

SOUNDWALK IN PAKLENICA NATIONAL PARK, CROATIA

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Abstract

Sounds significantly affect our experience of natural environments and presence of people changes the acoustic environment, creating an interactive system driven largely by human perception. This study explores soundscape in the Paklenica National Park (PNP). A soundwalk was conducted in Velika Paklenica canyon during a peak tourist weekend. The soundwalk route connected two educational trails, cultural heritage sites (two historical mills), viewpoints, historical filming locations, an underground interpretation centre, UNESCO-protected primeval beech forest and a world-famous mountain climbing site. The soundwalk with 20 participants applied ISO 12913 standard for the evaluation of acoustic environment in a natural setting along the trail with seven evaluation spots. The participants were invited from three key groups of stakeholders: 1. planning, design and research experts (architects, urban planners, acousticians, natural scientists); 2. local experts (residents and PNP staff); 3. tourists. The study reveals the perception of cultural heritage in a touristic attractive location (dominated by human sounds) and locations dominated by natural heritage (without human sounds). The results contribute towards enhancing management and planning of national parks as well as protecting natural and cultural heritage.

Keywords: soundscape questionnaire, Velebit, cultural heritage, overtourism

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1. Introduction

The acoustic environment plays a fundamental role in shaping visitors' experiences of natural and cultural sites. Within the soundscape framework defined by the ISO 12913 series, soundscape is understood as the acoustic environment as perceived, experienced and/or understood by people in context, highlighting the importance of human perception in assessing environmental quality in a context-dependent way. The type of a setting is a major physical non-acoustic factor shaping human perception of acoustic environments [1]. As visitor numbers continue to increase in many protected areas due to overtourism, human presence itself becomes a significant contributor to the acoustic environment, influencing both the sounds that are produced and how the environment is perceived. Understanding these interactions is therefore essential for supporting sustainable visitor management and preserving the experiential quality of natural landscapes.

1.1 Protected natural areas and tourism

Natural protected areas, designated to conserve biodiversity, ecosystem services, and natural / cultural heritage, often are also tourist attractions. While tourism can provide benefits, such as financial support for conservation, economic development for local communities, and environmental education, it also introduces anthropogenic pressures, such as wildlife disturbance, habitat degradation, pollution and waste generation. These opposed effects highlight the need for integrative and adaptive planning and sustainable tourism management [2], [3] in which soundscapes influence ecological processes, visitor experience, well-being, and conservation outcomes. Utilizing soundscapes in active nature protection, visitor-

management frameworks, sustainable tourism promotions, including acoustic mapping and monitoring, quiet-area zoning, visitor and community engagement [4], [5], [6] is still an emerging field of research and practice.

1.2 Natural and cultural heritage in protected natural areas from the soundscape perspective

While natural protected areas, such as national parks, are well known for their natural beauty and values, they often feature various cultural heritage manifestations (tangible and intangible heritage, sites and artefacts, etc.). A study by Oberman et al. [7] has shown that in natural areas, the perceived overall visual landscape quality contributes to acoustic environments being perceived as more pleasant. Moreover, the visitors attracted to cultural heritage [8] and natural heritage [7] find the dominance of human sounds to be annoying. However, the influence of the presence of cultural heritage within natural protected areas on the overall perceived visual landscape quality and soundscape is still underexplored. Existing studies have investigated audio-visual interactions in protected areas [9], [10] highlighting the interrelationship between visual and acoustic characteristics that shape visitors' perceptions within protected areas. Yet further research is needed to explore how specific components and cultural heritage features contribute to the integrated experience. Moreover, a study by Yang and Liu [11] showed that visual landscape and soundscape influence place attachment, suggesting that understanding how cultural heritage shapes soundscape perception may provide further insight into how sensory experiences form meaningful and engaging connections with protected areas.

This research is a part of ongoing doctoral research on quiet areas within a wider interdisciplinary research context of MYspace project and the *Silenzi in Quota* initiative. Croatia has eight National parks and eleven Nature parks. Velebit mountain range is protected Nature Park and includes two National Parks, one of which, the Paklenica National Park (PNP) was selected for the first soundwalk route within the MYspace project.

This study investigates the soundscape of the canyon of Velika Paklenica creek in PNP, Croatia, through an *in situ* soundwalk conducted during the peak tourist weekend of 1 May 2026, with the aim of examining the perception of active touristic sites (dominated by human sounds).

2. Methodology

The focus of this paper is on developing and applying *in situ* soundwalk method in the Croatian context. The objectives of the soundwalk study were following: i. to establish and strengthen soundscape research group at the University of Zagreb; ii. to conduct a soundwalk in PNP, Velebit, Croatia with interdisciplinary participants; iii. to evaluate perception of soundscape in PNP through a soundwalk questionnaire (based on ISO 12913) and a workshop.

2.1 Easy study site

Velika Paklenica canyon is an area of exceptional geomorphological value on southern slopes of Velebit mountain (protected as UNESCO Biosphere Reserve and Croatian Natural Park) belonging to the karst mountain range of Dinaric Alps (Dinarides). The significant natural value of the Velika Paklenica area includes the largest and best-preserved forest complex in Dalmatia, which is also recognised by UNESCO as World Heritage of Ancient and Primeval Beech Forests (Suva Draga - Klimenta). PNP as part of the Ecological Network Natura 2000, is an area significant for species and habitat types. PNP attracts between 100,000 and 150,000 visitors annually. The 14.5 km long and 400 m deep canyon of Velika Paklenica is also recognised climbing centre with around 600 various climbing routes (the famous climbing wall of Anića Kuk) [12]. Overall, PNP is popular even beyond boundaries of Croatia and therefore prone to overtourism. The soundwalk route in PNP, with carefully selected seven listening stops (Table 1. with selection criteria described in 2.2. section), is a linear ascending hike connecting two educational trails (Pjeskarica and Paklenica Trail), cultural heritage sites (two historical mills), viewpoints, historical filming locations, an underground interpretation centre, climbing sites, and UNESCO-protected primeval beech forest.

2.2 Criteria for Listening Stops Selection

The selection criteria for listening stops were diverse landscape characteristics of the area along the Velika Paklenica canyon; locations of cultural heritage and tourist attractive areas; limiting the number of stops to maximum of seven (7) due to duration of the walk with group of people.

The initial criteria in identifying the listening stops in PNP was analysing and identifying areas of different landscape characters along the route. The analysis consisted of mapping the route and the existing content (activities, uses and structures) along the route. These main diversity criteria identified walking parts along the Velika Paklenica stream, infrastructure areas (such as PNP entrance, visitor centre and Lugarnica restaurant), uphill part of canyon, and UNESCO protected forest.

The final check in selecting the listening stops was establishing the exact location during the field research in March 2026 and after consulting the "Paklenica National Park" Public Institution for confirming the compliance of the selected listening stops (Table 1) with the nature protection conditions.



Table 1. Overview of the listening stops along the soundwalk route in PNP.

Listening stop	Main site characteristic	View of each listening stop
1. National Park entrance	Area of tourist / user interest (Pjeskarica trail)	
2. Visitor centre - Underground City of Paklenica	Area of tourist / user interest (public space & amenities area)	
3. Bridge over Paklenica creek	Natural heritage feature	
4. Viewpoint within the Paklenica cliffs	Iconic view of Velika Paklenica canyon	
5. Marko's watermill	Cultural heritage feature	
6. Forest House Lugarnica	Area of tourist / user interest (restaurant)	
7. UNESCO-protected primeval beech forest	Natural heritage feature	

2.3 Soundwalk participants

The participants were invited from three key groups of stakeholders; a) built and natural environment professionals (such as architects, urban planners, acousticians, natural scientists); b) local experts (residents and PNP staff); c) tourists (PNP visitors). The call for the participation was sent via *Silenzi in Quota* and PNP websites and other online news as well as through e-mail invitations. 20 adults between 20 and 70 years old participated in the soundwalk on May 1, 2026 (11 female and 9 male).

2.4 Soundwalk procedure and questionnaire

The soundwalk was conducted following recommendations from the ISO/TS 12913-s: 2018 [13] and the practice established by *Silenzi in Quota* [7] along the seven listening stops.

Questionnaires were deployed in paper form. Binaural measurements were conducted using the head worn calibrated binaural kit (BHS II with SQobold by HEAD acoustics GmbH) worn by the operator and a head and torso simulator (BSU with SQobold) at a height of $1.6 \text{ m} \pm 0.1 \text{ m}$.

All the participants walked along the predetermined route following the guide and the research team. At each of the seven stops, the research team would choose the view for the group to look at during the assessment. The participants would then listen to the acoustic environment for three minutes (during which acoustic measurements, audio and video recordings were made) upon which the research team would invite them to fill in the questionnaire.

The questionnaire had three parts. First the general questions about the participant and their reasons for visiting the site with the evaluation of their expectations regarding the hiking route and its benefits. The second part were evaluation questions on the topics of soundscape (according to ISO standards) and natural / cultural heritage. This part was the same for every evaluation listening spot (1-7) with the possibility of freely adding any comments regarding the audio-visual relation at each stop. The third and final part of the survey came after evaluating the last listening stop, where the participants again answered the questions regarding their initial expectation to check how much they learned and how was their overall experience. The 18 participants used questionnaire forms in Croatian, 2 used forms in English. The second part of questionnaire for the listening stops included the following question: "To what extent do you notice human-made features (e.g. paths, buildings, monuments, information boards)? to better understand the perception of the present elements of cultural heritage in the observed environment."

2.5 Workshop

On the second day, the research team met the participants in the lecture hall provided by the "Paklenica National Park" Public Institution. Following the educative introductory talks by the local bioacoustics' expert, soundscape research team and environmental noise consultancy, four breakout groups were formed to share experiences from the soundwalk, remembering its most memorable parts and discuss how this experience combined with their individual and local knowledge can inform future soundscape planning in a natural protected area.

The workshop was structured around five topics: 1) an ice breaker-type question about participants' preferences about everyday sounds (tell us about your preferred everyday sound), 2) recalling sounds observed during the soundwalk and drawing them as a map, 3) recalling cultural heritage features observed during the soundwalk and drawing them as a second map, 4)

discussing a potential of sound to be cultural heritage, 5) exit-type question about recalling an iconic sound participants may have experienced before. Three groups discussed in Croatian, while one group was international and organised in English. The workshop results were transcribed manually, maps were scanned.

2.6 Data analysis

In this paper, we present only initial results and analysis, focused on the soundwalk questionnaire. The software packages used for analysis were TIBCO Statistica™ (version 14.0.0.) and Soundscapy™ (version 0.8.5) [14]. Non-parametric Kruskal-Wallis test (K-Wt) and accompanying multiple comparisons post-hoc tests were applied for comparing differences in measured parameters among seven listening stops.

3. Soundwalk results

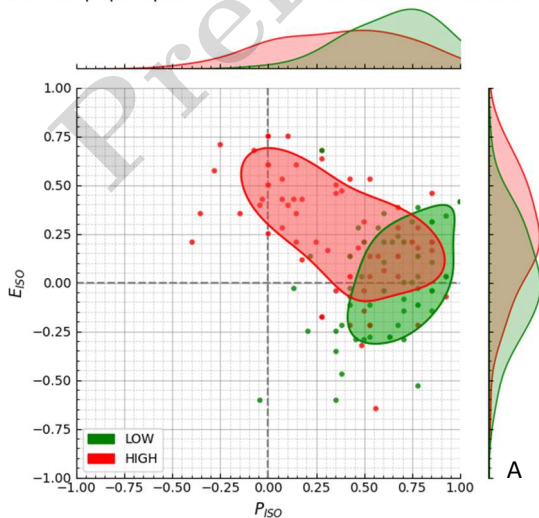
The results presented in this paper are focused on differences in the perception between the listening stops and the influence of human and natural sounds on the perceptual outcomes. All other results and insights based on the soundwalk and workshop data will be a topic of future publications.

140 data points were collected and there was no invalid questionnaire inputs detected.

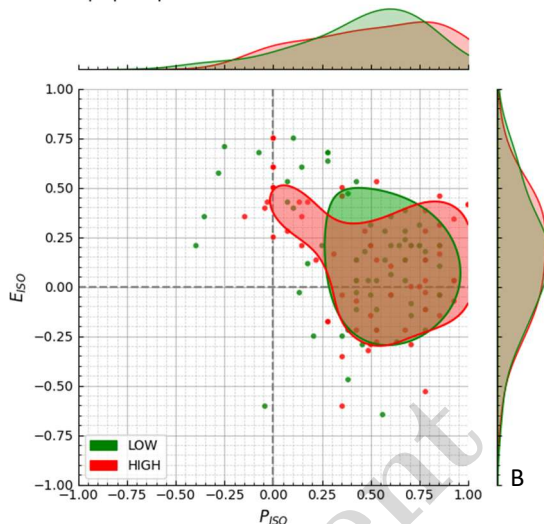
3.1 Sound source dominance

The results presented as scatterplots with 50th percentile contours on Fig. 1 show groups of perceived low (a little or not at all) and high (completely, a lot, or moderately) dominance of human sounds (Fig. 1A), animal sounds (Fig. 1B), wind noise (Fig. 1C), and flowing water sound (Fig. 1D) by taking into account all the listening stops and participants responses. Results shown in Fig. 1a confirmed our expectations that a high dominance of human sounds in PNP leads to perceptual outcomes spread over vibrant and partially chaotic quadrants, not reaching the calm quadrant, in line with [7]. As expected, high dominance of the natural sounds of animals, wind and water was associated with perceptual outcomes in calm and vibrant quadrants, characterised by high soundscape pleasantness.

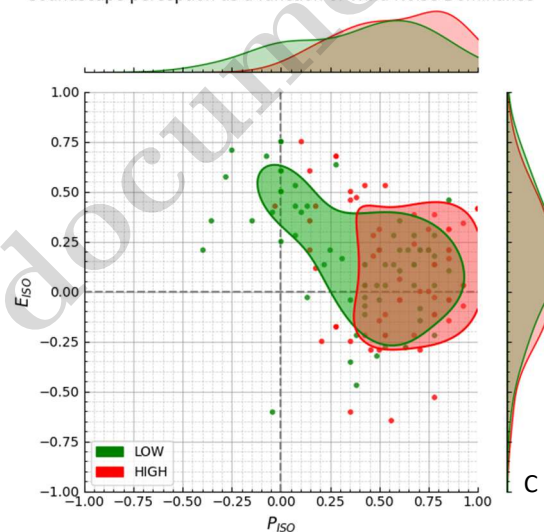
Soundscape perception as a function of Human Sound Dominance



Soundscape perception as a function of Animal Sound Dominance



Soundscape perception as a function of Wind Noise Dominance



Soundscape perception as a function of Flowing Water Sound Dominance

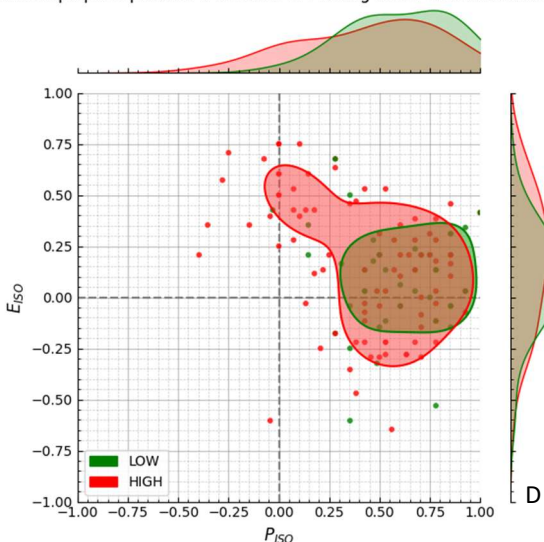


Figure 1. Comparison of soundscapes based on the dominance of (A) human sounds, (B) animal sounds, (C) wind noise, (D) flowing water sound

3.2 Perceived acoustic and visual quality

Here we explore the range of perceived acoustic and visual quality measurements along the seven listening stops. At this stage, limited to pleasantness and eventfulness for soundscape, perceived presence human made feature as a proxy for perceived presence of listed buildings and other material cultural heritage assets, as a visual quality characteristic.

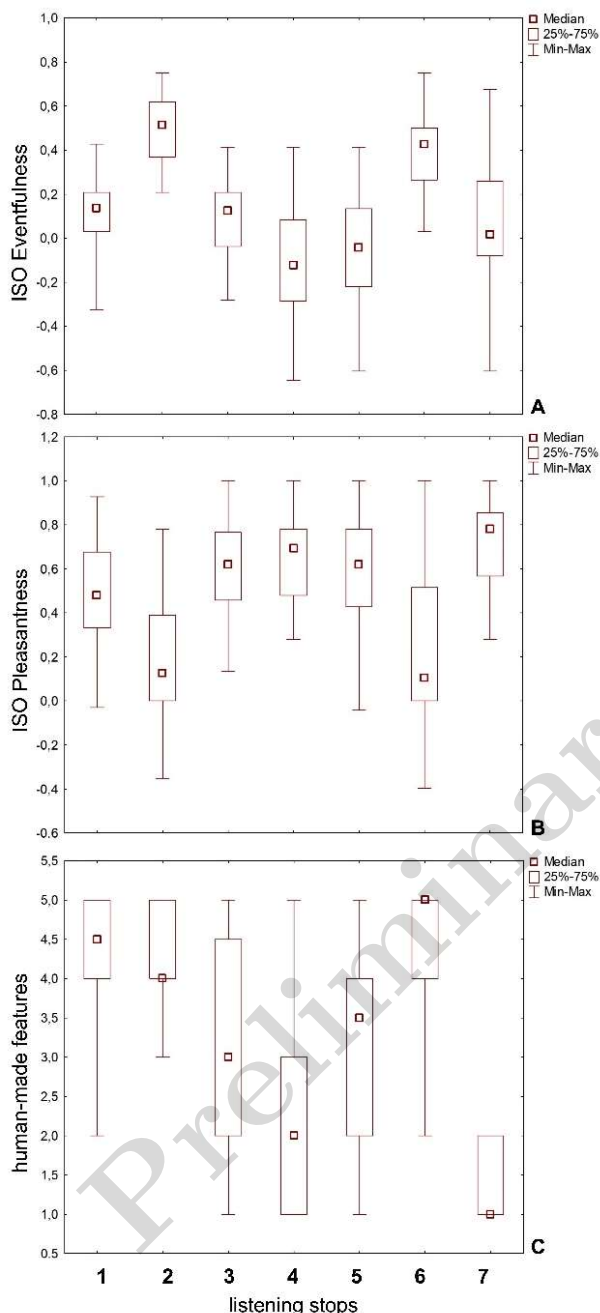


Figure 2. Comparison of listening stops in PNP soundwalk according to: A) ISO eventfulness parameter, b) ISO Pleasantness parameter, c) human-made features.

Significant differences (K-Wt: H (6, N = 140) = 69,329; $p < 0.05$) among listening stops were detected in the perception of the eventfulness parameter. Multiple

comparisons post-hoc analysis revealed that listening stops 2 and 6 had significantly higher eventfulness values than listening stops 1, 3, 7, 5, and 4 respectively (Fig. 2A). This means that stop 2 had the highest value eventfulness score, followed by stops 6, 1, 3, 7, 5 and 4. Significant differences (K-Wt: H (6, N = 140) = 45,801; $p < 0.05$) among listening stops were detected in the perception of the pleasantness parameter. Multiple comparisons post-hoc analysis revealed that listening stops 7, 5, 4, and 3 had significantly higher pleasantness values than listening stops 6 and 2 respectively (Fig. 2B).

Significant differences (K-Wt: H (6, N = 140) = 71,950; $p < 0.05$) among listening stops were detected in the perception for human-made features. Multiple comparisons post-hoc analysis revealed that listening stops 6, 1, and 2, had significantly higher values than listening stops 4 and 7. Additionally, the stops 3, and 5 had significantly higher values than stop 7 while stop 1 had a significantly higher value than stop 4 (Fig. 2C).

3.3 Binaural

Finally, the binaural recordings are available for listening on the following webpage:
<https://on.soundcloud.com/3LQ08ioF6Nb6cDRh5y>.

4. Concluding remarks

This study has established an interdisciplinary and international cooperation between researchers in Croatia, Italy, and UK (i. objective) who successfully organised the soundwalk in PNP (HR) during a peak touristic weekend on May 1, 2026, with 20 participants, and a workshop on May 2, 2026 (ii. objective). The initial statistical results (iii. objective) indicate overwhelmingly positive soundscape outcomes, while the significant differences between the 7 listening spots reveal a larger spread in eventfulness and confirm the associations of human sounds dominance with lower pleasantness and higher eventfulness values. These results contribute towards enhancing management and planning of national parks and heritage sites.

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