Ecological Informatics 41 (2017) 1–10

Contents lists available at ScienceDirect

Ecological Informatics

journal homepage: www.elsevier.com/locate/ecolinf

A methodology for analyzing biological choruses from long-term passive acoustic monitoring in natural areas

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ARTICLE INFO

Keywords:
Soundscape ecology
Biological choruses
Long-term passive acoustic monitoring
Alcatrazes archipelago wildlife refuge

ABSTRACT

Long-term passive acoustic monitoring can provide important insights on the study of biological choruses, which represent a key component of natural environments. Nowadays, the development of methods for analysis and visualization of large acoustic datasets is an active area of research. In this context, the present paper addresses how the traditional computation of spectrograms and Sound Pressure Levels (SPL) could be used for analyzing large sound datasets. Additionally, a visualization tool named here as SPL-Gram and a method for automatic detection of trends in dawn and dusk choruses are presented. The dataset used as a case study represents 3 months of underwater sound collected in a marine wildlife refuge in southern Brazilian coast. Results reveal events with strong daily periodicity, originated by fish choruses in the frequency band from 0.01–2 kHz, and, in the higher frequencies, reflecting acoustic activity of crustaceans. The reported periodicities show a marked relation with sunrise and sunset through the studied period, thus revealing circadian cycles present in the monitored environment. The proposed methodology is not only easy for implementation, but also proves to be valuable in the description of daily and seasonal patterns of biological choruses in large acoustic datasets.

1. Introduction

1.1. Soundscape ecology, a relevant property of ecosystems

The compositions of sounds that emerge from an environment has been named as soundscape, which is described in the field of soundscape ecology proposed by Pijanowski et al. (2011a, 2011b). The soundscape is based on the sounds related to geophony (geological sounds), biophony (biological sounds), and anthrophony (human-produced sounds) (Erbe et al., 2015; Pijanowski et al., 2011a).

The soundscape of a particular habitat is strongly linked to its dynamics and local fauna, being an important indicator of the ecosystem health and quality (Harris et al., 2016; Joo et al., 2007; Pijanowski et al., 2011a). In this scenario, acoustic information represents a proxy for comprehension of environmental changes at daily and seasonal scales, biological diversity and species distribution (Farina and James, 2016; Sueur and Farina, 2015). Especially, biological choruses could be a major contributor of soundscape for natural areas (Erbe et al., 2015; Locascio and Mann, 2011; Pijanowski et al., 2011a). Describing the daily and seasonal patterns of biological chorus can provide insight into the timing of species behaviors (Gage and Axel, 2014; Locascio and Mann, 2011), thus enabling assessment of environmental changes due to anthropogenic or natural factors.

1.2. The challenge of summarizing and visualizing large acoustic datasets

Nowadays, technology allows collecting environmental sounds for periods of months or even continuously, by using autonomous or cabled acoustic systems respectively. In this context, Passive Acoustic Monitoring (PAM) systems generate a huge and complex amount of data (Towsey et al., 2014a), from which extracting relevant information represents a complex task. In fact, several methods, as for example the acoustic indices (Harris et al., 2016; Towsey et al., 2014b) have been recently developed to assist in the analysis of these big datasets. These procedures can be considered useful approaches, but their use is quite complex due to a diverse and non-uniform range of applications. Though several dozen acoustic indices have been proposed over the last decade, the ecological relevance and efficacy of these indices are still unclear (Eldridge et al., 2016). In contrast, traditional metrics such as spectrograms and Sound Pressure Levels (SPL) are well-established and still valuable techniques that could be effectively employed to explore large acoustic datasets.

This work addresses the use of median spectrograms and the visualization of daily 24-h SPL visualized by means of color maps images to summarize and visualize long-term acoustics recordings. The use of these metrics, in conjunction with automatic detection of trends in dawn and dusk choruses, constitutes the proposed methodology, which

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http://dx.doi.org/10.1016/j.ecoinf.2017.07.001
Received 18 January 2017; Received in revised form 4 July 2017; Accepted 4 July 2017
Available online 05 July 2017
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could be a valuable tool both for either terrestrial or aquatic long-term acoustic monitoring.

1.3. Dataset used as case study: 3 months of continuous recordings in a marine wildlife refuge

Marine Protected Areas (MPAs) generally involve restrictions to fishing, navigation and other activities that can represent a threat to aquatic organisms. These areas serve as a reference for the comprehension of ecological functioning without significant human interference, allowing comparisons with impacted areas and providing information for restoring impacted environments.

The present study describes three months of continuous underwater sound records from a marine natural reserve (Hoff et al., 2015), in the southwest Brazilian coast, the Alcatrazes Archipelago Wildlife Refuge, created in August 2016. The underwater acoustic monitoring and analysis presented in this paper are parts of a pilot underwater study that has been conducted in this area of Brazilian waters.

2. Methodology

2.1. The passive monitoring system and its deployment

An autonomous passive monitoring system (OceanPod 3.0), developed at Laboratory of Dynamics and Instrumentation (LADIN) of the Polytechnic School of the University of Sao Paulo, was deployed at Alcatrazes Wildlife Refuge. An illustration of the equipment and its location are represented in Fig. 1. The OceanPod system comprises a hydrophone, an acquisition unit, a battery pack, and a sealed enclosure (Fig. 1(a)). The hydrophone and its stainless steel protection are mounted on the outer top surface of a cylindrical enclosure. The remaining components are situated inside the enclosure, which has been tested to 30 bar of hydrostatic pressure. The equipment has four slots for microSD memory cards for data storage. Device autonomy depends on the recording configuration: sample frequency (maximum of 48 kHz), scheduling data acquisition and power of the internal battery pack (until 45 D-size battery).

The data used in this paper was recorded with 24 kHz sampling rate (fs), 16 bit resolution, and with an in house made hydrophone with sensibility of -153.8 dB re 1 V μPa^{-1}. Data was continuously stored in four microSD cards of 128 GB each, in "wav" files format of 15 min durations each. With the described system configuration, the amount of collected data was approximately 390 GB. The acoustic signal dataset was collected from March 7th to June 7th, 2016, totalizing 93 days of continuous recordings.

2.2. Data analysis

2.2.1. Calculation of daily Pxx matrices

The signal processing analysis, in this work, is based on the Power Spectral Density (PSD) (Proakis and Manolakis, 2007) estimation of the daily acoustic data sets. In order to accomplish that, it was used the Welch method (Welch, 1967) with 1-s Hamming window, 1025 frequency points, 50% of overlap, with 60-s temporal signal segments. Therefore, with these parameters, time resolution is 60 s and frequency resolution is 12.2 Hz. The parameters for calculating PSD were selected aiming to facilitate comparisons with others underwater monitoring studies (Coquereau et al., 2016; Jordão et al., 2012; Merchant et al., 2014; Parsons et al., 2016a; Parsons et al., 2016b) and to obtain an appropriated time-frequency spectrogram resolution for the present analysis.

The processing resulted PSD matrices are defined here as Pxx (n,m,k), where n, m and k are minute of day, frequency, and number of day indexes, respectively. The daily Pxx matrices were used as basic blocks for the Sound Pressure Levels (SPL), spectrograms and statistical calculations presented in the Section 3. Details for the implementations of these computational calculations are described in the appendix 1 related material of Merchant et al. (2015).

2.2.2. Selection of frequency bands for SPL calculation

For soundscape analysis, a common practice is to divide the spectrum by frequency bands (Staaterman et al., 2014). For this study, the range of frequencies between 0.01 and 2 kHz was designated Low frequency Band (Low-FB), and that between 2 and 12 kHz, High Frequency Band (High-FB). It is possible to state from literature (Staaterman et al., 2014), and from our own observations (Sánchez-Gendriz and Padovese, 2016) that Low-FB comprises most of the sounds produced by fish. On the other hand, High-FB is dominated by crustacean sounds (Bohnenstiehl et al., 2016; Staaterman et al., 2014).

Also the SPL values calculated in the selected frequency bands (Low-FB and High-FB) were used to explore the existence of an occasional relation between acoustic activity and moon phases.

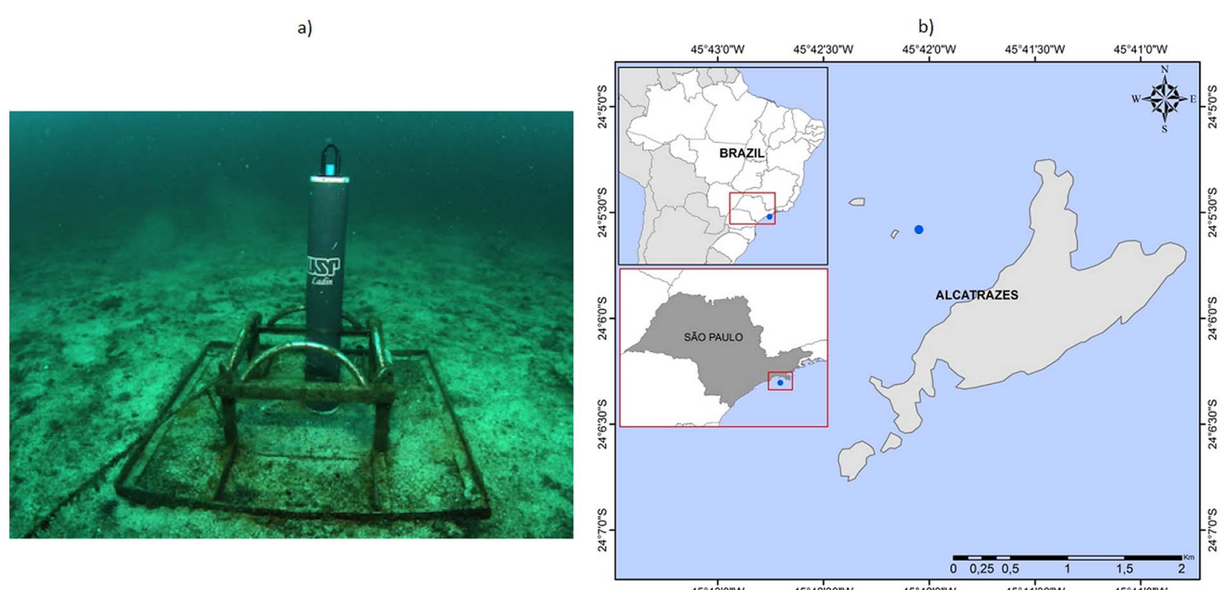

Fig. 1. a) Image of the OceanPod system anchored at sea floor; b) Alcatrazes island localization and hydrophone position (blue marker). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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