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Universidade do Algarve

AZORES'22 Sea Trial Data Report

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Abstract	This document reports the outcome of the AZORES'22 sea trial that took place in May - June 2022, in the area between the Islands of Faial and Pico, in the Azores.
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Foreword and Acknowledgment

Warm thanks are due to the various partners and colleagues that directly participated in the AZORES'22 sea trial, among which: Rui Prieto (IMAR-OKEANOS) for his advice and help with equipment and moorings' setup, Bruno Castro the master of the IMAR RHIB during equipment deployment and recovery, and Cristiano Soares (Marsensing, Lda) for his care during equipment preparation and shipment to/from Azores.

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Executive Summary

Among the various tasks covered under project JONAS, activity A5.3 aimed at developing and testing strategies for calibrating sound maps with actual field acoustic data. Those strategies, generically termed as "field calibration", concentrated on a data set acquired in June 2018, at three locations of the Faial - Pico area (Azores). Field calibration implicitly assumes that the observed data is the ground truth, and that sound maps may show some degree of mismatch inherent to errors due to modeling or model inputs. However, questions were raised regarding the quality of the data itself both in terms of level and equipment self-noise limitations. A topic of interest would be to perform a direct calibration by comparison with a second calibrated recorder under sea trial conditions. There were expectations that comparison would allow to derive correction hints for recovering the 2018 data set.

Since May - June is normally a period of intense activity for baleen whales in the area, another topic of interest would be to explore the capabilities of vector hydrophones for detecting, localizing and tracking eventual whales' vocalizations. A vector hydrophone allows for relatively simple bearing estimation by combining x-y channel outputs over the frequency band of interest.

These two objectives formed the main drivers for performing the AZORES'22 experiment. Three moorings were deployed on May 19 and recovered on June 24, 2022. Two of the moorings were deployed on the south entrance of the Faial-Pico shallow channel, in close proximity to the initial positions used in the 2018 setup. The third mooring was deployed on the north side of the channel facing the area between the channel and S. Jorge Island. Each mooring was setup with two recorders: one Ecological Acoustic Recorder (EAR) and one additional recorder provided by UALg, either a self-recording hydrophone (SR1 type) or a vector hydrophone (Geospectrum M35), with the objective of comparing EARs and SR1/M35 outputs. All recorders were synchronized and setup for compatible duty cycles and sampling rates. Moorings were deployed at approximately 150 m water depth.

All three moorings were safely recovered, although several issues were found both with the SR1, vector hydrophone and also with the EARs. This preliminary data report carefully accounts for those issues, attempting to identify the data sets with sufficient quality for further processing. Preliminary data assessment shows that due to various equipment failures in crossed moorings only a small data set of approximately 8 hours could be used to fulfil the initial objective of EAR - SR1 comparison. Also, due to an inundated battery pack the vector hydrophone was found with no data, and therefore the second objective could not be achieved.

Clearly, the objectives of this sea trial were not attained. Equipment failure was the main reason so, the recommendation is that careful additional testing and preparation needs to be performed prior to future sea trials.

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Contents

List of Figures

Abstract

The AZORES'22 sea trial took place from May 19 to June 24, 2022, in the proximity of the shallow channel between Faial and Pico Islands in the Azores. Three moorings were deployed: two on the southern approaches to the channel and one in the northern side. Each mooring had two recorders: one EAR and one SR1 or M35 vector hydrophone. After recovery, several technical issues were noticed both with the SR1 and M35 recorders provided by UALg and with the EARs provided by IMAR. Based on a small set of 8 hours of data overlap between EAR-SR1 recording in the same mooring, preliminary analysis shows that there is a significant difference between EAR and SR1 outputs, both in level over the whole band up to 25 kHz, and in the low frequency band below 300 Hz. In that band, which is very relevant for shipping noise analysis, the EAR output is progressively attenuated as the frequency decreases down to approximately 20 Hz. The objectives of the sea trial were only partially met due to equipment failure, which sets requirements of further equipment testing and maintenance in the preparation of future trials.

Chapter 1

Introduction

Marine species depend on sound to sense their surroundings, in a very similar way terrestrials depend on vision. A broad variation of ocean sound level due to non-natural causes has an impact on marine life and biodiversity which amplitude and extent is not completely understood. There are a variety of ocean sound sources that contribute to that increase, many of which are reported in great detail in chapter 21 of the Second World Ocean assessment report of 2021[2]. The sound level generated by non-natural sources is commonly termed as anthropogenic noise, broadly covering ship noise, oil and gas activities, defense, offshore wind construction and others. In particular there are reports that ocean sound has been increasing due to global ship traffic at an approximate pace of 3 dB per decade in the last 60 years [3]. Therefore, being able to predict ocean sound is a matter of concern for species protection policy implementation, and also represents a considerable scientific challenge.

Project JONAS - Joint Framework for Ocean Noise in the Atlantic Seas, addresses the challenge of ocean noise impact on marine life and biodiversity in the North Atlantic area, roughly defined as the European Atlantic. In order to tackle the objectives, the project work plan covers a number of tasks, among which ocean sound modelling for the area of interest, both overall at low resolution and in selected areas at high resolution. A crucial step of ocean sound modelling is prediction validation. That is not an easy step since it requires actual acoustic data, obtained through recording platforms, ideally, for long periods of time and with a significant spatial coverage. Further to validation is the usage of the acoustic data to adjust ocean sound model predictions, correct for bias or other modelling issues. This adjustment is normally termed as field-calibration. Activity A5.3 of the work plan covered these two aspects: model validation and field-calibration, and are included in deliverable D5.3, under the responsibility of partners SHOM and UALG. Two data sets were used in that deliverable: one obtained in the west of Brittany for validation (SHOM) and another obtained in the area to the south west of islands of Faial and Pico in the Azores for field calibration testing (UALG). The validation and field calibration steps normally assume that the observed data is the ground truth. However, the Azores data set was found to have significant recorder dependent self-noise and, possibly some persistent, but unknown, bias at least in part of the frequency band. It became therefore necessary to make some equipment calibration in order to validate the recorded data.

The sea trial objectives may therefore be set forth as follows: to calibrate data recorders used in the Azores data set and find frequency dependent biases, if any; if possible, to determine correction factors to be applied to the data used in the field-calibration test. An additional objective was to test acoustic detection and bearing estimation capabilities of vector hydrophones, for determining the localization of big whales from their vocalizations. These objectives are inline with objectives of WP5, specifically task A5.3 of the JONAS work plan. In principle, the fulfillment of these objectives requires calibration by comparison of previously used recorders to calibrated recorders in the same location and at the same time. The fulfillment of big whales bearing estimation requires the deployment of a low frequency vector hydrophone capable of horizontal x-y field estimation. As we will see in the sequel, these requirements were met in the sea trial setup, even though equipment failure has severely decreased the extent of the attainable results.

This report is organized as follows: chapter 2 gives a generic account of the area and environmental description of the sea trial; chapter 3 describes the equipment being used, the mooring lines and the experimental setup; chapter 4 describes the data gathered during the sea trial and the preliminary results that could be obtained and finally, chapter 5 draws some conclusions and makes recommendations for forthcoming work.

Chapter 2

Area description and deployment location

This section gives a survey of the environmental characteristics of the target area, focusing on the bathymetry and historical water column variability for the month of June. The objective is to setup the likely scenario to be encountered and that motivates the experiment.

2.1 Area bathymetry

The bathymetry of the area of the central group of Azorean islands of Faial, Pico, São Jorge and Terceira is shown in Fig. 2.1 (from the GEBCO database[1]). The black frame shows the area where the acoustic recorders were moored in 2018, the data set that was used in deliverable D5.3. The area is typical deep ocean with water depths over 2000 m

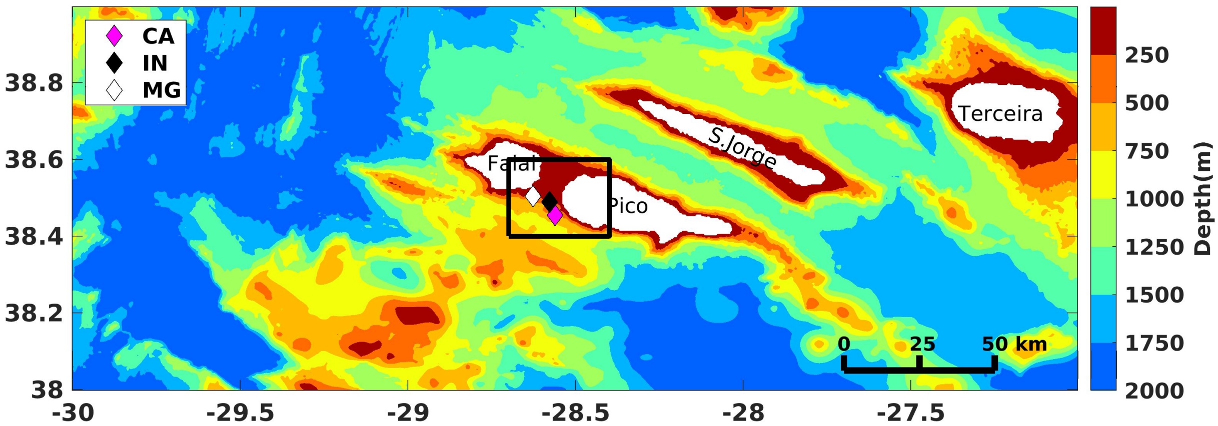

Figure 2.1: *Bathymetry of islands of the Azores central group according to the GEBCO database[1] (the island of Graciosa to the north is not shown).*

almost everywhere and steep bottoms close to the islands, that are of volcanic origin. There are several shallow banks to the south west of Faial-Pico and the very shallow channel (80 m mean water depth) separating Faial and Pico, which is a unique feature in all the islands of Azores. The approaches of that channel either from the south or from the north allow to place the recorders in a sort of balcony listening to the deeper areas where big whales normally rest, while being somehow protected from noise and currents that sweep the shallow channel.

This is shown in greater detail in the high resolution bathymetric map of Fig. 2.2 where the three recorders locations used in the 2018 experiment are marked MG, IN and CA. A fourth location marked OF was also used in other experiments. As we will see below

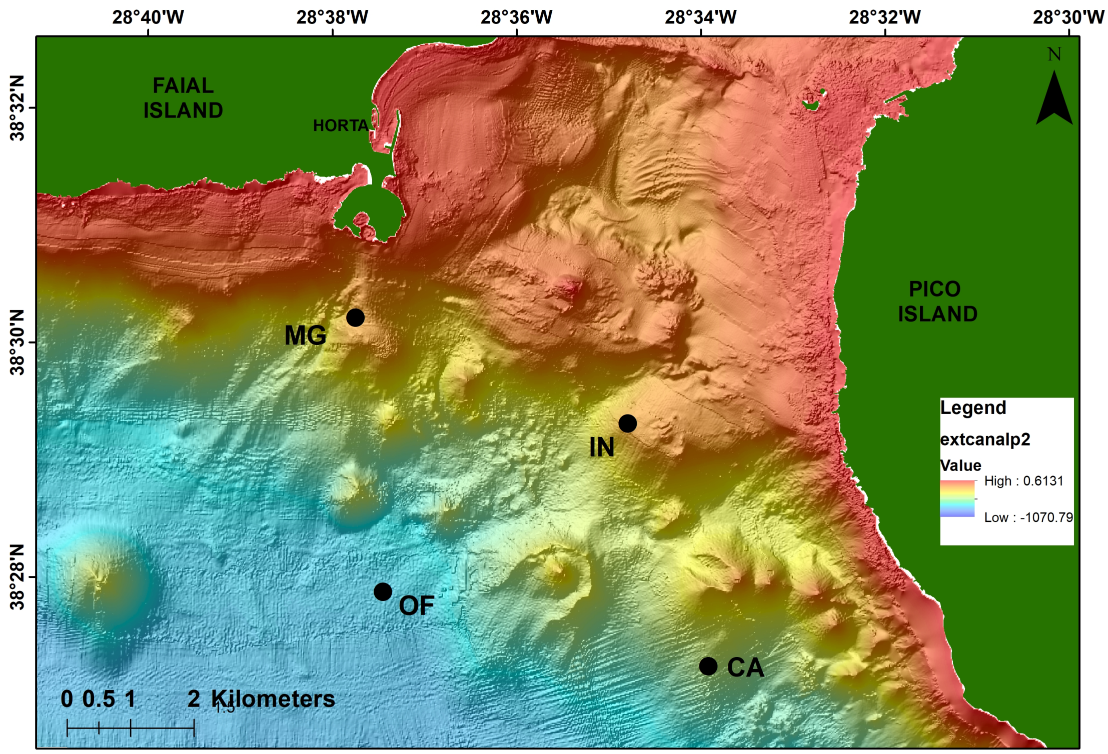

Figure 2.2: *High resolution bathymetry of the Faial-Pico islands channel south west approaches, with 2018 mooring locations [Source: EMEPC, DOP-UAz, Project TRIPAREA/J.Luis/UALg-CIMA].*

(Fig. 3.4 in section 3.2) these positions were kept in mind for the deployment taking place in this experiment.

2.2 Sound speed

Water column temperature is the main driver for determining sound speed. Temperature was obtained from the Copernicus database for June 2018, and is shown in Fig. 2.3 for latitudes 38.2, 38.4 and 38.8 deg North in plots top left, top right and bottom left, respectively. The variation of temperature through the whole month of June 2018 at a single location just to the south of Faial - Pico channel is shown in Fig. 2.3 (bottom right). For reference, latitude lines and single location (star sign) are shown over the area bathymetry in Fig. 2.4. The temperature, salinity and sound velocity profiles are shown superimposed in Fig. 2.5 from left to right, respectively. Within acoustic range of

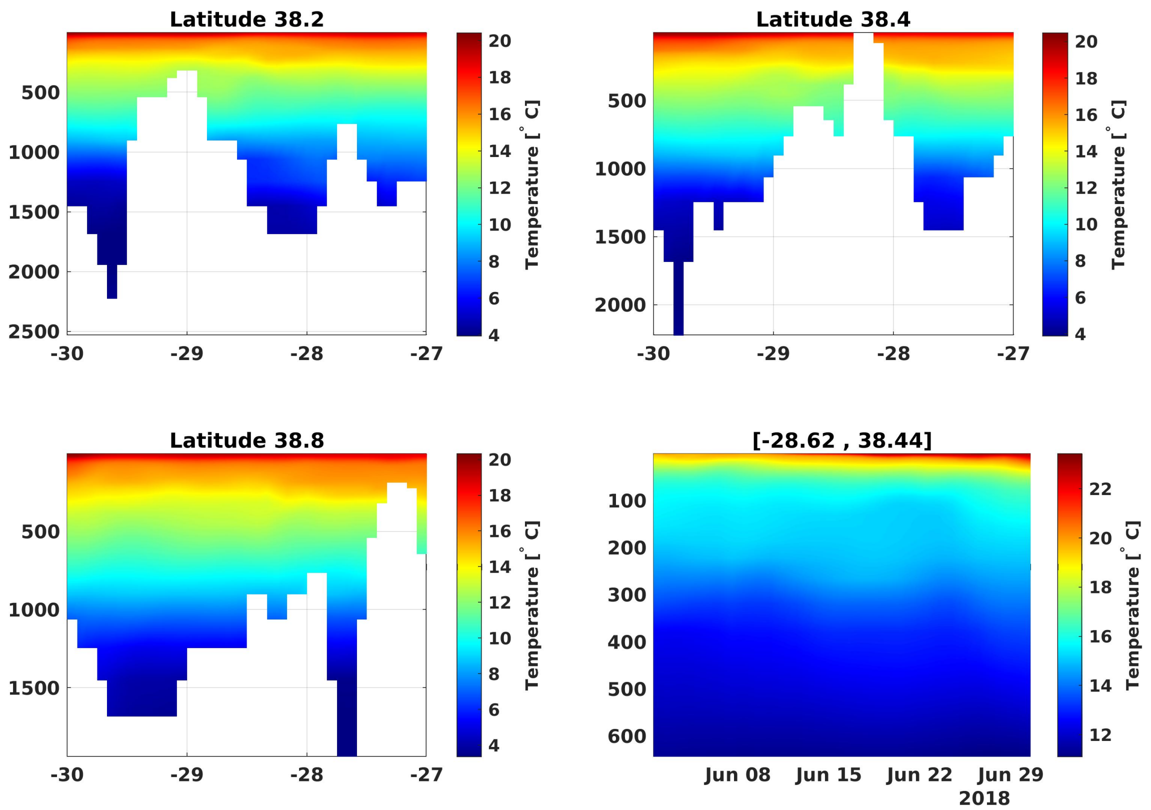

Figure 2.3: *Predicted temperature for month of June 2018, from Copernicus database: across latitudes 38.2 (top left), 38.4 (top right) and 38.8 (bottom left). Temperature over depth and time for the whole month at coordinates lon-lat -28.62,38.44 (bottom right).*

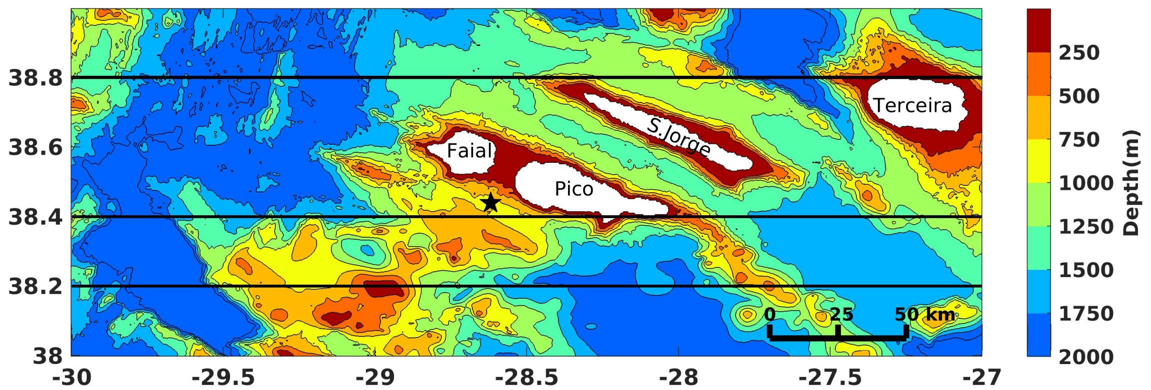

Figure 2.4: *Locations for temperature prediction. Bathymetry data credits: GEBCO database [1].*

the southern channel opening the water depth seldom attains 1000 m so the sound speed profile is purely downward refracting with a thermocline of amplitude 20 m/s extending to approximately 100 m depth, at maximum. Sound speed is, of course, highly variable in time and space (as shown in Fig. 2.5) but the overall evolution should keep similar characteristics from year to year and therefore set the sound propagation conditions that may be expected in the area during the sea trial. Note that the data made available in the Copernicus database is not measured data but ocean circulation model derived data. At some locations and time periods model data is assimilated with actual data collected

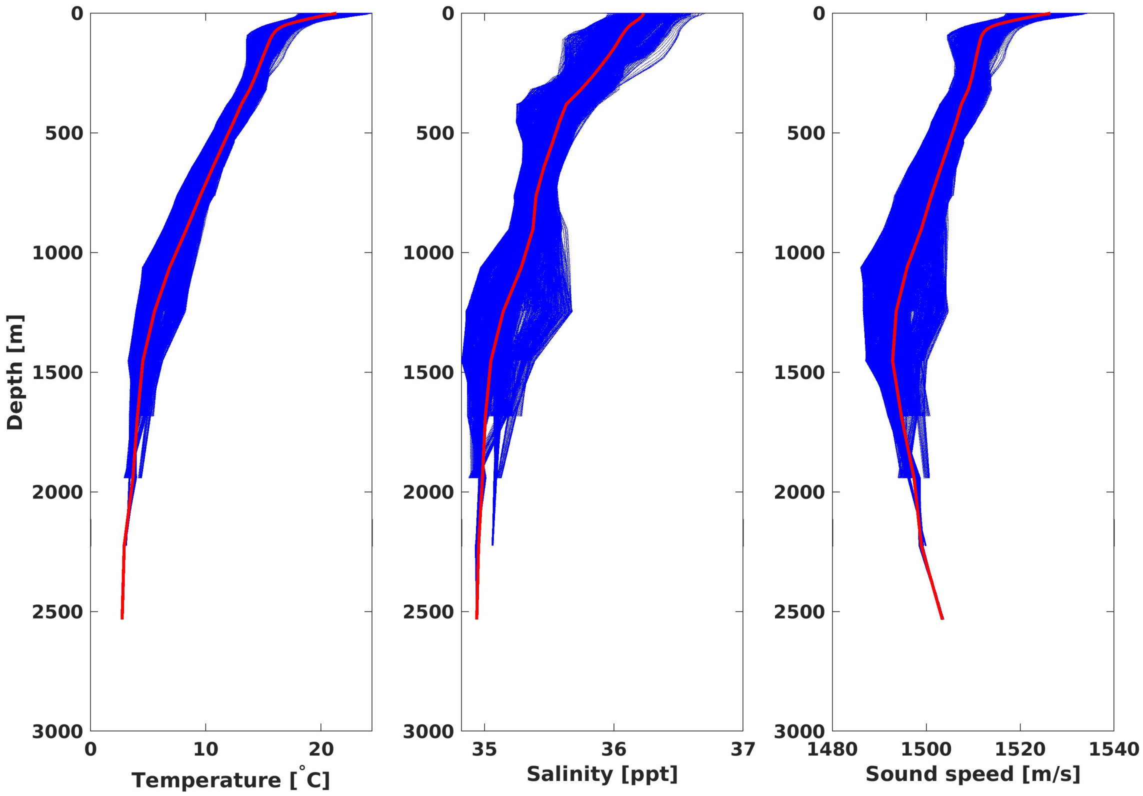

Figure 2.5: *Superimposed depth profiles for temperature (left), salinity (middle) and sound speed (right), from Copernicus database for the month of June 2018. Red line shows mean profiles.*

at sea, but these are relatively rare.

Chapter 3

Equipment, moorings and setup

3.1 Equipment

A list of equipment with its main characteristics and setup is shown in table 3.1. Not mentioned in this table is the fact that the M35 max depth is limited to 200 m by the battery container. Note that gain refers to the total acquisition chain gain which, in the case of the SR1 includes a fixed pre-amplifier gain of x39 and the user programmable gain array (PGA) that during the AZORES´22 experiment was set to x32. These two values together achieve a total gain of 61.9 dB. A duty cycle of 4 minutes ON every 10 minutes was set for the EAR, while a duty cycle of 1 minute ON every 10 minutes was set for the SR1 and M35. Start times were synchronized between all recorders. Pictures

Type	Duty cycle ON/OFF (min)	Band (Hz)	Samp. (kHz)	Depth (m)	Sensitivity (dB//μPa/V)	Gain (dB)	ADC (V)
EARs	4/6	10-25000	50	1000	-194	47.5	1.25
SR1	1/9	20-26368	52,734	200	-193.5	61.9	2.5
M35	1/9	1-16384	32,768	1000	-163	0	2.5

Table 3.1: Equipment list with main technical characteristics and setup.

of the equipment types EAR, SR1 and M35 are shown in Fig. 3.1 left, middle and right, respectively. Due to the maximum depth limitations of some pieces of equipment, it was decided to select deployment locations at depths of approximately 150 m.

3.2 Mooring design and setup

A drawing of the moorings is shown in Fig. 3.2. The moorings were designed for deep water with acoustic releasers and a ballast made out of a large stone for environmental concerns. The buoyancy element was provided by the EARs' high density float. The total height of the mooring above the bottom was kept as low as possible in order to avoid excessive tilt due to currents. SR1 recorders were simply zip-tied to the cable (as shown in Fig. 3.1(b)). The Geo-Spectrum M35 vector hydrophone requires to be vertical

Figure 3.1: *Equipment: EAR (left), SR1 (middle) and Geospectrum M35 (right).*

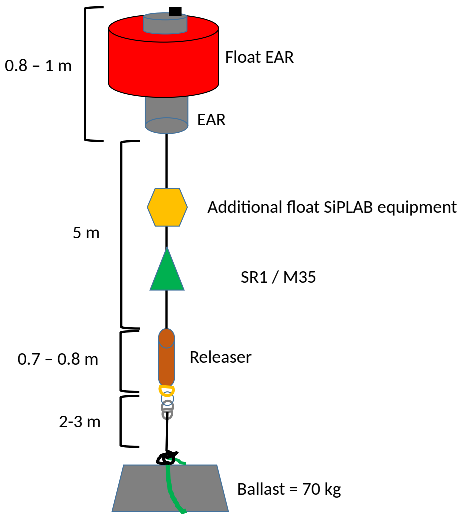

Figure 3.2: *Mooring design: two moorings with SR1 and one with M35 vector hydrophone.*

pointing up (within a 10 degree angle) for the compass to work properly and be able to compensate x-y channels to north and east, respectively. The support structure is shown in Fig. 3.3: it comprises a vertical pole that supports the M35 sensor, and two horizontal specially designed and 3D printed strips (yellow parts) that attach the pole to the mooring cable. Security zip ties and scotch tape were used to secure the vertical pole.

As already mentioned, mooring locations were carefully selected using a high resolution bathymetric map of the area with the objective of ensuring relatively flat surfaces within 150 m depth, on the slopes of the Faial-Pico channel towards south west and north. The actual mooring locations as well as CTD locations (red dots) are shown in Fig. 3.4 over the area bathymetry. Actual coordinates and other mooring information is shown in table 3.2. The actual moorings were deployed within a few meters of the planned locations. CTD results are described in section 4.1. Note that deployment and recovery times are given in UTC which is the same as local daylight saving time, currently adopted in the Azores. Taking into account the duty cycle set for the various equipment, a total of over 86 hours of recording is expected for the SR1 and M35, and 4 times as much for the EAR.

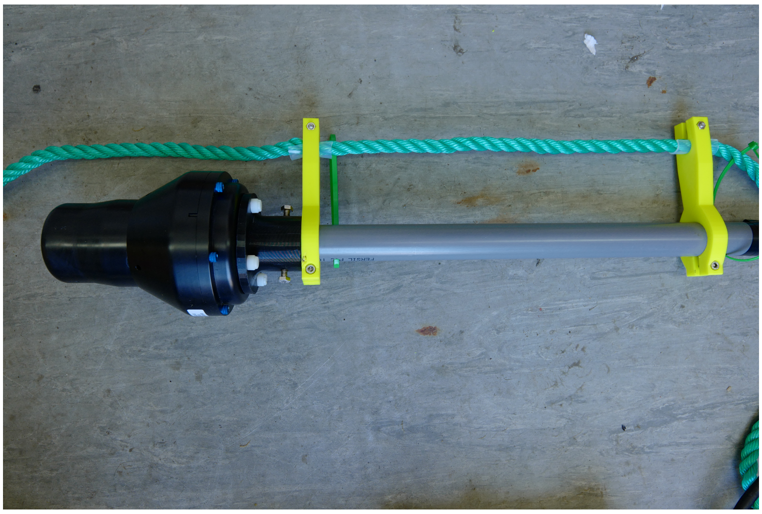

Figure 3.3: *M35 vector hydrophone support assembly for mooring.*

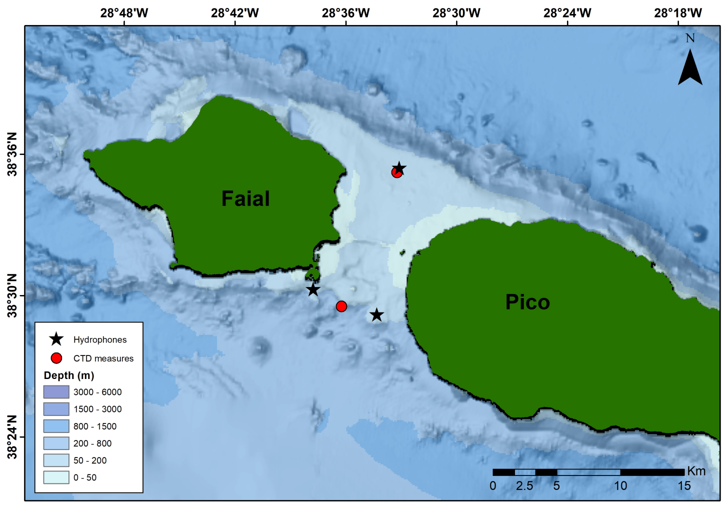

Figure 3.4: *Actual mooring locations for AZORES'22 sea trial and CTD locations (red dots). All moorings were within a few meters of the planned spot [Bathymetry data credits: IMAD-DOP/UAz, EMDONET 2018].*

Recorder	Loc	Lat (deg)	Lon (deg)	Depth (m)	Deploy (UTC)	Recov (UTC)
EAR+SR1A	MG	38.50839	-28.62513	162	19/05/2022 15:49	24/06/2022 10:42
EAR+SR1B	IN	38.49139	-28.56738	159	19/05/2022 16:12	24/06/2022 11:18
EAR+M35	N	38.59530	-28.54957	153	19/05/2022 17:02	24/06/2022 09:59

Table 3.2: Mooring coordinates, depth and deployment and recovery times. Daylight saving time in the Azores corresponds to UTC, so UTC = local time at the date of the sea trial.

Chapter 4

Data description and preliminary results

4.1 Environmental data

To obtain sound speed profiles in the area during the deployment period, two vertical conductivity, temperature and depth (CTD) casts were performed on the 18th of June 2022 . One CTD measurement was done at the northern position at 07:44 (approx. depth: 110 m) and another one at a central point between the two southern hydrophone deployments at 08:28 (approx. depth: 95 m), see Fig. 3.4 for locations. CTD profiles were made with a miniCT probe (Valeport, Devon, UK). Temperature and salinity profiles correspond to measures during the downcast and are shown in Fig. 4.1 for the two locations.

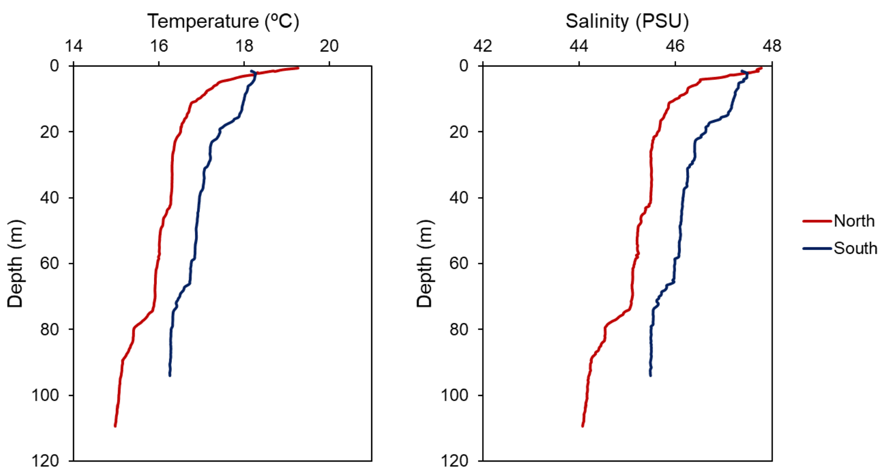

Figure 4.1: *Vertical CTD profiles: temperature (left) and salinity (right) at a north and south location of the Faial-Pico channel, Azores.*

4.2 Marine traffic

Marine traffic is one of the main sources of ocean noise. Automatic Identification System (AIS) is often used as information database for providing ship movements but is limited to those ships that are equipped with AIS transponders. Among those that are not equipped with AIS are, for example, small fishing or leisure boats and / or speed boats used by whale watching (WW) companies, very common in this area. With the purpose of WW noise matching four WW boats provided GPS tracks during the period of the AZORES'22 experiment. These are shown in Fig. 4.2 and the boat characteristics are listed in table 4.1. There are over 15 WW companies operating in the Faial-Pico area, so these four

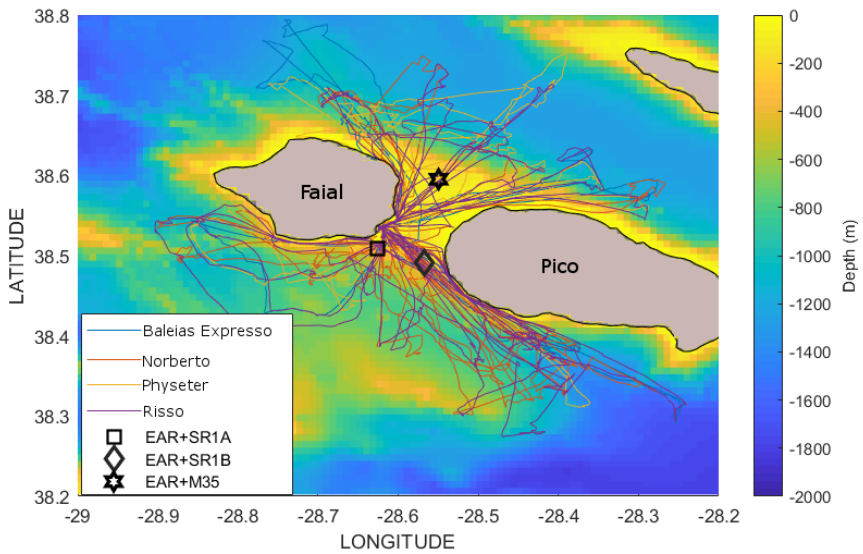

Figure 4.2: *Cumulative GPS tracks of four whale watching boats during the period of May-June 2022 in the Faial-Pico channel area.*

Boat	Type	Length (m)	Engine	Power (hp)
Risso	RHIB	8.5	1 outboard	300
Physeter	Catamaran	12	2 inboard	2x325
Norberto	RHIB	8.5	1 outboard	300
Baleias Expresso	Cabin	9	2 inboard	2x330

Table 4.1: Whale watching boats main characteristics.

boats represents a small sample of the whole fleet, but is a start towards a better coverage of these non AIS noise sources that are quite active in the area.

4.3 Preliminary analysis of acoustic recordings

4.3.1 Acoustic data sets

Table 4.2 shows a list of usable acoustic data sets gathered during the Azores'22 sea trial. Start and end times are given in UTC (or local time) and take into account the actual recording times at sea so, data files before departure and after recovery are excluded. It is clear from this table that the only period of overlap recording of EARs and SR1's are the approximately 9 hours of the SR1 at the IN mooring.

	Recorder	Start	End
MG	EAR	(no data)	
	SR1A	19/05/22 16:00 (#0170)	24/06/22 10:40 (#5322)
IN	EAR	19/05/22 16:20	24/06/22 11:10
	SR1B	19/05/22 16:20 (#0032)	19/05/22 22:00 (#0066)
		28/05/22 04:50 (#0068)	28/05/22 05:00 (#0069)
		28/05/22 12:20 (#0072)	19/05/22 14:30 (#0085)
N	EAR	19/05/22 17:10	09/06/2022 02:28
	M35	(no data)	

Table 4.2: Acoustic data sets gathered during AZORES'22 sea trial with start and end times (UTC). On SR1, WAV format data files are sequentially number with # indicated.

4.3.2 Starting pulse

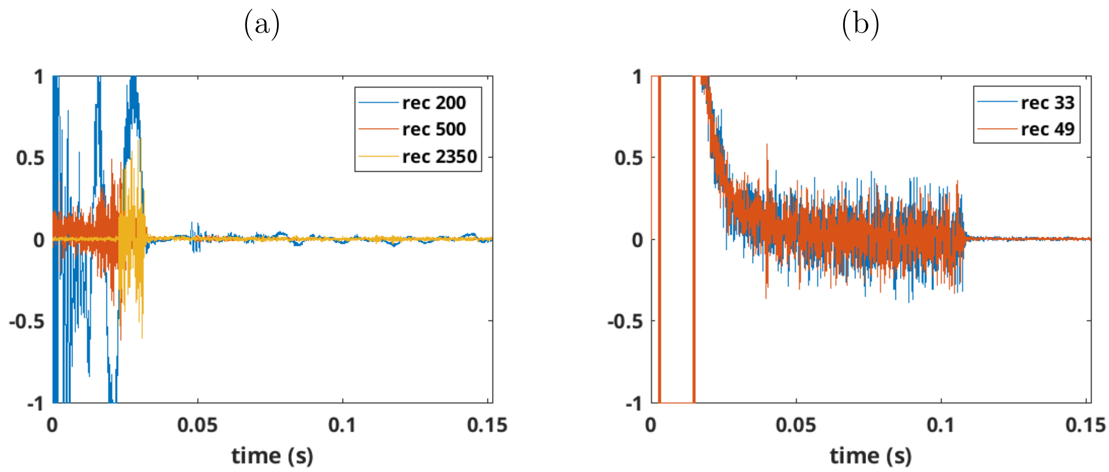

Figure 4.3: *Time waveform for initial 0.15 s of recorded data for SR1A records 200, 500 and 2350 (a) and for SR1B records 33 and 49 (b).*

It was noticed that both SR1A and B had starting bumps on each recorded file, throughout the days. This is illustrated in Fig. 4.3 for SR1A (a) and SR1B (b). For SR1A it is particularly annoying that this bump changes along time. Initially the bump saturates the recorder and starts from the initial sample of each file (see record 200). At record 500, the bump is no longer located at the file start and is not saturating. Record 2350 is one of the last bumps on SR1A, after which the bump disappears (or is buried into the noise, what is even more concerning). Record 2350 corresponds to 19:20 of June 3, 2022. For SR1B the initial recording bumps look very similar throughout the recording period (only a few hours) and include a period of saturation with a progressive decrease of amplitude within approximately 120 ms. **The first 120 ms of data were therefore excluded for each processed file.**

4.3.3 SR1A at MG

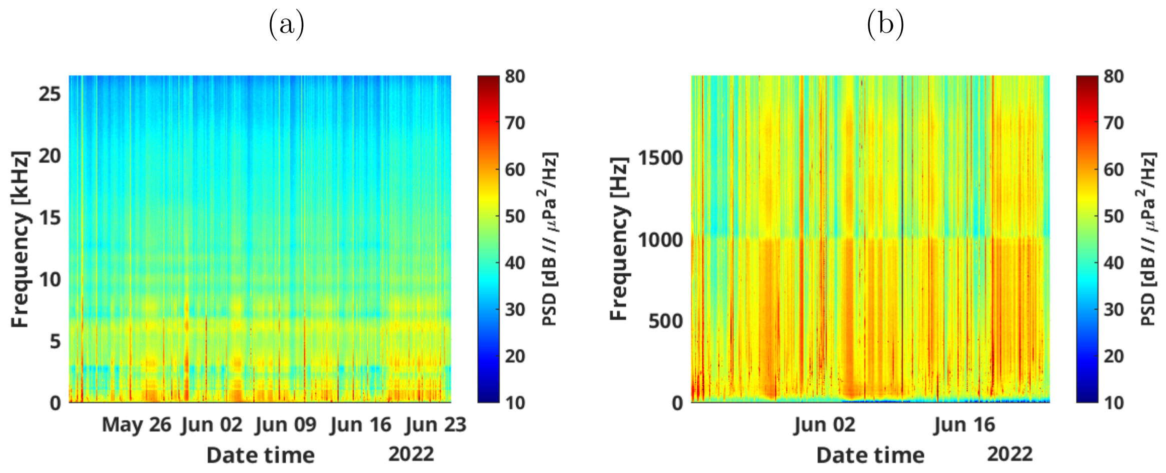

Figure 4.4: *Spectrogram for the SR1A recorder data located at Monte da Guia (MG) mooring for the full 26 kHz band (a) and for the 2 kHz low band (b).*

Fig. 4.4 shows the full band spectrogram (a) and the low 2 kHz band (b) over one month of data gathered on Monte da Guia (MG) SR1A recorder. The digital data was duly calibrated through the hydrophone sensitivity, chain gain and ADC input max voltage (for full output range). Power spectrum density (PSD) was obtained using the Hann weighted without overlap Welch periodogram by averaging in every 1 minute of recording with a time interval of 1 second. Therefore, a frequency resolution of 1 Hz is sufficiently narrow to assume that the PSD is constant and therefore the SPL is well approximated by the product PSD $\times$ frequency band, and since the frequency band is 1, the SPL is simply given by $10 \log_{10} PSD(f)$. In order to cope with the calculation of these plots, only one recorder of 1 minute out of 6, is shown every hour. A number of short spikes extending up to 5 kHz can be seen along time. Those could be generated by speed boats passing in the vicinity of the mooring. Up to, say, 10 kHz there are power amplitude oscillations while, for frequencies above the power spectra continuously decreases. For the lower band, Fig. 4.4(b) shows an attenuation line across the spectrum at approximately 1 kHz. The high-pass filter at approximately 50 Hz may be clearly observed.

Fig. 4.5 shows the estimated spectral power density for the full band (a) and for a zoom into the low 2 kHz band (b). This figure is obtained as a series of histograms over the whole data set, with a 1 dB binning where the number of samples falling in each PSD interval is divided by the total number of samples, as an estimate of level probability. The maximum power level of 62 dB is attained at $\approx$100 Hz. Power oscillations up to 12 kHz can be noticed, and a 1 kHz $\approx$5 dB ripple is noticed in plot (b). Fig. 4.6 shows the mean power spectral density also for the full band (a) and for the low 2 kHz band (b). The ripple at 1 kHz is now perfectly clear in plot (b).

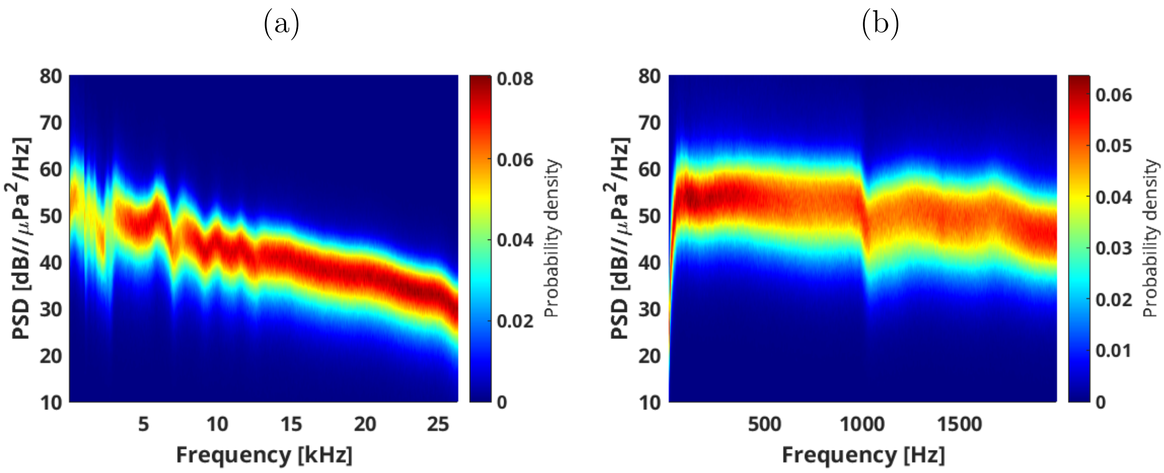

Figure 4.5: *Spectral probability density for the SR1A recorder data located at Monte da Guia (MG) mooring for the full 26 kHz band (a) and for the 2 kHz low band (b).*

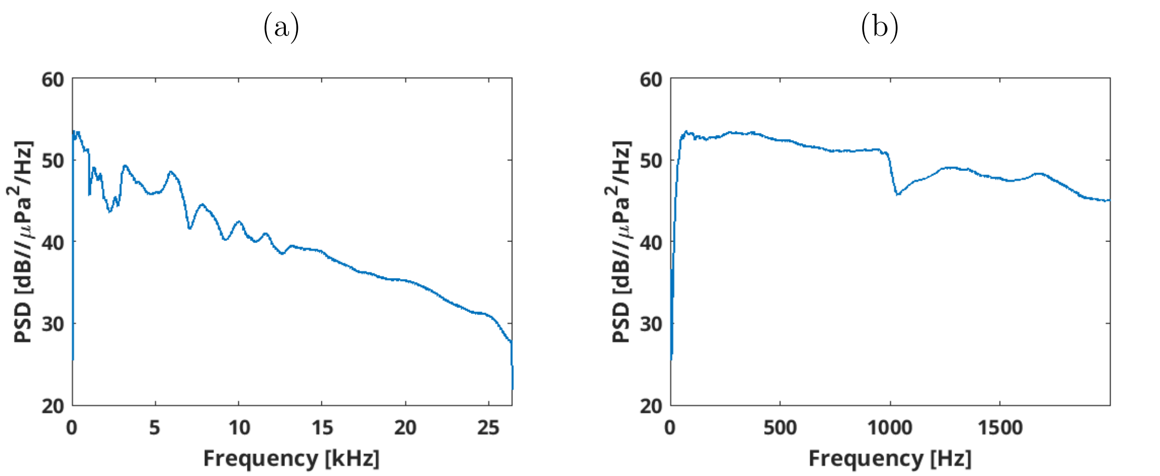

Figure 4.6: *Mean spectral power density for the SR1A recorder data located at Monte da Guia (MG) mooring for the full 26 kHz band (a) and for the 2 kHz low band (b).*

4.3.4 SR1B at IN

Fig. 4.7 shows the spectral probability density of the data received at the SR1B recorder for the full frequency band (a) and for the low 2 kHz band (b). The general behaviour is similar to that of SR1A: the same overall level, the high-pass cutoff and the ripple of 5 dB at 1 kHz. The oscillations throughout the frequency band are also similar with the overall attenuation to the upper band.

The mean value of the SPD for the data of the SR1B recorder is shown in Fig. 4.8 for the full band (a) and for the low 2 kHz band (b). The results are in all main aspects similar to that of the SR1A.

The opportunity to look in detail at the few hours of data recorded on SR1B showed the crossing of several slow ships and some speed boats, with spectra extending up to 5 kHz or more. The superimposed vocalizations of several dolphins can also be heard,

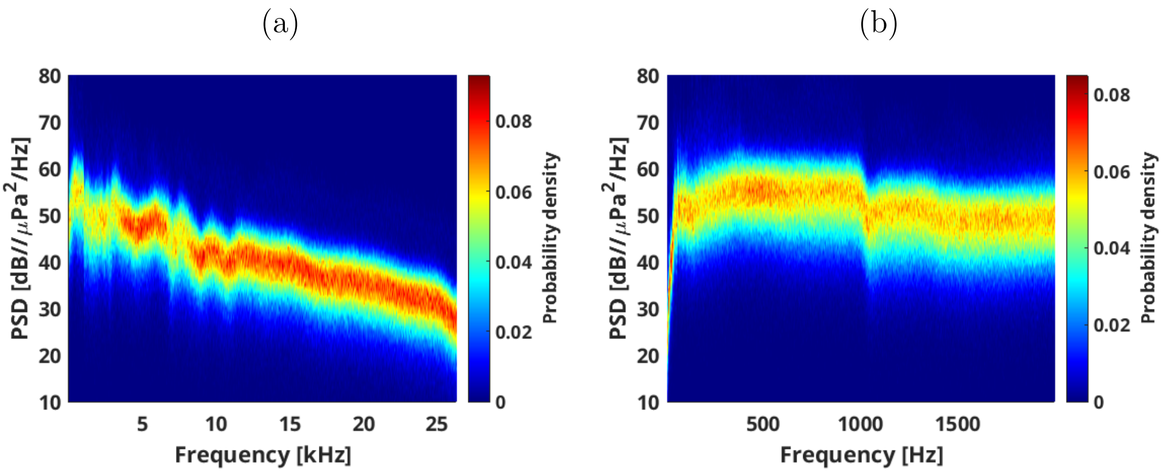

Figure 4.7: *Spectral probability density for the SR1B recorder data located in the chanel (IN) mooring for the full 26 kHz band (a) and for the 2 kHz low band (b).*

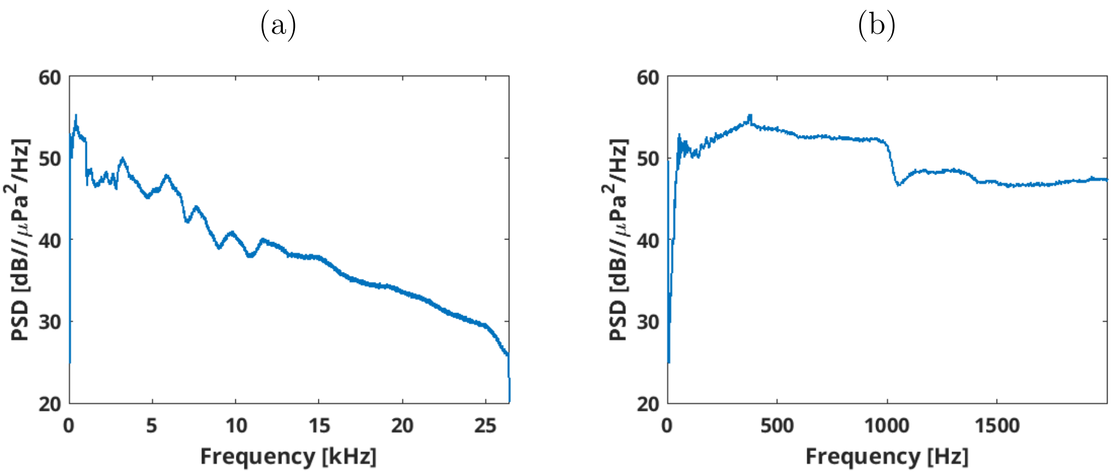

Figure 4.8: *Mean spectral power density for the SR1B recorder data located in the channel (IN) mooring for the full 26 kHz band (a) and for the 2 kHz low band (b).*

which spectrogram is shown in Fig. 4.9 (this data is not calibrated).

4.3.5 EAR at IN

Fig. 4.10 shows long term spectral average (LTSA) spectrograms for the full 25 kHz band (a) and the low 2 kHz band (b) over approximately one month of data (19/05 – 15/06) collected by the EAR at the IN location. The digital data was calibrated by using the technical specifications of the EAR such as the hydrophone sensitivity, chain gain and ADC input maximum voltage. Intermittent, short and loud events reaching a maximum frequency of 10 kHz were identified as boats passing close to the hydrophone (Fig. 4.10 (a) and (b)). Wind-generated noise was more continuous and showed maximum energy below 10 kHz. Above 15 kHz, noise levels decreased (Figs. 4.10 (a) and 4.11(a)) except from a few accounts, when the presence of dolphin whistles increased noise levels in the

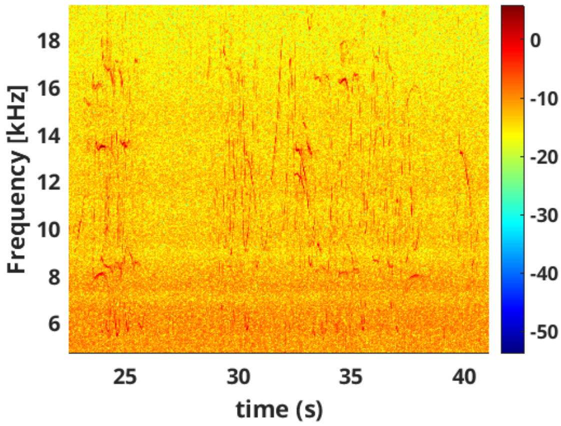

Figure 4.9: *Spectrogram zoom of data record 42, where dolphins sounds in the band 5 - 20 kHz can be seen and heard.*

band between 10 and 25 kHz (Fig. 4.10(a) – 10th of June). In the lower band LSTA noise levels decreased at very low frequencies (¡100 Hz) (Fig. 4.10(b)), which confirms the decreasing EAR sensitivity at these frequencies.

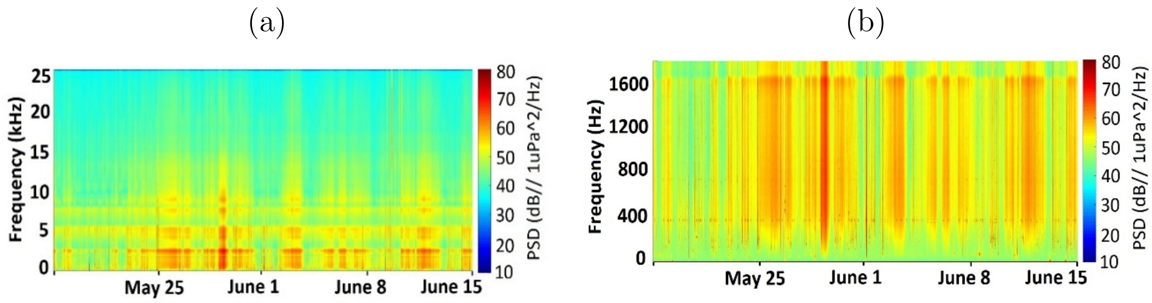

Figure 4.10: *Long term spectral average (LTSA) spectrogram at a resolution of 1 Hz for the full 25 kHz band (a) and for the low 2 kHz band (b) at IN location.*

Fig. 4.11 shows power spectral density (PSD) plots for the full 25 kHz band (a) and the low 2 kHz band (b) at IN location. Power spectrum density plots were obtained using the a Hann weighted time window with 50% overlap and averaging every 60 s of recording. Maximum median noise levels of ≈60 dB were found around 2.5 kHz (Fig. 4.11(a)) probably caused by wind-generated noise. Four bands with higher levels of noise were present in the recordings and obvious in both, the LTSA and PSD figures, from ≈2 to 10 kHz (Figs. 4.10(a) and 4.11(a), respectively). For the low band, a tonal noise at ≈400 Hz repeated all along the sampled period and noticeable in the low band LTSA and PSD (90th and 99th percentiles) (Fig. 4.10(b) and 4.11(a), respectively). A manual examination of recordings identified this tonal noise as a passing ship. This characteristic is perhaps the signature of just one ship that regularly crosses the channel, like for example a ferry. Further analysis would confirm this hypothesis by correlating the ferry's crossing times with the occurrence of this particular noise.

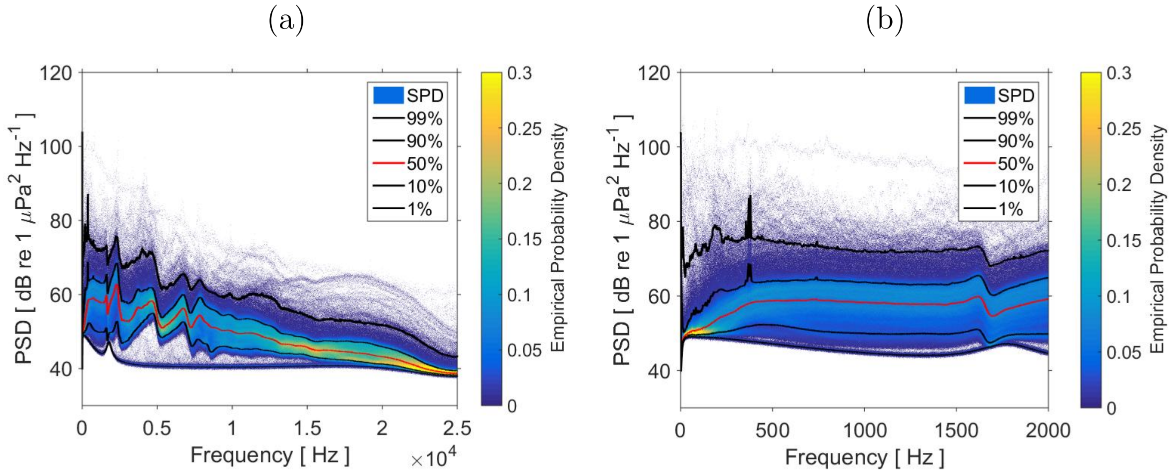

Figure 4.11: *Power spectral density (PSD) for the full 25 kHz band (a) and for the low 2 kHz band (b) at IN location.*

4.3.6 EAR - SR1 comparison

As reported in table 4.2 the recorder SR1B provided data only in three periods covering a total duration of 8 hours and 10 min in two days: 19 and 28 of May. The exact same time periods where selected on EAR-IN, that is in the same mooring, and on SR1A that is on the MG mooring, approximately 4.5 km to the west (see Fig. 3.4). The comparison of these three data sets may allow to get some conclusions on possible deviations between instruments.

The SPD over the full band is shown in Fig. 4.12 for SR1B (a), EAR at IN (b) and SR1A (c). Plots (a) and (c) are repeated from the figures above in order to allow comparison with the data recorded at EAR-IN, plot (b). Clearly levels are different when comparing EAR and SR1. The frequency band level oscillations do exist in both recorders but have different amplitudes and are not at the same frequency (note that the x-axis scale is not exactly the same for EAR and SR1). These differences may be better seen by plotting the means over the band, as shown in Fig. 4.13 for the full band (a) and for the low 2 kHz band (b). The two SR1 have similar level while the EAR is approximately 5 dB above the level of the SR1's over the whole band but below 500 Hz. In fact when the frequency decreases below, say 1 kHz the level of the EAR and SR1 get closer, with the EAR gradually attenuated below 500 Hz. At 200 Hz both recorders have approximately the same level, with the EAR progressively showing lower values than the SR1B as the frequency decreases. At very low frequency, below 40 Hz, the SR1 has a high-pass filter and strongly attenuates the signal, while for the EAR, that attenuation is gradual so it regains a level that is higher than that of the SR1 for frequencies below 30 Hz. The ripple at 1 kHz does not exists on the EAR that as, instead, a smaller oscillation at 1.7 kHz.

Finally, Fig. 4.14 compares the histograms of the SPL data received on the three recorders SR1B, EAR-IN and SR1A for the 1/3 octave bands over the full band but divided in two plots: below (a) and above 1 kHz (b). The levels of the distributions are in agreement to what we have seen in the previous results: EAR above SR1 below 50 Hz, very close values between 50 and 300 Hz, progressively showing higher values from 400 Hz and above. Data spread is generally higher on the SR1's than on the EAR which is probably due to higher dynamic (24 versus 16 bits ADC). Distributions are generally uni-modal at low frequencies and become bi-modal or multi-modal at higher frequencies,

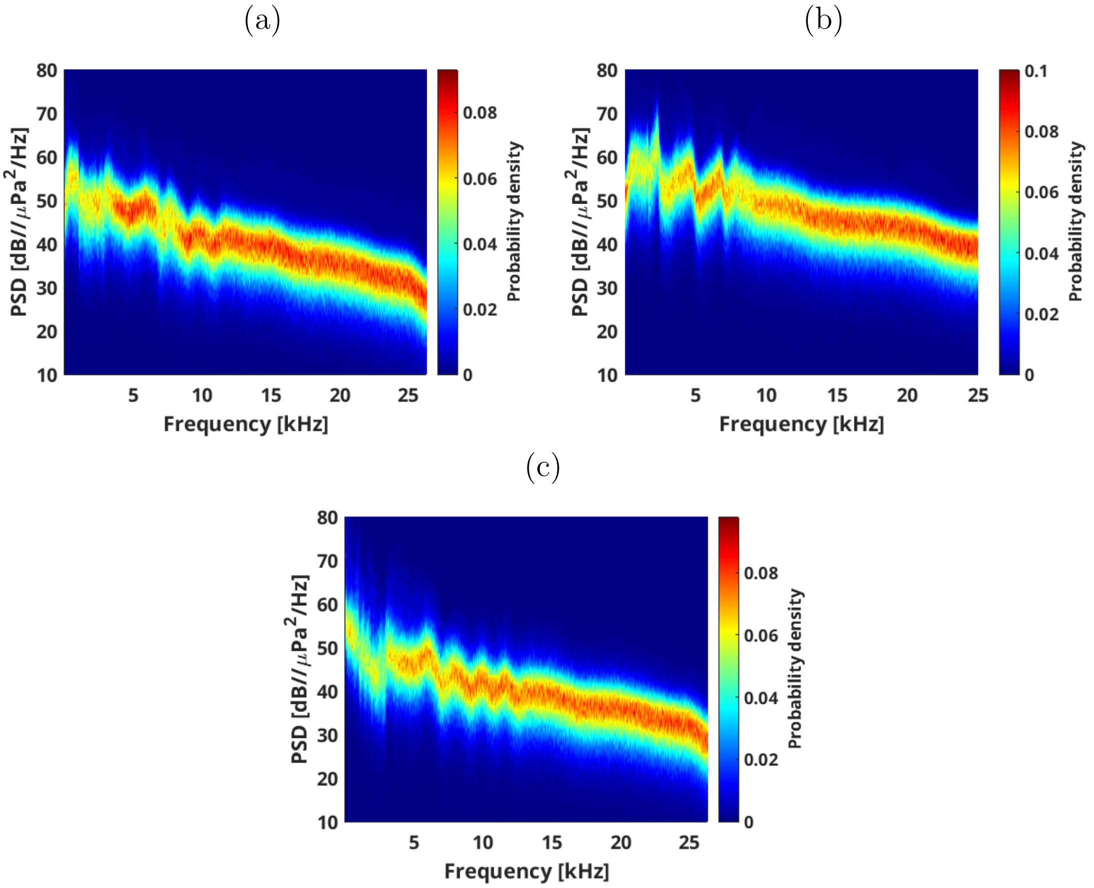

Figure 4.12: *Spectral probability density for the full band and SR1B dataset : SR1B (a), EAR at IN (b) and SR1A (c). Note that SR1B and the EAR are in the same mooring, while SR1A is approximately 4.5 km away.*

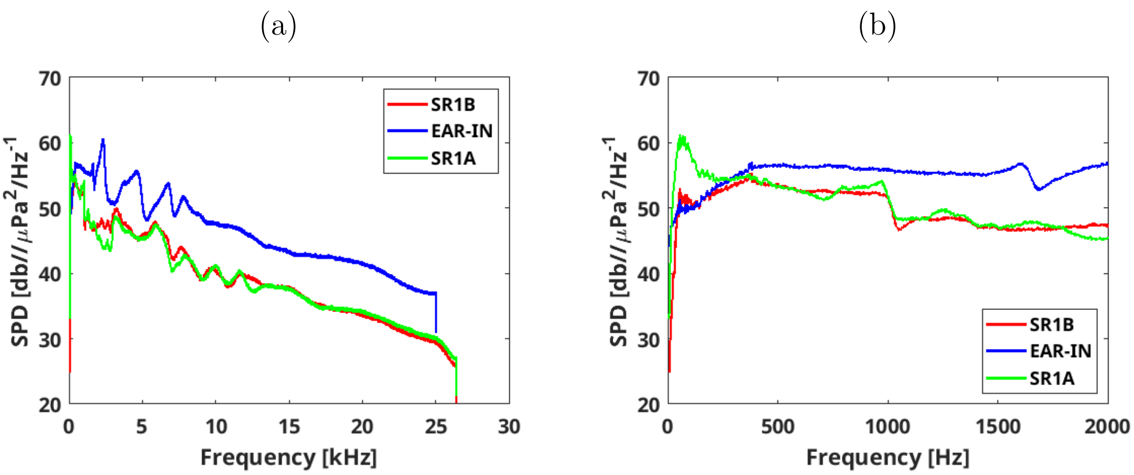

Figure 4.13: *Mean spectral power density for the SR1B, EAR-IN and SR1A recorders data located in the channel (IN) mooring for the full 26 kHz band (a) and for the 2 kHz low band (b).*

say, above 800 Hz.

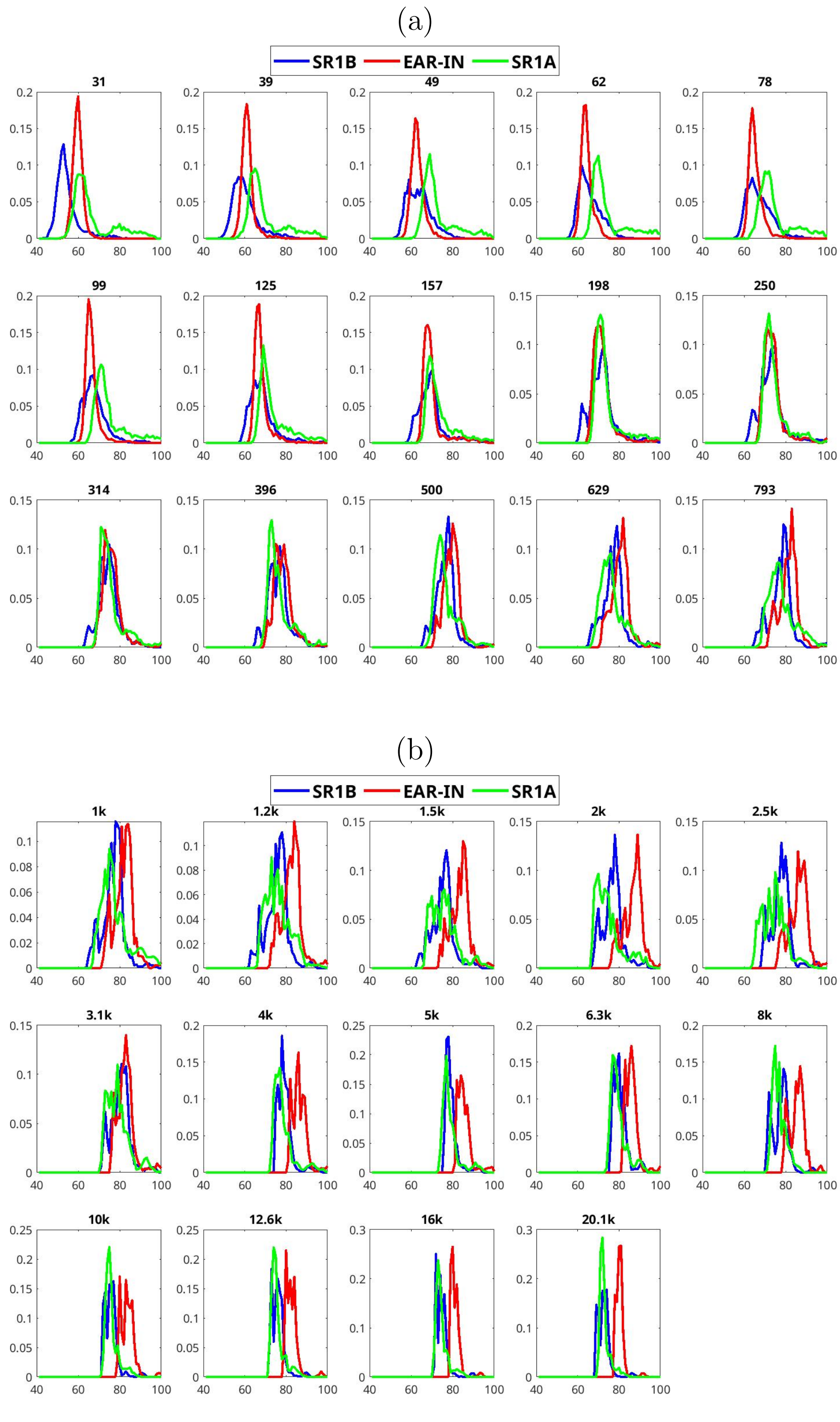

Figure 4.14: *Histograms of the SPL data received at SR1B, EAR-IN and SR1A recorders for the 1/3 octave frequency bands for 20-1000 Hz (a) and 1-25 kHz (b).*

4.3.7 EAR at N

Fig. 4.15 shows the full band LTSA spectrogram (a) and the low 2 kHz band (b) over three weeks of data (19/05 – 09/06) collected by the EAR at the N location. The same method than for EAR IN (see section 4.3.5) was used to create LTSAs. The same noise sources than at EAR IN were identified here, intermittent, short and loud events attributed to passing boats (up to 10 kHz), dolphins (10 – 25 kHz) and wind-generated noise (maximum energy up to 10 kHz) (Figs. 4.15(a) and (b)). Compared to EAR IN, located south of the Faial-Pico channel, noise levels in the north of the channel were generally higher. The recording did not seem to show higher number of intermittent events attributed to boats than the location IN. Thus, higher levels of noise at the northern location may be attributed to a higher exposure to wind and current. Also, we observed up to 6 continuous bands attributed to system noise at frequencies below 2 kHz that were not noted in the EAR IN recordings. As in EAR IN, noise levels decreased below 100 Hz, attributed to the low sensitivity of EARs at low frequencies (Fig. 4.15(b)). Curiously, the low frequency band LTSA at EAR N showed the same tonal noise at 400 Hz than at EAR IN, identified as a boat (Fig. 4.15(b)). Fig. 4.16 shows PSD plots for the full 25 kHz band (a) and the low

(a) (b)

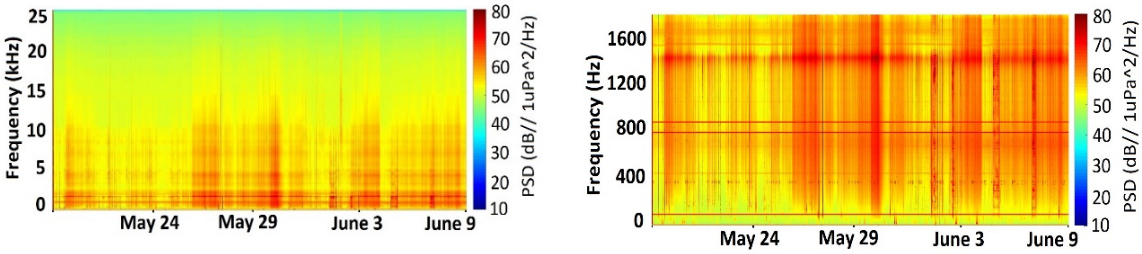

Figure 4.15: *Long term spectral Average (LTSA) spectrogram at a resolution of 1 Hz for the full 25 kHz band (a) and for the low 2 kHz band (b) at the N location.*

2 kHz band (b) at the N location. The same method than for EAR IN (see section 4.3.5) were used to create PSDs. Maximum median noise levels were attained at ≈70 dB below 2 kHz, then levels decreased rapidly above 10 kHz (Fig.4.16(a)). A band with continuous high noise at around 1500 Hz appeared in the LTSA and PSD (Figs. 4.15(b) and 4.16(b), respectively), which resembles the four bands identified in EAR IN recordings.

(a) (b)

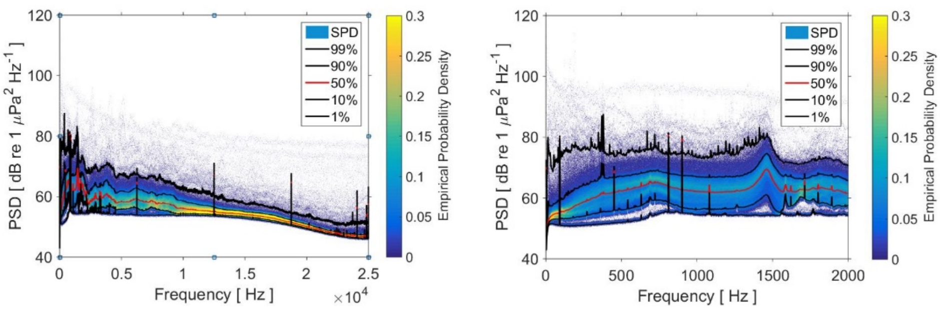

Figure 4.16: *Power spectral density (PSD) for the full 25 kHz band (a) and for the low 2 kHz band (b) at N location.*

Chapter 5

Conclusions

Although this is a preliminary data report, a number of candid conclusions and recommendations may be drawn :

- the comparison between SR1 and EAR, supported only by a few common hours of data at the IN location allows to conclude:
    1. there is a constant SPL difference over the whole spectrum, the EAR recorder providing higher values than the SR1 of approximately 5 dB re 1μPa/Hz,
    2. this SPL difference progressively disappears below 500 Hz as the frequency decreases, leading to EAR levels below those of the SR1 between 100 and 300 Hz
    3. below 50 Hz a high pass filter cuts the SR1 data while the EAR continues to have a relevant sensitivity at very low frequency,
- a ripple of approximately 5 dB amplitude at 1 kHz, of unknown origin could be seen on the SR1 but not on the other recorders,
- a bump of variable amplitude and position could be seen at the start of each SR1 recording. These where variable in time (eventually disappearing after several days) and vary with recorder (A or B).

In conclusion, one may claim that the EARs are not suited recorders for soundscape analysis because of the lack of calibration, purpose filtering in the low frequency band and reduced dynamic. On the other hand, the EARs may be suited for listening to big whales vocalizations in the 10-30 Hz band.

The SR1 seems to be better suited for soundscape recordings, but some specific issues require attention, such as the starting bumps on each recording and the 1 kHz ripple.

As a generic comment this experiment teaches us that a more careful testing and preparation for sea trials is clearly required. Also the failure of the battery package of the M35 recorder requires maximum depth certification of all equipments.

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