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ANTHROPOGENIC NOISE IN NATURAL SOUNDSCAPES OF NATURE - PROTECTED AREAS

Gianni Pavan
Department of Earth and Environmental Sciences University of Pavia, Pavia, Italy

ABSTRACT

We live in a noisy world where transportation noise affects an important part of the European population and extends to natural habitats, including pristine and protected ones belonging to the Natura 2000 network. Effects on human beings are well known, but studies are concerned mainly with the effects on the human population. However, the problem is underestimated when low and very low frequencies are concerned. Low frequencies can impact humans and ecosystems even far from the sources. Other than having physiological and psychological effects also related to extra-auditive perception, low-frequency noise can mask communication signals in many animal species and impact a population level. The effect of low-frequency sound is also underestimated because of the use of "A" weighting, and it is poorly studied when it impacts animals and natural ecosystems. This work presents spectral measures taken in different ecosystems to show anthropogenic noise levels compared to biophony and geophony. The Soundscape and the Acoustic Environment, extended to infrasound and ultrasound, require new metrics to harmonize measures in different contexts to have an objective global vision for the benefit of human well-being and the protection of the natural acoustic environment.

Keywords: *bioacoustics, ecoacoustics, ecosystem acoustics, impact of noise, low-frequency sound*

* ***Corresponding author****: gianni.pavan@unipv.it*

1. INTRODUCTION

Bioacoustics and Ecoacoustics are emerging disciplines for studying the acoustic environment of animals and humans. Bioacoustics is a historical discipline that studies the emission and acoustic reception of animals and humans for communication, perception of the surrounding environment and, in some zoological groups, echolocation. Ecoacoustics, an evolution of acoustic ecology, was born at an international meeting at the Natural History Museum in Paris in 2014.
Ecoacoustics [1] combines bioacoustics and ecology to study the acoustic relationships between living organisms, including humans, and between them and the environment. For this reason, biophony (produced by living organisms), geophony (produced by physical phenomena), and anthropophony (produced by man) are the components of the acoustic environment. Within the anthropophony, we recognize a component called technophony, which was substantially born with the industrial revolution and which in many cases is considered pollution (noise).
Anthropophony, in addition to the negative aspect of pollution due to technophony, however, has an important component, named cultural anthropophony, which expresses man's presence and represents culture, work, traditions, religion, and historical era.
Ecoacoustics embraces the themes of "Soundscape Ecology" [2,3], also capturing the need to overcome the limitations and contradictions of the concept of soundscape, often brought to the limits of scientific acceptability, for example, with "new age" musical movements.

2. SOUNDSCAPE AND ACOUSTIC ENVIRONMENT

The idea of soundscape comes from Schafer, in the 70s of the last century [4], with an anthropocentric vision and limited to human hearing. However, another vision emerged in 1962 with the book "Silent Spring" [5], in which Rachel Carson highlights in the songs of birds, amphibians and insects the expression of the vitality of the environments in which she lived, but which were increasingly compromised by the advance of industrialized agriculture that altered habitats, used chemicals harmful to humans and fauna, which disappeared with its sounds, making his campaign quieter and quieter. Hence the title "Silent Springs" became an ecological manifesto in Italy and worldwide. After Schafer, the idea of soundscape has been increasingly extended to include the sounds of nature, with esoteric aspects often beyond the boundaries of the objective and scientific approach.
At the end of the last century, the soundscape began to be considered by bioacousticians, zoologists and ecologists as a sound expression and an essential component of ecosystems [1,2,3,6,7]. The soundscape thus becomes not only an aesthetic expression but an ecological component and indicator. In the 2000s, the National Park Service of the United States recognized the soundscape as an essential element of ecosystems that must be studied, monitored, protected, and even restored where altered by human action [7].
Questionnaires distributed to tourists of US National Parks evidence that quietness and natural sounds are essential components for the sensation of “wilderness” and should match the visual landscape and its ecological features. In this sense, the soundscape becomes an ecological sound mark that defines sonotopes well-matched with the observed and heard biotopes.
The soundscape is what we humans feel, but the natural soundscape is much more extensive. Following ISO 12913 standards, the soundscape is what man senses, with its physiological and neural limitations of frequencies, modulations and detectable levels. However, if we want to extend this vision to the natural world, we must also consider infrasound and ultrasound. These are emitted and perceived by animals to communicate and echolocate, but they are also produced by the physical environment, human activities, and machines (technophony).
In this vision, extended beyond the human senses, we consider the acoustic environment, detected and described instrumentally with special sensors. In addition, we should consider the connection with vibrations transmitted to the soil, organisms living there, and plants [8], which are also sensitive to sound and infrasound. Biotremology [9] and a new type of soundscape, called "vibroscape", are born on these themes.
The acoustic environment is more extended than our auditory perception, but the boundaries are unclear. In addition to the individual natural variability and sensitivity decrease related to age, the transition zones between infrasound, sound and ultrasound is uncertain and conditioned by the extra-auditory perception of lower frequencies. The weighing curve "A" is adopted to make the measurements of perception objective (by man) by giving a different weight to the various frequencies depending on the typical sensitivity curve, which attenuates the lowest and highest frequencies.
The decreased sensitivity at low frequency is a typical feature of the mammalian ear, both terrestrial and marine, which, with evolution, has adapted the sensitivity curve to attenuate the physical noise of the natural environment that increases towards low frequencies. It protects the auditory system from being continuously overloaded by low-frequency noise and maximizes the perception of the most useful frequencies. The low frequencies propagate over greater distances than the high frequencies. Each species has found a compromise between its physical and physiological characteristics with the need to hear, communicate and echolocate at distances useful for its needs, minimizing environmental disturbance.

3. NOISE POLLUTION

Technophony [10] is considered a form of noise pollution expressed indoors, typically in work environments, where it can be effectively controlled to prevent damage to exposed personnel, and in open environments, where it is more difficult to manage. Outdoor, low-frequency components propagate over great distances, are challenging to control, and significantly impact humans and the natural environment where low frequencies are usually almost absent [11] - Fig 1-3.
According to EEA and WHO reports [12:13], the main noise source in European countries is represented by transport systems, land, air and sea. The reports define the damage caused to man and the related economic and social costs, thus defining "quietness" [14] as an essential value for our health and the economic qualification of residential areas.

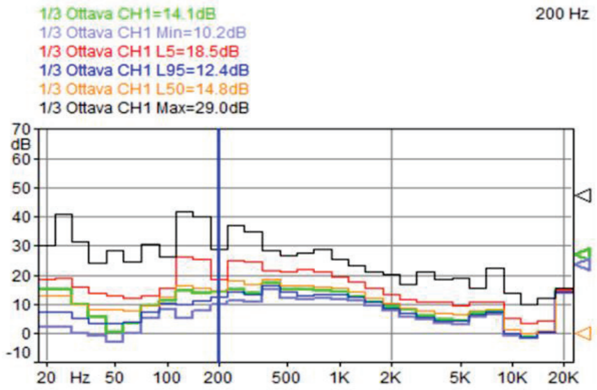

Figure 1 - 1/3 octave analysis with percentiles to show the frequency distribution and the level statistics in 300s recording. Nature Reserve “Sasso Fratino”.

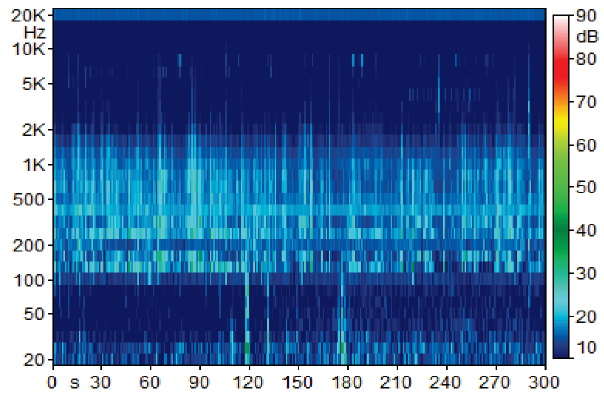

Figure 2 - 1/3 octave spectrogram of the same time frame shown in previous figure. Noises in the range 100 Hz – 2 kHz are produced by flying insects. The lowest frequencies, below 50 Hz are due to air movement. The overall background is almost clean.

Besides general underestimation, low-frequency noise is a particularly sensitive and often underestimated topic. We have a continuum of perception between "audible" frequencies and those perceived physically, extra-auditorily; the lower frequencies, below 30 Hz, can vibrate our internal organs and generate a sense of strong discomfort, including anxiety. The engines of cars and heavy vehicles generate low frequencies (see Fig. 4-7) that can be perceived physically, with a sense of discomfort, even inside nearby buildings, as well as influencing the acoustic environment of vast uninhabited areas. The knowledge on infrasound and its effects are scarce, and even the techniques for measuring sound levels are often unsatisfactory as they are generally based on the weighing curve "A" that attenuates infrasound and ultrasound, not considering that below a particular frequency the perception gradually shifts from auditory to extra-auditory.

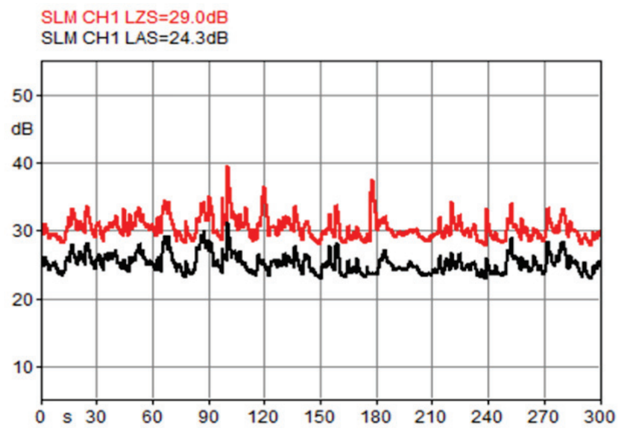

Figure 3 - Same time frame as previous figure. Sound level vs time (LZS and LAS) can’t provide useful info on the structure of measured sound.

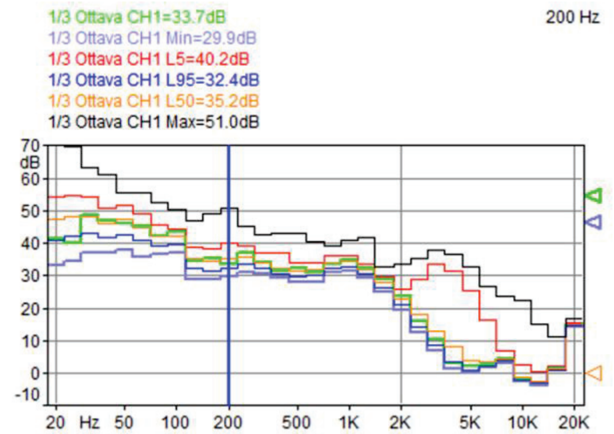

Figure 4 - 1/3 octave analysis with percentiles to show the frequency distribution and the level statistics of a 300s time frame recorded outdoor in a residential area. Sound levels below 2 kHz are pretty constant, while sounds above 2 kHz are intermittent, emitted by birds.

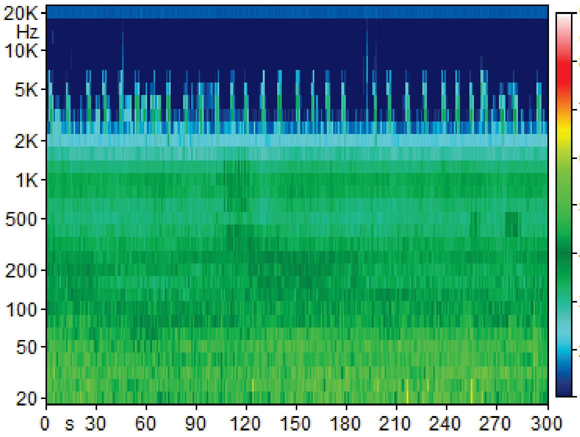

Figure 5 - 1/3 octave spectrogram of the 300s time frame analyzed in Fig 4. Frequencies below 2 kHz show a pretty constant and high noise. The traces above 2 kHz are birds singing at and beyond the upper limit of anthropogenic noise generated by the roads around.

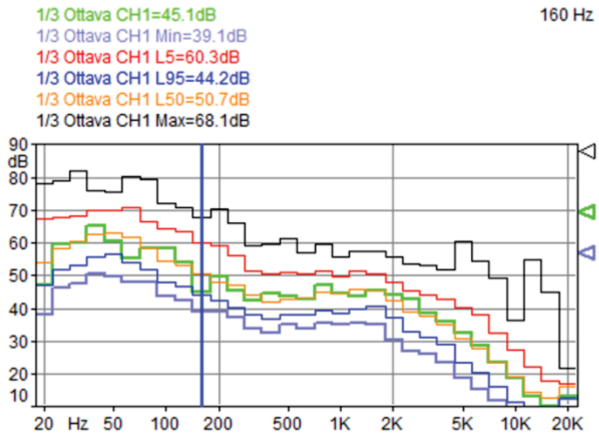

Figure 6 - 1/3 octave analysis with percentiles to show the frequency distribution and the level statistics in a 300s time frame recorded on the side of a town road. Note the dB scale, different from the one in Fig. 4.

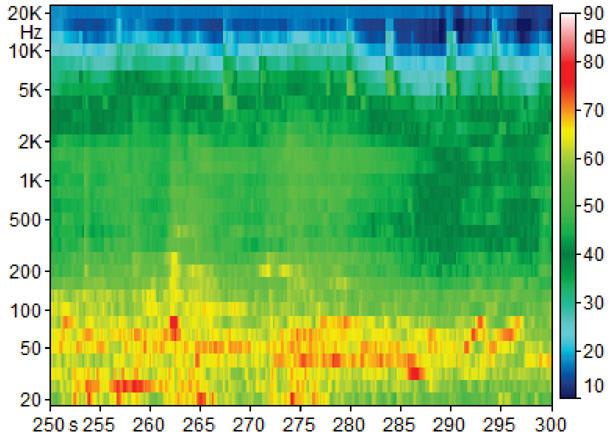

Figure 7 - 1/3 octave spectrogram of a 50s time frame recorded on the side of a town road. Noise extends up to 10 kHz and loud engines noise is clearly shown below 100 Hz.

This knowledge gap also emerges in the evaluation of the effects of wind farms, whose noise is acceptable compared to current legislation, but without considering the infrasonic component, which can drop to a few Hz or even less with changes in pressure, inducing various effects in the population not yet well understood [15,16]. In the human field, we have specific metrics to objectively evaluate the soundscape in which we are immersed, mostly to assess the level of well-being offered in work, residential and recreative spaces, but often not considering noise propagation in uninhabited areas.

The EAA reports [12, 14], and many other studies and experiences show that the noise of transport systems extends over large natural areas, also affecting protected areas belonging to the EU Natura 2000 Network, with ecological impacts and consequences still little known. In the ecological field, there are still no established methods for measuring the effects of noise, and the relationship between ecoacoustic measures and metrics used for humans is not yet clear. It is therefore essential to develop an adequate metric that harmonizes the measures in the two different contexts to have an objective global vision for the benefit of human well-being and the protection of the natural acoustic environment (Fig. 8).

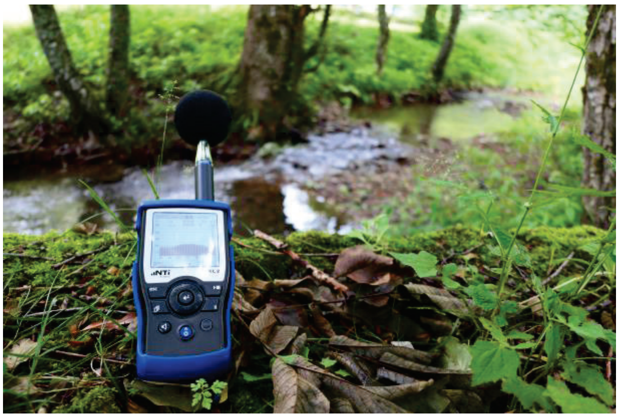

Figure 8 – Noise measures with 1/3 octave analysis and audio recording for complete post-processing.

4. SOUND, NOISE AND WELL-BEING

The silence, quietness and sounds of nature are considered essential for our well-being and our health, physical and mental; for this reason, they are also recognized as therapeutic [17]. On the other hand, our society imposes increasingly fast and alienating rhythms immersed in noises of various kinds, disconnected from the natural rhythms of the day / night cycle, which is also increasingly altered by artificial light (light pollution). These conditions negatively affect the biological cycles of humans, animals and plants, preventing even seeing and admiring the night sky with the stars of the Milky Way.

Figure 9 – An emblematic image taken by the Author in Stockholm.

Nature sounds and quietness are becoming an attraction for visiting natural and protected areas. This is a clear indication that we humans need to define a new relation and connection with the natural world; this is also a request for more quiet and pleasant working and living places.
Getting closer to nature and the use of all our senses, sight, smell, hearing, and touch, induces us to fully perceive the passing of time, in antithesis with the daily anxiety of life as it is imposed on us by contemporary society.
With this vision, it becomes necessary to find a unification in the criteria for measuring and evaluating the soundscape and the acoustic environment both in inhabited and natural areas to pursue the goal of offering acoustic well-being to humans and animals and protecting the entire sound biosphere, or sonosphere. Protected areas also preserve acoustic habitats that are functional to animal life and can reveal biodiversity and richness to scientists [18] and to visitors [19].
Nature and biodiversity protection must consider the acoustic environment as an ecosystemic component to be protected and even restored where necessary. Do not let our "Solar powered Juke Box" [20] be silenced, neither be overloaded by our noise.

5. ACKNOWLEDGMENTS

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