# Hellenic Petroleum Exploration & Production of Hydrocarbons SA

# KYPARISSIAKOS 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, data processing, and the preliminary results of the ITEM 1C "Monitoring of the 5 predefined locations with spot measurements – “Post-End phase” of the Kyparissiakos Gulf Acoustic Monitoring Project.

The Kyparissiakos Gulf Acoustic Monitoring Project is measuring the acoustic levels before, during and after the 2D Marine Seismic Survey which will have been carried out by HELPE S.A.

The Kyparissiakos 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, from March 09$^{th}$ to 11$^{th}$ and 13$^{th}$ to 14$^{th}$ 2022.

# 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 2.1.1.1 presents the specifications of the vessel.


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

Table 2.1.1.1. 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 five 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 were 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.

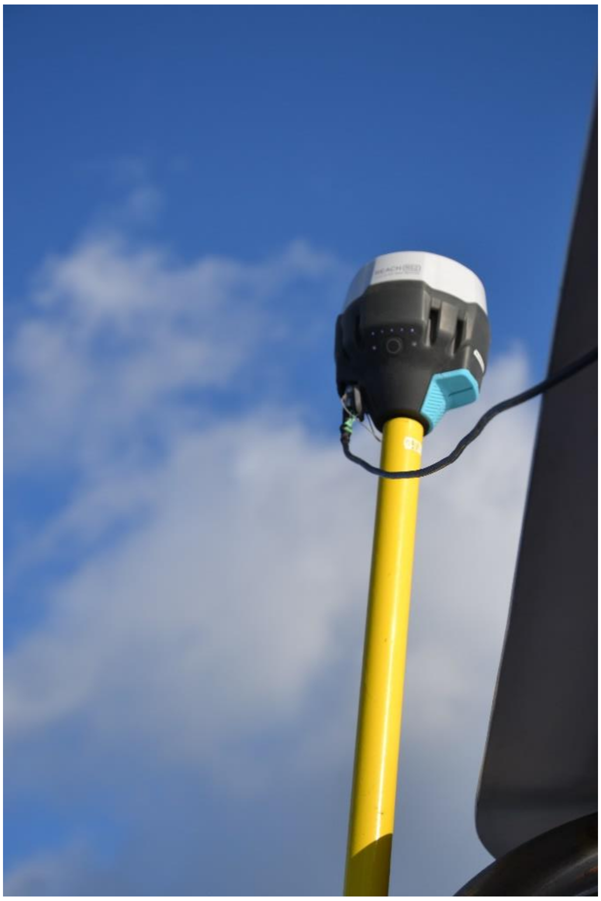

Fig. 2.1.2.3. The EMLID Reach GPS.

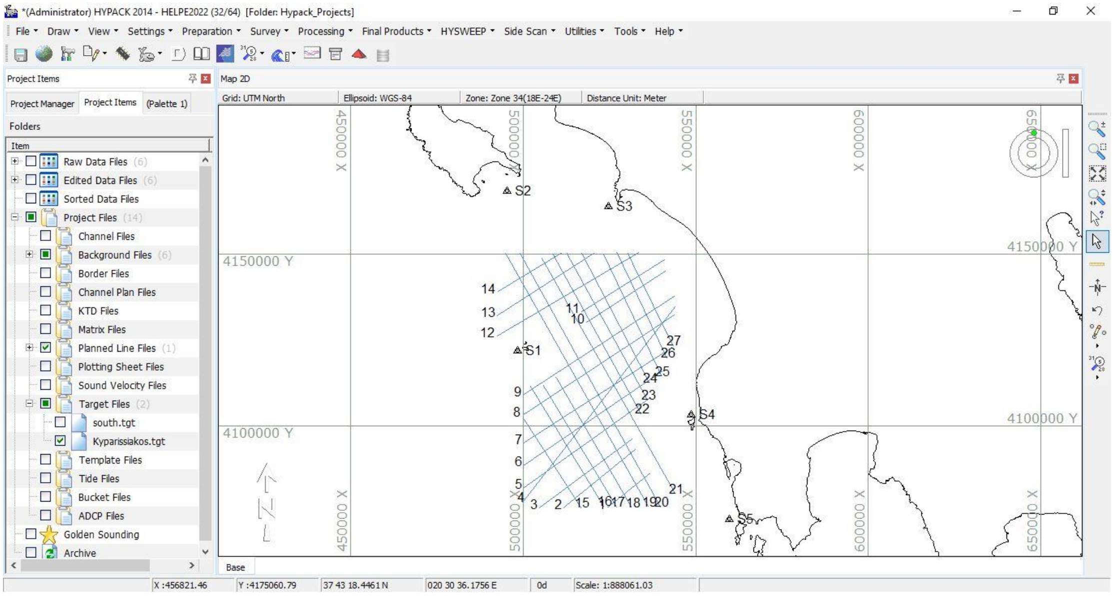

Fig. 2.1.2.4. Hypack 2014 navigation software.

The deployment of the acoustic system was performed using a floating rope where 3 buoys were attached at an 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).

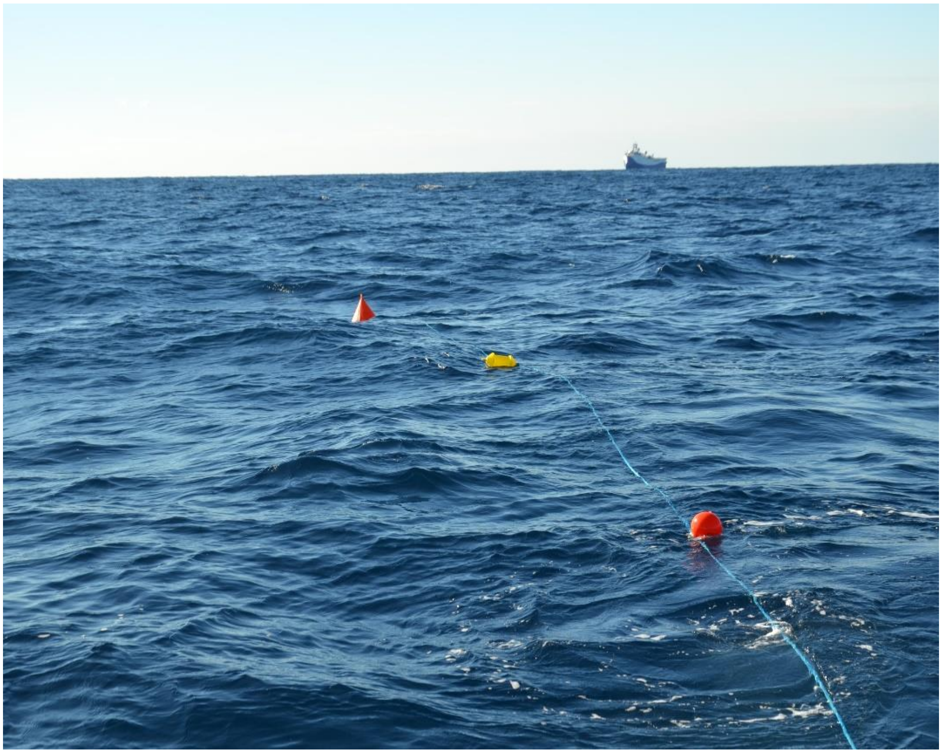
Fig. 2.1.2.5. Monitoring deployment system, using buoys.

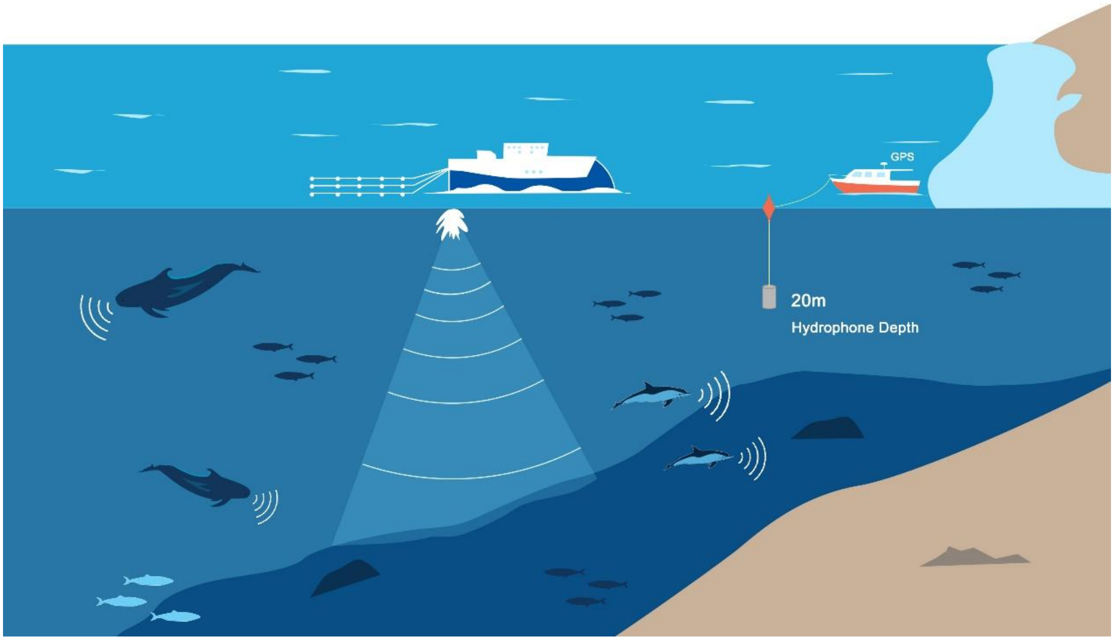


Fig. 2.1.2.6 Schematic visualization of the acoustic monitoring project.

## 2.2. Survey Planning

ITEM 1 stage includes (1) Ambient noise measurements (prestart and post completion of seismic activities) and (2) Seismic noise monitoring, at the proximity of the five (5) predefined locations (Fig. 2.2.1.). The five locations proposed by HELPE are:

- Location 1 (S1) refers to SW of the Strofades Island.
- Location 2 (S2) refers to the Gulf of Laganas, in Zakinthos island.
- Location 3 (S3) refers to the Western area of Katakolo promontory.
- Location 4 (S4) refers to the area of Marathoupoli, in the Northern part of Proti island.
- Location 5 (S5) refers to the Southern part of the survey area outside the area of Methoni.

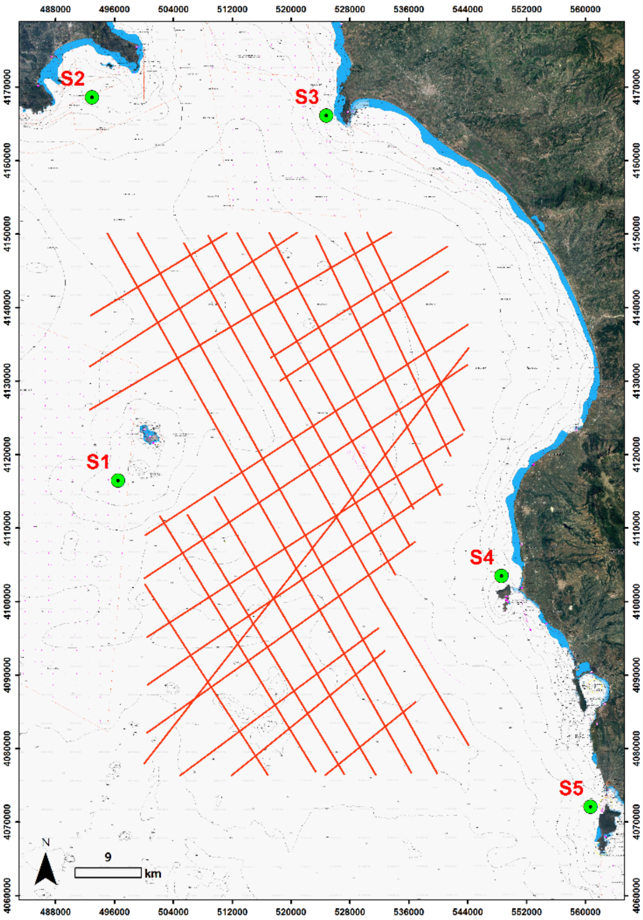


Fig. 2.2.1. Map locating the seismic survey area (tracklines) and the five (5) locations where spot acoustic measurements took place in the Post-End phase.

During the ambient noise measurements (Post-End phase), a total of 5 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.

Table 2.2.1. Ambient noise measurements sorted by date and station

| Date | Strofades | Zakinthos | Katakolo | Marathoupoli | Methoni |
|---|---|---|---|---|---|
| 09/03/2022 | √ | | | | |
| 10/03/2022 | | √ | | | |
| 11/03/2022 | | | √ | | |
| 13/03/2022 | | | | | √ |
| 14/03/2022 | | | | √ | |

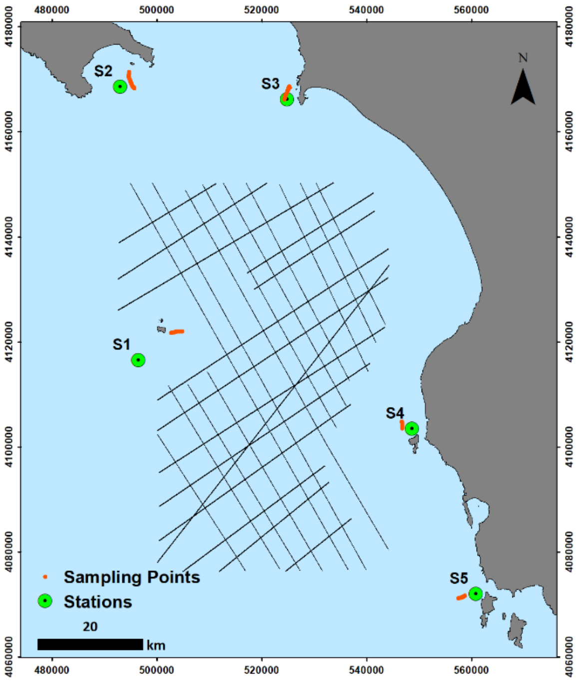


Fig. 2.2.2. Map showing the spot measurements and the track lines of the vessel during the measurements at the five sampling locations.

### 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 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:

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

   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 (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 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 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 a logarithmic scale 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 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 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.

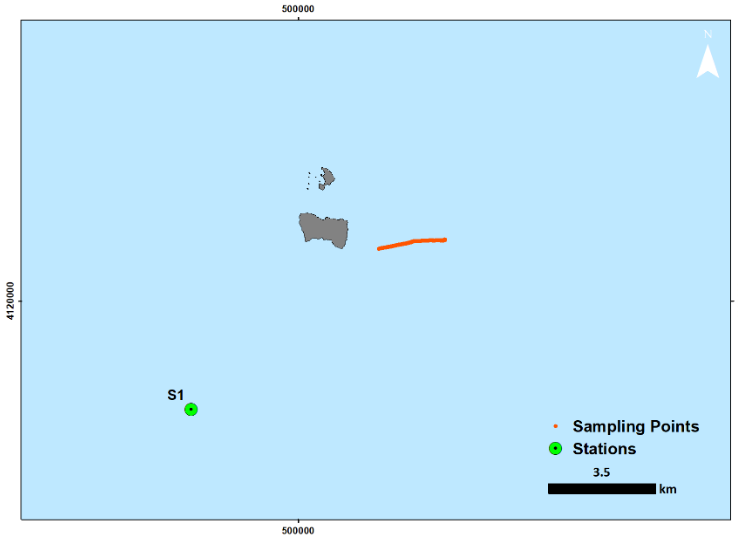


Fig. 3.1.1. Sampling locations at Strofades station.

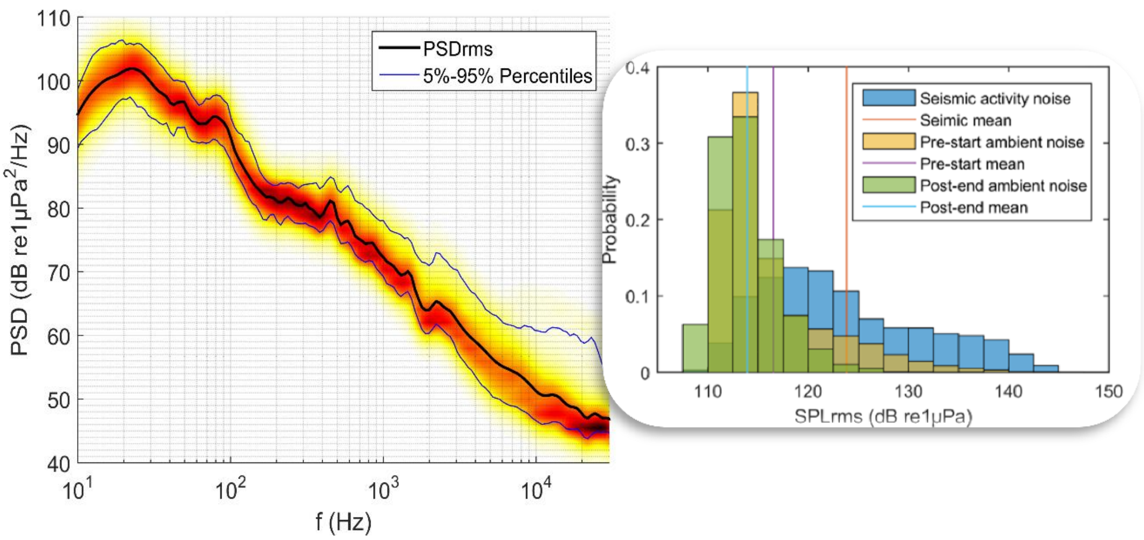


Fig. 3.1.2. Aggregated 30 sec PSDs concerning Strofades station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

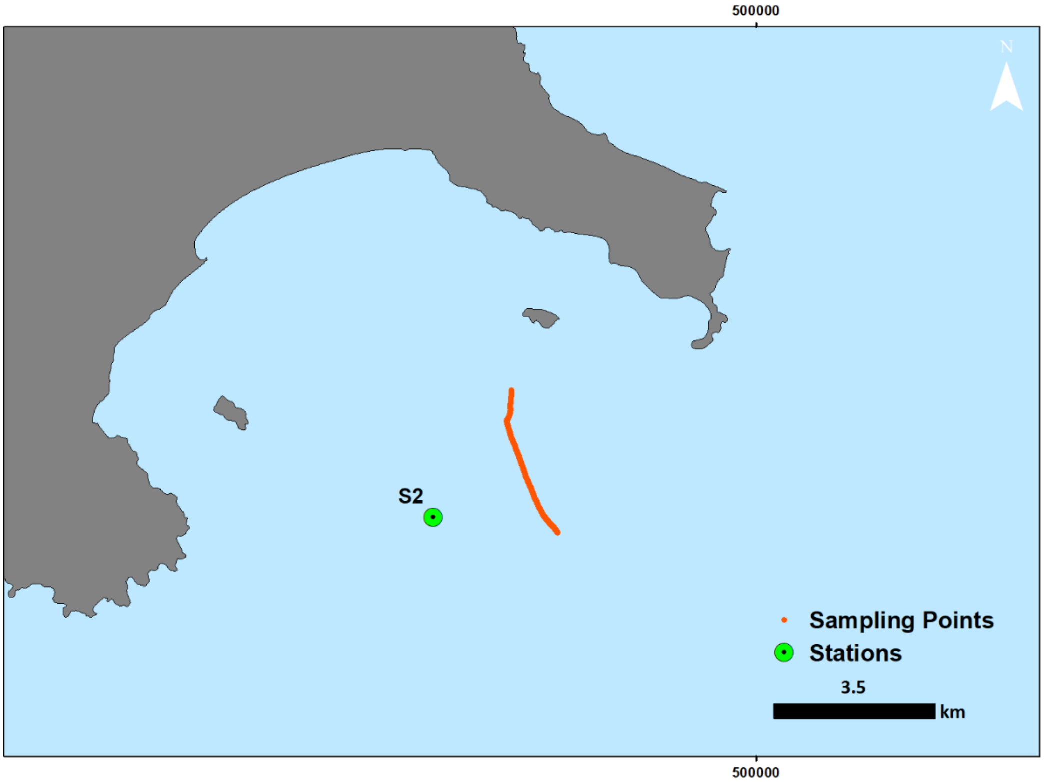


Fig. 3.1.3. Sampling locations at Zakinthos station.

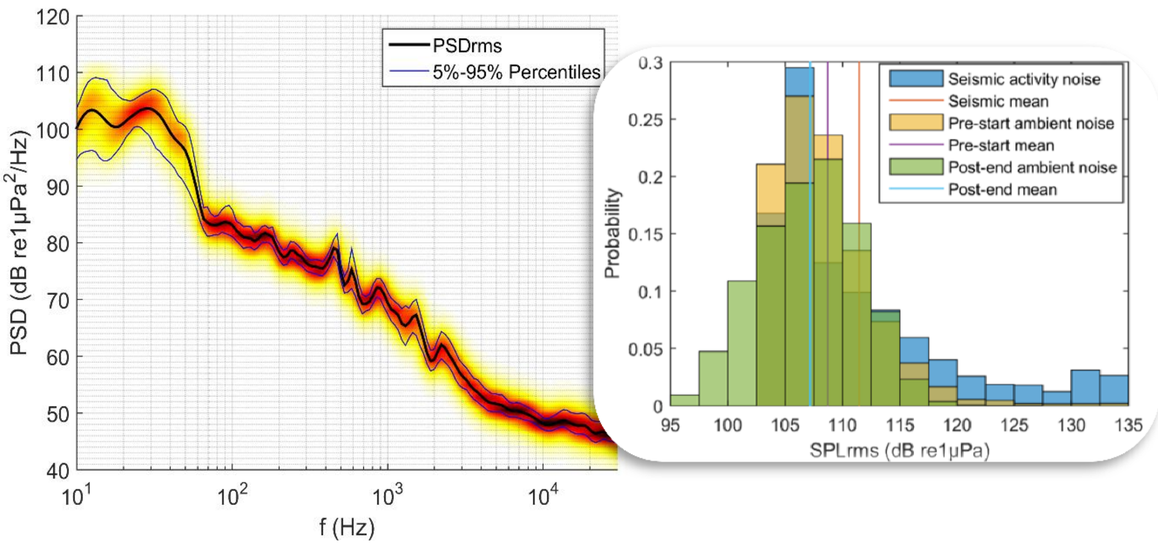


Fig. 3.1.4. Aggregated 30 sec PSDs concerning Zakinthos station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

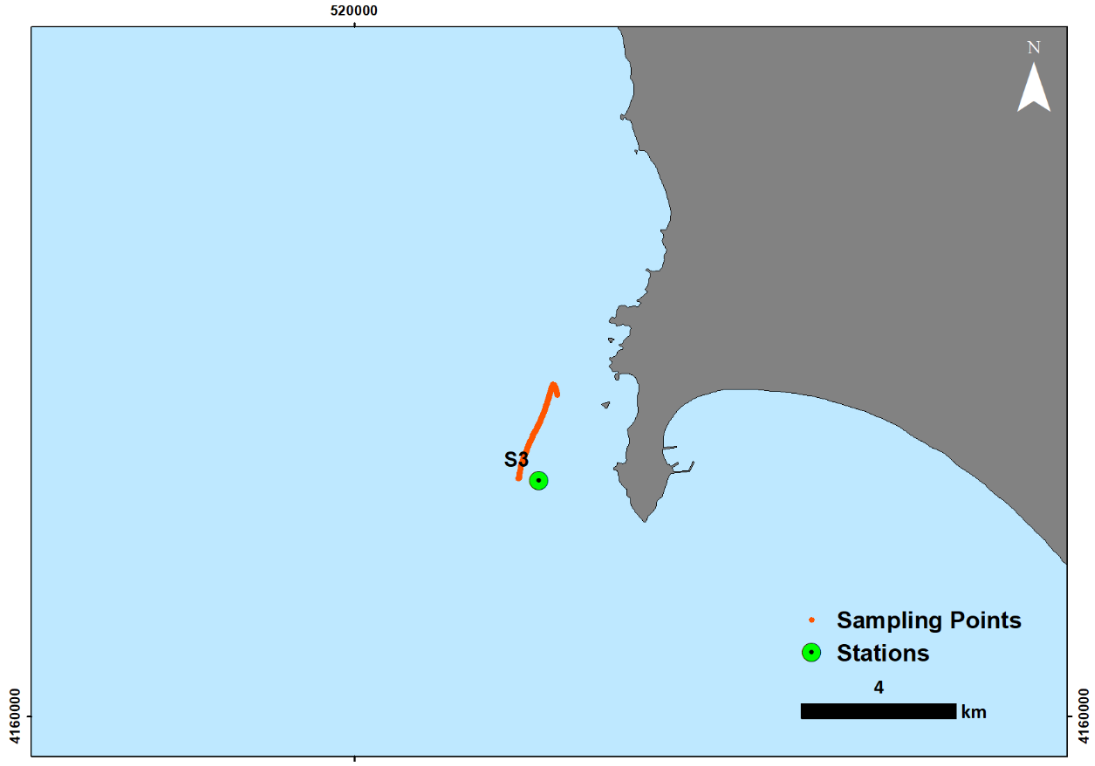


Fig. 3.1.5. Sampling locations at Katakolo station.

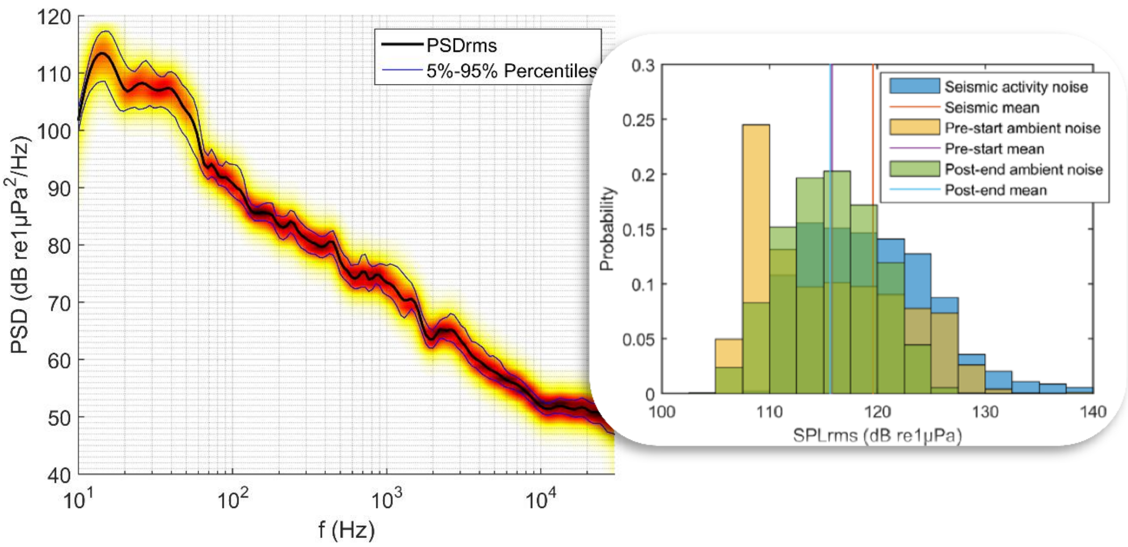


Fig. 3.1.6. Aggregated 30 sec PSDs concerning Katakolo station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

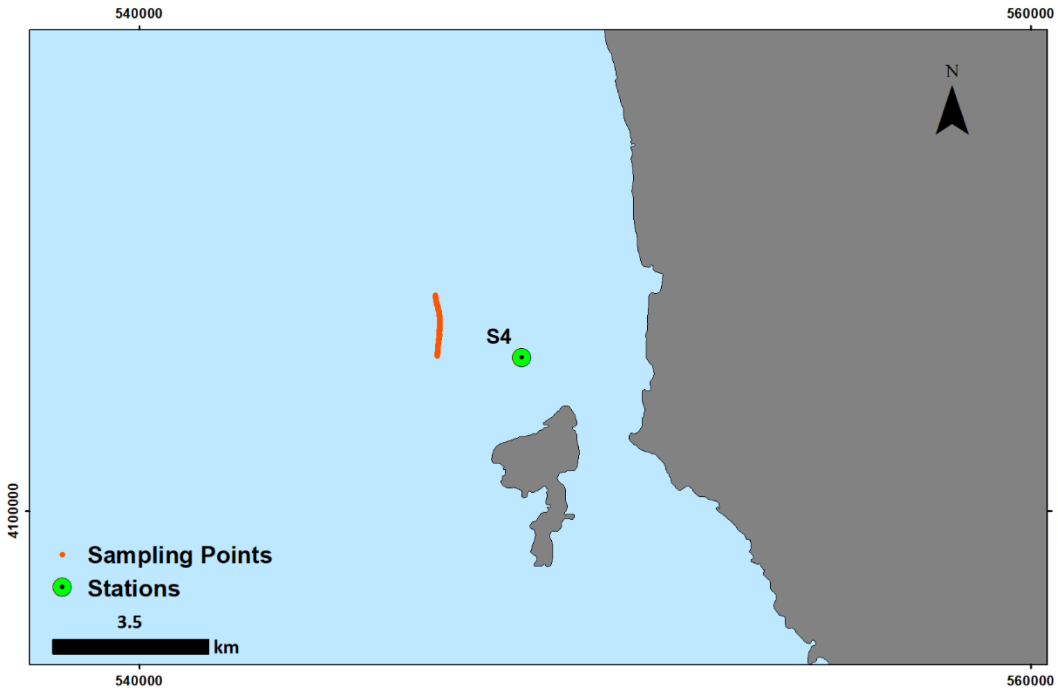


Fig. 3.1.7. Sampling locations at Marathoupoli station.

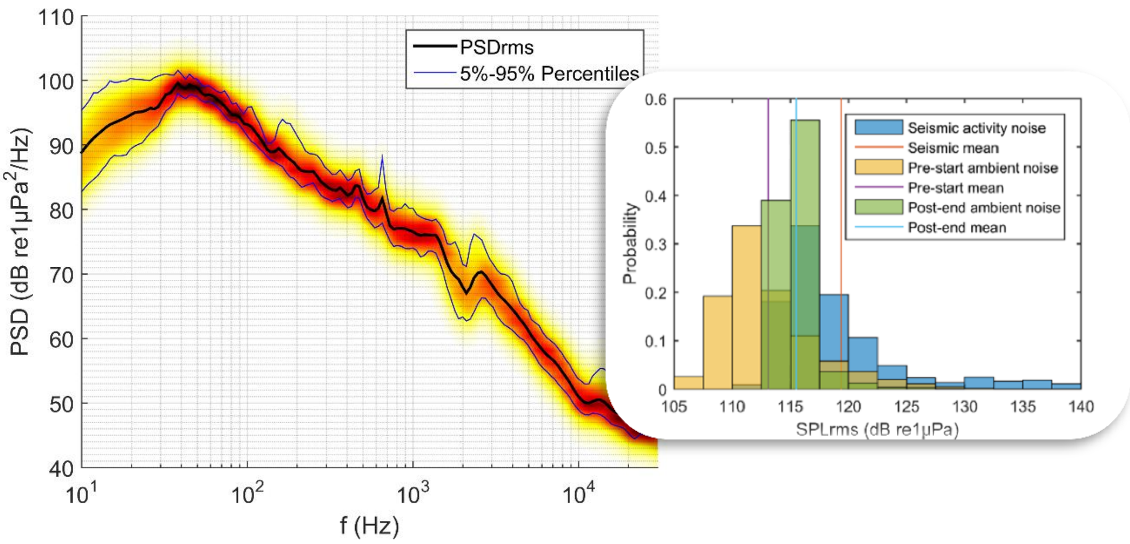


Fig. 3.1.8. Aggregated 30 sec PSDs concerning Marathoupoli station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

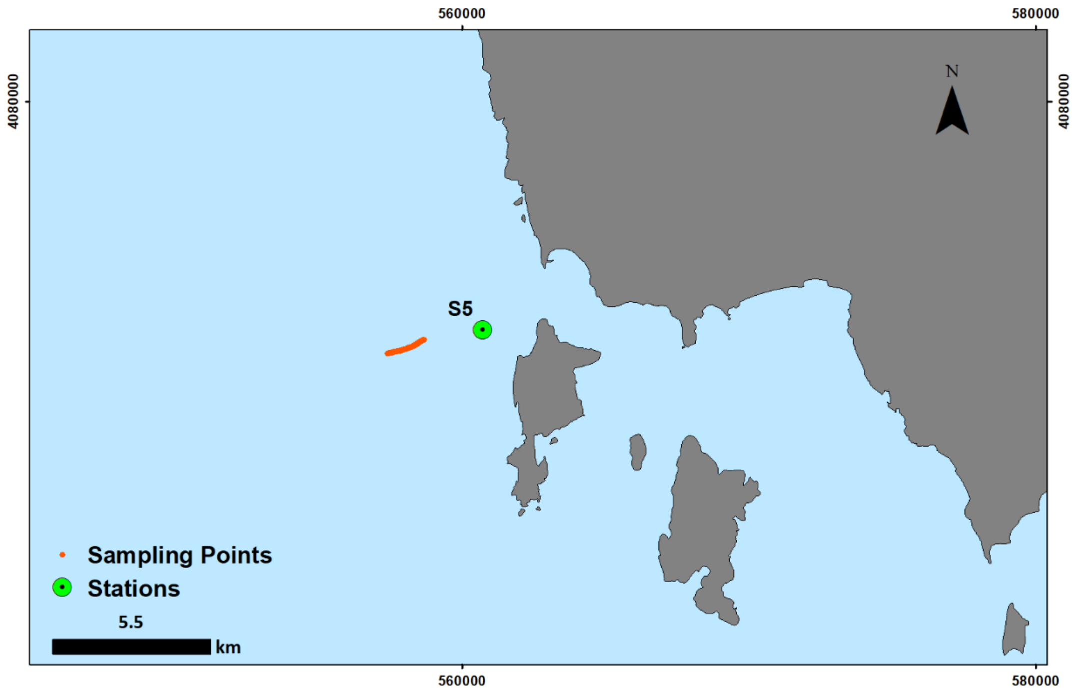


Fig. 3.1.9. Sampling locations at Methoni station.

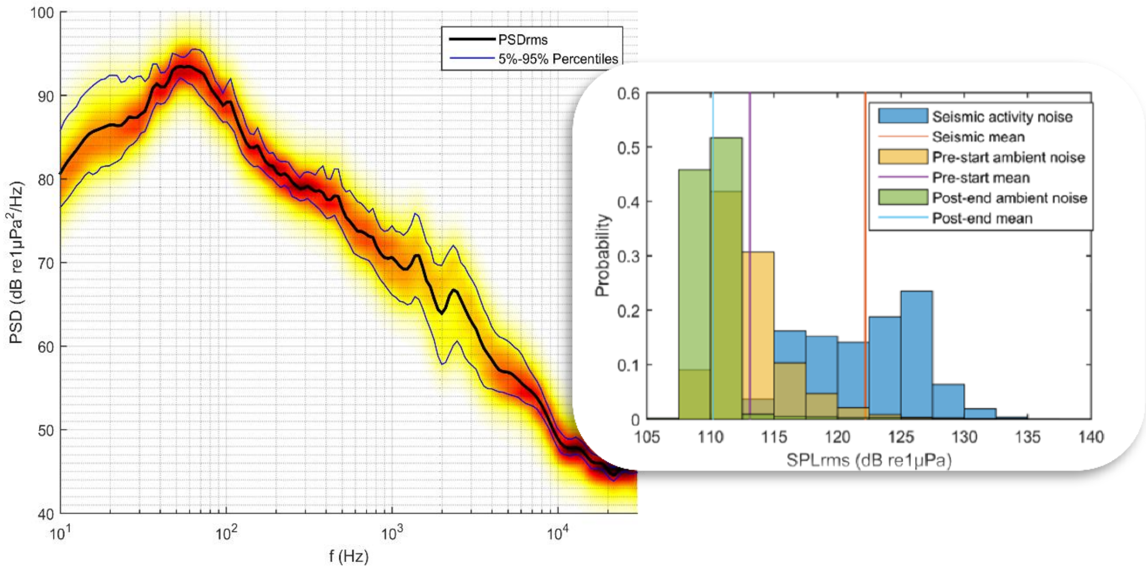


Fig. 3.1.6. Aggregated 30 sec PSDs concerning Methoni station and SPLrms histogram (din width 2.5 dBre1μPa) with average value indication, comparing between seismic activity, prestart and post-end ambient noise levels.

## 3.2. Preliminary analysis

### 3.2.1. General sound sources

Intense deviations in the frequency domain that are 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 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).

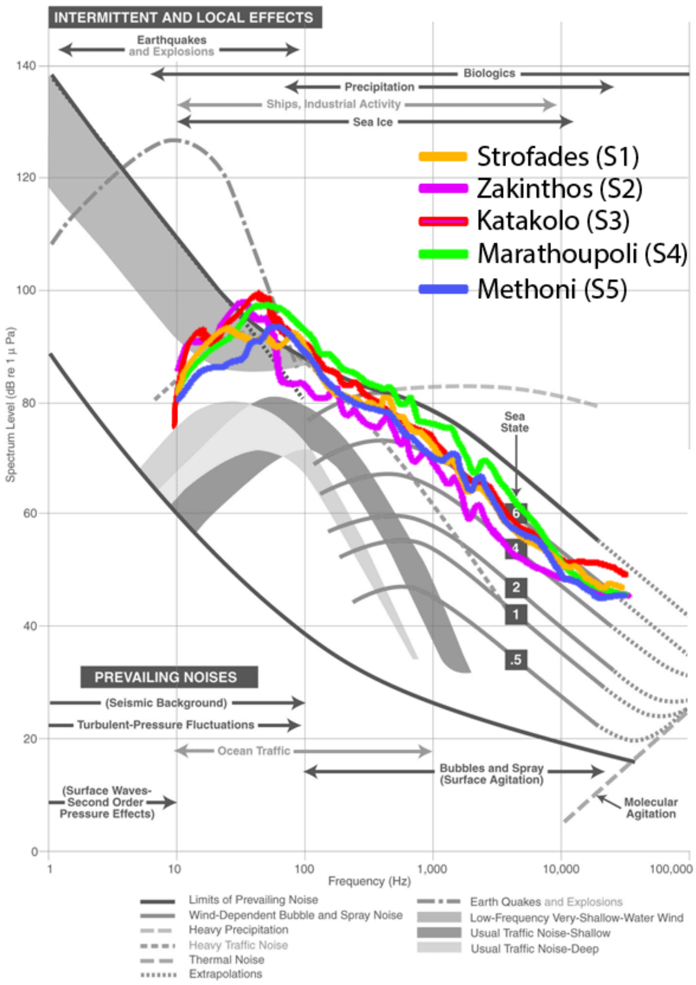


Fig. 3.2.1. Wenz curves describing pressure spectral density levels of marine ambient noise from weather, wind, geologic activity, and commercial shipping, superimposed by the rms PSDs of the five sampling locations (Adapted from Wenz, 1962).

The comparison of the Wenz curves with the rms PSDs retrieved by the 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 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), the weather conditions were moderate, around sea state 3-4 Beauforts.

Concerning the middle to low band frequencies (10-1000Hz), PSDs exhibited common distributions between all but 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 about 5dB to 10dB (Strofades and Methoni). The differences between the pre-start and post-end ambient noise monitoring periods were not significant.

### 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 3.2.3, PSD and SPLrms the main traffic noise detected incidences are presented, that seem to increase the ambient sound pressure levels between 2 and 7dB.

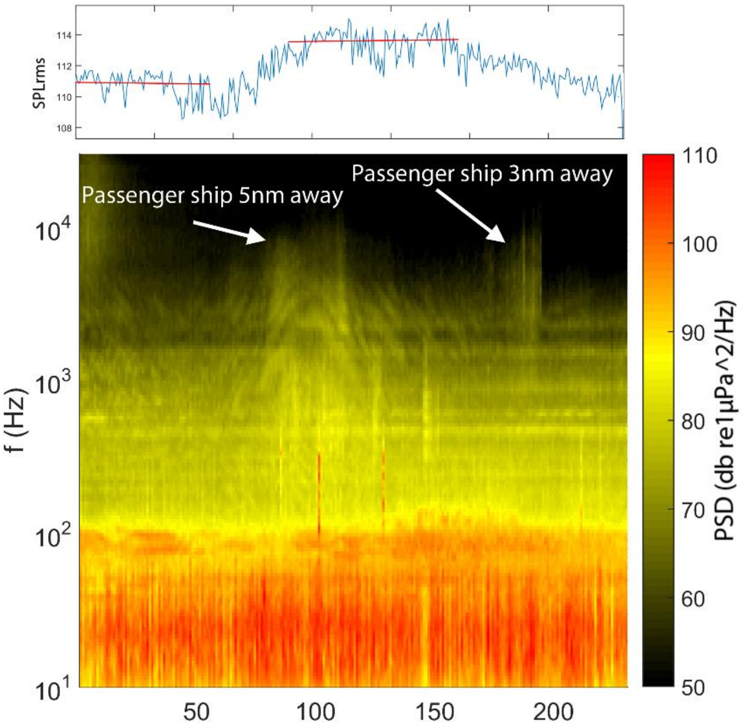


Fig. 3.2.2 SPLrms and PSD spectrogram for traffic noise evident in the sound recording of Strofades station, indicating two passenger ships 5nm and 3nm away the recording station, increasing the ambient noise about 3dB (SPLrms) respectively.

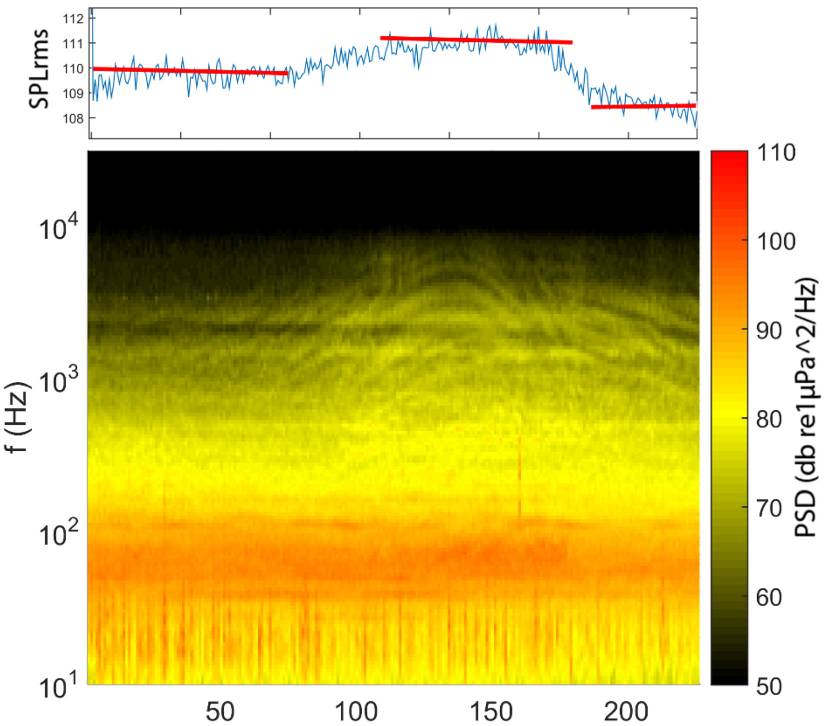


Fig. 3.2.3 SPLrms and PSD spectrogram for traffic noise evident in the sound recording of Methoni station, indicating a passenger, increasing the ambient noise less than 2dB (SPLrms).

### 3.2.3. Other impulsive and sonar sounds

Loud impulsive sounds have been detected in all stations but Marathoupoli. Their exact origin and distance of the sound source cannot be known. However, these loud impulsive sounds are usually linked to underwater explosions owed to military and/or fishing purposes. During the acoustic data acquisition period, the broader area of Kyparissiakos Gulf was used as a target practice area by the Greek navy, thus it is possible that these sounds were linked to military exercises. They don’t seem to have a constant repetition time-pattern and they are random. Their frequency range is between 10Hz and 600Hz. Somes of the 12 detected impulsive sounds during the Post-End phase of the Kyparissiakos survey are shown between Figs 3.2.4 and 3.2.5 indicating the overall stations’ PSD spectrograms that made the detections possible.

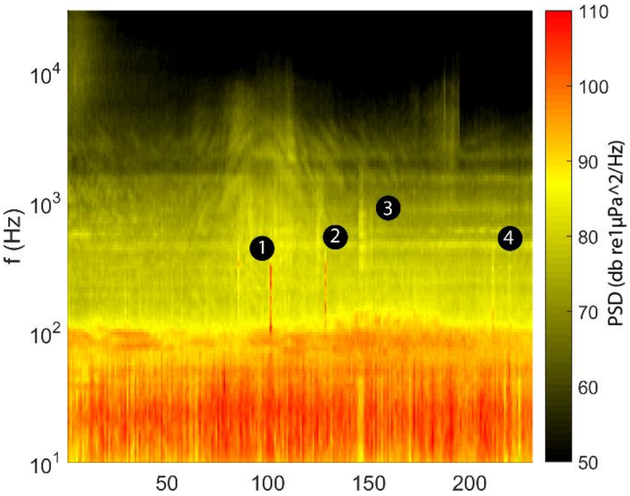


Fig. 3.2.4. PSD spectrogram indicating the four impulsive sounds detected in Strofades station.

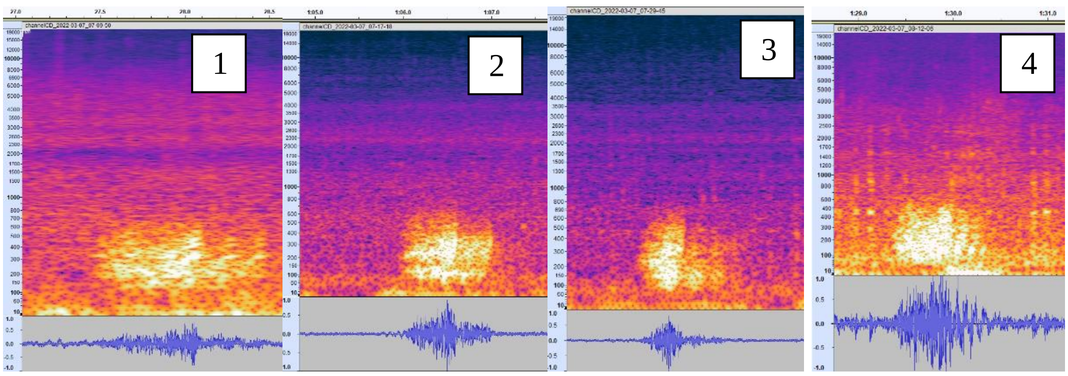


Fig. 3.2.5. PSD spectrogram of the four impulsive sounds detected in Strofades station. They increase the ambient sound noise by no more than 5dB.

## 4. Personnel

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

| Name | Responsibility |
|---|---|
| **Prof. George Papatheodorou** | Project leader |
| **Dr. Dimitris Christodoulou** | Fieldwork leader, Data processing and reporting Personnel |
| **Dr. Elias Fakiris** | Data processing and reporting leader-Fieldwork Technical Personnel |
| **Dr. Nikos Georgiou** | Fieldwork Technical/ Data processing and reporting Personnel |
| **Mr. Alexandros Menegatos** | Field work Technical Personnel |
| **Capt. Gerasimos Sotiropoulos** | Vessel Captain |