

## **BIOACUSTICA E ECOACUSTICA APPLICATE AL MONITORAGGIO E ALLA GESTIONE AMBIENTALE**

## **BIOACOUSTICS AND ECOACOUSTICS APPLIED TO ENVIRONMENTAL MONITORING AND MANAGEMENT**

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### **RIASSUNTO**

Bioacoustics and ecoacoustics are emerging tools in biodiversity science and conservation: from the recognition and monitoring of individual species through to soundscape analysis and description, they provide new insights and approaches for science, conservation, and education. Ecoacoustics is an interdisciplinary science, derived from bioacoustics and ecology, very close to soundscape ecology, that investigates natural and anthropogenic sounds and their relationship with the environment. Ecoacoustics operates in all types of terrestrial and aquatic ecosystems extending the scope of acoustics and bioacoustics and providing tools for the monitoring and the management of the environment.

### **ABSTRACT**

La bioacustica e l'ecoacustica sono discipline emergenti nelle scienze della biodiversità e della conservazione: dal riconoscimento e monitoraggio delle singole specie fino studio del paesaggio sonoro, forniscono nuove informazioni e strumenti per la scienza, la conservazione e l'educazione. L'ecoacustica deriva dalla relazione fra bioacustica ed ecologia, molto vicino alla "Soundscape ecology", studia i suoni naturali e di origine antropica e il loro rapporto con l'ambiente. L'ecoacustica considera tutti gli ecosistemi terrestri e acquatici estendono il campo di applicazione della bioacustica e dell'acustica e fornendo nuovi strumenti per il monitoraggio e la gestione dell'ambiente.

Parole chiave: bioacustica; ecoacustica; paesaggio sonoro, ecologia del paesaggio sonoro.

Keywords: bioacoustics, ecoacoustics, soundscape, soundscape ecology.

## **1. Introduction**

The rate of biodiversity loss is continuing at an unprecedented rate in historical times. Bioacoustics and ecoacoustics are emerging tools in biodiversity science and conservation: from the recognition and monitoring of individual species through to soundscape analysis and description, they provide new insights and approaches for science, conservation, and education [1-9]. However, the complexity of the acoustic world is difficult to manage and requires trained experts together with dedicated instruments and smart algorithms to process the data and extract useful and easy to handle information [2, 5, 10].

Soundscape analysis also provides insights into the noise pollution problem, a topic not considered in the present work but with a great potential interest for monitoring and conservation issues [9, 11, 12].

With the advent of digital Automatic Recording Systems (ARS), the possibility to use autonomous recorders has outlined a number of obvious advantages, which are determining their success and usage on a large scale for the study and monitoring of many taxa (10, 13, 14, 15) and for environment monitoring in general. The advantages are represented by the large amount of acoustic data that can be acquired in the absence of an operator, with flexible scheduling at every times of the day, under extreme conditions and in hardly reachable places. Once deployed and activated, the absence of human operators allows for recording the real habitat conditions with the minimum disturbance, which permits greater reliability in the data analysis and greater possibility to contact shy and elusive species.

## **2. Ecoacoustics**

Ecoacoustics is an interdisciplinary science, derived from bioacoustics and ecology, very close to soundscape ecology [6, 16], that investigates natural and anthropogenic sounds and their relationship with the environment over a wide range of study scales, both spatial and temporal, at individual, community and population level. Ecoacoustics operates in all types of terrestrial and aquatic (freshwater and marine) ecosystems extending the scope of acoustics and bioacoustics and providing tools for the monitoring and the management of the environment.

In this context, nature sounds can be both the subject and tools of ecological research. As the subject, sounds are investigated in order to understand their evolution, functions and properties under environmental pressures. As tools, sounds are used to study and monitor animal diversity, abundance, behaviour, dynamics and distribution, and their relationship with ecosystems and the environment.

The acoustic monitoring of habitats provides information about the presence of vocalizing animals, the level of anthropogenic noise and other impacts related with human activities. An analytic approach allows to identify the vocalizing species, however this is time expensive and requires experts. To easily process huge amounts of acoustic data, ecoacoustic research is aimed at developing new metrics, e.g. "indices", to describe the acoustic environment in terms of quality, quietness, richness, complexity and diversity. Research is also addressed at developing algorithm for automatic classification of acoustic scenes to make easier and faster the search of acoustic objects or situations within huge amounts of recorded data.

## **3. The SABIOD project**

The current research is being developed within the SABIOD (Scaled Acoustic Biodiversity) project granted by the French CNRS MASTODONS Project on Big Data

acquisition, analysis and processing. SABIOD started in 2014 in cooperation with the University of Toulon (DYNI LSIS team) and the JASON (Joint Acoustic Survey for Online Biodiversity) Project.

The research developed by CIBRA is aimed at describing the acoustic environment, or soundscape, of natural habitats with different level of protection and human presence. By extending in time the monitoring, we plan to collect information useful for assessing the changes in soundscape structure related with both short term and long term habitat changes, in particular those connected with anthropogenic impacts and climate changes.

By using autonomous recorders (Wildlife Acoustics SM3) able to record sounds for months (typical monitoring cycles are 2 months, recording 10 minutes every 30 minutes, repeated to cover a whole year) it is possible to get a picture of a soundscape (Fig. 1-3), that is composed by the sounds produced by the animals (biophony), the noise produced by atmospheric events (wind, rain, thunders) and by human activity (car traffic, airplanes, other activities). Temperature and humidity data loggers are used to monitor the two parameters, with the daily solar cycle, that mainly drive the acoustic behaviour of animals.

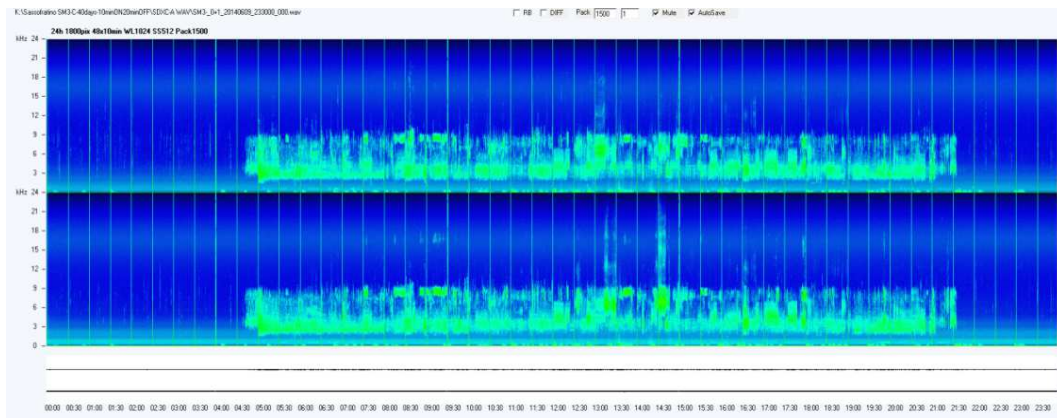


Fig. 1 - Packed spectrogram of one day stereo recording in Sassofratino (day 20140609), 10 min every half-hour (48 frames/day), it shows sharp transitions at dawn and dusk and a high density of biological acoustic activity in between. Airplanes produce the traces on the x axis. (x-axis 24 h, y-axis 24 kHz) - Spettrogramma compatto di un giorno di registrazione in Sassofratino (20140609), 10 minuti ogni mezz'ora (48 sezioni), che mostra una netta transizione all'alba e al tramonto e una intensa biofonia nelle ore diurne. Le tracce a frequenze molto basse rappresentano il passaggio di aerei. (asse x 24 ore, asse y 0-24 kHz).

The project has the support of the Italian Forestry Police (CFS – Corpo Forestale dello Stato, UTB – Ufficio Tutela Biodiversità) that provides logistic support and the access to nature reserves, including Integral Nature Reserves, such as the RNI Sassofratino, in the National Park “Foreste Casentinesi” where we develop the core of the project. The RNI Sassofratino, the first Italian nature reserve, created in 1959, has a high level of biodiversity and stability, received the European Diploma and is taken into consideration for the UNESCO “Millenarium Forests” program.

Within the project, three other habitats have been identified and monitored, two on the Alps (from June to October 2014), and one on the Isle Palmaria in National Park “Cinque Terre” (from June to September, in 2014 and 2015).

In 2015 and 2016 the program focuses more on the RNI Sassofratino and adjacent reserves with three recorders, two located in the dense forest core and one in an open transitional area, to provide synchronous recording aimed at describing the soundscape variability in a same area.

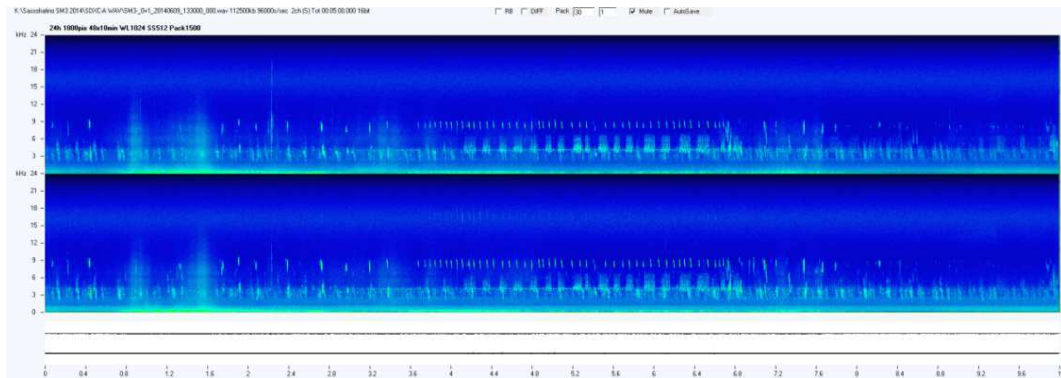


Fig. 2 - Packed spectrogram of 10 minutes (day 20140609 at 13:30). On the left, wind appears as low frequency rumble plus wideband noise produced by the leaves. (x-axis 10 min, y-axis 24 kHz) - Spettrogramma compatto di 10 minuti di registrazione (20140609 alle 13:30). A sinistra il vento produce rumore sia a bassa frequenza che a larga banda, quest'ultimo generato dalle foglie. (asse x 10 min, asse y 0-24 kHz).

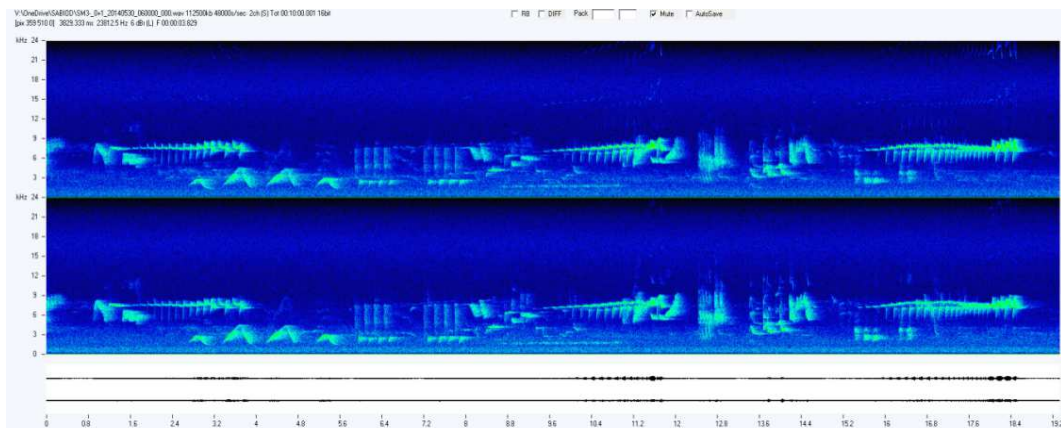


Fig. 3 - High resolution spectrogram. The high density of songs often makes difficult to “isolate” and extract individual songs. (x-axis 19.2 seconds, y-axis 24 kHz) - Spettrogramma ad alta risoluzione temporale. La densità delle vocalizzazioni rende difficile l'estrazione di singoli canti. (asse x 19.2 s, asse y 0-24 kHz).

By working also on the hardware and software side, a set of new instruments are being developed and tested; among these, a multichannel autonomous recorder dedicated to bat monitoring, and a web-connected acoustic recorder with temperature,

humidity and light level logger able to publish in near real-time the spectrographic images of recorded sounds (audio range) and ultrasounds up to 120 kHz (Fig. 4). Depending on the wireless connection speed, the transfer of recordings to a central server is also allowed.

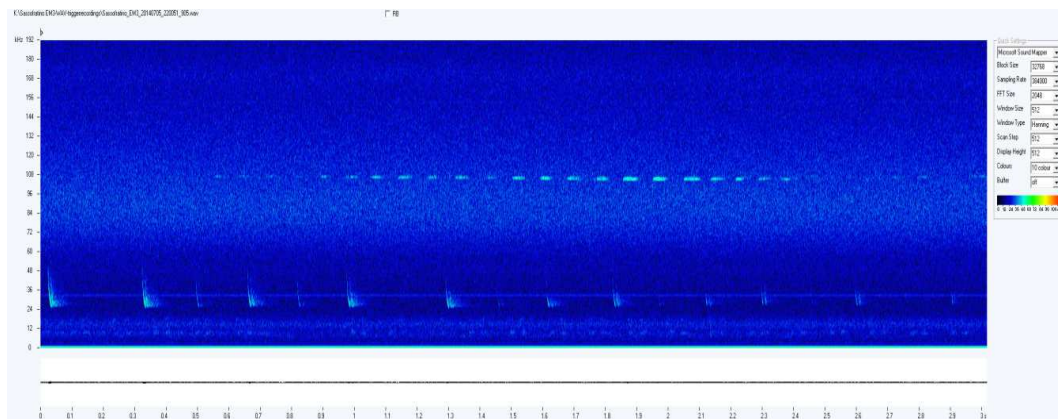


Fig. 4 - Spectrogram of echolocation sequences of two bat species with main frequency components at about 25 kHz and 108 kHz; the highest is very typical of *Rhinolophus ferrumequinum*. (x-axis 3 s; y-axis 0-192 kHz) - Spettrogramma di sequenze di ecolocalizzazione di due specie di pipistrelli a circa 25 kHz e 108 kHz; la più alta in frequenza è tipica di *Rhinolophus ferrumequinum*. (asse x 3 s; asse y 0-192 kHz).

Specific software to analyze long recordings [17] has been improved to provide the spectrographic image of the acoustic environment in 10 minutes, 1 hour, 6 hours, 24 hours, 1 week, 1 month time frames. Results given by “indices”, e.g. ACI (Acoustic Complexity Index) and others [2, 5, 7, 16], are compared with these compact spectrograms and with the acoustic categorization results given by experts.

A more analytic and traditional approach is aimed at monitoring species of birds listed in Annex 1 of the European Directive 2009/147/EC (target species). These bird species are particularly protected in the whole continent as declining in trend and distribution, very rapidly in some cases. This decline represents a serious threat to the conservation of the natural environment, because of the biological balances threatened thereby. The acoustic monitoring with a network of sensors is a real conservation tool to monitor the sensitive habitats and develop suitable management and conservation strategies.

#### 4. Preliminary results

The first year of the project has been dedicated at building a reference database of high quality recordings of natural habitats, primarily Integral Nature Reserves and Nature 2000 sites. The analysis of the recordings produced a reference library for species identification (to be used for building classifiers) and indices of quality, quietness, bioacoustics richness, bioacoustics complexity, bioacoustics diversity. In literature there are no information about the noise level and acoustic structure of natural sites. By analyzing the noise of the quietest place, the RNI Sassofratino, a reference noise model will be developed for comparing and scoring habitats affected by

anthropogenic noise and assessing the impact on animal communities (e.g. communication masking). In the RNI there is no noise from human activities with the exception of airplane passages; the residual background noise (no wind, no birds or insects singing) lies below the self-noise of usual sound level meters and thus special low-noise microphones are required to perform accurate measures.

Results given by “indices” developed by other researcher are compared with compact spectrograms and with the analytic results given by experts to setup a protocol and standard metrics for analyzing and comparing habitats.

The effectiveness of new low-cost web-connected instruments for acoustic monitoring is also experimented to build a real-time monitoring network with multi-sensorial capabilities.

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