METHODOLOGICAL GUIDE V3.1:
GUIDANCE ON UNDERWATER NOISE MITIGATION MEASURES

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INTRODUCTION

Underwater noise is recognised as a threat for marine wildlife and the conservation of endangered species. The ACCOBAMS Agreement has addressed the impact of underwater noise on cetacean species through a varied range of actions:

- Resolution 2.16 (2004), 3.10 (2007), 4.17 (2010), 5.13 (2013), 6.17 (2016), 7. 13 (2019): juridical tools promoting the adoption and the dissemination of mitigation measures to stakeholders of each Contracting Party
- Recommendations from the Scientific Committee identifying scientific priorities as well as proposing science-based conservation measures
- Scientific studies aimed at increasing our understanding of the noise issue

This document is a guide to the implementation of operational measures to mitigate the impact of underwater noise generated by human activities at sea. It is intended to be used by industry, scientists, regulators, technicians and other stakeholders involved in the environmental management of such activities.

The first guide was released in 2013, and reviews were issued in 2016 and 2019. This new version includes the following updates:

- An Annex with Deckforms for Marine Mammal Observers and Passive Acoustic Monitoring operators onboard seismic vessels
- Updates on technologies and mitigation procedures

The global scheme for mitigating the impact of underwater noise (upstream considerations, mitigation during works, downstream tasks) appears to have consolidated in recent years and latest reviews present comparable protocols and procedures than presented here (see for example HELCOM 2016). It is foreseeable than future updates of this guide will mainly concern new available technologies as well as adjustments to mitigation procedures for impulsive noise emissions.

Conscious that the measures contained in this document may represent operational constraints, these should not limit their use and solutions should be found to meet cetacean protection targets

This version of the guide addresses both continuous and impulsive noise sources as these are equally concerning with regards to marine life.

The guide is thought to outline practices and technologies that should be used during, instead, or in addition to conventional techniques producing underwater noise, with the aim of reducing the acoustic impact of human activities at sea. References are also included for those technologies which are deemed likely to become increasingly used (and market available) in the next future.

ACCOBAMS




ACCOBAMS Methodological Guide:

Guidance on underwater noise mitigation measures

V. 3.1.

This work was done thanks to the coordination of the ACCOBAMS Secretariat, with the financial support of the Principality of Monaco

Gouvernement Princier
PRINCIPAUTÉ DE MONACO

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This document is an update of previous versions that were developed thanks to the contributions of further members of the Joint ACCOBAMS/ASCOBANS/CMS Noise Working Group and its Industry Advisory Group, as well as the Ecole Polytechnique de Paris.

CONTENT

1. FOREWORD

Underwater noise is recognised as a threat for marine wildlife and the conservation of endangered species. The ACCOBAMS Agreement has addressed the impact of underwater noise on cetacean species through a varied range of actions:

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Photos:

Unsplash.com (cover)
Pexels.com (cover)
BOEM
Bill Hall/Caltrans
Stefan Nehring
Patrice Kunte
Trianel GmbH/Lang
Kurt Thomsen

2. BACKGROUND

For the purpose of this guide, *noise* can be defined as sound that causes negative effects. Recalling also the work carried out for the implementation of the Marine Strategy Framework Directive of the European Union, noise can be classified in two categories:

- Impulsive noise, defined as a sound emitted by a point source comprising one or more pulses of short duration and with long gaps between these pulses[1]

According to the European Commission, sources of impulsive underwater noise of major concern are the following:

- Seismic surveys (airguns)
- Offshore construction (pile driving)
- Military Sonar
- Use or disposal of explosives

- Continuous noise, meaning sound generated continuously by some anthropogenic source. In this case, shipping is considered the main contributor to the rising of ocean ambient noise.

This version of the guide addresses both continuous and impulsive noise sources as these are equally concerning with regards to marine life.

The guide is thought to outline practices and technologies that should be used during, instead, or in addition to conventional techniques producing underwater noise, with the aim of reducing the acoustic impact of human activities at sea. References are also included for those technologies which are deemed likely to become increasingly used (and market available) in the next future.

Further, this guide reviews information on areas where spatial mitigation measures should be applied in the Mediterranean and Black Seas, i.e. areas where activities having an acoustic impact on cetaceans should be avoided as far as possible.

[1] A deeper insight of how an impulsive sound is defined, and especially what is considered to be a *short pulse* and a *long gap*, is given in the report of the TSG Noise (Van der Graaf and al 2012)

3. IMPACT OF IMPULSIVE UNDERWATER NOISE

Impulsive noise may cause negative effects of different magnitude, according to the characteristics of the noise emissions. The following table gives an indicative view about the impacts caused in both individuals/groups and populations. It has been derived from the work done within the Convention of Biological Diversity (CBD 2012), the *Service Hydrographique et Océanographique de la Marine* (Stéphan and al. 2012) and early work of TG Noise (Van der Graaf and al. 2012).

However, this table represent an important simplification of a highly more complex situation. Reaction of marine mammals to noise depends on such factors as species, individual, age, sex, prior experience with noise and behavioural state. Observed reactions to noise in marine mammals could theoretically result in impacts such as decreased foraging efficiency, higher energetic demands, less group cohesion, higher predation, decreased reproduction, and thus seriously impact the population. Moreover, repeated exposures to impulsive noise may lead animals to abandon an area, an effect considered as habitat loss due to acoustic disturbance (Brandt et al., 2018; Graham et al., 2019 and Thompson et al., 2013) which may correspond to a reduction in the carrying capacity of an environment and hence a decline in the population size in the long term (Tougaard et al 2013). On the other hand, injuries or deaths of animals may not have an impact on the population if there are few relative to the size of the population (Weilgart 2007).

EFFECT TYPE	IMPACT ON INDIVIDUALS AND GROUPS	POTENTIAL IMPACT ON POPULATIONS
NONE	Perturbation under ambient noise level or under detection threshold of species	None
	Perturbations are detected but individuals/groups show no reactions	None
BEHAVIOURAL	Perturbations are detected and animals show slight response	Low
	Individuals modify their behaviour but normal activities are not affected	Low
	Individuals modify their behaviour and stop their normal activities	Medium
PHYSIOLOGICAL	Hearing is temporarily altered	Medium/High
	Hearing is permanently damaged	High
	Tissue damages, haemorrhages	Very high
	Injuries leading directly to animal death	Very high

4. IMPACT OF CONTINUOUS UNDERWATER NOISE

A significant portion of the continuous underwater noise generated by human activity is produced by commercial shipping (Hildebrand, 2009). The IMO recognizes that underwater-radiated noise from commercial ships may have both short and long-term negative consequences on marine life, especially marine mammals (IMO 2014). As shown is the example hereafter (Figure 1), multiple continuous noise sources (ships) create sound fields propagating for tens to hundreds of km, overlapping each other, and finally resulting in diffused increase of ambient noise levels. This increase represents a modification of the natural acoustic conditions of cetacean habitats.

It is worth noting that for a broad range of marine mammals, masking effects (on communication, navigation, prey/predator detection etc.), caused by rising continuous noise levels are likely to have an increasingly prevalent impact on a longer term (Pavan 2010). In the worst cases, the predicted decreased communication range for baleen whales is in the order of hundreds to thousands of km, owing to increases in ambient noise due to shipping (Okeanos Foundation 2008).

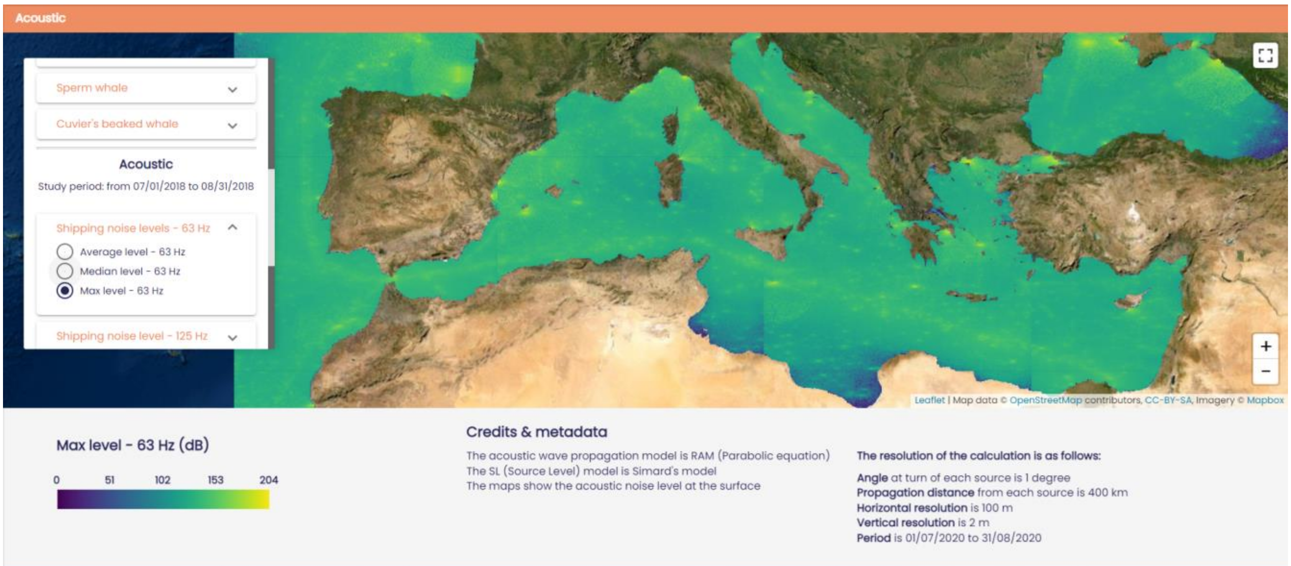


Figure 1. Shipping noise in the Black Sea, the Mediterranean Sea and the contiguous Atlantic area. Map available in the NETCCOBAMS platform.

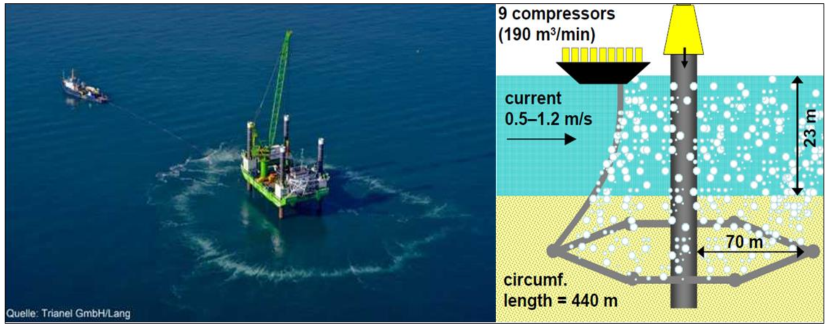
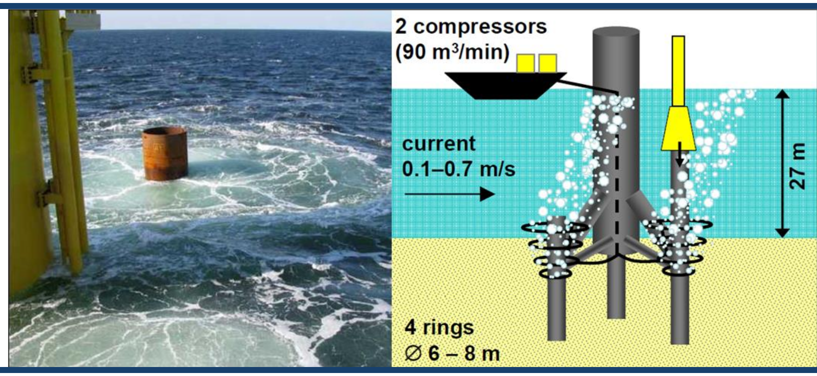
5. TERMS & DEFINITIONS

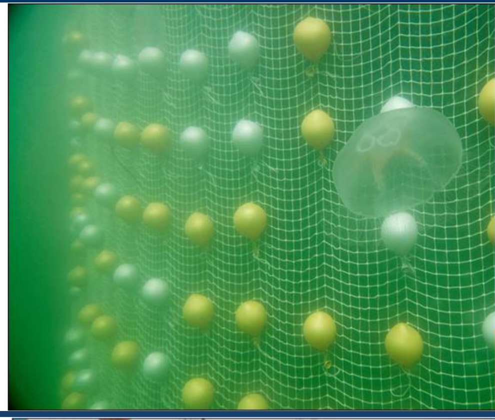
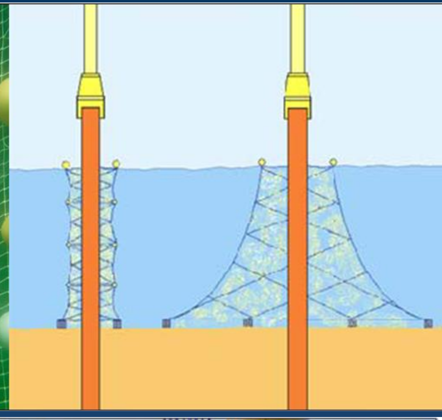
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and the contiguous Atlantic area
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
AMD	Acoustic Mitigation Devices. This terminology is employed to include all devices which use acoustics as a means of mitigating interactions between cetaceans and human activities. Usually AMDs encompass Acoustic Deterrent Devices (ADD), developed for cetaceans, and Acoustic Harassment Devices (AHD), conceived for seals.
EIA	Environmental Impact Assessment.
EcAp	Ecosystem Approach process in the Mediterranean Sea.
EZ	The Exclusion Zone is defined as the area within which no animals must be present during noise emissions. An individual or a group entering this zone trigger the application of mitigation procedures/practices. The extent of the EZ should be determined on the basis of a scientific approach, i.e. by means of sound propagation modelling verified in the field. The limit of the EZ should be set following existing science on safe/harmful exposure criteria. However, such criteria are controversial and hence a precautionary approach should can be employed.
IMO	International Maritime Organization
LFAS/MFAS	Low- and Mid-Frequency Active Sonar employed during military exercises
LACS	Low level Acoustic Combustion Source. A proposed alternative to the seismic airgun. More details are provided in the section *ALTERNATIVE TECHNOLOGIES*.
MMO	Marine Mammal Observers are experienced observers employed to visually detect the presence of marine mammals within a defined zone. Animals can be spotted by the naked eye or by means of appropriate binoculars
MSFD	Marine Strategy Framework Directive of the European Union aims to achieve Good Environmental Status (GES)
MV	Marine Vibroseis. Vibroseismic source employed thus far for inland seismic exploration. Extension of this technology to maritime exploration is underway. More details are given in the section *ALTERNATIVE TECHNOLOGIES*;
PAM	Passive Acoustic Monitoring signifies the activity of recording continuous underwater sound by means of hydrophones. Several configurations exist to set up a PAM system. Marine mammal detection by means of towed PAM systems (as used by PAM operators during seismic exploration) is only one of the possible ways of PAM monitoring.
SEL	Sound Exposure Level. It is a measure of the accumulated sound energy over a defined period of time.
SPL	Sound Pressure Level. It is a measure of the pressure of a sound.
TG-Noise	Technical Groupe on Underwater Noise of the European Commission. This group addresses the implementation of the Descriptor 11 of the MSFD

6. NOISE MITIGATION FRAMEWORKS

6.1 NOISE MITIGATION TECHNOLOGIES RELATED TO IMPULSIVE NOISE

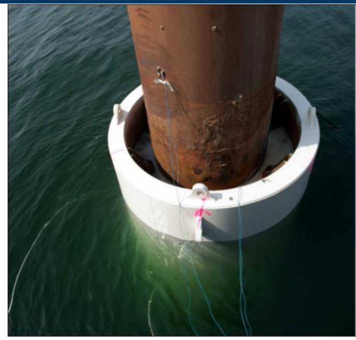
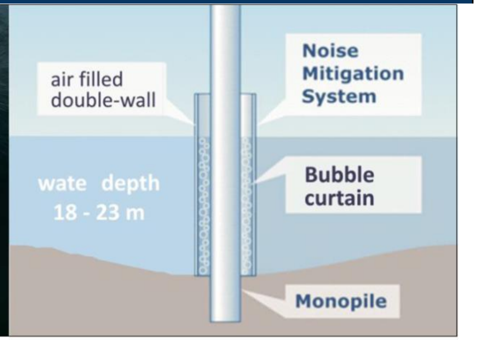
The following mitigation technologies apply to common construction techniques used in shallow waters that generate loud impulsive noise emissions underwater. Deep waters construction techniques (e.g., deep water drilling for oil and gas extraction, deep water piling, etc.) have different constraints and operational limits that require adaptations of current solutions frow shallow waters or development of new ones that fit these challenging environments. Values presented in the table are broadband and come from experiences carried out to reduce impact piling noise in shallow waters. Differences in the pile diameter and hammer size for each experience do not allow a direct comparison of the noise reduction efficiency between techniques.

MITIGATION TECHNOLOGY	NOISE REDUCTION	APPLICATION	OVERVIEW
Big Air Bubble Curtain (BBC) A hose with drilled holes, supplied with compressed air, placed on the sea bed. The air escaping from the holes forms the bubble screen. (Photo : Trianel GmbH/Lang / Reference: Verfuß 2012, Koschinski & Lüdemann 2013, Bellmann 2014, Merck & Werner 2014, Andersson and al. 2016)	Single bubble curtain : - 12 dB (SEL), 14 dB (peak) - 11 dB (SEL), 15 dB (peak) - 10 – 15 dB (SEL) Double bubble curtain : - 17 dB (SEL), 21 dB (peak) - 15 – 18 dB (SEL)	Pile driving Drillng Dredging Detonations Shallow waters	
Small Air Bubble Curtain (SBC) A small bubble curtain can be customized and placed much closer to the noise source than the big bubble curtain. It may consist of a rigid frame placed around the source. Several configurations are possible. (Reference: Verfuß 2012, Koschinski & Lüdemann 2013, Bellmann 2014, Merck & Werner 2014, Andersson and al. 2016)	Several tests : - 12 dB (SEL), 14 dB (peak) - 11-13 dB (SEL) - 4-5 dB (SEL) - 14 dB (SEL), 20 dB (peak)	Pile driving Drilling Shallow waters	

MITIGATION TECHNOLOGY	NOISE REDUCTION	APPLICATION	OVERVIEW
Hydro Sound Damper (HSD) This technology consists of fishing nets with small balloon filled with gas and foam - tuned to resonant frequencies- fixed to it. It can be applied in different ways. Photo: Patrice Kunte / Reference: Verfuß 2012, Koschinski & Lüdemann 2013, Bellmann 2014, Merck & Werner 2014, Andersson and al. 2016)	4 - 14 dB (SEL) 8 – 13 dB (SEL)	Pile driving Drillng Dredging Detonations Shallow waters	 
Cofferdam The cofferdam consists of a rigid steel tube surrounding the pile. Once the pile is stabbed into the cofferdam, the water is pumped out (Photos: Kurt Thomsen / Reference: Verfuß 2012, Koschinski & Lüdemann 2013, Bellmann 2014, Merck & Werner 2014, Andersson and al. 2016)	up to 22 dB (SEL) and 18 dB (Peak) 10 – 20 dB (SEL)	Pile driving Drilling Shallow waters	 

<table>
<tr><th>MITIGATION TECHNOLOGY</th><th>NOISE REDUCTION</th><th>APPLICATION</th><th>OVERVIEW</th></tr>
<tr><td>IHC Noise Mitigation System
The IHC-NMS is a double layered screen, filled with air. Between the pile and screen there is a multi level and multi size bubble injection system.

(Photo : Patrice Kunte / Reference: Verfuß 2012, Koschinski & Lüdemann 2013, Bellmann 2014, Merck & Werner 2014, Andersson and al. 2016)</td><td>5 – 20 dB (SEL)
10 – 14 dB (SEL)</td><td>Pile driving
Drilling

Shallow waters</td><td>



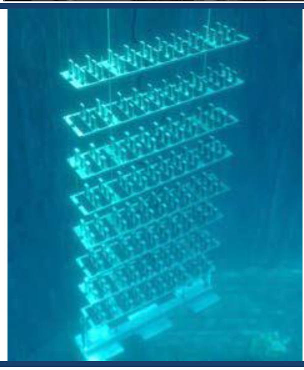
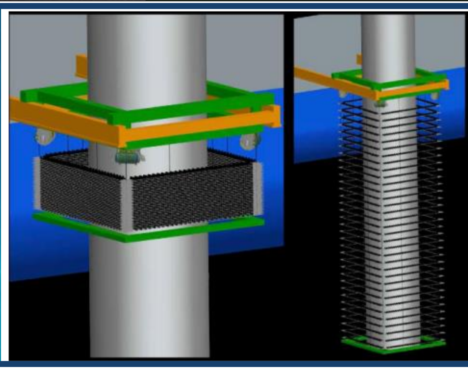
</td></tr>
<tr><td>BEKA_shells
- Double steel wall with polymer filling
- Inner and outer bubble curtain
- Acoustic decoupling (vibration absorber)

(Photos: Patrice Kunte / Reference: Verfuß & Jülich 2012, Koschinski & Lüdemann 2013, Merck & Werner 2014)</td><td>6-8 dB (SEL)</td><td>Pile driving
Drilling

Shallow waters</td><td>

</td></tr>
<tr><td>Tuneable resonator system
This noise abatement system, inspired from Helmholtz resonators, uses a simple collapsible framework containing arrays of acoustic resonators with two fluids (air and water).

(Photos & Reference: Wochner and al. 2016)</td><td>>20 dB in the 20 Hz to 20 kHz band</td><td>Pile driving
Drilling
(Some) seismic sources

Shallow waters</td><td>


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6.2 ALTERNATIVE, LOW-NOISE CONSTRUCTION TECHNIQUES

ALTERNATIVE TECHNOLOGIES	EMISSIONS	APPLICATION	REFERENCES/COMMENTS	Market Availability
Drilled foundation Drilling can be done within a concrete pile. The drill head can be placed outside the pile if there is resistance. The pile will sink within the drilled hole	No information available	Replace pile driving for any application	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)	Yes
Vibro-drilling. Vibro-drilling combines a vibrator tandem PVE and a drill head in one unit. The pile is driven into the sea floor by vibrating. Drilling is applied when there is resistance with vibrating	Less than 130 dB re 1 µPa at 750 m expected (not measured yet)	Replace pile driving for any application	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)	Yes
Concrete Gravity Foundations. These structures are reinforced, self-buoyant concrete structures. They are towed to a site and directly placed to the seabed.	No emissions	Replace pile driving for any application	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)	Yes
Bucket foundation. A bucket foundation is a large steel caisson which is founded in the seabed by suction pumps. The water is pumped out of the cavity underneath the caisson. The vacuum in combination with the hydrostatic pressure makes the caisson penetrate into the seabed up to its final depth	Very low noise expected (not measured yet)	Replace pile driving for any application	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)	Yes
Marine Vibroseis (MV). Hydraulic and electromechanical MVs can be towed in the same configuration as airgun arrays or operated in a stationary mode much like land vibrators; MV's will have lower source signal rise times, lower peak pressures, and less energy above 100 Hz	Source Level : 203 dB re 1µPa; 6-100 Hz	Complement or replace airguns	System from Geokinetics licenced for shallow water available mid 2014 (CSA Ocean Sciences Inc. 2013, Weilgart 2013, Castellote, pers. comm.)	Within the decade
Other alternative technologies are being developed or are already available in the market (vibropiling, floating wind turbine, etc.).			More information on Merck & Werner 2014	

6.3 MITIGATION PROCEDURES DURING IMPULSIVE NOISE EMISSIONS

6.3.1 Use of Acoustic Mitigation Devices (AMD)

- Prior to the beginning of the emissions, AMD should be used to drive away groups or individuals of marine mammals
- Only AMDs allowed in the ACCOBAMS area are to be employed (see ACCOBAMS Resolution 4.9, 2010 for cetacean devices)
- The duration of use of AMDs should not be less than 10 min.

6.3.2 Soft start protocol

- Noise emissions should begin at low power, increasing in equal steps until full power is reached
- The soft start procedure should be of 15 min duration at least
- After 10 minutes of inactivity of sound source a soft start should occur before recommencing operations.

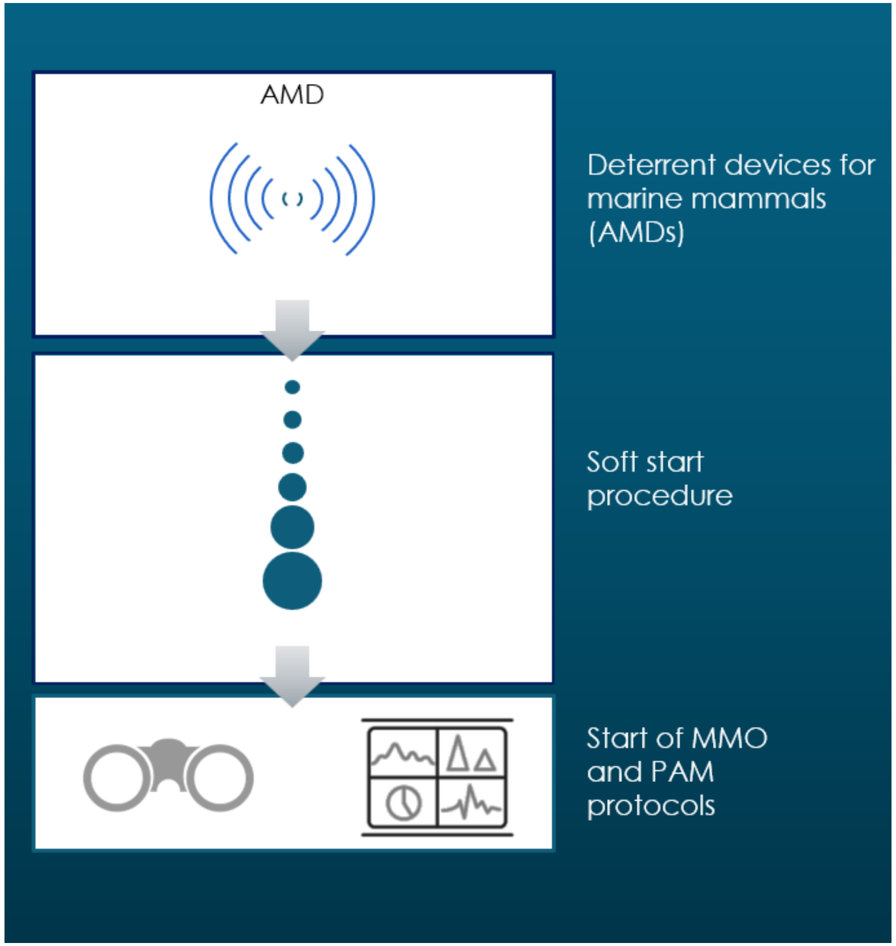


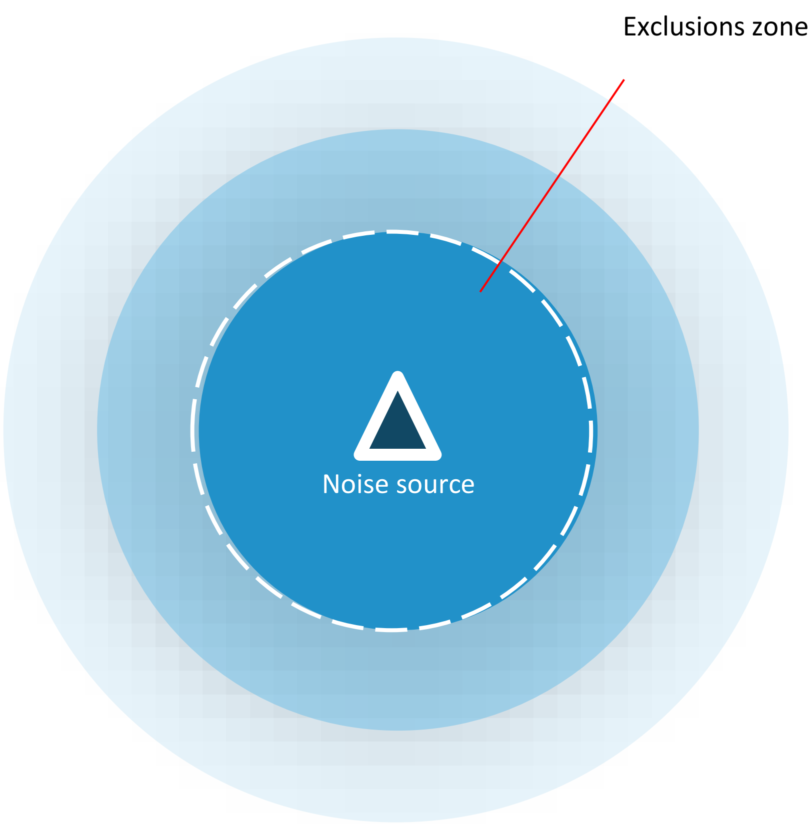
Figure 2. Sequence of mitigation practices for impulsive noise emissions.

6.3.3 Marine Mammal Observation protocol

- Dedicated and independent Marine Mammal Observers (MMO) should watch the Exclusion Zone (EZ) for 30 min before the beginning the soft start procedure (120 min for highly sensitive species).
- The soft start procedure should be delayed if cetaceans enter the EZ
- Continuous watch should be kept for the entire duration of noise emission
- The activity should be stopped (or powered down) if cetaceans enter the EZ
- In case of a halt in noise, a new 30 min watch should be kept without animals in the EZ before re-starting noise emissions (120 min for highly sensitive species)
- In the case of endangered species anywhere in the monitoring area shutdown of operations should occur.

6.3.4 Passive Acoustic Monitoring protocol

- Acoustic monitoring should be used to alert the observers (MMO) to the presence of cetaceans
- Continuous acoustic monitoring should be performed for the entire duration of the noise emission
- If activities are carried out at night or during bad weather conditions, acoustic monitoring is to be used as the main monitoring tool
- In such conditions, noise emissions should be stopped, or powered down, if acoustic detections of cetaceans occur.
- If PAM system fails then it must be restored in 30 minutes or survey operations should halt. A spare PAM system should be readily available to replace the system (or component) that failed.



6.4 MMO & PAM OPERATORS, EQUIPMENT AND TASKS

6.4.1 For Marine Mammal Observers

- MMO personnel should have completed a training under the ACCOBAMS *Highly Qualified MMO/PAM Certification*[2] and being experienced in the identification of species living in the ACCOBAMS Area.
- The number of MMOs employed in mitigation should be adequate to the specific conditions of the operation:
  - For seismic surveys, at least three MMOs should be aboard seismic vessels , observing the survey zone continuously. Shifts should never exceed 2 hours and MMOs must be able to rest between shifts.
  - For operations requiring the use of explosives, pile driving, and other activities generating loud impulsive noise signals underwater, the Risk Assessment and/or Impact Assessment documents are consulted to adjust the number of MMOs to the sensitivity of the area and species. When such documents are incomplete or not sufficiently developed, the same rules than for seismic surveys apply with regards to the number of MMOs to be employed.
- MMOs should be equipped with reticule binoculars (rangefinder) and a standard “Cetacean Sighting Form" made available by ACCOBAMS (Annexed to this document)

Three tasks have to be systematically fulfilled:

- Implementing mitigation procedures whenever necessary (e.g., soft start, shut down, etc.).
- Collecting abundance, distribution and behavioural data throughout the operation.
- Reporting, at the end of the operation.

6.4.2 For Passive Acoustic Monitoring operators

- PAM personnel should have completed a training under the ACCOBAMS *Highly Qualified MMO/PAM Certification*[2] and be experienced bio-acousticians, familiar with the vocalisations of cetaceans of the ACCOBAMS Area.
- At least 1 operator should be in the PAM position during night and bad weather conditions. Likewise MMOs, operators in the PAM position should be able to shift every two hours. This may require either dedicated PAM operators or MMOs with double skills
- PAM equipment should detect and localise cetaceans. The capability of transmitting in real-time the recordings is also a crucial need. Market-available instruments can meet these needs and the list is continuously evolving due to fast technological developments. No specific guidance about hardware is given as any recommendation may quickly become obsolete.
- With regards to software, PAMGuard is a proven software that is suggested here because it is an industry standard tool which is open source and easily downloadable for free[3]. Also, it is foreseeable that PAMGuard will remain a widely used and supported software in the coming years. Further PAM software exist although more complex to obtain and use. Such software can be obviously used provided the performance is demonstrated (e.g. when supported by scientific publications).

[2] https://accobams.org/main-activites/mmo-certificate-school/

[3] http://www.pamguard.org/

7. MITIGATE THE ACOUSTIC IMPACT OF MAN-MADE IMPULSIVE NOISE

7.1 PILE DRIVING/DRILLING/DREDGING

Bill Hall, Caltrans

Pile driving is a conventional technique employed in many coastal and offshore constructions, such as wind farms, offshore platforms, harbour extensions etc. The growth of the wind energy sector caused a great increase in the use of this technique both in coastal and offshore environments. Other sources, like drilling and dredging, may be cause for concern, although these techniques are not as intense as impact pile driving.

Source level	*228 dB re 1µPa m (Peak) or*
	243 – 257 dB re 1µPa m (P-to-P)
Bandwidth	*20 Hz – 20 kHz*
Major amplitude	*100 Hz – 500 Hz*
Duration	*50 ms*
Directionality	*Omnidirectional*

ref: CEDA 2011; OSPAR 2009

Conventional impact pile driving should be avoided, as far as possible, in areas of importance for cetaceans (maps shown in pages 24-25 and 28)

	Mitigation Framework for pile driving, drilling and dredging
Planning phase (expected outcomes of the EIA)	1. Review the presence of cetaceans in the candidate periods for the works and carry out or fund research where the information is non-existent or inadequate 2. Select periods with low biological sensitivity 3. Use sound propagation modelling results, verified in the field, to define the extension of the exclusion area (EZ) 4. Plan the lowest practicable source power 5. Consider alternative technologies (p. 13) 6. Plan Noise Mitigation Technologies in case no alternatives are possible (p. 10-11-12)
Real-time mitigation practices (p. 14)	1. Use Acoustic Mitigation Devices prior to the beginning of the work 2. Use the soft start protocol 3. Use the visual monitoring protocol* 4. Use the acoustic monitoring protocol*
Post-activity	1. Detailed reporting of real-time mitigation**

** PAM and MMO equipment (p. 15)*
****** Detailed reports of the mitigation activity should follow a standard form made available by ACCOBAMS*

7.2 SEISMIC SURVEYS

The airgun is presently the most employed technology for carrying out marine seismic exploration. Such surveys are pervasive worldwide, in shallow and deep water as well as in coastal or offshore environments.

Source level* *220 – 262 dB re 1µPa m (P-to-P)*
Bandwidth *5 Hz – 100 kHz*
Major amplitude *10 Hz – 120 Hz*
Duration *10 – 100 ms*
Directionality *Downwards*

ref: CEDA 2011; OSPAR 2009

Airgun use should be avoided, as far as possible, in areas of importance for cetaceans (maps shown in pages 24-25 and

Mitigation Framework for seismic surveys	
Planning phase (expected outcomes of an EIA)	1. Consider the adoption of alternative technologies (p. 13) 2. Review the presence of cetaceans in the candidate periods for the survey and carry out or fund research where the information is non-existent or inadequate 3. Define no-survey zones (biological reserves, especially protected areas etc.) 4. Select periods with low biological sensitivity 5. Use sound propagation modelling to define the extent of the exclusion area (EZ)
Real-time mitigation practices (p. 14)	1. Use the visual monitoring protocol* 2. Use the acoustic monitoring protocol* 3. Use the soft start protocol
Post-activity	1. Detailed reporting of real-time mitigation**

** PAM and MMO equipment (p. 15)*
*** Detailed reports of the mitigation activity should follow a standard form made available by ACCOBAMS*

Specificities of soft start for Seismic Surveys:

- The soft start procedure should be of 15 min duration at least and 20 minutes minimum for airgun arrays of more than 8 airguns.
- Single airgun testing and surveys do not require a soft start
- Soft start steps should be as much as possible in equal increases of sound pressure (6dB is a doubling of sound pressure). This can be achieved by doubling the number of sound sources (airguns) on each step. Therefore 1 to 2 to 4 to 8 airguns and so on until the entire array is active. This follows the basic principles of sound sources giving approximately 6dB sound pressure increases.
- Once soft start is complete, data acquisition (first good shot point) should occur within a maximum of 20 minutes.

INFRARED CAMERAS

Infrared (IR) cameras are becoming a mature technology able to enhance mitigation effectiveness of visual monitoring protocols. IR cameras can detect by temperature contrast whale blows as well as the surfacing portion of the body of several marine mammals (including pinnipeds). The use of this technology makes it possible to carry out visual monitoring at night, and can be a remarkable support for MMOs, particularly for the monitoring of the Exclusion Zone. Currently, marketed solutions only apply for cold water environments (polar-subpolar) but technological progress will probably achieve a wider use of IR cameras even for temperate regions as the Mediterranean (Weissenberger & Zitterbart 2012, Zitterbart and al. 2013, Boebel & Zitterbart 2014).

Source: Graber and al. 2010 / Baldacci and al. 2005

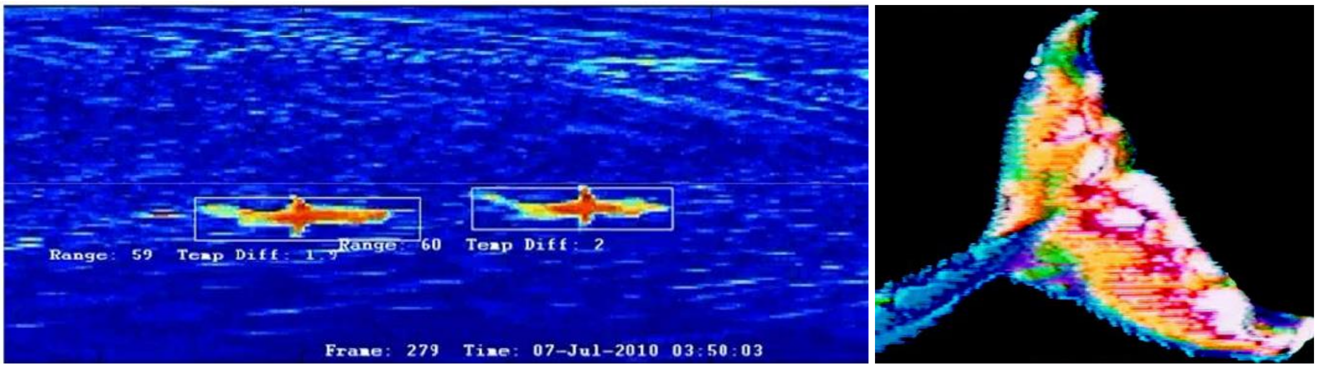


Figure 3. Exemple of the use of the infrared camera for cetacean monitoring.

In study reports from Graber and al. 2010, infrared observations are predicted to provide a 74% increase in hours of possible detection compared with visual observations. However, subjects (whale fins) are very large and thus create an easier target for infrared than other species. Moreover, detections are limited to surfacing animals only because of water is non transparent to thermal radiation (Baldacci and al. 2005). This same study reported how performance of the IR system was strongly affected by weather conditions and sea state that it was practically useless in rain, fog or haze, high humidity and increasing sea states. Nevertheless, IR systems are capable of seeing at night and remain one of the few night-time mitigation systems, in addition to radar and acoustics.

More information concerning IR real-time detection can be found here: http://www.rheinmetall-defence.com/en/rheinmetall_defence/systems_and_products/c4i_systems/reconnaissance_and_sensor_systems/automatic_marine_mammal_mitigation/index.php

7.3 EXPLOSIVE USE

Underwater detonations may occur for the disposal of explosives or may be planned during maritime construction, e.g. to fragment rock prior to dredging. This is the loudest source of underwater noise and need to be treated with particular care.

Underwater detonations should be avoided, as far as possible, in areas of importance for cetaceans (maps shown in pages 24-25 and 28).

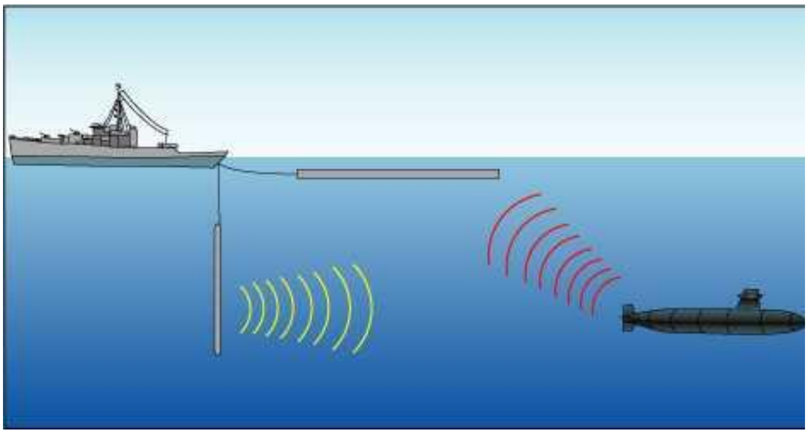
Source level (0.5 – 50 kg)	*272 - 287 dB re 1µPa m (Peak)*
Bandwidth	*2 Hz – 1 kHz*
Major amplitude	*6 Hz – 21 Hz*
Duration	*1 – 10 ms*
Directionality	*Omnidirectional*

ref: CEDA 2011; OSPAR 2009

Mitigation Framework for use or disposal of explosives	
Planning phase (expected outcomes of the EIA)	1. Review the presence of cetaceans in the candidate periods for the work and fund research if information is inadequate 2. Select periods with low biological sensitivity 3. Use sound propagation modelling results to define the extent of the exclusion area (EZ) 4. Plan the lowest practicable charge
Noise Mitigation Technologies	1. Use noise mitigation technologies: • Big Air Bubble Curtain (p. 10) • HydroSound Damper net (HSD-net, p. 11)
Real-time mitigation practices (p. 14)	1. Use Acoustic Mitigation Devices prior to the work 2. Use the soft start protocol (small charges prior to operational charges) 3. Use the visual monitoring protocol 4. Use the acoustic monitoring protocol
Post-activity	1. Detailed reporting of real-time mitigation*

** PAM and MMO equipment (p. 15)*
*** Detailed reports of the mitigation activity should follow a standard form made available by ACCOBAMS*

7.4 SONAR USE



Low-, mid- and high frequency active sonars (LFAS, MFAS, HFAS) are employed during military exercises as well as during academic and industrial surveys, such as fish stock estimations and bathymetric surveys. Especially, low- and mid-frequency naval sonars are of great concern given the mass stranding events of cetaceans linked in space and time with military exercises and need to be addressed with particular care

High-powered active sonar should should be avoided, as far as possible, in areas of importance for cetaceans (maps shown in pages 24-25 and 28).

	NAVAL SONAR	ACADEMIC and INDUSTRIAL SONAR
Source level	*235 dB re 1µPa m (Peak, LFAS)* *223 – 235 dB re 1µPa m (Peak, MFAS)*	*203 – 240 dB re 1µPa m (rms)*
Bandwidth	*100 Hz – 500 Hz (LFAS)* *2 kHz – 8 kHz (MFAS)*	*1 kHz – 400 kHz*
Major amplitude	*3.5 kHz (MFAS)*	*Various*
Duration	*6s – 100s (LFAS)* *0.5s – 2s (MFAS)*	*0.2 ms – 100 ms*
Directionality	*Horizontally focused*	*Depends on sonar type*

ref: CEDA 2011; Lurton and Antoine 2007; OSPAR 2009

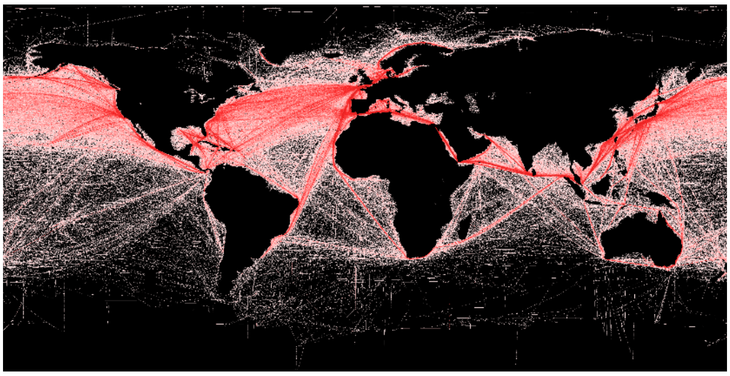
Mitigation framework for military and civil sonar use	
Planning phase (expected outcomes of an EIA)	1. Review the presence of cetaceans in the candidate periods for the survey/exercise and fund research if information is inadequate 2. Define no-exercise zones (biological reserves, especially protected areas etc.) 3. Define buffer zones 4. Select periods with low biological sensitivity 5. Use sound propagation modelling to define the extent of the exclusion area (EZ)
Real-time mitigation practices (p. 14)	1. Use the visual monitoring protocol* 2. Use the acoustic monitoring protocol* 3. Use the soft start protocol
Post-activity	1. Detailed reporting of real-time mitigation**

** PAM and MMO equipment (p. 15)*
*** Detailed reports of the mitigation activity should follow a standard form made available by ACCOBAMS*

8. MITIGATE THE IMPACT OF MAN-MADE CONTINUOUS NOISE

8.1 SHIPPING

Complete guidelines for minimizing underwater noise from commercial ships to address the adverse impacts of underwater noise on marine life are available (IMO/MEPC Circ. 833, more information in http://www.imo.org/). This section summarises main guidelines related noise radiated from ships.



Shipping noise should be controlled through appropriate management measures, as far as possible, in areas of importance for cetaceans (maps shown in pages 24-25 and 28).

Source level	*120 – 180 dB*
Bandwidth	*6 Hz – 30 000 Hz*
Major amplitude	*5 Hz - 1000 Hz*
Duration	*Continuous*
Directionality	*Omnidirectional*

ref: Wright 2008, Renilson 2009, Li and Hallander 2015

Mitigation tools for shipping (non exhaustive list) (adapted from IMO/MEPC Circ. 833 and Renilson Marine Consulting Pty Ltd 2009)	
Ship design	1. Low noise propeller: many models with higher efficiency or reducing cavitation on the blades 2. Minimized propeller/rudder interaction: twisted rudder, rudder fins, hull form… 3. Onboard machinery configuration: installation and proper location of equipment, foundation structures, type of propulsion, vibration isolation
Additional technologies for existing ships	1. Improving wake flow to reduce cavitation: Schneekluth duct, Mewis duct… 2. Changes or adds to hull form: curves fins attached (grothues spoilers), re-shaped nozzle, air injection to propeller
Operational and maintenance considerations	1. Cleaning propeller/hull and other conventional maintenance 2. Regulating ship speed. This is a critical issue as ship speed influence other issues: risk of whale-ship strikes; atmospheric gas emissions, fuel consumption, delivery time, navigation duration, etc.; the concept of *Smart Steaming* is being developed to address the trade-off among environmental and economic drivers 3. Rerouteing and other operational decisions

Details on Structural solutions and propeller noise and cavitation for shipping

Structural solutions	Noise reduction	Implementation
Structural damping The goal is to reduce the noise produced by the vibration of the structure of the ship, through a decrease in the amplitude of the resonances.	5-10 dB	Has to be implemented during the shipbuilding stage.
Increasing hull thickness Reduce sound transmission by increasing the spacing between stiffeners.	Up to 10 dB in the 100 Hz-5 kHz range	Has to be implemented during the shipbuilding stage.
Use of lightweight materials like FRP (Fiber Reinforced Plastic) - Lighter ship, requiring less power and creating less noise - Higher internal damping than steel - Non-magnetic properties - Can however exhibit larger vibration levels	Up to 50% weight reduction of the ship	At the shipbuilding stage. Not used in vessels larger than 50m because of the lack of tools and methods

Propeller noise and cavitation	Noise reduction	Implementation
Propeller repair or maintenance Little imperfections can reduce ship efficiency and increase the noise impact.	Increase the efficiency of a propeller by 2%	Easy to implement, during routine dry dockings in order to reduce costs
Propeller modification or change Propellers are often designed for fixed navigation conditions: full load condition, wake distribution… which don't match with reality. After several years of navigation, we can better know how to design an optimal propeller for the ship.	Noise will be reduced by reducing the ship power necessary to reach a certain speed.	Propeller replacement in one week dry docking.
High skew propellers Reduction of propeller induced vibration	Used in warships and in high powered merchant ships.	Easy to implement, during routine dry dockings in order to reduce costs.
Schneekluth duct device installed on the hull of the ship in order to improve the flow on the upper part of the propeller and decrease cavitation	Reduction of vibrations up to 50%. Propulsion efficiency up to 4%.	Easy to implement, during routine dry dockings in order to reduce costs.
Becker Mewis Duct A duct positioned in front of the propeller along with an integrated fin system	Energy saving up to 8%	Easy to implement, during routine dry dockings in order to reduce costs.
Propeller boss cap fins improves the propeller performance characteristics via minimising the hub vortex and resultant rudder cavitation.	3-5% reduction in fuel consumption	Easy to implement, during routine dry dockings in order to reduce costs, maintenance free after installation
EnergoProFin (Wartsila) an energy saving propeller cap with fins that rotate together with the propeller	Average fuel savings of 2%.	Easy to implement, during routine dry dockings in order to reduce costs.
ECO-Cap (Nakashima) Newly designed propeller cap for propeller hub reduction.	Energy saving effect of 3%.	Easy to implement, during routine dry dockings in order to reduce costs.

9. SPATIAL MANAGEMENT TOOLS FOR MARITIME ACTIVITIES

Following maps are examples of existing spatial management tools which should be used to manage human activities at sea.

9.1 Areas of special concern for Beaked whales

The map hereafter is based on a modelling exercise to estimate favourable habitat areas for Cuvier's beaked whale and on the analysis of stranding data.

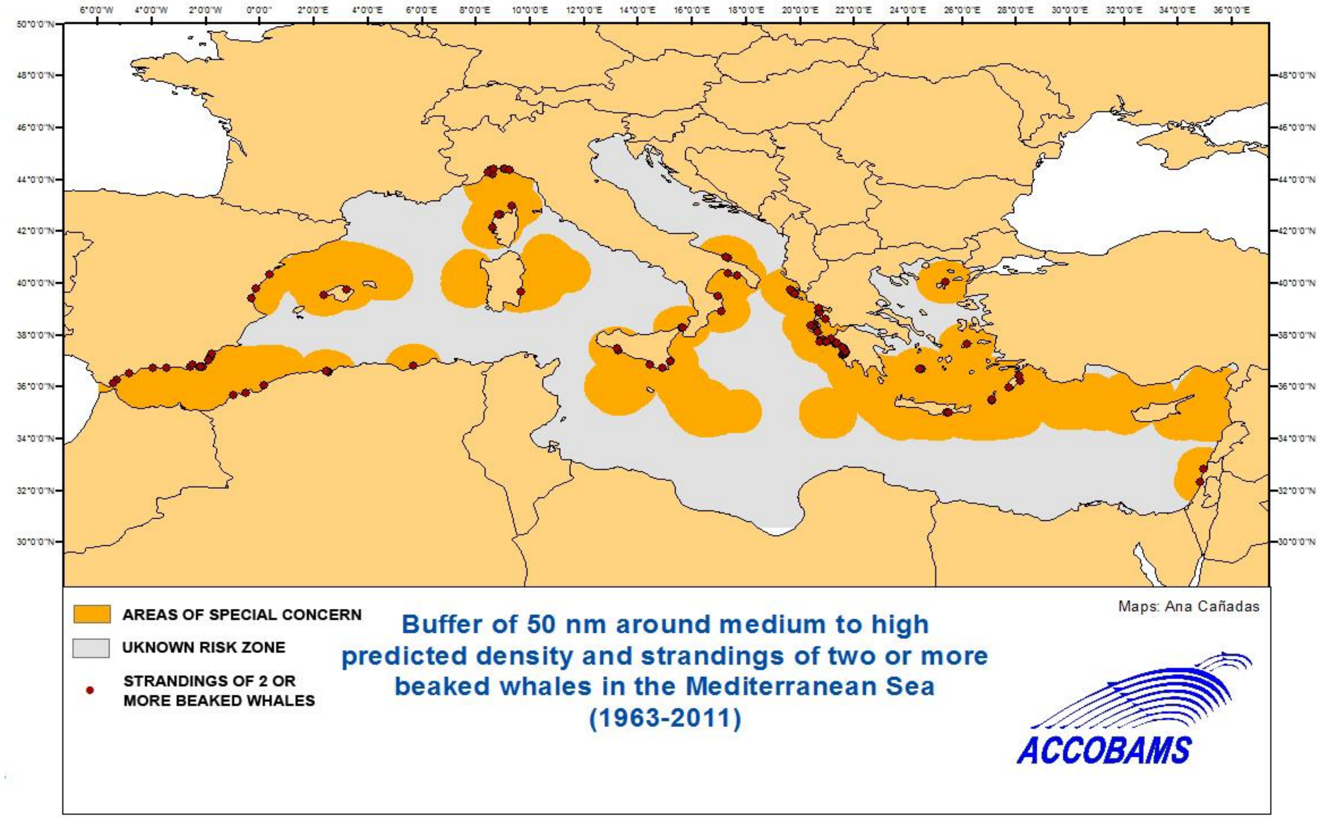


Figure 4. Areas of special concern for Beaked whales as approved by the ACCOBAMS Scientific Committee. Source: Cañadas et al. (2010).

9.2 Marine Protected Areas in the Mediterranean as available from MAPAMED

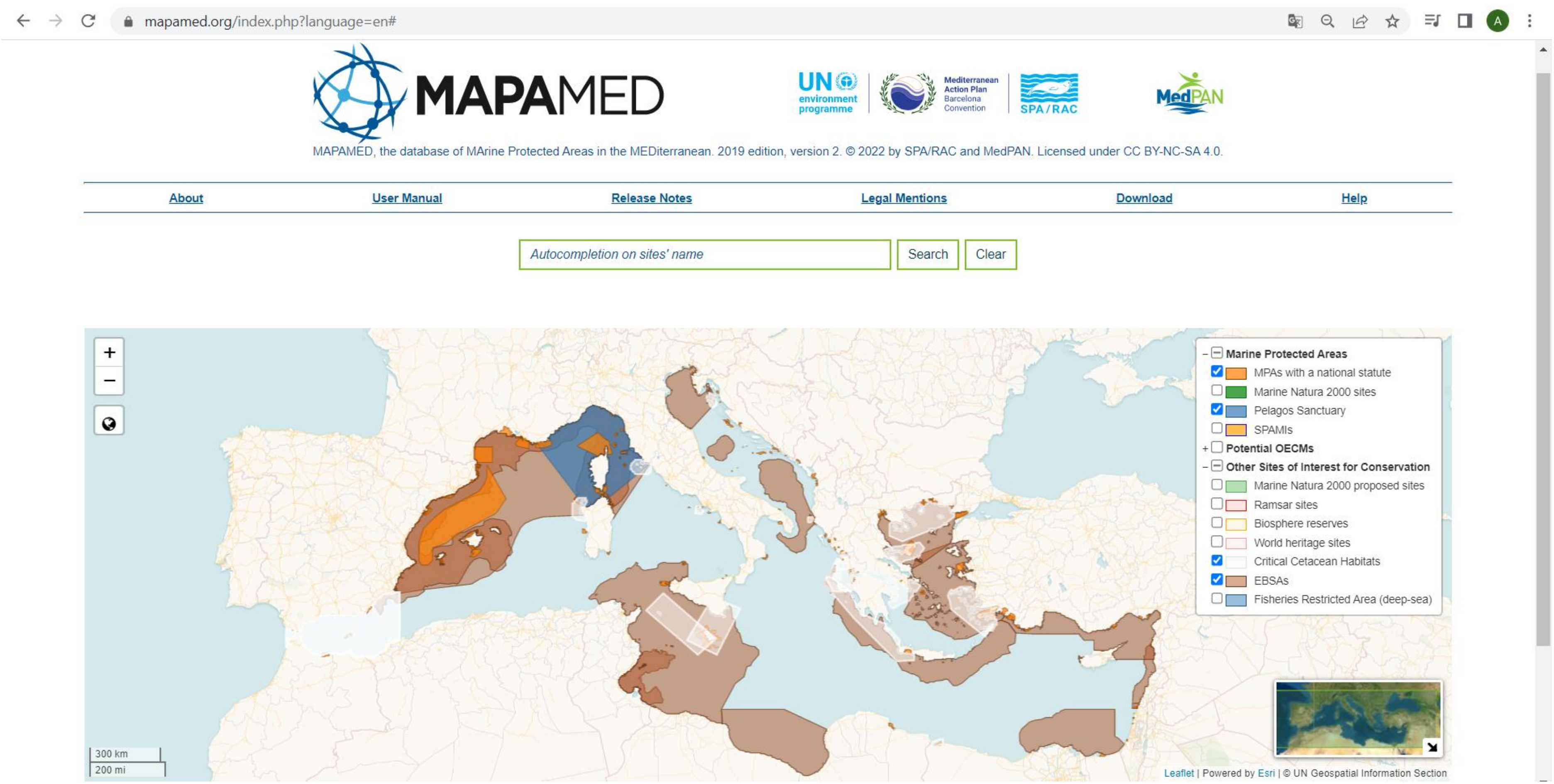


Figure 5 ; Atlas of Marine Protected Areas in the Mediterranean Sea (accessed 24/10/2022). The designations employed and the presentation of the information on this document do not imply the expression of any opinion whatsoever on the part of ACCOBAMS concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

9.3 Overview of the noise hotspots in the ACCOBAMS Area

Main outputs of the two Noise Hotspots reports ("Overview of the Noise Hotspots in the ACCOBAMS Area", 1st and 2nd edition, 2016 and 2022, respectively),are shown hereafter. Maps are intended to show the cumulative coverage of impulsive noise sources in the ACCOBAMS area. However, that the temporal aspects are equally important to assess the risk for cetaceans but are not visible in this map. Impulsive noise sources are used indeed during works that may last a few days to several months and hence the areas shown in the map are not continuously exposed to impulsive noise.

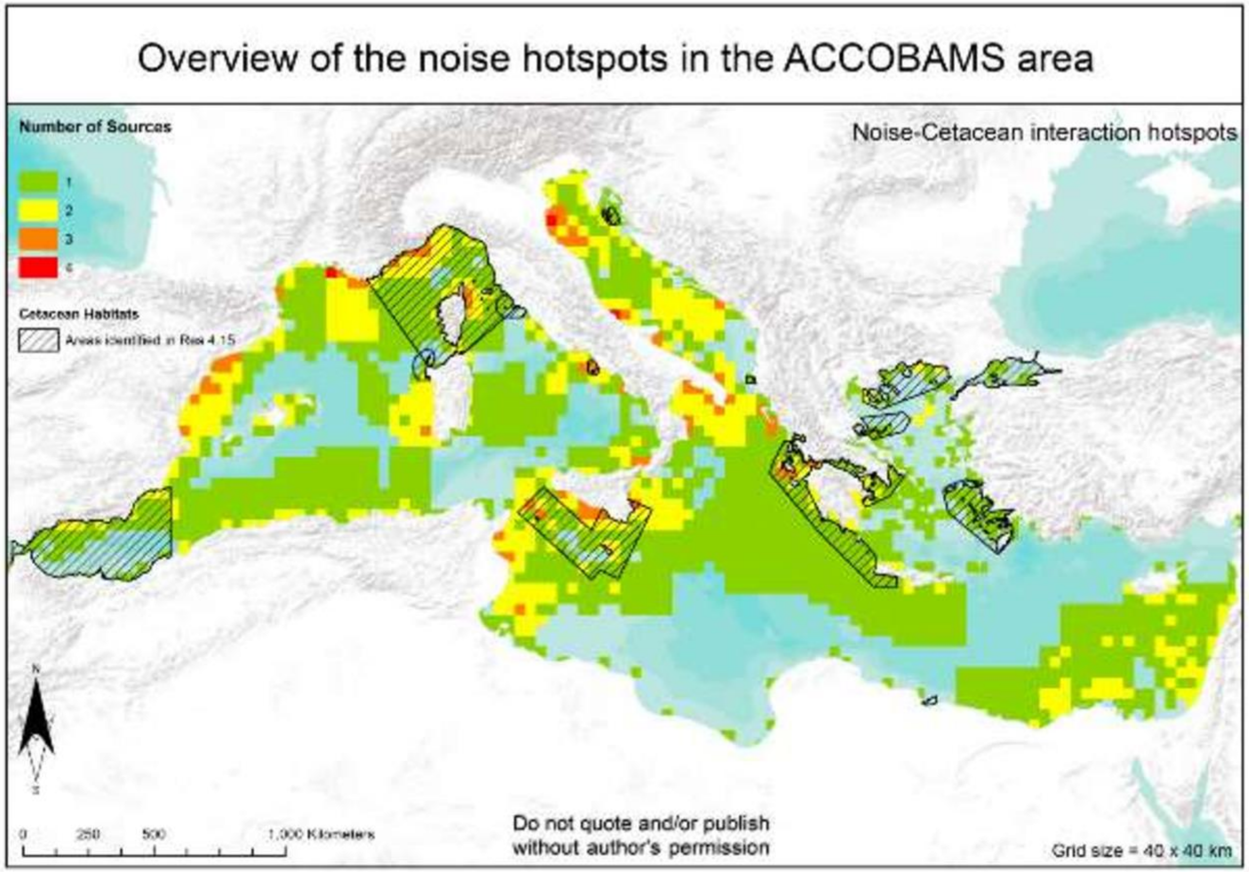


Figure 6. Overview of the noise hotspot areas and overlap with some important habitat of cetaceans: noise sources include seismic surveys, harbour activities, offshore energy sites, naval exercises (data incomplete in some areas). Period of data collection (2005 – 2015). Source : Maglio et al. 2016.

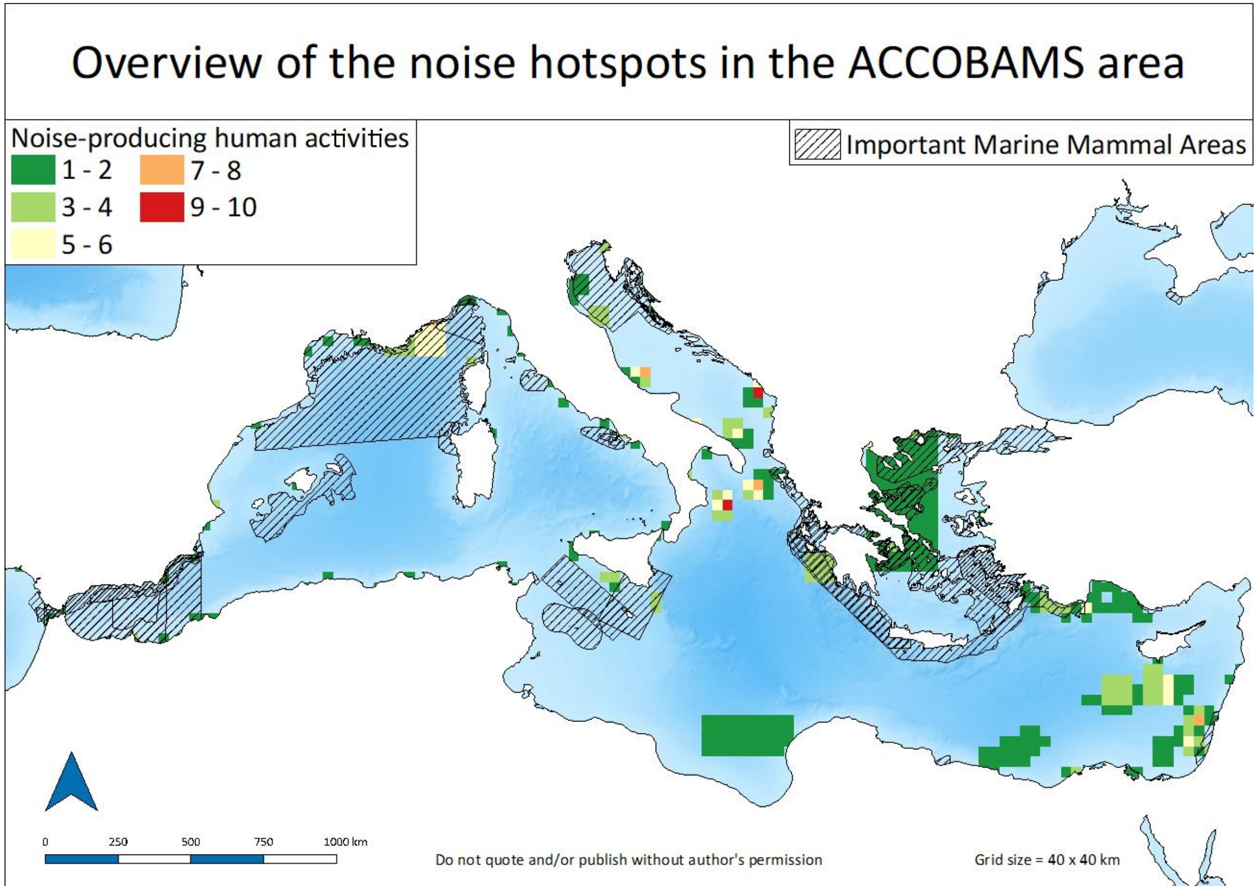


Figure 7. Overview of the noise hotspot areas and overlap with some important habitat of cetaceans: noise sources include seismic surveys and harbour activities (data incomplete in some areas). Period of data collection (2016 – 2022).

9.4 Impulsive Noise Register of the Mediterranean Sea Region – INR MED

This web-GIS site has been created as a joint tool to provide and to share information regarding anthropogenic impulsive sound in water in support of the implementation of the MSFD and EcAp in the Mediterranean Sea Region. The same consideration about temporal aspects than the previous map (Chapter 9.3) apply. Especially, in this map we can see points were explosions have occurred and squares were seismic surveys have occurred. The duration of exposure to such noise events last a few milliseconds (explosions) or days to weeks (seismic surveys).

Figure 8. Example of impulsive noise events recorded from 2017 to 2021 (http://80.73.144.60/CTN_Geoportal/map/).

9.5 Important Marine Mammal Areas (IMMAs)

Important Marine Mammal Areas (IMMAs) are deisgnated through a process set up by a dedicated task force supported by several international bodies[4]. IMMAs consist of areas that may merit place-based protection and/or monitoring. IMMAs could be considered also by industry for the implementation of mitigation measures related to their activities.

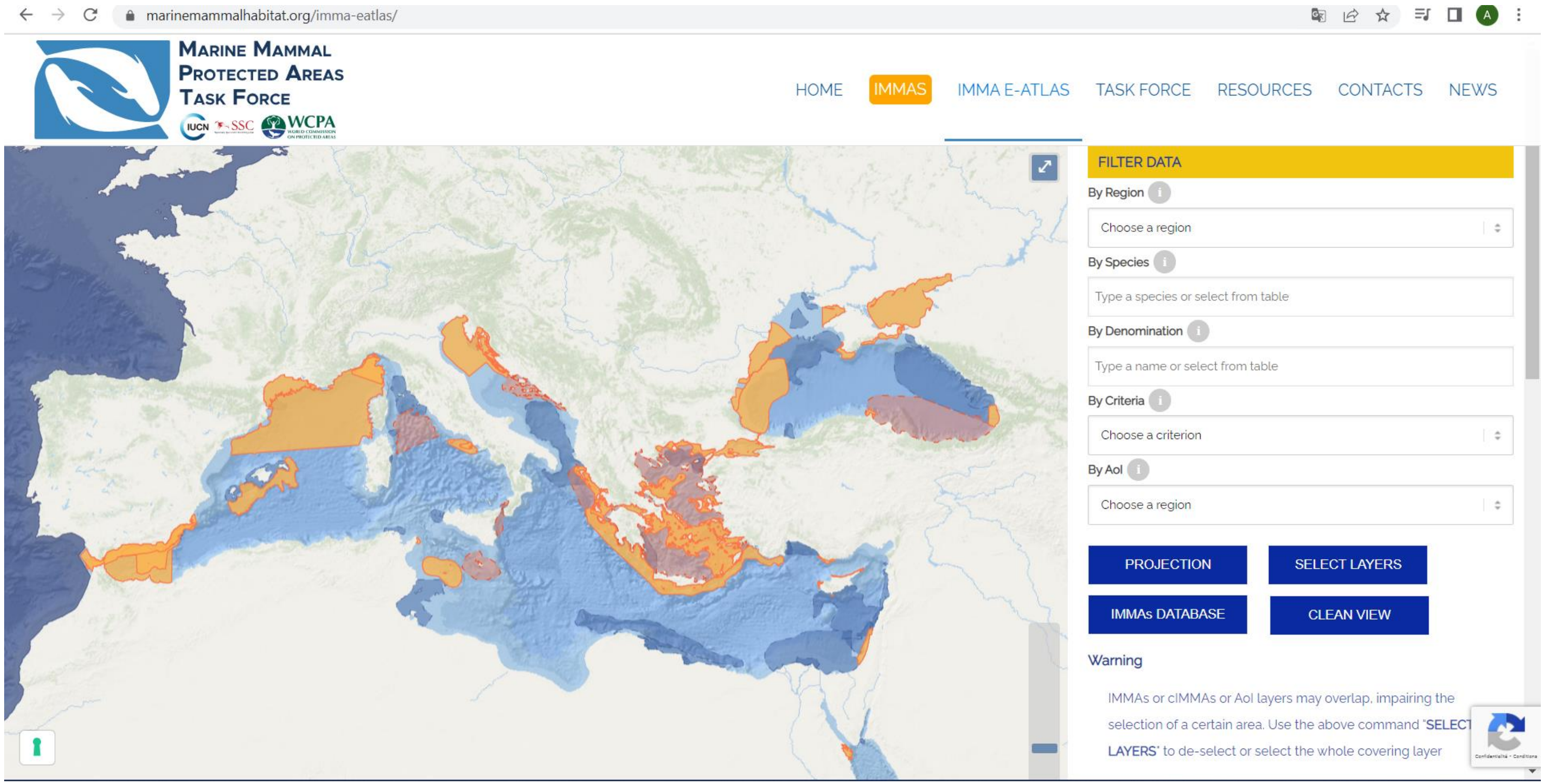


Figure 9. Important Marine Mammals Areas as displayed on the website marinemammalhabitat.org (accessed 24/10/2022).

[4] The International Committee on Marine Mammal Protected Areas (ICMMPA), the International Union for Conservation of Nature's (IUCN) World Commission on Protected Areas (WCPA) and members of the IUCN Species Survival Commission (SSC).

10. Template for reporting MMO and PAM operations

MMO/PAM REPORT FOR THE ACCOBAMS AREA

(To be sent within one month after the completion of the operation)

Contact details: Name; email; phone number

Content:

- ➢ Area and characteristics of the survey
  - Date and location (including mapping*) of survey
  - Objectives of the survey
  - Number and types of vessels involved in the survey
  - Contact details of all MMO and PAM operators aboard the vessel(s)
  - Material and method used as MMO/PAM
  - Total number and volume of the airguns used
  - Nature of airgun array discharge frequency (in Hz), intensity (in dB re. 1µPa or bar meters) and firing interval (seconds), and / or details of any other acoustic energy used
- ➢ Records
  - A record of all occasions when the airguns were used (copy of the forms*)
  - A record of the watches made for marine mammals, including details of any sightings and the seismic activity during the watches (copy of the forms and/or excel filled if possible*)
- ➢ Details of any problem encountered during the seismic survey including instances of non-compliance with the ACCOBAMS guidelines

Annexes*:
The excel file filled* (example ACCOBAMS Marine Mammal Recording Forms adapted from JNCC forms) – Guidance, Cover page, Operations, Effort and Sightings. Please read the Guide to Using ACCOBAMS Marine Mammal Recording Forms prior to use (Annexed to this document).

Support:

- email to the Executive Secretariat of ACCOBAMS (secretariat@accobams.net)
- or paper send to the following address:

ACCOBAMS
Secrétariat Permanent
Jardin de l'UNESCO
Terrasses de Fontvieille
98000 Monaco

Date

Signature

** : in case of data confidentiality, please send a copy of the paragraph specifying the terms of confidentiality and the delay, and send the data after the period of confidentiality.*

11. Annexes: Standard Cetacean Sighting Forms

Three standard files should be used during MMO and PAM operations:

- Deckforms (PDF), intended for recording hand-written observations during visual monitoring.
- Recording forms (Excel spreadsheet), intended for transcription of recordings from the Deckforms.
- Guide for Marine mammal recording forms (PDF), a user guide of the Recording forms.

These files are available upon request to the Secretariat of ACCOBAMS.

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