Managing and designing soundscape experiences in nature: the influence of humans in natural sound sources (biophony)

IGLESIAS-MERCHAN, Carlos[1]; ORTIZ-URBINA, Esther[2]; EZQUERRO, Marta[3]; DIAZ-BALTEIRO, Luis[4]

[1,2,3,4] Department of Engineering and Forest and Environmental Management, Universidad Politécnica de Madrid
C. José Antonio Novais 10, 28040 Madrid, Spain

ABSTRACT

International standards define soundscape as the acoustic environment perceived or experienced by a person or people. Meanwhile, the acoustic environment is the sound from all sources (natural sources or not) around a receiver. Therefore, the probability of wildlife presence within a natural area, for instance, may determine the soundscape experience of visitors in national parks. This fact becomes a challenge when human presence, or anthropogenic noises, not only mask the sounds of biophony but may scare away some animal's species for long periods of time and large areas.

Noise modelling tools are well known for assessing and managing environmental noise pollution in both urban and natural ecosystems. However the potential effects of noise on natural sources of the acoustic environment may not be just a matter of decibel predictions.

We have assessed the influence of road traffic noise in a bird species area distribution by approaching wildlife maximum-entropy modelling methods in combination with road traffic noise mapping. Results may assist parks managers in predicting the spatial distribution of natural sound sources and designing soundwalks in nature. This information could be of valuable help to guide visitors regarding the probability of enjoying an ecological soundscape experience when visiting natural areas.

Keywords: National Park, Soundwalk, Wildlife
I-INCE Classification of Subject Number: 65, 68

[1] carlos.iglesias@upm.es

[2] e.ortizdeurbina@upm.es

[3] marta.ezquerro@upm.es

[4] luis.diaz.balteiro@upm.es

1. INTRODUCTION

Soundscape studies based on different procedures, measurements and approaches are being increasingly performed all over the World during the last decade [1]. At the same time, recent research reveals that one of the reasons to visit national parks is the expectation of living an experience of contact with nature. In this sense, visitors explore a wild place where the sounds of nature are expected to be listened and enjoyed [2]. However, the expectations of visitors in protected natural areas may be limited because of the massive presence of the public. When this is the case, they suddenly realize loud voices, horns, ringing phones, etc. and, above all, a noisy intrusion due to motor vehicles. Therefore, it is not surprising that human-caused noise can detract from the quality of the visitor experience in national parks [3].

The private vehicle is the main mode of transportation to access to national parks. In addition, many of them are crossed by roads that support passing traffic, which means that they do not necessarily stop at the park. Indeed, noise pollution from transport infrastructures represents an increasingly challenging environmental problem in sensitive areas [4, 5, 6].

Anthropogenic noise intrusion is often the main object of attention in soundscape research and an extensive list of indices, tools and methods allow to quantify noise pollution over a natural acoustic environment. As well as the potential effects of human-made noises on behavioural animal responses [7, 8, 9]. In contrast, few research have been done in terms of lost opportunities to enjoy a valuable soundscape experience because of the degradation of natural soundscapes due to the absence of significant animal species which may be sensitive to anthropogenic noise.

For instance, Cinereous vulture (*Aegypius monachus*) has been defined as a sensitive species to noise pollution. Previous studies [7] reveal that road surrounding areas exposed to equivalent continuous sound pressure level (Leq$_{24h}$) higher than 40 dB(A) may be considered not suitable habitat, or excluded areas, for Cinereous vulture nesting. The Cinereous vulture may be considered a flagship species of the European fauna, or an umbrella species, which should condition land management of large territories at the landscape scale [10].

The Cinereous vulture is the largest bird of prey and their nests are frequently located in mature trees. It is certainly not a singing species but may be used as indicator of important accompanying more influent wildlife species in terms of their stamp on the acoustic environment and its related potential to be experienced by nature-based tourists. Therefore, Cinereous vulture seems to be appropriate as indicator species for monitoring environment-friendly management of natural areas. In Ecology, there are tools and consolidated methods frequently used to estimate the potential distribution area of a species, and its probability of presence, depending on the characteristics of the environment. These tools, in combination with noise modeling procedures, could in turn also be used to assess and manage the quality of natural soundscapes to offer, for instance, an appropriate soundscape experience to national park visitors.

2. MANUSCRIPT FORMAT
2.1 Study Area

The present study took place in Valsaín forest, which is located in the Central Mountains of Spain (Fig. 1), in the municipality of Real Sitio de San Ildefonso (province of Segovia). The forest belongs to the State and is subject to the jurisdiction of Sierra de Guadarrama National Park. The main tree species is Scots pine (*Pinus sylvestris*), that covers about 7,500 ha on this area. One of the most important European breeding colonies of Cinereous vulture is located within this forest and, currently, approximately 131 nests have been inventoried within the Scots pine trees. The study area is crossed by two regional roads (road CL-601 and road SG-615). Average daily traffic data is approximately 5,000 vehicles in road CL-601 and 650 vehicles in road SG-615.

2.2 Noise Mapping and Potential Habitat Prediction of Endangered Species

On the one hand, a road traffic noise map was calculated within the study area (Fig. 1) following the French national computation method referred to in the French standard "XPS 31-133". Digital elevation model was based on the official 1:25,000 scale topographic digital maps (10 m contour lines) from the National Geographic Institute (Instituto Geográfico Nacional). Road traffic speed and traffic density were obtained from official publications of the Road and Transport Department of the Regional Government of Castile and León (Junta de Castilla y León). The Computer Aided Noise Abatement software (CadnaA Version 2018 MR 1, 32-bit) was used to produce the road traffic noise map.

On the other hand, wildlife species distribution models are widely used for many purposes in biogeography, conservation biology and ecology. This models frequently estimate the relationship between species records at sites and the environmental and spatial characteristics of those sites [11]. Among available tools, the maximum entropy approach is one of the most widely used for predicting species distributions and it is currently available in the software *MaxEnt* [12]. Cinereous vulture is a flagship species which may be relatively easily inventoried. Therefore we used *MaxEnt* to predict potential nesting habitat of Cinereous vulture based on current nest locations (official data provided by the forest managers) within the study area. The road noise map was included as input data together with vegetation, terrain slope, slope aspect, altitude and distance to trails and unpaved roads obtained from the official cartography.

3. RESULTS
### 3.1 Cinereous Vulture Exclusion-Areas

Noise maps revealed that the exclusion area for Cinereous vulture nesting occupied approximately 645 ha within the Scots pine forest. However, this only means that the rest of the forest (approximately 6855 ha) are few or not enough disturbed by road traffic noise. According to the above mentioned sound pressure level threshold to define the Cinereous vulture nesting potential area. However, this is not such valuable information in terms of habitats' soundscape management. Indeed, this complete surface area may not be able to offer the actual listening experience of a particular natural habitat type, e.g. the Cinereous vulture nesting habitat which is considered of high quality in this study case.
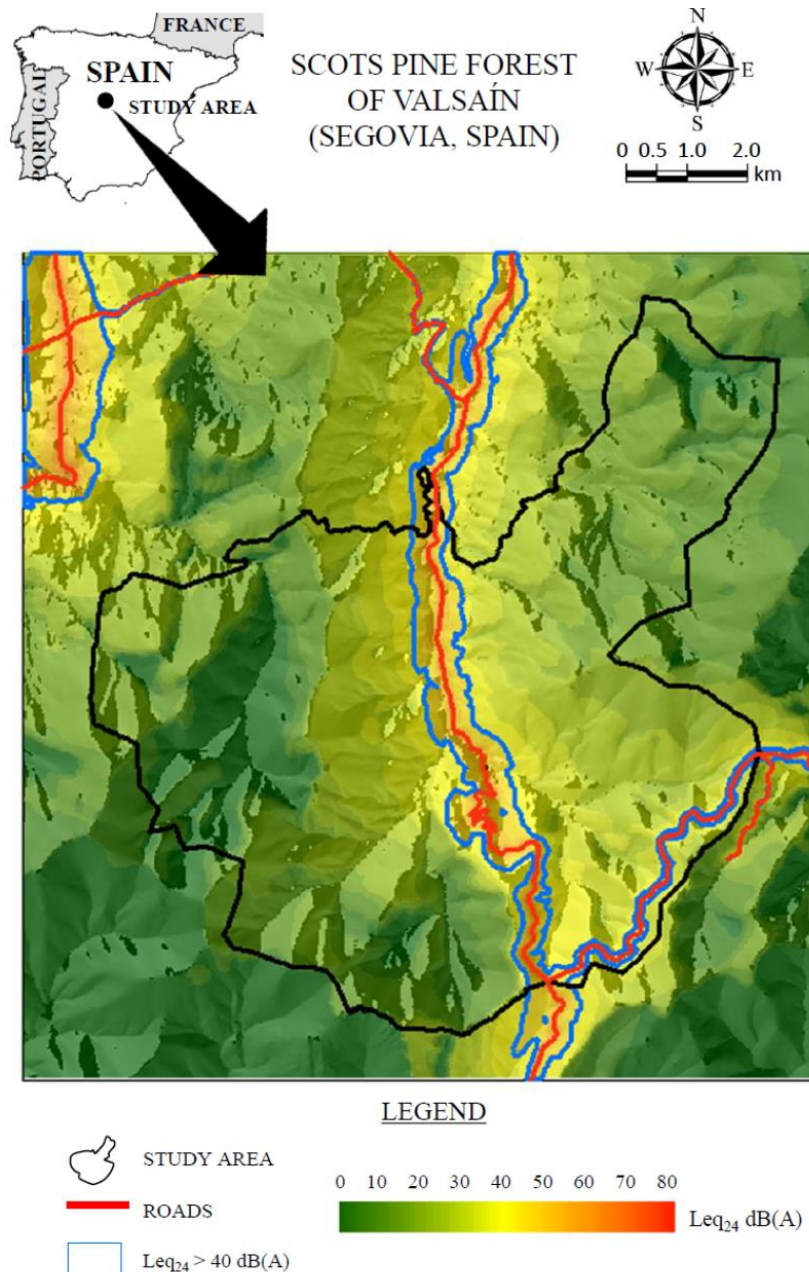
Figure 1. *Study area location and road traffic noise map*

3.2 The Cinereous Vulture Habitat Soundscape Experience

MaxEnt results allowed us to locate and quantify the actual potential nesting habitat of Cinereous vulture taking into account noise pollution due to road traffic within the study area (Fig. 2). We found that only 19,5 % of the Scots pine forest offer a probability of presence higher than 0.7 (Table 1). Which means that less than 20 % of the surface area within the forest (a successful protected area for the threatened species reproduction) offer a real opportunity to experience the more appropriate acoustic environment by a combination of both natural and anthropogenic variables. For this purpose, only continuous surfaces higher than 100 ha were plotted in order to be considered as susceptible of management for visitors searching for an experience of high potential quality acoustic environment.
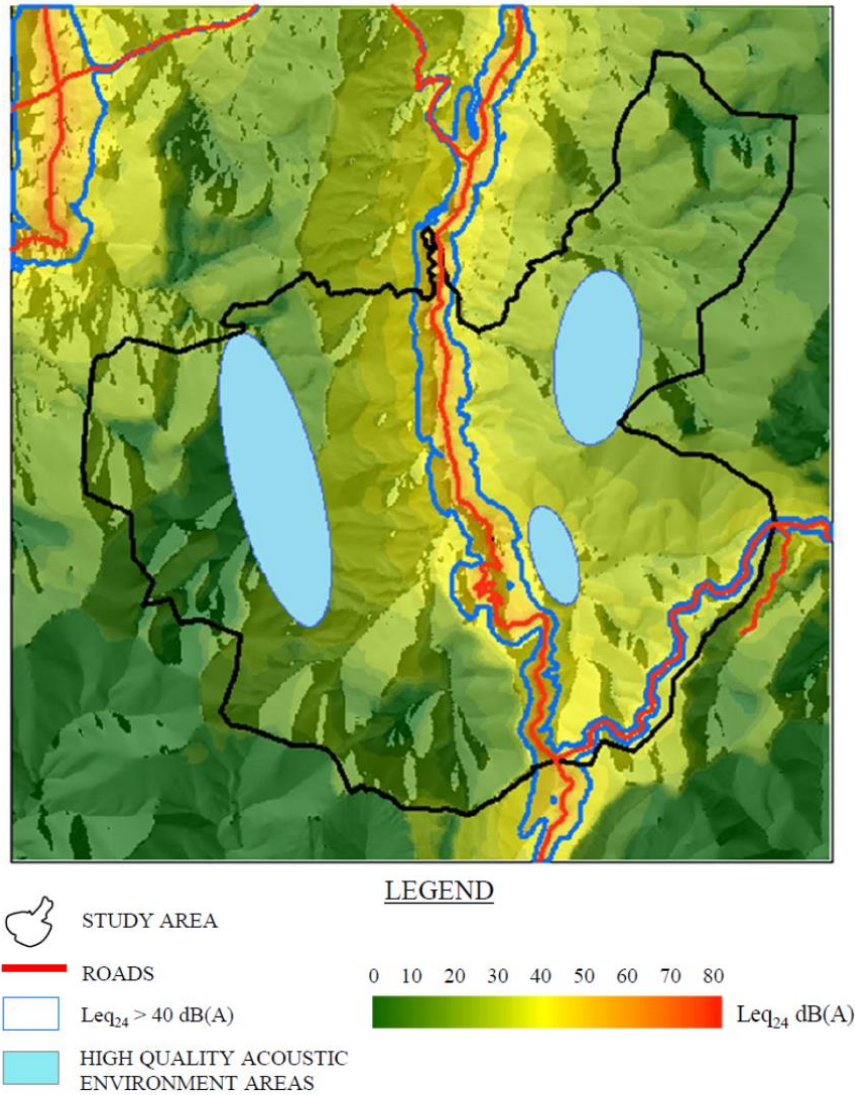
Figure 2. *Quantification of high quality acoustic environment areas in order to manage the soundscape experience within Cinereous vulture nesting habitat (Note: Polygons appear displaced for security reasons)*

Table 1. *Patches of probability of presence of Cinereous vulture nests within the Scots pine forest*

Probability of presence	Area (ha)	Area (%)
0.0 – 0.1	1056	13.9
0.1 – 0.2	892	11.7
0.2 – 0.3	800	10.5
0.3 – 0.4	930	12.2
0.4 – 0.5	915	12.0
0.5 – 0.6	808	10.6
0.6 – 0.7	724	9.5
0.7 – 0.8	640	8.4
0.8 – 0.9	550	7.2
0.9 – 1.0	295	3.9

4. CONCLUSIONS

A growing research body has documented that quietness, solitude, and natural sounds are factors that define the quality of visitor experiences in national parks [3 Nevertheless, multiple methods and tools are applied to study and research the perception of acoustic environments by people. Although several methods are frequently applied and the ISO technical specification ISO/TS 12913-2 has been recently released, new methods and tools for exploring further how humans perceive and try to manage their acoustic environments should not be prevented of development [13].

On the other hand, scientific productivity concerning the potential impact of anthropogenic noise on wildlife is just as, if no more, abundant. In this sense, the influence of visitors could negatively impact on sensitive habitats and species. However, this is part of the conflicting interests in day to day management of national parks (i.e. the conservation of nature and the promotion of these places as recreational spaces) [14]. Nevertheless, guiding visitors to high quality natural soundscapes may also be a way to encourage them to listen discriminately and to make critical judgments about the sounds heard and their contribution to the balance or imbalance of the acoustic environment [15]. It is obvious that park managers have to evaluate the opportunity to use each natural resource in accordance with the aims of the protected area.

In this particular case, the opportunity could be given by the fact that the same couple of vultures uses a single nest each year [16]. However, the number of nests used over time by the same pair is variable and the total number of nest sites have defined the potential nesting habitat where a particular soundscape condition may be expected according to models. Nevertheless, these scenarios should be conveniently monitored [17].

In conclusion, maximum-entropy models combined with noise mapping can accurately manage sensible habitats as well as guide visitors for high quality experiences through a natural resource of particular interest (i.e. the biophony o geophony associated to this species habitat). Obviously, without avoiding to minimize associated negative impacts on protected area resources [18].

5. ACKNOWLEDGEMENTS

6. REFERENCES

1. Genuit, K., & Fiebig, A. (2014). The measurement of soundscapes-Is it standardizable?. In Inter-Noise and Noise-Con Congress and Conference Proceedings

(Vol. 249, No. 4, pp. 3502-3510). Institute of Noise Control Engineering. Melbourne, Australia.

2. Jensen, M., & Thompson, H. (2004). Natural soundscapes in the national park system. In The George Wright Forum (Vol. 21, No. 1, pp. 14-17). George Wright Society.

3. Pilcher, E. J., Newman, P., & Manning, R. E. (2009). Understanding and managing experiential aspects of soundscapes at Muir Woods National Monument. Environmental Management, 43(3), 425.

4. Dumyahn, S.L., & Pijanowski, B.C. (2011). Beyond noise mitigation: managing soundscapes as common-pool resources. Landscape Ecology, 26, 1311–1326.

5. Mace, B.L., Corser, G.C., Zitting, L., & Denison J. (2013). Effects of overflights on the national park experience. Journal of Environmental Psychology 35, 30-39.

6. Miller, N.P. (2008). US National Parks and management of park soundscapes: A review. Applied Acoustics, 69(2), 77–92.

7. Iglesias-Merchan, C., Diaz-Balteiro, L., & de la Puente, J. (2016). Road traffic noise impact assessment in a breeding colony on cinereous vultures (Aegypius monachus) in Spain. The Journal on the Acoustical Society on America, 139(3), 1124-1131.

8. Iglesias-Merchan, C., Horcajada-Sánchez, F., Diaz-Balteiro, L., Escribano-Ávila, G., Lara-Romero, C., Virgós, E., Planillo, A., & Barja, I. (2018). A new large-scale index (AcED) for assessing traffic noise disturbance on wildlife: stress response in a roe deer (Capreolus capreolus) population. Environmental monitoring and assessment, 190(4), 185.

9. Martínez-Marivela, I., Morales, M. B., Iglesias-Merchan, C., Delgado, M. P., Tarjuelo, R., & Traba, J. (2018). Traffic noise pollution does not influence habitat selection in the endangered Little Bustard. Ardeola, 65(2), 261-270.

10. González Ávila, S., & Rosselló, E. (2009). Patrón ecológico de los paisajes de las áreas de distribución del buitre negro (Aegypius monachus L.) en España. Spanish Forest Congress. Ávila, Spain.

11. Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E., & Yates, C. J. (2011). A statistical explanation of MaxEnt for ecologists. Diversity and distributions, 17(1), 43-57.

12. Morales, N. S., Fernández, I. C., & Baca-González, V. (2017). MaxEnt's parameter configuration and small samples: are we paying attention to recommendations? A systematic review. PeerJ, 5, e3093.

13. André Fiebig. (2018). Does it make a difference to have soundscape standards? Euronoise 2018 Conference. Heraklion - Crete, Greece.

14. Benfield, J. A., Bell, P. A., Troup, L. J., & Soderstrom, N. C. (2010). Aesthetic and affective effects of vocal and traffic noise on natural landscape assessment. Journal of environmental psychology, 30(1), 103-111.

15. Adams, M. D., Bruce, N. S., Davies, W. J., Cain, R., Jennings, P., Carlyle, A., Cusack, P., Hume, K., & Plack, C. (2008). Soundwalking as a methodology for understanding soundscapes.

16. de la Puente, J. (2007). Capítulo 3 Gestión del hábitat del buitre negro. In: Moreno-Opo, R. y Guil, F.(Coords.). Manual de gestión del hábitat y de las poblaciones de

buitre negro en España. Dirección General para la Biodiversidad. Ministerio de Medio Ambiente. Madrid.

17. Leung, Y. F. (2012). Recreation ecology research in East Asia's protected areas: Redefining impacts?. Journal for Nature Conservation, 20(6), 349-356.

18. Marion, J. L., & Reid, S. E. (2007). Minimising visitor impacts to protected areas: The efficacy of low impact education programmes. Journal of sustainable tourism, 15(1), 5-27.