OVERVIEW OF THE NOISE HOTSPOTS IN THE ACCOBAMS AREA

Part I – Mediterranean Sea

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Final Report

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Executive Summary

Identifying areas of high anthropogenic pressure on the marine environment is a key element for an effective environmental management and for mitigating impacts. As underwater noise is considered a major threat for cetaceans, the ACCOBAMS Agreement has undertaken a work aiming at identifying noise hotspots and areas of potential conflicts with cetacean conservation. The global aim of this project is to gather baseline knowledge on noise-producing human activities in the Mediterranean Sea. Specific tasks planned for this study included:

- Making an inventory of noise-producing human activities
- Mapping areas where such activities are carried out
- Recommending, on the basis of the findings, a methodology to monitor noise from human pressures and noise sources over time.

For practical reasons, it was decided to limit the study area between the Strait of Gibraltar and the Bosporus, thus including the whole Mediterranean Sea, but excluding the Black Sea and the Atlantic area of the Agreement. Efforts in data collection were focussed on activities using noise sources identified as being of primary concern for cetacean conservation (coastal and offshore activities, geophysical surveys, naval exercises, marine traffic). Data were collected through various means such as dedicated internet search, AIS data-bases, official online repositories, and contacts with relevant stakeholders. For all target activities except marine traffic, data were collected for the period 2005 to 2015 and for the near future (activities potentially carried out in the next 5 years). For marine traffic, ship positions were sampled every 10 minutes for a period considered representative of the real ship traffic (i.e. the month of July 2014).

We recorded the position of 1446 harbours, 228 drilling platforms for hydrocarbon exploitation, 52 wind farm projects, 830 seismic exploration areas, a number of military areas, and 7 millions vessel positions. Concerning marine traffic, ship density was calculated over a grid of 1 minute in latitude and longitude. We found an average value of around 1500 vessels contemporarily present in the area at any time. Areas of heaviest traffic levels are mainly identified in the northern and western part of the basin and in Greek waters. For the other activities, raw geographical data were plotted to identify the position of each category of noise-producing human activities. Then, summary GIS maps were created using a grid resolution of 40x40 km. Available data for seismic surveys allowed for calculating the surface annually bestowed to this activity in the past 10 years throughout the study area. The highest value was attained in 2013 with seismic survey areas covering around 675 000 km², representing 27% of the surface of the Mediterranean. On the opposite, 2005 yielded the lowest value with around 67 000 km² used (3.8% of Mediterranean surface). An increasing trend over the study period is highlighted.

Areas accumulating noise-producing activities (*noise hotspots*) are pointed out, with a focus on zones overlapping with important cetacean habitat as identified by ACCOBAMS Parties through Resolution 4.15 (2010). Results revealed several noise hotspots overlapping important cetacean habitat such as the Pelagos Sanctuary, the Strait of Sicily, and the upper portion of the Hellenic Trench.

Finally, a proposal has been developed for the establishment of a web-based common database at the international level centralising structured data on human activities producing impulsive noise in the Agreement area.

Our results provide key information on the spatial extent of different noise-generating activities in the Mediterranean Sea and yield the first basin-wide overview on areas where potential conflicts between noise-producing activities and cetacean conservation may occur. Moreover, these results provide strong evidence of multiple stressors acting on the marine environment and of the need for urgent management and conservation actions. However, for future studies, it is crucial to increase the information concerning time frames in which target activities are carried out.

CONTENT

1. CONTEXT & OBJECTIVES

Anthropogenic underwater noise is a form of pollution considered as a major threat for the conservation of marine wildlife, thus requiring the development of monitoring and management tools (Southall *et al.*, 2007; Weir and Dolman, 2007; Pavan, 2008; Popper and Hastings, 2009; Dolman *et al.*, 2011). In particular, the impact of noise on marine mammals is a source of concern given that they heavily depend on acoustic signals to fulfil their vital functions. Their "acoustic habitat" appears nowadays altered by anthropogenic noise having both direct and indirect effects on individuals and populations (NRC (National Research Council), 2000, 2003; Simmonds *et al.*, 2004).

It has been demonstrated that naval exercises involving the use of mid-frequency active sonars caused several mass stranding events of Cuvier's beaked whales along the coasts of the Mediterranean Sea and in other sea areas at least during the last 20 years (Frantzis, 1998; Fernandez *et al.*, 2004; Martin *et al.*, 2004; Agardy *et al.*, 2007; Podestà *et al.*, 2007; Filadelfo *et al.*, 2009). Such correlation has not been identified with the same accuracy with any other anthropogenic noise source, although this cannot be ruled out for the case of geophysical surveys (e.g. Castellote and Llorens, *in press*). Also, a mass stranding of melon-headed whales in Madagascar occurred in 2008 was the first known such event closely associated with relatively high-frequency mapping sonar systems, i.e. a 12 kHz echo-sounder in that particular case (Southall *et al.*, 2013). Furthermore, ship noise has been demonstrated to reach levels that may have an impact on marine mammals (Pavan, 2015; Sciacca *et al.*, 2015). For example, a study on Mediterranean beaked whales highlighted significant behavioural response of an individual of this species in reaction to ship noise (Aguilar de Soto *et al.*, 2006). Also, it has been demonstrated that different effects (displacement and/or acoustic behavioural disruption) occur for Mediterranean fin whales in response to low frequency impulsive noise at very long ranges, reaching more than 200 km (Borsani *et al.*, 2008; Castellote *et al.*, 2012). Finally, based on IUCN Redlist assessments, several cetacean species are experiencing a decreasing population trend, e.g. short-beaked common dolphin, the bottlenose dolphin, and the sperm whale (Bearzi, 2012, Notarbartolo di Sciara et al,. 2012; Bearzi et al,. 2012).

In this context, ACCOBAMS has undertaken several actions aimed at addressing the issue of underwater noise in the Agreement area in the past 13 years. The ACCOBAMS Working Programme 2014-2016 addresses underwater noise through different Conservation Actions (CA). Particularly, CA2-b4 has the purpose of gathering an overview of the anthropogenic noise/cetaceans interactions hotspots in the ACCOBAMS area. The present study is aimed at meeting the objective of this CA. The main tasks include:

- Inventorying noise-producing human activities:
  - Marine traffic (including, *inter alia*, intense recreational vessel zone)
  - Coastal and Offshore constructions (harbour extension, marine renewable energy projects, oil platforms, etc.)
  - Seismic survey areas
  - Military operation areas
- Mapping areas where such activities are carried out
- Recommending, on the basis of the findings, a methodology to monitor noise from human pressures and noise sources over time.

2. METHODS

2.1. General methodology

The present project addresses human activities identified as being of most concern with respect to the acoustic impact entailed to endangered species like cetaceans: geophysical surveys, coastal and offshore industrial projects (especially harbour development works, oil and gas platforms and wind farms), military operations, and finally marine traffic. During such activities, all noise sources usually recognised as causing impacts may be used: airguns, sonars, pile drivers, drilling, underwater detonations, ships and recreational crafts. According to the methodology currently proposed by the European Commission (EU-MSFD), two separate methodologies are needed to monitor the pressure on the marine environment of two different kinds of noise: impulsive noise and continuous low-frequency noise. In this study we use the definitions of impulsive and continuous noise proposed by the technical subgroup on underwater noise of the European Commission (Van der Graaf *et al.*, 2012)

Concerning impulsive noise sources, in accordance with the EC guidance on underwater noise monitoring, ACCOBAMS recommended making an inventory of impulsive noise sources being used over an area and a period. To do that, a relational database model was designed with MySQL. Then, a simplified database was developed starting from the SQL model. The need of a simple tool to organise data is motivated by the short time available to carry out the project. Also, this is the first time that data on noise-producing human activities at sea are collected over an area as large as the Mediterranean Sea, and hence neither previous experience nor existing tools were available. MS Excel was chosen as tool to build this simplified database. The reason of this choice is that MS Excel is a widely known and used tool, and that data can be readily organised, entered, and displayed. Furthermore, data stored in one or more Excel sheets can be injected into more complex databases, as those built in SQL, and also read and analysed by powerful software like, *inter alia*, R, MATLAB and ArcGIS. The study period was fixed to the period going from 2005 to 2015. Planned projects for the near future were also inventoried. As MS Excel cannot handle spatial data, shapefiles are stored in a dedicated directory in the common workspace. This simple method allows making queries in the Excel database and selecting the corresponding shapefiles and go ahead towards the analysis phase. Also, a stakeholder's list has been drawn in order to link request for data to contacts that were established.

With respect to ambient noise sources, the present project aims at identifying main commercial ship lanes and areas exploited by recreational craft, through the use of the AIS system, therefore vessels less than 300 tons are not reflected here.

For practical reasons it was decided to focus the effort on the Mediterranean Sea, thus the Black Sea and the Atlantic area of the Agreement are not considered in this study.

2.2. Data: Marine traffic

Data available from *aishub.net* (a web-based platform for AIS data sharing) were stored in a dedicated SQL database. AIS data contain the following fields: ship ID, timestamp, speed, status (navigating or mooring), geographical coordinates, and ship type. Considering precedent works having focussed on ship traffic in different Mediterranean sub-areas (Maglio *et al.*, 2013; Vaes and Druon, 2013), 1 month of AIS data was considered sufficient to provide a picture of the average ship density in the investigated area. Also, it was assumed that the location of main vessel routes remained similar in the last 10 years. Therefore, it was decided to take the consecutive 30 days yielding the best marine traffic data quality in recent years. After a quick check in row AIS data, the month of July 2014 appeared as the one providing the best quality data (in terms coverage of the Mediterranean) and was chosen for ship density analysis. Data comprehend the whole Mediterranean basin. However, some zones (i.e. the Adriatic Sea and the western Alboran Sea, and the south-western Peloponnese) were not well covered by the AIS service, due to a lack of AIS land stations in such areas, and hence were not reflected in this analysis. Nonetheless, this does not prevent to gather an overview of the main shipping density areas of the Mediterranean.

AIS data were extracted from the *aishub.net* platform for the period July 1st to 31st 2014 and organised in CSV files, and then stored in the SQL database. A timestamp of 10 minutes was used, meaning that every 10 minutes from July 1st to 31st a snapshot of ships present in the area was recorded. Therefore, 4464 AIS files could be stored, consisting of around 7 millions of ship positions. From this database it is possible to extract locations of recreational craft vessels voluntarily carrying and AIS device or exceeding 300 tons, and hence intense recreational vessel zones were also identified.

2.3. Data: Coastal and Offshore work

With regard to human activities potentially generating loud underwater noise in coastal and offshore waters, we addressed harbour developments, renewable energy projects (wind farm construction and operation) and oil and gas platform operations. Data were gathered through extensive searches in internet official websites and through direct contact to stakeholders (see section 7 – Appendices – for list of websites and contacted stakeholders). Considering offshore windfarms, only projects with an estimated good probability to be implemented were considered. In practice, only projects with an EIA completed and approved for environmental compatibility were included in the database.

Usually, publicly available information consists of document where geographical coordinates of project locations are shown. In case coordinates were not shown, existing published maps were stored for subsequent geo-referencing using GIS tools. In some cases, data were directly available to download from official websites (e.g. websites databases from the Ministries of Industry and Energy of various countries). Finally a partnership established with the Regional Marine Pollution Emergency Center (REMPEC) made it possible to gather data on the position of Mediterranean harbours (ports and marinas).

2.4. Data: Seismic survey areas

Seismic exploration is a very common methodology employed both for commercial and scientific geophysical studies. Commercial seismic surveys are conducted by specialised private companies, normally commissioned by public or private oil and gas companies which actively search for hydrocarbon reservoirs with the aim of commercially exploiting them. On the other hand, scientific surveys are usually conducted by public national institutions for public geophysical/geological research purposes.

Data were sought through extensive searches of the internet and by contacting stakeholders of the hydrocarbon extraction sector and of geophysical research (see section 7 – Appendices – for list of websites and contacted stakeholders). Data gathered included licensing blocks, areas of the so called "multi-client" surveys (large surveys usually covering the whole or a great portion of the maritime space of a country), and real routes of data acquisition vessels (available for public research only). Data concerning licensing blocks were mainly found in the websites of the Ministries of each country surrounding the Mediterranean Sea. Only licensing blocks with active exploration/exploitation permits or blocks where seismic surveys have been carried in the recent past were included here Also, useful information could be accessed in the websites of companies conducting large multi-client surveys. Finally, information concerning scientific surveys was accessed upon request to the scientific institutions identified in our search. Data collected were in different formats: licensing block maps, shapefiles, kml files, text files with geographical coordinates, etc.

Accurate data about the spatial extent of exploration areas were found both for commercial and scientific surveys, while satisfactory data about time frames (i.e. the year in which surveys where carried out) where only found for scientific surveys and a part of commercial surveys (multi-client surveys). Satisfactory information was rarely available concerning time frames for the rest of commercial surveys (i.e. those carried out inside a valid exploration permit). In such cases, we used start-end dates of exploration permits instead. This way, we could delimitate the global period in which seismic surveys could be carried out. It should be noted that a valid exploration permit can last several years but surveys are not carried out every year. In the framework of this project, we could not go more in depth with data collection on time frames. Therefore some results on seismic survey areas are to be regarded as areas where surveys potentially occurred.

2.5. Data: Military exercises

Given the confidential or classified nature of much information concerning military exercise activities, we could gather public data only on the spatial extent of military areas of some Mediterranean countries, namely Spain, France, Italy and Greece. Further some public information was found concerning NATO areas of exercise. On the other hand, few or no data were found concerning exact periods, noise related equipment, and other details on such activities. However, data on military exercise areas for the aforementioned countries could be easily accessed through different tools: for Spain, information was found in documents related to the Marine Spatial Planning Directive (MSP, www.marineplan.es), while for France, the CNRS (*Centre National de la Recherche Scientifique*) in collaboration with the SHOM (*Service Hydrographique de la Marine*) provided relevant maps on its website (www.dt.insu.cnrs.fr/flottille/cartes_marines.php). Finally, for Italy and Greece, information was found through the respective national hydrographical institutes of the Navies of the two

countries (www.marina.difesa.it, www.hnhs.gr). No information was found concerning potential areas of naval exercises for the other countries surrounding the Mediterranean.

2.6. Analysis

Concerning marine traffic, after cleaning data from outliers and other frequent errors in AIS broadcasting, an algorithm implemented in MATLAB was used to perform traffic density analysis. Traffic density was calculated in terms of total count of vessels per grid cell of 1' in latitude and longitude (WGS84) within the month of July 2014. Results are presented in logarithmic scale in order to highlight main vessel routes.

Data about seismic exploration and military areas activities were stored in the form of polygons (ESRI shapefile format). Data on harbours, oil and gas platforms and wind farms projects were stored as points (ESRI shapefile format). ArcGIS 10 and the *R* language were used to treat row data. In order to highlight the extent and the occurrence of noise-producing human activities, a spatial grid was built with cell size 40 x 40 km. Through the use of this spatial grid we performed the following analyses:

- Harbour density (n° harbours per grid cell)
- Offshore operation density (n° of oil and gas platforms and wind farms per grid cell over the period 2005 - 2015)
- Occurrence of seismic survey areas (grid cells covered by at least a seismic survey or an exploration permit, by year over the period 2005 – 2015)
- Accumulation of noise-producing human activities (noise hotspots)
- Noise-cetacean potential interactions

According to current recommendations concerning noise assessments related to the Marine Strategy Framework Directive (MSFD) of the European Union and to the Ecosystem Approach initiative (EcAp) of the Barcelona Convention, continuous and impulsive noise sources are to be addressed separately, as two different methods were proposed for the assessment of their pressure on the marine environment. Therefore, in this study the identification of noise hotspots and potential noise-cetacean interaction hotspots is based on the accumulation of all noise-producing human activity except shipping, which is the only source of continuous noise addressed in our study.

With regard to military activities, as data were gathered for only a few countries, analysis consisted of plotting row data on Navy exercise areas (polygons) in the central and Western Mediterranean Sea.

Furthermore, the total annual surface (km²) covered by seismic survey areas (actual surveys and/or exploration permits) was calculated and related to the surface of the Mediterranean Sea, as to obtain a view of the percentage of the Mediterranean Sea surface involving seismic surveys and/or exploration permits in the last 10 years, and for the near future.

3. RESULTS

With regard to the data collection process, 75 stakeholders were contacted concerning four impulsive noise categories: military activities, harbours, seismic exploration, renewable energies (see fig. 1), whereby general reply rates varied from 100% (military activities, harbour construction, renewable energies) to 23% (seismic exploration) and replies with data provision varied from 100% (harbours) to 6% (seismic exploration).

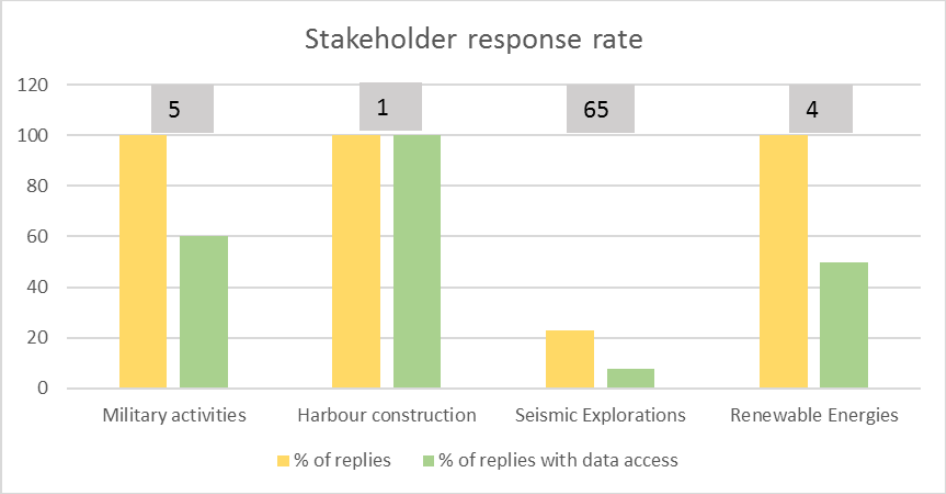


Figure 1. Response rate (%) of contacted stakeholders. Numbers in grey squares indicate the number of total contacted stakeholders (# of persons = 100%). Note that the number of contacted stakeholders with reference to military activities was restricted to four countries, namely France, Italy, Spain, and Greece (see section 2.5) and that all necessary data concerning harbour localisation was gathered through one stakeholder

Main results in terms of data gathered are the following:

- Around 7 Million ship positions recorded via the AIS were analysed for July 2014
- 285 ports (harbours with industrial and/or fisheries activities) and 1161 marinas (harbours for recreational boats) located
- 280 Coastal an Offshore sites inventoried for the last 10 years, including
    - 228 drilling platforms for hydrocarbon exploitation
    - 52 wind farm projects (planned or in construction)
- 830 Seismic exploration areas: currently active areas or that were active at some period within the past 10 years
- Military areas in Spain, France, Italy and Greece covering almost 455 000 km² of sea surface in the western Mediterranean area

Summary maps of noise-producing human activities are shown hereafter.

3.1. Marine traffic density

Concerning marine traffic, the main vessel routes are highlighted in figure 2. It is possible to observe that areas yielding most of ship traffic lie in the North-Western Mediterranean Sea, In Greek waters and in the Strait of Sicily. It is visible as well a major ship lane going from the Strait of Gibraltar to the Suez Canal. The logarithmic scale has been adapted in order to better highlight the wide variability of

ship density. The maximum value in the map reaches around 11 000 ships (total ship count per cell), meaning 1 800 hours of ship traffic over a month (july 2014). Based on our data, around 1500 vessels are present in the area at any time on average.

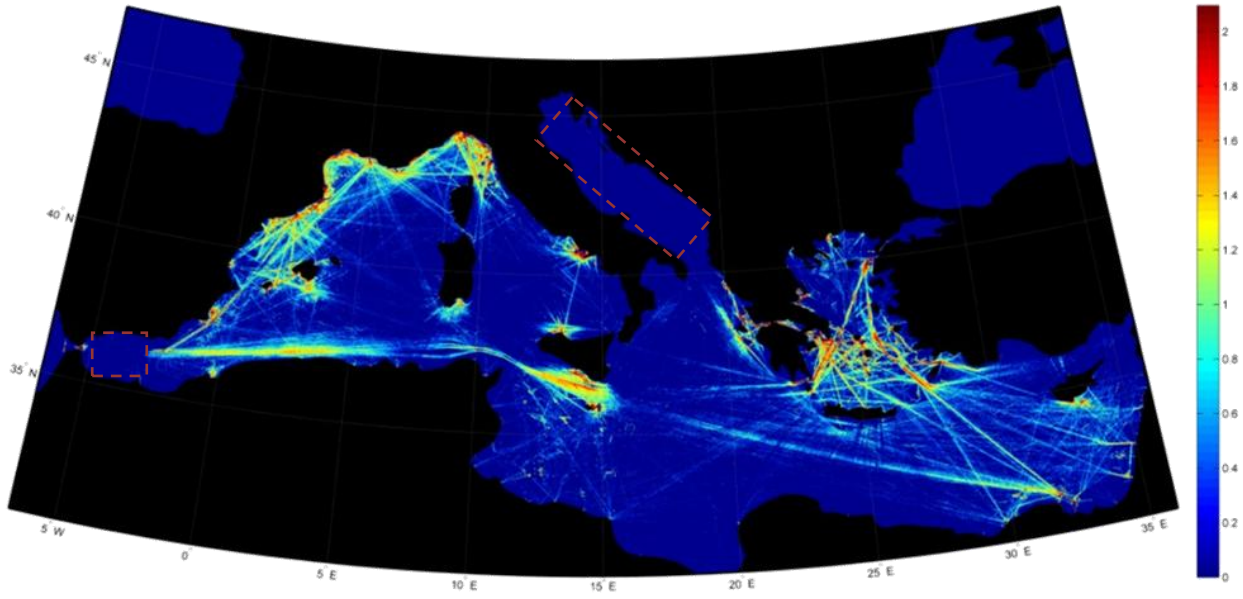


Figure 2. Ship traffic density (ship count) per grid cells of 1' in longitude and latitude per month (July 2014), in logarithmic scale. Dashed areas represent very limited AIS coverage.

A focus was done on traffic from relative recreational craft (voluntary vessels or over 300 tons) (figure 3). As the AIS system is not mandatory for ships with tonnage less than 300 (as most of recreational vessels), it should be taken into account that the density map represents a good indicator of the spatial distribution of pressure areas (except areas of very limited AIS coverage), but ship density values are very likely to be underestimated. The same logarithmic scale for traffic density from all ships has been used to show relative recreational craft density, thus allowing for comparison.

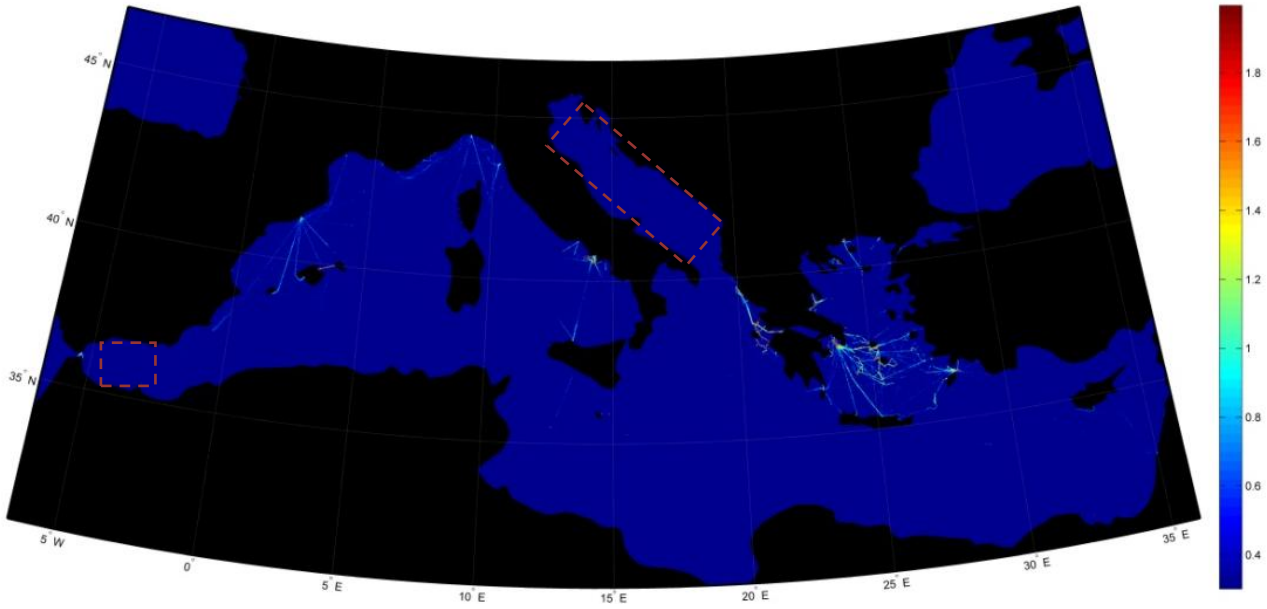


Figure 3. Relative recreational craft density (ship count), per grid cell of 1' in longitude and latitude per month (July 2014), in logarithmic scale. Dashed areas represent very limited AIS coverage

Considering relative recreational craft, most of traffic is found in Greek Aegean Sea, in Greek Ionian Sea, along the Italian coast of Campania in the southern Tyrrhenian Sea, in the Northern part of the Ligurian Sea and in the Balearic Sea and a focal concentration in the Strait of Gibraltar.

3.2. Coastal and Offshore works

A total of 1448 harbours were identified in the study area (286 ports, i.e. harbours with industrial and/or fisheries activities and 1162 marinas, i.e. harbours for recreational craft; table 1). Most of them are located in the Northern part of the basin. Areas of very high concentration (more than 12 harbours by grid cells of 40 x 40 km) are located in the Côte d'Azur and Gulf of Fos (France), Gulf of Naples and the Campanian Archipelago (Italy) and the Gulf of Trieste (Italy/Slovenia), as shown in figure 4.

High numbers of harbours (6 to 11 harbours per grid cell) are also found in the Aegean Sea, where the presence of a very high number of islands is likely to be the cause of lower densities of harbours on the mainland coastline of Greece, in the coasts of Mallorca and Cartagena (Spain), and in a great part of Italian and Croatian coasts.

Table 1. Harbours (ports and marinas) by countries (data of 2015)

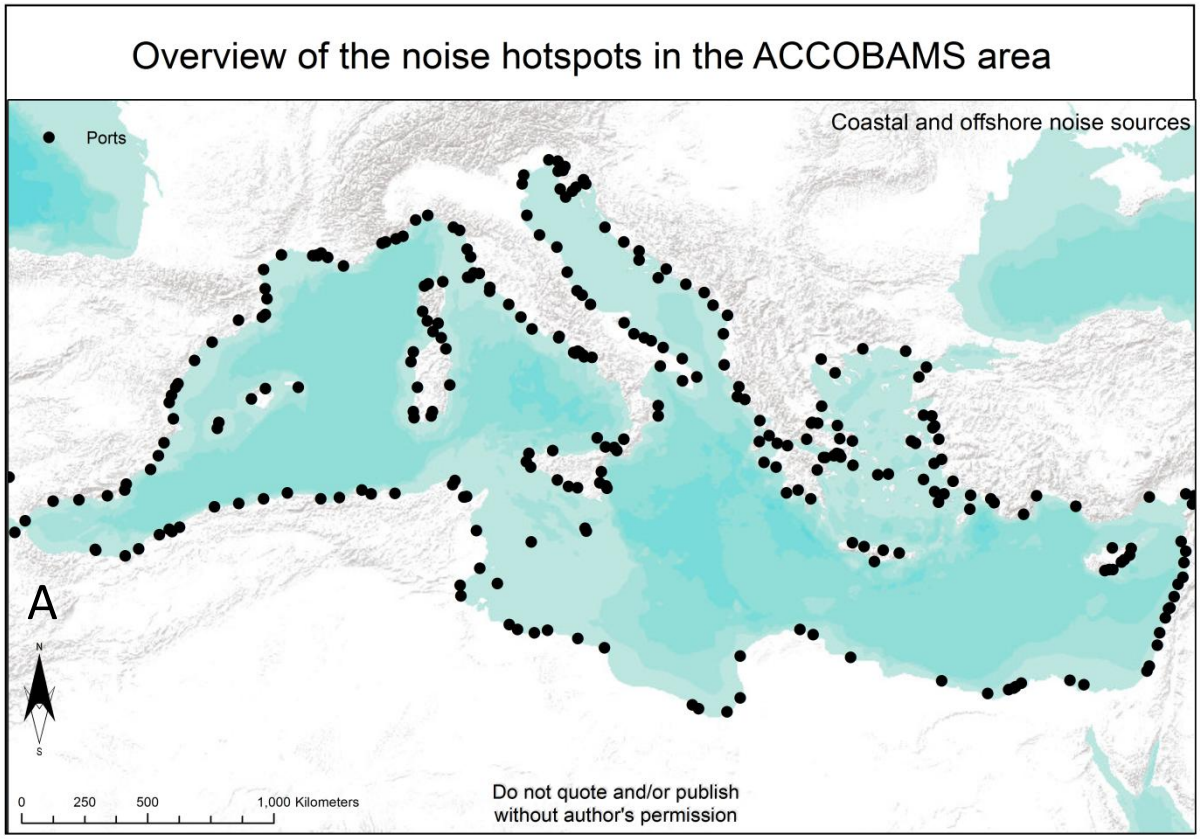
Country	Ports	Marinas	TOT (Harbours)
Monaco	1	3	4
Montenegro	1	4	5
Syria	3	3	6
Malta	2	5	7
Lebanon	6	3	9
Slovenia	3	8	11
Morocco	2	10	12
Egypt	8	5	13
Israel	4	9	13
Cyprus	8	7	15
Libya	14	15	29
Algeria	15	25	40
Tunisia	10	25	35
Turkey	19	51	70
Croatia	13	93	106
France	18	132	150
Spain	30	156	186
Greece	48	203	251
Italy	76	405	481

With regard to wind farms, projects exist for Italy, France, Greece and Spain, at different stages of development. In this work we only focussed in projects that are likely to be developed in the near future, which have an approved EIA by the national environmental authority.

We found 7 projects in Italy at an advanced stage in the application and authorisation process. In July 2015, the first fully commissioned offshore wind farm in the Mediterranean Sea (Gulf of Taranto, Southern Italy) obtained the approval for starting construction within 18 months after the approval. On the other hand, Spain holds wind farm projects in all its maritime spaces, including the Mediterranean Sea. However, today priority seems to be given to developing the first projects in the Canary Islands and in Atlantic areas, and hence projects for the Mediterranean area have not yet

started construction and thus are not shown in this study. France has recently authorised the development of floating wind farms in the Gulf of Lion (3 projects), where pilot projects are underway (2 projects) in the same area. In Greece several little projects exist (around 40 wind farm under application process). Such projects can be located in 5 main areas: North of Corfu, Eastern Crete, 1 zone located in the central Aegean Sea, two zones in the Northern Aegean Sea, and finally 1 project exist in the Gulf of Corinth.

Finally, results on oil and gas wells drilled in the last 10 years clearly highlights areas where hydrocarbon extraction activities have been concentrated in this period: northern Adriatic Sea, Strait of Sicily and Levantine areas. 190 oil wells were drilled in the Italian Adriatic Sea in this period, 32 wells in Israel waters, 6 in Cyprus, 5 in Spain. Also, Tunisia and Egypt seemed to have an intense offshore drilling activity but reliable data on the number of wells drilled in the last 10 years could not be gathered. Instead, the position of oil & gas fields discovered and developed in this period was used as an indicator of the potential position of drilling sites (and indirectly also for seismic exploration). No activity was recorded concerning waters of Morocco and Algeria, Greece and countries on the Eastern Adriatic Sea in the last 10 years. No data are currently available for Libya.


Overview of the noise hotspots in the ACCOBAMS area
Ports
Coastal and offshore noise sources
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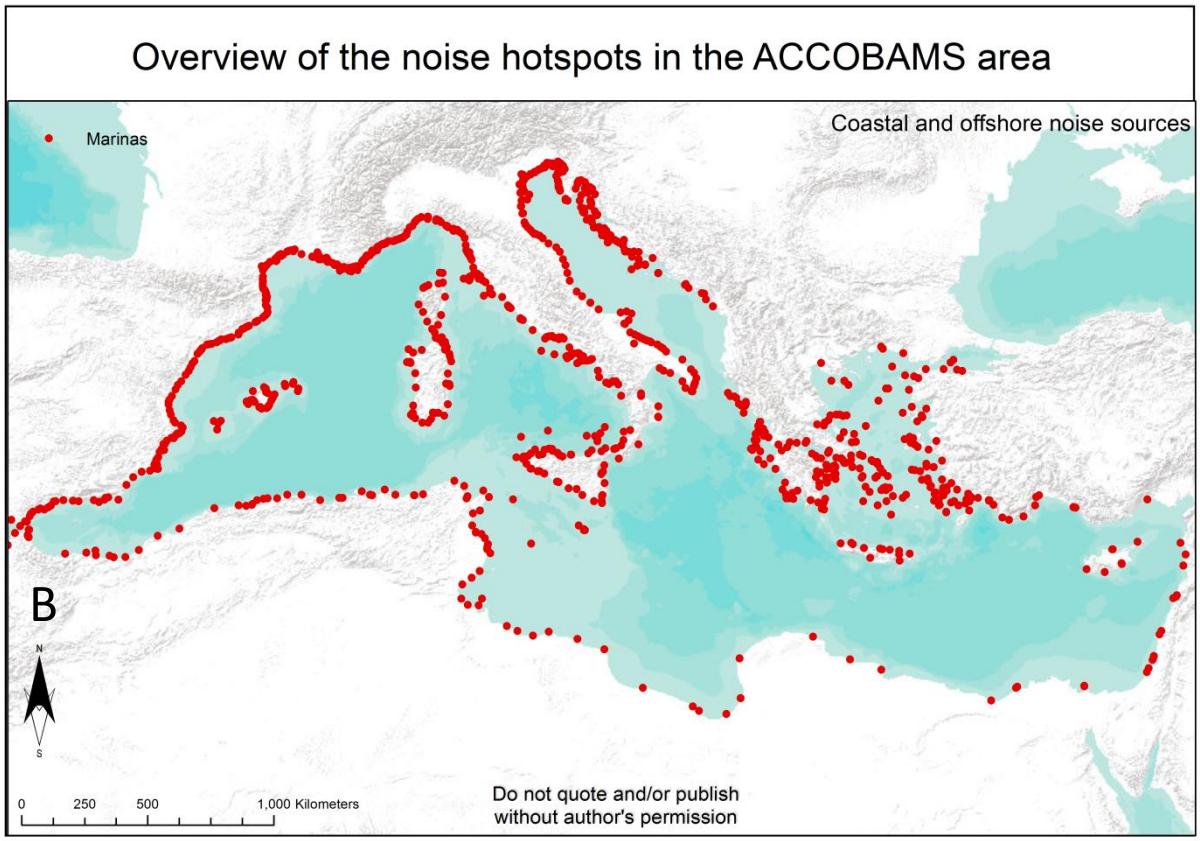
Overview of the noise hotspots in the ACCOBAMS area
Marinas
Coastal and offshore noise sources
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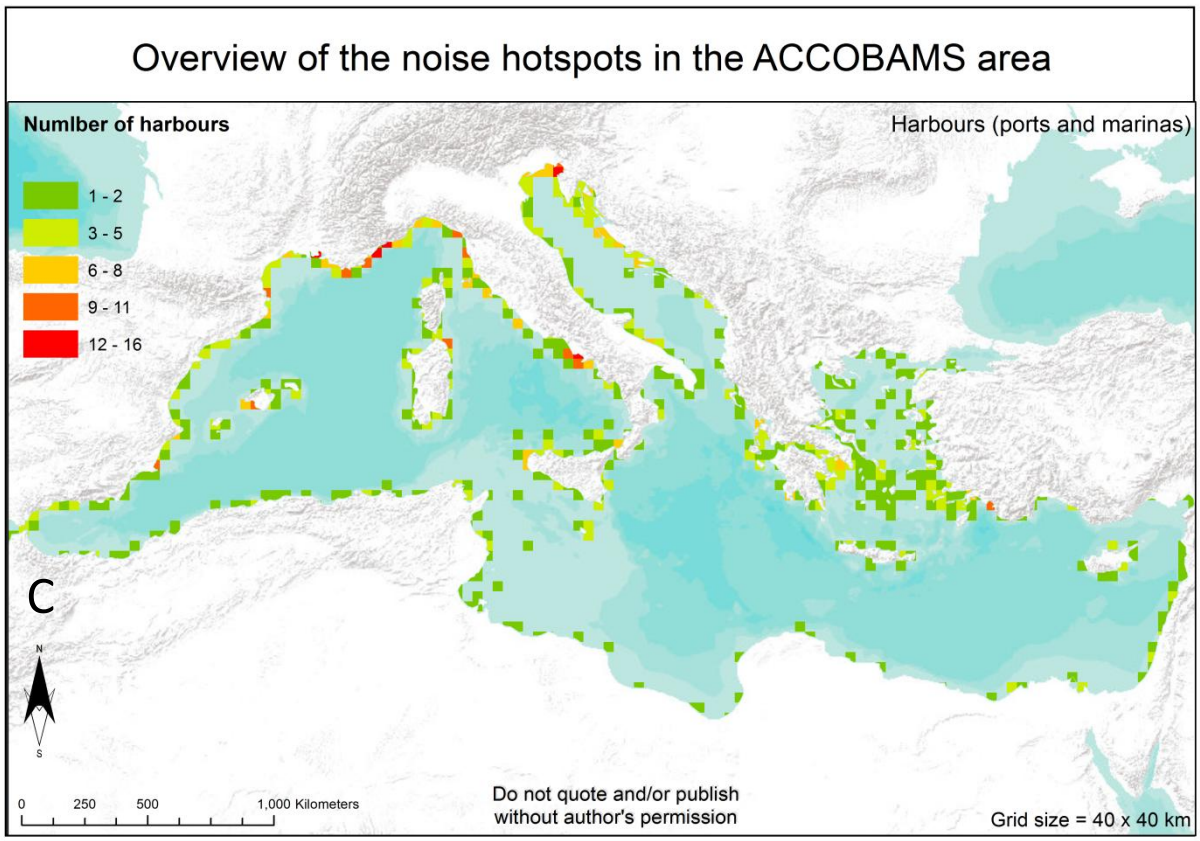
Overview of the noise hotspots in the ACCOBAMS area
Numlber of harbours
1 - 2
3 - 5
6 - 8
9 - 11
12 - 16
Harbours (ports and marinas)
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1,000 Kilometers
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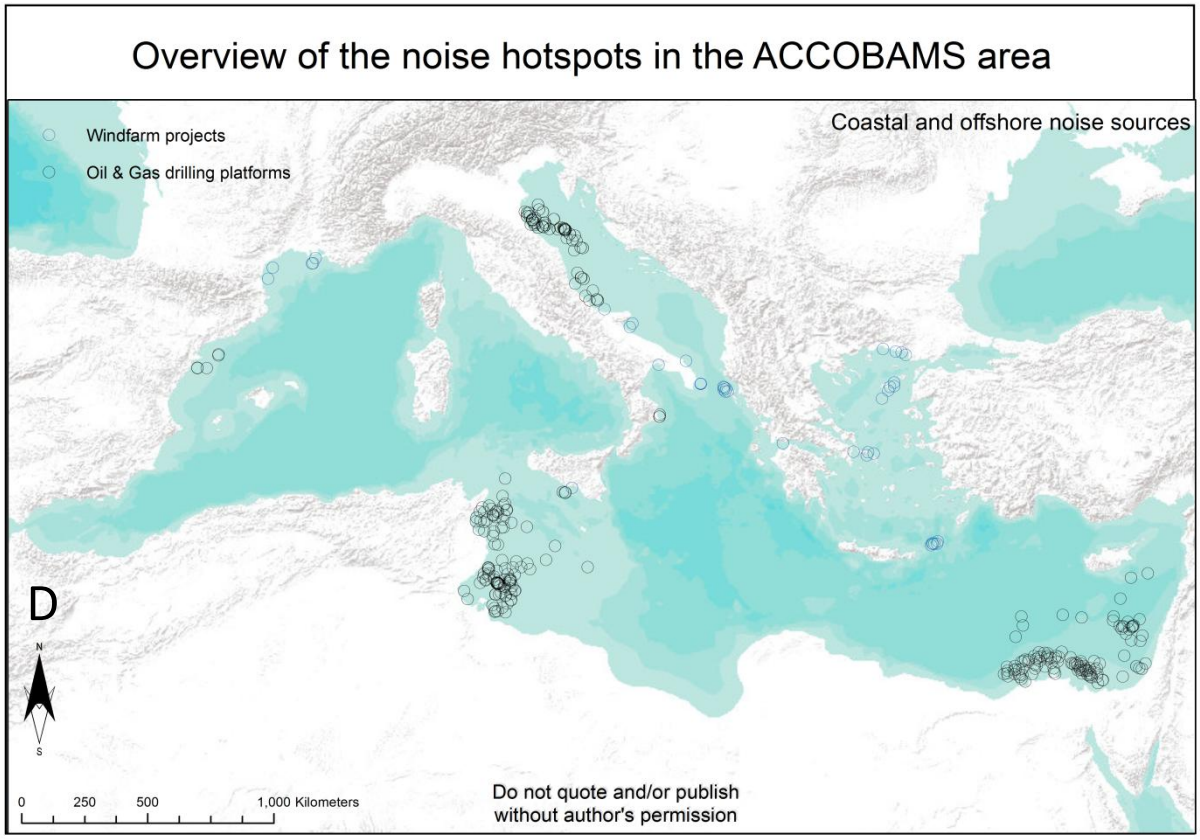
Grid size = 40 x 40 km


Overview of the noise hotspots in the ACCOBAMS area
Windfarm projects
Oil & Gas drilling platforms
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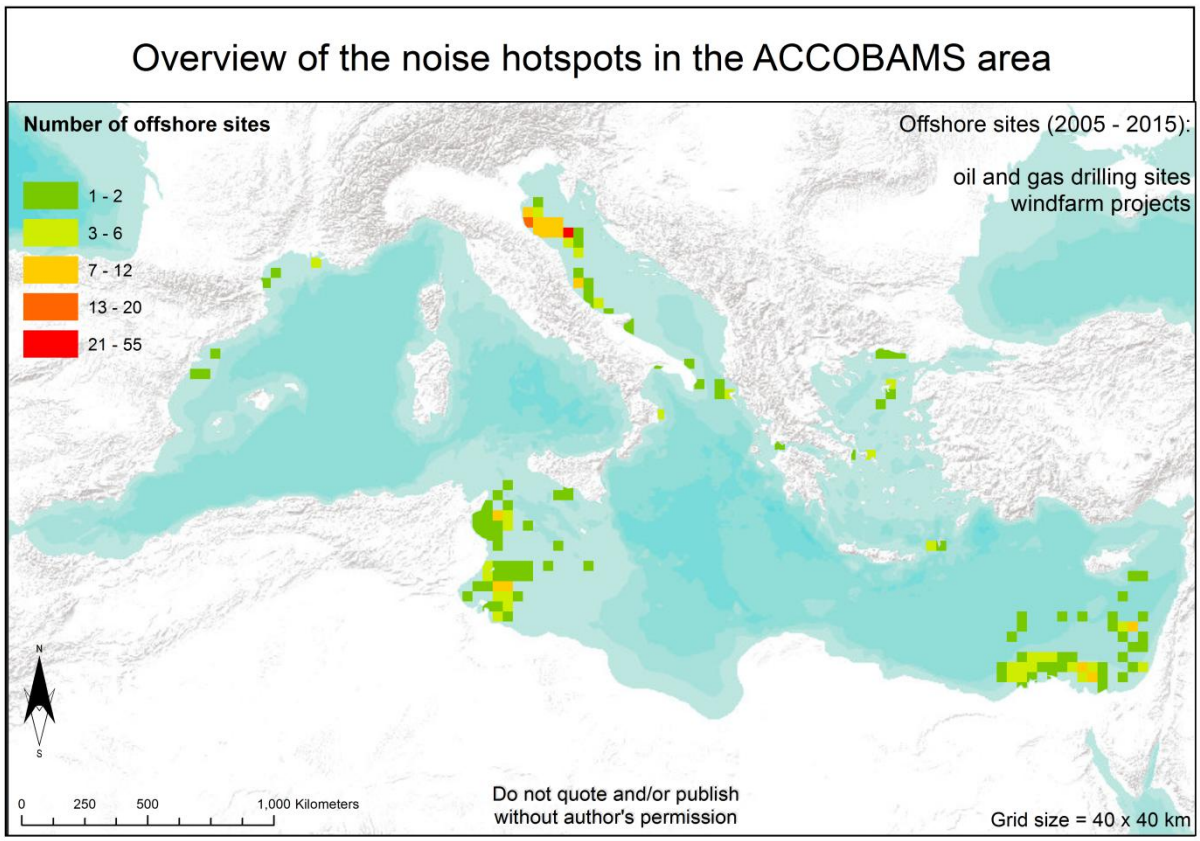
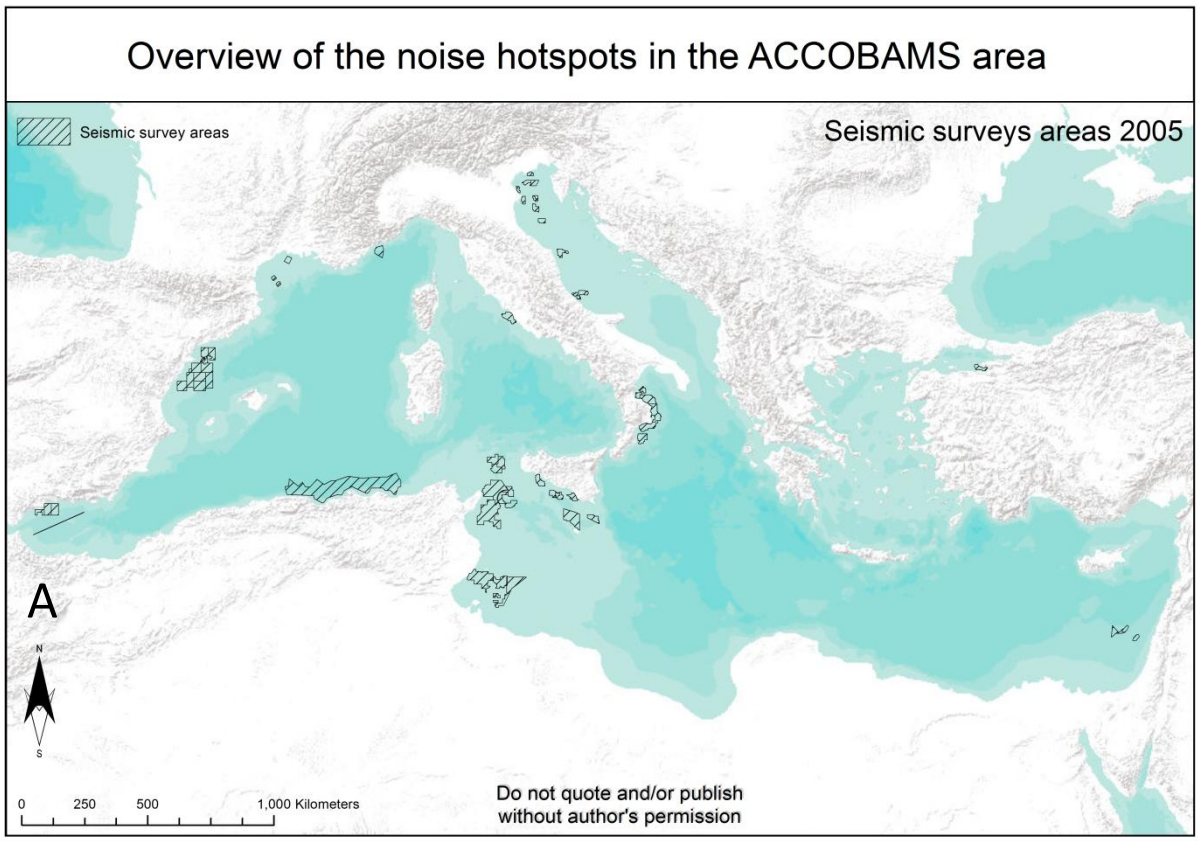


Figure 4. Locations of coastal and offshore activities. A) Location of ports, i.e. harbours with industrial and/or fisheries activity; B) Location of marinas, i.e. harbours for recreational craft; C) harbour density over a 40 x 40 km spatial grid; D) position of oil & gas drilling platforms; E) oil and gas platform density over a 40 x 40 km spatial grid

3.3. Seismic Surveys

In the last 10 years and in the near future, around 830 exploration areas were inventoried. Most of them belong to survey blocks allocated to private specialised companies. However, we found that largest surveys are carried out in the framework of multi-client projects aiming at exploring the potential of countries for offshore hydrocarbon extraction. Generally, countries with a long history in offshore oil & gas industry do not have a fixed spatial management grid for licensing blocks and permits are delivered for a particular area defined by the spatial distribution of potential for productivity, accorded on a case-by-case basis. This is the case of Italy, Spain, Egypt, and Tunisia). Conversely, countries with a recent history in this sector, or which are currently opening their maritime space to the hydrocarbon sector, developed a fixed block system.

As described in section 2.4 (Data: Seismic survey areas), the following maps (figure 5, all panels) display both areas where seismic surveys were effectively conducted and areas with valid exploration permits, where commercial surveys could be carried out. This appears a useful indicator of the situation created by an unregulated permit delivering process at the international level (regional or sub-regional). Annual maps are shown hereafter together with a map showing the surveyed area in the last 10 years and a map showing planned survey projects, potentially carried out in the next 5 years.


Overview of the noise hotspots in the ACCOBAMS area
Seismic survey areas
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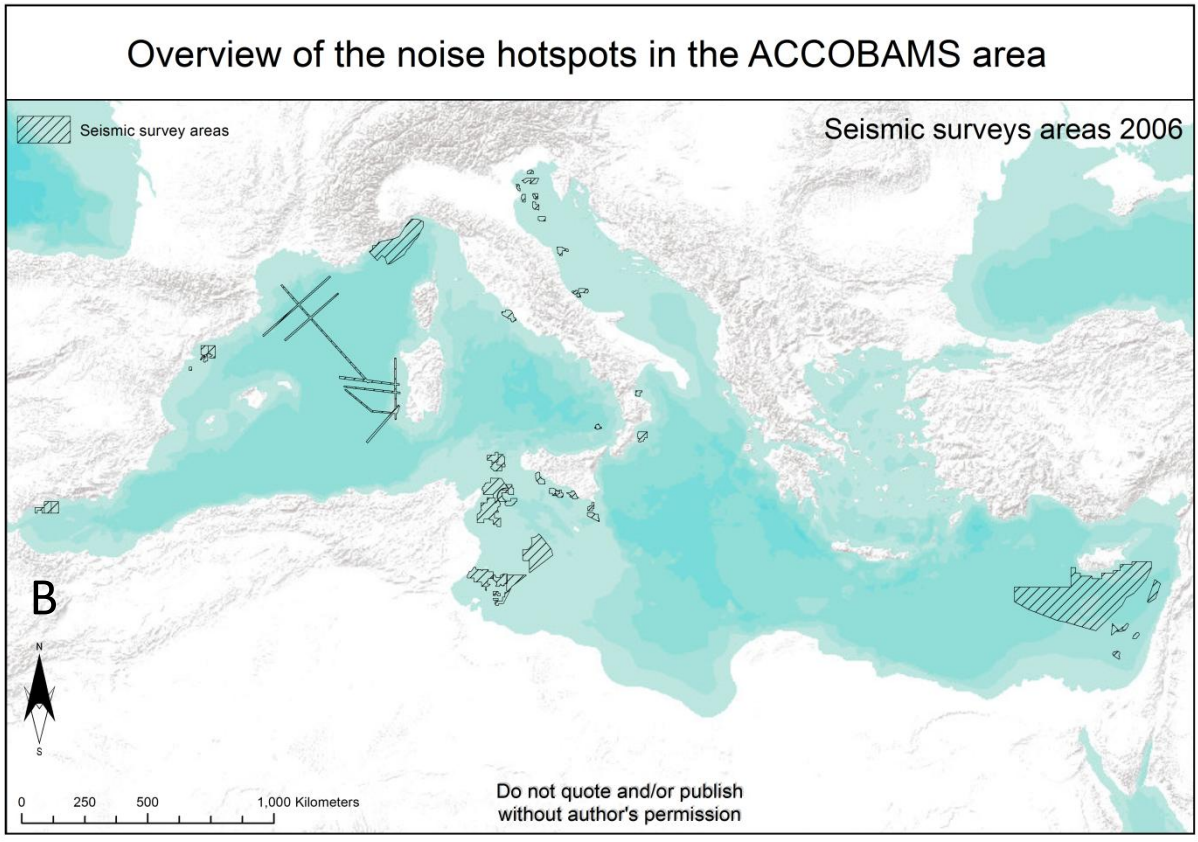
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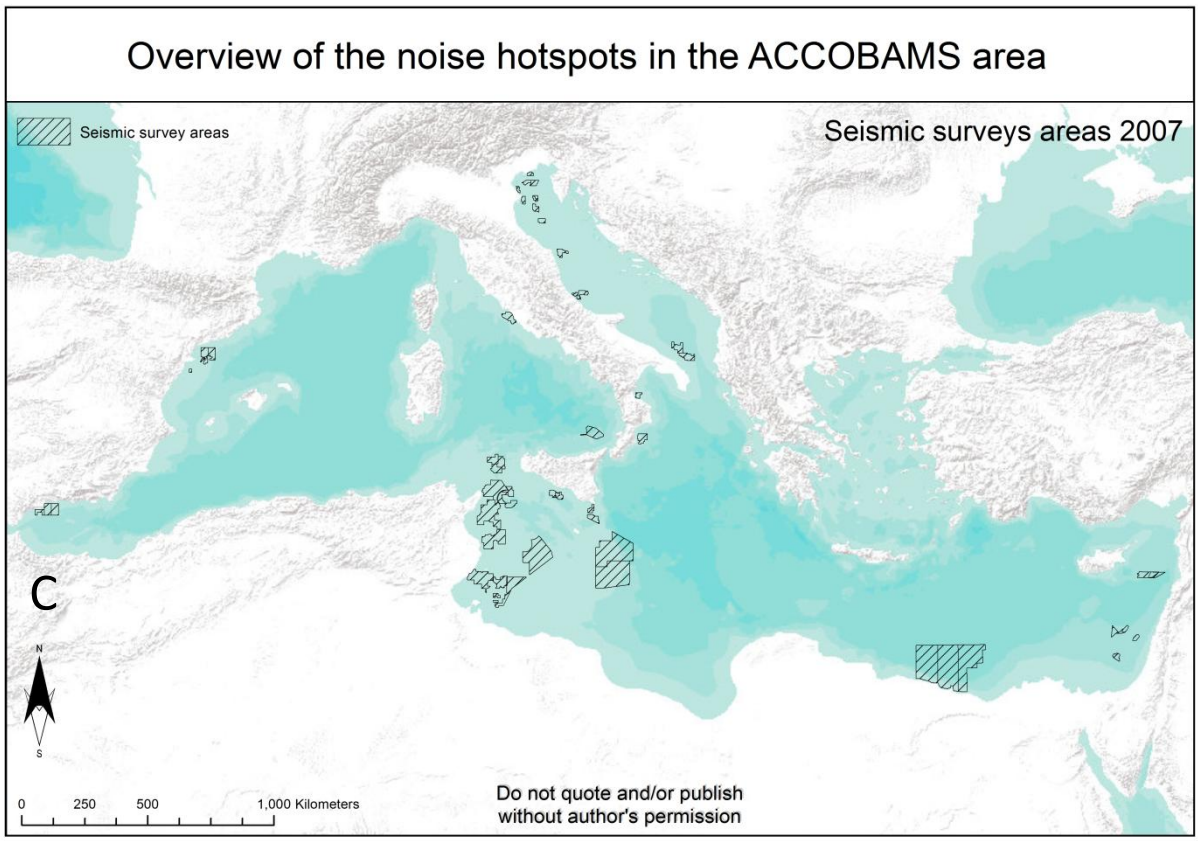
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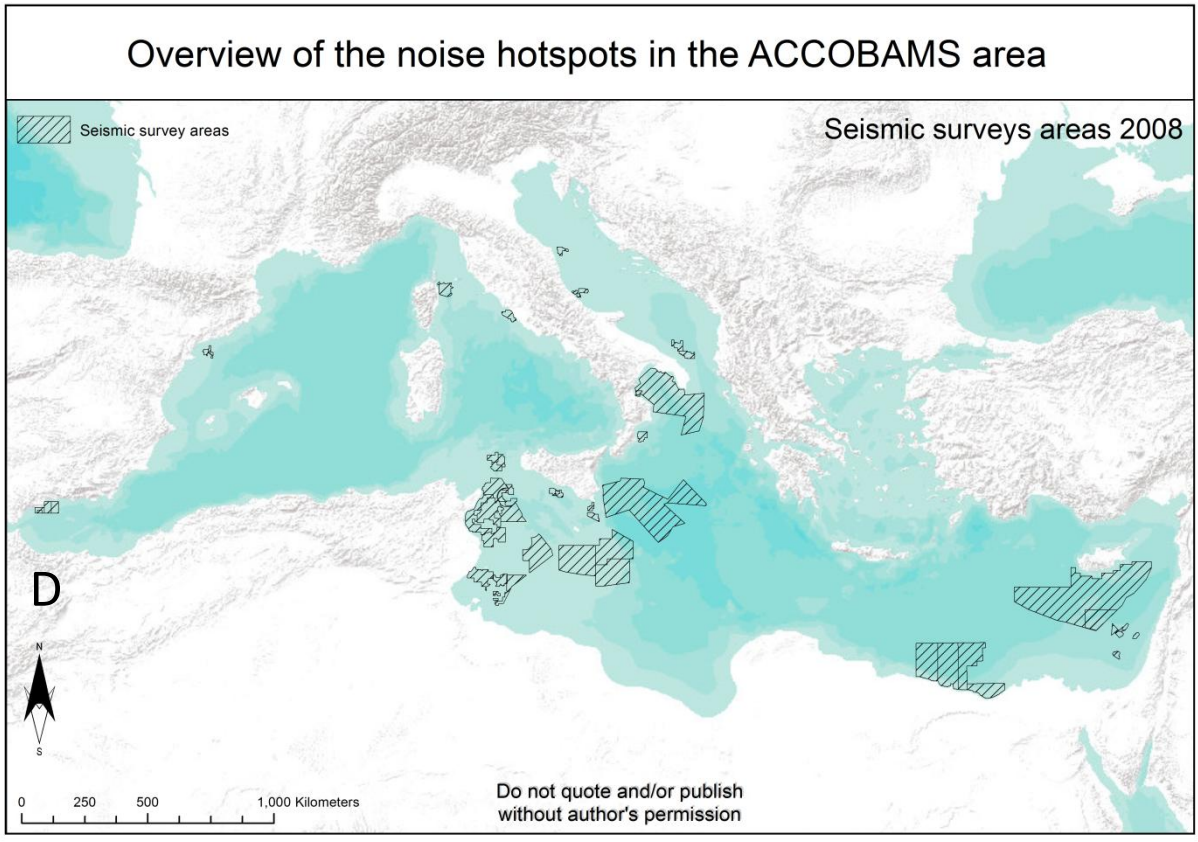
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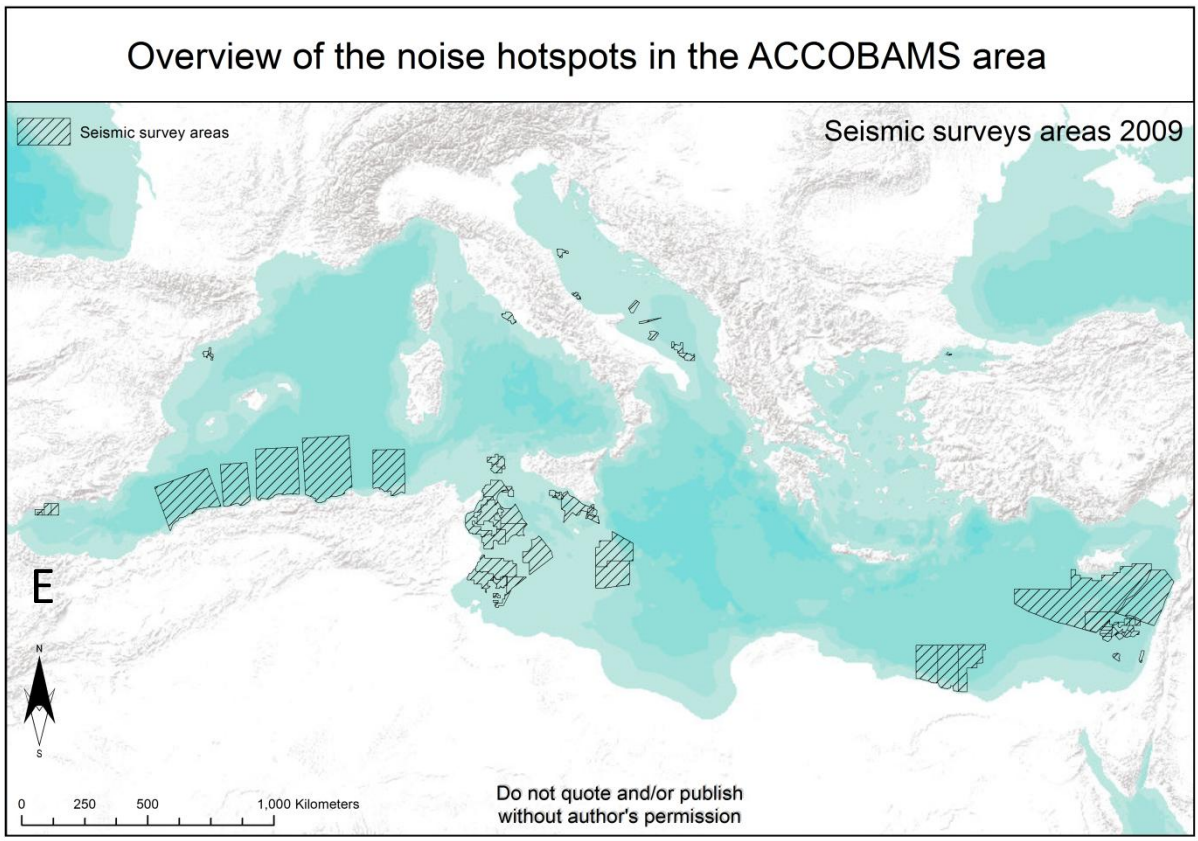
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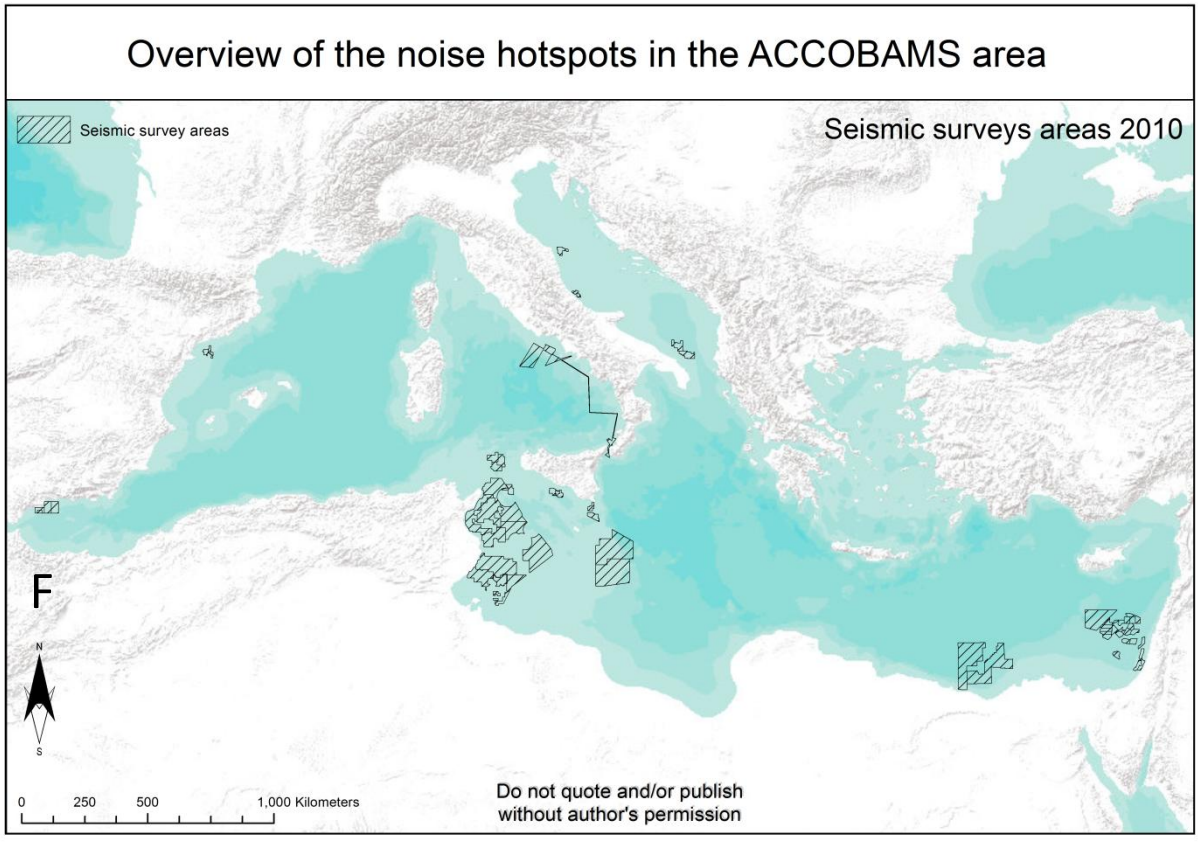
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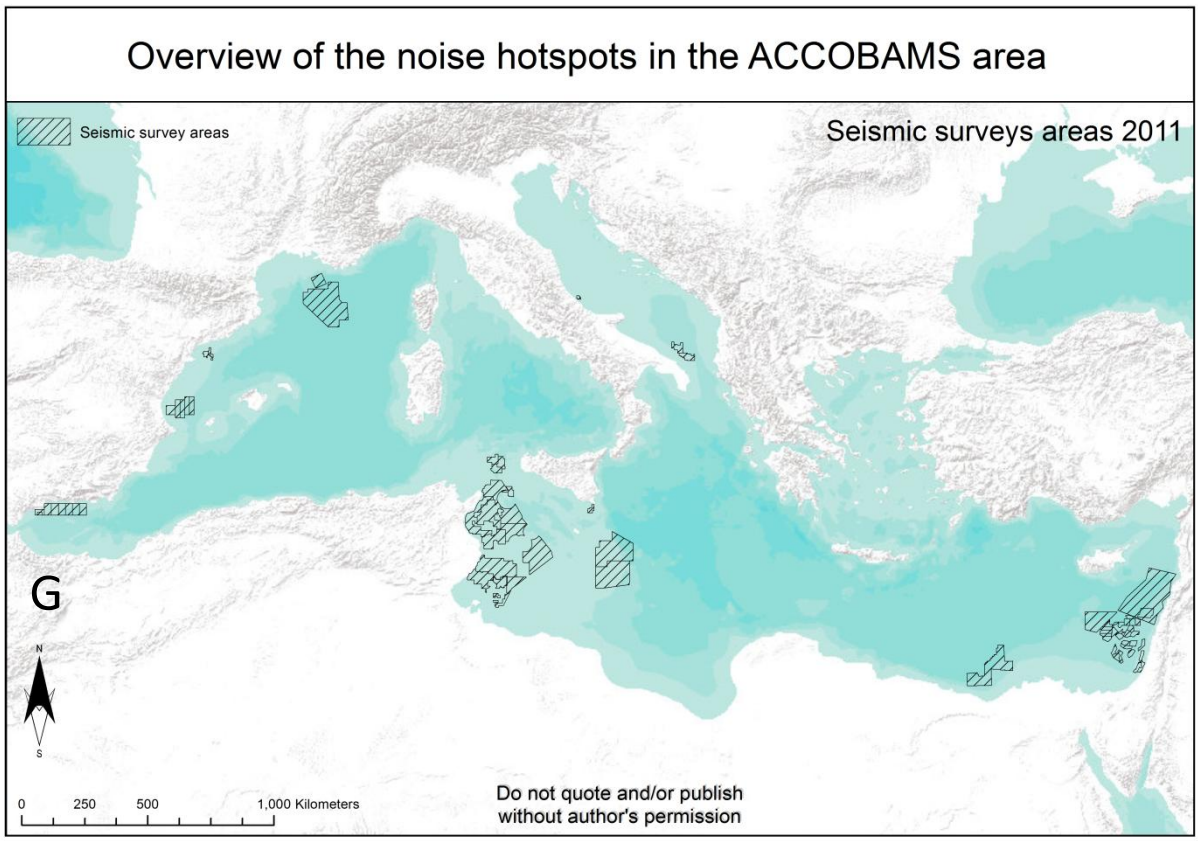
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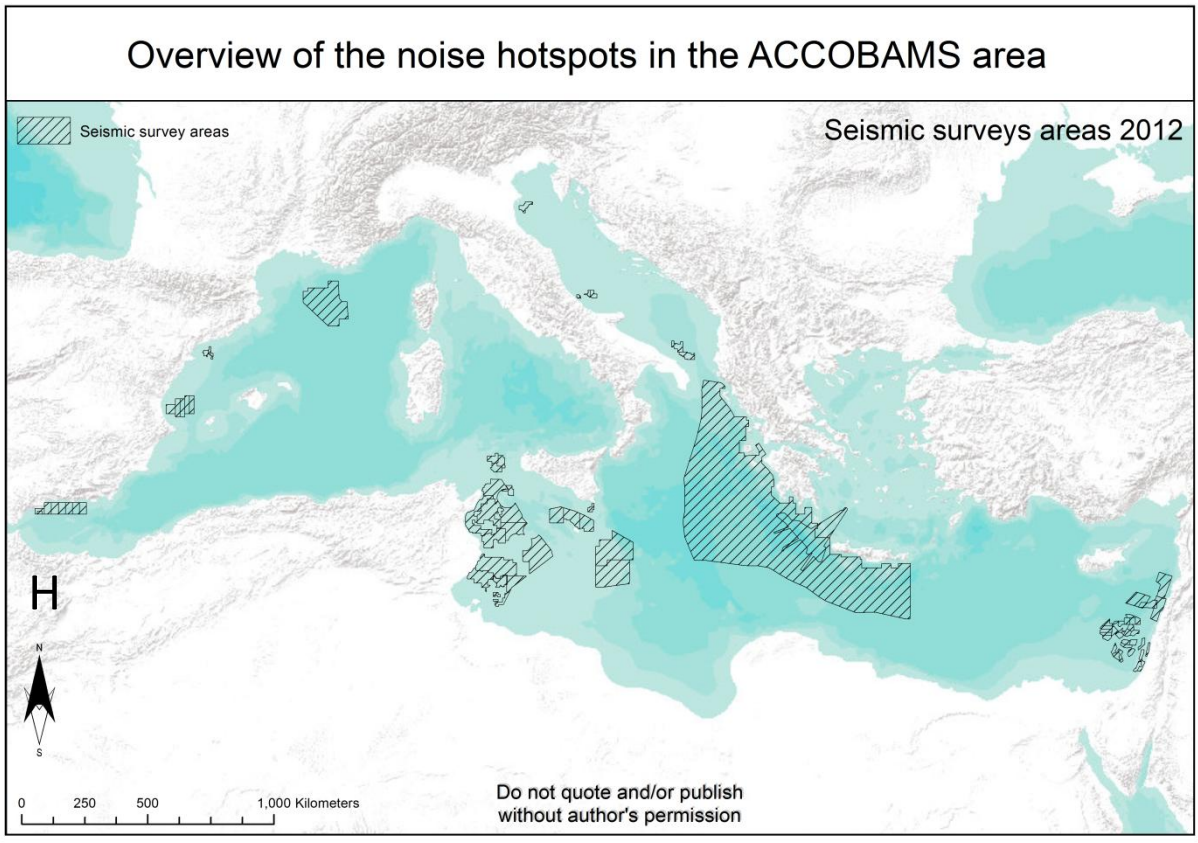
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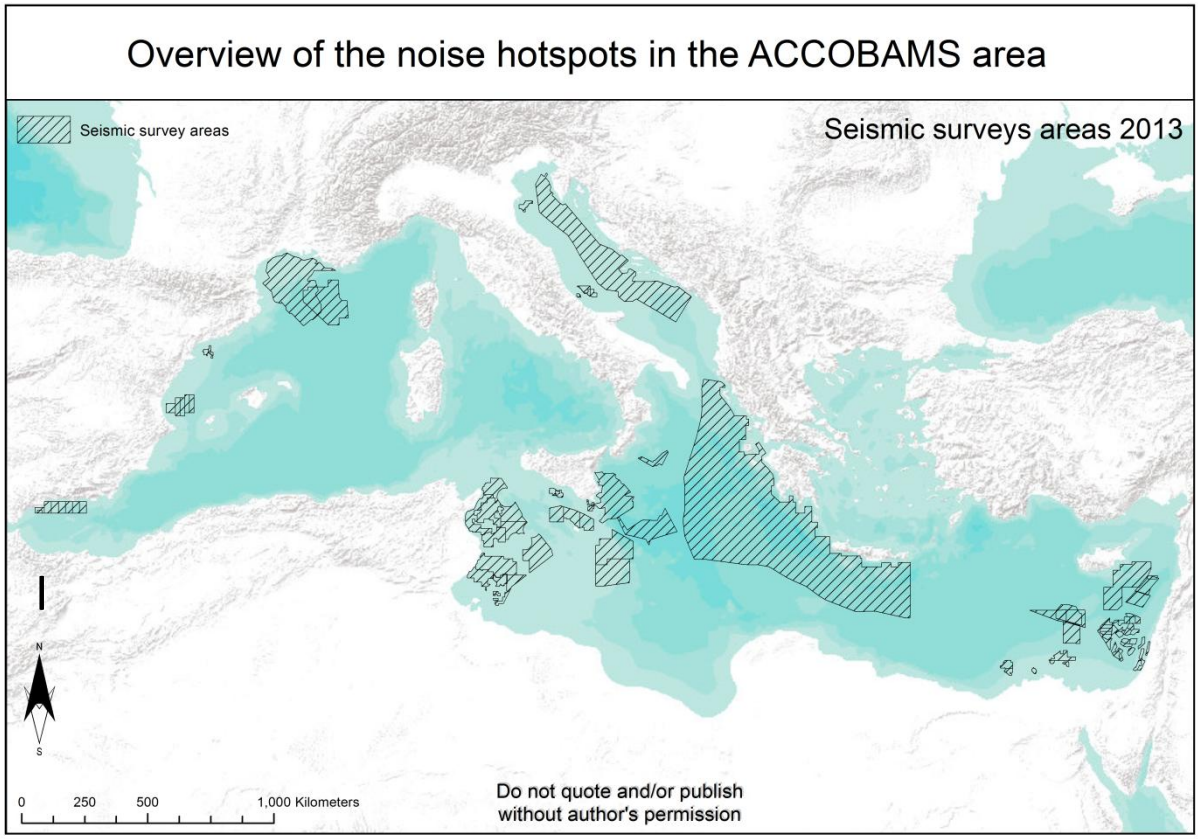
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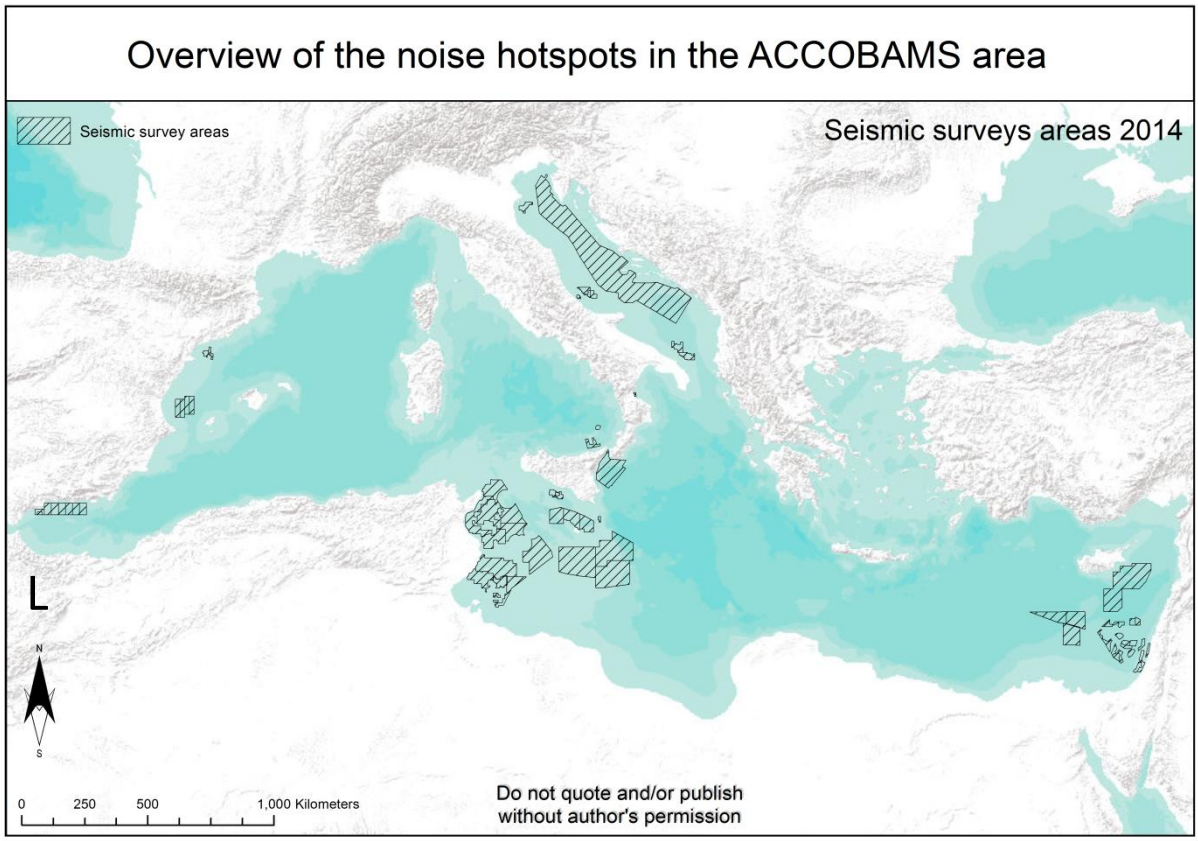
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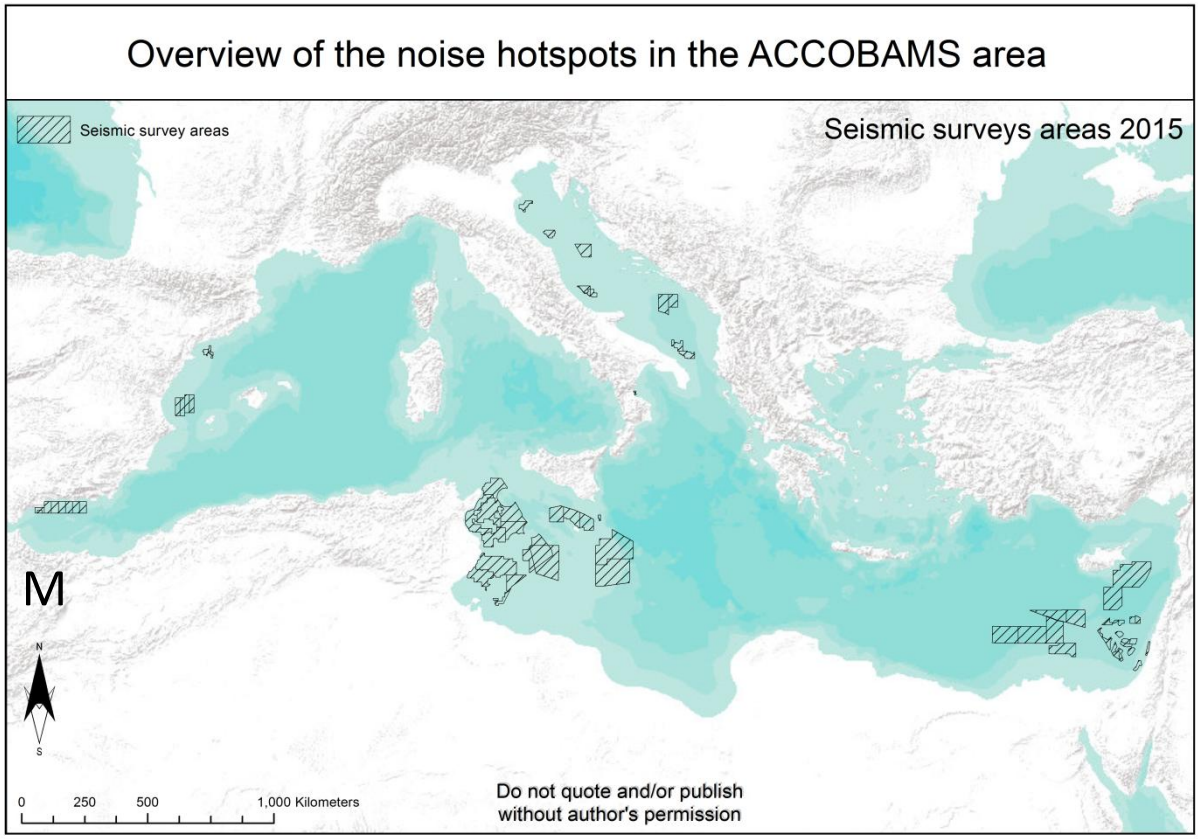
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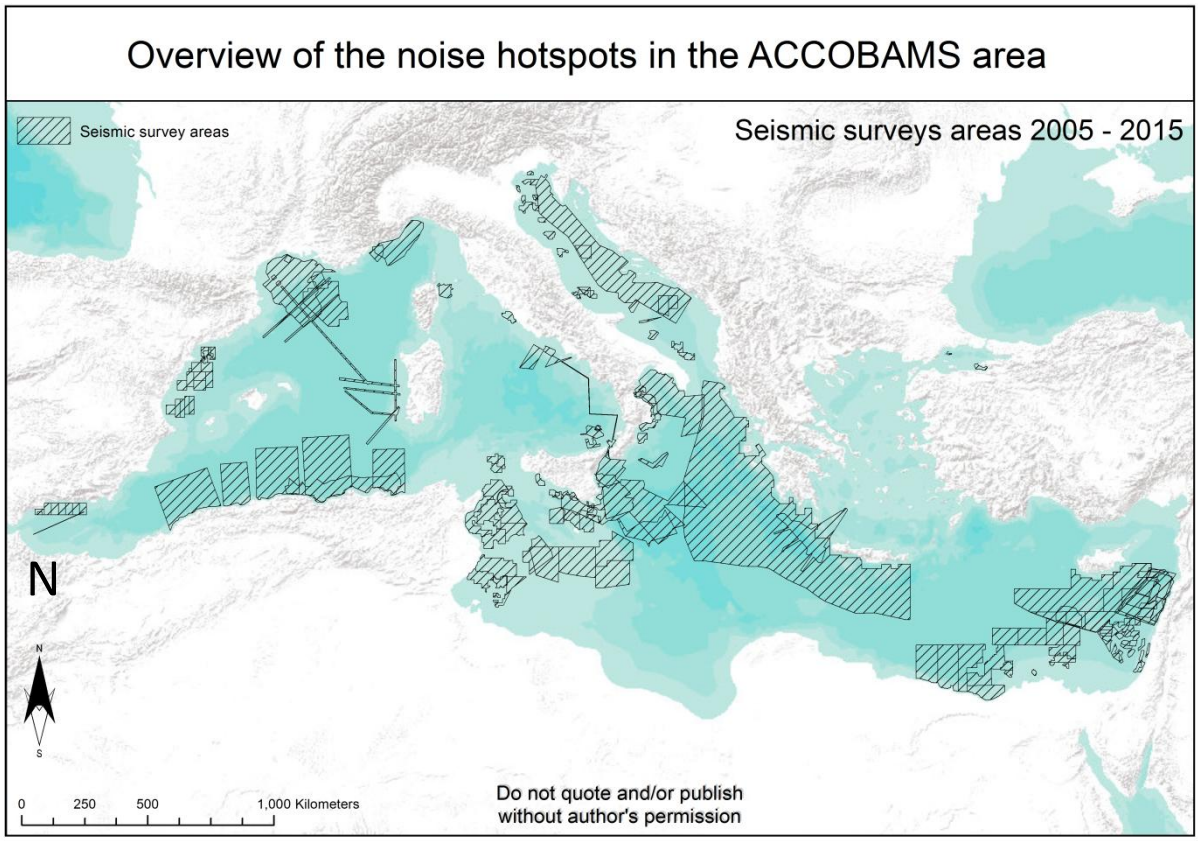
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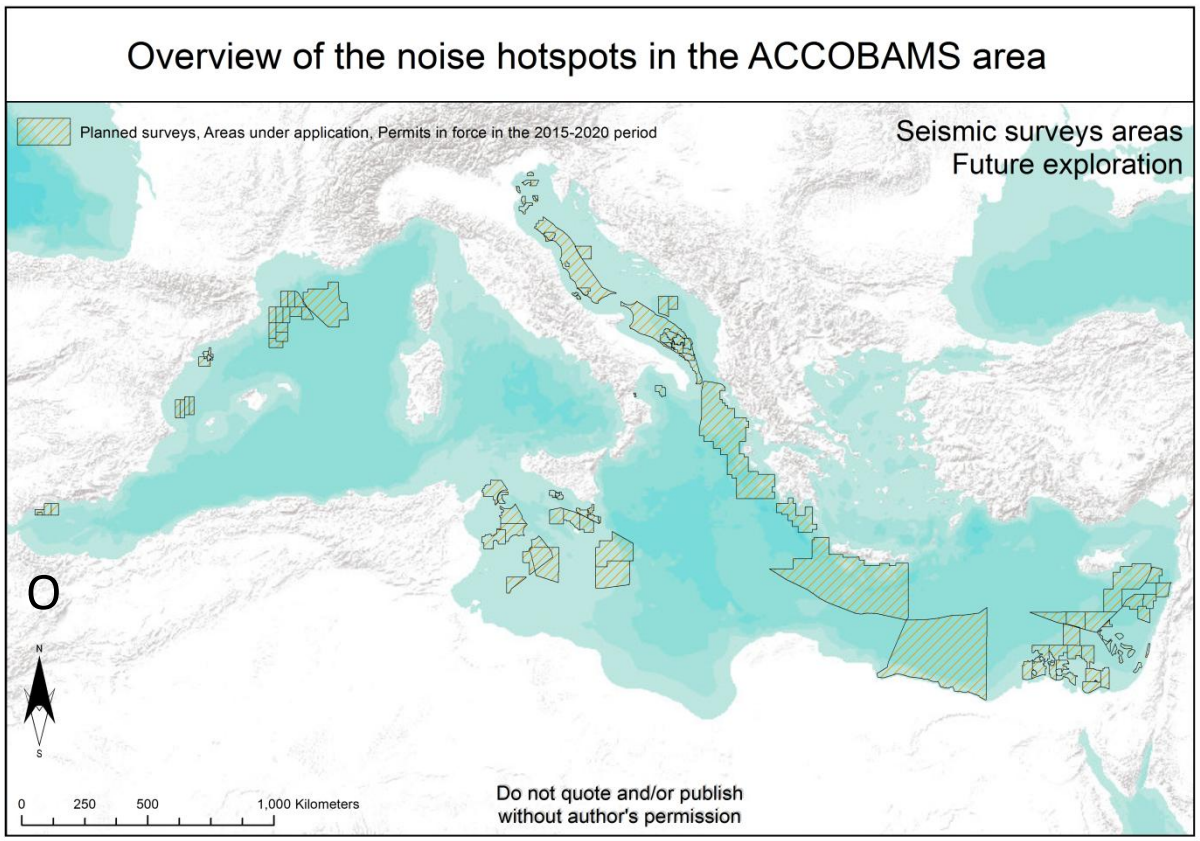

Figure 5. Seismic survey areas. Panels A to M) annual maps from 2005 to 2015; N) cumulate view of areas surveyed in the 10 year period 2005 to 2015; O) Planned surveys, areas under application, and permits in force in the 2015-2020 period

Areas where most seismic exploration areas (actual surveys and/or exploration permits) concentrated in the last 10 years are found in the Adriatic Sea, the Strait of Sicily, the Ionian Sea and the Levantine Sea. Spanish waters lying on the continental shelf of Spanish mainland (Gulf of Valencia and Alboran Sea) seem also to be regularly covered by seismic exploration areas. On the other hand, the Ligurian Sea (thus including the Pelagos Sanctuary area), the Thyrrenian and the Aegean Sea appear as less concerned. In such areas very few scientific surveys were recorded except in the Aegean Sea which appear then as the only area completely free of seismic exploration in the Mediterranean for the last 10 years. We recorded no seismic exploration in the Mediterranean Moroccan waters in the last 10 years, while activities were concentrated in the Atlantic coast. However information for Moroccan waters might not be complete and hence further research is needed to confirm this information. Finally, some data for seismic exploration in Libyan waters are available but not sufficiently clear and therefore they are not shown.

The annual use of the Mediterranean Sea by seismic exploration was calculated in terms of absolute and relative surface, computed in squared kilometres and percentage of Mediterranean surface, respectively. For Mediterranean surface we used 2.5 M km². Results, shown in figure 6, highlight a growing trend from 2005 onwards. The highest value of surface used was attained in 2013 with seismic survey areas covering around 675 000 km², representing 27% of the surface of the Mediterranean. On the opposite, 2005 yielded the lowest value with around 67 000 km² used (3.8% of Mediterranean surface). Considering that data for Libyan waters are not included, such results represent an underestimation of the actual situation.

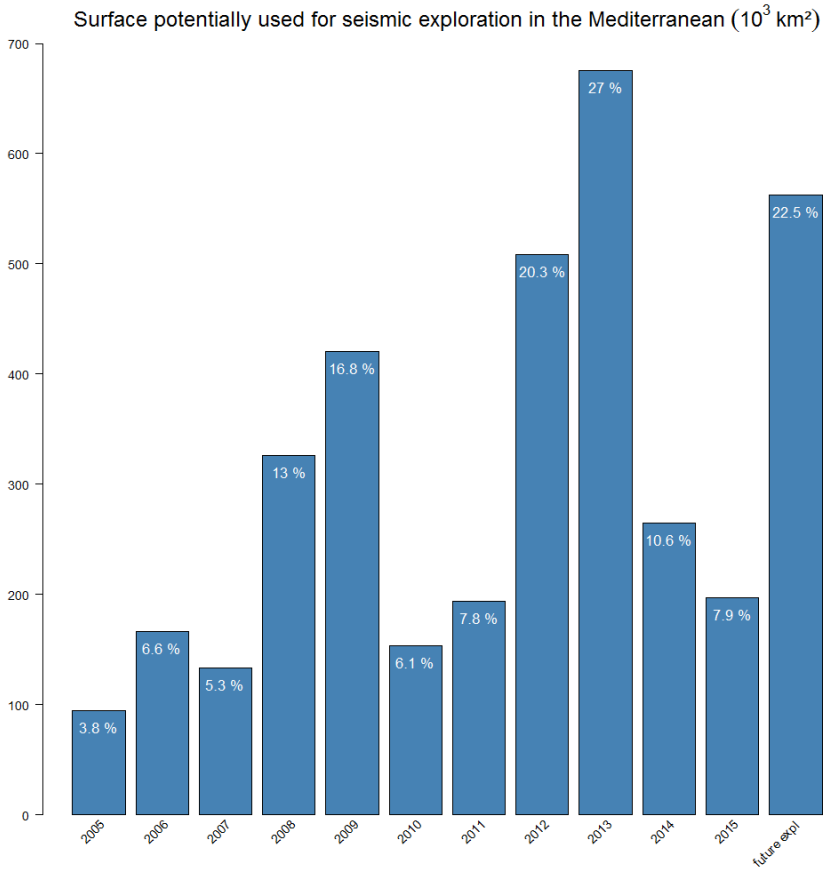

Figure 6. Annual spatial coverage of potential seismic exploration areas in the Mediterranean Sea for the period0 2005-2015 and future

Finally, we analysed the 10-year potential frequency of occurrence of seismic survey areas over a grid with grid size 40 x 40 km. In the following map (figure 7), we show how many times in the last 10 years areas were covered by seismic surveys or by an exploration permit (where surveys potentially occurred). As described before, it should be noted that a valid exploration permit usually lasts several years but surveys are not carried out every year and hence figure 7 should be regarded as an indicator of the total Mediterranean coverage of regulated licensing blocks rather than density of seismic survey activity.

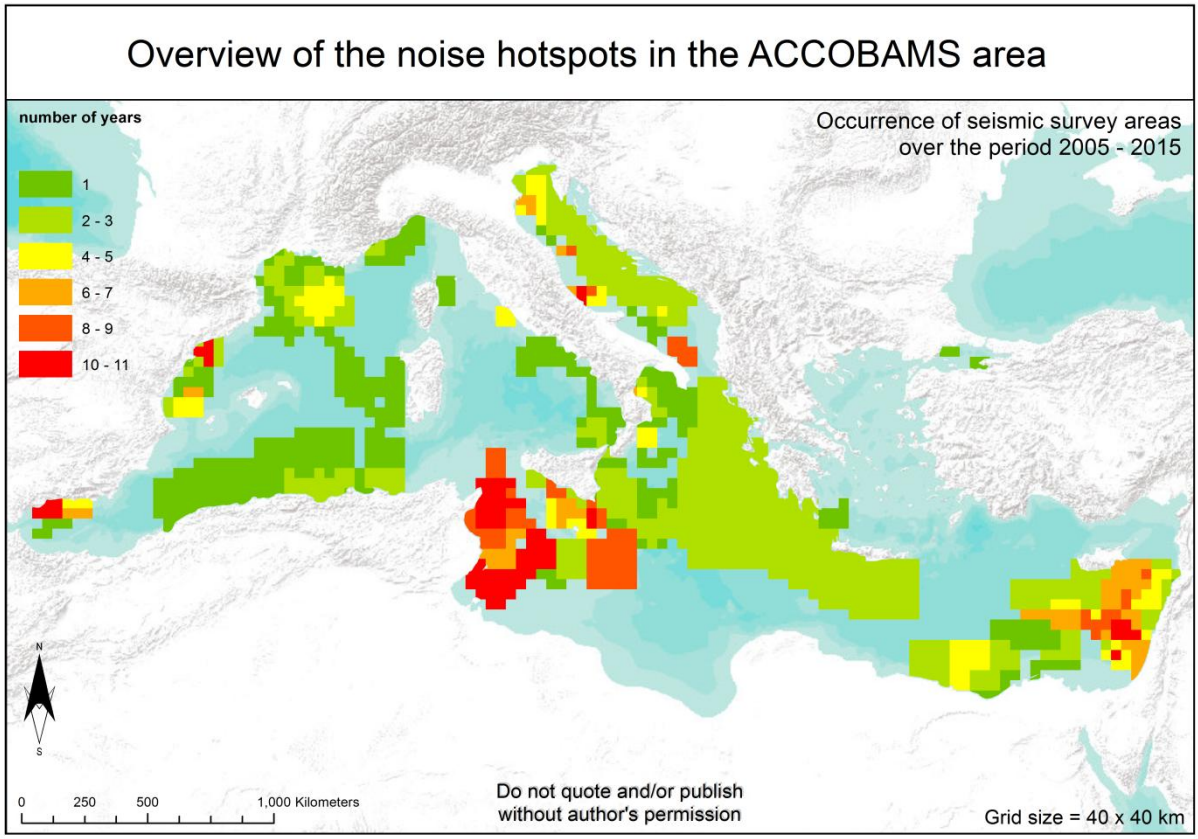

Figure 7. 10-year frequency of occurrence of seismic licensing blocks where seismic surveys are permitted. N.B.: Incomplete list of real surveys and exploration permits are included in the analysis

Again, the Strait of Sicily, the Adriatic Sea, the Levantine Sea, the Gulf of Valencia and the Spanish part of the Alboran Sea appear as constantly covered by either seismic surveys or exploration permits.

3.4. Military areas

Available data on military areas for Spain, France, Italy, Greece and NATO are plotted in the figure hereafter.

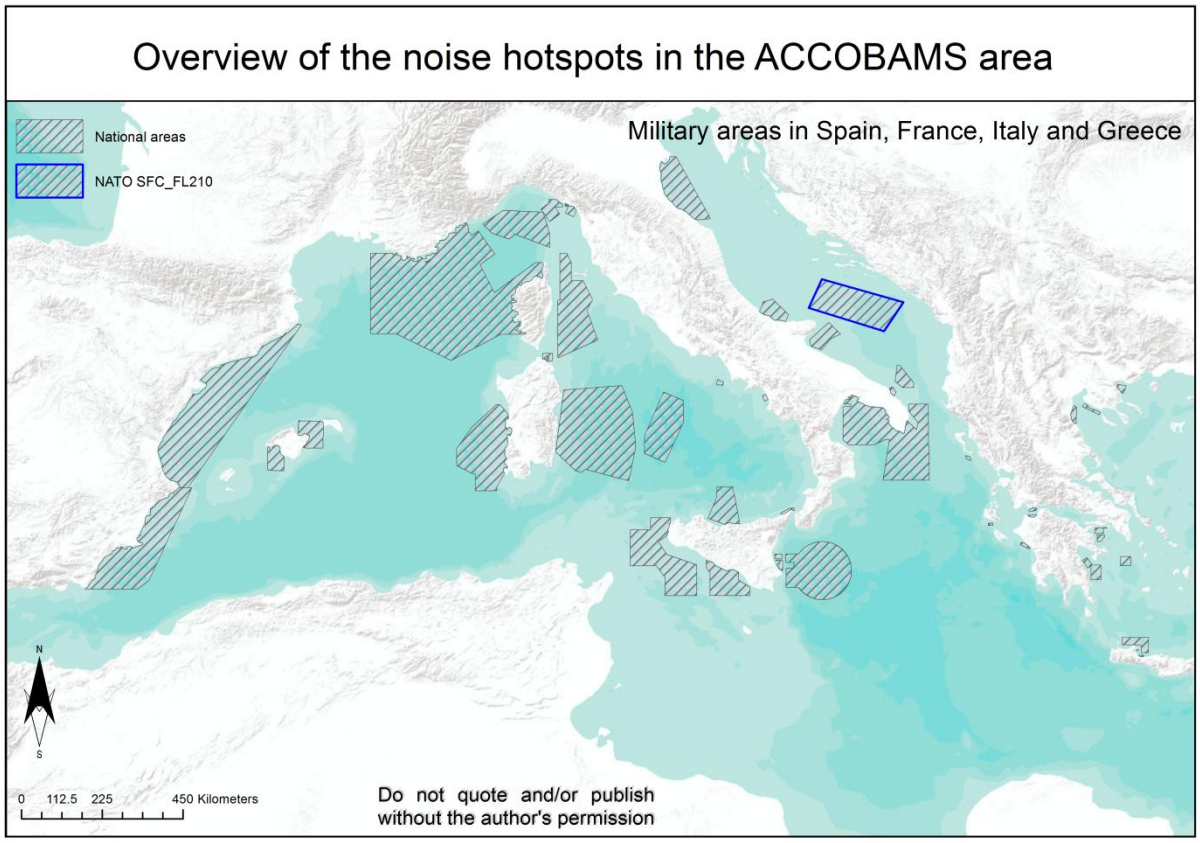

Figure 8. Navy exercise areas in the Western Mediterranean Sea (data from Spain, France, Italy and Greece)

It can be observed that military areas cover very large portions of the Western Mediterranean Sea. Particularly, most of the Ligurian Sea (and thus the Pelagos Sanctuary) appear covered by military areas, as well as large portions of Spanish and French coastal waters, of the Thyrrenian Sea and the Italian part of the Strait of Sicily and Ionian Sea. On the opposite, Military areas in Greek waters appear as covering smaller portions of jurisdictional waters.

3.5. Noise and noise-cetacean interaction hotspots

The number of noise-producing human activities was computed on a spatial grid (grid size = 40 x 40 km, figure 9). As stated in section 2.6, only activities using impulsive noise sources were addressed in this analysis. Values vary from 0 (no impulsive noise-producing human activity recorded) to 4 (all activities using impulsive noise sources considered in this study were recorded). Areas showing highest values (3 and 4 types of activity) are located in the Italian part of the Adriatic, in the Strait of Sicily, in the French Mediterranean from the Côte d'Azur to the Gulf of Fos, in the Gulf of Valencia, in North-eastern Corsica, the higher Ionian Sea, and the coast of Campania.

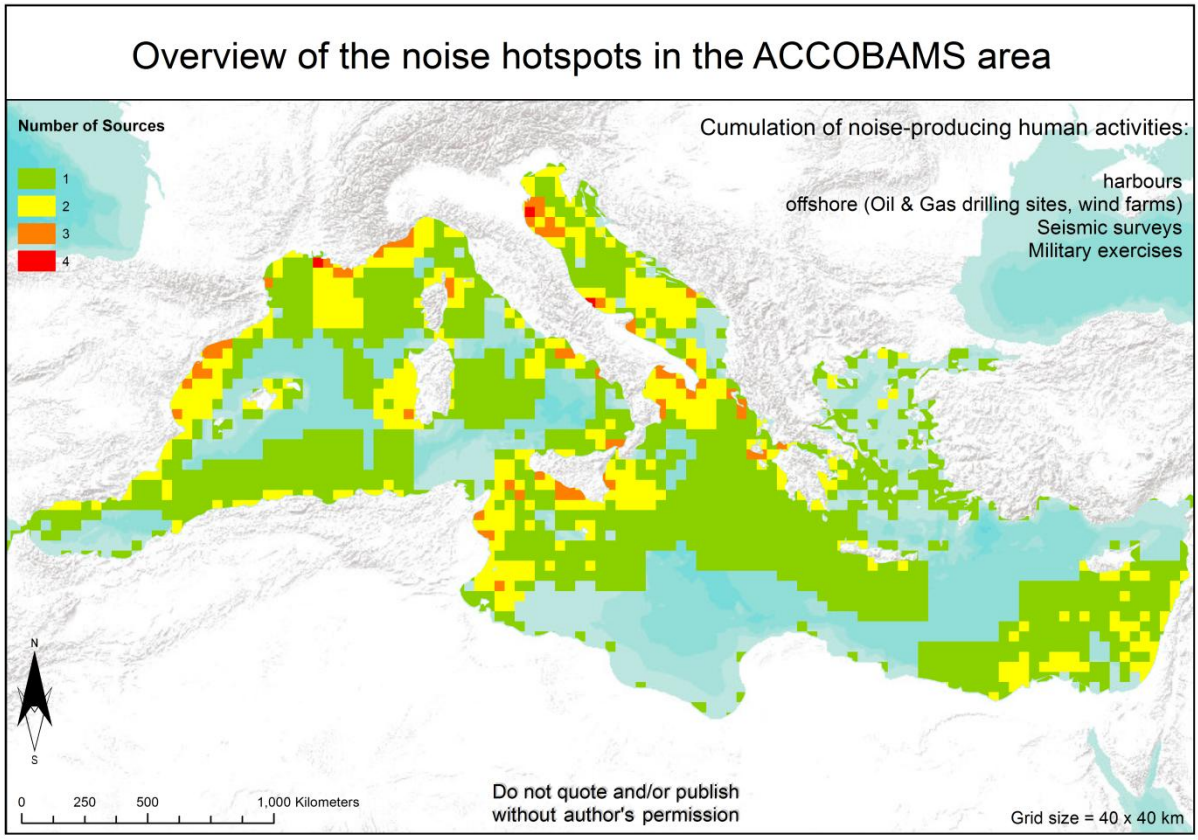

Figure 9. Noise Hotspots: Number of noise-producing human activities over a 40 x 40 km spatial grid

Finally, we superimposed this last map to the layer of important cetacean habitats as identified and recognised by Parties to ACCOBAMS through Resolution 4.15, adopted in 2010 (figure 10). This result yields important information of areas where potential conflicts between human activities and cetacean conservation might occur, in the framework of noise pollution. Such areas appear to be the Pelagos Sanctuary, the Strait of Sicily, and the area of the northern part of the Hellenic Trench.

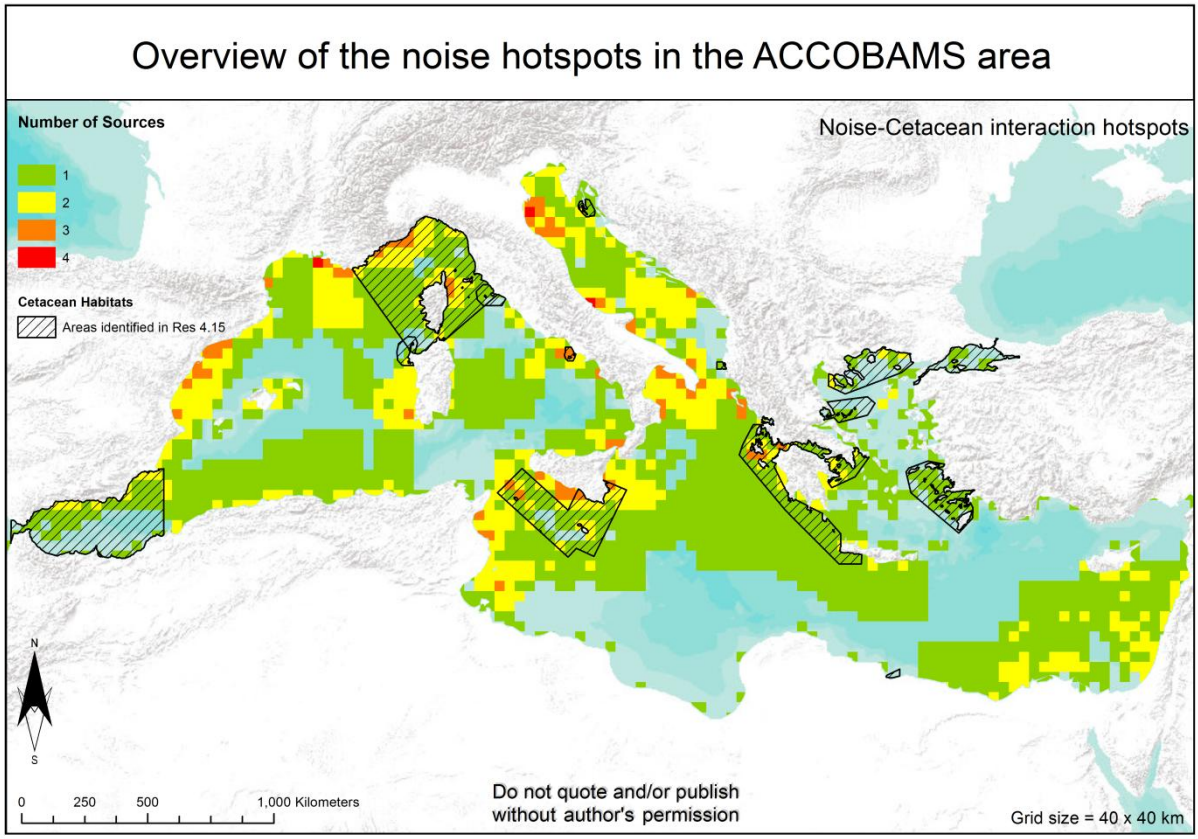

Figure 10. Noise-cetacean interaction hotspots: overlap of noise hotspots and important cetacean habitats (ACCOBAMS Resolution 4.10, 2010)

4. DISCUSSION and CONCLUSIONS

The maps shown in this report, along with quantitative data on number of potential noise-producing activities and their spatial coverage, represent the first overview of the Mediterranean wide spatial distribution of main noise-producing human activities. We are aware that this review is quite incomplete and that many other projects within the listed activities were missed in our review. The resulting maps shown here allow highlighting that great portions of the Mediterranean Sea appear chronically exposed to noise-producing human activities. Activities appear not equally distributed over the whole area. Most harbours (ports and marinas) and wind farm projects are concentrated in Northern Mediterranean coasts while zones of intense oil and gas drilling activities are located in the higher Adriatic Sea, the Strait of Sicily and the Levantine Sea. Also, in terms of commercial marine traffic, ships concentrate in narrow lanes (compared to the whole Mediterranean surface), while areas of more diffused commercial ship density appear in the North-western Mediterranean and in Greek waters. Highly touristic zones are exposed to high levels of recreational traffic, with Aegean waters yielding the highest and the most spread traffic density. According to other published works on ship density in different Mediterranean sub-areas through AIS data analysis, additional zones yield high ship traffic levels, namely the Adriatic Sea and the Alboran Sea (Vaes and Druon, 2013), as well as the southern Peloponnese (Frantzis *et al., 2013*). However, it is noteworthy that several AIS networks exist and that the two studies aforementioned used different data platforms with respect to the present work. Therefore, coverage and other technical issues related to using different AIS networks should be addressed before proceeding to more in-depth quantitative ship traffic studies, in order to avoid spatial coverage bias and allowing consistent comparisons with other literature.

Seismic exploration, based on licensing blocks in its majority, appears to be more important in the southern and eastern part of the basin as well as in the Adriatic Sea. Also, Spanish continental shelf (Gulf of Valencia and northern Alboran Sea), appear to be regularly affected by active licensing blocks. As mentioned in section 2.4, we included in the analysis areas of both actual surveys (when the year in which they were carried out was known) and exploration permits (when we just knew the start and end date of the exploration permit which can last several years). The result of this analysis provides a view of the cumulative situation created by independent management of geophysical surveys (both commercial and scientific) at the national level, disregarding regional and sub-regional transboundary effects, that are well exceeded by this activity's noise disturbance. Trend analysis results suggest the environmental pressure has increased considerably over the past 10 years, and will continue to do so in the near future. Our results show that up to 27 % of the Mediterranean Sea was potentially bestowed to commercial and/or scientific surveys during a single year. Although information about the temporal coverage of such surveys is clearly needed (in terms of days where seismic acquisition occurred within each licensing block over a year for example), the following questions can be already addressed: was this potential spatial coverage acceptable considering the requirements for the conservation of cetaceans and their habitats in the Agreement area? Are we able to interpret the potential for noise disturbance within their habitat in terms of good or bad environmental status?

With regards to military activities, the partial information obtained in this study highlights large portions of the Western Mediterranean disturbed by potential noise-producing military activities, including naval exercises using low- and mid-frequency active sonars and underwater and surface detonations. However, areas displayed in figure 7 might represent an overestimation of the actual

situation. Plotted polygons represent public available information on military areas, but it seems possible that multiple smaller exercise areas be located within the large polygons displayed and only a smaller proportion of these being currently active. No information is available concerning south-eastern portions of the basin.

In light of these findings, areas exposed to multiple noise-producing human activities (i.e. noise hotspots) can be preliminarily pointed out. These are the Italian part of the Adriatic Sea, the Strait of Sicily, the French Mediterranean from the Côte d'Azur to the Gulf of Fos, the Gulf of Valencia, the North-eastern part of Corsica, the higher Ionian Sea, and the coast of Campania. All these areas accumulate all considered types of noise-producing activities in this study: commercial and recreational marine traffic, harbour activities, commercial and scientific seismic surveys, oil and gas drilling activities, wind farms projects, military exercises. Hence, a great question needs to be addressed in future studies: how to measure the synergic and cumulative effect of all these activities?

Finally, when overlapping cetacean habitats with identified noise hotspots, potential conflict areas are shown for the Ligurian Sea, the Strait of Sicily and the Northern part of the Hellenic Trench. Assuming that strandings of Cuvier's beaked whales are an indicator of where the pressure from military sonar noise is higher, we can compare our results with maps of strandings of Cuvier's beaked whales (figure 11) and find that effectively mass strandings occurred in the identified noise-cetacean interaction hotspots. However, strandings of other species known to be sensitive to noise (e.g. sperm whales and fin whales) should also be compared to our results to help the interpretation in ecological terms.

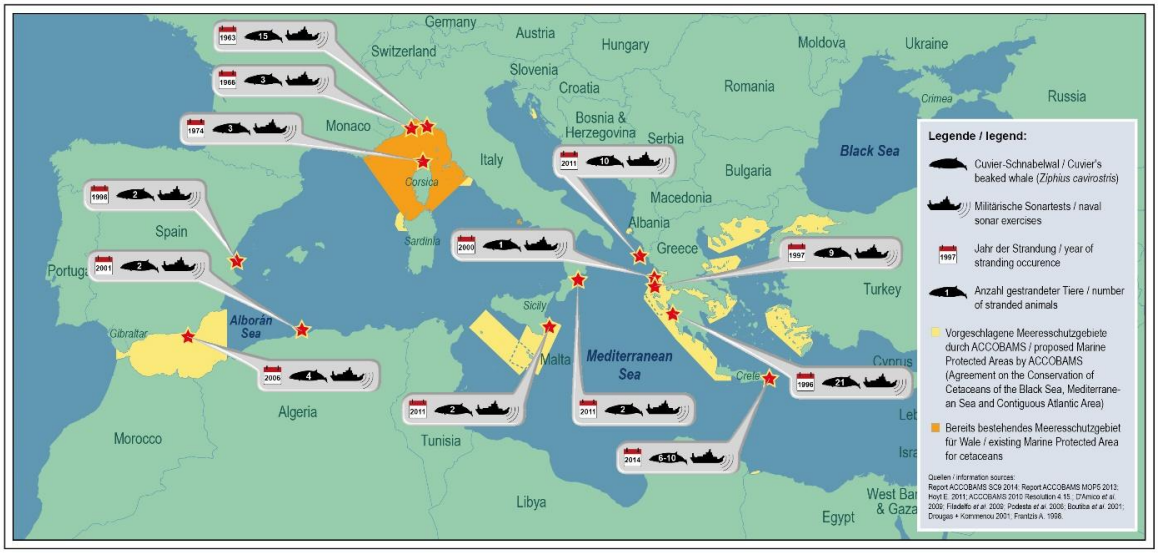

Figure 11. Summary of strandings of Cuvier's beaked whales in correlation with military sonar between 1993-2014 along the coasts of the Mediterranean Sea (source: OceanCare based on Frantzis, 1998; Drougas & Kommenou, 2001; Boutiba et al, 2001; Podestà et al, 2006; Filadelfo et al., 2009; D'Amico et al, 2009; ACCOBAMS Resolution 4.15, 2010; Hoyt, 2011; ACCOBAMS MOP5 Report, 2013; ACCOBAMS SC9 Report, 2014).

The results of this report should be interpreted as a first rough review of the real situation in the Mediterranean Sea. A lot of important information was partially accessible or not accessible at all. Many ACCOBAMS countries have not provided details on their underwater noise producing activities. And most importantly, almost all the results presented here are incomplete to some extent. A lot of work is still to be done in order to achieve a full assessment of noise-producing human activities in the ACCOBAMS area and of their impact of cetaceans in the long term:

- From a general point of view, this study focussed on a set of human activities using noise sources identified as being of primary concern for cetacean conservation. This is in line with studies and assessments carried out in different contexts (see for example the "Scientific synthesis on the impacts of underwater noise on marine and coastal biodiversity and habitats" (CBD, 2012), or the recommendations from the TG Noise concerning the assessment of the pressure from impulsive and continuous noise on the marine environment (Dekeling *et al.*, 2014)). For this reason, not all underwater noise sources, like several active acoustic transducers, are directly addressed in this study. Nonetheless, it is important to underline that the contribution of all noise sources within cetacean hearing should be taken into account while assessing the status of the marine environment within the ACCOBAMS framework.
- In terms of data and their accessibility, we found that accurate information on recently past, present and future and/or planned commercial seismic surveys is rarely available. Scientific surveys are also difficult to track since few ACCOBAMS Countries maintain an archive of this activity. Also, this study is missing reliable information for some southern basin countries and particularly for Libyan waters, where seismic exploration and offshore activities exist. Our results further highlight the lack of consistent control and regulation for seismic activities in most of the southern basins of the Mediterranean Sea. Considering the magnitude of the acoustic footprint of commercial and scientific surveys, it would be important to account for this information in any Mediterranean wide noise analysis such as the present study. Also very poor information could be gathered for waters of Montenegro, Albania and Turkey, although the small surface of jurisdictional influence by these three countries in the Mediterranean basin, only partially affects the global aim of this project. Finally, as mentioned in the introductory part of this document, the Black Sea and the Atlantic portion of the Agreement area were not addressed in this project for practical reasons. Future efforts should be focussed at filling current gaps.
- AIS data as a measure of ship traffic spatial and temporal distribution should properly account for differences in data sources, data coverage (e.g., shadow areas) as well as differential representation of vessel class (e.g. only commercial vessels over 300 tons)
- Concerning the analysis, the method used in this study to identify potential noise-cetacean interaction hotspots is based on the accumulation of noise-producing human activities recorded in the last 10 years calculated over a regular spatial grid. This analysis includes all major noise-producing human activities except shipping. In fact, ship traffic is a source of continuous noise while all other human activities addressed in this study are identified as generating impulsive noise. Based on current recommendations concerning noise assessments related to the Marine Strategy Framework Directive (MSFD) of the European Union and to the Ecosystem Approach initiative of the Barcelona Convention, continuous and

impulsive noise sources are to be addressed separately, as two different methods were proposed for the assessment of their pressure on the marine environment. On the other hand, including the ship traffic layer into the hotspot analysis would allow gathering a global view of the spatial coverage of major noise-producing human activities. The relevance of performing such an exercise should be evaluated. Finally, it is important for future assessments to weight the available results with information about time. In fact, a grid cell where a certain noise-producing activity occur several times in the same year and across years should weigh more that a grid cell where a certain activity only occurred once. However, information about time frames of noise generating activities was available in some cases but not to a sufficient extent as to be integrated in the analysis. Future studies should focus on including the temporal coverage of noise-producing human activities in the analysis.

In conclusion, this study is the first to provide a rough overview of the spatial occurrence of major noise-producing human activities in the Mediterranean Sea. Activities targeted in this study are recognised as causing impacts to cetaceans: airguns, sonars, pile drivers, drilling, underwater detonations, and ship and recreational craft noise. The significant amount of data gathered in this study for all these targeted activities, covered almost the whole Mediterranean basin. However, it is far to be complete and this study should not be considered exhaustive. An important conclusion of our work is that, considering the current lack of international coordination and data archiving mechanisms, a substantially major effort would be required to properly account for all the underwater noise producing activities and their temporal and spatial occurrence within the ACOBAMS area. However, despite the limited resources and time dedicated to this review, noise hotspots where acoustic disturbance is concentrated have been identified and mapped against important areas for cetaceans. On the basis of these results it is recommended that future efforts be focussed in 1) gather the important data gaps identified in this study (e.g. improve information on southern Mediterranean basins, the Black Sea and the Atlantic area of the Agreement) and 2) gather further information on the temporal occurrence of these main noise-producing activities.

5. RECOMMENDATIONS FOR FUTURE WORK

5.1. Challenges for data collection

As already mentioned above, the present project is the first to roughly address a basin-wide assessment of major noise-producing human activities. The methodology proposed to achieve the goal that was established was based on the extensive search of the internet and the direct contact with stakeholders identified as relevant data owners. Following the data collection phase, we express the following considerations:

- The reply rate from contacted stakeholders was generally low and replies with helpful information were rare (see figure 1)
- We observed a general lack of engagement by several Contracting Parties and/or their ACCOBAMS focal points
- There is generally a lack of knowledge of activities in the southern Mediterranean areas. This is important as most activities occurring in the southern offshore and coastal regions will influence the soundscape of the rest of the basin.
- Most helpful replies mainly came from public entities which were not directly involved in actions coordinated by ACCOBAMS
- Information about time frames of several noise-producing human activities is rarely accessible, particularly for commercial seismic surveys
- Scientific seismic surveys are not archived by most countries and rarely controlled when occurring in international waters
- Accessible national databases on ocean-based human activities exist for some countries of the Northern Mediterranean Sea and one Southern country. In such databases, data can be found but they are not structured in such a way to be easily used for acoustic pollution assessments

Such considerations make it possible to point out some key elements not only for improving our results, but also for setting up a solid basis for a robust basin-wide assessment and monitoring programme:

- This study should not be interpreted as a conclusive report. Most of the data used in our analysis was incomplete or imprecise.
- More time and means should be allocated to better address the ambitious goal of carrying out a basin-wide assessment of noise-producing human activities
- Clearly, there is a need for better data accessibility, archiving and a closer cooperation with ACCOBAMS stakeholders. Particularly, it is important to highlight the need for much more collaboration/participation by industry and the Navies in addressing this global issue. Enhancing the cooperation with industry and military authorities of ACCOBAMS Contracting Parties has the potential to improve our results and enable a good management framework of the acoustic pollution caused by industrial development and naval exercises
- We believe it is time to think over the implementation of a common and transparent, exhaustive database at the international level centralising structured data on human activities producing impulsive underwater noise in the Agreement area.

This last element is also a recommendation by the European Commission related to the implementation of the MSFD, and also by ACCOBAMS concerning the implementation of the EcAp (Ecosystem Approach). We believe that there is a strong potential to find the necessary support to develop such a common noise database.

5.2. The implementation of an international noise register

Following the considerations expressed in section 5.1, this section presents a methodological proposal for the implementation of a common and transparent noise database, which could serve as the basis for an international noise register as recommended by TG Noise in the framework of the MSFD process and by ACCOBAMS in the framework of the EcAp initiative (Dekeling *et al.*, 2014; UNEP/MAP, 2015a, 2015b). Further, as the ACCOBAMS scope is directly linked to cetacean conservation, the proposed common database could be used to feed noise prediction tools such as www.oceannoisemap.com. This way, for each noise source inventoried it would be possible to perform a noise propagation modelling, in order to assess the acoustic footprint of the use of one or multiple impulsive noise sources and predict their impact on cetaceans and other marine wildlife.

In the present work, a relational database model was designed with MySQL as this is a powerful tool for managing huge amounts of data and for connecting to other software for data handling and analysis (MS Access, ArcGIS, MATLAB, web tools, etc.). However, developing such a database was not possible in the present work. Instead, it was decided to use simpler tools for data organisation and to focus efforts on gathering data and producing cartography. Experience gathered in handling data and information during the present project allowed us to make recommendations on how to implement a (cost-) effective noise database aimed at monitoring the occurrence of noise-producing human activities in a given area of interest (as the Mediterranean Sea). To do that, we further developed the original SQL model and developed a first tool formed by the following elements:

- A web server to host the database
- A software toolbox connected to the database
- A web interface for data entry and verification process

In practice, this database is hosted on a web server and data are entered through a web interface. The user log in and can enter data concerning one or more projects on position, date, noise source characteristics (frequency range, source level etc.), type of activity, etc. At the end of the process the user can check on a web mapping service (e.g. Google maps) the information entered in the interface for verification process. Data are then stored in the web server and can be accessed again and analysed for both the spatial and temporal domain through the same web interface, thus obtaining results on noise indicators (figures 11 and 12).

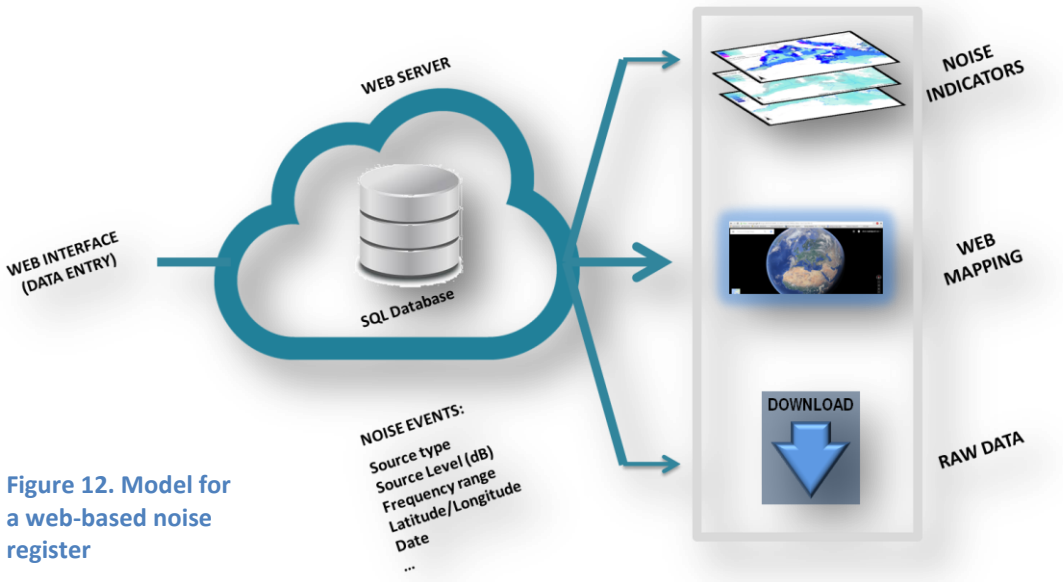

Figure 12. Model for a web-based noise register

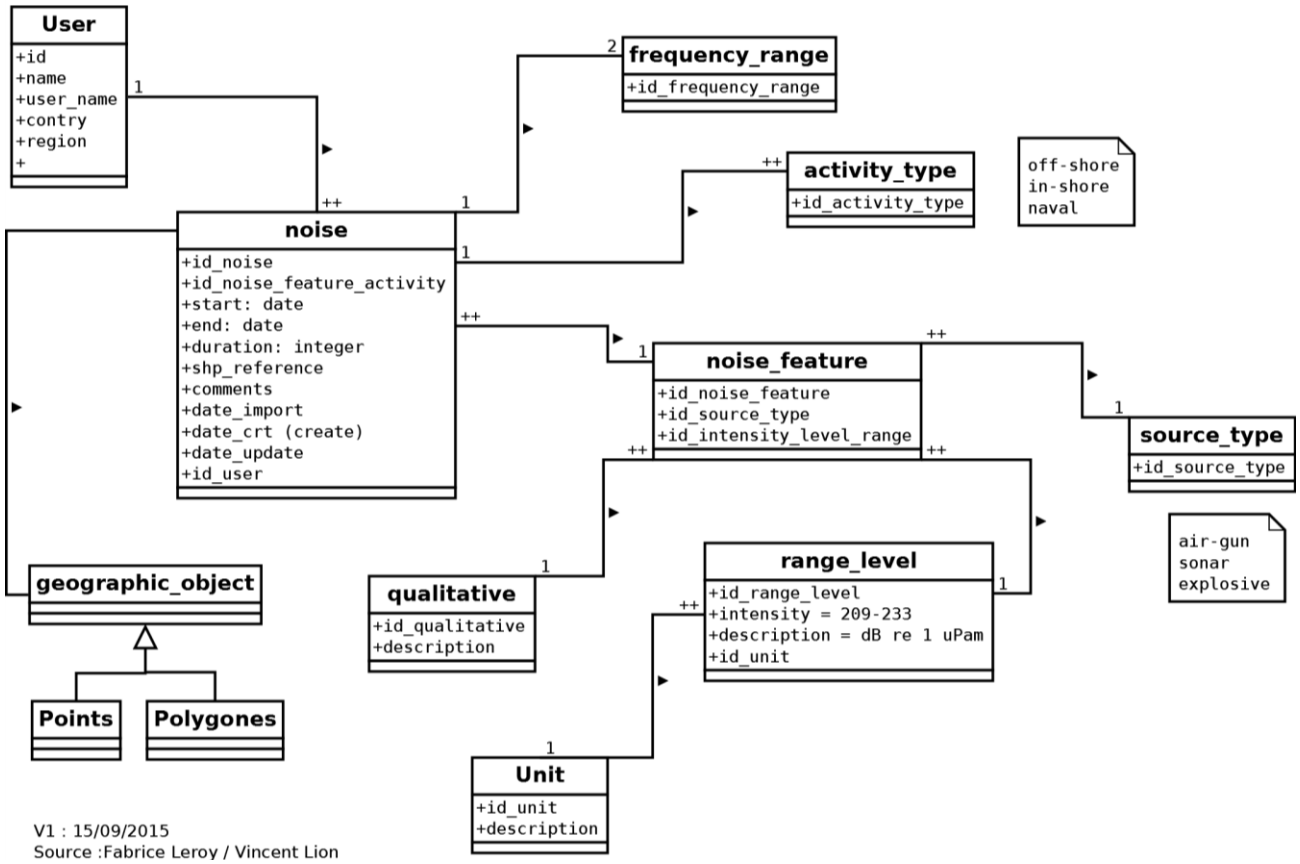

Figure 13. The SQL database is formed by several related tables in which inventoried noise events are described

Finally, the user of the noise register needs to be identified. The user should be the personnel who collects the information on industrial, military, scientific and other activities using target noise sources and enters it in the system. Given the heterogeneity of noise-producing human activities, several stakeholders might hold the necessary information, including national and local authorities, industry, marine protected areas, etc. Once the users have been identified and trained, the system is able to provide a periodical assessment of the pressure on the marine environment from impulsive noise sources at the regional, sub-regional and local level. Finally, reading access to this registry should be transparent.

6. REFERENCES

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7. APPENDICES

7.1. List of accessed websites

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http://www.amna.gr/english/articleview.php?id=3353
http://www.reuters.com/article/2015/04/20/eurozone-greece-oil-idUSL5N0XH2M020150420
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7.2. List of references for seismic surveys conducted by IFREMER

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DEVERCHERE Jacques (2005), MARADJA/2 cruise, SUROIT R/V

DEVERCHERE Jacques (2005), SAMRA cruise, SUROIT R/V

GUTSCHER Marc-André (2005), DELSIS cruise, SUROIT R/V

LURTON Xavier (2005), CALIMERO 2 cruise, SUROIT R/V

SAGE Françoise (2005), MAGIRAA 2005 cruise, TETHYS II R/V

SAVOYE Bruno (2005), MARADJA/2 cruise, SUROIT R/V

THOMAS Yannick (2005), CALIMERO 2 cruise, SUROIT R/V

YELLES Abdelkrim (2005), SAMRA cruise, SUROIT R/V

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GELI Louis (2006), SARDINIA cruise, ATALANTE R/V

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RABINEAU Marina (2013), AM-MED-1 LEG1 cruise, SUROIT R/V

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7.3. List of contacted stakeholders

MILITARY		
Stakeholder	**Type***	**Status**
Hellenic Navy Hydrographic Service (GR)	Local Authority	Reply: yes Data access: yes; data available on website in the "notice to mariners"
Etat Major (FR)	Local Authority	Reply: yes Data access: yes; provided helpful information on where to find data (CNRS INSU SHOM)
Ministerio de la defensa (ES)	Local Authority	Reply: yes Data access: no
Marina Militare Italiana (IT)	Local Authority	Reply: yes Data access: yes; information on data available on website in the "notice to mariners"
Hellenic Centre for Marine Research	Research	Reply: yes Data access: no; answer: "no access to such info exist".

HARBOURS		
Stakeholder	**Type***	**Status**
REMPEC	Policy	Reply: yes Data access: yes

GEOPHYSICAL SURVEYS		
Stakeholder	**Type***	**Status**
ACCOBAMS Focal Points (29 persons contacted)	Policy	Reply: no Data access: no
CMS Focal Points (3 persons contacted)	Policy	Reply: yes (1 reply, 2 no replies) Data access: no
Ecology Departments, Head Science Division, Israel Nature and Parks Authority	Local Authority	Reply: yes Data access: no; answer: "I will consult with our Med. Marine Ecologist and send you an answer although I am not sure as to the level or resolution of our knowledge regarding specific noise events".
ACCOBAMS Black Sea Sub Regional Coordination Unit	Policy	Reply: no Data access: no
Turkish Marine Research Foundation	Research	Reply: no Data access: no
Israel Marin Mammal Research and Assistance Center (IMMRAC)	Research	Reply: yes Data access: no; answer: "as no access to such data exist better to contact government official and the contractors directly".

Blue World institute for Marine Research and Conservation	Research	Reply: no Data access: no
Morigenos	Research	Reply: yes Data access: no; answer: “ability to access data limited, no larger surveys planned”.
OGP (5 persons contacted)	Industry	Reply: yes (2 replies; 3 no replies) Data access: no; answer: “there is no access to such information and OGP is not in a position to request such info from members”.
IFAW	Research	Reply: yes Data access: no; no data available on the topic of seismic explorations
JNWG	Policy	Reply: no Data access: no
Ministerio de Medio-Ambiente (ES)	Local Authority	Reply: yes Data access: yes
Ministerio de Industria Energia y Turismo (ES)	Local Authority	Reply: yes Data access: yes
EU Commission	Policy	Reply: yes Data access: no
EU TG Noise (10 persons contacted)	Policy	Reply: yes (2 replies, 8 no replies) Data access: no
IFREMER	Research	Reply: yes Data access: yes
Hydrometerological Institute of MONTENEGRO	Research	Reply: no Data access: no
Institut National de Recherche Halieutique (INRH) Morocco (2 persons contacted)		Reply: no Data access: no
Northern Petroleum	Industry	Reply: yes Data access: yes
Hellenic Centre for Marine Research	Research	Reply: yes Data access: yes; provided helpful information

WIND FARMS		
Stakeholder	**Type***	**Status**
ISMAR (Istituto di Scienze Marine)	Research	Reply: yes Data access: no: answer: “data are not ready yet”
DIRM Med (Direction Interrégionale de la mer Méditerranée)	Local Authority	Reply: yes Data access: yes
Pelagos Secretariat	Policy	Reply: yes Data access: no
EDF-EN	Industry	Reply: yes Data access: yes; provided helpful information

* Type: the stakeholders contacted were classified into four categories: policy (regional and international bodies), industry, research (research institutes and NGOs), and local Authorities