EXPLORING THE UNDERWATER SOUNDSCAPE IN A PORTUGUESE COASTAL REGION

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Abstract: *Due to the increasing of anthropogenic activities in the ocean, animals are exposed to a variety of sounds, such as shipping, seismic exploration, sonar and construction of offshore infra-structures. These are particularly relevant when they overvlap with sounds used by several marine species to communicate, to socialize and search for food. Noise from these activities imply certainly changes on the ocean soundscape of those areas. Recently, the European Union aimed to regularize the underwater noise production and soundscape under the Marine Strategy Framework Directive, which establishes several criteria to monitor and assess the spatial distribution, temporal extent, and the levels of anthropogenic noise.*

Passive Acoustic Monitoring (PAM) is widely used to characterize the soundscape of a habitat by assessing noise source, animal vocalizations and other biodiversity sounds, in a given location and time. In this study, we analyse the soundscape of a coastal region in Portugal during one month of data recording, using data from PAM hydrophones deployed in Sesimbra region. The presence/absence of dolphins was estimated through the identification of whistles and other vocal repertoire like gulps and grunts and anthropogenic noise level was measured. Environmental metrics, such as weather conditions (Time of the day, Lunar phases, Tide state) data were used to explain noise levels.

This study pretends to give an initial view of Sesimbra underwater soundscape, where a resident population of bottlenose dolphins is known and a technology free zone is implemented. The Sado-Estuary nature reserve is located adjacently to the study area, where cargo ships, fishing and recreational activities are known to occur, highlighting the importance of acoustic monitoring projects in this region. The overall information of this study is currently permitting the *development and training of an AI-based automatic algorithm to detect dolphin vocalizations, which requires accurate and rigorous scientific data.*

Keywords: *PAM, underwater noise, dolphins, soundscapes*

1. INTRODUCTION

Anthropogenic activities are increasing worldwide in the aquatic environment. These activities are mainly related to shipping, fishing, offshore constructions and even military exercises. Due to these, the general ocean marine soundscape might be changing over years and what was once dominated mainly by wind, waves and biological sounds is now ruled by marine vessel traffic sources [1]. Shipping activity may produce frequency sounds ranging from 1 kHz to 10 kHz, which might overlap with the hearing frequency of animals [2]. Fish and marine mammals use sound for several ecological purposes like communication with conspecifics, cooperative feeding behaviour or reproductive purpose [3]. Consequently, anthropogenic activities influence how marine species interact in the ocean. This has raised awareness among the international community to assess and monitor underwater noise in the ocean. Recently, it has become an important indicator of the Marine Strategy Framework Directive (MSFD) under the European Commission in 2008, which considers the spatial and temporal distribution of loud impulsive noise, as well as trends in low-frequency continuous noise [3].

Typically, coastal areas closer to harbours of crowd cities are more vulnerable to anthropogenic activities, mainly related to fishing and cargo ship activities, where coastal marine species are exposed to different types of underwater noise and daily time fluctuations. Coastal species, such as Bottlenose dolphins (*Tursiops truncatus*) and Common dolphins (*Delphinus delphis*), might be exposed to continuous noise, being essential to implement monitoring programs for these species. These animals have a wide complexity of acoustic repertoire for socializing or for feeding purposes, such as whistles or food related calls [4], leading to a good candidate for Passive acoustic monitoring programs (PAM).

Portugal has a vast maritime coastal area with several important seaports, where cargo ships supply European countries. Setúbal, a region with a seaport known to have cargo ships activity and fishing boats, is also known for the presence of a small resident population of bottlenose dolphins, inhabiting in in Sado river Estuary [5].

Several studies were conducted mainly inside the Sado estuary waters [5], but not in the adjacent waters, which turns out to be the estuary entrance channel for cargo ships and fishing boats. Here, bottlenose dolphins might occur as well as other cetacean's species like common dolphins [6]. Moreover, on these adjacent waters, specifically in the Sesimbra region, a free technological zone for robotic experimentation and prototyping with Maritime Unmanned Systems for safety and defence has been recently established. Within the Scope of these programs, it is easily to obtain a significant of amount of acoustic data, where the use of advanced automatic AI-based algorithms would be of extreme valuable. In order to obtain strong automatic detection algorithms, it is important to obtain accurate and robust scientific information.

The objective of this study is therefore to characterize the Sesimbra underwater soundscape and assess the acoustic presence of dolphins in this region and contribute with baseline data for the development of AI-based algorithms.

2. METHODS

The study area is located in the coastal area of Sesimbra (Fig 1). The area is located near a local fishing community and the commercial harbor of Setúbal. It is also known for the unique resident population of bottlenose dolphins (*Tursiops truncatus*) in Portugal mainland. The sampling point was in the geographical position 38°26.088'N 09°00.398'W (water depth ≈ 80 m).

Fig. 1- Study-area, with the location of the hydrophone.

Acoustic data was collected using a Soundtrap ST300HF. The equipment was deployed according to the scheme present in the (Fig. 2) between 10/09/2021, 10:30 AM and 18/09/2021, 09:40 AM. The REP(MUS) exercise was carried out in same period. The equipment was set up to record continuously, creating new files every 10 min (Settings: high pass filter off; pre-amplifier gain high; Sample rate 192kHz).

Since the acoustic recordings were used for the purpose of training artificial intelligence algorithms there was a need to reduce the amount of data for manual labelling. Therefore, only files recorded every 20 min were selected (e.g. first file at 10:30, the next file selected at 10:50). To estimate broadband sound pressure level (BB SPL) for each recording of selected files PAMGuide tool, EDF Version [7] was used (settings: Window type- Hann; Window length: 1 seconds, Window overlap- 50%; low freq. 20 kHz, high freq. 96 kHz ; time-average data: 10 min calibration end to end -176 dB). To assess differences in BB SPL during the day Wilcoxon statistic test was used. Time of the day period was categorized in morning (from 7 AM to 8 PM) and night (from 8 PM to 7 AM).

To assess the variation of dolphin presence during the recording period all the selected files were analysed based on the visual identification of vocalisations (whistles, grunts, gulps) using Audacity. Since significant differences were found on vocalizations, generalized linear model was used to explain which factor was influencing more the difference (factors: SPL, time of the day, lunar phases, Tides).

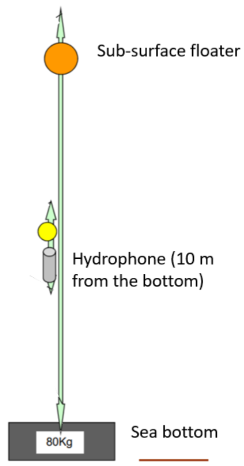

Fig. 2- hydrophone deployment.

3. RESULTS

Of a total of 288 acoustic recordings analyzed, the presence of vessels was identified in all of the acoustic recordings. During the recording period BB SPL varied between 100 dB re 1 µPa and 130 dB re 1 µPa, with an average of 109 dB re 1 µPa (5 dB re 1 µPa). Looking at the variation of BB SPL along the recording period, it was found to be different between day and night, with high levels during the day (W = 12172, p-value = 0.004958) (Figure 3).

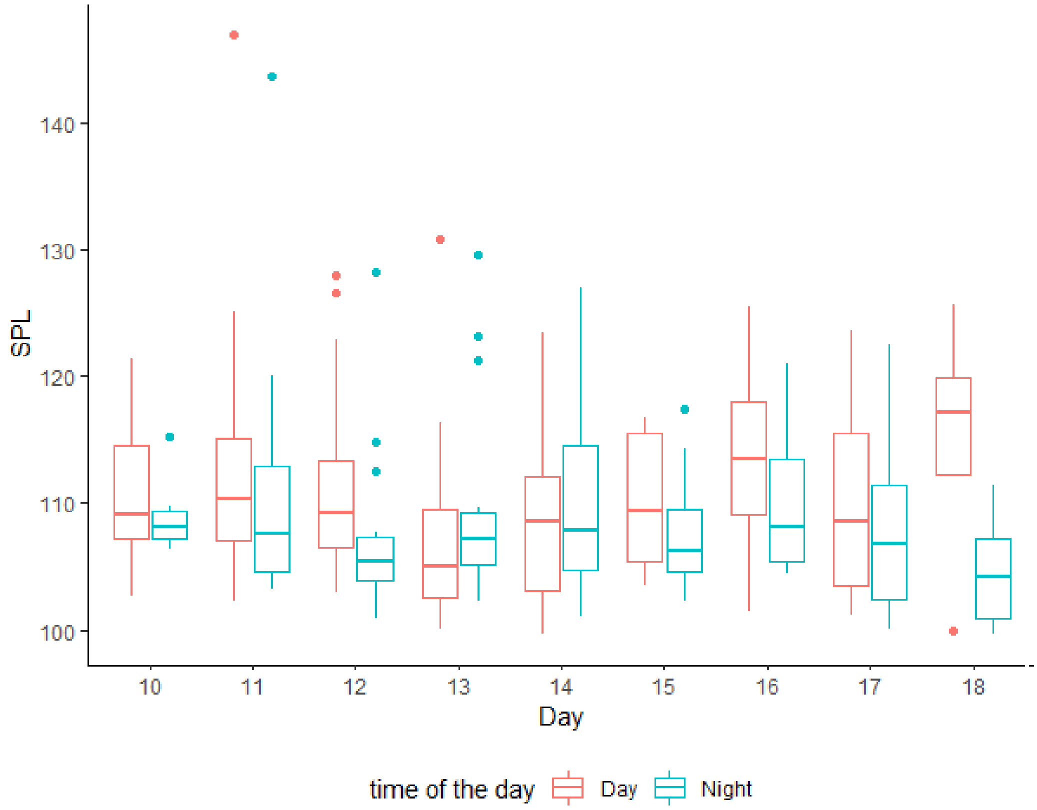

Fig.3: Broadband Sound Pressure Level variation during day and night, along 9 days of measurement.

Of all of the acoustic recordings analyzed (n= 288), the presence of dolphins were registered in 24,6 % of the acoustic recordings (n= 71). On these acoustic recordings, whistles were present in all (n= 71), Gulps in 26,7 %(n=19) and Grunts 9,8 % (n= 7). The vocal repertoire identified is presented in figure 4. The whistles were observed ranging from 5 kHz until 20 kHz. The gulps were characterized as short lower frequency sounds, below 3 kHz, and grunts as broad high frequency sounds, higher than 3 kHZ. The environmental variables that explain the presence of dolphins were "Time of the day" and "Lunar Phases". The higher probability of identifying the presence of dolphins was during the night and new moon (Figure 5), according to GLM model ((*Pr(>|z|):* time of the day`Night = 6.82e-05***; Lunar Phases`New Moon: 2.51e-07***; TidesLow tide: 0.0677 *; Intercept: 1.39e-14***; p-value <0,000; AIC= 285.72).

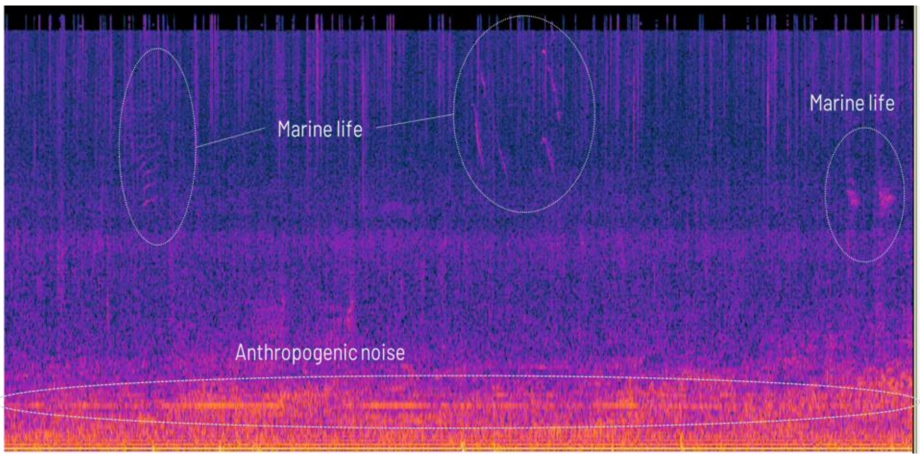

Fig.4: Detection of acoustic sources.

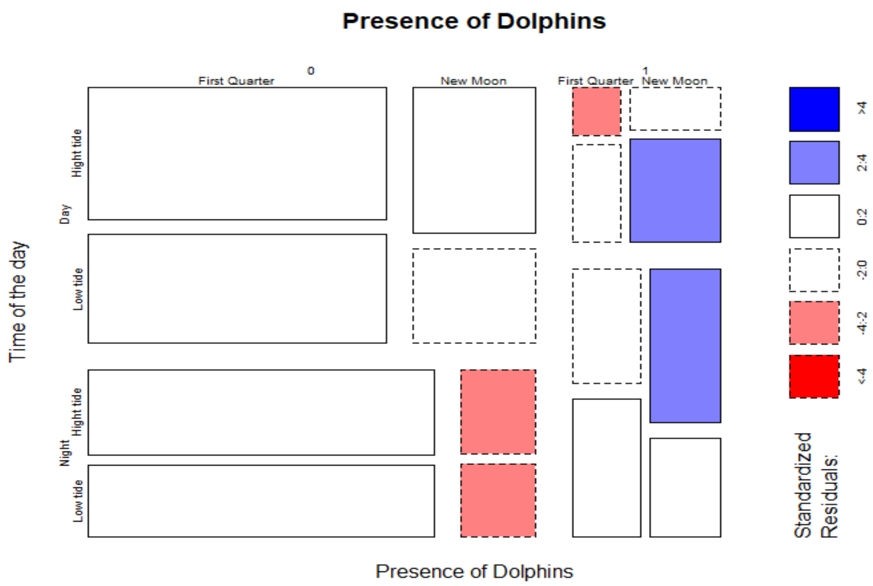

Fig.5: Contingency table of the categorical variable considered to explain the presence of dolphins.

Of all the types of vocalizations identified (whistles, grunts and gulps), only ”Gulps” were shown to have significant differences with the Lunar phases, when compared to all other environmental variables. The higher probability of the presence of Gulps was during new moon (Figure 6) according to the GLM model (*Pr(>|z|):* time of the day`Night = 0.07247; Lunar Phases`New Moon: 0.00363 ***; Intercept: 1.35e-13 ***; p-value <0,000; AIC= 134.4)

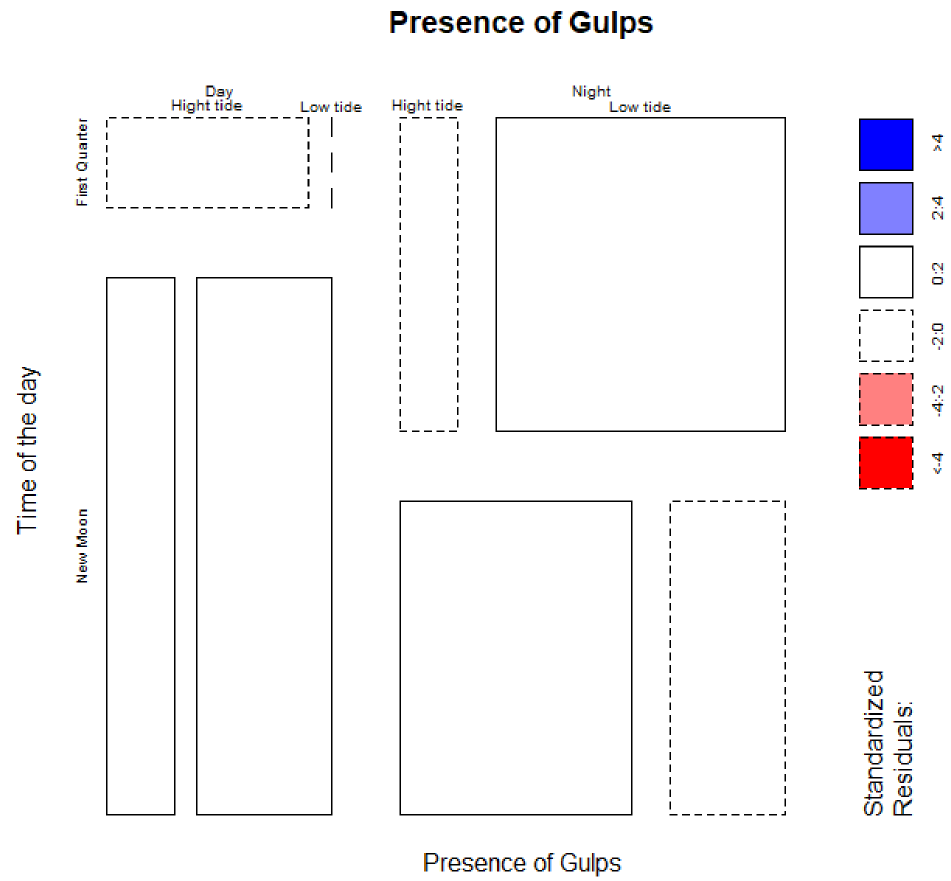

Fig.6: Contingency table of the categorical variable considered to explain the presence of Gulps.

4. DISCUSSION

The marine soundscape in the Sesimbra region in September 2021 was mainly characterized by the presence of vessels, during all the sampling period. The level of SLB was significantly different between day and night, which might indicate different shipping activity throughout the day. According to the Setubal harbour, between the sampling period of this study there were 150 cargo ships operating [8]. The activity at harbour is principally during the day. Setubal harbour is considered the principal seaport of Ro-Ro ships, which supply the Portuguese automobile industry [9], therefore enhancing the strong anthropogenic activity present in the study area. The continuous presence of maritime traffic through our sampling period is consistent with what is happening in other coastal areas, where this type of traffic is the principal contributor to the increasing levels of noise and it is considered the main contributor to background noise in European waters [10].

The sampling period of this study was during day and night, while other acoustic studies of Setubal and adjacent waters were more focused in day-light hours [5]. In fact, this study shows one of the first evidence regarding the daily activity of dolphins, where the presence of dolphins were acoustically more detected during night. These results could be explained, effectively, that dolphins could be more active during night and so more audible or, on the other hand, less communicative as a behaviour response to boat traffic in noisy moments [5].

It is known that night vertical fluctuations of fish might influence the activity of dolphins and increase feeding and foraging behaviour [11], [12]. Moreover, Lunar phases influence the presence of fish [13] and so it is expected that feeding and foraging behaviour of predators, like dolphins, will increase as well. Gulps were identified in the vocal repertoire of bottlenose dolphins and defined as Bray-call [14], which is a complex and poorly understood type of call, but probably related with cooperative feeding techniques [4], [15].

In this study, was not possible to identify the dolphin species presented in the dataset however, the identification of the vocal repertoire of dolphins allows the development of a refined automatic AI- algorithm to for future studies related with PAM programs. Both Bottlenose dolphins (*Tursiops truncatus*) and Common dolphins (*Delphinus delphis*) are commonly in the study area and produce vocalizations in the frequency range observed [16], [17]. Further analysis needs to be conducted to identify the signature whistles of both species.

Even though the sampling period of this study was short, it was possible to perform a first characterization of Setubal's adjacent waters soundscape and understand that anthropogenic activities are strongly present and overlapping with dolphin presence. Future analyses are highly recommended to identify the dolphin species and deeply characterise other sound sources, like types of vessels present in the study-area. Moreover, it would be prudent to analyse a wider temporal soundscape in the area and have a better clue of the underwater noise over the year.

Overall this study highlight the importance of accurate of passive monitoring programs in areas of heavy traffic vessels and where dolphins occur.

5. ACKNOWLEDGEMENTS

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