Gulf of Lion case study

Mapping exposure risk of marine megafauna to concomitant pressures

07 January 2019

Version 2

SIMWESTMED

Co-funded by the European Union

Supporting Implementation of Maritime Spatial Planning in the Western Mediterranean region

European Commission
Directorate-General for Maritime Affairs and Fisheries
Grant Agreement: EASME/EMFF/2015/1.2.1.3/02/SI2.742101

Component: **1.3.6.** Establishing case studies on approaches to MSP implementation

Sub-component: CS#2 Assessment of cumulative pressures in the Gulf of Lion

Deliverable Lead Partner: **French Biodiversity Agency, CEDEX, IEO**

Start Date of Project: **01/01/17**

Duration: **24 Months**

Version: **2.0**

Contributors (in alphabetical order): Alloncle, N., AFB; Bliard, F., AFB; Campillos-Llanos, M., IEO; Cervera-Núñez, Cristina, IEO; Dalleau, C., AFB; Gimard, A., AFB; Gómez-Ballesteros, María, IEO ; Grassa, JM., CEDEX; Lloret, A., CEDEX; Murciano, C., CEDEX; Punzón, A., IEO; Quemmerais-Amice, F., AFB.

Dissemination Level		
PU	Public	
PP	Restricted to a group specified by the consortium (including the Commission services)	
RE	Restricted to other programme participants (including the Commission services)	
CO	Confidential, only for members of the consortium (Including the Commission services)	

Document Information

Deliverable Title	Gulf of Lion case study - Mapping exposure risk of marine megafauna to concomitant pressures
Coordinator	Alloncle N. , Gimard A.
Authors	Dalleau Chloé, Bliard Fanny, Quemmerais-Amice Frédéric, Murciano Carla, Cervera-Núñez Cristina, Campillos-Llanos Monica, Gimard Antonin, LLoret Ana, Grassa José María, Punzón Antonio, Gómez-Ballesteros María, Alloncle Neil
Recommended Citation	Dalleau, C., Bliard, F., Quemmerais-Amice, F., Murciano, C., Cervera-Núñez, C., Campillos-Llanos, M., LLoret, A., Punzón, P., Grassa, J.M., Gómez-Ballesteros, M., Gimard, A., Alloncle, N. (2018). Mapping exposure risk of marine megafauna to cumulative pressures. EU Project Grant No.: EASME/ EMFF/2015/1.2.1.3/02/SI2.742101. Supporting Implementation of Maritime Spatial Planning in the Western Mediterranean region (SIMWESTMED). AFB. 60pp. DOI: 10.5281/zenodo.2599697

Version History

Date	Document version	Reviewer	Revision
05/12/2018	1.0	Dalleau Chloé, Bliard Fanny, Quemmerais-Amice Frédéric, Gimard Antonin, Alloncle Neil, Murciano Carla	Initial draft
20/12/2018	2.0	Dalleau Chloé, Bliard Fanny, Quemmerais-Amice Frédéric, Gimard Antonin, Murciano Carla, Alloncle Neil	Structural and content revision

Table of contents

List of figures

List of tables

Acronyms

ACCOBAMS	Agreement for the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
AFB	French Biodiversity Agency
AIS	Automatic Identification System
CEDEX	Center of Studies and Experimentation of Public Works (Spain)
CNRS	National Center for Scientific Research (France)
CI	Confidence Index
CPI	Concomitant pressures index
CRPM	Conference of Peripheral Maritime Regions
DG Mare	Directorate-General for Maritime Affairs and Fisheries, European Commission
DPMA	Marine Fisheries and Aquaculture Branch of the Agriculture and Fishing Ministry (France)
EEZ	Exclusive Economic Zone
GES	Good Environmental Status
GPS	Global Positioning System
IEO	Spanish Institute of Oceanography
IMA	Index of Multi-Activities
ITU	International Telecommunication Union
MAGRAMA	Spanish Ministry of Agriculture, Food and Environment
MAP	Mediterranean Action Plan, Barcelona Convention
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
REX	Exposure risk to a single pressure
REXC	Exposure risk to concomitant pressure
SAMM	Aerial Monitoring of Marine Megafauna
SCANS	Small Cetacean Abundance in the North Sea and Adjacent waters
SHOM	Hydrographic and Oceanographic Service of the Navy (France)
SIMCELT	Supporting Implementation of Maritime Spatial Planning in the Celtic Sea
SIMWESTMED	Supporting Implementation of Maritime Spatial Planning in the Western Mediterranean Region
SPI	Single Pressure Index
SQL	Structured Query Language
UNEP	United Nations Environment Programme
VMS	Vessel Monitoring System

Credit

Cover photography: Common dolphins and Scopoli's shearwaters © Steven Piel - AFB

Warning

This is a warning concerning the interpretation of the results presented in this report. The human activities and pressures considered in this work remain incomplete and only represent a fraction of the diversity of uses, their interactions, pressures and the effect of these pressures on the environment. The choice of human activities and pressures studied in this report must not be considered representative of the processes at work across the study area. These choices are a compromise between advances in methodological developments, effectively usable data and the SIMWESTMED project schedule. They are designed to illustrate the analysis and working methodology and to enable comparisons and methodological discussions with SIMWESTMED project partners. Any use of this work for the management of the territory studied would be incomplete and misplaced.

INTRODUCTION

1. Context

The sea and the coastal shores and waters are an essential legacy to our societies. This space is submitted to the continuous increase of a variety of different demands, concretizing different stakes:

- Economic stakes that can be seen by evolution, densification and diversification of human activities linked to exploitation of sea and coastal space, use of marine resources, living and minerals;
- Strategic stakes that can be seen by the multiplication into multi-sectoral approaches, increase of competition for space and resources and de facto by conflicts linked to the existence of activities;
- Ecological stakes that can be seen by degradation of the ecological status. This degradation is due to terrestrial and marine human activities which generate physical, chemical and biological pressures. These pressures can impact marine species, populations and communities, ecological functions and ecosystems services.

The progressive consideration of these multiple stakes and the obvious difficulty to balance them are the basis of new and ambitious public policies. In the European Union, the Integrated Maritime Policy aims to develop sustainable development, the maritime economy and coordination between activities, and between activities and the environment. This policy is declined into several directives including: the Marine Strategy Framework Directive (MSFD, 2008/56/EC), the environmental pillar, and the Marine Spatial Planning Directive (MSP, 2014/89/EC), coordination and economic pillar.

Marine spatial planning, as defined by the MSP Directive, enables stakeholders to apply coordinated, integrated and transboundary approaches. MSP seeks to balance demands for development with the need to protect the environment, achieving social, environmental and economic objectives.

The co-construction of these policies depends on the collaboration between maritime actors, state administrations and the ability to mobilize knowledge for describing, understanding and synthesizing the processes and interactions in place. Their realization must consider:

- Knowledge of the ecological status of communities and ecosystems, and their spatial repartition;
- Species, habitats and sites of major interest for protection and with management stakes;
- Knowledge of the spatial and temporal repartition of pressures from human activities;
- Knowledge of the effects that these pressures may have on the different parts of the ecosystems.

2. SIMWESTMED

The Supporting Implementation of Maritime Spatial Planning in the Western Mediterranean region project (SIMWESTMED) brings together a number of partners - research organizations, marine planning authorities and marine management bodies from France, Spain, Italy and Malta which are officially mandated to carry out national MSP processes in the countries of the project. These bodies have an extensive experience with regard to maritime planning, policy and management. SIMWESTMED focuses on the two key objectives stated in the call of proposal of DG Mare:

- Support the implementation of the Directive on MSP in Member States' marine waters;
- Launch and carry out concrete, cross-border MSP cooperation between Member States in the Western Mediterranean region, involving four Member States and the relevant authorities responsible for MSP in the selected area, the UNEP/MAP representation and the CPMR for the level of the Regions.

SIMWESTMED partners address both key objectives through a variety of approaches, including: literature and desktop research; future trend analysis; collaborative scenario development; practitioner/stakeholder interview; development of case studies; and stakeholder engagement mechanisms. Sub-themes relevant to both of the key objectives provide the context and scope for how each of the methodological elements will be used. Such sub-themes include:

- Understanding current and potential future demands relevant to transboundary areas and issues;
- Development and testing of approaches to stakeholder engagement within marine planning processes in relation to transboundary areas and issues;
- Consideration of potential options for transboundary cooperation in preparing maritime spatial plans.

SIMWESTMED outputs are practitioner focused, and aim at the identification and sharing of best practice on: technical, (e.g. data management), scientific (e.g. ecosystem based management), and social (e.g. stakeholder engagement processes) aspects of MSP implementation that address barriers to implementation of the MSP Directive and effective cooperation on transboundary working for MSP.

In this global context, with an enormous complexity of natural and human processes, this action of SIMWESTMED aim to improve the understanding of interactions, to develop support for the MSP processes on a transboundary context and to improve collaboration and information sharing between partners about cumulative assessments.

The SIMWESTMED project includes a case study dedicated to the cumulative effects assessment of anthropogenic pressures on the marine environment. This case study seeks to explore tools, methods and data to assess environmental effects of maritime uses in the context of MSP and transboundary issues. In this context it was chosen to work on marine mammals and seabirds and on the most relevant anthropogenic pressures in terms of the likely effects on these communities and in terms of spatial planning issues. The objectives of the case study are to share datasets between partners and to facilitate the comparison of these datasets using a common grid, while also integrating them in a cumulative pressures assessment tool in order highlight the exposure risk of marine megafauna to concomitant pressures and to compare the results depending on the datasets used.

Consequently of the approach regarding cumulative effects, this work is also going to be a transboundary exercise between institutions from Spain and France. Sharing data, exchanges about methodologies in place in each country, comparison and working on a common and transboundary area are topics which are going to be described. Implementation of MSP is described as transboundary and this exercise can be a supporting experiment and provide lessons learned to improve the Ecosystem Based Assessment and cooperation between planners.

3. Marine megafauna issues in the case study area

The choice to study marine mammals and seabirds as ecological components is due to their high mobility, which allows them to cover the entire case study area. Thus, these species are common for Spain and France, which share conservation interests and target the same species in their Marine Protected Areas. This study is a good example and an opportunity to develop cooperation and projects between Spain and France in line with the recommendations of the MSFD and MSP Directives.

Moreover, cumulative effects of anthropogenic pressures have been much less addressed for pelagic ecosystems and top predators than for benthic ecosystems. This case study is therefore a first attempt for France and Spain to develop a method that provides information on these issues in order to inform public maritime policies.

The case study area includes French and Spanish waters, corresponding to the Gulf of Lion and the marine area east of the Catalan and Valencian coast. This area includes the marine coastal waters, continental shelf and slope, submarine canyons, and a large bathyal plain (Figure 1).

The Gulf of Lions is a passive, prograding continental margin that extends from Cabo de Creus in Spain to Toulon in France (Louis, 1914; Russell, 1942; Ulses *et al*., 2008). It has an unusually large continental shelf which is well defined at 100-200 m depth and a complex network of submarine canyons reaching 2000 m depths. Some submarine canyons are located close to the shore, such as the Cabo de Creus Canyon.

The area is among the most Mediterranean productive regions; it has particular climatic and oceanographic conditions which determine its great productivity. Nutrients from rivers end in continental shelf waters and in addition, frequent Tramontana and Mistral winds contribute to the mixture of superficial waters and to the formation of deep and rich waters on both the shelf and offshore. These particular conditions result in high seasonal concentrations of plankton in certain locations of the submarine canyons, playing a key role as a refuge and reproductive habitat for a variety of benthic and demersal species of commercial interest (e.g. anchovy and sardine as small pelagics, hake, sharks and rays as demersal species).

The western Mediterranean is an important ecological zone for marine mammal populations facing numerous threats related to human activities (UNEP 2013b; Panigada *et al*., 2017). These conservation issues are taken into account in the context of the ACCOBAMS[1] agreement and have motivated the creation of specific marine protected areas close to or overlapping the study area.

Overlapping with the south part of the case study area, the "Cetacean migration corridor of the Mediterranean" is a new Marine Protected Area (MPA) declared in June 2018 by the Spanish Government according to the Royal Decree 699/2018, of 29th of June. Indeed, several studies (UNEP 2013a; Domínguez-Carrió *et al*., 2014; Gili *et al.*, 2011) demonstrate the high biodiversity and concentration of numerous cetacean species in the area and its special relevance as a migratory zone in connection with breeding and feeding areas in the north Mediterranean Sea. The corridor has an area of 46,385.70 km² and is circa 85 km of average in width. The area extends from nearly Cape Creus (in Gerona) in the north to Cabo de la Nao (in Alicante) in the south; to the east, it is located parallel to the coasts of Ibiza, Mallorca and Menorca Islands, at a distance of about 13 km; and to the west, also parallel to the Catalan and Valencian coasts, at around 38 km.

The north-eastern boundary of the case study area is bordered by the Pelagos Sanctuary[2]. The Pelagos Agreement, creating the Sanctuary for Mediterranean Marine Mammals, was signed in

[1] http://www.accobams.org/

[2] https://www.sanctuaire-pelagos.org/en/

1999 by France, Italy and the Principality of Monaco, where the project was officially registered. Implemented since 2002, the agreement seeks to coordinate the three countries in their initiatives to protect cetaceans and their habitats from all sources of disturbance: pollution, noise, bycatch and injury, disruption etc. The Pelagos Sanctuary for Mediterranean Marine Mammals is managed by three different authorities and includes coastal areas and international waters forming a large ecosystem of major scientific, socio-economic, cultural and educational interest.

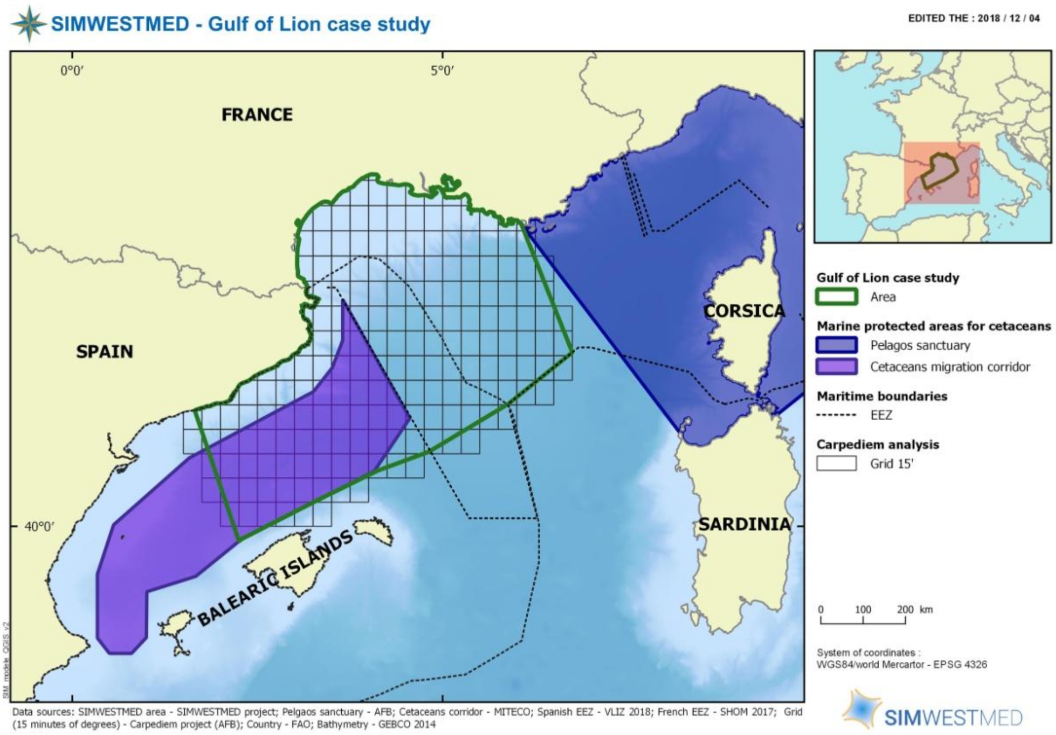

Figure 1 - The Gulf of Lion case study area in green. The map also displays the “Cetaceans’ corridor” in purple, the “Pelagos sanctuary” in dark blue, as well as the 15’ resolution square grid used in the SIMWESTMED analysis.

Several maritime sectors are using the area and are concerned with MSP. Most of these activities such as maritime transport, fishing, seismic survey, leisure activities and urbanization are producing the most important pressures suffered by marine mammals and seabirds populations such as collisions with vessels, visual disturbance, bycatch, entanglement in fishing gear, ingestion of pollutants and waste, prey depletion, loss of habitats, disturbance from constructions or exploration and underwater noise (Spitz et al., 2017; Morel et al., 2018). The impacts of these pressures on these different species are relatively unknown or under study. The analysis focuses on activities and pressures for which the effects on the marine megafauna are estimated relevant today.

Maritime traffic can be a source of a lot of disturbance. The main disturbances are behavioural (change in both short-term and long-term), collision and underwater noise. Only the two last pressures will be covered in this report and limited on marine mammals. Collisions between vessels and marine mammals have been treated in several studies, which show that several types of ships and a large range of speeds are involved in collisions (GIS 3M et al., 2010; Laist et al., 2001). Collisions can imply lethal damage and less frequently corporal damage. However, gathering data about effects and localisation of collision is very difficult. The main factor for estimated collision risk is by the overlapping of cetacean habitat and shipping routes (GIS 3M et al., 2010). Maritime traffic can also generate noise, but data about this pressure, considering this activity is available directly so no new estimation will be pursued in this study.

Fishing is responsible for several pressures cited previously. In France, the national stranding network and the Pelagis observatory, responsible for the MSFD Good Environmental Status

(GES) assessment of the marine mammals' component of the Descriptor D1 "Biodiversity", identify bycatch as one of the main causes of cetaceans' mortality (Spitz et al., 2017; Dars et al., 2017). Seabirds suffer also from bycatching in nets, longlines and from competition by the exploitation of their preys.

Over the last decades, the assessment of underwater noise and its impacts on marine organisms has increase and became an important research topic. A wide range of scientific papers have pointed out the effects of underwater noise on marine life, focusing on both behavioural and physiological effects, and a series of reviews are nowadays available (Williams et al., 2015; Peng et al., 2015; Kight and Swaddle, 2011, among others). Anthropogenic underwater noise may affect many taxonomic groups, although research has mostly focused and highlighted effects on marine mammals and fish (Annex I).

In addition, cetaceans and seabirds suffer from ingestion of **marine litter** and entanglement. Fossi *et al.* (2018) counted the number of studies focusing on these interactions and suggested that they have been documented in over 60% of all cetacean species. Moreover, the number of seabird species negatively impacted by litter increased from 138 to 174 over the past two decades. The ingestion of litter can occur directly (confusion of a waste and a prey) or indirectly (consumption of preys that contain particles, regurgitation from adults to juveniles). Ingestion of wastes such as plastics can cause several impacts (false feeling of satiation, blockage of the digestive tract, reduction of fat stores and body condition, bioaccumulation of toxic chemicals) and can ultimately lead to death. Entanglement can occur in ghost or active fishing gear and other types of plastic debris. Impacts are injury, drowning, strangulation, and may compromise feeding, reproduction, growth and longevity.

In this context of high threats but complex interactions processes, the methodological approach chosen has been to explore data, methods and tools and assess the **likely risk of exposure** of marine mammals and seabirds to anthropogenic pressures. The approach describe below is also a first contribution in order to produce diagnosis supporting the implementation of the marine spatial planning in a transboundary context.

MATERIAL AND METHODS

1. Overview of the methodological approach and tools

The methodological approach used for exposure risk analysis is based on previous developments made within the framework of the SIMCELT project and the CARPEDIEM project in France. First methodological developments were carried out within the framework of the SIMCELT projet[3] (Quemmerais-Amice *et al*., 2017) and focused on the analysis of cumulative effects on benthic habitats. The general approach is based on previous works dealing with the cumulative effect assessment at global or regional scale (Halpern *et al*., 2008; Andersen *et al*., 2013; Robinson *et al.*, 2014; Van der Wal & Tamis, 2013; Korpinen & Andersen, 2016). The method includes activities and pressures typologies as well as a relationship matrix between human activities and pressures, and a sensitivity matrix describing the ecological sensitivity of benthic habitats to different pressures. These matrix were developed on the basis of scientific and experts knowledge and allow to create a rational and explained connection between benthic habitats and impact induced by human activities. Associated with geographic information describing human activities intensity and benthic habitats distribution they allow producing map of risk of cumulative effects.

The objective of the CARPEDIEM project, started in 2016, is to develop, supply and use a spatial analysis methodology on a tool, providing a diagnosis on the interactions between anthropogenic pressures and marine ecosystems. The tool intends to produce synthesis maps of ecosystems, human activities, anthropogenic pressures and interactions between these pressures and ecosystems. All of this work is presented in detail in the CARPEDIEM project methodological report (Vanhoutte-Brunier *et al*., 2018).

For the SIMWESTMED case study dedicated to the assessment of cumulative pressures in the Gulf of Lion, it was decided to work on marine mammals and seabirds and on the most relevant anthropogenic pressures probably affecting them, and in terms of spatial planning challenges.

The method is divided into two main stages. The first step is to produce maps of human activities and major pressures affecting marine mammals and seabirds. The second step is to produce maps of the potential exposure risk for marine mammals and seabirds in order to locate and rank the likely areas of overlap between the anthropogenic pressures and the marine communities studied. As marine mammals and seabirds are highly mobile species, and human activities vary in time and space, the analysis involves seasonal data (summer and winter) to take the temporal dimensions into account. Meetings among SIMWESTMED partners have defined the activities and pressures to be taken into account in the exercise, as well as the common grid to be used.

The analysis is based on structuring descriptive data on the marine environment. Descriptive statistical and spatial data on human activities, pressures and ecosystem components are summarised, harmonised and distributed across a marine area grid with a resolution of 15 minutes of degrees (~28 km) (Figure 1). This resolution has been defined based on the coherence on mobiles stakes and resolution of the raw data. Since marine mammals and birds are highly mobile species and the raw data are limited, this resolution seems consistent to describe the general distribution of the populations studied. In addition, within the framework of the project, this resolution is a compromise allowing the exchange of human activities data between the partners, without being constrained by the confidentiality or the statistical secrecy related to the data.

The main steps of the data analysis are shown in Figure 2. At each step of mapping analysis, intermediate results are produced (multi-activities maps, multi-pressures maps, synthesis map of

[3] EU Project Grant No.: EASME/EMFF/2014/1.2.1.5/3/SI2.719473 MSP Lot 3. Supporting Implementation of Maritime Spatial Planning in the Celtic Seas (SIMCELT).

marine mammals and seabirds), which provide a background knowledge for interpreting the final analysis result.

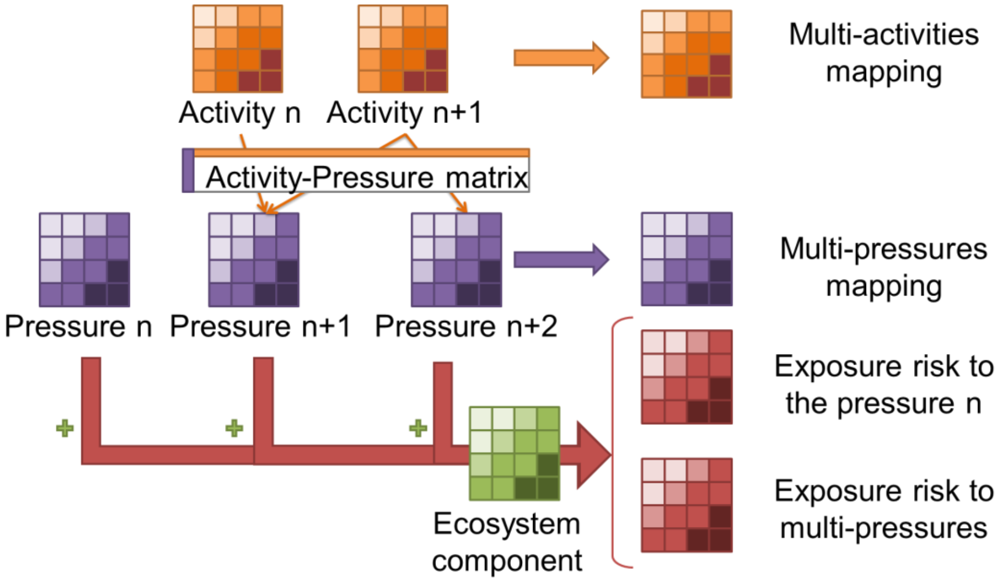

Figure 2 - Overview of the 2 mains steps of analysis.

The assessment of the risk of exposure of marine mammals and seabirds to cumulative pressures involves a specific vocabulary. The term “**risk**” puts the scope of results into perspective, as they are not a quantitative expression of the measurable effects on biological communities. Uncertainties linked to the results of the assessment are significant, due to methodological assumptions aiming to simplify real conditions and the way in which species and populations respond when they are exposed to a number of pressures. In our case, the term “risk” has no statistical meaning as we are not seeking to calculate the probability that an effect will occur. The word “**pressure**” refers to a change of status in space and/or time of the physical, chemical and biological parameters of the environment that affect the ecosystem. Pressures are generated by human activities on land and at sea, and influence the environment either directly or indirectly. The expression “**ecosystem component**” can refer to benthic habitats, pelagic habitats, fish and cephalopods, marine mammals, turtles or seabirds, etc. The term “**concomitant**” is preferable to “cumulative” as the notion of “cumulative” implies that there are only additional, linear effects when several pressures are exerted on a habitat or species. Many studies underline that there are various types of interactions between effects, including additive effects, synergistic effects and antagonistic effects (Korpinen & Andersen, 2016).

Two analysis possibilities were explored to produce maps of the risk of exposure of marine mammals and seabirds to concomitant pressures. One of the most important issues was to collect and harmonize coherent datasets between Spain and France, to try to carry out an analysis combining datasets from both countries:

- First analysis: Conduction of the analysis with French datasets;
- Second analysis: Conduction of the analysis with mixed Spanish and French datasets: Spanish datasets on shipping, fishing and underwater noise along with French datasets on waste, fishing, marine mammals and seabirds, on account of the lack/ unavailability of Spanish information in these fields.

Datasets are managed and used with a spatial database management system, PostgreSQL-PostGIS, using the pgAdmin software suite. Each cell has a unique identification code and can be selected and requested according to various criteria. Some data processing and maps have been made using the QGIS software, which very easily interfaces with the database. Statistical analysis has been carried out using the R software. Figure 3 shows the main steps in the data processing chain.

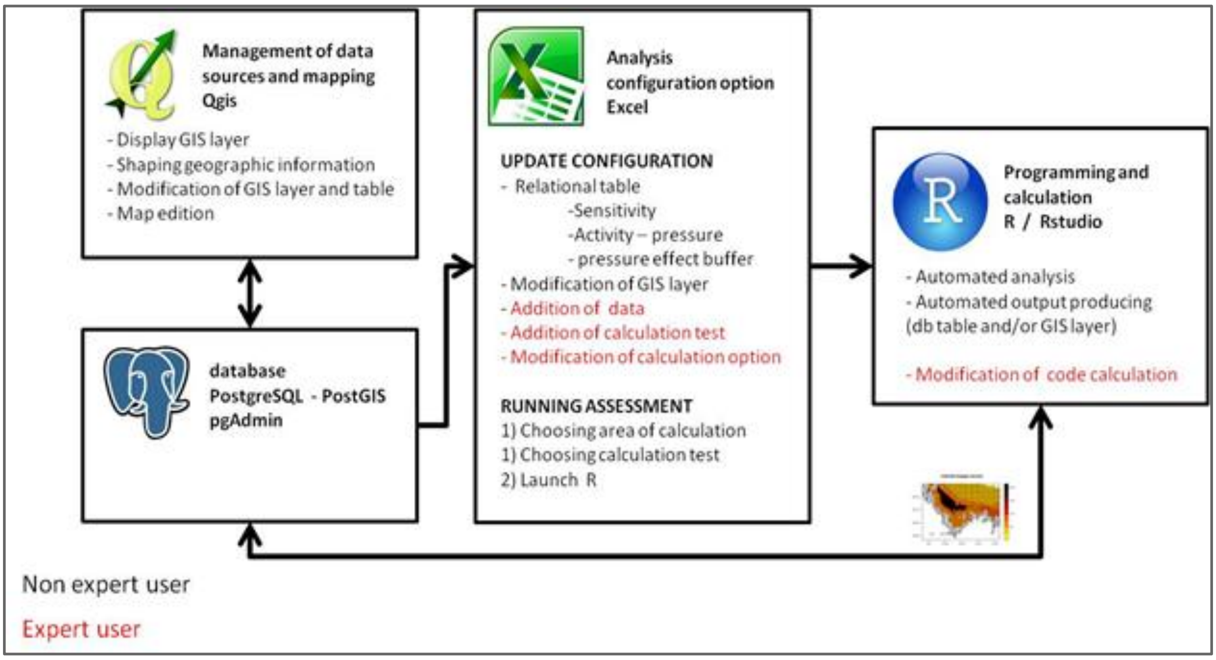

Figure 3 - Software and processing chain for CARPEDIEM project

2. Datasets description

Identification, collection, quality assurance and raw data edition has been done. This very time-consuming work has produced standardized data sets usable in the exposure risk analysis tool. A major effort was made to produce datasets with a seasonal consistency (Table 1), a dataset corresponding to winter and a dataset corresponding to summer (four months for each season).

This section presents the main information describing the origin and nature of the data sources, the processing performed and the final datasets created. Datasets refer to a few species or groups of marine mammals species and seabirds, shipping and fishing activities and associated pressures, as well as pressures like underwater noise and marine litter.

One of the most important issues was to collect and harmonize coherent datasets between Spain and France, to try to carry out an analysis combining data from both countries. Datasets exchanged between partners are described in technical reports presenting essential information about data sources, processing methods, units, coding, and data type.

Table 1 - Periods covered by datasets used to produce seasonal information

Season	Start	End	Years considered (France)	Years considered (Spain)
Winter	1st November	28 or 29 February	2011 - 2012 2016	2009 - 2010 2015 - 2016 2016 - 2017
Summer	1st May	31st August	2012 2016	2010 2016 2017

2.1. Marine mammals and seabirds datasets

Datasets describing spatial and seasonal distribution of marine mammals and seabirds usually come from observations from boat or plane. Several surveys were realized in recent years: SCANS (1994, 2005, 2016), SAMM (2011-2012, 2018-2019), ACCOBAMS (2018).

In this case study, modelization of habitat of marine mammals and seabirds (Table 2), conducted by the Pelagis observatory and based on SAMM campaigns (air tracking of the marine megafauna in France Metropolitan waters) and realized in winter 2011-2012 and summer 2012 (Pettex *et al*., 2014), were used. These models provide a **daily predicted mean of the marine mammals' and seabirds' densities (number of individuals per km²) per season** (Figure 4). For winter, the period considered goes from 17th November 2011 to 12th February 2012 and for summer, from 16th May 2012 to 8th August 2012. The density prediction is made on a grid of 0.05 degrees of resolution.

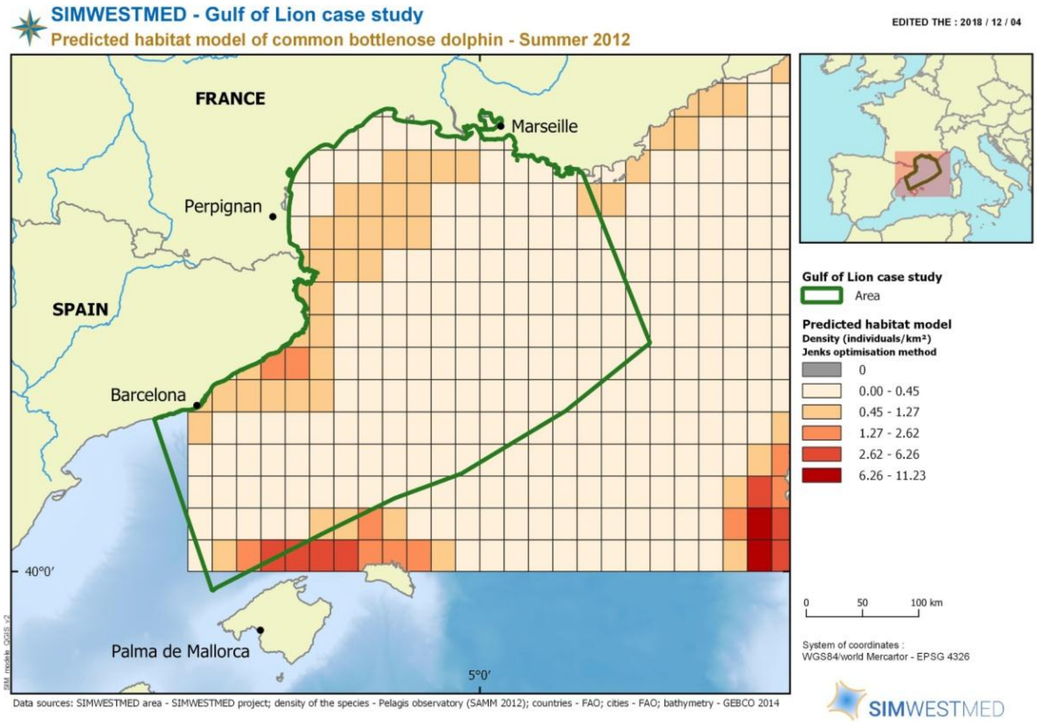

Figure 4 - Predicted habitat model of small dolphins during summer 2012 in the Gulf of Lion (15' grid)

Table 2 - Groups of species (in dark blue) or species (in light blue) for which predicted habitat models are available (checked box) (adapted from Pettex, 2014)

SEABIRDS				MEDITERRANEAN SEA	
Family	**Group or species modeled**	**Latin name of species associated**	**English name of species associated**	**winter 2011/2012**	**summer 2012**
Alcidae	Alcidae	*Fratercula arctica*	Atlantic Puffin	insufficient	absent
		Uria aalge	Common Guillemot		
		Alca torda	Razorbill		
Phalacrocoracidae	Cormorants/shags	*Phalacrocorax carbo*	Great cormorant	insufficient	insufficient
		Phalacrocorax aristotelis	European shag or common shag		
Sulidae	Northern gannet	*Morus bassanus*	-	insufficient	insufficient
Procellariidae	Northern fulmar	*Fulmarus glacialis*	-	absent	absent
	Little shearwaters	*Puffinus puffinus*	Manx shearwater	x	x
		Puffinus yelkouan	Yelkouan shearwater		
		Puffinus mauretanicus	Balearic shearwater		
	Great shearwaters	*Puffinus gravis*	Great shearwater	insufficient	x
		Puffinus griseus	Sooty shearwater		
		Calonectris diomedea	Scopoli's shearwater		
Laridae	Great grey gulls	*Larus argentatus*	European herring gull	x	x
		Larus michahellis	Yellow-legged gull		
	Great black gulls	*Larus marinus*	Great black-backed gull	absent	absent
		Larus fuscus	Lesser black-backed gull		
	Terns	*Sterna paradisaea*	Arctic tern	x	x
		Sterna hirundo	Common tern		
		Sterna albifrons	Little tern		
		Thalasseus sandvicensis	Sandwich tern		
	Gulls	*Larus ridibundus*	Black-headed gull	x	x
		Larus melanocephalus	Mediterranean gull		
	Little gull	*Larus minutus*	-	insufficient	no model
	Black-legged kittiwake	*Rissa tridactyla*	-	insufficient	absent
Hydrobatidae	Petrels	*Hydrobates pelagicus*	European storm petrel	insufficient	x
		Hydrobates leucorhous	Leach's storm petrel		
		Hydrobates castro	Band-rumped storm petrel		
Stercorariidae	Great skua	*Catharacta skua*	-	insufficient	insufficient
Anatidae	Scoters	*Melanitta nigra*	Common scoter	absent	absent
		Melanitta fusca	Velvet scoter		
Gavidae	Divers	*Gavia stellata*	Red-throated loon	absent	absent
		Gavia arctica	Black-throated loon		
		Gavia immer	Common loon or great northern diver		

CETACEANS				MEDITERRANEAN SEA	
Family	**Group or species modeled**	**Latin name of species associated**	**English name of species associated**	**winter 2011/2012**	**summer 2012**
Under-family Globicephalinae	Globicephalinae	*Globicephala melas*	Long-finned pilot whale	x	x
		Grampus griseus	Risso's dolphin		
Under-family Delphininae	Little delphininae	*Delphinus delphis*	Short-beaked common dolphin	x	x
		Stenella coeruleoalba	Striped dolphin		
	Common bottlenose dolphin	*Tursiops truncatus*	-	x	x
Phocoenidae	Harbour porpoise	*Phocoena phocoena*	-	absent	absent
Balenopteridae	Fin whale	*Balaenoptera physalus*	-	x	x
Physeteridae	Sperm whale	*Physeter macrocephalus*	-	insufficient	insufficient

Predicted density values provided by the Pelagis observatory were processed in order to incorporate them to the 3 minutes of degrees' grid and then to the 15' grid of the project. Statistics were calculated at this stage: maximum value, average value, median value and coefficient of variation. They aim to minimize the loss of information due to switching to a grid of less resolution.

Table 3 synthesizes the main characteristics of cetaceans and seabirds data available and used in the analysis.

Table 3 - List of cetaceans and seabirds data

Data	Intensity parameter	Unit per cell	Spatial resolution	Temporal resolution	Data source
Cetaceans	daily mean density of cetaceans per season	individuals/km²	3 min 15 min	Winter 2011-2012 Summer 2012	Pelagis Observatory (France) Processed by AFB
Seabirds	daily mean density of seabirds per season				

2.2. Human activities and pressures datasets

2.2.1. Fishing

Fishing data are based on the vessel monitoring system (VMS) which provides, at regular intervals, data to the fisheries authorities on the location, course and speed of vessels. The compulsory VMS tracking for fishing vessels over 12 m in length was launched by the European Union in 2009 (Council Regulation N°1224/2009). These data allow monitoring behaviour of fishing vessels in real-time, in particular for control purposes.

In France, the Marine Fisheries and Aquaculture Directorate (DPMA) of the Agriculture and Fishing Ministry is responsible for the VMS data. They provided formatted data of the French fishing effort in terms of fishing time (hours) and ship numbers per type of gear, at a 3' resolution and for each month of the winter season 2011-2012 (November 2011 to February 2012) and the summer season 2012 (May 2012 to August 2012). However, these data are not exhaustive because only French boats are considered and some data are undisclosed (if there is less than 3 boats per cell per period).

Data were incorporated in the 3' and 15' grids with statistics on the fishing effort:

- Number of ships per type of gear, season;
- Average and maximum number of ships per type of gear, month, season;
- Number of hours per type of gear, season (Figure 5);
- Average and maximum number of hours per type of gear, month, season.

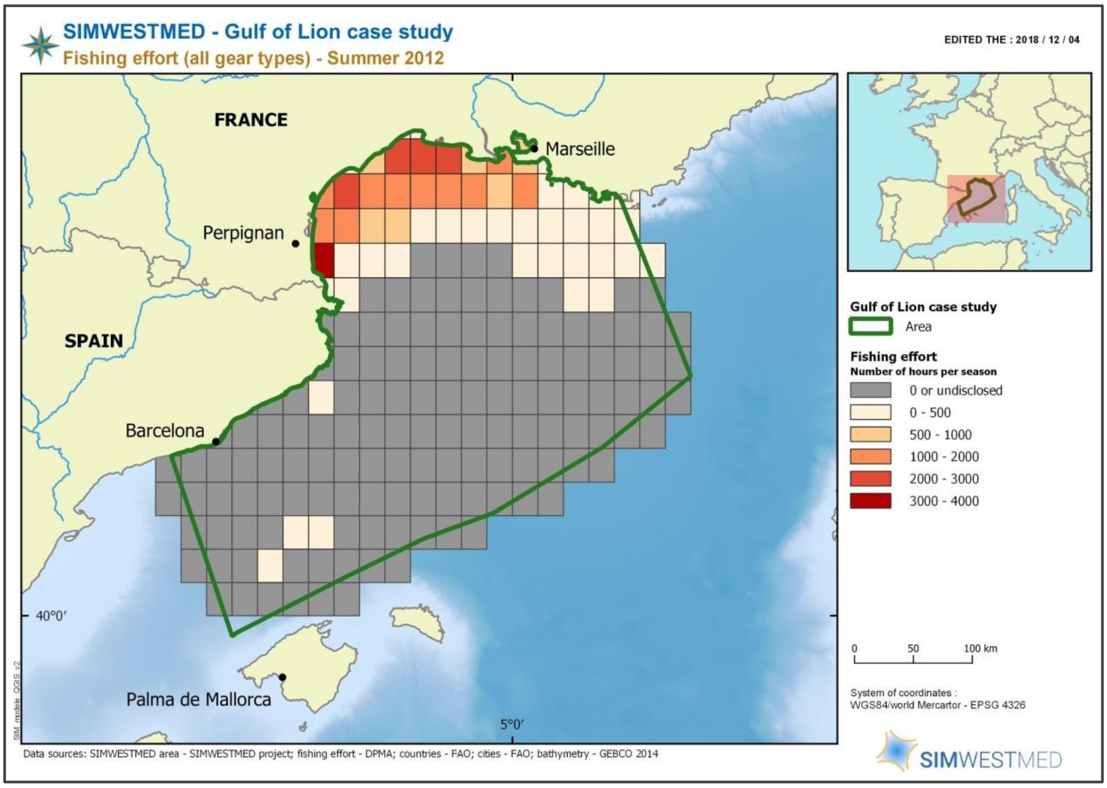

Figure 5 - French fishing effort during the summer 2012 in the Gulf of Lion, all gear types combined (15' grid)

In Spain, the spatial distribution of the activities of the industrial fishing fleet has been analysed using the information contained in logbooks and VMS. The information in logbooks corresponded to the period 2007-2010. VMS and logbook data were provided by the former Spanish Ministry of Agriculture, Food and Environment (MAGRAMA, in Spanish) the actual Ministry for the Ecological Transition.

Regarding VMS, this tracking device sends a signal every two hours (ping) that contains the code of the emitting ship, date, time, position (latitude and longitude), speed in knots, course, and whether the vessel is carrying out fishing operations or not. There are many filters and processing techniques used to eliminate signals not related to fishing activity (Lee *et al*., 2010; Hintzen *et al.*, 2011). In this study, the following processing technique was used: the time interval and the Euclidean distance between successive signals were obtained, and each of these values were associated with the first signal of each corresponding pair; when the time interval between signals was longer than four hours, the beginning and end of each fishing expedition was determined; the average speed of the vessel was calculated using the interval between successive signals (pings); vessels with less than ten signals in a year were eliminated; signals recorded within a distance of three miles or less from the closest fishing harbour were also eliminated. Each signal coinciding with a fishing trip registered in the logbooks (according to the vessel code and the capture date) was associated with a fishing gear and a fishing tactic. Based on the distribution of the frequencies of average speeds, a working range for each fishing gear was defined, and all signals with associated velocities out of the working range were eliminated (Hintzen *et al.*, 2011).

The frequency distribution of the average velocities was used to determine the average speed ranges at which we considered the fishing activity was carried out. The identification of these ranges can be achieved by either locating changes in the tendency through the use of regression models (segmented regression) or using available information from the fleet and observers aboard. In the case of dynamic fisheries (trawling and hand-line trawling), both methods are used, whereas in the case of static fisheries (purse-seine fishing, gillnet, long-line fishing and hand-line fishing), it is better to use the information provided by observers aboard and the information obtained from the fleet according to the frequency distribution.

On wide continental shelves with sedimentary bottoms such as in the North Sea, fishing grounds are generally very wide. In these cases, after filtering and analysing VMS data, the distribution of the fishing effort can be clearly observed. Therefore, areas containing points with no fishing activity are scarce (Hintzen *et al.*, 2011). However, fishing areas located on narrow continental shelves with rocky mosaic bottoms or on continental slopes are generally tight and short. In these cases, it is frequent to find areas where fishing activity is apparently being carried out when, in reality, there is no activity. To eliminate false fishing activity, it is necessary to apply thresholds to define when fishing activity is actually carried out.

Thresholds were applied to determine whether filtered data from VMS corresponded to the real fishing activity. Thus, the effort value was assigned to each corresponding point where presence of fishing was detected. Subsequently, it was necessary to set a threshold for the effort value below which fishing activity was considered to be negligible or non-existent. Many methods are available for that purpose (Jiménez-Valverde and Lobo, 2007) yet the techniques providing the best outcomes were based on applying quartile thresholds. Points where fishing presence was detected were eliminated according to the distribution of the effort frequencies. The use of other statistics based on the generation of pseudo-absences to distinguish points with real fishing presence was not fruitful due to the fact that efforts were located in specific areas. Thus, when pseudo-absences were generated and those corresponding to locations of real activity were eliminated, it was found that pseudo-absences were always placed over zones of no activity; consequently, threshold values were so low that we could not distinguish between real and false presences.

Thresholds can be applied to fishing tactics or to fishing gear. If the relative importance of thresholds is small, it is better to apply them to fishing tactics; otherwise, it is more effective to apply them to fishing gear. In any case, 0.2 was considered to be an optimum threshold value. The spatial effort estimation was carried out using a grid spacing of 15'.

Table 4 synthesizes the main characteristics of fishing data available and used in the analysis.

Table 4 - List of fishing data

<table>
<tr><th>Fishing data</th><th>Intensity parameter</th><th>Unit per cell</th><th>Spatial resolution</th><th>Temporal resolution</th><th>Data source</th></tr>
<tr><td>All gear types</td><td rowspan="11">Sum of fishing effort in summer or winter.
Monthly average of fishing effort in summer or winter.</td><td rowspan="11">-Ships/season (sum)
-Ships/month (average, max)
-Hours/season (sum)
-Hours/month (average, max)</td><td rowspan="11">3 min
15 min</td><td rowspan="11">Winter 2011-2012
Summer 2012</td><td rowspan="11">DPMA (France)
Processed by AFB</td></tr>
<tr><td>Nets</td></tr>
<tr><td>Seines</td></tr>
<tr><td>Surrounding nets</td></tr>
<tr><td>Pelagic trawls</td></tr>
<tr><td>Bottom trawls</td></tr>
<tr><td>Dredges</td></tr>
<tr><td>Rods and lines</td></tr>
<tr><td>Longlines</td></tr>
<tr><td>Traps</td></tr>
<tr><td>Other gear</td></tr>
<tr><td>Nets</td><td rowspan="6">Sum of fishing effort in summer or winter.</td><td rowspan="6">Hours/season (sum)</td><td rowspan="6">15 min</td><td rowspan="6">Winters
2007-2008
2008-2009
2009-2010

Summers
2007
2008
2009
2010</td><td rowspan="6">IEO (Spain)</td></tr>
<tr><td>Surrounding nets</td></tr>
<tr><td>Bottom trawls</td></tr>
<tr><td>Rods and lines</td></tr>
<tr><td>Longlines</td></tr>
<tr><td>Traps</td></tr>
</table>

See Annex II for more details on fishing category.

2.2.2. Navigation

Navigation data is based on the Automatic Identification System (AIS) which is an automatic tracking system used in collision avoidance, coastal surveillance and traffic management. This system transmits messages including three information categories: static data (ship's identification), dynamic navigation sensor data (ship's position and movement) and manually inputted voyage-related data (destination) (Robards *et al.*, 2016).

Since 2002, AIS is mandatory under the SOLAS convention (IMO, SOLAS Convention, Chapter V, Regulation 19) and the European Directive 2002/59/EC for new ships (constructed after 1 July 2002) of 300 gross tonnage and upwards. The implementation of the AIS for existing ships of that gross tonnage was distributed between 2003 to 2007 according to the type of ship and the gross tonnage.

Concerning fishing vessels, the AIS system is mandatory since 2012 for fishing vessels of 24 meters and over, 2013 for fishing vessels of 15 meters and over, and 2014 for fishing vessels of 15 meters and over.

In this way, the AIS system provides real-time information on nautical operations through the exchange of radio messages, according to the ITU-established (International Telecommunication Union) standard met by both ships and coastal stations, which are operated by maritime authorities. Up to 27 defined types of messages provide position reports, static ship data, base station reports, search and rescue aircraft position reports, security messages and other management of telecommunications. Besides its use as a real-time information system of great utility for maritime security, the information contained in such messages appears useful to conduct a variety of analyses: the use of maritime areas in ports, maritime traffic intensity, compliance of restrictions in navigation, fishing effort, underwater noise generated by traffic, to mention a few examples. To that end, it is necessary to store the messages in an appropriate way so that their subsequent analysis conducted with greater flexibility.

In France, all AIS messages received in the French reception area are stored in the CEREMA database. FBA used the Envigis tool, developed by CEREMA, to extract and process this data. This application allows querying the database with some filters, for example: temporal extent, spatial extent, kind of ship, maximal calculated speed. Then it proposes several functions to process the data. The selected function in this case study gives an intensity map (grid composed by cells of 1 minute): average number of ship tracks (per 24 hours) in each cell of the grid. Data are extracted per ship category, season and year. Ships categories are based on type of use: passenger, fishing, pleasure craft and dive, special ship, freight transport, high speed craft and other ship. The seasons correspond to the summer (May to August 2016, 2017) and the winter (November 2015 to February 2016, 2016-2017).

To sum up, the first part of the process is made by using the Envigis tool. The output is an intensity grid (1 minute x 1 minute): average number of ship tracks average (per 24 hours). The second part of the process is to average the both years and to aggregate data in grids of different size: 1', 3', 5', 10', 15' (Figure 6).

French AIS data could underestimate the marine traffic. Indeed, a ship is counted only one time in a cell during 24 hours, thus the round trip of a ship it's not considered. This no-recount time of ship is an input parameter, but it's difficult to determine an average time of round trip for each ship category. Thus, this input parameter has been set for all ship categories at 24 hours in order to allow a comparison of the traffic according to the ship categories.

Regarding the Spanish side, the data source used was the historical AIS database (named *db_ais_data*) developed by CEDEX from the AIS data flow provided by the Spanish Maritime Safety Agency[4] in the context of the PRISMA Project[5]. Independent partitioned tables store 12 out of the 27 types of AIS messages (see Annex III for more information).

It should be noted that the origin of the information are coastal stations receiving AIS messages. Therefore, signal out-of-shore reach is limited and dependent upon weather conditions, generally recording a longer reach during summer seasons. In any case, a good coverage of AIS signals in Spanish jurisdictional waters (i.e. EEZ) is estimated throughout the year.

[4] SASEMAR, Sociedad de Salvamento y Seguridad Marítima.

[5] Conducted by CEDEX for the Directorate-General for the Merchant Marine (Spanish Ministry of Development).

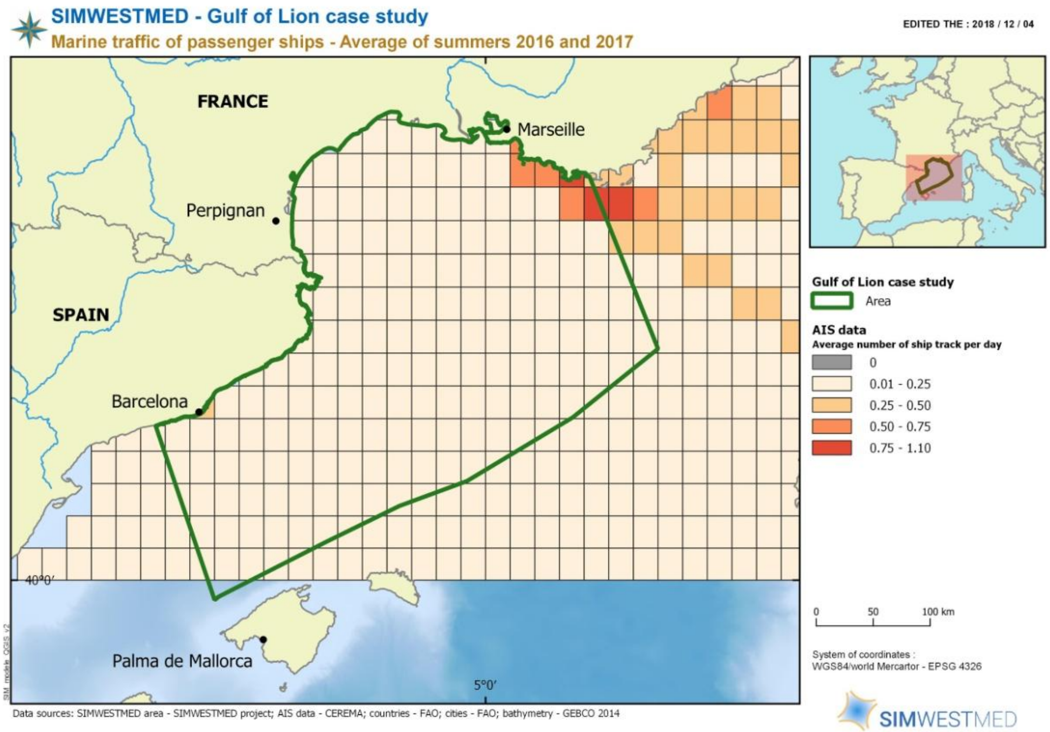

Figure 6 - Daily average marine traffic of passenger ships during the summers 2016 and 2017 in the Gulf of Lion (15' grid)

An additional limitation of the AIS data comes from the fact that some of the fields in certain messages are manually defined, making them prone to errors. This fact does not affect the position data, which are mostly automatic readings of a GPS positioning system, but may generate errors related to, *inter alia*, vessel type, destination, dimensions, etc. Given the scope of this particular study, a systematic check of such incidents was not carried out, although they are estimated to affect around 10% of the data.

Representative values of maritime traffic density within the temporal periods and the study area agreed have been obtained from the database via SQL queries, providing "snapshots" of the spatial locations of 9 vessel types (Table 5) present in the area, in a number of randomly selected moments within each one of the assessment periods. All boats have been considered for the purposes of maritime traffic analysis, whether navigating or not (moored, etc.).

Each snapshot represents the spatial distribution of the maritime transport activity at the query time, as it displays instant vessel density maps projected onto the grid. The joint consideration of multiple snapshots allows for the statistical assessment of maritime traffic in the study area for a defined time period. The dataset available within each snapshot includes, for each ship, their category (Table 5), position and speed. To conduct the analysis, 4 000 snapshots have been captured (one snapshot every 45 minutes, on average), which is considered sufficient for the adequate estimation of the indicators needed. These capture moments are chosen randomly within each station to eliminate possible biases due to repetitive positions in fixed hours for regular high-intensity traffic. See Annex IV for more detailed information on the processing methods.

Table 5 synthesizes the main characteristics of navigation data available and used in the analysis.

Table 5 - List of navigation data (according to French and Spanish sources)

<table>
<tr><th>Navigation data</th><th>Intensity parameter</th><th>Unit per cell</th><th>Spatial resolution</th><th>Temporal resolution</th><th>Data source</th></tr>
<tr><td>All categories</td><td rowspan="10">Average number of ship tracks per day, per cell and per season</td><td rowspan="10">Ships tracks/day</td><td rowspan="10">1 min
3 min
5 min
10 min
15 min</td><td rowspan="10">Winters 2015-2016, 2016-2017

Summers 2016,2017</td><td rowspan="10">CEREMA (France) Processed by AFB</td></tr>
<tr><td>Cargo</td></tr>
<tr><td>Tanker</td></tr>
<tr><td>Passenger</td></tr>
<tr><td>Fishing</td></tr>
<tr><td>Pleasure craft and dive</td></tr>
<tr><td>High speed craft</td></tr>
<tr><td>Special (military ops, dredger)</td></tr>
<tr><td>Special (law enforce, special craft, medical trans, anti-pollution, tug, SAR, port tender, local vessel)</td></tr>
<tr><td>Other</td></tr>
<tr><td>All categories</td><td rowspan="9">Ship density, number of ships per unit area and within a defined cell. (Standard deviation, as well as 90, 95 and 99 percentiles also available);</td><td rowspan="9">Average number ships/ unit area / cell and season</td><td rowspan="9">1 min
5 min
15 min</td><td rowspan="9">Winters 2015-2016, 2016-2017

Summers 2016, 2017</td><td rowspan="9">CEDEX (Spain)</td></tr>
<tr><td>Cargo</td></tr>
<tr><td>Small tankers (<187,5 m)</td></tr>
<tr><td>Large tankers (>187,5 m)</td></tr>
<tr><td>Fishing and sport vessels</td></tr>
<tr><td>Passenger</td></tr>
<tr><td>High speed craft</td></tr>
<tr><td>Special and port ships</td></tr>
<tr><td>Other</td></tr>
</table>

2.2.3. Underwater noise

Underwater noise can be divided in two categories: continuous noise and impulsive noise. Continuous noise is related to a low frequency noise generated mostly by the marine traffic and can be modelled from AIS data or measured with hydrophones in-situ. Impulsive noise corresponds to impulsive signals produced by seismic prospection, underwater explosions and construction of coastal and offshore infrastructures.

In France, SHOM is in charge of the GES assessment of MSFD Descriptor 11: noise disturbances of anthropic origin (Le Courtois, 2017). In this context, its team created 0.25 degrees grids at the metropolitan scale of impulsive sound and continuous sound:

- **Number of days of impulsive noise in 2016** (Figure 7);
- **Maximum sound level value (in dB) in the water column in 2012 and 2016, for the frequencies 63 Hz and 125 Hz** (Figure 8).

Impulsive noise data were collected directly from the operators and / or the state's training services and integrated the impulsive emissions register called SIRENE (Stephan, 2016). As the grid produced does not match with the project's 15' grid, a work of data processing was done. Statistics were calculated at this stage: maximum value, average value, median value and coefficient of variation. They aim to minimize the loss of information due to switching to another grid.

Continuous noise data came from ambient noise models based on maritime traffic and environmental parameters (bathymetry, sound speed profile and seabed composition), and were validated by hydrophone measurements in-situ. The ambient noise was modelled at 63 Hz and 125 Hz because of the predominance at these frequencies of the noise of marine traffic on any other source of noise (including natural sounds) (Stéphan, 2013). These grids required little data processing as they corresponded to the 15' grid of the project.

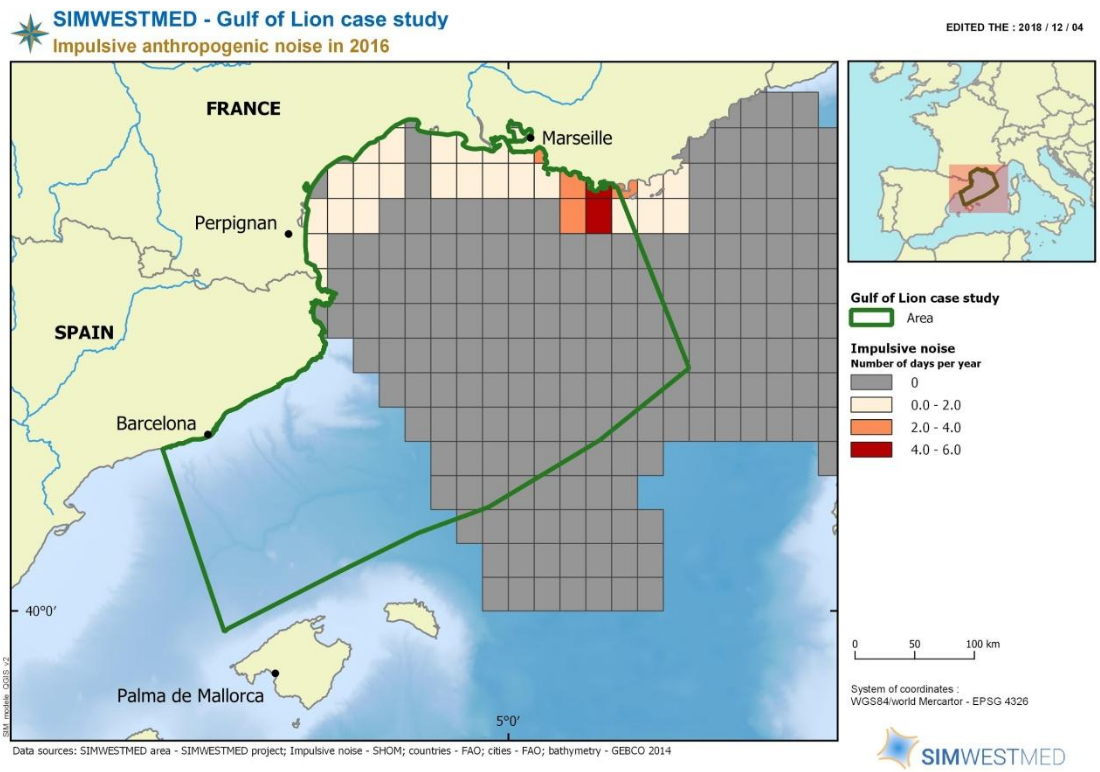

Figure 7 - Impulsive anthropogenic noise in 2016 in the Gulf of Lion (15' grid)

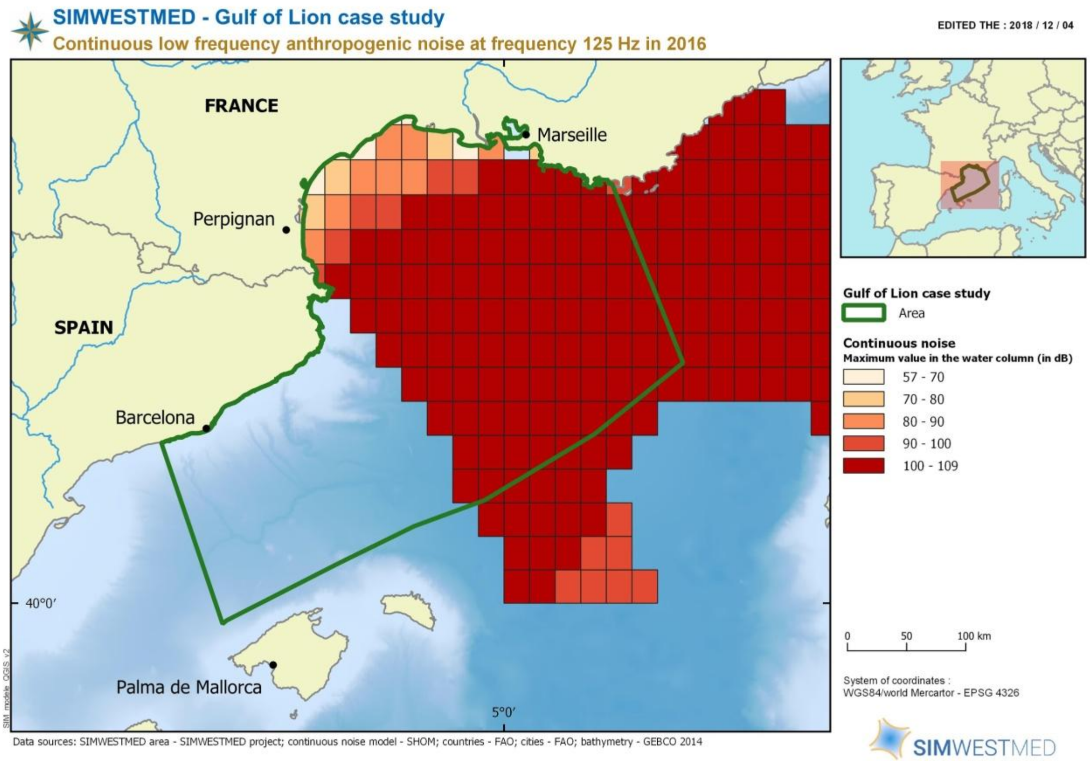

Figure 8 - Continuous low frequency anthropogenic noise at frequency 125 Hz in 2016 in the Gulf of Lion (15' grid)

On the other hand, the estimation of underwater noise in Spanish waters has been carried out based on the assessment of maritime traffic density using AIS data (see part 2.2.2. Navigation). In this case, only ships sailing with a speed over 1 knot have been considered as contributors to underwater noise. Vessels have also been classified in several categories; in this sense, their different characteristics have been used in the model to assess their different contribution to underwater noise.

For the purposes of estimating the noise level emitted by each boat, the RANDI[6] method has been used. This method is based on cataloging 5 classes of boats according to two parameters, length and speed. The formulation is as follows:

$$L_s(f, v, l_s) = L_{s0}(f) + 60 \cdot \log\left(\frac{v}{12}\right) + 20 \cdot \log\left(\frac{l_s}{300}\right) + df \cdot dl + 3.0$$

Parameters:

v: vessel speed in knots;

ls: vessel length in feet;

df = 22,3 - 9,77 x log (f), in the range (28,4 < f ≤ 191,6);

dl = (ls x 1,15) / 3 643,0; and

LS0 (f) = - 10 x log (10 - 1,06 x log(f) - 14,34 + 103,32 x log(f) - 21,45) for (f <500 Hz).

Calculations have been conducted for two frequencies, 63 Hz and 125 Hz, as recommended by Dekeling et al. (2014). Table 6 shows the corresponding categories and values.

[6] J. Ernest Breeding, Jr & Lisa A. Pflug. Research Ambient Noise Directionality (RANDI) 3.1. Physics Description. Ocean Acoustics Branch, Acoustics Division. August 8, 1996

Table 6 - Noise level per vessel for the frequencies 63 and 125 Hz

Frequency (Hz)/ Type	Fishing Vessels, dB	Passenger Vessels, dB	Cargos, dB	Small Tankers, dB	Large Tankers, dB
63	133,974	172,414	163,925	159,871	164,918
125	124,536	161,895	153,530	149,883	154,398

For the purposes of obtaining such groupings and specific emission values, the characteristics of vessels sailing in Spanish jurisdictional waters have been analysed, relating their average speeds to their lengths, and thereby defining and characterising a small number of categories according to the aforementioned formula.

For the purposes of the underwater noise assessment, received sound levels (RL, Received Level) have been estimated by subtracting losses by transmission from the source level (SL, Source Level) according to the following expression:

$$RL = SL-TL = SL - 15 \log(R)$$

In practice, for the calculation in the 15’ grid, received sound levels are composed of the sum of the sounds emitted in each cell plus the contributions of noise emitted in neighbouring cells, taking into account the corresponding transmission losses in each case. To assess the received sound in each cell due to the noise emitted in that same cell, an average propagation distance according to its dimensions is assumed. For more details on the methodology adopted for the estimation of underwater noise, see Annex V.

Results are displayed on a map, which shows both sound values emitted in each cell, but, above all, for received levels associated to average traffic densities. Defined stations, frequencies and level of detail of the calculation grid are available for consultation.

Table 7 synthesizes the main characteristics of underwater noise data available and used in the analysis.

Table 7 - List of underwater noise data

<table>
<tr><th>Underwater noise data</th><th>Intensity parameter</th><th>Unit per cell</th><th>Spatial resolution</th><th>Temporal resolution</th><th>Data source</th></tr>
<tr><td>Impulsive noise</td><td>Number of days of impulsive noise</td><td>number of days</td><td rowspan="2">15 min</td><td>Year 2016</td><td rowspan="2">Shom (France) Processed by AFB</td></tr>
<tr><td>Continuous noise</td><td>Maximum sound level value (in dB) in the water column per year and for the frequencies 63 Hz and 125 Hz</td><td>decibels</td><td>Years 2012, 2016</td></tr>
<tr><td>Continuous noise</td><td>Mean value of received sound levels (in dB) per season for the frequencies 63 Hz and 125 H</td><td>decibels</td><td>1 min
5 min
15 min</td><td>Summer 2016

Winter 2016-17</td><td>CEDEX (Spain)</td></tr>
</table>

2.2.4. Litter

The spatial distribution of marine litter (macro-waste and micro-plastics) data usually come from visual counting by boat or plane, collecting on beaches or stomach dissection of fish, cetaceans, turtles and birds. In most cases, variability of data sources and local scale of the studies prevents large-scale representation of waste in the marine environment.

Floating macro-waste data used in this analysis come from SAMM campaigns (air tracking of the marine megafauna in France Metropolitan) of winter 2011-2012 and summer 2012 organized by Pelagis observatory (Pettex et al., 2014) and the Biological Studies Center of Chizé - CNRS. The items, having a size above 30 centimeters, were counted following the strip transect methodology (width strip of 200 meters at both sides of the plane). The other types of litters were not used in this evaluation, due to a lack of knowledge and data available to modelize them.

Those data was pre-processing by Pelagis observatory to produce forecasting data considering sample effort. This pre-processing is based on statistic model, generalized additive models (Hilbe, 2014), which models non-linear relationship between marine litter data and explanatory variables. Six explanatory variables were considered in this case: longitude, latitude, slope, distance from the coast, distance from the 200 meters isobaths and distance from the nearest canyon. For each dataset (summer or winter in Northern Atlantic Ocean or Western Mediterranean sea), models with maximum of four variables are tested to fit the data. The models with the best fitting are selected for the dataset forecasting. The two main hypotheses of this method are: all the marine litter float on the water surface and the observers detected all items in the two strips of 200 meters. The major limits of this method come from the data collection: items with a size smaller than 30 centimeters could not be observed, several subjects are recorded during a survey and marine litter were not the first priority, the observing conditions are not constant (light, wind,…) and it could have a seasonal effect (the water is more rough in winter and moves the marine litter in the sub-surface of the water which reduces the detection from the aircraft).

Density models were processed in order to calculate a **daily mean density of floating macro-waste per season that is the number of items per km²** and to incorporate them in the 5, 10 and 15 minutes of degrees grids of the project (Figure 9). Statistics were calculated to minimize the loss of information due to switching to a grid of less resolution: maximum value, average value, median value and coefficient of variation value.

Unfortunately, the estimation of litters was made only on French waters (location of the airplane tracks).

Table 8 synthesizes the main characteristics of macro-waste data available and used in the analysis.

Table 8 - List of marine litter data

Marine litter data	Intensity parameter	Unit per cell	Spatial resolution	Temporal resolution	Data source
Floating macro-waste	daily mean density of floating macro-waste per season	items/km²	5 min 10 min 15 min	Winter 2011-2012 Summer 2012	Pelagis Observatory (France) Processed by AFB

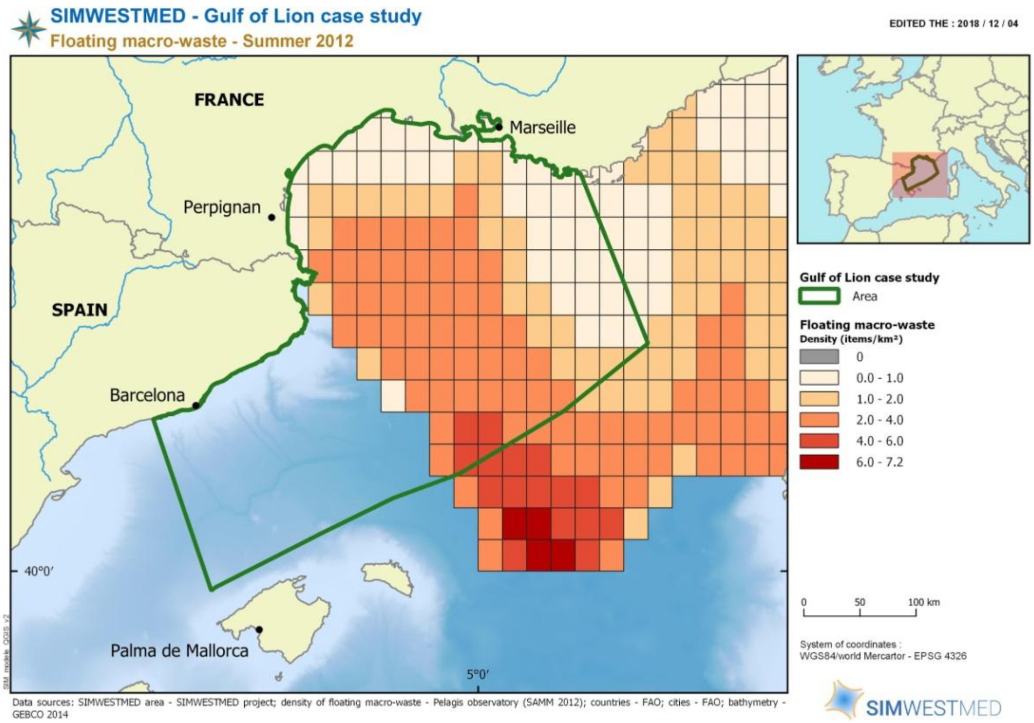

Figure 9 - Density of floating macro-waste during the summer 2012 in the Gulf of Lion (15' grid)

3. Methodology for exposure risk analysis

3.1. Multi-activities mapping

A multi-activities map gives a qualitative and quantitative overview of the use of marine and coastal areas, which is useful for marine planning. This spatial representation will show sectors with potentially strong interaction between the activities themselves and between the activities and the marine environment. Areas with fewer constraints between activities and with the environment may also be located. It's important to remain that only two activities are taken account in this analysis and not represent all activities that generates pressures, as some of them are located on land.

Two indicators are calculated from the activities data for mapping the human activities:

- **Index of multi-activities presence** (IMA_option1) corresponds to the number of activities present in each cell over a defined period. The periods defined in SIMWESTMED project are the winter and the summer. The diversity of datasets not allows focusing on one specific year but only recent years (>2009) are considered.

$$IMA_{option\ 1} = \sum_{i=1}^{n_i} A_i$$

Where: A_i Presence/absence of the activity i [0/1]

n_i Number of activity sectors

- **Index of multi-activities intensity** (IMA_option2) corresponds to the cumulative intensities of each activity in each cell. For this approach, the intensity data for each activity is normalized between 0 and 1 using a log transformation. This operation allows using a large diversity of units. To avoid the fact that the sum of these intensities (IMA_option2) could be found in different value ranges, depending on the number of activities present, the result is also normalized between 0 and 1.

$$IMA_{option2} = f_{norm}\left(\sum_{i=1}^{n_i} f_{norm}(A_i)\right)$$

Where: A_i Intensity of the activity
n_i Number of activity sectors
f_{norm} Log transformation and normalizing function to obtain value in [0-1]

Descriptive data on human activities can then be used to map the pressures but some pressures can be mapped without representing the source activities like underwater noise and marine litter.

3.2. Activities - Pressures - Species relationship matrix

Intensity is the combined magnitude, frequency and duration of a pressure (La Rivière *et al.*, 2015). However, in this analysis just the magnitude is taking account and it is assumed that just the location and intensity of the activity can be used to estimate the location and intensity of the pressure. Furthermore, one activity can be the source of multi-pressures and one pressure can be caused by several activities. In order to estimate the theoretical link between activities and pressures which can be suffered by the marine megafauna, a theoretical relation matrix between the activities, pressures and species has been developed with AFB experts of cetaceans and seabirds (Table 9). The risk of exposure is also determined for the pressures directly assessed: ambient noise, impulsive noise and floating macro-waste.

A confidence index for each relationship describes the level of expertise involved in establishing the relationship between the activity and pressure. Interpreting the confidence index will help update the matrix by identifying the relationships with insufficient expertise. For that relationship matrix, the confidence index value was set at 3 because the experts were consulted only one time. The matrix lists all pressures created by human activities and the theoretical exposure risk of each species. It's a qualitative assessment because the value of the exposure risk will be calculated later. Using this list, the descriptive data on activities needed to map each pressure can be identified.

Table 9 - Relationship matrix between activities listed in table 1 and pressures. Relationship 0: no exposure risk, 1: low exposure risk, 2: significant exposure risk, NA: unknown interaction. Confidence index (1): insufficient, (2): low, (3): medium, (4): high, (5): very high, (NA): not assessed

Human activity	Resultant pressure	Globicephalinae	Little delphinae	Common bottlenose dolphin	Harbour porpoise	Fin whale	Little shearwaters	Great grey gulls	Terns	Gulls	Great shearwaters	Alcidae	Great black gulls
Pressure directly assessed	Ambient noise (low frequency ~100 Hz)	NA(NA)	NA(NA)	1(3)	2(3)	2(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Impulsive noise (>180 dB)	2(3)	2(3)	2(3)	2(3)	NA(NA)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Floating macro-waste	2(3)	1(3)	1(3)	1(3)	2(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Fishing: nets	Bycatch	0(3)	1(3)	1(3)	2(3)	0(3)	2(3)	0(3)	0(3)	0(3)	1(3)	2(3)	0(3)
Fishing: Surrounding nets	Bycatch	0(3)	1(3)	1(3)	0(3)	0(3)	2(3)	1(3)	NA(NA)	1(3)	1(3)	1(3)	0(3)
Fishing: pelagic trawls	Bycatch	0(3)	2(3)	1(3)	0(3)	0(3)	1(3)	1(3)	1(3)	1(3)	1(3)	2(3)	1(3)
Fishing : bottom trawls	Bycatch	1(1)	1(1)	1(1)	1(1)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
Fishing : seines	Bycatch	1(1)	1(1)	1(1)	1(1)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
Marine traffic: passenger ships	Collision	1(3)	0(3)	1(3)	0(3)	2(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	1(3)	0(3)	1(3)	0(3)	0(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Marine traffic: cargo ships and tankers	Collision	NA(NA)	0(3)	0(3)	0(3)	2(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	0(3)	0(3)	0(3)	0(3)	0(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Marine traffic: pleasure craft and dive	Collision	1(3)	0(3)	1(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	1(3)	0(3)	1(3)	0(3)	0(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Marine traffic: fishing ships	Collision	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	0(3)	0(3)	0(3)	0(3)	0(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Marine traffic: high speed crafts	Collision	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Marine traffic: specific vessels	Collision	NA(NA)	0(3)	0(3)	0(3)	1(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	0(3)	0(3)	0(3)	0(3)	0(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)
Marine traffic: other ships	Collision	0(3)	0(3)	0(3)	0(3)	1(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
	Disturbance	0(3)	0(3)	0(3)	0(3)	0(3)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)	NA(NA)

As said before, some descriptive data on pressures are already available without needed to use activities data and relation matrix; it is the case for underwater noise and marine litter.

3.3. Single pressure and multi pressure mapping

3.3.1. Single pressure index (SPI)

The location and intensity of each pressure come from the descriptive data on pressures or activities. In this analysis, the influence zone of the pressure and its persistency are not taken account. Like the intensity of activities, the intensity of pressures is integrated into the grid.

In most cases, pressures are generated by several activities on land or at sea. Pressure intensity can therefore be estimated by calculating the sum of the activity - pressure pairings intensities. The methodological challenge of this calculation step is to assess the respective contribution of each activity-pressure pairing to pressure intensity. For example, the navigation of cargo ships and tankers generates a greater collision pressure than the navigation of pleasure crafts. To resolve this methodological issue, a frame of reference needs to be developed to compare the intensity of the pressure generated by one-off events caused by anthropogenic practices on a unit of area. Until additional work is able to be carried out by experts to compensate this lack of knowledge, this project uses the assumption that activities make an identical contribution to the pressure if they generate it. The equation to calculate the intensity of pressure can therefore be written as follows:

$$P_j = \sum_{i=1}^{n_i} \left(\gamma_{A_i P_j}\right) \times A_{i\,norm}$$

Where:

P_j Intensity of pressure j

$\gamma_{A_i P_j}$ Contribution of activity i to pressure j.

Determined from the relationship matrix

- If activity i generates the pressure j : $\gamma_{A_i P_j} = 1$
- If activity i does not generates the pressure j : $\gamma_{A_i P_j} = 0$

$A_{i\,norm}$ Intensity of activity i, normalized between 0 and 1

According to the number of activities which generate each pressure, the intensities of each pressure can be in different ranges of value. For example, a pressure generated by 5 activities has intensity value between 0 and 5 whereas a pressure generated by only one activity has intensity value between 0 and 1. To correct this bias, the intensity pressure Pj is normalized to always have a value between 0 and 1. This value corresponds to the single pressure index.

$$SPI = f_{norm}(P_j)$$

Where:

SPI Index of single pressure j

P_j Intensity of pressure j

f_{norm} Log transformation and normalizing function to obtain value in [0-1]

3.3.2. Concomitant pressures index (CPI)

Two indicators are calculated from the pressures data for mapping the concomitant pressures:

- **Index of multi-pressures presence** (CPI_option1) corresponds to the number of pressures present in each cell over a defined period. The periods defined in SIMWESTMED project are the winter and the summer. The diversity of datasets not allows focusing on one specific year but only recent years (>2009) are considered;

$$CPI_{option\ 1} = \sum_{j=1}^{n_j} P_j$$

Where: P_j Presence/absence of the pressure j [0/1]

n_j Number of pressures types

- **Index of multi-pressures intensity** (CPI_option2) corresponds to the cumulative intensities of each pressure in each cell. For this approach, the intensity data for each pressure is normalized between 0 and 1 using a log transformation. To avoid the fact that the sum of these intensities (CPI_option2) could be found in different value ranges, depending on the number of pressures present, the result is also normalized between 0 and 1.

$$CPI_{option2} = f_{norm}\left(\sum_{j=1}^{n_j} f_{norm}(P_j)\right)$$

Where: P_j Intensity of the pressure j

n_j Number of pressures types

f_{norm} Log transformation and normalizing function to obtain value in [0-1]

3.4. Risk of exposure mapping

3.4.1. Exposure risk to a single pressure (REX)

The first step in calculating the exposure risk to concomitant pressures involves assessing the exposure risk of a species to each pressure. Exposure risk of one species of cetaceans or seabirds to a single pressure is calculated from normalized intensities of pressures and normalized density of the species studied.

$$REX_{Pj} = E_{norm} \times P_{j\ norm}$$

Where: $P_{j\ norm}$ Normalized intensity of pressure j

E_{norm} Normalized intensity of the species studied

3.4.2. Exposure risk to concomitant pressures (REXC)

The next step to obtain the exposure risk of the species to concomitant pressures is to sum the exposure risks to each pressure. This index is also normalized between 0 and 1.

$$REXC = f_{norm}\left(\sum_{j=1}^{n_j} REX_{Pj}\right)$$

Where: REX_{Pj} Normalized exposure risk to pressure j

f_{norm} Log transformation and normalizing function to obtain value in [0-1]

3.5. Assessment of the results quality

The quality of data sets used in this methodology is variable and qualified thanks to a quality index attributed to each data set. Furthermore, the assessment of the exposure risk is based on approximations and theoretical working assumptions. These drawbacks are an integral part of this type of analysis and should not be avoided, especially if we wish to better identify the data whose quality is a problem and / or the working assumptions that must be redefined. The evaluation of the quality of the results will provide an estimation of the confidence that can be placed in the results and will guide the work needed to advance the overall quality of the analysis and will support requirements for data acquisition and/or additional scientific expertise.

Calculating confidence index (CI) of the exposure risk to concomitant pressures takes into account the data quality, the CI attributed to each pressure-species pairings and the predominance of activities in each cell. For example, the calculation will give more importance to the quality index of the activity predominant in one cell. The different steps and indexes calculated in this analysis to assess the quality of the results are presented in this part.

3.5.1. Step 1 : calculation of confidence index for each pressure ICpj

For each cell, each pressure *Pj* will be associated to two indexes between 0 and 1:

- **Confidence index of the theoretical relations activities-pressures-species associated to Pj (ICRT_AP_Pj)**

  It is based on the confidence indexes of the links activities-pressures-species (IndConf_$g_{j,i}$) which were weighted by the intensity of the different activities (Ai). For example, if only one activity is present in the cell, this index will only depend of the confidence index of the links between this activity and the pressure Pj. If no activity is present in the cell, the index will have the maximum value. In fact, if the activities are not present, the links activities-pressures will not have incidence on the final result.

$$ICRT\_AP\_P_j = \begin{cases} \dfrac{\sum\left(A_i \times IndConf_{\gamma\, j,i}\right)}{5 \times \sum A_i} \; if \sum(A_i) \neq 0 \\ 1 \; if \sum(A_i) = 0 \end{cases}$$

- **Quality index of the activity data associated to Pj (ICQ_AP_Pj)**

  It is based on the quality indexes of the activities data (IQ_{Ai}) which were weighted by the links between the activities Ai and the pressure Pj ($g_{Ai/Pj}$). If the pressure depends on only one activity, then the index will only depends on the $IndConf_{Ai}$ value. If the pressure does not depend on any activities used in the demonstrator, then the activities data will not have an incidence on the final result ; the index value is 1 (maximal value) in this case.

$$ICQ\_AP\_P_j = \begin{cases} \dfrac{\sum\left(IQ_{Ai} \times \gamma_{Ai/Pj}\right)}{\sum\left(\gamma_{Ai/Pj}\right)} \; if \sum\left(\gamma_{Ai/Pj}\right) \neq 0 \\ 1 \; if \sum\left(\gamma_{Ai/Pj}\right) = 0 \end{cases}$$

From these two indexes, a confidence index for the pressure Pj (IC_{pj}) can be calculated:

$$IC_{Pj} = ICQ\_AP\_P_j \times ICRT\_AP\_P_j$$

3.5.2. Step 2 : Calculation of confidence index of the exposure risk to each pressure IC_REX_Pk

The CI in the pressure Pj (ICpj) and the quality index of the species data (IQ_E) will be used to calculate the CI of the exposure risk to each pressure Pj (IC_REX_Pj). Three cases can be distinguished:

- If the density of the species in the cell is equal to zero (E = 0) but not the intensity of the pressure j (Pj ≠ 0), then the exposure risk is null. In that case, it considered that the confidence index of the exposure risk to the pressure j (IC_REX_Pj) only depends on the quality index of the species data (IQE);
- Conversely if the intensity of the pressure j in the cell is equal to zero (Pj = 0) but not the density of the species (E ≠ 0), then the exposure risk is null. In that case, it considered that IC_REX_Pj only depends on the confidence index in the pressure Pj (ICpj);

- Finally, in the other two cases (either the density and the pressure are equal to zero or they are different from zero) the value of the exposure risk depend both on E and Pj. In that case, it considered that IC_REX_Pj depends on IQ_E and ICpj.

$$IC\_REX\_P_j = \begin{cases} IQ_E \ \ if \begin{cases} E = 0 \\ P_j \neq 0 \end{cases} \\ IC_{Pj} \ \ if \begin{cases} E \neq 0 \\ P_j = 0 \end{cases} \\ IQ_E \times IC_{Pj} \ \ if \begin{cases} E \neq 0 \\ P_j \neq 0 \end{cases} or \begin{cases} E = 0 \\ P_j = 0 \end{cases} \end{cases}$$

3.5.3. Step 3: calculation of confidence index of the exposure risk to concomitant pressures ICrexc

The CI of the exposure risk to concomitant pressures (ICrexc) is calculated from the confidence indexes of the exposure risk to each pressure (IC_REX_Pj). This index expresses the confidence that can be afforded to the exposure risk in the cell considered. Here there are also two cases to consider:

- If the sum of REXCpj is equal to zero, then the exposure risk to concomitant pressure of the cell is equal to zero and ICrexc depends on all IC_REX_Pj in the same way and will be calculated as an average of REXCpj;
- If REXCpj is positive, a greater importance will be done to the IC_REX_Pj of the most important REXCpj in the calculation of ICrexc. Thus an average of the IC_REX_Pj weighted by the REXCpj value will be calculated.

$$IC_{REXC} = \begin{cases} \dfrac{\sum\left(REXC_{Pj} \times \ IC\_REX\_P_j\right)}{\sum\left(\ REXC_{Pj}\right)} \ if \sum\left(\ REXC_{Pj}\right) \ \neq 0 \\ avg\left(\ IC\_REXC\_P_j\right) if \sum\left(\ REXC_{Pj}\right) = 0 \end{cases}$$

RESULTS

To illustrate the case study, simulations of exposure risk for one cetacean and one group of seabirds are presented in this report. The other simulations are listed in the Annex VI and stored in the document "Maps collection" (without maps comment).

The first simulation is based on French data and compares summer and winter exposure risk to concomitant pressures of common bottlenose dolphin.

The second simulation concerns little shearwaters in summer, using a mix of Spanish and French data. (Table 10). These species were chosen due to their high number of individuals (in comparison with the other marine megafauna data) and the overlay with anthropogenic activities and pressures. For this analysis, fishing data were used to calculate pressures of collision and visual disturbance in place of AIS data of fishing boats, which can be incomplete as the AIS device is not mandatory for all fishing boats. Moreover, impulsive underwater noise and floating macro-waste were not used as pressures due to lack of data in Spanish waters.

Table 10 - Source of datasets used for the both simulations. (Sim. = simulation, FRA = French data, SPA= Spanish data, Mixed = mixed Spanish and French data)

Theme	Data type	Data	Sim. n°1	Sim. n°2
Activity	Fishing	Nets	FRA	Mixed
		Surrounding nets	FRA	Mixed
		Pelagic trawling	FRA	FRA
		Bottom trawl	FRA	Mixed
		Seines	FRA	FRA
	Marine traffic	Passenger	FRA	SPA
		Cargo	FRA	SPA
		Tanker	FRA	SPA
		High Speed Craft	FRA	SPA
		Fishing, pleasure craft, dive and specific (military ops and dredger)	-	SPA
		Pleasure craft and dive	FRA	-
		Fishing	-	-
		Specific (military ops and dredger)	FRA	-
		Specific (law enforce, special craft, medical trans, anti-pollution, tug, search and rescue, port tender, pilot vessel, local vessel)	FRA	SPA
		Other	FRA	SPA
Pressure	Underwater noise	Continuous (125 hertz)	FRA	SPA
		Impulsive	FRA	not available
	Marine litter	Floating macro-waste	FRA	not available
Ecological component	Cetacean	Common bottlenose dolphin	FRA	FRA
	Seabirds	Little shearwaters	FRA	FRA

See Annex II for more details on fishing categories.

1. Simulation n°1: Summer winter comparison with French data

1.1. Activities - Pressures - Species relationship matrix

Activities and pressures taken into account in this analysis were selected with regards to their effect on the species considered, thanks to expert judgment (Table 11). Then, the activities and pressures considered impacting common bottlenose dolphin are fishing and marine traffic, bycatch, visual disturbance, continuous and impulsive underwater noise and floating macro-waste.

Table 11 - Activity-Pressure relationship matrix for common bottlenose dolphin

Activity	Activity type	Pressure	Common bottlenose dolphin
Fishing	Nets	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	not sensitive
	Surrounding nets	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	not sensitive
	Pelagic trawls	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	not sensitive
	Bottom trawls	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	not sensitive
	Seines	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	not sensitive
Marine traffic	Passenger	Collision	sensitive
		Visual disturbance	sensitive
	Cargo	Collision	not sensitive
		Visual disturbance	not sensitive
	Tanker	Collision	not sensitive
		Visual disturbance	not sensitive
	High Speed Craft	Collision	unknown
		Visual disturbance	unknown
	Pleasure craft and dive	Collision	sensitive
		Visual disturbance	sensitive
	Specific (military ops and dredger)	Collision	not sensitive
		Visual disturbance	not sensitive
	Specific (law enforce, special craft, medical trans, anti-pollution, tug, search and rescue, port tender, pilot vessel, local vessel)	Collision	not sensitive
		Visual disturbance	not sensitive
	Other	Collision	not sensitive
		Visual disturbance	not sensitive
-	-	Continuous underwater noise	sensitive
		Impulsive underwater noise	sensitive
		Floating macro-waste	sensitive

1.2. Species habitat model

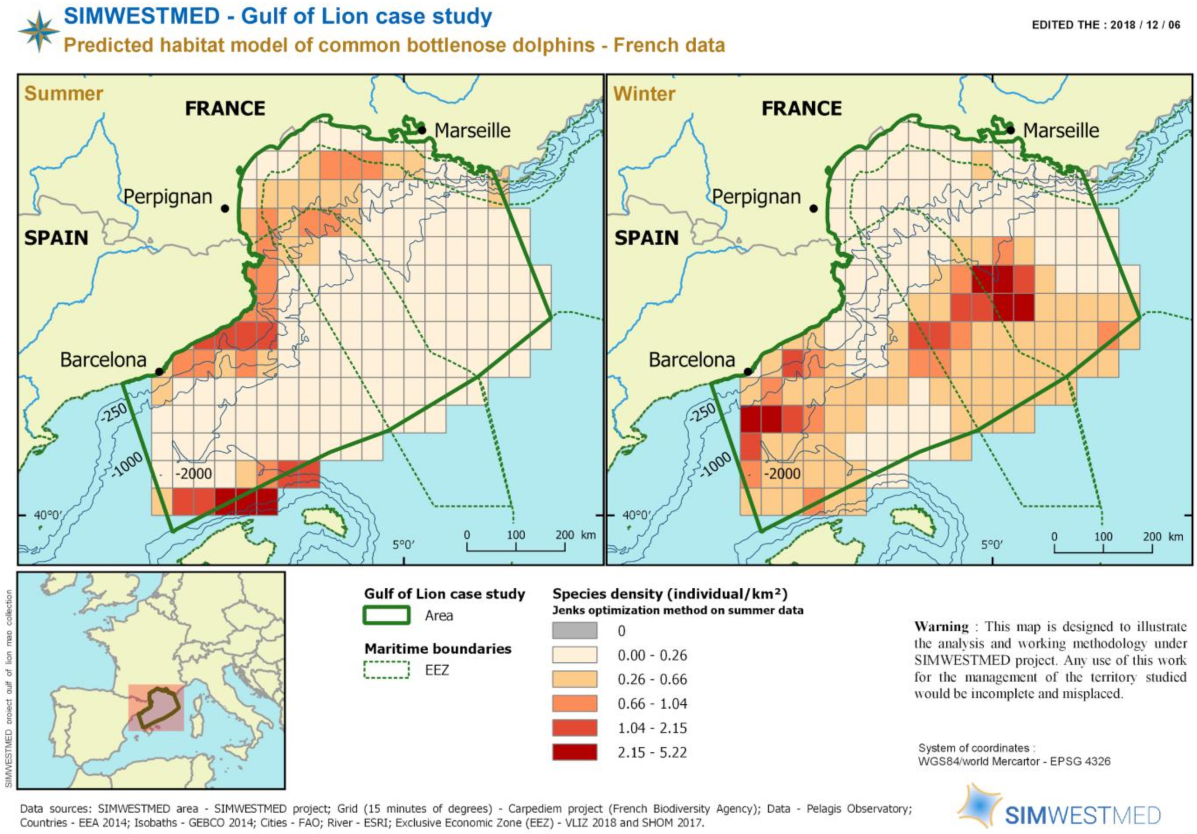

Figure 10 - Predicted habitat model of common bottlenose dolphin

In summer, Common bottlenose dolphin is more frequently observed along the coast on the continental shelf, with a slightly higher abundance along the Spanish coasts and on the northern part of Balearic Islands. In winter, this species is more frequently observed along the Spanish coast and on the French banks, with a minimal depth of -1000 meters. (Figure 10)

As data came from a unique aerial survey campaign realized in 2011-2012, the assessment has to be interpreted with caution.

1.3. Human activities: multi-activities mapping

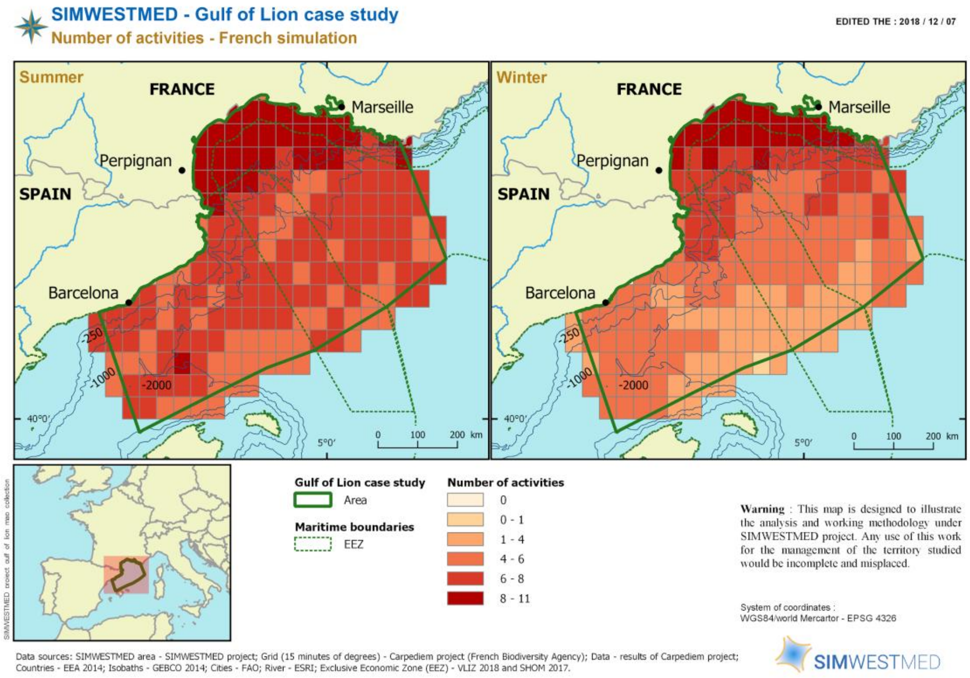

Figure 11 - Number of activities for French simulation

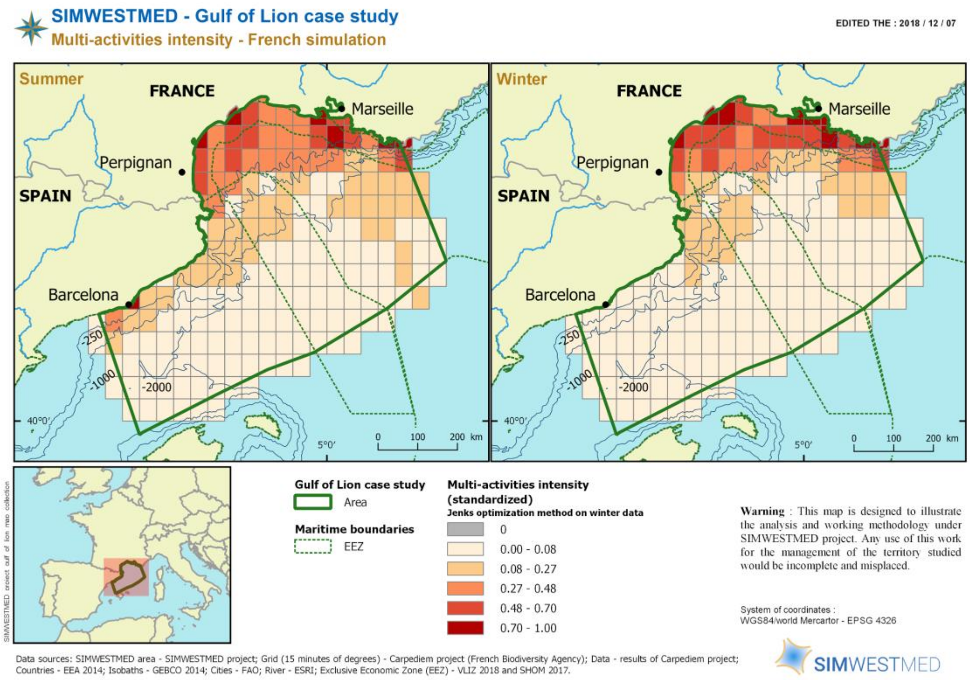

Figure 12 - Multi-activities intensity for French simulation

In this analysis, the activities considered are fishing and navigation. For both seasons, there are more activities (Figure 11) and a higher multi-activities intensity index (Figure 12) on the French coast than the Spanish coast. It is explain by the data source: only French fishing boats and navigation data received by French AIS stations were taken into account.

There are overall more activities during summer. For the both season, the cumulative activities intensity is concentrated on the continental shelf.

1.4. Multi-pressures maps: concomitant pressures index (CPI)

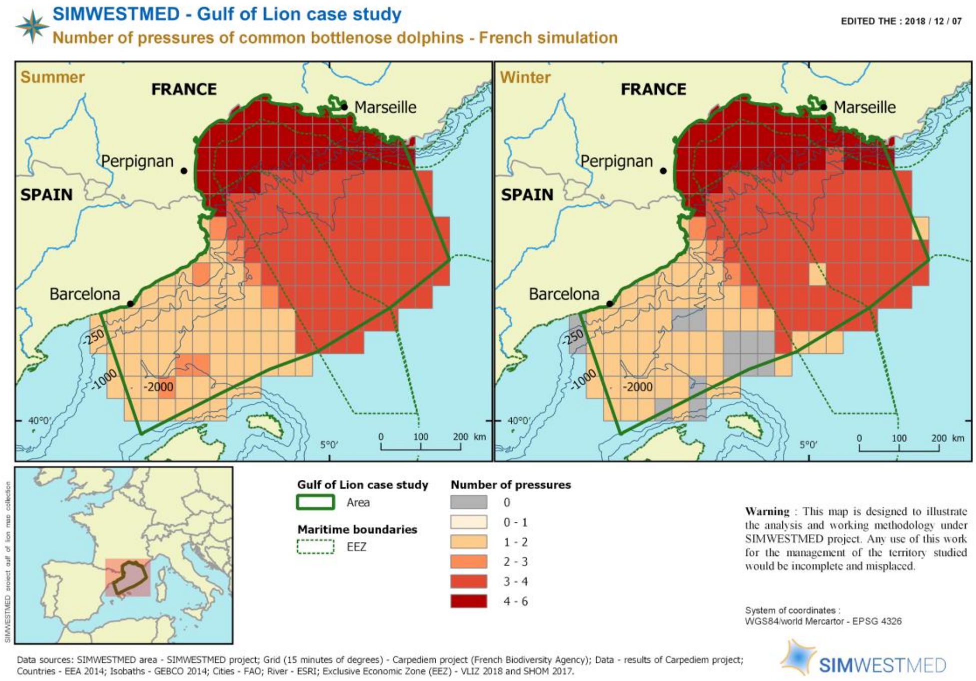

Figure 13 - Number of pressures which can interact with common bottlenose dolphin for French simulation

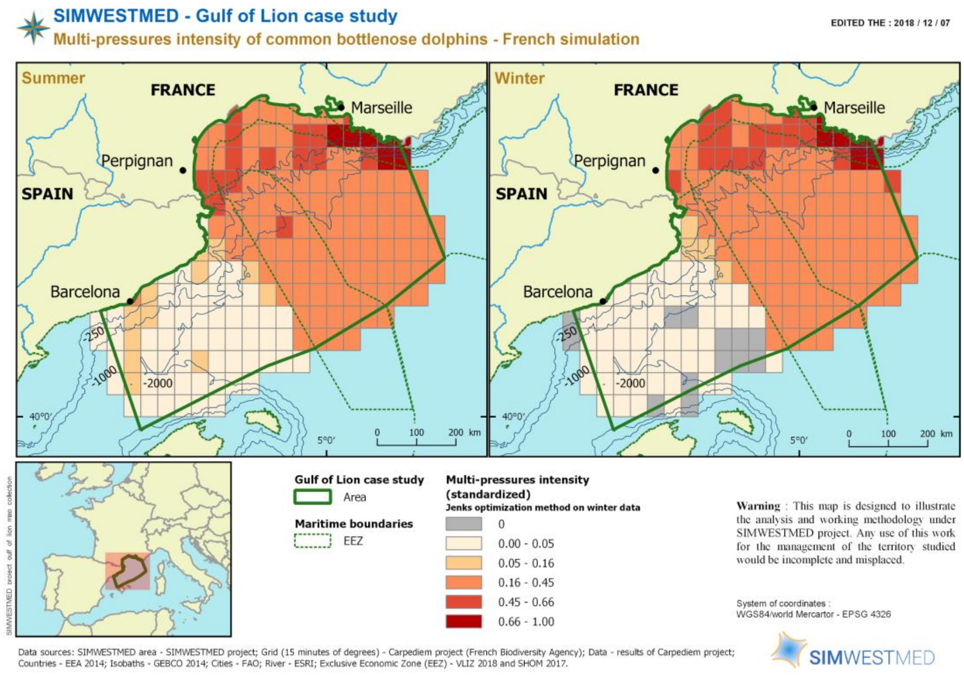

Figure 14 - Intensity of multi-pressures which can interact with common bottlenose dolphin for French simulation

Pressures are only observed on the French side due to lack of input data on the Spanish side.

For both seasons, all the pressures occur on the continental shelf and extend up to the bank except for bycatch and impulsive underwater noise which mainly occur along the coast (Figure 13). The cumulative pressures intensity is high and concentrated on the continental shelf with peaks in the east of Marseille (Figure 14).

1.5. Risk of exposure maps

1.5.1. Exposure risk to a single pressure

It should be noted that marine litter, continuous and impulsive underwater noises data are available only on the French side of the case study.

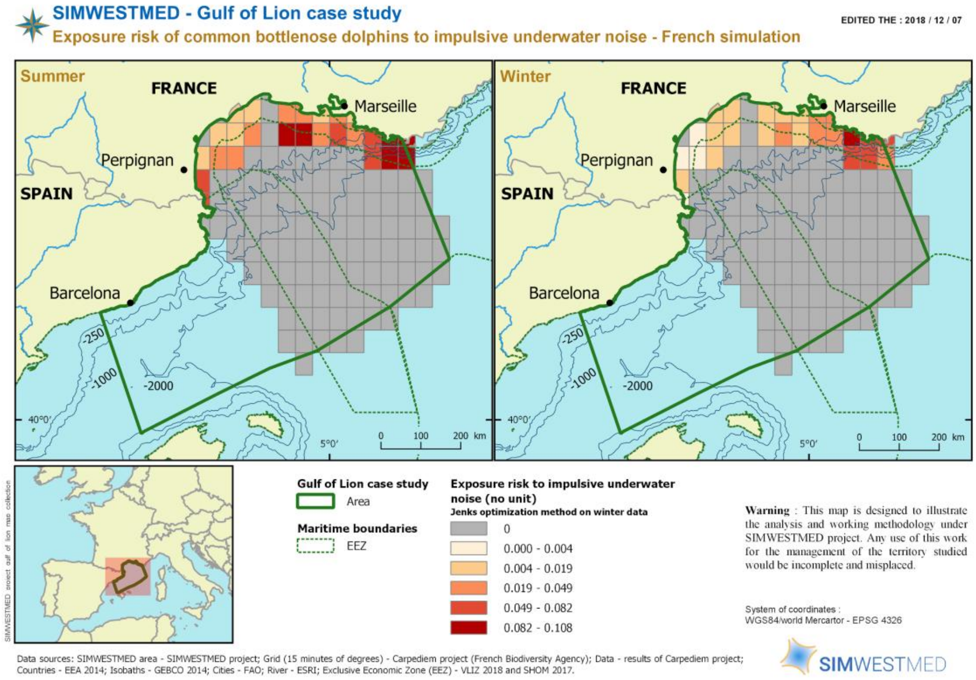

Figure 15 - Exposure risk of common bottlenose dolphin to impulsive underwater noise for French simulation

The impulsive underwater noise is concentrated along the coast. The exposure risk to impulsive underwater noise is overall low (maximal value: 0.1) but higher in summer than winter (Figure 15). Few dolphins are concerned by this pressure.

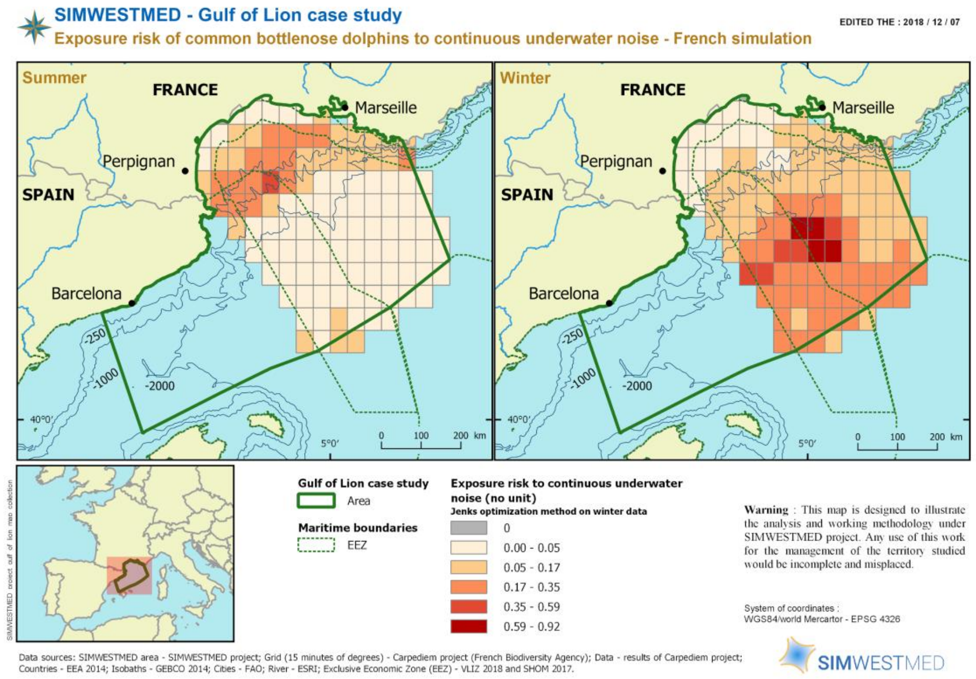

Figure 16 - Exposure risk of common bottlenose dolphin to continuous underwater noise for French simulation

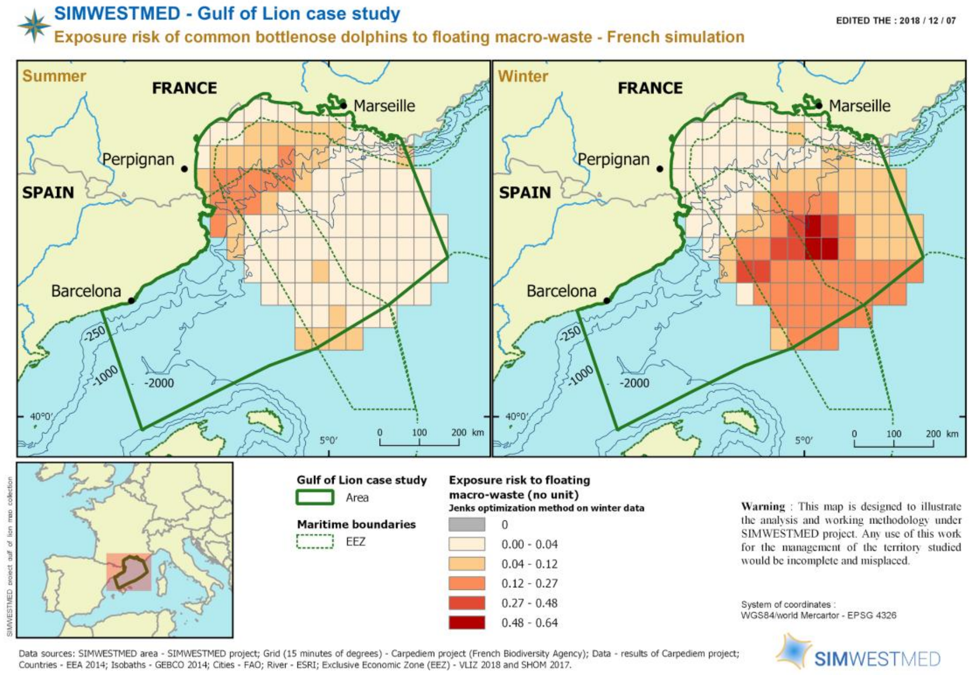

Figure 17 - Exposure risk of common bottlenose dolphin to floating macro-waste for French simulation

The exposure risk to marine litter and continuous underwater noise is higher along the coast in summer and on the bank in winter, where the anthropogenic pressures overlap most with the habitat of this species of dolphin (Figure 16 and Figure 17).

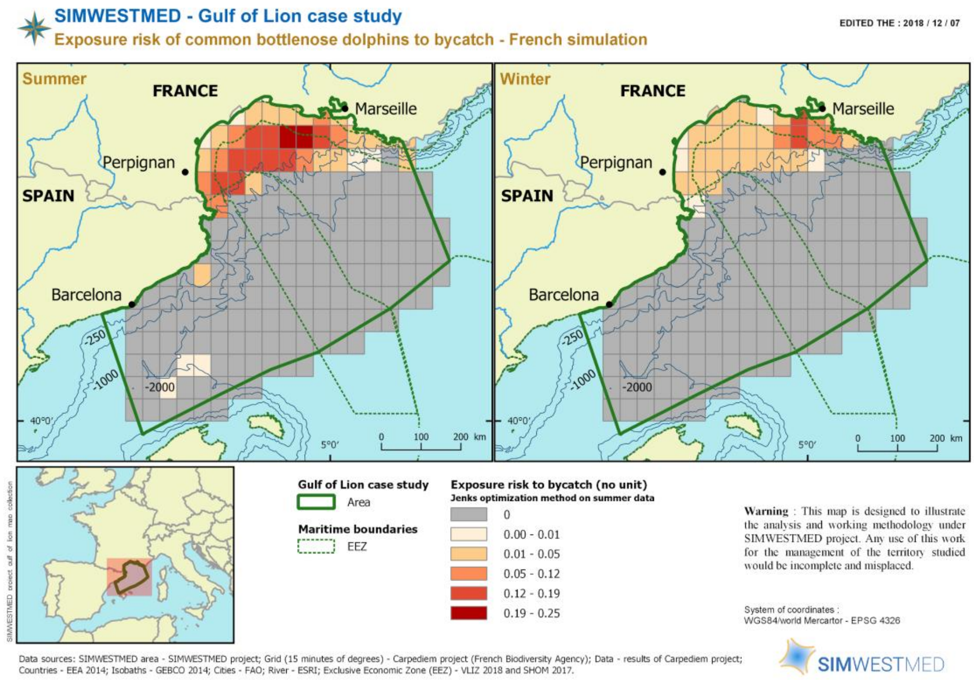

Figure 18 - Exposure risk of common bottlenose dolphin to bycatch for French simulation

Bycatch is calculated from French fishing activities selected under the project. The exposure risk to bycatch is concentrated along the French coast and higher in summer than winter (Figure 18).

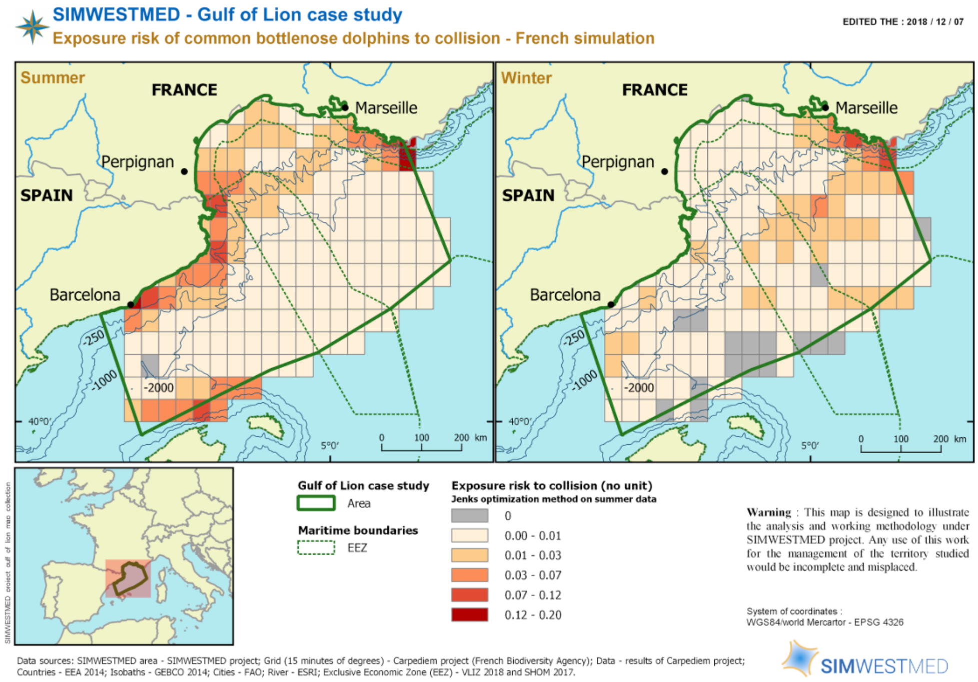

Figure 19 - Exposure risk of common bottlenose dolphin to collision for French simulation

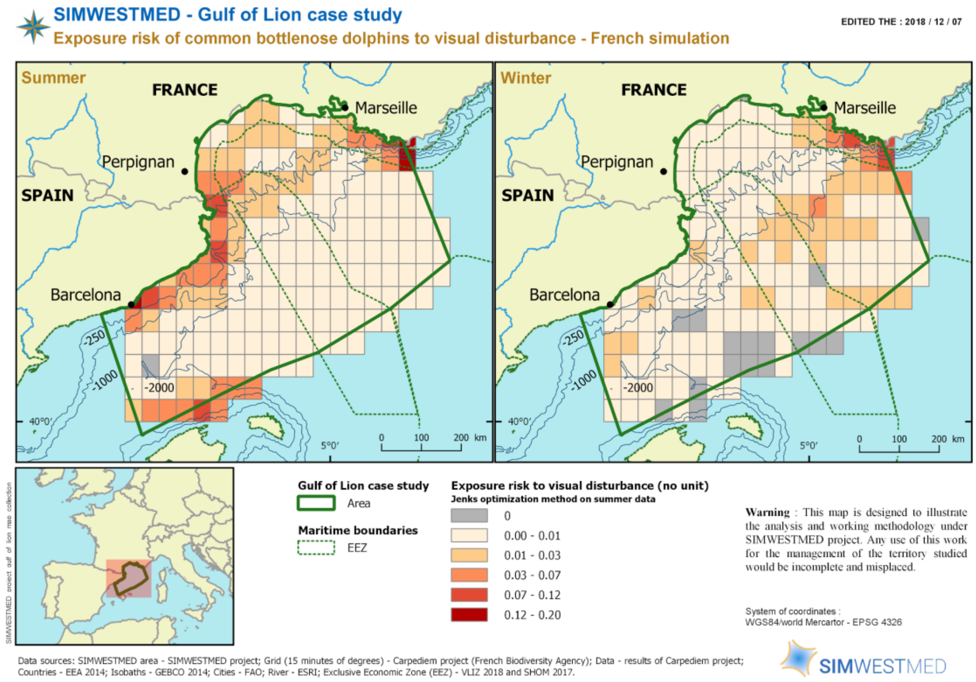

Figure 20 - Exposure risk of common bottlenose dolphin to visual disturbance for French simulation

Collision and visual disturbance pressures are calculated from marine traffic data. The common bottlenose dolphin is sensitive to pleasure craft, dive and passenger navigation for both pressures (that is why the maps are the same). The exposure risk to both pressures is overall low (maximal value: 0.2) (Figure 19 and Figure 20).It is higher along the coast, with peaks on the Spanish coast, north of the Balearic islands and the east of Marseille in summer; and only one peak the east of Marseille in winter. The peaks in the Spanish side are explained by the high abundance of dolphins and the peak on the French side is explained by a high pressure of navigation.

1.5.2. Exposure risk to concomitant pressures (REXC)

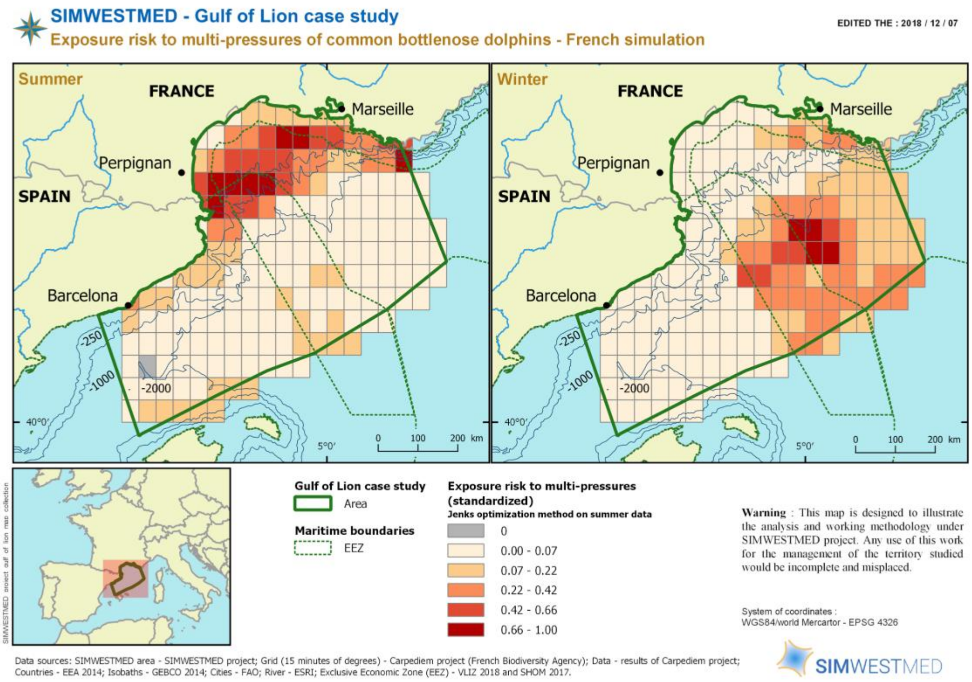

Figure 21 - Exposure risk of common bottlenose dolphin to multi-pressures for French simulation

The exposure risk to multi-pressures is only observed on the French side due to lack of input data of activities and pressures on the Spanish side (Figure 21). That is why the intensity is low along the Spanish coast despite the abundance of dolphins. In the French side, the exposure risk is higher along the coast during summer and on the bank during the winter. The summer peak is explained by a high multi-pressures intensity and a moderate abundance of dolphins. The winter peak is explained by a high abundance of dolphins despite a low multi-pressures intensity.

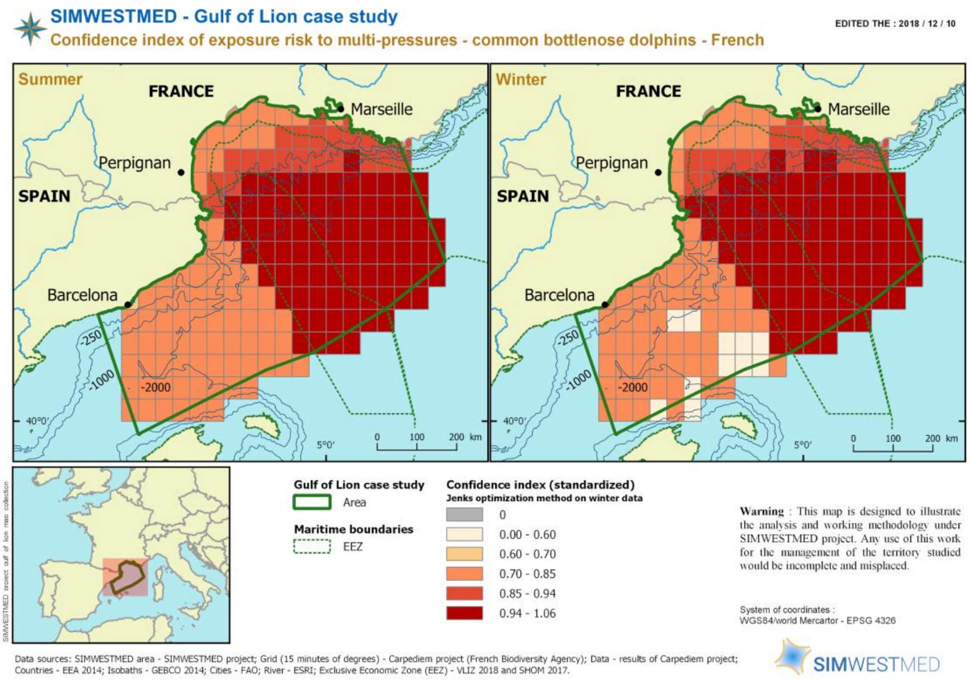

Figure 22 - CI of exposure risk to multi-pressures of common bottlenose dolphin for French simulation

The confidence index is overall high on the whole area (minimum of 80 percent) for both seasons (Figure 22).The lower index on the coast is explained by the confidence index of the input data: the majority of the input data is concentrated on the coast and has a lower index than the input data on the bank.

2. Simulation n°2: Mixed Spanish and French data

2.1. Activities - Pressures - Species relationship matrix

Activities and pressures taken into account in this analysis where selected with regards to their effect on the species considered, thanks to expert judgment. Then, the activities and pressures considered impacting little shearwaters in summer are fishing and so bycatch (Table 12).

Table 12 - Activity-Pressure matrix of little shearwater

Activity	Activity type	Pressure	Little Shearwater
Fishing	Nets	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	unknown
	Surrounding nets	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	unknown
	Pelagic trawls	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	unknown
	Bottom trawls	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	unknown
	Seines	Bycatch	sensitive
		Collision	not sensitive
		Visual disturbance	unknown
Marine traffic	Passenger	Collision	not sensitive
		Visual disturbance	unknown
	Cargo	Collision	not sensitive
		Visual disturbance	unknown
	Tanker	Collision	not sensitive
		Visual disturbance	unknown
	High Speed Craft	Collision	not sensitive
		Visual disturbance	unknown
	Fishing, pleasure craft, dive and specific (military ops and dredger)	Collision	not sensitive
		Visual disturbance	unknown
	Specific (law enforce, special craft, medical trans, anti-pollution, tug, search and rescue, port tender, pilot vessel, local vessel)	Collision	not sensitive
		Visual disturbance	unknown
	Other	Collision	not sensitive
		Visual disturbance	unknown
-	-	Continuous underwater noise	not sensitive

2.2. Species model habitat

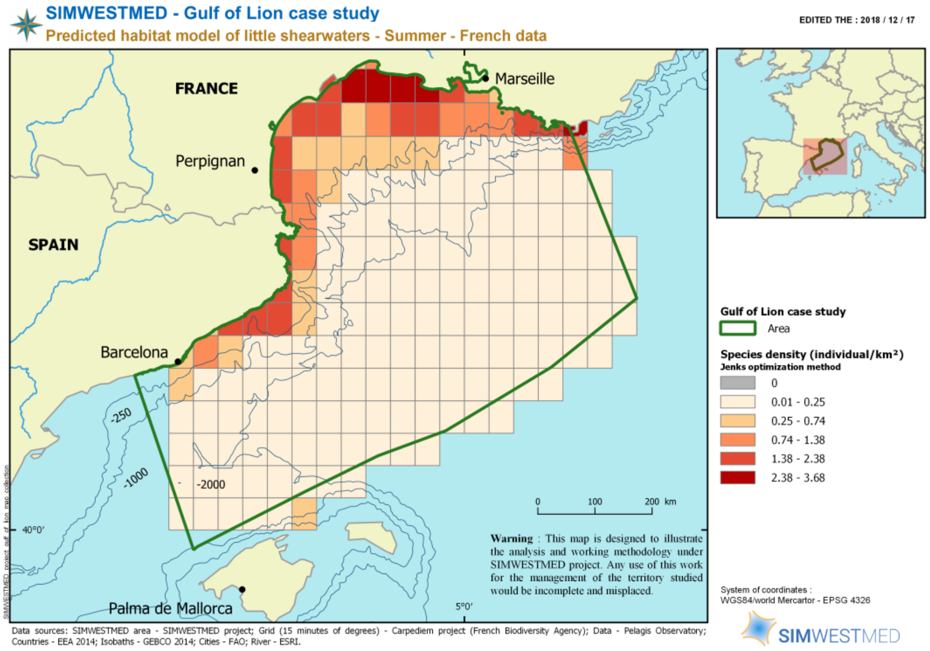

Figure 23 - Predicted habitat model of little shearwater in summer

Little shearwaters are more frequently observed along the coast on the continental shelf, with a slightly higher abundance along the French coasts (Figure 23). As data came from a unique aerial survey campaign realized in 2011-2012, the assessment has to be interpreted with caution.

2.3. Human activities and pressures

2.3.1. Multi-activities mapping

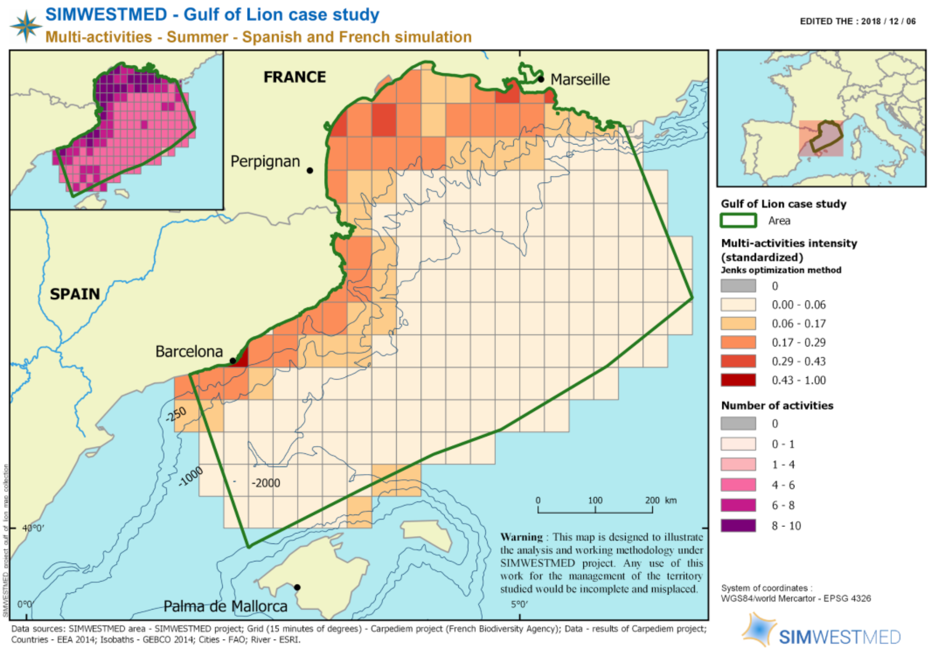

Figure 24 - Multi-activities of little shearwater for Spanish and French simulation

The multi-activities map illustrates the fishing (using mixed French and Spanish sources) and marine traffic data (using Spanish sources). The activities are concentrated on the continental shelf (Figure 24). As the fishing effort is underestimated (due to lack of data), the assessment has to be interpreted with caution.

2.3.2. Concomitant pressures index (CPI)

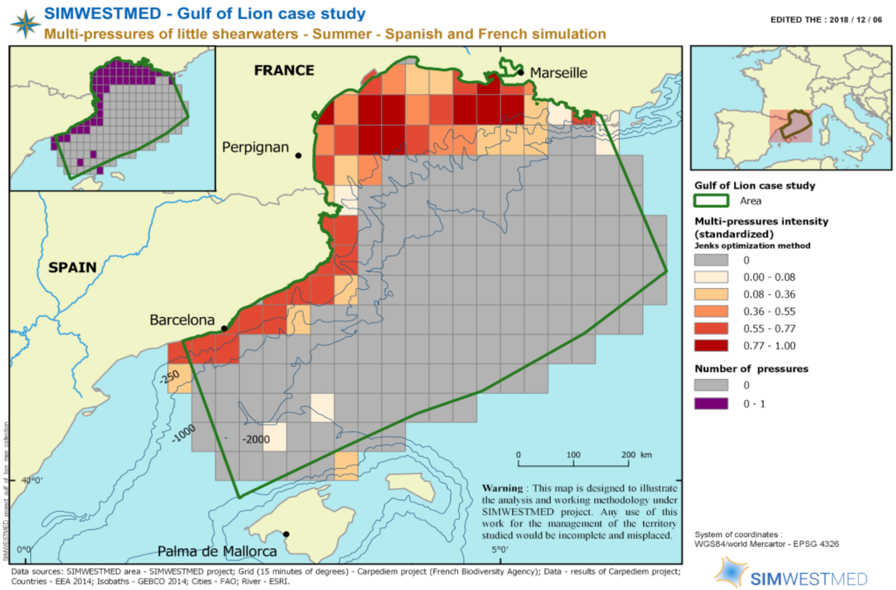

Figure 25 - Multi-pressures of little shearwater for Spanish and French simulation

According to Activities-Pressures relationship matrix of little shearwaters, this group of species is sensitive to bycatch. Bycatch is mainly occurs along the coast. Its intensity is high and concentrated on the continental shelf (Figure 25). Some peaks are observed in the French coats.

2.4. Risk of exposure maps: exposure risk to concomitant pressures (REXC)

For seabirds' simulations with Spanish and French mixed data, the map of the exposure risk to one pressure is the same as one of the exposure risk to multi-pressures, due to the initial number of pressures considered: only bycatch. Thus, only the last map will be explained.

The exposure risk to bycatch is higher along the coast, with peaks on the French coast, where the anthropogenic pressures overlap most with little shearwaters habitats (Figure 26).The confidence index is higher on the continental shelf than the bank because the majority of activities data are on the coast.

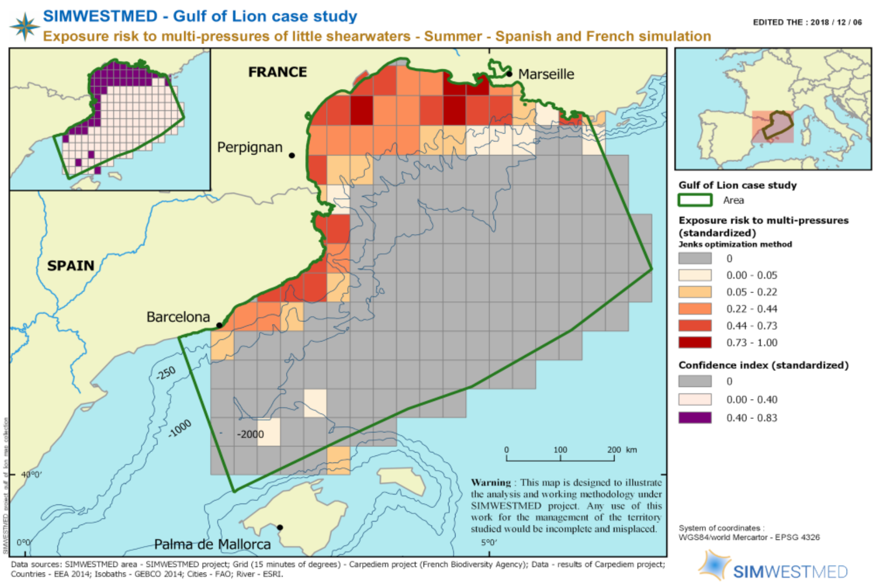

Figure 26 - Exposure risk of little shearwater to multi-pressures for Spanish and French simulation

DISCUSSION

1. Lessons from this cross-border exercise

a) The networking between partners from the two countries involved in the project is an important and needed first step for a better assessment of transboundary stakes and issues. Discussion addressed many topics in order to lay the foundations for a mutual understanding. These discussions began in February 2018 during the Task group interactions meeting in Marseille (Gimard *et al*., 2018). The discussions continued later in 2018 and focused on the following topics:

- The perception of marine ecosystem management and spatial planning issues on both sides of the border;
- Analysis methods and technical questions (data, tools, spatial and temporal resolution, uncertainties, validation of results, transparency ...);
- The possible use of these approaches and their results in the framework of the marine spatial planning: how to present and explain the results, in which instances to bring them to the discussion;
- Data sharing and aspects related to confidentiality.

The work carried out in 2018 laid the foundations for a relationship between the project partners. The constitution of this network, still fragile, is a necessary first step if one wishes to develop coherent planning and management approaches on both sides of the maritime borders. The work presented in this report ultimately illustrates the advances that have been made together.

After the end of the project, **this network should be supported, politically and technically, to continue to work and to progress on raised issues**. Mutual understanding and the development of shared and accepted methods must be considered in the framework of a partnership that goes beyond the end of the SIMWESTMED project. The MSP Platform is progressively taking up the topic to build and create this network at a European level. This initiative is really coherent with the lessons learned from this exercise, and a declination of it, at the state level and technically oriented, should be relevant too.

b) A very important part of the work concerned the development of a coherent and operational dataset to implement and illustrate the method. The Spanish and French partners tried to mobilize and prepare the datasets to form one interoperable between the two countries. This fairly original exercise is particularly important for developing a shared and transparent understanding of transboundary planning issues, very relevant regarding the marine world. Datasets presented in this report illustrate this work. Many constraints and limitations were encountered and required an adaptation of the desired ambition for the results. The main technical difficulties in building a coherent cross-border dataset are:

- Data sources may not contain 100% raw data, jeopardising the possibility to manipulate the data as wished (i.e. the possibility to produce comparable datasets);
- The methods are sometimes different to produce the datasets;
- The units and parameters are sometimes different;
- Not all datasets are available over common time periods and geographical areas,
- Some datasets do not accurately describe human activities and pressures and ecological component;
- The right of access (confidentiality) to certain data and sharing with international partners is not sufficient/ granted.

Some of these difficulties can be faced with methodological development, but they imply limits in the interpretation done with the results. However, some difficulties cannot be solved at the project partners' level (among others, accessibility).

c) The consideration of mobile stakes in Cumulative Effect Assessment is not as well developed as for the habitats. This approach, new for the partners, has led to very interesting developments in the methodologies, and improved the knowledges of issues to take into account in the processes:

- Starting the reflexion on an exposure matrix for marine mammals and birds, improving the knowledge about interactions of these ecological compartments with activities.
- Integrate temporal variations for ecological stakes
- Gathering of new pressures evaluation, and methodological development associated (underwater noise, floating macro-wastes).

This work can be easily linked to current works in progress and will need to be maintained, considering improvements identifies in this project but not solvable in its duration. The development of a global assessment of concomitant effects, very relevant for MSP, is still in development and will need time and lots of efforts to be reach a permissible level of confidence.

2. Contribution for maritime spatial planning

The implementation of the MSP and MSFD policies faces many challenges in the analysis, cross-checking and synthesis of descriptive data of the marine system. This context should favour the development of multi-purposes tools and cross-cutting approaches. Mapping the risk of interaction between ecosystem component and human activities, including temporal aspects, is an objective to address the entire complexity of the marine system, both human and ecological. As such, this objective is inclusive to advance analytical approaches that truly integrate the human activities planning issues and the challenges of achieving and / or maintaining good ecological status. At the European level, recent studies argue in this sense the need to develop cross border and multi-objectives tools to meet these challenges (Depellegrin *et al*., 2017; Fernandes *et al.*, 2017). These studies and this report argue that the implementation of these marine policies, including the general question of "cumulative pressures assessment" need to be addressed in a holistic manner with multi-objectives tools.

In the current state and despite the many imperfections, the methods and tools developed within the framework of the project make it possible to produce synthetic seasonal maps covering both sides of the maritime boundary. These maps relate to human activities and major pressures potentially interacting with marine mammal and seabird communities. These results could be greatly improved, while they could serve as a basis of shared knowledge and discussion for decision makers in order to develop a coherent marine spatial planning on both sides of the border. This taking into account conservation issues of our common natural heritage as well as economic, social and temporal aspects of the activities occurring in "shared" marine spaces.

In addition, this "common, transboundary work approach" favours discussions and exchanges on (and/or sharing of) data, methods and tools. It may lead to the identification of data produced by scientific/ technical groups in other countries and therefore enhance data sharing.

It still remains many questions and challenges for integrating such approaches into the MSP process. There are many data and methodological challenges to be addressed to improve these analytical approaches for MSP. From this case study point of view of a cross-boundary approach, the development of common methods and dataset is fundamental. This can be considered as an opportunity to make teams of both countries working together with the concrete operational objective to develop interoperable datasets and common methods and tools that can contribute to MSFD and MSP issues. However, this objective points at the need for an effective coordination (vision, aligned perspectives…) between the national administrations in charge of the MSP implementation, as well as a clear mandate for the scientific and technical organisms involved in the generation / provision of appropriate data and methods.

This cross-boundary approach should be truly integrated into the MSP process and not only on short projects. It could be interesting to integrate the MSP end-users of these analyses very early and to involve them in the development of methods and analysis choices. Appropriate communication on these methods and results in the context of the MSP should also help to better explain and value this kind of approach.

CONCLUSION

In the European Union, Marine Spatial Planning (MSP), as defined by the EU Directive (2014/89/UE), is “a tool that enables stakeholders to apply coordinated, integrated and transboundary approaches. MSP seeks to balance demands for development with the need to protect the environment, achieving social, environmental and economic objectives, in an open and planned approach”. By allocating space to maritime sectors and setting up clear rules for those activities, MSP aims at addressing both economic and environmental issues linked with the blue growth.

MSP, as a process, must be based on a strong and shared knowledge of planned areas. Distribution of each activity and its future spatial needs has to be evaluated as well as the location of species and habitats, associated with a good comprehension of ecosystems functionalities. Moreover, the understanding of how human and ecological components of the system interact is crucial. This concerns both interaction between various maritime uses (conflict or synergies) and between uses and environment (pressures and impacts).

The case study focused on the question of mapping the risk of interactions between a set of human activities and multi pressures and some populations or groups of species of marine mammals and seabirds. The main objective was to explore methods and tools for producing synthetic cartographic information based on scientific/ technical data as well as on repeatable analytical approaches. The ultimate goal is to produce diagnosis useful to managers and decision-makers involved in MSP.

The maps displayed in this report and the map collection associated are good illustrations of transboundary issues for conservation of marine biodiversity, particularly in the context of MSP. For example, the distribution map of common bottlenose dolphins and little shearwater, in summer or winter, shows the need to develop a coherent and coordinated management approach on both sides of the maritime frontiers. In the same way, the example maps showing the multi-activities index, multi-pressures index and risk of exposure shows that the pressures on these species are distributed on both sides of the border and that it is necessary to develop a coordinated management of these activities. These maps also show significant challenges in building common interoperable datasets that are necessary to have a comprehensive and shared view of the issues. All of these issues are well known in the context of implementation of MSFD and MSP.

This experimentation could serve as a basis for developing cumulative effect assessment methods which could help implement MSFD and MSP with common tools and approaches. These methodologies and tools can play a key role in delivering ecosystem-based management approaches into MSP.

The main challenge faced by this case study was the collection and production of coherent datasets from both France and Spain. The other challenges was the methodological and technical development for the assessment of the risk of exposure and the numbers of variation factors to consider on ecological components like marine mammals and seabirds as a model relevant for the MSP.

The main interest of the work carried out concern the networking of Spanish and French teams involved in the project and the technical and methodological developments. The major risk, regardless of the results and methodological approaches explored, is that this networking stops directly at the end of the project. Indeed, the project has highlighted the potential of a shared technical work, in terms of identifying scientific and technical teams across countries, identifying common needs, identifying opportunities to cover knowledge/ methodological/ data gaps in neighbouring areas/ countries, or exchanging and building common methods for common analyses, for the purposes of answering to concrete administrative requirements or needs. Mutual understanding and development of shared and accepted methods must be considered in the framework of a partnership that goes beyond the end of the SIMWESTMED project.

BIBLIOGRAPHY

Andersen, J.H., Stock, A. (eds.), Mannerla, M., Heinänen, S. and Vinther, M. (2013). Human uses, pressures and impacts in the eastern North Sea. Aarhus University, DCE - Danish Centre for Environment and Energy. 136 pp.

Dars, C., Peltier, H., Dabin, W., Demaret, F., Dorémus, G., Spitz, J. et Van Canneyt, O. (2017). Les échouages de mammifères marins sur le littoral français en 2016. Rapport scientifique de l'Observatoire PELAGIS, Université de La Rochelle et CNRS. 46 pp.

David, L. and Di-Méglio, N. (2013). Important areas for the conservation of cetaceans in the Gulfof Lions shelf and slope area: synthesis of existing data on cetaceans and threats. UNEP-MAP Ed. RAC/SPA, Tunis. 37 pp.

Dekeling, R., Tasker, M., Van der Graaf, A. J., Ainslie, M., Andersson, M., André, M., Castellote, M., *et al*. (2014). Monitoring Guidance for Underwater Noise in European Seas. JRC Scientific and Policy Report EUR 26557 EN, Publications Office of the European Union, Luxembourg.

Depellegrin, D., Menegon, S., Farella, G., Ghezzo, M., Gissi, E., Sarretta, A., Venier, C. and Barbanti, A. (2017). Multi-objective spatials tools to inform spatial planning in the Adriatic Sea. Science of the Total Environnement 609: 1627-1639 pp.

Domínguez-Carrió, C., Requena, S. y Gili, J.M. (2014). Sistema de Cañones Submarinos Occidentales del Golfo de León. Proyecto LIFE+INDEMARES. Ed. Fundación Biodiversidad del Ministerio de Agricultura, Alimentación y Medio Ambiente 2014. 100 pp.

European Parliament and the Council (2002). Directive 2002/59/EC of 27 June 2002 establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC. Official Journal of the European Union L 208, 05/08/2002, pp.10-27.

Fernandes, M.L., Esteves, T.C., Oliveira, E.R. and Alves, F.L. (2017). How does the cumulative impacts approach support maritime Spatial Planning? Ecological Indicators 73: 189-202 pp.

Fossi, M.-C., Panti, C., Baini, M. and Lavers, J.L. (2018). A review of Plastic-Associated Pressures: Cetaceans of the Mediterranean Sea and Eastern Australian Shearwaters as Case Studies. Front. Mar. Sci. 5:173. doi 10.3389/fmars.2018.00173.

Gili, J.M., Madurell, T. y Requena, S. (2011). Caracterización y Ecología del área marina del Cap de Creus, Instituto Ciencias del Mar (ICM, CSIC). 272 pp.

Gimard, A., Quemmerais, F., Alloncle, N., Carval, D., Loyer, S., Reux, S., Farella, G., Sarreta, A., Murciano, C., Lloret, A., Nunez, C., Bliard, F., Giret, O. and Moirano C. (2018). Interactions between uses, between uses and environment, including cumulative impacts - Review of evaluation methods carried out in France, Spain and Italy. EU Project EASME/EMFF/2015/1.2.1.3/02/SI2.742101, SIMWESTMED. 157 pp.

GIS 3M, Pélagos, Ecoocéan Institut (2010). Synthèse des connaissances sur l'impact du trafic maritime. Pelagos France.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C. and Fox H.E. (2008). A Global Map of Human Impact on Marine Ecosystems. Science 319 : 948-952 pp.

Hilbe, J.M. (2014). Modeling count data. Cambridge University Press.

Hintzen, N., Bastardie, F., Beare, D., Piet, G., Ulrich, C., Deporte N., Egekvist, J. and Degel H. (2011). VMStools: Open-source software forthe processing, analysis and visualization of fisheries logbook and VMS data. Fish. Res. 115: 31-43.

International Maritime Organization (IMO) (2002). International Convention for the Safety of Life at Sea (SOLAS), Chapter V - Safety of Navigation, Regulation 19.

Jiménez-Valverde, A., and Lobo, J. (2007). Threshold criteria for conversion of probability of species presence to either–or presence–absence. doi:10.1016/j.actao.2007.02.001.

Kight, C.R., and Swaddle, J.P. (2011). How and why environmental noise impacts animals: an integrative, mechanistic review: Ecology Letters, v. 14, iss. 10, p. 1052–1061. DOI: 10.1111/j.1461-0248.2011.01664.x.

Korpinen, S. and Andersen, J.H. (2016). A Global Review of Cumulative Pressure and Impact Assessments in Marine Environments. Front. Mar. Sci. 3:153. doi: 10.3389/fmars.2016.00153.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S., Podesta, M. (2001). Collisions between ships and whales. Mar. Mammal Sci. 17, 35-75.

La Rivière, M., Aish, A., Gauthier, O., Grall, J., Guérin, L., Janson, A.-L., Labrune, C., Thibaut, T. et Thiébaut, E. (2015). Méthodologie pour l'évaluation de la sensibilité des habitats benthiques aux pressions anthropiques. Rapport SPN 2015-69. MNHN. Paris, 52 pp.

Le Courtois, F., Kinda, G. B. et Stéphan, Y. (2017). Rapport d'évaluation du descripteur 11 relatif aux perturbations sonores d'origine anthropique. Evaluation du Bon Etat Ecologique des eaux marines métropolitaines. Directive Cadre Stratégie pour le Milieu Marin. SHOM, 166 p.

Lee, J., South, AB. and Jennings, S. (2010). Developing reliable, repeatable and accessible methods to provide high-resolution estimates offishing-effort distributions from vessel monitoring system (VMS) data. ICES J. Mar. Sci. 67: 1260–1271.

Lurton, X., et Antoine, L. (2007). Analyse des risques pour les mammifères marins liés à l'emploi des méthodes acoustiques en océanographie. Ifremer, 88 pp.

Louis G (1914). La lithologie sous-marine du golfe du Lion. Annales de Géographie. 130: 351-355.

Morel, C., Gimard, A., Quintela, A., Lloret, A., Alloncle, N., Alves Fatima, L., Ballesteros Gómez, M., Buceta Jose, L., Giret, O., Marques, M., Plaza, M., Silva, A., Sousa, L., *et al.* (2018). Annex 1 to Initial Assessment: Marine Environment. EU Project Grant No. : EASME/EMFF/2015/1.2.1.3/03/SI2.742089. Supporting Implementation of Maritime Spatial Planning in the European Northern Atlantic (SIMNORAT). Deliverable Lead Partner. 172 pp.

Panigada, S., Lauriano, G., Donovan, G., Pierantonio, N., Cañadas, A., Vázquez, J.A. and Burt, L. (2017). Estimating Cetacean Density and Abundance in the Central and Western Mediterranean Sea Through Aerial Surveys: Implications for Management. Deep Sea Research Part II: Topical Studies in Oceanography 141, 41–58. doi:10.1016/j.dsr2.2017.04.018.

Peng, C., Zhao, X. and Liu, G. (2015). Noise in the Sea and Its Impacts on Marine Organisms. International journal of environmental research and public health, 12(10), 12304-23. doi:10.3390/ijerph121012304.

Pettex, E., Lambert, C., Laran, S., Ricart, A., Virgili, A., Falchetto, H., Authier, M., Monestiez, P., Van Canneyt, O., Dorémus, G., Blanck, A., Toison, V. et Ridoux, V. (2014). Suivi Aérien de la Mégafaune Marine en France métropolitaine - Rapport final. Univ. Rochelle UMS 3462 - 169p. doi: 10.13140/2.1.2698.5287.

Quemmerais-Amice, F., Vanhoutte-Brunier, A. and Alloncle, N. (2017). Mapping risk of cumulative effects – Recommendations from the approach tested within French Celtic Sea waters. EU Project Grant No.: EASME/EMFF/2014/1.2.1.5/3/SI2.719473 MSP Lot 3. Supporting Implementation of Maritime Spatial Planning in the Celtic Seas (SIMCELT). French Agency for Biodiversity. 49 pp.

Robards, M., Silber, G., Adams, J., Arroyo, J., Lorenzini, D., Schwehr, K., Amos, J. (2016). Conservation science and policy applications of the marine vessel Automatic Identification System (AIS) a review. Bull. Mar. Sci. 92, 75–103.

Robinson, L.A., Culhane, F.E., Baulcomb, C., Bloomfield, H., Boehnke-Henrichs, A., Breen, P., Goodsir, F., Hussain, S.S., Knights, A.M., Piet, G.J., Raakjaer, J., van Tatenhove, J. and Frid, C.L.J. (2014). Towards delivering ecosystem-based marine management: The ODEMM Approach. Deliverable 17, EC FP7 Project (244273) 'Options for Delivering Ecosystem-based Marine Management'. University of Liverpool. ISBN: 978-0-906370-89-6 : 96 pp.

Russell, R.J. (1942). Geomorphology of the Rhone delta. Annals of the Association of American Geographers, 32(2): 149-254.

Sardà, J.M.G. and Domínguez-Carrió, C. (2013). Description of the ecology of the Gulf of Lions shelf and slope area and identification of the areas that may deserve to be protected. UNEP-MAP. Ed. RAC/SPA, Tunis. 64 pp.

Spitz, J., Peltier, H., Authier, M. (2017). Évaluation du Bon État Écologique – Descripteur D1, composante « Mammifères Marins ». Rapport scientifique de l'Observatoire PELAGIS – UMS 3462, Université de La Rochelle / CNRS, 160 pp.

Stephan, Y. (2013). Programme de Surveillance - Thème 11 "Perturbations sonores". Chantier 2, livrable 5, 28 pp.

Stéphan, Y. (2016). Sons Impulsifs: Registre National des Emissions (SIRENE). Spécifications d'ensemble, Shom, Brest.

The Council of the European Union (2009). Council Regulation N°1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy. Official Journal of the European Union L 343, 22/12/2009.

Ulses, C., Estournel, C., Puig, P., Durrieu de Madron, X., Marsaleix, P. (2008). Dense shelf water cascading in the northwestern Mediterranean during the cold winter 2005: Quantification of the export through the Gulf of Lion and the Catalan margin. Geophysical Research Letters 35, L07610, doi:10.1029/2008GL033257.

Van der Wal J.T. and Tamis J.E. (2014). Comparing methods to approach cumulative effects in the North-East Atlantic: CUMULEO case study. Imares Report number C178/13. 61 pp.

Vanhoutte-Brunier, A., Barrere, J. et Quemmerais-Amice F., (2018). Méthodologie pour la cartographie du risque d'effets concomitants sur les habitats benthiques. Projet CARPEDIEM. Version 3, juin 2018. 93 pp.

Williams R., Wright, A.J., Ashe, E., Blight, L.K., Bruintjes, R., Canessa, R., Clark, C.W., Cullis-Suzuki, S., Dakin, D.T., Erbe, C., Hammond, P.S., Merchant, N.D., O'Hara, P.D., Purser, J., Radford, A.N., Simpson, S.D., Thomas, L. and Wale M.A. (2015). Impacts of anthropogenic noise on marine life: Publication patterns, new discoveries, and future directions in research and management. Ocean & Coastal Management, V. 115, Pages 17-24, ISSN 0964-5691.

ANNEXES

Annex I: Cetacean communication

Cetaceans use sounds to communicate, recognize and exploit the natural or artificial environment and detect preys and obstacles (Lurton *et al*., 2007). Marine mammals have a hearing scale that ranges from 10 Hz to 200 kHz. Odontocetes and especially dolphins communicate at frequencies above 100 Hz (optimum between 10 to 100 kHz) and have an effective hearing at frequencies above 500 Hz. Mysticetes like whales communicate at lower frequencies than odontocetes: from 12 Hz to 8 kHz (often below 100 Hz) and their hearing efficiency is not known but they are sensitive to low frequencies. SHOM (Le Courtois *et al*., 2017) has listed the impacts of noise disturbances of anthropogenic origin on cetaceans in their report of the MSFD GES assessment for the descriptor 11. Background noise (continuous noise) generated by maritime traffic can cover animal communications. This phenomenon, called masking, presents a risk of disturbances of the vital behaviors (reproductive success, cohesion of groups, etc.). In the long term, the increase in background noise could weaken the health of individuals and lead to a decline in populations. Moreover, exposure to signals of limited duration but of high power (impulsive noise) can cause physiological trauma (temporary hearing loss, deafness, embolism, etc.) or acoustic disturbances that may impact animal behaviors (interruption of vital activities, stress, fatigue, avoidance or even desertion of habitats, etc.). These pressures lead to risks of direct or indirect mortality.

Annex II: Detail of fishing categories

Table 13 - Detail of fishing categories

Fishing type	Fishing boat
Pelagic trawling	Midwater otter trawl and pelagic pair trawl
Bottom trawl	Bottom otter trawl, multi-rig otter trawl, bottom pair trawl and beam trawl
Seines	Fly shooting seine, anchored seine, pair seine, beach and boat seine
Surrounding nets	Purse seine and lampara nets
Nets	Trammel net, set gillnet and driftnet

Annex III: Spanish AIS data source: the db_ais_data database

The *db_ais_data* database stores information in independent tables, which are partitioned by months, and which stock 12 out of the 27 types of AIS messages along with the number of messages per type over a defined time period. This is indicative of the database dimension, which currently stores over 10 000 million records corresponding to the initial loading period, July 2015 - December 2017 (Table 14). Since then, the database has been subject to routine maintenance, involving monthly addition of new records (January - October 2018).

Table 14 - Types of messages stored in the *db_ais_data* database, according to the frequence recorded in July 2017

Type	Name	Number of messages
1	Position report	426,382,761
2	Position report	489,939
3	Position report	68,317,752
4	Base station report	47,959,755
5	Static / dynamic navigation report	14,778,296
9	SAR aircraft flight position report	238,006
12	Addressed security message	5,457
14	Delivered security message	492
18	Position report equipment class B	28,406964
19	Position report equipment class B extended	25,971
21	Aids to navigation report	3,783,644
24	Static data report	4,765,520

Annex IV: Gathering and processing AIS data for the Spanish analysis of maritime traffic

Each “snapshot” (i.e. instant capture of the maritime traffic activity) provides, for each ship:

1. Its most recent position register (type 1, 2 or 3,Table 14) prior to the date and time defined (within a short time period related to the intervals of time between messages set in the standard), in combination with;
2. The corresponding message (for this same ship) on the static/ dynamic navigation report (type 5,Table 14) immediately preceding the position.

As detailed in Section 2.2 (datasets), 4 000 snapshots that were considered to conduct the statistical analysis of maritime traffic (per season). Therefore, it should be noted that the treatment of the total dataset was not intended, as the work was planned and carried out by means of a statistical sample (although the one considered in the present analysis it is considerably extensive).

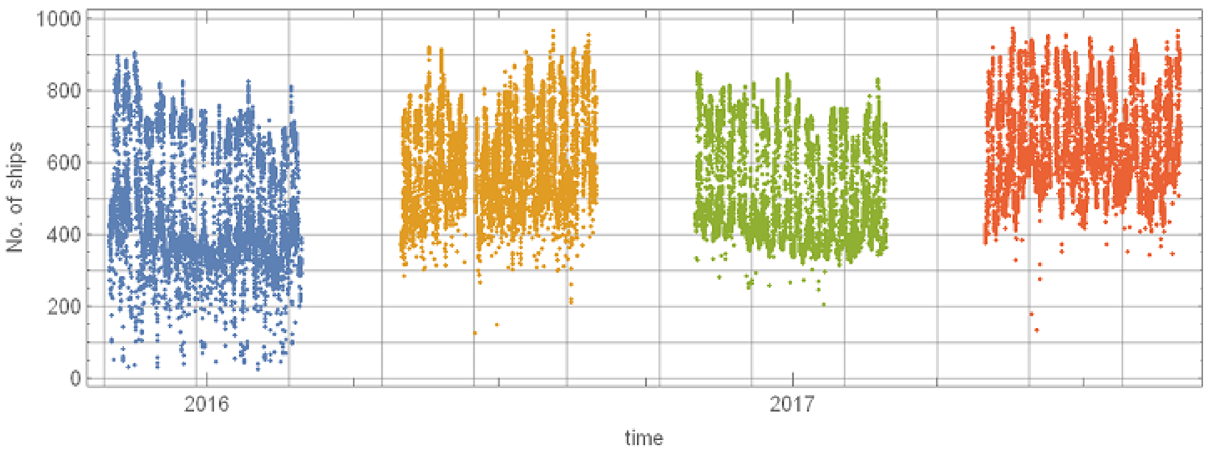

Figure 27 - Amount of data per snapshot for the four seasons considered in the Gulf of Lion.

Figure 27 shows the variability in data among snapshots for the different time periods considered in the study. It should be highlighted that in the second time period, corresponding to the summer season of 2016, in a span of a few days no data was recorded by reason of a discontinuity in the data flow that feeds the Database. Due to the statistical approach adopted, such discontinuity is not believed to affect the results in a remarkable way.

Results have been evaluated for the following 9 boat categories:

- "Other", not assimilable to the following;
- Fishing and sport vessels;
- High-speed craft;
- Special and port boats;
- Passenger ships;
- Cargo ;
- Small tankers (length < 187.50 m);
- Large tankers (length > 187.50 m);
- All types of ships simultaneously considered.

Regarding the navigation status, two values were distinguished (and kept) to conduct the two different analysis based on AIS data: for the maritime traffic assessment, all boats were considered; in contrast, the evaluation of underwater noise involved vessels navigating at speeds over one knot.

For the vessels categories defined, and for each of the four stations and cells in the three indicated resolutions, the following density statistics have been evaluated:

- Middle value;
- Typical deviation;
- Percentiles of 90, 95 and 99.

Selected data have resulted in 9 x 2 x 4 x 3 x 5 = 1 080 output tables that may be made available in multiple formats (e.g. MS Excel).

Figure 28 shows a simple output of integrated summary results for the area of the Gulf of Lion, together with the “Cetaceans Corridor” in Spanish jurisdictional waters (declared as a marine conservation figure by the Royal Decree 699/2018), along with the set of options indicated above.

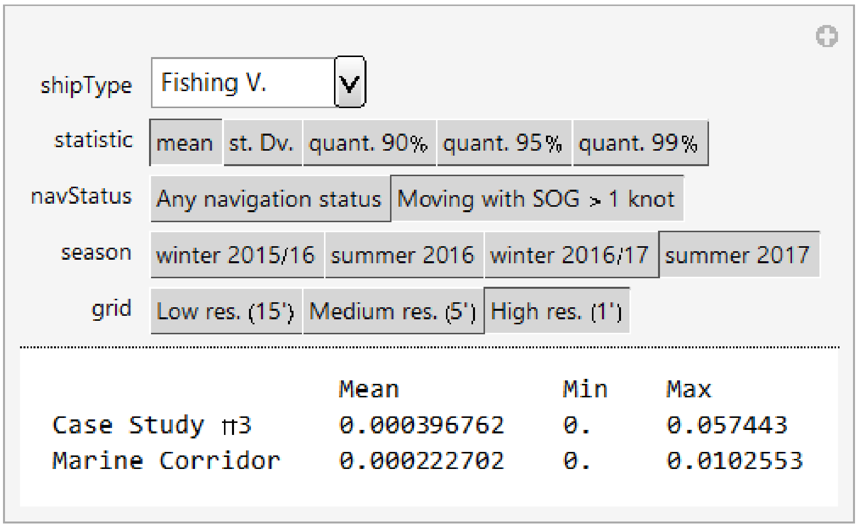

Figure 28 - Summary table of values in two study areas

In addition,Figure 29 shows a scoreboard graphically displaying the average traffic density of fishing vessels in motion during the summer season of 2016, in the 5' grid resolution.

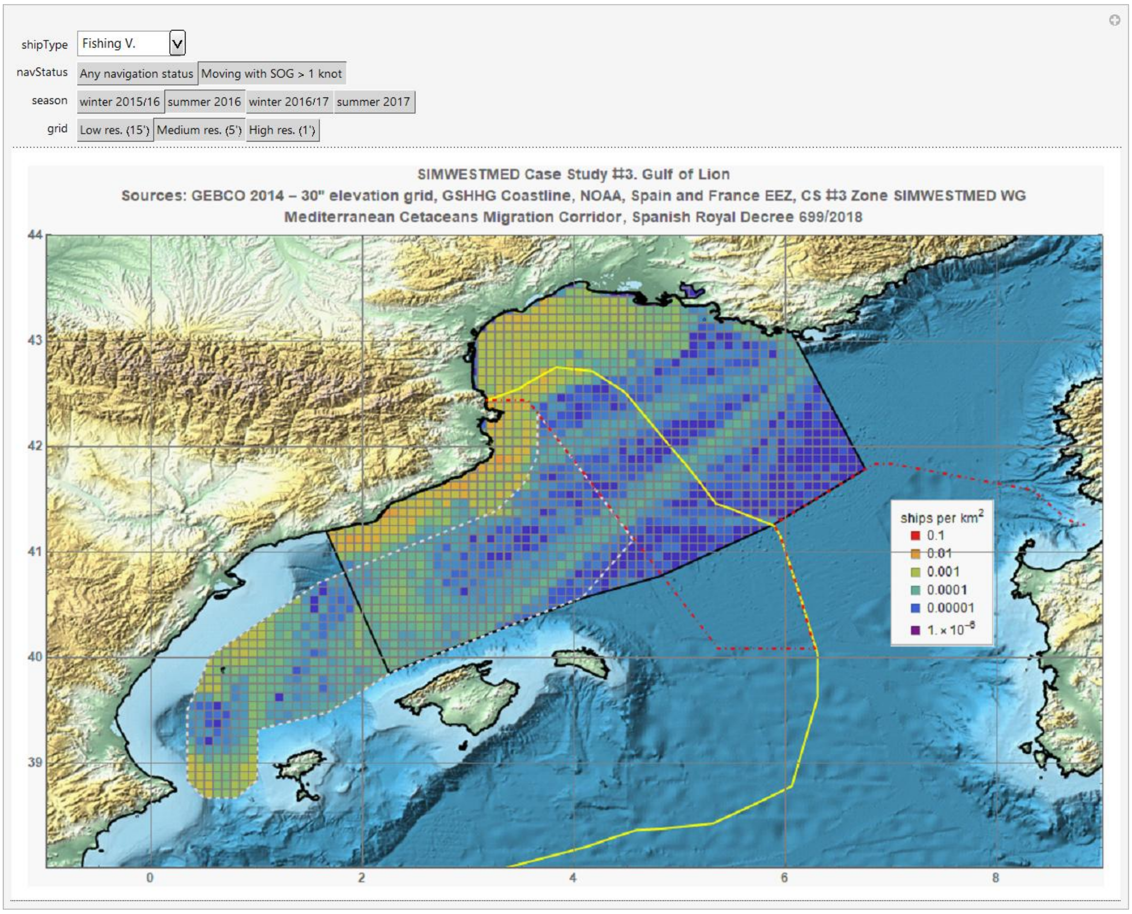

Figure 29 - Graphic representation chart of maritime traffic density in the Gulf of Lion. May-August 2016.

Annex V: Assessment of underwater noise propagation. Theoretical considerations

Summing up different sound levels

When two sound waves come from different sources or from a common source but through different paths, their effects overlap. While this overlapping results in the addition of pressures and instantaneous velocities, each wave maintains the ratio between its pressure and its velocity. For the present study, it has been assumed that sounds emitted by the different ships are not correlated within each other and, therefore, what have been added are the intensities and exposures, which are proportional to the powers and equivalent energies respectively.

When the magnitudes (Xi) to be added are expressed by their (XLi) levels in dB, the resulting level (in dB) is calculated by the following expression:

$$XL(dB) = 10\,log\left(\sum_i 10^{XL_i/10}\right)$$

The logarithmic scale is used, since it is frequent that adding amounts are of different orders of magnitude, meaning that their addition would result in a value close to the largest original quantity.

Geometric divergence

Sound sources generate waves. The fronts of these waves move away from the source, and their shape, in the vicinity of the source, is determined by the mechanism that generates the oscillations. For example, the sound generated by the vibrations of a ship's hull produces waves that initially have the same shape as the hull. As it moves away, the shape's front is modified in a way that is determined by the speed of sound and the driving direction in each point of the front.

In cases where the source has a finite size (as is usually the case), starting from a distance of around several times the largest dimension of the source, wave fronts would be indistinguishable from those that would be generated by a point source located at the geometric gravity center of the real font. Based on this fact, characterising/ assimilating a finite source to a point source is common practice. Indeed, in practice, measurements are made at fairly large distances due to the difficulties to approach sources, while related errors linked to the receiver positioning remain less relevant. Therefore, it is assumed that such a pressure would be equally produced by a point source and its corresponding power output is calculated.

If measurements do not record intensities with spherical symmetries, it is assumed that the source is anisotropic; therefore, the directional distribution of the power output is calculated and taken into account in subsequent simulations.

If the source records some symmetry and the medium is homogeneous, related wave fronts would also be symmetric. For example, wave fronts of a pulsating sphere are spheres and those of a pulsating cylinder are cylinders. Wave fronts of a vibrating plane are parallel planes.

Acoustic rays are lines perpendicular to wave fronts, and represent the pathways through which the acoustic energy generated by the source is propagated. In the three former cases, acoustic rays are straight lines because wave fronts are parallel to each other. In a spherical wave, acoustic rays start from the center (or the surface) of the pulsating sphere; in a cylindrical wave, acoustic rays start from the symmetry axis, perpendicular to it; in a plane wave, acoustic rays are the lines perpendicular to the plane; and, if it is a flat, vibrant sheet, acoustic rays start from the sheet, and are perpendicular to it.

In a spherical wave, field tubes are similar to cones that have a vertex at their origin. The energy flow is maintained along a field tube, and the intersection of this field tube with spherical wave fronts generate areas that increase according to the square of the distance; in this context, the acoustic intensity, which is the density of the energy flow, decreases according to this same proportion.

In cases of isotropic sources, the acoustic intensity at a point located at a distance *R* from the origin is:

$$I(R) = \frac{P}{4\pi R^2}$$

where P is the acoustic power emitted by the source. Acoustic power is usually expressed as intensity (W/m^2) at 1m distance, and not as power (W). Therefore, and considering this as a reference, the relative intensity is as follows:

$$\frac{I}{I_{ref}} = \frac{P/4\pi r^2}{P/4\pi} = \frac{1}{R^2}$$

Which, expressed as levels in dB, corresponds to:

$$IL\left(dB\ re\ I_{ref}\right) = -20\log R\ (m)$$

Therefore, a sound level reduction equivalent to 20 x log(*R)* dB is produced on account of the geometric divergence:

$$SPL(R\ m) = SPL(1\ m) - 20\log R(m)$$

The sound level reduction occurring during the propagation from 1 m off the source to any point is called Transmission Loss (or TL), a term that originates in signal detection studies (communications, sonar, seismic surveys) where all that is not reaching the recipient is considered a loss.

In this case:

$$TL\ (dB) = 20\log R(m)$$

For a cylindrical wave, field tubes are conoids with a straight directrix on the emission axis. In this case, the source is characterised by the power emitted per unit length (W/m) or by the intensity in a cylindrical surface of radius *I_ref*. Surfaces intercepted by a field tube grow proportionally to the distance *r* to the axis and, therefore, the reduction of sound levels by geometrical divergence is as follows:

$$SPL(r\ m) = SPL(1\ m) - 10\log\ r\ (m), \qquad TL(dB) = 10\log r(m)$$

In a flat wave, flow tubes are cylinders. No ray divergence occurs and the intensity is thus constant along the entire flow tube. For the estimation of transmission losses, geometric divergence has been prioritised over any type of anisotropy, continuous refraction, refraction and reflection in interfaces of different propagation speed, multipath and attenuation.

The approximation used in the calculations for transmission losses has been[7]:

TL(dB) =15 log (R)

Where R is the distance to the source.

[7] Modelled Mapping of Continuous Underwater Noise Generated by Activities. MMO Project No: 1097. Marine Management Organisation. August 2015

Annex VI: List of maps collection

All existing map are listed in Table 15 and stored in the document “Map collection”.

Table 15 - List of existing maps in the case study “Gulf of Lion”

<table>
<tr><th rowspan="2"></th><th colspan="2">global</th><th colspan="2">globice-phalinae</th><th colspan="2">little delphinidae</th><th colspan="2">common bottlenose dolphins</th><th colspan="2">fin whale</th><th colspan="2">little shearwaters</th><th colspan="2">great grey gulls</th><th colspan="2">terns</th><th colspan="2">gulls</th></tr>
<tr><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th><th>FR</th><th>SP</th></tr>
<tr><td>Habitat model</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Number of activities</td><td>X</td><td rowspan="2">X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Multi- activities intensity</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Number of pressures</td><td></td><td></td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td></tr>
<tr><td>Multi-pressures intensity</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Exposure to floating macro-waste</td><td></td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Exposure to continuous underwater noise</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Exposure to impulsive underwater noise</td><td></td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Exposure to visual disturbance</td><td></td><td></td><td>X</td><td>X</td><td></td><td></td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Exposure to bycatch</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>Exposure to collision</td><td></td><td></td><td>X</td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Exposure to multi- pressures</td><td></td><td></td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td><td>X</td><td rowspan="2">X</td></tr>
<tr><td>Confidence Index</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
</table>