DOI: 10.61782/fa.2023.0700

SOUNDSCAPE OF AN URBAN GREEN AREA OF MILAN

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ABSTRACT

Over the last century, anthropogenic activities have caused significant changes in soundscapes. These alterations are mainly caused by growing noise related to the expansion of cities and their connections (e.g. roads). It is urgent to understand the distribution of noise pollution and its effect on biodiversity, especially in large cities, aiming to propose legal regulations and mitigation actions to reduce its impact. In this study, we assessed the soundscape of the pocket-park Vivaio-Bicocca of Milan (Italy), in a highly anthropized urban context, as a starting point to understand the effect of noise pollution on the city wildlife. Audio recordings took place 24h a day from May 31st to June 14th 2022 (1 minute of recordings followed by 5-minutes pause) with autonomous recorders in three sites 45m apart, while noise level was measured using a Sound-Level-Meter. Soundscape analyses were performed calculating eco-acoustic indices (e.g. Acoustic Complexity Index, Acoustic Diversity Index, Normalized Difference Soundscape Index) in the R environment. As expected, the soundscape of the three sites resulted quite similar, composed of biophony and a high quantity of anthropophony. We hypothesize that the central site could be representative of the whole park and be used on its own for the soundscape characterization.

Keywords: *passive acoustic monitoring, noise pollution, soundscape, biodiversity.*

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1. INTRODUCTION

Noise pollution is increasing in scope and intensity with human population growth and urban development [1], causing a substantial and uncontrolled degradation of the sound environment [2]. Noise generated by human activities is widespread in nature, impacting terrestrial and aquatic habitats [3,4] and therefore, its biodiversity [5–7].

The study of the effects of noise pollution on the environment is carried out by a branch of acoustic called soundscape ecology. This discipline aims at characterizing the soundscape and defining the contributions of sound sources (divided into anthropophonies, geophonies and biophonies), quantifying anthropic annoyance and the alteration caused to the biological matrix and to the intra and interspecific relations [8]. The soundscape analysis is conducted by carrying out passive acoustic monitoring of the survey areas for a period of time (days/weeks/months). The recordings obtained are analyzed using various eco-acoustic indices as a tool to assess the environmental conditions and habitat quality. This type of study is of major interest in big cities where anthropogenic noise is omnipresent and it is directly impacting the biophony. In recent years, there is an increasing interest of the government and environmental agencies to focus studies on urban sustainability and quality. For instance, the city of Milan has started the Multilayer Urban Sustainability Action (MUSA - PNRR project) which focuses on urban planning for improving environmental and health quality. The University of Milano-Bicocca (UNIMIB) is part of this project proposing to redesign and greening the campus and rehabilitate the pocket-park Vivaio-Biccoca. To improve the quality status, and thus creating better habitat conditions, reducing anthropogenic stressors (i.e. noise) is necessary. Therefore, in this study we characterized the soundscape of the pocket park, to propose measures to reduce noise pollution and its impact on wildlife in the future.

2. MATERIAL AND METHODS

2.1 Site

The Vivaio-Bicocca pocket park of Milan, Italy (7000m2) is located in a highly anthropized urban context. The park was originally a private vivarium and is now used by the University as a proxy area for research activities and practical lessons. It is a low-density wooded area with approximately 100 trees, originally placed to provide shade, and a large central avenue (Fig. 1). It extends parallel to the de Marchi road and it is limited at its end by a railway trail. Since the road is a flyover, one side of the park presents an increasing vertical slope which protects it from road noise. On the opposite side of the railway, there is a small artificial pond (Fig. 2). The Vivaio is classified inside acoustic class IV (intense human activity area – Fig. 3) according to the Italian legislation (D.P.C.M. 14 novembre 1997 "Determinazione dei valori limite delle sorgenti sonore"). Three points were chosen to monitor the soundscape area: one close to the railway (woods/railway), one in the center of the park (center), and one next to the pond (pond/road). These points are 45m apart from each other (Fig. 1).

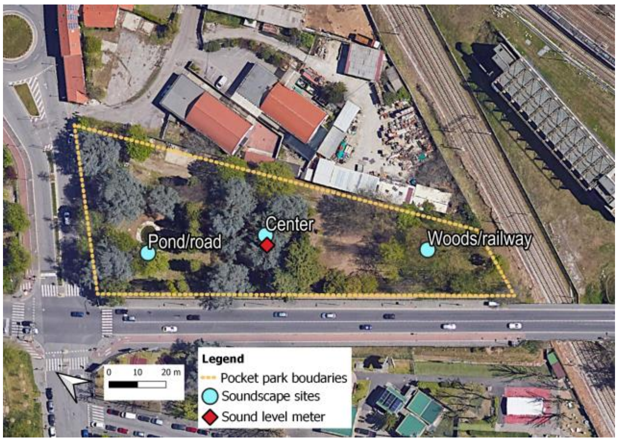

Figure 1. Vivaio-Bicocca (delimitated by the orange dotted line) and its measurement sites (light-blue) and sound level meter (red diamond).

2.2 Data collection

Passive Acoustic Monitoring (PAM) was used to collect acoustic data between May 31st to June 14th of 2022, 24h a day using autonomous audio recorders (Song MeterMicro, produced by the Wildlife Acoustic, Fig.2). These sensors were set to record for 1-minute followed by a 5-minute pause with a sample rate of 96kHz and a gain of +18dB. Parallel to soundscape recorders, a Sound Level Meter (Svantek SV 307A) was used to measure calibrated noise levels (dB re 20μPa). This device was placed at the center site and it monitored continuously the soundscape of the area.

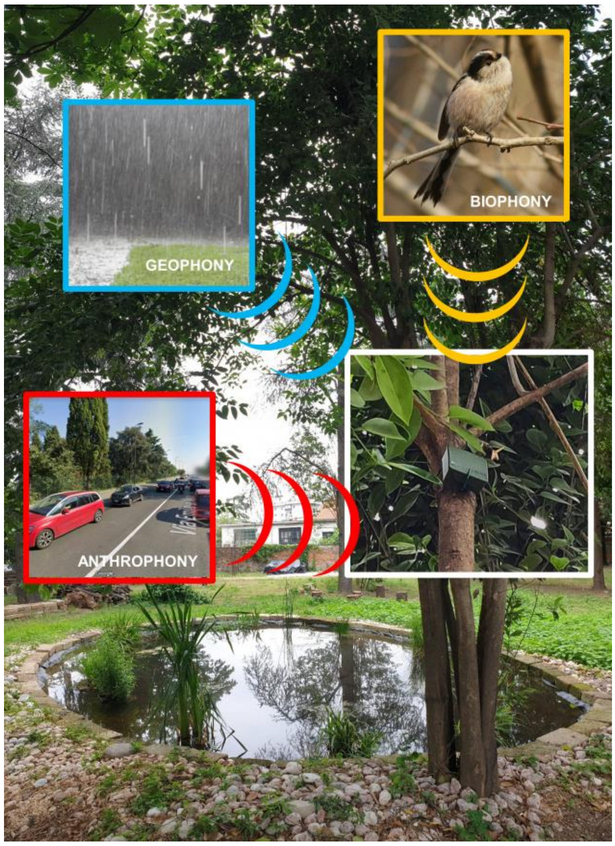

Figure 2. Representation of soundscape components at Vivaio-Bicocca (site pond/road) with the wildlife recorder (Song-Meter_Micro) placed on a tree.

2.3 Calculation of eco-acoustic indices

Soundscape analysis was performed using eco-acoustic indices in R v.3.5.3 [9] with the "soundecology" package [10]. The eco-acoustic indices employed in this work were calculated using an FFT 2048 point and with the following frequency values:

Acoustic Complexity Index (ACI) [11] (freq.range=500-12.000 Hz)

Acoustic Diversity Index (ADI) [12] (freq.max = 12.000 Hz, freq.step = 10 Hz)

Acoustic Evenness Index (AEI) [12] (freq.max = 12.000 Hz, freq.step= 10 Hz)

Bio-acoustic Index (BI) [13] (freq.range=2.000-12.000 Hz)

Acoustic Entropy Index (H) [14] (freq.range= 0-20.000Hz)
Normalized Difference Soundscape Index (NDSI) [15] (anthropic.freq.range= 500-1500Hz, bio.freq.range= 1500-12000 Hz);
Dynamic Spectral Centroid (DSC) [12] (freq.range = 500-12.000 Hz)
Zero-Crossing Rate (ZCR) [16,17] (freq.range= 500-12.000Hz)

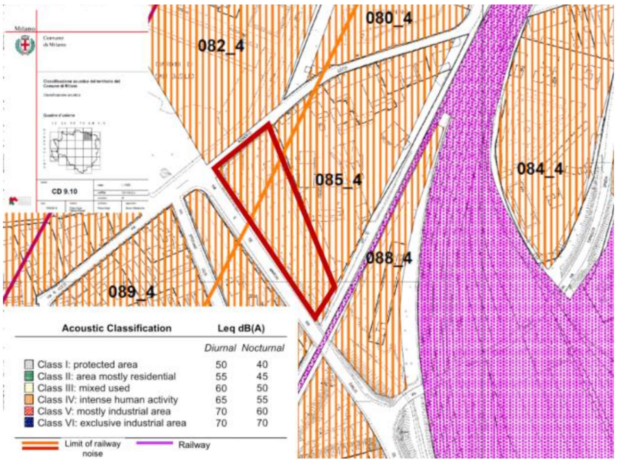

Figure 3. Extract from the Milan Municipality's Acoustic Classification Plan with the respective noise limits (highlighting the Vivaio-Bicocca area).

2.4 Data analysis

Eco-acoustic indices were further tested for temporal patterns (hour, day) by calculating the average value for each minute of the two-week campaign. Noise was analyzed using the L90 parameter (i.e., the sound level that exceeded 90% of the time of the measurement period, in urban areas generally assimilated to background noise) which was then compared with each eco-acoustic index of the Central site. By last, a diurnal and nocturnal LAeq (equivalent continuous sound pressure level A-weighted) was calculated for the Vivaio using the weekly averaged measurements at site Central. Plots and graphic designs were done using R packages: “dyplr”, “tidyr”, “ggplot2” (Wickham et al., 2018; Wickham and Henry, 2020; Wickham and Wickham, 2007).

3. RESULTS AND DISCUSSION

The boxplotxs (Fig.4) show the daily and nightly distribution of the eco-acoustic indices for each site. The graphs show that, as expected, the soundscape values of the three sites are quite similar due to their proximity. Furthermore, it is possible to observe that the nocturnal values of the eco-acoustic indices are lower than the diurnal, except for AEI which provides reverse information of ADI with high values identifying recordings with dominance of a narrow frequency band. ACI values are higher during the day and night in the center site probably due to the input of biophony and anthrophony from the other two sites. ADI, BI and H show that pond/road site is the richest one in frequency occupancy distribution; This can be explained by the road proximity, which does not allow the attenuation of high frequency, and by the presence of the pond, which attracts the avifauna. On the other hand, NDSI values were higher in the woods/railway site due to the acoustic barrier created by the flyover (which attenuates the lower frequencies), together with the high frequencies train whistles and probably a higher biophony (presence of a blackbird nest nearby). DSC index shows how the daily frequency barycenter is similar between the pond/road and center sites, while it increases in the woods/railway site. By last, ZCR was higher in the pond/road site due to high levels of traffic noise, both on day and night, compared to the other sites. Furthermore, the high range of variation during the night at this site reflects the presence of quiet and noisy periods.

When observing the mean daily trend of eco-acoustics indices (Fig. 5), it is possible to notice the same pattern observed in day/night values. More specifically, in ADI, BI, H and ZCR it is possible to notice the influence of anthropophony at high frequencies (which are due to the road proximity) which causes the indices to be higher in the pond/road site. The opposite happens with AEI values. The observed biases of ADI, AEI, BI, H and NDSI due to anthrophonies at high frequencies have also been reported by [18].

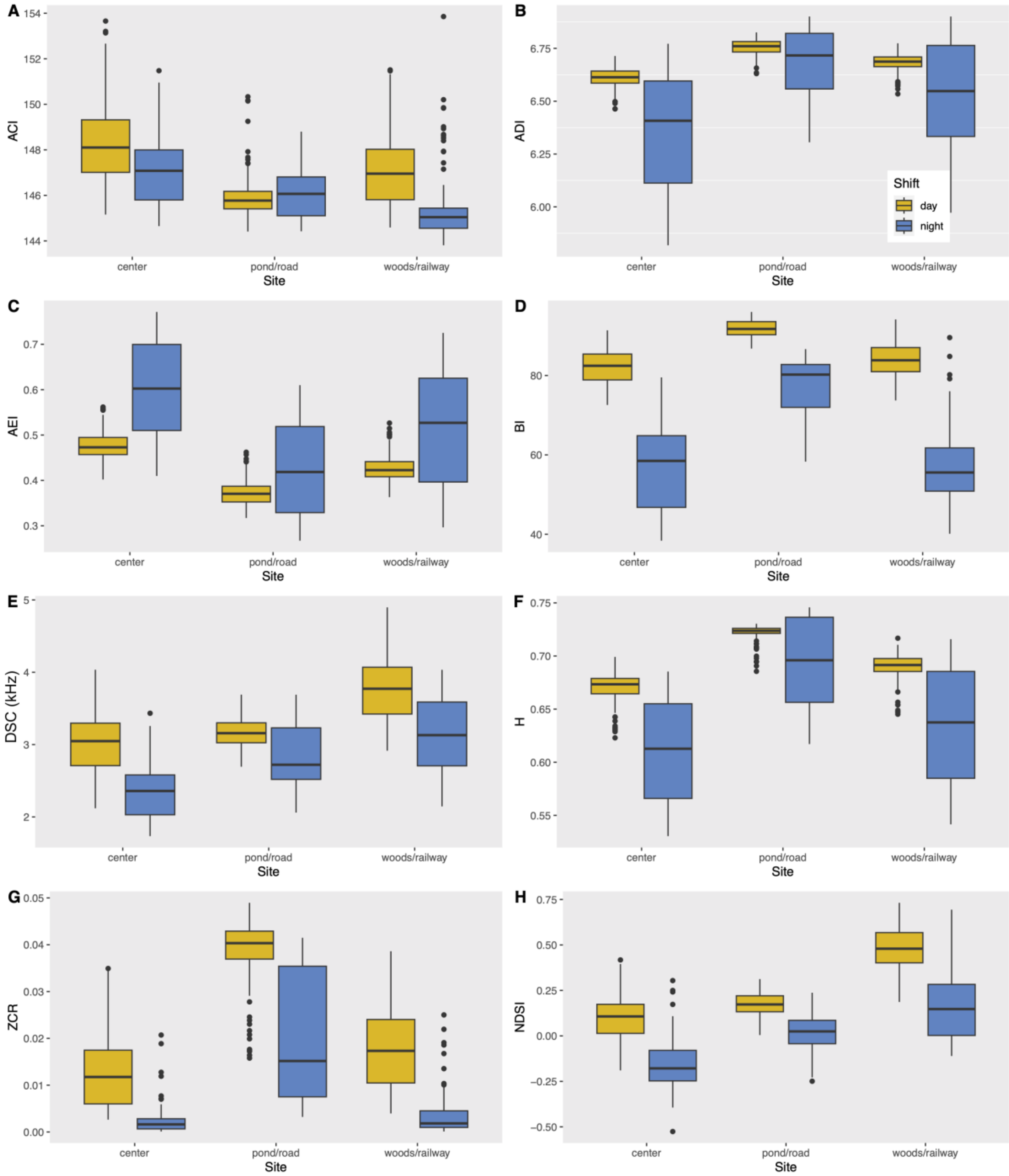

Figure 4. Boxplots of eco-acoustic indices of the Vivaio Bicocca (Italy) divided by day (yellow) and night (blue) for the three different sites. Each boxplot displays the median as a centreline, a variation of 1st and 3rd quartiles represented by the box, the full range of variation (from min to max) represented by the "whiskers" and the outliers as dots.

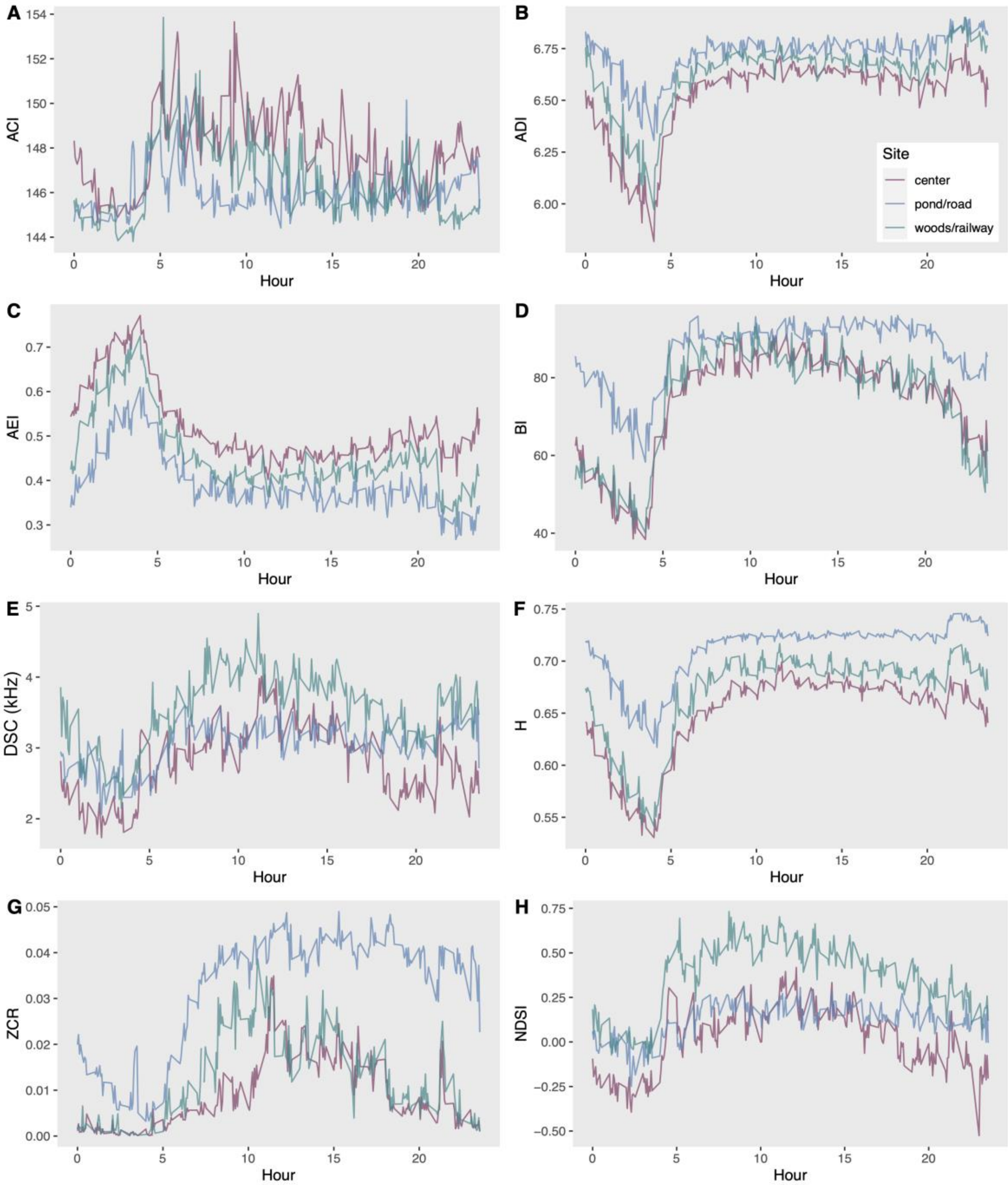

Figure 5. Mean daily trends of eco-acoustic indices (ACI, ADI, AEI, BI, DSC, H, ZCR, NDSI) of the Vivaio Bicocca (Italy).

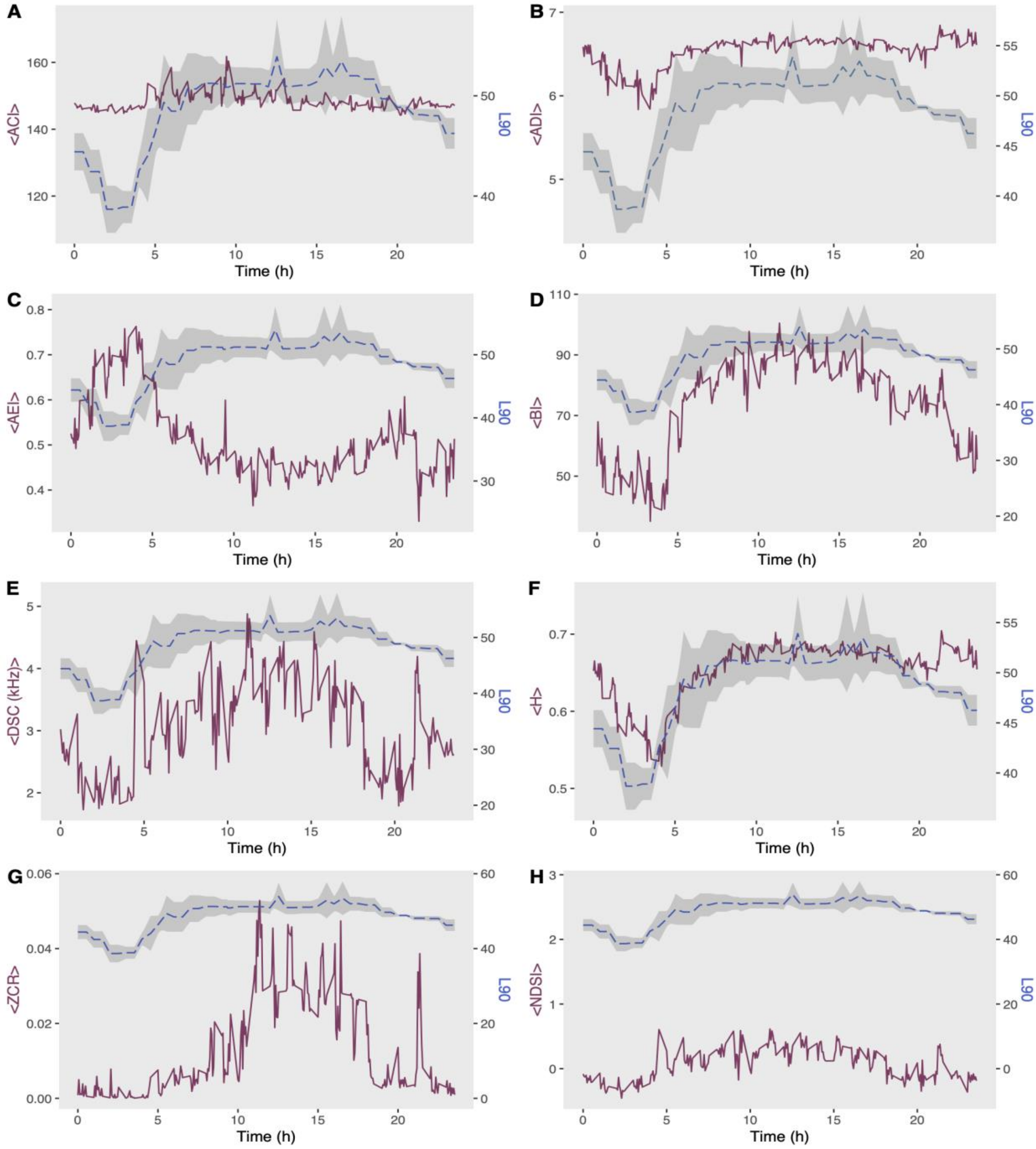

Figure 6. Mean daily trends of eco-acoustic indices (left axis, full purple line) and mean ± standard deviation of L90 (right axis, blue dashed line ± grey shadow) referring to the central site of the Vivaio Bicocca on a week.

Regarding noise level, the L90 percentile graph combined with the eco-acoustic indexes (Fig. 6) shows that ACI and ZCR are scarcely correlated (r=0.39 and r=0.59 respectively) with L90, while the other indices present daily trends similar to it (0.60<r<0.88). This relation was partially expected given that sound pressure level is used in the calculation of soundscape indices. However, the use of eco-acoustic indices to assess the soundscape of an environment is fundamental for a deeper understanding. Given the small dimension of the Vivaio, the short distance between the measurement sites and the similarity of the eco-acoustic indices (Fig. 4-6), we hypothesize that the central site could be representative of the whole park and be used on its own for the soundscape characterization. The results from the diurnal mean Leq (57.5dB(A)) and nocturnal (54.8dB(A)) showed that noise levels at the Vivaio comply with the limits of Italian legislation (diurnal period limit 65dB(A) and 55dB(A) nocturnal – Fig. 3). This results, however, regard the limits for humans, meanwhile the limits for the environmental and wildlife health are still to be defined. Hence, it is crucial to prioritize the ongoing research in soundscape ecology, develop advanced measurement tools, and comprehend the effects of noise on the environment and biodiversity. This knowledge will enable the formulation of effective mitigation strategies.

4. CONCLUSIONS

This study brings the use of eco-acoustic indices, parallel to the classic noise monitoring, for the description of the soundscape of an urban pocket park, which can be representative of the reality of other greater parks in big cities. Future steps involve the quantification of the biophony (by counting the avifauna vocalizations) to better assess the influence of environmental parameters on the soundscape and the prediction of the effects of an acoustic barrier on the soundscape to reduce the traffic and railway noise (by noise modeling).

5. ACKNOWLEDGMENTS

This study is within the MUSA (Multilayered Urban Sustainability Action) project funded by European Union-NextGenerationEU, under the National Recovery and Resilience Plan (PNRR) Mission 4 Component 2 Investment Line 1.5: Strengthening of research structure and creation of R&D "innovation ecosystems", set up of "territorial leaders in R&D".

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