Hellenic Petroleum Exploration & Production of Hydrocarbons SA

IONION GULF ACOUSTIC MONITORING PROJECT

ITEM 1C
"Postend ambient noise monitoring"

Technical Report

OCEANUS LAB

(Laboratory of Marine Geology & Physical Oceanography)

Department of Geology University of Patras

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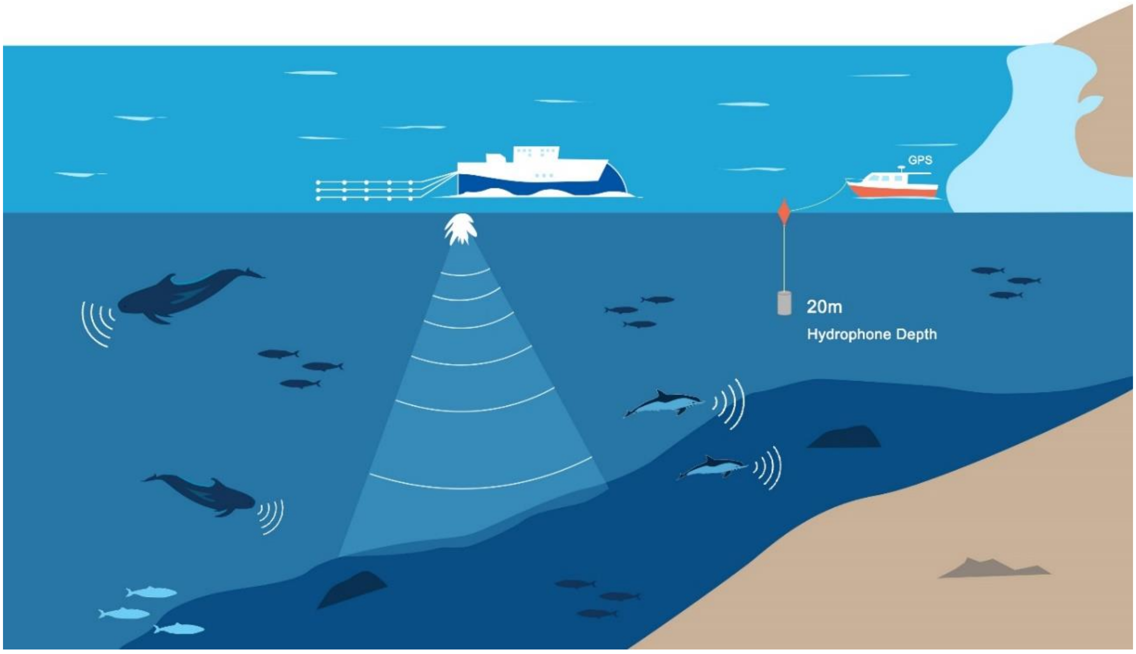

1. Introduction

This report describes the methodology, data processing, and the preliminary results of the ITEM 1C "Monitoring of the 4 predefined locations with spot measurements – "Post-End phase" of the Ionion Gulf Acoustic Monitoring Project.

The Ionion Gulf Acoustic Monitoring Project is a project for measuring the acoustic noise levels before, during and after the 3D Marine Seismic Survey carried out by HELPE S.A.

The Ionion Gulf Acoustic Monitoring Project has been planned and carried out by the Oceanus-Lab (Laboratory of Marine Geology and Physical Oceanography) of the Geology Department of the University of Patras.

The Post-End phase (ITEM 1-C) lasted five (5) days, between January 17th to January 21st 2023.

2. Methodology

2.1. Fieldwork

2.1.1. Survey vessel

The vessel "Sea Master" (Fig. 2.1.1.1.) was used to carry out the acoustic survey. "Sea Master" is a 9.98-meter long motor-yacht modified by the Oceanus Lab, University of Patras to reach the qualifications of a research vessel. The specific vessel has been chosen due to its ability to travel at very high speeds (max speed 30knots) and its building material (GRP plastic) which causes lower noise interference during the recordings. Table 2.1.1. presents the specifications of the vessel.

Fig. 2.1.1.1. The vessel "Sea Master" was used for the underwater noise monitoring project.

Table 2.1.1. Technical specifications of vessel "Sea Master"

Name :	Sea Master
Year and place of build :	2014 – Greece
Registry :	Argostoli 633
Flag :	Greek
Length :	9.98m
Breadth :	3.70m
Draft :	1.0m
Engines :	2 CUMMINS 380HP (261KW)
Max Speed :	30knots
Cruising Speed :	22knots
Generator :	Marine 5.5kVA/220V
Navigation equipment :	GPS, Magnetic Compass, Radar, Thermal Camera, Echosounder, VHF

2.1.2. Instrumentation

A portable recording system was used for the monitoring of the ambient noise on the four predefined stations. It includes a four-channel digital recorder, three hydrophones (high -170dB and low sensitivity -220dB ones) and a laptop carrying the interfaces for recording and visualizing the data. Using multi-sensitivity hydrophones assures that all dynamic ranges and amplitudes are successfully recorded without any signal clipping.

The underwater recording system was the compact autonomous recorder model EA-SDA14 (Fig. 2.1.2.1), provided by RTsys. RTsys systems are thoroughly calibrated to be compatible with all international regulations.

A second recorder was onboard at all times, serving as a backup system in case of failure (Fig. 2.1.2.2.).

Fig. 2.1.2.1. The RT-SYS portable unit which used for measuring the ambient noise.

Fig. 2.1.2.2. The backup RT-SYS portable unit.

The positioning of the vessel during the survey was acquired using a Global Positioning System (GPS) and specifically the EMLID Reach (Fig 2.1.2.3). The navigation of the vessel was carried out using the navigation software package HYPACK 2014 (Fig 2.1.2.4) for:

• Storing and displaying route navigation data,

• Continuous graphic presentation of the vessel movement (tracklines),

• Logging time and corresponding geographical coordinates.

The position of the vessel was time tagged and stored during the recording so that all recordings could be correctly geo-referenced.

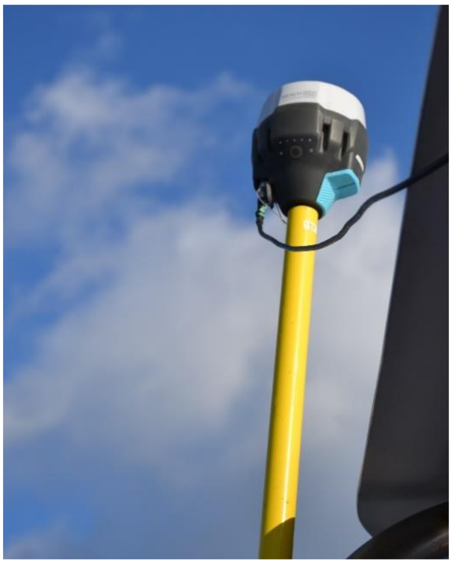

Fig. 2.1.2.3.

The EMLID Reach GPS.

Fig. 2.1.2.4. Hypack 2014 navigation software on-board the research vessel.

Surveyors, on board the survey vessel, deployed the recording unit with the hydrophones attached, suspended by an anti-heave buoy 20 m below the water's surface (Fakiris et.al., 2019). The buoy was attached to the research vessel via a floating rope (Fig. 2.1.2.5.).

Fig. 2.1.2.5. Monitoring deployment system, using buoys.

2.2. Survey Planning

ITEM 1 stage includes (1) Ambient noise measurements (prestart and post completion of seismic activities) and (2) Seismic noise monitoring, at the proximity of the four (4) predefined locations (Fig. 2.2.1.). The four locations proposed by HELPE are:

• Location 1 (N1), that refers to Lefkada island.
• Location 2 (N2), that refers to Paxoi-Antipaxoi islands.
• Location 3 (N3), that refers to Southern Kerkyra island.
• Location 4 (N4), that refers to Northern Kerkyra island.

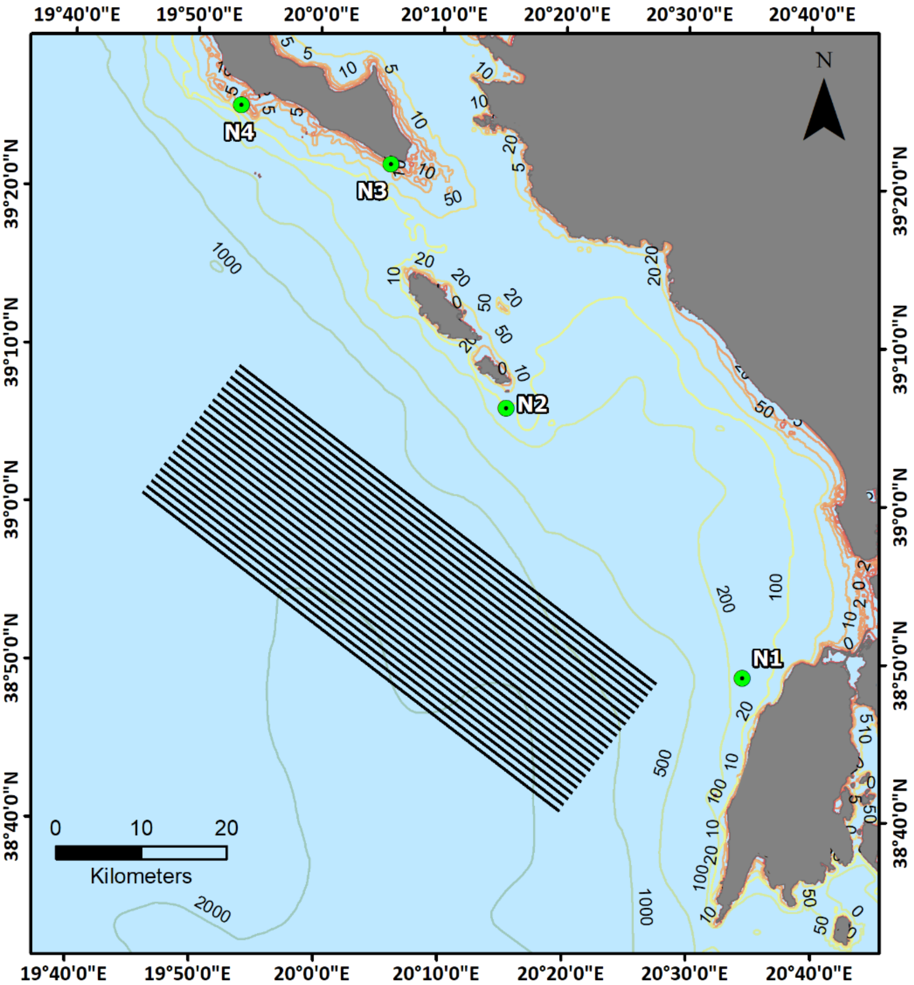

Fig. 2.2.1. Map locating the seismic survey area (tracklines) and the four (4) locations where spot acoustic measurements took place in the Post-end phase.

During the ambient noise measurements (Post-End phase), a total of five (5) deployments (two in Paxoi island) have been realized (Table 2.2.1.; Fig 2.2.2). For the realization of the measurements, the research vessel was approaching the station, stopped the engines to avoid any mechanical acoustic noise, and deployed the underwater recording unit at 20m water depth to uninterruptedly acquire sound data for 3-5 hours. In each deployment, the vessel was left drifting by the winds and the sea currents, hardly stabilized by using a floating anchor. Whenever the vessel has drifted far from the intending position, correction movements were realized, the time and duration of which were noted in the logbook to be excluded from the post-survey analysis. A total of 22 hours of raw data recordings have been acquired.

Table 2.2.1. Ambient noise measurements sorted by date and station.

Date	Lefkada (N1)	Paxoi (N2)	Kerkyra South (N3)	Kerkyra North (N4)
17/01/2023	√			
18/01/2023		√		
19/01/2023		√		
20/01/2023			√	
21/01/2023				√

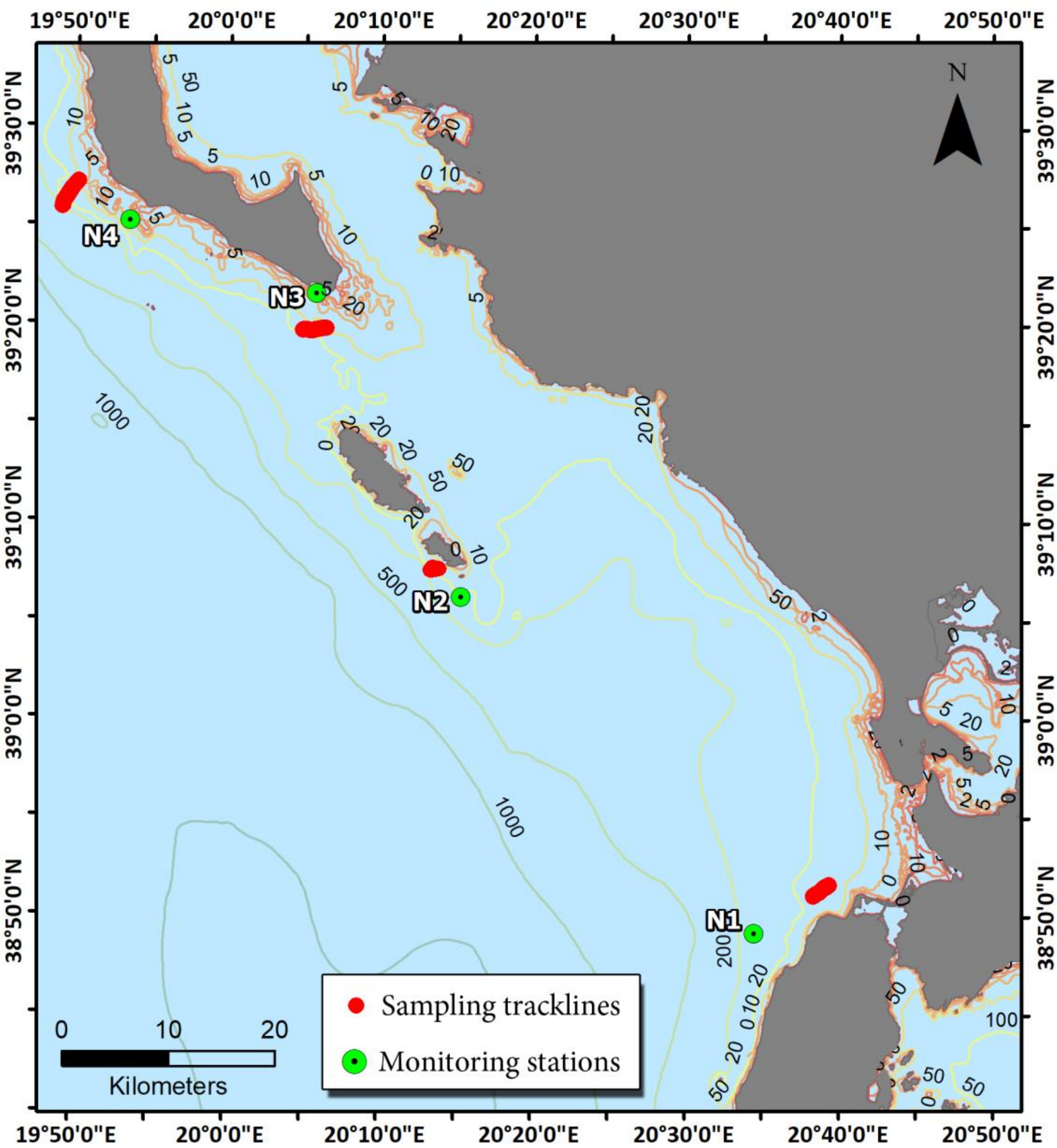

Fig. 2.2.2. Map showing the spot measurements and the track lines of the vessel during the measurements at the four sampling locations.

2.3. Data Processing and Reporting

The objectives of this acoustic study were to measure ambient sound levels as a function of sound frequency components, time and position as well as correlate acoustic anomalies to major acoustic sources within the survey areas. To meet the above, a suite of MATLAB codes has been implemented by the Oceanus Lab, Patras University. The data processing steps were as follows:

1. Apply queries based on the digital logbook entries to narrow data exclusively to effective recording times. List files by date/time and location.
2. Apply hydrophone sensitivity and digital conversion gain to digital recording units to convert to fully calibrated micro pascals (μPa).
3. Apply a high pass filter over 5Hz to remove the continuous components.
4. Determine start times of seismic pressure signals in digital recordings via the stored mission files by the recording unit and generate time-tagged recordings.
5. Associate recording time tags to GPS fixes to georeference the sound recordings.
6. Calculate the instantaneous sound pressure level in dB re 1μPa.
7. Calculate SPLpeak, SPLrms and SEL (as defined in the following) for a time interval of 1 sec of the recordings.
8. Calculate the Power spectral density (PSD) for every distinct period of 30 seconds of the recordings.

In detail, for each subsample of the complete sound files, the following parameters have been calculated:

1. Peak sound pressure level (SPL_{peak}) is the maximum absolute amplitude value in the signal during a specified time interval:

$$\mathrm{SPL_{peak}} = 20\log_{10}\frac{\mathrm{P_{peak}}}{1\cdot\mu Pa}$$

   where P_{peak} is the peak pressure and units are dB re 1 μPa.

2. Root mean square (RMS) sound pressure level (SPL_{rms}) is the log-transformed square root of the average square pressure of the signal over a specific time interval:

$$\mathrm{SPL_{rms}} = 20\log_{10}\frac{\mathrm{P_{rms}}}{1\cdot\mu Pa}$$

where P_{rms} is the root mean square (rms) pressure and units are dB re 1 μPa.

3. Sound exposure level (SEL), is the squared sound pressure integrated over a specific duration:

$$\mathrm{SEL} = 10\log_{10}\left(\frac{\sum_{i=1}^{n}\mathrm{P_i^2}(\mathrm{t})}{1\cdot\mu Pa}\cdot\Delta t\right)$$

where P is the pressure and units are dB re 1 $\mu Pa^2 \cdot s$.

4. Power spectral density (PSD) is the power in the signal per unit frequency throughout the signal (10secs in the present case). The PSD was computed using Welch's method, which divides the signal into overlapping segments that are windowed. The window function was set to be a hamming one, which is optimized to decrease the amplitude of the side-lobes in the spectrum. Frequency components have been estimated via Fast Fourier Transform (FFT). Units are dB re 1 μPa^2/Hz.

For each sampling location, all the 10 seconds integrated PSDs were combined under a single graph, using their rms value (*thick dark line* in the following PSDs figures) over frequency intervals and their relative occurrence densities over 1dB intervals. The frequency axis was set to a logarithmic scale to enhance low-frequency components. The relative density of the PSDs (one for each 10 seconds integration) in the frequency versus PSD Euclidean space, was presented using a yellow to a red color scale, with red denoting dominant frequencies; i.e. occurring most of the recording time.

3. Results

3.1. Reporting material

The diagrams considering the aggregated PSDs for 10 seconds intervals of the full recording period are presented for each sampling station, along with the sampling locations (Fig. 3.1.1 to 3.1.8). The histograms of the SPL distributions during the pre-start phase are also given to provide implications about ambient echotope of the surveyed areas (Fig. 3.1.1 to 3.1.8).

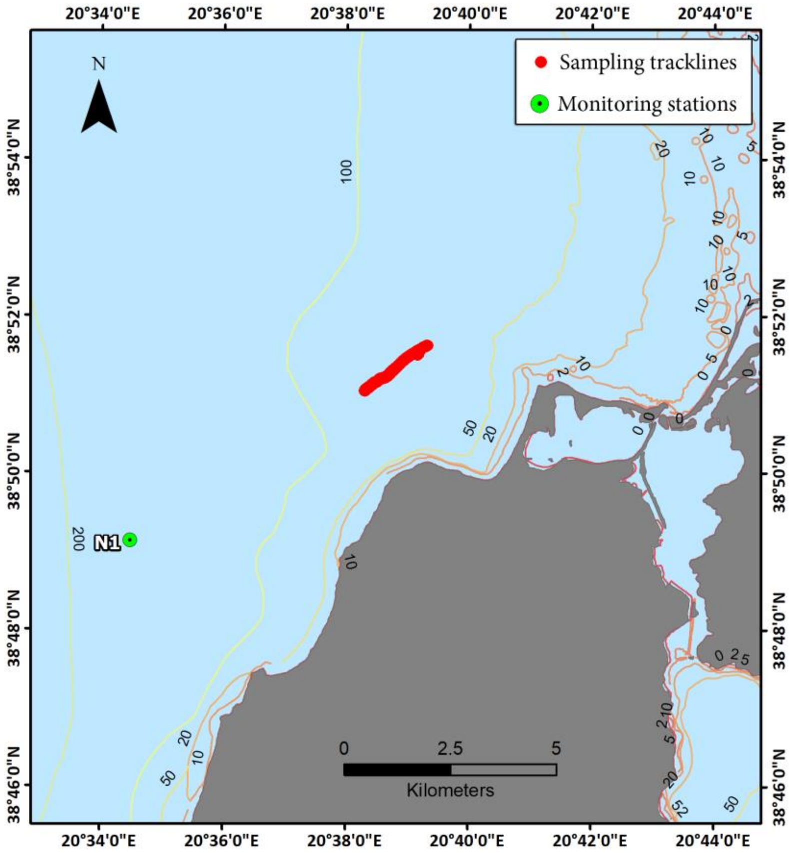

Fig. 3.1.1. Sampling locations at Lefkada station.

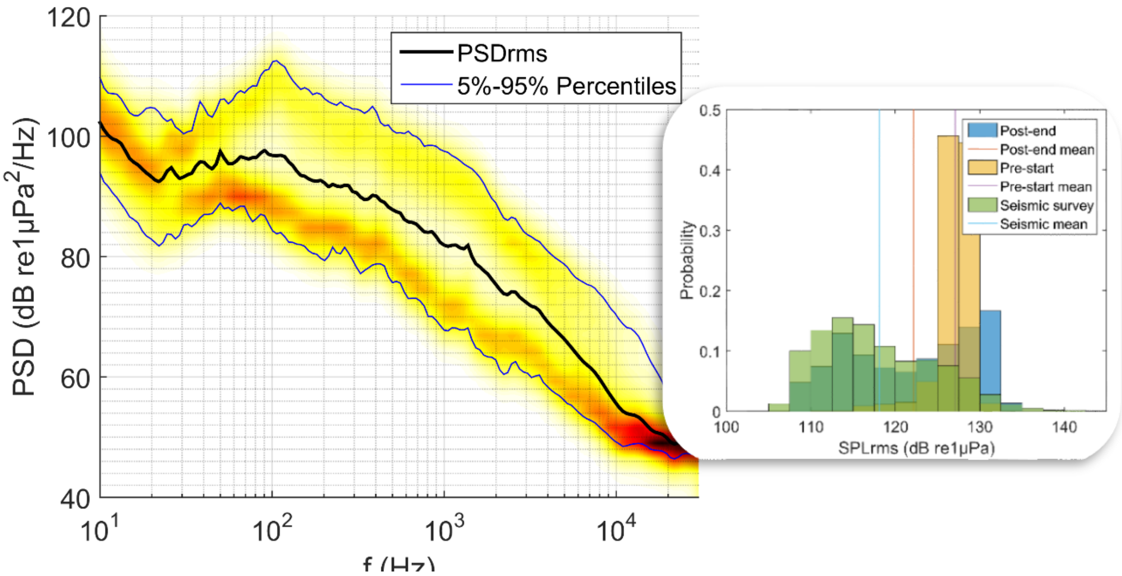

Fig. 3.1.2. Aggregated 10 sec PSDs concerning Lefkada station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication.

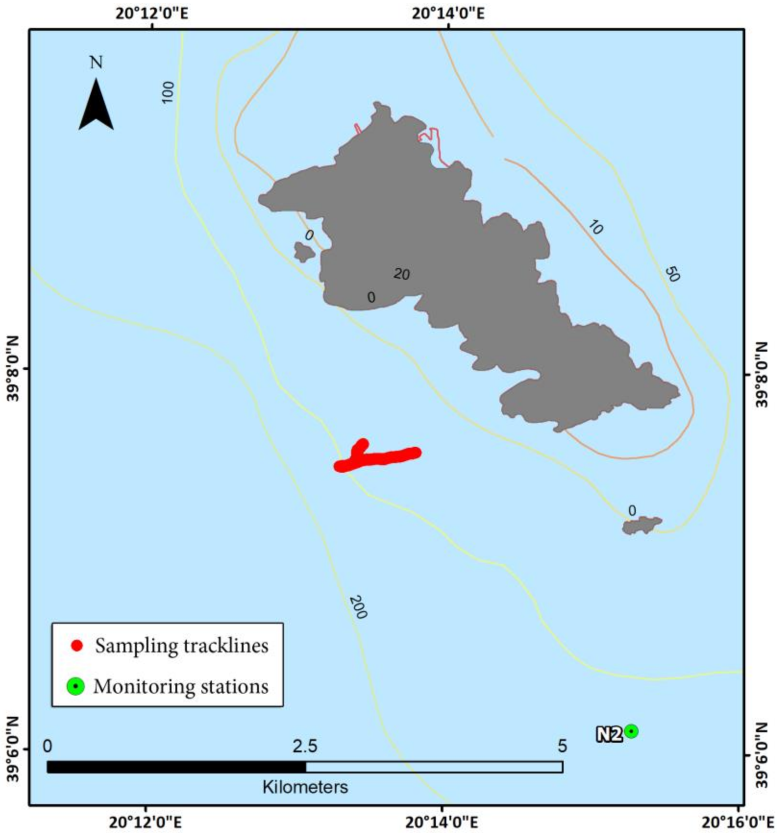

Fig. 3.1.3. Sampling locations at Paxoi station.

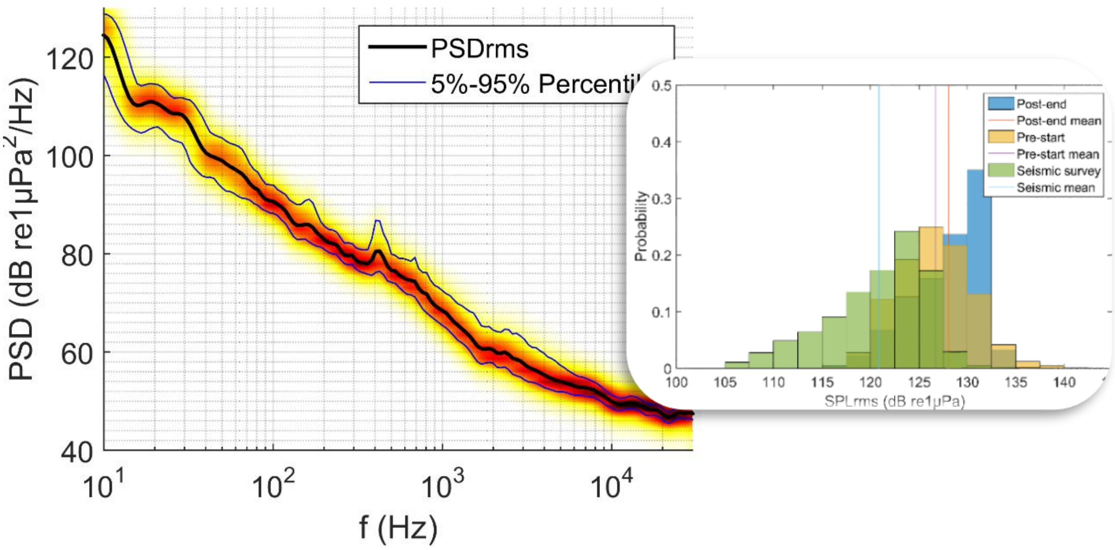

Fig. 3.1.4. Aggregated 10 sec PSDs concerning Paxoi station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication.

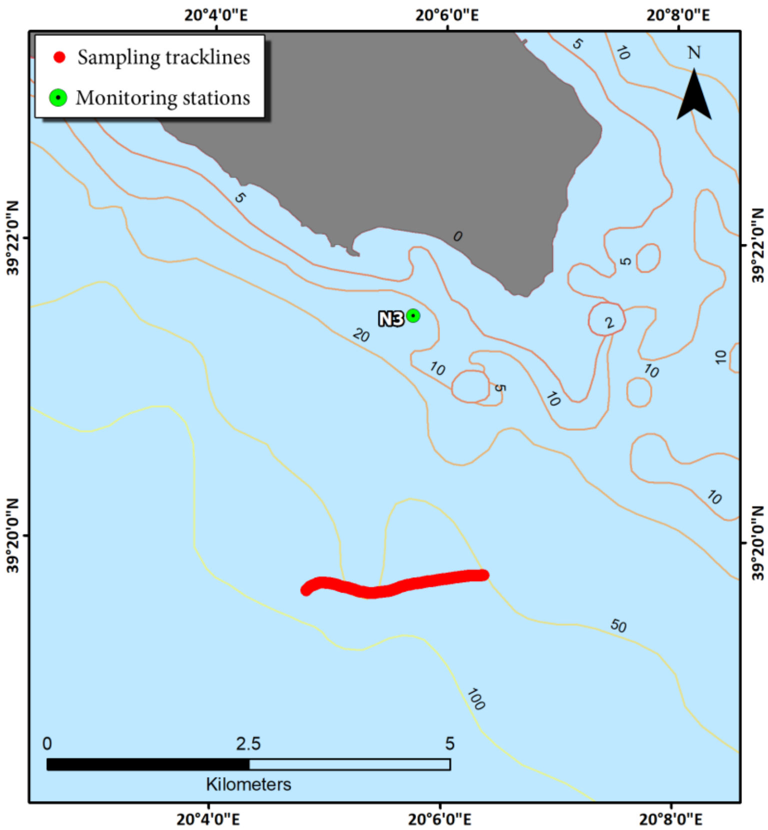

Fig. 3.1.5. Sampling locations at Kerkyra South station.

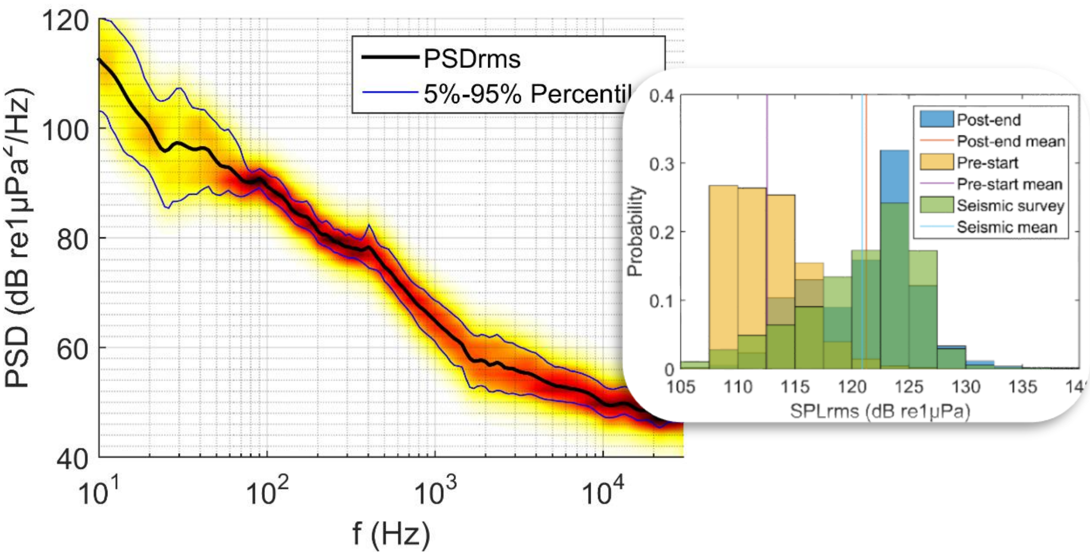

Fig. 3.1.6. Aggregated 10 sec PSDs concerning Kerkyra South station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication.

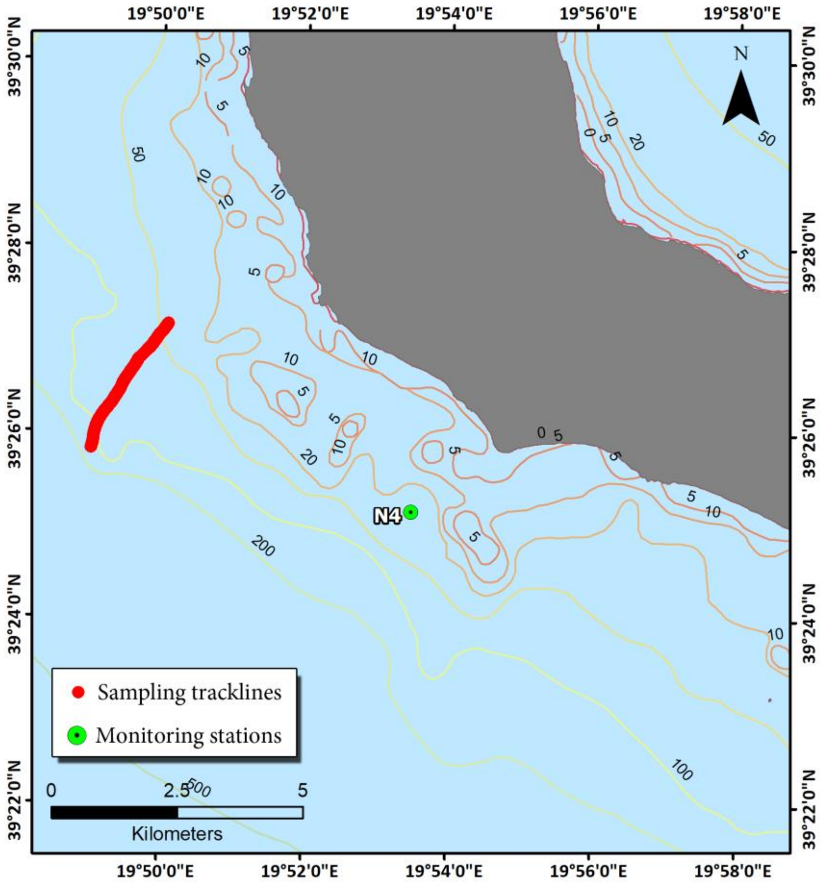

Fig. 3.1.7. Sampling locations at Kerkyra North station.

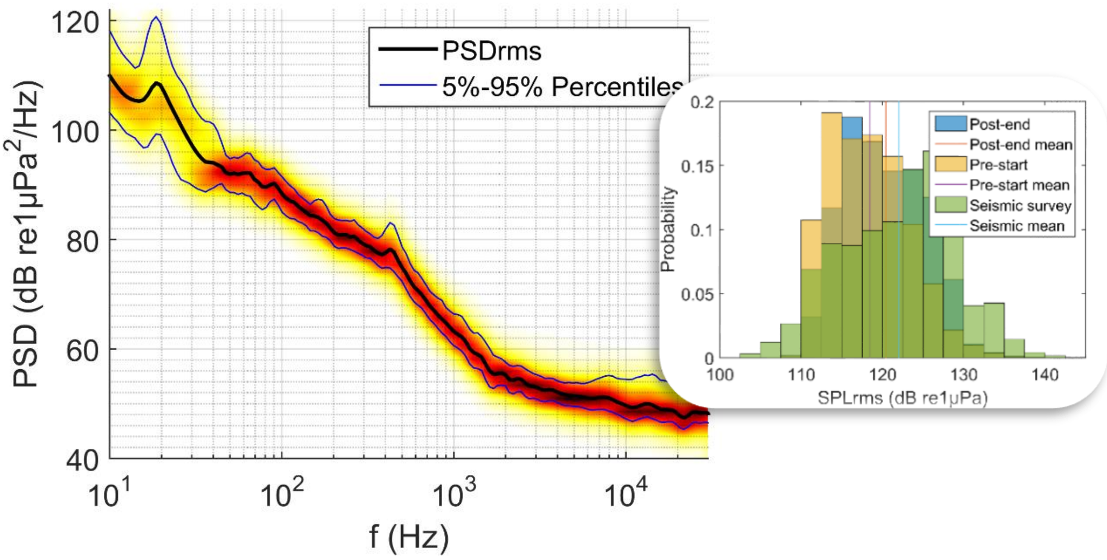

Fig. 3.1.8. Aggregated 10 sec PSDs concerning Kerkyra North station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication.

3.2. Preliminary analysis

3.2.1. General sound sources

Intense deviations in the frequency domain that are shown in the diagrams (Fig. 3.1.2, 3.1.4, 3.1.6 and 3.1.8) of paragraph 3.1 (*Reporting material*) can be interpreted in terms of: (1) weather conditions and sampling location (related to drift speed) changes during the full recording period, (2) marine traffic state, (3) proximity to time-lapsed "industrial" (mechanical) activity and (3) benthos/ mammals' noise. The interpretation of the diagrams that are given in paragraph 3.1. (*Reporting material*) is not straightforward. However, there are established rules about the sound sources governing the marine soundscape and their spectral characteristics are concentrated under the well-documented Wenz curves (Fig 3.2.1).

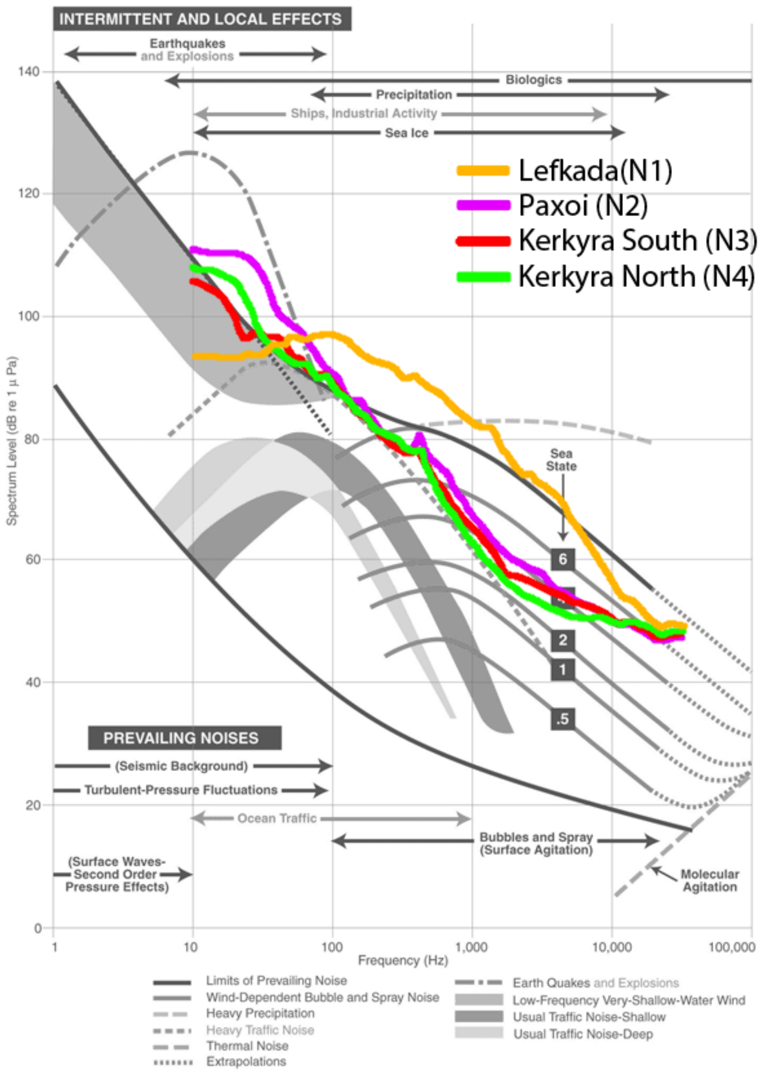

Fig. 3.2.1. Wenz curves describing pressure spectral density levels of marine ambient noise from weather, wind, geologic activity, and commercial shipping, superimposed by the rms PSDs of the five sampling locations (Adapted from Wenz, 1962).

The comparison of the Wenz curves with the rms PSDs retrieved by the corresponding sampling period from each station clearly shows some indications about their soundscape. In general, all stations exhibit high ambient sound levels concentrated on the top (or above) limit of the bibliographic prevailing ambient noise. This is partially due to the sampling procedure, which involved shallow deployment (in just 20m water depth) and close to the shore. The above induced high levels of benthos, sea surface bubble and spray and offshore turbulence fluctuations noises. Considering the high frequency components (1-10kHz), which are quite elevated, they are interpreted in terms of weather conditions which were moderate, around sea state 2-4 Beauforts. Due to the shallow deployment of the recording unit, and its proximity (<50m) to the research vessel, wave agitation and water splashing to the hull noises were quite elevated.

Concerning the middle band frequencies (100-1000Hz), PSDs, which are also quite elevated, exhibited common distributions between all stations. Those frequencies refer to most of the "industrial" (mechanical) and traffic noise affecting the soundscape (ship/ vessel noise, coastal recreational fishing, fish farming etc). Lefkada station had significantly increased noise at this frequency range, as it was dominated by traffic noise at the time of the recordings, as indicated by the aggregated PSDs of Figure 3.1.2 and the spectrogram of Figure 3.2.2.

The comparison of SPL_{rms} histograms between seismic noise, pre-start and post-end ambient recordings, showed that during the seismic activity the average sound pressure levels of the monitored areas was equal or even lower than during the ambient noise recordings. It was only in South Kerkyra station, where the pre-start noise was about 8-10 dB lower than the seismic noise (Fig. 3.1.6.). The increased sound pressure levels at the Pre- and Post-end ambient recordings are owed to the increased traffic and benthos noises (e.g. snapping shrimps Fig. 3.2.5) as well as to the harsher weather conditions (Fig.3.2.4) at the time of the recordings.

3.2.2. Traffic noise

The Wenz curves in Figure 3.2.1, suggest that all stations are moderately exposed to marine traffic noise, except for Lefkada station, which is heavily exposed. All visible ships that passed around the monitoring stations were validated in the online Marine Traffic visualization option of the research vessel's radar and were properly noted in the survey logbook, indicating their distance and ship type, to be examined in the data processing stage. In Figures 3.2.2, 3.2.3. and 3.2.4, PSD examples of traffic noise (cargo ships and fishing vessels) in Lefkada, Paxoi and South Kerkyra stations, respectively, are presented, increasing in some cases the ambient soundscape levels up to 20dB.

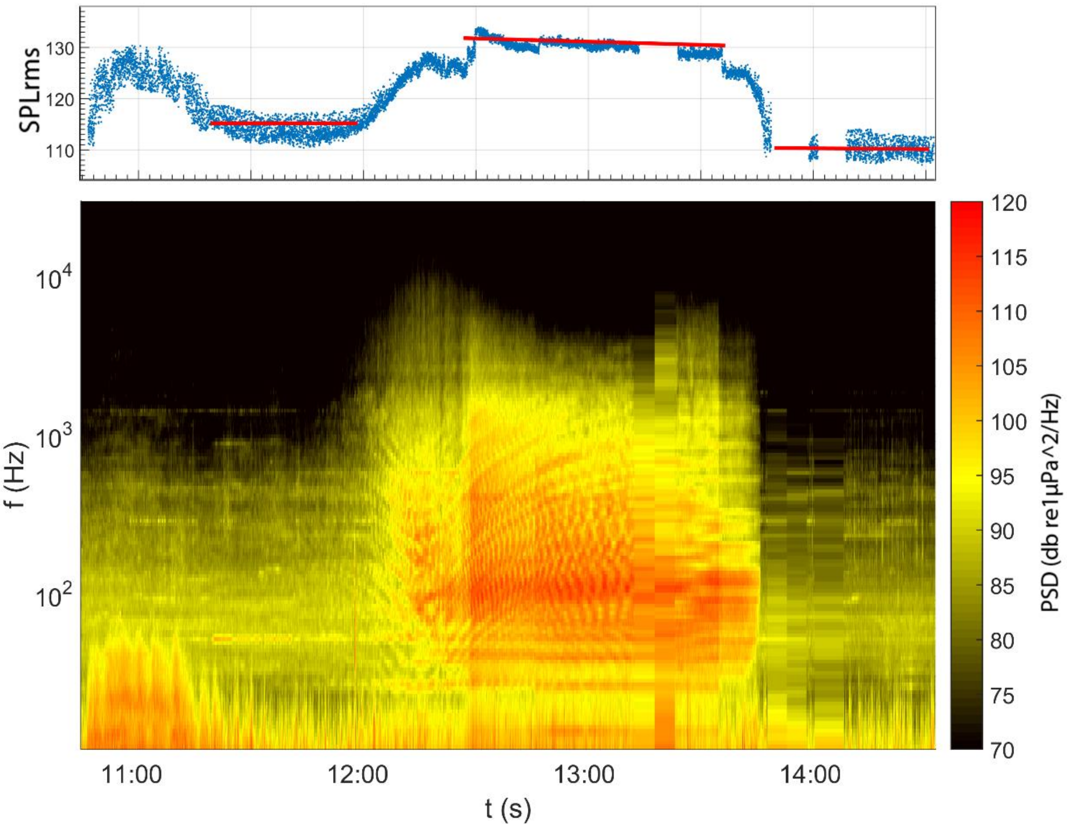

Fig. 3.2.2. SPLrms and PSD spectrogram for traffic noise evident in the sound recording of Lefkada station, indicating a cargo ship 5nm increasing the background ambient noise up to 20 dB re 1 μPa.

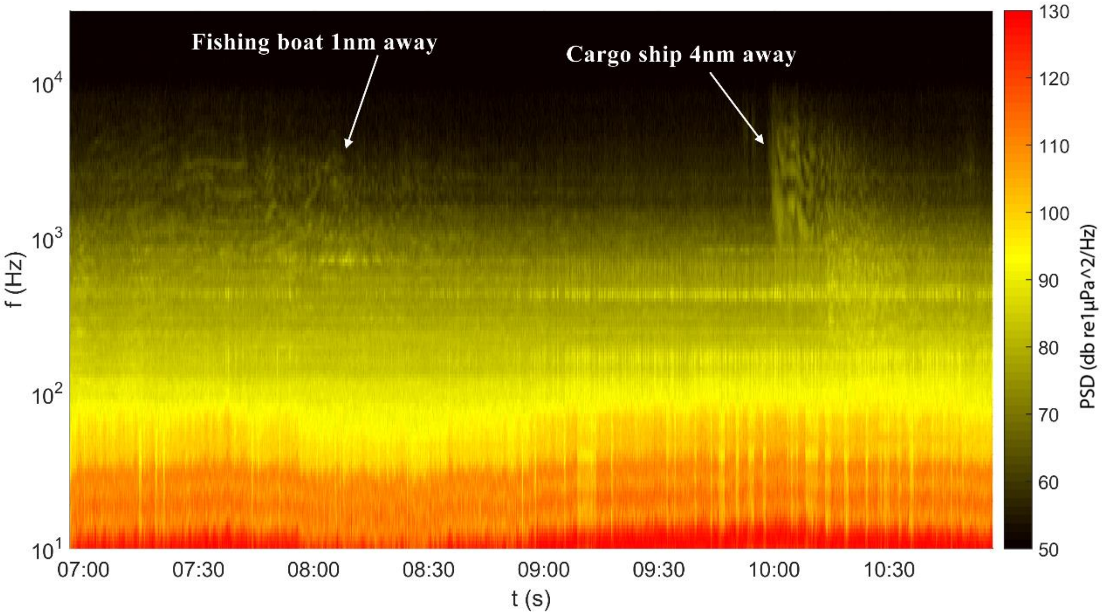

Fig. 3.2.3. PSD spectrogram for traffic noise evident in the sound recording of Paxoi station, indicating a fishing vessel 1nm and cargo ship 4nm away.

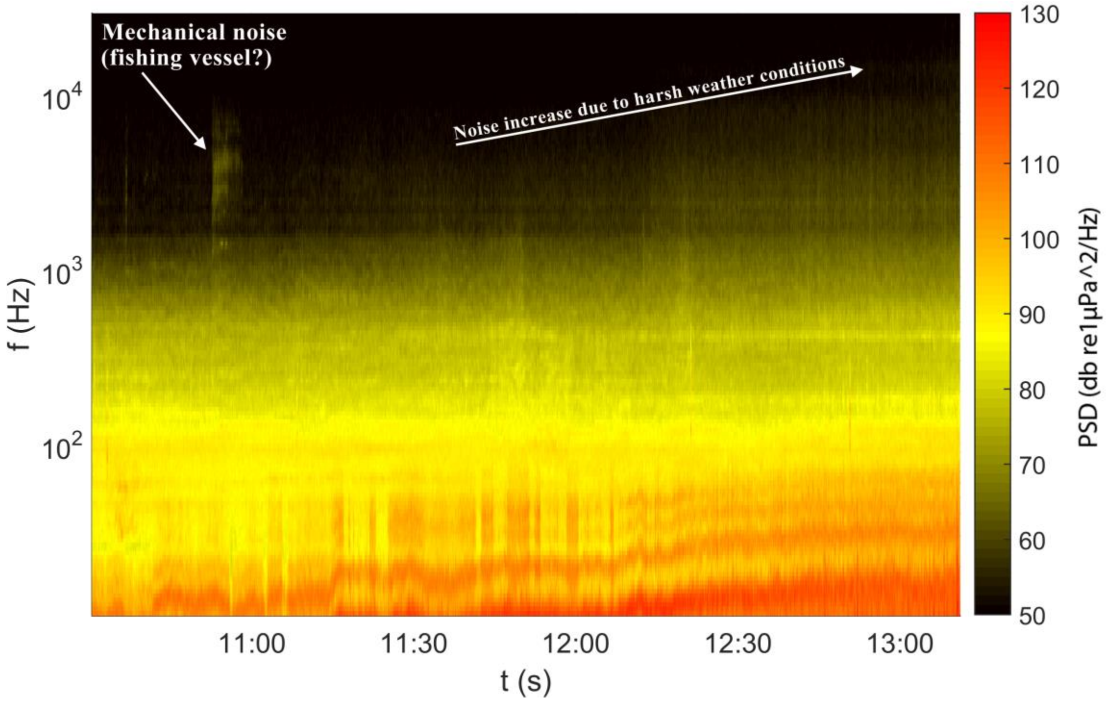

Fig. 3.2.4. PSD spectrogram for traffic noise evident in the sound recording of South Kerkyra station, indicating a mechanical noise and noise increase due to weather conditions' deterioration.

3.2.3. Other anthropophony and biophony

In some parts of the post-end ambient sound pressure level recordings, impulsive sounds have been detected in the North Kerkyra station. The exact origin and distance of their sound sources cannot be determined, but they resemble seismic noise activity. This activity can well be identified in the PSD spectrogram of Figure 3.2.5 (I and II).

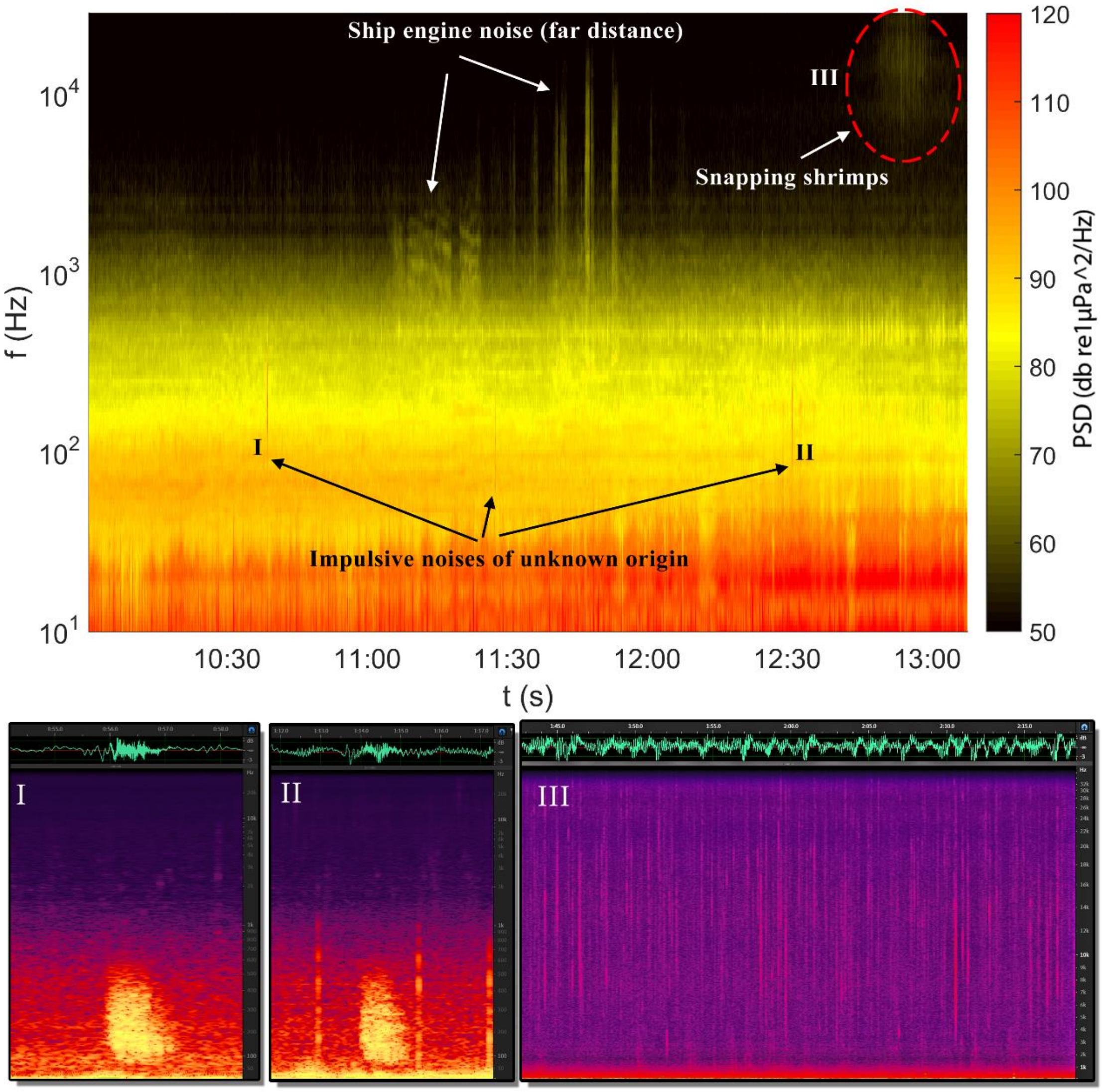

Fig. 3.2.5. PSD spectrograms indicating: (I, II) impulsive sounds, (III) snapping shrimp noises and ship engine noises detected in North Kerkyra station.

The biophony soundscape components detected in the post-end phase of the survey regarded numerous marine mammal and benthos noises. In the North Kerkyra station, a pod of dolphins was detected, and some example PSDs are presented in Figure 3.2.6, exhibiting extensive dolphin burst pulses. In Figure 3.2.5 (III) snapping shrimps' noises, detected in the shallowest parts of North Kerkyra station, are well separated in the PSDs, dominating the frequencies around 10 kHz.

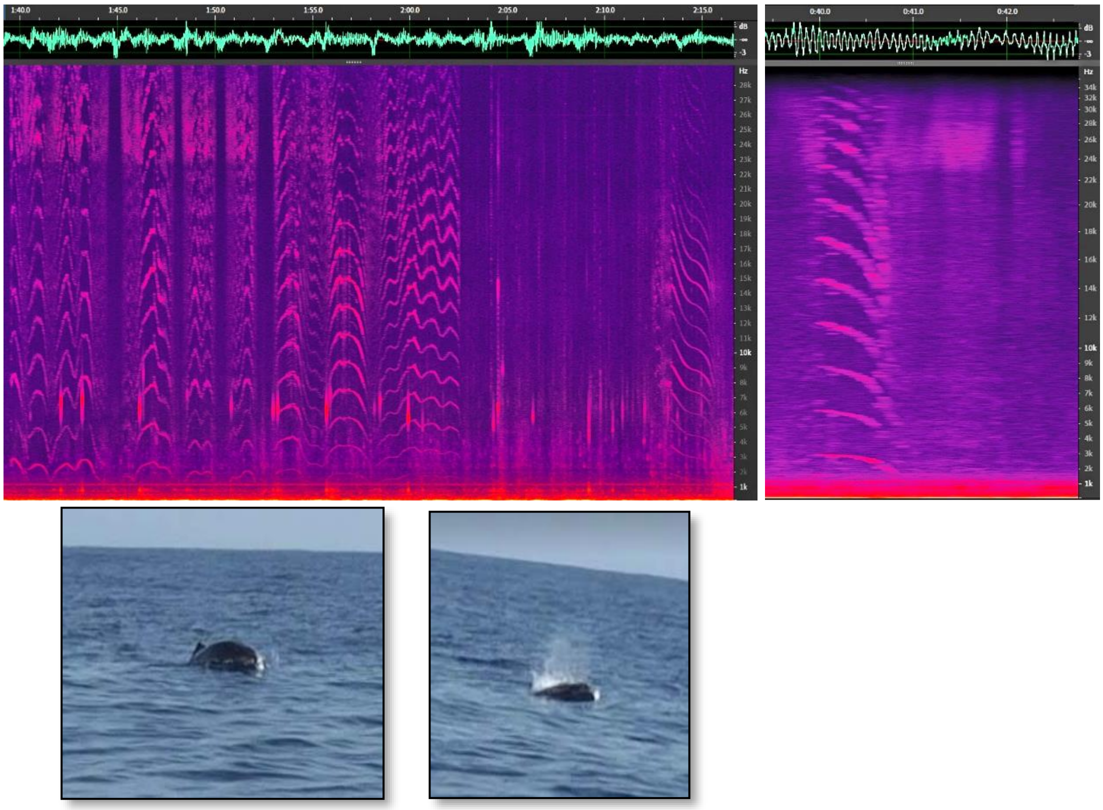

Fig. 3.2.6. Detailed PSD spectrogram of the mammal sounds (dolphin burst pulses) detected in North Kerkyra station. Bottom images are taken from the research vessel when a pod of dolphins has been encountered.

4. Personnel

The following personnel were employed for the field work and data processing stages from the Oceanus Lab, Department of Geology, University of Patras.

Name	Responsibility
Prof. George Papatheodorou	Project leader
Dr. Dimitris Christodoulou	Field work leader, Data processing and reporting Personnel
Dr. Elias Fakiris	Data processing and reporting leader- Field work Technical Personnel
Dr. Xenophon Dimas	Field work Technical/ Data processing and reporting Personnel
Capt. Gerasimos Sotiropoulos	Vessel Captain

5. REFERENCES

Fakiris, E., Christodoulou, D., Georgiou, N., Dimas, X., Papatheodorou, G., Blondel, P., Mikionatis, G., Zafiropoulos, G., & Symeonidis, F. (2019). The soundscape of the Inner Ionian Archipelago as evinced through the West Patraikos Gulf Ambient and Seismic Noise Monitoring Project. *Underwater Acoustics Conference and Exhibition, UACE-2019*, Crete, 30 June -5 July, 2019.

Wenz, G.M. (1962). Acoustic Ambient Noise in the Ocean: Spectra and Sources. *Journal of the Acoustical Society of America*, 34, 1936-1956.