Hellenic Petroleum Exploration & Production of Hydrocarbons SA

IONIAN GULF POST-END ACOUSTIC MONITORING PROJECT

ITEM 1C

Technical Report

OCEANUS LAB

(Laboratory of Marine Geology & Physical Oceanography)

Department of Geology University of Patras

1. Introduction

This report describes the methodology, the processing of the data, and the preliminary results of the ITEM 1-A "Monitoring of the 4 predefined locations with spot measurements – "Post-end phase" of the Ionian Gulf Acoustic Monitoring Project.
The Ionian Gulf Acoustic Monitoring Project is an ongoing project for measuring the acoustic levels before, during, and after the 2D Marine Seismic Survey which will be carried out by HELPE S.A.
The Ionian 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 1C) lasted six (6) days, from March 3rd to 8th ,2022.

2. Methodology

2.1. Field work

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" used for the underwater noise monitoring project.

Table 2.1.1.1. 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

One portable system was used for the monitoring of the ambient noise on the four predefined stations. Each unit includes a four-channel digital recorder, two hydrophones, and a laptop carrying the interfaces for recording and visualizing the data. On the hydrophone were attached a high sensitivity and a low sensitivity hydrophone. Using dual sensitivity hydrophones assures that all dynamic ranges and amplitudes will be successfully recorded without any signal clipping.

The underwater recording system was model EA-SDA14 which was provided by RTsys. EA-SDA14 is a compact autonomous recorder that can simultaneously acquire the data of 4 wideband hydrophones. RTsys systems are thoroughly calibrated to be compatible with all international regulations.

The underwater recording systems was deployed to acquire recording autonomously at 20m depth (Fig. 2.1.2.1.). A second recording was onboard at all times, serving as a backup system in case of any failure of the first one during the long term sound recording stages (Fig. 2.1.2.2.). Data processing stages, as described in paragraph 2.3., were applied exclusively to the data acquired by the first system.

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 a Global Positioning System (GPS) type EMLID Reach was used (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 can be correctly geo-referenced.

Fig. 2.1.2.3. The EMLID Reach GPS.

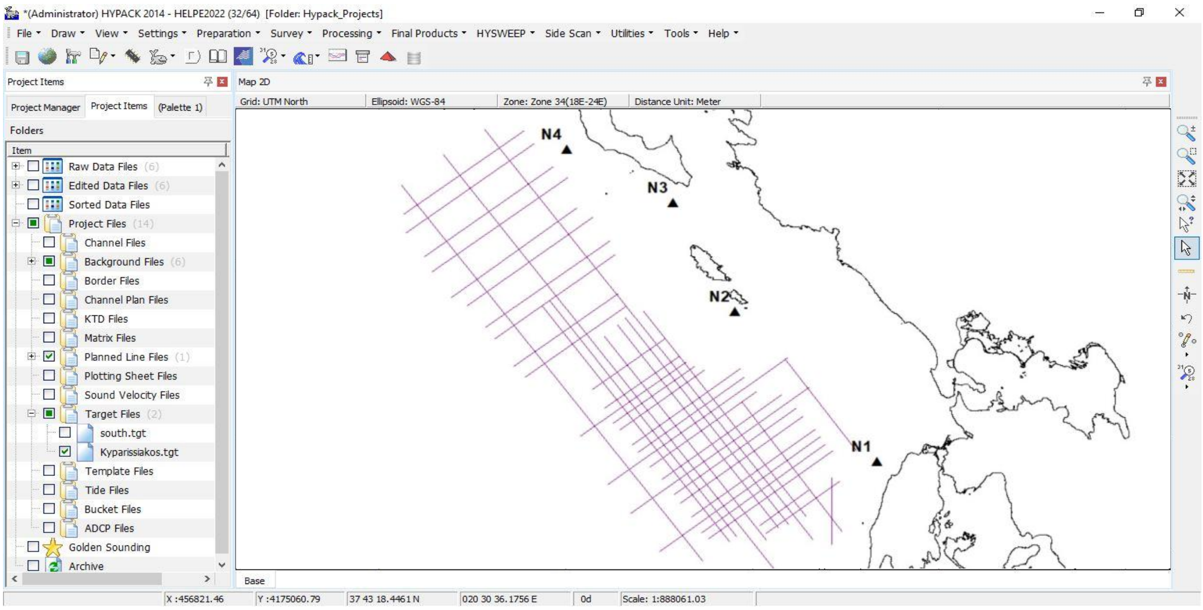

Fig. 2.1.2.4. Hypack 2014 navigation software.

The deployment of the acoustic system was performed using a floating rope where 3 buoys were attached in equal distance (Fig. 2.1.2.5.). At the end of the buoy array, the rope is sinking at a depth of 20m where the hydrophone is tethered (Fig. 2.1.2.6).

Fig. 2.1.2.5. Monitoring deployment system, using buoys.

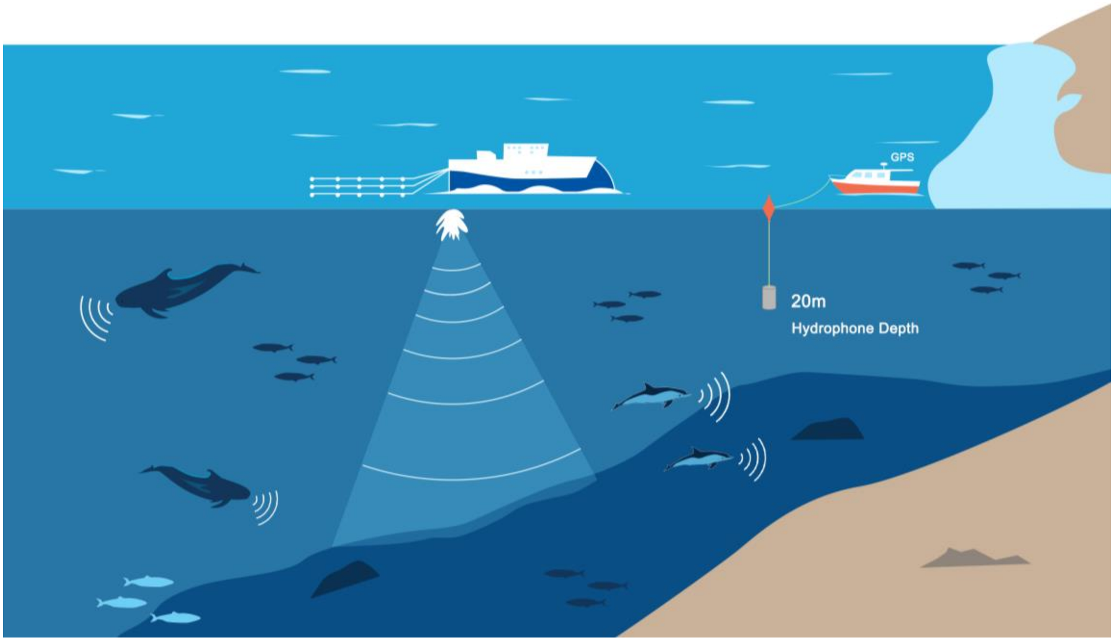

Fig. 2.1.2.6 Schematic visualization of the acoustic monitoring project.

2.2. Survey Planning

ITEM 1 stage includes: (1) Ambient noise measurements (Post-End 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) refers to Lefkada.
- Location 2 (N2) refers to Paxoi-Antipaxoi islands.
- Location 3 (N3) refers to Southern Kerkyra.
- Location 4 (N4) refers to Northern Kerkyra.

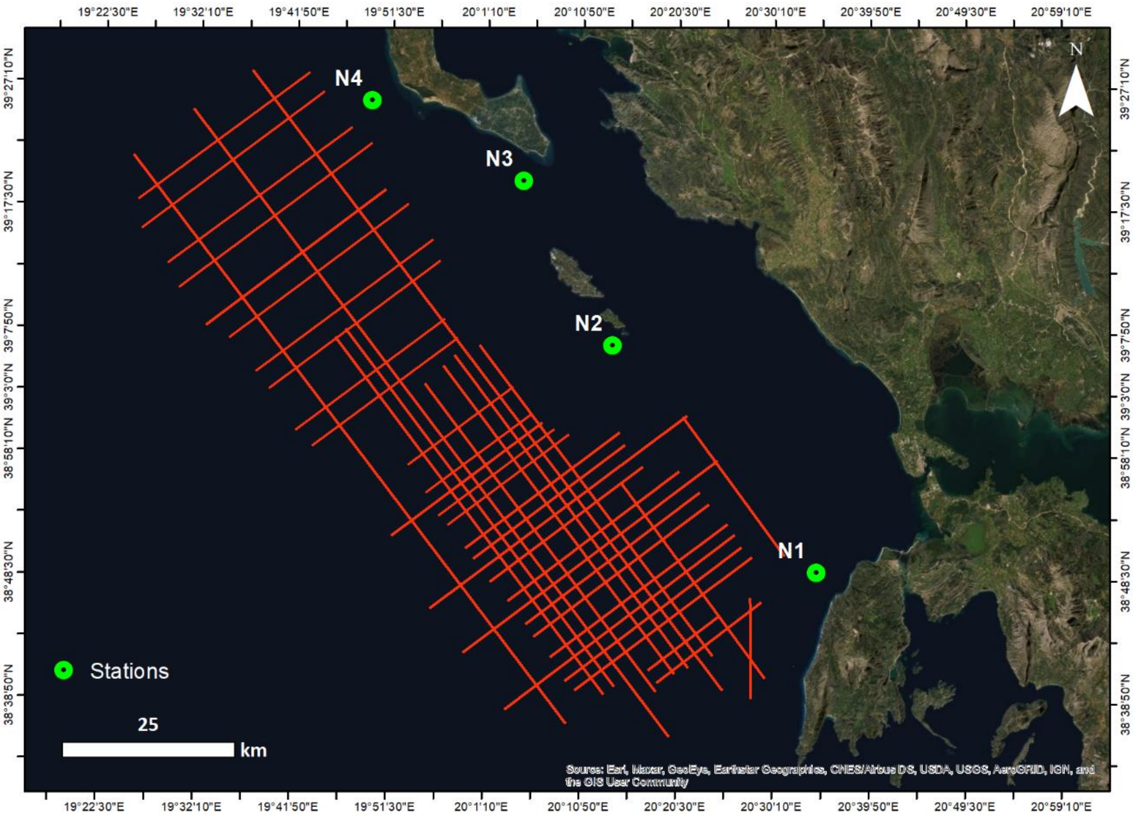

Fig. 2.2.1. Map locating the seismic survey area (tracklines) and the four (4) locations where spot acoustic measurements took place in the Post-End phase.

During the ambient noise measurements (Post-End phase), a total of 6 deployments 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 two 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 10 hours of raw data recordings have been acquired. The logbook of the deployments is provided in APPENDIX A.

Table 2.2.1. Ambient noise measurements sorted by date and station

Date	Lefkada	Paxoi	Kerkyra South	Kerkyra North
03/03/2022		√		
04/03/2022				√
05/03/2022			√	
06/03/2022			√	
07/03/2022		√		
08/03/2022	√			

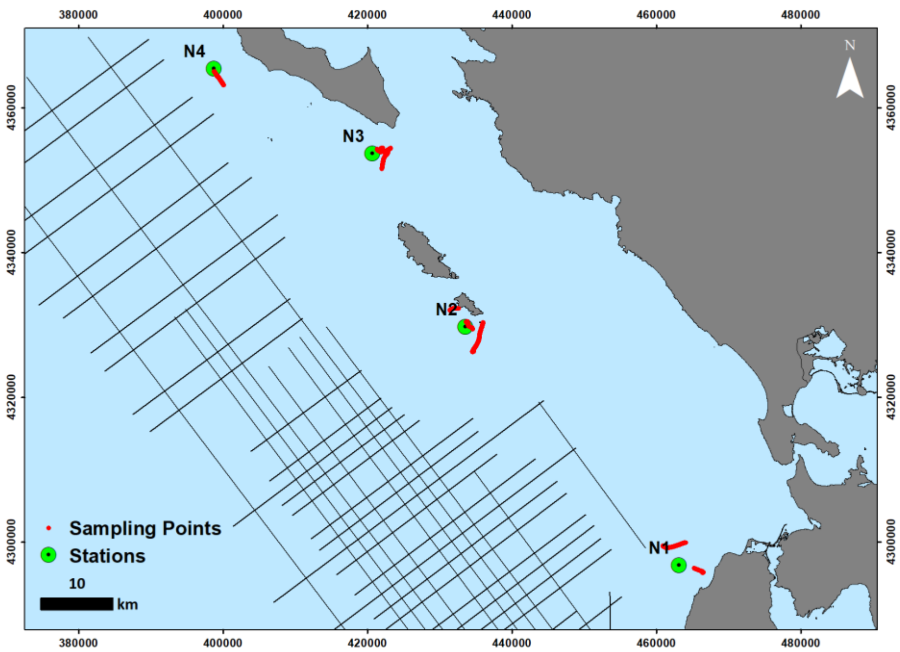

Fig. 2.2.2. Map showing the spot measurements and the track lines of the vessel during the measurements at the four sampling locations.

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 Univ. 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 micropascals (μPa).
3. Apply 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:

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

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:

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

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:

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

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 over the duration of the signal (30secs 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 decreasing 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 30 seconds integrated PSDs were combined under a single graph, using their rms value (thick dark line) over frequency intervals and their relative occurrence densities over 1dB intervals. The frequency axis was set to logarithmic scale in order to enhance low frequency components. The relative density of the PSDs (one for each 30 seconds integration) in the frequency versus PSD Euclidean space, was presented using yellow to 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 30 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 post-end phase are also compared to the pre-start and seismic activity ones to give implications about the impact of the seismic survey to the natural ambient echotope of the surveyed areas.

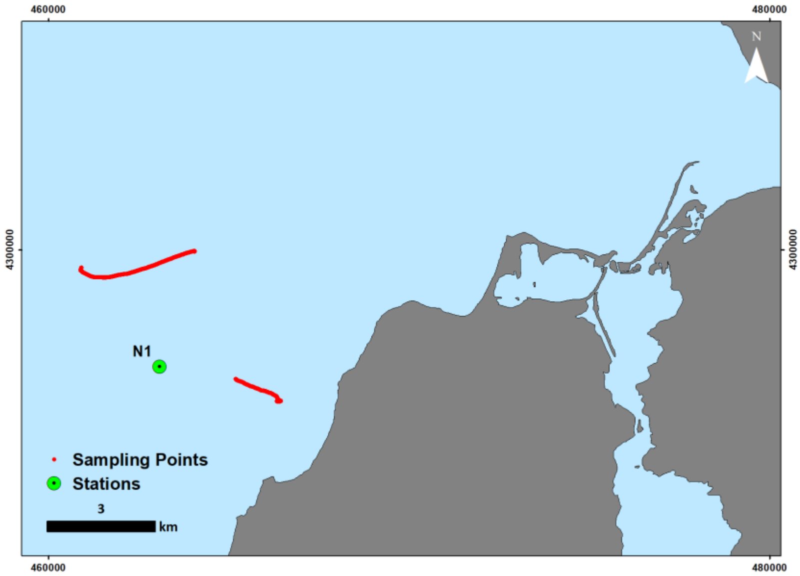

Fig. 3.1.1. Sampling locations at Lefkada station.

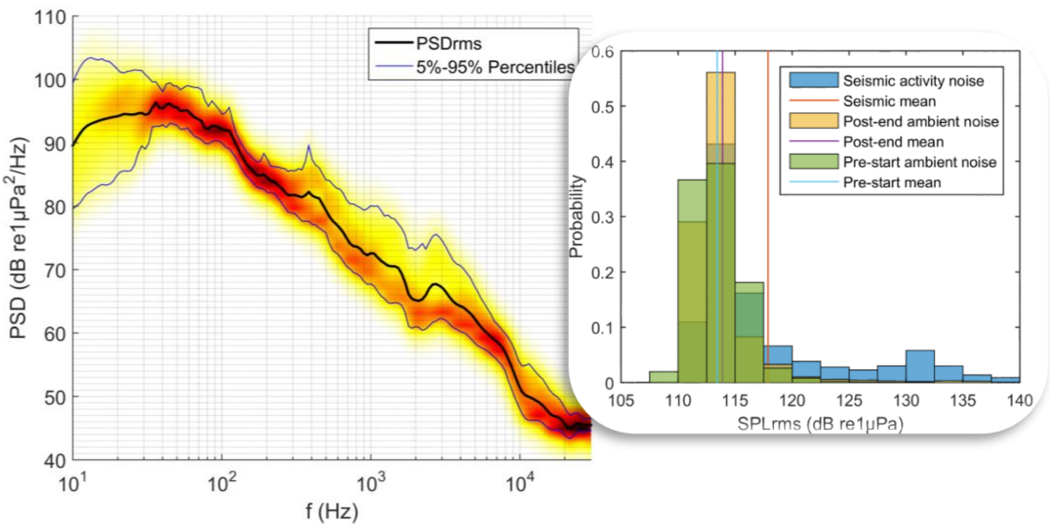

Fig. 3.1.2. Aggregated 30 sec PSDs concerning Lefkada station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

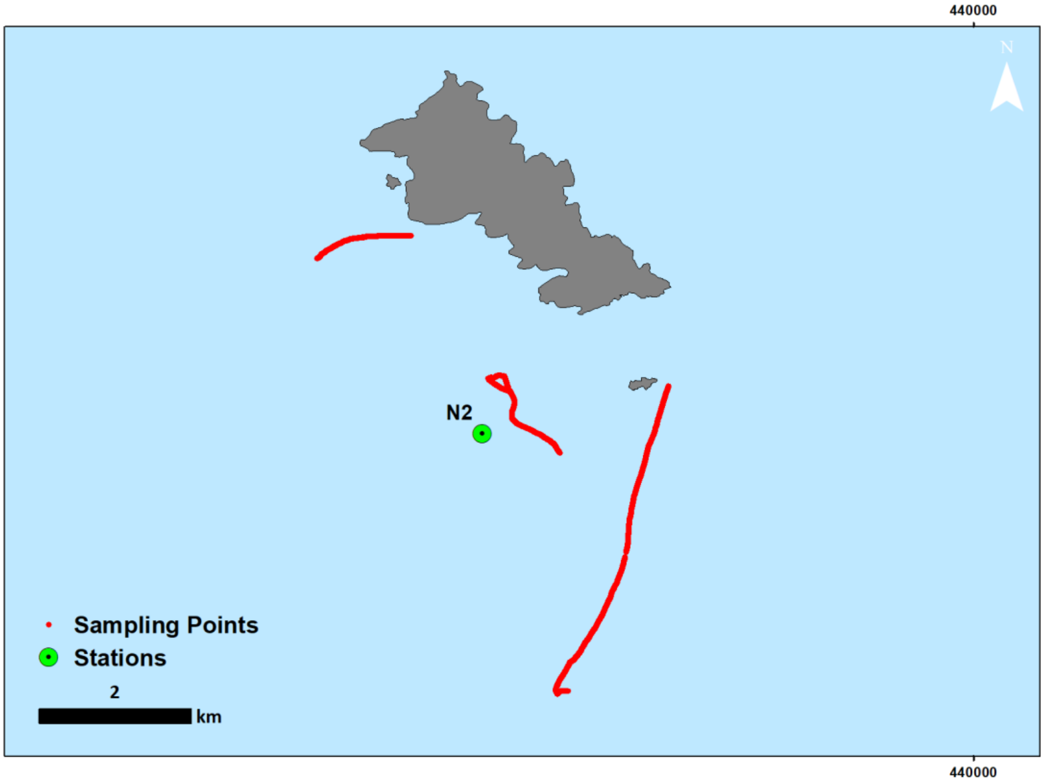

Fig. 3.1.3. Sampling locations at Paxoi station.

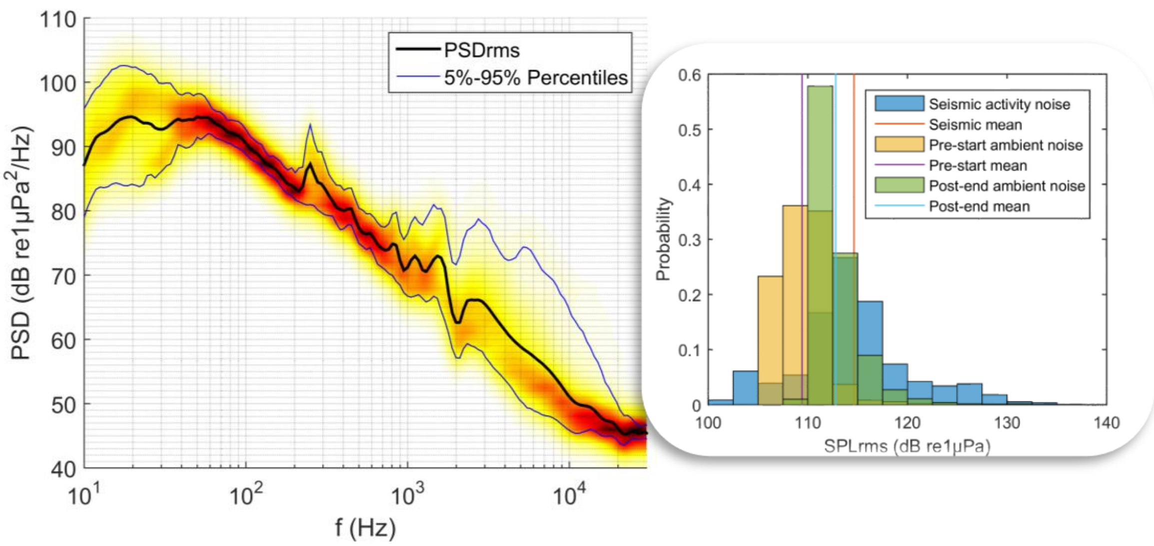

Fig. 3.1.2. Aggregated 30 sec PSDs concerning Paxoi station and SPLrms histogram (din width 2.5 dBre1µPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

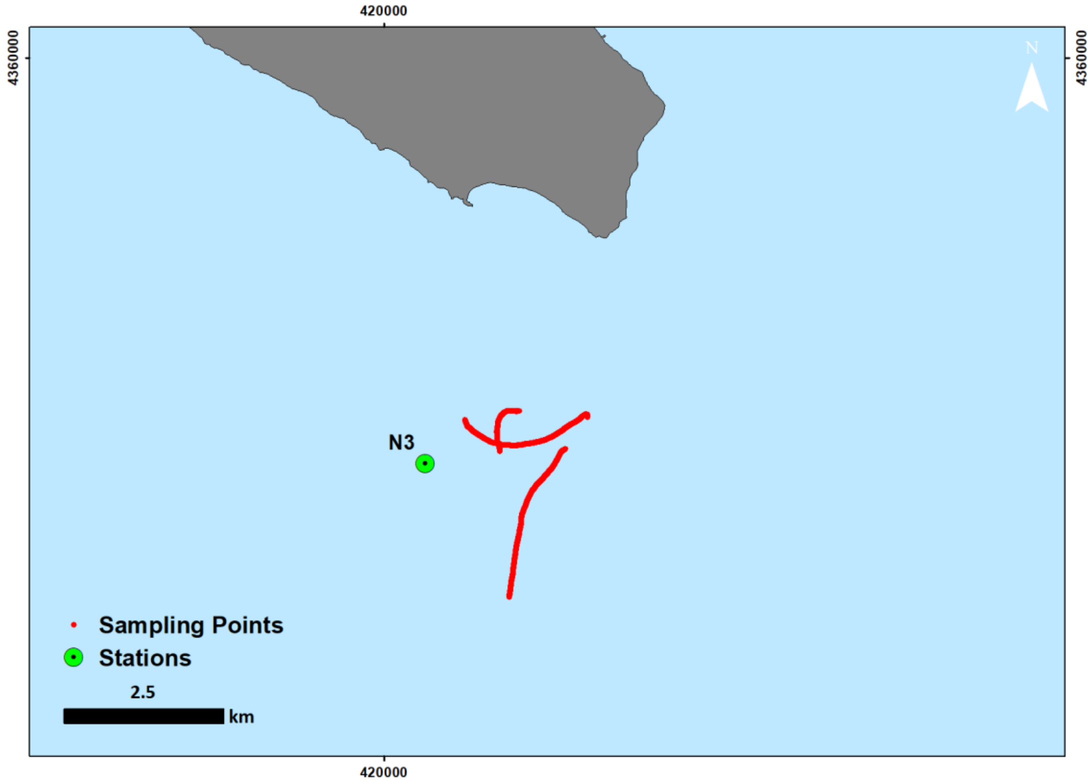

Fig. 3.1.5. Sampling locations at Kerkyra South station.

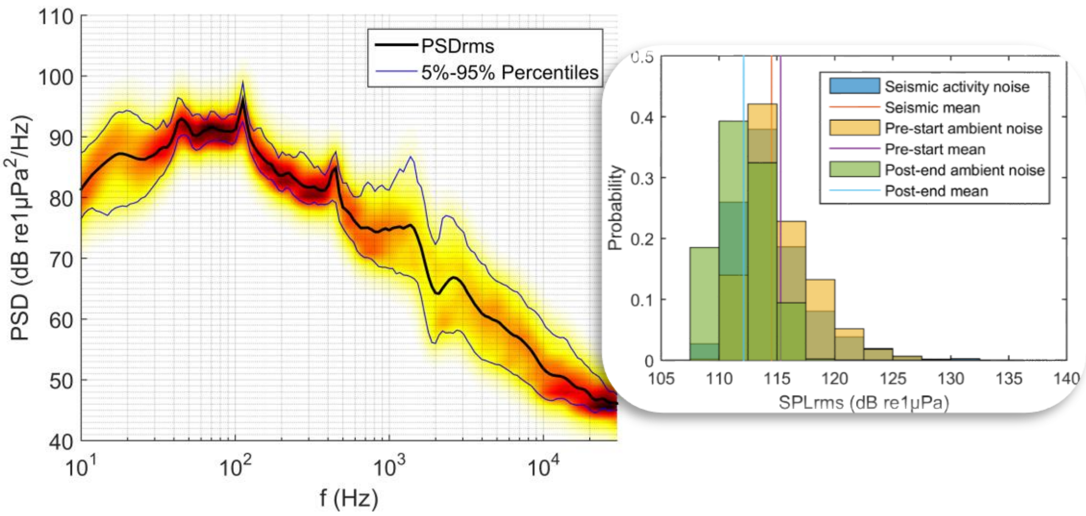

Fig. 3.1.2. Aggregated 30 sec PSDs concerning Kerkyra South station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

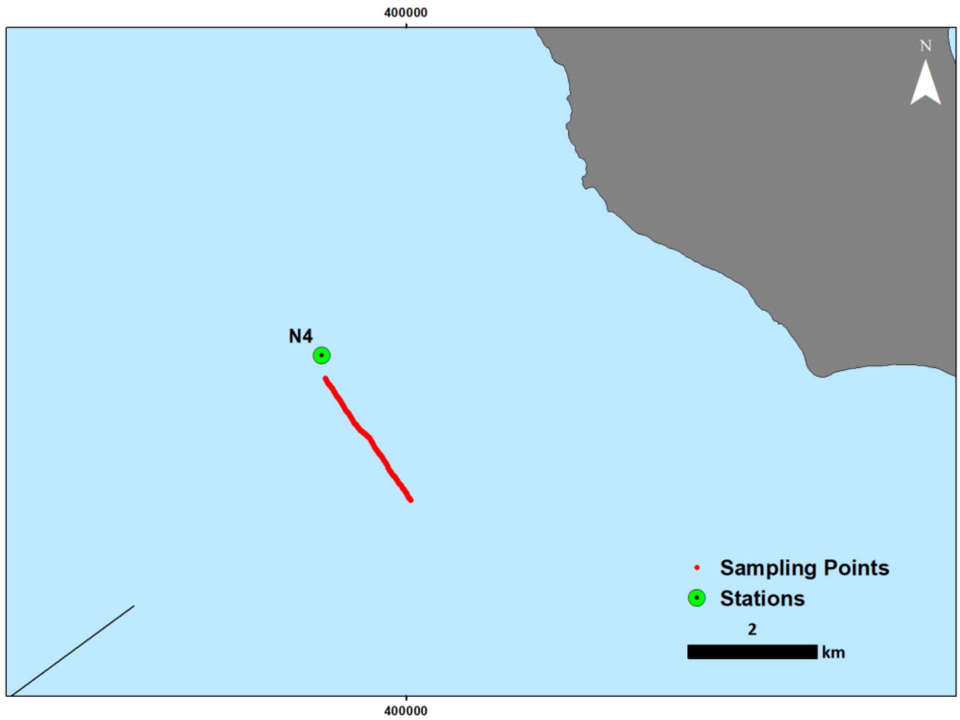

Fig. 3.1.7. Sampling locations at Kerkyra North station.

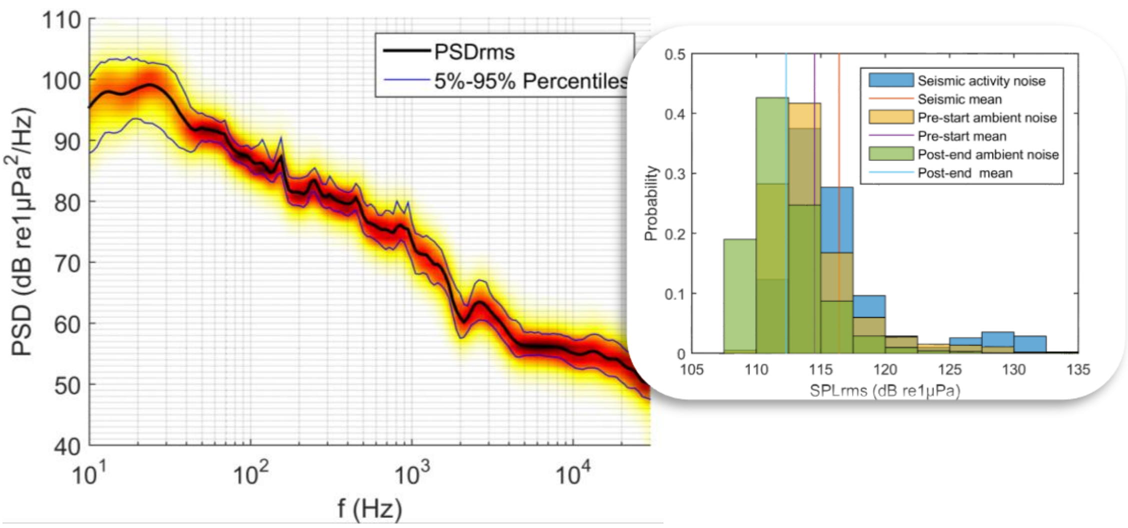

Fig. 3.1.2. Aggregated 30 sec PSDs concerning Kerkyra North station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

3.2. Preliminary analysis

3.2.1. General sound sources

Intense deviations in the frequency domain, shown in the diagrams of paragraph 3.1 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 noise. The interpretation of the diagrams that are given in paragraph 3.1. is not straight-forward. 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).

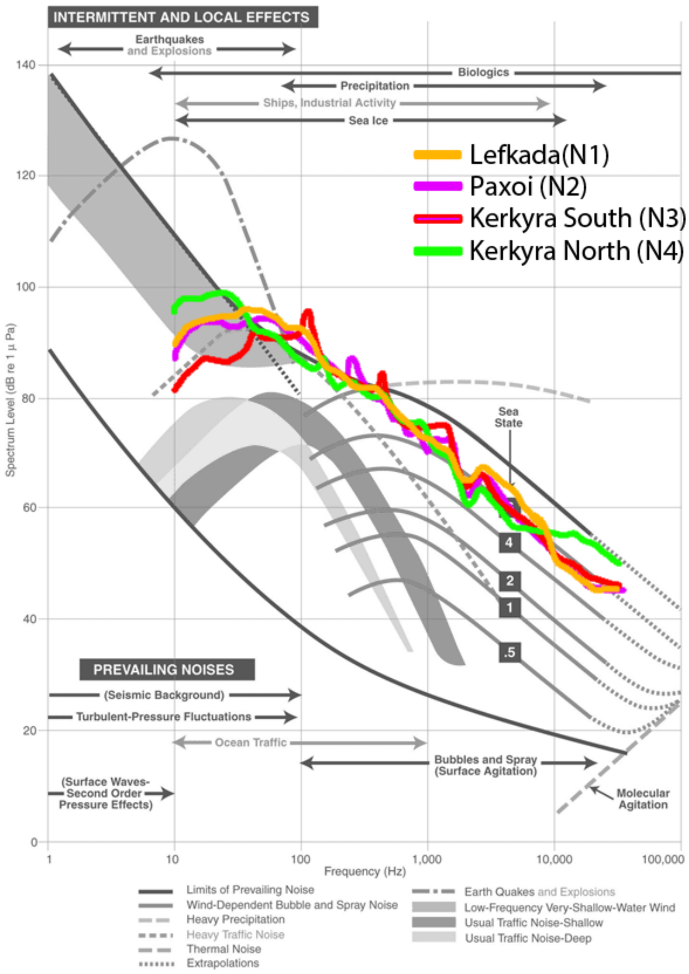

Fig. 3.2.1. Wenz curves describing pressure spectral density levels of marine ambient noise from weather, wind, geologic activity, and commercial shipping, superimposed by the rms PSDs of the four sampling locations (Adapted from Wenz, 1962).

The comparison of the Wenz curves with the rms PSDs retrieved by the current sampling period from each station, clearly shows some conclusions 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 bellow water surface) 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 (10-100kHz), the weather conditions were moderate, around sea state 2-3 Beauforts but also benthos noise was present.

Concerning the middle to low band frequencies (100-1000Hz), PSDs exhibited common distributions between all stations. Those frequencies refer to most of the “industrial” (mechanical) and traffic activities affecting the soundscape (ship/ vessel noise, fish farming etc).

The comparison of SPL_{rms} histograms between seismic noise, pre-start ambient and post-end ambient recording showed that during the seismic activity the average sound pressure levels of the monitored areas increased less than 5dB. The differences between the pre-start and post-end ambient noise monitoring periods were not significant except for the cases where increased traffic noise and other impulsive sounds had been captured, such as in Kerkyra South station, where the ambient noise seems not to be significantly lower or even it is higher than during the seismic activity phase.

3.2.2. Traffic noise

The Wenz curves in Fig 3.2.1, suggest that all stations being moderately to heavily exposed to marine traffic noise. All the visible vessels that passed around the monitoring stations were noted in the survey logbook to be examined in the processing stage. In Figures 3.2.2 through 3.2.4, PSD and SPLrms the main traffic noise detected incidences are presented, that seem to increase the ambient sound pressure levels between 2 and 7dB.

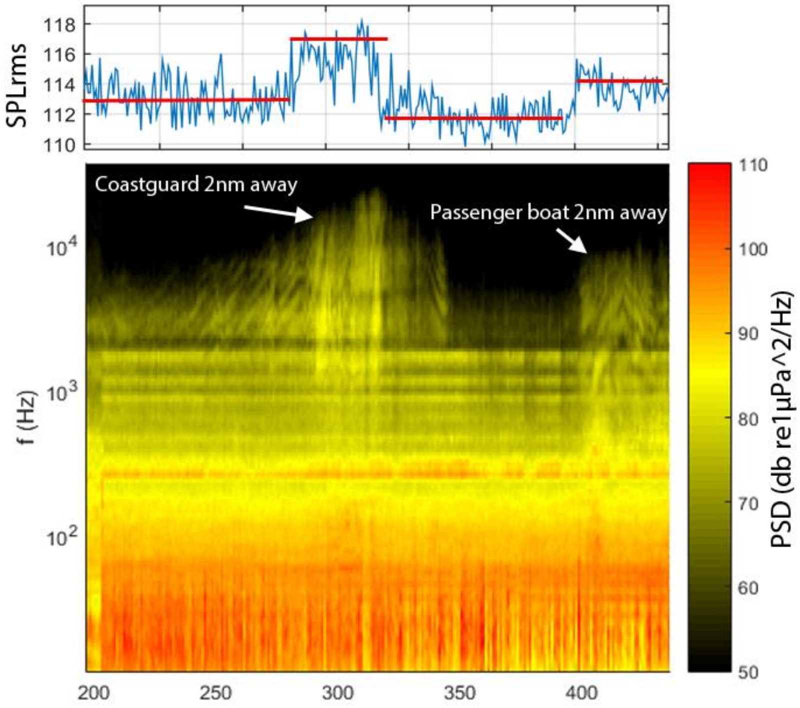

Fig. 3.2.2 SPLrms and PSD spectrogram for traffic noise evident in the sound recording of Paxoi station, indicating a coastguard boat 2nm and a passenger boat 2nm away the recording station, increasing the ambient noise about 4dB and 2dB (SPLrms) respectively.

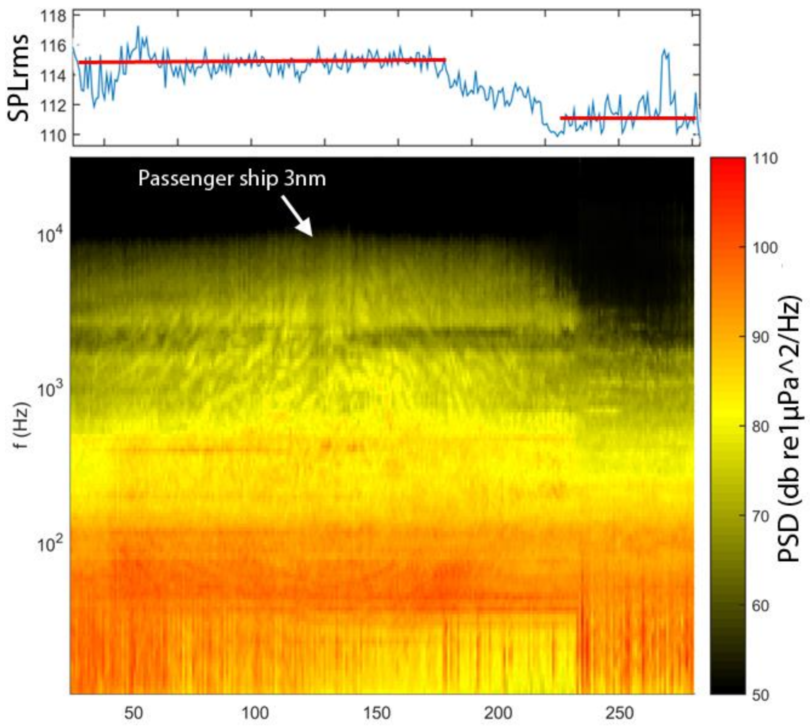

Fig. 3.2.3 SPLrms and PSD spectrogram for traffic noise evident in the sound recording of Lefkada station, indicating a passenger ship 3nm away the recording station, increasing the ambient noise about 4dB (SPLrms).

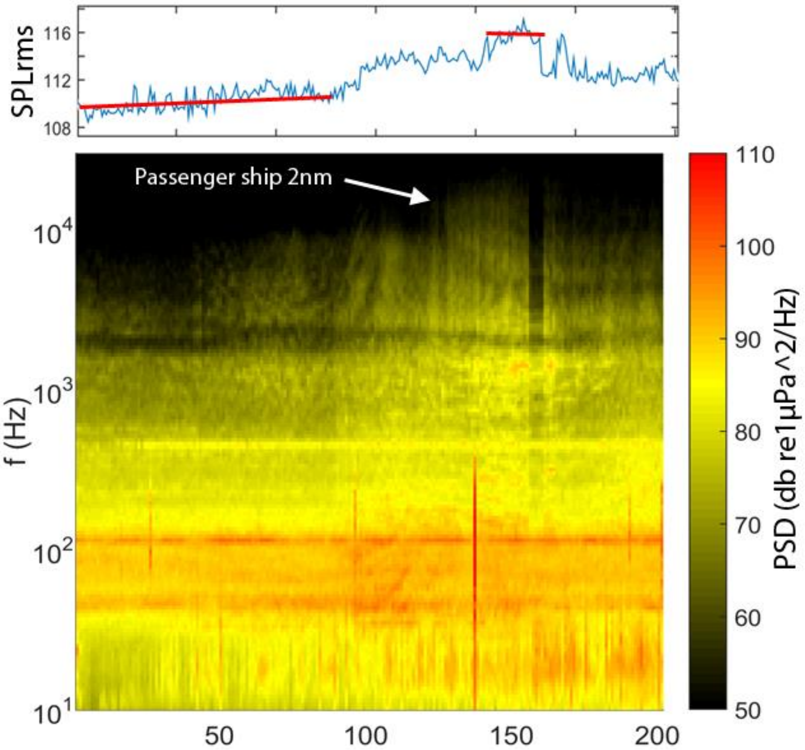

Fig. 3.2.4 SPLrms and PSD spectrogram for traffic noise evident in the sound recording of Kerkyra South station, indicating a passenger ship 2nm away the recording station, increasing the ambient noise about 7dB (SPLrms).

3.2.3. Other impulsive and sonar sounds

Loud impulsive sounds have been detected in Kerkyra South and North stations. Their exact origin and distance cannot be known but they are possibly due to military exercises regarding explosives within the wider Ionian/ Adriatic seas. They don't seem to have a constant repetition time-pattern and they are of random repetition. Their frequency range is between 10Hz and 600Hz. All the detected impulsive sounds detected during the Post-End phase of the Ionian survey are shown for Kerkyra South station between Figs 3.2.5 and 3.2.7 and for Kerkyra North station between 3.2.8 and 3.2.10, with Figs 3.2.5 and 3.2.8 indicating the overall stations' PSD spectrograms that made the detections possible.

In Lefkada station a dosen of sonar sounds have been detected, all of exactly the same frequency characteristics and with a random repetition rate but appearing in couples, 1 minute and 47 seconds apart from each other. Those where whistle-like sounds with frequencies between 3.5 and 4.5kHz (Figure 3.2.11), which is within the communication frequency domain of marine mammals. They are likely to be generated by military sonars operating in the wider Ionion-Andriatic area.

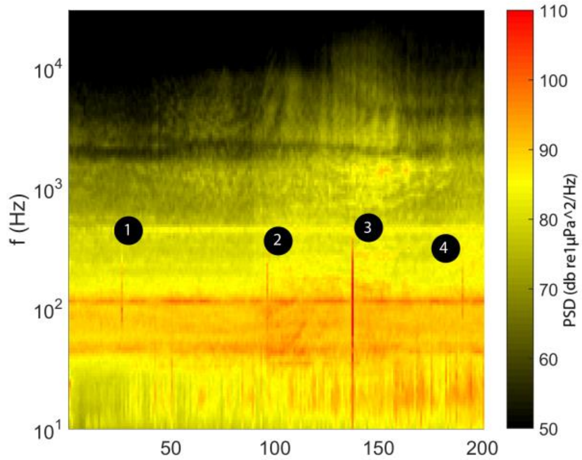

Fig. 3.2.5. PSD spectrogram indicating the four impulsive sounds detected in Kerkyra South station.

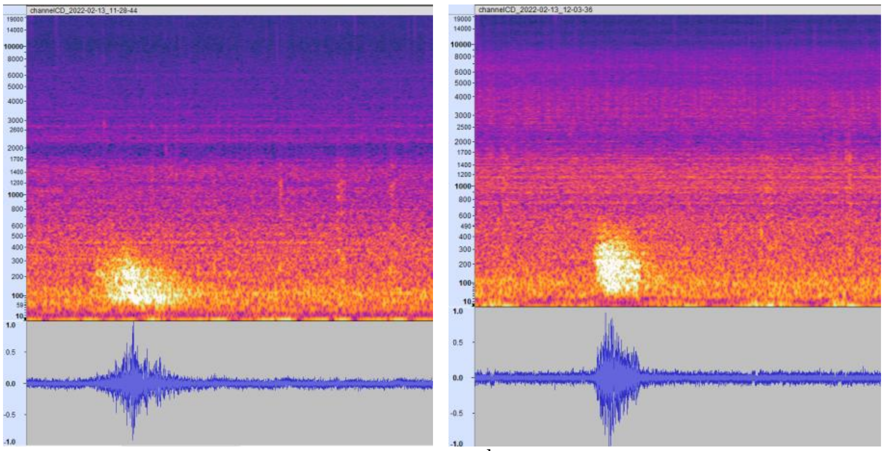
Fig. 3.2.6. PSD spectrogram of the 1st and 2nd impulsive sounds detected in Kerkyra South station. They increase the ambient sound noise by 20 and 15dB re 1 μPa (SPLp-p) respectively.

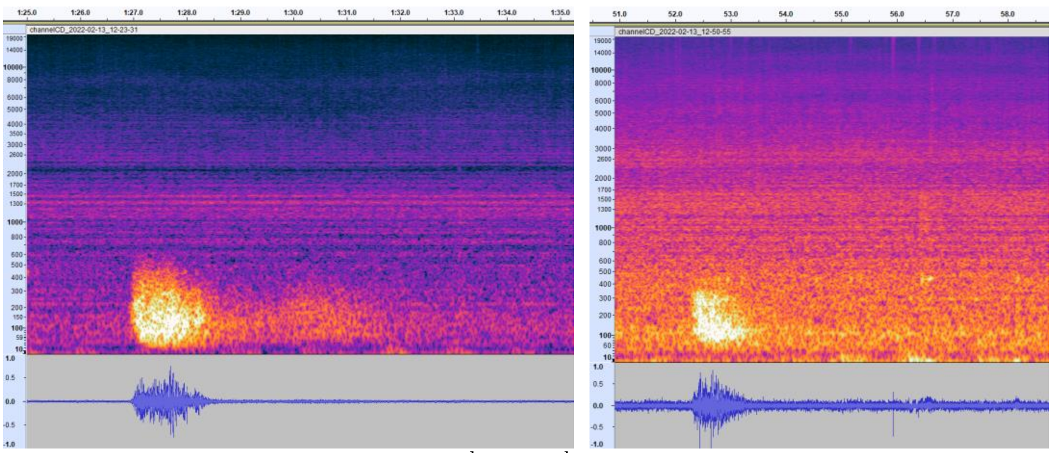
Fig. 3.2.7. PSD spectrogram of the 3rd and 4th impulsive sounds detected in Kerkyra South station. They increase the ambient sound noise by 35 and 15dB re 1 μPa (SPLp-p) respectively.

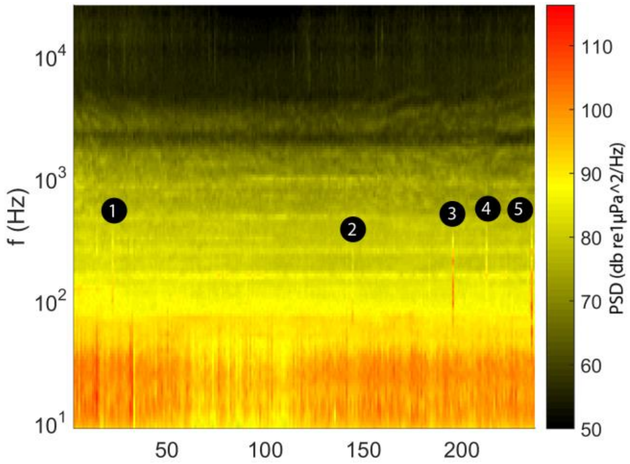

Fig. 3.2.8. PSD spectrogram indicating the five impulsive sounds detected in Kerkyra North station.

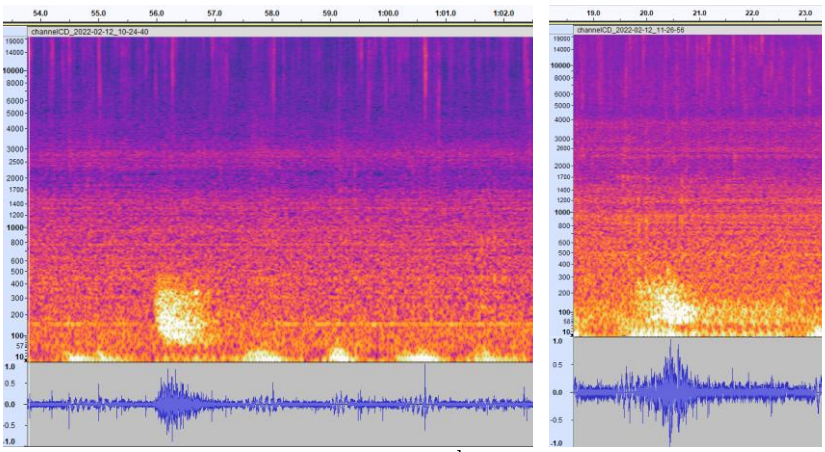

Fig. 3.2.9. PSD spectrogram of the 1st and 2nd impulsive sounds detected in Kerkyra North station. They increase the ambient sound noise by 20 and 15dB re 1 µPa (SPLp-p) respectively.

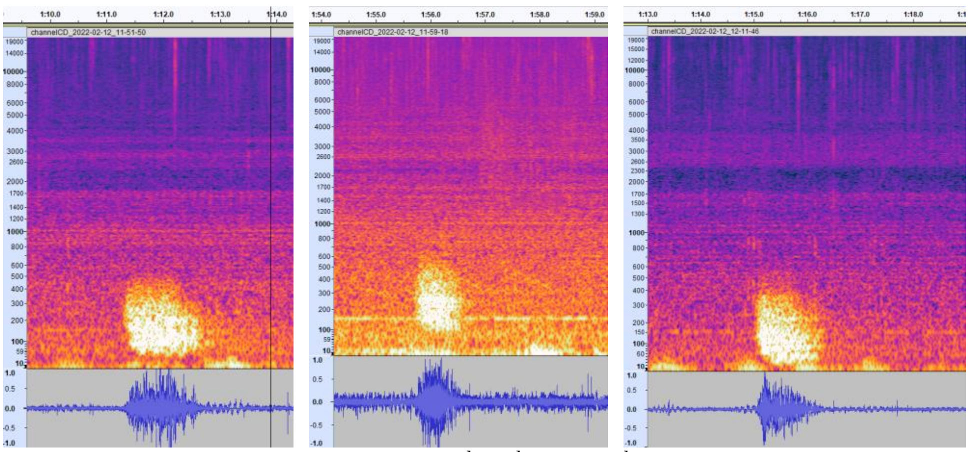

Fig. 3.2.10. PSD spectrogram of the 3rd, 4th and 5th impulsive sounds detected in Kerkyra North station. They increase the ambient sound noise by 25 and 20 and 25dB re 1 µPa (SPLp-p) respectively.

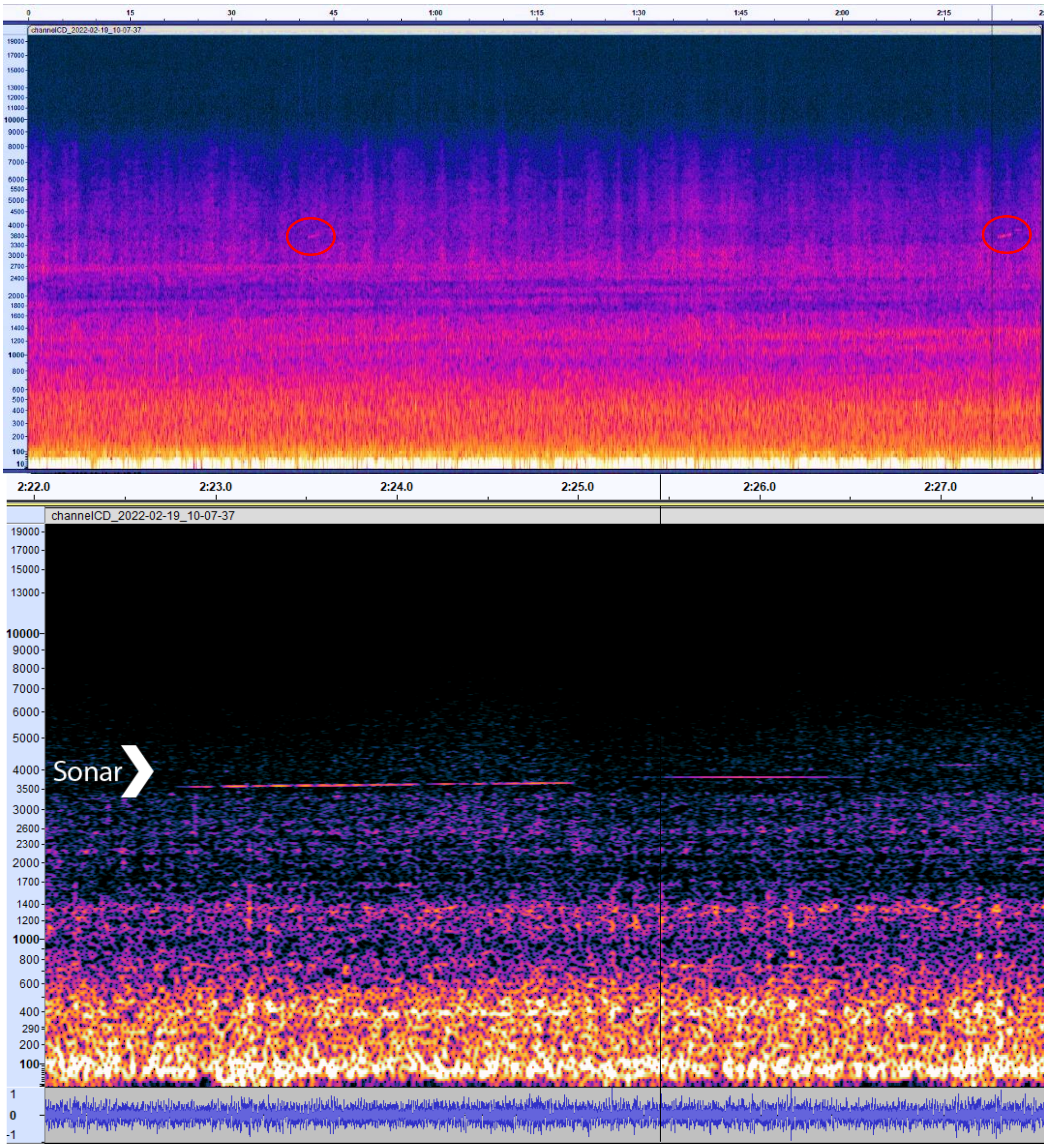

Fig. 3.2.11. PSD spectrogram of some of the many sonar sounds (likely from military exercises) detected in Lefkada station. They increase the ambient sound noise by 25 and 20 and 25dB re 1 μPa (SPLp-p) respectively.

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. Nikos Georgiou	Field work Technical/ Data processing and reporting Personnel
Mr. Alexandros Menegatos	Field work Technical Personnel
Capt. Gerasimos Sotiropoulos	Vessel Captain