Bay of Biscay case study

Mapping exposure risk of marine megafauna to concomitant pressures

January 2019

Version 2

Supporting Implementation of Maritime Spatial Planning in the Northern European Atlantic

---

European Commission
Directorate-General for Maritime Affairs and Fisheries
Grant Agreement: EASME/EMFF/2015/1.2.1.3/03/SI2.742089

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

Sub-component: CS#1 Assessment of concomitant pressures in the Bay of Biscay

Deliverable i.d.:	D16
Deliverable Lead Partner:	AFB, CEDEX, IEO
Duration:	25 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	Bay of Biscay case study - Mapping exposure risk of marine megafauna to concomitant pressures
Coordinator	Alloncle N., Campillos M. and Gimard A.
Authors (in alphabetical order)	Alloncle N., Bliard F., Campillos-Llanos M., Cervera-Núñez, C., Dalleau C., Gimard A., Gómez-Ballesteros M., Grassa JM., Lloret A., Murciano C., Punzón A., Quemmerais-Amice F.
Recommended Citation	Bliard, F., Dalleau, C., Quemmerais-Amice, F., Gimard, A., Alloncle, N., Campillos-Llanos, M., Cervera-Núñez, C., Gómez-Ballesteros, M., Grassa, JM., Lloret, A., Murciano, C., Punzón, A. (2019). Bay of Biscay case study - Mapping exposure risk of marine megafauna to concomitant pressures. EU Project Grant No.: EASME/EMFF/2015/1.2.1.3/03/SI2.742089. Supporting Implementation of Maritime Spatial Planning in the Northern European Atlantic (SIMNORAT). Deliverable Lead Partner. 75 pp. DOI: 10.5281/zenodo.2598150

VERSION HISTORY

Date	Document version	Reviewer	Revision
02/01/2018	1.0	Alloncle N., Bliard F., Campillos-Llanos M., Cervera-Núñez, C., Dalleau C., Gimard A., Gómez-Ballesteros M., Grassa JM., Lloret A., Murciano C., Punzón A., Quemmerais-Amice F.	Initial draft
17/01/2018	2.0	Alloncle N., Bliard F., Campillos-Llanos M., Cervera-Núñez, C., Dalleau C., Gimard A., Gómez-Ballesteros M., Grassa JM., Lloret A., Murciano C., Punzón A., Quemmerais-Amice F.	Structural and content revision

CONTENTS

LIST OF ACRONYMES

AFB	French Biodiversity Agency
AIS	Automatic Identification System
CEDEX	Center of Studies and Experimentation of Public Works (Spain)
CI	Confidence Index
CNRS	National Center for Scientific Research (France)
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-Activity
ITU	International Telecommunication Union
MAGRAMA	Spanish Ministry of Agriculture, Food and Environment
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
SIMNORAT	Supporting Implementation of Maritime Spatial Planning in the Northern European Atlantic
SIMWESTMED	Supporting Implementation of Maritime Spatial Planning in the Western Mediterranean Region
SQL	Structured Query Language
SPI	Single Pressure Index
UNEP	United Nations Environment Programme
VMS	Vessel Monitoring System

LIST OF FIGURES

LIST OF TABLES

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 SIMNORAT project schedule. They are designed to illustrate the analysis and working methodology and to enable comparisons and methodological discussions with SIMNORAT project partners. Any use of this work for the management of the territory studied would be incomplete and misplaced.

INTRODUCTION

1.1.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.

1.2. SIMNORAT

The Supporting Implementation of Maritime Spatial Planning in the Northern European Atlantic project (SIMNORAT) brings together a number of partners - research organizations, marine planning authorities and marine management bodies from France, Spain and Portugal 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. SIMNORAT 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 Northern European Atlantic, involving three Member States and the relevant authorities responsible for MSP in the selected area and the CPMR for the level of the Regions.

SIMNORAT 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;
- Access to data and data-specific barriers to transboundary cooperation;
- 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.

SIMNORAT outputs are practitioner focused, and aim at the identification and sharing of best practices 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, the present SIMNORAT action aims 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 SIMNORAT 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 focusing on similar/ equivalent themes 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.

As a result of the approach adopted to address cumulative effects, this work was also 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 among the main topics addressed and described. Implementation of MSP is described as transboundary and this exercise is believed to be a supporting experiment and provide lessons learned to improve the Ecosystem-Based Assessment and cooperation between planners.

1.3. 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. Moreover, on the technical aspect, the pelagic component had not been studied yet in the cumulative effects assessment tool CARPEDIEM; progress could be achieved. This large-scale 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.

The case study focuses on the southern area of the Bay of Biscay and includes French and Spanish waters (Figure 1). The geographical area is bounded on the north, on the French side, by the Natura 2000 marine protected area “Secteur de l’île d’Yeu” and on the west, on the Spanish side, by the marine protected area “El Cachucho”.

The Bay of Biscay is a well-differentiated geomorphological unit in the north-east Atlantic. The case study includes marine coastal waters, continental shelf and slope, seamounts, canyons and an abyssal plain reaching 4,800 m depth. The continental shelf is quite narrow at the south (Spanish coast), and wider in the north, increasing with latitude (French coast).

Concerning the primary production, high values of chlorophyll and several planktonic blooms can be observed over the continental shelf for most of the year. In contrast, the oceanic waters in the Bay of Biscay show an oligotrophic status with a single peak of biomass in spring. The temperate waters, the topographical complexity and the wide range of substrates on the continental shelf are at the origin of several types of habitat colonized by pelagic, benthic and demersal species: anchovy, sardine, mackerel, tuna, swordfish, sharks, hake, megrim, anglerfish or sole, but also by cetaceans: long-finned pilot whale, Risso’s dolphin, short-beaked common dolphin, striped dolphin, common bottle noise and harbour porpoise.

These characteristics allow for the development of important fisheries and shellfish farming of oysters and mussels. Maritime traffic is also important, rather coastal in this part of the North-East Atlantic, unlike the Britton and Galician coasts that are close to a highway of tankers and cargo ships.

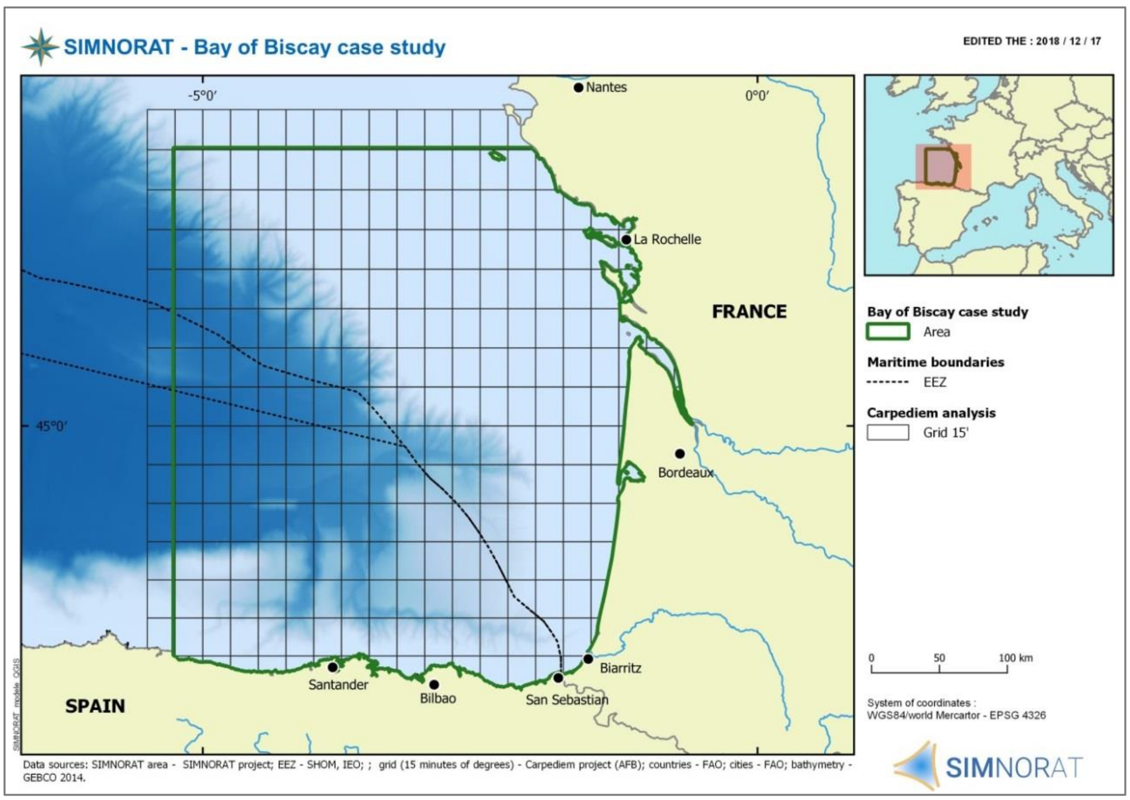

Figure 1: The Bay of Biscay case study area, in dark green. The map also displays the 15’ resolution square grid used in the SIMNORAT analysis.

Several other 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, bycatch, entanglement in fishing gear, ingestion of pollutants and waste, prey depletion, loss of habitats, disturbance from maritime traffic, 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 present 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 major disturbance. The main disturbances are physical damage resulting from collision and underwater noise, and behavioural alterations (both short-term and long-term) linked also to underwater noise and to visual disturbance which ships represent. Cetaceans need to alter their dive patterns to avoid encounters with vessel traffic (Marcotte *et al.*, 2015). Probable effects due to collision and underwater noise are considered in this report and restricted to 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 localization 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 also generates underwater 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, as 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). For the first MSFD cycle conducted between 2012 and 2018, the GES is not reached for marine mammals' component in the Bay of Biscay, due to the significant bycatch of small odontocetes, including common dolphins (Spitz *et al.,* 2017). Seabirds suffer also from bycatching in nets, longlines and from competition by the exploitation of their preys.

On the other hand, over the last decades assessments of **underwater noise** and its impacts on marine organisms have increased in number 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: Cetaceans communication).

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 waste 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 include injury, drowning, strangulation, and may compromise feeding, reproduction, growth and longevity.

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

2. MATERIAL AND METHODS

2.1. Overview of the methodological approach and tools

The methodological approach used for the assessment of the exposure risk analysis for the pelagic component (i.e. marine mammals and seabirds) is based on previous developments made within the framework of the SIMCELT project[1] and the CARPEDIEM project in France (Quemmerais-Amice *et al.*, 2017). This first methodological development focused on the analysis of cumulative effects on benthic habitats. The general approach was 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 adopted in the SIMCELT project included activities and pressure 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 matrixes were developed on the basis of scientific advice and experts' knowledge and allow creating a rational and explained connection between benthic habitats and impacts induced by human activities. Associated with geographic information describing human activities intensity and benthic habitats distribution, the method allows producing a 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 of 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 SIMNORAT case study dedicated to the assessment of cumulative pressures in the Bay of Biscay, it was decided to go one step further, focusing on marine mammals and seabirds and on the most relevant anthropogenic pressures probably affecting them and in terms of spatial planning challenges.

The method was developed in coordination for SIMNORAT and SIMWESTMED[2] projects, implying the same partner institutions. The method was divided into two main stages. The first step was to produce maps of human activities and major pressures affecting marine mammals and seabirds. The second step was to produce maps of the potential exposure risk to human pressures for marine mammals and seabirds, in order to locate and rank the areas of probable overlapping between anthropogenic pressures and the marine communities studied. As marine mammals and seabirds are highly mobile species, and since human activities vary in time and space, the analysis involves seasonal data (summer and winter) to consider both the spatial and temporal dimensions. Meetings among SIMNORAT 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). 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

[1] EU Project Grant N°: EASME/EMFF/2014/1.2.1.5/3/SI2.719473 MSP Lot 3. Supporting Implementation of Maritime Spatial Planning in the Celtic Seas (SIMCelt).

[2] EU Project Grant N°: EASME/EMFF/2015/1.2.1.3/02/SI2.742101 MSP Supporting Implementation of Maritime Spatial Planning in the Western Mediterranean Region (SIMWESTMED). Component 1.3.6 Establishing case studies on approaches to MSP implementation - CS#2 Assessment of cumulative pressures in the Gulf of Lion.

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-activity maps, multi-pressure maps, synthesis map of marine mammals and seabirds), which provide a background knowledge for interpreting the final analysis result.

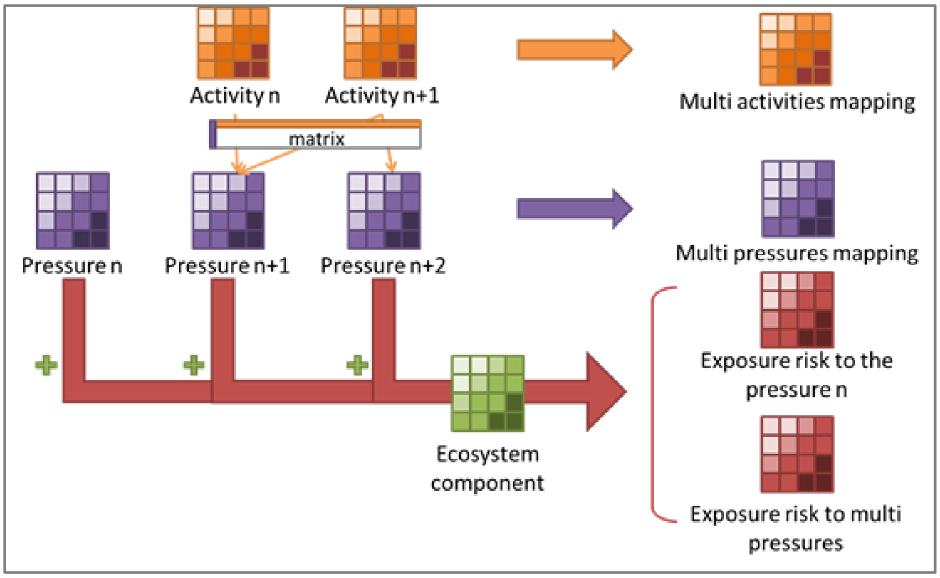

Figure 2: Overview of the 4 main steps of analysis. A: activity, P: pressure, E: Ecosystem component (marine mammal or seabird)

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 aim 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 were made using the QGIS software, which very easily interfaces with the database. Statistical analysis was carried out using the R software. Figure 3 shows the main steps in the data processing chain.

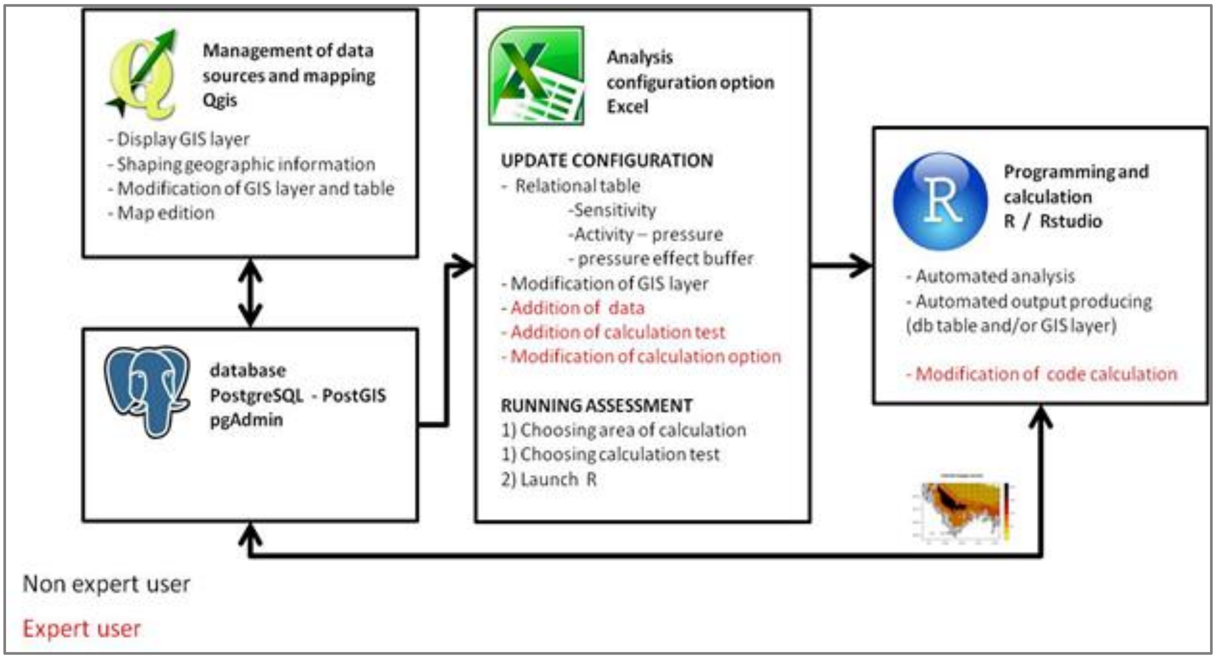

Figure 3: Software and processing chain for CARPEDIEM project

2.2.Datasets description

Identification, collection, quality assurance and raw data edition has been done. This very time-consuming work 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 and seabirds species, 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 chosen to produce seasonal information and years covered by datasets

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

2.2.1. 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, habitat models 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) 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.

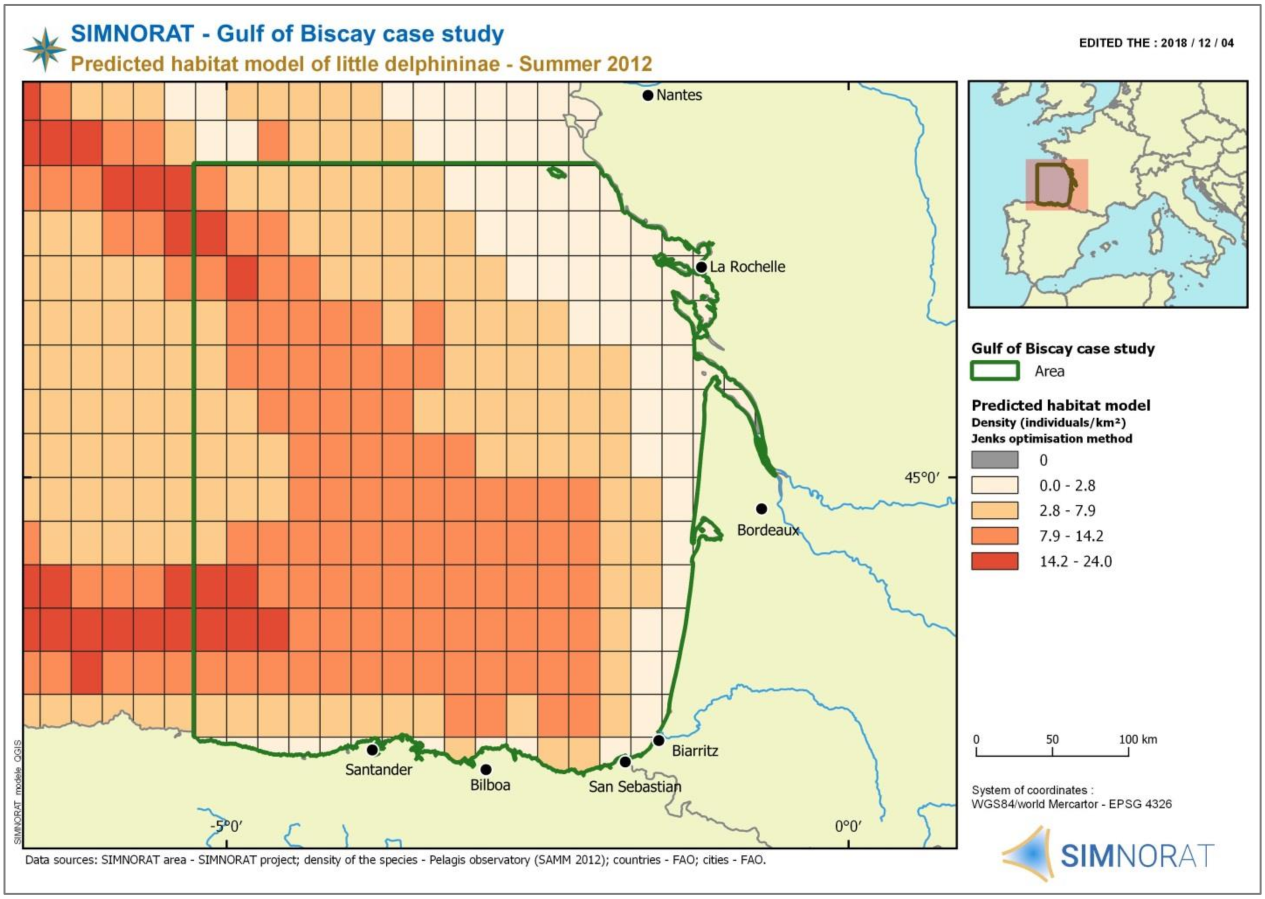

Figure 4: Predicted habitat model of little delphininae during summer 2012 in the Bay of Biscay (15' grid)

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				ATLANTIC OCEAN/ENGLISH CHANNEL	
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	X	X
		Uria aalge	Common Guillemot		
		Alca torda	Razorbill		
Phalacrocoracidae	Cormorants/shags	*Phalacrocorax carbo*	Great cormorant	X	X
		Phalacrocorax aristotelis	European shag or common shag		
Sulidae	Northern gannet	*Morus bassanus*	-	X	X
Procellariidae	Northern fulmar	*Fulmarus glacialis*	-	X	X
	Little shearwaters	*Puffinus puffinus*	Manx shearwater	insufficient	X
		Puffinus yelkouan	Yelkouan shearwater		
		Puffinus mauretanicus	Balearic shearwater		
	Great shearwaters	*Puffinus gravis*	Great shearwater	absent	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	X	X
		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*	-	no model	insufficient
	Black-legged kittiwake	*Rissa tridactyla*	-	X	X
Hydrobatidae	Petrels	*Hydrobates pelagicus*	European storm petrel	no model	X
		Hydrobates leucorhous	Leach's storm petrel		
		Hydrobates castro	Band-rumped storm petrel		
Stercorariidae	Great skua	*Catharacta skua*	-	X	X
Anatidae	Scoters	*Melanitta nigra*	Common scoter	X	insufficient
		Melanitta fusca	Velvet scoter		
Gavidae	Divers	*Gavia stellata*	Red-throated loon	just in English channel	absent
		Gavia arctica	Black-throated loon		
		Gavia immer	Common loon or great northern diver		

CETACEANS				ATLANTIC OCEAN/ENGLISH CHANNEL	
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*	-	X	X
Balenopteridae	Fin whale	*Balaenoptera physalus*	-	insufficient	insufficient
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				

2.2.2. Human activities and pressures datasets

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 to monitor 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 with 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.

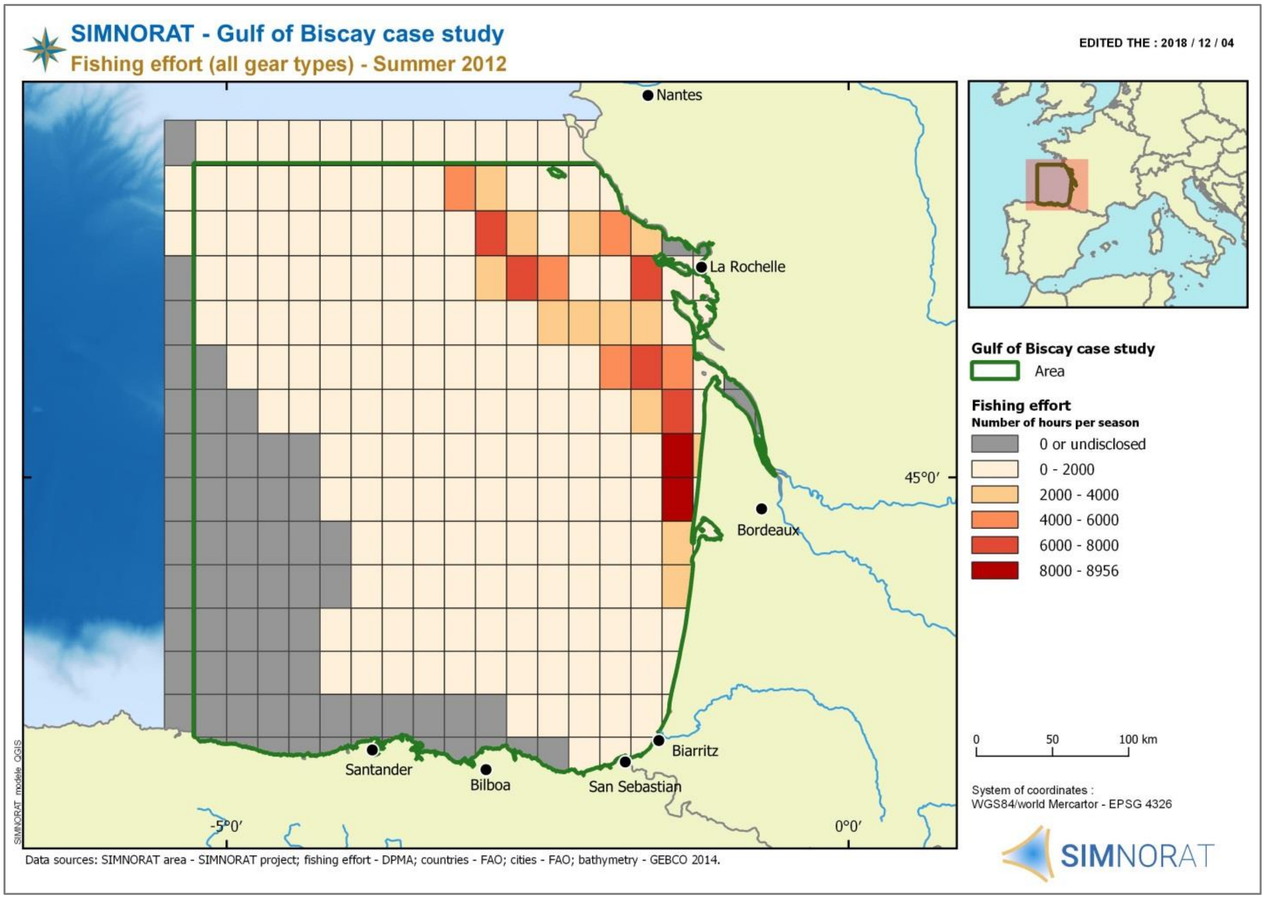

Figure 5: French fishing effort during the summer 2012 in the Bay of Biscay, all gear types combined (15' grid)

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 current Ministry for the Ecological Transition.

Regarding the 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 was 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 by using regression models (segmented regression) or by 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 while, 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 at which 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 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

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

See Annex II: Detail of fishing categories" for more details on fishing category.

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 to query 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.

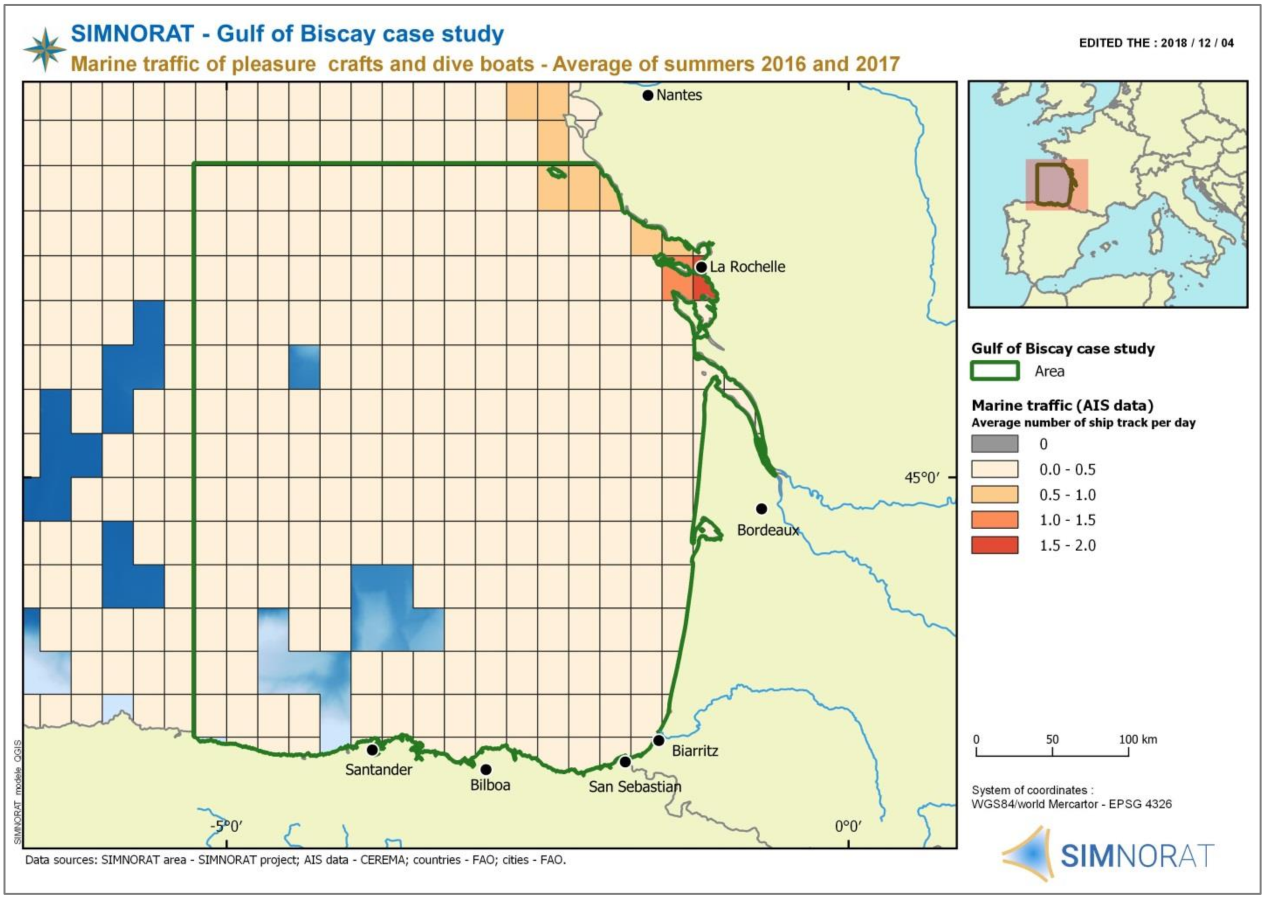

Figure 6: Average marine traffic of passenger ships during the summers 2016 and 2017 in the Bay of Biscay (15' grid)

Regarding the Spanish side, the data source used was the historical AIS database (named *db_ais_data*) developed developed by CEDEX from the AIS data flow provided by the Spanish Maritime Safety Agency[3] in the context of the PRISMA Project[4]. Independent partitioned tables store 12 out of the 27 types of AIS messages (see

Annex III: Spanish AIS data sourcefor 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.

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.

[3] SASEMAR, Sociedad de Salvamento y Seguridad Marítima.
[4] Conducted by CEDEX for the Directorate-General for the Merchant Marine (Spanish Ministry of Development).

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 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, 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: Gathering and processing AIS data for the Spanish analysis of maritime trafficfor 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)

Navigation data	Intensity parameter	Unit per cell	Spatial resolution	Temporal resolution	Data source
All categories	Average number of ship tracks per day, per cell and per season	Ships tracks/day	1 min 3 min 5 min 10 min 15 min	Winters 2015-2016, 2016-2017 Summers 2016,2017	CEREMA (France) Processed by AFB
Cargo					
Tanker					
Passenger					
Fishing					
Pleasure craft and dive					
High speed craft					
Special (military ops, dredger)					
Special (law enforce, special craft, medical trans, anti-pollution, tug, SAR, port tender, local vessel)					
Other					

All categories	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)	Average number ships/ unit area / cell and season	1 min 5 min 15 min	Winters 2015-2016, 2016-2017 Summers 2016, 2017	CEDEX (Spain)
Cargo					
Small tankers (<187,5 m)					
Large tankers (>187,5 m)					
Fishing and sport vessels					
Passenger					
High speed craft					
Special and port ships					
Other					

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.

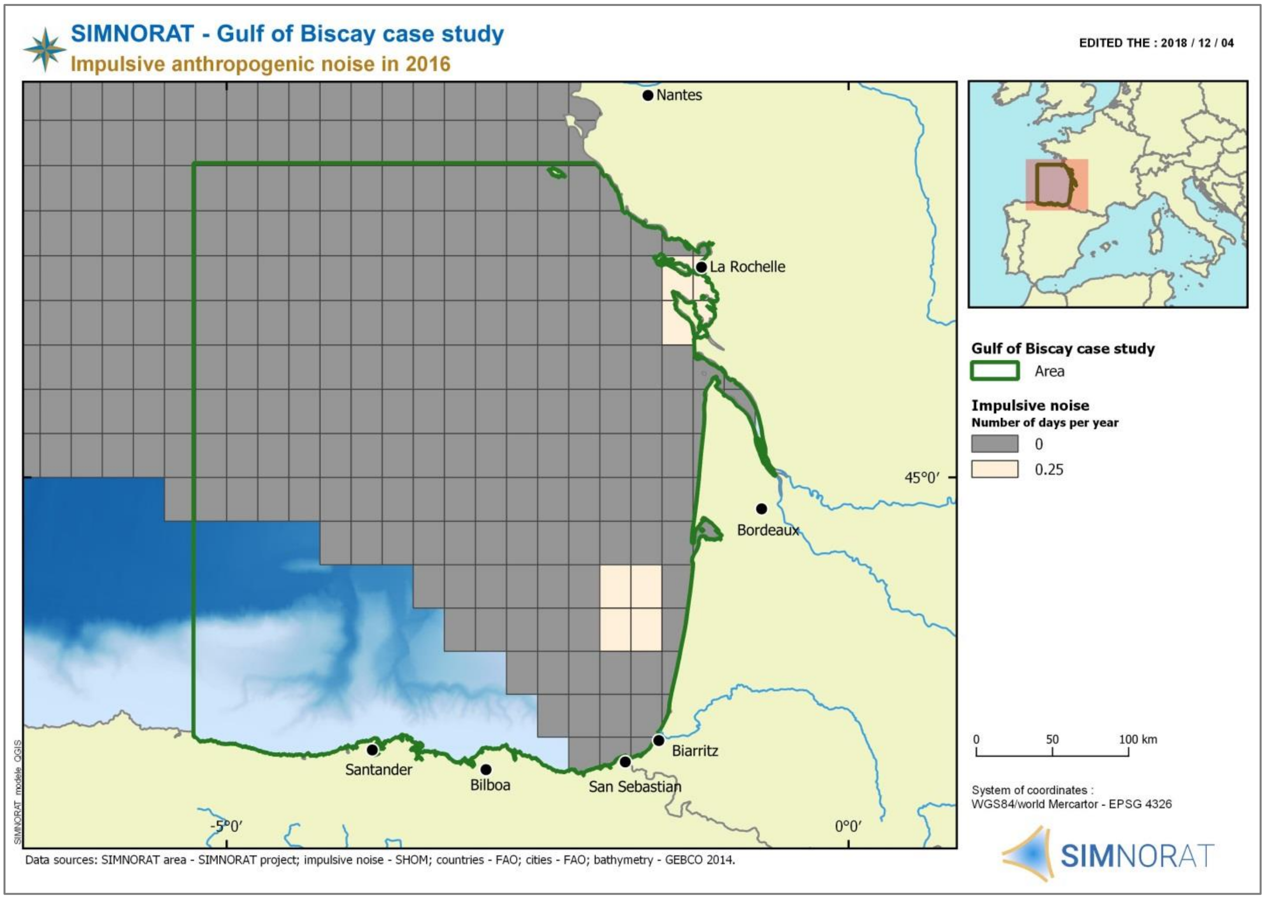

Figure 7: Impulsive anthropogenic noise in 2016 in the Bay of Biscay (15' grid)

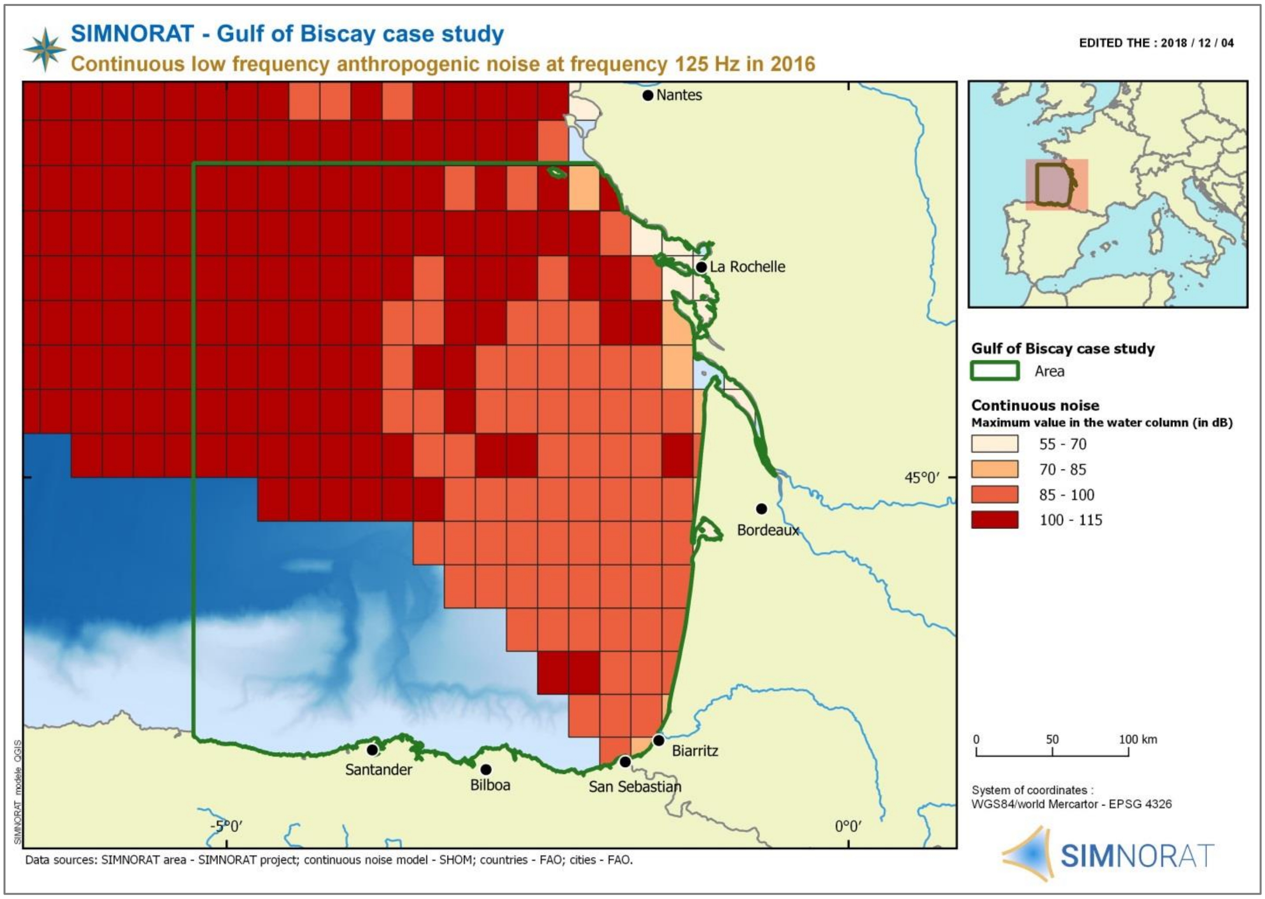

Figure 8: Continuous low frequency anthropogenic noise at frequency 125 Hz in 2016 in the Bay of Biscay (15' grid)

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[5] method has been used. This method is based on cataloguing 5 classes of boats according to two parameters, length and speed. The formulation is as follows:

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

Where v: vessel speed in knots;

l_s: 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;

$L_{s0}(f)$ = - 10 x log (10 - 1,06 x log(f) - 14,34 + 103,32 x log(f) - 21,45) for (f <500 Hz).

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

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.

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: Assessment of underwater noise propagation. Theoretical considerations.

Results are displayed on a map, which shows sound values emitted in each cell, but, above all, 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>
</table>

Continuous noise	Mean value of received sound levels (in dB) per season for the frequencies 63 Hz and 125 H	decibels	1 min 5 min 15 min	Summer 2016 Winter 2016-17	CEDEX (Spain)

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 assessment due to a lack of knowledge and data available to model them.

Those data were 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.

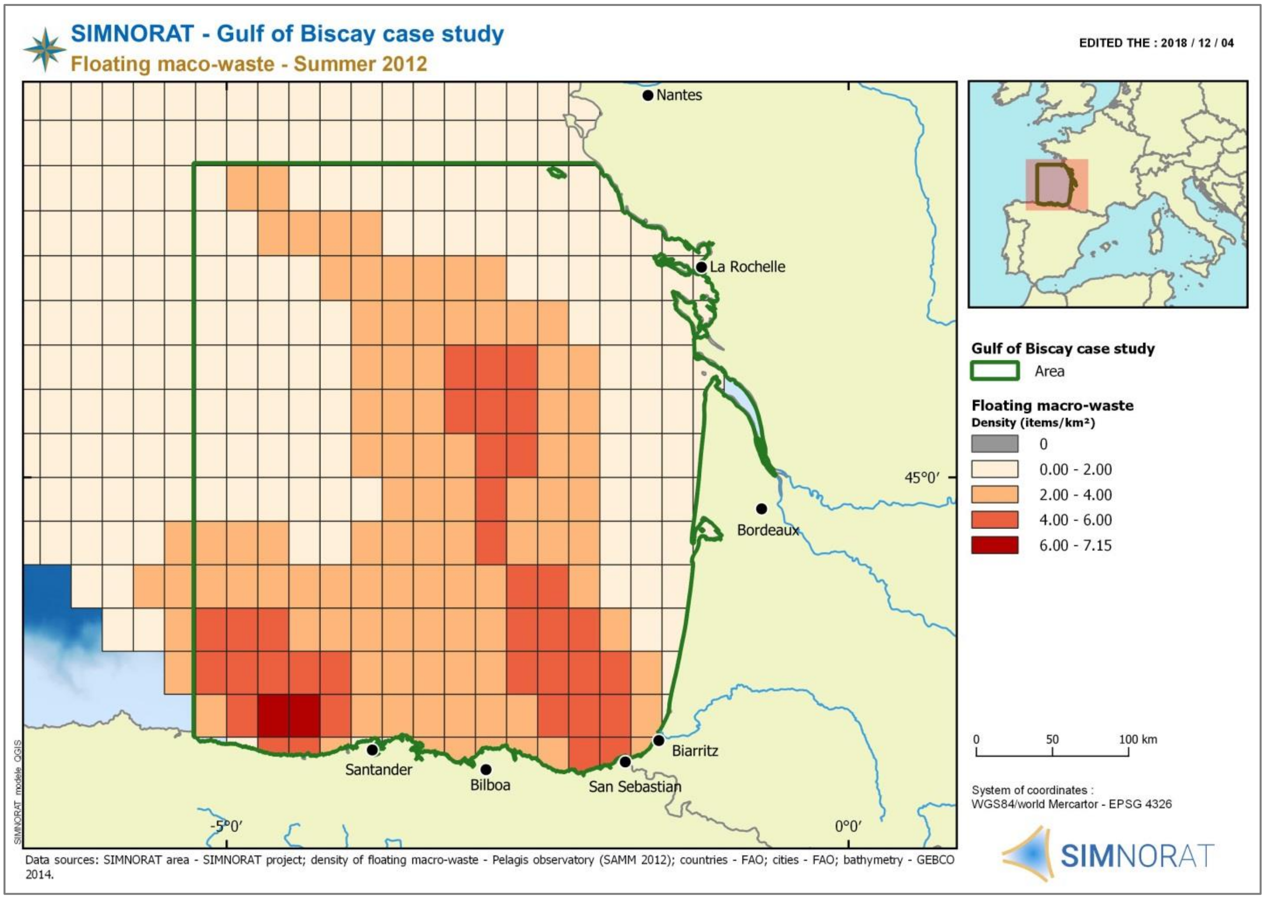

Figure 9: Density of floating macro-waste during the summer 2012 in the Bay of Biscay (15' grid)

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

2.3. Methodology for exposure risk analysis

2.3.1. Multi-activity mapping

A multi-activity map displays a qualitative and quantitative overview of the use of marine and coastal areas, which is useful for marine planning. This spatial representation presents 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 localised. It is important to remind that only two activities are taken into account in this analysis and do not represent all the activities that generate pressures, as some of them are located on land.

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

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

$$\mathrm{IMA\_option1} = \sum_{i=1}^{ni} A_i$$

Where: A_i presence/absence of the activity i [0/1]
ni number of activity sectors

- **Index of multi-activity 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 allow to use 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.

$$\mathrm{IMA\_option2} = f_{norm}\left(\sum_{i=1}^{ni} f_{norm}(A_i)\right)$$

Where: A_i intensity of the activity
ni number of activity sectors
f_{norm} log transformation and normalizing function to obtain a value in the range [0-1]

Descriptive data on human activities can then be used to map the pressures, although some pressures can be mapped without representing the activities at their origin, such as underwater noise and marine litter.

2.3.2. 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 taken into 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 affect the marine megafauna, a theoretical relationship matrix between the activities, pressures and species has been developed by consulting AFB experts on 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 updating 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 is a qualitative assessment because the value of the exposure risk is 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 relationship matrix; it is the case for underwater noise and marine litter.

2.3.3. Single pressure and multi-pressure mapping

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 be taken into account. Like the intensity of the 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 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 j can therefore be written as follows:

$$\mathrm{Pj} = \sum_{i=1}^{ni} (\gamma_{\mathrm{AiPj}}) \times \mathrm{Ai}_{\mathrm{norm}}$$

Where:
- Pj: intensity of pressure j
- γ_{AiPj}: contribution of activity i to pressure j. Determined from the relational matrix:
  - if activity i generates the pressure j : γ_{AiPj} = 1
  - if activity i does not generate the pressure j : γ_{AiPj} = 0
- Ai_{norm}: intensity of activity i, normalized between 0 and 1

According to the number of activities that generate each pressure, the intensities of each pressure can be expressed in different value ranges. For example, a pressure generated by 5 activities has an intensity value between 0 and 5 whereas a pressure generated by only one activity has an 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.

$$\mathrm{SPI} = f_{\mathrm{norm}}(\mathrm{Pj})$$

Where:
- SPI: index of single pressure j
- Pj: intensity of pressure j
- f_{norm}: log transformation and normalizing function to obtain value in [0-1]

Concomitant pressures index (CPI)

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

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

$$\mathrm{CPI\_option1} = \sum_{j=1}^{nj} \mathrm{Pj}$$

Where:
- Pj: presence/absence of the pressure j [0/1]
- ni: number of pressures types

- **Index of multi-pressure 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.

$$\text{CPI\_option2} = f_{norm}\left(\sum_{j=1}^{nj} f_{norm}(Pj)\right)$$

Where: Pj intensity of the pressure j
ni number of pressure types
f_{norm} log transformation and normalizing function to obtain value in [0-1]

2.3.4. Risk of exposure mapping

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.

$$REX_{Pj} = E_{norm} \times Pj_{norm}$$

Where: Pj_{norm} normalized intensity of the pressure j
E_{norm} normalized density of the species studied

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.

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

Where: REX_{Pj} normalized exposure risk to pressure j
f_{norm} log transformation and normalizing function to obtain value in [0-1]

2.3.5. 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 dataset. 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 of dubious quality 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 gives 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.

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.

$$\mathrm{ICRT\_AP\_Pj} = \begin{cases} \dfrac{\sum(A_i * \mathrm{IndConf}_{\gamma j,i})}{5 * \sum A_i} & \text{if } \sum A_i \neq 0 \\ 1 \text{ if } \sum A_i = 0 \end{cases}$$

- **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.

$$\mathrm{ICQ\_AP\_Pj} = \begin{cases} \dfrac{\sum(IQ_{Ai} * \gamma_{Ai/Pj})}{\sum \gamma_{Ai/Pj}} & \text{if } \sum \gamma_{Ai/Pj} \neq 0 \\ 1 \text{ if } \sum \gamma_{Ai/Pj} = 0 \end{cases}$$

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

$$IC_{Pj} = \mathrm{ICQ\_AP\_Pj} * \mathrm{ICRT\_AP\_Pj}$$

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 (IQ_E);
- 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.

$$
\text{IC\_REX\_Pj} = \begin{cases} \text{IQ}_\text{E} & \text{if } \begin{cases} E = 0 \\ P_j \neq 0 \end{cases} \\ \text{IC}_{\text{Pj}} & \text{if } \begin{cases} E \neq 0 \\ P_j = 0 \end{cases} \\ \text{IQ}_\text{E} * \text{IC}_{\text{Pj}} & \text{if } \begin{cases} E \neq 0 \\ P_j \neq 0 \end{cases} \text{ or } \begin{cases} E = 0 \\ P_j = 0 \end{cases} \end{cases}
$$

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.

$$
\boldsymbol{IC_{REXC}} = \begin{cases} \dfrac{\sum(\boldsymbol{REXC_{PJ}} * \boldsymbol{IC\_REX\_P_j})}{\sum \boldsymbol{REXC_{Pj}}} \boldsymbol{if} \sum \boldsymbol{REXC_{Pj}} \neq \boldsymbol{0} \\ \boldsymbol{avg(IC\_REXC\_Pj)} \ \boldsymbol{if} \sum \boldsymbol{REXC_{Pj}} = \boldsymbol{0} \end{cases}
$$

3. RESULTS

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

The first simulation is based on French data and compares summer and winter exposure risk to concomitant pressures of little delphininae (short-beaked common dolphin and striped dolphin).

The second simulation concerns the group of seabirds great grey gulls (European herring gull and yellow-legged gull), using a mix of Spanish and French datasets (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.

Table 10: Source of data used for 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 trawls	FRA	FRA
		Bottom trawls	FRA	Mixed
		Seines	FRA	FRA
	Marine traffic	Passenger	FRA	SPA
		Cargo	FRA	SPA
		Tanker	FRA	SPA
		High Speed Craft	FRA	SPA
		Pleasure craft and dive	FRA	-
		Fishing	FRA	-
		Specific (Military Ops and Dredger)	FRA	-
		Specific (Law Enforce, Anti-pollution, Port Tender, Pilot, Etc.)	FRA	SPA
		Fishing, pleasure craft, dive and specific (military ops and dredger)	-	SPA
		Other	FRA	SPA
Pressure	Underwater noise	Continuous (125 hertz)	FRA	SPA
		Impulsive	FRA	not available
	Marine litter	Floating macro-waste	FRA	FRA
Ecological component	Cetaceans	Little delphininae	FRA	FRA
	Seabirds	Great grey gulls	FRA	FRA

See Annex II: Detail of fishing categories for more details on fishing categories.

3.1. Simulation n°1: Summer and winter exposure risk to concomitant pressures of little delphininae (French datasets)

3.1.1. Activities - Pressures - Species relationship matrix

Activities and pressures taken into account in this analysis were selected with regard to their effect on the species considered, thanks to expert judgment (Table 11). Pressures considered affecting little delphininae are bycatch, floating macro-waste, continuous and impulsive underwater noise.

For this analysis, VMS data were used to calculate pressures of collision and visual disturbance created by fishing vessels in place of AIS data of fishing boats, which can be incomplete as the AIS device is not mandatory for all fishing boats.

Table 11: Activities-pressures relationship matrix of common bottlenose dolphin

Activity	Activity type	Pressure	Little delphininae
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	not sensitive
		Visual disturbance	not 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	not sensitive
		Visual disturbance	not sensitive
	Specific (military ops and dredger)	Collision	not sensitive

		Visual disturbance	not sensitive
	Specific (law enforce, special craft, medical trans, anti-pollution, tug, SAR, Port tender, local vessel and pilot 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-plastic	sensitive

3.1.2. Species habitat model

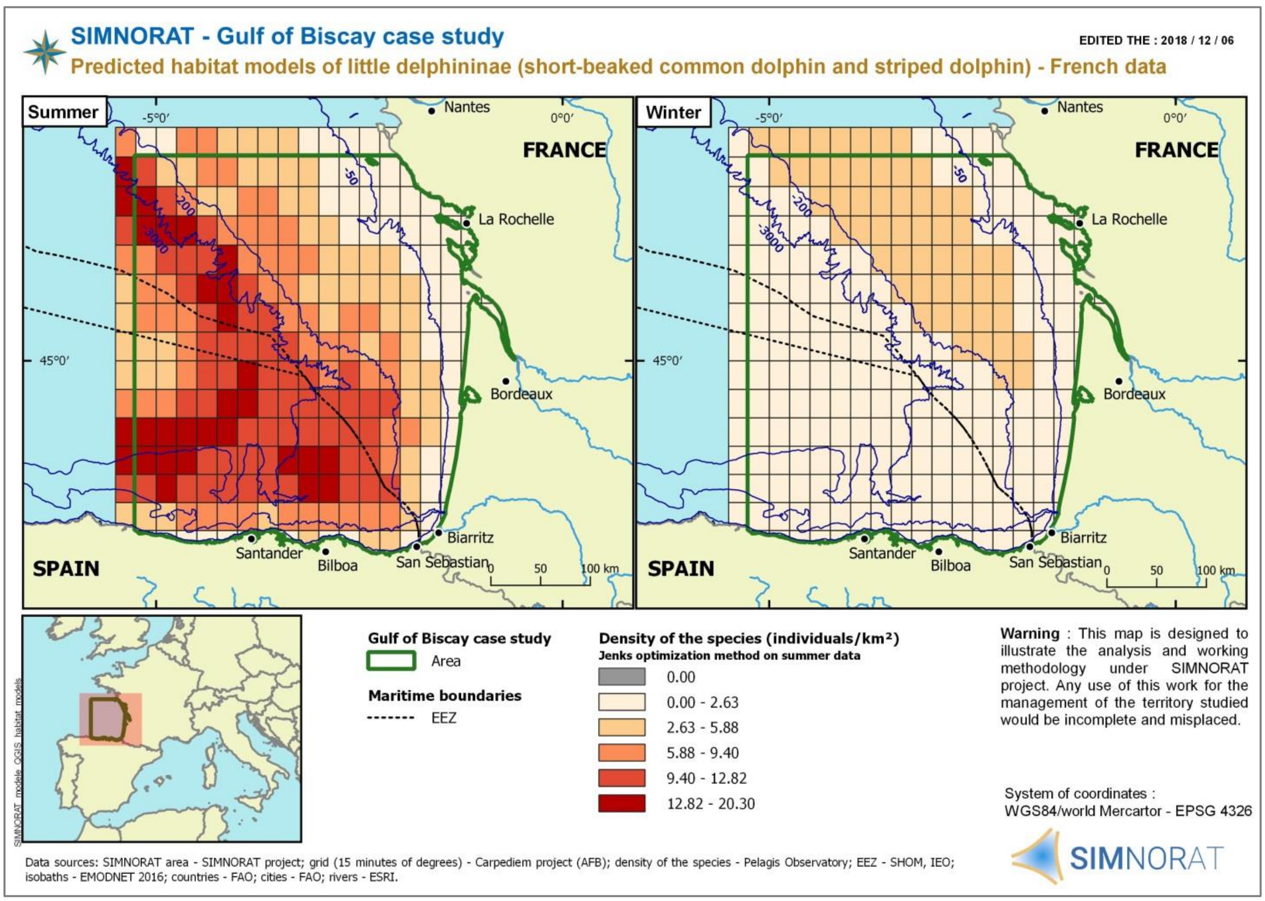

Figure 10: Predicted habitat model of little delphininae (short-beaked common dolphin and striped dolphin) in Bay of Biscay in winter 2011-2012 and summer 2012

The short-beaked common dolphin and the striped dolphin, classified as “little delphininae”, are the most abundant cetaceans in the region but their distribution is seasonally contrasted (Figure 10) (Pettex *et al.*, 2014). Short-beaked dolphins are dominant on the continental shelf whereas striped dolphins are rather located in offshore waters. In summer, little delphininae are more frequently observed in offshore waters, along the slope, with up to 20 individuals on average per day. Some individuals are also present on the continental shelf, after the isobaths of -50 m. In winter, they are less and concentrated on the French wide continental shelf between isobaths -50 m and -200 m. As data came from a unique aerial survey campaign realized in 2011-2012, the assessment has to be interpreted with caution.

3.1.3. Human activities: multi-activity mapping

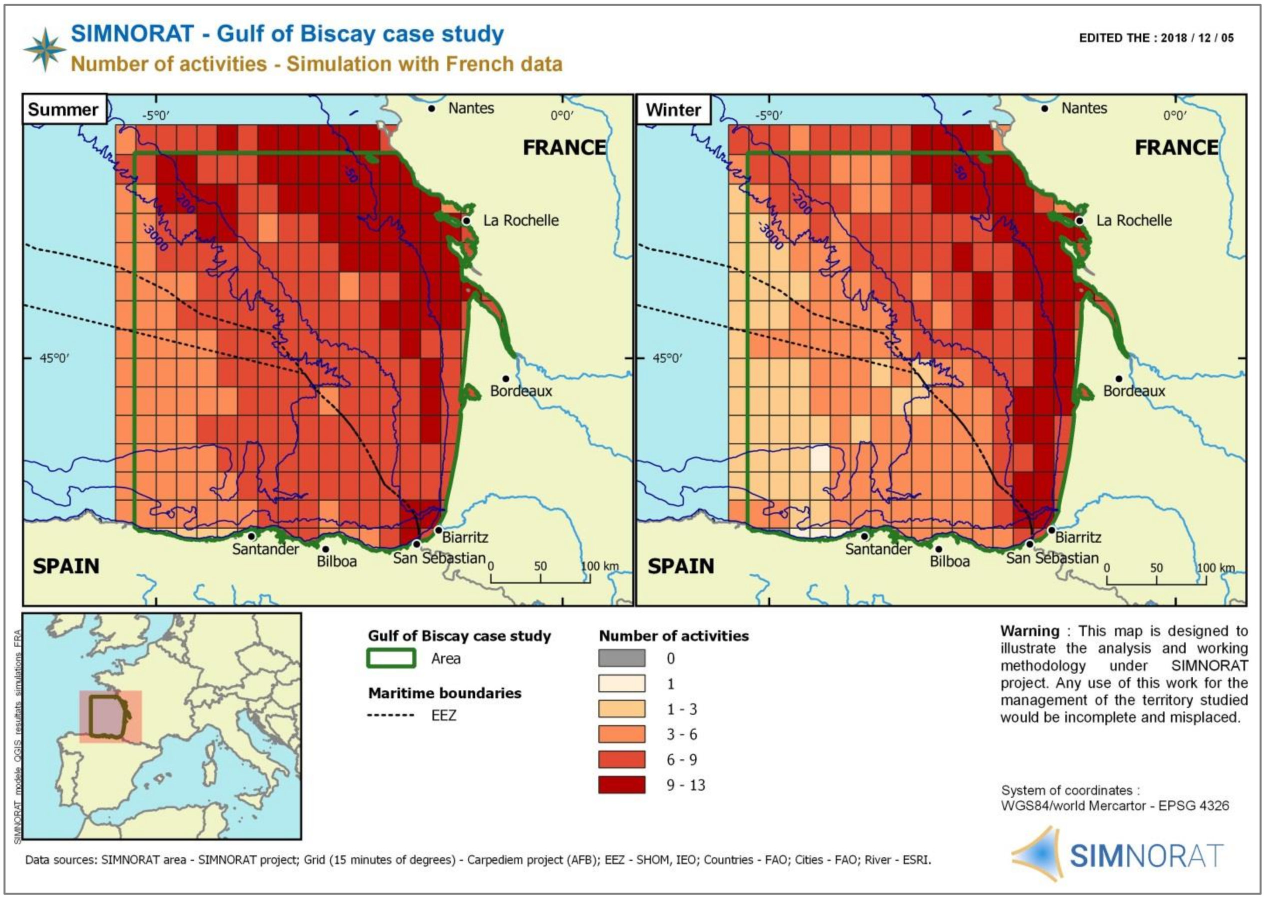

Figure 11: Number of activities (simulation with French datasets)

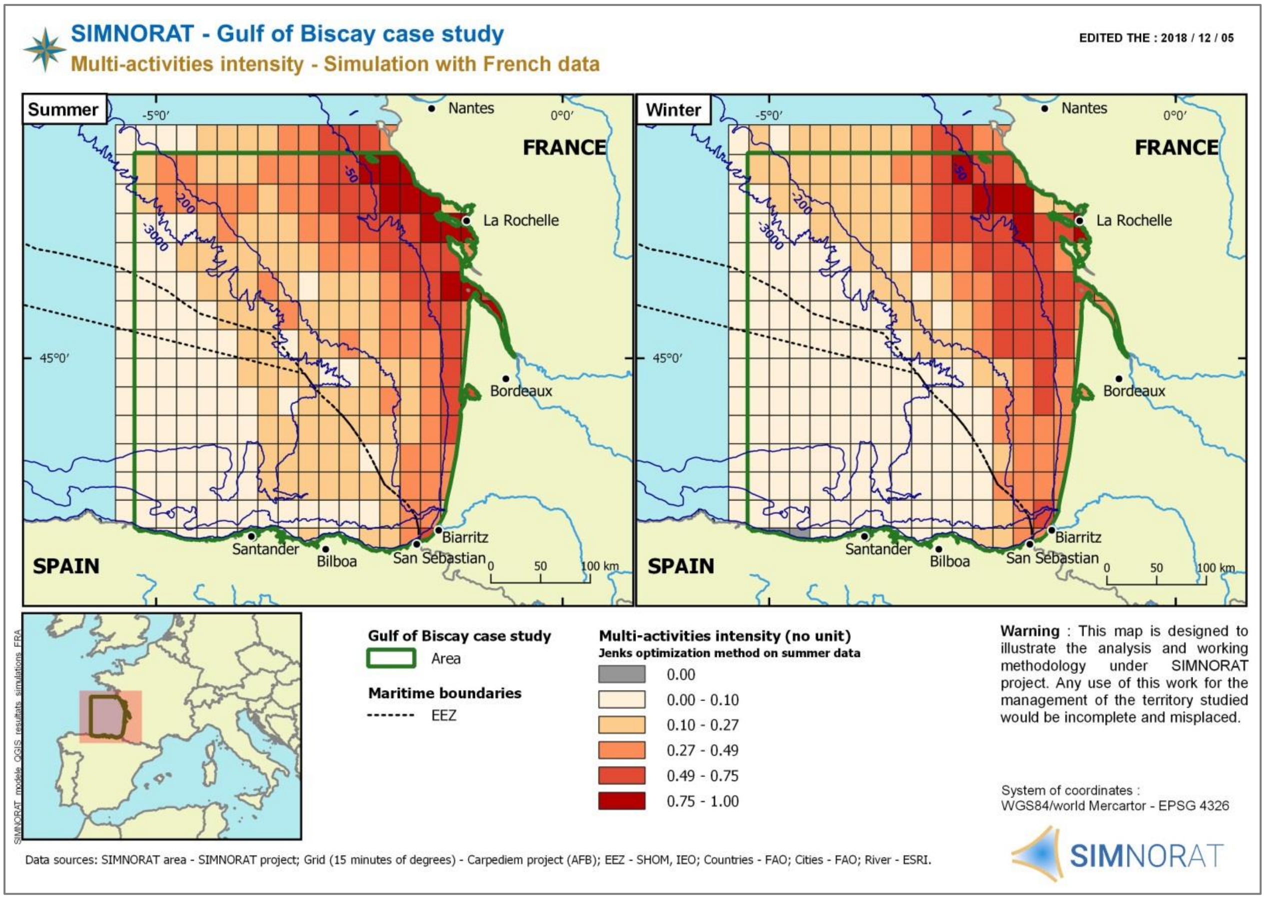

Figure 12: Multi-activity intensity (simulation with French datasets)

In this analysis, the activities considered are fishing and navigation. For both seasons, there are more activities (Figure 11) and a higher multi-activity intensity index (Figure 12) on the French continental shelf and particularly near the coast than in offshore waters and on the Spanish side. Indeed, fishing and navigation are rather coastal activities and datasets used only correspond to French fishing boats and navigation data received by French AIS stations. Moreover, there are overall more activities during summer. For both seasons, the multi-activity intensity index is concentrated on the continental shelf.

3.1.4. Concomitant pressures: multi-pressure mapping

According to the activities-pressures relationship matrix, little delphininae risk to be exposed to 4 pressures: bycatch, floating macro-waste, impulsive and continuous underwater noise.

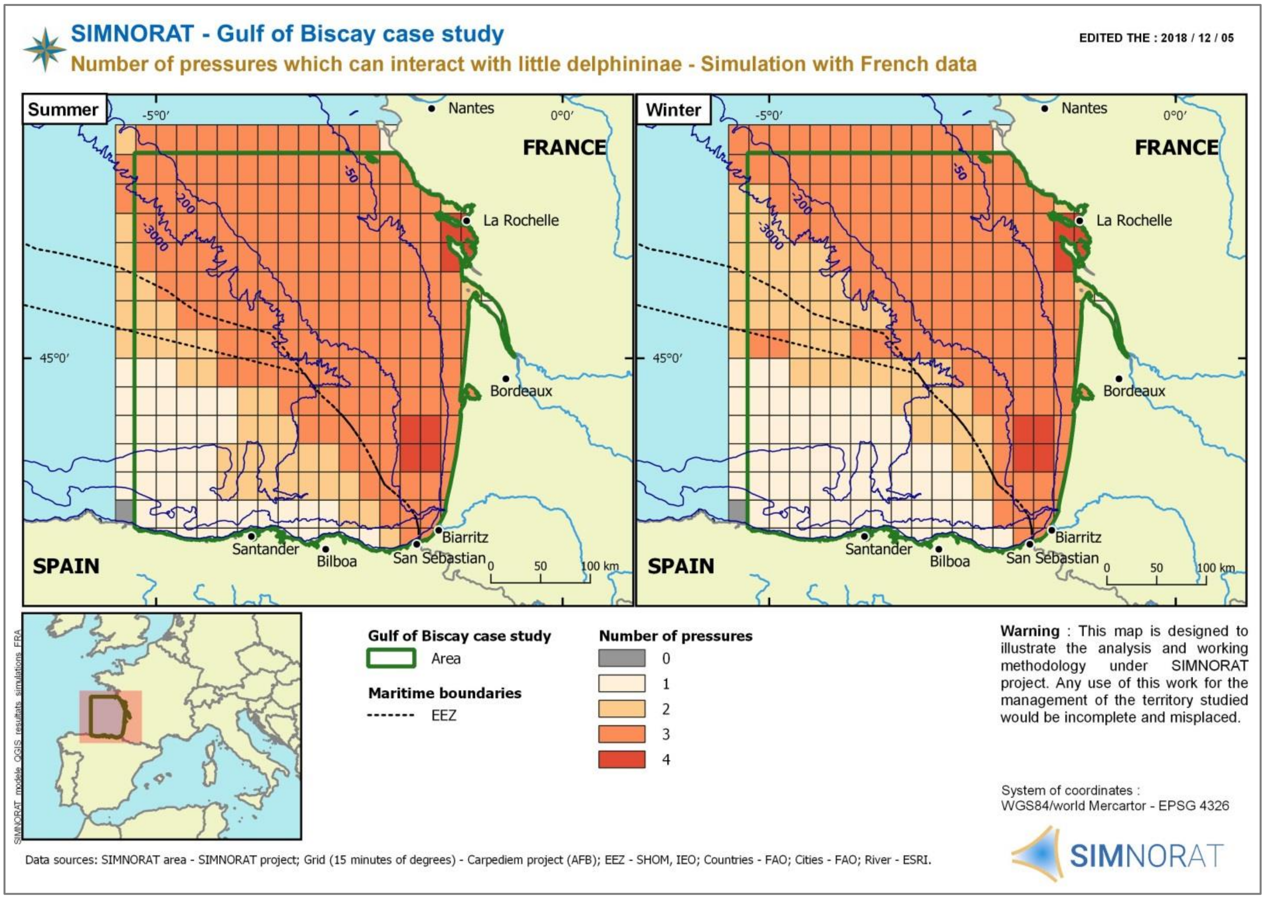

Figure 13: Number of pressures that can interact with little delphininae (simulation with French datasets)

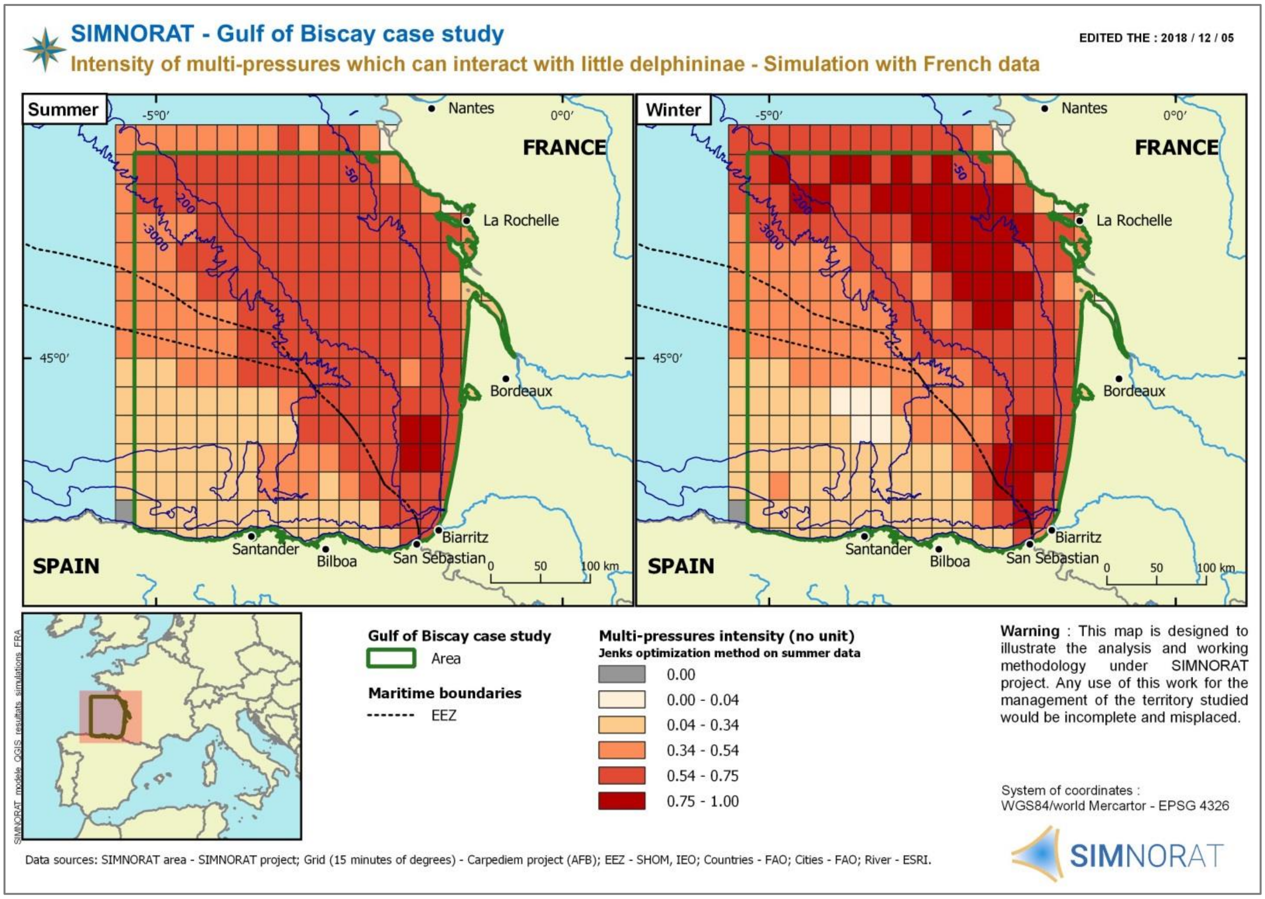

Figure 14: Intensity of multi-pressure that can interact with little delphininae (simulation with French datasets)

Pressures are mainly observed on the French side due to lack of input data on the Spanish side. For both seasons, the continental shelf displays the greatest number of cumulative pressures (Figure 13). Cells concerned by 4 pressures include the pressure of impulsive underwater noise.

The high multi-pressure intensity values are concentrated on the continental shelf (Figure 14). Maximal values (0,75 - 1) are located at the south-east of the case study and continental shelf in front of La Rochelle. It is principally explained by the bycatch pressure.

3.1.5. Risk of exposure mapping

The maps of the exposure risk of these cetaceans to single pressures are displayed below: bycatch, floating macro-waste, impulsive and continuous underwater noise.

Exposure risk to a single pressure

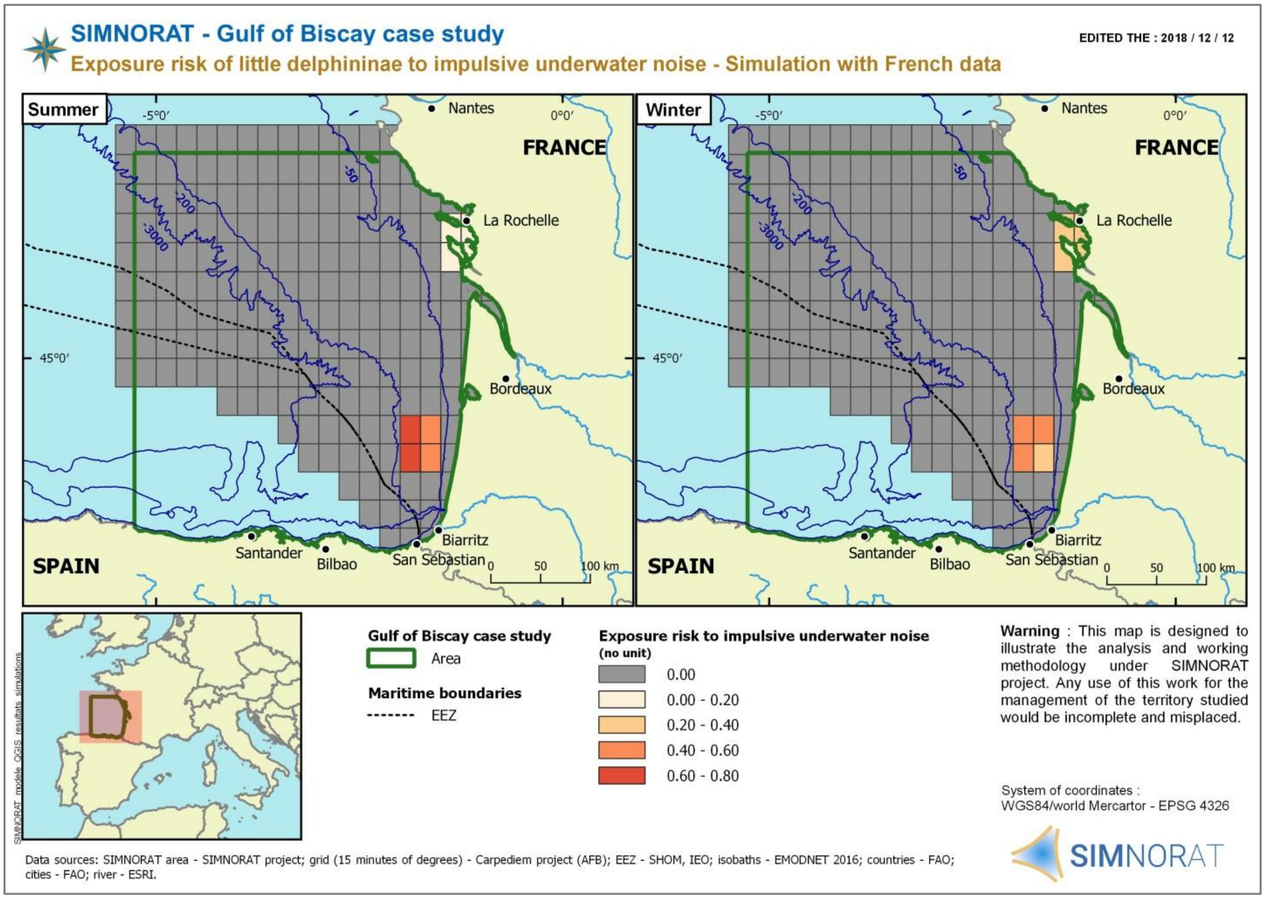

Figure 15: Exposure risk to impulsive underwater noise of little delphininae (simulation with French datasets)

Impulsive underwater noise data do not cover all the case study area, particularly in Spanish waters: few cells on the continental shelf. Therefore, few little delphininae are concerned by an exposure risk to the impulsive underwater noise pressure: only in the south-eastern area of the case study and between Ré and Oléron islands (Figure 15). As impulsive noise data result from the summing up of days over the year, difference of exposure risk values between winter and summer is explained by the density of little delphininae. Moreover, only the French database of impulsive sound emission was taken into account; therefore, the assessment has to be interpreted with caution.

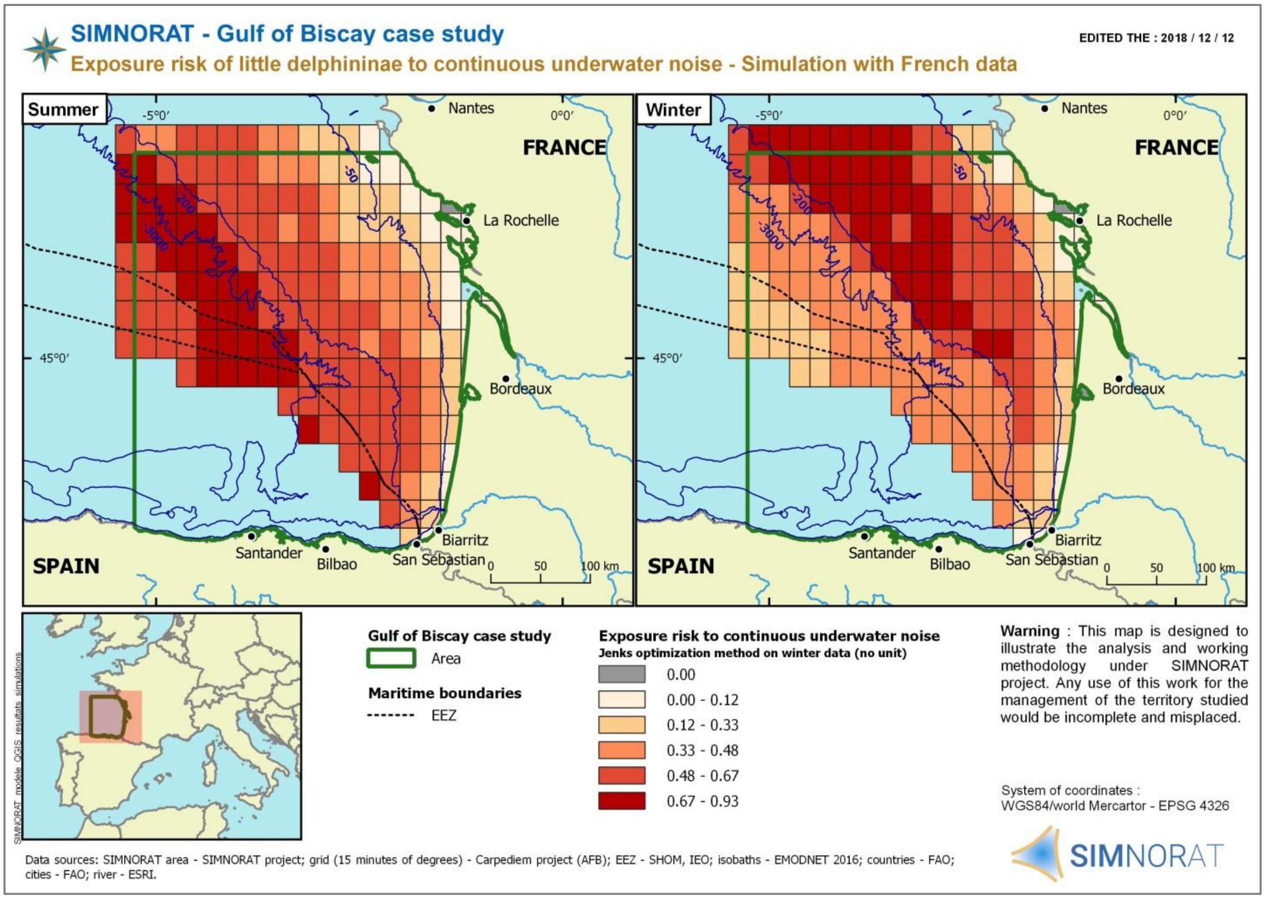

Figure 16: Exposure risk to continuous underwater noise of little delphininae (simulation with French datasets)

As in the case of impulsive noise, continuous underwater noise data just concern the French Economic and Exclusive Zone (Figure 16). Moreover, data are made up by annual averages, so the difference between winter and summer is explained by the density of little delphininae. In this way, the greatest exposure risk to continuous noise seems more important at the level of the continental slope in summer and on the continental shelf in winter.

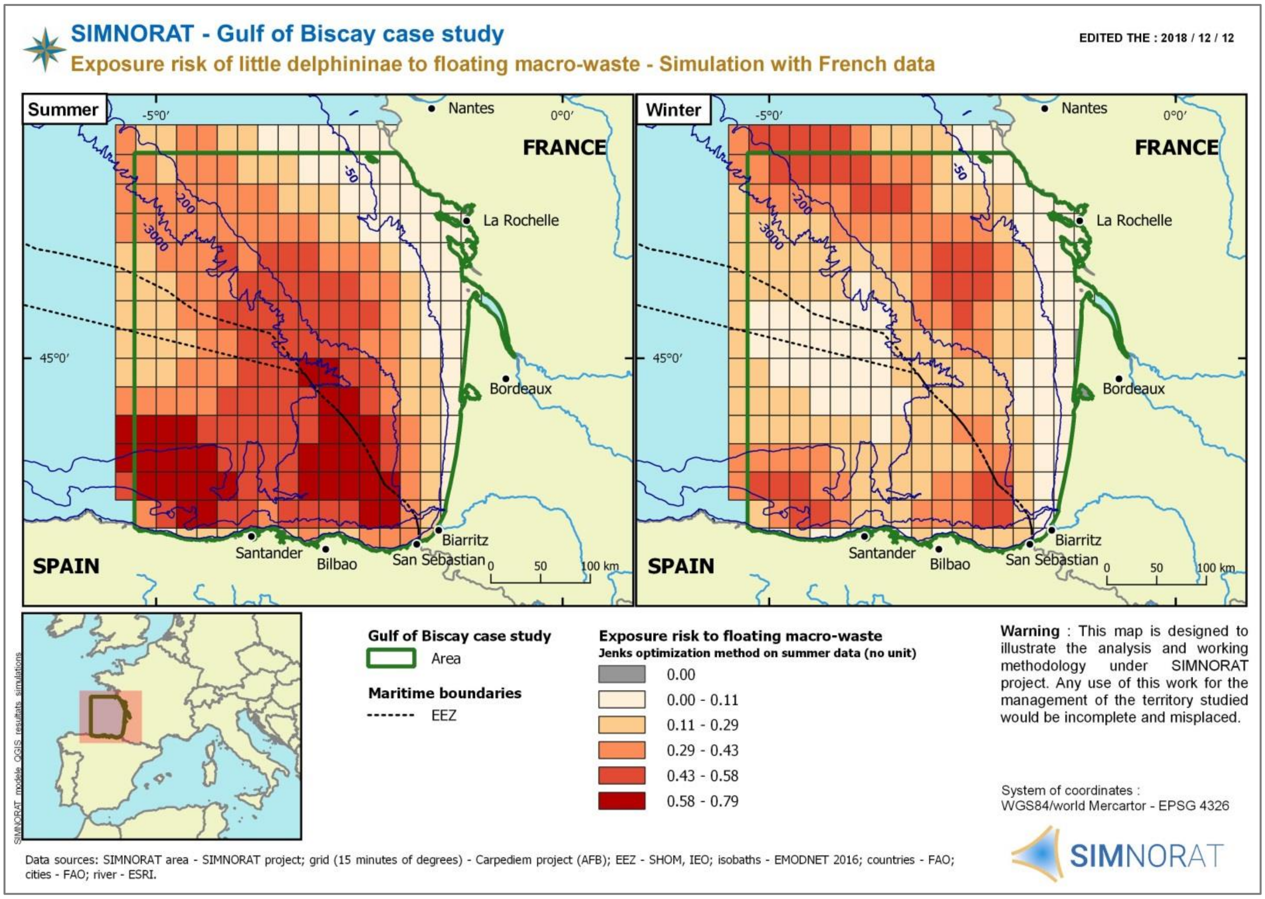

Figure 17: Exposure risk to floating macro-waste of little delphininae (simulation with French datasets)

Exposure risk of little delphininae to floating macro-waste is spatially different depending on the season (Figure 17). In summer, the greatest risk of exposure appears in the south of the Bay of Biscay whereas in winter several clusters appear along the continental shelf and slope.

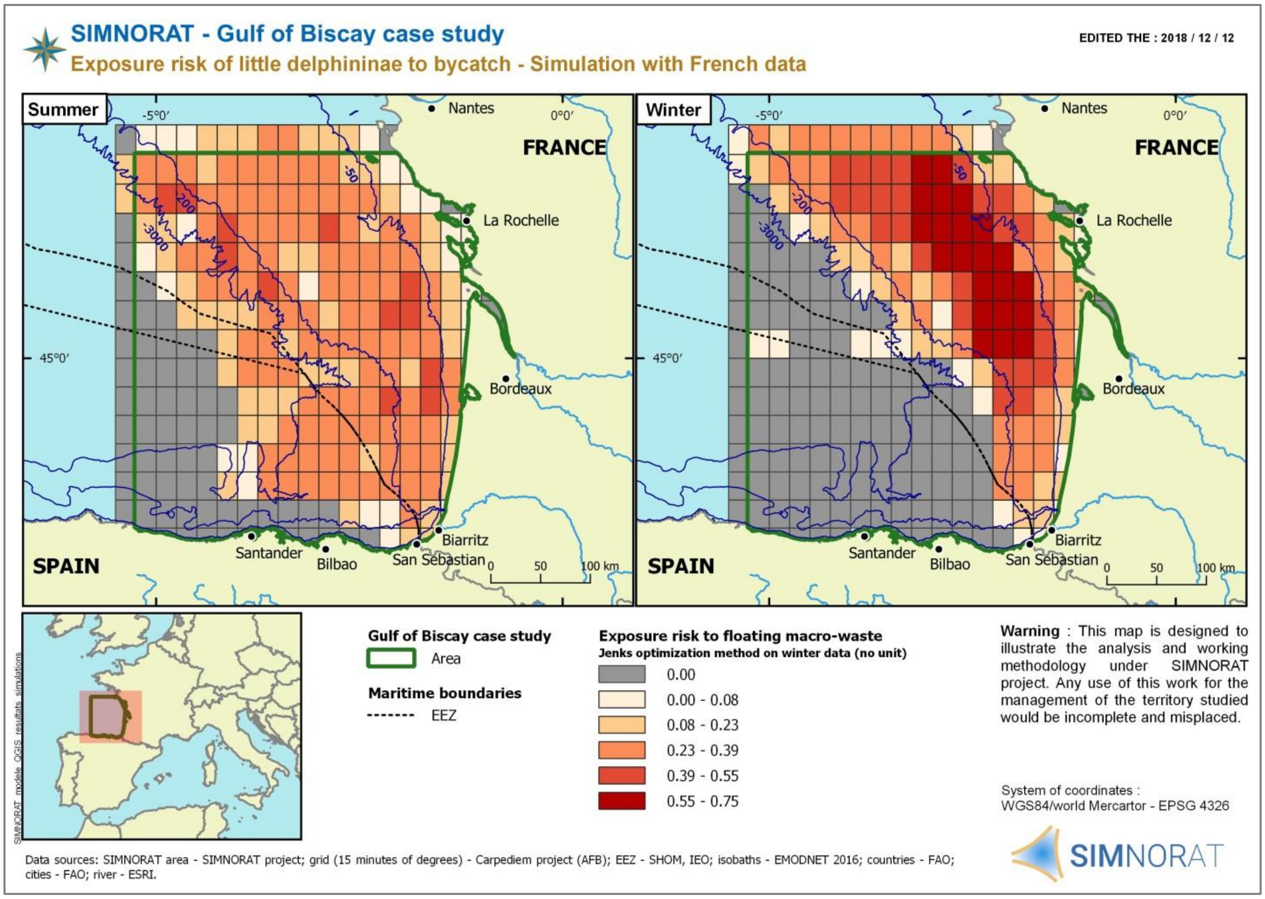

Figure 18: Exposure risk to bycatch of little delphininae (simulation with French datasets)

Little delphininae are more exposed to bycatch at the level of the continental shelf and slope and particularly in winter where the highest risk values are concentrated in the northern half of the case study (Figure 18). Exposure risk seems to be existing exclusively on French side because of the lack of data of Spanish fishing boats.

Exposure risk to concomitant pressures (REXC)

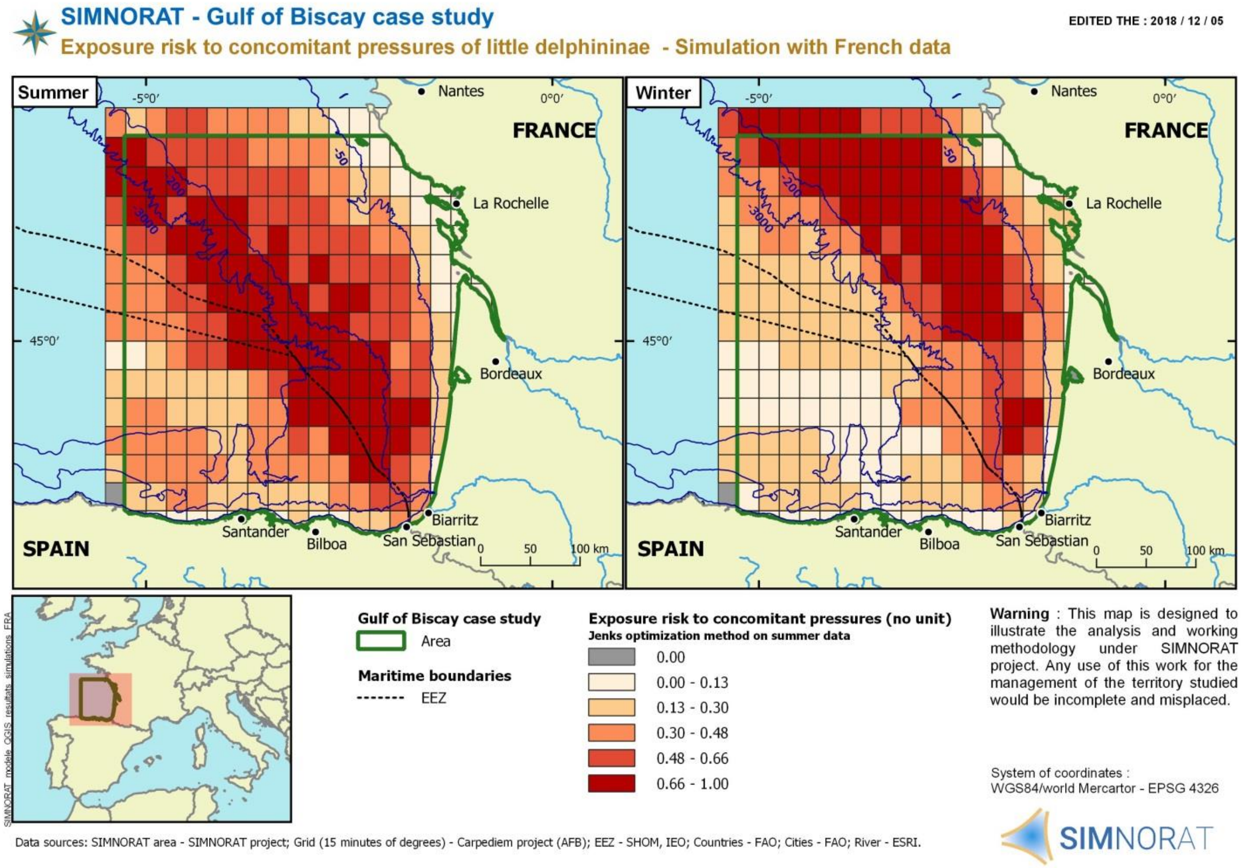

Figure 19: Exposure risk to multi-pressures of little delphininae (simulation with French datasets)

As for the majority of exposure maps to single pressures, the exposure risk to multi-pressures seems more important in French waters due to the lack of data of activities and pressures on the Spanish side (Figure 19). This is why the intensity is low in Spanish waters despite the abundance of dolphins, especially in summer. In French waters, the exposure risk is higher along the slope in summer and on the continental shelf during the winter. In summer this situation is explained by the important density of little delphininae and pressures along the slope. In winter, important values of exposure risk values are due to a high index of multi-pressures intensity and a moderate abundance of dolphins on the French continental shelf.

Confidence index of exposure risk to concomitant pressures

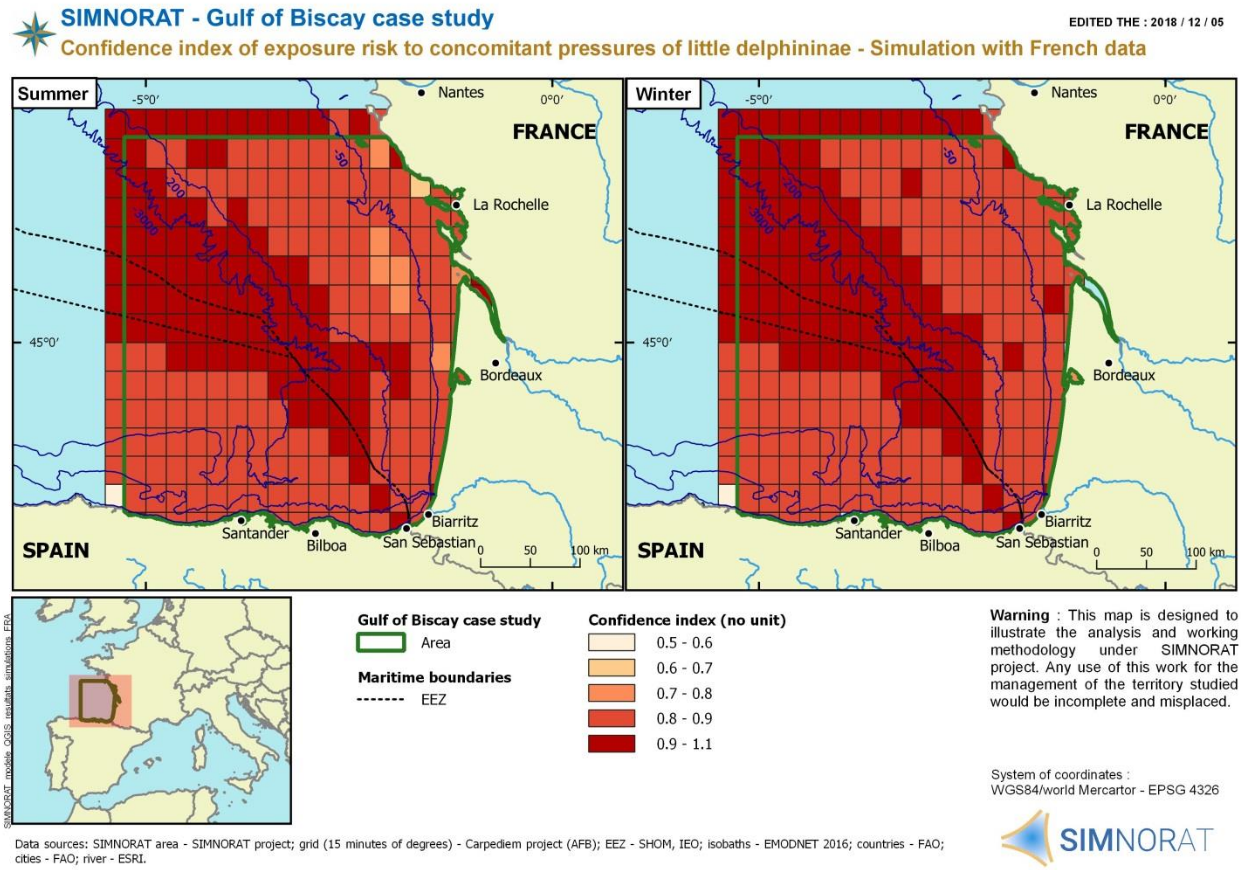

Figure 20: Confidence index of exposure risk to multi-pressures of little delphininae (simulation with French datasets)

The confidence index is overall high on the whole area (above 80 percent) for both seasons (Figure 20).The lowest values are explained by the quality index of the data or the confidence indexes of the activities-pressures relationship matrix.

3.2. Simulation n°2: Summer and winter exposure risk to concomitant pressures of great grey gulls (Spanish and French datasets)

3.2.1. Activities - Pressures - Species relationship matrix

Activities and pressures taken into account in this analysis where selected with regard to their effect on the species considered, thanks to expert judgment. Then, the activities and pressures considered impacting great grey gulls are identified in the Table 12.

For this analysis, VMS data were used to calculate pressures of collision and visual disturbance created by fishing vessels 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 was not used as pressure due to lack of data in Spanish waters.

Table 12: Activities-pressures relationship matrix of great grey gulls

Activity	Activity type	Pressure	Great grey gulls
Fishing	Nets	Bycatch	not 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	not sensitive
		Collision	not sensitive
		Visual disturbance	unknown
	Seines	Bycatch	not 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 crafts and specific (military ops and dredger)	Collision	not sensitive
		Visual disturbance	unknown
	Specific (law enforce, special craft, medical trans, anti-pollution, tug, SAR, Port tender, local vessel and pilot vessel)	Collision	not sensitive
		Visual disturbance	unknown
	Other	Collision	not sensitive
		Visual disturbance	unknown
-	-	Continuous underwater noise	not sensitive
		Floating macro-plastic	unknown

3.2.2. Species model habitat

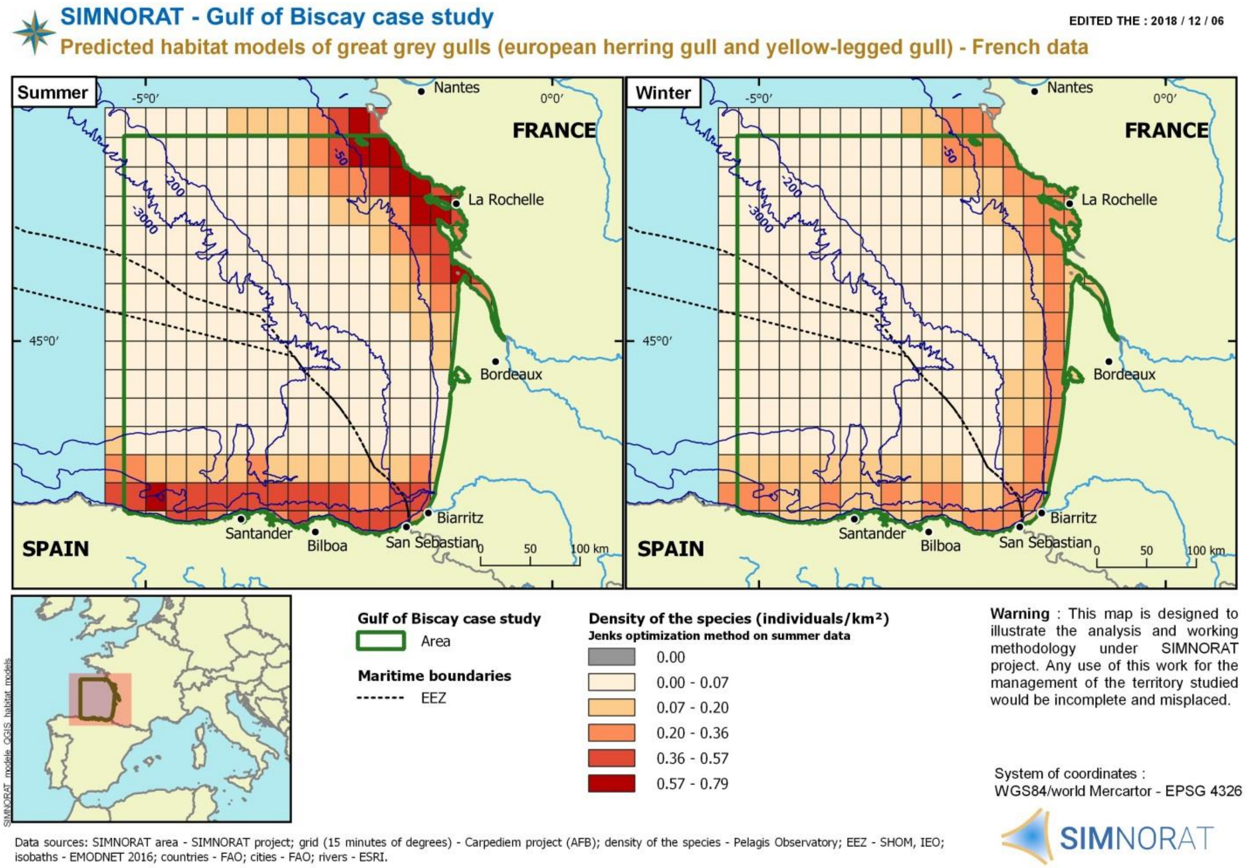

Figure 21: Predicted habitat model of great grey gulls (European herring gull and yellow-legged gull) in Bay of Biscay in winter 2011-2012 and summer 2012

Distribution of great grey gulls (European herring gull and yellow-legged gull) does not vary from summer to winter, except in density of individuals, less important in winter (Figure 21). In summer, great grey gulls remain more close to rocky shorelines (direct link with colonies), associated with weak monthly maximum currents, dynamic waters but mean altimetry equal to zero. These make up the reasons why they avoid the Nouvelle-Aquitaine coast. In winter, their distribution is mainly due to the distance to sandy coasts, with a preference for coastal areas where monthly maximum currents are low (Pettex *et al.*, 2014).

Density of great grey gulls does not exceed one individual per day in average but their distribution is similar between Spanish and French coasts. As data came from a unique aerial survey campaign realized in 2011-2012, the assessment has to be interpreted with caution.

3.2.3. Human activities: multi-activity mapping

1.1.1. Multi-activity mapping

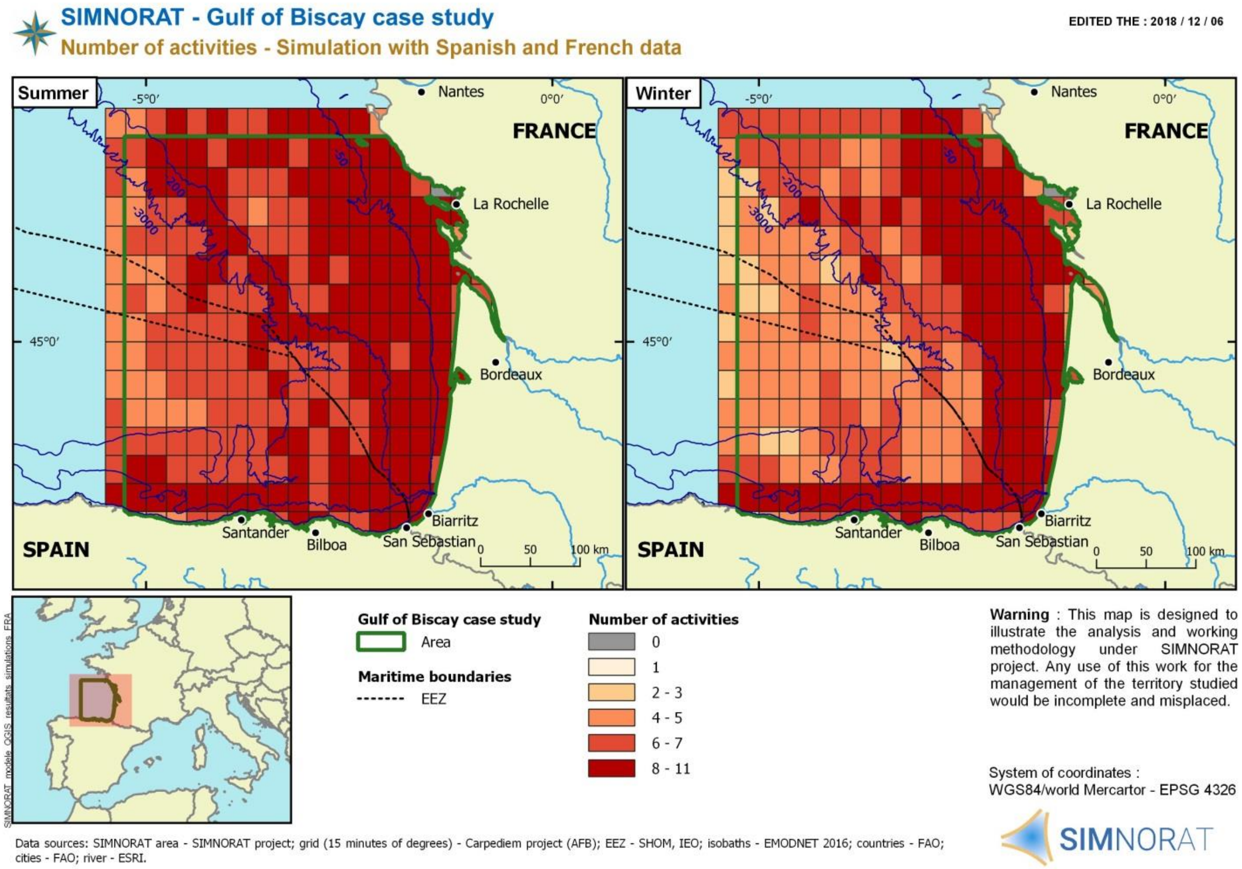

Figure 22: Number of activities (simulation with Spanish and French datasets)

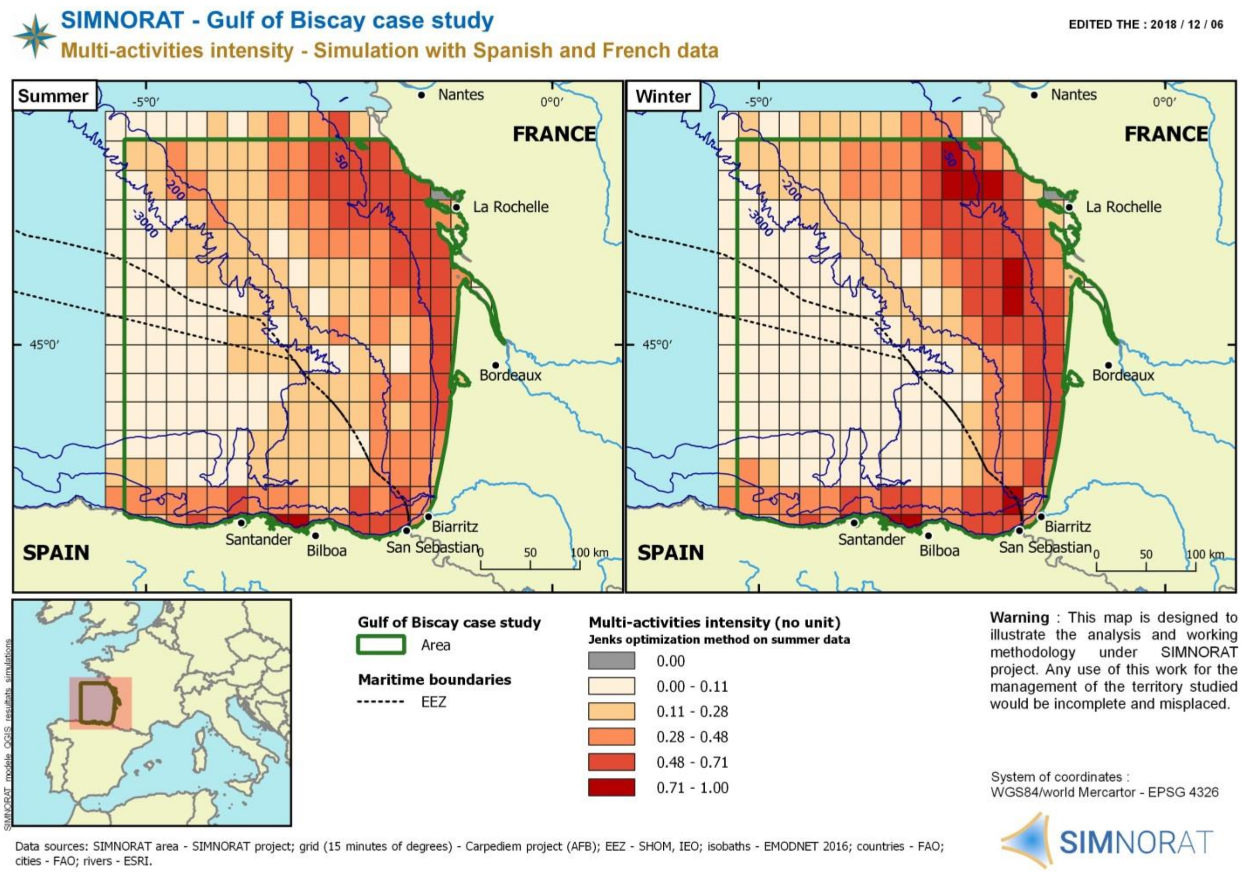

Figure 23: Multi-activities intensity (simulation with Spanish and French datasets)

In this analysis, the activities considered are fishing and navigation. For both seasons, there are more activities at the level of the continental shelf and slope (Figure 22). The higher multi-activity intensity values are concentrated near the coast and the isobath -50m (Figure 23). Indeed, fishing and navigation are more coastal activities. Moreover, there are slightly more activities during summer.

3.2.4. Concomitant pressures : multi-pressure mapping

According to activities-pressures relationship matrix, great grey gulls risk to be exposed to only 2 pressures: bycatch, and floating macro-waste.

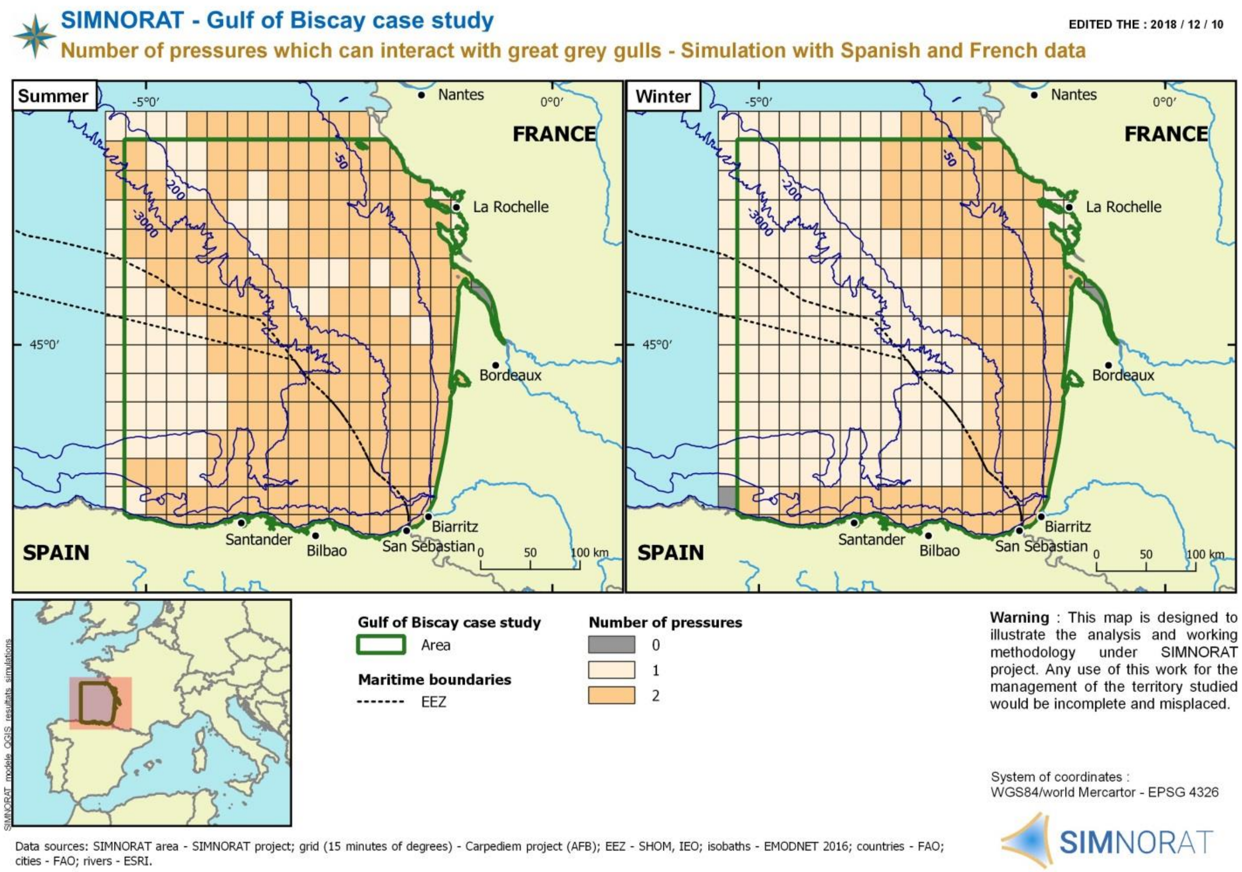

Figure 24: Number of pressures that can interact with great grey gulls (simulation with Spanish and French datasets)

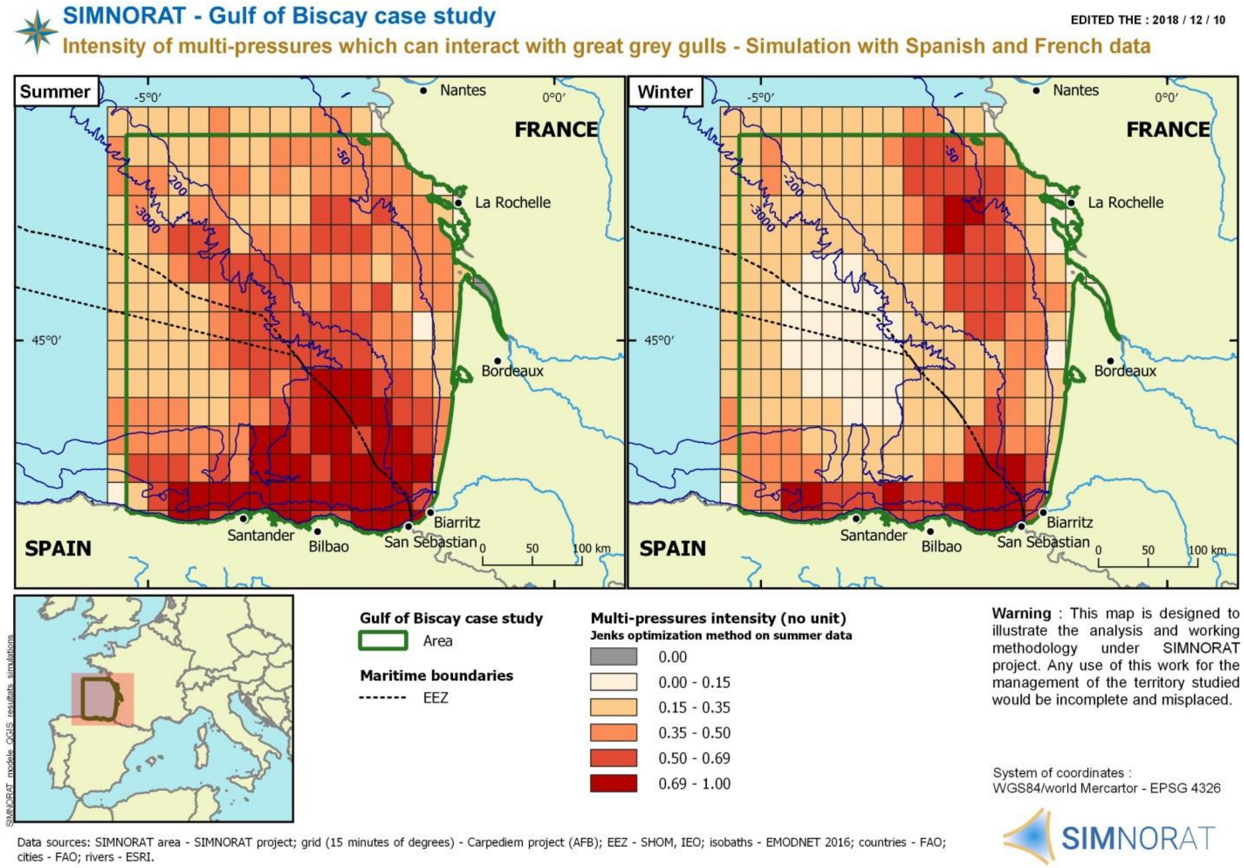

Figure 25: Intensity of multi-pressures that can interact with great grey gulls (simulation with Spanish and French datasets)

There are more cells recording two pressures in summer, distributed on almost all the case study area, whereas they are concentrated on the continental shelf in winter (Figure 24). This is due to more coastal fishing activities in winter. The south of the Bay of Biscay records higher intensities, especially in summer, due to the litter distribution (Figure 25).

3.2.5. Risk of exposure mapping

Exposure risk to concomitant pressures (REXC)

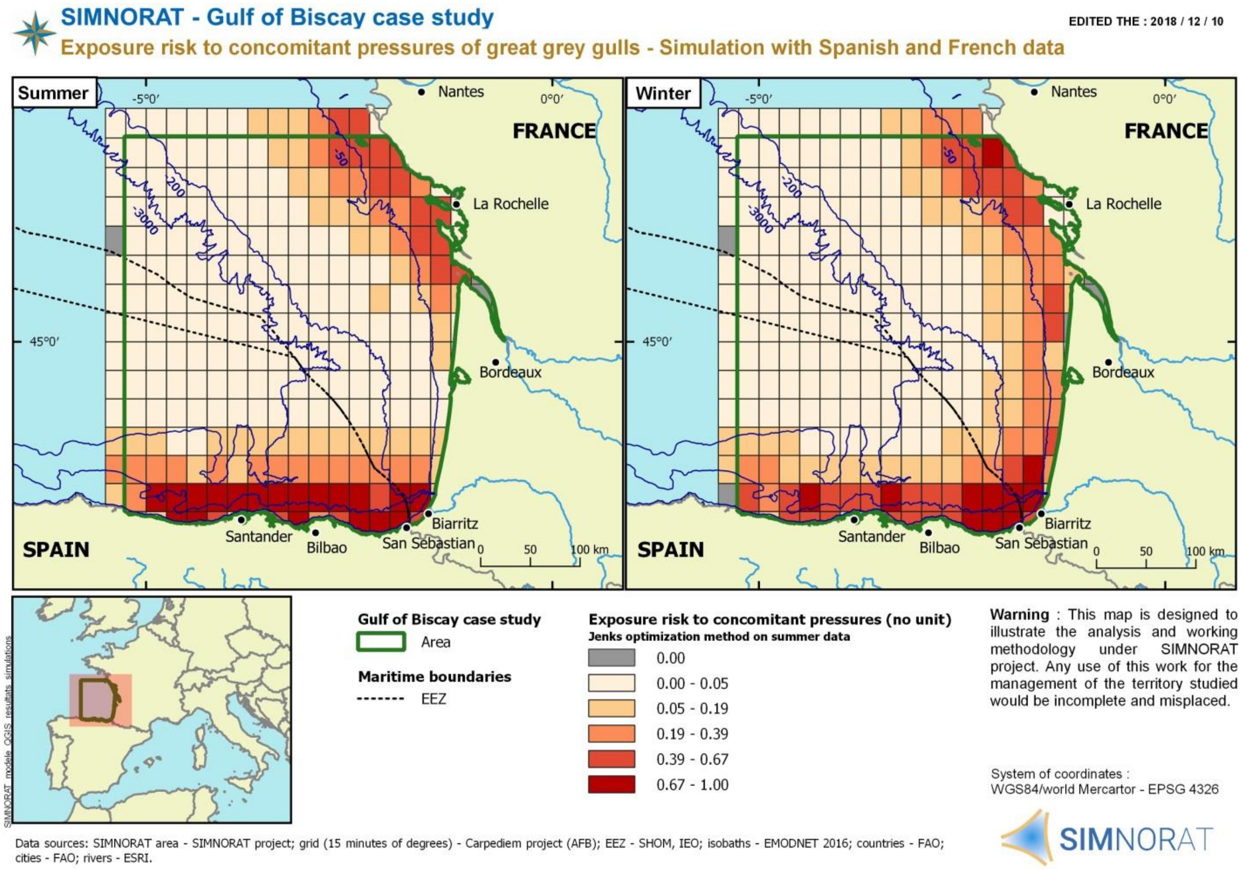

Figure 26: Exposure risk to multi-pressures of great grey gulls (simulation with Spanish and French datasets)

The exposure risk of great grey gulls to concomitant pressures is important on the continental shelf near the Spanish and French coast (Figure 26). It is the result of crossing high abundance of gulls and high multi-pressures intensity. Thus, as the multi-pressure intensity, the exposure risk is slightly more important at the south of the Bay of Biscay, on the Spanish coast.

Confidence index of exposure risk to concomitant pressures

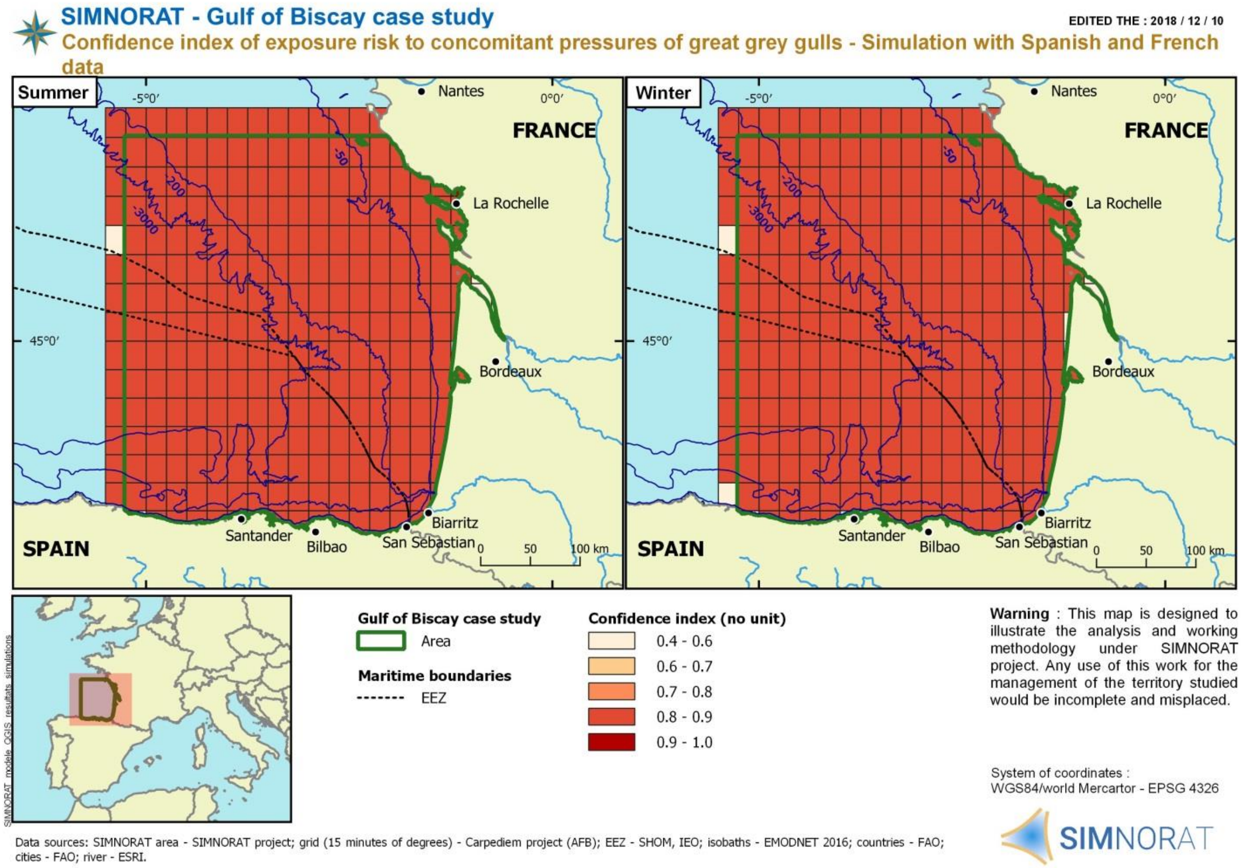

Figure 27: Confidence index of exposure risk to multi-pressures of great grey gulls (simulation with Spanish and French datasets)

The confidence index is overall high on the whole area (above 80 percent) for both seasons (Figure 27).The lowest values are explained by the quality index of the data or the confidence indexes of the activities-pressures relationship matrix.

4. DISCUSSION

4.1.Lessons from this cross-border exercise

a) The networking of partners from the two countries involved in the project is an important and needed first step for a better assessment of transboundary stakes. The discussion between them 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 in order to develop coherent planning and management approaches on both sides of the maritime borders. The work presented in this report ultimately illustrates some progress made together.

After the end of the project, **this network should be supported, politically and technically, to continue to work and to progress on these 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 SIMNORAT 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 lessons 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 has concerned the development of a coherent and operational dataset to implement and illustrate the method. The Spanish and French partners have tried to mobilize and prepare the datasets to form one interoperable dataset 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. The 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 addressed through methodological development, but they imply limits in the interpretation done with the results. However, some difficulties cannot be solved at the 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, and methodological development associated (underwater noise, floating macro-waste).

This work can be easily linked to current works in progress and will need to be maintained, considering improvement identified 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 greater efforts to reach a permissible level of confidence.

4.2.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 components and human activities, including temporal aspects, is an objective that integrates 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 of development and despite the many imperfections, the methods and tools developed within the framework of the project allowed 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 outputs could be greatly improved, while they could serve as a basis for shared knowledge and discussion for decision-makers. It could contribute to develop a coherent marine spatial planning on both sides of the border, 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 has contributed to the optimization of resources, through improvement of discussions and exchanges/sharing on data, methods and tools, which may lead to the identification and use of data developed by scientific/ technical groups in other countries.

Many questions and challenges for integrating such approaches into the MSP process still remain. There are many data and methodological challenges to be addressed to improve these analytical approaches for MSP. There are several academic studies in Europe dealing with cumulative effect assessment that could provide methodological guidelines in order to develop common approach between countries (Gimard *et al*., 2018). 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 for 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.

5. 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 are good illustrations of transboundary issues for conservation of marine biodiversity, particularly in the context of MSP. For example, the distribution map of little delphininae and grey gulls, in summer or winter, shows the need to develop a coherent and coordinated management approach on both sides of the maritime boundaries. In the same way, the example maps showing the multi-activity index, multi-pressure index and risk of exposure show 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 were the methodological and technical development for the assessment of the risk of exposure and the number of variation factors to consider on ecological components like marine mammals and seabirds as a model relevant for the MSP.

The main interests 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 is stopped 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 the development of shared and accepted methods must be considered in the framework of a partnership that goes beyond the end of the SIMNORAT project.

6. 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.

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 for the 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.

Marcotte, D., Hung, K. S., Caquard S. (2015). Mapping cumulative impacts on Hong Kong's pink dolphin population. Ocean & Coastal Management 109, 51-63. https://doi.org/10.1016/j.ocecoaman.2015.02.002

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.

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.

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.

7. ANNEXES

7.1. Annex I: Cetaceans 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.

7.2. 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

7.3. Annex III: Spanish AIS data source

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 signals 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

7.4.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 of 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 of Table 14) immediately preceding the position.

As detailed in Section 2.2 Datasets description, 4 000 snapshots 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).

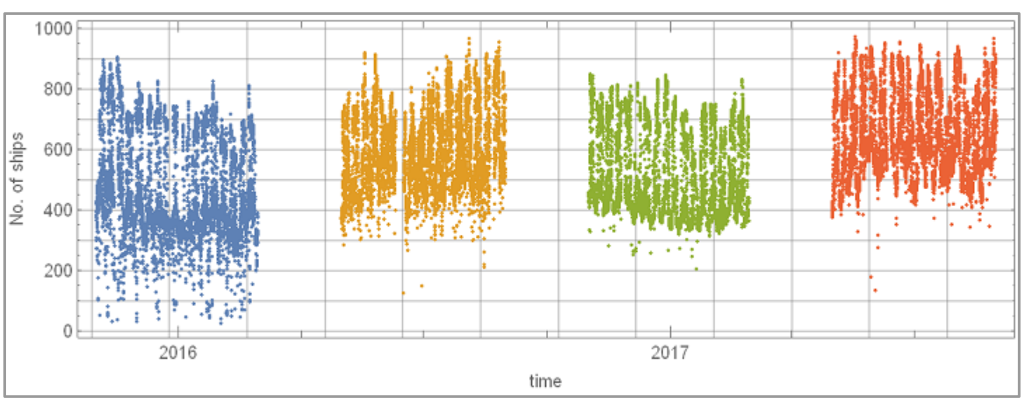

Figure 28: Amount of data per snapshot for the four seasons considered in the Bay of Biscay

Figure 28 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 29 shows a simple output of integrated summary results for the area of the Bay of Biscay, 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.

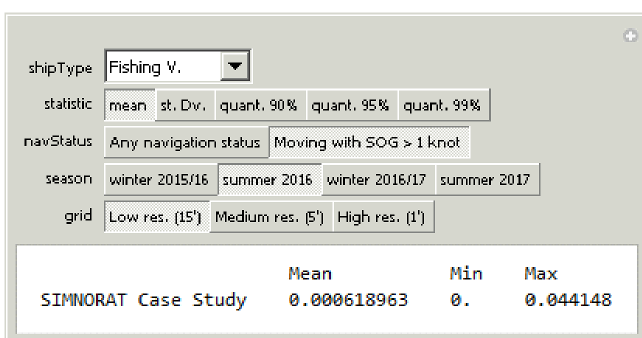

Figure 29: Summary table of values in two study areas

In addition, Figure 30 shows a scoreboard graphically displaying the average traffic density of fishing vessels in motion during the summer season of 2016, in the 15' grid resolution.

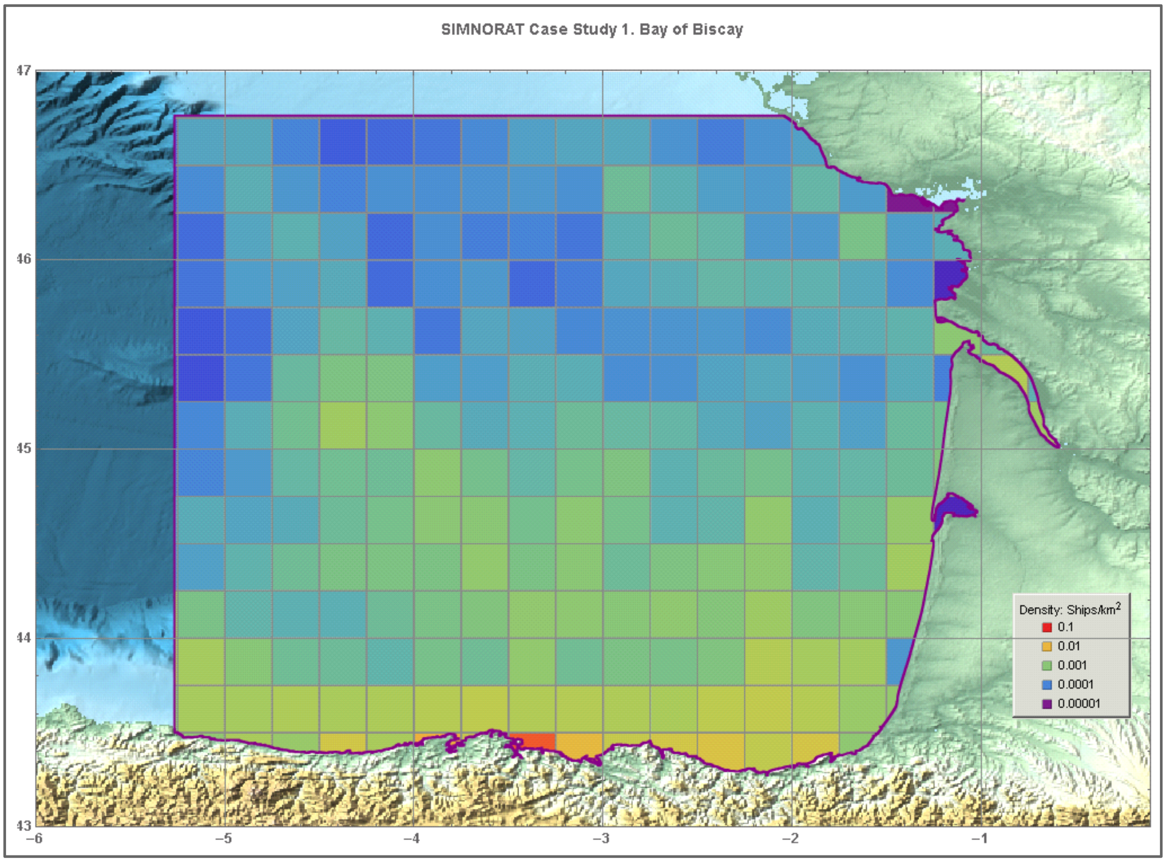

Figure 30: Graphic representation chart of maritime traffic density in the Bay of Biscay in summer (May - August 2016)

7.5. 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:

$$\mathrm{XL}\ (\mathrm{dB}) = 10\ \log(\sum_{i} 10^{\mathrm{XL_i}/10})$$

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, 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:

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

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

$$\mathrm{SPL(r\ m)} = \mathrm{SPL(1\ m)} - 20 \log \mathrm{R(m)}$$

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:

$$\mathrm{TL\ (dB)} = 20 \log \mathrm{R\ (m)}$$

For a cylindrical wave, field tubes are conoids with a straight directory on the emission axis. In this case, the source is characterized 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:

$$SPL\ (r\ m) = SPL(1\ m) - 10 \log r\ (m)$$

$$TL(dB) = 10 \log r(m)$$

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 prioritized 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[6]:

TL(dB) =15 log (R)

Where R is the distance to the source.

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

7.6. Annex VI: Map collection

Table 15: List of maps realized for each species or group of species of cetaceans and seabirds as part of the exposure risk to concomitant pressures assessment in the Bay of Biscay. Columns 1 correspond to simulations with French datasets; columns 2 correspond to simulations with Spanish and French datasets. All simulations are available for summer and winter seasons.

Species or group of species	**Globicephalinae**		**Little delphininae**		**Common bottlenose dolphin**		**Harbour porpoise**		**Alcidae**		**Great grey gulls**		**Terns**		**Black-headed and Mediterranean gulls**		**Great black gulls**	
Map	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Predicted habitat model	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Number of activities	X																	
Multi-activity intensity	X																	
Number of pressures	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Multi-pressure intensity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Exposure risk to floating macro-waste			X															
Exposure risk to continuous underwater noise			X															
Exposure risk to impulsive underwater noise			X															
Exposure risk to bycatch			X															
Exposure risk to collision																		
Exposure risk to visual disturbance																		
Exposure risk to concomitant pressures	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Confidence index	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

All the maps are stored in the annexed document entitled “Map collection”.