Interactions between uses, between uses and environment, including cumulative impacts.

Review of evaluation methods carried out in France, Spain and Italy

Western Mediterranean Sea

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Version 2

SIMWESTMED

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Acronyms

AFB	Agence Française pour la Biodiversité
CEA	Cumulative Effect Assessment
CEDEX	Centro de Estudios y Experimentación de Obras Públicas
CEREMA	Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement
CNR-ISMAR	Consiglio Nazionale delle Ricerche - Istituto di Scienze Marine
DG MARE	Directorate-General for Maritime Affairs and Fisheries
EU	European Union
GES	Good Ecological Status
GIS	Geographic Information System
IEO	Instituto Español de Oceanografía
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
SHOM	Service Hydrographique et Océanographique de la Marine
SIMNORAT	Supporting the Implementation of Marine Spatial Planning in the Northern European Atlantic
SIMWESTMED	Supporting the Implementation of Marine Spatial Planning in the Western Mediterranean sea

1 Introduction

1.1 Context

Blue economy has considerably been developped over the last decades. Oceans, coastal shores and waters are facing increasing demands linked to the use of sea and coastal space, explotation of living or mineral marine ressources. These demands come from new maritime sectors as marine renewable energy, aggregate extraction as well as from historical activities such as fishing or commercial navigation.

This situation raise two major issues. On a hand, the need to ensure cohexistance between uses that are developping into the same areas or targueting linked ressources. On the other hand, the need to ensure that maritime economy is developping with respect to the good status of the marine environment, and the need to limitate impacts of maritime uses on marine ecosystems.

The progressive consideration of this multiples stakes and the obvious difficulty to balance them are the basis of new and ambitious public policies. 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 groth.

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

Here, we focus on approaches seeking to evaluate and map effects of human activities in marine ecosystems. Various tools and approaches have been developped throughout the world to do so. Their use as source of information to feed MSP is a ongoing question. This report aims to detail and compare the mains caracteristics of the tools developed in SIMWESTMED countries. A better comprehension of divergence between approches is a step toward an increased transboundary coherence for MSP processes.

1.2 SIMWESTMED

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

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

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

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

SIMWESTMED **outputs are practitioner focused**, and **aim the identification and sharing 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.

2 Methodology

2.1 Desk analysis on cumulative impacts

The desk analysis has been conducted using peer-review scientific articles, national authorities' reports and books. Most of the research has been done on the internet, using specific browsers (Web of science, Google scholar etc.) but sometimes the author of the paper, or the publisher of the report, has been contacted directly.

2.2 Summary of the existing tools among partners

Country	Partner	Tool name	Main objective
France	CEREMA	-	Help MSP National process to evaluate interactions between activities
France	AFB	Carpe Diem	Estimate Cumulative Impacts of activities on Marine environment to support public policies (MSFD, MSP…)
France	SHOM	DESEASION	Support maritime decision making through decision aiding processes and a platform
Italy	CNR-ISMAR	Tool4MSP	Estimate Cumulative Impacts of activities on Marine environment to support public policies (MSFD, MSP…)
Spain	CEDEX	-	Estimate Cumulative Pressures of activities to support MSFD

Table 1 : Existing tools among partners

2.3 Comparison of tools already existing among partners

The methodology for the comparison of the tool has been set up during a meeting between partners in Marseille (March 2018).

After a first round of presentations, it has been highlighted the need for a common methodology in the comparison between the SIMNORAT and SIMWESTMED projects. The objective was then to define a common list of criteria to use in order to proceed to this comparison. The workshop has been conducted by using sticky notes to allow each participant to propose criteria to proceed to the analysis. Finally raised criteria have been regrouped into categories in a plenary session to agree collectively on the criteria list. In a second time, the method to use for redaction of this comparison has been discussed.

Figure 1: Ideas collection time

This activity has highlighted the following criteria:

Categorization	Criterion cited
Processes	Spatial indicators for pressures
	Transformation of data into pressures
	Calculation of spatial distribution of pressures
	Distance took into account (distance based model / size of cells / buffers)
	Intensity
	Capacity to integrate different models (environment, activities, uses, pressures)
	Methods for pressure aggregation (weighting)
	Temporal aspects
Scale	Scope and resolution
	Scale
	Extent of the model to incorporate land/sea interaction
	Size of the cell grid
Implementation for MSP	Usefulness for planners
	The degree of take up for practitioners / planners
	Dissemination and communication
	Outputs results, analysis, evaluation
	Performance of tools in strategies
	Stakeholders involvement in the processes
Uncertainty	Degree of validity and certainty to use for plan making
	Level of knowledge (data) to inforce the tool
	Capacity to address the uncertainty (scientific approach)
	Uncertainty of each method (quantitative or qualitative)
	Capacity to address the uncertainty (easiness of interpretation)
Scenarios	Scenario analysis
	How is the time dimension integrated (data currency, scenario building)
Activities	List of activities and pressures
	Level of details (activities)
	List of precise activities data we can share
	Socio-economic data analysis
Skills	User interaction friendly
	Capacity to involve different actors during the decision process
	Level of skills to run the tool
	Accessibility of matrix method
Link between ecosystems and pressures	Evaluation of sensitivity (criteria…)
	Sensitivity matrix
	Share matrix of relationships
	Habitat sensitivity matrix
Ecosystems	Ecosystem compartments to consider
	Chose one or more ecosystem compartment
Data / Replicability	Open source
	Documentation availability
	Can one tool be used for different areas?
	Can the tool be interoperable through modules
	Input data availability and accessibility

	Data availability
	Capacity to integrate various data format
	Replicability
	Transparency of the tool
Various	Share the same vocabulary
	Sustainability of the tool
	Define the final result we want

Table 2: Transcription of the sticky notes

This work ended up with a list of 10 themes to consider for the method description and for their comparison.

It has been decided that each partner is going to fulfil a fiche describing the methods according to this list of 10 themes. AFB is going to wrap up all the fiches in order to produce a report of the comparison, and make it circulated among the partners for validation, inputs and remarks.

Those topics were not described as fluently and in categories for the themes 5 to 10. As such, during the analysis phase, the inputs have been summarized on short key messages, and then use then on a more global scale analysis.

3 Cumulative Impacts context

3.1 Cumulative Impacts in Europe, methodologies

3.1.1 Cumulative Effects Assessment in Europe

Cumulative Effects Assessment (CEA) could be defined as "A systematic procedure for identifying and evaluating the significance of effects from multiple sources / activities and for providing an estimate of the overall expected impact in order to inform management" (Judd et al., 2015).

The publication of (Halpern et al., 2008) (Figure 2), evaluating cumulative impacts from 17 activities/pressures on 20 ecosystems, has been the starting point of numerous CEA studies worldwide (Ban et al., 2010; Korpinen et al., 2012; Selkoe et al., 2009).

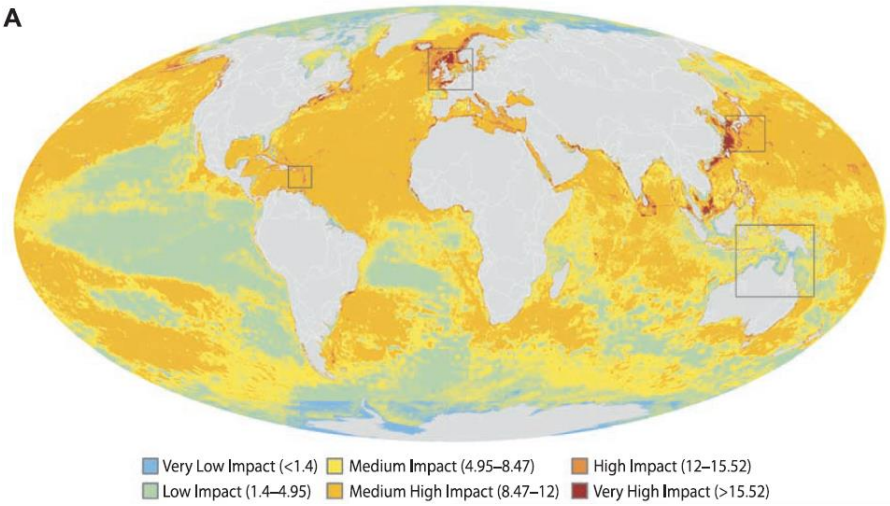


Figure 2: Global map of the impact of human activities on 20 marine ecosystems (Halpern et al., 2008).

Several recent reviews exists in scientific papers regarding this topic (Korpinen and Andersen, 2016; Stelzenmüller et al., 2018). They show that Cumulative Effects Assessment is a constant ongoing field of research throughout Europe.

3.1.2 Methodologies

In their study, (Korpinen and Andersen, 2016) reviewed 40 cumulative pressures and effects tools, among them half have been developed in Europe. Authors noted a general homogeneity of the methodologies. However, an evolution between old publications and new publications is noted, taking into account the limits and problems identified in CEA (Halpern and Fujita, 2013).

If some progresses still need to be done, some of the studies bring a more general overview and methodological recommendations for the tools developed in the different countries (Aish et al., 2016; Clark et al., 2014; Judd et al., 2015). These evolutions are resumed in Figure 5.

Cumulative Effects are also treated in regional sea conventions, for example the Intersessional Correspondence Group on Cumulative Effects (ICG-CE) in the OSPAR convention has for objective to prepare the use of CEA for the next Quality Status Report of 2021 (OSPAR Commission, 2017). Among their work, a comparison overview of three families of methodologies used in Europe has been done. It concerns three well renowned methods which actually share a quite common approach: HARMONY (Andersen et al., 2013), CUMULEO (Wal and Tamis, 2014) and ODEMM (Goodsir et al., 2015; Knights et al., 2015; Robinson et al., 2014)

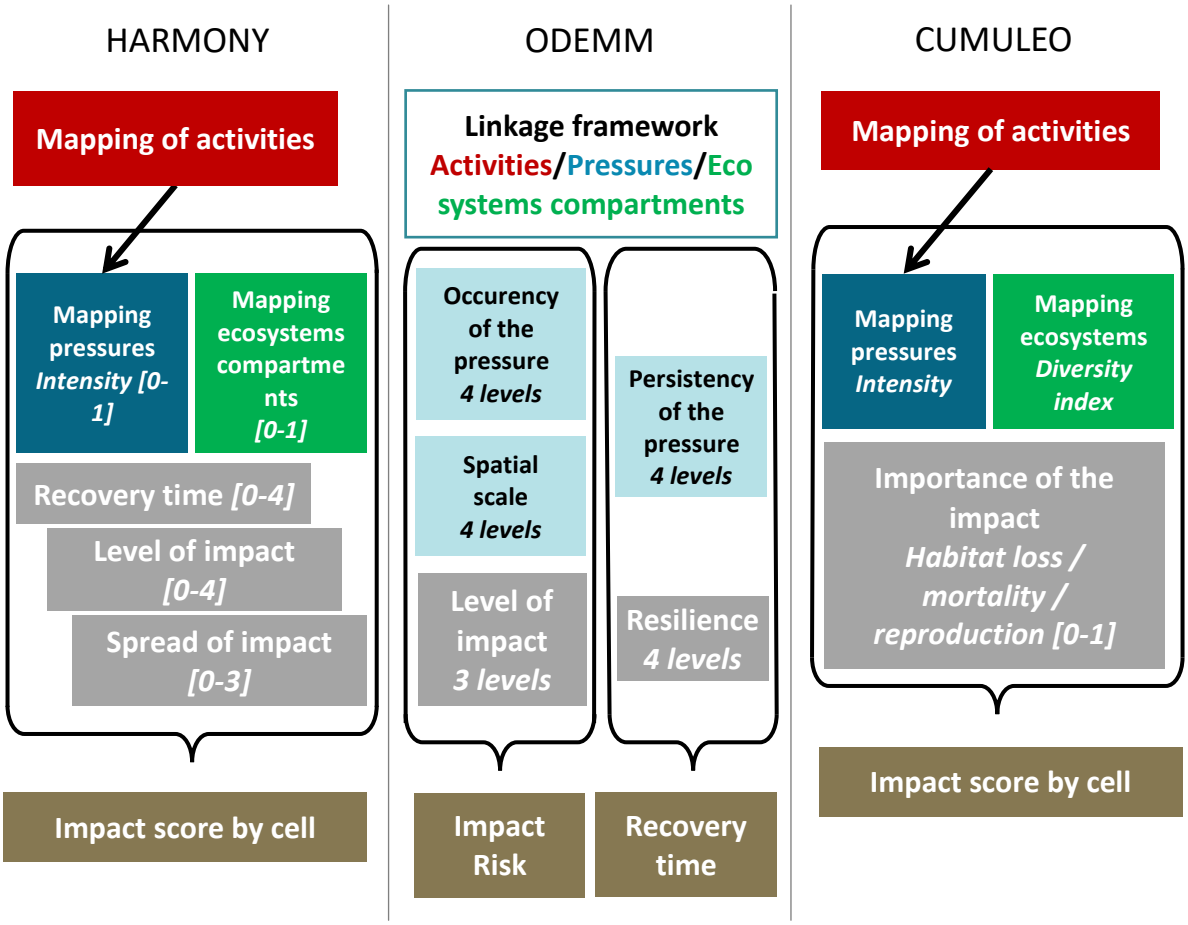


Figure 3: Steps of calculation and main results in each of the 3 main families of methodologies: HARMONY/ODEMM/CUMULEO.

These three methods are based on a common set of relationships between data (Figure 3):

- Identification of activities and pressures links (Figure 4),
- Identification of pressures and ecosystems compartments links (Figure 4),
- Evaluation of exposure of ecosystems compartments to pressures,
- Evaluation of sensitivity of ecosystems compartments to pressures.

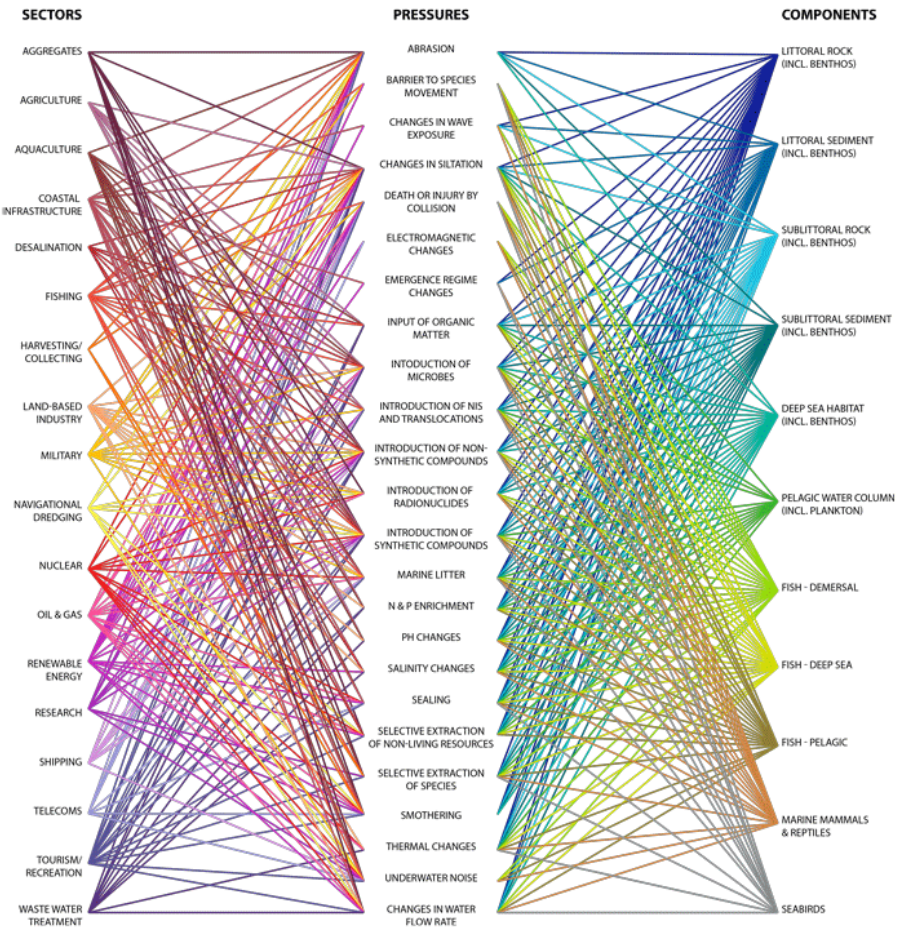


Figure 4: Example of the relationships between activities, pressures and ecosystems compartments in the ODEMM methodology.(Robinson et al., 2014)

However these methods also have differences, for examples:

- Calculation of impact scores and outputs: 2 results in ODEMM methodology (impact score and recovery time). In the other methods, recovery time is part of the evaluation of the impact (include in sensitivity.
- Estimation of the sensitivity: in ODEMM methodology, the sensitivity is also dependent of the use producing the pressure. In the other methods, the sensitivity is defined regarding a pressure only.
- Estimation of the habitat data: in CUMULEO, represented with species diversity. In the other methods with typology based on the nature of the habitats.

It has to be noted that more and more scientists find unrealistic to provide a cumulative impact evaluation assessing all the environmental compartments. This way, approaches sometimes take the side of addressing ecological compartment one by one, like for example in the next Quality Status Report of OSPAR (OSPAR Commission, 2017).

3.1.3 Next steps

The majority of CEA activities in Europe so far were short-term and project-based. Only a few examples were longer term initiatives or incorporate formally CEA in national policies (European MSP Platform, 2018). Another main challenge identified is so to use this interesting diversity of tools and methods as a key for a wider collaboration on a transboundary context. In the future developments of CEA, some reviews (Aish et al., 2016; Clark et al., 2014; Halpern and Fujita, 2013; Korpinen and Andersen, 2016) are quoting other challenges in implemented CEA, summarized in the Figure 5.

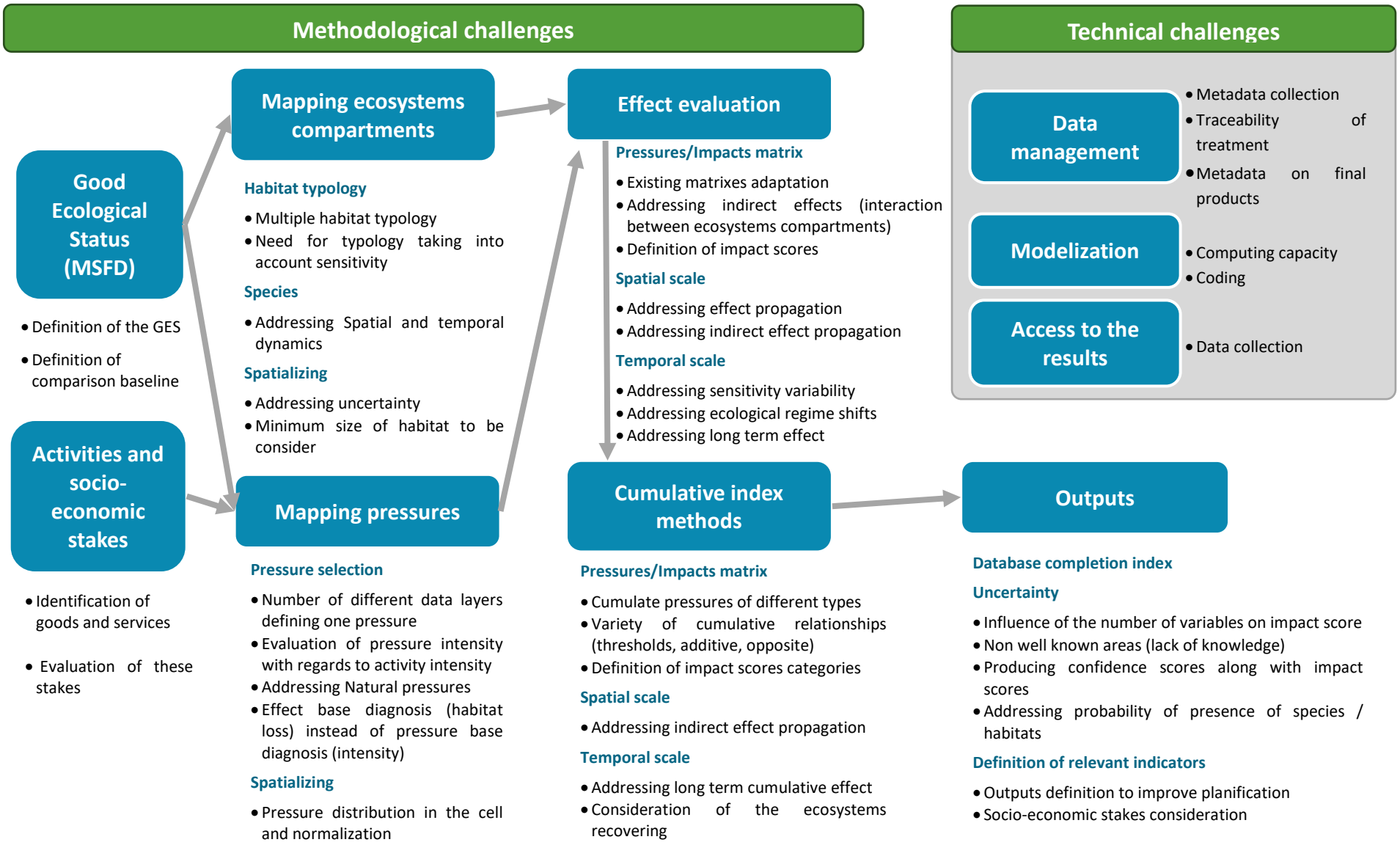


Figure 5: Synthesis of technical and methodological challenges in CEA

3.2 Cumulative impacts implementation within maritime policies

Cumulative Effects Assessment (CEA) has been a subject of recurring interest for the implementation of national policies (UNESCO and European Commission, 2017) and their articulation (Foley et al., 2017).

MSP is a policy with a clear connection to CEA (UNESCO and European, 2017). Since ecosystem based approach is a pillar of MSP, dealing with cumulative effects is one of the key supporting the development of MSP itself (Ardron et al., 2008; Depellegrin et al., 2017; Douvere, 2008; Kidd et al., In Progress). Experimentations of MSP CEA-led have already been implemented, like in the Shetland Islands (Kelly et al., 2014). In this study authors have used scenarios based on environmental risks, crossed with stakeholder's views in order to update the maritime plan in place.

Several experimentations on others sectorial policies have been already studied:

- the application of CEA in relation to marine renewable energy (Berkenhagen et al., 2010; Dolman and Simmonds, 2010; Willsteed et al., 2017);
- the application of CEA in relation to shipping (Erbe et al., 2012);
- the evaluation of environmental management, like MPA networking, (Batista et al., 2014; Fernandes et al., 2018; Micheli et al., 2013);
- The work undertaken on the scope of the OSPAR Agreement in the Dutch waters (OSPAR Commission, 2016) incorporate CEA into the processes of evaluation on areas handled by the sea convention.

However, articulation between national policies and CEA remains a challenge yet. Moreover, involvement of experts are still required, as many of the early CEA tools were judged to be technically complex and only suitable for the use by scientists or programmers (Stelzenmüller et al., 2013).

4 Comparison of tools already existing among partners

The existing tools are listed in part 2.2 Summary of the existing tools among partners.

This comparison is built with the inputs of each partner concerning CEA approaches enforced in the countries of the project. If some topics are very technical (topic 1 to 4), other are more focused on methodological problems occurring in the construction of CEA, and the relationships between national policies.

4.1 Topics and related data addressed

Most of the CEA tools share the particularity to be very data demanding. However, needs could be different in terms of quantity or quality. This section aims to evaluate similarities and differences between datasets required by compared tools.

4.1.1 Activities and pressures

Activities and pressures considered in the different tools are listed in Table 3.

Activities/Pressure	Number of tools addressing the topic	Comment
Maritime Traffic	4	
Ports activities	4	Could be separated in several activities or pressures according to the tool (dredging, ports facilities through coastal urbanization etc.)
Fishing	4	
Dredging deposition	4	
Aggregate dredging	4	
Cables Pipelines	4	
Tourism and leisure activities	4	
Aquaculture	4	
Litters	3	Approach by pressure, estimated directly, and considered partly as LSI
Pollution	3	Approach by pressure, estimated directly, and considered partly as LSI
Marine Renewable Energy	2	
Anchorages	2	
Defense	3	
Oil and Gas Prospection and Exploitation	2	
Coastline urbanization	1	
Artificial reefs	1	
Industrial plants (nuclear, thermal etc.)	1	
Research activities	1	

Table 3: Summary of activities and pressures considered in the tools

The majority of pressures are estimated through datasets define intensity level of activities (including in the CEREMA tool, not yet used and kept for further developments), but some can be estimated directly such as litters or pollutants inputs for marine activities. Land based pressures are estimated with direct measurements as well, such as (rivers and watersheds inputs for examples).

In the CEREMA analyses, land based pressures are not considered by the study because of the indirect influence of MSP in their management, and because of the focus the spatial conflicts between activities (Annex 5.Describing Fiche CEREMA).

The high diversity shown in this table is also due to the classification system in each tool. Globally, the activities

addressed are similar, but sometime the data used to describe one activity, or the grouping of several activities can change from one to another. A good example to illustrate this is the way to address fishing effort (Table 4 : Differences in the estimation of the fishing activity.).

Tool	Unit for fishing effort valuation	Number of categories of activities
CEREMA	Number of fishing ships for 2 years	2: Fixed and dragged gears
CARPE DIEM	Hours per year	12: benthic trawls, bottom nets, bottom longlines, scoubidou, L. hyperborean dredge, mollusk dredges, pelagic trawls, beam trawls, pelagic longlines, purse seine, pelagic nets, bottom traps.
TOOL4MSP	Hours of fishing	2: Small scale and trawling
CEDEX	Hours per year	6: bottom trawling, purse seine, lines, bottom longlines, gillnets, traps (however, the cumulative approach hasn't been pursued for fishing)

Table 4 : Differences in the estimation of the fishing activity.

In the contrary, pressures addressed are taken from the list of pressures coming directly from the MSFD classification, so are much closer among tools. A better alignment with the MSFD especially with its annex 3 could improve the linkage between tools (see Annex 2. Extract from Annex 3 of MSFD: Indicative lists of ecosystem elements, anthropogenic pressures and human activities relevant to the marine waters).

A shared remark by tools developers is that the evaluation of activities and pressures are predominantly influenced by the availability of the data, and the technical specificities (units, time, resolution) provided by the owner.

4.1.2 Ecological compartments

It has to be noted that CEREMA and CEDEX tools are specifically working on activities/pressures so are not included in this chapter.

Topic (not exhaustively)	Number of tools
Benthic habitats	2
Marine mammals	2
Seabirds	2
Turtles	1
Giant Devil Ray	1

Table 5: Ecological compartments taken into account in the different tools

Compartments listed in Annex 3 MSFD	Consideration
Macroalgae	Yes (included into benthic habitats)
Invertebrate bottom fauna	Yes (included into benthic habitats)
Angiosperms	Yes (included into benthic habitats)
Seabirds	Yes
Seabed habitats	Yes
Marine reptiles	Yes
Marine mammals	Yes
Fish populations	Partially
Zooplankton	No (included into pelagic habitats)
Water column habitats	No (included into pelagic habitats)

Phytoplankton	No (included into pelagic habitats)

Table 6: MSFD requirements for the consideration of ecological compartments

Origins of the ecological data are various, but more generally coming from scientific research or administrations.

The lack of mapping and scientific knowledge about some compartments, such as pelagic habitats and plankton limits the opportunity to consider them into the partner's tools. This lack of knowledge can come from the difficulty to consider all parameter and to carry out monitoring on this ecological compartment.

Not surprisingly, the best well covered compartment concerns the benthic habitats, for which lots of mapping work have been carried out, and are easier to analyse as non-mobile issues. In three over the five compared tools, benthic assessment is ready to be used.

As a general remark, it seems that ecological data are always imperfect, without enough details, and submitted to a lot of interpretation limits, especially in the mobile species. A work on several species has been the opportunity to develop tools and the methodologies, but an ecosystem consideration is still missing.

This is coherent with the a wide desk review (Korpinen and Andersen, 2016) where authors pointed out that a lot of work still have to be done to include all the ecosystems compartment in CEA analysis, concerning both data acquisition and tools development.

4.1.3 Data accessibility

Partners mostly used institutional (public) and scientific data. Public bodies (CEREMA, CEDEX, AFB…) can take advantage of their missions of public interest to get access to a lot of datasets. The scientific organisms (CNR-ISMAR) can access the data by themselves, or use the mission given by a public organism, usually funder of the programs involving their teams.

However, some data owners still limit the access to their information. This is particularly the case regarding data about economic sectors such as fishing for example. Those restrictions can also affect the diffusion of the results and the explanation of the diagnosis, by limiting accessibility of information about raw data.

To sum up:

To sum up: Most of the data used on the tools have the same diversity of nature. The limits for the development of CEA on this topic is mostly linked with a lack of knowledge on specific ecosystems compartments (like plankton), restriction in the access on activities data and restrictions in the tool methodology defined their conception.

4.2 Analysis scale

The diversity of data types and resolution, of the geographical area of study and of methodological choices implies variation in the scale of CEA tools. This section aims to evaluate similarities and differences between the scales of compared tools.

Most of the tools have been sized with regard to constrains brought by the datasets themselves. Two big categories of areas are developed in tools: national (Exclusive Economic Zones) and transboundary. They are representative to the two categories of datasets scales, very often transboundary, according to the mobility of some activities or ecological features, but conditioned by administrative boundaries. Moreover, many datasets are issued from transboundary projects. Some of the tools (AFB, CEDEX and CNR-ISMAR) also consider inputs from land so the geographical area is not only restricted to the sea.

Most of the compared tools use square grids as analysis unit. Only DESEASION is developing the geographical division directly on the raw data and there shape, in order to create areas by overlay the different datasets. Grid resolution can be very different among tools: 1', 5' or 15' (AFB), 3' (CEREMA), 5' (CEDEX) 500m or 2km (CNR-ISMAR). This diversity of resolution is due to the diversity of study areas (larger the area, coarser is the

resolution) and the diversity of the dataset resolution. Methodological choices play an important role in resolution choice: it's sometime needed to lose precision given by raw data, and miss or over-represent a problem non-existing with smaller resolution, in order to be able to build an evaluation on a homogeneous scale. It has notably been highlighted in the detection of interactions between activities (see input N°22 in Annex 1.Table of key messages for analysis.).

To sum up:

It can be stated that finer the resolution is, better the result will be; but chosen resolutions often rely on data and the size of the area of interest. In order to improve the ability of member state to collaborate, it could be valuable to propose a common geographical reference grid at sea, matching as much as possible with the national ones.

4.3 Technical processes

Processes to analyze data and provide a diagnosis can be various (see 3.1.2 Methodologies) and be a summary of different methodological choices. This section aims to evaluate similarities and differences between processes of compared tools.

Each of the processes is described in the corresponding fiche. For the 2 tools specifically dedicated to Cumulative Impacts (CNR-ISMAR, AFB); the methodologies are very similar, impulse by scientific work (Andersen et al., 2013; Halpern et al., 2008; Korpinen and Andersen, 2016)

- **Step 1**: Formatting activities and environmental data on a grid. The intensities of the activities are normalized between 0 and 1 to allow comparison by a common scale.
- **Step 2**: Deduce pressures from the activities.
- **Step 3**: Define the impact of the pressures on the ecosystems compartments.

The CEDEX tool has developed a methodology based on similar logic, but in a reverse order. The starting point is the list of pressures given in the MSFD (see Annex 2. Extract from Annex 3 of MSFD: Indicative lists of ecosystem elements, anthropogenic pressures and human activities relevant to the marine waters), which are regrouped in broad categories and linked to activities. Only therefore the data are gathered and aggregate. This reverse approach allow to have a clearer vision of what are the gaps to evaluate pressures/activities according to MSFD, but it is necessary to be vigilant about additional data or pressures gathered and not listed in the MSFD annexes.

The relationships between activities, pressures and ecosystems compartments are the most often defined using expert judgement and previous scientific studies. 2 different approaches can be taken:

- By estimating in a first time which pressures are induced by each uses (using an activity/pressure matrix) and then estimating effect of each pressure on each ecosystem component, using a sensitivity matrix (AFB - "Carpe Diem Benthic", (Halpern et al., 2008)). With this approach, the origin of the pressure is not taken into account when overlapping with ecosystem components to estimate impact.
- By taking into consideration the origin of the pressure when estimating impacts on ecosystems. A matrix linking couples activity/pressure and environmental features is necessary (AFB - "Carpe Diem Pelagic", (Andersen et al., 2013), CEDEX). This approach, developed when an impact is necessarily implied by the activity producing the pressure, has a higher accuracy. For example, when considering the pressure "bycatch", some species are sensitive to one fishing technique but not to another which can accidentally catch other species. This methodology, necessary in some cases, leads however to an increased amount of work.

The consideration of the propagation/diffusion of pressures can also lead to different methodological approaches. Different degrees of complexity are used to estimate the propagation distance of pressures. The

most sophisticated tool (CNR-ISMAR) use a model to estimate the pressure diffusion (Gaussian kernel function), CEDEX estimating buffers in meters and AFB estimates propagation between 1 and 3 cells, also with regard to their distance of effect. This topic is not addressed in the CEREMA methodology and can be addressed through the SHOM tool if diffusion rule is set by the user. It has to be considered that more the estimation of the propagation distance is precise, the more the cumulative impact score and uncertainty associated is going to be improved. This topic is studied in a lot of cumulative impact tools (Ban et al., 2010; Holon et al., 2015; Korpinen and Andersen, 2016), connected with the propagation of pressures coming from land (Álvarez-Romero et al., 2011), and is a key development currently happening in European tools.

Even if this subject is going to be developed in the part 4.6 Outputs, it can be highlighted that different processes are used in the definition of the outputs (maps, "communicative" maps, graphics, diagrams etc.).

Regarding the involvement of stakeholders, it has been highlighted the specific approach of the SHOM tool DESEASION. This web-tool allows to consider the decision maker expertise in order to define the methodological choices and link between layers, in addition to the scientific work. In the other tools, the approach is only based on scientific works and hypothesis.

4.3.1 Future developments

In two tools (AFB and CNR-ISMAR), experimentations are done for new methodological developments:

- Test of different ways to cumulate pressures (antagonistic, additive, dominant effect). This choice can change the diagnosis and is important to consider in the methodology and in the uncertainty evaluation.
- Test of different response of the ecosystems to an exposure to one or several pressures. This mean not only consider a linear relationship between the intensity of the pressure and its impact on an ecosystem compartment, but also various dynamic like threshold answer, exponential answer etc.
- Back sourcing evaluation (only in CNR-ISMAR tool). This kind of diagnosis aims to link estimated impact within a cell to the activities producing the pressures and their area of influence.

In the other (CEDEX and CEREMA), the tool was built in order to answer to a specific need (MSFD evaluation or MSP consultations). Therefore they weren't plan on a long term use objective, and their future is going to be linked with future requirements from public policies.

Neither methodology considers a socio-economic approach. A socio economic approach is defined by using variables not related to the ecological sciences. For example adding in the cumulative tool the richness brought by an economy, the cultural heritage of an ecosystem etc. It's plan to be addressed with a foresight approach for the AFB tool, but it has been evaluated very data demanding (Marcone, 2017) and require a high level of expertise. In the bibliography, socio-economic dimension can be consider through ecosystem services (Arkema et al., 2015; Menegon et al., 2018b) and some of the developments considered ecosystem services.

To sum up:

A variety of methodological choices, at several processes steps, are possible. They are made according to the development level of the tools, the complexity implied and lead to a better assessment of impacts.

The development of processes and their improvement are extremely dependent to available time and human resources. In order to facilitate the cooperation between the organisms, the networking aspects, by the way developed by the MSP platform, are essentials.

4.4 Problems occurring in the construction of CEA, and the use in the case of MSP.

The key messages from each fiche are presented in the table in Annex 1.Table of key messages for analysis. From this point, the comparison conducted is going to be based on them, and on issues met.

4.5 Uncertainty

Defining uncertainty can be targeted differently according to all steps of the diagnosis construction. However this topic is a keystone to insure a robust scientific analysis. This section aims to evaluate similarities and differences among compared tools about this subject.

AFB and CNR-ISMAR have developed similar approaches regarding uncertainty: confidence in each layer defined by experts or with a set of rules, and Monte Carlo simulations. The 3 other tools don't address this topic.

Monte Carlo simulations (Manly, 2006) is a statistical analysis which consists on carrying out a lot of simulation run, changing randomly key methodological choices which are not entirely sure, and which can influence the final results. Then, variability of the numerous results is analysed to assess the level of influence of changed parameters on the final result.

(Stelzenmüller et al., 2018) advises an overall approach considering not only uncertainty of data sources, but the accumulation of uncertainty throughout various steps of the process as well. In the same publication (Stelzenmüller et al., 2018), criteria have been given in order to compare the assessment of uncertainty. They have been applied on the different tools, and summarized in the Table 7.

Criteria to qualify uncertainty assessments	AFB	CNR-ISMAR	SHOM	CEREMA	CEDEX
(1) Pressure data: the effect of missing pressures data on CEAs;	N	N	N	N	N
(2) Sensitivity weights: CEA models use sensitivity weights to estimate the effect of each pressure on each ecosystem compartment, often derived by expert judgment or models, and some are highly uncertain;	Y	Y	N	N	N
(3) Spreading of effects from point sources: uncertainty on how the effect from a point source decays with the distance from the source;	N	Y	N	N	N
(4) Non-linear responses to pressure: CEA models commonly assume linear responses to pressure intensity but often responses of ecosystems to pressures are non-linear, this assumption adds uncertainty to the CEA results;	Y	Y	N	N	N
(5) Reduced analysis resolution: the effect of the spatial resolution of the CEA analysis on the result;	N	N	N	N	N
(6) Reduced pressure resolution: the effect of low spatial resolution of some pressures (and thus the need of downscaling) on CEA results;	N	N	N	N	N
(7) Mean or sum of effects: CEA calculate the human effect scores either as the sum of effects over all ecosystem compartments that are present in a given cell or as the mean effect across all ecosystem compartments, this decision affects the CEA outcomes;	N	N	N	N	N

(8) Transformation type: various transformations to make stressors comparable have been applied (e.g. log-transformation, P-transformation) – the selection of transformation type affects the final result;	N	N	N	N	N
(9) Modelling multiple pressure effects: commonly it is assumed that the effects of multiple pressures add up, yet, non-additive effects and interactions are common in nature and models that do not account for them affect CEA outcomes;	Y	Y	N	N	N
(10) Spatial distribution of ecological features: Data gaps in the available maps of ecological features (habitats or species) often results in high uncertainty.	N	N	N	N	N

Table 7: Uncertainty criteria (Stelzenmüller et al., 2018) in the tools (Y for yes and N for no)

One of the most important criteria doesn't taken into account yet is the impact of missing data (pressures or ecological) in the final CEA evaluation.

To sum up:

The evaluation of uncertainty among partners is based on the same methodology, for the tools available, facilitating transboundary cooperation. The uncertainty is a key element, but it's addressed by few tools yet. It can be considered as a priority for the tools which does not estimate it. However, even for the tools evaluating uncertainty, improvements according to the criteria of (Stelzenmüller et al., 2018) can be done.

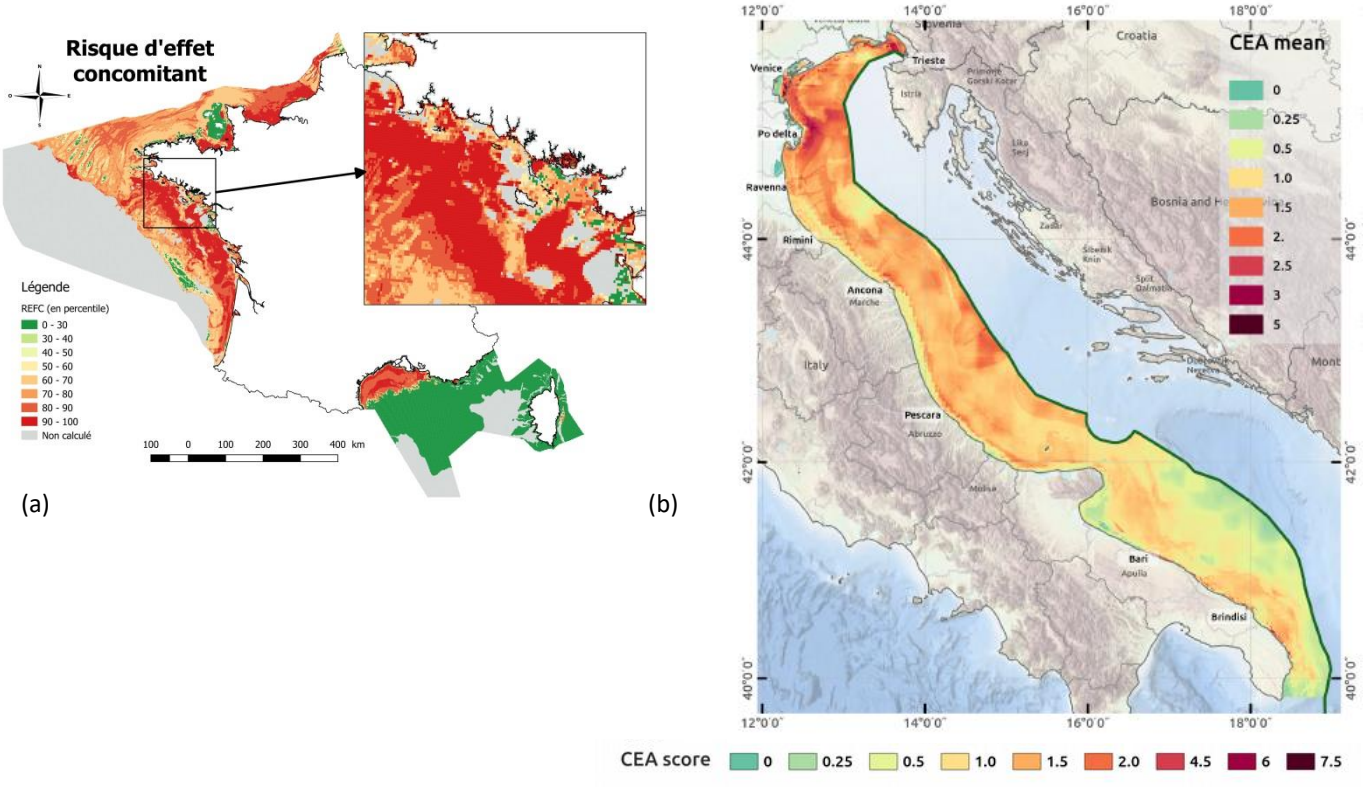
4.6 Outputs/Deliverables

A variety of different outputs can be produced by the tools, and used in national policies. They are related to the history of CEA, the choices of developers and people participating to the tool development. This section aims to evaluate similarities and differences among compared tools about this subject.

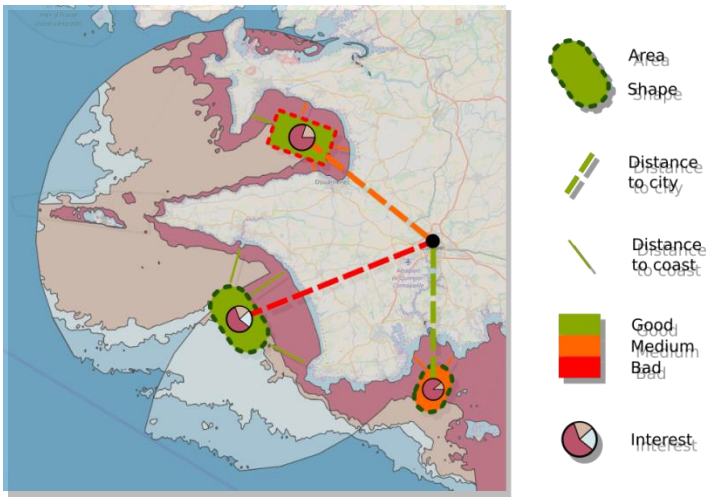
	Outputs			***Outputs dissemination***		***Outputs construction***
	Maps	Diagrams/graphics	Scenarios	Use in National MSP	Use in European projects	Stakeholder involved in outputs construction
AFB	Y	Y	N	N	Y	N
CNR-ISMAR	Y	Y	Y	N	Y	Y
SHOM	Y	N	Y	N	Y	Y
CEREMA	Y	N	N	Y	N	Y
CEDEX	Y	N	N	N	N	N

Table 8: Outputs and implementation among partners' tools (Y for yes and N for no)

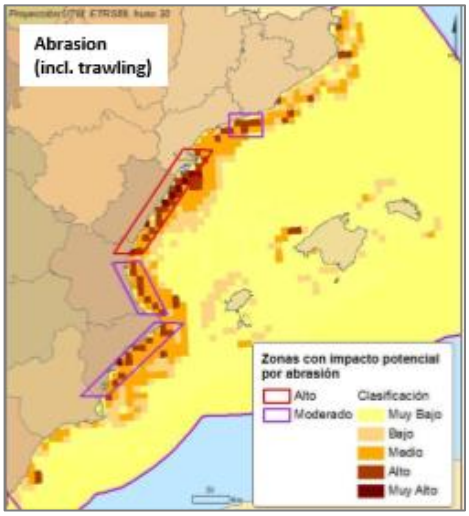
As shown in Table 8, the main output produced by every tool is the maps of cumulative impact scores (or cumulative pressures), allowing the visually transcribe the areas where problems occurs between human activities, and between human activities and environment (Figure 6).



(c)



(d)



(e)

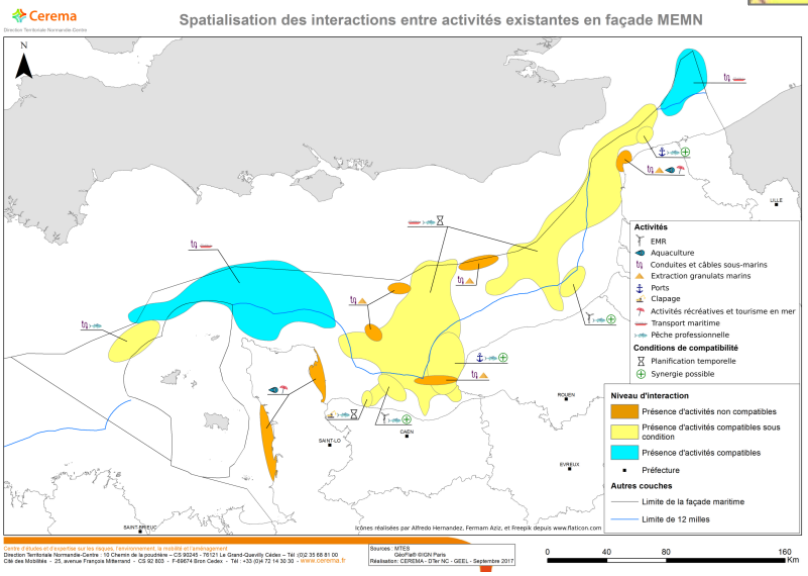


Figure 6 : Cumulative maps produced with (a) AFB tools, (b) CNR-ISMAR tool, (c) SHOM tool, (d) CEDEX tool, (e) CEREMA tool.

The correct understanding of the diagnosis is a key principle for its use in MSP. Graphics and diagrams, produced along with maps can enhance results understanding, especially when stakeholders are involved in this development. Graphics showing the weight of each pressure and activity into the final results are a powerful help for planners, for example Sankey diagrams (Menegon et al., 2018a), flowcharts, etc.

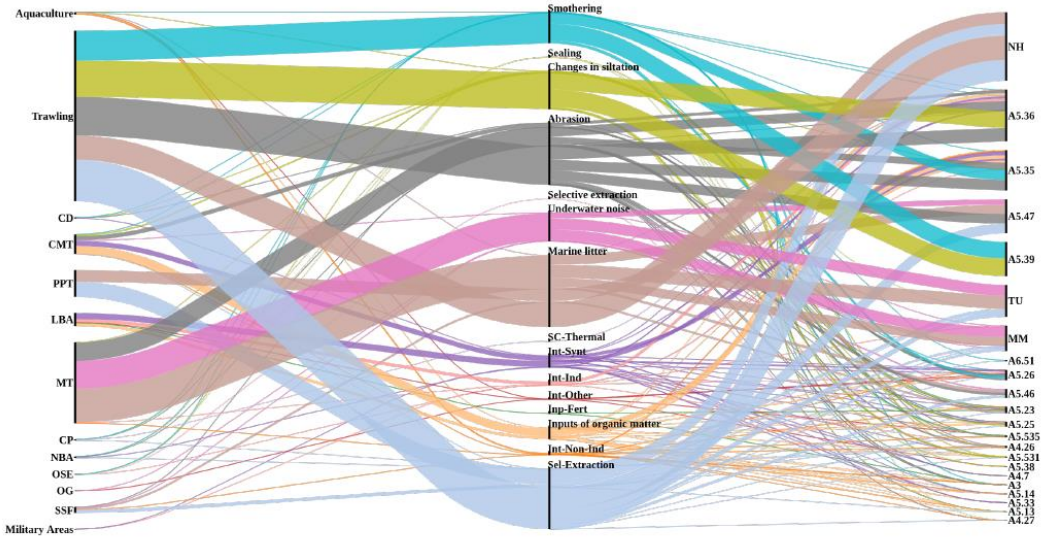


Figure 7 : Example of Sankey Diagrams developed in (Menegon et al., 2018a)

In the same way, explanations about data, methodology and sources of the results are an output recommended by the partners' tools. Descriptions of each step to the result, recommendations for planners accompanying the map, are developed in some's (SHOM, CEREMA). In the outputs development, those tools are also involving stakeholders, in order to improve their dissemination.

Scenarios are very useful in order to support public policies (Fernandes et al., 2018). Their development is one of the final objectives for all tools, and a very concrete way to help planners to the consequences of a plan.

To sum up:

Outputs are mostly maps, and some tools are developing additional graphics and explanation to complete the diagnosis. There is a strong need to enhance communication and explanation on results from each compared tool to foster their consideration in the decision making processes. The involvement of stakeholders and planners to design the outputs is a key principle highlighted.

4.7 Use in MSP and Implementation

The dissemination to the decision makers and the public is addressed with different approaches. They are related to the history of CEA, the choices of developers and people participating to the tool development. This section aims to evaluate similarities and differences between compared tools about this subject.

For some partners (CNR-ISMAR and SHOM), a web platform is a preferential way to use their tool, and communicate the outputs (see Table 9). For other partners the availability of information has been conditional, with a priority given to insure the robustness of the method first.

It has to be considered that, in some methods, the stakeholders and planners are widely consulted and are part of the construction of the methodology (SHOM and CEREMA). It is not very restrictive to consider that the public targeted by the access of the information is mostly stakeholders and planners. Under this hypothesis, a participative way to build methodology and diagnosis contribute to public consultation.

Except for the CEREMA tool (developed for MSP) and the CEDEX tool (developed for MSFD), the current utilisation of CEA is experimental, and developed only through European MSP projects:

- ABF in SIMNORAT, SIMWESTMED and SIMCELT
- CNR-ISMAR in ADRIPLAN, SIMWESTMED and SUPREME
- SHOM in SIMWESTMED

The CEREMA, which has built his tool with stakeholders, has been judged by stakeholders globally more interesting for the discussion that raised by his implementation than the final results itself (Input N°22, see Annex 1.Table of key messages for analysis.). It shows stakeholder's can and will use CEA as a support for discussion.

The national planners are mostly sea authorities, also financing most of the CEA tools. This allows planners to have information about CEA, but not yet to use it in MSP. However, the use of the tools has already being planned in other public policies such as MSFD (Input N°21) and Priority Conservation Areas (Input N°25, (Fernandes et al., 2018)).

To sum up:

The implication of planners and stakeholders during the CEA construction is one of the key to improve the implementation in national policies. During the definition of the issues that CEA tools seek to address, the planners have an important role to play in order to share more specific problematics. Indeed, a wide overview of CEA is complex to build and so takes time, explaining why CEA is not as used in MSP as it could be.

4.8 Transparency

This thematic refers to the methodology in place to communicate the results and methods to the public and the scientific community.

Availability of methodologies details is a differing priority according to the nature of the organism. If universities and scientific labs (CNR-ISMAR) describe their methodology in scientific papers, public bodies (CEREMA, CEDEX and AFB) are more focused on technical compatibility between public bodies and internal or project methodology reports.

Most of the tools require skills in coding, numeric languages (R, Python, SQL) and GIS. The knowledge in marine ecology, understanding of the activities and how can they impact the environment is also very important. Lots of tools are making efforts in using only Free and Open Source Software, which improve clearly the possibility to disseminate them. This has led some partners to develop a web portal and/or a two profile approach (Table 9).

- A first profile is the developer/designer: he designs the tool, master informatics languages and science, define the relationships between pressures and ecological data based on scientific work, and explain the mechanisms of the CEA methodology.
- A second profile is the user: he has the opportunity to use the tool in a simplest way, and to explore the methodology and have the opportunity to choose some parameters of the diagnosis.

	Web interface	User Profile	Developer Profile
AFB	N	Y	Y
CNR-ISMAR	Y	Y	Y
SHOM	Y	Y	Y

CEREMA	Y	N	Y
CEDEX	N	N	N

Table 9: Dissemination development in the tools (Y for yes and N for no)

To sum up:

The spread of the methodology among the CEA community is insure through reports, publications and the use of FOSS, by are not understandable for a wide public. The complexity of the interactions and the diversity of skills required have led most of the partners to a development of 2 profiles: users and developer.

4.9 Future of the tools

This thematic aims to evaluate similarities and differences between compared tools about available information's regarding visibility on the developments of the tools.

It has to be consider that the tools have different perspectives. If some are considered finished (CEREMA, CEDEX), other are in development, with a purpose to be finished (SHOM) or not, due to the constant improvement of the knowledge (CNR-ISMAR, AFB).

	AFB	CNR-ISMAR	SHOM	CEREMA	CEDEX
Years Guaranteed	0	5	3	Finished	Finished

Table 10: Years guarantied for the development of the different tools

The support of MSP in this context can be easier when the perspectives of tools are good. It has to be pointed out that all projects are developed with public funds, and a majority with the contribution of EU.

To sum up:

The partner's tools have various perspectives. Consolidation of the funding is very important to guarantee a constant work an improvement for diagnosis on CEA. For example, implementation of the tools in the national MSP can be a way to consolidate the funding's on longer perspectives than European Projects, which have a define duration.

5 Conclusion

All along this report, the comparison of the partner's tools has led to several remarks in order to improve the collaboration and the development of a transboundary vision of CEA.

5.1 Global summary of relevant methodology (step by step and global matrix?) and the integration of each step into MSP processes

In regards to the bibliography and the comparison of partner's tools evaluated in this report, some advices, in several steps, can be drawn to enhance CEA implementation and link it to national policies.

1. Define the priority topics that the tools have to deal with. These topics will help to prioritize the work on the tool development, to choose the priority among the activities or ecological compartments. This step have to be done in collaboration with planners, with regards to their needs, and if possible with the implication of stakeholders. This definition will be a key element to rely the work on cumulative assessment to national policies such as MSP.

2. Define the desired outputs and how can they answer about topics defines in **1.** . Is a map of cumulative impact going to be enough? Is there a need to highlight other relationships (for example interactions between activities)? Do the results need to be accessible to a wider public?

3. If the area of work is transboundary, or close to a border, it is needed to consult the organisms in other countries in order to define bridges among approaches. This clarification will provide for the CEA team and the planners a clear view on the transboundary area and improve the coherence of the work in both sides of the border.

4. Gathering as much relevant data as possible of relevant activities and ecological compartments.

5. Before implementing data in the tool, insure the use spatial references in order to make the resolution comparable to other tools (linked with Step 3).

6. Defining the relationship between activities, pressures and ecological features. This step is very time consuming. Those links can be assessed with regards to existing methodologies, done by expert judgement or by bibliography research. It is judged very interesting to discuss this with stakeholders.

7. Once the results are ready, sharing them and the associated methodology (with scientific publications, conferences, reports, popularization etc). Improving the impact of the diagnosis by spreading them to the scientific community, working also on CEA, and to partners involved in step 1.

8. **(Optional)** Using the feedbacks from step 6 to improve the tool, collect ideas for new developments. And going back to step 1 and start to work on a new topic!

5.2 Key opportunities and developments

The development of CEA in Europe is an ongoing process. Some possible methodological improvements have been listed as key point for the future of CEA tools:

- Working on a detailed and common list of activities and pressures.
- Working on mobiles species.
- Consolidate the developments of the tools (by consolidating funding and the teams) in order to assess the most globally cumulative effects.

- Open the access to data, either activities data (in possession of administrations and economic sectors mostly) or environmental data (in possession of administrations, scientists and environmental consultancy firms).
- Align the grids on a common reference and geodetic system between the tools.

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7 Annexes

7.1 Annex 1.Table of key messages for analysis.

	Organism	Topic	Key messages
1	**AFB**	*05 Uncertainty*	Step 1: Uncertainty associated to a layer is defined according a set of rules (give a score from 1 to 5). Step 2: Monte Carlo simulations (random variation on the methodological choices), which take into consideration the coefficient of variation of the data (deviation standard/result).
2	**CEREMA**	*05 Uncertainty*	Not developed yet, but can be developed for data uncertainty and uncertainty about qualification of interactions.
3	**CNR-ISMAR**	*05 Uncertainty*	Almost Monte Carlo method of 1000 simulations (variation random on the methodological choices). Consideration of the confidence delivered on expert judgments (construction of the matrixes). Coefficient of variation (deviation standard/result) taken into account. The general analysis (context, data, model, parameters, inputs) on confidence is established with stakeholders, experts and available for Adriatic and Ionian sea (Gissi et al., 2017).
4	**SHOM**	*05 Uncertainty*	As for the processes, no methodology has been defined yet for uncertainty. However, the rules applicable to data can be taken into account in uncertainties, or new rules can be created by the participants
6	**AFB**	*06 Flexibility*	Preparation of data, including new activities, or new mechanism is possible but implied a big amount of technical work, mobilization of scientific expertise etc. However, it is also necessary to kettle R language.
7	**CEREMA**	*06 Flexibility*	Only use GIS tools can be adapted. The actual parameters and choices have been designated through technical workshops gathering stakeholders and technical experts.
8	**CNR-ISMAR**	*06 Flexibility*	Use of a grid approach in any case. Currently under development: climate change, ecosystem services, conflicts and synergies between uses. Python language is used. It is possible to use the box Tool4MSP as package, use it through Jupyter Notebook (on line platform), to support, experiment and try to code new ideas.
9	**SHOM**	*06 Flexibility*	Rules are coded according to the desire of participants. The flexibility is considered strong.
11	**AFB**	*07 Transparency*	A set of technical reports exists, including the ones already developed for the SIMCELT projects, in English.
12	**CEREMA**	*07 Transparency*	The grid has been developed in concertation with other public bodies, in order to use a united one (GIMEL, 2017). Methodology has been described (CEREMA, 2016), since has been developed with internship (Jobin, 2017) and through the SIM projects.

13	**CNR-ISMAR**	*07 Transparency*	The tool use Free and Open Source Software (can be downloaded and reuses, (Menegon, 2018); several scientific articles have been published (Menegon et al., 2016, 2018a, 2018b). Dataset also have an open access.
14	**SHOM**	*07 Transparency*	The description of the tool is available online. Tutorial available soon, scientific articles are planned.
16	**AFB**	*08 Outputs*	The outputs are maps at each time of the process (including uncertainty) and graphics. The Stakeholders are not involved. The map are planned to be used as discussion starters in stakeholder meeting (in European projects). Scenarios can be explored by building simulated activities datasets. The development of a seasonal approach is in progress.
17	**CEREMA**	*08 Outputs*	The outputs are interactions maps. The all processes, results and datasets has been discussed, designed and decided with all the stakeholders.
18	**CNR-ISMAR**	*08 Outputs*	The outputs are maps and Sankey diagrams, made in relation with planners and scientists. Scenarios development is in progress.
19	**SHOM**	*08 Outputs*	The outputs are shapefiles for the different level of interactions and recommendations for the planning stage. The participants are involved in the construction of the data and rules, and not in the elaboration of outputs. Explanations about methodological sources, linked to the results are under development.
21	**AFB**	*09 Implementation*	The tool is not use in national MSP or by stakeholders (poor level of dissemination). It is implied in transboundary European projects, and it use is planned on the next MSFD cycle. There is a need to improve communication to MSP users community.
22	**CEREMA**	*09 Implementation*	Implementation was closely linked with planners. The use of the results can varied according to the maritime region. Discussions about the methodology have raised questions and been globally judged more interesting than the final map produced. There is a big importance of the grid size for conflicts between activities. An important to work has been done on the adaptation of methods for stakeholders and communication to facilitate reception/absorption of the maps.
23	**CNR-ISMAR**	*09 Implementation*	The tool is not use in national MSP, but the experts and planners implied in MSP are the same than those implied in the methodology definition, outputs construction, and in the tests in European projects.
24	**SHOM**	*09 Implementation*	The implementation is done through the participating process and via the web platform.
26	**AFB**	*10 Sustainability*	GIS, SQL, R (FOSS tools) and Excel are used. The configurations file has been designed to improve the possibility to use the tool without coding skills. The work is in progress to disseminate results through European projects. The future of the tool is still uncertain.
27	**CEREMA**	*10 Sustainability*	There is a need to have GIS skills to use the tool. A web Interface has been developed.

28	**CNR-ISMAR**	*10 Sustainability*	The diffusion is an important but complex topic. All data are accessible or discoverable into a web platform; efforts have been done to explain the method to scientific and non-scientific public. The use of free and open software allow sharing improve sustainability of the project. The involvement through European project and the team involvement in several research organisms allow to consider at least a 5 year perspective of work on the tool.
29	**SHOM**	*10 Sustainability*	There is a need to kettle Python language and have animation skills during the reunions of construction of the methodology. The tool is going to be developed for at least 3 years. On a long term approach, there is a risk linked to the obsolescence of libraries and connections.

7.2 Annex 2. Extract from Annex 3 of MSFD: Indicative lists of ecosystem elements, anthropogenic pressures and human activities relevant to the marine waters

Anthropogenic pressures on the marine environment

with particular relevance for points (a) and (b) of Article 8(1), and Articles 9, 10 and 11

Theme	Pressure (Note 1)	Possible parameters	Relevant qualitative descriptors laid down in Annex I (Notes 2 and 3)
Biological	Input or spread of non-indigenous species	Intensity of, and spatial and temporal variation in, the pressure in the marine environment and, where relevant, at source. For assessment of environmental impacts of the pressure, select relevant ecosystem elements and parameters from Table 1	(2)
	Input of microbial pathogens		
	Input of genetically modified species and translocation of native species		
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species		
	Disturbance of species (e.g. where they breed, rest and feed) due to human presence		
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)		(3)
Physical	Physical disturbance to seabed (temporary or reversible)		(6); (7)
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)		
	Changes to hydrological conditions		
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition		(5)
	Input of organic matter — diffuse sources and point sources		
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events		(8); (9)
	Input of litter (solid waste matter, including micro-sized litter)		(10)
	Input of anthropogenic sound (impulsive, continuous)		(11)
	Input of other forms of energy (including electromagnetic fields, light and heat)		
	Input of water — point sources (e.g. brine)		

Uses and human activities in or affecting the marine environment

with particular relevance for points (b) and (c) of Article 8(1) (only activities marked * are relevant for point (c) of Article 8(1)), and Articles 10 and 13

Theme	Activity
Physical restructuring of rivers, coastline or seabed (water management)	Land claim
	Canalisation and other watercourse modifications
	Coastal defence and flood protection*
	Offshore structures (other than for oil/gas/renewables)*
	Restructuring of seabed morphology, including dredging and depositing of materials*
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)*
	Extraction of oil and gas, including infrastructure*
	Extraction of salt*
	Extraction of water*
Production of energy	Renewable energy generation (wind, wave and tidal power), including infrastructure*
	Non-renewable energy generation
	Transmission of electricity and communications (cables)*
Extraction of living resources	Fish and shellfish harvesting (professional, recreational)*
	Fish and shellfish processing*
	Marine plant harvesting*
	Hunting and collecting for other purposes*
Cultivation of living resources	Aquaculture — marine, including infrastructure*
	Aquaculture — freshwater
	Agriculture
	Forestry
Transport	Transport infrastructure*
	Transport — shipping*
	Transport — air
	Transport — land
Urban and industrial uses	Urban uses
	Industrial uses
	Waste treatment and disposal*
Tourism and leisure	Tourism and leisure infrastructure*
	Tourism and leisure activities*
Security/defence	Military operations (subject to Article 2(2))
Education and research	Research, survey and educational activities*

Notes related to Table 2

Note 1: Assessments of pressures should address their levels in the marine environment and, if appropriate, the rates of input (from land-based or atmospheric sources) to the marine environment.

Note 2: The numbers in this column refer to the respective numbered points in Annex I.

Note 3: Only pressure-based qualitative descriptors (2), (3), (5), (6), (7), (8), (9), (10) and (11), which have criteria laid down in accordance with Article 9(3), are listed in Table 2a. All other, state-based, qualitative descriptors under Annex I may be relevant for each theme.'

7.3 Annex 3.Template for the describing Fiche.

Template – Methods Describing Fiche

Developed in the task C.1.3.4. Tools and methods to support MSP processes

Summary

Reminder – Purpose of this fiche

The workshop held in Marseille in February 2018 has been able to feed the reflections, and make progress in the definition of action plans in the actions C.1.3.4. The following action plan for the comparison of interaction methods has been set up:

C.1.3.4.: Comparison between methods for the evaluation of interaction

Step 1: Proposal of a template to describe each methods, according to the criteria's defined during this workshop (for the end of February)
Step 2: Feedbacks about this template, validation of a final version (mid-March)
Step 3: Filling of the Methods fiche by each partner (for the end of June)
Step 4: Writing of the first draft of the comparison report (July-August)
Step 5: Validation, inputs of the lessons of the Cases Studies in the comparison report (end of November)
Step 6: Final report (for the end of November)

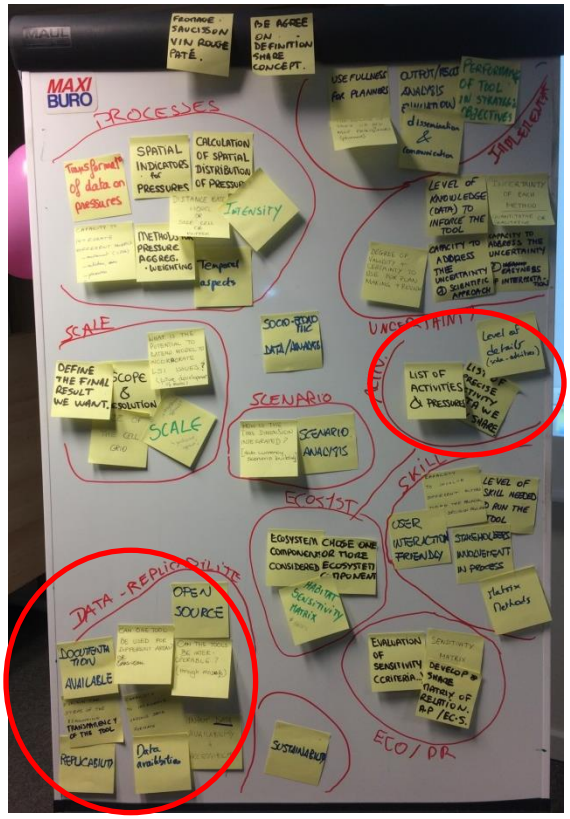
Using the criteria's defined during this workshop; this template has for objectives to help the partners to create a fiche describing their methods with the criteria's cited. This template is going to circulate for validation among partners in March.

It is to be highlighted that all the criteria's cited during the workshop are not really fitted for an objective comparison. Some of them (like in the *Implementation for MSP*, or *Skills* categories) are going to be quite difficult to evaluate. For example, the sharing of the same vocabulary is going to be analyzed in the light of the answer of each partner to this template. In this template, a work on defining precise scales of evaluation is going to be conducted and submit to the validation of partners.

Once all the partners have fulfilled their methods fiche, the wrap-up is going to be done by the AFB.

The maximum length of this comparison fiche is 21 pages. Guidelines are provided in each topic, but you can adapt the length of your answers according to your methodology (in the limit of 21 pages).

Topic 1: Data

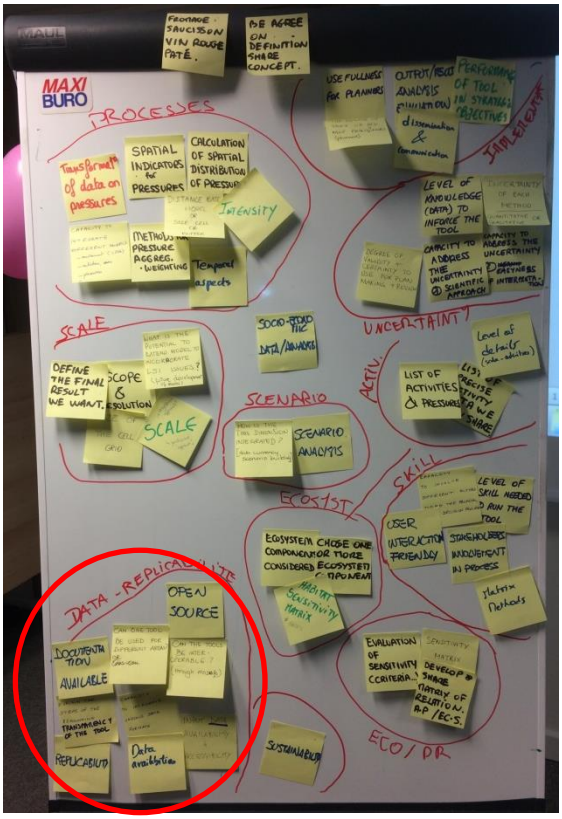


The objective of this part is for you to describe the data used in your tool, the way to select them and their time dimension. The maximum length of this part is 5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Can you provide a detailed list of activities the tool considers?*
- *If you have excluded some's, how do you have defined the activities to take into account in your tool?*
- *If you have excluded some's, how do you have defined the activities to take into account in your tool?*
- *Can you provide a detailed list of pressures the tool considers?*
- *If you have excluded some's, how do you have defined the pressures to take into account in your tool?*
- *Can you provide a detailed list of ecosystem components the tool considers?*
- *If you have excluded some's, how do you have defined the ecosystem components to take into account in your tool?*
- *What is the temporal aspects take into account in the data? (Year, Season, month, hours etc.)*

Topic 2: Data/Accessibility

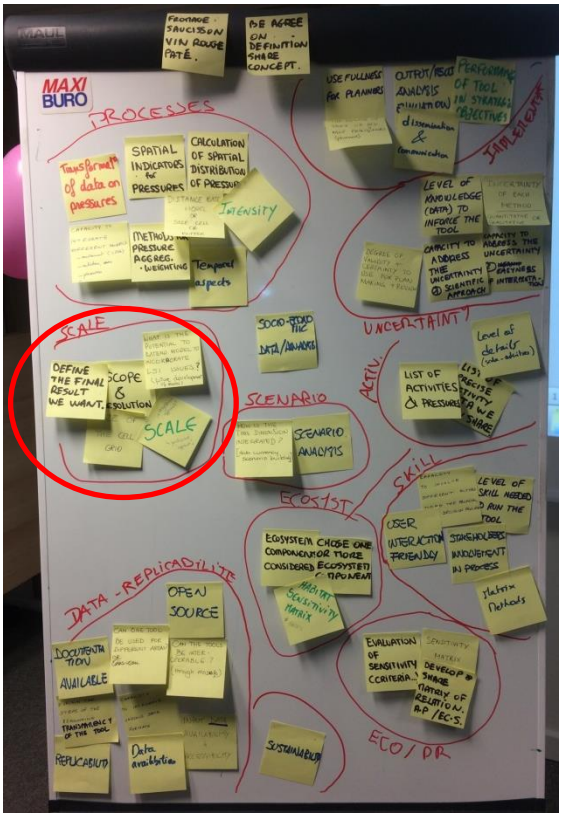


The objective of this part is to make a focus on the availability of your data and the variability in formats you got. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *How many and what kind of data format in entrance do you have? has the tool the opportunity to use new one easily? How? (For example : shape by dots / lines / polygons)*
- *Are a lot of data protected by a broadcast convention?*
- *How do you characterize your method accessibility according to this topic? Can you judge it weak/mean or strong and explain why?*

Topic 3: Processes / Scale

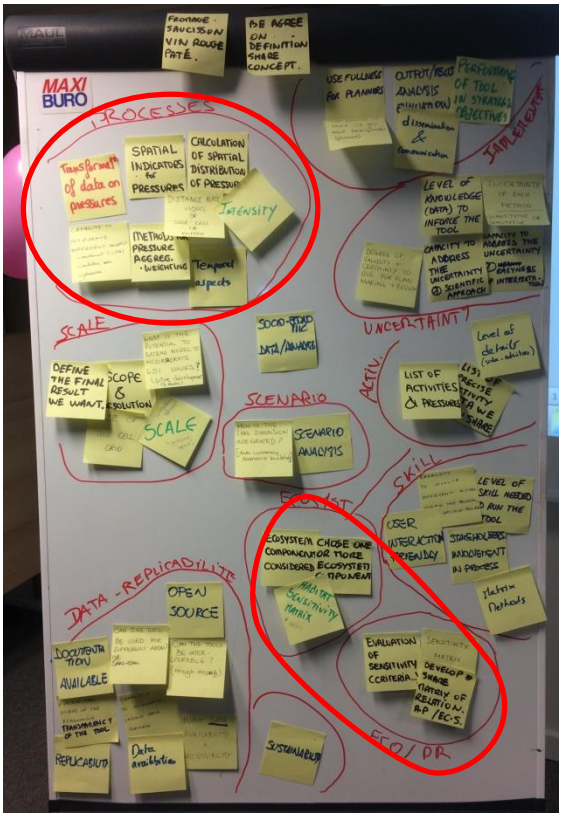


The objective of this part is to describe on which geographic scale your tool is based, and if this scale could be adjusted easily. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *What is the size of the cell grid?*
- *What is the geographic scale used by the tool?*
- *Is the tool usable on new areas? On which conditions?*
- *Is the model or can be extended to incorporate land / sea interaction?*

Topic 4: Processes



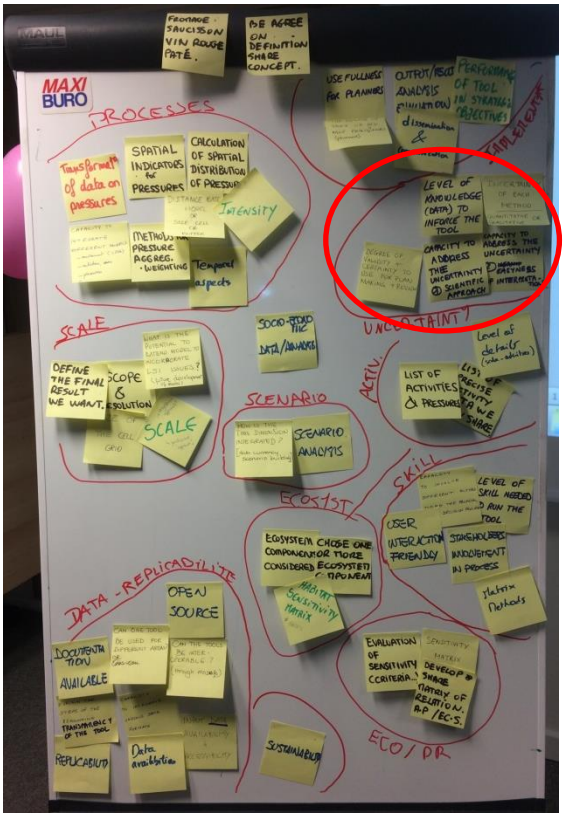
The objective of this part is to describe the processes to transform the original data on a final decision map (for example map of impacts or pressures). This is the methodology of your tool. The maximum length of this part is 6 pages

The following questions are given for examples, but they are NOT mandatory!

- *How do you determine the intensity of an activity?*
- *Do you aggregate the activities? If yes, how?*
- *What are the steps to relate an activity to a pressure? How do you have built them? (What is the method of the matrix you have?)*
- *How do you determine the intensity of a pressure?*
- *Did the tool take distance of pressures into account (distance based model / size of cells / buffers)?*
- *Do you aggregate the pressures? If yes, how?*
- *How do you determine the intensity of an impact?*
- *During the tool process,are some stakeholders or experts consulted? How?*
- *Do the tools process a socio-economic analysis? If not, do you plan to do so? How?*

- *How do you characterize your method complexity according this topic? Can you judge it weak/mean or strong and explain why?*

Topic 5: Processes / Uncertainty

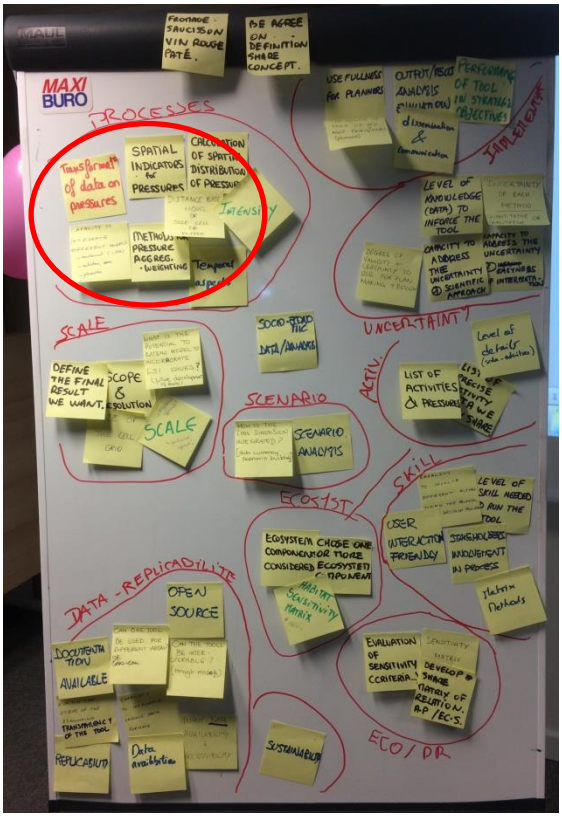


The objective of this part is to speak about the uncertainty of the evaluation. This contains the scientific uncertainty, but also the requirement of certainty by the planners. The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *Does the tool have the ability to address the uncertainty? How?*
- *Does this uncertainty have been transpose in an output, or output add-on, easy to interpret?*
- *What is the minimum of data to inforce the tool and the uncertainty associated?*
- *Is there a minimum of certainty require using your tool or it's outputs for plan making? (For example required by administrations, stakeholders, your own requirements? What is the percentage of pressures actually occurring take into account by your tools in your opinion?)*
- *How do you characterize your efficiency in taking into account uncertainty? Can you judge it weak/mean or strong and explain why?*

Topic 6: Processes / Flexibility

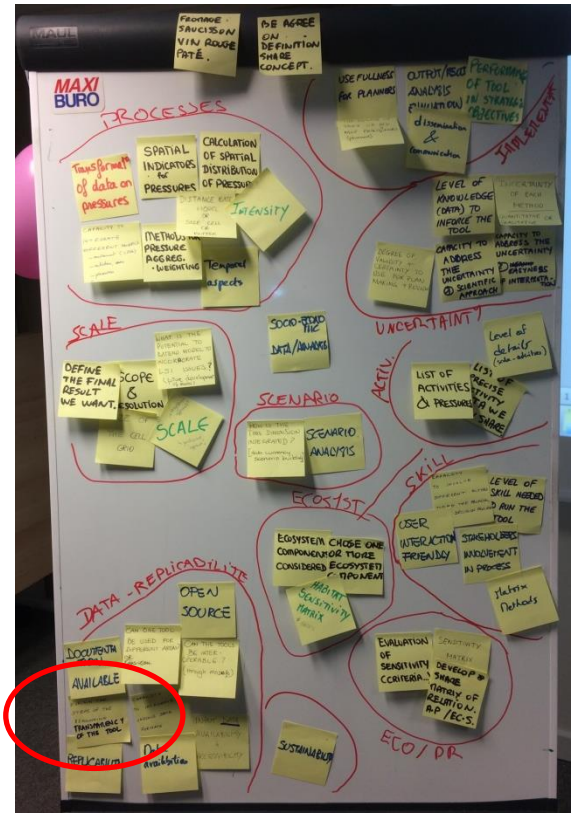


The objective of this part is to provide a good idea of the modification that your tool can afford. This is a wrap-up of the flexibility of the criterions in the "Processes" parts. The maximum length of this part is 1.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Does the tool have the ability to integrate different models (environment, activities, uses, resources)?*
- *Did all the others criteria's about processes could be easily modulated?*
- *How do you characterize your method complexity according this topic? Can you judge it weak/mean or strong and explain why?*

Topic 7: Transparency

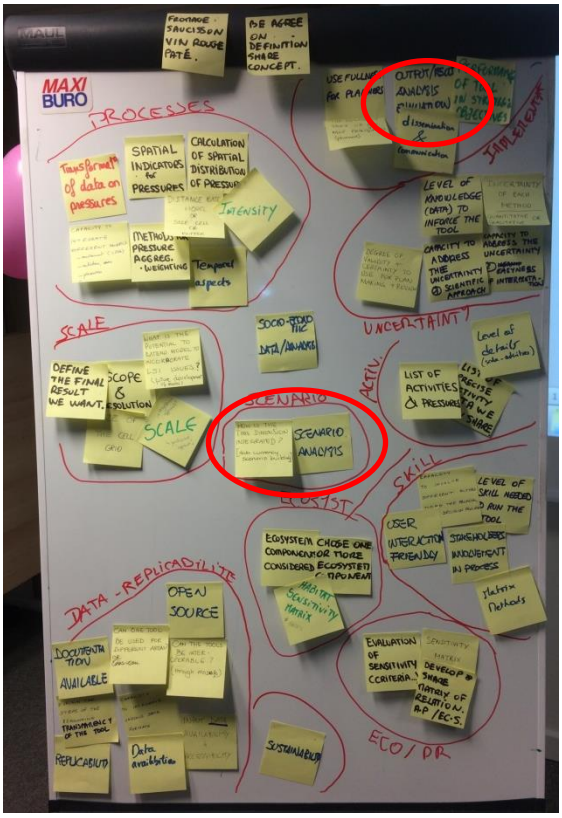


The objective of this part is to provide a good idea of the transparency of your tool, its methodology, the documentation provided with it etc. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Is the documentation about your method available? If not, do you plan make it available? How?*
- *Is the documentation about the method used to build matrixes / links available? If not, do you plan to do so? How?*

Topic 8: Outputs

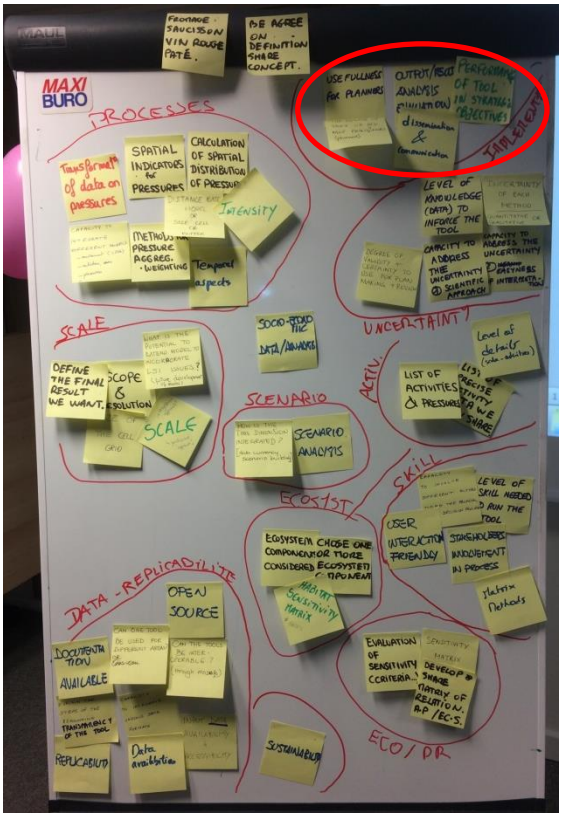


The objective of this part is to describe the methodology you have used to define the outputs, and the futures evolutions planned for them (scenarios for example). The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *How do you have defined the outputs of the tool?*
- *Were any time of concertation implied?*
- *Do you plan to do some?*
- *Did the tool provide evolutive analysis based on scenarios? How? If not, do you plan to do so? How?*
- *If yes, how the time dimension is integrated?*

Topic 9: Outputs / Implementation

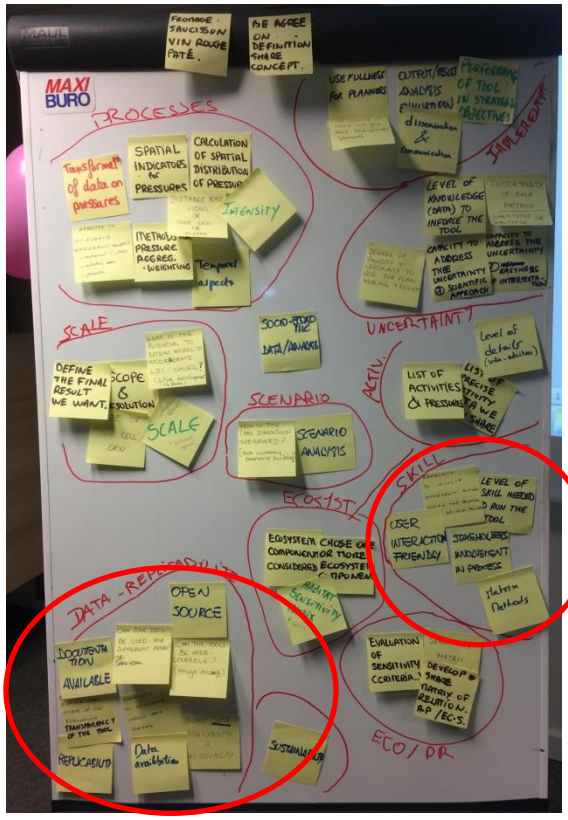


The objective of this part is to give information about the articulation of your work on national MSP processes. This contains use of the outputs, concertation with stakeholders about the results, dissemination etc. The maximum length of this part is 1 page

The following questions are given for examples, but they are NOT mandatory!

- *Are some stakeholders or experts consulted for validation / comments on the outputs? How? If not, do you plan to do so? How?*
- *Is your tool or its outputs disseminated and communicate to planners? If not, do you plan to do so? How?*
- *Do you have feedbacks of planners about your tool or its outputs?*
- *Do you have an idea of the degree of take up of your tool or its outputs for practitioners / planners?*
- *Do you plan on conducted analysis of the use of your tool or its outputs? If yes, how?*
- *How do you evaluate the efficiency of your method? Can you judge it weak/mean or strong and explain why?*

Topic 10: Accessibility and Sustainability



The objective of this part is to describe the skills needed for running the tool, the key dissemination modules developed for the use of it and the wished duration of this work. The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *What is the level of skills needed to run the tool? (For guidelines: how many informatics languages does it use? What is the weight (in octet) of the tool without data? From 1 to 20, how do you evaluate its complexity?).*
- *Is the tool user interaction friendly? (For guidelines: can a stakeholder run an analysis? Have some developments been done to make your tool more accessible?).*
- *Is the tool an open source? Is it using open source software's?*
- *Can the tool be interoperable through modules?*
- *For how much time you are sure that the work on your tool could be pursuing?*
- *For how much time do you plan to do so?*
- *How do you characterize your method sustainability? Can you judge it weak/mean or strong and explain why?*

7.4 Annex 4.Describing Fiche AFB – Carpe Diem

CARPEDIEM Describing Fiche

Developed in the task C.1.3.4. Tools and methods to support MSP processes

Summary

Figures

Reminder – Purpose of this fiche

The workshop held in Marseille in February 2018 has been able to feed the reflections, and make progress in the definition of action plans in the actions C.1.3.4. The following action plan for the comparison of interaction methods has been set up:

C.1.3.4.: Comparison between methods for the evaluation of interaction

- **Step 1:** Proposal of a template to describe each methods, according to the criteria's defined during this workshop (for the end of February)
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- **Step 6:** Final report (for the end of November)

Using the criteria's defined during this workshop; this template has for objectives to help the partners to create a fiche describing their methods with the criteria's cited. This template is going to circulate for validation among partners in March.

It is to be highlighted that all the criteria's cited during the workshop are not really fitted for an objective comparison. Some of them (like in the *Implementation for MSP*, or *Skills* categories) are going to be quite difficult to evaluate. For example, the sharing of the same vocabulary is going to be analyzed in the light of the answer of each partner to this template. In this template, a work on defining precise scales of evaluation is going to be conducted and submit to the validation of partners.

Once all the partners have fulfilled their methods fiche, the wrap-up is going to be done by the AFB.

The maximum length of this comparison fiche is 21 pages. Guidelines are provided in each topic, but you can adapt the length of your answers according to your methodology (in the limit of 21 pages).

Introduction

The tools, data and methods presented in the following fiche were developed as part of the Carpe Diem project, conducted by the French Agency for Biodiversity between 2016 and 2018. The general objective of the project was to propose tools, methods and results for the cumulative effects assessment as part of the implementation in France of the European Marine Strategy (MSFD) and Marine Spatial Planning (MSP) Directives. Participation in the SIMCELT[1] project laid the foundation of the methodology for the assessment of cumulative effects on benthic habitats. This methodology was then improved and further developed to provide a specific tool and method to produce map of risk of cumulative effects on benthic habitats "Carpe Diem-benthic". Participation in the SIMWESTMED and SIMNORAT projects is an opportunity to continue these developments and to adapt them to produce map of risk of exposure on pelagic communities "Carpe Diem-pelagic". These two parts of the project “Carpe Diem-benthic” and “Carpe Diem-pelagic” are briefly described here in the different fiche.

[1] Co-funded by the EU Directorate General for Maritime Affairs and Fisheries, SIMCELT is a two-year project which aims to promote practical cross-border cooperation between Member States on the implementation of the Maritime Spatial Planning Directive in the Celtic Seas.

Topic 1: Data

The objective of this part is for you to describe the data used in your tool, the way to select them and their time dimension. The maximum length of this part is 5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Can you provide a detailed list of activities the tool considers?*
- *If you have excluded some's, how do you have defined the activities to take into account in your tool?*
- *If you have excluded some's, how do you have defined the activities to take into account in your tool?*
- *Can you provide a detailed list of pressures the tool considers?*
- *If you have excluded some's, how do you have defined the pressures to take into account in your tool?*
- *Can you provide a detailed list of ecosystem components the tool considers?*
- *If you have excluded some's, how do you have defined the ecosystem components to take into account in your tool?*
- *What is the temporal aspects take into account in the data? (Year, Season, month, hours etc.)*

The ability of cumulative effects assessment to assist in marine diagnostics and management is highly dependent on the quality and resolution of the data used to perform the analysis. Also within the project a special effort is made to recover, harmonize and prepare relatively accurate data sets with precise typology and acceptable spatial and temporal resolution.

In the two parts of the project, the analysis is based on a structuring of the descriptive data of the marine environment in clearly defined and known geographical units. Descriptive statistical and spatial data on human activities, pressures, and ecosystems components are synthesized, structured, and mapped in gridded map at 1 minute of degree resolution for "Carpe Diem-benthic" and 15 minutes of degree resolution for "Carpe Diem-pelagic". The data typology on human activities and pressures is coherent with the MSFD typology and is built to allow a relatively good accuracy and resolution of data. The benthic habitats typology used in "Carpe Diem-benthic" is EUNIS, which is relevant for transboundary comparison and European projects. The marine mammals and birds typology used for "Carpe Diem-pelagic" is either based on the Latin scientific binomial nomenclature or on groups of species made by scientific experts.

In the context of "Carpe Diem-benthic", even though a lot of work has been done on the preparation of precise and high quality data sets, it is not currently possible to perform analysis at the season's time resolution. For the moment, in this project the temporal resolution is the year and it is possible to calculate inter-annual mean for most of the data. However on non-mobiles organisms, this annual consideration has less impact on the quality of the diagnosis than on mobile species. Conversely, in the context of "Carpe Diem-pelagic" it seems that it is possible to perform analysis on a small set of seasonal data only for a short period of one or two years.

a) Human activities data

In the two parts of the project, descriptive data of human activities is collected from the French administrative bodies responsible for monitoring and managing the different uses of the sea. The data is prepared in order to describe the presence or absence of activities in each cell, along with their intensity in different units (number of ships, quantity, time, etc.).

For the study under "Carpe Diem-benthic", an attempt was made to record and collect descriptive data on the main activities exerting direct physical pressures on benthic habitats. A special work is being undertaken to identify and collect descriptive data on chemical and biological pressures from land-based activities.

Human sector of activity	Intensity parameters	Unit per cell	Period of available data	Major human activities that can be used in the analysis	Progress
Aggregate dredging	Interannual average quantity of dredged material	tonne / year	2011-2014	calcareous sand and siliceous sand and gravel	ok
Submarine cables	Sum of linear cables	linear km	continuous	submarine cable	ok
Navigational dredging	Interannual average quantity of dredged material	tonne / year	2011-2015	Navigational dredging operation	ok
Immersion of dredged material	Interannual average quantity of dumped material	tonne / year	2005-2013	Immersion of dredging material	ok
Aquaculture	estimation of maximum quantity of livestock farming	tonne	unknown	Oyster and mussel on net	ok
			unknown	Intertidal mussel pole culture « bouchot »	ok
			unknown	Intertidal oyster bag culture	ok
			unknown	mollusc culture on floor	ok
Fisheries activities	Interannual average fishing effort (from VMS data)	hours / year	2013-2016	Benthic trawls	ok
				Bottom nets	ok
				Bottom longlines	ok
				Scoubidou device for kelp harvesting	ok
				L. hyperborea dredge	ok
				Mollusc dredges	ok
				Pelagic trawls	ok
				Beam trawl	ok
				Pelagic longlines	ok
				Purse seine	ok
				Pelagic nets	ok
				bottom traps	ok
Mooring	Number of ship places	nb of ship places	unknown	Mooring on buoy	work in progress
Anchoring	Interannual average number of ship anchoring (AIS data)	nb of ship/ year	2012 to 2016	Anchoring	work in progress
Surface navigation	Interannual number of ship tracks (AIS data)	nb of route / year	2012 to 2016	surface navigation for 7 groups of ships	work in progress
Shoreline artificialisation	% of the artificial shoreline	km	unknown	Artificialisation of the shoreline, artificial reefs and building on coastline	work in progress
Leisure coastal activities (surf, scuba diving, snorkeling, sealing…)	several different parameters				to do

Figure 1 : list of the major human activities data used in the Carpe Diem project

b) Pressure data

Pressure	Methods of estimation	Progress
Physical loss (to land or freshwater habitat)	Intensity of the activities contributing to the pressure	ok
Physical change to another substratum or sediment type	Intensity of the activities contributing to the pressure	ok
Habitat structure changes - removal of substratum (extraction)	Intensity of the activities contributing to the pressure	ok
Penetration and/or disturbance of the substratum below the surface	Intensity of the activities contributing to the pressure	ok
Abrasion/disturbance at the surface of the substratum	Intensity of the activities contributing to the pressure	ok
Smothering and siltation rate changes (low)	Intensity of the activities contributing to the pressure	ok
Smothering and siltation rate changes (high)	Intensity of the activities contributing to the pressure	ok
Emergence regime changes (includes tidal level change considerations)	Not yet defined	
Water flow (tidal current) changes (including sediment transport considerations)	Not yet defined	
Wave exposure changes	Not yet defined	
Changes in suspended solids (water clarity)	Not yet defined	
Temperature changes (decrease or increase)	Not yet defined	
Salinity changes (decrease or increase)	Not yet defined	
Transition elements & organo-metal (e.g. TBT) contamination.	Not yet defined	
Synthetic compound contamination	Not yet defined	
Hydrocarbon & PAH contamination	Not yet defined	
Synthetic compound contamination	Not yet defined	
Radionuclide contamination	Not yet defined	
Introduction of other substances (solid, liquid or gas)	Not yet defined	
Nutrient enrichment	Dissolve nitrogen concentration medialization	Ok (in Atlantic and English Channel)
Organic enrichment	Not yet defined	
De-oxygenation	Not yet defined	
Litter	Direct evaluation of the pressure by MSFD pilot	work in progress
Noise changes	Direct evaluation of the pressure by MSFD pilot	work in progress
Electromagnetic changes	Not yet defined	
Introduction of light	Not yet defined	
Barrier to species movement	Not yet defined	
Genetic modification & translocation of indigenous species	Not yet defined	
Introduction or spread of invasive non-indigenous species (INIS)	Not yet defined	
Introduction of microbial pathogens	Not yet defined	
Removal of target species	Not yet defined	
Removal of non-target species	Intensity of the activities contributing to the pressure	work in progress
Death or injury by collision	Intensity of the activities contributing to the pressure	work in progress
Visual disturbance	Not yet defined	

Figure 2 : major list of pressures used in the Carpe Diem project

c) Ecological component data

Ecological components	Progress
Benthic habitats	ok for Carpe Diem-benthic
Pelagic habitats	to do
Marine mammals	work in progress for "Carpe Diem-pelagic"
Marine birds at sea	work in progress for "Carpe Diem-pelagic"
Marine birds on land	to do
Demersal fishes	to do
Sea turtles	to do

Figure 3 : Accessibility of the method of data formatting.

The activities, pressures and ecological components take into account are based on the lists defined on the Marine Strategy Framework Directive. However, all the data are not currently ready to be used for Cumulative Effects Assessment.

The origins of the data are very varied. Most of them have been identified through the Marine Strategy Framework Directive (MSFD) implementation and are produced by state administration involved in management, by university and scientific laboratories and by European project. It has to be raised that the data collected are in very variable formats, units and resolutions which require an important time for comparison and formatting steps before they can be used in the analyses.

The major goal of this step is to make rational methodological choice and data choice, in order to produce harmonized data collection, covering the whole of the area of interest with standardized unity, confidence index and typological and spatial resolution.

This data can be represented by points, lines and polygons; they are all transferred into a grid of a minimum 1 minute of degree, in order to convert all the different data into a single format, according to the following method:

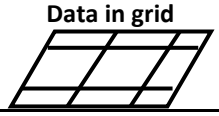
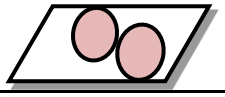
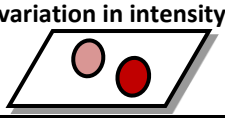
Types of data	Methodology from origin to a grid
Data in grid 	If the resolution is bigger : estimation of the mean by cell, If the resolution is lower : interpolation in a point, then extrapolation into the grid
Polygons / points without variation in intensity 	Polygons: estimation of the percentage of the cell occupied by the polygon and extrapolation. Points : number of points and their values by cell
Polygons / points with variation in intensity 	Polygons: estimation of the total intensity in each cell, pro-rata based in the surface of the polygons superposed to the grid. Points: estimation of the total intensity in each cell, pro-rata based in the number of points in the grid.
Lines 	Length of the line into the cell, number of lines by cell, total time in the grid if the line represents a movement.

Figure 4 : Methodology to grid all the different sources of data

The prepared data are then incorporated into a PostGreSQL/PostGis database which allow to management large volume of data, to back up, to share and to analyze data with powerful tool.

Topic 2: Data/Accessibility

The objective of this part is to make a focus on the availability of your data and the variability in formats you got. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *How many and what kind of data format in entrance do you have? Has the tool the opportunity to use new one easily? How? (For example : shape by dots / lines / polygons)*
- *Are a lot of data protected by a broadcast convention?*
- *How do you characterize your method accessibility according to this topic? Can you judge it weak/mean or strong and explain why?*

The different data are provided by a lot of different sources:

- European databases and project, e.g. Emodnet-EUSeamap (Populus et al. 2017)
- State administration and services databases
- National institutes involved in the gathering of data
- Scientific institutes and universities

This data used for the purposes of the project are very largely data produced by public bodies and are, or should be, freely available to the public and to public administrations. However it is not the case all the time and some data are protected with an agreement.

The diffusion of the results and their availability are under the same limits: if the global maps regrouping diagnosis are the property of AFB and so freely available, some layers, reflecting too much the raw data protected by an agreement, are submitted to the same restriction.

Topic 3: Processes / Scale

The objective of this part is to describe on which geographic scale your tool is based, and if this scale could be adjusted easily. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *What is the size of the cell grid?*
- *What is the geographic scale used by the tool?*
- *Is the tool usable on new areas? On which conditions?*
- *Is the model or can be extended to incorporate land / sea interaction?*

For the Carpe Diem project, 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 gridded map on a $^1/_{60}$ of degree (1 minute of degree cells) for "Carpe Diem-benthic" assessment and on $^1/_4$ of degree (15 minutes of degree cells) for "Carpe Diem-pelagic" assessment. Each cell has a unique code and can be selected and sorted according to various criteria.

The gridded maps used in the Carpe Diem project cover all the French Exclusive Economic Zone and parts of neighborhood countries seas to allow transboundary analysis like SIM European projects, as show in the Figure 5.

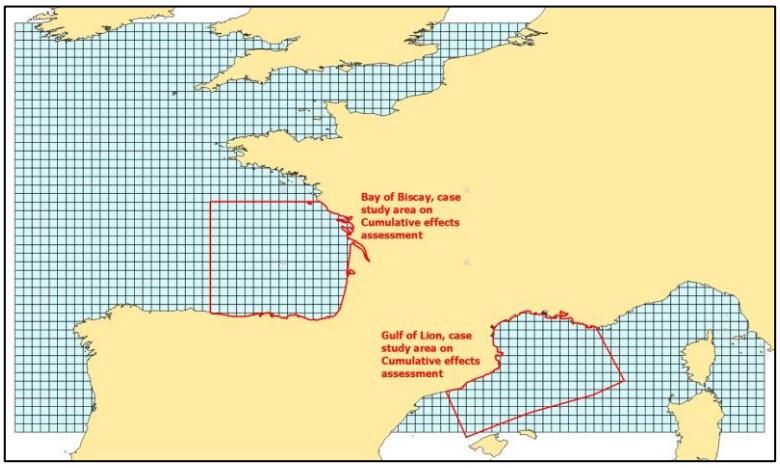


Figure 5 : Area covered by the Carpe Diem gridded map (15' x 15') and limits of the Cumulative effects assessment cases study areas SIMWESTMED and SIMNORAT

The only obligation linked to the use of the tool is to have data (activities, pressures, and ecological components) integrated in a mesh of the same resolution and sharing the same identifier (ID) for each mesh. The tool can totally include new areas if the all the data used are integrated in a common grid.

Land-sea interaction are included in the data collected so in this scale.

Topic 4: Processes

The objective of this part is to describe the processes to transform the original data on a final decision map (for example map of impacts or pressures). This is the methodology of your tool. The maximum length of this part is 6 pages

The following questions are given for examples, but they are NOT mandatory!

- *How do you determine the intensity of an activity?*
- *Do you aggregate the activities? If yes, how?*
- *What are the steps to relate an activity to a pressure? How do you have built them? (What is the method of the matrix you have?)*
- *How do you determine the intensity of a pressure?*
- *Did the tool take distance of pressures into account (distance based model / size of cells / buffers)?*
- *Do you aggregate the pressures? If yes, how?*
- *How do you determine the intensity of an impact?*
- *During the tool process, are some stakeholders or experts consulted? How?*
- *Do the tools process a socio-economic analysis? If not, do you plan to do so? How?*
- *How do you characterize your method complexity according this topic? Can you judge it weak/mean or strong and explain why?*

The processes are detailed according to the different outputs and steps of the methodology.

a) Mapping human activities

A multi-activity map gives a qualitative and quantitative overview of the use of marine and coastal areas, which is useful for marine planning. In particular, it must produce relatively homogeneous areas with similar types and intensities of human activities. The definition and analysis of these areas will show sectors with potentially strong interaction between the activities and between the activities and the marine environment. Areas with fewer constraints between activities and with the environment may also be located. Three complementary methods are proposed for mapping human activities.

a) **Calculation of the index of multi-activity presence (IMA1), corresponding to the cumulative number of activities present in each cell over a defined period.** The period may be defined to take into account the diversity of sets of data. The activities with several years of available data may be taken into account using an inter-annual average. Activities with just one year of available data may only be taken into account with this annual data, until more information is available.

b) **Calculation of the index of multi-activity intensity (IMA2), corresponding to the cumulative intensities of each activity in each cell**. For this approach, the intensity data for each activity is normalised between 0 and 1 [0-1] using a log transformation. This operation is used to work with

source data in very diverse units. For approaches a) and b), the index of multi-activity (IMA) is calculated as follows:

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

Where: A_i presence/absence of the activity [0/1] or intensity of the activity which has been log transformed and normalised [0-1]

ni number of activity sectors

Descriptive data on human activities can then be used to map the pressures. Mapping marine activities does not represent all activities that generate pressures, as many of them are located on land, especially agricultural and industrial activities which generate significant pressures on marine habitats and ecological functions. Some pressures, especially chemical and biological pressures, can be mapped without representing land or coastal activities. The biological and chemical pressures generated by land activities, such as farming, industry and coastal urbanisation, are very important and significantly contribute to the effects on marine habitats and communities. However, given the advances in methodological developments made in 2016, 2017 and 2018, they were not still taken into account in this study.

b) Mapping the pressures

For the purposes of analysis, it is assumed that the intensity of the activity (see Figure 1) can be used to estimate the intensity of the pressure.

A theoretical relationship matrix between the activities and pressures has been developed in order to establish a theoretical link between the activities and pressures. Figure 6 shows an extract of the matrix developed for "Carpe Diem-benthic". It uses the same activity and pressure types as the MSFD and the activity-pressure relationships previously defined by other projects, in particular the "sensitivity" project led by UMS 2006 PatriNat (La Riviere et al. 2017) and the technical and economic guidelines drawn up by the French Biodiversity Agency (Maison et Abellard 2009; Le Fur et Abellard 2010; Ragot et Abellard 2010; Guégan et Germain 2014). The matrix was produced in two stages. First, during a workshop in December 2016, with the scientific and administrative teams involved in the 2018 assessment of the MSFD. Second, during an internal FBA workshop, which completed and presented arguments for the relationships in the matrix. A confidence index for each relationship describes the level of expertise involved in establishing the relationship between the activity and pressure. Interpreting the confidence index will help update the matrix by identifying the relationships with insufficient expertise. The matrix lists all human activities that contribute to each pressure. Using this list, the descriptive data on activities needed to map each pressure can be identified.

Human activity \ Pressure	Physical loss	Physical change	Removal of substratum (extraction)	Abrasion/disturbance of the substrate	Penetration and/or disturbance of the substrate below the surface of the seabed	Smothering and siltation rate changes (Light)	Smothering and siltation rate changes (Heavy)	Water flow (tidal current) changes, including sediment transport considerations	Changes in suspended solids (water clarity)	Temperature change (decrease or increase)	Salinity change (decrease or increase)
Benthic trawls	0(5)	0(5)	0(5)	1(5)	1(5)	1(5)	0(5)	0(5)	1(5)	0(2)	0(2)
Dredge	0(5)	0(5)	1(5)	1(5)	1(5)	0(5)	0(5)	0(5)	0(5)	0(2)	0(2)
Bottom nets	0(5)	0(5)	0(5)	1(5)	0(5)	0(5)	0(5)	0(5)	1(5)	0(2)	0(2)
Bottom longlines	0(5)	0(5)	0(5)	1(5)	0(5)	0(5)	0(5)	0(5)	0(5)	0(2)	0(2)
L. hyperborea dredge	0(5)	0(5)	1(5)	1(5)	1(5)	0(5)	0(5)	0(5)	1(5)	0(2)	0(2)
Scoubidou	0(5)	0(5)	1(5)	1(5)	1(5)	0(5)	0(5)	0(5)	1(5)	0(2)	0(2)
Oyster and mussel on net	0(2)	0(2)	0(4)	0(2)	0(2)	1(2)	0(2)	1(3)	1(3)	0(1)	0(1)
Intertidal mussel pole culture « bouchot »	0(2)	0(2)	0(4)	0(2)	0(2)	1(3)	1(3)	1(2)	1(4)	0(1)	0(1)
Intertidal oyster bag culture	0(2)	1(2)	0(1)	1(2)	1(2)	1(2)	1(2)	1(2)	1(4)	0(1)	0(1)
Mollusc culture on floor	0(2)	0(2)	0(4)	1(2)	1(2)	1(2)	0(2)	0(2)	1(4)	0(1)	0(1)
Kelp culture on net	0(2)	0(2)	0(4)	0(2)	0(2)	0(2)	0(2)	0(2)	1(4)	0(1)	0(1)
Navigational dredging	0(NA)	1(NA)	1(NA)	1(NA)	1(NA)	1(NA)	0(NA)	NA (NA)	1(NA)	0(NA)	0(NA)
Immersion of dredged material	0(NA)	1(NA)	0(NA)	0(NA)	1(NA)	1(NA)	1(NA)	1(NA)	1(NA)	0(NA)	0(NA)
Submarine cables	0(NA)	1(NA)	0(NA)	1(NA)	1(NA)	1(NA)	0(NA)	0(NA)	0(NA)	1(NA)	0(NA)
Aggregate dredging	0(NA)	1(NA)	1(NA)	1(NA)	1(NA)	1(3)	0(NA)	1(NA)	1(NA)	0(NA)	0(NA)
Coastline artificialization	1(NA)	1(NA)	0(3)	1(3)	1(3)	1(3)	0(3)	1(3)	1(3)	1(NA)	1(NA)

Figure 6 : Example of the relational matrix between activities and pressures develop for "Carpe Diem-benthic" (0: activity doesn't generate the pressure, 1: activity generates the pressure, NA: not assessed, (1): very low confidence index, (2): low, (3): medium,

The calculation of each activity-pressure pairing P_jA_i (pressure j generated by activity i) can be expressed as an equation. To compare the distributions of pressures, avoid over-representation of extreme values and correct any frequency distribution bias (Andersen *et al.*, 2013), the pressure intensities are log transformed (log[X+1]) and normalised (N function), with regard to the maximum pressure intensity value in the area (all cells 1 to nz). All mapping of P_jA_i therefore has an intensity of between 0 and 1. These considerations result in the intensity of pressure *j* generated by activity *i* in a cell *z* being calculated as follows:

$$P_jA_i = \mathrm{N}\left[Log\left[A_i \times \gamma_{P_jA_i} \times f(Dist\_P_jA_i) + 1\right]\right]_{z=1,nz}$$

Where: A_i intensity of activity *i*

$f(Dist\_P_jA_i)$	the spatial model for mapping pressure *j* from activity *i*. In this study, its value is 1, as no spatial model was developed or used
$\gamma_{P_jA_i}$	the presence or absence of pressure *j* generated by activity *i*
N	normalisation between 0 and 1 of the value obtained in the cell

A confidence index is established for each estimation of P_jA_i by combining the confidence index of the activity-pressure relationship matrix between A_i and P_j ($\gamma_{P_jA_i}$) and a confidence index for estimating the zone of influence of the pressure ($Dist\_P_jA_i$).

In most cases, pressures are generated by several activities on land or at sea. Pressure P_j can therefore be estimated by calculating the sum of the activity - pressure pairings P_jA_i. The methodological challenge of this calculation step is to assess the respective contribution $c_{i,j}$ of each activity - pressure pairing P_jA_i to pressure P_j. For example, the compaction caused by a fish trap is not of the same intensity as compaction caused by wind turbine construction work, regardless of the duration of the activity. To resolve this methodological issue, a frame of reference needs to be developed to compare the intensity of the pressure generated by one-off events caused by anthropogenic practices on a unit of area. Until additional work is able to be carried out by experts to compensate for this lack of knowledge, this project uses the assumption that activities make an identical contribution to the pressure for standard events ($c_{i,j}$ =1). The equation to calculate the single pressure index can therefore be written as follows:

$$P_j = \sum_{i=1}^{ni} P_jA_i \times c_{i,j}$$

Where: P_j	intensity of pressure *j*
P_jA_i	intensity of pressure *j* generated by activity *i* normalised between 0 and 1
$c_{i,j}$	relative contribution of activity *i* to pressure *j*

The cumulative pressures index is calculated using the sum of pressures P_j. The cumulative pressures index (CPI) is calculated as follows:

$$CPI = \sum_{j=1}^{nj} P_j$$

where: P_j intensity of pressure j

nj number of pressures

Land-Sea interactions are a very complex area of studies. If the use of this kind of effect can be integrated into the tool, the methodology associated, in order to define the geographic limits of the impact for example, has not yet been pursued. In addition, a lot of pressures resulting from land sea interactions are take into account into the data models (for example the rivers flows for eutrophication), themselves developed by experts for Marine Strategy Framework Directive (MSFD), Water Framework Directive (WFD) etc.

c) Benthic habitats' sensitivity to pressure: sensitivity matrix

Assessing the risk of effect requires information on the sensitivity of habitats to the pressures to which they are exposed. Along with the assessment of the exposure of ecosystem components to pressures, the sensitivity matrix is used to estimate a risk of effect of pressures on the ecosystem components.

As no suitable assessments on the sensitivity of benthic habitats in France is available for the English Channel and bay of Biscay, the MarLIN-MarESA[2] matrix (Tillin, Hull, et Tyler-Walters 2010; Tillin et Tyler-Walters 2014) was selected for carrying out the initial technical tests. A sensitivity index between pressure j and habitat k was developed, expressed as, $\mu_{j,k}$. This index was used to estimate the theoretical level of interaction for each benthic habitat - pressure pairing. The index was calculated using the assessments carried out under MarLIN-MarESA. Associating the sensitivity index with the effectively mapped benthic habitats requires significant preparatory work.

[2] The Marine Life Information Network – marine Evidence based Sensitivity Assessment http://www.marlin.ac.uk/species/sensitivity_rationale

code_eunis	pr_p2_1_pre	pr_p2_2_pre	pr_p1_1_pre	pr_p1_2_pre	pr_p1_3_pre
A6	NA	NA	NA	NA	NA
A5.37	3	3	3	3	3
A5.27	3	0	0	3	3
A6.4	NA	NA	NA	NA	NA
A4.33	NA	NA	NA	NA	NA
A5.15	0	2	0	0	2
A4.27	3	3	NA	5	5
A4.2	NA	NA	NA	NA	NA
A5.14	3	3	1	4	3
A4.1	NA	NA	NA	NA	NA
A4.12	0	0	3	0	4
A5.13	3	3	4	4	4
A6.3	NA	NA	NA	NA	NA
A5.25	0	3	2	0	2
A3.3	NA	NA	NA	NA	NA
A4.3	NA	NA	NA	NA	NA
A3.1	NA	NA	NA	NA	NA
A5.23	5	4	2	2	5

Figure 7 : Extract of the activity/pressures matrix

The MarLIN-MarESA sensitivity matrix was developed for benthic habitats in the British Isles. Habitats mapped within the SIMCELT study area in France may therefore have no direct equivalence in the matrix. Furthermore, the EUNIS level of the benthic habitats mapped is often lower than the EUNIS level of the habitats whose sensitivity is assessed. The EUNIS habitat types are ranked by level, meaning that a sensitivity score can be attributed to the EUNIS level 4 habitats mapped which are not listed in the sensitivity matrix, providing that there are "sub-"habitats at a higher EUNIS level in the matrix. For these cases, the rules for determining sensitivity scores are presented in the Figure 8. Attribution of a sensitivity score is only possible for habitats mapped at least at level 4 of the EUNIS typology, in accordance with the choices made previously.

In order to perform digital calculations on the risks of effects, the semi-quantitative sensitivity scores, established using resistance and resilience scores, are converted into quantitative scores (Figure 8).

Sensitivity index $\mu_{j,k}$		Resilience				
		None >25 years	Low 10-25 years	Medium 2-10 years	High 1-2 years	Very High < 1 year
Resistance	None	Very high (1.0)	High (0.75)	High (0.75)	Medium (0.50)	Low (0.25)
	Low	High (0.75)	High (0.75)	Medium (0.50)	Medium (0.50)	Low (0.25)
	Medium	High (0.75)	Medium (0.50)	Medium (0.50)	Low (0.25)	Low (0.25)
	High	Medium (0.50)	Medium (0.50)	Low (0.25)	Low (0.25)	Very Low (0.0)

Figure 8 : Semi-quantitative MarLIN-MarESA matrix sensitivity scores and correspondence with the quantitative scores used for the analyses (in red).

d) Mapping the cumulative effects on benthic habitat "Carpe Diem-benthic"

The first step in calculating the risk of concomitant effects involves assessing the risk of effect for each pressure on an ecosystem component. Figure 9 presents the different calculation steps, considering activity A1 which generates pressure P1 on ecosystem component C1.

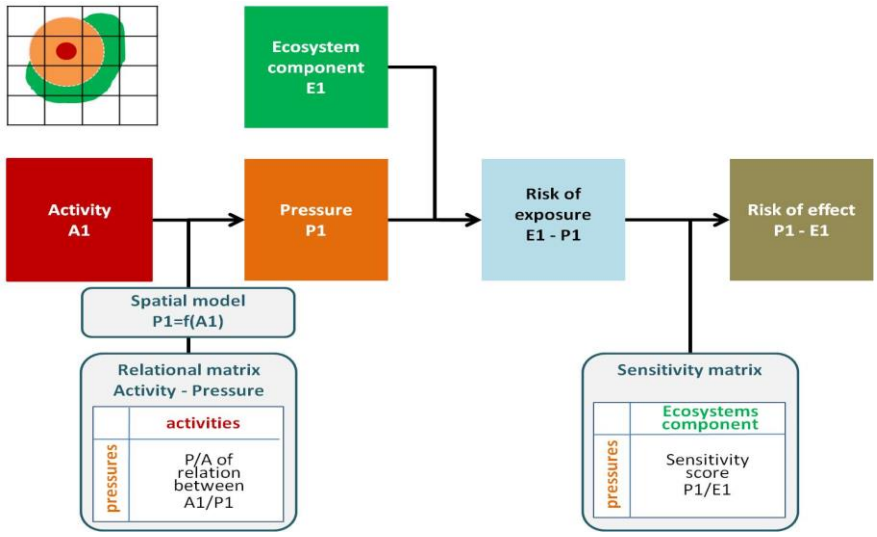


Figure 9: Simplified diagram of the assessment of the risk of effect of a pressure P1 generated by an activity A1 on the benthic habitat C1.

This calculation first requires assessment of the risk of exposure as calculated in the "Carpe Diem-benthic" and in "Carpe Diem-pelagic", corresponding to the overlap in space and time between the pressure and habitat. For each habitat *k*, the risk of exposure to a pressure *j* ($REX\_P_jE_k$) is calculated as follows:

$$REX\_P_jE_k = P_j \times E_k$$

where: P_j normalised intensity of pressure *j* [0-1]

E_k normalised surface area of habitat *k* [0-1]

This risk of effect for pressure *j* on habitat *k* (*REF_P_jE_k*) only for "Carpe Diem-benthic" is calculated by multiplying the risk of exposure by the sensitivity, considering that the intensity of pressure *j* calculated in the risk of exposure takes into account all activities generating this pressure:

$$REF\_P_jE_k = REX\_P_jE_k \times \mu_{j,k}$$

where: $REX\_P_jE_k$ exposure of habitat *k* to pressure *j*

$\mu_{j,k}$ sensitivity index between habitat *k* and pressure *j*

The method for calculating the risk of cumulatives effects (*REFC*) assumes the additivity of effects as follows:

$$REFC = \sum_{j=1}^{nj} \sum_{k=1}^{nk} REF\_P_jE_k$$

where: $REF\_P_jE_k$ the risk of effect of pressure *j* on habitat *k*

During all this process, stakeholders involved into MSP are not consulted, but the experts who have participated to the construction of the different matrixes came from different organisms involved in the support of MSP.

The tool does not take into account the socio-economic analyses. However this topic has been analyzed in a preparatory study. Some of the data available and proposed methodologies are describe into a report (Marcone 2017).

The methodology used is mostly the same than the one in the different other tools using Cumulative impacts. If the sense of the methodology is not particularly complicated, it has to be noted that the complexity of this type of evaluation is the diversity of problematics encounter in it.

Topic 5: Processes / Uncertainty

The objective of this part is to speak about the uncertainty of the evaluation. This contains the scientific uncertainty, but also the requirement of certainty by the planners. The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *Does the tool have the ability to address the uncertainty? How?*
- *Does this uncertainty have been transpose in an output, or output add-on, easy to interpret?*
- *What is the minimum of data to inforce the tool and the uncertainty associated?*
- *Is there a minimum of certainty require using your tool or it's outputs for plan making? (For example required by administrations, stakeholders, your own requirements? What is the percentage of pressures actually occurring take into account by your tools in your opinion?)*
- *How do you characterize your efficiency in taking into account uncertainty? Can you judge it weak/mean or strong and explain why?*

2 approaches have been developed in order to estimate uncertainty.

Approach 1: Confidence Index based on quality

Assessing cumulative effects imply to manipulate a lot of datasets and to make hypothesis and simplification in order to elaborate an impact map. Uncertainty is present at each step of this process, from original data gathering to calculations. In Carpe Diem, several confidence indexes are established to estimate this uncertainty. In the data already implemented and ready to use, an index is linked to each dataset, giving a numerous value of the uncertainty (1 point for each "yes" in the following questions) :

Uncertainty of benthic habitats	Uncertainty of activities
Does the dataset include benthic habitats mapped with EUNIS Typology?	Does the data resolution describe precisely location of the activity/pressure? Considered validated under 1 minute of degree resolution.
Does the data is less than 10 years old?	Does the dataset provide informations on at least two years between 2010 and 2017?
Does the data hass been submitted to a validation process?	Is the dataset is well structured on the scale of French EEZ, on the space, time, and thematic dimension? Considered validated if the formatting of the data does not imply to do hypothesis on those dimensions.
Is the scale higher or equal to 1/50000 (1 cm for 500 m)?	Is the data giving direct information about intensity of the activity? Regarding the fact that producers of the data are considered experts and that the intensity is verifiable and given without implying calculations, hypothesis or extra data.
Is the data has been validating with a campaign on the field?	Does the dataset can be considered complete regarding presence and distribution of the activity? Considered validated if the actual knowledge don't

	highlight a lack in the dataset.

Figure 10 : Criteria for uncertainty about the origins of data.

The confidence in the link between the activity and the pressures is defined according 5 criteria:

Confidence Index	Definition
1	Individual estimation made by a non-expert person, without a comparison (matrixes, literature etc.)
2	Individual estimation made by a non-expert person, based on a comparison (matrixes, literature etc.)
3	Estimation made by an expert group having met once
4	Estimation transposed directly from existing matrixes
5	Estimation made by an expert group having met several times, or transposed from the work done by scientific pilots involved in the Marine Strategy Framework Directive (MSFD).

Figure 11 : Criteria for uncertainty in the link activity/pressures

Each of this confidence indexes are mapped on the same resolution than the data they are linked with it. The final estimation of cumulative impact take into account the uncertainty associated to each dataset, of the calculation, and a global map of uncertainty is produced associated to each diagnosis.

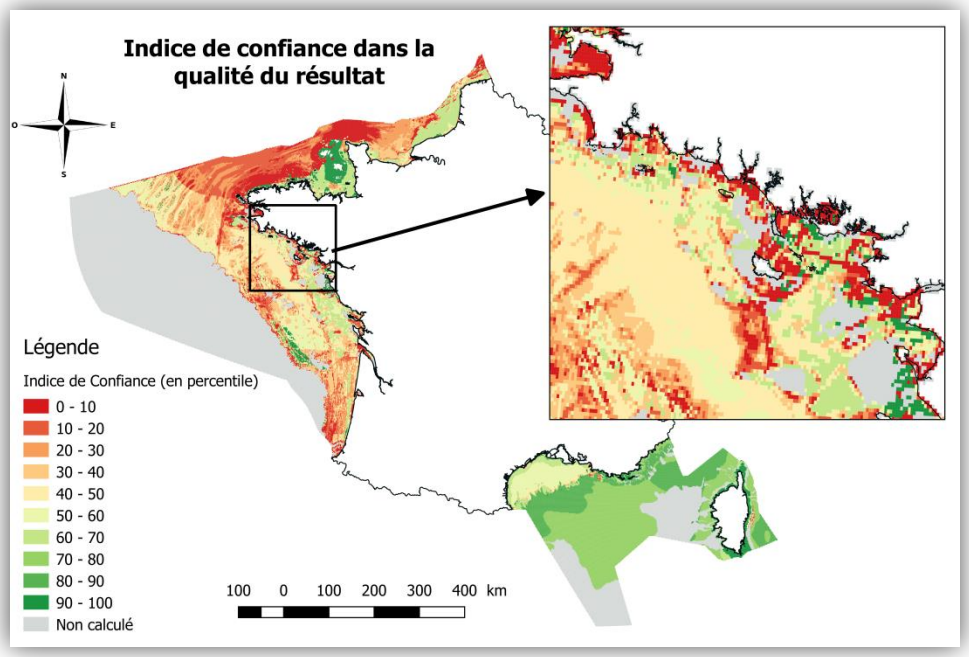


Figure 12 : Map of the uncertainty estimated with confidence indexes

To inforce the tool, at least one data describing an ecological component and one data associated to an activity/pressures have to be used.

Approach 2: Monte Carlo simulations

In our tool, Monte Carlo simulation is a mathematical technique used to generates random variables for modelling the variability of the risk of cumulative effects results. The random variables or inputs are modelled on the basis of probability distributions such as normal, log normal, etc linked with the confidence index of the data. Several simulations are run for generating paths and threshold describing the variability of the result. The random variables are chosen to represent methodological choices that are particularly important in the model, such as describe in the table:

Random variable = Methodological key point	Variation in the simulations
Aggregation of the pressures	Additive, antagonist, synergistic
Relationship Activity/Pressures	Linear, logical, optimistic, pessimistic
Errors in the sensitivity matrix	Variation of the sensitivity scores according to their confidence index
Errors in the Activity/Pressures matrix	Variation of the scores according to their confidence index
Errors in the activities mapping	Variation of the intensity of activities according to their confidence index

Distance of the effect of the activities	Distance relationship between 0 and 3 cells
Aggregation of habitats	Precaution principal or median score

For each cell, the different simulations lead to several results. The cells are ordered one to another in order to reflect their variability according to the variation of their rank in the different simulations. The results of Monte Carlo are presented on a map, where two different types of cells are highlighted:

- The cells in light blue, medium blue and deep blue are the less impacted cells (25% of cells with the lowest values of risk in at least 25% of the simulations). The darker the blue is, the more this risk is low and stable despite the random simulations (deep blue are cell with the lowest values of risk in at least 75% of the simulations).
- The cells in yellow, orange and red are the most impacted cells (25% of cells with the highest values of risk in at least 25% of the simulations). The darker the color is, the more this risk is strong and stable despite the random simulations (red are cell with the highest values of risk in at least 75% of the simulations).

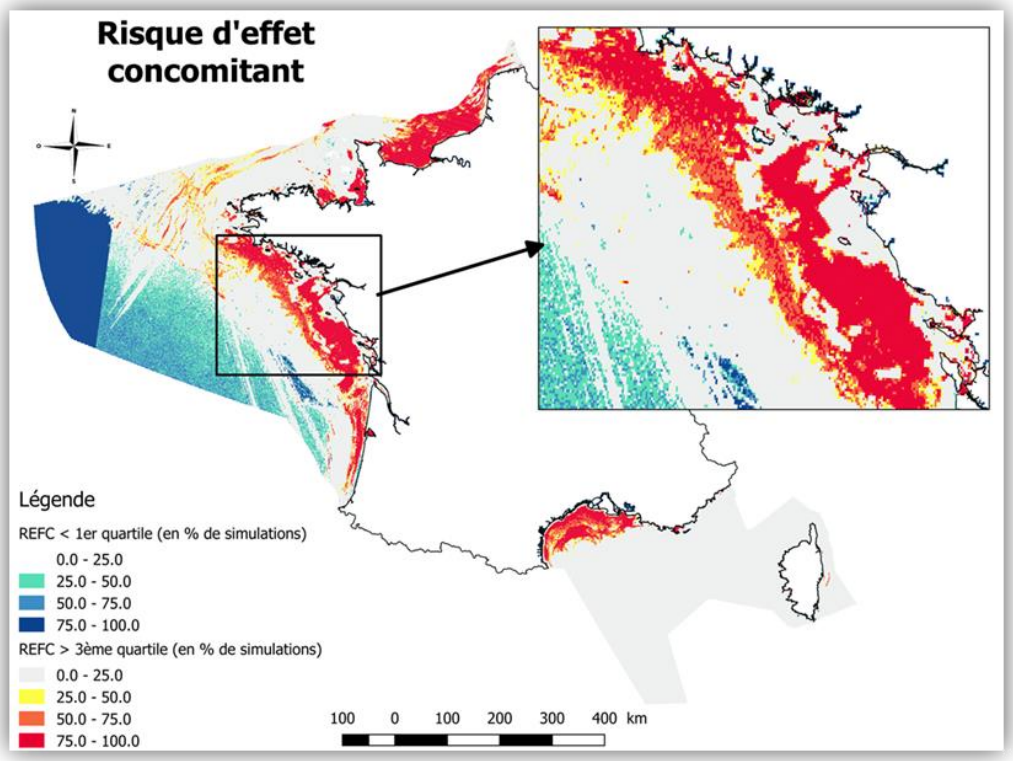


Figure 13 : Example of results of the Monte Carlo simulations after 69 simulations

These two approaches are complementary and give different vision of how interpreted the results. The approach by confidence index is incorporated into the Monte Carlo simulations.

This global estimation of the confidence of the method is quite developed and allow to have a great view of uncertainty of the analysis. A lot of cells are however not consider as stable (in low o high risks) so it could be relevant to consider this results for plan making but with a higher confidence in the diagnosis only in the "stable" cells.

Topic 6: Processes / Flexibility

The objective of this part is to provide a good idea of the modification that your tool can afford. This is a wrap-up of the flexibility of the criterions in the "Processes" parts. The maximum length of this part is 1.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Does the tool have the ability to integrate different models (environment, activities, uses, resources)?*
- *Did all the others criteria's about processes could be easily modulated?*
- *How do you characterize your method complexity according this topic? Can you judge it weak/mean or strong and explain why?*

Not all the steps in the methodology are very flexible. The situation can be described as follow:

Step of Methodology	Flexibility	Comment
Integration of data	Low	A lot of different data, models etc. can be integrated to Carpe Diem. The actual raw data are dots, lines polygons and raster files. However, the recovery and preparation of new activities/pressures/ ecological component is possible, but requires a significant investment in time and technical expertise.
Matrix activities/Pressures	Medium	The creation of the activity-pressure relationship matrix requires significant work to mobilize, coordinate and synthesize scientific expertise to inform the relationships. An update, an improvement and an evolution of the matrix therefore implies potentially important work also. However the technical modification in a link between an activity and a pressure can be done very easily.
Matrix Sensitivity	Medium	The creation of the sensitivity matrix between benthic habitats and pressures requires significant work to mobilize, coordinate and synthesize scientific expertise to inform relationships. This work has not been done in the framework of the Carpe Diem project. An update, an improvement and an evolution of the matrix therefore implies potentially important work. However the technical modification in a link between a pressure and an ecological component can be done very easily.
Processes	Medium	The creation and also the evolution of the

		analysis tool imply a significant mastery of the R language and to be able to work on complex script of several thousand lines. Therefore this language is very used in the scientific community and open source. In order to integrate the problem of R comprehension, the parameter Excel file resuming all the settings and methodological choices has been created. In the beginning of the analysis, the script imports the settings of this file and allow a non R-friendly user to the analysis.

The development of the methodology and tool, including several meeting with scientific team involved in the MSFD implementation, as well as the mobilization and preparation of the necessary data and relationship matrix required a lot of work involving about 5.5 full-time work persons over 3 years only for the "Carpe Diem-benthic" part. Very good technical skills in the processing of spatial and statistical data were needed. Minor evolutions of the methodology, data and tool are possible easily, but overall the approach is not very flexible.

Topic 7: Transparency

The objective of this part is to provide a good idea of the transparency of your tool, its methodology, the documentation provided with it etc. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Is the documentation about your method available? If not, do you plan make it available? How?*
- *Is the documentation about the method used to build matrixes / links available? If not, do you plan to do so? How?*

For now, no peer-reviews article about the tool has been published. However, the uses of Carpe Diem into the SIMCELT project have led to several publications:

- A methological report available on the SIMCELT website : http://www.SIMCELT.eu/wp-content/uploads/D11a_cs2_CEA_French-waters.pdf
- A peer-review article in progress, about the use of CEA in the SIMCELT project (including the exercise in the Irish sea) : *Kidd et al, 2018, "Integrating Cumulative Effects Assessment in MSP Processes" submitted to Marine Policy*.

Moreover, a methodological report describing in details each steps of the methodology is available in French since beginning of june 2018. Regarding the specific methods of construction of the different matrixes used, a report has already been published in French: Vanhoutte-Brunier A., (2017). Matrice activités-pressions développée par le groupe de travail AFB. Note technique. Version 1, septembre 2017. Agence française pour la biodiversité. 41 p.

Topic 8: Outputs

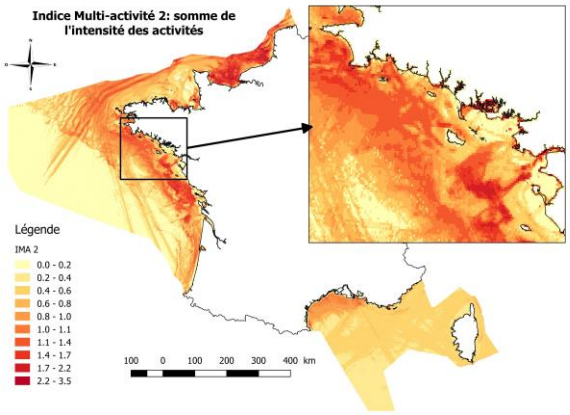
The objective of this part is to describe the methodology you have used to define the outputs, and the futures evolutions planned for them (scenarios for example). The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

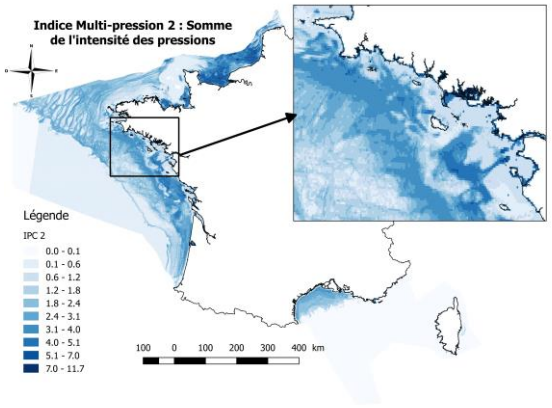
- *How do you have defined the outputs of the tool?*
- *Were any time of concertation implied?*
- *Do you plan to do some?*
- *Did the tool provide evolutive analysis based on scenarios? How? If not, do you plan to do so? How?*
- *If yes, how the time dimension is integrated?*

The outputs of the tools are maps. Different maps can be created:

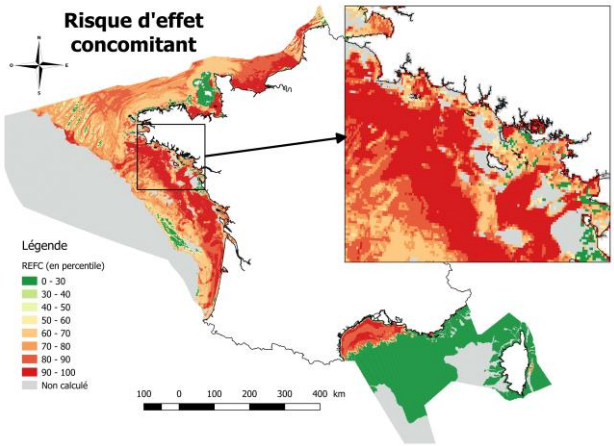
- **Mono activity map**: This type of cartography is very similar to the raw data, but incorporated in a grid.
- **Multi-activity index (IMA1)**: cumulative number of activities present in each cell over a defined period as defined in Topic 4: Processes**Multi-activity index (IMA2)**: cumulative normalized intensities of each activity in each cell as defined in Topic 4: Processes.



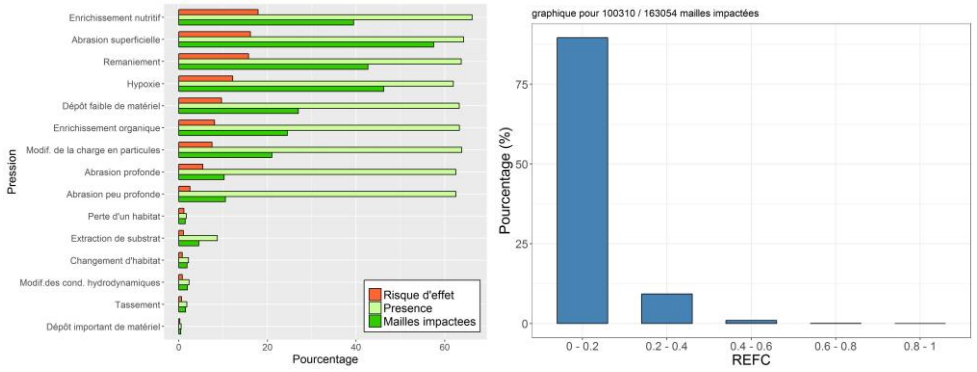
- **Mono pressure index:** this map shows the distribution and the intensity of a single pressure into a grid.
- **Multi pressure index:** cumulative normalized intensity of each pressure in each cell as defined in the methodology fiche.

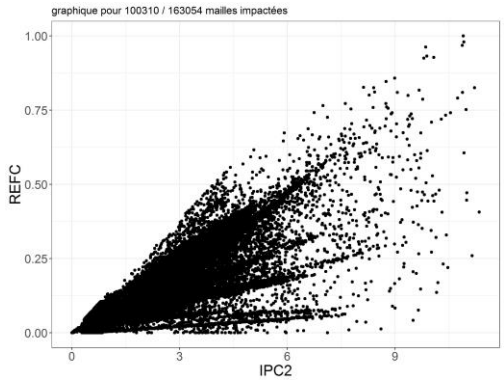


- **Index of cumulative effects:** as describe Topic 4: Processes. A huge diversity of this kind of map can be produced, regarding the pressures and ecological components to consider.



For each of this outputs, confidence index map could be produced. The tool also allows to automatically producing a series of graph describing the distribution of values and results: types of habitats more impacted by an activity, repartition of a pressures according the activities present etc.





At French scale, and in the current state of the Carpe Diem project, the results are not yetnot submitted to the validation, or concertation with stakeholders. However, it is planned to use the maps describing an activity as a discussion starter in the workshop organized into the SIMNORAT project. The background documents for a workshop organize by the French Biodiversity Agency, the University of Western Brittany and AZTi tecnalia during September with stakeholders coming from Spain and France.

The tool does not provide concrete evolutive analysis based on scenarios. However the parallel between the current situation and the projects (for example Marine Renewable energy projects) can help the decisionners to balance the choices. It is also relay possible, even if not developed yet, to build artificial datasets with predictions of the activities in order to establish the different diagnosis and design the possible scenarios through maps.

The majority of data are year based, to the outputs are also year based. But in the SIMNORAT and SIMWESTMED projects, the development of seasonal diagnosis will develop of time relationship between these two periods.

Topic 9: Outputs / Implementation

The objective of this part is to give information about the articulation of your work on national MSP processes. This contains use of the outputs, concertation with stakeholders about the results, dissemination etc. The maximum length of this part is 1 page

The following questions are given for examples, but they are NOT mandatory!

- *Are some stakeholders or experts consulted for validation / comments on the outputs? How? If not, do you plan to do so? How?*
- *Is your tool or its outputs disseminated and communicate to planners? If not, do you plan to do so? How?*
- *Do you have feedbacks of planners about your tool or its outputs?*
- *Do you have an idea of the degree of take up of your tool or its outputs for practitioners / planners?*
- *Do you plan on conducted analysis of the use of your tool or its outputs? If yes, how?*
- *How do you evaluate the efficiency of your method? Can you judge it weak/mean or strong and explain why?*

At the current stage of the Carpe Diem project, there is no official consultation of stakeholders leading to a modification of the diagnosis. However, Carpe Diem has been implied in as workshop aiming to establish wider stakeholder views on the practicalities of integrating CEA methodologies within MSP processes (SIMCELT Final conference, November 2017). It reveals a general view that CEA is an important and fundamental tool for MSP that should be a priority area for future development. This has highlighted the usefulness of this tool, specifically in defining/analyzing existing conditions and implementing and enforcing the plan measures, for stakeholders. From a CEA perspective, participants emphasized the importance of remembering and engaging end users in CEA development. In this respect clear outputs and effective communication with the MSP user community were put forwards as key messages from the workshop.

This tool has originally been conducted in order to contribute to the evaluation of cumulative effects within the Marine Strategy Framework Directive (MSFD) second cycle implementation. This objective was implying the tool to be operational during 2018. Unfortunately, the development of the tool and the time implied by data gathering and matrixes building has not made the tool ready in time. However the opportunity to use it for the program of measures or the third cycle of the MSFD is still possible.

Regarding MSP directly, Carpe Diem has been used a lot in transboundary European project (SIMCELT, SIMNORAT and SIMWESTMED) which target directly the support of the Implementation of MSP. The outputs of the different cases studies represent a cover of a part of the French EEZ, and can be used for the creation/improvement/revision of the regional plans (Seafront Strategic Document).

The Carpe Diem project is still very experimental, with current methodology development in place and not a lot of dissemination information available. This has for consequence a poor efficiency of the method concerning the use of it by stakeholders and planners.

Topic 10: Accessibility and Sustainability

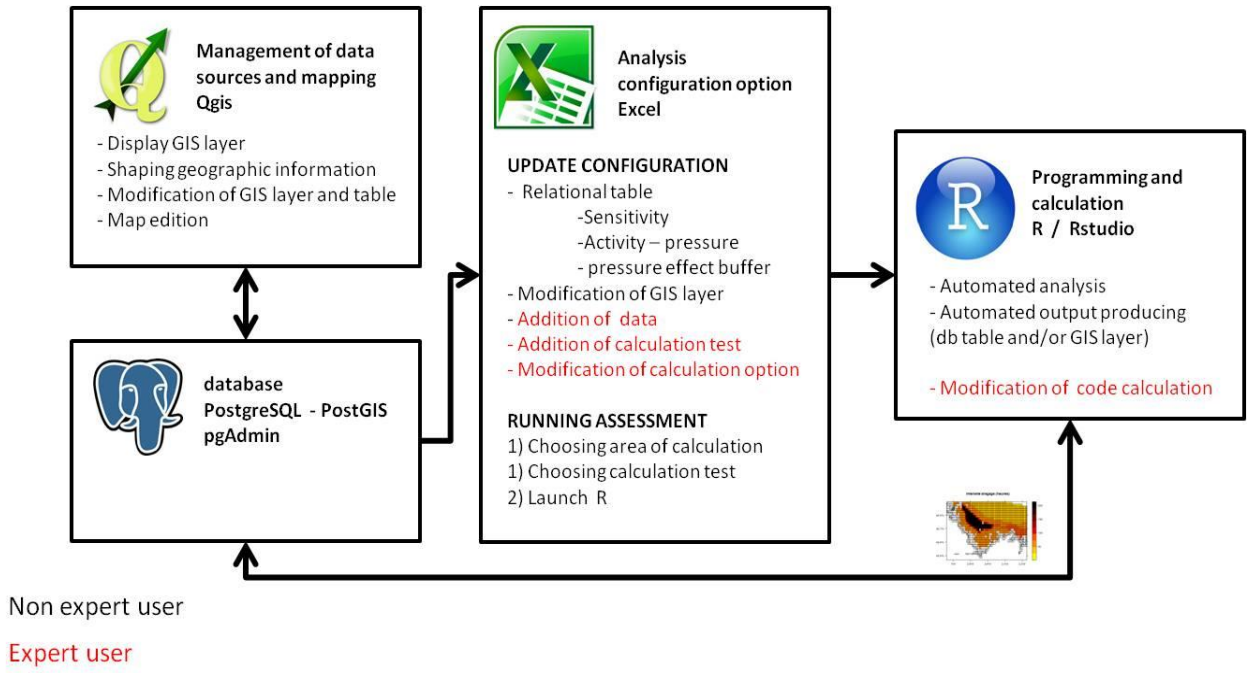
The objective of this part is to describe the skills needed for running the tool, the key dissemination modules developed for the use of it and the wished duration of this work. The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *What is the level of skills needed to run the tool? (For guidelines: how many informatics languages does it use? What is the weight (in octet) of the tool without data? From 1 to 20, how do you evaluate its complexity?).*
- *Is the tool user interaction friendly? (For guidelines: can a stakeholder run an analysis? Have some developments been done to make your tool more accessible?).*
- *Is the tool an open source? Is it using open source software's?*
- *Can the tool be interoperable through modules?*
- *For how much time you are sure that the work on your tool could be pursuing?*
- *For how much time do you plan to do so?*
- *How do you characterize your method sustainability? Can you judge it weak/mean or strong and explain why?*

The tool used several software in the different steps of the analysis:

1. The ready to use data are stored into a PostgreSQL-PostGIS database. This tool is using SQL language and is open source and free.
2. The processes of calculation of each steps in the methodology is done by an R script, using R language. This tool is open source and free.
3. The preparation of the data and the visualization of the results is made by the cartography software QGis. This tool is open source and free. The link between the database and QGis is possible using the PostGIS spatial extender for PostgreSQL. This extension is open source and free.
4. Microsoft Excel software is used to set up the analysis.



We can distinguish two different user profiles.

- The developer with serious skills in programming and database management.
- The user who can theoretically use only the Excel file to configure the analysis and simply must have a good knowledge of the contents of the database and knowledge of the calculation methods he want to implement.

This setting file is a progress in order to make the tool more accessible to other people. Free and open source softwares used are based on very dynamic communities of users and developers, which is a guarantee of longevity and regular updates. These free softwares also make it easy to spread tools to new partners.

The tool did not offer a free access via a web platform or an app. The main maps produces are accessible through the SIM projects outputs. However, it is plan in the end of the year to make available those outputs into cartographic web portals, showing also the intermediate indexes, the confidence indexes, and the raw data. This work could really improve the visibility of the outputs, the understanding of the methodology and of the origins of a diagnosis performed through Carpe Diem.

To carry out the entire analysis for "Carpe Diem-benthic" at the scale of the French waters (about 180 000 square cells with 1 minute of degree resolution) in a reasonable time (a few days) it is necessary to have a relatively powerful computer, with a frequency of processor quite high and a RAM of at least 16 GB.Carpe Diem project is going to continue at least until the end of the year 2018. A lot of actions in order to define needs and wishes concerning Carpe Diem tool are actually in progress in order to continue to work on this tool for a few years, improve is diffusion to the planners and stakeholders, and explain the methodology. The fact that Carpe Diem is owned and finance by public money is a real

advantage in order to incorporate it into national processes and to have access to data and experts, however there is a lack in the connection to the scientific networks through publications.

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7.5 Annex 5.Describing Fiche CEREMA

Analysis of Interactions between Maritime and Coastal Activities
Overview

Interactions between maritime and coastal activities were analysed by Cerema in 2016 and 2017, informing the French government's work to produce coastline strategy documents for the National Strategy for the Sea and Coast.

The purpose of this research was to identify spaces in which maritime and/or coastal activities are likely to interact. In such spaces, interactions can lead to conflicts of use or prompt regulations governing cohabitation.

This overview document is organised around the topics defined by the “cumulative effects task group” workshop in February 2018:

- Topic 1: Data
- Topic 2: Data/accessibility
- Topic 3: Processes/scale
- Topic 4: Processes
- Topic 5: Processes/uncertainty
- Topic 6: Processes/flexibility
- Topic 7: Transparency
- Topic 8: Outputs
- Topic 9: Outputs/implementation
- Topic 10: Accessibility and sustainability

Topic 1: Data

The proposed analysis considers that interactions are liable to occur when two activities are carried out - even intermittently - in the same space. To lay the groundwork for analysing this coexistence of activities in maritime and coastal areas, this section begins by describing the maritime and coastal activities included in the analysis scope, and then explains how they are spatially represented based on the available data.

1. Activities included in the interaction analysis

Maritime and coastal areas accommodate a wide range of traditional and emerging activities. In order to provide a comprehensive overview of the interactions between activities along coastlines, the analysis takes a synthetic approach, based on the following activity groups. These groups, some of which cover a wide range of activities, were chosen for their consistency with the coastline strategy documents. Activities have been grouped together with the aim of producing an interaction matrix simple enough to enable an overview map of the interactions to be generated.

- **Marine transportation and ports**

Marine transportation includes activities relating to the shipping fleet and commercial seaports carrying goods (dry and liquid bulk cargo, hydrocarbons, as well as containerised and non-containerised goods) and passengers (ferries and cruise ships). Marine transportation is a major activity for France: in 2015, the country's 66 commercial seaports handled nearly 350 million tonnes of freight and carried 32 million passengers, with more than 80% of French sea traffic being funnelled through its largest ports[1].

- **Offshore works**

Offshore works are represented by two activities that are treated separately for the purpose of the interactions analysis. Firstly, the dumping of sediment dredged from ports and channels in order to keep ports open to marine transport, fishing and recreational vessels. Secondly, operations by cable-laying ships to lay and maintain underwater telecommunications and electric power cables and conduits.

- **Professional fishing**

Professional fishing is an iconic sector of the economy in France's offshore and coastal waters, with almost 4,500 ships registered in metropolitan France in 2014, operating along the coastline and out to the limits of the continental shelf. France has a diversified fleet operating multiple trades (bottom and midwater trawling, net and basket fishing, etc.) catching a variety of species.

- **Aquaculture**

The term aquaculture covers all farming of animal and plant crops in aquatic environments. It is particularly prevalent along the sea shore: oyster and mussel growing, seaweed and fish farming, etc. In particular, France is Europe's second-largest shellfish producer, with almost 50,000 concessions in the maritime public domain, representing nearly 15,500 hectares of beds.

- **Renewable marine energy**

Renewable marine energy (RME) covers all technologies that enable electricity to be produced from forces or resources encountered in the marine environment (including fixed-foundation and floating wind turbines, as well as tidal and wave power systems). In 2018, with the exception of two facilities currently in operation (the Rance tidal power plant and the Paimpol-Bréhat tidal array), the various renewable marine energy projects have been contracted out via competitive bidding processes.

- **Marine aggregate extraction**

Marine aggregate is extracted as a means of diversifying the source of supply for the construction and public works sectors. Deposits located in the English Channel and along the Atlantic coastline are worked by dredging the sea floor at depths between 10 and 50 m.

- **Recreational and tourist activities**

Recreational and tourist activities cover a broad range of activities, whether along the coast or far offshore. Examples include bathing, recreational fishing, sailing, kitesurfing, motor boating and water skiing, diving, sand-yachting, canoeing and kayaking, rowing, sea walking, lifesaving and sea rescue, spear fishing, open water swimming, rambling, horse-riding, cycling and beach sports.

1 https://www.ecologique-solidaire.gouv.fr/ports-maritimes-france

In addition to these activity groups chosen for the analysis, the coastal strategy document review incorporates an analysis of other activities and uses of the sea and coast, based on the activity list presented in the "Marine Environment Strategy" framework directive (see Table 2b in Appendix III), and in particular: industrial activities (sale and processing of seafood products, shipbuilding, etc.), coastal farming, environmental protection, urban uses and defence-related activities. These other activities were excluded from the spatial analysis of activity interactions for several reasons:

- The proposed analysis focuses on coastal and offshore activities operated from the shore. As the main aim is to support France's inaugural maritime planning exercise, a number of land-based activities were excluded from the activity interaction analysis. This is because land-based activities are already addressed by numerous, increasingly diverse planning tools that have been in use for nearly 50 years[2].
- The proposed analysis examines the co-existence of activities in the same space, and does not address the influence of geographically separate activities, such as, for example, the effect of urban, industrial or agricultural uses on pollution of the marine environment, the quality of which is essential to fishing and aquaculture activities.
- Environmental protection activities involving the creation of marine protected areas have been excluded from the analysis in the light of discussions with the French Biodiversity Agency (*Agence française de la biodiversité*), in order to dissociate the analysis of inter-activity interactions from the analysis of interactions between activities and the environment (in a pressure/impact approach) being conducted simultaneously as part of the second cycle of the Marine Environment Action Plan.
- Military defence and maritime security activities were excluded from the analysis of co-existent activities at the request of certain project partners, and in particular the Eastern Channel-North Sea maritime prefecture, which considers defence as an issue with regulatory zones applicable to other activities: all other activities are prohibited in certain zones (e.g. protection zones around nuclear power plants), whereas in others, activities are permitted subject to compliance with regulatory requirements (as on firing ranges, for example).

2. Spatial representation of activities

A spatial representation of the activities selected for the analysis was generated using the data available in 2016 and 2017 (see Table 1). The geographic information used to describe activities conducted along coastlines is very disparate in terms of its nature and format, as well as the spatial and time scales to which it applies.

Activities may be described using various types of data:

- **data describing observed practices:** for example, fishing vessel and merchant shipping traffic in maritime spaces.
- **data resulting from sector-specific planning processes:** for example, areas conducive to marine aquaculture defined in regional marine aquaculture schemes, or areas under assessment or already designated for offshore wind farms.
- **regulatory data:** for example, the boundaries of marine aggregate extraction concessions.

2 Numerous territorial planning tools covering a variety of scales (from regional to local) currently exist, including where applicable aspects specific to onshore coastal areas (regional schemes for planning, sustainable development and territorial equality, regional integrated development plans and intercommunal local urban development plans). Onshore land planning is also supported by thematic tools relating to water (e.g water development and management schemes), risks (e.g. natural risk prevention plans), the environment (e.g. regulatory or contractual protected areas), etc.

Activities are spatially represented with a distinction between:

- **“static” activities,** carried out within a defined permitted scope, such as dredged sediment dumping grounds, marine aggregate extraction sites, aquaculture facilities, and sites approved for renewable marine energy projects.
- **“mobile” activities,** including marine transportation and offshore fishing activities that rove freely across most waters, subject to compliance with applicable management measures (such as port approach lanes, traffic separation measures and fishing regulations).

Data may be presented in a variety of formats:

- **isolated data points:** for example, the positions of ships equipped with the VMS monitoring system;
- **area data:** for example, regulatory zoning data relating to human activities (such as dumping or aggregate extraction) ;
- **linear data:** for example, submarine cable routes.
- **pre-analysed data:** for example, AIS data converted to yield a gridded density indicator.

The temporal characteristics of activities are important when analysing their interactions. The analysis factors in several temporal characteristics:

- **Temporality of static activities:** certain activities use space for a limited time (e.g. marine aggregate extraction or dredged sediment dumping). This dimension is included in the analysis to describe the degree of compatibility between activities. Time-oriented planning may enable activities to co-exist. Other static activities are conducted in phases (e.g. installation, operation and subsequent decommissioning in the case of aquaculture or renewable marine energy projects). This dimension is not reflected in the analysis. The analysis treats each modelled activity as being in its operational phase.

- **Temporality of mobile activities:** mobile marine transportation and fishing activities are characterised based on the presence of vessels in the analysis grid over a period of one or two years (see topic 4). The presence in maritime spaces of such activities within a particular year may vary (due to factors such as the summer tourist season, the presence or absence of fished species, open/closed fishing seasons, etc.). This dimension is not reflected in the analysis.

- **Temporality of planned activities:** most of the activities considered in this analysis already exist in the maritime spaces, with the exception of projects to establish renewable marine energy facilities and sites well suited to aquaculture (in the Mediterranean). Project zoning data is shown, even where the activity does not yet exist. Areas represented in the analysis as accommodating existing activities alongside planned activities are therefore areas of potential co-existence.

Table 1: Data used to spatially represent activities

Activity type	Raw data used for analysis	Producer	Format	Data access
Marine traffic	Total number of ships (all classes) in 2016, per grid cell of 0.005 minutes x 0.005 minutes, based on AIS signals sent by ships	French ministry responsible for the environment - Cerema	Gridded data	Open licence
Port activities	Port authority boundary	Maritime prefectures	Polygons	Subject to authorisation
Aggregate dredging	Marine aggregate extraction areas	UNICEM and Ifremer	Polygons	Subject to authorisation
Immersion of dredged material	Dredged sediment dumping areas	French ministry responsible for the environment - Cerema	Points	Open licence
Submarine pipelines and cables	Cables and pipelines	SHOM and French ministry responsible for the environment - DIRM	Polylines	Open licence
Fishing	GPS position data from French and foreign vessels equipped with VMS systems over 2 years (2013 and 2014), anonymised and aggregated in a grid	National fishing monitoring centre, satellite-based vessel monitoring system (VMS) - Cerema	Gridded data	Subject to authorisation
Aquaculture	Aquaculture registry for all coasts	French ministry responsible for the environment (DDTM) - Cerema	Polygons	Open licence
	Sites suitable for aquaculture in the regional marine aquaculture plan (for the Mediterranean)	DIRM Mediterranean - Cerema	Polygons	Subject to authorisation
Marine renewable energy	Sites approved for marine renewable energy	French ministry responsible for the environment - Cerema	Polygons	Open licence
Marine leisure and tourism	Supervised bathing areas	French Health Ministry (Baignades-sante.gouv.fr)	Points	Open licence
	Individual and collective moorings	DDTM and maritime prefectures	Points and polygons	Subject to authorisation

Topic 2: Data/Accessibility

The data used in the method is either copyright-free or else provided to Cerema in the context of its mission to support the production of coastline strategy documents (see Table 1). Consequently, data accessibility is dependent on the distribution policies of the respective producers. In most cases, this data is accessible for the purpose of performing public service missions. Certain data may be restricted, however, generally for reasons relating to industrial and commercial confidentiality. This applies to the VMS data used to characterise professional fishing, which includes vessel names, times spent at sea, locations, embarked vehicles, etc. Such data might aid a competitor by revealing fishing areas. To overcome this severe restriction, VMS data is anonymised and aggregated in a grid format that totally smooths the compiled information. Despite this precaution, the French Ministry of Agriculture and Food's Maritime Fishing and Aquaculture department requires an authorisation request before providing data.

Géolittoral, the sea and coastline portal operated by the Environment Ministry[3], provides certain data that is produced by Cerema and used in this method (dumping sites for sediment dredged from ports, sites approved or under consideration for marine renewable energy projects, shipping traffic data, etc.). This data is available to download from the site[4] and is accessible via WxS[5] shared view services[5]. The grid used to link data is also available on Géolittoral. Cerema also provides map viewers able to display geographic data:

- One viewer accessible on Géolittoral[6] showcases the data used to produce coastline strategy documents. It presents the data collected by Cerema thematically. The first theme focuses on maritime and coastal activities. Geographic data can be viewed in thematic groups: use of living resources (e.g. fishing and aquaculture), use of non-living resources (e.g. marine renewable energy and marine aggregate extraction), marine transportation, maritime works (e.g. ports, shipping traffic and regulatory zoning), coastal and maritime tourism (e.g. supervised bathing areas and moorings).
- A second working viewer has been created to serve the needs of the Eastern Channel-North Sea inter-regional directorate, enabling it to cross-reference geographic data relating to maritime and coastal activities with environmental data, providing inputs for technical reports on the relationships between socioeconomic and environmental issues.

Topic 3: Processes / Scale

In order to provide an overview of the interactions between activities at coastline scale, the scale of the general-purpose maps was adjusted to allow all coastlines to be shown on a map in A3 format (see Table 2). Area maps have been produced at larger scales at the request of the agencies responsible for producing coastline strategy documents. The analysis uses a grid at a resolution of 3 minutes x 3 minutes, with the various maritime activities represented in the grid cells (see Topic 4). This grid is designed to take the land-sea interface into consideration. Accordingly, it covers territorial waters and coastal communities.

3 www.geolittoral.developpement-durable.gouv.fr
4 http://www.geolittoral.developpement-durable.gouv.fr/telechargement-en-ligne-donnees-geolittoral-a802.html
5 http://www.geolittoral.developpement-durable.gouv.fr/services-web-d-interoperabilite-a803.html
6 http://cerema.maps.arcgis.com/apps/MapJournal/index.html?appid=b25ad4b280304f5891af975141716a3f

Table 2: Geographic Scale of the Interaction Analysis

Coastline	Scale of coastline interaction maps	Scale of zoomed coastline area sub-maps
Eastern Channel - North Sea	1:1,304,400	1:266,600
North Atlantic – Western Channel	1:1,613,000	1:266,600
Mediterranean	1:1,556,000	1:266,600
South Atlantic	1:1,535,500	1:266,600

Topic 4: Processes

In a multi-stage process, Cerema converted the raw data to data that could be processed in an analysis of interactions between activities, yielding results that in turn serve as inputs to maritime planning strategies.

1. Stage 1: Assignment of the raw data in a grid

The geographic information required in order to describe activities conducted at sea is extremely varied, multi-thematic, and extremely heterogeneous in terms of spatial and time scales. To enable this data to be analysed jointly, a continuous, uniform grid extending over the maritime domain is highly desirable. Consequently, Cerema and the French Biodiversity Agency developed a uniform grid, geometrically consistent with existing reference frameworks such as the statistical rectangles used in the French fishery information system (SIHF) and the International Council for the Exploration of the Sea (ICES/CIEM), the fishing areas defined by the UN Food and Agriculture Organisation (FAO), and the grid adopted for the VALPENA project that centres on the assessment of fishing practices[7]. This consistency enables data to be directly linked and aggregated across grids at various resolutions. This grid has a mesh of 1 degree minute by 1 degree minute, and it can be resized for smaller scales. The grid adopted for the interaction analysis is an aggregate 3 minute by 3 minute grid, to enhance the legibility of analyses at coastline scale.

The collected raw data was assigned to this grid using a “zonal clipping” method. The principle underpinning this method centres on an entity's contribution to a tile. Data is assigned in two stages:

- **Intersections between objects and the grid:** The total surface area of objects intersected by a grid cell is calculated for each cell, together with the ratio of the area thus calculated to the area of the grid cell (this information is not used in the method, but is retained for use in the event of methodological changes).
- **Grid cell assignment:** Allowing for the analysis resolution scale, grid cells are assigned to activities whenever an object intersects a grid cell. Inasmuch as the aim of the analysis is to identify spaces in which activities are liable to interact, it is preferable to maximise the grid cell assignment, rather than apply a reductive rule, in particular the majority surface area rule[8]. This rule works well for high-resolution grids, but not for a 3-minute resolution. At this resolution, applying the assignment rule would downsize certain objects having either a small surface area or an unusual shape. For example, long, narrow areas (relative to a 3

7 Grid available on Geolittoral http://www.geolittoral.developpement-durable.gouv.fr/telechargement-en-ligne-donnees-geolittoral-a802.html#sommaire_13

8 If the entities occupy more than 50% of a grid cell, the cell is set to the value of the cells. Conversely, if it is less than 50% occupied, the cell is treated as empty.

minute x 3 minute mesh) assigned using the majority area rule may disappear or lose their original shape (alternating empty and assigned cells).

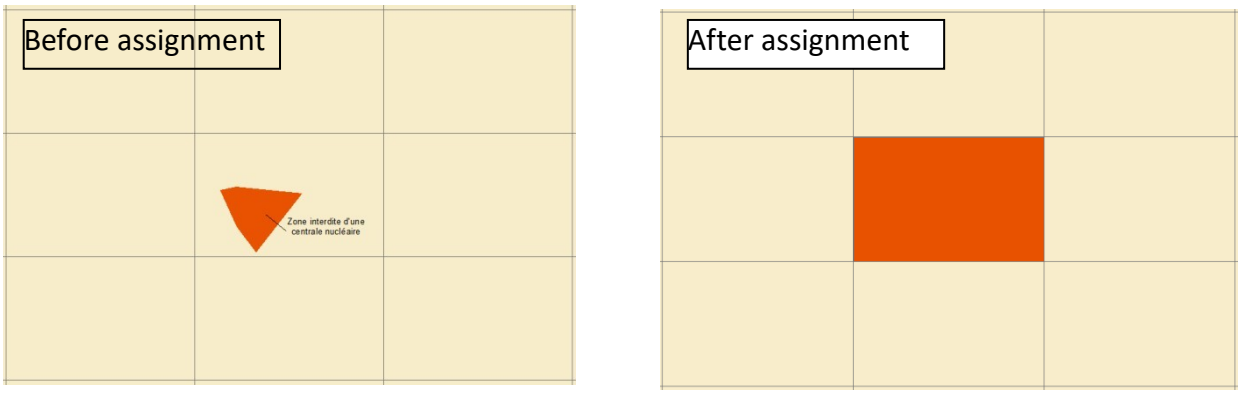


Figure 1: Illustration of the Data Assignment Method

2. Stage 2: Analysis of the distribution of mobile activities along coastlines

The distribution of mobile transport and fishing activities was analysed in order to identify the areas subject to the most intensive use, implying a high probability of generating interactions between activities.

In order to represent the **fisheries most used by** French and foreign vessels, several geomatic and statistical processes were applied, based on the GPS data from the VMS system:

- create a selection of vessels assumed to be fishing. This was achieved by applying a threshold criterion to retain only vessels travelling no faster than 4.5 knots.
- calculate the number of hours in which these ships were present in the cells of the 3 minute x 3 minute grid over a period of two years.
- perform a statistical analysis of the distribution across the various coastlines of the number of hours that fishing vessels were present, based on discretising the variable by decile.

For example, the zone selected with project partners to represent the busiest fisheries along the Eastern Channel - North Sea coastline covers half the surface area of the coastline and contains almost 90% of the hours of presence of fishing vessels equipped with VMS systems.

Equivalent statistical processing was performed in order to characterise the **principal shipping lanes used by the vessels**. The statistical analysis focused on the distribution across the various coastlines of the number of vessels passing through each grid cell over the course of a year, based on discretising the variable by decile (Figure 2). For example, the zone selected with project partners to represent the areas with the densest shipping traffic along the Eastern Channel - North Sea coastline covers half the surface area of the coastline and consists of the cells through which more than 240 ships passed over the course of a year. This zone forms an envelope in which major and secondary shipping lanes are identified.

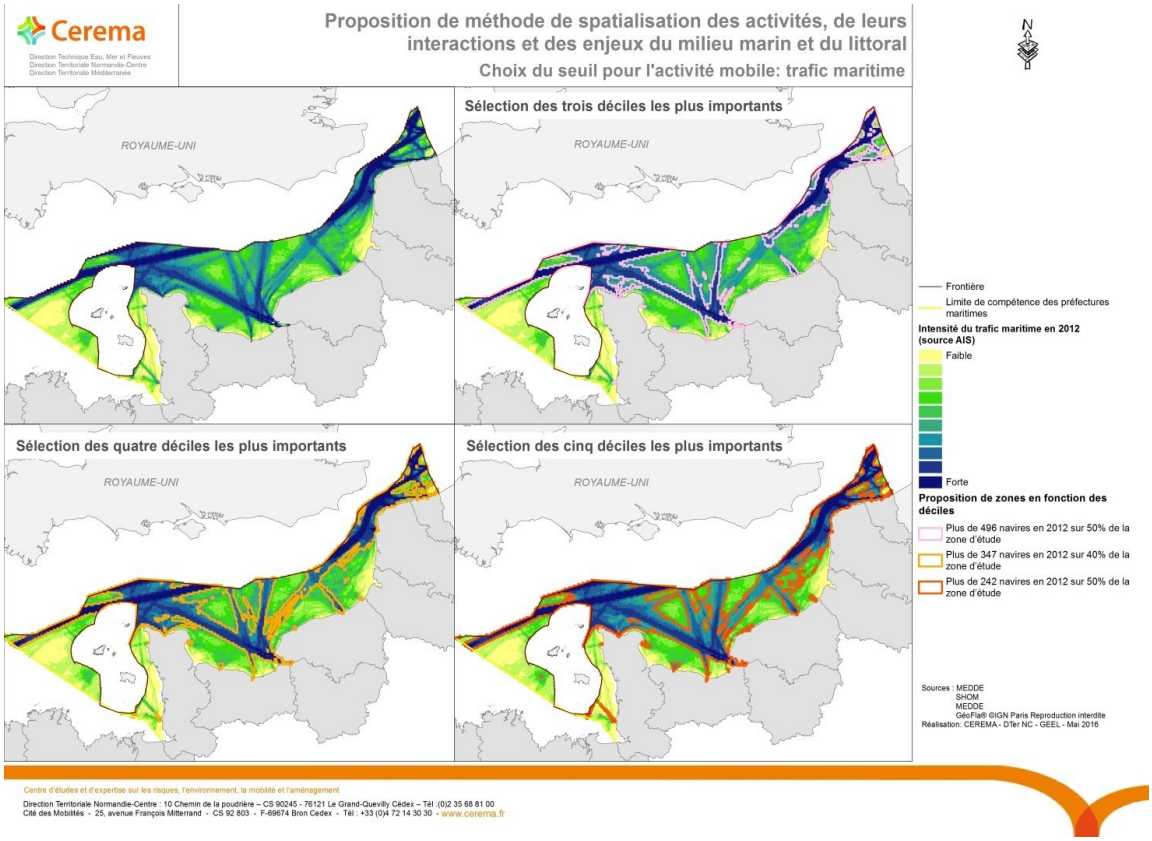


Figure 2: Proposed zones submitted to project partners to represent the areas with densest shipping traffic

3. Stage 3: Interaction map generation

The activity interaction analysis is based on generating gridded layers containing individual pairs of activities to which compatibility levels are assigned, based on an activity combination matrix (Figures 3 and 4). These layers are overlaid to create a technical map representing the interactions. Figure 4 illustrates the various stages in the map generation process.

Several activity combination matrices were developed in partnership with government agencies for the purpose of producing interaction maps. In the light of these discussions, the Eastern Channel - North Sea (MEMN), South Atlantic (SA) and Mediterranean (MED) inter-regional directorates adopted the following matrix (Figure 4). In this matrix, interactions are characterised in terms of the degree of compatibility of activities conducted in a particular area: Three compatibility levels have been defined (compatible, compatible subject to conditions and non-compatible) for use in conjunction with a characterisation of the interactions (possible synergy, potential negative impact) or a compatibility condition (temporal planning of activities).

Most activities carried out along coastlines are either compatible or compatible subject to conditions. Mobile activities (traffic, fishing, recreational activities and tourism) are generally compatible subject to conditions (yellow cells) with other activities, provided that they comply with existing or future technical, regulatory or temporal cohabitation guidelines. Activities considered to be compatible (blue cells) include indissociable activities such as marine transportation and port activities, and activities performed at different depths (e.g. cables and shipping).

Static activities are responsible for more cases of incompatibility (orange cells), whether for legal or technical reasons. Aquaculture-related activities are considered to be incompatible with marine transportation, marine aggregate extraction, dredged sediment dumping and offshore recreational and tourist activities. Marine aggregate extraction and dredged sediment dumping activities cannot be carried out in areas containing submarine pipelines and cables or marine renewable energy installations.

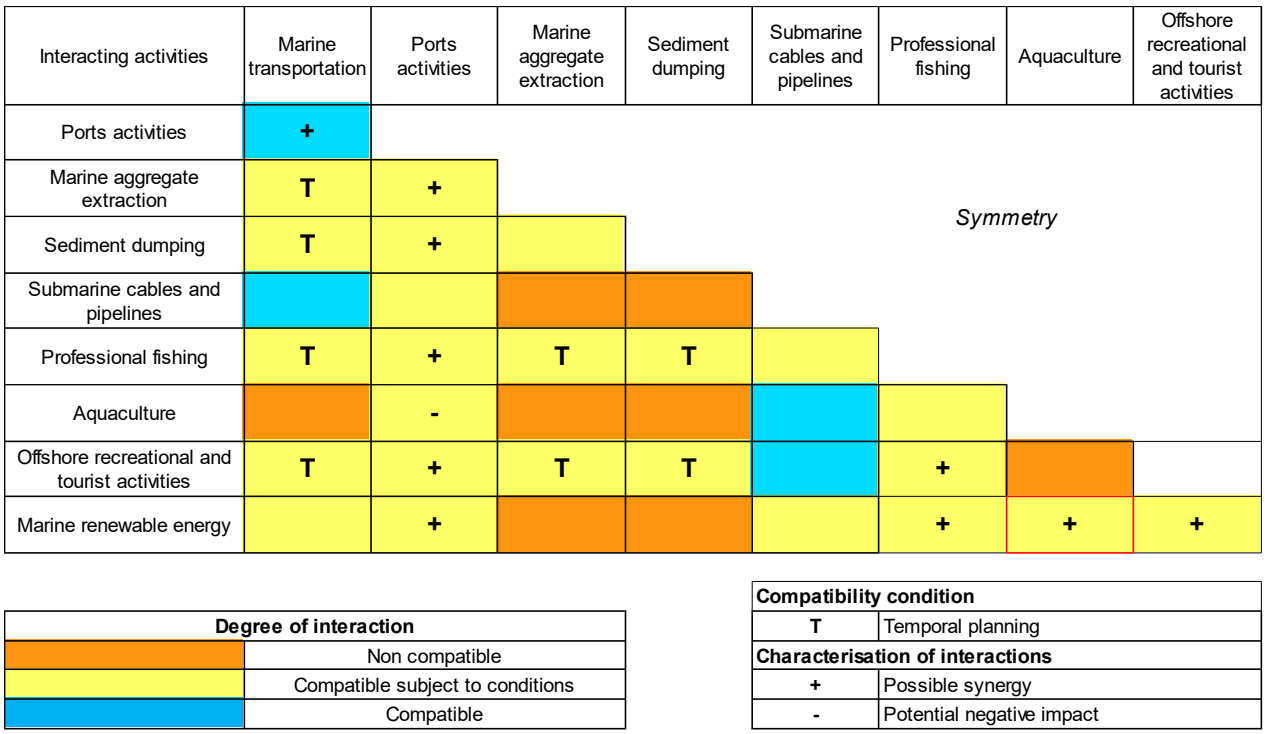
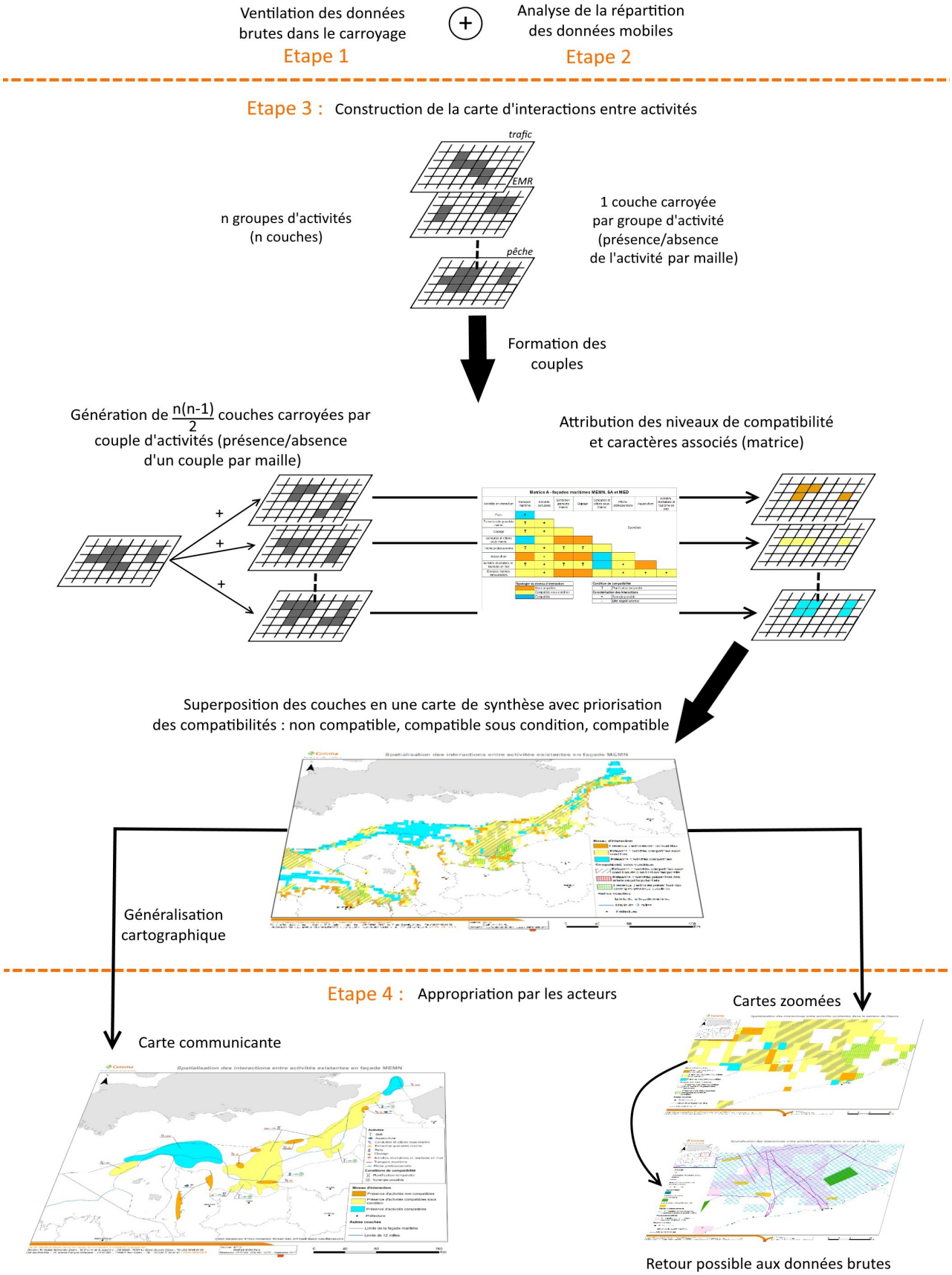


Figure 3 : Sample activity compatibility matrix

4. Stage 4: Production of summary maps

Several maps were produced to facilitate collaboration with other project partners relating to the spatial representation of interactions : 1 summary map per coastline; area-specific interaction maps (several zooms per coastline); and area maps showing the raw data, to aid comprehension of the results. A summary map is based on a cartographic generalisation of the various areas subject to interactions. Activities liable to interact in such areas are identified using pictograms.

Figure 4: Interaction map construction process



Topic 5: Processes/Uncertainty

The principal sources of uncertainty in the method relate to knowledge gaps when spatialising activities or describing the nature of interactions between activities.

Firstly, the available data does not provide a sufficient basis for producing a comprehensive representation of certain activities that would more faithfully reflect the reality perceived by project partners. This applies to the VMS data used to represent professional fishing activity. This data concerns vessels longer than 12 since 2013, scallop fishing vessels and vessels landing more than 300kg of sole annually since 2015. Other fishing vessels are not tracked by the VMS system. The representation of small-scale inshore fishing activities is therefore limited; the impact of this shortcoming on the fishing activity model varies according to the size of the fleet of small fishing boats along coastlines. According to DIRM, VMS data covers approximately 80% of fishing vessels on the Eastern Channel - North Sea coastline, and approximately 40% on the North Atlantic - Western Channel coastline. Similarly, the volume of usable, homogeneous data relating to all French coastlines to describe traffic on beaches and areas used for pleasure boating and sea sports is limited, and the mobile nature of such activities (such as sailing) makes them difficult to represent spatially.

Secondly, defining the interactions between existing activities and planned activities (particularly RME installations) is subject to uncertainty and represents a challenge from a maritime space planning perspective, as the interactions between activities can vary between locations and according to the social acceptability of the planned activities. However, experience acquired in neighbouring North Sea countries that have built marine renewable energy installations enables such interactions to be documented.

The proposed method does not include scientific uncertainty measurements. The grid-based approach enables this concept to be incorporated by calculating confidence indices relating to the presence of activities in a particular cell, or the robustness with which interactions between activities are understood.

Topic 6: Processes / Flexibility

Several changes may be considered, to adapt the proposed interaction analysis for alternative purposes:

- the choice and types of activities could be modified, to suit project partners' requirements and to reflect the activities carried out in maritime and coastal areas. In particular, the analysis could be expanded to include coastal communities.
- the spatial representation of activities, according to the available data collected. It would be possible to include more resource-related data (such as fish stocks) in order to characterise activities, or incorporate areas under assessment for new marine renewable energy projects.
- the grid resolution adopted for the current analysis (3 minutes x 3 minutes) could be increased or decreased when analysing different spaces.
- thresholds could be set to model the spaces used most intensively by mobile activities.
- the temporality of activities could be represented by performing analyses for each season or by weighting grid cells for activities carried out occasionally over the course of the year (such as dredged sediment dumping grounds or marine aggregate extraction sites).
- weighting factors could be defined to give particular importance to certain spaces in which activities are carried out: for example, weighting fishing activities according to the economic weight of fisheries.

- the nature of the interactions between activities could be revised.

These aspects were discussed extensively with project partners while developing the method, which evolved to reflect the technical debate, gradually converging toward a set of shared choices that were used to produce standardised activity interaction maps for the four coastlines.

This flexibility - enabling partners' points of view to be taken into account - is a key benefit of the method. Over the course of the technical discussions, this work fuelled the debate on planning for maritime spaces.

Topic 7: Transparency

The grid produced by Cerema and AFB that was used to map the interaction analysis was approved by France's National Geographic Information Council (CNIG), via the national working group on geo-information for the sea and coast (GIMeL), and the method used to construct the grid is explained in a methodology report published on Géolittoral[9].

The interaction analysis method developed since 2015 is described in an intermediate methodology report that formed the basis for discussions with partners responsible for producing coastline strategy documents. This methodology report was published by the Eastern Channel - North Sea inter-regional directorate[10]. It describes various methodological options, the benefits and limitations of some of the data used, and several choices made with partners. The method subsequently evolved until the maps were finalised in 2017 with the aid of a post-graduate Geomatics student[11] on a vocational internship with Cerema. European projects in support of maritime spatial planning offer the opportunity to describe the interaction map creation process and gain insights from the experience.

Topic 8: Outputs

Cerema developed an initial method for analysing interactions, based on:

- a literature study informed by earlier research: a research project on planning in the maritime space in Belgium (Project GAUFRE, 2003-2005), the PhD thesis of M. De Cacqueray (2011), the Medtrends project (WWF, 2016), and an analysis of uses in the eastern Baie de Seine (CAF, Cerema, 2015)
- data collected and provided for the purpose of producing coastline strategy documents.

This method was submitted to coastline stakeholders at a series of technical meetings held over an approximately 18-month period:

- with the government agencies responsible for producing the four coastline strategy documents (Eastern Channel - North Sea, North Atlantic - Western Channel, South Atlantic and Mediterranean), at coastline administrative committee meetings. Several contributions were received from government agencies and local public institutions: maritime prefecture, regional directorate for the environment, land use planning and housing (DREAL), Marine Protected Areas Agency.

9 http://www.geolittoral.developpement-durable.gouv.fr/telechargement-en-ligne-donnees-geolittoral-a802.html#sommaire_13

10 http://www.dirm.nord-atlantique-manche-ouest.developpement-durable.gouv.fr/commission-permanente-du-conseil-maritime-facade-a713.html

11 http://www.dirm.nord-atlantique-manche-ouest.developpement-durable.gouv.fr/commission-permanente-du-conseil-maritime-facade-a713.html

- with the central services of the Ministry for the Sea (Sea and Coastline Directorate).
- with partners on the Eastern Channel - North Sea and North Atlantic - Western Channel Maritime Councils for the Coast. Several contributions were received from civil authorities (Normandie regional council), large sea ports (Le Havre and Dunkerque) and industry associations in the fishing, shellfish and marine aggregate sectors.
- with fishing industry stakeholders along the North Atlantic - Western Channel coastline and the VALPENA scientific consortium, in order to discuss the spatial representation of professional fishing activities.

These exchanges resulted in an iterative effort with partners to define the interaction analysis method. All stages of the development process were debated at these meetings, including activity types, data collection, the spatial representation of the selected activities, the nature of the interactions between activities, the spatial representation of the interactions and the manner of communicating the results obtained. In the light of these discussions, additional data was collected in order to spatially represent activities, modify certain methodological choices for producing the interaction maps and performing uniform work at the scale of the four French coastlines.

Topic 9: Outputs / Implementation

Cerema's analysis of the interactions between activities was closely coordinated with the maritime spatial planning initiatives undertaken by the French government. Cerema provides technical support to the government agencies tasked with producing coastline strategy documents. In this context, the Eastern Channel - North Sea inter-regional directorate requested a map providing an overview of the activities conducted along the coastline. For this overview, Cerema analysed the interactions between activities in order to provide inputs to maritime planning processes, and in particular, enable “existing or foreseeable conflicts of use” (cf. Decree 2017-724 of 3 May 2017) to be taken into consideration. This work was then repeated for the remaining three coastlines for the other inter-regional sea directorates.

More generally, the proposed approach provided a basis for discussion, in the form of a compatibility matrix transposed onto maps by spatially representing the interactions between activities. Such maps can be used as a decision-making tool before new activities are introduced, in order to anticipate any potential conflicts of use. The maps make it possible to identify areas subject to dense activity, in which planning additional new activities might be particularly problematic, due to extensive interactions or incompatibility between activities, the technical complexity of enabling cohabitation with new activities, or challenges in terms of social acceptability in areas where multiple stakeholders are fighting to defend their respective activities. Conversely, the maps reveal areas in which activities are scarce; planning new uses in such areas would pose fewer cohabitation problems. French government agencies used the results in different ways on different coasts. For example, on the Eastern Channel - North Sea coastline, the compatibility matrix was held up as a tool for encouraging inter-activity usage guidelines. On the Mediterranean coastline, the Inter-Regional Directorate for the Sea (DIRM) produced an alternative map in the light of this joint experience, to approach interactions between activities from a qualitative and quantitative perspective (based on cumulative activity intensities).

Two key insights emerged from discussions with government agencies during this initiative supporting the coastline strategy document production process.

Firstly, the process used to generate the interaction maps was deemed to be more important than the mapping results. The method fostered a multilateral discussion on cohabitation between activities, which is the central focus of this maritime planning approach. Through these exchanges, project partners shared knowledge and adopted a common vocabulary. The analysis was produced in a highly iterative approach integrating the spatial representation of interactions, the theoretical activity relationships matrix and the raw data. The data processing history was documented, enhancing adoption and facilitating review of the design choices, and giving due consideration to the points of view of the various partners. The iterative aspect of the approach focussed in particular on comparing the mapping results against the real-life conditions experienced by project partners. A number of methodological choices were reviewed in the light of these comparisons, as there was a tendency for areas to be incorrectly shown as having incompatible activities due to a grid scale effect rather than an actual incompatibility. In practice, the instances of incompatibility identified in the matrix are rarely observed in the field: either it is already technically or legally impossible to conduct incompatible activities in the same location, or else the relevant industries are already regulated, prompting activities to self-adjust. Consequently, spaces flagged as subject to non-compatible activities tend to be spaces accommodating activities at a higher density or intensity, liable to generate interactions (resulting in positive or negative impacts by one activity on another, adjustments to enable more harmonious cohabitation, etc.).

Secondly, there is scope to improve the transfer of interaction-oriented methods from the scientific to the operational sphere. Particular focus should be given to adapting working documents and the means of communicating results to ensure that they are readily adopted by project partners (and where applicable, the general public). The concept of interactions between activities is central to spatial planning of maritime spaces, and is the subject of an extensive body of scientific literature. Nevertheless, the initial methodological discussions and the first maps produced were considered by certain partners to be “too technical”, despite the proposed method being relatively simple in comparison to the existing alternative methods. This adoption problem was due in particular to the production of a globalising analysis of interactions rendered on a gridded map. Producing “summary” maps facilitated adoption, subject to being able to refer to the source data or known zoning information (via pictograms that enable users to locate interacting activities or visualise raw data). Government agencies then modified the maps, focussing on how they could be interpreted in the context of their own maritime spatial planning strategy. During this stage, project partners were particularly sensitive to the key used for the interaction maps and the colour code used to represent areas subject to interactions, and sought to promote a positive approach to planning aspects (highlighting what is possible rather than flagging “incompatibilities” or “prohibited activities”).

At the end of the process, the mapping results were not distributed in public relations materials. They are still treated as working documents and decision-making tools for government agencies. This sequence of events illustrates the difficulty of building a consensus relating to strategic mapping for coastline strategy documents. In addition to their technical aspect, this is precisely what makes them interesting: these maps *“stimulate debate by materialising the topics for discussion”* (Lussault, 2003, p.55) in planning projects, where the concepts of consultation and social acceptability are crucially important.

Topic 10: Accessibility and Sustainability

Producing interaction maps (see Topic 4) requires advanced geomatics skills and powerful GIS workstations, in order to process large volumes of data, assign the data to a grid and submit geomatic queries with a view to linking the map layers. Although the method is not automated in a collaborative tool accessible to project partners, it is possible to provide models. Use of the method by other users may require knowledge transfer.

The proposed approach also uses map viewers accessible to the general public as well as project partners, for use at coastline strategy document drafting and consultation and meetings (see Topic 2). Such tools satisfy project partners' stated need to be able to refer to the raw data characterising their respective activities. Cerema built these viewers using an authoring tool that enables descriptive text, photographs and mapping content to be linked to create a user-friendly web application (Figure 5). The viewers provide intuitive access to geographic data via dropdown menus that display the chosen layers of geographic information against a user-defined background map. Several options popular with web users were implemented in these viewers, including a drawing option, measurement tools (for areas, distances and geograhic locations) and options to print a section of the map or add third-party data. These tools are not interoperable: they either integrate data stored on private servers or point to layers of geographic information streamed (via WMS or WFS) by Cerema or project partners. These tools, developed to support the production of coastline strategy documents, provide inputs to a future-proof maritime and coastal planning data viewer that will be accessible via Géolittoral. This viewer will be upgradable, to enable new data relevant to usage planning to be integrated as it becomes available.

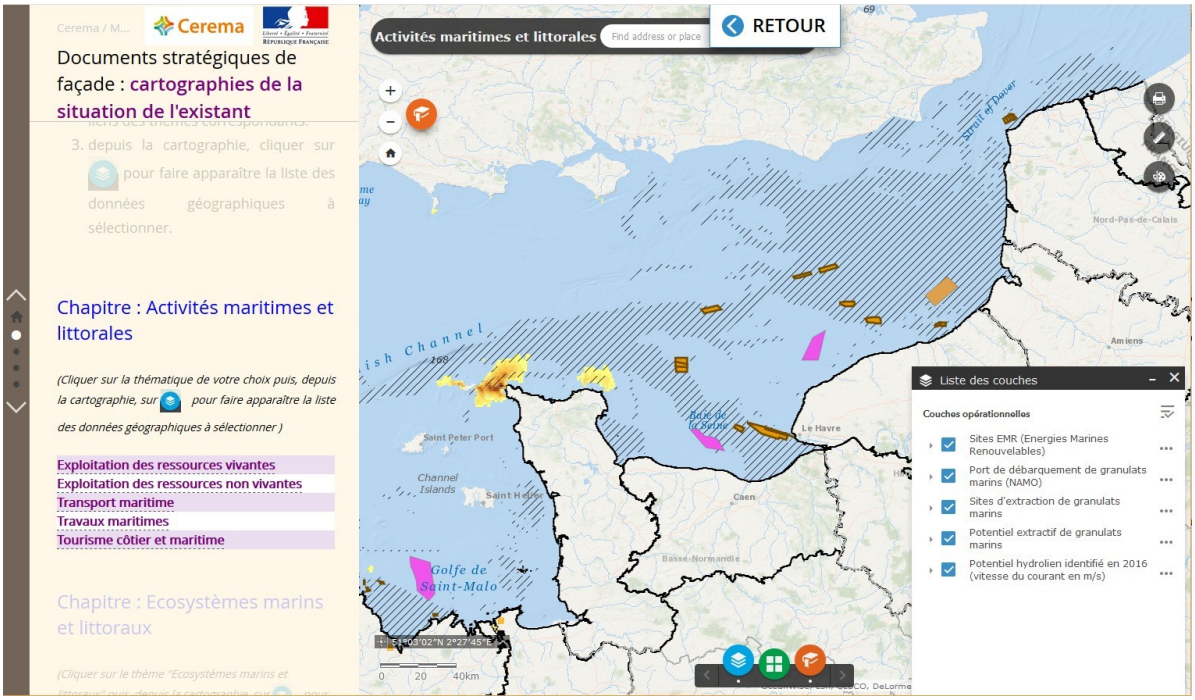


Figure 5: Coastline strategy document geographic data viewer developed by Cerema

http://cerema.maps.arcgis.com/apps/MapJournal/index.html?appid=b25ad4b280304f5891af975141716a3f

7.6 Annex 6. Describing Fiche SHOM – DESEASION

Methods Describing Fiche – DESEASION

Developed in the task C.1.3.4. Tools and methods to support MSP processes

Summary

Topic 1: Data

➢ DESEASION overview

AILERON is a scientific collaboration between the French hydrographic and oceanographic office (Shom) and a research team specialized in decision support at IMT Atlantique and the CNRS laboratory Lab-STICC.

The objective of the project is to develop a methodology and algorithms to help maritime decision making, when several decision-makers are involved, as well as to propose a software platform, called **DESEASION** (http://recherche.imt-atlantique.fr/deseasion/) to support the decision aiding process and to facilitate the collaboration on marine assessment or decision making issues.

In that context, Maritime Spatial Planning (MSP) is a possible application, which could benefit from this general methodology and tool.

The software platform is developed so that it can bring together the different actors of the decision problem around the same tool, either locally or remotely.

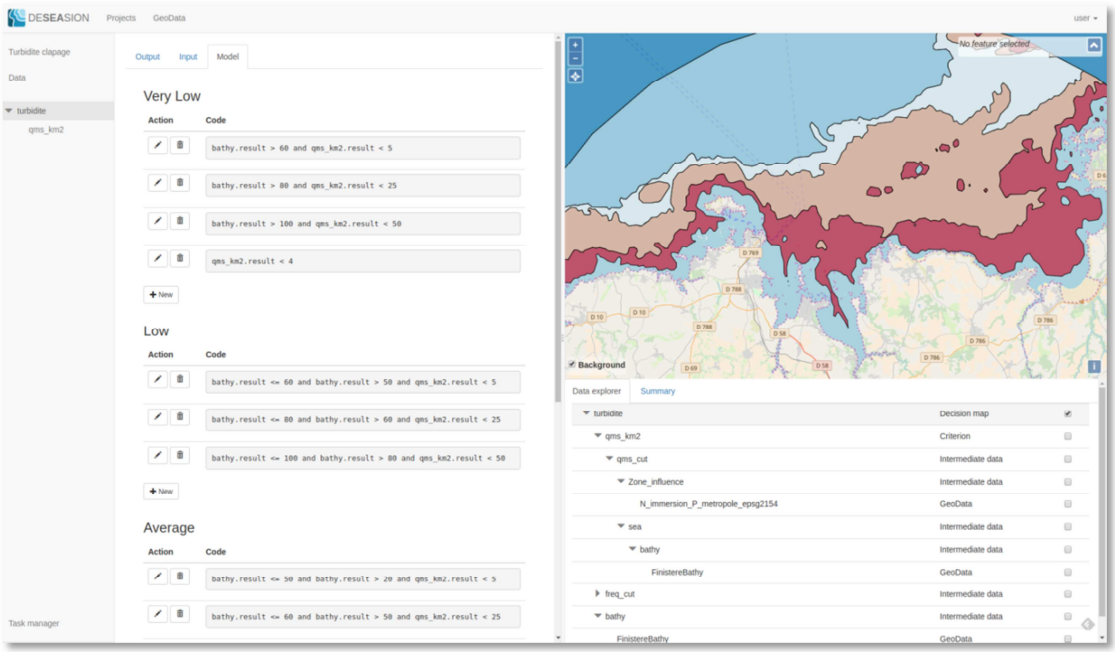


Figure 1: Screenshot of the DESEASION support platform

Next to MSP, other possible uses cases of the platform are : impact assessment on ecological ecosystems, installation of renewable energy sources, controlled ship stranding, development of maritime areas or the coast ... So any decision problem involving multiple perspectives and stakeholders, and related to activities at sea, can be handled with DESEASION.

The decision problem is structured hierarchically, which means that activities can be divided into sub-activities, and so on. The aggregation of the sub-activities is totally personnalisable, which means that any aggregation operator can be used.

➢ DESEASION inputs

There is no limit on the data which can be imported in the platform, as long as they are available. The formats can be shapefiles or raster files. Currently data streams cannot be used as data sources.

In the platform, the uploaded raster files are converted into shapefiles:

- either completely, by considering all the information available in the raster file,

- or through a discretization step, which can be parametrized, and that allows to adapt to the various scales of the model.

Time can be integrated, as long as it is available as an attribute in the data, or as information in the meta-data of the data. It can then be used in any aggregation or filtering rule.

Topic 2: Data/Accessibility

Any type of data (vector or raster) can be uploaded in the platform. Currently, data streams are not supported.

The data selected for the case to be processed is imported into the platform and stored on a server.

Access rights can be defined for each data (read / write), which allows to respect the original licenses of use of the data.

For example, AIS data with a restrictive license may be made unreadable and unusable by users of the platform who do not have access rights to this data. In the future, one development envisaged is to diversify access rights, in particular by making it possible in certain cases to process data even when the original data is not readable.

Topic 3: Processes / Scale

The tool keeps the geometries of the source data throughout the process. The crossing of different geometries generates new geometries, which preserve the resolution of the initial data, as well as the content.

For example, a pressure indicator in a grid cell crossed with an isobath generates 2 new zones corresponding to the division of the grid cell by the isobath. Their values correspond to the two original data and no generalization of either the geometry or the values is made.

Topic 4: Processes

The objective of the platform is to support maritime decision making, when several criteria, activities or decision-makers are involved. DESEASION is therefore meant to support the decision aiding process and to facilitate the collaboration on marine assessment or decision making issues. In that context, Maritime Spatial Planning (MSP) is a possible application, which could benefit from this general methodology and tool. The software platform is an online tool, so that the different actors of the decision problem can collaborate locally or remotely.

DESEASION addresses the decision problem via several (possibly iterative) steps:

1. Hierarchical structuring of the decision problem, where sub-problems are identified, pressures, activities, actors and decision makers are determined and the necessary data is collected and uploaded.

2. Evaluation of the area, which consists of applying a selection of evaluation models (expert rules, aggregated impacts, multi-criteria decision aiding), based on the decision-makers' expertise, to obtain the overall assessment of the various involved geographical zones.

3. Area recommendations for maritime activities, based on constraints expressed by the involved decision-makers.

4. Validation of the final recommendation through a guided explanation of the results and a negotiation phase (which can result in returning to previous steps with updated information).

As an example, consider that the overall impact depends on several pressures. In the hierarchy, each pressure depends on multiple activities. Each activity impacts the corresponding pressure according to its model. These impacts are aggregated using a higher level evaluation model, to obtain an overall model of the pressure. Then, the pressures can be aggregated using an ever higher-level evaluation model, to obtain the overall impact. These evaluation models depend on the context, on the knowledge of the involved experts, and can therefore be personalized for each problem. Due to this hierarchical structuring of the problem, each intermediate result can be visualized, which contributes to the transparency of the aggregation.

The aggregation of the intermediate results produces specific areas of impacts keeping the original aggregated geometries and values, without generalization (*read more in topic 3*).

Thus the final decision map presented to the decision makers preserves the information contained in the original input data, as well as the reasoning of the various aggregation and evaluation steps involved in the hierarchy.

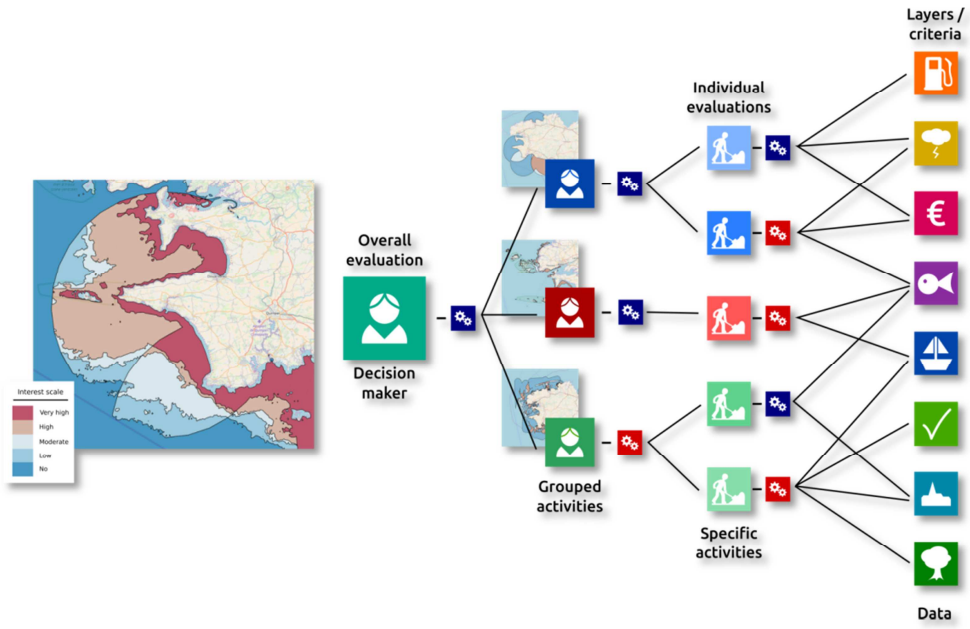


Figure 2: Hierarchical structuring of the decision problem, multiple decision-makers, intermediate and overall assessments (steps 1 and 2)

During the evaluation step, three possible evaluation models can be implemented.

· Aggregation models from the field of Multi criteria decision aiding, which integrate precise preference models of the decision maker with the data to generate evaluations respecting the decision maker's priorities. The preferences are determined through supervised learning algorithms.

· Expert rules inferred from the decision maker's expertise.

· Or any aggregation operators, as weighted sums, e.g.

All the manipulated data are vectorial, but it is also possible to add raster data in the platform through a conversion tool. The attributes can either be numerical or textual. The generated maps are exportable in shape format.

Once the assessment step is finalized (corresponding to the final decision map that has been generated), it is possible to use an algorithm that generates several recommendations to locate an activity. The algorithm behind this functionality is a genetic algorithm that proposes a set of solutions that facilitates the discussion to reach a consensus, for example for MSP.

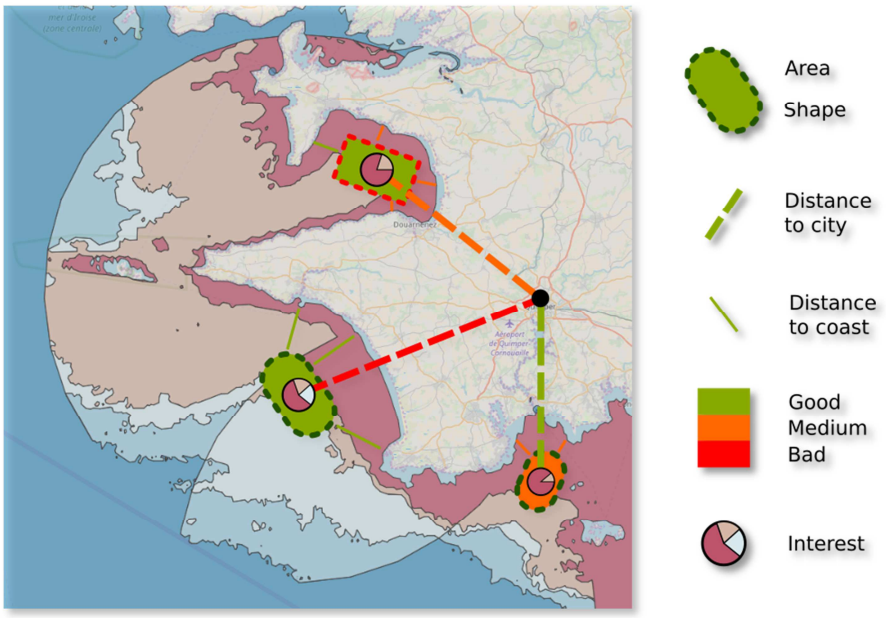


Figure 3: Recommendation of multiple possible zones for an activity (step 3)

The architecture of the software platform is based on a web solution in which the data are stored on a server and calculations are performed remotely. Consequently, the users do not have anything to install on their computers, heavy calculations are transferred to servers and it makes it easier for users to collaborate on the same project (in particular if they are not located at the same place, or in an asynchronous way).

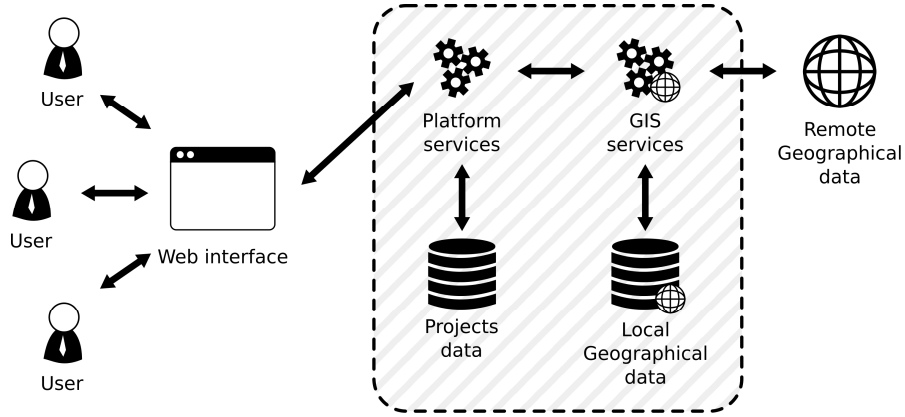


Figure 4: Architecture of DESEASION

Topic 5: Processes / Uncertainty

Uncertainty is handled similarly as any data in the tool. If the information on the uncertainty exists as a piece of data, it can be taken into account by evaluation models and thus propagated through the hierarchy. Thus intermediate uncertainty maps can be produced, which are associated with their corresponding intermediate activity or sub-activity.

Topic 6: Processes / Flexibility

The tool is not fixed on a given interaction matrix or on a standard. The models are based on a coding of rules or aggregation models based on what experts say. This provides a lot of flexibility on how to approach a problem and transparency. Indeed, one can go ex post through the whole reasoning and explain a result. This can be useful, for example, during the negotiation phase so that everyone

understands the choices. The explanation of the results can be done thanks to the intermediate results of the hierarchical structure and can be generated automatically in the future.

Topic 7: Transparency

Further information on DESEASION can be found on the following web-page: http://recherche.imt-atlantique.fr/deseasion/.

Also, a tutorial, with access to the DESEASION platform will soon be available online for training. A research article on the platform is also planned.

Topic 8: Outputs

The outputs for each of the assessments (individual assessments of each of the sub-models, or overall assessment on the geographical areas concerned) are :

- a shape file from each of the models/sub-models; each model provides its map that can be visualized and analyzed before being integrated into the higher level model (example: individualized mapping of the impact of an activity on a pressure)

- a list of attributes dedicated to the interpretation and subsequent use of this data

The resolution of the final product depends on the geometries of the input data and the new geometries resulting from the overlap between the layers of information and the cuts they generate.

The final result at the end of the planning stage is a shape file with recommendations for areas taking into account all activities and criteria. These recommendations must identify the best locations for an activity focus on the best areas according to the constraints and the problem posed).

The decision-makers are involved in the tool via the structuring of the decision problem, the choice of the models, and their configuration (parameters). They can also be involved to modulate a scenario by modifying a rule or data within the model/sub-model tree. All results are subsequently updated from this new information.

When recommending zones (final stage, currently under development), the tool will be able to provide an explanation on the rules implemented and on the constraints that led to the emergence of one zone rather than another. This also highlights a notion of transparency in the procedure.

These functionalities facilitate exchanges and feed discussions.

Topic 9: Outputs / Implementation

Experts are involved via :

- the structuring of the decision problem: identification of the different expert profiles requested, identification of the problems / sub-problems of each of these profiles and choice of input data.

- the choice of evaluation models implemented to evaluate problems/sub-problems (expert rules, cumulative impact), based on experts' opinions.

The tool is implemented as a web platform, which allows different actors to collaborate more easily on the same project by bringing them together around the same tool. It also allows to access at any time the latest results (and to each of the results from the submodels). DESEASION is also a dynamic tool : nothing is fixed, each scenario can be replayed or reassessed in meetings, in the presence of the various actors.

Topic 10: Accessibility and Sustainability

Skills to run the tool:

- an administrator is needed to implement the codes corresponding to the various models and to animate the implementation of the decision-making problem (interface between all the actors)

- the programming language for the code is Python

- the connection to the tool is done via a web browser (which requires no installation on the user's machine)

Future:

The tool is under development, and this development will be continued over the next 3 years (continued Shom/IMT Atlantique collaboration).

Sustainability of the method:

A risk is linked to the potential obsolescence in connection with the libraries and programming languages used (for the web interface and platform services) / autonomy of GIS functions (no coupling with QGIS or other).

7.7 Annex 7. Describing Fiche CNR-ISMAR – Tool4MSP

Tools4MSP Cumulative Effects Assessment (CEA) tool

Developed in the task C.1.3.4. Tools and methods to support MSP processes

Summary

Reminder – Purpose of this fiche

The workshop held in Marseille in February 2018 has been able to feed the reflections, and make progress in the definition of action plans in the actions C.1.3.4. The following action plan for the comparison of interaction methods has been set up:

C.1.3.4.: Comparison between methods for the evaluation of interaction

- **Step 1:** Proposal of a template to describe each method, according to the criteria's defined during this workshop (for the end of February)
- **Step 2:** Feedbacks about this template, validation of a final version (mid-March)
- **Step 3:** Filling of the Methods fiche by each partner (for the end of May)
- **Step 4:** Writing of the first draft of the comparison report (July)
- **Step 5:** Validation, inputs of the lessons of the Cases Studies in the comparison report (end of November)
- **Step 6:** Final report (for the end of November)

Using the criteria's defined during this workshop; this template has for objectives to help the partners to create a fiche describing their methods with the criteria's cited. This template is going to circulate for validation among partners in March.

It is to be highlighted that all the criteria's cited during the workshop are not really fitted for an objective comparison. Some of them (like in the *Implementation for MSP*, or *Skills* categories) are going to be quite difficult to evaluate. For example, the sharing of the same vocabulary is going to be analyzed in the light of the answer of each partner to this template. In this template, a work on defining precise scales of evaluation is going to be conducted and submit to the validation of partners.

Once all the partners have fulfilled their methods fiche, the wrap-up is going to be done by the AFB.

The maximum length of this comparison fiche is 21 pages. Guidelines are provided in each topic, but you can adapt the length of your answers according to your methodology (in the limit of 21 pages).

Topic 1: Data

The input data for the CEA Tools4MSP are subdivided in the following categories:

1. geospatial layers to represent human uses
2. geospatial layers to represent environmental components
3. geospatial layers to represent MSFD pressures
4. use-specific relative pressure weights and distance of pressures propagation
5. sensitivities or more general ecological models that describe the response of the environmental components to a specific pressure

The detail list for each category is related to the specific case study application.

The geospatial dataset implemented for Adriatic Case Study (Menegon et al. 2018a) features 45 layers (accessible at https://doi.org/10.5281/zenodo.1173764): 28 environmental components (E), 13 human uses (U) and 4 estimated pressures (P) from Land Based Activities (LBA). The following table presents an overview of the geospatial dataset implemented. The units of the spatial indicators U and E are presence/absence (P/A), intensity indicators (I), estimated indicators (E). Land-based activities (LBA) were modelled for salinity distribution, nutrient distribution, Nitrogen and Phosphorus exerted by 80 rivers in the sea basin and 40 coastal urban areas using SHYFEM (Shallow Water Finite Element Model; Umgiesser et al., 2004).

The temporal dimension is not fixed and varies greatly between the different layers; this depends on the availability and characteristics of the source data. In general, layers are referred to recent years (1-5 years old) and with aggregated values (mean or sum) referring to from 1 year (e.g. traffic density) to several years (e.g. distribution of marine mammals and turtles).

Table 1: Description of the layers included in the geospatial dataset implemented for the Adriatic Case Study

CEA dataset	**Unit**
Human uses (U)	
Aquaculture, Cables and Pipelines, Coastal Defence Work, Dumping area for dredging, LNGs, Military areas, Off-shore sand deposit, Oil and Gas Extraction, Oil and Gas Research	P/A
Coastal and Maritime Tourism	I/E - distance from the marinas and number of boats/marinas
Naval Based Activities	I/E - distance from the cargo ports and

	port capacity
Maritime Transport	I - Traffic density (vessels/year)
Small Scale Fishery	I - fishing effort expressed in 5 classes of intensity: from very low to high)
Pair Pelagic Trawling, trawling	I - hours of activities calculate through Vessel Monitoring System (VMS)
Environmental components (E)	
Marine Mammals, Giant Devil Ray, Turtles, Marine seabed habitats, nursery habitats	P/A
Seabirds	P/A
Pressures from LBA (E)	
Inputs of fertilisers and other nitrogen and phosphorus-rich substances	I distribution of Nitrogen and Phosphorus
Inputs of organic matter	I distribution of organic matter
Introduction of synthetic compounds	I/E distribution of organic matter
Introduction of radio-nuclides.	P/A/E salinity plume
Introduction of other substances	P/A/E salinity plume
Introduction of non-synthetic substances and compounds	P/A/E salinity plume

Topic 2: Data/Accessibility

Most of the geospatial data are accessible and/or discoverable at the Tools4MSP Geoplatform (http://data.tools4msp.eu) through standard and interoperable OGC services supporting multi-format download (e.g. GeoTIFF, SHP). The geospatial datasets are accompanied with metadata describing use restrictions and (if available) license. Restrictions on the reuse of data depend on the data policy applied by the owner of the source data.

A ready-to use and complete geospatial dataset for Cumulative Effects Assessment in the Italian Adriatic Sea can be also downloaded from Zenodo (https://zenodo.org/record/1173764).

Topic 3: Processes / Scale

Different cell resolutions have been adopted depending from the case study applications. The resolutions vary from 500 m for the Emilia-Romagna and North Adriatic case studies to the 2 km for the Adriatic-Ionian region.

The tool implements a scalable modelling framework that can be used on new areas with different grid resolutions and can be flexibly deployed to different geospatial contexts ranging from macro-regional to local/regional level assessments. In particular, the CEA tool has been transferred on several geographical areas: at local scale (Barbanti et al., 2017), models were applied in the Emilia-Romagna Region in the context of an institutional collaboration agreement for study and research among the Regional Department of Land and Environmental Department and CNR-ISMAR (Barbanti et al. 2017a/2017b, Barbanti et al. 2018). At regional level, a model was applied with advanced CEA algorithms within the RITMARE Project, with applications in the Adriatic and Ionian Region (Gissi et al. 2017), in the Adriatic Sea (Depellegrin et al., 2017), and Italian Adriatic Sea (Menegon et al., 2018a). Currently, the Tools4MSP has been adopted to support the case study implementation for the SUPREME project (North-Adriatic case study) and SIMWESTMED project (Sicily-Malta Channel case study and Tuscan Archipelago focus area of the Tyrrhenian case study). In the near future further CEA model advancements will be operated within the PORTODIMARE Project.

The Land/Sea interactions has been incorporated applying a hydrodynamic model to estimate the pressures derived from rivers and coastal cities runoffs.

Topic 4: Processes

Tools4MSP CEA is based on current assessment standards such as implemented around the globe (Halpern et al. 2008, Andersen et al. 2013), but has been further extended to incorporate a distance model to propagate the pressures. The CEA model considers the 15 pressures identify by the Marine Strategy Framework Directive (MSFD, 2008/56/EC, Annex III) (European Union, 2008). Compared to archetypal CEA implementations, the presented CEA incorporates a set of methodological advancements:

1. Implementation of a non-linear response function ranging from linear to S-shaped to represent the response of an ecosystem to anthropogenic pressures. In order to address modelling challenges related to the assessment of non-linear response to a cumulative pressure exerted by multiple uses (Korpinen and Andersen, 2016), the original sensitivity scores are divided into two parts: a sensitivity score to estimate the impact elicited by a certain pressure and related effects, and the use-pressure relative weights, as a measure of the relative importance of different uses contributing to a certain pressure.

2. Implementation of a flexible distance model, based on a 2D spatial convolution with a Gaussian kernel function to assess the propagation of the pressure (P) generated by anthropogenic uses impacting an environmental component (E).

3. Extension of the traditional additive effects with a flexible approach that models dominant effects (where the CEA score of a cell depends only on the effects having the highest impact on each environmental component) and mitigative/antagonistic effects on environmental components (where the combined effect is produced by the action of two or more pressures, being less than the sum of their separate effects).

4. Implementation of a CEA backsourcing (CEA-B) model that spatially identifies sources of pressures generated by anthropogenic uses on environmental components and quantifies the relative contribution of each cell to the CEA score within an area of influence.

5. Visualization of the CEA impact chain through a Sankey diagram, representing complex human use-pressure/effects-environmental component flows.

The sensitivities parameters and parameters indicating the buffer influence of the human activities were defined through desk research and expert elicitation process. For each of these first parameters, the experts have also associate a confidence value (c) that characterizes the level of reliability of their judgments (the elicitation process is described in Gissi et al. 2017).

Topic 5: Processes / Uncertainty

A combined methodology for global uncertainty and sensitivity analysis has been developed and implemented in conjunction with the Tools4MSP CEA Model.

In addition to the geospatial input dataset of human uses and environmental components, the CEA model requires four groups of input parameters: sensitivity scores (s), buffers for the distance model (M), multi-effect combination factor (mecf) and response function (rfunc). The knowledge gaps related to mecf, rfunc, the uncertainty in expert based sensitivity scores and buffer distance implied the application of a quasi-Monte Carlo Method based on 1000 model runs (N) (Lilburne and Tarantola, 2009): the mecf parameter was randomly varied within a range from 0 (additive) to 1 (dominant). The rfunc parameter has been parameterized by two variables: the shape of the function that was randomly varied from 0 (linear) to 1 (S-shaped) and the function mid-point that was randomly varied between 0.3 and 0.7. Finally, to take into account the expert confidence, the sensitivity scores and buffer distances varied following a triangular distribution, assuming the modal values from expert judgment on sensitivities (s) and the variance from the confidence (c).

The CEA coefficient of variation (CEA cv) was calculated as measure of uncertainty of the CEA model. The advantage of the coefficient of variation is to compare the grid cells having widely different means and to spatially represent the CEA's relative uncertainties. The CEA cv is estimated as the ratio between the standard deviation and the CEA.

The general analysis of uncertainty related to modelling cumulative impacts applied at regional scale for the Adriatic and Ionian Region is published in Gissi et al. 2017, including also general uncertainty elements related to the setting of the CEA model within the MSP process (context, input data, model, parameters, and outputs), in addition to those specific for the CEA tool. The general uncertainty analysis was developed with the contribution of experts and stakeholders involved in the definition of locations and types of the uncertainty of adopting the CEA model within the MSP framework. All details of the conceptual framework and application in Gissi et al. 2017.

Topic 6: Processes / Flexibility

The tool adopts a grid-based approach to compute geospatial analysis. This aspect facilitates the improvement and integration with new analysis models. Some improvements and integration will be developed in the next months:

- incorporate exogenic pressures such as climate change in order to align the methodology to other CEA assessments around the globe (Halpern et al., 2015; Clarke Murray et al., 2015);
- integrate and combine maritime use conflicts and synergies analysis;
- incorporate marine ecosystem services indicators.

The tool supports on-the-fly data transformation operations to perform data pre-processing. The expressions are written with a python-based syntax that allows the user to select and combine one or more layers, apply filters, apply masking conditions, perform grid-cell-based arithmetic and other data transformations (e.g. normalization, logarithmic scaling, gaussian convolution). In this sense, the tool cuts down the need of manual data preparation and standardization activities.

The Tools4MSP package can also be downloaded and used as stand-alone library. The library can be efficiently used through Jupyter Notebook, a web-based computational environment that provides one of the most convenient user interfaces for interactive analysis. The software allows the authoring of shareable and reproducible notebook documents which allow a combination of input code, rich media representations of the output results, explanatory text, mathematics, images forming a rich computational narrative. Regarding the Tools4MSP development, the Jupyter Notebook supports rapid prototyping of new features, experimentation with new ideas and advanced analysis of the Case Studies.

Halpern, B.S., Frazier, M., Potapenko, J., Casey, K.S., Koenig, K., Longo, C., Lowndes, J.S., Rockwood, R.C., Selig, E.R., Selkoe, K.A., Walbridge, S., 2015. Spatial and temporal changes in cumulative human impacts on the world's ocean. Nature Communications 6, 7615. https://doi.org/10.1038/ncomms8615

Clarke Murray, C., Agbayani, S., Ban, N.C., 2015. Cumulative effects of planned industrial development and climate change on marine ecosystems. Global Ecology and Conservation 4, 110–116. https://doi.org/10.1016/j.gecco.2015.06.003

Topic 7: Transparency

The tool has been released as Free and Open Source Software (FOSS) (Menegon, 2018b), thus allowing the software to be downloaded and reused. The software documentation is not yet available, however several scientific publications have been published to describe the method (Menegon et al., 2018a), software details (Menegon et al., 2016) and case studies application (Menegon et al., 2018c).

The most updated version of the geospatial dataset can be freely download at https://doi.org/10.5281/zenodo.1173764. A full dataset including sensitivity and distance matrix will be available in the next weeks.

Topic 8: Outputs

The tool outputs have been designed to specifically support the MSP activities carried out through different EU and Italian founded projects. The design of the outputs has been concerted with planners and scientific researchers.

The tool doesn't directly support scenario or evolutive analysis, however with the ongoing project PORTODIMARE a specific tool to combine end evaluate case study differences will be design and implemented.

Topic 9: Outputs / Implementation

The outputs of the CEA tool have not been used yet in any formal national or local MSP plan.

Anyway, the tool and its outputs have been developed in collaboration with scientific experts and stakeholders at various levels.

The sensitivities scores have been defined and assessed with the involvement of experts in various environmental and maritime fields (details of the process in Gissi et al. 2017), while the outputs have been produced, discussed and improved during national and international projects where stakeholders, administrations and planners were involved through workshops, dissemination events and specific discussion tables.

At the European level, the SUPREME and SIMWESTMED projects have included the direct involvement of the authorities responsible of the national implementation of the MSP Directive. CEA tool is one of the tools that are tested in the projects and the outputs will be used and evaluated.

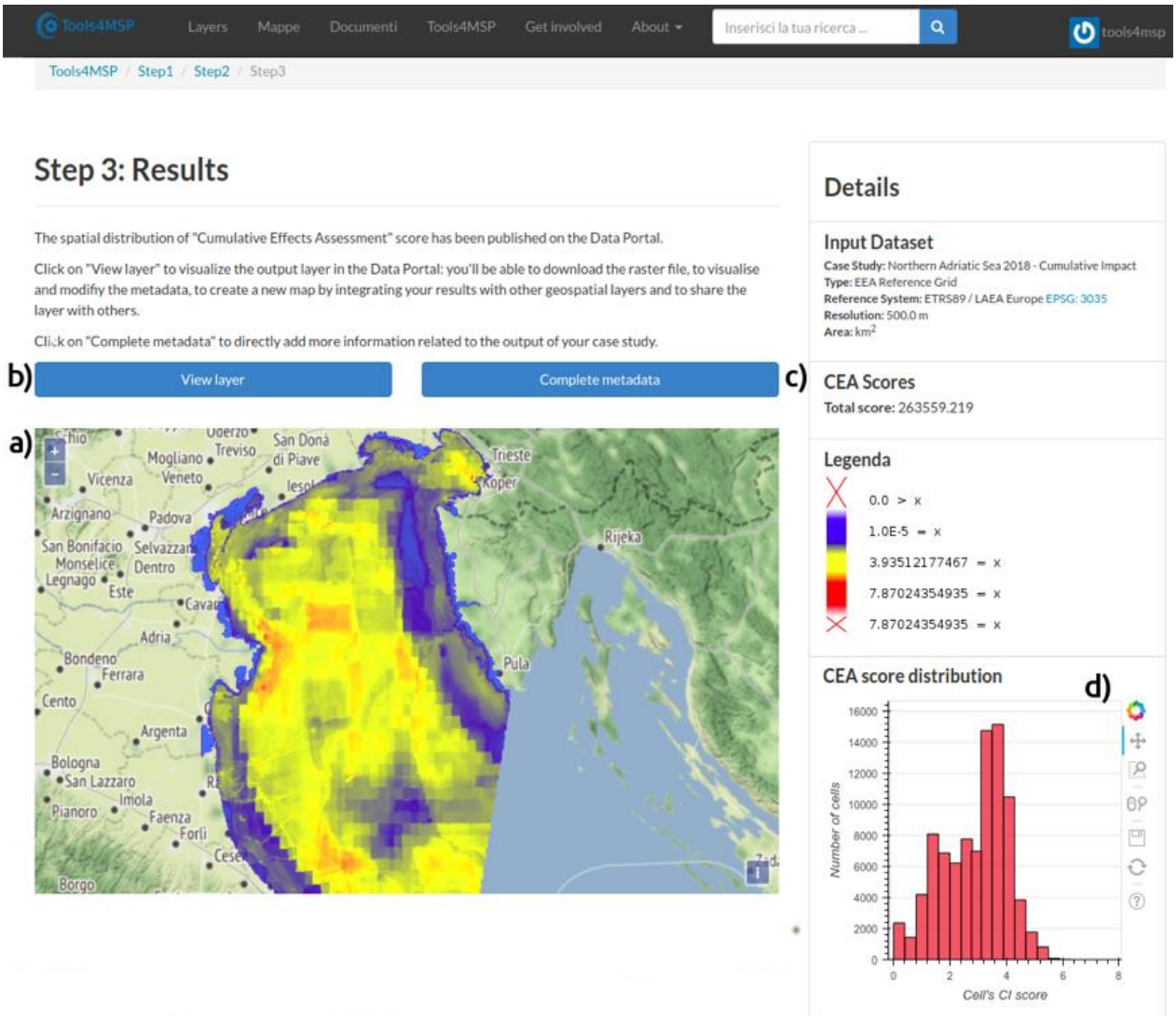
Topic 10: Accessibility and Sustainability

Analysis of cumulative impacts of human activities on the marine environment is per se a complex issue, involving a multitude of variables and domains, and for this reason its developments, the dissemination of its results, and the use of the outputs are not a trivial task. So, the use of the tool is inherently complex and requires some knowledge on data and environmental dynamics related to a specific area. Anyway, some effort was put to make the tool understandable and usable by a wider audience.

In addition to the production of technical and scientific information, a few non technical reports were produced to disseminate the results of the application of the CEA tool also outside the scientific field (see References section).

A specific page in the Tools4MSP Geoplatform was created (http://data.adriplan.eu/tools4msp/) to guide the understanding and running of the tools, also through a Graphical User Interface (GUI).

An example of the GUI available in the Tools4MSP Geoplatform representing results of web-tools application is presented in the Figure below, illustrating the (a) geospatial outputs for CEA modelling, (b) view layer button enabling users to download geospatial results in GeoTiff format, (c) complete metadata button supporting metadata description of results by the user and (d) statistical result in terms of distribution of CEA score by number of cells



The CEA tool, as well as the whole Tools4MSP software suite, is a Python-based Free and Open Source Software (FOSS), available under the GPL licence at: https://github.com/CNR-ISMAR/tools4msp

It is built on top of other FOSS modules and is continuously improved by a small group of developers.

The sustainability of the tools is being supported by the participation of the group of researchers (that mainly includes CNR-ISMAR and IUAV) in various national and EU-funded projects and the incremental development and improvement of the Tools4MSP software suite during the course of recent years. Currently, there's at least a medium term (5 years) perspective for maintenance and improvement of the tools and the platform, but a longer perspective is a core objective of the group of researchers that are involved.

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7.8 Annex 8. Describing Fiche CEDEX

CEDEX Describing Fiche

Developed in the task C.1.3.4. Tools and methods to support MSP processes

Summary

Reminder – Purpose of this fiche

The workshop held in Marseille in February 2018 has been able to feed the reflections, and make progress in the definition of action plans in the actions C.1.3.4. The following action plan for the comparison of interaction methods has been set up:

C.1.3.4.: Comparison between methods for the evaluation of interaction

Step 1: Proposal of a template to describe each methods, according to the criteria's defined during this workshop (for the end of February)
Step 2: Feedbacks about this template, validation of a final version (mid-March)
Step 3: Filling of the Methods fiche by each partner (for the end of May)
Step 4: Writing of the first draft of the comparison report (July)
Step 5: Validation, inputs of the lessons of the Cases Studies in the comparison report (end of November)
Step 6: Final report (for the end of November)

Using the criteria's defined during this workshop; this template has for objectives to help the partners to create a fiche describing their methods with the criteria's cited. This template is going to circulate for validation among partners in March.

It is to be highlighted that all the criteria's cited during the workshop are not really fitted for an objective comparison. Some of them (like in the *Implementation for MSP*, or *Skills* categories) are going to be quite difficult to evaluate. For example, the sharing of the same vocabulary is going to be analyzed in the light of the answer of each partner to this template. In this template, a work on defining precise scales of evaluation is going to be conducted and submit to the validation of partners.

Once all the partners have fulfilled their methods fiche, the wrap-up is going to be done by the AFB.

The maximum length of this comparison fiche is 21 pages. Guidelines are provided in each topic, but you can adapt the length of your answers according to your methodology (in the limit of 21 pages).

Topic 1: Data

The objective of this part is for you to describe the data used in your tool, the way to select them and their time dimension. The maximum length of this part is 5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Can you provide a detailed list of activities the tool considers? Can you provide a detailed list of pressures the tool considers?*
- *If you have excluded some's, how do you have defined the activities to take into account in your tool?*

  A wide range of the activities happening -and even potentially happening in the future, not present today- were taken into account in the analysis conducted; for those for which data was not available or not found, a short description was included although their pressure intensity was not quantified;

Pressures described	**Activities related that have been considered (including those for which data was unavailable)**
Physical loss	
Smothering or alteration of seafloor	Exploitation of submarine deposits Port dredging Beach regeneration and beach artificial creation Cables and pipelines Artificial reefs and wrecks
Sealing	Port infrastructure and operations (dredging) Defence infrastructure Offshore exploration/ exploitation of oil and gas: wells, platforms, single-buoys and docks Artificial reefs and controlled vessel sinking (wrecks) *Offshore wind farms*
Physical damage	
Changes in siltation	Port infrastructure Defence infrastructure Fluvial flow regulation in dams and other regulation infrastructures Exploitation of submarine deposits Port dredging Artificial reefs and controlled vessel sinking (wrecks) Beach regeneration and beach artificial creation Farming of mussels on wooden platforms
Abrasion	Extraction of fish commercial species: trawling Boat anchoring Exploitation of submarine deposits *Port dredging* *Scuba diving*
Selective extraction	Exploitation of submarine deposits Port dredging Offshore exploration and exploitation of oil and gas: wells and platforms
Other physical disturbance	

Underwater noise	*Cables and pipelines* *Offshore exploration and exploitation of oil and gas* *Research activities* *Discharges of port dredging material* *Exploitation of submarine deposits* *Port dredging* *Port infrastructure* *Defence infrastructure* Shipping
Marine litter	Land-based marine litter *Shipwrecks* *Munitions and obsolete weaponry*
Other physical disturbance	*Permanent offshore structures: aquaculture cages, hydrocarbon exploitation platforms, single-buoys…* *Exploitation of submarine deposits* *Port dredging* *CO_2 / gas storing* *Seawater extraction*
Interference with hydrological processes	
Significant changes in thermal regime	*Energy generation facilities: Thermal plants* *Energy generation facilities: Nuclear power plants* *Energy generation facilities: Regasification plants* *Industrial facilities (other than energy producers)*
Significant changes in salinity regime	Desalination plants Sewage plants
Contamination by hazardous substances	
Accidental or uncontrolled releases	Accidental releases Fluvial inflows Atmospheric deposition Run-off waters
Systematic or intentional releases, solid and liquid	Controlled solid discharges Controlled liquid discharges
Introduction of radio-nuclides	Energy generation: Nuclear power plants
Nutrient and organic matter enrichment	
Inputs of fertilisers and other nitrogen and phosphorous-rich substances Inputs of organic matter	Direct discharges Fluvial inflows Aquaculture Sold discharges Atmospheric deposition Run-off waters
Biological disturbance	
Introduction of microbial pathogens	Waste water treatment plants (WWTPs) discharges Aquaculture and shellfish farming Shipping (ballast water discharges) Recreational activities (bathing waters)

Introduction of non-indigenous species and translocations	Shipping (Biological fouling) Shipping (Ballast water discharges) Recreational and commercial fishing (Live bait and seaweeds used in packaging) Trawling Recreational activities Aquaculture Recreational activities (Aquariums) Discharges of port dredging material *Research activities* *Biological control* *Alteration of natural water flows* Infrastructure construction or habitat alteration
Selective extraction of species, including incidental non-target catches	*Commercial fishing* *Commercial shellfish harvesting* *Aquaculture* *Recreational fishing* *Accidental by-catch*

Not included in the cumulative pressure analysis

- *If you have excluded some's, how do you have defined the pressures to take into account in your tool?*

  The method tried to include in a comprehensive manner the list of pressures detailed in Annex III – Table 2 of the MSFD (2008/56/EC); although the objective was to quantify their intensity, those pressures for which data was not available were only described.
- *Can you provide a detailed list of ecosystem components the tool considers?*

  Since this method was focused on a cumulative pressure analysis, ecosystem components were not considered at any time as impacts (and thus severity of impacts) was not quantified.
- *If you have excluded some's, how do you have defined the ecosystem components to take into account in your tool?*

  NA.
- *Type of data used*
  - Official data reported by Spain to International Conventions (OSPAR, UNEP/MAP)
  - Official data reported by Spain to the EU
  - Public information published by official entities belonging to the General State Administration
  - Public information published by Regional Governments (Communities of Catalonia, Valencia, Murcia, Andalusia and Balearic)
- *What is the temporal aspects take into account in the data? (Year, Season, month, hours etc.)*

  See table containing data details in Topic 2.

Topic 2: Data/Accessibility

The objective of this part is to make a focus on the availability of your data and the variability in formats you got. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *How many and what kind of data format in entrance do you have? (For example: shape by dots/ lines/ polygons)*

Existing quantitative data has been adapted to be spatially displayed and analysed, by means of different proxies based on available scientific and technical literature (scientific literature, IUCN/ EU reports,

Detail of data used and how indicators were adopted in the basis of such data and then used can be found in the table below.

Activity	Data used	Format for CEA analysis in GIS analytical tools
Sand extraction	Data of the former Ministry of the Environment on sand extractions carried out during the period 2000-2010	Polygon
Port dredging	Annual inventory of port dredging in Spanish Ports, data from 1975 to 2010, annual updates carried out by CEDEX since 1992.	Polygon
Discharge at sea of dredged material	Annual inventory of port dredging in Spanish Ports, data from 1975 to 2010, annual updates carried out by CEDEX since 1992. Used data: 2006-2009	Polygon Raster
Artificial beach creation or beach regeneration	Data on beach regeneration, Directorate General of Sea and Coast Sustainability, period 2002-2007	Line converted to Polygon (application of a 200 m radius)
Cables and pipelines	Nautical charts from the Navy Hydrographical Institute	Line converted to Polygon (application of a 5 m radius)
Artificial reefs	Data of the former Ministry of the Environment, and Rural and Marine Environments, Methodological guidelines for the installation of artificial reefs, 2008	Polygon
Damming for water resources storage	System of water indicators, former Ministry of Agriculture, Food and Environment, 1900-2006 White book of water in Spain, former Ministry of the Environment, 2000; for the period 1940-1995 Data on River Basin Plans (WFD), for the period 1980-2005	Raster
Fishing	VMS database for fishing vessels >15m for the period 2007-2010 Operating Fishing Fleet Census of the former Ministry of the Environment, and Rural and Marine Environments,	Raster
Aquaculture	Inventory of aquaculture facilities (Directorate- General for the conservation of marine resources and aquaculture & National Advisory Board for Marine Crops (JACUMAR)) for year 2011;	Raster Polygon
Exploration and	Data of the former Ministry of Industry, Energy and Tourism	Points and polygons

exploitation of HC	on annual crude production for the period 2004-2010	
CO_2 Storage	Directorate General of the Energy and Mining Policy	Points or polygons
Port and defence infrastructures	Database of pressures in coastal and transitional waters (CEDEX for the WFD, 2004)	Raster
Maritime transport	AIS data, 2010 VMS Database of the Secretariat-General of Maritime Fisheries	Raster
Maritime transport (Oil spills)	Databases of the International Maritime Organisation and of the "Centre de documentation, de recherche et d'expérimentations sur les pollutions accidentelles des eaux (CEDRE, FR)" on accidental oil spills for the period 2005-2009 ; Data of oil spills in Spanish Ports;	Points
Maritime transport (Intro sp)	Consultation of questionnaires sent to Port Authorities by the Directorate- General for the Merchant Marine, Spanish Ministry of Public Works.	Polygon
Maritime transport (Wrecks)	Directorate- General for the Merchant Marine, Spanish Ministry of Public Works.	Point converted to polygon (Application of a 75 m radius).
Industrial plants	Database of pressures in coastal and transitional waters (CEDEX for the WFD, 2004); Database of Spanish desalination facilities (CEDEX); Water Information System (SIA), Ministry of Ecological Transition; National PRTR Register (Contaminant emissions and sources).	Polygons Raster
Recreational activities	Bathing waters register (former Ministry of the Environment)	Lies or Polygons
Research and education	Spanish National Research Council CSIC (seismic campaigns) Spanish Mining & Geology Institute IGME (seismic campaigns)	Lines

- *Has the tool the opportunity to use new one easily? How?*
  Not applicable to this case, as it is a method and not an (online) tool.

- *Are a lot of data protected by a broadcast convention?*
  Raw data originate from official sources; spatialized/ resulting data mostly comes from proxies and therefore are not official data and cannot be publicly distributed; they are however considered as a CEA method result.

- *How do you characterize your method accessibility according to this topic? Can you judge it weak/mean or strong and explain why?*
  Not applicable.

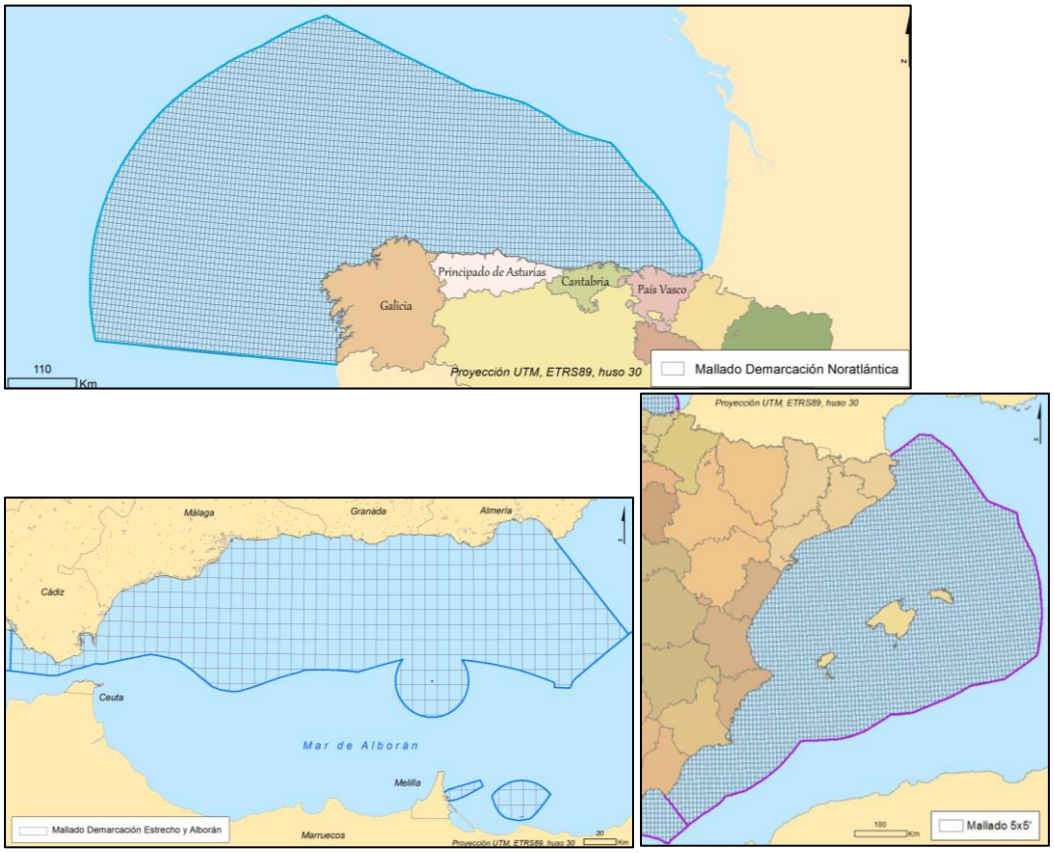
Topic 3: Processes / Scale

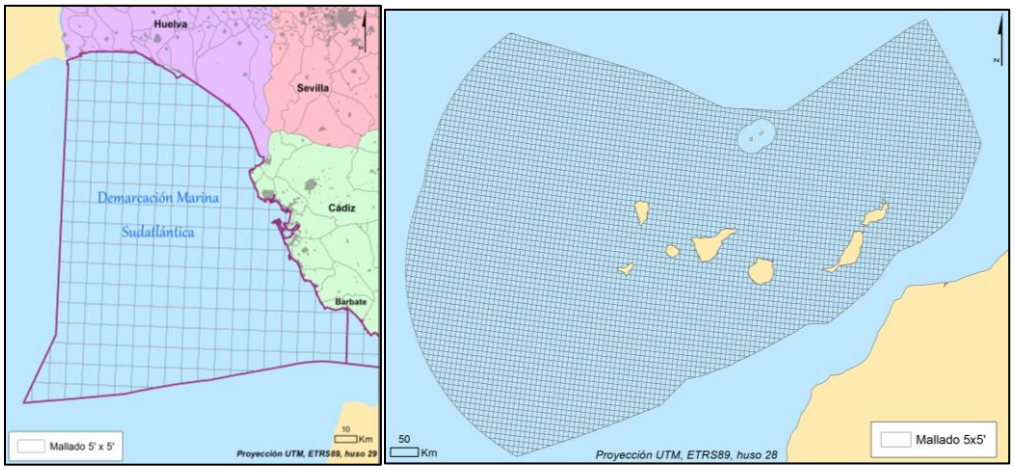
The objective of this part is to describe on which geographic scale your tool is based, and if this scale could be adjusted easily. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *What is the size of the cell grid?*
  The analysis was conducted using GIS Tools (ArcGIS) and a grid of 5 x 5'.
- *What is the geographic scale used by the tool?*
  The cumulative pressure analysis was conducted for all Spanish jurisdictional waters (EEZ), at the scale of each of the 5 marine districts that were differentiated to implement the MSFD (see figures below):
  - Levantine Balearic marine district
  - Strait of Gibraltar and Alboran Sea marine district
  - North Atlantic marine district
  - South Atlantic marine district
  - Canary Islands marine district

  Therefore, a total of 5 spatial analyses, following the same criteria, were undertaken.





- *Is the tool usable on new areas? On which conditions?*
  Not "really" applicable question. The method, as it was defined in 2012, can be re-used; the key point is that substantial work would be necessary to compile the spatial information needed in such new area. In addition, some of the methods used to analyse some of the pressures would need to be updated, according to new data sources and new methods available in the literature.
- *Is the model or can be extended to incorporate land / sea interaction?*
  Most of the processes related to sea-land interaction (water inflows, erosion processes…) were included and quantified in the method, based on hypothesis and proxies.

Topic 4: Processes

The objective of this part is to describe the processes to transform the original data on a final decision map (for example map of impacts or pressures). This is the methodology of your tool. The maximum length of this part is 6 pages

The following questions are given for examples, but they are NOT mandatory!

- *How do you determine the intensity of an activity?*
- *Do you aggregate the activities? If yes, how?*
- *What are the steps to relate an activity to a pressure? How do you have built them? (What is the method of the matrix you have?)*

To spatially characterise environmental pressures, a series of stages were followed:

1. Based on MSFD, and its list of pressures included in its Annex III – Table 2, a variety of pressures, sub-pressures and pressure indicators were identified and selected;
2. Each pressure category was related to the human drivers at its origin (as shown in the previous table, displayed in Topic 1), as well as to its impacts on marine ecosystems;
3. The link with the Spanish legislation in charge of managing these human activities was established;
4. Out of the list of pressure indicators, the most suitable ones were selected to address and characterise each pressure;
5. The different sources of data and the data available were searched and consulted to adapt the indicator to the existing information (restricted to official sources);
6. Methods to adapt the data to the different Spanish marine districts were defined, in order to obtain the temporal and spatial analysis of the pressures acting on the marine environment.

Data processing and analysis. Characterization of the indicator:

- Temporal aspects: provided that information is available, the time series 2005-2009 was analysed, as it was considered representative of the state of the system. In several cases, longer time series were considered in order to determine the long-term evolution of the indicators.
- Spatial characteristics: Integration of data into a geodatabase; in cases where pressures are spatially located, the corresponding point, line or polygon layer was created. In cases where the location of the pressure is known but not its area of influence, buffers have been created around them. The values chosen to draw these buffers are specified in the data processing methodology for each of the particular pressures. The individual layer is integrated into a geodatabase, re-projected to the UTM system, ERTS-89.

- *Did the tool take distance of pressures into account (distance based model / size of cells / buffers)?*
  Yes (see table below)
- *Do you aggregate the pressures? If yes, how? How do you determine the intensity of a pressure?*

Yes, although partially.

The method used consists of several stages:

1. Pressures were aggregated by broad pressure categories, according to Table 2 in Annex III of the MSFD (left column), and according to the series of pressure indicators established.
2. For each cell, in each one of the five Spanish marine districts, the sum of corresponding pressures was calculated, using either quantitative indexes, i.e. percentage of the area covered or affected by each pressures; or using semi-quantitative indexes related to presence or absence of pressures, or to the proximity to them.
3. Aggregation:
   - Pressures were cumulated/ aggregated by types, according to the list of general pressures included in Table 2, Annex III of the MSFD. Therefore, only partial cumulative pressure assessments were conducted, and a variety of maps were generated to illustrate the 8 different pressure categories, in each one of the 5 Spanish marine districts.
   - When summing up the different pressures (by type), some of them were weighted according to their intensity or relative importance.
   - Hypothesis and proxies were used to sum up the different pressure indicators.

How do you determine the intensity of an impact?

No impacts were quantified.

- *During the tool process, are some stakeholders or experts consulted? How?*

  No experts were consulted; quantification of pressure indicators was carried out on the basis of (more/less) realistic proxies and hypothesis.

- *Do the tools process a socio-economic analysis? If not, do you plan to do so? How?*

  No socioeconomic analysis was conducted, nor is planned for future assessments.

- *How do you characterize your method complexity according this topic? Can you judge it weak/mean or strong and explain why?*

  This type of analysis, named cumulative pressure analysis, conducted for the implementation of the first cycle of the MSFD, was the first assessment of this nature that has been carried out for the totality of the Spanish jurisdictional areas. Despite the fact that, in its conception, it might appear as relatively simple, on account of the large amount of work that it involves (definition and population of pressure indicators; search for available and existing data; determination of the different proxies to be used, and consultation of available literature, etc.) we consider that its level of complexity is medium to high.

Pressures described	Related activities	Pressure indicators	Summing up pressures Proxies used
Physical loss			
Smothering or alteration of seafloor	• Exploitation of submarine deposits • Port dredging • Beach regeneration and beach artificial creation • Cables and pipelines	• Annual amount of sand extractions & total extraction / area (cell) • Annual amount of dredging for navigation & total dredging / area (cell) • Annual amount of dumping of dredged	Adding pressures together: • % cell area occupied by pressures / total cell area • Determination of "potential impact" thresholds

	• Artificial reefs and wrecks	material, total area of dumping sites • % beaches in the marine district with nourishment • Total length of cables • Total surface of artificial reefs • % artificial coastline • Surface of oil & gas constr.	• Identification of potentially impacted areas Associated radius when area not available: • Ship wrecks: 75 m • Cables & pipelines: 5 m • Artificial & nourished beaches: 200 m
Sealing	• Port infrastructure • Defence infrastructure • Offshore exploration and exploitation of oil and gas: wells, platforms, single-buoys and docks • Artificial reefs and wrecks • Offshore wind farms	• Number and area of anchoring and sand & dredging / area (cell) • Annual amount of dumping of dredged material, total area of dumping sites • % beaches in the marine district with nourishment • Total length of cables • Total surface of artificial reefs • % artificial coastline • Surface of oil & gas constructions	Adding pressures together: • % cell area occupied by pressures (causing sealing) / total cell area • Determination of "potential impact" thresholds • Identification of potentially impacted areas Associated radius when area not available: • Artificial coast transformed into a polygon layer using a 100m radius buffer
Physical damage			
Changes in siltation	• Port infrastructure • Defence infrastructure • Damming • Exploitation of submarine deposits • Port dredging • Artificial reefs and wrecks • Beach regeneration and beach artificial creation • Farming of mussels on wooden platforms	• Authorised dumping of dredged material • Surface/ presence of sand extraction sites • <500m from artificial/ regenerated beaches • <100m from artificial coastal stretches • <500m from ports • Surface of/ presence of wrecks • Surface of artificial reefs • Location at <2 km from mouths of hydrologically modified rivers • Containing highly modified waters according to the WFD • <100m from eroded coastlines.	Adding pressures together: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Application of the formula, using coefficients according to pressures: **Changes in siltation index**= 0,1*(wreck + artificial reef) + 0,25*(dredged material + sand extraction + artificial or regenerated beaches) + 0,5*(artificial coasts + ports + rivers) + 1*(highly modified water mass + eroded coastline) • Determination of "potential impact" thresholds
Abrasion	• Extraction of fish commercial species: trawling • Boat anchoring • Exploitation of submarine deposits • Port dredging • Scuba diving	• % cell area occupied by pressures / total cell area (for anchoring & sand extraction) • Abrasion (from fishing trawling): - Spatial grid, 4 years VMS data (2007-2010), vessels > 15m. - Nº of hours of trawling fisheries/ year	Adding pressures together: • % cell area occupied by pressures / total cell area • Determination of "potential impact" thresholds • Identification of potentially impacted areas.
Selective extraction	• Exploitation of submarine deposits • Port dredging • Offshore exploration and exploitation of oil and gas: wells and platforms	• % of surface altered by any of the activities described (sand extraction areas, port dredging areas, HC exploitation permits)	Adding pressures together: • % cell area occupied by pressures / total cell area • Determination of "potential impact" thresholds • Identification of potentially impacted areas.
Other physical disturbance			
Underwater noise	• Cables and pipelines • Oil & gas exploration & exploitation • Research activities • Port infrastructure and dredging • Dumping of port dredged material • Exploitation of submarine deposits • Defence infrastructure • Shipping	• Continuous noise (maritime transport): - VMS data for fishing vessels - AIS data for commercial shipping	Adding pressures together: • Different weights assigned to different signal intensity intervals (according to the amount of vessels per cell) • Final result = summing up all weights in each cell. • Determination of "potential impact" thresholds

Marine litter	• Urban centres (landfills, etc.) • WWTP • (Wrecks) • (Obsolete weaponry)	Variables considered / cell: • Population associated to coastal urban areas within a 10 km radius • Area of ports located within a 10 km radius • Tourist population associated to bathing water areas • Presence/ absence of landfills located inland <2km from the coastline • Presence/ absence of river mouths	Only for **land-based marine litter**: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Determination of "potential impact" thresholds
Other physical disturbance	• Permanent offshore structures: aquacult. cages, platforms, buoys… • Exploitation of submarine deposits • Port dredging • CO_2 / gas storing • Seawater extraction	No data for these type of pressures	Cumulative pressure assessment not carried out
Interference with hydrological processes			
Significant changes in thermal regime	• Energy generation: thermal plants • Energy generation: nuclear power • Energy generation: regasification plants • Other industrial plants	Cumulative pressure assessment not carried out	
Significant changes in salinity regime	• Desalination plants • Sewage plants	Variables considered / cell: • Containing brine dumping from a >60.000m^3/day production facility • Location at <5 km from a water treatment plant • Location at <5 km from the mouth of a major hydrologically altered river	Adding pressures together: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Application of the formula, using coefficients according to pressures: **Salinity regime alteration index**= 1*(PRTR not reporting WWTP) + 2*(PRTR reporting WWTP) + 3*(desalination plants <60.000) + 4 (desalination plants >60.000) + 5*(altered rivers) • Determination of "potential impact" thresholds
Contamination by hazardous substances			
Accidental or uncontrolled releases	• Accidental releases • Maritime transport (Oil spills) • Fluvial inflows • Atmospheric deposition • Run-off waters	Variables considered / cell: • Containing single-buoys • Containing offshore platforms • Location at <500 m from authorised dumping of dredged material • Presence of hazardous substances-enriched EMEP cells • Location at <5 km from PRTR1 facilities with no reporting obligation • Location at <2 km from river mouths • Located <2km from landfills • Located <5km from mining areas • Location at <2 km from WWTP not requiring PRTR reporting • Location at <2 km from ports1 not recording traffic of hazardous subst. • Location at <5 km from PRTR2 facilities (with reporting obligation) • Location at <5 km from ports2 recording traffic of hazardous subst.	Adding pressures together: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Application of the formula, using coefficients according to pressures: **Pollution index**= 0,1*(single-buoys + platforms) + 0,25*(dumping + EMEP cells + PRTR1 + WWTP + river mouths + landfills+ mining) + 0,5*(ports1) + 0.75 (rivers/ transitional waters not meeting GCS + PRTR2) + 1*(coastal waters not meeting GCS + ports2) • Determination of "potential impact" thresholds
Systematic or intentional discharges, solid & liquid	• Controlled solid discharges • Controlled liquid discharges		
Introduction of radio-nuclides	• Nuclear power plants		

		• Including or located < 2km from rivers or water masses not meeting good chemical status (WFD)	
Nutrient and organic matter enrichment			
Inputs of fertilisers & other N & P-rich subst.	• Direct discharges & fluvial inflows • Aquaculture • Solid discharges • Atmospheric deposition • Run-off waters	Variables considered in each cell: • Location at <500 m from authorised dumping of dredged material • Presence of nutrient-enriched EMEP cells • Presence/ absence aquaculture pan or facility • Location at <2 km from river mouths / altered rivers, hydrologically or according to WFD • Location at <5 km from PRTR facilities (industrial or WWTP1) • Location at <2 km from WWTP2 not requiring PRTR reporting • Containing/ location at <2km highly modified coastal or transitional water masses according to the WFD	Adding pressures together: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Application of the formula, using coefficients according to pressures: **Nutrient index**= 0,25*(dredged material + nutrient-enriched atm. deposition + WWTP2 + aquaculture & pan) + 0,5*(river mouths) + 0,75*(altered rivers/ transitional modified waters + PRTR facilities + rivers) + 1*(modified coastal waters) • Determination of "potential impact" thresholds
Inputs of organic matter	• WWTP • Aquaculture • Solid or liquid inputs • Artificial reefs	IDEM (Nutrients)	IDEM (Nutrients)
Biological disturbance			
Introduction of microbial pathogens	• Waste water discharges • Aquaculture and shellfish farming • Shipping (ballast water discharges) • Recreational activities (bathing waters)	Variables considered in each cell: • Location at <5 km from WWTPs • Presence/ absence aquaculture pan or facility • Location at <2 km from river mouths • Location at < 500m of a bathing area	Adding pressures together: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Summing up pressures: Each pressure = 1, except for: - Presence of PRTR reporting WWTPs = 2 • Determination of "potential impact" thresholds
Introduction of non-indigenous species and translocations	• Shipping (biofouling, ballast water discharges) • Recreational & commercial fishing • Discharges of port dredged material • Recreational activities (live bait & seaweeds used in packaging) and aquariums • Aquaculture • Research activities Other (favouring) activities: - Biological control - Alteration of natural water flows - Infrastructure construction.	Variables considered in each cell: • Intersecting/ containing aquaculture facilities; • Intersecting/ containing Ports of General Interest (PGI) & other ports • Intersecting/ containing single-buoys or moorings • Intersecting/ containing offshore platforms • Containing authorised dumping of port dredged material • Areas < 5km from any aquarium	Adding pressures together: • Semi-quantitative index applied, taking into account: - Presence of pressures - Proximity of pressures • Summing up pressures: Each pressure = 1, except for: - Presence of PGI= 2 - Presence of port recording bulk traffics > 6 m. Tons = 4 • Determination of "potential impact" thresholds
Selective extraction of species, including incidental non-target catches	• Commercial fishing • Commercial shellfish harvesting • Aquaculture • Recreational fishing • Accidental by-catch	Cumulative pressure assessment not carried out, as it was considered that the different pressures exerted by the variety of drivers causing species extraction affects to many environmental compartments and cannot be summed up.	

Two of the results of the cumulative pressure analysis are shown below (see Figure 1 and Figure 2).

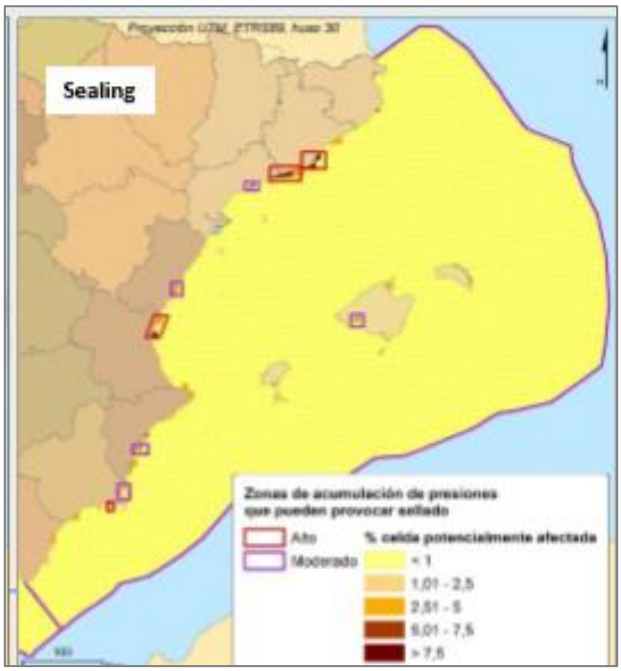


Figure 1 Results of cumulative pressures generating sealing

Figure 2 Results of cumulative pressures generating abrasion

Topic 5: Processes / Uncertainty

The objective of this part is to speak about the uncertainty of the evaluation. This contains the scientific uncertainty, but also the requirement of certainty by the planners. The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *Does the tool have the ability to address the uncertainty? How?*
- *Does this uncertainty have been transpose in an output, or output add-on, easy to interpret?*
- *What is the minimum of data to inforce the tool and the uncertainty associated?*
- *Is there a minimum of certainty require using your tool or it's outputs for plan making? (For example required by administrations, stakeholders, your own requirements? What is the percentage of pressures actually occurring take into account by your tools in your opinion?)*
- *How do you characterize your efficiency in taking into account uncertainty? Can you judge it weak/mean or strong and explain why?*

Not applicable. No uncertainty (ies) associated to the spatial distribution estimated for pressures was/werer addressed.

Topic 6: Processes / Flexibility

The objective of this part is to provide a good idea of the modification that your tool can afford. This is a wrap-up of the flexibility of the criterions in the "Processes" parts. The maximum length of this part is 1.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Does the tool have the ability to integrate different models (environment, activities, uses, resources)?*
- *Did all the others criteria's about processes could be easily modulated?*
- *How do you characterize your method complexity according this topic? Can you judge it weak/mean or strong and explain why?*

  Not applicable.

Topic 7: Transparency

The objective of this part is to provide a good idea of the transparency of your tool, its methodology, the documentation provided with it etc. The maximum length of this part is 0.5 pages

The following questions are given for examples, but they are NOT mandatory!

- *Is the documentation about your method available? If not, do you plan make it available? How?*
- *Is the documentation about the method used to build matrixes / links available? If not, do you plan to do so? How?*

Since the method described was applied in analysis of pressures included in the official national Initial Assessment documents submitted to the EC to comply with MSFD requirements, the data used (i.e. type, year, source), the methods applied and the list of references consulted have been exhaustively detailed. These documents can be found and freely accessed via both EC and Spanish Ministry of the Environment's websites[1].

As stated in the documents, the pressure analysis uses an approximation approach and is built on many proxies. It is noteworthy that all information sources consulted are official, as follows:

- Spanish national information submitted to international conventions (e.g. UNEP/MAP – Barcelona Convention, OSPAR, etc.);
- Spanish national information submitted to the EC;
- Spanish national information published by official entities belonging to the General National Administration;
- Information published by the regional administrations (i.e. Autonomous Communities) of Catalonia, Valencia Community, Murcia, Andalusia and the Balearic Islands.

[1] - EC: http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation/reports_en.htm
- Spanish Ministry of Ecological Transition: https://www.mapama.gob.es/es/costas/temas/proteccion-medio-marino/estrategias-marinas/default.aspx

Topic 8: Outputs

The objective of this part is to describe the methodology you have used to define the outputs, and the futures evolutions planned for them (scenarios for example). The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *How do you have defined the outputs of the tool?*
  Overall, the output of the analysis made up the analysis of environmental pressures integrating the national submission to the EC in the MSFD framework.
  The description and analysis of the data used to characterise the different pressures set by the MSFD (Annex III, table 2) allowed for a cumulative pressure analysis. This cumulative pressure analysis was conducted partially, as it did not focus on integrating or adding together the totality of the pressures acting on the environment. On the contrary, it was carried out by summing up the sub-pressures that resulted in one of the pressures listed by the MSFD. Its objective was hence to highlight the different areas of the Spanish marine environment that were affected by each type of pressure, as well as to get an idea on their potential intensity and consequences for the environment, in order to facilitate the definition of management measures or improving monitoring programs.
  In this sense, potential impact thresholds have been defined, resulting in 5 different categories of potential impacts ranging from very low to very high, based on the result of the cumulative analysis conducted for each pressure.

- *Were any time of concertation implied?*
  No.
- *Do you plan to do some?*
  No.
- *Did the tool provide evolutive analysis based on scenarios? How? If not, do you plan to do so? How?*
- *If yes, how the time dimension is integrated?*
  No evolution/ future trend modelling based on scenarios was applied, and it is not intended for the future. However, trend analysis was provided for some of the activities –and consequent pressures- considered in the assessment, over the years previous to 2012.

Topic 9: Outputs / Implementation

The objective of this part is to give information about the articulation of your work on national MSP processes. This contains use of the outputs, concertation with stakeholders about the results, dissemination etc. The maximum length of this part is 1 page

The following questions are given for examples, but they are NOT mandatory!

- *Are some stakeholders or experts consulted for validation / comments on the outputs? How? If not, do you plan to do so? How?*
- *Is your tool or its outputs disseminated and communicate to planners? If not, do you plan to do so? How?*
- *Do you have feedbacks of planners about your tool or its outputs?*
- *Do you have an idea of the degree of take up of your tool or its outputs for practitioners / planners?*
- *Do you plan on conducted analysis of the use of your tool or its outputs? If yes, how?*
- *How do you evaluate the efficiency of your method? Can you judge it weak/mean or strong and explain why?*

There are no links between the CEA conducted for the purposes of MSFD (1st cyle) and the MSP process.

Topic 10: Accessibility and Sustainability

The objective of this part is to describe the skills needed for running the tool, the key dissemination modules developed for the use of it and the wished duration of this work. The maximum length of this part is 2 pages

The following questions are given for examples, but they are NOT mandatory!

- *What is the level of skills needed to run the tool? (For guidelines: how many informatics languages does it use? What is the weight (in octet) of the tool without data? From 1 to 20, how do you evaluate its complexity?).*
- *Is the tool user interaction friendly? (For guidelines: can a stakeholder run an analysis? Have some developments been done to make your tool more accessible?).*
- *Is the tool an open source? Is it using open source software's?*
- *Can the tool be interoperable through modules?*
- *For how much time you are sure that the work on your tool could be pursuing?*
- *For how much time do you plan to do so?*
- *How do you characterize your method sustainability? Can you judge it weak/mean or strong and explain why?*

Not applicable.