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Cumulative impacts and Strategic Environmental Assessment: Literature review

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Glossary

Blue Growth – "the 'long-term strategy to support sustainable growth in the marine and maritime sectors as a whole, recognising oceans as drivers for the European economy with great potential for innovation and growth'. Blue Growth is the European Commission's initiative to further harness the potential of European oceans, seas and coasts for jobs, value and sustainability. There are five sectors with high potential for sustainable blue growth, including renewable energy, biotechnology, coastal and maritime tourism, aquaculture and mineral resources". European Commission (2014) Blue Growth Infographic, available at: https://ec.europa.eu/commission/index_en

Cultural services/non-material benefits - the non-material benefits people obtain from ecosystems such as those derived from a setting. Examples include outdoor education, recreation, health, fitness and well-being, as well as historical and cultural heritage. Millennium Ecosystem Assessment 2006

Cumulative Effects Assessment - "Cumulative effects assessment is a systematic procedure for identifying and evaluating the significance of effects from multiple pressures or activities." OSPAR Intersessional Group on Cumulative Effects (OSPAR, 2013)

Cumulative effects: "changes to the environment that are caused by an action in combination with other past, present and future human actions". Hegmann et al., 1999. Available at https://www.ceaa.gc.ca/default.asp?lang=En&n=43952694-1&toc=show&offset=6

Cumulative Impacts – "Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project." European Commission, May 1999. Available at: https://ec.europa.eu/environment/archives/eia/eia-studies-and-reports/pdf/guidel.pdf

Ecosystem based management/approach – "holistic approach with a focus on preserving/restoring marine ecosystems and maintaining ecosystem services to support human needs. It should provide spatial solutions for the management of human activities in a way that is compatible with the achievement of good environmental status and the capacity of marine ecosystems to respond to human-induced changes". BalticSCOPE (2017) The ecosystem approach in MSP – A checklist toolbox, available at: http://balticscope.eu/presentations/project-results-ecosystem-checklists/

Ecosystem services – "the benefits that humans derive from ecosystem functions, either directly or indirectly, including provisional, regulating, cultural and supporting services" Nature, https://www.nature.com/articles/387253a0 or Millennium Ecosystem Assessment http://pdf.wri.org/ecosystems_human_wellbeing.pdf

Ecosystem - A dynamic interlinked complex of plant, animal and micro-organism communities and their non-living environment interacting as an ecological unit. An ecosystem can range in size, e.g. from the size of an intertidal pool to the size of the Earth's oceans. Millennium Ecosystem Assessment 2006

Environmental Impact Assessment (EIA) - the process of examining the anticipated environmental effects of a proposed project (site level) from design stage, through consultation and preparation of an Environmental Impact Assessment Report, evaluation of the report by a competent authority, and the subsequent decision as to whether the project should be allowed to proceed, encompassing public response to that decision.

Integrated Maritime Policy (IMP) - "the European Union's coherent approach to maritime issues, with increased coordination between different policy areas, focusing on issues that do not fall under a single sector-based policy e.g. Blue Growth and issues that require the coordination of different sectors and actors e.g. marine knowledge. The objective of the IMP is to support the sustainable development of seas and oceans and to develop coordinated, coherent and transparent decision-making in relation to the Union's sectoral policies affecting the oceans, seas, islands, coastal and outermost regions and maritime sectors, including through sea-basin strategies or macro-regional strategies, whilst achieving good environmental status as set out in Directive 2008/56/EC. Directorate General for Maritime Affairs and Fisheries (2017). Integrated Maritime Policy. Available at: https://ec.europa.eu/maritimeaffairs/policy_en

Maritime Spatial Planning - "a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process." Ehler, Charles, & Fanny Douvere, 2009. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000186559

Provisioning services - goods obtained from ecosystems. This includes food from finfish and shellfish, seaweed fertiliser, wave and tidal energy, pharmaceutical products, and tourism revenue. Millennium Ecosystem Assessment 2006

Regulating services - these include pollution regulation through waste breakdown, detoxification and climate regulation. Millennium Ecosystem Assessment 2006

Strategic Environmental Assessment (SEA) – "the process by which environmental considerations are required to be fully integrated into the preparation of Plans and Programmes and prior to their final adoption" (UNEP, 2004). Environmental Impact Assessment and Strategic Environmental Impact Assessment – Towards an Integrated Approach, available at: www.unep.ch/etu/publications/textONUBr.pdf. "SEA is a systematic, on-going process for evaluating, at the earliest appropriate stage of publicly accountable decision-making, the environmental quality, and consequences, of alternative visions and development intentions incorporated in policy, planning, or program initiatives, ensuring full integration of relevant biophysical, economic, social and political considerations" (Partidário, 1998, p.15; Partidário and Clark, 2000). Applies at the strategic level.

Supporting services - those which provide the basic infrastructure of life and upon which other ecosystems depend, e.g. primary production (capture of energy from the sun), soil and sediment formation and nutrient cycling. Millennium Ecosystem Assessment 2006

Acronyms

AP – Allocation plans (Planos de Afetação)

CE – Cumulative effects

CEA – Cumulative Effects Assessment

EEZ – Exclusive Economic Zone

ES – Ecosystem services

EU – European Union

GIS – Geographic Information Systems

ICES – International Council for the Exploration of the Seas

IMARES – Institute for Marine Resources and Ecosystem Studies

IMP – Integrated Marine Policy

MCAA – Marine and Coastal Access Act [UK]

MSFD – Marine Strategy Framework Directive [EU]

MSP – Maritime Spatial Planning

NMP – National Marine Plan

PSOEM – Situation Plan (Plano de Situação do Ordenamento do Espaço Marítimo)

SA – Sustainability Appraisal

SEA – Strategic Environmental Assessment

1 Introduction

SIMAtlantic: “Supporting Implementation of Maritime Spatial Planning in the Atlantic” is a European project with the involvement of France, Ireland, Portugal, Spain, and the United Kingdom. This project aims to support the establishment and implementation of Maritime Spatial Planning (MSP) and also foster cross-border cooperation on issues of common concern. SIMAtlantic focuses particularly in 4 themes: 1- Governance; 2- Cumulative Impacts and Strategic Environmental Assessment; 3- Data Use and Sharing; and 4- Land-Sea interactions. This literature review will focus on theme 2: Cumulative Effects assessment (CEA), Strategic Environmental assessment (SEA) and Ecosystem Services (ES) in the MSP context.

The Blue Growth Communication (COM(2012) 494 final) released in 2012 can be considered the booster for MSP in Europe. In this document, MSP is indicated as one of the specific measures for the integrated maritime policy (IMP), critical to organizing the different uses of the oceans, to minimize their impacts on each other while, simultaneously, protecting the ecological and biological characteristics of the marine environment [1,2]. This Communication launched the process that placed blue economy and blue growth on the agenda of member states as a tool for obtaining a more sustainable economy and environment. The concept of MSP evolved, in the European Union (EU), as a way to avoid a sectoral approach to the governance and management of the marine environment and to achieve the sustainability of marine ecosystems.

MSP has been described as a cross cutting policy tool that promotes an integrated management and an ecosystem based approach to the maritime space [3,4]. The EU describes MSP as “*a process by which the relevant Member State’s authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives*” [5]. This way, MSP seeks to balance the demands of Blue Growth with the demands of Good Environmental Status (GES), required by the Marine Strategy Framework Directive (Directive 2008/56/EC) [6,7] .

Considering all activities and uses of maritime space on a temporal and spatial analysis, MSP usually results in plans, and has strong links to permits and other administrative tools. Maritime spatial plans are likely to have significant effects on the environment, and there is a legal requirement for the Plans to undergo a Strategic Environmental Assessment (SEA) process.

In 2001, the European Union adopted Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment, known as the SEA directive [8]. This Directive applies to a wide range of public plans and programmes, and it is mandatory for some activities such as fisheries, energy, transport, water management and others. Strategic environmental assessment is an important tool for integrating environmental considerations into the preparation and adoption of plans and programmes which are likely to have significant effects on the environment, because it ensures that such effects are taken into account during their preparation and adoption [8]. SEA complements the preparation process of MSP plans, providing a mechanism for the consideration of environmental effects, assessment of plan alternatives and potential development of mitigation measures. It can be said that SEA also contributes to the implementation of the ecosystem-based approach, as it frames the evaluation of effects on species and habitats of conservation importance.

Cumulative effects are a key aspect of SEA for MSP, given the broad scale and diversity of proposed development. Cumulative effects are "*changes to the environment that are caused by an action in combination with other past, present and future human actions*" [9]. The growing demand of activities and uses for the maritime space, requires a good understanding of how human and ecological components of the system interact, including the interaction between maritime uses (conflicts or synergies) and between uses and environment (pressures and impacts) [10,11]. Cumulative effects from human activities in the maritime space usually lead to ecosystem degradation or even collapse [12,13]. The need to assess the pace of change requires the development of cumulative effects assessment (CEA). CEA is a "systematic procedure for identifying and evaluating the significance of effects from multiple pressures or activities" [14,15]. CEA requires several data in order to identify and assess the direct and indirect interactions between multiple activities with multiple receptors (e.g. species) [16]. The aim of CEA is to understand the causes (the source of pressures and effects), producing an estimate of the expected impact, and assist in management decisions based on possible scenarios of the spatial and temporal effects of the causes identified [16]. The EU has still little or no guidance for CEA, and since it is necessary under many legal requirements (SEA and EIA), this leads to different approaches and methodologies being used in different contexts (and different Member States), so there's no 'common' approach to CEA and this is an obstacle for transboundary cooperation. CEA is still complex and has some challenges to overcome [15,16].

MSP has a clear connection to CEA, since the ecosystem based approach is a fundamental requirement of MSP, dealing with cumulative effects is one of the main supports for the development of MSP itself [3]. In addition, since the capacity to develop measures and strategies depends greatly on our understanding of the functioning and provisioning services of existing marine social and ecological systems, and the pressures and potential impacts that activities will have on the marine environment. Spatial analysis of human activities/uses and their cumulative impacts in the marine environment is consequently necessary for implementing the ecosystem-based approach to MSP. It has also been argued that SEA provides a suitable impact assessment framework for addressing cumulative effects because it is applied at the strategic level to plans and programs with broad boundaries, avoiding a sectoral approach to CEA [17].

With a rapid increase in frequency, type and magnitude of pressures in the marine environment that affect marine ecosystems, it is necessary to ensure that MSP takes into account all pressures [16,18]**.** Applying CEA and SEA to MSP is the best way to ensure that all the interactions between human activities/uses and the marine ecosystem are being considered in our MSP approaches.

This Literature Review will analyse some examples of SEA, CEA/CIA and Ecosystem Services related to the MSP process. Some examples of the methodologies applied, and tools developed by different countries are used for SEA, CEA/CIA and ES. These examples were chosen based on the availability of information and published results. We conclude with an identification of challenges and opportunities for SEA, CEA/CIA and ES which will be helpful to the development of the SIMAtlantic case study #3 "Transboundary Impact Assessment" between Portugal and Spain.

2 Approaches

2.1 SEA – MSP:

2.1.1 Italy – Croatia

Italy and Croatia have developed a Cross-Border Cooperation programme from 2014-2020, to promote cross country cooperation in the region of the Adriatic Sea. Both countries are part of a transnational cooperation programme – ADRION, alongside with Greece, Slovenia, Albania, Montenegro, Bosnia and Herzegovina and Serbia. The overall strategic goal of the ADRION programme is to act as a policy driver and governance innovator fostering European integration among Member and non-Member states, utilising the rich natural, cultural and human resources surrounding the two seas and enhancing economic, social and territorial cohesion in the programme area. The Programme focuses its efforts on four priority axes, which includes an axis for Sustainable region including biodiversity and ecosystem services.

A Strategic Environmental Assessment (SEA) was carried out for the Adriatic Ionian Cooperation Programme 2014-2020 (ADRION) [19]. Firstly, they defined the objectives of SEA for the ADRION programme taking into account the geographical area of relevance, the period of time to be relevant for trends and effects and the relevant environmental issues, which should be considered within the SEA (scoping phase).

The Assessment methodology involved the identification and evaluation of the likely significant effects on the environment of implementing the ADRION programme and possible reasonable alternatives. For that they defined a matrix approach to include scoping and detailed assessments, and when possible descriptive cumulative effects assessment.

The assessment of the potential impact of the programme encompasses a great deal of uncertainty since the ADRION programme only defines the framework and type of actions and/or projects to be supported (some potential impacts will depend directly of the type of project/plan supported). So, this SEA could only estimate potential and non-quantifiable impacts. The effectiveness of these potential impacts will depend on the orientations followed by the projects, but also from external factors. In addition, the effects of the Specific Objectives (SO) of the ADRION programme assessed in this report are mostly indirect effects, induced by expected changes which are difficult to assess.

In the first step of the assessment process (the relevance/scoping assessment) they identified the likely adverse, beneficial, neutral and uncertain effects of the ADRION programme on the environment. The result was presented in matrix format, and the assessment ascertains how well each of the SO and thematic objectives meet each of the SEA objectives defined previously. Some uncertainty was identified over whether impacts would be beneficial or adverse across the sustainability topics, particularly for biodiversity, but also for soil, water, air, climate, and cultural heritage, landscape, and ecosystem services. The matrix assessment was followed by a discussion on uncertain and potentially adverse effects and on the reason for these uncertainties. The priorities and activities to which these uncertain/adverse effects relate were then explored further through the detailed matrix assessment.

This matrix assessment is not a conclusive tool or model since its purpose is to identify those SOs for which uncertainties or potential impacts may arise. These SOs are the ones that had further scrutiny at the detailed matrix assessment further ahead in the SEA process. The analysis of the impacts on the environment was based on a non-exhaustive list of guided questions for each SO. The answers to these questions allowed them to describe the likely impacts of actions, regarding their nature.

The estimate was completed by assumptions on each potential impact in terms of:

- probability of the impact to occur;
- frequency throughout space and/or time of the impact to happen;
- duration of the impact (long-term or short-term);
- impact reversibility;
- transboundary impact effects (outside the Adriatic area).

The SEA was then subject to public consultation in each of the partner countries.

2.1.2 UK - Scotland

Scotland has an EEZ of approximately 462,263 km^2. In 2009, the UK (which includes Scotland) approved the Marine and Coastal Access Act (MCAA) for a more holistic and integrated approach to marine governance. The MCAA was the first statutory Act focused on the improvement of the management of marine and coastal environment, putting in place a more integrated effective management system, promoting clean, healthy, safe, productive and biologically diverse seas and oceans.

In 2010, Scotland approved the Marine (Scotland) Act, which paved the way for a statutory marine planning system in the country. The resulting National Marine Plan (NMP), published in March 2015, gives overall guidance to managing the country's coastal and marine environments. The NMP divides the maritime space in 12 regions [20].

In 2002, the government of Scotland established the Scottish Sustainable Marine Environment Initiative (SSMEI). This initiative aims to improve sustainable management of the Scottish marine environment and its natural resources through the development of new and innovative approaches to marine planning.

The development of the NMP was supported by a Sustainability Appraisal (SA) that includes a Strategic Environmental Assessment (SEA) and a Business and Regulatory Impact Assessment (BRIA). The Environmental Assessment (Scotland) Act of 2005 provides the legal framework for the development of SEA. An SEA is required to provide a high-level assessment of the potential environmental impacts or issues from certain plans or programmes. The SEA process should provide a mechanism for identifying and assessing environmental effects and ensuring that these are fully considered and that, where necessary, appropriate mitigation measures are detailed to offset any significant adverse effects[21].

SEA and the Sustainability Appraisal (SA) were undertaken jointly, and SEA comprises the environmental component of the SA.

Scotland applied the following methodology [22]:

1. Scope of the plan to be assessed – identification of the national marine vision, of the objectives of the plan based on the national environmental policies, assessment of

sector-specific objectives and general-sector policies. A baseline characterization of the environment of Scotland's marine environments was carried out in this step.

2. Scope of the areas to be assessed and approach to the assessment – SA has a broad scope and covers economic, social/community and environmental interests. A matrix was created for a detailed appraisal of SA objectives and standard assessment marking system. SA objectives were developed based on the environmental objectives and the review of the existent environment, and these objectives take the form of questions.
3. Assessment of alternatives – alternative approaches were analyzed, based on stakeholders and expert judgement.
4. Approach to mitigation – an initial review of the activities and uses in Scottish the marine environment was carried out, in order to identify potential effects. Some measures for avoidance and reduction of some effects were proposed.

2.1.3 Sweden

The Swedish marine area is the largest in the Baltic Region, with an EEZ of approximately 60,000 km^2. Sweden has developed their MSP plans for 3 areas: Gulf of Bothnia, Baltic Sea and Skagerrak/Kattegat. The Ministry of Environment and the Swedish Agency for Marine and Water Management (SwAM) are the national authorities for MSP. The proposal for the three marine plans of Sweden were drawn in 2016, and in 2018 they were subjected to a strategic environmental assessment. The three plans were finally submitted to the government in December 2019, and they will be adopted by March 2021.

The SEAs were based on the results of the cumulative impact assessments made with the Symphony-tool. Symphony is an assessment method that has been developed as an aid for Swedish marine spatial planning, based on the ecosystem approach (see topic 2.2.2.). The objective is to show on a general level how environmental effects differ between different areas and how planning affects this distribution. During 2018, SwAM had several consultation meetings with a broad range of stakeholders (e.g. municipalities, central government agencies, NGOs, academia, neighbouring countries). The objective of the Swedish SEA was to integrate environmental aspects in the planning and decision-making so that sustainable development can be promoted. SEA must be carried out when the implementation of a plan is assumed to entail a significant environmental impact, which is the assumption for the preparation of a MSP plan. One of the main tasks for the environmental assessment of the MSPs is to indicate the marine spatial planning possibilities of contributing to good environmental status (under MSFD) and to assess what significant impact different uses of the sea might entail [23–25].

Sweden adopted the following methodology for the development of SEA for the marine plans:

1. Identification of connections between sectors and pressures: environmental assessment based on the sectors defined in the MSPs within the themes. The sectors' impact is linked to the type of potential impact (pressures) as defined in the Marine Strategy Framework Directive (MSFD).
2. Description of the values, environmental impacts, and environmental effects: sectors environmental impact and environmental effects are identified and the basic conditions in the marine spatial planning area are described.
3. Assessment of environmental consequences: scope of the environmental effects that arise as a result of the marine sector's impact is assessed. The scale used in the impact assessment was: positive consequences; small negative consequences; moderate negative consequences; large negative consequences.

The data used for this analysis were based on the results of the application of Symphony.

2.1.4 Portugal

Portugal has one of the largest maritime areas in Europe, with an EEZ of approximately 28,7521 km^2. Portugal MSP legislation defines two types of MSP instruments: the Situation Plan (PSOEM –Plano de Situação do Ordenamento do Espaço Marítimo) and allocation plans (AP – Planos de Afetação) [26]. PSOEM identifies the spatial and temporal distribution of existing and potential uses and activities to be developed under a private use regime, and it also identifies the natural and cultural values of strategic importance. PSOEM is divided into four sub-divisions: continent, extended continental shelf, Madeira and Azores. The allocation plans are the instrument to allocate new areas or space for new activities, not included in PSOEM [7,26,27]. The Directorate General for Natural Resources, Safety and Maritime Services (DGRM), under the supervision of the Ministry of the Sea, has the responsibility for developing the PSOEM for the continent and extended continental shelf subdivisions, which was approved in December 2019 [28]. The PSOEM for the Madeira subdivision was also approved in 2019 and the PSOEM of the Azores subdivision is under development. Simultaneously to the development of PSOEM, a SEA was carried out in order to identify the potential impacts of the implementation of the plan [7,29].

Portugal adopted the following methodology for SEA in the mainland subdivision [7,30]:

1. <u>Identification of the conservation values to protect</u> – the aim was to analyse the marine conservation values (habitats and species) under the Natura 2000 network. The standard distribution, conservation goals and major threats were analysed. The information was compiled for each protected area.
2. <u>Identification and mapping of the pressures arising from potential activities/uses foreseen in PSOEM</u> – firstly, the pressures and possible impacts on the conservation values, of the activities and uses predicted in PSOEM, were analysed. This analysis enabled a framework between activities/uses-pressures-impacts to be built. The identification of the pressures followed the orientations of Annex III of the MSFD [31]. Some activities/uses can cause effects at a local scale but they can also produce effects some kilometres away, so it quantified the limiting distance at which the pressures ceased to have impacts [32]. For each activity-pressure a distance radius was applied, which was based on the information developed by other studies [30,32,33]. Based on the influence distance, each pressure was mapped and then overlapped with the Natura 2000 protected areas, and only the pressures that overlapped with protected areas were considered in the following analysis.
3. <u>Impact assessment</u> – the impacts were assessed based on two factors: 1) exposure of the natural values to the pressures and within each site of community importance (SCI) and Special Protected Areas (SPA) and; 2) potential interactions between pressures and natural values. The degree of exposure varied between High, Medium and Low and the interactions between pressures and natural values were categorised as Probable, Possible, Unlikely and Unknown. The resulting assessment is a combination of the two factors. A High degree of impact means that a certain pressure caused by certain activity will likely cause a significant effect on Natura 2000 habitat or species [7].
4. <u>Identification of mitigation measures</u> – this step involved the identification of possible mitigation measures that would help to reduce or annul potential significant impacts.

This methodology was analysed by experts from other national institutions, where the steps were presented and discussed, and accepted by all the stakeholders involved.

2.1.5 France

France has chosen to develop maritime and coastal strategy Documents (DSF) to meet the obligation to implement two European framework directives in one planning process [34]:

- EU Directive 2008/56/EC of 17 June 2008, known as the Marine Strategy Framework Directive, which aims to achieve or maintain good marine environmental status by 2020;
- EU Directive 2014/89/EU of 23 July 2014 establishing a Framework for Maritime Spatial Planning, which calls upon Member States to coordinate their activities at sea.

This particular context of development of the DSF gives this SEA certain specificities; it concerns a strategic document in the field of sustainable development at sea, which therefore pursues environmental objectives. Therefore, the initial state of the environment and the objectives to be achieved in this area are consubstantial with the DSF, through its marine environmental component, made up of the Action Plan for the Marine Environment (PAMMs). It is part of an iterative consultation process, because the DSF participates in the implementation of two European directives which do not have the same precedence.

The French environmental code provides that the DSF is made up of:

- a strategic component comprising the inventory (current situation), the 30 socio-economic and environmental strategic objectives, the vocations map and the vision of the stakeholders for the sea basin by 2030;
- the operational component consisting of the monitoring mechanism and the action plan [35].

DSFs should be subject to an assessment of implications for each of these components. The purpose of this environmental assessment is to ensure the relevance of the choices made with regard to environmental issues by forecasting the positive and negative impacts, and by proposing, if necessary, measures aimed at avoiding, reducing or compensating for the negative impacts [34,36]. For the first part, this evaluation was carried out by a group of consulting firms, responsible for producing the report, and followed by a steering committee made up of ministry of the environment, the four government departments responsible for planning and public institutions providing scientific and technical support for the development of the DSF (AFB, IFREMER and CEREMA). It defines a methodology which should be applied subsequently for the operational component.

Several steps have been retained for this methodology [34]:

- Identification of the environmental challenges of the facade. - Seventeen environmental issues have been identified, relying on the descriptors of good ecological status within the meaning of the MSFD;
- Analysis of potential impacts - It targets the potential impacts of environmental objectives, socio-economic strategic objectives, of the vocations map, and potential impacts on NATURA 2000 zones;
- Analysis of measures taken to avoid, reduce or compensate for potential impacts;
- Indicators for monitoring potential impacts - An analysis of the indicators proposed in the DSF was carried out in order to understand their ability to monitor the main risks of environmental impacts identified during the analysis.

2.2 CEA/CIA – MSP:

Human activities/uses and the resulting pressures can have serious effects on the health of ecosystems [11,12,37]. The marine uses and activities have expanded and coastal and offshore waters worldwide are being used in new ways which can bring new pressures and impacts on marine ecosystems [38]. Cumulative effects are defined as "*changes to the environment that are caused by an action in combination with other past, present and future human actions*" [9] and they can also result from individually minor but collectively significant actions taking place over a period of time or across an area [39]. This makes their consideration and assessment especially relevant for transboundary contexts. The effects of the pressures applied in ecosystems, may have various types of interactions such as additive effects, synergistic effects or antagonistic effects. The need for assessment of cumulative effects is required to support management decisions by decision makers and is particularly relevant in the development of MSP. Identifying, mapping and quantifying the cumulative effect of human activities on ecosystems is crucial to operationalising the practice of an ecosystem-based management approach, demanded in MSP [5,32].

Cumulative effects assessment (CEA) can 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*" [15]. Since the publication of Halpern et.al.,2008 [11], several papers and studies have addressed CEA studies and the need for development of a more suitable methodology for CEA [9,16,32,40–42].

Cumulative effects assessment still has some challenges to overcome, such as the level of complexity of CEA methodologies, the lack of some specific data (species, habitats, impacts, etc.), the double counting of impacts, among others [16]. This report will address some of CEA methodologies that have been applied to specific cases.

2.2.1 Tools4MSP

Tools4MSP started to be developed as part of the Adriplan project (http://adriplan.eu/) and it has been updated through the work of other projects. The Tools4MSP Geoplatform is a community-based, open source portal based on GeoNode, a web-based Content Management System for developing geospatial information systems (GIS) and for deploying spatial data infrastructure [43]. The Geoplatform uses data from other projects and enables access to standard services from other geoportals.

Tools4MSP offers a set of 3 different tools: 1- cumulative effects assessment; 2- sea use conflict analysis; and 3- Ecosystem services capacity assessment.

The cumulative effects assessment tool aims to support the MSP process under an ecosystem-based approach by assessing the potential cumulative impacts of maritime activities on the marine environment. It is the core tool of Tools4MSP and the tool was tested for the Adriatic-Ionian sub-basin [44]. The methodology followed to obtain the CEA tool was:

1. Gathering of geospatial datasets on human activities and environmental components (e.g. seabed habitats; nursery areas, etc.). Each layer was spatially normalized using the regular spatial grid (1km2 resolution) of the European Environmental Agency Reference Grid (EEA, 2012).

2. Expert-based analysis of sensitivity scores by associating a pressure (P) generated by human use (U) to the target environmental component (E) by considering impact extent, impact level and recovery time, buffer area.
3. Computation and visualization of geospatial results of the CEA assessment.

The main outputs of the tool were the development of cumulative impact maps, sea use overlay analysis maps, the generation of statistical outputs on impact scores (plots and tables) for single sea uses and environmental components, and the analysis of gaps in terms of data availability and input data based on data availability maps and statistical outputs.

Tools4MSP also developed the maritime use conflicts (MUC) analysis and the marine ecosystem services threat assessment (MES-Threat) tool.

MUC aims to (1) support MSP process through reallocation of maritime uses, (2) creation of collaborative conflict scores analysis; (3) repetition of the analysis over different time periods through integration of new conflict scores and geospatial datasets on sea uses, (4) sea use scenario analysis and (5) overlay analysis [44].

The marine ecosystem services threat assessment (MES-Threat) tool combines the expert-based marine ecosystem services supply index with the cumulative effects assessment modelling capabilities generating a threat index, describing the risk of reduction of ecosystem services capacity, loss or impairment of use due to cumulative effects from anthropogenic impacts [45].

2.2.2 Symphony

Symphony is a tool developed by Sweden to support the implementation of ecosystem-based MSP. During the development of marine spatial plans, the Swedish Agency for Marine and Water Management (SwAM) realised they needed a tool to help them find out the areas of particularly high cumulative environmental impact [46]. The model represents, through maps and other graphical representations, how ecosystem components respond to human pressures. The Symphony method provides valuable analyses for MSP in any context and informs planners of the baseline conditions and the potential effect of various planning options on the cumulative impacts in different areas.

Symphony calculates the cumulative impact from the sum or the average of all pressures' effect on all considered ecosystem values (ecosystem components). The sensitivity of each ecosystem component to each pressure is accounted for. This calculation is done for every cell within Swedish territorial waters and exclusive economic zone (EEZ) with a resolution of 250 by 250 metres. Despite the high spatial resolution, the results are interpreted at a more coarse level given the many uncertainties in data. The impact values can be illustrated in colour, in order to facilitate interpretation.

The method can be summarized in five steps:

1. Ecosystem components – Development of distribution maps of ecosystem components, based on compilations of already existing data. Symphony includes about 25 different ecosystem components (for example: cod, porpoise, seal, spawning areas, mussel reefs).
2. Pressures – Creation of marine pressure maps, showing the spatial extent of pressures from human activities. Pressures from activities governed by the MSP are then aligned with the respective user areas in the plans, in order to study the impact

of drafted plans and enable comparisons of different plan alternatives. Symphony included about 30 different pressures (e.g. fish catch, sediment spill, underwater noise, oil spills). These pressures are in turn related to human activities such as fishing, dredging and shipping. In Symphony land-based pressures such as eutrophication and pollution were also included since they all contribute to the cumulative impact in the sea.

3. Sensitivity matrix - Development of a matrix describing how sensitive each ecosystem component is to each of the pressures. This sensitivity matrix is based on expert opinion.
4. Baseline results - The cumulative impact is calculated for every geographic unit, using the equations below. This represents the impact in the current situation.

$$P_{sum} = \sum_{i=1}^{n}\sum_{j=1}^{m} B_i \times E_j \times K_{i,j} \qquad P_{mean} = \sum_{i=1}^{n}\frac{1}{m}\sum_{j=1}^{m} B_i \times E_j \times K_{i,j}$$

Figure 1: Cumulative impact (P) is calculated as the sum or mean of the product of all pressures' (B) effect on all ecosystem components (E), given the particular sensitivity (K) of every ecosystem component to every pressure.

5. Results - The result is interpreted and recalculated for different plan options in order to compare alternatives and find solutions. The specific impact contribution from different sectors can be calculated and compared for a given area. The results are used in the planning process with the goal of obtaining sustainable marine plans.

Symphony is based on spatial information represented in maps, and most maps are based entirely on pre-existing data, meaning that they have utilised the work of previous research and monitoring studies. Since spatial data is often scarce, SwAM used other models for extrapolation and to overcome data limitations [7].

The synthesizing work within Symphony was carried out in collaboration between SwAM and several other governmental bodies, universities, and consultancies. The software used for the analyses were "EcoImpacMapper" and "SeaSketch".

The methodology behind Symphony derived from the scientific work on Cumulative Impact Assessments, first developed by Halpern et al. in *Science* 2008 [11]. Based on this work, Symphony went a step further, to integrate ecosystem based maritime spatial planning. For quality assurance during the development and implementation of Symphony, SwAM sought guidance from experts.

Symphony integrates the distribution of ecosystem components, the spatial extent of pressures and the sensitivity of ecosystems to the pressures, based on expert opinion [7].

2.2.3 CUMULEO

CUMULEO (acronym for CUMULative Effects of Offshore windfarms) is a research project by IMARES (Institute for Marine Resources and Ecosystem Studies, Netherlands), which is investigating a methodology for scaling human pressures to population level impacts in the marine environment.

Like Harmony, the CUMULEO method develops a spatialized approach with a fairly limited number of activity sectors, pressures and ecological receptors in the North East Atlantic [47,48]. The approach of CUMULEO assumes that effects are a function of the intensity of pressures caused by activities and the sensitivity of ecosystem components to those pressures[47]. It also assumes that each pressure can affect multiple ecosystem components.

The approach used in CUMULEO for the CEA was [47]:

<u>1. Scoping phase</u>

a. Definition of spatial and temporal boundaries (determine the area and time frame of concern).
b. Identification of ecosystem components, pressures, and activities.

<u>2. Assessment phase</u>

a. Description of intensity of activities.
b. Assessment of the intensity of pressures.
c. Description of the sensitivity of ecosystem components.
d. Assessment of the cumulative effects.

During the scoping process they used consultations, questionnaires, matrices, spatial analysis and expert opinion to identify the ecosystem components, pressures and activities [49]. In this CUMULEO case study, they have identified as activities: offshore wind parks (OWP) and fisheries. For these two activities, a total of 5 pressures were identified, three for OWP and two for fisheries (e.g. underwater noise for OWP; and abrasion for fisheries). Four ecosystem components were identified: Benthos, Birds, Fish and Marine mammals. In the assessment phase, maps and tables were made to assess the intensity of activities and pressures and to describe the sensitivity of the ecosystem components and the cumulative effects.

The CUMULEO approach has been improving over the years to meet the requirement of new projects and to include new concepts.

2.2.4 HARMONY

The HARMONY project was one of the first attempts to map human activities, pressures and potential cumulative impacts in the eastern parts of the North Sea. The overall objective of HARMONY (2010-2012), was to provide tools for a harmonized and optimized approach in assessing Baltic Sea biodiversity and nature conservation status in the context of the pressures applied [33].

The mapping for the project was based on existing data on human activities from Denmark, Germany, Norway and Sweden. Ecosystem components, such as broad-scale benthic habitats, fish, birds and marine mammal were also mapped.

The project had to two main challenges: - to gather and harmonize ecological information; and - to collect data on the spatial distribution and intensity of human activities in the respective sea areas.

The methodology of Harmony is based on the scientific work developed by Halpern et al. [11], and the mapping of cumulative impacts of human activities and uses was adjusted to include the requirements of the MSFD. It involves mapping ecosystem components and activities which generate pressures on the marine environment.

They made an explicit distinction between human uses of the sea and the pressures this uses cause, based on Annex III, Table 2 of the MSFD. In addition, different pressures caused by the same human use were analyzed separately, as they show different patterns of distribution and affect different components of the ecosystem.

Spatial models were recommended by experts, models defined by distance or estimated area and its ecosystem impacted by potential human pressures against a described sensitivity score. These models were used for all activity-pressure combinations to describe the spatial extent of the pressures.

Afterwards they used predictive distribution models of key species listed in Annex III, Table 1 of the MSDF. These models can be adapted to specific studies, depending on the area, type of pressure and ecosystem to be impacted. It also covers a broad range of uses and ecosystems and therefore can be applied both at local and more broader levels.

Instead of using simple presence-absence maps for ecosystem components, the distribution has been modelled as the probability of presence. This methodology is particularly relevant for mobile components such as fish, birds and mammals.

The mapping was based on different but harmonized sets of data, combined with information from a survey among experts. The datasets as well as the maps were created with standard GIS software (ESRI ArcGIS 10).

The Harmony methodology allows decision makers to calculate indices, in order to explore the effects of turning on and off particular human activities, pressures and ecosystem components. This will help them to better understand the impact of human activities in the marine environment.

2.2.5 Carpe Diem

Carpe Diem was a project developed by the French Agency for Biodiversity (*Office Français de la Biodiversité, OFB*) between 2012 and 2018. The global aim of the project was to propose tools methods and results for cumulative effects assessment as part of the implementation of the MSFD and MSP Directives in France. With participation in several projects such as SIMCELT, SIMWESTMED and SIMNORAT, it was possible to develop a methodology for the assessment of cumulative effects on benthic and pelagic habitats [10].

The methodology adopted in Carpe Diem was:

1. <u>Collection of data regarding human activities, pressures and ecosystem components</u>. Data on activities and pressures based on the MSFD typology. Since the data is collected from various sources, it must be converted to the same format. Descriptive statistical and spatial data on human activities, pressures and ecosystem components are summarized, harmonized 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.

2. Mapping:

   a. Human activities – calculation of the index of multi-activity presence (IMA1), corresponding to the cumulative number of activities present in each cell over a defined period; calculation of the index of multi-activity sensitivity (IMA2), corresponding to the cumulative intensities of each activity in each cell. Also, descriptive data can be used to map the pressures.
   b. Pressures – a theoretical relationship matrix between activities and pressures was developed to establish a link between activities and pressures (uses the same activity and pressure types as the MSFD). The matrix was produced in two steps, first at a workshop with scientific and administrative teams, and second at an internal workshop. A confidence index was made to describe the level of expertise between activities and pressures.
      The calculation of the intensity of the pressure is a challenge, and a frame of reference needs to be made to compare the intensity of the pressure generated by one-off events caused by anthropogenic practices on a unit area.
   c. Habitat Sensitivity – assessing the risk of effect requires information regarding the habitat sensitivity to pressures. A sensitivity index was developed between pressure and habitat. The index was used to estimate the theoretical level of interaction for each habitat/ pressure pairing.
   d. Cumulative effects on the habitat – First is necessary to calculate the risk of simultaneous effects, which involves the assessment of the risk of effect for each pressure on an ecosystem component. For each habitat, a risk of exposure to a pressure is calculated. In the end, the risk for cumulative effects is calculated based on the following equation:

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

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

Figure 2: Equation of the calculation of cumulative effects in Carpe Diem

This tool does not consider social and economic analyses.

2.2.6 CEAF tool

In 2016, north Seas Energy Ministers signed a Political Declaration on energy cooperation [52]. One of the four working areas for collaboration is MSP. To assist with the delivering of MSP objectives, an environmental working group was asked to develop a common environmental assessment framework (CEAF) for assessing ecological cumulative effects of plans and projects with regard to offshore renewable energy development [52].

The Common Environmental Assessment Framework (CEAF) is meant to become a commonly accepted set of tools for MSP decision support regarding assessing and dealing with unwanted potential ecological impacts of wind farm developments. Within CEAF, a tool for cumulative ecological effect assessment for potential use in Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) has been developed.

For the Cumulative Effect Assessment, a stepwise approach is proposed, based on the OSPAR Cumulative Effect Approach for QSR 2023 [53]. This OSPAR approach is risk based, focusing on ecosystem components and has a transparent and flexible character. The cumulative effect assessment tool focusses on selected species (see: A prioritised selection of representative species potentially vulnerable to effects of installing and / or operating offshore windfarms in the North Sea / Irish Sea region). As a consequence of this focus on species CEA takes into account the developments in the entire biogeographical region (within the jurisdiction of collaborating countries) of the possible affected population of the species. Coherence with the OSPAR approach is deemed important because all CEAF partners are Contracting Parties to OSPAR and the offshore area, covered by the participating partners in CEAF, is a substantial and the most intensively used part of the OSPAR area.

The following steps are distinguished in the CEA:

a) Scoping - what is the scope of the CEA?
b) Defining the relevant stressors.
c) Pathways; stressor - receptor relations.
d) Spatial and temporal scale.
e) Assessment of cumulative effects.
f) Evaluation [54].

This tool aims to benefit cross-border cooperation. Many species of conservation concern are indeed highly mobile and are therefore not restricted by national borders. CEAF should provide opportunities for more effective cooperation by:

- Facilitating the identification and use of commonly accepted, best practice methods and models, with which to estimate potential effectiveness;
- Facilitating collaborative research;
- Providing common ambitions for mitigation goals and innovative measures.

This tool has been tested with a case study within the SEANSE project (https://northseaportal.eu/). This project focused on developing a Common Environmental Assessment Framework (CEAF), through:

- Development of a coherent approach to SEAs, with a focus on renewable energy and testing it in practice through case studies;
- Creation of a coherent understanding of how and when to use this part of the SEA through knowledge transfer and information exchange;
- Demonstration of the benefits of the implementation of a coherent SEA approach for the preparation of national MSPs;
- Facilitation of the efficient implementation of the "Political Declaration on energy cooperation between the North Seas Countries".

In the SEANSE-project, three baseline studies were performed:

- A comparison of planning criteria for offshore windfarms;
- A comparison of North Sea SEAs and EIAs;
- Development of the CEAF methodology;
- Two main case studies were commissioned in which the CEAF-methodology was tested;
- German-Dutch case study on the cumulative effects of North Sea wide offshore wind energy;
- Regional case study on the cumulative effects of offshore wind energy in East-Scotland [55].

This guidance provides an overview of the approach and the steps for cumulative effect assessment (CEA), including models and methods used and assumptions made for a test within the SEANSE project [54].

2.3 CEA/CIA transboundary approaches

2.3.1 ICES (International Council for the Exploration of the Sea)

The International Council for the Exploration of the Sea (ICES) has a specific expert group on Cumulative effects – WGCEAM (Working Group on Cumulative Effects assessment Approaches in Management). This group has the purpose of developing a common framework for cumulative assessments to be applied in the context of ecosystem-based management. In 2019, ICES hosted a “Workshop on Cumulative Effects Assessment in Management” that focused on the relevance of EA in environmental policies and in maritime planning.

The workshop concluded that a “CEA should inform the integrated ecosystem assessment (IEA) process regarding the potential cumulative effects of a given project while informing Strategic Environmental Assessment (SEA) and marine spatial planning (MSP) initiatives as to the sustainability of development that is being considered including the socio-economic repercussions" and should be, “used in conjunction with an integrated assessment as is currently done for several ICES marine regions to identify if the implemented technical measures have actually succeeded in achieving the policy objectives "[50].

ICES WGCEAM held at the first ICES WG meeting, a cumulative effects assessment framework for management was developed and two case studies (North Sea and the Gulf of St Lawrence) were identified as areas for proof of concept, to be reviewed in 2020.

The case study for the North Sea implies CEA to assess the vulnerability of the ecosystem and its components to the cumulative pressures of the combined human activities. They suggest the following steps to initiate CEA [51]:

- Assess the vulnerability of the ecosystem – vulnerability (V) is a function of Exposure (Ex) and Effect potential (EP). The exposure can be constructed from the spatial overlap (So) and temporal overlap (To). Effect potential can be determined by the pressure of sensitivity of the ecosystem component. Equation - V = f(Ex EP);
- The exposure is determined by the spatial and temporal overlap. Spatial overlap calculates an impact score. Temporal overlap assumes that the spatial overlap applies throughout the assessment year;
- Effect potential is calculated based on the pressure intensity and sensitivity.

2.3.2 OSPAR Commission

The OSPAR Commission’s activities under the North East Atlantic Environment Strategy are guided by the application of the Ecosystem Approach. Understanding and assessing cumulative effects is at the heart of implementing an ecosystem-based approach to the management of human activities in the OSPAR Maritime Area. As such, OSPAR has a group dedicated to CEA methodology, the ICG-EcoC (Intersessional Correspondence Group on Cumulative Effects Assessment) that has been developing a methodology for the assessment of cumulative effects of human activities in the North East Atlantic, similar to the ICES methodology.

2.4 Ecosystem services – MSP:

Marine ecosystems are associated with varied structures and functions capable of providing goods and services, of immaterial and material nature, which contribute to human well-being through the suppression of basic and economic needs. Ecosystem services are defined as "*the benefits that people obtain from ecosystems*"[56]. Some of the main ecosystem services associated with the marine environment are food, primary production, and climate regulation, among others [57]. Ecosystem services are created through interactions among numerous biotic (species groups) and abiotic components which create processes such as nutrient cycling or predator-prey relationships [56,58]. Ecological research developed over the past decades has aimed to understand these interactions as well as linkages between biodiversity and ecosystem functioning.

Table 1 describes the main ecosystem services associated with the marine environment, based on the Millennium Ecosystem Assessment (MA). According to the MA, ecosystem services include: provisioning services (such as food, water, timber, and fiber); regulating services (such as the regulation of climate, floods, disease, wastes and water quality); cultural services (such as recreational, aesthetic, and spiritual benefits); and supporting services (such as soil formation, photosynthesis, and nutrient cycling).

Table 1 –Ecosystem services associated with the marine ecosystem. (UNEP, 2006)

Ecosystem services	Type of ecosystem service
Supporting	• Nutrient cycle • Primary production • Resilience and Resistance • Habitat
Provisioning	• Food (e.g. fisheries) • Raw materials (e.g. mineral resources) • Genetic resources (e.g. Biotechnology) • Biochemists resources (e.g. Pharmaceuticals) • Organisms extraction for other uses
Regulating	• Climate regulation • Erosion • Water purification and pollutant bioremediation • Protection against extreme climate events
Cultural	• Heritage and cultural identity • Recreation and leisure • Cognitive (research and literacy) • Aesthetic • Human well-being

The high pressure on marine resources and the growing demand for marine ecosystem services motivated the inclusion of this issues in some environmental and biodiversity polices, such as the MSFD that provides that member states take the necessary measures to achieve or maintain a good environmental status of marine environment by 2020, through an ecosystem approach.

The mapping and assessment of ecosystem services (ES) has become an important instrument for environmental management and conservation priority-setting. ES are the benefits people obtain from nature, upon which socio-economic development and human well-beign are dependent, so their management is crucial for the sustainability of these resources [59]. Creating tools to understand ecosystem - ecosystem service relationships as well as the trade-offs among them is particularly essential in the marine environment, since it can be an important tool for policy makers and marine managers, specially regarding MSP. Van der Biest et al.(2020) [60] state that "*the ecosystem approach, marine spatial planning (MSP) and ecosystem-based management all focus on combining biodiversity, conservation and sustainable and equitable use rather than on isolated, sectoral objectives such as individual species/habitats or economic benefits".*

Quantifying the contributions provided by ecosystem is often referred as valuing ecosystem services [57]. Valuing the services associated with habitat and regulatory functions is often challenging, since the value of these services needs to be determined indirectly through their support for valuable production activities or other important economic assets. Additional progress in the process of valuing critical marine ecosystem services is dependent on understanding how the ecological production of these services arises and, in turn, how these services directly and indirectly lead to economic benefits [57].

Broszeit et al. (2019) show the development of a conceptual model to link multiple ecosystem services to ecological research [61]. In this study, the authors recommend that the identification of ecosystem proceses linked to services and the development of a unified conceptual model, be made by resorting to expert judgement. The result was the development of a conceptual diagram linking ecosystem process and components to four selected ecosystem services.

Van der Biest et al.(2020) developed a methodology to include ES in coastal spatial planning policies in Belgium. The methodology is divided into several steps: 1) identify external drivers of change; 2) identify habitat and ecosystem services targets; 3) prioritize ecosystems services and habitats; 4) describe ecosystem processes; 5) identify synergies, trade-offs and conflicts. This approach starts from an anlysis of the processes that are essential to create ES and habitats, and from there defines targets to stimulate ES and habitats. The author identifies knowledge availability as one of the limitations of this method, since the relationships between the processes and the habitats and ES are usually expressed by using expert-based scores and thus strongly depend on the knowledge of the involved experts, and of the knowledge available for a certain ecosystem.

Ivarsson et al. (2017) indicate that the process for establishing the connections between maritime activities and marine ecosystem services is guided by several steps. The first entails the choice of a suitable typology of ecosystem services to which the activities should be linked. At present, there are several overarching classification systems, some with thematic specifications available [62]. The second step concerns the identification and definition of the maritime activities and sectors that might be included in the analysis. For use in the practical tool, they suggest the classification made by the European Commission in the revision of annex III to the MSFD [31]. This step also includes the identification of environmental pressures associated with the activities in the sectors. In the third step, the environmental pressures identified and compiled in the second step are used to identify affected ecosystem services in the policy area. The three steps briefly described lay the ground for assessing the impact on the provision and quality of ecosystem services that may result from different planning scenarios. By adopting a methodology focusing on selecting activities, pressures and ecosystem services exclusively relevant for the policy area, the scope of the analysis becomes narrowed down and manageable [31]. The application of the tool follows a series of steps covering the process from identification of the policy area to valuation of economic consequences. This will involve evaluations of economic impacts from implementing opposing or alternative planning scenarios in a marine area, it could also be delimited to assessing the impact on a single sector.

The objective of the economic valuation is to describe changes in wellbeing. When possible, this is done by means of monetized values of changes (e.g. changes in net income from fishing due to changes in the availability of fishing grounds), in other cases, they may have to be described semi-quantitatively (with scores), quantitatively (hectares, tons etc.) or qualitatively (text). The assessment can partly be a cost benefit analysis (CBA) in the sense that it also includes issues, or criteria, outside a traditional CBA.

The authors, Ivarsson et al. (2017) also applied this methodology to a case study in the Baltic Sea, and they concluded: “making use of this methodology enables and facilitates the incorporation of and accounting for ecosystem services in the planning process. However, in order to further facilitate ecosystem services analysis in marine spatial planning, and other applied contexts, there is a need for further adaptation and development of the indicators used for evaluation of changes in the provision and quality of ecosystem services. Future studies need to focus on improving the alignment of indicators used to evaluate ecosystem services, and indicators applied in MSFD and BSAP (HELCOM). Optimally, the same indicators should be used to evaluate the impacts on Good Environmental Status (GES) from environmental pressures originating from maritime activities and ecosystem services at the same time”[31].

The necessity to integrate supporting ES information in sustainable management calls for MSP that is rooted in an ecosystem-based (EB) approach. MSP represents an opportunity for planners and decision makers to spatially assign human uses at sea to favour socio-economic development, preserving the good status of the marine environment and the sustainable use of its resources, meeting both ecological, economic and social objectives [59].

3 Challenges and opportunities of the above approaches (SEA/CEA/CIA/ES)

Several authors and experts have underlined some of the limitations and opportunities for applying SEA, CEA/CIA and ES in ecosystem based MSP such as the ones described in Table 2 and Table 3 [15,16,57,63].

Table 2 – Challenges in CEA, SEA and ES.

Challenges	SEA	CEA/CIA	ES
The complexity of models (Models are usually complex and, most MSP planners do not have the background knowledge to fully understand them.)	X	X	X
Data availability and access to tools (Data availability and access of the tools and the geographical coverage and resolution of the data. This limits accuracy and usefulness of the results.)	X	X	X
Data format (Since most of the data used for the assessments comes from multiple sources, usually the data comes with different formats and scales.)	X	X	
Uncertainty (Many ecosystem features and functions are yet to be fully researched, therefore most analysis have a degree of uncertainty regarding data input. This way, the results must be analysed considering the level of uncertainty indicated.)	X	X	X
Temporal conditions (The ability to account for future conditions is limited, mainly by ecological understanding and corresponding data. In CEA, most tools are not equipped to consider season factors in the assessment.)		X	X
Interpretation of results (Usually the output of CEA are maps, which do not capture the multi-dimensional nature of the assessment. The results need to be analysed following some criteria guidelines.)		X	
The limitation in recognising and predicting the numerous interactions and (indirect) effects of pressures.	X	X	X
Sustainability of the tools (Most of the tools used in CEA were developed for a short-term use. As knowledge will evolve and more information will be available, there is the risk that most of the tools will not be prepared to be used in long-term.)		X	
Sectoral approach to assessment (Cumulative effects and ecosystem services are particularly difficult to quantify and manage in the marine environment because of the multitude of impacts and activities interacting.)	X	X	X
Complexity of the marine environment (The dynamic and complex nature of the marine environment, its high connectivity and widespread of species and spatial distributions of any ecological limits the support of ES assessment.)			X
Stakeholder involvement in the planning process	X	X	

Communication and dissemination of results (Most of the projects, tools and studies carried out in these areas of knowledge lack the dissemination necessary to reach more stakeholders. The technical language can be a barrier to the dissemination of the results.)	X	X	X
Open access to the tools developed		X	
Absence of a comprehensive analyses of the different approaches (With the development of several methodologies to face the challenges of SEA, CEA and ES assessment, there is an absence of a comprehensive analyses of the different approaches.)	X	X	X
Connectivity between the several policies (The EU has a vast range of directives and policies regarding the management of the maritime space. There is the challenge of establishing the connectivity between the several policies.)	X	X	X

Table 3 – Opportunities in CEA, SEA and ES.

Challenge	Opportunities
Data format	Development of initiatives to centralised data, to serve as data repositories.
Uncertainty	The importance of expert judgement as an initial basis for model inputs, which can be further supplemented to increase certainty as more knowledge and data is collected.
Temporal conditions	Defining and analysing future conditions to allow for longer term predictions resulting from MSP.
Interpretation of results	Development of guidelines for result interpretation.
Sectoral approach to assessment	Develop methodologies that promote an integrated analysis of cumulative impacts and Ecosystem services.
Stakeholder involvement in the planning process	Close collaboration between tool developers, scientific researchers and MSP planners or another target group can ensure that outputs are customised to inform decisions related to clearly defined MSP objectives and impact / risk assessment criteria. In CEA, for instance, by working hand-in-hand on tool development with this common basis in mind, there is an improved likelihood of tool results being used in MSP decision making.
Communication and dissemination of results	The results of the tools and methodologies used in SEA, CEA and ES assessment have the potential to be used for raising awareness among stakeholders about the ecosystem-based approach and to make sure the scenarios developed will be considered during the MSP process. Sharing results and processes with stakeholders engaged in MSP can

	help clarify conceptual definitions, risks and decision criteria, allowing them to gain better understanding of these planning and management concepts in a demonstrative way.
Open access to the tools developed	Several of the existing tools are web-based and ready for use, and others under development will be made available online as well. Given that data is already gathered in the correct formats for use in the tool/model, online tool availability makes it easy for multiple planners to use a specific tool.
Absence of a comprehensive analyses of the different approaches	The identification of similarities between methodologies and tools will allow further collaborations and the development of best practices guidelines for future use and implementation in the MSP process.
Establishing the connectivity between the several policies	Most of the tools and approaches developed for CEA, SEA and ES provide a connection to other relevant policies (MSFD; Natura 2000, etc.). This can help MSP authorities with 'coherence' between MSP and MSFD, for instance, and fulfil one of the minimum requirements of the MSP Directive.

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