Underwater Acoustics for Ecosystem Research:
Current Advances and Perspectives in Northeast Brazil

Acústica Subacuática para la Investigación de Ecosistemas:
Avances y Perspectivas en el Nordeste de Brasil

Acoustique Sous-marine pour la Recherche sur les Écosystèmes:
Avancées et Perspectives dans le Nnord-est du Brésil

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ABSTRACT

Recent improvements (e.g. multi-frequency, broad-band echosounders) allow to simultaneously characterise physical structures (e.g. thin layers, internal waves, eddies) and organisms (from zooplankton to whales) patterns of distribution across scales from meters to thousands of kilometres. These progresses open a variety of perspectives for understanding complex processes. On this basis we are developing in Northern Brazil the 'Acoustic along the Brazilian Coast' (ABRAÇOS) project. The main objective is to establish a 3D characterisation of the abiotic and biotic compartments and their interactions in coastal and oceanic ecosystems. The project is based on two multidisciplinary at-sea surveys performed on-board the IRD R/V Antea in Sept. – Oct. 2015 and April – May 2017 as well as small scale surveys using vessels of opportunity. The study area includes the Northeast coast Brazil and an oceanic area including the Archipelagos of Fernando de Noronha, the Atoll das Rocas and oceanic seamounts. These campaigns have three specific objectives: (i) characterisation of the water masses and their dynamics; (ii) ecosystem acoustics with the collection of multi-frequency acoustic data (38, 70, 120 and 200 kHz) coupled with pelagic and bottom trawls, zooplankton net sampling and video images; and (iii) biodiversity and trophic structure with the study of benthic, demersal and pelagic biodiversity, patterns of distribution, trophic ecology and contamination (mercury). First results provide a new vision of the ecosystem structure and dynamics and reveal, among other, the importance of gelatinous in both coastal and oceanic ecosystems. The perspectives include comprehensive mapping of demersal and pelagic patterns of distribution according to the habitat characteristics including coral reef areas.

KEYWORDS: Ecosystem acoustics, mutifrequency classification, North-East Brazil, video

INTRODUCTION

Recent improvements (e.g. multifrequency, broad-band echosounders) allow to simultaneously characterize physical structures (e.g. thin layers, internal waves, eddies) and organisms (from zooplankton to whales) patterns of distribution across scales from meters to thousands of kilometres (Bertrand et al. 2014, Benoit-Bird and Lawson 2016). These progresses open a variety of perspectives for understanding complex processes. On this basis we are developing in Northern Brazil the 'Acoustic along the Brazilian Coast' (ABRAÇOS) project. The main objective is to establish a 3D characterisation of the abiotic and biotic compartments and their interactions in coastal and oceanic ecosystems. The project is based on two multidisciplinary at-sea surveys performed on-board the IRD R/V Antea in Sept. – Oct. 2015 and April – May 2017 as well as small-scale surveys (Abracinhos) performed using vessels of opportunity. The study area includes the Northeast coast Brazil and an oceanic area including the Archipelagos of Fernando de Noronha, the Atoll das Rocas and oceanic seamounts. These campaigns have three specific objectives:

i. Characterisation of the water masses and their dynamics,
ii. Ecosystem acoustics with the collection of multifrequency acoustic data coupled with pelagic and bottom trawls, zooplankton net sampling and video images, and
iii. Biodiversity and trophic structure with the study of benthic, demersal, and pelagic biodiversity, patterns of distribution, trophic ecology, and contamination (mercury).

METHODOLOGY

If we focus more specifically on the acoustic side of the project, our research has several objectives. It is the first time that a multi-frequency acoustic approach is used in this area, and the main goal is to reach an exhaustive characterization of the ecosystem. The two ABRAÇOS surveys provided data from an EK60 at four frequencies (38, 70, 120, and 200 kHz), with the purpose to describe the distribution of the biotic components and to determine their composition by means of a classification using the frequency characteristics completed by the net samples and the video images. Two supervised methods are currently under development, using RGB color compositions to highlight separated layers, then design an

algorithm to classify these layers that are considered at this step as "acoustic populations", while composed mainly of mixing of organisms, but presenting homogeneous behavior and frequency responses. Knowing the informative potential of the frequency signatures of a set of organisms to classify them (Lavery et al. 2007, Benoit-Bird and Lawson 2016), these algorithms use combinations of Sv differences and sums between frequencies, inspired from the Ballón et al. (2011) algorithm. This latter has been designed with two frequencies for the Peruvian ecosystem, but it is in this work adapted and complexified for four frequencies. Another approach is inspired by the Zscores calculations from De Robertis et al. (2010) but applied to combinations of sums of Sv at several frequencies and combinations of differences of Sv at two frequencies.

Another objective is to characterize the relationships between the biotic components of the ecosystem and their distribution, and the abiotic parameters of the environment. Usually physical data are provided very punctually from CTD profiles. Previous research developed in Peru provided, from the acoustic data, continuous estimate of the depth of the oxygen minimum zone in the Humboldt system (Bertrand et al. 2010, 2014), and a description of the physical structures (Grados et al. 2016), at various scales of interest (meso, sub-meso scales and internal waves). In the ecosystem of Northeast Brazil, the same approach is used to order to extract "clines" from the acoustic data. The first step consists in exploring the relationships between the CTDO profiles and particular structures observed on the echogram, distribution of particular class of organisms. Further steps will be the use of more integrating statistical methods (functional data analysis, GLM, …) to understand these relationships and if possible determine preferential habitats at the scale of the ecosystem. Approaches such as wavelet may be used to characterize the physical structures such as internal waves, like in Grados et al. (2016). Another important aspect of the Abraços survey consists in the use of video fitted in a variety of devices: bottom and pelagic trawl, Rosette. The video allows observing elements escaping the traditional sampling such as pelagic algae or gelatinous.

The other type of surveys, at smaller scale (the "Abracinhos surveys"), started in September 2017 in Fernando de Noronha, onboard a ship of opportunity, with the aim to make regularly twice surveys per year, linked with seabird behavior studies, to get a time series of the 3D characterization of the abiotic and biotic structure of the ecosystem around the island (see for instance Bertrand et al., 2014), which is a partly protected area. The first survey has been performed with two EK80 echosounders, centered on 70 and on 200 kHz. "Lowcost" video acquisition with Gopro™ cameras with the boat drifting, allowed recognizing the species of fish detected on another side on the echosounders as individual targets. It was the first use of the EK80 echosounder in this area and for the survey's staff, and during these video stations either data in CW or in FM were acquired, FM when the weather was calm. CTD profiles were performed up to 160 m using a fishing pool equipped with an electric reel.

RESULTS AND PERSPECTIVES

The finalization of a classification algorithm adapted to the organisms present in the Northeast area of Brazil is the subject of the G. Vargas PhD that currently starts at the Rural Federal University of Pernambuco. However first results have been presented at the Rio Acoustics' 2017 conference (Vargas et al. 2017) that provide a new vision of the ecosystem structure and dynamics and reveal, among other, the importance of gelatinous organisms (class $HR38_1$ on Figure 1) in both coastal and oceanic ecosystems. The gelatinous composition of the $HR38_1$ class (mainly large salps) has been validated in several points during the surveys by means of trawl samples. Among the classification algorithm, a bottom classification tool will be included also, for which video information and sediment grab samples are available for validation. The perspectives include comprehensive mapping of demersal and pelagic patterns of distribution according to the habitat characteristics including coral reef areas.

The first observations on relationships between the organisms' distribution and the physical parameters highlight at least at some stations, the importance of the temperature profile, with layers delimited by the thermocline structure. A deep study of these interactions and the determinations of the "clines" is the subject of another PhD (R. Assunção) which is just starting at the Federal University of Pernambouco.

During the Abracinhos' survey in last September, a large amount of Ballista fish was observed during the video acquisition and the short perspective is to work on the TS of this species, improving in a next experiment the mean to estimate the size of the fish. A constant observation during this survey is the higher amount of targets detected at 70 than at 200 kHz, both frequencies detecting fish but the 70 kHz detecting a lot of small targets filling the water column, that may correspond to small pieces of algae or of gelatinous organisms, visible on some video acquisitions. Such observations have been done also during the ABRAÇOS surveys, of acoustic responses higher at 70 than at 200 kHz and with the same type of hypothesis from the nets or video samples. The processing of this survey will be made during a Master thesis (J. Salvetat). The analysis of the frequency responses within the two bands of the WBT used (~ 50-85 kHz and ~ 150-250 kHz) is an approach we hope will help us characterize these detections that are stronger in 70 kHz, and is mainly a new field of investigation.

In the scope of these small-scale surveys upcoming, is also a better description of the seabirds' preys distribution, thus a better sub-surface acoustic detection, with a methodology still to be designed.

A more general perspective of this project is to create a Chair in ecosystem acoustics in Northeast Brazil, because it is not taught at all, and we started in August 2017 to provide a first 10 days training course at the University of Recife to introduce this discipline in masters' and PhD's cursus; it will be renewed and expanded in 2018.

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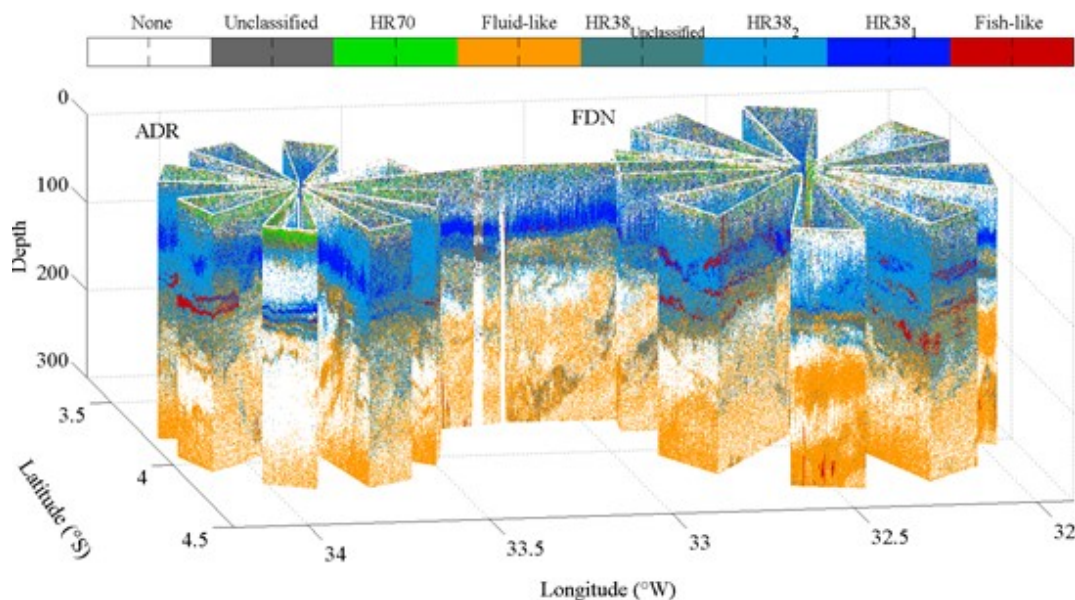
Figure 1. Distribution of the biotic components of the oceanic islands ecosystems, classified by the Vargas et al. (2017) method.