55.
- [3] A.L. Brown, J. Kang, T. Gjestland, Towards standardization in soundscape preference assessment, *Appl. Acoust.* 72 (2011) 387–392.
- [4] J. Liu, J. Kang, H. Behm, T. Luo, Effects of landscape on soundscape perception: Soundwalks in city parks, *Landsc. Urban Plan.* 123 (2014) 30–40.
- [5] P.J. Lee, J.Y. Hong, J.Y. Jeon, Assessment of rural soundscapes with high-speed train noise., *Sci. Total Environ.*
- [6] N.P. Miller, US National Parks and management of park soundscapes: A review, *Appl. Acoust.* 69 (2008) 77–92.

- [7] M.E. Nilsson, B. Berglund, Soundscape quality in suburban green areas and city parks, *Acta Acust. United with Acust.* 92 (2006) 903–911.
- [8] B. Szeremeta, P.H.T. Zannin, Analysis and evaluation of soundscapes in public parks through interviews and measurement of noise, *Sci. Total Environ.* 407 (2009) 6143–6149.