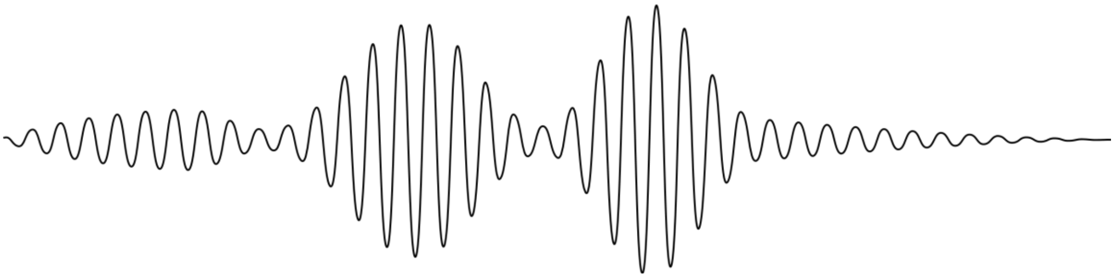
Hellenic Petroleum Exploration & Production of Hydrocarbons SA



KYPARISSIAKOS GULF ACOUSTIC MONITORING PROJECT

ITEM 2
“Verification of the Exclusion Zone”

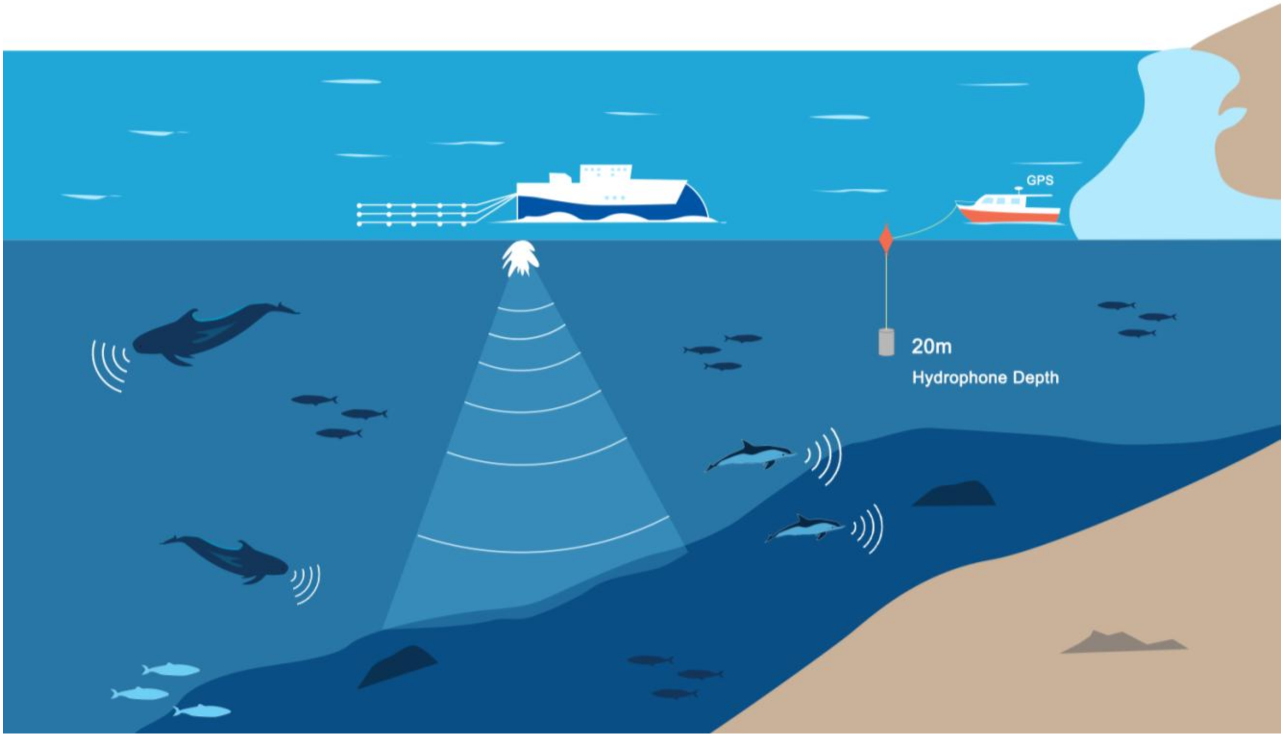
Technical Report

OCEANUS LAB

(Laboratory of Marine Geology & Physical Oceanography)

Department of Geology University of Patras

Table of contents



1. Introduction

The present report describes the data collection, data processing methods, and the results of ITEM 2 "Verification of exclusion zone" regarding the Kyparissiakos Gulf Acoustic Monitoring Project. The ITEM2 project survey aims to monitor the propagation and attenuation rate of the impulse sounds around the seismic source (Airgun arrays) to validate the geometry of the predefined exclusion zone.

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.

Results presented in this report refer to acoustic data collected during January 26th and 28th of 2022.

2. Data acquisition

“Sea Master” vessel stood in positions agreed with the SW COOK navigation team, deploying the sound recorder at 20m depth, at distances no less than 900m from the seismic source (air-guns) and while SW COOK executed its prearranged survey lines. Pictures from the fieldwork survey are presented in Figure 2.1. Attention has been paid so that sound measurements were obtained from both the forward and broadside directions relative to the fore-aft axis of the seismic source. Each recording station lasted for about 30-40minutes intended to acquire sound pressure levels regarding more than 3km distance both fore and aft sides of the seismic vessel. Boat engines were set on for retaining the desired position as well as for safety reasons. Figure 2.2 shows the positions where sound level recordings took place concerning the seismic lines.

The navigational data of SW COOK were sent to the data processing team in a daily fashion after a valid exchange data format had been agreed upon. Those included time-stamped coordinates of the pulse emitting Airguns from time intervals where Airgun shots occurred.

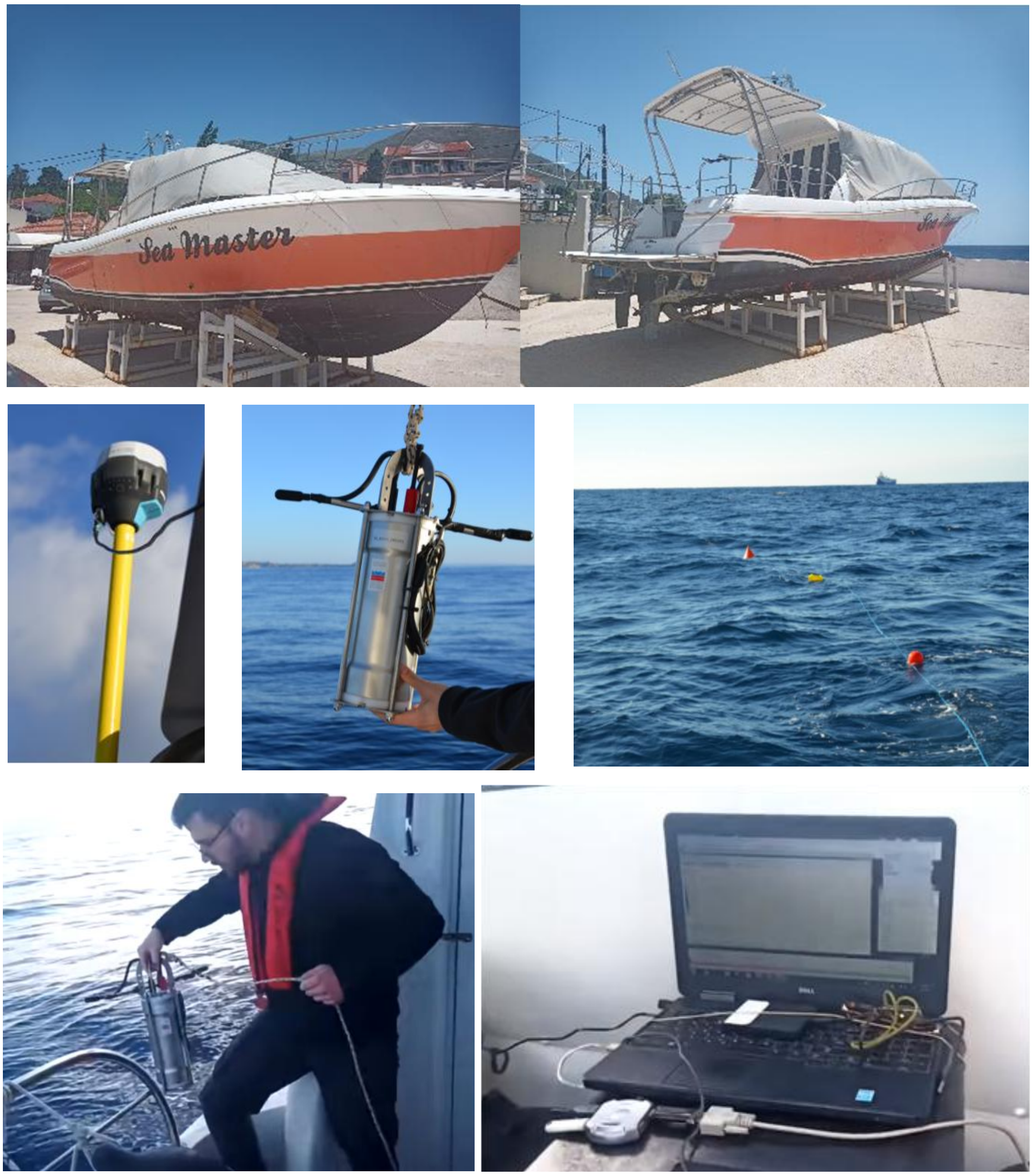


Fig. 2.1. Selected pictures from the fieldwork survey during the ITEM 2 phase.

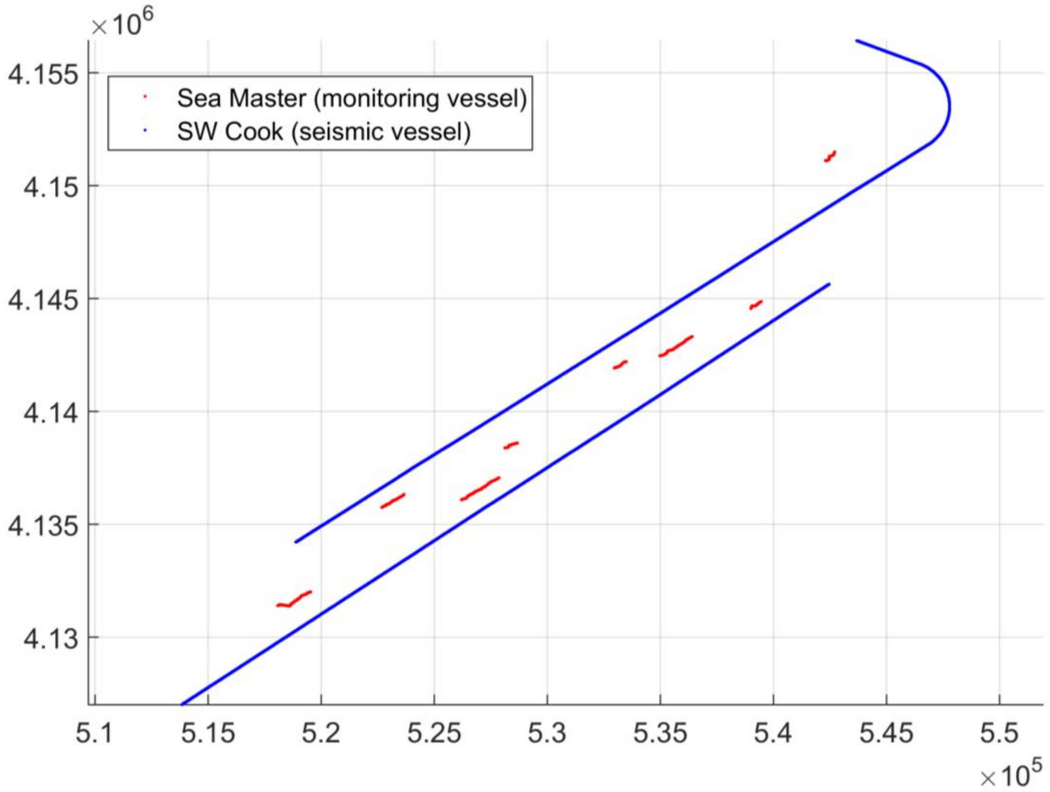


Fig. 2.2. The “Sea Master” stations (red dots) and the relative seismic lines of SW COOK (blue dots) have been monitored for seismic impulse noise on January 26th, and 28th 2022. **Coordinates in UTM 34N*

3. Data Processing Methodology

The objective of ITEM 2 is to measure impulse sound pressure levels around the seismic source (Airguns) to record and study the seismic noise attenuation levels and validate specified mitigation zones. To meet the above, a suite of MATLAB codes has been implemented by the Oceanus Lab. The data processing steps were as follows:

1. Apply queries based on the operator's 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. Detect any Airgun pulses in the sound waveforms and specify the time occupied by the central portion of the pulse, where 90% (T5% - T95%) of the pulse energy resides.
8. Calculate SPLp-p, SPLpeak, SPLrms, and SEL (as defined in the following) for every detected impulse sound (associated with air-gun pulses). All sound pressure metrics are estimated with an integration time equal to the T5% - T95% of each Airgun pulse.
9. Estimate the distance and the azimuth between “Sea Master” and SW COOK for each detected impulse sound, considering their synchronized navigational data. Use polar (θ - d) or Cartesian (x - y) coordinates to estimate relative positions of SW COOK and “Sea Master”.

3.1. Airgun pulse detection and T_5-T_{95} estimation

Impulse sound detection and 90% impulse energy duration estimation was performed automatically first by applying a peak detector to the RMS smoothed sound waveform and then by determining the 5% - 95% rise time of the cumulative of the squared signal (see fig 3.1.) around each detected impulse sound.

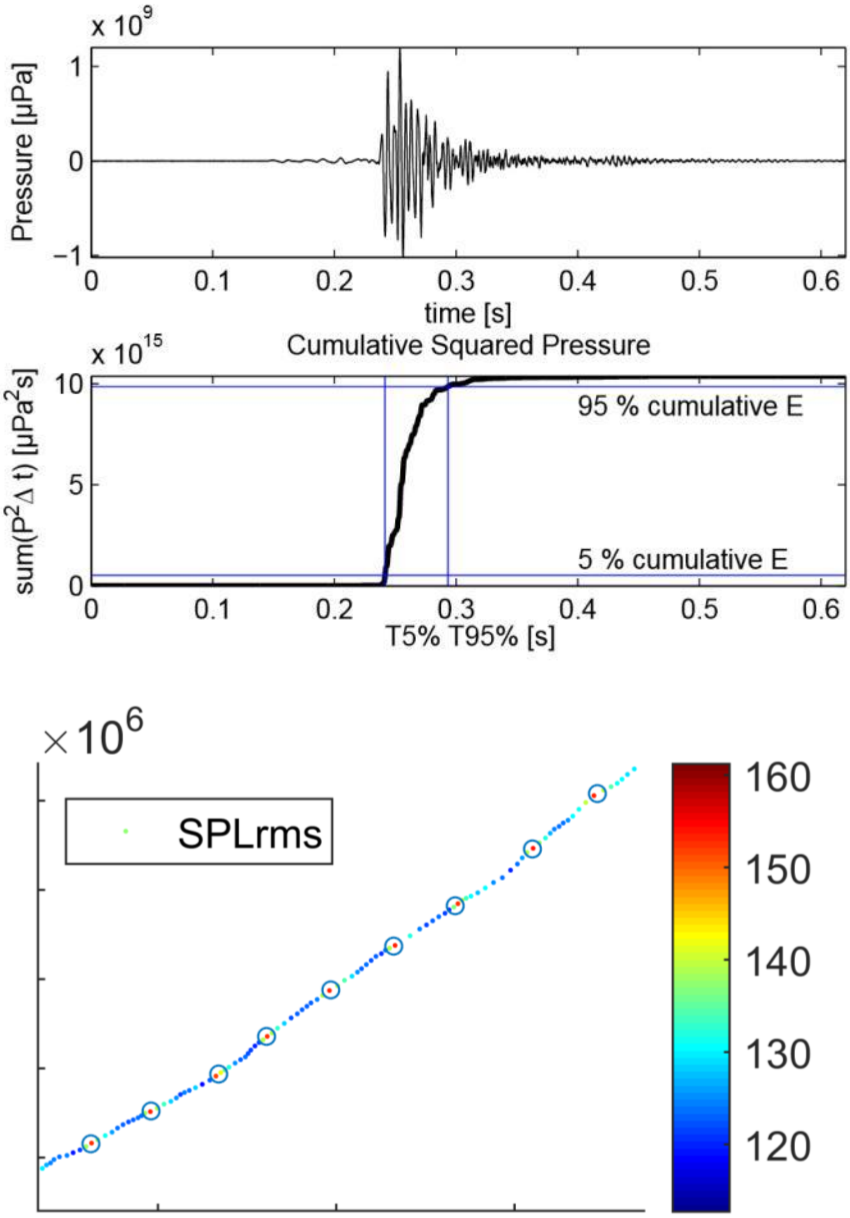


Fig. 3.1. Estimation of the 5% - 95% energy time intervals for an Airgun impulse sound through the cumulative squared pressure of the raw signal (Top Figures). SPLrms were recorded on the monitoring line (colored dots) and detected impulses (circles). Colorbar corresponds to SPLrms dBre1μPa (Bottom Figure).

3.2. Sound Pressure Levels

For each Airgun impulse sound, and considering a T5% - T95% time duration, the following parameters have been calculated:

1. Peak to peak Sound Pressure Level (SPLp-p). The sum of the peak compressional pressure and the peak refractional pressure during the 5% - T95% time interval. This quantity is typically most useful as a metric for a pulsed waveform.

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

   where $P_{p\text{-}p}$ is the difference between the minimum and the maximum pressure in the time interval.

2. Peak sound pressure level (SPL_{peak}) is the maximum absolute amplitude value in the signal during the 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.

3. Root mean square (RMS) sound pressure level (SPL_{rms}) is the log transformed square root of the average square pressure of the signal over the 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.

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

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

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

3.3. Approximation of relative position of “Sea Master” around SW COOK

To study the attenuation of impulse sounds around the seismic source the relative position of “Sea Master” and each emitting Airgun of SW COOK needs to be estimated, such as SW COOK is considered stationary and “Sea Master” is moving around it collecting sound level samples. A solution of the above is to estimate the polar coordinates of “Sea Master” regarding SW COOK at a specified time (t1), using the heading and x, y position of SW COOK, the distance (d) between the two vessels, and the X, Y position of “Sea Master”. SW COOK's heading can be estimated using its position at two consecutive times (t1 and t2) while the azimuth between the two vessels (θ) can easily be specified using the defined triangle between “Sea Master” and the two consecutive positions of SW COOK.

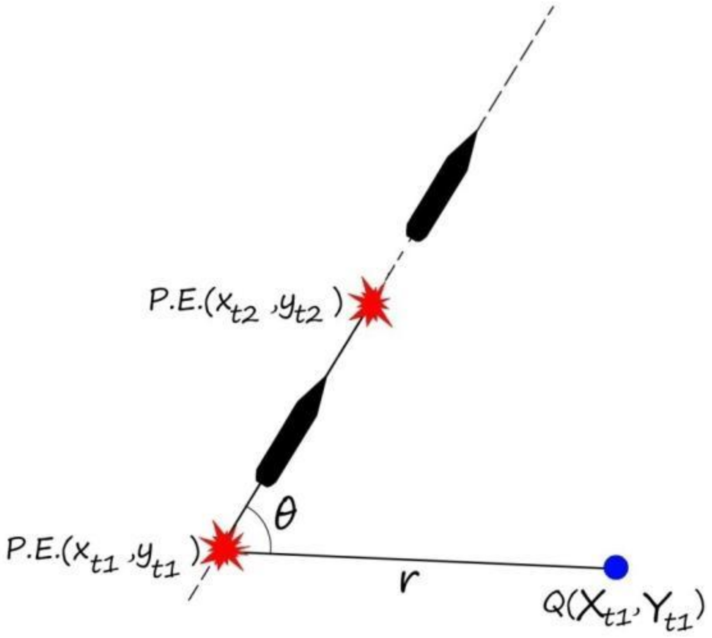


Fig. 3.2. Estimating the polar coordinates (Θ, d) for the relative position of Sea Master (Q) around SW Cook (P.E.) at time 1.

4. Results

4.1. Relative position of “Sea Master” around SW COOK

Figure 4.1. presents the relative positions of “Sea Master” around SW COOK during all effective recordings on January 26th and 28th 2022. Relative coordinates between the two vessels can be presented either in a polar or a Cartesian manner. Based on the instructions of SW COOK's navigation team, the minimum distance between the two vessels was ~900m.

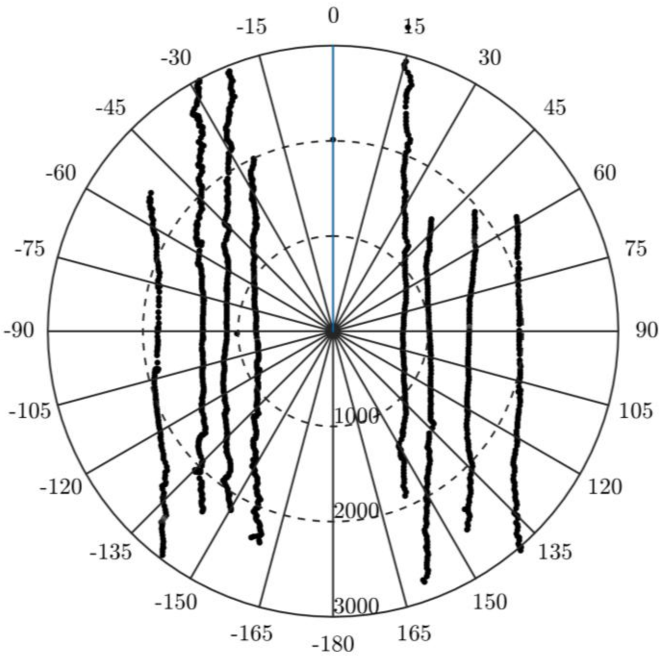


Fig. 4.1. The relative positions of “Sea Master” around the sound emitting Airgun during all effective recordings on January 26th and 28th 2022, using polar coordinates.

A total number of 8 effective stations has been realized, having relative distances to the SW COOK from -3000 to +3000m (negative values indicate the sound recorder being on the aft side of SW COOK) in the along-track direction and 2000m, the across-track direction. Due to safety reasons, recordings have been realized at least 900m away from both the port and the starboard of the seismic source in the across-track direction.

4.3. Reporting results

Figure 4.1. shows an example of the recorded SPLpeak around the seismic vessel, where the impulse sounds are evident (peaks) reaching around 175-180 dBre1μPa. Figure 4.2. shows a representative PSD spectrogram of the recorded impulse sound data. Figures 4.5, through 4.5, present the results regarding all available sound recordings around SW COOK. The spatial distribution of all the extracted impulse sound pressure level metrics (SPLpeak, SPLp-p, SPLrms, and SEL) are presented through suitable color-scale in polar coordinates.

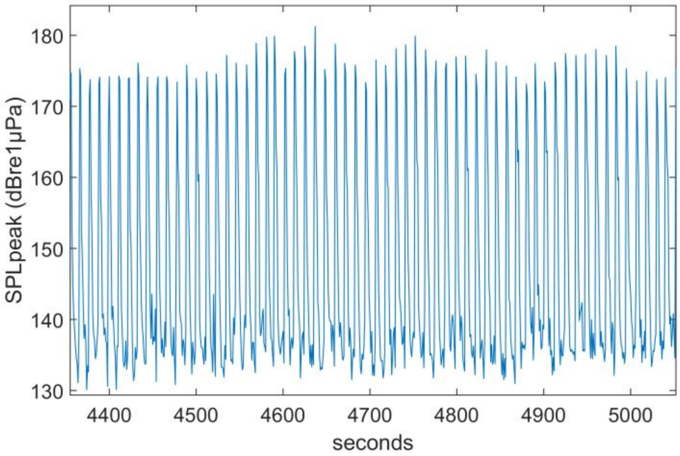


Fig. 4.2. An example of the recorded SPLpeak around the seismic vessel.

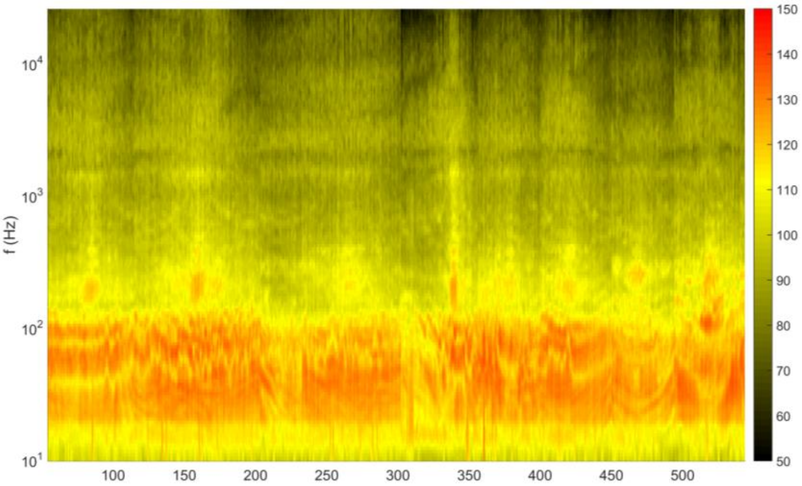


Fig. 4.3. A representative PSD spectrogram of the recorded sound data around the seismic vessel. **Colorbar units: dB re 1μP^2/Hz. Y-axis represents 30sec integrations.*

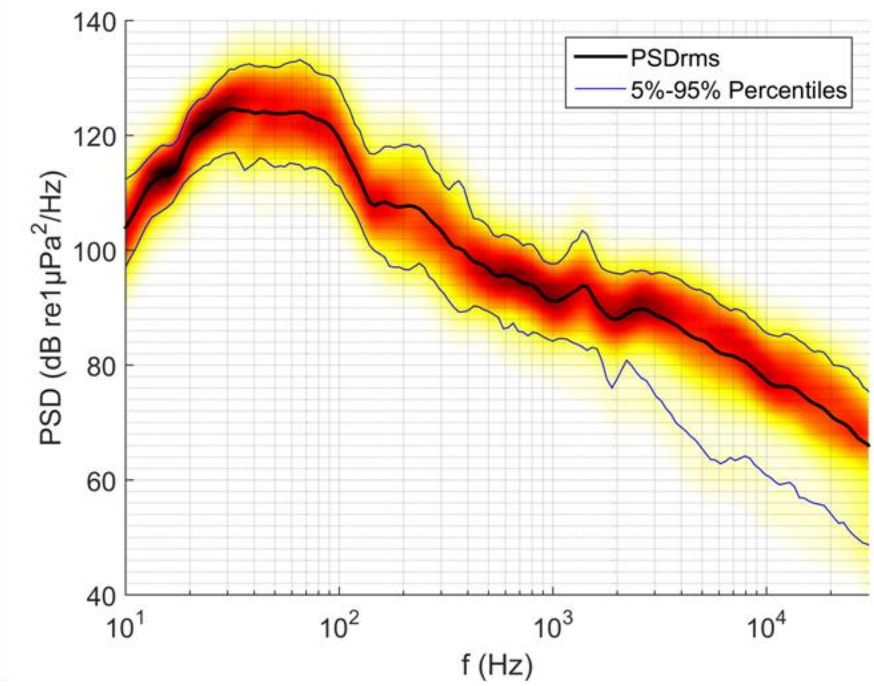


Fig. 4.4. Aggregated 30 sec PSDs concerning the full exclusion zone sound recording dataset.

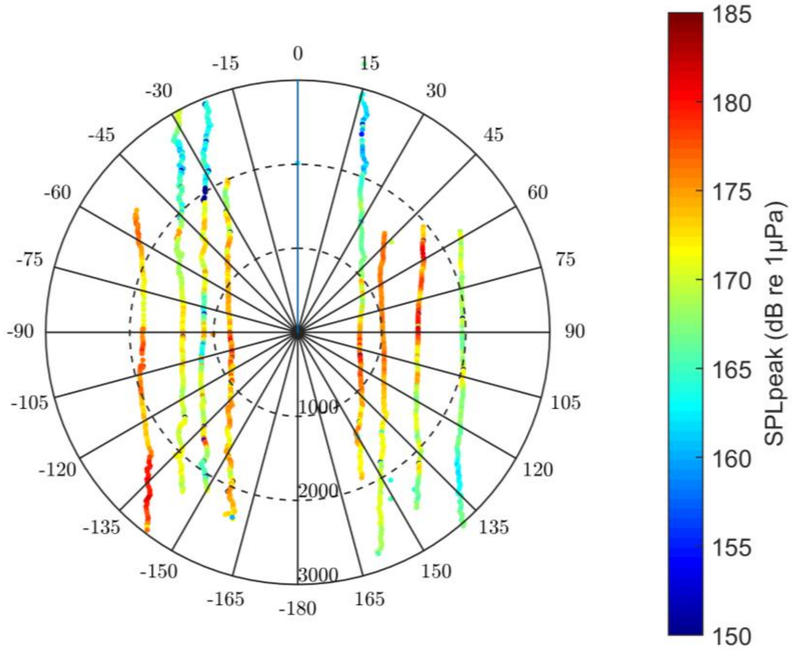


Fig. 4.5. Spatial distribution of estimated zero to peak impulse sound pressure levels (SPLpeak) around the seismic source.

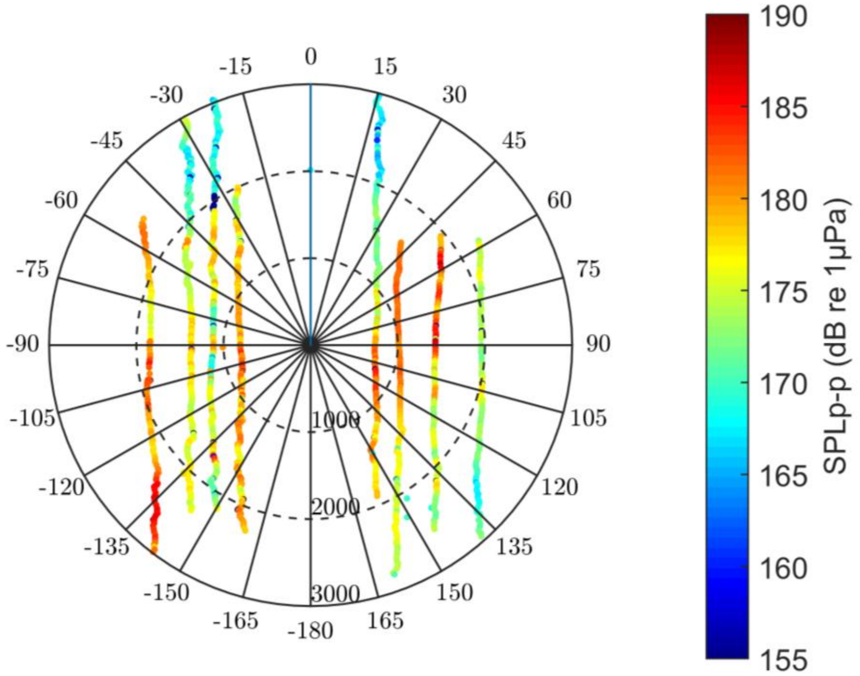


Fig. 4.6. Spatial distribution of the estimated peak to peak impulse Sound Pressure Levels (SPLp-p) around the seismic source.

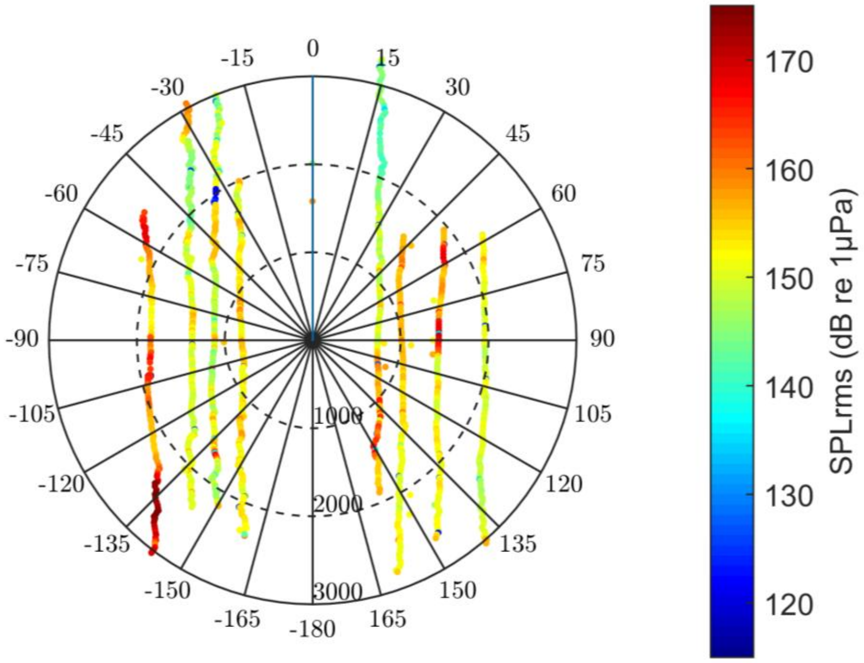


Fig. 4.7. Spatial distribution of estimated root mean squared impulse Sound Pressure Levels (SPLrms) around the seismic source.

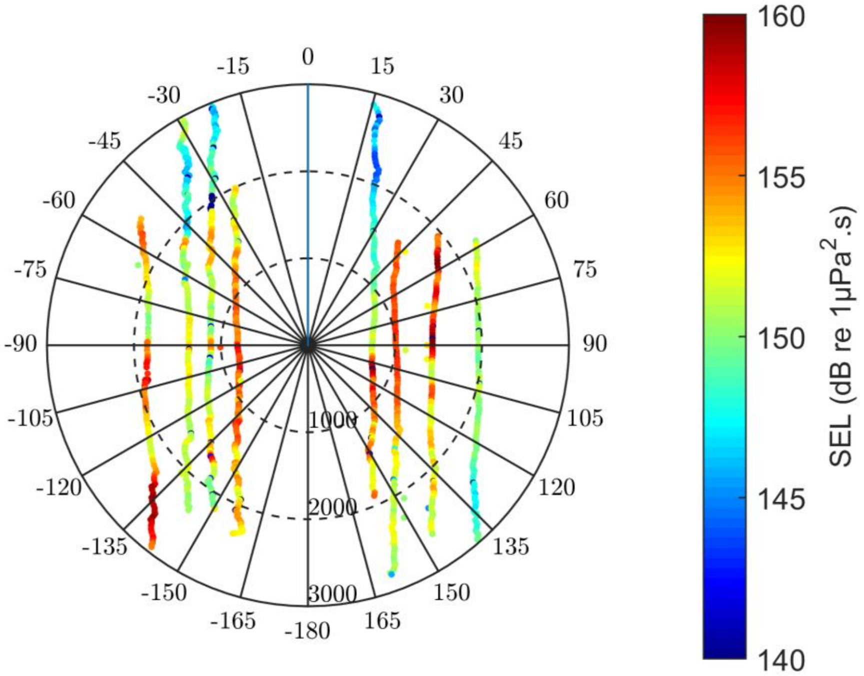


Fig. 4.8. Spatial distribution of estimated Sound Exposure Level (SEL) around the seismic source, integrated for each single T_5-T_{95} impulse sound duration.

Examining the variability and the trend of impulse sound pressure levels versus absolute distance to the source is an important means for exploring its attenuation level. In Figure 4.9, SPLpeak and SEL of the detected impulses are plotted against the absolute distance to the seismic source, each one superimposed by its best linear fit. Although the best fit line is a fair indicator of the average trend of sound energy over distance, maximum SPL values are those that constitute environmental risk factors.

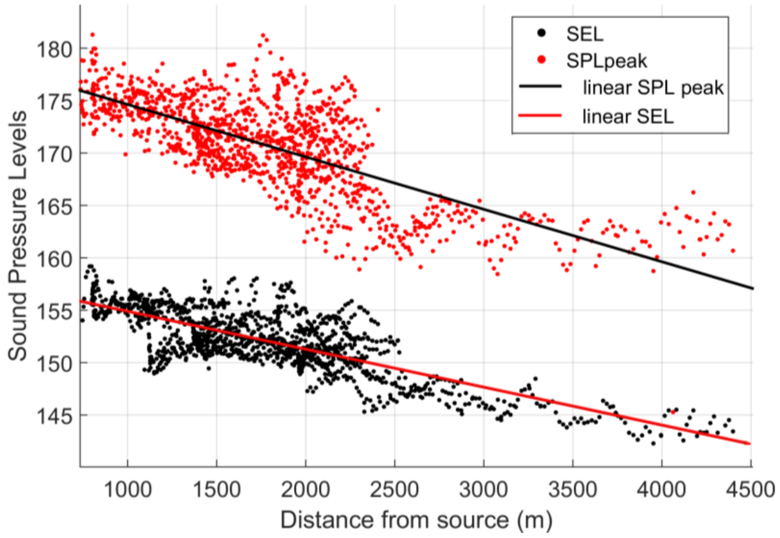


Fig. 4.9 SPLpeak and SEL of each detected Airgun impulse sound versus the absolute distance to the seismic source superimposed by linear fits. **Y axis units: dB re 1μPa*

In 2002, the U.S. National Marine Fisheries Service (NMFS) Ocean Acoustics Program assembled a panel of scientists to address the challenging task of auditory hazards in marine mammals. They reviewed all available information and developed methods to evaluate and quantify noise exposure levels for different anthropogenic sources expected to cause (1) behavioral responses of varying severity and (2) reductions in auditory sensitivity changes, including both temporary threshold shifts (TTS) and permanent threshold shifts (PTS). This resulted in the auditory exposure criteria described in Southall et al. (2019). Of all the criteria specified within this document, the worst-case scenario drawn is for very high-frequency cetaceans, including dolphins and physeters, that may experience temporary auditory effects over 196 dB re 1μPa. Figure 4.10 shows the comparison of these limits to the average and maximum expected SPL at the limits of the exclusion zone, making clear that they are well below the specified risk levels.

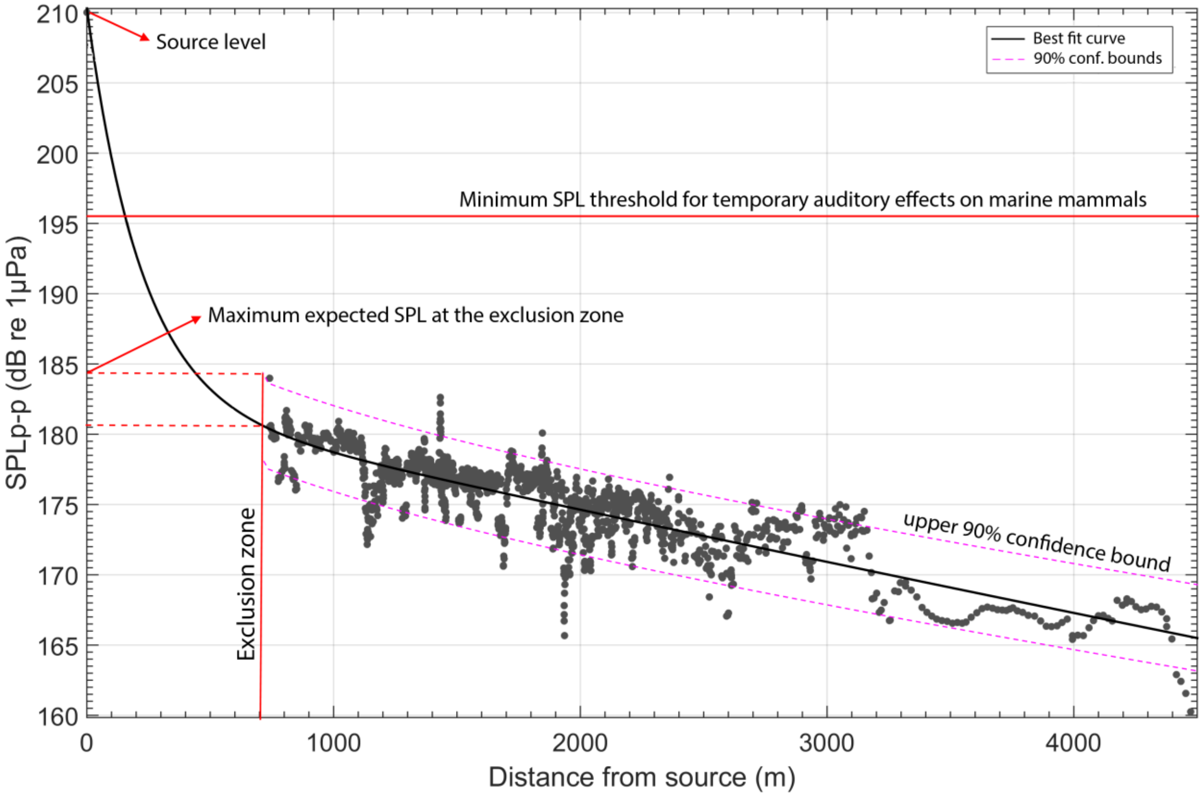


Fig. 4.10 The peak to peak SPL (SPLp-p) of each detected airgun impulse sound versus the absolute distance to the seismic source. The average and maximum expected SPL at the limits of the exclusion zone are compared to the minimum SPL threshold for temporary auditory effects on dolphins and physeters, as reviewed in Southall et al. (2019).

5. 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