Seventh Meeting of the Parties to ACCOBAMS

Istanbul, Republic of Turkey, 5 - 8 November 2019

21/10/2019
English
Original: English
ACCOBAMS-MOP7/2019/Doc 31Rev1

METHODOLOGICAL GUIDE
GUIDANCE ON UNDERWATER NOISE MITIGATION MEASURES

Methodological Guide:

Guidance on underwater noise mitigation measures

V. 3.0.

PRINCIPAUTÉ DE MONACO
Ministère d'État

This document has been realised thanks to the financial support of the Principality of Monaco

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

Preparation of the document:

SINAY: Pierre-André Farque, Alessio Maglio

Contribution for the continuous noise part:

Ecole Polytechnique Paris: Laura Recuero Virto, Thomas Théry-Dupressoir, Marc Jouslin de Noray

CONTENT

FOREWORD 5

BACKGROUND 6

IMPACT OF IMPULSIVE UNDERWATER NOISE 8

IMPACT OF CONTINUOUS UNDERWATER NOISE 9

TERMS & DEFINITIONS 10

NOISE MITIGATION FRAMEWORKS 11

NOISE MITIGATION TECHNOLOGIES 11

ALTERNATIVE TECHNOLOGIES 14

REAL-TIME MITIGATION PRACTICES 15

MMO & PAM EQUIPMENT AND TASKS 16

MITIGATE THE ACOUSTIC IMPACT OF MAN-MADE IMPULSIVE NOISE 17

PILE DRIVING/DRILLING/DREDGING 17

SEISMIC SURVEYS 18

EXPLOSIVE USE 20

SONAR USE 21

MITIGATE THE IMPACT OF MAN-MADE CONTINUOUS NOISE 22

SHIPPING 22

ENVIRONMENT TOOLS USED TO MANAGE ACTIVITIES 24

Areas of special concern for Beaked whales 24

Protected areas and cetacean critical habitats as identified by ACCOBAMS 25

Overview of the noise hotspots in the ACCOBAMS Area 26

Impulsive Noise Register of the Mediterranean Sea Region – INR MED 27

Template for reporting MMO and PAM operations 29

CITED LITERATURE 30

PRINCIPAUTÉ DE MONACO
Ministère d'État

ACCOBAMS

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:

- Resolution 2.16 (2004), 3.10 (2007), 4.17 (2010), 5.13 (2013) and 6.17 (2016): 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

After the original guide released in 2013, and reviewed in 2016, this third version include some important improvements:

- ✓ an updated template for reporting mitigation operations by Marine Mammal Observers and Passive Acoustic Monitoring operators
- ✓ Information on new science concerning human activities and the effectiveness of mitigation technologies in operational environment
- ✓ Inclusion of a chapter dedicated to continuous noise (shipping)

On the other hand, little or no evolution was observed with respect to the global scheme for mitigation procedures (upstream considerations, real-time mitigation, downstream tasks) and recent reviews (see for example HELCOM 2016) present comparable protocols and procedures than presented here.

Photos:

BOEM (p.17)
EDMAKTUB (p. 6)
Vincent Bretille (p. 14, 15)
Bill Hall/Caltrans (p.16)
Alessio Maglio/SINAY (cover)
Stefan Nehring (p. 19)
Patrice Kunte (p. 11, 12)
Ministerio de Agricultura, Alimentacion y Medio Ambiente (cover)
Trianel GmbH/Lang (p. 10)
Kurt Thomsen (p. 11)

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 (airgun)
- 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 third version of the guide addresses both continuous and impulsive noise sources as these are equally concerning with regards to marine life.

It is thought to outline practices and technologies that should be used during or instead conventional maritime activities producing underwater noise. References are also included for those technologies which are very 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 Sea, i.e. areas where activities having an acoustic impact on cetaceans should be avoided.

In conclusion, it is important to underline that this is thought to be a living guide and that it will be regularly updated as long as new technologies become available or new practices and procedures are established to reduce the impact of underwater noise on cetaceans.

[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)


EDMAKTUB

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 TG Noise (Van der Graaf and al. 2012).

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

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, animals showing no avoidance or changes in activities may still suffer important, even lethal, consequences. 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).

A significant portion of the continuous underwater noise generated by human activity seems to be related to commercial shipping. 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.

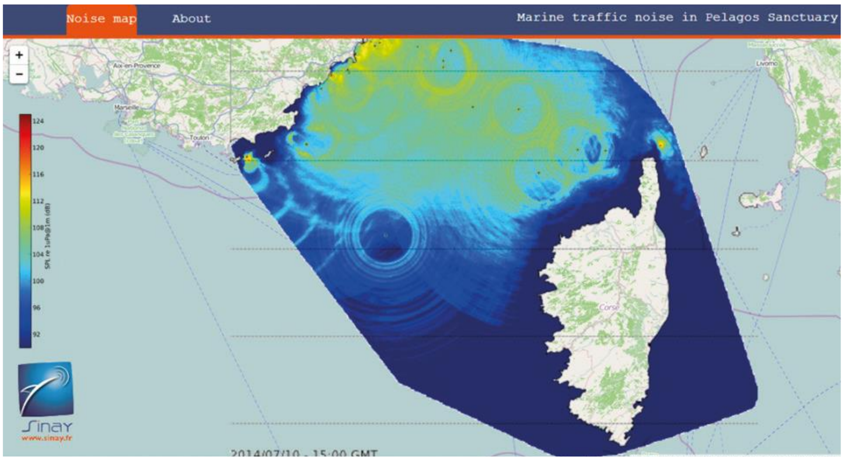
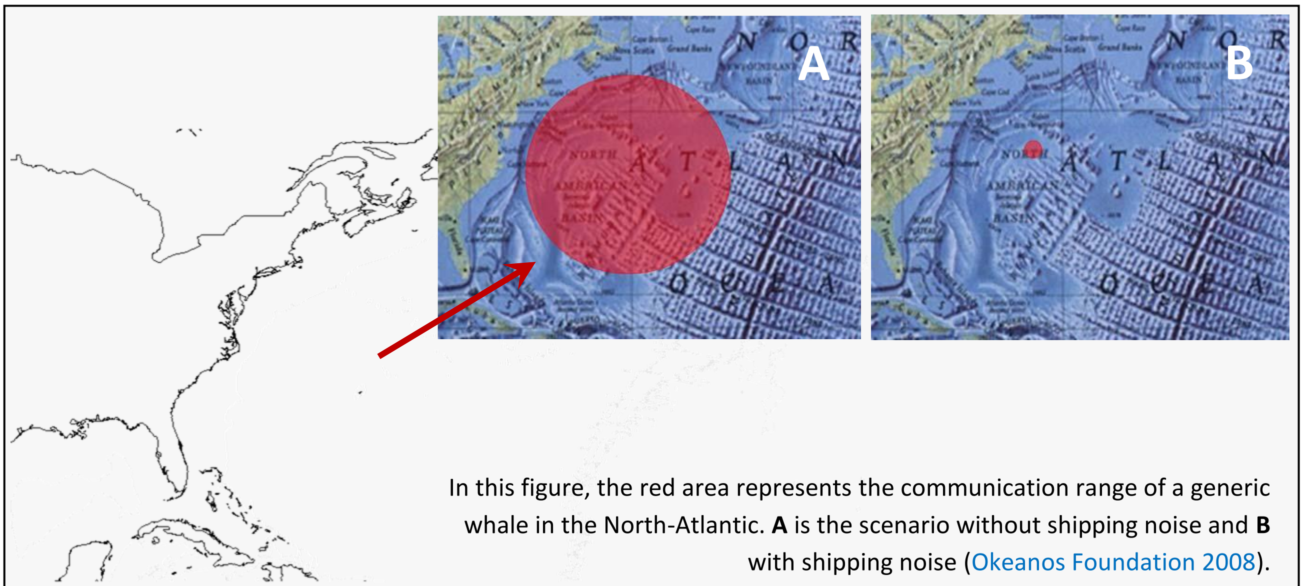


Figure 1. Overlapping sound fields created by multiple ships navigating in the Ligurian Sea. Depth layer is 80 meters; date/hour: October 10th, 2014 at 15:00 GMT (Greenwich Meridian Time). In this picture, 22 ships are simultaneously navigating in the area. Dark red points represent noise levels exactly downward the position of ships. Concentric circles are zones of higher noise far from the source due to the sinusoidal propagation of sound waves (Maglio and al. 2015).

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). The below picture shows an example of the predicted decreased communication range for baleen whales, owing to increases in ambient noise due to shipping (Okeanos Foundation 2008). See more details how to mitigate impact of shipping noise p.21.



In this figure, the red area represents the communication range of a generic whale in the North-Atlantic. **A** is the scenario without shipping noise and **B** with shipping noise (Okeanos Foundation 2008).

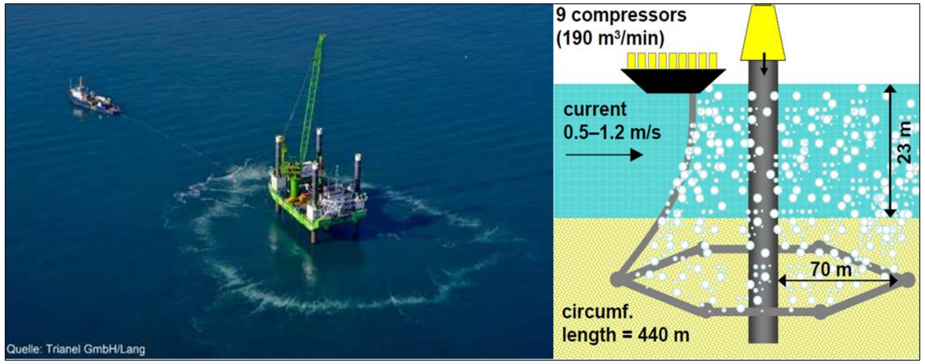
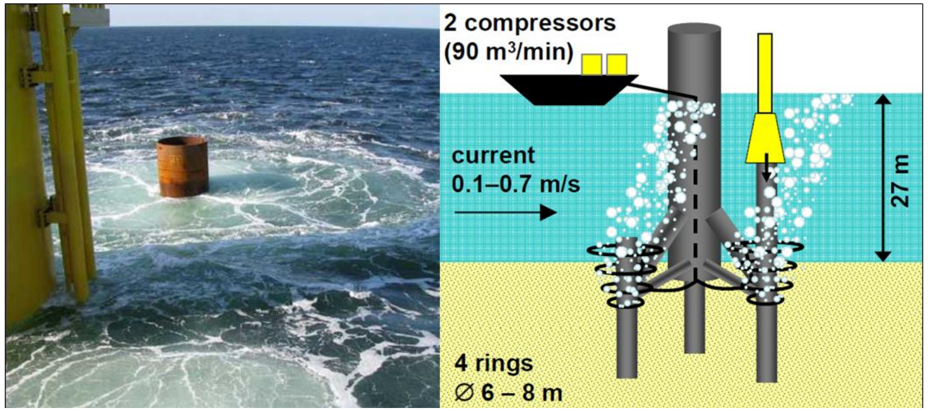
TERMS & DEFINITIONS

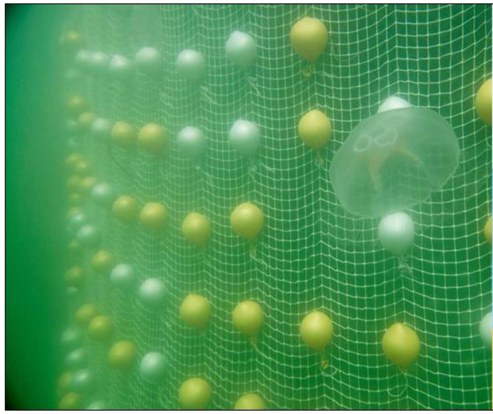
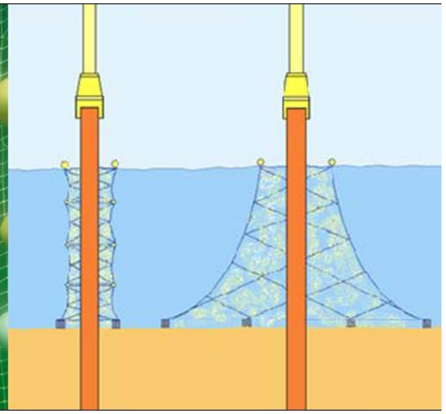
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and the contiguous Atlantic area
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
AMD	Acoustic Mitigation Devices. This terminology is employed to 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

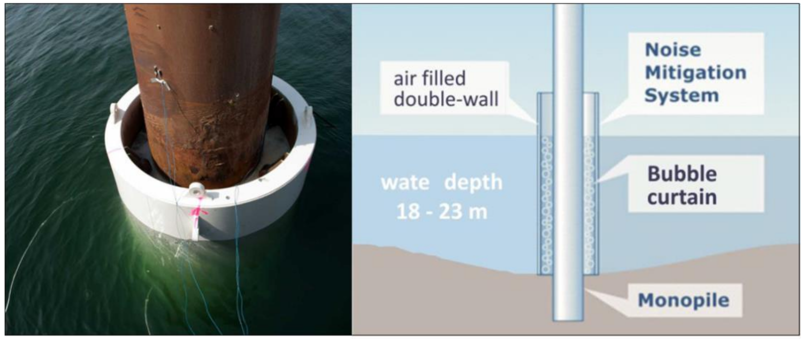
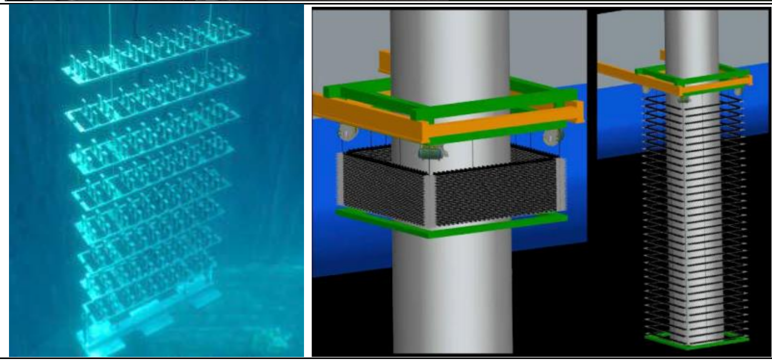
NOISE MITIGATION FRAMEWORKS

NOISE MITIGATION TECHNOLOGIES RELATED TO IMPULSIVE NOISE

This following table aims to provide an overall view of mitigation technologies with some examples of the achievable impulsive noise reduction. Values presented in the table are broadband values and come from experiences carried out to reduce impact piling noise. 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 large bubble curtain consists of a hose with drilled holes, supplied with compressed air. The hose is placed on the sea bed and 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	
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	

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	 
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	 

MITIGATION TECHNOLOGY	NOISE REDUCTION	APPLICATION	OVERVIEW
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)	5 – 20 dB (SEL) 10 – 14 dB (SEL)	Pile driving Drilling	
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)	6-8 dB (SEL)	Pile driving Drilling	
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)	>20 dB in the 20 Hz to 20 kHz band	Pile driving Drilling Seismic sources	

ALTERNATIVE TECHNOLOGIES

ALTERNATIVE TECHNOLOGIES	EMISSIONS	RELEVANT ACTIVITIES	REFERENCES/COMMENTS
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	Not information available	Any activity that would require pile driving (offshore wind farms, harbour extensions, bridges etc.)	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)
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 @ 750 m expected (not measured yet)	Any activity that would require pile driving (offshore wind farms, harbour extensions, bridges etc.)	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)
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	Any activity that would require pile driving (offshore wind farms, harbour extensions, bridges etc.)	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)
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)	Any activity that would require pile driving (offshore wind farms, harbour extensions, bridges etc.)	(North Sea Foundation 2012, Verfuß 2012, Koschinski & Lüdemann 2013)
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	Seismic surveys (p. 17)	System from Geokinetics licenced for shallow water available mid 2014 (CSA Ocean Sciences Inc. 2013, Weilgart 2013, Castellote, pers. comm.)
Low level Acoustic Combustion Source (LACS) The LACS system is a combustion engine producing long sequences of acoustic pulses at a rate of 11 shots/s with low intensity at non-seismic (>100 Hz) frequencies. The system is suitable for shallow-penetration, towed-streamer seismic surveys or vertical seismic profiling	Source Level : 218 dB re 1µPa Peak-to-Peak	Seismic surveys (p. 17)	Market available (Askeland and al. 2009, CSA Ocean Sciences Inc. 2013)

Many other alternative technologies are being developed or are already available in the market (vibropiling, floating wind turbine, etc.) - See more information on Merck & Werner 2014 (OSPAR)

MITIGATION PROTOCOLS

Use of Acoustic Mitigation Devices (AMD)

- Prior to the beginning of the work, 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)

Soft start protocol

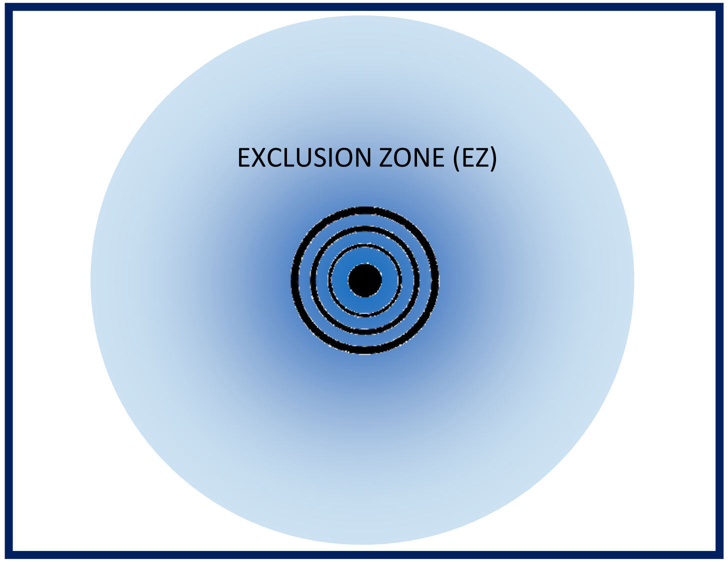
- Noise emissions should begin at low power, increasing gradually until full power is reached
- The soft start procedure should be of 20 min duration at least

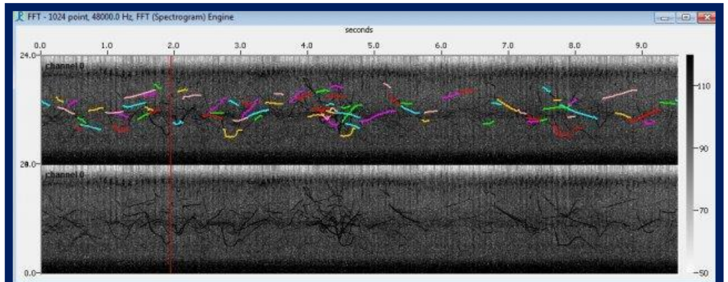
Marine Mammal Observation protocol

- 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)

Passive Acoustic Monitoring protocol (PAM)

- 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





PRINCIPAUTÉ DE MONACO
Ministère d'État

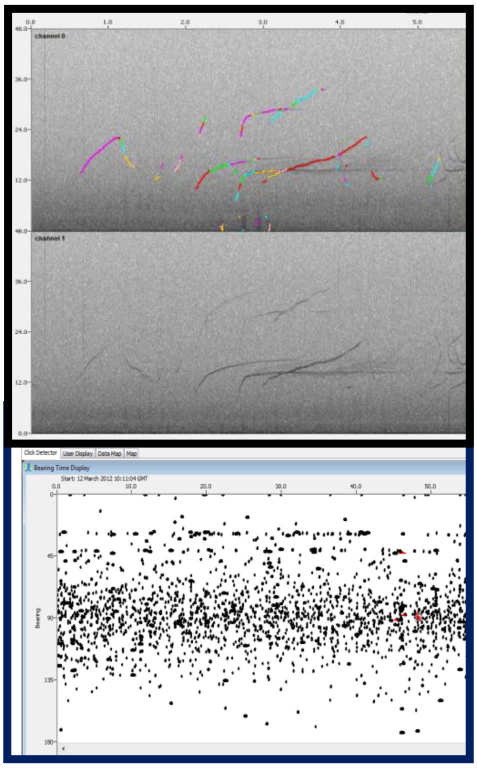
ACCOBAMS

Marine Mammal Observers (MMO)

- The MMO should be equipped with distance measuring binoculars and a standard “Cetacean Sighting Form" made available by ACCOBAMS
- At least two MMOs should be aboard seismic vessels operating in the ACCOBAMS area, observing the survey zone continuously. Shifts should never exceed 2 hours and MMOs must be able to rest between shifts.

Three tasks have to be systematically fulfilled:

- Implementing mitigation procedures whenever necessary (cf MMO protocol, p. 15)
- Collecting abundance, distribution and behavioural data throughout the survey. This task has to be performed both during seismic acquisition and transit
- Reporting



Passive Acoustic Monitoring (PAM)

PAM equipment should be able at least to detect and localise cetaceans. The following software tools are suggested. PAM operators should be experienced bio-acousticians, familiar with the vocalisations of cetaceans in a determined area.

SOFTWARE	*MORE INFOS AND/OR DOWNLOAD*
PAMGUARD	http://www.pamguard.org/
SEAPRO & PAM WorkStation	http://www-3.unipv.it/cibra/seapro.html
ISHMAEL	(Mellinger 2001)
RAINBOWCLICK	http://www.marineconservationresearch.co.uk/
WHISTLE	www.ifaw.org

MITIGATE THE ACOUSTIC IMPACT OF MAN-MADE IMPULSIVE NOISE

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*

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 28)

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*

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

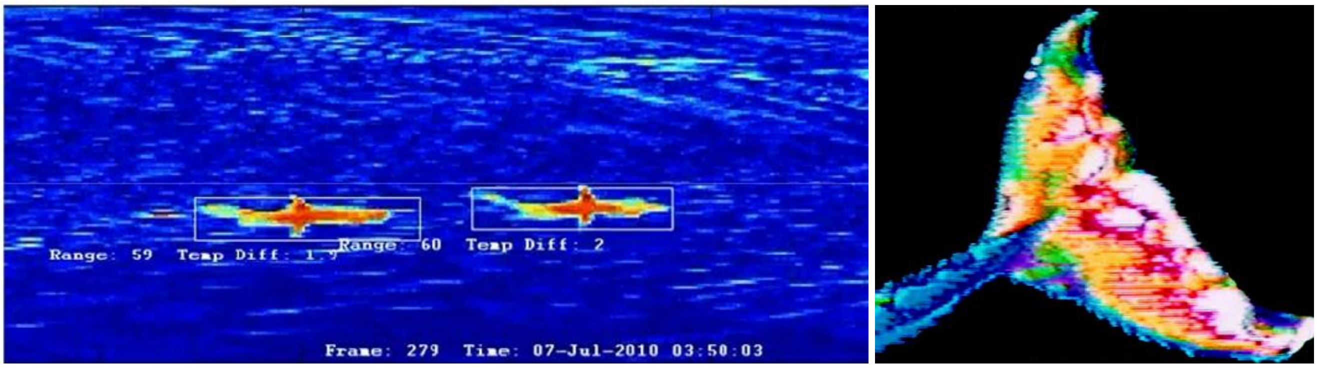


Figure 2. Exemple of the use of the infrared camera for cetacean monitoring.

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

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*

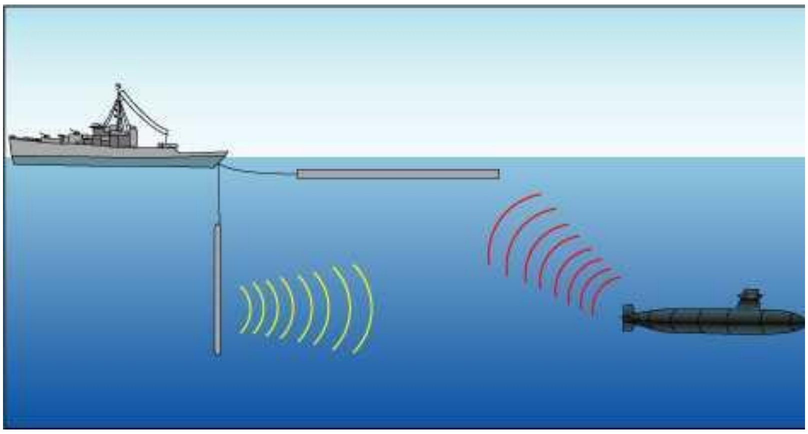
ref: CEDA 2011; OSPAR 2009

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*

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**

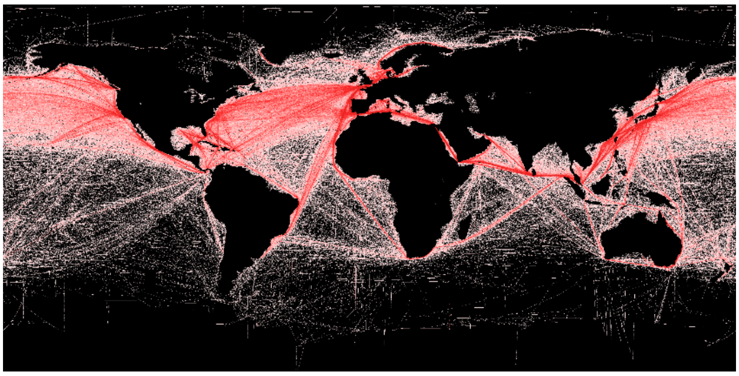
** PAM and MMO equipment (p. 15)*

***** Detailed reports of the mitigation activity should follow a standard form made available by ACCOBAMS***

MITIGATE THE IMPACT OF MAN-MADE CONTINUOUS NOISE

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

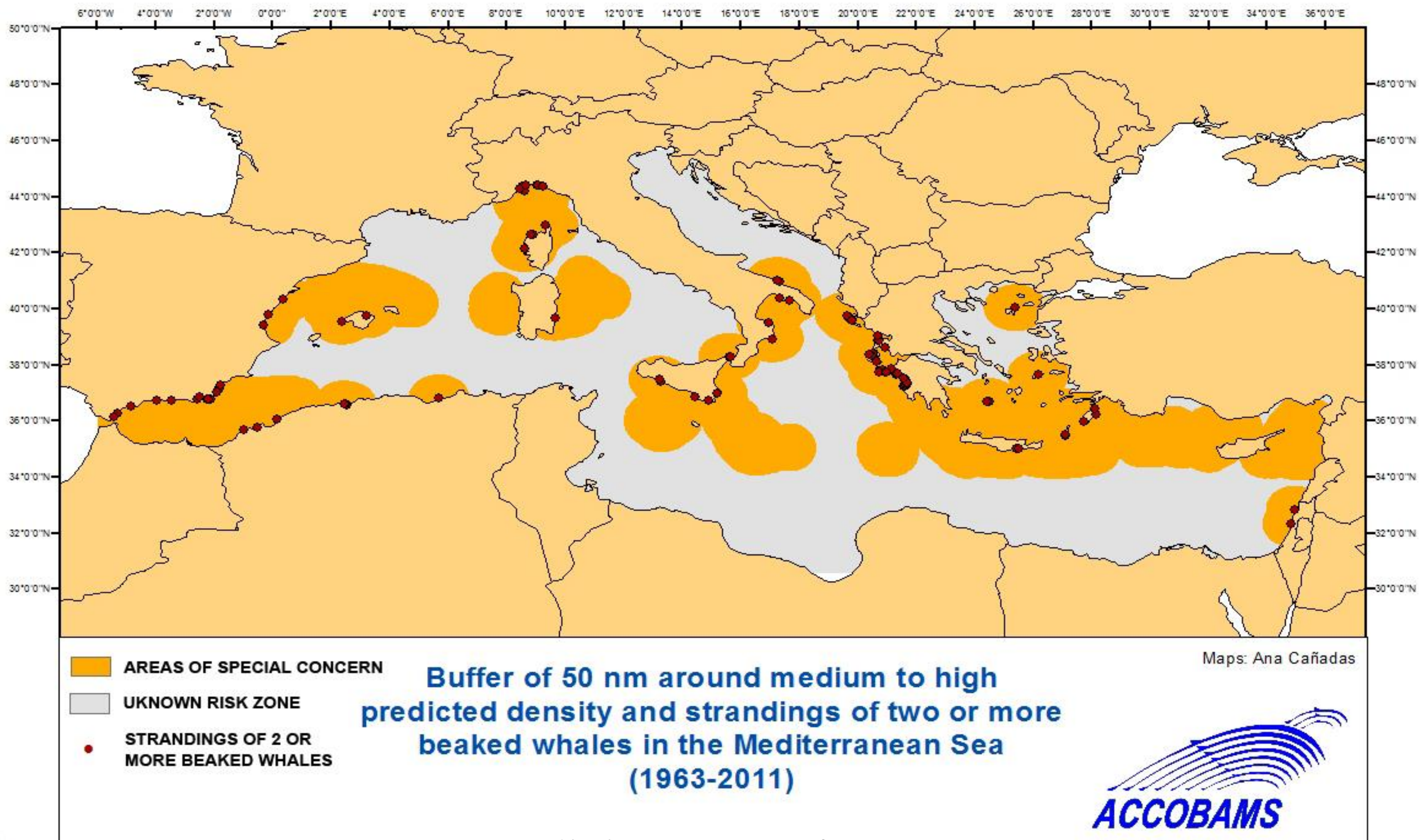
Details on Structural solutions and propeller noise and cavitation for shipping

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.

ENVIRONMENT TOOLS USED TO MANAGE ACTIVITIES

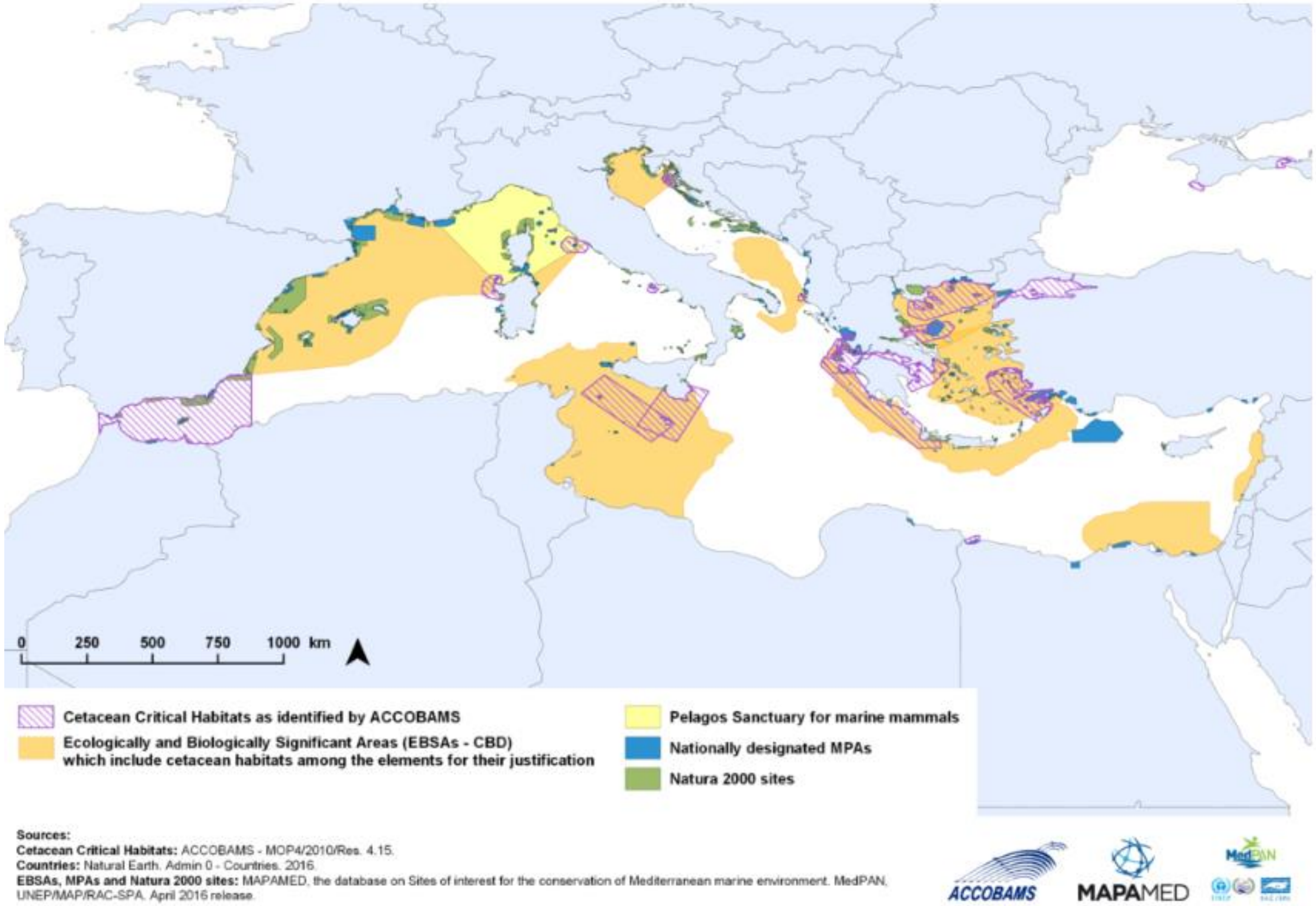
Following maps are examples of existing spatial management tools which should be used to manage human activities at sea.

Areas of special concern for Beaked whales

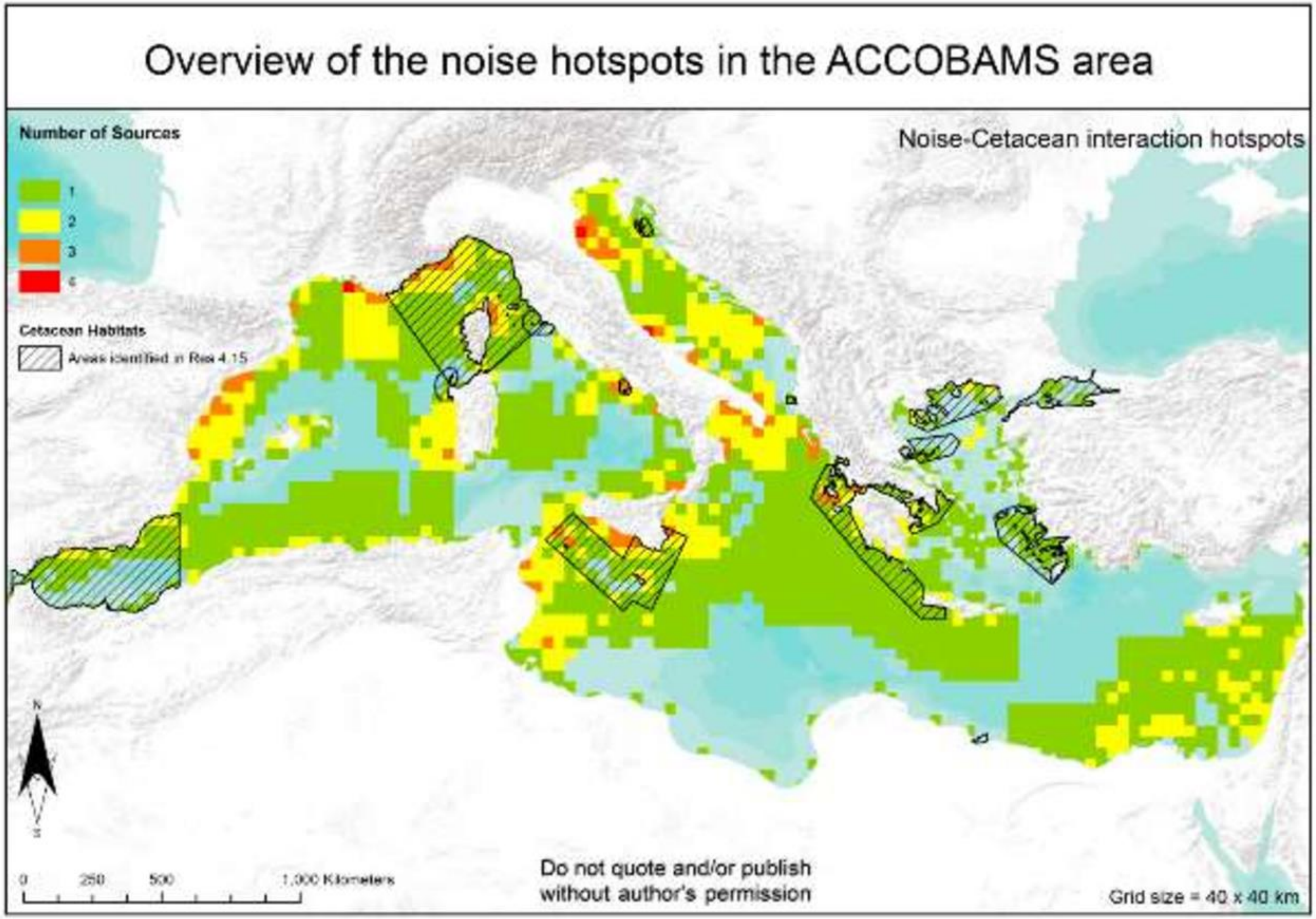


Approved by the ACCOBAMS Scientific Committee

Protected areas and cetacean critical habitats as identified by ACCOBAMS

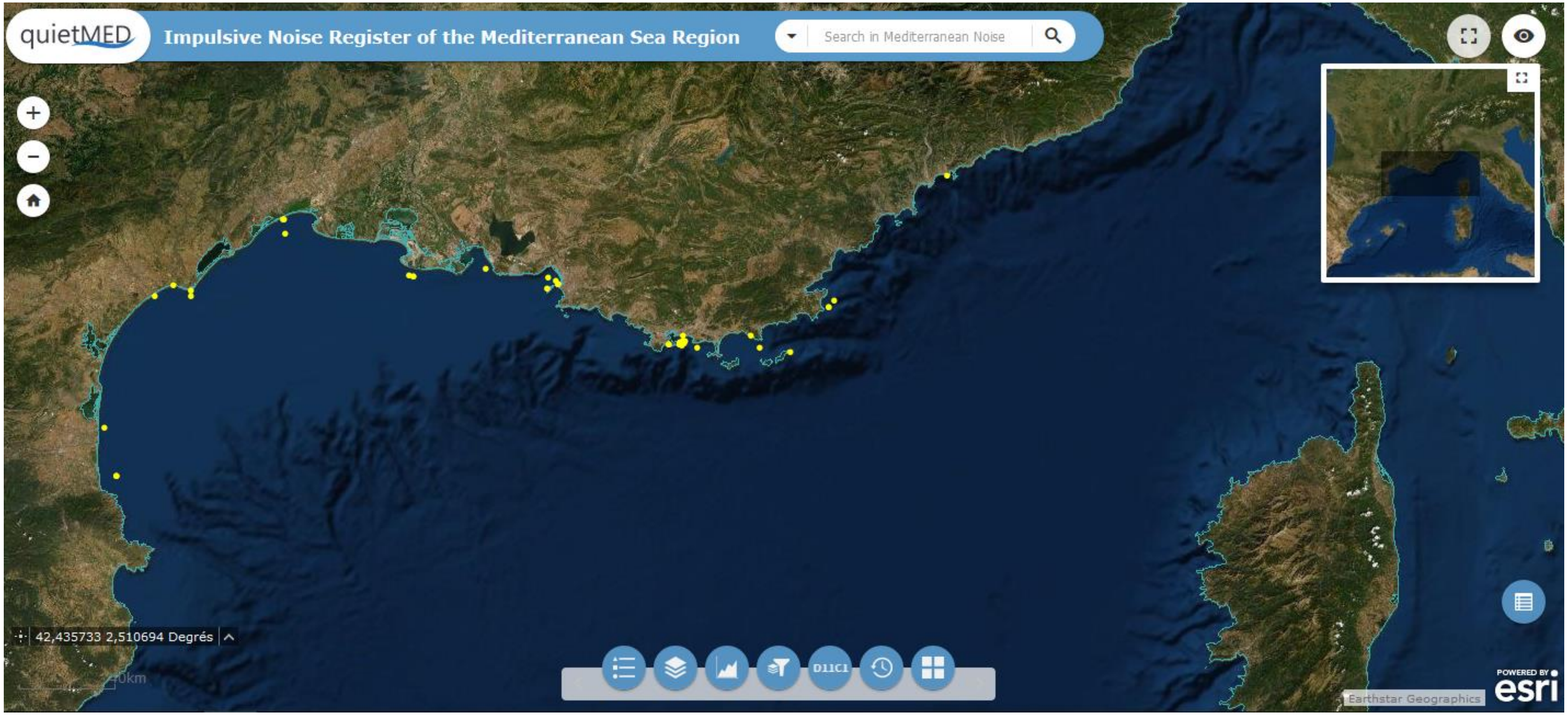


Source : Workshop “INPUTS TO THE ACCOBAMS … MEDITERRANEAN AND BLACK SEAS”, held during the 31stECS Conference (30thApril 2017, Middelfart, Denmark)



Source : Maglio and al. 2016

Noise sources include seismic, shipping, harbour traffic, offshore energy sites, naval exercises (data incomplete in some areas).

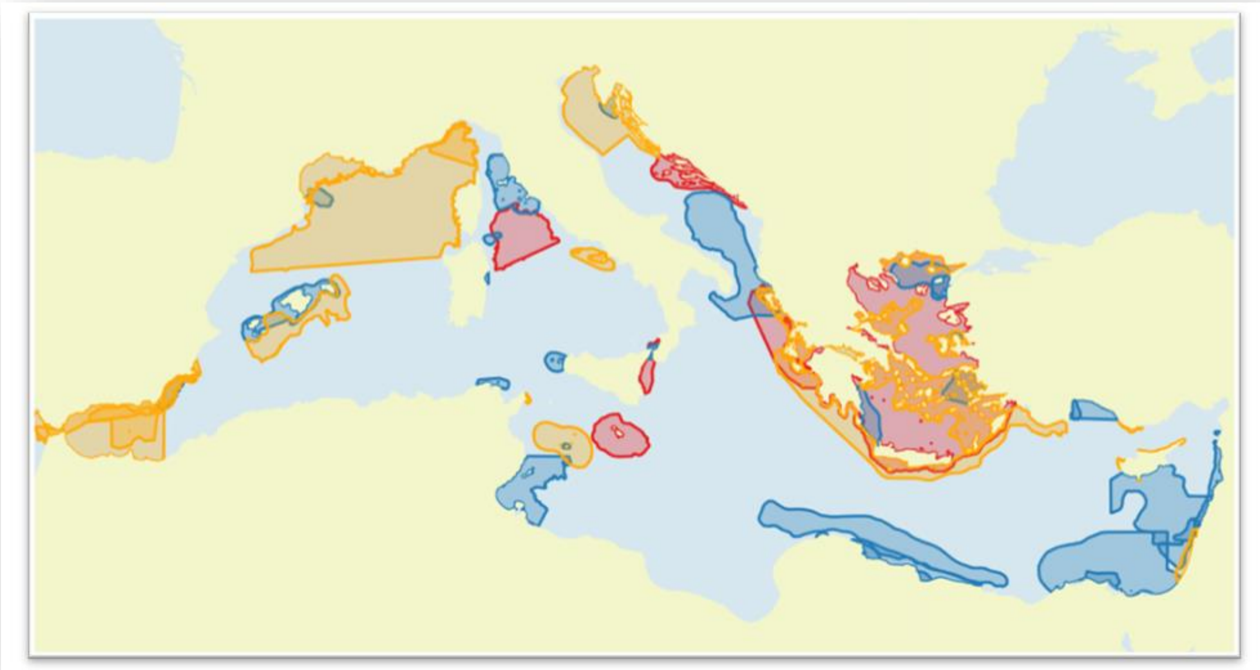


Example of impulsive noise events recorded in French coastal waters in 2017 (http://80.73.144.60/CTN_Geoportal/map/)

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 second cycle of the MSFD and EcAp in the Mediterranean Sea Region.

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[2]. IMMAs consist of areas that may merit place-based protection and/or monitoring. Although IMMAs are descibed as a marine mammal layer indicative of biodiversity and potentially ecosystem health for consideration by governments, intergovernmental organisations, conservation groups, and the general public (https://www.marinemammalhabitat.org/activities/immas/), they could be considered also by industry for the implementation of mitigation measures related to their activities.



IMMAS = Important Marine Mammal Areas

cIMMAS = Candidate IMMAs

AOI = Area Of Interest

[2] The Marine Mammal Protected Areas Task Force (MMPATF) has been created by the International Committee on Marine Mammal Protected Areas (ICMMPA), the International Union for Conservation of Nature's (IUCN) World Commission on Protected Areas (WCPA) Marine Vice Chair, and members of the IUCN Species Survival Commission (SSC).

MMO/PAM REPORT FOR THE ACCOBAMS AREA

(To be sent within one month after the completion of the operation)
Report template available – see on www.netccobams.com

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 (this is available to download from Netccobams)

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.*

CITED LITERATURE

Aguilar de Soto N, Cañadas A, Frantzis A, Notarbartolo di Sciara G (2013) A voluntary moratorium to naval sonar: from the Canary Islands success to the Mediterranean. In: Effects of Noise on Aquatic Life. Budapest

Andersson, M.H., Andersson, S., Ahlsén, J., Andersson, B.L., Hammar, J., Persson, L.K.G., Pihl, J., Sigray, P., Wikström, A. 2016. A framework for regulating underwater noise during pile driving. A technical Vindval report, ISBN 978-91-620-6775-5, Swedish Environmental Protection Agency, Stockholm, Sweden.

Askeland B, Ruud B, Hobæk H, Mjelde R (2009) A seismic field test with a Low level Acoustic Combustion Source and Pseudo Nosie codes. Jounal Appl Geophys 67:66–73

Baldacci, A., Carron, M., and Portunato, N. 2005. Infrared detection or marine mammals, NURC Technical Report SR-443

Bellmann MA (2014) Overview of existing Noise Mitigation Systems for reducing Pile-Driving Noise. In: Inter.noise 2014. Melbourne, Australia 16-19 november 2014, p 11

Boebel O, Zitterbart DP (2014) Exploring the Thermal Limits of IR-Based Automatic Whale Detection (ETAW).

CBD (2012) Scientific synthesis on the impacts of underwater noise on marine and coastal biodiversity and habitats. Montreal, Canada

Central Dredging Association (2011) Underwater Sound In Relation To Dredging.

CSA Ocean Sciences Inc. (2013) Quitening Technologies for reducing noise during seismic surveying and pile driving.

Dahl PH, Miller JH, Cato DH, Andrew RK (2007) Underwater ambient noise. Acoust Today:23–33

Dekeling, R.P.A., Tasker, M.L., Van der Graaf, A.J., Ainslie, M.A, Andersson, M.H., André, M., Borsani (2014). Monitoring Guidance for Underwater Noise in European Seas- Part II: Monitoring Guidance Specifications. Luxembourg : Publications Office of the European Union, 2014. JRC Scientific and Policy Report EUR 26555 EN.

Graaf S Van der, Ainslie MA, André M, Brensing K, Dalen J, Dekeling R, Robinson S, Tasker ML, Thomsen F, Werner S (2012) European Marine Strategy Framework Directive Good Environmental Status (MSFD-GES): Report of the Technical Subgroup on Underwater noise and other forms of energy.

Graber J., Thomson J., Polagye B., Jessup A. (2010). Detecting Southern resident Killer Whales, Puget Sound, Washington, USA using a land-based Infrared system (FLIR Thermovision A40M) - Land-based infrared imagery for marine mammal detection. Northwest National Marine Renewable Energy Center, University of Washington, Seattle, WA, USA. Applied Physics Laboratory, University of Washington, Seattle, WA, USA. 2010.

HELCOM (2016) Underwater noise mitigation measures. In: 3rd Meeting of the Working Group on Reduction of Pressures from the Baltic Sea Catchment Area. Gothenburg, Sweden, p 10

IMO (2014) Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life. ASCOBANS Noise working group, MEPC.1/Circ.833, 7 April 2014

Inputs to the ACCOBAMS ongoing effort to map human threats on cetaceans in the Mediterranean and Black seas – 31stECS Conference (30thApril 2017, Middelfart, Denmark)

Koschinski S, Lüdemann K (2013) Development of Noise Mitigation Measures in Offshore Wind Farm Construction 2013. Vilm, Germany

Li D.Q. and Hallander J., 2015. Shipping and underwater radiated noise. Sweden SSPA Highlights 61 / 2015

Lurton X, Antoine L (2007) Analyse des risques pour les mammifères marins liés à l ’ emploi des méthodes acoustiques en océanographie.

MAGLIO A., SOARES C., BOUZIDI M., ZABEL F., SOUAMI Y., PAVAN G., 2015. Mapping shipping noise in the Pelagos Sanctuary (French part) through acoustic modelling to assess potential impacts on marine mammals. Sci. Rep. Port-Cros natl. Park, 29: 167-185 (2015)

Maglio A., G. Pavan, M. Castellote, S. Frey (2016). Overview of the Noise hotspots in the ACCOBAMS Area, Part 1 – Mediterranean Sea. ACCOBAMS Technical report, January 2016. DOI: 10.13140/RG.2.1.2574.8560/1

Mellinger DK (2001) Ishmael 1 . 0 User ’ s Guide ISHMAEL : Integrated System for Holistic Multi-channel Acoustic Exploration and Localization.

Merck T. and Werner S. (2014). Inventory of measures to mitigate the emission and environmental impact of underwater noise – OSPAR Commission 2014

North Sea Foundation (2012) Symposium Sound Solutions. Foundation North Sea

Okeanos Foundation (2008) Shipping Noise and Marine Mammals. Hamburg, Germany

OSPAR (2009) Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR

Pavan G (2010) The shipping noise issue.

Renilson Marine Consulting Pty Ltd 2009. Reducing underwater noise pollution from large commercial vessels.

Stéphan Y, Boutonnier J-M, Pistre C (2012) Bilan des activites anthropiques génératrices de bruit sous marin et de leur récente évolution en france metropolitaine.

Verfuß T (2012) Noise Mitigation Measures & Low-noise Foundation Concepts – State of the Art.

Verfuss U.K., Gillespie D., Gordon J., Marques T.A., Miller B., Plunkett R., Theriault J.A., Tollit D.J., Zitterbart D.P., Hubert P., Thomas L. (2017).Comparing methods suitable for monitoring marine mammals in low visibility conditions during seismic surveys.

Weilgart L (2007) A Brief Review of Known Effects of Noise on Marine Mammals. Int J Comp Psychol 20:159–168

Weilgart L (2013) Marine Vibroseis: a Quieter Alternative Technology to Seismic Airguns for Collecting Geophysical Data.

Weissenberger J, Zitterbart DP (2012) Surveillance of marine mammals in the safety zone around an air gun array with the help of a 360° infrared camera system. Soc Pet Eng - SPE/APPEA Int Conf Heal Saf Environ Oil Gas Explor Prod 2012 Prot People Environ - Evol Challenges 3:2731–2739

Wochner M., Lee K., McNeese A., Wilson P. (2016). Underwater noise mitigation from pile driving using a tuneable resonator system. Wind Farm Noise: Paper ICA2016-0503, 22nd International Congress on Acoustics, Buenos Aires.

Wright, A.J. (Ed.) 2008, “Underwater Radiated Noise of Ocean-Going Merchant Ships”. International Workshop on Shipping Noise and Marine Mammals, Hamburg, Germany, 21st-24th April 2008, held by Okeanos - Foundation for the Sea

Zitterbart DP, Kindermann L, Burkhardt E, Boebel O (2013) Automatic Round-the-Clock Detection of Whales for Mitigation from Underwater Noise Impacts. PLoS One 8:2–7