

Sound Phenomena in Forest Areas

Janusz Piechowicz

AGH University of Science and Technology, 30059 Krakow, E-Mail: piechowi@agh.edu.pl

Introduction

Sounds of nature are changing over time, during the day, month, and season. At the result of changes in human lifestyle also irrevocably changes soundscape different geographical areas. This is especially true when it comes to the forests, where the sounds of nature are particularly audible. The research project was dedicated to archiving the sounds of the surrounding environment, and to observe how the process of urbanization is affecting on the nature. We performed acoustic measurements in the two oldest Polish forests in the Bialowieza Forest and the Niepolomice Forest (Figure 1). Historically, a few centuries ago, both were hunting grounds for Polish kings, and those forests were under special royal protection. Nonetheless, a large animal like aurochs (*Bos primigenius*), extinct and today we do not know his voice.

Although the history of development both Forest proceeded differently. Bialowieza Forest, located on the border between Poland and Belarus grew without of industry and urbanization preserving its natural potential. It was the first national park in Poland, established in 1932. It has been inscribed on UNESCO World Heritage List in 1979, later extended to the Belarusian part in 1992. It is a place where we can find really quietness [5].

The Niepolomice Forest remained near Krakow, which developed over the centuries. There is a huge steelwork factory in Nowa Huta. Recently very close to the Forest the A4 motorway was built and modernization of railway line was made for high-speed trains i.e. Pendolino, which runs through the forest. In addition, nearest neighborhood of the forest is full of many sources of noise such as car traffic, small business, tourism, fieldwork, logging, etc. This noise affects the acoustic climate of the forest and the quality of sound recordings.



Figure 1: Spots of sound recording: Bialowieza Forest and Niepolomice Forest.

Sound recordings in forest

According to Bernard Krause [1], soundscape is made up of three basic sources. The first source is the geophony, or the nonbiological sounds that occur in any given habitat. The second is the biophony. The biophony is all of the sound that is generated by live organisms in a particular environment. And the third is all of the sound that we humans generate that is called anthrophony. Each forest has an unique landscape and also a specific soundscape. It consists of the sounds of animate and inanimate nature.

Sound recordings have been carried out in the depths of each forests [2],[3],[4] (Figure 2).



Figure 2: Spots of sound recording: Bialowieza Forest and Niepolomice Forest.

Acquisition of acoustic signals was performed using two methods [2],[7]:

- surround recordings using first order SoundField microphone ST350 with AD/DA converters and preamplifiers integrated in RME Fireface 800 device (ambisonic technique),
- the determination of the physical parameters of sound with sound level meter and microphone, also acting as a reference microphone.

SoundField's multi-capsule microphone systems capture the sounds around the microphone in three dimensions as a four-channel signal and registered signals in B-format. Description of operating principles of the SoundField microphone, as well as ambisonic recordings can be found in several publications [2],[6],[12].

Hardware processors or software can be used to decode the B-format audio and reproduce the captured sound field. SoundField B-Format recordings may be decoded to mono, stereo, 5.1, 6.1, 7.1 and other forms of surround.

Sounds registered of the both forests have been processed using a listening room equipped with an ambisonic multi-channel reproduction system in The Auralization Laboratory at AGH – University of Science and Technology in Cracow [6] (Figure 3). Sound reproduction system is composed of 16 Genelec 6010A two-way self-powered loudspeakers. Listener is positioned in center of surrounded loudspeakers.



Figure 3: The Auralization Laboratory at AGH – UST in Cracow.

Sound phenomena in forest

Man who immerse himself in the forest environment experiencing many sounds. In the forest several groups animals coexist: mammals, birds, amphibians, insects and invertebrates. In the animals world the important role plays communication by sound. Many of their sounds can be found on the spectrograms of analyzed recordings. Another group of sounds has geophysical origin: rain, lightning, storm, the wind, water in the stream, the crack of branches, etc.

The propagation of sound in the forest is affected by the presence of trees, undergrowth, low vegetation, terrain and weather conditions. The acoustic background in the Bialowieza Forest is silent or biophonic and geophonic sounds of the forest, but in the Niepolomice Forest these are the noise of the highway and other sounds associated with human activity.

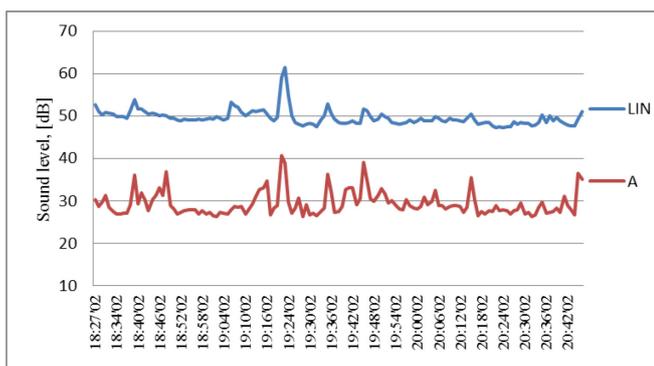


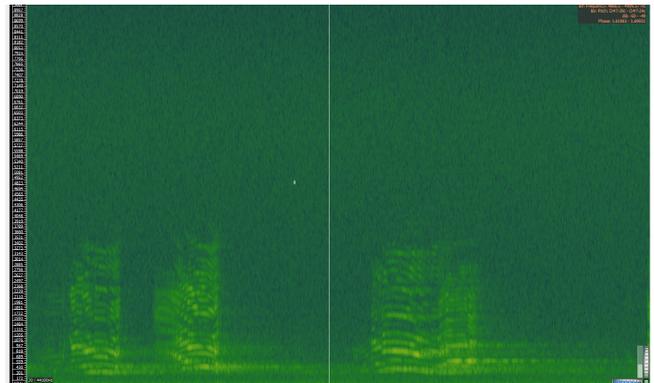
Figure 4: A-weighted and Z-weighted (LIN) sound pressure level over two hours period registered in Niepolomice Forest during the deer rutting [3]

An example of more than two hours time history of sound events, described by levels L_{Aeq} and L_{Zeq} , registered in Niepolomice Forest during the deer rutting is shown on Figure 4. The A4 motorway is near two kilometers away from measurement point and motorway in this section has an acoustic screen with a height of 4 to 6 meters along the edge of the forest. Mostly low frequency sounds are transmitted to the forest direction.

At the time course of the acoustic signal, you can see the difference of about 20 dB between the signal filtered A-weighting and Z-weighting (LIN). It should be assumed that is mainly due to low frequency noise coming from the A4 highway. This fact may be important of animal sound communication studies. It is well known that animals (e.g., birds) change the frequency of singing under the influence of background sound [9],[11].

In the forests you can meet a variety of interesting acoustic events. The most spectacular sounds of the forest is called dawn chorus. Early in the morning all the birds in the area resound which creates wonderful acoustic phenomenon. Another poignant acoustic phenomenon is the deer rut. It is held at the end of summer and at this time, the whole forest is full of stags sounds. However, the records shown (Figure 5) that not only the voice of a deer is present on the spectrogram. One can see, that motorway hum is present on Niepolomice Forest spectrogram at the lower frequencies and sounds of crickets are at higher frequencies.

The roaring of the stag from Bialowieza Forest



The roaring of the stag from Niepolomice Forest

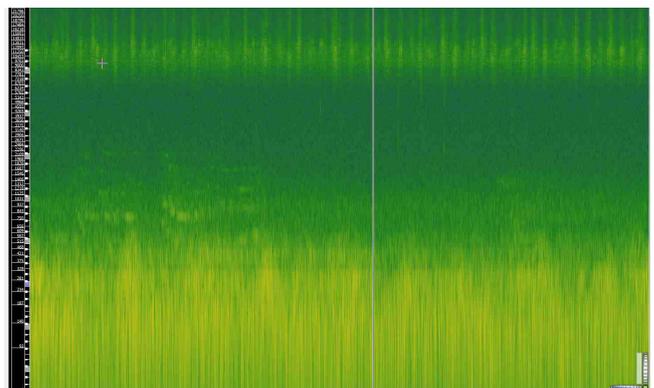


Figure 5: Spectrograms of the stag roaring recordings: Bialowieza Forest (upper) and Niepolomice Forest (bottom) [8].

The spectrogram [Figure 6] shows a short time period of almost two minutes recording of the Niepolomice Forest.

You can see here spectrum of different sounds, such as: the roaring of the stag, noise of a plane, sound of the fire siren and the hum of highway.

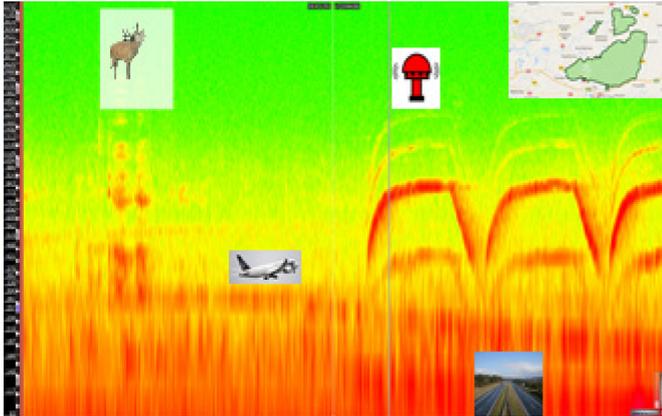


Figure 6: Sound recording in Niepolomice Forest.

The acoustic environment is the combination of all the sound resources within a given area, natural sounds and human-caused sounds. As you can see in the Niepolomice Forest, there are frequent sounds of anthropogenic origin.

Conclusion

There are many recorded voices of various animals and birds on the internet websites. Our recordings are related with a particular place of observation, in particular the Forest, including the spirit of time and genius loci. Aggressive and encroaching human activity is changing not only the natural landscape, but also the soundscape of the Forests.

In our study, we have come across two different forests, from an acoustic perspective. Both have centuries-old history, but their development was completely different. One is inscribed on the Unesco Heritage List and enjoys us unspoiled soundscape. The second one – Niepolomice Forest unfortunately has been degraded from the acoustics point of view.

One of our goals was to leave to our successors present sound recordings of the Bialowieza Forest. It was created CD "The four seasons at the Bialowieza Forest, the oldest forest in Europe". By using the CD, you can see photographs of wildlife Bialowieza Forest accompanied by the sounds recorded during all seasons.

Another issue of this project is to compare the change of soundscapes in both forests in successive time intervals - in a year, in five years and so on. We have to continue our recordings.

Acknowledgments

The project described in this paper has been executed within the project No. 11.11.130.955 in Department of Mechanics and Vibroacoustics of AGH - University of Science and Technology. The author wish to express his gratitude to the staff of the Bialowieza National Park and Niepolomice Forest for their support. We would like to thank everyone who kindly participated in our experiment.

Literature

- [1] Krause B., Anatomy of the Soundscape: Evolving Perspectives, *Journal of the Audio Engineering Society*. Audio Engineering Society 56(1/2):73 - 2008
- [2] Małecki P., Ozga A., Piechowicz J.: Soundscape analysis based on ambisonic recordings executed in a primeval forest, *Proceedings of 22nd International Congress on Acoustics 5–9 September 2016 Buenos Aires*.
- [3] Piechowicz J., Ozga A., Mleczo D., Kasprzak C., Stryczniewicz L.: *Acoustic ecology in forest areas*, AGH. KMiW, Kraków, 2015 (in polish).
- [4] Piechowicz J., Małecki P., Ozga A., Mleczo D.: Sounds of deer mating season in Białowieza National Park, *Proceedings of 22nd International Congress on Acoustics 5–9 September 2016 Buenos Aires*.
- [5] Wiciak J., Mleczo D., Ozga A., Wszółek G., Wierzbicki J., Piechowicz J., Małecki P.: Quietness in the soundscape of the Białowieza National Park, *Acta Physica Polonica. A*; vol. 128 no. 1-A: *Acoustical Engineering 2015*, A-79–A-84.
- [6] Małecki P., Sound source localization accuracy of ambisonic microphone in anechoic conditions, *Proc. Internoise 2014, Melbourne Australia, 2014*
- [7] Małecki, P.; Wiciak, J.; Ozga, A.; Mleczo, D.; Piechowicz, J. Ambisonic sounds of the ancient forest and the difficulty of silence recording. *ICSA 2015: 3rd International Conference on Spatial Audio, Graz, September 18–20, 2015*.
- [8] Piechowicz J. et al. Sounds in the Niepołomicka Forest (Natura 2000). *7th Forum Acusticum 2014; 61st open seminar on acoustics; Polish Acoustical Society – Acoustical Society of Japan special session stream* : Kraków, 7–12.09.2014
- [9] Benítez-López A., Alkemade R., Verweij P.A., The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis; *Biological Conservation* 143 (2010) 1307–1316
- [10] Cannam C., Landone C., Sandler M.; *Sonic Visualiser: An Open Source Application for Viewing, Analysing, and Annotating Music Audio Files*, in *Proceedings of the ACM Multimedia 2010 International Conference*.
- [11] Nemeth E., Pieretti N., Zollinger S.A. et al, Bird song and anthropogenic noise: vocal constraints may explain why birds sing higher-frequency songs in cities. *Proceedings of the Royal Society B: Biological Sciences.*;280(1754): 2013.
- [12] Soundfield ST350 Manual, URL: http://www.radikaltr.com/LeCatalogue/imagenes/attachments/Soundfield_ST350_Manualpdf