QUIETMED – Joint programme on noise (D11) for the implementation of the Second Cycle of the MSFD in the Mediterranean Sea

Deliverable

D3.6 Detailed report on ambient noise measurements in Crete, Malta and Cabrera and the analysis of the measured data

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Document Number: QUIETMED – D3.6.

Delivery date: 5th December, 2018

Call: DG ENV/MSFD Second Cycle/2016

Grant Agreement: No. 11.0661/2016/748066/SUB/ENV.C2

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4	Service Hydrographique et Océanographique de la Marine	SHOM	France
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Abstract

The QUIETMED project is running a number of pilot runs for monitoring and consequently establishing trends in acoustic noise present in the Mediterranean Sea according to requirements and guidelines adopted in the MSFD. Three research areas are the target of this monitoring; namely Cabrera (Spain), Maltese Islands, and Crete (Greece). Each site has his own equipment and procedure for deployment, retrieval and post-processing to meet the MSFD requirements.

In this document one finds, even in the presence of heterogeneity, how the partners in the pilot projects select their deployment site, prepare the equipment (including calibration of recording rig), deploy and retrieve and eventually process and co-relate the collected sound data to report indicators required by the MSFD.

The latter part of this report shows the results at local level by using comparative methods on each the three site datasets and explain these, for each site, through location profile and local shipping activities. These results give quantitative measure of the indicators required by the MSFD.

Table of Contents

List of figures

List of tables

List of Abbreviations

CTN	Centro Tecnológico Naval y del Mar
IEO	Instituto Español de Oceanografía
UPV	Universitat Politècnica de València
SHOM	Service Hydrographique et Océanographique de la Marine
ISPRA	Ispra Instituto Superiore per la Protezione e la Ricerca Ambientale
IZVRS	Inštitut za vode Republike Slovenije
ACCOBAMS	Permanent Secretariat of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
UoM	The Conservation Biology Research Group, the University of Malta
IOF	Institute of Oceanography and Fisheries
FORTH	Foundation for Research and Technology - Hellas
MSFD	Marine Strategy Framework Directive

1 Introduction

The QUITMED Project is funded by DG Environment of the European Commission within the call "DG ENV/MSFD Second Cycle/2016". This call funds the next phase of MSFD implementation, in particular to achieve regionally coherent, coordinated and consistent updates of the determinations of GES, initial assessments and sets of environmental targets by July 2018, in accordance with Article 17(2a and 2b), Article 5(2) and Article 3(5) of the Marine Strategy Framework Directive (2008/56/EC).

The QUIETMED project aims to enhance cooperation among Member States (MS) in the Mediterranean Sea to implement the Second Cycle of the Marine Directive and in particular to assist them in the preparation of their MSFD reports by 2018 through: i) promoting a common approach at Mediterranean level to update GES and Environmental targets related to Descriptor 11 in each MS marine strategies ii) development of methodological aspects for the implementation of ambient noise monitoring programs (indicator 11.2.1) iii) development of a joint monitoring programme of impulsive noise (Indicator 11.1.1) based on a common register, including gathering and processing of available data on underwater noise. The Project has the following specific objectives:

- ✓ Achieve a common understanding and GES assessment (MSFD, Article 9) methodology (both impulsive and continuous noise) in the Mediterranean Sea.
- ✓ Develop a set of recommendations to the MSFD competent authorities for review of the national assessment made in 2012 (MSFD, Article 8) and the environmental targets (MSFD, Article 10) of Descriptor 11- Underwater Noise in a consistent manner taking into account the Mediterranean Sea Region approach.
- ✓ Develop a common approach to the definition of threshold at MED level (in link with TG Noise future work and revised decision requirements) and impact indicators.
- ✓ Coordinate with the Regional Sea Convention (the Barcelona Convention) to ensure the consistency of the project with the implementation of the EcAp process.
- ✓ Promote and facilitate the coordination of underwater noise monitoring at the Mediterranean Sea level with third countries of the region (MSFD Article 6), in particular through building capacities of non-EU Countries and taking advantage of the ACCOBAMS-UNEP/MAP cooperation related to the implementation of the Ecosystem Approach Process (EcAp process) on underwater noise monitoring.
- ✓ Recommend methodology for assessments of noise indicators in the Mediterranean Sea basin taking into account the criteria and methodological standards defined for Descriptor11 (Decision 2010/477/EU, its revision and Monitoring Guidelines of TG Noise).
- ✓ Establish guidelines on how to perform sensor calibration and mooring to avoid or reduce any possible mistakes for monitoring ambient noise (D 11.2.1). These common recommendations should allow traceability in case the sensor give unexpected results and help to obtain high quality and comparable data.
- ✓ Establish guidelines on the best signal processing algorithms for the pre-processing of the data and for obtaining the ambient noise indicators (D 11.2.1).
- ✓ Implement a Joint register of impulsive noise (D11.1.1) and hotspot map at Mediterranean Sea Region level by impulsive noise national data gathering and joint processing.
- ✓ Enhance collaboration among a wide network of stakeholders through the dissemination of the project results, knowledge share and networking.

To achieve its objectives, the project is divided in 5 work packages which relationships are shown in Figure 1.

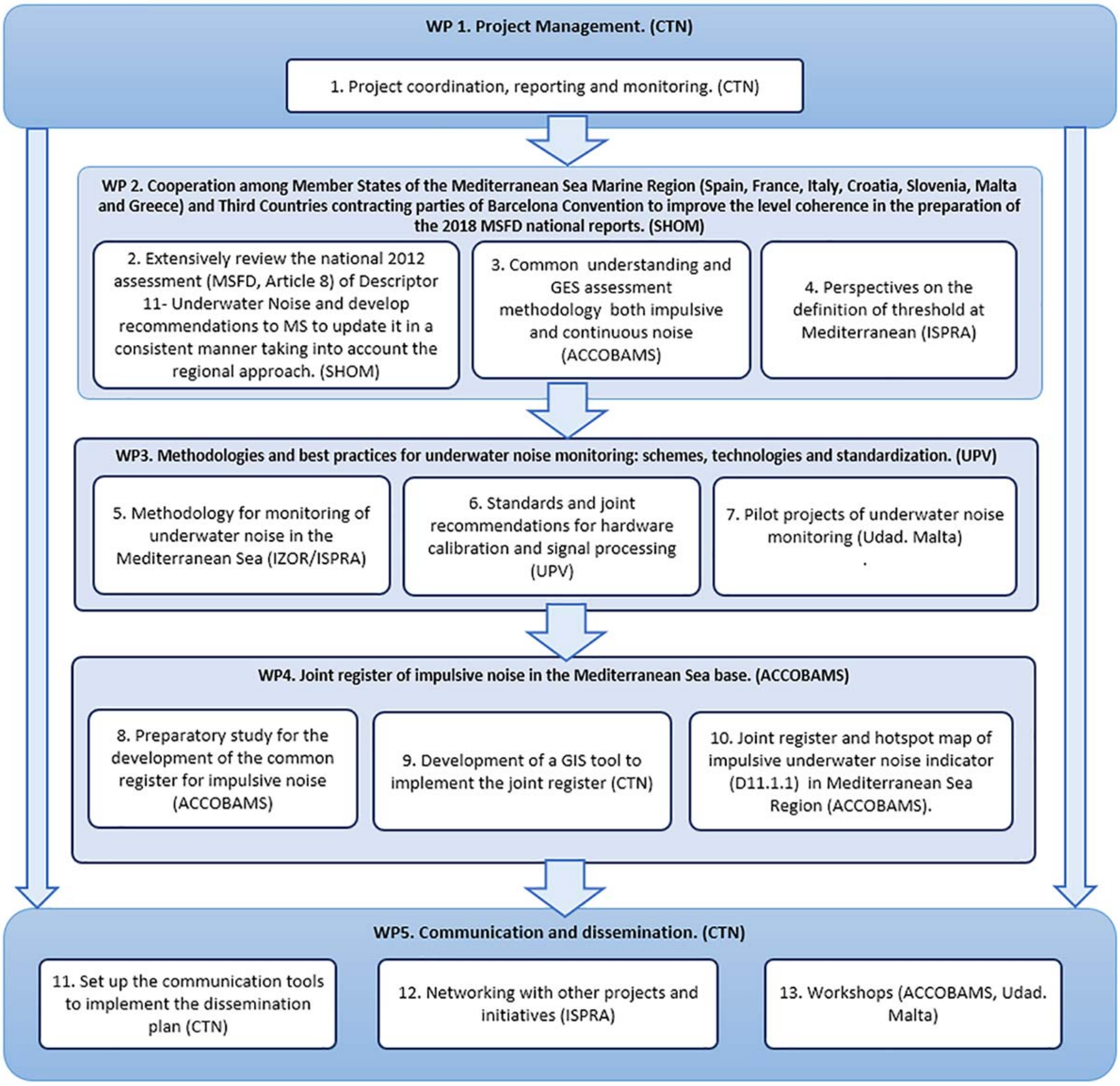


Figure 1. Work Plan Structure

The project is developed by a consortium made up of 10 entities coordinated by CTN and it has a duration of 24 months starting on January 2017.

This report illustrates the methods and procedures undertaken by the members of the QUIETMED project who are part of a pilot project for deployment of acoustic recording equipment to measure and compute the MSFD indicators for marine noise at three locations in the Mediterranean. Whereas each pilot has his own set of recording equipment, recording equipment calibration techniques, and even variety in project area where measures are undertaken, it is important that the directive's indicators are obtained and the pilot project methods adhere to a set of best practices such that the results derived from these pilots are consistently presented and comparable. This document places greater emphasis on the high level description of each pilot project and how these are indeed comparable and can effectively provide a common statement while explaining any differences at a local scale rather than differences in equipment and methods adopted at each pilot.

This document is structured with a number of sections. The next section scopes the aims and objectives of the pilot deployment in context of MSFD and QUIETMED project. Section 3 describes, justifies and compares the pilot deployment sites. In section 4 describes the array of recording equipment adopted by each pilot participant and the various calibration methods applied to each pilot rig. The latter part of this section describes associated data processing procedures required. In section 5 a description of the pilot project's preparation for deployment, actual deployment and eventual retrieval are described. Results extracted from each pilot project are given in section 6. Section 7 concludes this document.

2 Pilot projects purpose

With the adoption of the Marine Strategy Framework Directive (MSDF) for underwater noise (Descriptor 11) and implied monitoring requirements to derive output indicators by 2018, a sense of urgency is present to heighten the needs of these requirements and bridge the gap between regulation, knowledge and pragmatic implementation.

The justifications for QUIETMED to undertake three pilot projects for monitoring acoustic noise to meet the MSFD requirements for the Mediterranean Sea are:

- ✓ Considerable knowledge is now available in relating underwater noise and its impact on the marine ecosystems;
- ✓ Marked level of diversity in physical, habitat and fauna characteristics in the Mediterranean Sea;
- ✓ High level of anthropogenic sources of underwater noise in this Sea;
- ✓ Difficulties of member states to meet monitoring requirements.

The main aim of the pilot projects is to show how a marine acoustic monitoring exercise leads to establish a noise trend for each of the pilot site. This aim is reached by finding solutions to the following objectives: address knowledge gaps; increase and build complementary data profiles that are known to relate to acoustic noise; develop, adopt, and evaluate standardized methodologies for recording, processing and calibrating the acoustic recording equipment; and issue standardized and comparable data.

As it is expected that there is heterogeneity between the three pilot projects, e.g. recording equipment and site of recording, the QUIETMED pilot projects have the added objective to compare and contrast results and practices against each other.

The pilot project development and output are to be finally made available to other countries and organizations to follow suit by learning and benefitting from the pilot project effort and its results.

3 Description of the research areas

Three Mediterranean Sea areas participated in this pilot project; namely Cabrera (Spain), the Maltese Islands, and Crete (Greece) – see Figure 2. Whilst Cabrera is the western most, Crete is on the opposite end. The approximate distance, in a straight line, from Cabrera to Malta is of 1100 km east and the distance from Malta to Crete is 1000 km east.

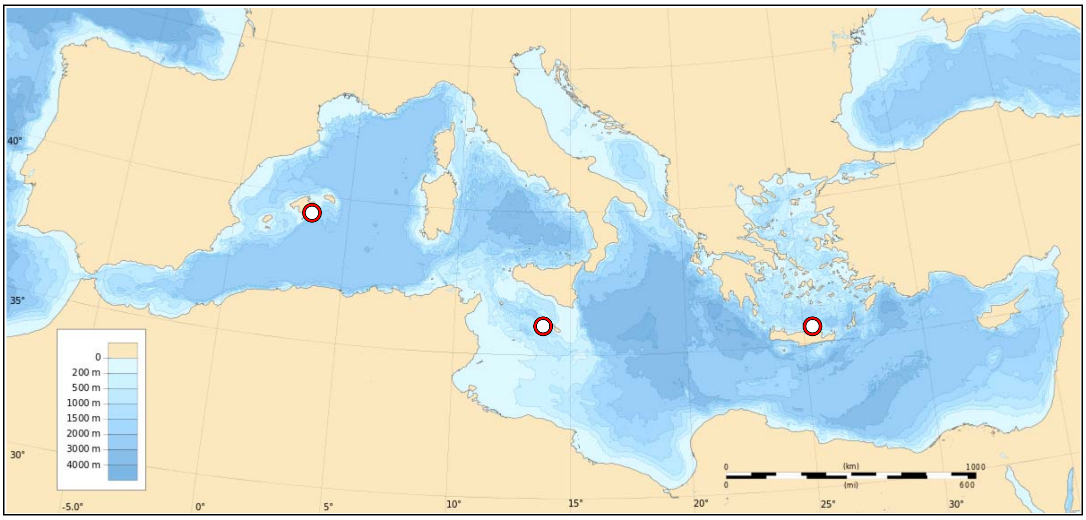


Figure 2: Pilot project across the Mediterranean Sea (Cabrera, Malta and Crete - from west to east)
https://commons.wikimedia.org/wiki/File:Mediterranean_Sea_Bathymetry_map.svg

Each of the selected pilot project areas is useful to consider best practices indicated for the adoption of the Marine Strategy Framework Directive (MSFD) for monitoring underwater noise [1] [2].

Each area is close to one or more main shipping lane (e.g. for bulk cargo and container shipping) as can be seen in Figure 3 depicting traces of shipping activities around the Mediterranean Sea. Furthermore each site is in an active intra and inter island sea based transport system; these activities are also seasonal.

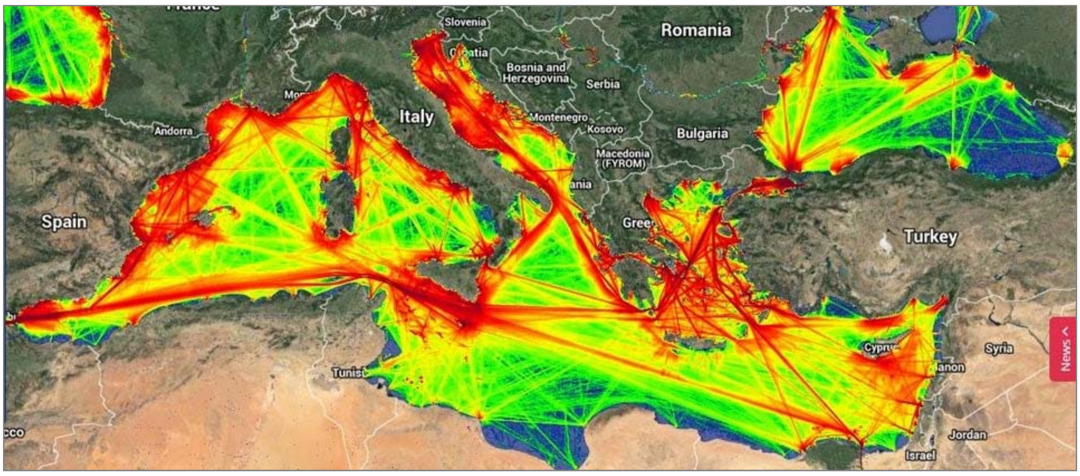


Figure 3: Shipping lines in the Med
https://www.reddit.com/r/MapPorn/comments/4lggtu/ship_traffic_in_mediterranean_1090_x_472/

On the Islands of Malta the port of Marsaxlokk (located at the south east of the main island – see Figure 6) is the main cargo port and also a significant transshipment hub for the central Mediterranean.

At Cabrera the anthropogenic pressures, such as shipping activities, from commercial fishing boats, cruises and cargo vessels (goods and passengers) are well known as the site in the Balearic Islands is an important MPA (established in 1991).

The island of Crete is also exposed to anthropogenic pressures.

3.1 Crete, Greece

Two areas for monitoring underwater noise were selected around the island of Crete: the northern site is close to the smaller island of Nisos Dia (see Figure 4) [3] [4]; whilst the southern site is near the village of Palaiohora (see Figure 5) [5]. Both sites are intended to capture ambient noise (i.e. specifically for indicator 11.2.1 on continuous low frequency sound)

The northern monitoring area is classified as both a Bird Directive Site (SPA) and Habitat Directive Site (pSCI, SCI or SAC) – vide http://natura2000.eea.europa.eu/.

The southern monitoring site is in an area, called the Thalassia Periochi Dytikis Kai Notiodytikis Kritis, which is included in the Habitat Directive Sites (pSCI, SCI or SAC) – vide http://natura2000.eea.europa.eu/. This site has three declared bird directive sites in its environs: two terrestrial sites are close by and a relatively distant marine site, 35 km south east (22 nm), called the Notiodytiki Gavdos Kai Gavdopoula reserve.

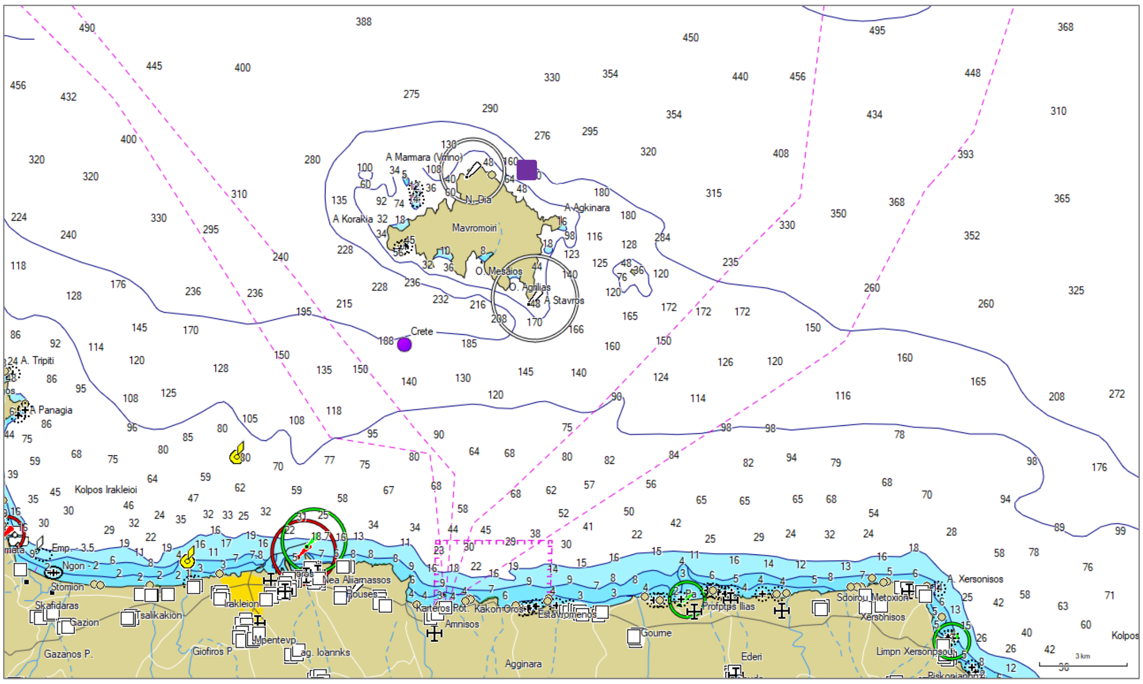


Figure 4: North Crete's Research Area
(a violet circle (North1 and North2 experiments) and a violet square (for North3 experiment) and scale is in lower right corner)
Map data: BlueChart, Garmin

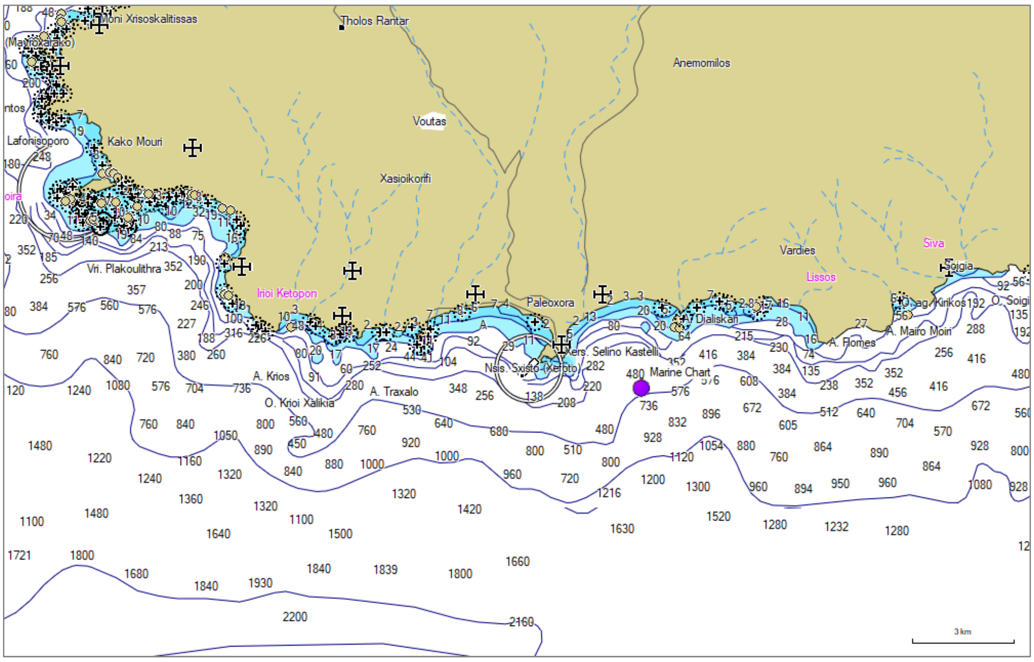


Figure 5: South Crete's Research Area (a violet circle and scale is in lower right corner)
Map data: BlueChart, Garmin

3.2 The Maltese Islands

Two sites were selected for the Maltese Islands for underwater noise monitoring. For Descriptor 11 and specifically for indicator 11.1.1 on low and mid frequency impulsive sounds the Gozo Island's northern area was chosen (see Figure 7); and specifically for indicator 11.2.1 on continuous low frequency sound (ambient noise) the Maltese island's southern area was chosen (see Figure 6).

Both of the Maltese areas have a predominantly silt seabed, with the southern area having some spread rocks. (This data was extracted from Transport Malta's Mapping Unit).

The southern area is close to a Marine Protected Area (Marine Zone in the environs of Ghar Lapsi and Filfla – Habitat Directive Sites (pSCI, SCI or SAC)) and within a Bird Directive Site (SPA) named South West. The island of Filfa and its reefs are protected by law. The northern area is close to a Marine Protected Area (Marine Zone stretches from Zebbug (Gozo) to Qawra (Malta) – Habitat Directive Sites (pSCI, SCI or SAC)) and within a Bird Directive Site (SPA) named Gozo Seas. Vide http://natura2000.eea.europa.eu/. The islet of Filfla, and its immediate surrounding sea, has been a protected bird reserve by law since 1980.

Relative permits, for example from the planning and environmental authorities, have been obtained and notifications of deployment to port authorities have been arranged prior to the start of deployments.

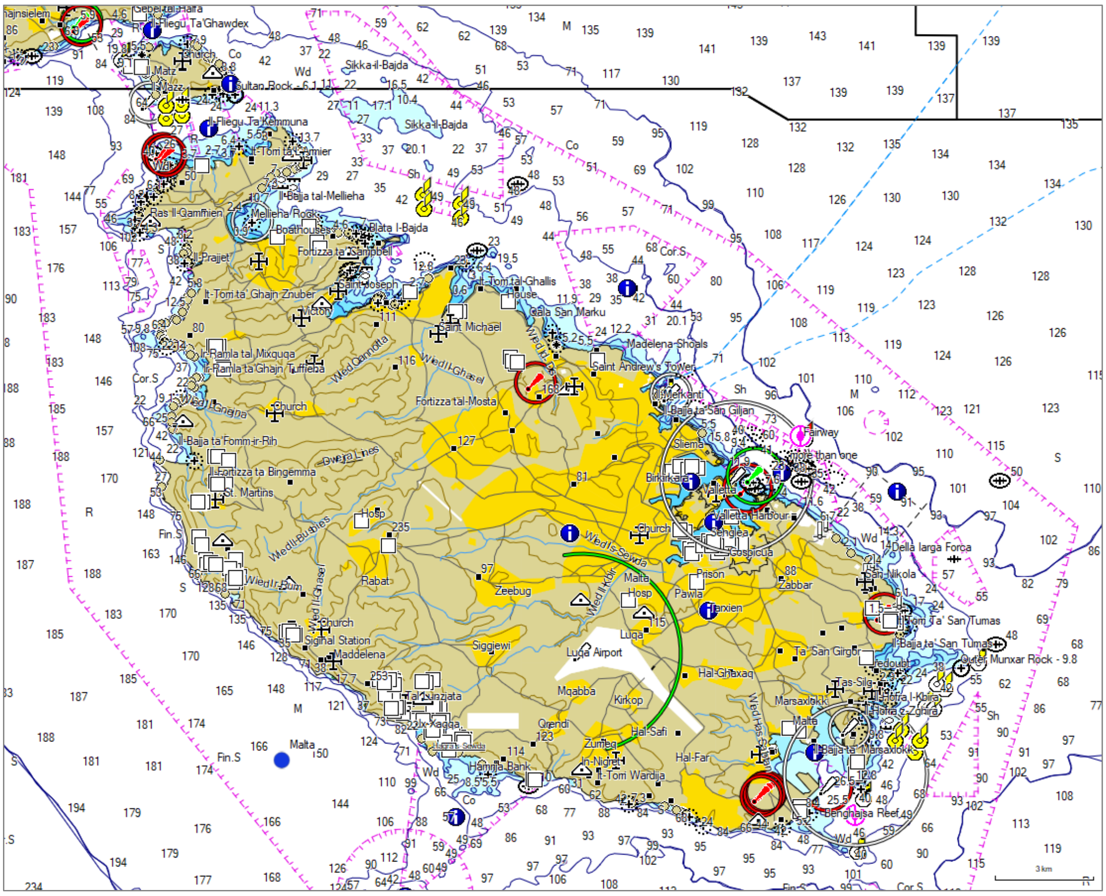


Figure 6: Maltese Island Southern Research Area (blue circle and scale is in lower right corner)

Map data: BlueChart, Garmin

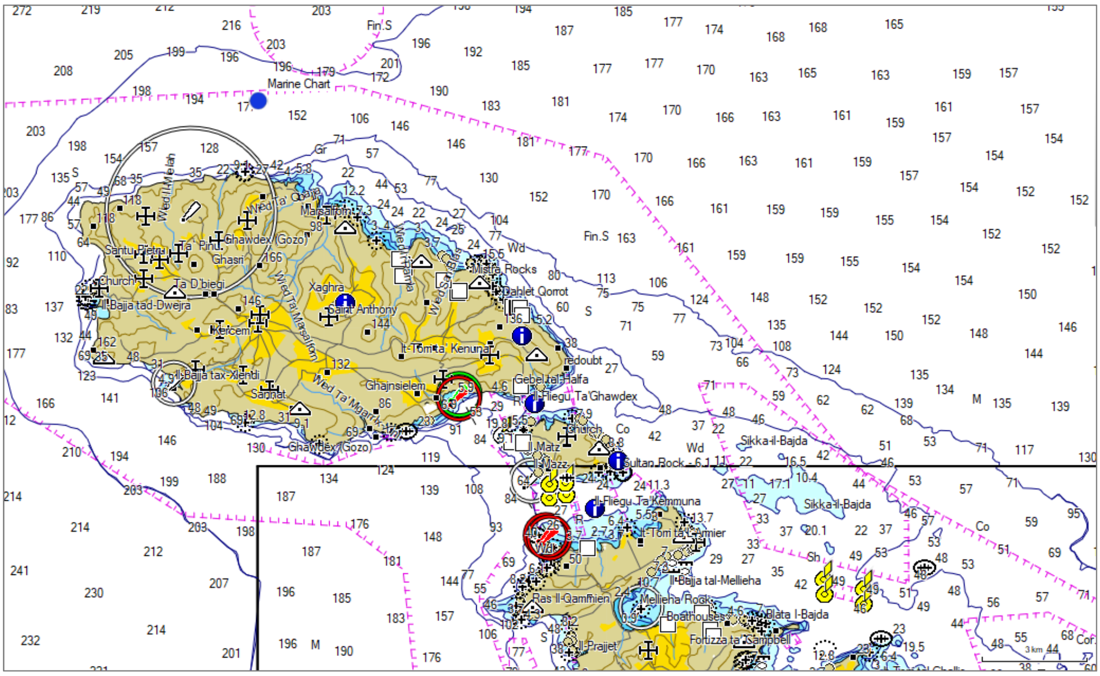


Figure 7: Maltese Island Northern Research Area (blue circle and scale is in lower right corner)

Map data: BlueChart, Garmin

3.3 Cabrera, Spain

Both the island of Cabrera and the surrounding sea are classified as a Bird Directive Site (SPA) and a Habitat Directive Site (pSCI, SCI or SAC) – vide http://natura2000.eea.europa.eu/. The MPA was established in 1991 with an area of 100.21 km^2, of which 87.03 km^2 is maritime and comprises 19 small islands. Anchorage and navigation are not allowed in most places, and the low degree of human activity ensures the evolution of species in a natural and pristine environment [6].

The area for monitoring underwater noise was selected off the island of Cabrera (see Figure 8). The site is to capture Category A monitoring requirements. The exact deployment site is within the MPA itself, have an acceptable distance from a shipping lane, and whose bottom is of soft material [7].

Relative permits have been obtained and notifications of deployment to port authorities have been arranged prior to the start of deployments.

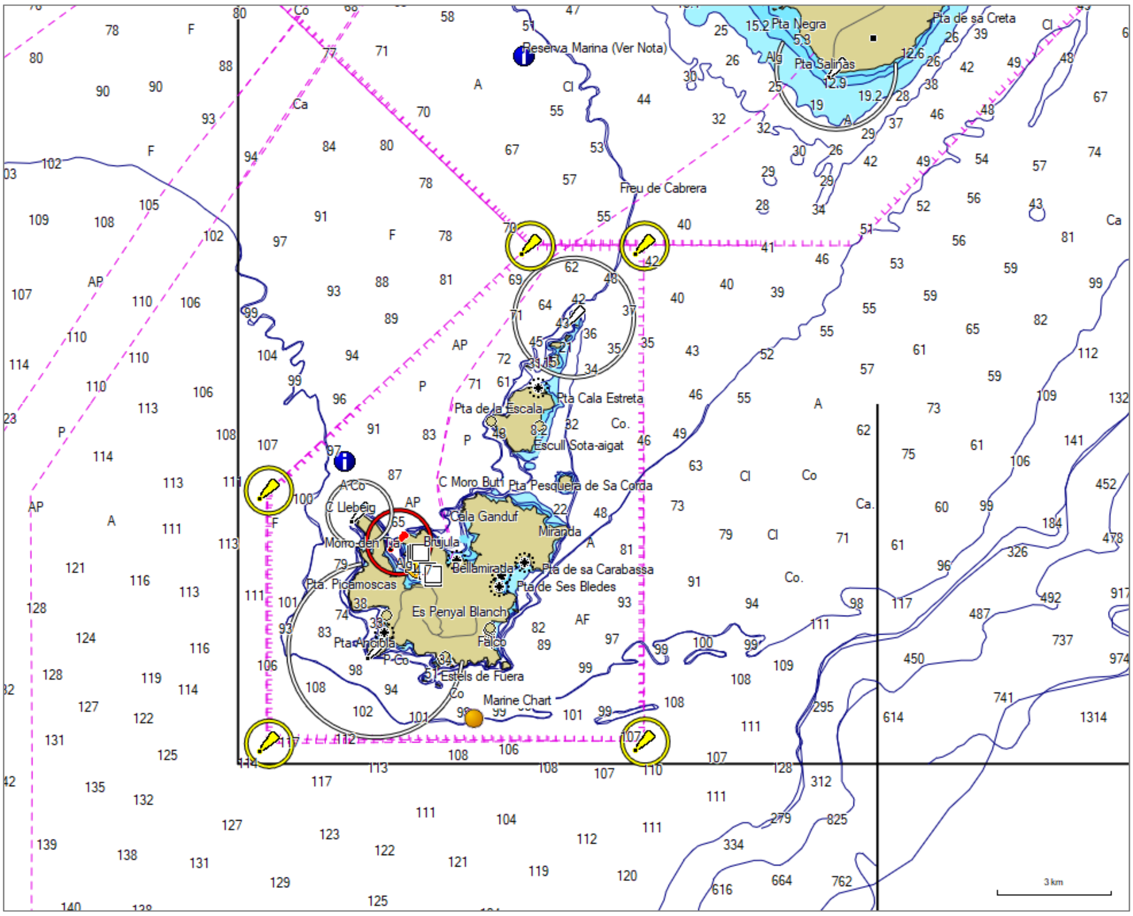


Figure 8: Cabrera Research Area depicted (orange circle and scale is in lower right corner)

Map data: BlueChart, Garmin

3.4 Research Areas Comparison

Table 1 and Table 2 give an overview of each site and their noise monitoring requirements respectively.

Table 1: Comparative physical features of pilot sites

	Cabrera	Malta South	Malta North	Crete South	Crete North
Depth (m)	100	155	155	500	190
Distance to closest Shore (nm)	1.0	1.7	1.1	1.1	1.5
Distance to Closest Port (nm)	5	12	10	2	4
Bottom substrate / sediments	Silt	Silt and some rocks	Silt	Sand	Sand

Table 2: Site and monitoring category cross tabulation

	Cabrera	Malta South	Malta North	Crete South	Crete North
Category A Monitoring (low and impulsive sound)	Yes		Yes		
Category B Monitoring (ambient noise)		Yes		Yes	Yes

4 Equipment and Technical specifications

To meet the acoustic monitoring requirement's outputs a set of equipment for recording underwater sound is required in order to capture sounds and convert them to data files. The aim of this set of equipment is to capture underwater sound in a reliable, resilient (to the natural elements), with minimal addition of noise during its working deployment. The collected data is recorded from calibrated instruments to enable absolute computations of indicators required for the monitoring. Consequently, another set of equipment is required to calibrate the recording equipment's components and as a whole in a variety of conditions that cover an actual deployment at sea; the deployed equipment have to meet the criteria recommended in the MSFD.

In the QUIETMED pilot Projects, a wide variety of equipment is utilized. For each site, the recording equipment is based on the following systems, specifically (see Figure 9):

- Samaruc for Cabrera (http://samaruc.webs.upv.es) [7] [8];
- RTSYS for the Maltese Islands (https://rtsys.eu/en/underwater-acoustic-recorders/);
- FORTH's PAM device for Crete, Greece [3].

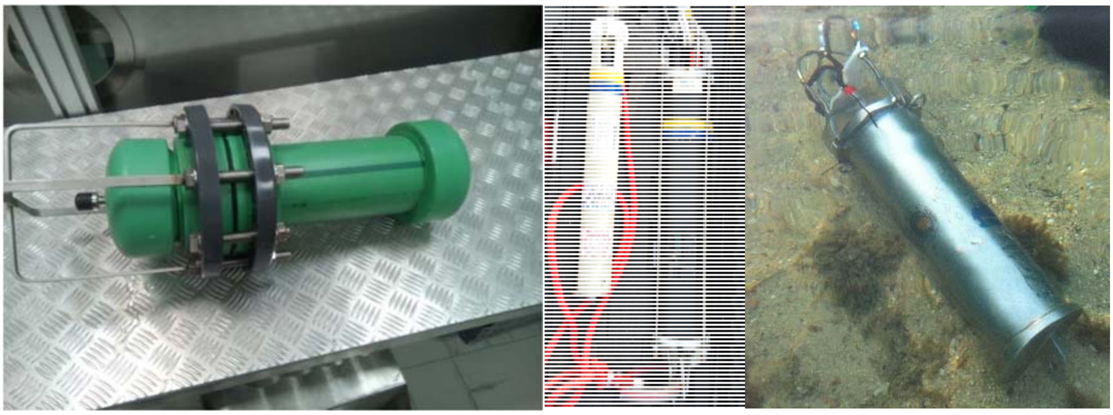


Figure 9: The recording devices (from left): UL1, RTSys and SAMARUC.

4.1 Recording Equipment

A comparison of the equipment is provided in Table 3. Some entries indicate the values set at each pilot rather than the range each respective device provides.

Table 3: Summary of acoustic monitoring equipment choices and characteristics by system

	SAMARUC	RTSys SDA14	FORTH UL1
Pilot	Cabrera	Maltese Islands	Crete
Supplier	Custom, UPV (iTEAM)	RTSys	Custom, IACM-FORTH
Control	Offline while recording	Offline while recording	Offline while recording
Hydrophone	C57 – note 1	HTI 99 HF – note 2	H2C – note 3
System Frequency Range	20Hz - 192kHz	2Hz - 125kHz	20Hz - 48kHz
Hydrophone frequency range and sensitivity	15Hz - 45kHz (+/- 3dB)	10Hz - 100kHz (+/- 4dB 20Hz - 4kHz)	10Hz - 100kHz (+/- 3dB 20Hz - 4kHz)
Recording Method	Programmed and Continuous	Programmed and Continuous	Programmed and Continuous
Data file type	Wave (.wav) file	Wave (.wav) file	Wave (.wav) file
Sampling frequency used (kHz, bit)	24, 16	39, 16	96, 24
Max Deployment Depth of system (m)	1000	250	70
Actual Deployment Depth of system (m)	100	155	30, 50 & 70
Power type	Internal Battery	External and Internal battery	Internal Battery
Power supply autonomy	1 month with project duty cycle	3 to 4 weeks with project duty cycle	1 to 3 weeks with project duty cycle
Storage	SD Card	SD Card	SD Card
Release Mechanism (from anchor)	Independent unit required	Independent unit required	N/A
Rig	Anchor at bottom and vertical rig	a) Anchor at bottom and vertical rig (actual); b) Anchor at bottom and vertical circular rig to attach recording & hydrophone (tested).	a) Surface towed with weight b) Rig attached to a surface buoy and secured with a weight released to the bottom.
Other equipment		Recovery beacon with satellite communication.	GPS (later with a GSM connection), Temperature and

	depth meters

Notes to Table 3:

1) https://www.cetaceanresearch.com/hydrophones/c57-hydrophone/index.html

2) http://www.aquarianaudio.com/AqAudDocs/H2c_manual.pdf

3) http://www.hightechincusa.com/products/hydrophones/hti99hf.html

4.2 Equipment Rig and Assembly

Supporting the recording unit are a number of components and a harness, or rig, which acts as the backbone during deployment. The rig needs to protect the equipment, add little to the sound capture (i.e. silent as possible – see following subsection), and addresses electrical isolation through its units (e.g. galvanometric discharges – see following subsection). Supplementary data collectors, e.g. temperature and depth measures as in the Crete pilot project rig, are attached to the rig too. The structure of the rig is also influenced by the deployment method and in our pilot projects we have adopted two: namely bottom anchored with rig pulled straight and up by floatation devices as in Cabrera (UPV) and Maltese Islands (UM) pilots (see Figure 10 and Figure 17 for the rigs used in pilot runs and from which results are presented here); and a rig attached to a surface floating buoy with a weight to pull recorder down (see Figure 11) as in the Greek pilot. In the case of the Greek deployment, FORTH and IACM use another rig to hold most of the sound calibration equipment for calibrating system at deployment site (i.e. in sea water) – their rig is tied to a large boat and a surface buoy holds the rig which is pulled straight down by a weight (see Figure 11). This kind of deployments was used during the first two pilot experiments (North1 and North2). In a later deployment, in southern Crete (South1), FORTH adapted a rig to be anchored on the sea bed with a 700m roped anchor. Another line, tied to a naturally buoyant float, held the recording equipment at 70m and 150m of depth below sea level (see Figure 12). This was also used during the third shallow water experiment (North3)

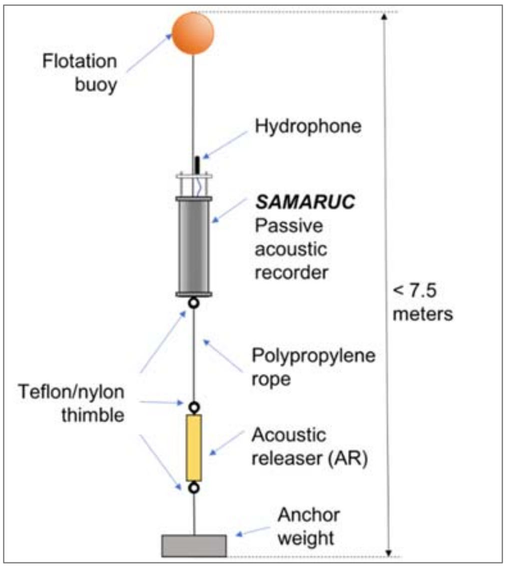


Figure 10: UPV's rig at bottom stretched up by buoy

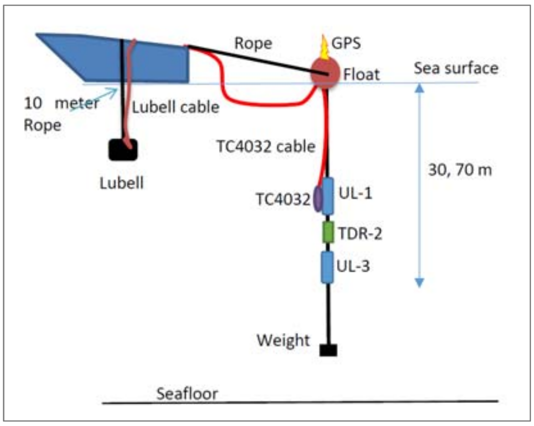


Figure 11: FORTH's rig attached to a surface float and secured to a boat (North1 and North2)

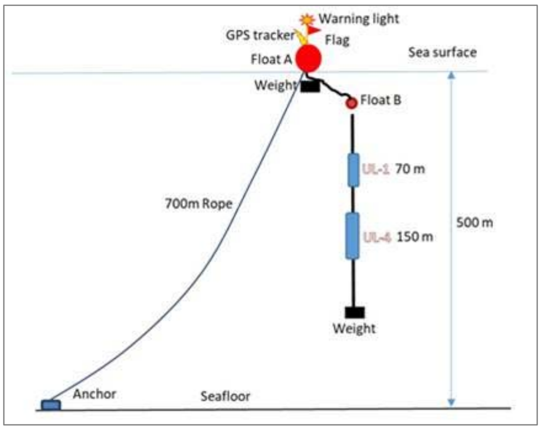


Figure 12: FORTH's rig attached to a bottom anchor and suspended down from a surface buoy (South1 and North3)

Another type of harness used, in a test run of the Maltese Islands pilot project, had the recording unit, hydrophone and retrieval beacon assembled on a circular platform with attached buoys (see Figure 13). From the test run data files retrieved and examined, marginal indications of sound echoing and occultation suggest that this rig requires modifications to address these; namely have the hydrophone at a longer distance from the platform. None the less the actual pilot run in Malta opted for a rig similar to Cabrera and diagrammatically explained in Figure 17.

Figure 13: UM's circular rig attached with floaters (used in a test run)

Avoiding undesired noises due to metal-metal contact and rope friction

It is important to reduce any undesired noise coming from the different elements of the deployment. For this purpose, it is important to avoid metal-metal contact of the different elements (shackles and recording device for instance). Metal-metal contact should also be avoided due to the fact of the different metal compositions and possible galvanic corrosion that might endanger the integrity of the deployment. For these two reasons, in the QUIETMED project we have employed plastic sheaths strategically placed to avoid metal-metal contact and friction noise.

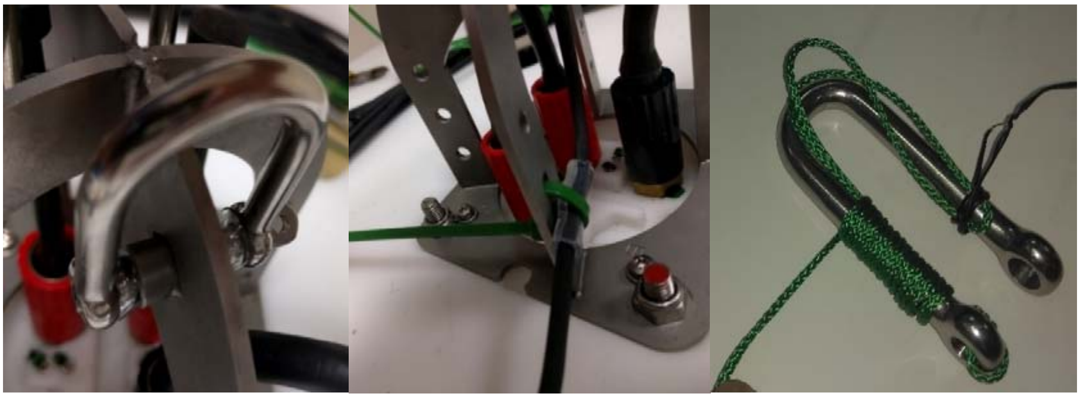


Figure 14: Insulation, protection and noise reduction methods employed during assembly
Detail of the transparent plastic (left) on the shackle pin used to separate metals, and fixing the hydrophone cable to the metal plate by using a plastic sheath to reduce the cable's chafing (centre), and whipping twine string over metal to reduce metal on metal clunking noise (right)

This same plastic sheath was used to fix the cable of the hydrophone to the metal plate, thus avoiding the friction between them (see Figure 14). We also employed self-amalgamating tape or whipping twine to cover metal elements to avoid undesired noises (see also Figure 16).

Figure 15: Knots, knot security, and loop protection
Detail of the knot to be made at the end of a rope to produce a loop (left) with three recommended cable ties, shown in green, and detail of the plastic hose to protect rope and reduce noise

As regards the knots, we employed bowline knots, with plastic cable ties placed as shown in Figure 15 for greater security. A transparent plastic hose cover was used in some places to prevent contact and friction with the shackles and metal plates. Another useful knot, if stranded rope is employed, is splicing stranded rope and employing tie clips over the splicing.

Another crucial part to be checked to avoid undesired noise is the hydrophone's position. Hydrophones must be placed in vertical position away from any element that might produce undesired echoes and suspended so that any stretching from the ropes that connect the acoustic recorder to the flotation buoys is minimized. For this purpose we employed rubber rings that act both as mechanical clamping and vibration reducers for the hydrophone (see Figure 17).

Figure 16: Securing components of the rig
Detail of the upper part of the acoustic releaser, with flanges on the sides of the shackle View of shackle and plastic pipe with the rope (left), and detail of the plastic pipe covering the screws (right)

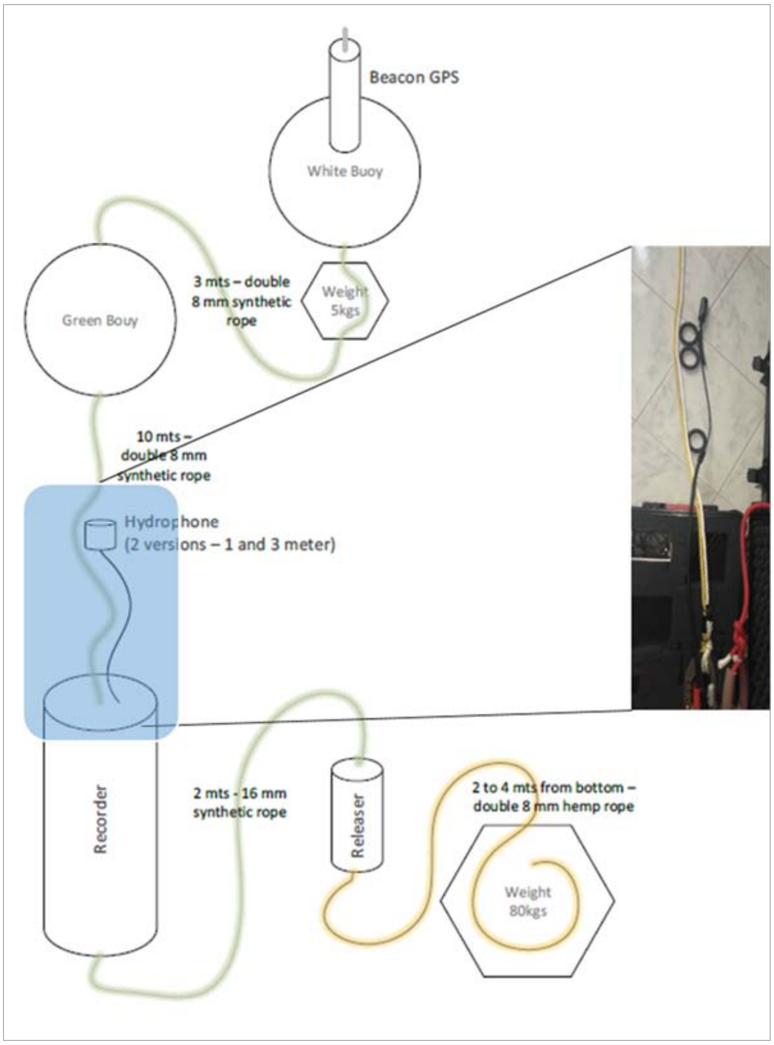


Figure 17: Drawing of the Malta Pilot Project deployment rig
Detail of the rubber rings used to suspend the hydrophone in insert

Avoiding undesired Galvanometric discharges

Electrical devices, even battery powered ones, which are deployed in sea water need to be protected from corrosive action on its metal components initiated by electrical consumption and the presence of other metals in and around them during their submerged state. It is best to insulate metal parts from direct contact and even connect sacrificial anodes to each device, for example well scarped zinc anodes, as this offers protection to the devices' metals during their submerged period. For each of the Maltese rigs, two devices were fitted with sacrificial anodes; i.e. the RTSys recorder (see Figure 18) and the GPS Beacon.

It is also recommended that part of post deployment activity checks for corrosive activities and addresses any visible signs of. Furthermore sacrificial anodes only work when submerged in water.

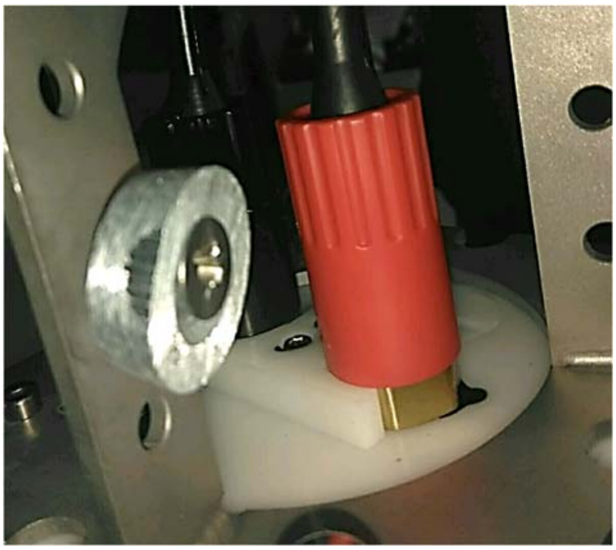


Figure 18: Sacrificial anode connected to the recording unit

Checking the buoyancy of the deployment system

Once the complete rig is set up, one needs to check its buoyancy by testing with anchor and without anchor in a water tank. Due to the fact that it is not easy to find a water tank deep enough to test the complete system as it will lay on the seabed, we employed short ropes for connecting everything as close as possible during the buoyancy tests. The photo in Figure 19 (left) shows how all the elements remain underwater when tied to the anchoring weights (biodegradable jute sacks holding pebbles as used in the Malta deployment), whereas the photo in Figure 19 (right) show how once the system is released from its anchor all the elements float on the surface.

It should be noted that all the rig's components, for example the recording equipment and the flotation elements, must withstand the water pressure at the depth of the deployment. Ideally all components are to be tested in situ and individually so as not to compromise a rig's retrieval or loss of data capture from a run.

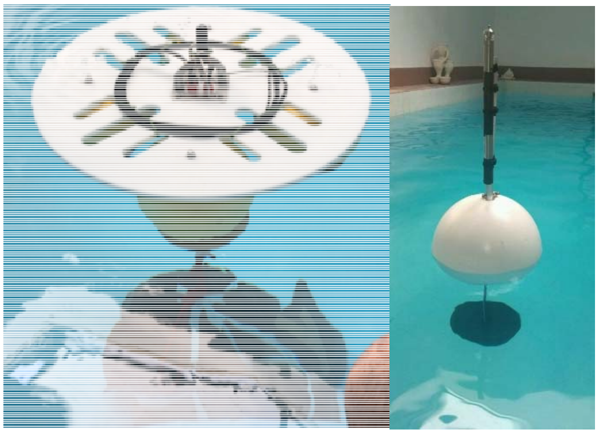


Figure 19: Buoyancy Test of rig in a pool
Rig in a pool with the jute bags attached (left), and positive buoyancy test of the rig (right)

4.3 Recording Equipment Calibration

Various acoustic sound monitoring methodologies, as well as documented justification, insist that a hydrophone and its monitoring system must have an ad hoc calibration curve for the system's sensitivity at least over the lower frequency range. Furthermore MSFD demands additional requirements to standard best practices for calibration for monitoring underwater noise: specifically checking the suitability of the systems signal to noise ratio for target indicators; and avoid clipping and nonlinearity for high amplitude signals. The QUIETMED partner UPV have the air and water (i.e. tank) based calibration equipment [2]. The QUITEMED partner CTN have an air and water (i.e. tank) based calibration lab too. FORTH, another QUIETMED partner, have equipment capable to determine their recording unit sensitivity at their labs (for air) and at sea [9] [3].

The calibration procedure is divided into two different stages. In the first stage, each system is calibrated in the frequency range of 5 kHz – 50 kHz. A second stage consists in the calibration of a system in the frequency range of 50 – 3150 Hz. The calibration is based on a reference microphone for air and a reference hydrophone for water.

The FORTH team uses the following components for their air and sea water calibration (see Figure 20 and reference [9]):

- Reson TC4032 as a reference hydrophone;
- Voltage amplifier EC6081;
- Acquisition card USB 9215A, NI;
- Board band underwater sound source Ludell LL9162T; and
- Continuous signal generator BK-Precision 3003.

Figure 20: FORTH's Lubell source prior to use (left) and the signal generator & amplifier (right)

UPV have a 10x5x1.5 m^3 water tank (Figure 21) and anechoic chamber (Figure 23) to conduct the water and air calibrations [2]. The UPV team uses the following components for their air and water calibration respectively (see Figure 22 and Figure 23):

- Personal computer as a Signal generator;
- Red Pitaya data capture board;
- A sound level meter Brüel & Kjær 4189;
- A dodecahedron sound source (12-speaker omnidirectional OmniPower TM Type 4292-L).
- Brüel & Kjær 8103D as a reference hydrophone.

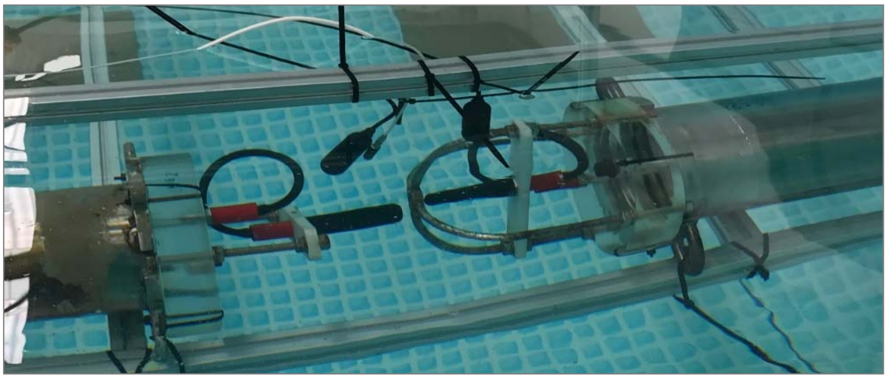


Figure 21: UPV's tank showing placement of PAM devices and referenced device for calibration

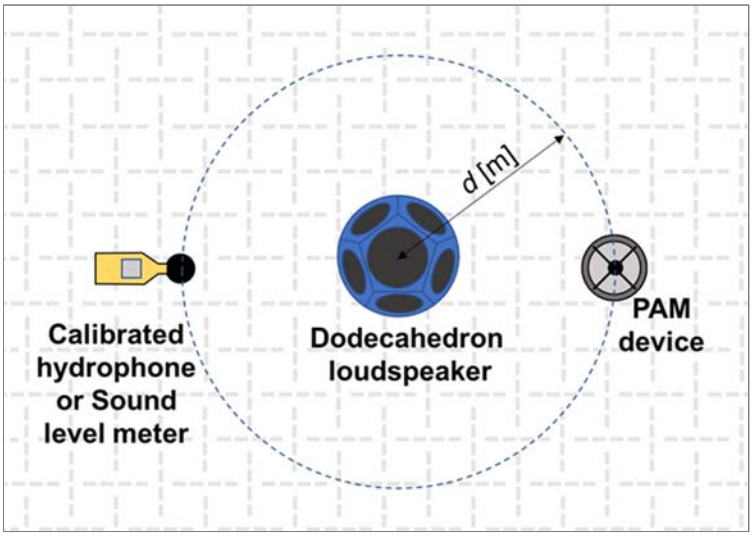


Figure 22: Layout of the elements for the self-noise calibration in an anechoic chamber

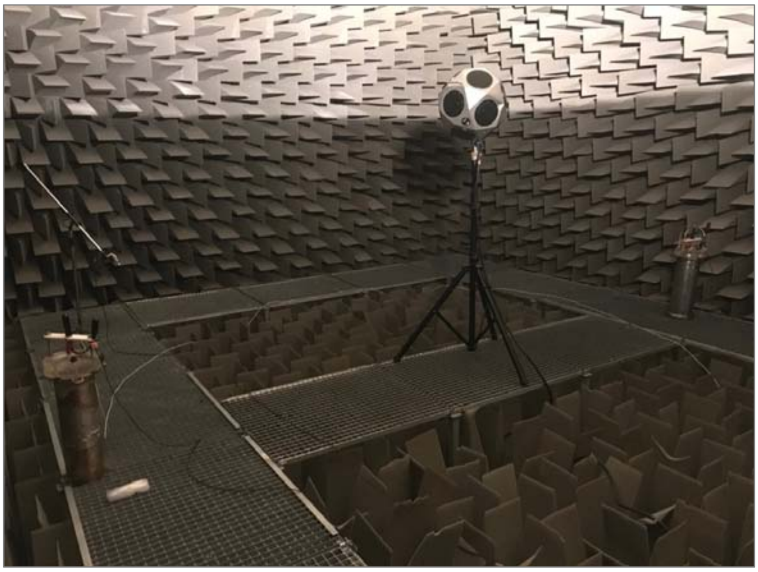


Figure 23: UPV's anechoic chamber layout for simultaneous calibration of 2 PAM devices

CTN has a tronco-conical tank (see Figure 24 and Figure 25) and its shape is designed to delay the first early reflections so that the echo-free time window when acoustic measurements are carried out is lengthened, which leads to the possibility of having a more stable sound and being able to work with lower frequencies stimuli which have to be fitted into the echo-free time window. The tank has a 10 m depth and is able to calibrate two hydrophones concurrently in the frequency range of 0.01 Hz to 1 MHz following the IEC 60565 standard. The CTN team uses the following components for their air and water calibration respectively:

- Sound Card EMU Tracker;
- Brüel & Kjær Nexus Sound Amplifier;
- Sound Power Amplifier Wadia A-340;
- Pistonphone G.R.A.S. 42AA Class 1;
- Brüel & Kjær 4189 reference microphone;
- Brüel & Kjær Sound Calibrator 4231

- Omnidirectional 12-speaker – OmniPowerTM Type 4292-L.

- National Instruments Data Acquisition Chasis (PXle-1073) and multi I/O cards (PXle-6124);
- Brüel & Kjær 8103D as a reference hydrophone;
- Reson EC60-70 Sound Amplifier;
- Electronics and Innovation 1040L Radio Frequency and Ultrasonic Power Amplifier;
- Pistonphone G.R.A.S. 42AA Class 1;
- Reson TC4033 Reference Hydrophone;
- Reson TC4040 Projector.

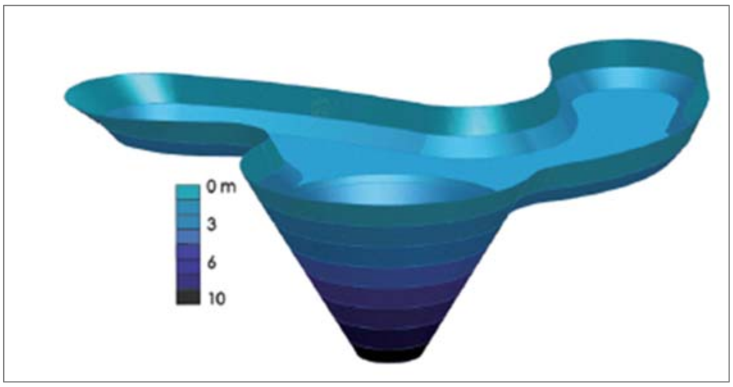


Figure 24: 3D model of the tronco-conical tank facility at CTN (to scale)

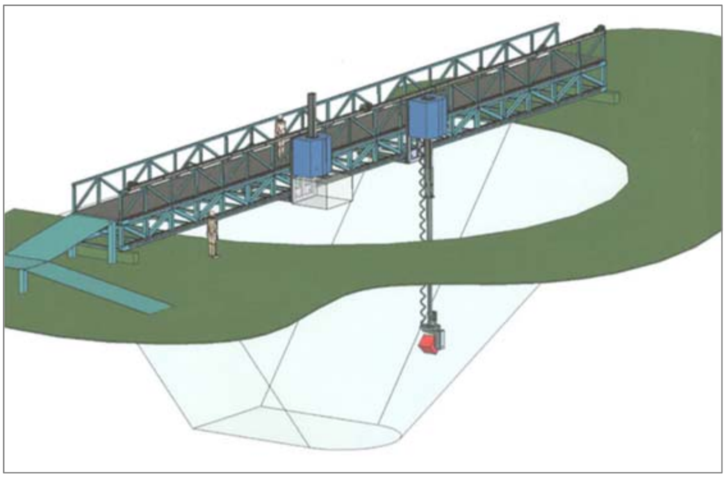


Figure 25: 3D model of the tronco-conical tank with rig showing one system under test at CTN

In table 4 one finds the techniques and settings used for the ad hoc calibration of hydrophones and respective systems used by the three of QUIETMED partners undertaking calibration.

Table 4: Summary of acoustic monitoring equipment calibration characteristics by test center

	FORTH	UPV	CTN
Equipment Tested	UL1	SAMARUC RTSys	SAMARUC RTSys
Associated pilot sites	Crete	Cabrera, & Maltese Islands	Cabrera, & Maltese Islands
Scope of testing	Sensitivity at low frequencies	Sensitivity at low frequencies	Sensitivity at low frequencies
Main premise to check	Flat sensitivity at stated scope	Flat sensitivity at stated scope	Flat sensitivity at stated scope
Main method	Comparative to reference equipment and various combinations of frequency, amplitude and distances	Comparative to reference equipment and various combinations of frequency, amplitude and distances	Comparative to reference equipment and various combinations of frequency, amplitude and distances
Ambient	Air, water tank, and sea water	Air and water tank	Air and water tank
Unit Testing (e.g. hydrophone)	Yes	Yes	Yes
Aggregate Testing (PAM and hydrophone)	Yes	Yes	Yes
Air: Test frequency range and steps	50 – 700 Hz, x13	50 – 3150 Hz, x17	40 – 2000 Hz, varying
Water/sea: Test frequency range and steps	200 – 1000 Hz, x5 or x7	2kHZ – 10kHz, varying	24 kHz – 39 kHz, varying
High pass filter employed?			
Low pass filter employed?			
Hydrophone stated sensitivity (dB re 1V/ µPa)	- 180 +/- 3 dB	-187	-165
Hydrophone computed sensitivity (dB re 1V/µPa)	- 183	-187	-165
System stated sensitivity (dB re 1V/µPa)	- 140, -145, -155 -160	-167	-155

Calibration Results for Crete, Greece

Calibration sheets for FORTH's system are found in Figure 26 and Figure 27. The calibration modality, given that additions to each system were made at each deployment, is repeated on each deployment. For example, Figure 26 shows sensitivity for the North1 run (reported in [3]). In [9] FORTH show that the system's other components sensitivity is flat in the audio spectrum. Each sea bound calibrations is supplemented with sea water temperature gradient taken at the vicinity of the site of calibration (see forthcoming section 6.1).

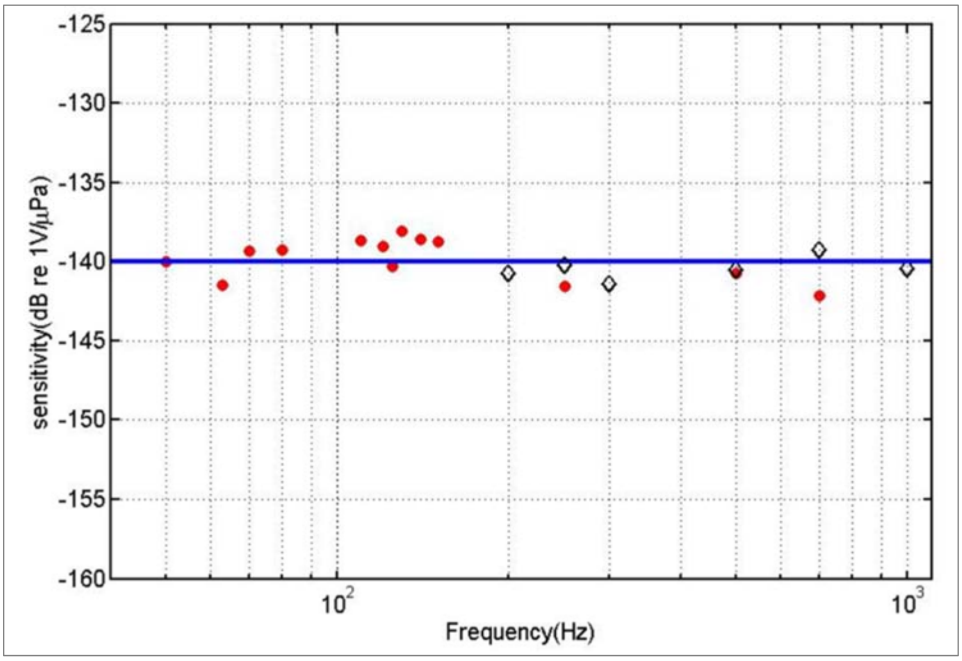


Figure 26: Sensitivity of FORTH UL1 in air (red), in sea (black) and average (blue) reported in [9]

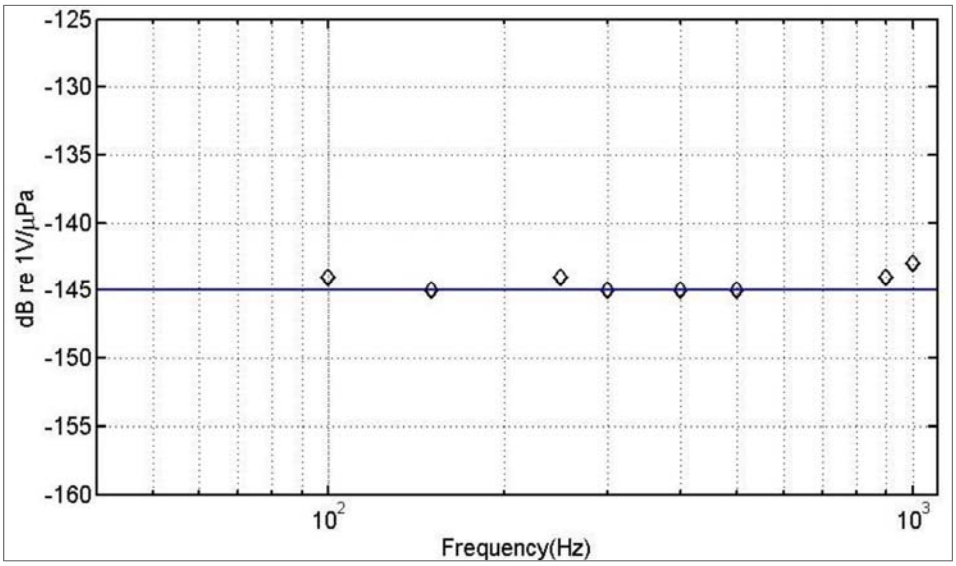


Figure 27: Sensitivity of FORTH UL1 during the north 2 run [4]

Calibration Results for the Maltese Islands

In Figure 28 one finds the calibration sheet produced by CTN for RTSys recorders deployed in the Maltese islands. A similar exercise by UPV produces calibration curves reconcilable with CTN's.

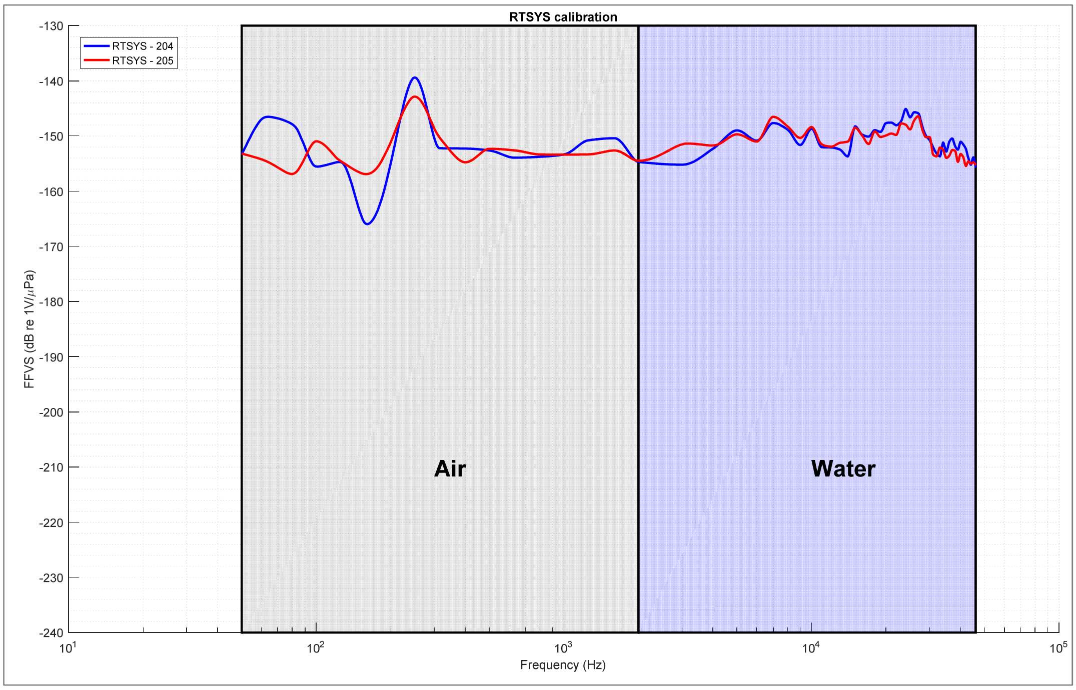


Figure 28: Calibration sheet for RTSys systems used in the Maltese Islands (computation by CTN)

Calibration Results for Cabrera, Spain

The characteristics of the Cabrera sensitivity are provided in Figure 29. For more details refer to relative report in another QUIETMED work package (i.e. D3.1).

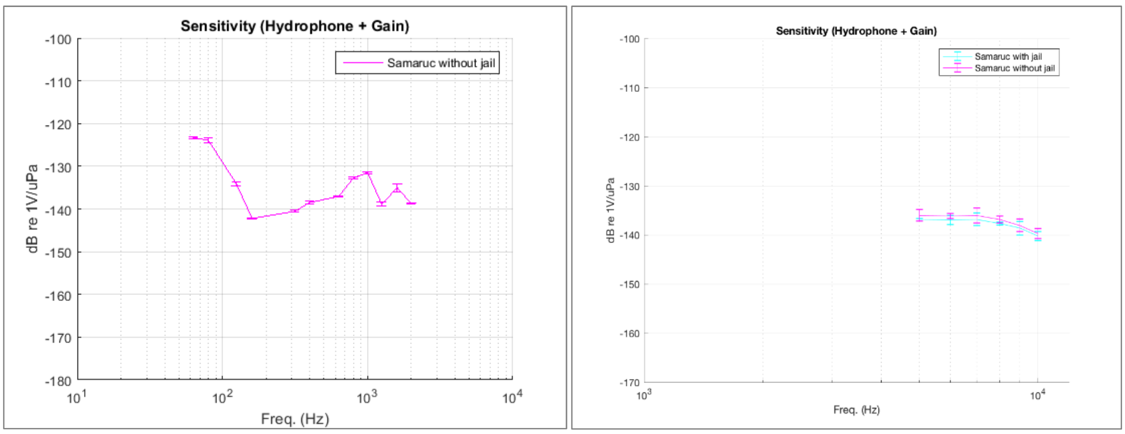


Figure 29: Air and water calibration sheet for SAMARUC system used in Cabrera (computations by UPV)

4.4 Data processing procedures

After the recording equipment is retrieved and raw audio files are extracted then the principle aim of establishing a baseline level and compute the MSFD noise level indicators can start. Generally, there are four phases to follow:

- ✓ Data back-up process (of batch, online and streaming data);
- ✓ Pre-processing the raw data sets,
- ✓ Processing of the available data to extract indicators, and
- ✓ Evaluation and dissemination of the results.

Depending on the data source and its related extraction a data back-up process needs to be in place. Data sources can be on-line (pull data from a data source through an API – e.g. weather data from openweather web-site), streaming (data is broadcast by the data server at will and the consumer needs to capture it and store it – e.g. AIS data transmission), and batch from an off-line source (e.g. our acoustic data recorders). Ideally a three level back-up, also known as 3-2-1 back-up, is undertaken – i.e. two copies local and the third off site.

The later three steps are largely sequential but it is sometimes required to restart the process when a new indicator or measure is required.

During the pre-process the audio files need to be checked for consistency and quality. Furthermore, any other data collected, e.g. weather and AIS, is read in and integrated. An important aspect of pre-processing is cleaning the data. In the case of the audio files a good example of cleaning is the searching for detecting any clipping (see Figure 30). Another example of cleaning is establishing if there is any missing data, e.g. in AIS streaming, and determining if any interpolation is necessary. Yet another technique implemented in this phase is transforming and possibly indexing the data; this is done to allow and facilitate the computational processes required in the following phases. (For example, prepare and encode audio data to be used by a deep learning algorithm for proposing better noise level occurrence models).

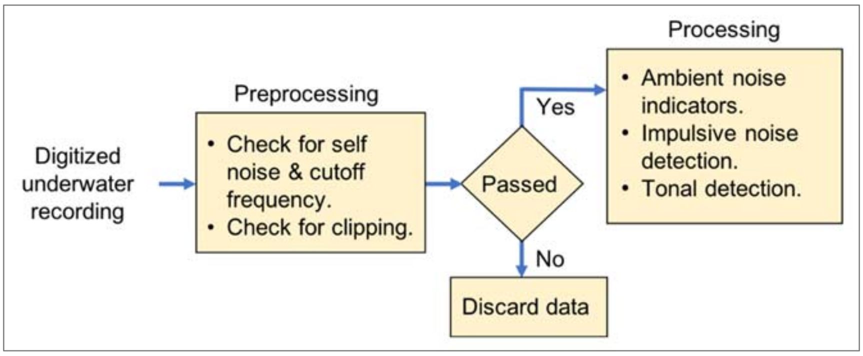


Figure 30: Pre-processing and extraction of noise indicators from audio data files [10]

The next phase is processing the available data to compute the MSFD indicators [10]. It is ideal to start with an exploratory overview of the datasets – e.g. processed acoustic data and the corresponding shipping activities reports. Also basic data on the number of files, dates and summarized values from the data files are tabulated.

An important part of this process is to compute details on the audio files available for determining basic noise indications: this is through sound pressure levels (SPL). Table 5 lists the basic indicators by frequency and scope. Since this is a multi-variate extraction it is common to represent it in various graphs:

- ✓ SPL for various octave bands (e.g. 63, 125, 2000 and 5000 Hz) versus time;
- ✓ SPL level histograms for an octave band (one of e.g. 63, 125, 2000 and 5000 Hz);
- ✓ SPL density (average or range) versus frequency for a point in time.

At this point, it is also possible to extract details of tonal and impulsive events if additional bandwidth is present in the acoustic data collected from the pilot project. An effective method, from [11], is based on first computing the SPL per frequency per time and the amplitude per time and secondly taking ratios of the former two and search for any ratio that is higher or lower than a user given dB level (e.g. 3dB). The higher may denote impulsive noise and the lower may denote tonal episodes. Miralles [11] and Best Practice for Signal Processing [10] give indications of how to evaluate these findings.

Table 5: Summary of noise indicators

Frequency Range	Remark
63 Hz	Ambient noise indicator
125 Hz	Ambient noise indicator
2 kHZ	Ambient noise peaks
5 kHz	Ambient noise peaks
Variable, low and over time	Tonal noise episodes
Variable, high and over a short interval	Impulsive noise episodes

The last process has particular characteristics as it can have a greater variety from one run to another and from one partner and site to another. The results extracted during the processing needs to be evaluated. This evaluation, in the case of the QUIETMED project, is at two levels: the first and obvious is per research area; whilst the second is a comparison between the three pilot sites. Furthermore, in Miralles' [11], it is being recommended that data from each research area is forwarded to the other partners for them to compute and compare the indicators; this is being called the Round Robin tests. This evaluation ensures that our computation of indicators are comparable too.

Given that the datasets have relatively long runs and the number of data variables are a few, the presentation and assimilation of results is a known challenge. To address this, state of the art visualizations are used.

Overall techniques, that are useful in these data intensive areas with a large number of raw and processed data files, include: Hashing each file, e.g. by using an MD5 function that uniquely keys each file, to identifying data files that are no longer a bit image of the original. For example it is easy to identify a raw data file from its clean equivalent as each would have a different MD5 hash even if file size is identical; implementing a computerized chain of custody system over the raw and processed data files so that each result is traceable on a data file and operation trail (e.g. script).

5 Experimental procedure

The running of marine acoustic monitoring surveys to meet the MSDF requirements related to determining its indicators come with challenges. Furthermore, for meaningful and comparative results coming from across a very varied Mediterranean Sea, best practices are required to scope, plan, execute and compute the indicators from a monitoring run.

In the case of QUIETMED we have three sites across the Mediterranean where pilots' acoustic surveys have been run. As can be seen in this report and the corresponding reports written by each pilot project partner, it's evident that best practices have been employed though there is heterogeneity in the equipment utilized to monitor the sound in water and in the calibration of the equipment, and each pilot project area presents its own particularities. Nonetheless this heterogeneity in each pilot project does not hinder the adoption of a general experimental procedure. Figure 31 depicts an informal activity plan and workflow for the pilots' deployment.

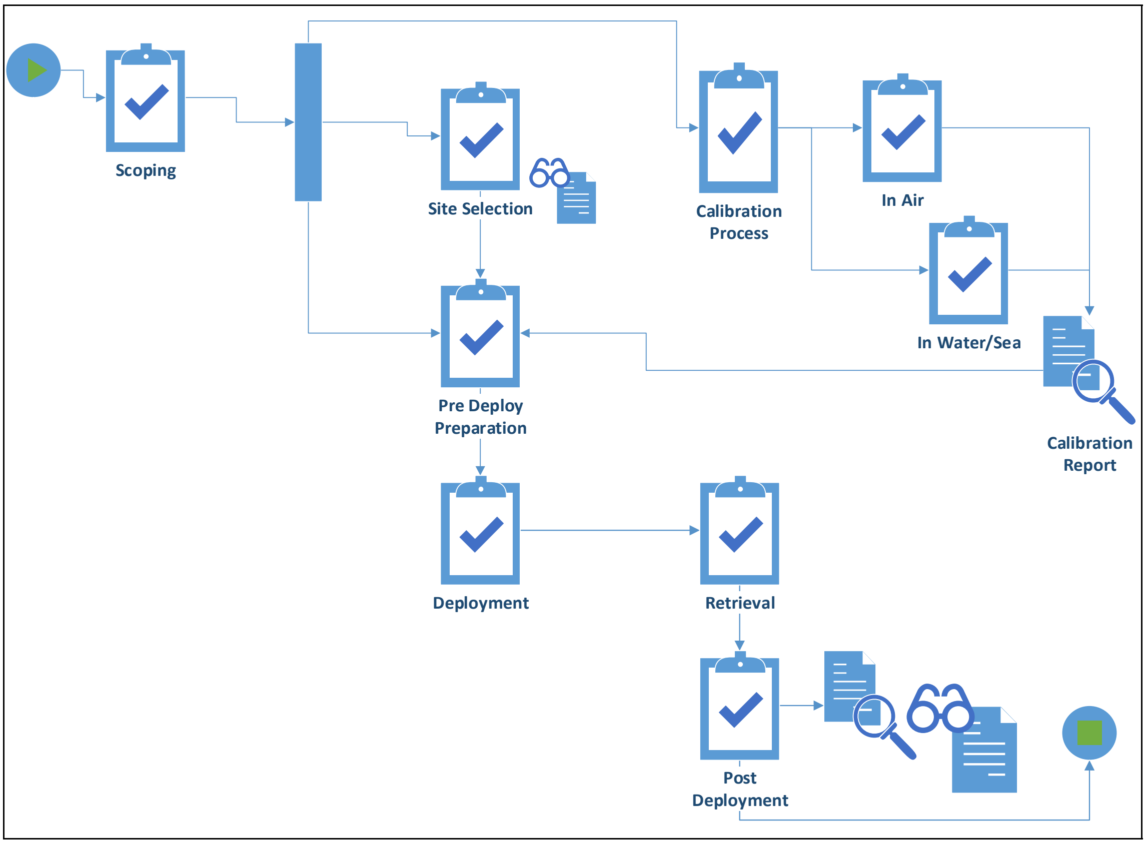


Figure 31: An acoustic monitoring pilot project program workflow

5.1 Preparation of the systems

The project starts with a scoping exercise; in this initial phase the pilot project members determine the goals of the monitoring exercise, as per MFSD requirements, and draw up, at a high level, the equipment requirements, procedures and practices to adopt, ensure computations required are satisfied with data to be collected, and identify a number of risk factors and consider their possible attenuation. At the end of this stage a pilot project's aim and objectives are known and listed and a method statement is drawn up. Although workflow in Figure 31 is meant for a pilot project, during the QUIETMED's project progression all pilot projects sites teams (i.e. from Crete, Greece, Maltese Islands, and Cabrera, Spain) and other members (e.g. CTN, ISPRA) of the project communicated together and shared and corroborated these requirements during this scoping phase.

Given the eventual and broad agreement between QUIETMED project members each pilot project team needed to ensure that the following three goals are executed successfully prior to a run (their timing could be concurrent).

A) The research area site selection, for category A and B monitoring, as per best practices (refer to section 3 of this document) is one of the first jobs. The team could have a shortlist of possible locations and their scope identified (e.g. category A or B). Each shortlisted area needs to have its bathymetry data and other features determined. Eventually an area is selected from the short list and consequently any permits (e.g. environmental, maritime and planning) are sought. Method statement drawn-up during scoping is a useful basis for explaining the pilot's modus operandi to the authorities. Site selection process needs to be run at least once in each pilot project area (i.e. other and eventual deployments can use the same area).

B) The calibration of the hydrophone and recording equipment is undertaken; the expected output is a calibration report. Given that the monitoring objectives have already been worked out (i.e. in scoping) the calibration processes, i.e. in air and in water, are initiated. Any deviations from suppliers' stated performance needs to be investigated and explained. This job needs to be done at least once and ideally every time a recording system component is changed (e.g. hydrophone). The calibration report is required in eventual sub tasks (e.g. pre deployment and post deployment operations). This job has logistical implications as, i.e. the Maltese Islands, needed to redirect its acoustic equipment to the calibration centers in Spain. Consequently, shipping of equipment lost valuable time, as did the difficult shipping requirements for batteries.

C) The pre-deployment preparation phase is an extensive one and does depend on having the site selection done, calibration report in hand, and equipment available and in a working order. A special note has to be made, again, on the availability of batteries – air shipping of some types of batteries is complicated (e.g. Lithium Ion type). All the deployment equipment components need to be tested (individually and as an aggregate). Testing includes functionality (e.g. recording, and battery capacity) and fit for purpose (e.g. buoyancy of rig). The rig structure and anchorage (if applicable) are also assembled and tested. Just prior to deployment the following need to be initiated: data acquisition based on streaming for non-acoustic data (e.g. AIS and weather data), recording type and duty cycle for data recorder, and set-up emergency beacon, if available, for unexpected surfacing.

5.2 Deployment and Retrieval

The deployment phase is relatively straightforward. It does need careful planning to move equipment and also finding the right weather window. The master of the boat is briefed on type of equipment and deployment procedure for adopted rig. In the case of surface rigs (i.e. Crete, Greece) specific instructions and look-out are required during deployment. Careful annotation of the deployment exercise is required; when on site all easily verified parameters need to be rechecked (e.g. depth and maritime activities). During deployment one needs to monitor any ongoing operations, if accessible. For example if reading AIS data from a streaming site then an adequate mechanism is required to flag any loss of data capture (e.g. is it the AIS site down or is the local data server out of storage space?).

In the case of pilot runs where the rig has been released and anchored then a date for retrieval, based on duty cycle duration and permitting weather needs to be established. Again the master of the boat needs to be briefed and an effective look-up procedure adopted. If retrieval is not successful then the pilot's notes taken and good communication with supplier and projects partners can throw light on occurrence and possibly came up with a solution for an alternative retrieval.

On returning to the local lab, streaming data sources are closed and the rig's status is annotated (e.g. visual examination).

5.3 Post Deployment / Retrieval

The main activity after retrieval is of course data extraction from a recording device. Data back-up is the very first activity. Also it would be useful to check the data files for naming, file date stamps and other features (e.g. being wave files one can extract metadata, e.g. total time, frequency and sampling word bit length). Some data recorders could possibly include other metadata that are written together with the wave files; these too need backing up.

All equipment that was placed in the sea needs proper cleaning; batteries need to be unplugged and pulled out. As indicated earlier, a check for electrical corrosion is important.

Once the files are backed-up domain specific pre-processing starts. It's expected that an evaluation of self-noise (i.e. recording equipment rig self-noise at site), and clipping are investigated. An explanation of this, including possible methods to compute these, are given in reference [10].

After the preprocessing the extraction of the ambient noise indicators can start and in accordance to procedures and analysis described in QUIETMED Deliverable 3.2. On issuance of these indicators a more involved evaluation can also be undertaken. To facilitate this a set of scripts, developed by UPV, are made available to all pilot partners.

Other and more refined pre-processing involves indexing and transforming the data files, or indexing of raw or processed files, as this facilitates more elaborate operations on them. This further pre-processing facilitates knowledge extraction that requires more computationally intense programs; e.g. clustering, and motif searching in the data files, and as input to neural networks.

6 Results

This section describes the pilot's project outputs derived from the processing of the collected acoustics data. The primary goal is to enumerate the various acoustic level indicators detected from computations over the recorded data and also explain, at intra and inter site level, patterns and trends derived from same source data.

6.1 Analysis

For each marine acoustic data collection run, and considering the data collection data cycle employed, massive datasets are built. After the appropriate and indicated pre-processing is undertaken, the actual extraction of the ambient noise indicators together with appropriate visualizations for conveying results and trends is started. Figure 32 schematically illustrates the different elements involved to produce graphical representations of the main noise indicators. Three are the most common graphical representation schemes for ambient noise indicators: SPL versus time, SPL histograms, and Spectral representations (for 1/3 octave and narrowband). All three have been employed in the QUIETMED project.

We present some examples of other graphical representations using data from the QUIETMED Pilot projects in the following sub-sections.

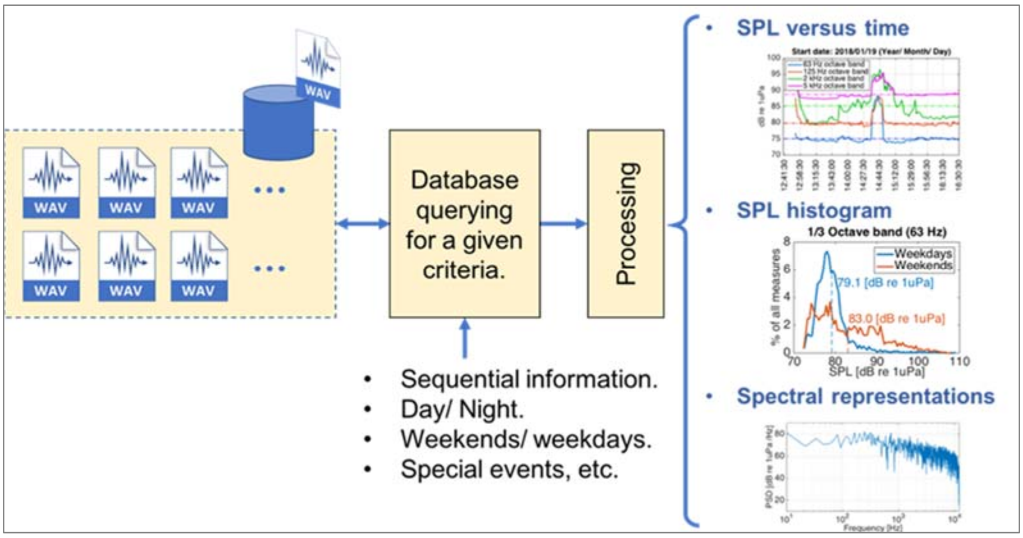


Figure 32: Workflow for monitoring indicators computations and visualization

Analysis of the Crete Pilot project data

Using the acoustic data from the periods where no source signal was emitted and taking into account the computed sensitivity value for each run, one-third octave band noise levels were estimated and corroborated with reference hydrophone readings too. Figure 33 shows the noise levels at the central frequency of each 1/3 octave band up to 1 kHz for UL1 depth equal to 30 m [4]. The selected period is during noise measurements when the UL1 was at 30m depth. This period was about 20 minutes during the first experiment and about 30 minutes during the second experiment [12], [13].

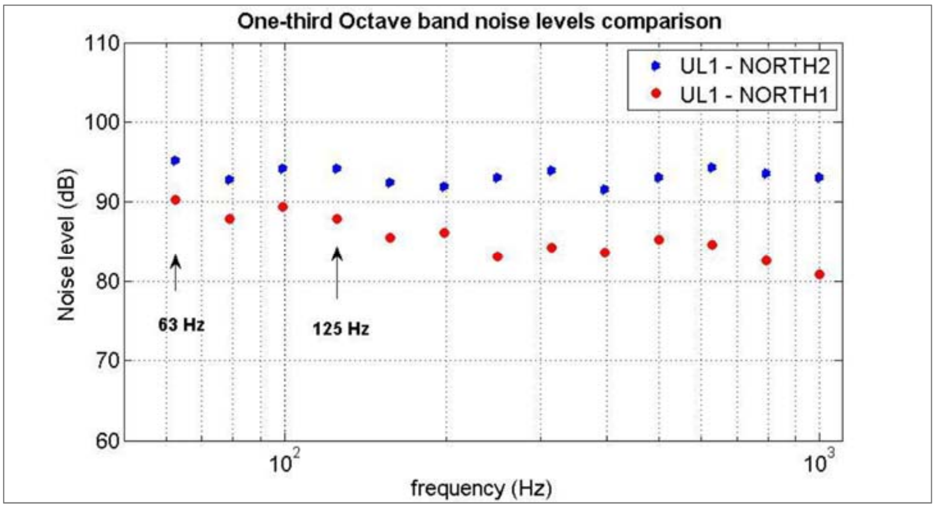


Figure 33: Noise levels comparative calculations from the UL1 data during FORTH's two pilot runs

It can be seen in Figure 33 that the noise levels during the north 1, which took place in May, are about 5 to 10 dB less than those during north 2, which took place in December. This difference can be attributed to [4]: marked differences in sound speed profiles (see Figure 43); shipping levels during north 2 was higher; recording periods insufficient to explain differences between runs; and experimental site ambient noise is overloaded from multiple anthropogenic noise sources. In Figure 34 one finds noise levels during the experiments for frequencies between 50 and 1050 Hz during the North2 run.

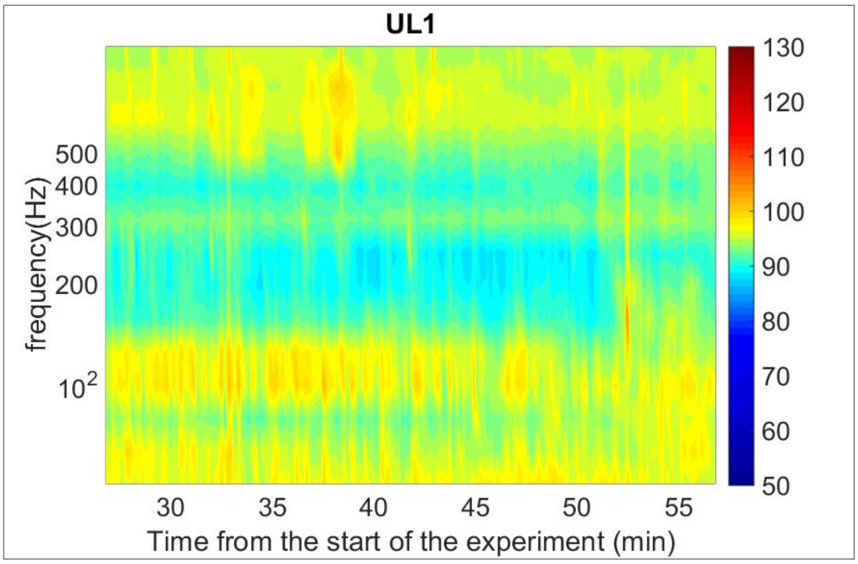


Figure 34: Noise levels calculated from UL1 data during FORTH's North 2 pilot experiment

Figure 35 shows the noise levels at the central frequency of each 1/3 octave band up to 1 kHz for UL1 during South1 run [5]. The x-axis gives the date (24, 25 and 26 April 2018) and the time. Every 4 minutes recording corresponds to a column. It can be seen that the noise at 63 Hz is higher than the one at 125 Hz and that there are two periods (in the morning and about midnight of April 25) where the noise was higher at all frequencies. Two distinct peaks can be seen at around 06:00 on April 25 and 00:30 on April 26. Listening to the recorded signal a vessel's engine can be heard in both cases. The signals can be attributed to a medium size vessel (first case) and a fishing boat (second case).

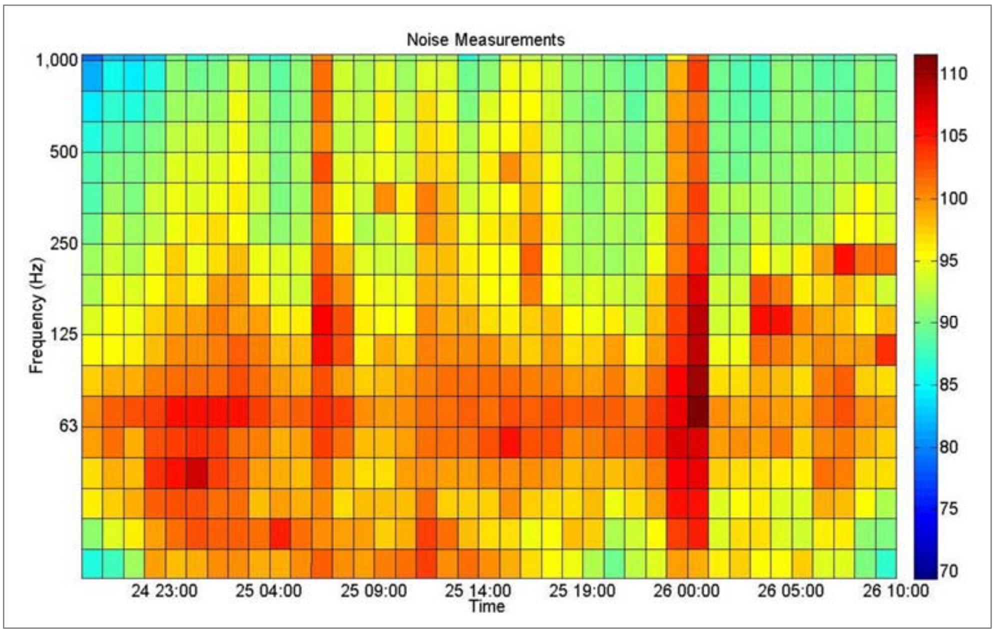


Figure 35: 1/3 Octave noise levels calculated using data recorded by FORTH's UL1 for South1 experiment

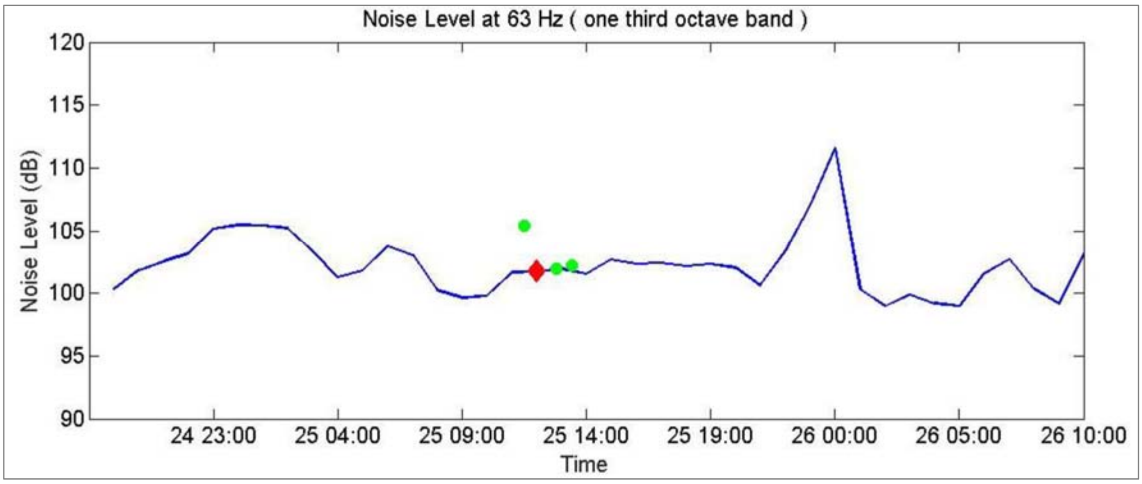


Figure 36: The noise level recorded by FORTH's UL1 during the South1 experiment at 63Hz (blue line)

The noise levels recorded by UL1 during the South1 run at 63Hz (blue line) and 125Hz (blue line) are shown in Figure 36 and Figure 37 respectively. Noise levels measurements calculated using the TC4032 hydrophone and circa 5 nm from deployment site done on April 25 (represented with a red diamond in same figures) and in other positions in the area (green dots) are also shown superimposed.

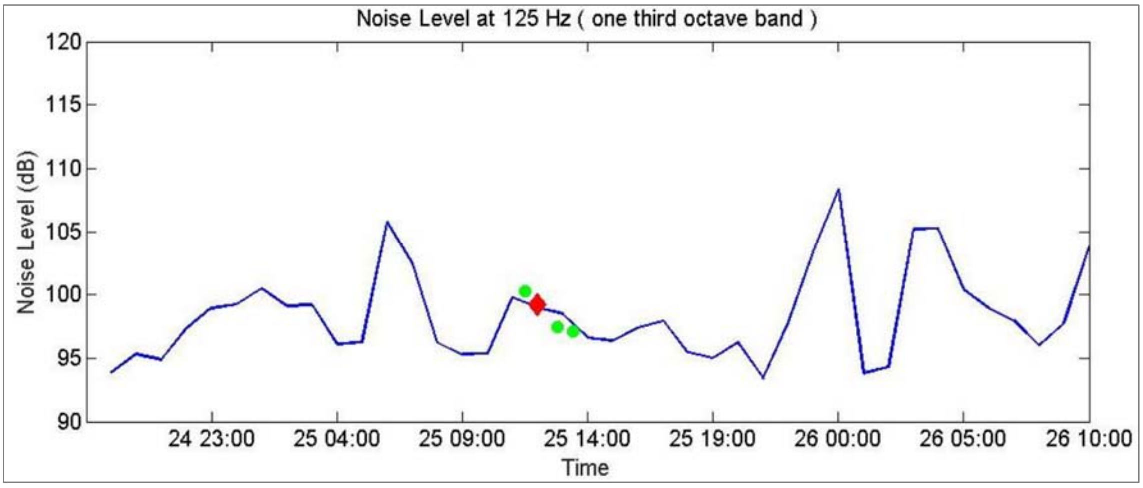


Figure 37: The noise level recorded by FORTH's UL1 during the South1 experiment at 125 Hz (blue line)

Another pilot shallow water experiment took place for a 7 day period at the north of Dia island [14] (violet square in Figure 4). During this experiment 3 minute measurements of ambient noise every two hours were recorded over 7 days. Figure 38 shows the ambient noise levels recorded. In this figure each column corresponds to the average noise level during a 3 minute period.

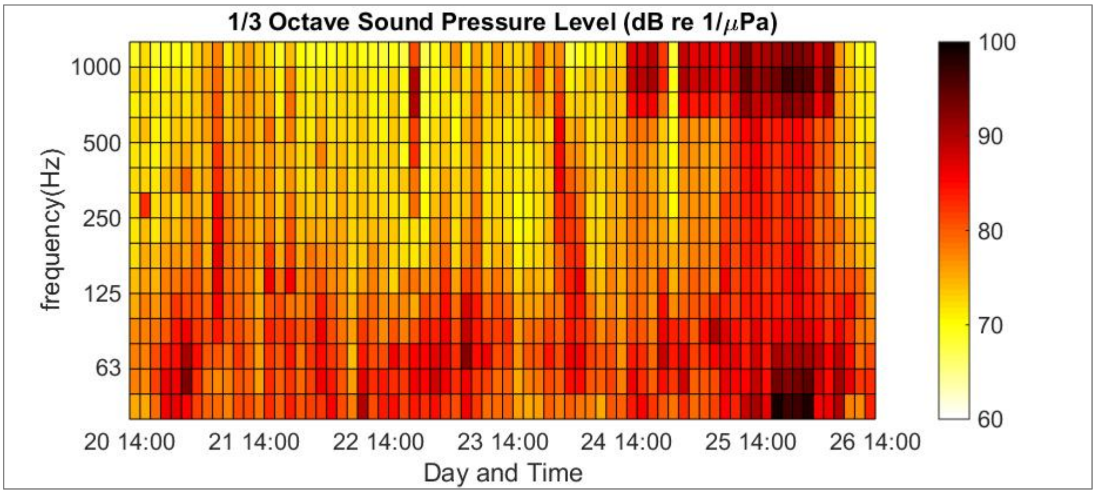


Figure 38: 1/3 Octave noise levels calculated using data recorded by FORTH's UL1 for North3

Figure 39 present the noise levels at the 63 and 125 Hz 1/3 octave bands respectively. Xxx represents the histogram distribution of the 63 and 125 Hz 1/3 octave bands for the whole run.

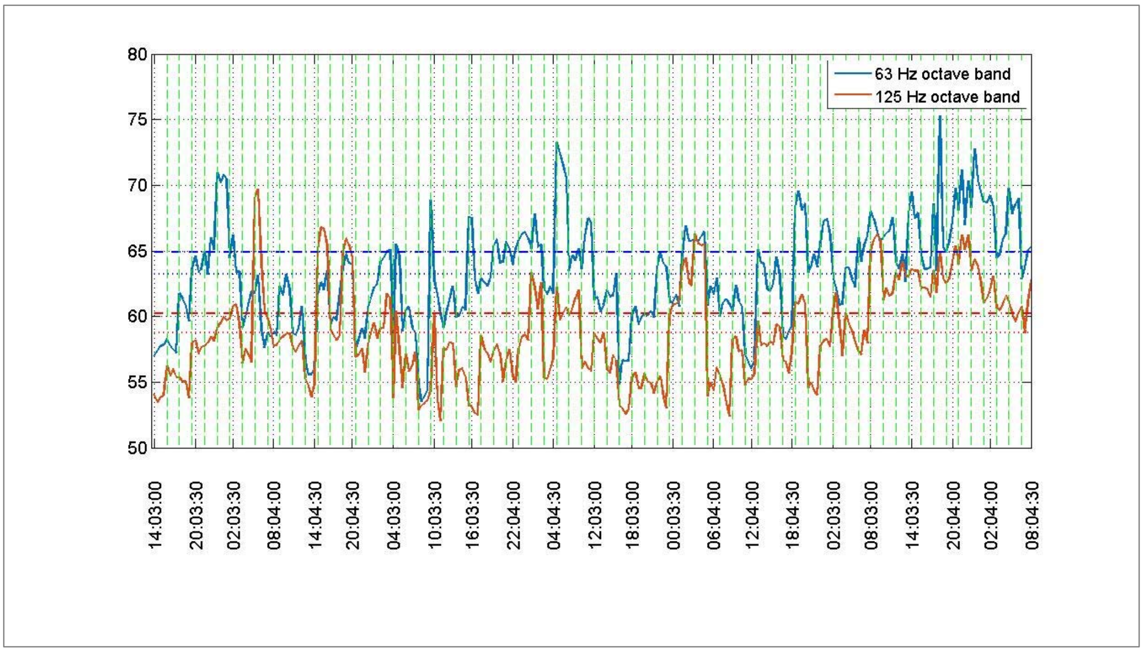


Figure 39: The ambient noise level recorded by FORTH's UL1 during the North3 experiment at 63Hz and 125Hz

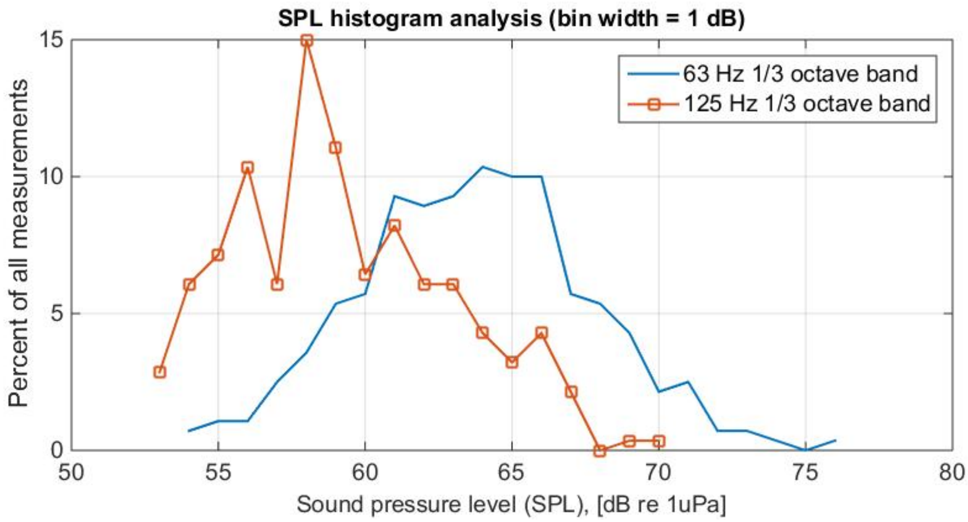


Figure 40: SPL histogram analysis at FORTH's UL1 during the North3 experiment

Another visualization useful to assimilate daily trends of the 63 and 125 Hz 1/3 octave bands is the box plot. Figure 41 and Figure 42 for such plots and represent the North3 run.

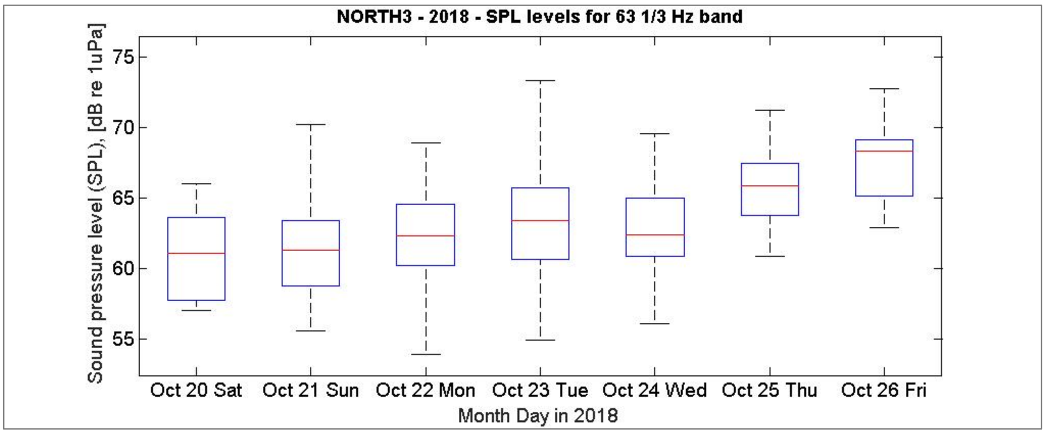


Figure 41: 63 Hz 1/3 octave ambient noise evolution for a week of North3 pilot run

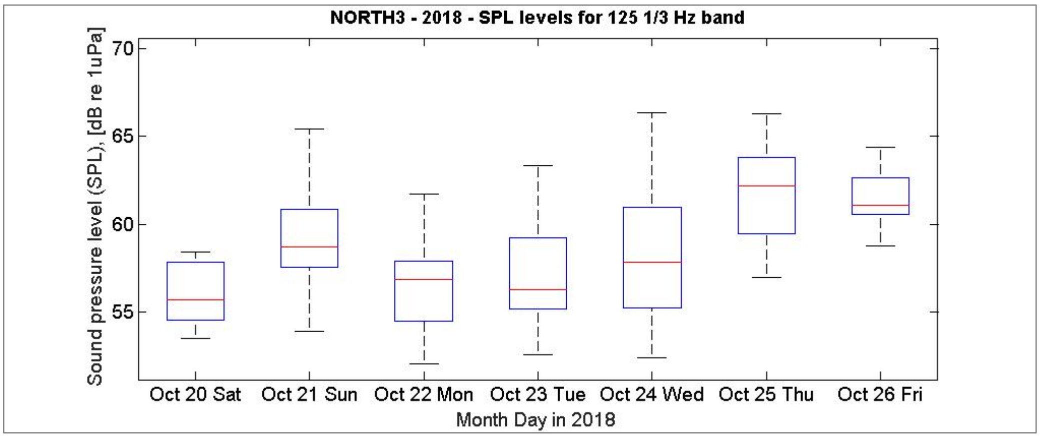


Figure 42: 125 Hz 1/3 octave ambient noise evolution for a week of North3 pilot run

The Crete project, on each deployment and each site, measured the sound speed profile – see Figure 43. The sound speed profile for North1 experiment ((a) in Figure 43) is a typical Spring profile while North2 and North3 profiles ((b),(c) in Figure 43) are typical Winter and Fall profiles for the Northern Crete. Figure 43 (d) presents a deep water profile measured during the South1 experiment at Southern Crete.

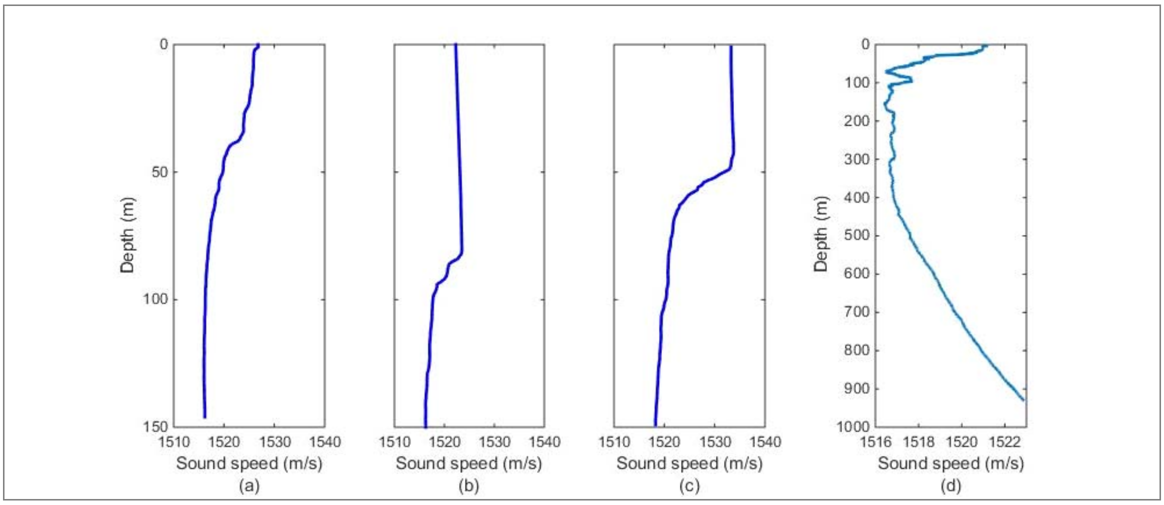


Figure 43: The sound speed profile during (a) North1, (b) North2, (c) North3 and (d) South1 experiments

Analysis of the Cabrera Pilot project data

An overview of the data indicates that 19 days of data were recorded. The data was processed to obtain SPL in dB ra 1 uPa. Measures in the 1/3 octave band 63 Hz, 125 Hz and 2k Hz have been computed according to [15]. All 1/3 octave indicators were extracted employing the techniques and scripts described in QUIETMED's Deliverable 3.2 [7].

Examples of the octave indicators output derived from scripts developed by UPV are given in Figure 44 and Figure 45. These figures show the evolution of the SPL in dB re 1uPa in the different frequency bands for a whole deployment day (January 20, 2018 for Figure 44 and January 22, 2018 for Figure 45) [7].

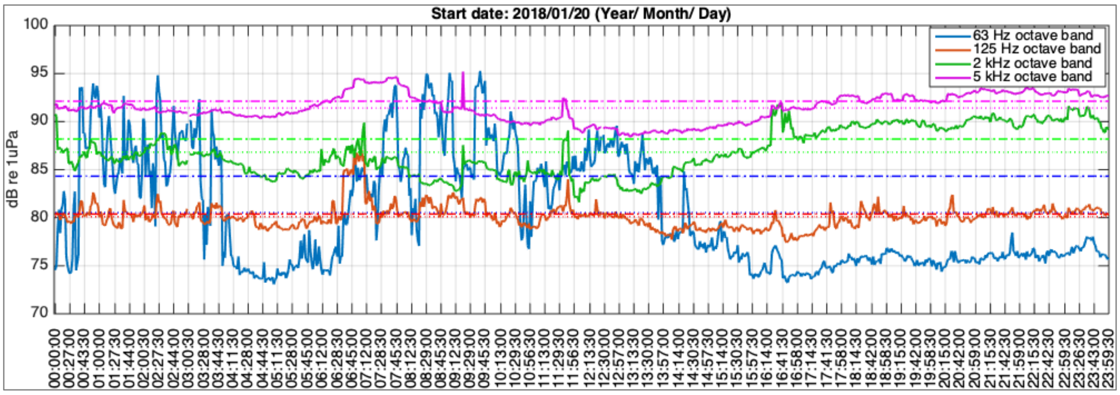


Figure 44: Ambient noise levels on 20th January 2018 at 63, 125, 2k and 5k Hz in 1/3 octave bands at Cabrera

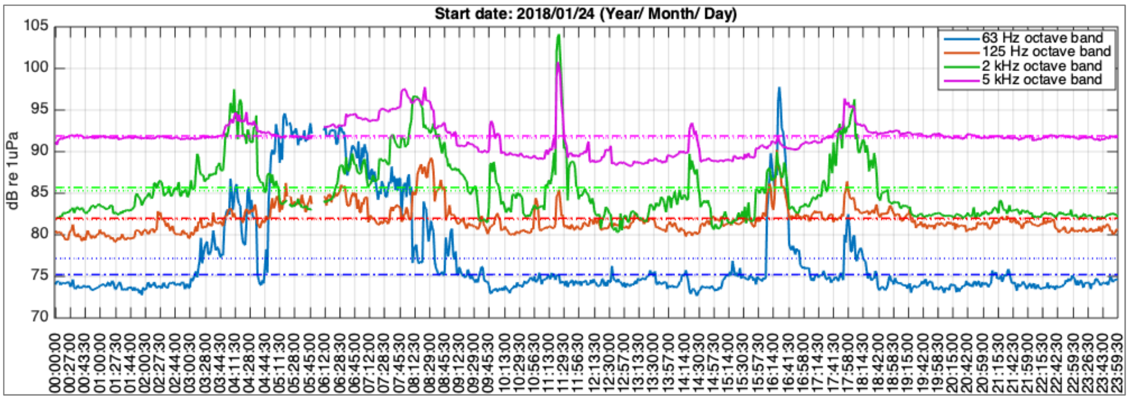


Figure 45: Ambient noise levels on 24th January 2018 at 63, 125, 2k and 5k Hz in 1/3 octave bands at Cabrera

Further analysis of the recordings have revealed severe clipping and system saturation in two periods: January 27th from 10:00 AM – 23:59 and from February 2nd at 7:30 AM until February 3rd at 4:11 AM. The clipping seems to be due to an animal lying and moving very close to the hydrophone.

The comparison of the SPL for the whole deployment are shown as a level histogram for all 4 1/3 octave bands in the Figure 46.

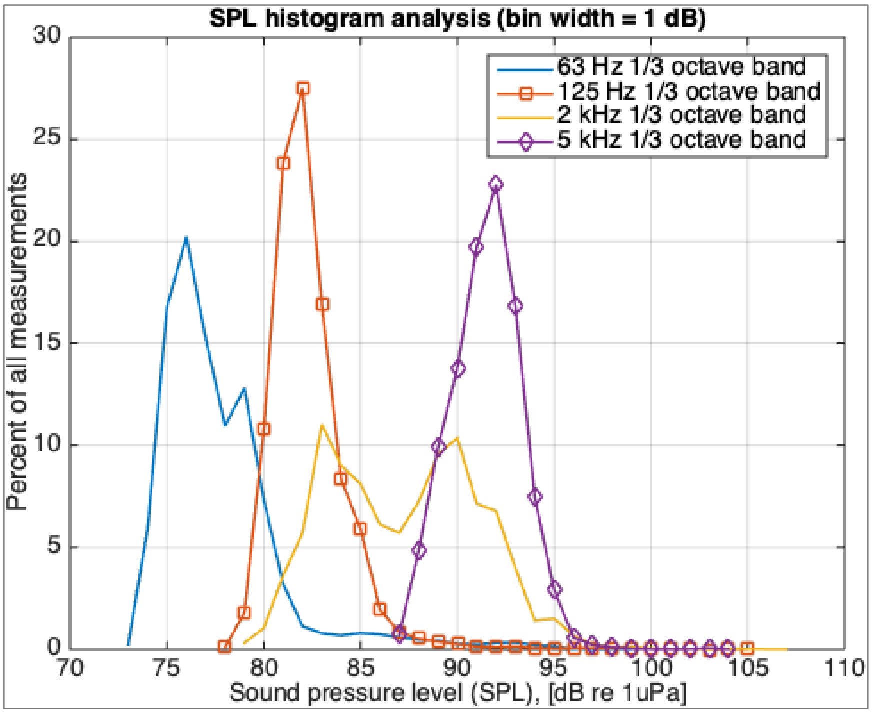


Figure 46: Histogram in the 4 1/3 octave bands for the Cabrera Pilot project deployment

Analysis of all the bands in the range from 20 Hz-1000 Hz was also performed and pseudo colour maps were obtained as illustrated in the xxx for some specific files.

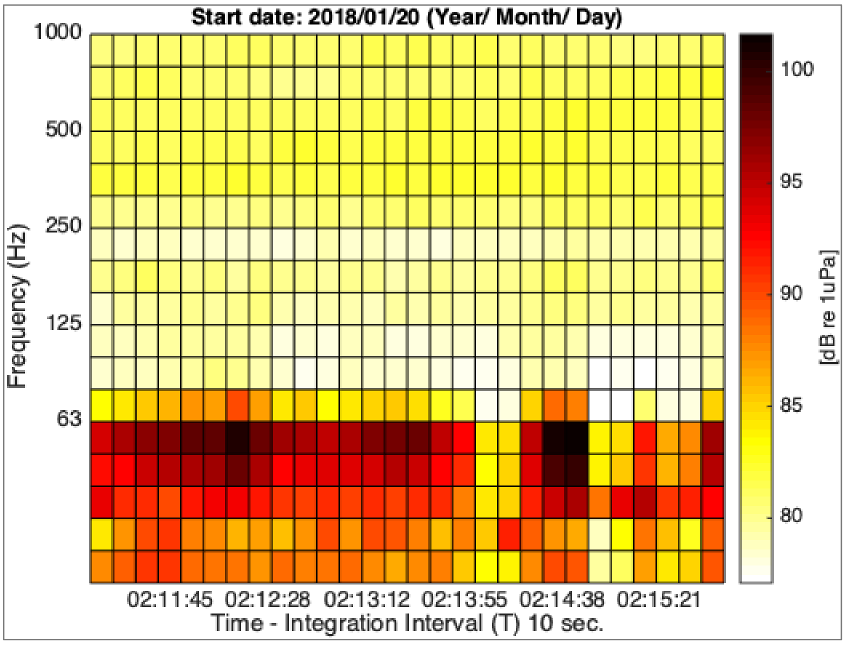


Figure 47: Analysis of all 1/3 octave bands in the range from 20 Hz-1000 Hz for the Cabrera Pilot Project

In addition to traditional *XY* graphs UPV have employed a new representation technique to allow the visualization ambient noise indicators over a longer period of time [16]. The new visualization technique consists in arranging the data in two dimensions such as (Hour, Day) and employing heat maps in a similar way as it is done in geospatial visualizations. Each cross bin of the heat map corresponds to a previously determined time span (i.e. set to 15 minutes). The colour of the bin is then a representation of the $SPL_{1/3}$ in the given time span and it was obtained by averaging all $SPL_{1/3}$ in that time span for an integration interval *T* (*T*=30s in this representation). Figure 48, Figure 49, Figure 50 and Figure 51 show respectively the heat map representations of ambient noise (1/3 octave indicators) for the bands of 63 Hz, 125 Hz, 2 kHz and 5 kHz for the complete deployment (19 days). Black bins correspond to marked regions where clipping has occurred.

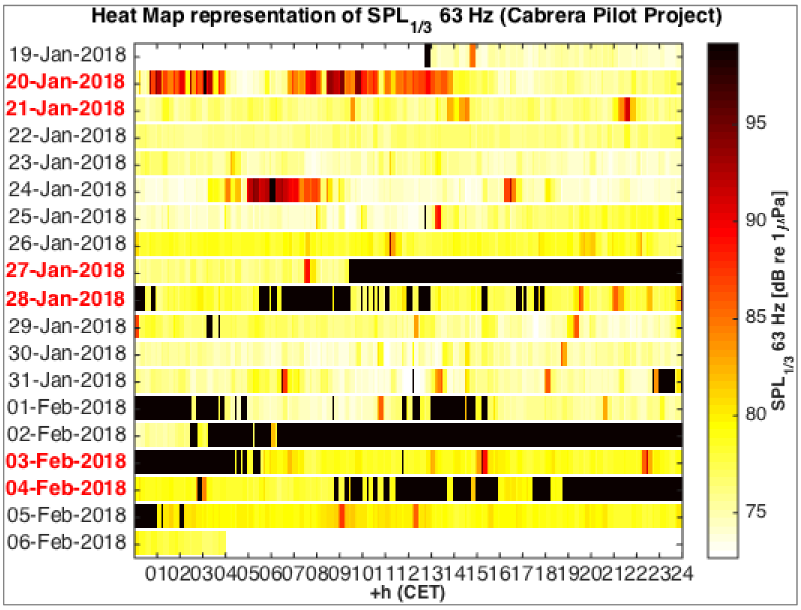


Figure 48: Heat map of the SPL1/3 at 63 Hz for all days of the Cabrera run

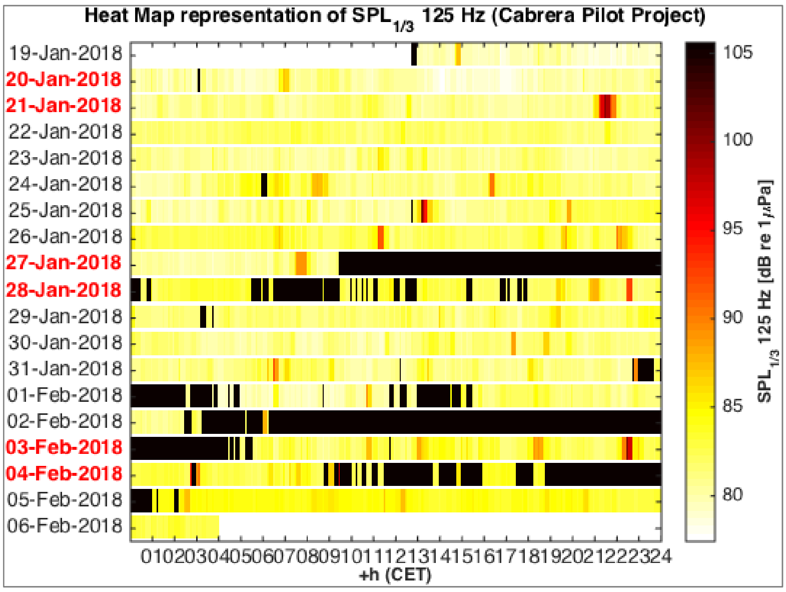


Figure 49: Heat map of the SPL1/3 at 125 Hz for all days of the Cabrera run

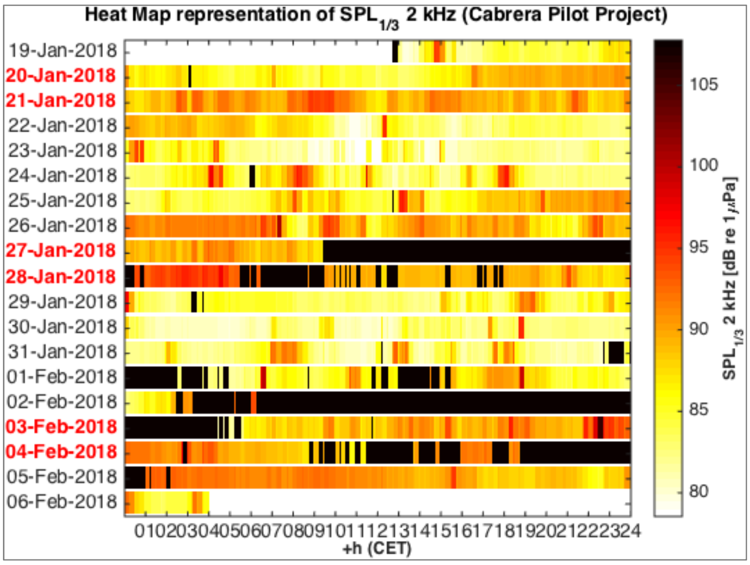


Figure 50: Heat map of the SPL1/3 at 2 kHz for all days of the Cabrera run

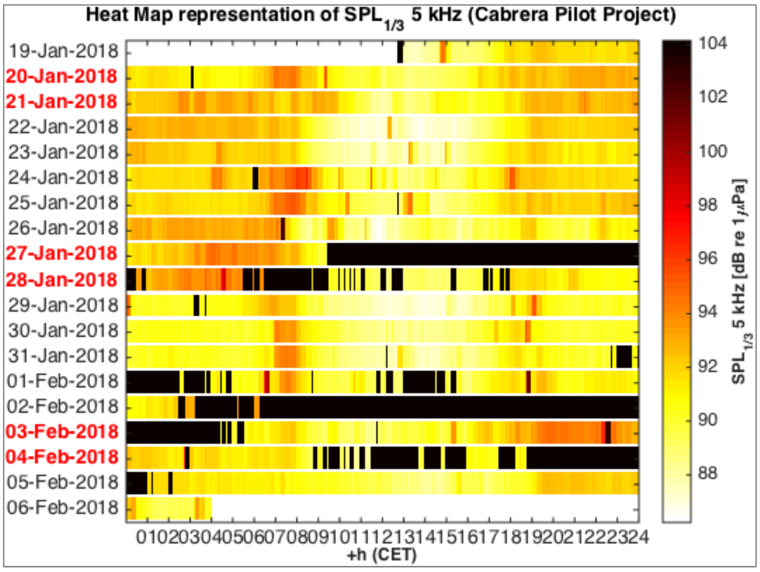


Figure 51: Heat map of the SPL1/3 at 5 kHz for all days of the Cabrera run

We have represented the boxplot of the 63 Hz and 125 Hz per week of the deployment (see Figure 52 for the 63 Hz band and Figure 53 for the 125 Hz band). Outliers have been removed from the representation.

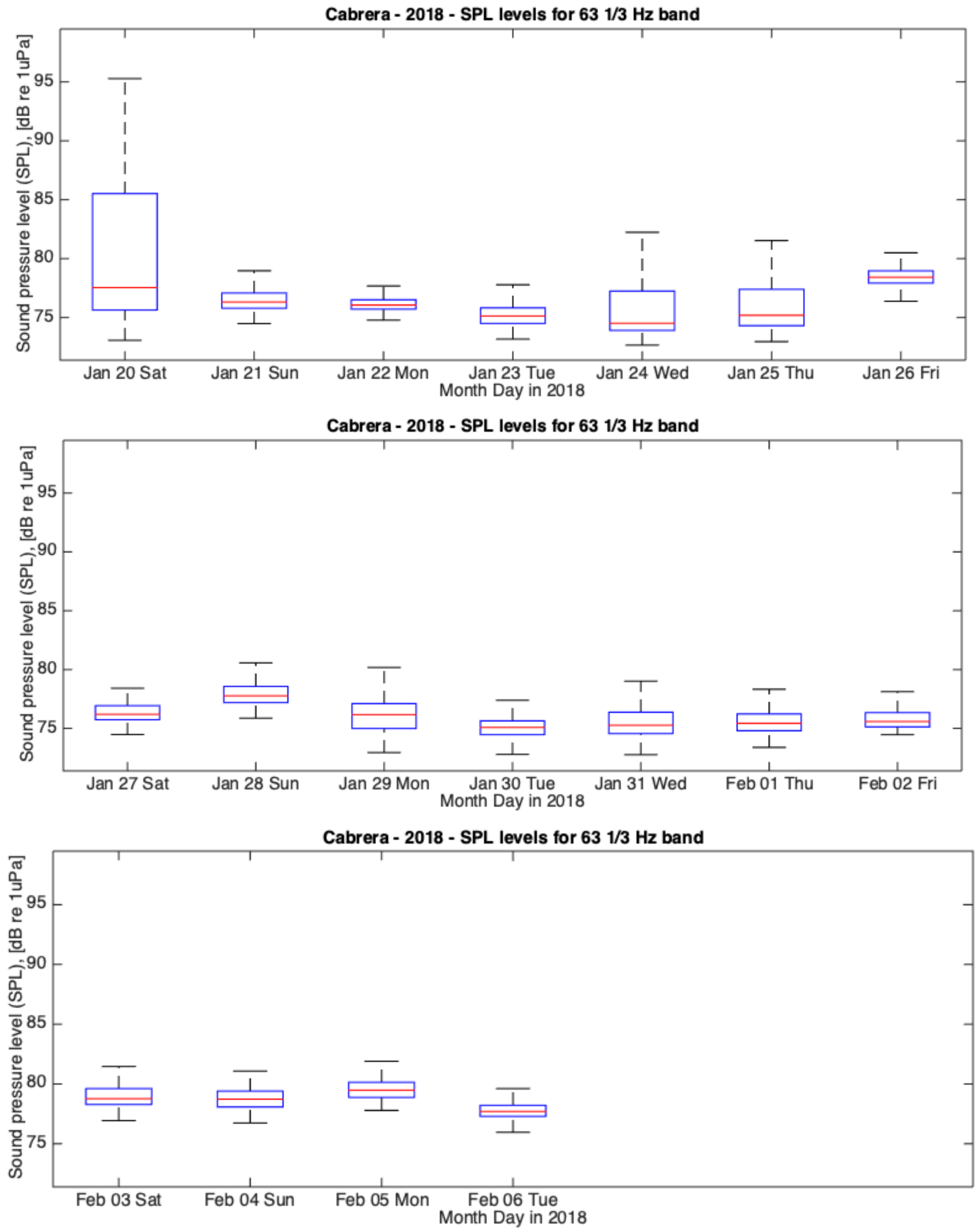


Figure 52: 63 Hz 1/3 octave ambient noise evolution in the three weeks of Cabrera Pilot project

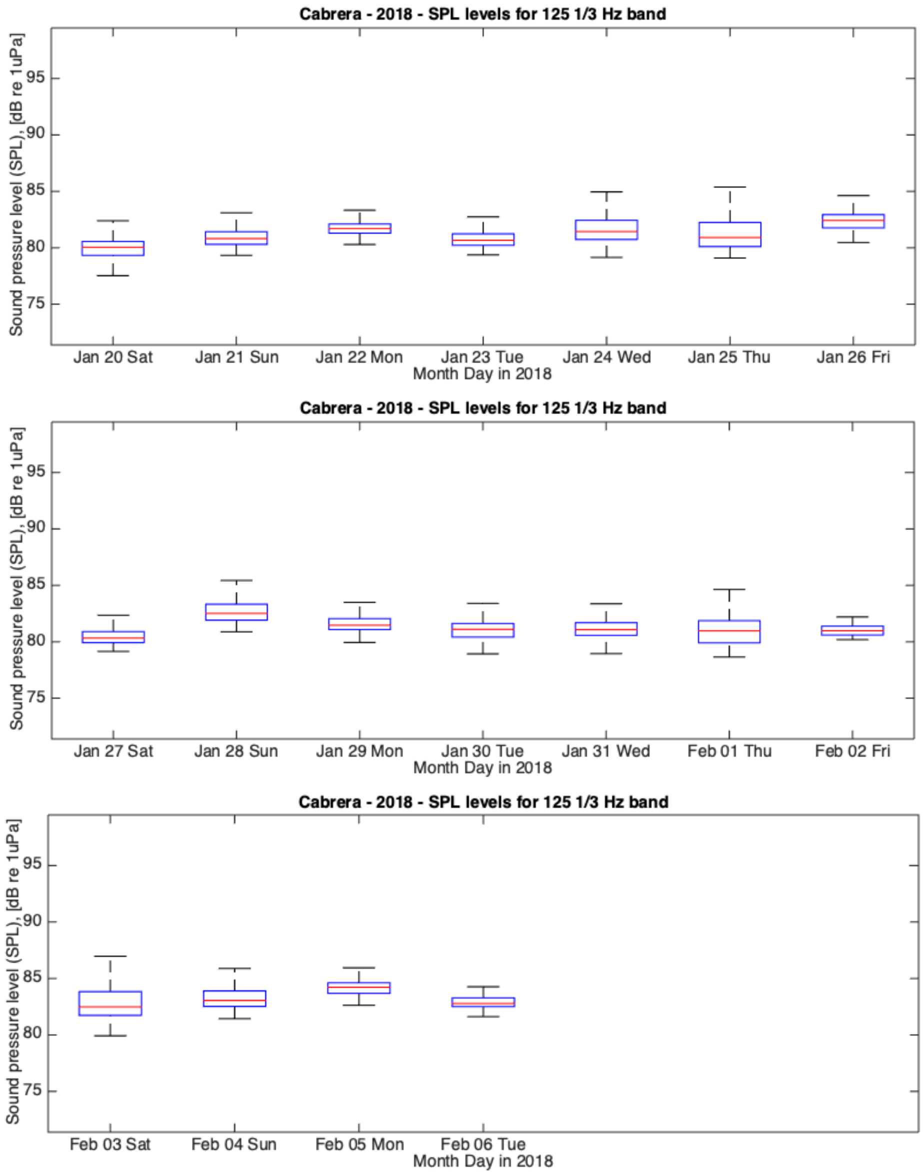


Figure 53: 125 Hz 1/3 octave ambient noise evolution in the three weeks of Cabrera Pilot project

Averages of ambient noise indicators over a time period very often have a cyclical nature. This may make polar area diagrams an appropriate technique for their representation. Polar area diagrams look like a traditional pie chart, but the sectors differ from each by how far they extend out from the center of the circle. As an example, the circle can be divided into 24 equally spaced sectors and represent the daily changes (by hours) of a specific ambient noise indicator.

This can be used to detect the presence of daily repeating events always happening at the same time of the day as well as to determine how the values of some ambient noise indicators may be related to circadian rhythms. We have created those polar diagrams for the Cabrera Pilot Project (see Figure 54 and Figure 55). Both figures include the sunrise and sunset variations within the deployment period as a light grey sector as well as the night time as a dark grey sector.

The figures show that an ambient noise indicator at 5 kHz has a higher level during the night that it has during the days, producing circle shape slightly flattened during sun hours. This may be due to noise produced by organisms as a result of the diurnal (or diel) vertical migration induced by light.

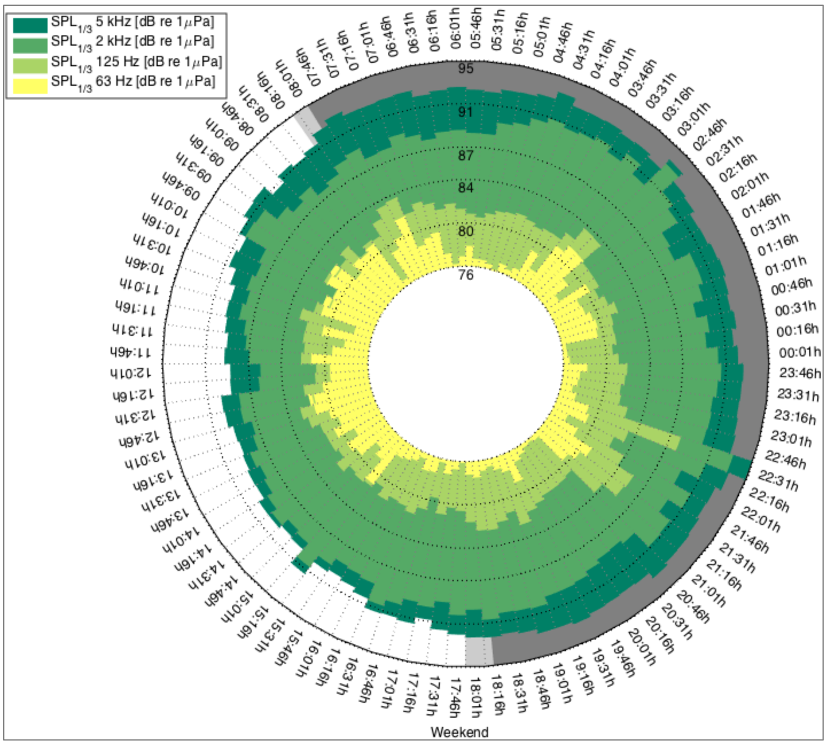


Figure 54: Polar area diagram of the Cabrera Pilot Project experiment (weekend)
Ambient noise indicators averaged over the weekend. White/ grey sectors indicate day/ night calculated for longitude, latitude, and for all deployment dates using a generic astronomy calculator.

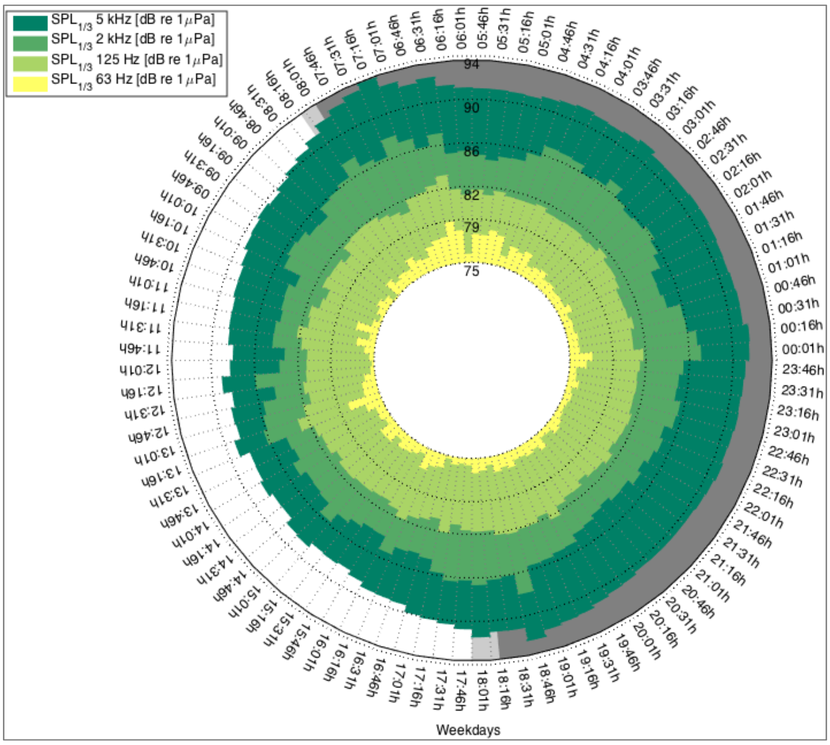


Figure 55: Polar area diagram of the Cabrera Pilot Project experiment (weekday)
Ambient noise indicators averaged over the week days. White/ grey sectors indicate day/ night calculated for longitude, latitude, and for all deployment dates using a generic astronomy calculator

In addition to the ambient noise indicators, the analysis of the recorded data has allowed us to identify the presence of dolphins using both: echolocation clicks and whistles.

Analysis of the Malta Pilot project data

Two concurrent deployments were undertaken around the Islands of Malta (over the months of July and August 2018) and following set-up and operating modes mentioned in previous sections. The two sites were Filfla (south of Malta) and northern part of Gozo (north west of Malta) - see Figure 6, Figure 7 and Table 1. For a duty cycle of 5 minutes on and 5 minutes off, the recorders captured data for 31 days from Filfla and 21 days from Gozo.

The raw data recorded was used to extract the Sound Pressure Levels (SPL) in [dB re 1 uPa] through scripts developed by QUIETMED partner UPV [10]. All wave files were pre-processed and any explainable clipping addressed; for example some recording files showed initial self-noise that decayed quickly. The “MSFD Decision 2010” requires computation of measures in the 1/3 octave band 63 Hz and 125 Hz and also recommends SPL computation for higher frequency 1/3 octave indicators for the 2 kHz and 5 kHz bands. Figure 56 represents a day of computed SPLs from Gozo (specifically for the 20th July, 2018) and Figure 57 is for a day (28th July, 2018) from Filfla. These XY graphs represented a time series of SPL data for the specified four bands, together with average and medium for the whole day for each band.

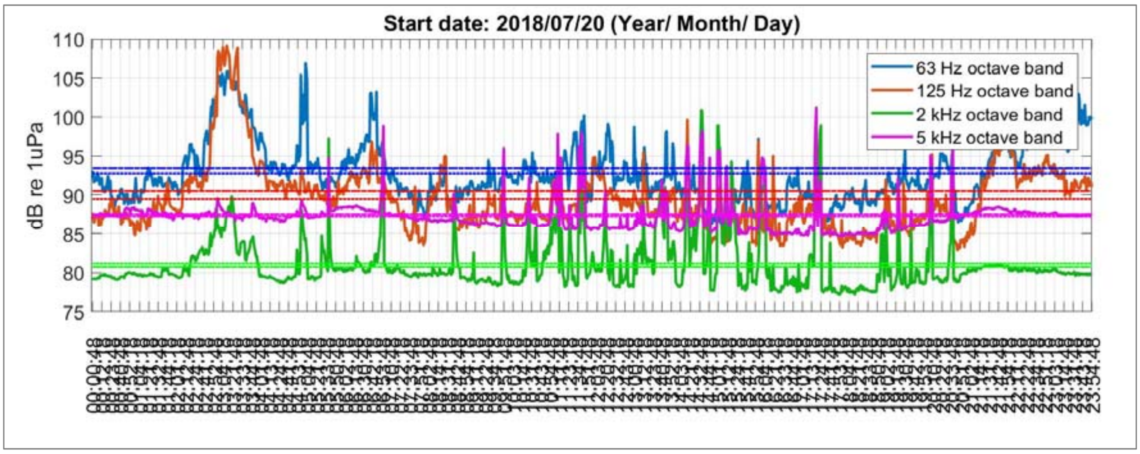


Figure 56: Gozo: Day’s ambient noise levels at 63 Hz, 125 Hz, 2 kHz and 5 kHz in 1/3 octave bands

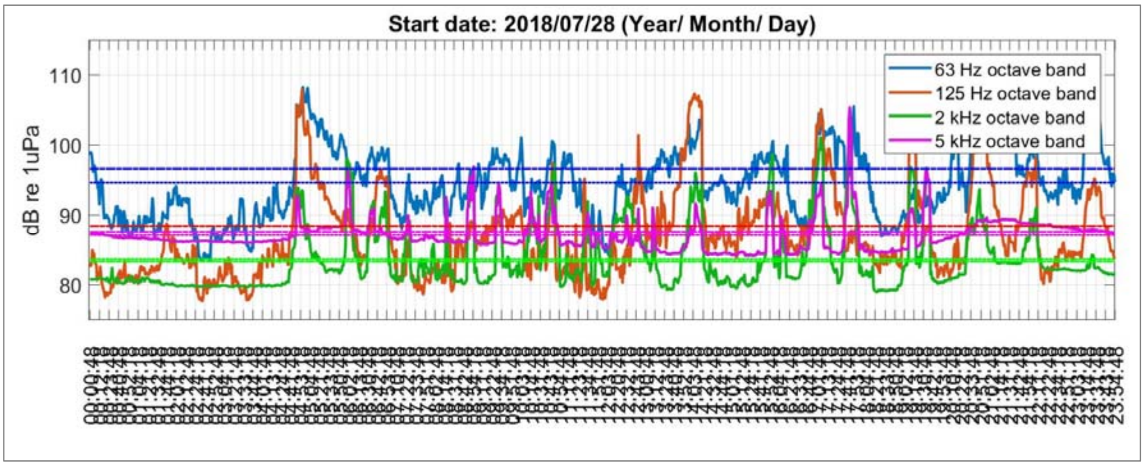


Figure 57: Filfla: Day’s ambient noise levels at 63 Hz, 125 Hz, 2 kHz and 5 kHz in 1/3 octave bands

For each deployment site, a frequency distribution for each band based on computed SPL is given in Figure 58 and Figure 59. The curve was fitted over ten equally sized sound frequency (Hz) bins where the ten bins range cover the sound frequency detected in the extracted SPL for each site and all four 1/3 octave bands. In either site, the 1/3 octave for 65Hz and 125Hz frequency show a skewed normal distribution.

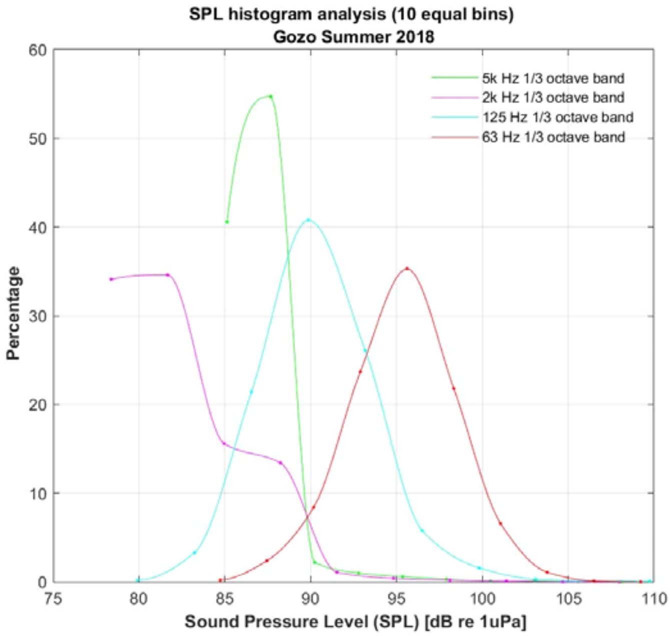


Figure 58: Gozo deployment SPL 1/3 active bands distribution

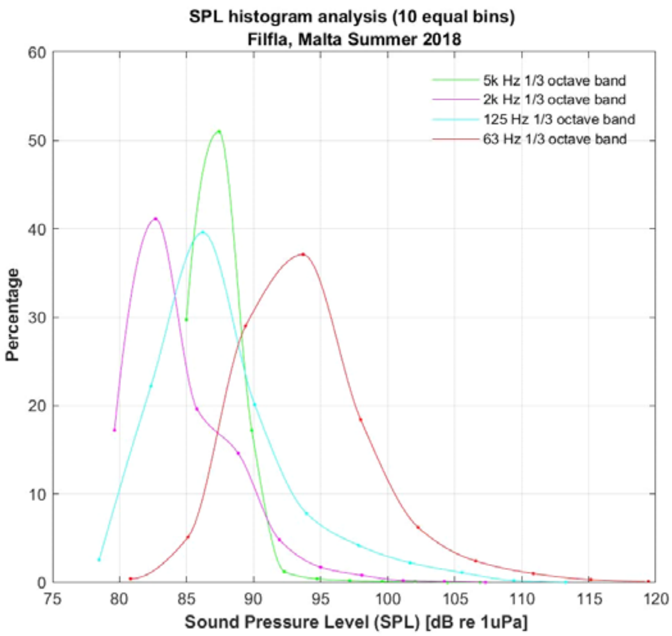


Figure 59: Filfla deployment – SPL 1/3 active bands distribution

Figure 60 shows the 1/3 octave for 65Hz and 125Hz frequency for each of the Maltese sites.

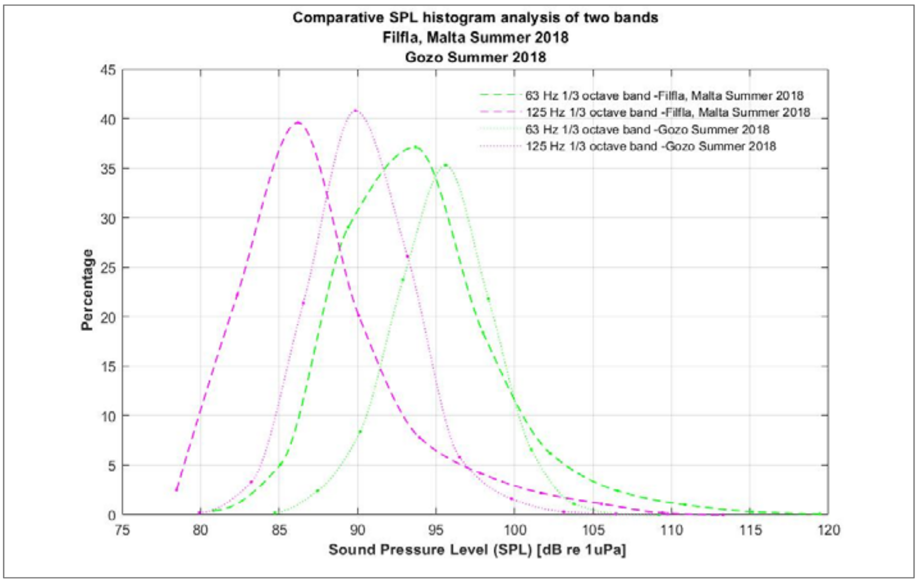


Figure 60: Filfla and Gozo comparison of frequency distribution for 63 and 125 Hz 1/3 octave

The islands of Malta are sandwiched between busy shipping lanes that run parallel to its coastline (see Figure 3); in fact, to the north of the Islands, i.e. the Sicily channel, a number of shipping lanes interleave over this strait (distance from Valletta to closet point in Sicily is 93 km) and consequently increases the shipping movement density in the area. A distinguishable shipping lane is also present in the south of the islands. Shipping noise around the islands comes from a very wide range of ship types; e.g. tankers, bulk carries, container ships, and cruise liners. For example, a "cargo" classified ship conveyance, as per MarineTraffic portal (vide https://www.marinetraffic.com/), approaching to and receding from the Fifla, Malta recording deployment site, shows the noise generated. The picture in Figure 61 shows the actual cargo ship steaming on location and corresponding event noise profile is shown in Figure 62 (i.e. SPL levels for that time internal together with an emphasis the actual event). Furthermore wide band calculation, up to 1000 Hz, for a five minute interval during same event is given in Figure 63 through a heat map representation (script from UPV [10]).

Figure 61: Ship conveyance close to the Filfla recording rig during deployment

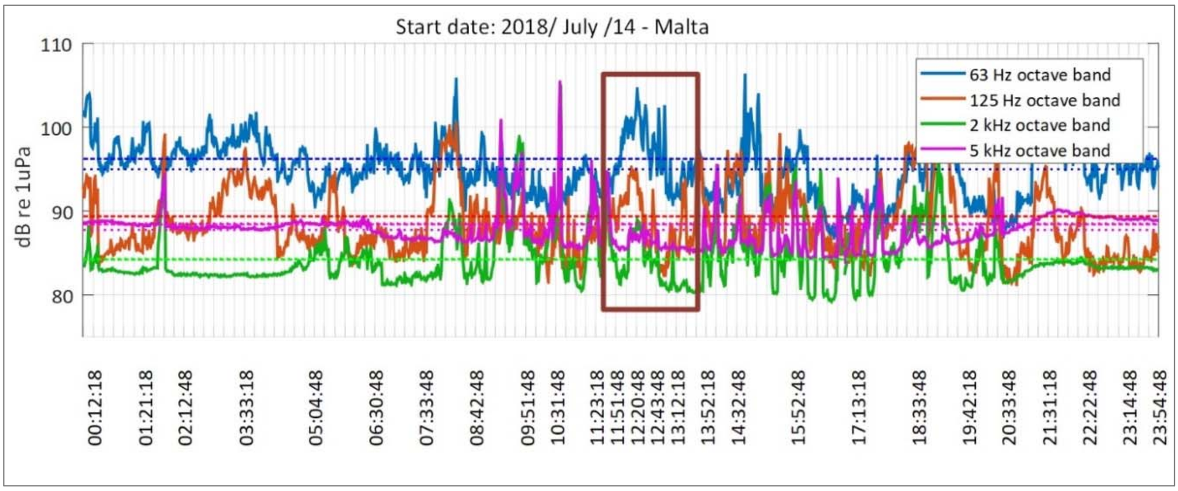


Figure 62: Filfla: Day's ambient noise levels at 63 Hz, 125 Hz, 2 kHz and 5 kHz in 1/3 octave bands with incident boxed

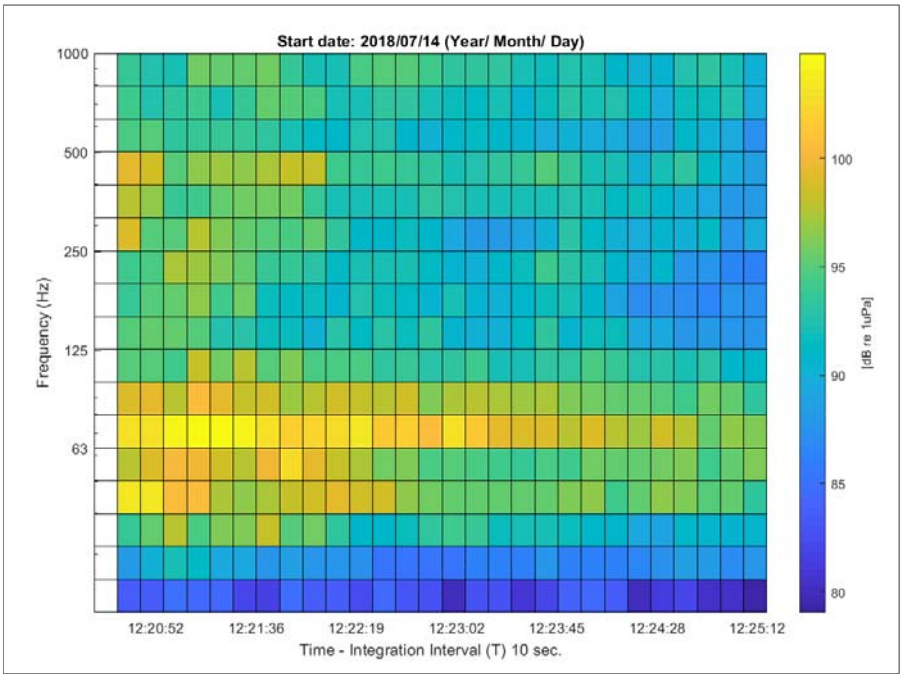
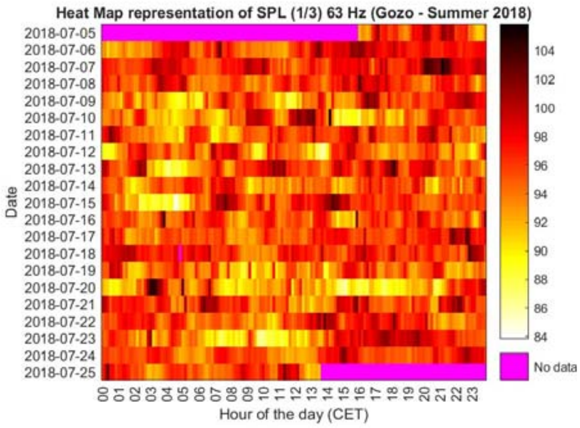


Figure 63: Filfla: Analysis of all 1/3 octave bands up to 1000 Hz for a 5 minute interval during ship conveyance

The SPL data computed from both deployments was also used to build a representation, as advocated in the Cabrera pilot project, to generate heat maps for ambient noise (1/3 octave indicators) for the 63 Hz, 125 Hz, 2 kHz and 5kHz bands that span the deployment duration against the days' time period (i.e. of 24 hour interval). The heat map data value if an average of the underlying computed SPL values for ambient noise. Figure 64 show the heat maps for the Gozo deployment and Figure 65 for the Filfla, Malta deployment.

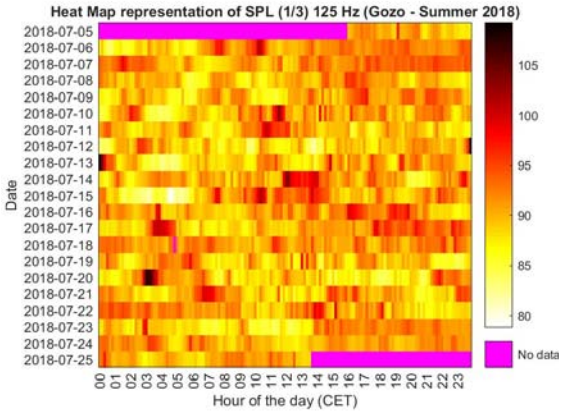
63 Hz (1/3 Octave)

Heat map scale in SPL 1/3 [db re 1 uPa]



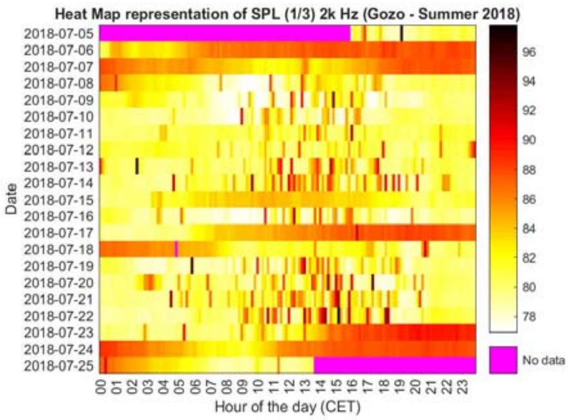
125 Hz (1/3 Octave)

Heat map scale in SPL 1/3 [db re 1 uPa]



2k Hz (1/3 Octave)

Heat map scale in SPL 1/3 [db re 1 uPa]



5k Hz (1/3 Octave)

Heat map scale in SPL 1/3 [db re 1 uPa]

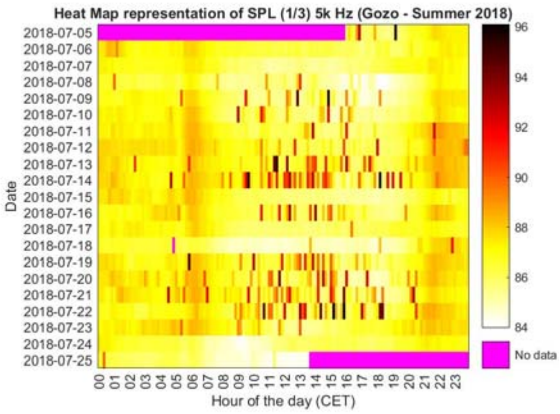
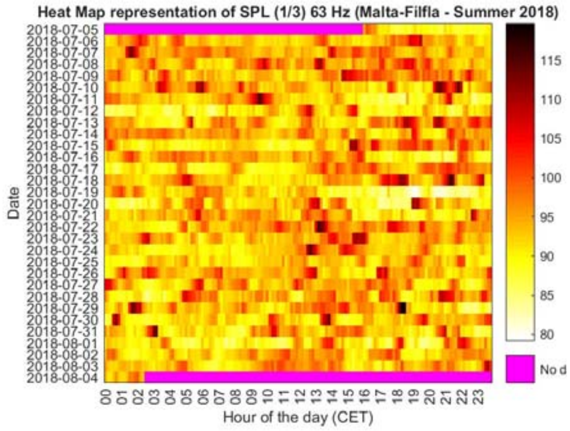


Figure 64:Gozo Heat map representation of the SPL1/3 at 63 Hz, 125 Hz, 2 kHz and 5 kHz for all days Each pixel gives an averaged ambient noise indicator over a 30 seconds interval when on duty.

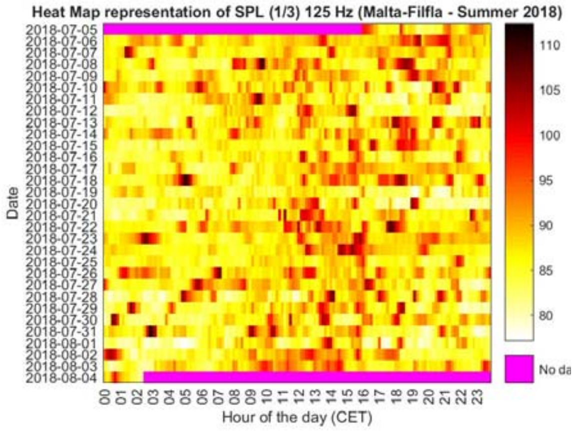
63 Hz (1/3 Octave)

Heat map scale in SPL $_{1/3}$ [db re 1 uPa]



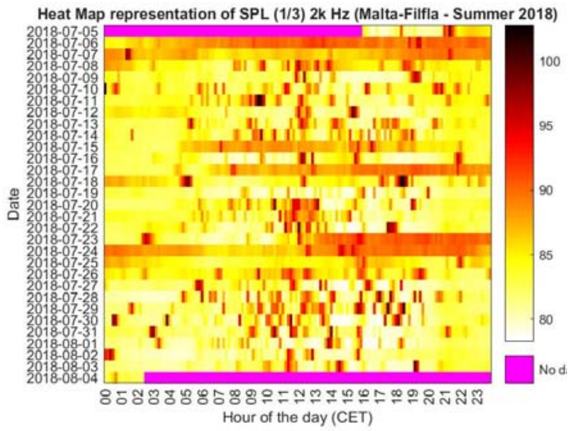
125 Hz (1/3 Octave)

Heat map scale in SPL $_{1/3}$ [db re 1 uPa]



2k Hz (1/3 Octave)

Heat map scale in SPL $_{1/3}$ [db re 1 uPa]



5k Hz (1/3 Octave)

Heat map scale in SPL $_{1/3}$ [db re 1 uPa]

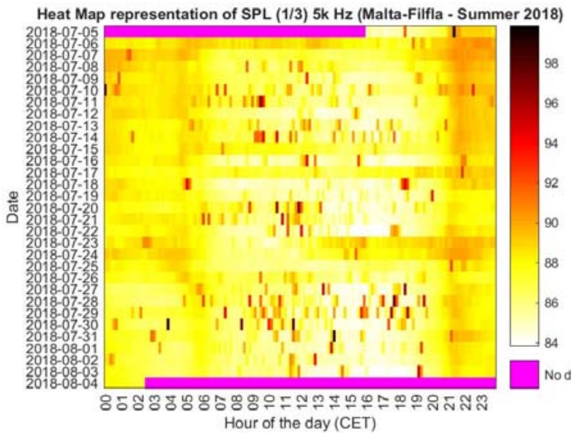


Figure 65: Filfla Heat map representation of the SPL1/3 at 63 Hz, 125 Hz, 2 kHz and 5 kHz for all days Each pixel gives an averaged ambient noise indicator in a 30 seconds interval.

Another perspective to the heat map, i.e. it is using the same for ambient noise (1/3 octave indicators) for the 63 Hz, and 125 Hz bands data source, is a box plot representation where daily average and spread, excluding outliers, are placed adjacent to each other on weekly basis. This was possible for the data extracted from the Maltese deployments and for the lower bands. Figure 66 and Figure 67 are for the Gozo deployment whilst Figure 68 and Figure 69 are for the Filfla deployment.

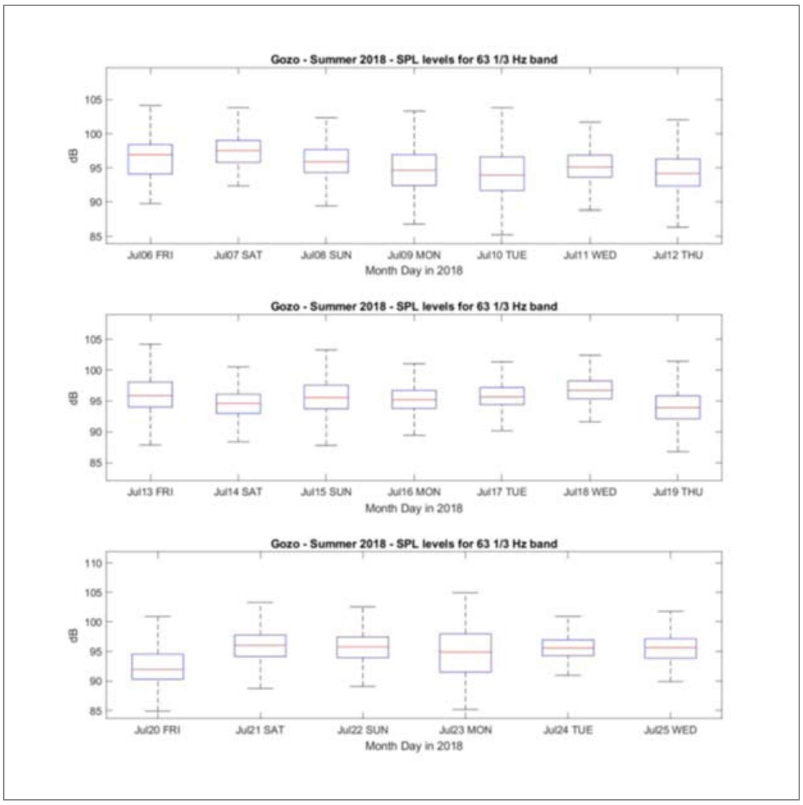


Figure 66: Gozo: 63 Hz 1/3 octave ambient noise (SPL [dB re 1uPa])

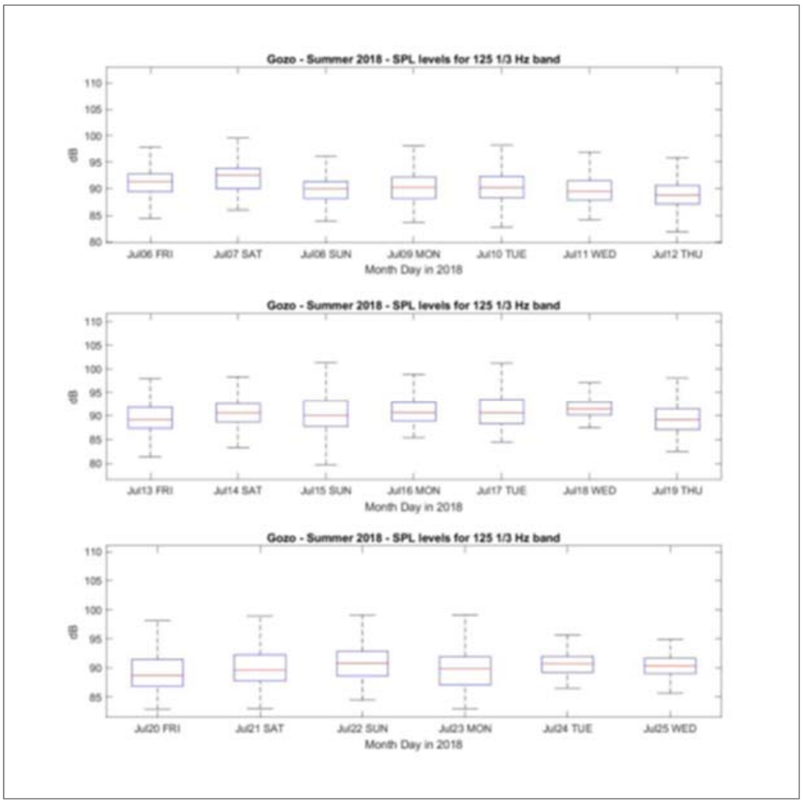


Figure 67: Gozo: 125 Hz 1/3 octave ambient noise (SPL [dB re 1uPa])

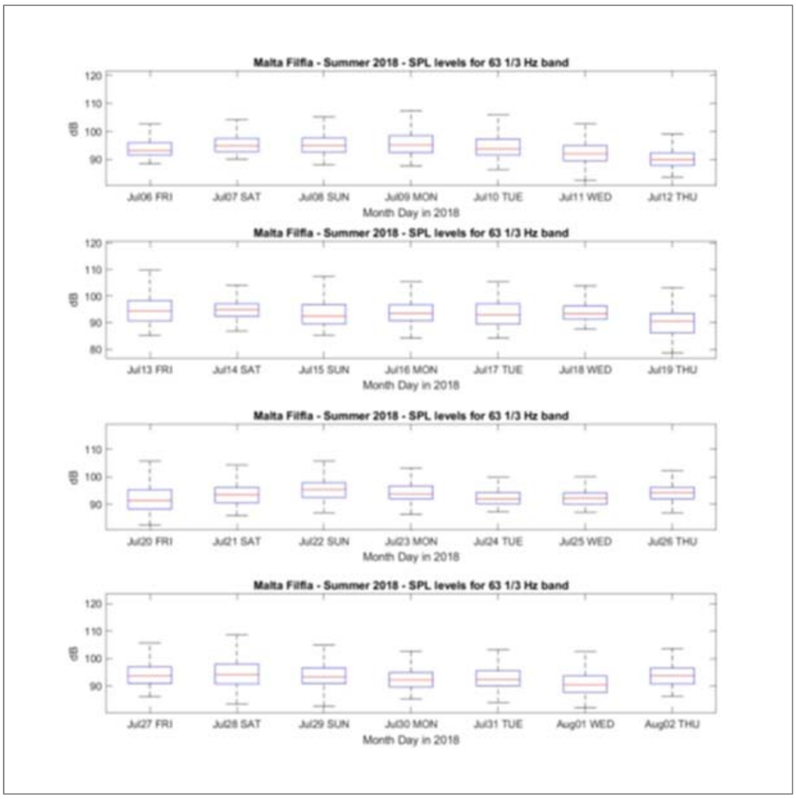


Figure 68: Filfla, Malta: 63 Hz 1/3 octave ambient noise (SPL [dB re 1uPa])

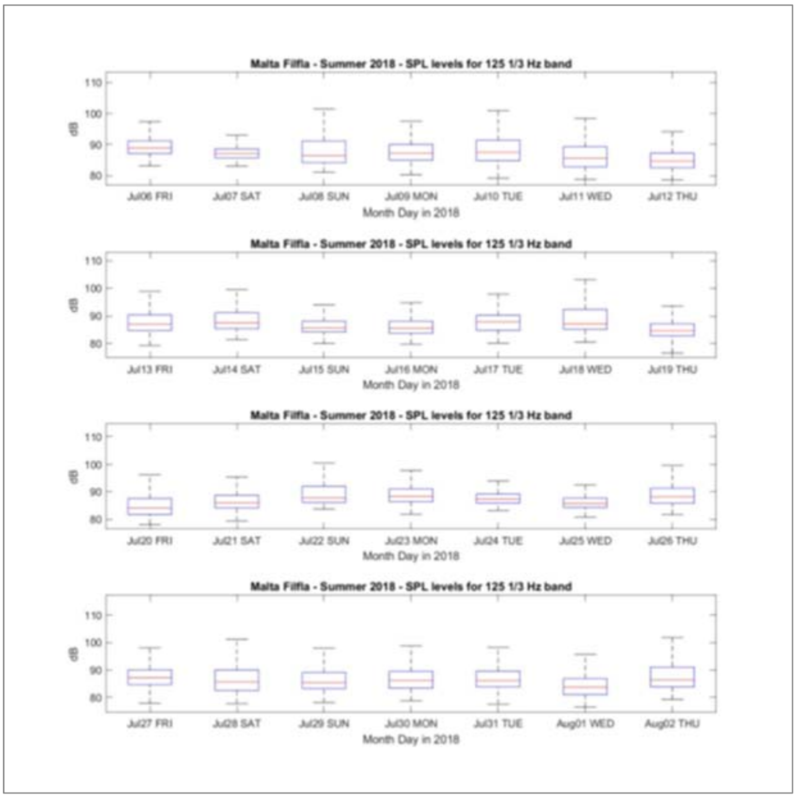


Figure 69: Filfla, Malta: 125 Hz 1/3 octave ambient noise (SPL [dB re 1uPa])

7 Conclusions

During the deployment of this work package it was amply clear on how important planning, as per MSFD requirements, is for capturing data that enables relative extraction of sound levels to build an acoustic profile for the Mediterranean Sea. These requirements determine the choice of equipment and its calibrations, site selections, set-up and duty cycle whilst in deployment, and pre-processing and post-processing data analysis. This report also highlights why, when and how other data is required to supplement the recorded underwater acoustics at the selected sites.

In summary, three regional sites across the Mediterranean Sea have been selected and various deployments have been executed. In each site, although some activities were common, e.g. post processing of data, there is a marked variety in methods and procedures between the three partners. None the less, because of the requirement's being set early and meet during the pilot project execution, this heterogeneity in equipment, location, anthropogenic activities and some procedures, it was shown that it is possible to meet aspects of the MSFD and extract a noise profile for each participating region.

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