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Marine and coastal ecosystem services on the science–policy–practice nexus: challenges and opportunities from 11 European case studies

Evangelia G. Drakou[a,b], Charlène Kermagoret[a], Camino Liquete[c], Ana Ruiz-Frau[d], Kremena Burkhard[e], Ana I. Lillebø[f], Alexander P. E. van Oudenhoven[g], Johanna Ballé-Béganton[a], João Garcia Rodrigues[h,i], Emmi Nieminen[j], Soile Oinonen[j], Alex Ziemba[k], Elena Gissi[l], Daniel Depellegrin[m], Kristina Veidemane[n], Anda Ruskule[n], Justine Delangue[o], Anne Böhnke-Henrichs[p], Arjen Boon[k], Richard Wenning[q], Simone Martino[r], Berit Hasler[s], Mette Termansen[s], Mark Rockel[q], Herman Hummel[t], Ghada El Serafy[k] and Plamen Peev[v]

[a]UMR M101, AMURE, CNRS, OSU-IUEM, Université de Brest, Brest, France; [b]Department of Geo-Information Processing, Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, Netherlands; [c]European Commission, Joint Research Centre (JRC), Ispra, Italy; [d]Department of Global Change Research, Instituto Mediterráneo de Estudios Avanzados, IMEDEA (CSIC-UIB), Esporles, Spain; [e]Institute of Environmental Planning, Leibniz Universität Hannover, Hannover, Germany; [f]Department of Biology & Centre for Environmental and Marine Studies (CESAM), University of Aveiro,, Aveiro, Portugal; [g]Institute of Environmental Sciences CML, Leiden University, Leiden, The Netherlands; [h]Faculty of Political and Social Sciences, University of Santiago de Compostela, Santiago de Compostela, Spain; [i]Campus Do*Mar – International Campus of Excellence, Vigo, Spain; [j]Finnish Environment Institute (SYKE), Marine Research Centre, Helsinki, Finland; [k]Marine and Coastal Systems Department, Deltares, Delft, The Netherlands; [l]Department of Design and Planning in Complex Environment, University Iuav of Venice, Venice, Italy; [m]Institute of Marine Science, National Research Council, Venice, Italy; [n]Baltic Environmental Forum, Riga, Latvia; [o]French Committee of IUCN, Paris, France; [p]Environmental Systems Analysis Group, Wageningen University, Wageningen, The Netherlands; [q]Ramboll Environ, Portland, ME, USA; [r]Laurence Mee Centre for Society & Sea, Scottish Association for Marine Science, Oban, UK; [s]Department of Environmental Science, Aarhus University, Roskilde, Denmark; [t]Royal Netherlands Institute for Sea Research, Yerseke, The Netherlands; [v]BlueLink Foundation, Sofia, Bulgaria

ABSTRACT
We compared and contrasted 11 European case studies to identify challenges and opportunities toward the operationalization of marine and coastal ecosystem service (MCES) assessments in Europe. This work is the output of a panel convened by the Marine Working Group of the Ecosystem Services Partnership in September 2016. The MCES assessments were used to (1) address multiple policy objectives simultaneously, (2) interpret EU-wide policies to smaller scales and (3) inform local decision-making. Most of the studies did inform decision makers, but only in a few cases, the outputs were applied or informed decision-making. Significant limitations among the 11 assessments were the absence of shared understanding of the ES concept, data and knowledge gaps, difficulties in accounting for marine social–ecological systems complexity and partial stakeholder involvement. The findings of the expert panel call for continuous involvement of MCES 'end users', integrated knowledge on marine social–ecological systems, defining thresholds to MCES use and raising awareness to the general public. Such improvements at the intersection of science, policy and practice are essential starting points toward building a stronger science foundation supporting management of European marine ecosystems.

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Introduction

The planet's oceans and coasts are rapidly changing (Duarte 2014; McCauley et al. 2015; Cloern et al. 2016) and humans worldwide experience the consequences (Worm et al. 2006; Ruckelshaus et al. 2015; Bennett et al. 2016). The recognition of this no longer stays within the scientific community, but society has also begun to face the impacts of such changes to the point where even popular media begins to engage in this discussion (e.g. The Guardian, February 2017). The impacts of sea level rise are experienced in cities, the over-exploitation of marine resources impacts the well-being of coastal communities and the accumulation of microplastics in the oceans now reaches the seafood consumed worldwide. Under this broad societal recognition, the need to safeguard the marine and coastal social–ecological systems is imperative.

To that end, policy instruments and Directives have been established at a global and European level. In the European Union (EU) in particular, the Maritime Spatial Planning Directive (MSPD) (89/2014/EC), the Marine Strategy Framework Directive (MSFD) (2008/58/EC), the Water Framework Directive (WFD) (2000/60/EC) and the Habitats Directive (92/43/EEC) set the legislative framework for the management of activities in marine and coastal areas. International conventions like OSPAR,[1] HELCOM[2] and the Barcelona Convention for the Mediterranean[3] require that marine resources are

CONTACT Evangelia G. Drakou e.drakou@utwente.nl

protected and managed with an aim to achieve a balance between long-term sustainability and economic growth (Lillebø et al. 2017). Several national and municipal management strategies with shared or different sets of objectives are in place in the EU to safeguard marine and coastal ecosystems and associated livelihoods. Such requirements, due to the multiplicity of sectors, stakeholders and societal groups involved, demand an interdisciplinary approach with respect to the underlying research and a transdisciplinary approach for managing this complex adaptive socio-ecological system (Berkes et al. 1998; Oinonen et al. 2016).

The ecosystem services (ES) concept has been rapidly adopted as a framework that accommodates interdisciplinary approaches and accounts for human–nature interactions while standing on the science–policy–practice interface (Maes et al. 2012). For instance, for the implementation of the WFD in transitional and coastal waters, ES assessments help highlight societal, economic and environmental benefits of the WFD (Atkins et al. 2011). Also, the reformed version of the Common Fisheries Policy (CFP) provides a framework for analyzing the impacts of fisheries on biodiversity and on the supply of ES, including impact assessment for environmental, social and economic sustainability (Sissenwine and Symes 2007). Marine and coastal ES (MCES) assessment is often oriented toward specific management and policy needs from local and national (e.g. Arkema et al. 2015) to supranational scales (Liquete et al. 2016; Mononen et al. 2016; Oinonen et al. 2016). For instance, EU Member States are required to use a set of indicators that measure their regulatory efforts to achieve good environmental status (GES) in marine waters as required by the MSFD (Borja et al. 2013; Beaumont et al. 2014).

Yet, despite the environmental Directives at the EU level, there are very few examples or 'success stories' of the actual inclusion of MCES assessments to decision-making (Laurans et al. 2013). The consideration of ES for marine and coastal ecosystem management is still at an early stage with few such assessments completed to date, and many others underway (Boulton et al. 2016). Indeed, a policy requirement is not enough to guarantee the inclusion of scientific information (on MCES and beyond) in decision-making. The latter is the after effect of several parameters, including the credibility of scientific information, enabling conditions and institutional capacity (Ostrom and Nagendra 2006). Several studies developed frameworks guiding ES assessments in order to strengthen their integration into decision-making processes. For instance, Lopes and Videira (2013) present a participatory framework to identify the values that different stakeholder groups place on MCES and determine how these values may be incorporated into decision-making processes. Hattam et al. (2015) suggest a framework based on the integration of different ES assessment and valuation methods to highlight complexities of management outcomes that would not become apparent using a single method approach. Ruckelshaus et al. (2015) proposed a framework that decomposes the science–policy–practice pathway and allows researchers to rate 'what it takes' for scientific research to produce policy-relevant outcomes useful to decision-making.

Considering the limited amount of MCES research that becomes ultimately integrated into decision-making, there is a need to identify where existing MCES assessments stand on the science–policy–practice interface. To do this, in this paper, we take stock of a set of different European case studies addressing different marine policy and research objectives and make an overview of the focal MCES, the methods used and the objectives addressed. We identify the conceptual and methodological challenges from a researcher and practitioner's point of view. The results are used to make recommendations for researchers and practitioners on how to optimize applied MCES research in the future.

Framing our narrative

To explore the relevance of MCES scientific research to policy and practice, we organized a theme session entitled 'Informing marine and coastal policy using ecosystem service assessments: evidence from real world applications', during the European Ecosystem Services Partnership Conference, in September 2016 (Antwerp, Belgium). We invited participants to share their experience on the observed science–policy–practice link through their projects. We asked them to elaborate on the policy relevance of their research, the observed impact of their research, and the methodological and conceptual challenges they faced in using MCES assessments to inform decision-making and the desired ways to overcome such challenges.

We selected an information-oriented sample, with studies carried out in a broad range of European countries with a combination of scientists and practitioners. No policy or decision makers were directly involved in the process, since we selected one to two representatives per case study. However, most results discussed were the outputs of multidisciplinary and even transdisciplinary projects. All participants had experience in marine social–ecological systems and ES research at the local, national or supranational level. Studies that were underway or still in scoping phase were excluded from the analysis, since we were interested in analyzing not only the policy driver of the studies but also the policy relevance of the outcome. A post-conference survey was circulated to the selected case studies to extract all the required information for the analysis. A detailed overview of the information extracted from the survey is given in the Appendix.

The information collected per case study broadly focused on (Table 1) (1) case study description, (2) links to policy objectives and stakeholder involvement, (3) the way MCES were used and their associated impact on

Table 1. Information extracted from each of the selected case studies, in order to evaluate how ES were used in the science–policy–practice interface.

Information group	Information extracted	Description
Study Description	Name of the area	The name of the case study area
	Spatial scale of the assessment	The spatial scale at which the assessment took place: local, national, supra-national, Large Marine Ecosystem
	Author	The names of the authors who contributed in this study
	Aim of the study	A short description on the aim and objectives of the study
	Methods/Tools used	The methods and tools that were used to carry out the assessment (e.g. mapping, modeling, valuation, stakeholder interviews).
	Associated project (s)	The project that funded this case study.
	Project time frame	The time and duration of the project.
Policy / Decision-making links	Specific policy/decision-making need for the work	The authors identified to which policy needs their study responded to, if any.
	Scale of policy implementation (local, regional, etc)	The scale at which that specific policy was implemented (e.g. EU level, national)
	Stakeholder groups involved	The types of stakeholders involved in the case study, if any.
Ecosystem Services	Ecosystem services assessed	The list of ecosystem services assessed within the study. [Note: the authors were not given a predefined ES classification, but all used CICES (1)].
	Ecosystem services used as…	The way the ecosystem services concept was used in each assessment, i.e. as a tool for decision-making, as a communication tool, as a direct objective of the study.
Challenges in including ES in the analysis	Conceptual	The top three (3) conceptual challenges (e.g. terms or conceptual frameworks used) the authors faced when using ecosystem services.
	Methodological	The top three (3) methodological challenges (e.g. lack of training, knowledge) the authors faced when using ecosystem services.
	Challenges overcome (Y/N)	The authors responded about whether they managed to overcome the challenges they mention and how.
Solutions	Proposed / Desired solutions	The authors identified desired solutions that could help them solve these issues in using ES as a tool to integrate science-policy-practice.

decision-making, (4) conceptual and methodological challenges faced in the use of MCES, and (5) the established or desired solutions. References to the latter are given throughout the paper, indicating the coordinates of the cell of the table (from A1 to K16) containing more information.

To estimate the impact different MCES case studies had on decision-making, we adapted the framework proposed by Ruckelshaus et al. (2015), which uses a classification of pathways followed throughout the ES assessment process. The four pathways follow a gradient from a less to a more strong impact on policy: Conduct Research (Pathway 1 – least impact on policy), Perspective Change (Pathway 2 – provides new understanding), Action Generation (Pathway 3 – influences decision-making), Outcomes Produced (Pathway 4 – produces actual policy outcomes). Within each pathway, there are different steps that account for the impact of the assessment on decision-making (Table 2).

Table 2. The pathways of research that have an impact on decision-making and policy, as presented in the framework developed by Ruckelshaus et al. (2015).

Pathway 1	Pathway 2	Pathway 3	Pathway 4
Conduct research	*Perspective change*	*Action generated*	*Outcomes produced*
Results produced	People aware of, understand and discuss ES	Alternative choices based on ES	Enhanced and balanced ES provision
Published	Stakeholders use and articulate different ES positions	Plans and policies consider ES impact assessment	Improved outcomes for ES and human well-being
Disseminated	Stakeholder differences are transparent and mediated	New policy and finance mechanisms established	

For each pathway, the different steps have an increasing impact from top to bottom (the darker the color, the higher the impact).

Evidence from the field

Case studies description

Among the 11 MCES case studies, 7 were carried out at the local, 2 at the national, and 2 at the supranational level. The location and spatial extent of the studies are shown in Figure 1. The different case studies aimed at carrying out an ES assessment through valuation and/or mapping (e.g. Adriatic-Ionian – B4, Latvian coast – D4), producing strategic frameworks for management (e.g. the Bulgarian coast – E4) or proposing sustainable management solutions as part of large projects with broader objectives (e.g. the Delfland coast – H4). A range of assessment methods was used among the 11 MCES studies, depending on the policy and research objectives, the time, knowledge and expertise available. In general, local case studies focused on coastal issues using participatory approaches, economic valuation tools and multi-criteria assessments. Larger scale MCES studies also considered the open ocean and were more likely to use geospatial mapping and environmental modeling tools.

Links to policy objectives and stakeholder involvement

Links to policy objectives

The research carried out in 10 out of 11 case studies, was driven by, or aimed at, informing one or more European policy or legislative frameworks. Most of the studies were designed to address the requirements of one specific policy agenda, namely the MSPD (e.g. Latvian Coast – D5), the WFD (e.g. the Ria de Aveiro – I5) or the Habitats and Birds Directive (Council of the European Communities 1992) (C5; F5; K5) (Figure 2). For instance,

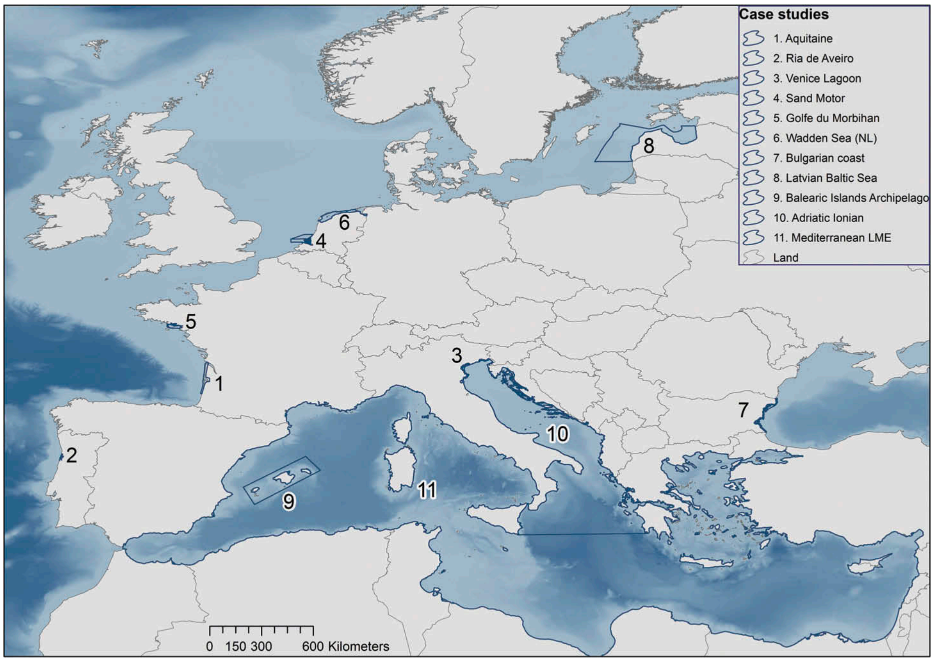

Figure 1. Map showing the distribution of European case studies taken into account for this paper. Studies 1–6 and 9 are local level studies; 7–8 are national ones and 10–11 are supranational assessments.

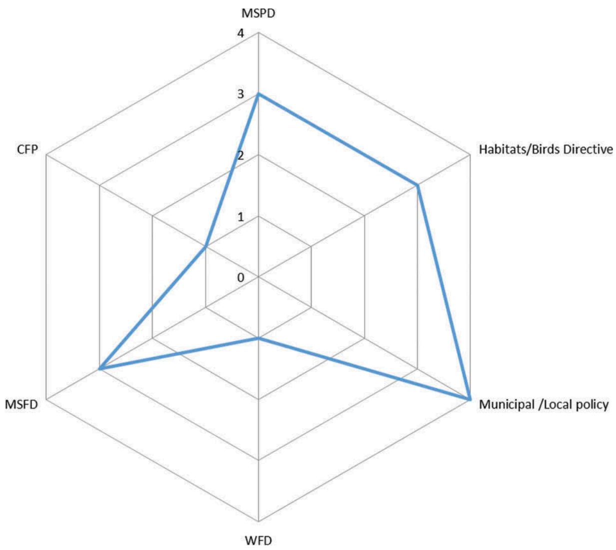

Figure 2. The number of different policy objectives, from local and municipal priorities to European Directives, that were tentatively addressed in the case studies assessed.

in Ria de Aveiro (Portugal) ES provided by transitional and coastal waters were assessed in the context of the WFD to increase the connection between research and policy (Lillebø et al. 2015). In that case, MCES research had a core position in establishing a link between the European level at which policy objectives are set and the national or local levels at which practical management issues are fixed.

In two of the local level case studies – the Gulf of Morbihan and the Wadden Sea – and two supranational assessments – the Adriatic-Ionian region and the Mediterranean Large Marine Ecosystem (LME) – the MCES assessment was used to address more than one policy objectives simultaneously (K5; C5; B5; A5). Given that some of the EU Directives are inter-related and so are some of their objectives, or knowledge required to achieve them, the MCES concept proved to be a useful tool to maximize the benefits of scientific effort. For instance, the integration of the ES concept in the Latvian coast was used to facilitate the application of the ecosystem-based management (D6), which is an overarching principle in both the MSPD and MSFD.

Lastly, most of the assessed cases used the MCES concept to address policy objectives at the municipal or local level (C6; F6; G6; H6; J6; K6), to inform local legislation (e.g. on the coastal zone management in Bulgaria – E6) and to support innovative management measures [e.g. the Delfland case delivered scientific advice for solutions to protect the Dutch coast, through beach nourishment (Bontje and Slinger 2017) – H6].

Stakeholder involvement

Nine out of 11 case studies involved stakeholders throughout the assessments (C7; D7; E7; F7; G7; H7; I7; J7; K7). Two cases did not consult stakeholders, because the study area was too broad and trans-boundary (A7; B7), henceforth stakeholder involvement was time and budget restrictive (B7), or because it was not envisaged by the project (A7). When stakeholders were consulted, different groups were involved throughout the project (Figure 3). Regional administration and decision makers were involved in almost all cases, providing consultation mostly at the beginning and the end of the project. Local level administration and NGOs were also involved during the consultation process (C7; D7; E7; F7; G7; H7; J7). It is worth mentioning that some of the cases focused on

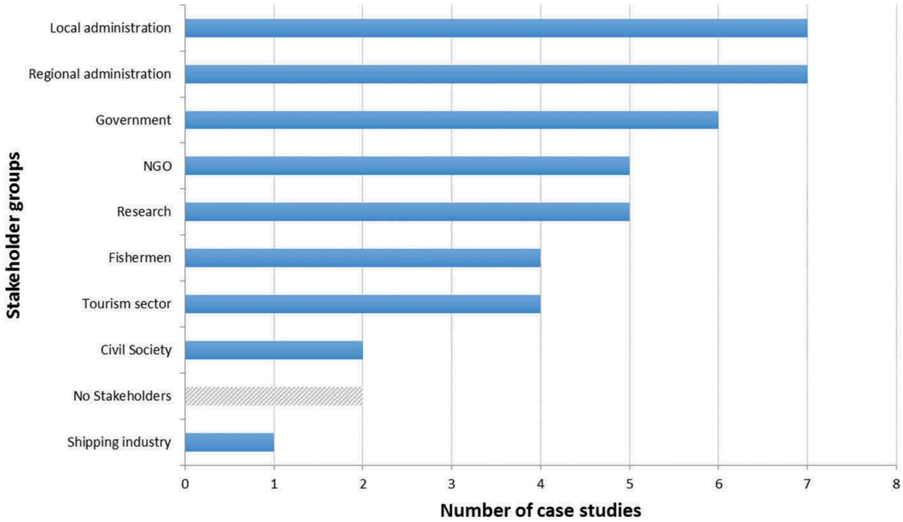

Figure 3. Main groups of stakeholders involved or consulted in the case studies. Note that, in most cases, many different groups of stakeholders were consulted for one case study. The grey bar indicates the two case studies in which no stakeholders were consulted.

coastal areas across municipalities within the same country (e.g. Wadden Sea – E7, Gulf of Morbihan – K7); therefore, administrative bodies from multiple regions and at multiple levels (i.e. local, municipal, national) were involved. Other stakeholders involved, although at a lesser extent, included researchers, members of the tourism industry and the shipping sector (D7; E7; F7; G7; H7; I7; K7). The most commonly used methods for stakeholder involvement were interviews, surveys and workshops. Especially, the workshops occurred at different stages throughout the projects. In few cases, stakeholders were involved through the organization of symposia, public hearings (e.g. in the coast of Latvia – D8) or citizen juries (e.g. in the Ria de Aveiro – I8).

The stakeholder selection was based on whether they (1) represented the main users and beneficiaries of the MCES (e.g. fishers, residents); (2) were the principal managers of MCES (e.g. public bodies in charge of managing water resources; marine spatial planners) or (3) participated in tools development for MCES assessments. A key priority identified through those case studies was that the final research outputs were adapted to the needs of beneficiaries and managers. This was achieved by stakeholder involvement throughout the projects, avoiding the one-off consultation at the beginning or the end of the project. For instance, at the Gulf of Morbihan (K8) around 50 interviews, 6 workshops and a choice experiment survey were conducted at the beginning of the project to capture the user requirements and a conference involving all stakeholder groups at the end of the project. Similarly, the Bulgarian Black Sea coast project (E8) started with an expert elicitation workshop and surveys to capture a broader set of stakeholder requirements, followed by interviews with high-level decision makers (i.e. municipality mayors and one regional governor) and a final stakeholder consultation conference to validate the study outputs. In all projects, the continuous stakeholder involvement was considered essential for an uptake of any products or downstream services derived from the MCES assessments. This point proved to be critical to ensure that information and tools addressed research goals, while fitting the practical aims for transmitting sufficient information at an appropriate technical level to non-academic end users.

MCES use in the assessment and associated impact

Some MCES studies focused on multiple ES provided by the project area, e.g. the Bulgarian coast (E9) and the Ria de Aveiro (I9) cases focused on all ES as specified by CICES. Other MCES studies targeted multiple ES that are provided by specific species or habitat types (e.g. the Balearic Islands case assessed all ES generated by *Posidonia oceanica* seagrass meadows – G9 and the Gulf of Morbihan those provided by *Zostera marina* and *noltei* – K9). The way the ES concept was used in the different case studies affected the MCES use to inform policy and decision-making. In some cases, the MCES assessment was the direct objective of the case study (e.g. in the Northern Venice lagoon – F9, the Balearic Islands – G10 and the Aquitaine region – J10). In others, the MCES concept was mostly a method to generate spatial information which could be used by decision makers, e.g. in the Wadden Sea (E10). In a large number of cases, MCES were used to convey social–ecological information to decision makers and propose alternative management measures. For instance, the Ria de Aveiro (I10) and the Delfland coast cases (H10) used MCES to reveal stakeholders' management preferences, while for the Bulgarian Black Sea coast (E10), it was used to communicate and integrate a sustainable ecosystem-based approach into planning.

To evaluate the impact MCES assessments had on decision-making, we adapted the framework provided by Ruckelshaus et al. (2015), as explained in the Framing our Narrative section. The majority of cases provided scientific evidence that informed decision-making (Figure 4). However in only a few cases, research outcomes were taken into account by decision makers. Two studies were research oriented (A4; G4), which means that although researchers consulted stakeholders, the assessment outputs were limited to publication in peer-reviewed scientific journals. In the Mediterranean case (A4), the extent of the area did not allow for an immediate observation of the impact of the assessment, while in the Balearic case, the results plan to be communicated to the regional government. None of the studies assessed had sufficient capacity to influence decision-making and trigger a policy change or an adaptation of specific management measures (Pathway 4, Table 2). It is important to note that most of the studies included in this work were completed within the past 2 years. Hence, time is required to assess the long-term impact of these initiatives on decision-making.

Conceptual and methodological challenges in the use of MCES research in policy and practice

An overview of the challenges presented in the different case studies, along with the applied solutions, is given in Table 3. A ubiquitous challenge for applying MCES to decision-making was *communication* from science to policy and practice and vice versa. In particular, ES terminology was new and unclear for many stakeholders and decision makers (C9; E9; F9; G9; H9), which proved to be time-consuming during the assessments. The Ria de Aveiro (I9) and the Wadden Sea (C9) cases encountered difficulties in applying existing ES classification schemes in a decision-making context, as the adopted CICES classification in some cases seemed too 'ecologically oriented'. Understanding and interpreting policy requirements and how these could be addressed by ES concepts proved to be a challenge for many MCES studies (e.g. the Venice lagoon – F11, Latvian coast – D11). Differences in the interpretation of specific policy and legislative terms tended to create confusion and disagreement both over how ES assessments should be carried out to produce suitable outcomes to inform decision-making and over the most adequate actions to be adopted.

A second challenge was the *knowledge gaps* on marine ecosystem functioning and its link to MCES. Such gaps entail understanding the interactions among ecosystem components, the supply of regulating and cultural MCES, the valuation of certain MCES features that are hard to understand and assess. For instance, the link between ecosystem structure and the provision of cultural ES proved to be hard to address in several cases (A11; D11; K11). This may be due to an elusive link between marine ecosystems and several intangible values (e.g. sacred, sense of place) and unclear distinctions among services, benefits and associated values (e.g. existence or bequest values). The lack of well-documented knowledge on the types of interaction between human activities and ecosystems was also identified as limitation. For instance, the role of seagrass beds in coastal protection, considered in the Gulf of Morbihan (K12) case, remains the subject of ongoing research (Liquete et al. 2013b). Finally, assigning social and economic

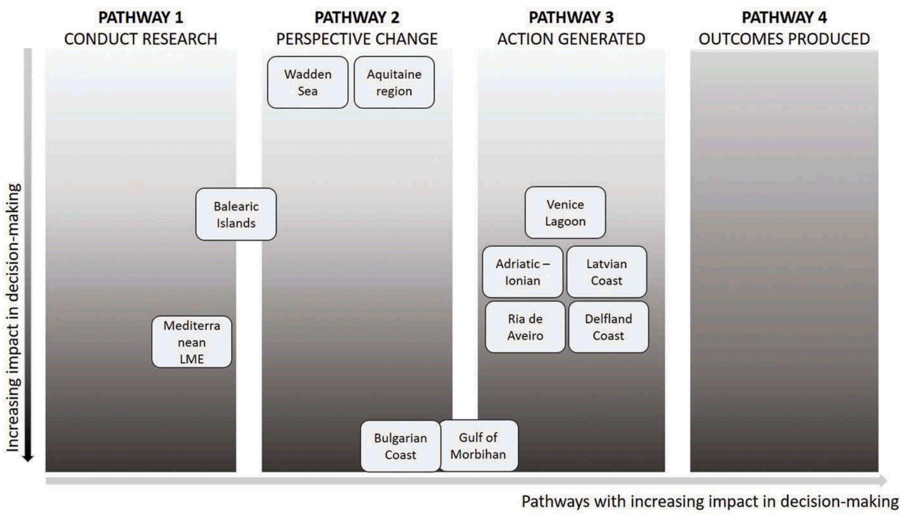

Figure 4. Sorting of the ES assessments addressed based on the observed impact they had to decision-making and policy. The sorting is based on an adapted version of the framework proposed by Ruckelshaus et al. (2015) on the pathways of ES research to decision-making. The *conduct research* pathway stands for scientific research that get published and disseminated. The *inform decision-making* pathway has impact on decision makers, by influencing their perception and raising their awareness on ES. The *decision-makers actions* pathway, stands for the research that influences decision-making to an extent, that it is reflected in their management and policy actions. The *policy change/adaptation* pathway of ES research is able to modify policy and promote the development of new mechanisms.

Table 3. The major challenges encountered in the case studies, observed impacts and applied or proposed solutions.

	Major challenges (conceptual & methodological)	Observed Impacts	Applied solutions
Terminology & understanding	• MCES concepts are not equally understood among researchers and decision-makers • Lack of single, agreed upon MCES classification framework • The use of CICES classification in decision-making context • Policy requirements are too broad and hard to interpret	• Multiple approaches, ES classification systems • Time-consuming • Misinterpretation and mistrust • Disagreement among research-practice-policy	• MCES terms are translated and adapted to target audience • Translate broad policy terms in ES language • Need for practical recommendations on how to use ES for decision-making • Involve experts on legal and policy frames
Knowledge gaps	• Link between ecosystem state and MCES • Regulating and cultural MCES are hard to understand • Impact of human activities on functions and ES • Lack of scientific expertise	• Weak methods and results • Difficulty in assigning values to regulating and cultural ES	• Differentiate ES supply and demand • Inter- and multi-disciplinary teams
Addressing complexity	• Integrate biophysical and socio-economic information • Difficulty in including drivers of change, pressures and impacts in existing ES frameworks	• Increased uncertainty • Partial assessment	• Include the analysis of pressures in existing ES frameworks for management support • Inter- and multi-disciplinary teams
Data and methodological gaps & inconsistencies	• Lack of data • Data heterogeneity in quality, resolution and scales • Scale mismatch among data sources, study extent and policy objectives • Data accessibility • Difficulty in applying existing mapping methods	• The use of expert opinion instead of empirical data created mistrust to decision-makers • Not all relevant ES can be assessed within available time-frame • Uncertainty • Difficulty in assessing trade-offs • Double-counting of values	• Inter- and multi-disciplinary teams • Additional data collection campaigns • Couple mapping methods with knowledge on marine ecosystem functioning
Stakeholders involvement	• Lack of engagement of certain stakeholder groups • Consultation is time-consuming and the managerial agendas may change during the process • Conflicting interests among sectors (tourism, fisheries, shipping)	• Propagated uncertainty starting from data and methodological gaps to partial stakeholder involvement	• Communicate uncertainties • Give time • Raise awareness

The links among challenges, impacts and solutions are not one to one.

values to MCES, although requested by decision makers, was a big challenge for MCES such as nitrogen abatement (F9). Such knowledge gaps generated difficulties in differentiating ES supply from demand (or capacity, flow, benefit) in several MCES studies (e.g. in Ria de Aveiro – I11).

The third set of challenges focused on the difficulty to adequately account for the *complexity* of the marine social–ecological system. The challenges revolved mostly around the integration of biophysical and socio-economic information and the inclusion of drivers of change in the assessment. This was crucial for studies that responded to management needs (e.g. the impact of human activities on seagrass functions and services in the Gulf of Morbihan – K12). The lack of both social and economic expertise in research teams in many cases proved to be critical for such issues (e.g. in the Delfland Coast – H12). Although there are several proposals for integrative assessments of pressures–impacts–ES (Atkins et al. 2011; Maron et al. 2017), they are not easily adapted to the marine system. Still, some cases overcame this shortcoming by identifying and ranking drivers of change in stakeholder discussions (e.g. the Bulgarian coast – E13), using the Millenium Ecosystem Assessment (2003) framework of drivers (direct and indirect) – impacts on ES and well-being – responses (policy and management).

The fourth set of challenges was linked to *data and methodological gaps* in MCES assessments. These entailed (1) lack of empirical or modeled data, particularly geo-referenced socio-economic data (A12; B12; D12; E12; F12; H12; K12); (2) data inconsistencies across spatial-temporal scales (B12; E12); (3) heterogeneity in data format and resolution (B12; C12; D12; E12) and (4) data inaccessibility (C12). The lack of empirical evidence and the need to replace it with expert opinion kept emerging in several MCES studies but had an impact on the confidence of decision makers to the results (e.g. in the Bulgarian coast – E12). Additionally, data reporting units (e.g. administrative) were not always relevant for the MCES operationalization and use by decision makers (e.g. in the Mediterranean case – A12). Incompatibility of units across ES made the calculation of ES trade-offs difficult. Also in many cases, the lack of large-scale data for features such as benthic species distribution (e.g. the Adriatic-Ionian Sea – B9) was unavailable at the required extent and was substituted by large-scale habitat distribution models. Lastly, a considerable number of data sets describing uses of marine and coastal environment were sensitive, confidential (e.g. ES with an associated commercial value) or privately owned, making them inaccessible for research. Methodology-wise, the spatial representation of MCES provided by large, multi-dimensional (benthic/pelagic) ecosystems proved to be a challenge. For example, in the Latvian coast (D12), the use of standard land-use-based mapping approaches proved to be difficult and uncertain.

Lastly, from a researcher's and practitioner's point of view, the *involvement of stakeholders* led to several challenges (C11; F11; I11). Many stakeholders were not eager to participate in the consultation process. That was mostly due to the fact that some perceptions that consultations are 'too scientific', asymmetrical power relations among participants, or lack of trust. Budget and time limitation also hindered the success of the stakeholder engagement process in several MCES studies. Consultation is time-consuming and managerial agendas often change during the process. Lastly, the trade-offs among different marine sectors generated conflicts during the stakeholder consultation (e.g. the Bulgaria Sea Coast – E11), preventing in some cases reaching consensus.

Applied solutions

Several approaches have been followed by the case studies to overcome the encountered challenges (Row 13, appendix). In most cases, the methodological challenges were overcome with the use of additional expertise (e.g. modelers in the Mediterranean case – A13), the adoption of new methods (e.g. quantification of uncertainty in the Adriatic-Ionian – B13) or an adaptation of scale (e.g. Latvian case – D13). Challenges in the use of ES were overcome with simplification of terminology (e.g. in the Balearic Islands and the Delfland coast cases, the term 'ecosystem services' was replaced with terms like 'ecosystem benefits', 'benefits derived from ecosystems' or 'nature's services' to facilitate stakeholder comprehension – G11; H11), especially for stakeholder consultation, or by merging some of the existing CICES classes to fit the case study specificities (e.g. in the Wadden Sea – C13, or the Bulgarian Black Sea coast – E13). Cases that didn't overcome the encountered challenges, like for instance in the Aquitaine coast (J13), were mostly attributed to lack of scientific knowledge on the actual contribution of a specific ecosystem component to the provision of MCES.

Discussion

The purpose of this paper was to examine where MCES research stands relative to different marine policy and management agendas in Europe, in order to identify ways to operationalize the results gained from MCES studies in the future. Such policy agendas, e.g. on sustainable Blue Growth,[4] implicitly recognize that the marine environment is a complex adaptive system with humans being an inherent part of its dynamics. Therefore, economic growth strategies pertaining to the marine environment should be taking into account environmental well-being, acknowledging the reciprocal role that humans play both as a driver of change and a recipient of the impact of those changes. This is important since ES research claims to account for such interactions and is used to facilitate the way scientific research in social–ecological systems is communicated and considered in decision-making (Maes et al. 2012; Lillebø et al. 2017).

Within the diversity of spatial extents and policy requirements addressed in this narrative's case studies, the MCES approach was used in three main ways: (1) as a way to simultaneously address multiple targets of different marine and coastal policies (e.g. in the Adriatic-Ionian study, MCES was used to balance the MSPD and MSFD objectives that account for sustainable growth); (2) as a way to 'translate' EU-wide policies to the local or national level (e.g. in the Latvian case to interpret the MSPD at the national level) (3) and as a method that produces scientific evidence to inform and to be used in decision-making (e.g. in the Bulgarian coast to inform regional strategic documents and sectorial policies). In the following paragraphs, we use the collective evidence gained by this work to outline and discuss what it takes to operationalize MCES research, and we give suggestions for future research.

The 11 MCES studies included in this paper were ranked using the Ruckelshaus et al. (2015) framework to gauge the extent to which the work actually or potentially informed policy and decision-making (Figure 4). About half of the MCES studies considered, generated scientific outputs that informed decision-making and generated actions (Pathway 3). Still none produced outcomes that improved directly ES provision or human well-being (Pathway 4). Certainly, the research–policy–practice link is not linear (Beck 2011), but rather complex, and there are several interactions, feedback loops, dynamics and power relationships within it that are not always easy to decode (Wesselink et al. 2013).

MCES operationalization: what does it take?

The role of MCES in establishing the science–policy–practice link is still challenged by several conceptual and methodological gaps, as it was clearly stated in this study. However, we believe there are ways to operationalize MCES assessments and help science, policy and practice move toward a more operational pathway in which scientific outcomes are relevant to decision-making and have an impact on environmental and social well-being (Pathway 4, Table 2).

Involvement of 'end users' in MCES assessment

The creation of 'enabling conditions' for MCES operationalization requires a substantial end-user engagement. 'End users' (policy-makers, decision makers, practitioners) will use the generated scientific information in the decision-making process. Structured advocacy and communication is needed to support the process through research and implementation. To achieve this, MCES assessments need to

a. ***Consider underlying values, power relations, attitudes and expectations of involved stakeholders.*** Tools and instruments like collaborative decision-making, participatory mapping and modeling (Voinov and Bousquet 2010; Palomo et al. 2013), increase legitimacy of scientific outputs. In many cases, the decision-making process is driven by welfare economics to assess e.g. the benefits of improving coastal water quality (Hynes et al. 2013), or the monetary benefits of achieving GES in EU marine waters (Norton and Hynes 2014). However, economic decisions based on utilitarian approaches, limited ecological knowledge of MCES and unknown preferences from consumers fail in providing robust monetary valuation of MCES, e.g. for deep sea habitats (Jobstvogt et al. 2014) or regulating MCES (Papathanasopoulou et al. 2014).
b. ***Communicate the level of confidence in scientific results in a comprehensive way in order to increase trust by decision makers in research outputs.*** Many data sets used for MCES assessments are incomplete, leading to the use of qualitative methods or modeling approaches (Druon et al. 2012) to fill in information gaps. The level of confidence is also linked to point (a), since the inclusion of a biased set of end users could lead to biased results. Quantifying and communicating uncertainties is therefore crucial to increase the trust of decision makers to scientific outputs (Gissi et al. 2017).
c. ***Focus on the development integrative and flexible ontologies.*** Most of the existing ontologies and terminology used are rigid and targeted to well-trained scientific audiences. Although these are necessary for researchers and decision makers (Glaeser 2016), less jargon needs to be used during stakeholder participation and MCES policy or research concepts, need to be translated into layman's terms and employ 'user-oriented' approaches.
d. ***Communicate*** scientific, technical and practical ***challenges*** to funding agencies (Bremer et al. 2015).
e. Insist on the need for ***data and information sharing***, while ensuring that scientific outputs are published in open source databases (Drakou et al. 2015).

Knowledge integration

Scientific research needs to set the prerequisites for new knowledge and expertise to be spread by incorporating inter- and transdisciplinary approaches within different research fields. It is noteworthy, for instance, how the scientific communities that employ Ecosystem-Based Management approaches, besides a few exceptions (Granek et al. 2010), are rarely linked to those that deal with MCES. To achieve this, integration and collaboration with a broader research community is essential. That will facilitate the way various policy objectives and (EU) Directives are simultaneously addressed (Gissi and de Vivero 2016; Verutes et al. 2017).

At the same time, there is no need to 're-invent the wheel', but since the MCES concept is multi-disciplinary by definition, it can make use of the tools and methods that are at hand. For instance, MCES mapping proved to be really limited in our set of case studies, fact also agreeing with previous reviews of the literature (Böhnke-Henrichs et al. 2013; Liquete et al. 2013a; Hattam et al. 2015). Efforts to adapt mapping methods developed on land for MCES, e.g. the 'matrix-based' approach (Burkhard et al. 2012), require taking into account the specificities of the marine ecosystems (e.g. Burdon et al. 2017), while filling the spatial data gaps. Therefore, research efforts need to be directed toward the improvement of available data for the marine environment. Collection of *in situ* or satellite data is costly, but more efforts should be made toward improving the available remote sensing products that can be used to map MCES (Fretwell et al. 2014; Kavanaugh et al. 2016; Valentini et al. 2016).

Establishing thresholds on MCES use

Marine ecological systems research uses thresholds and tipping points extensively, especially with reference the establishment of fishing quotas that set limits to the exploitation of marine resources (Karr et al. 2015; Kittinger et al. 2015). At the same time, European directives like the MSFD require Member States to maintain a Good Ecological Status (GES) and to monitor it with a set of indicators. There is already a lot of work done in marine and coastal ecosystems, toward assessing ecosystem health (Halpern et al. 2012), and ecological functions linked to the supply of ES e.g. on nutrient cycling regulation (Hofmann and Schellnhuber 2009) and food provision from fisheries (Chu 2009). However, until now, such indicators, thresholds and tipping points in marine ecosystems focus either solely on ecological or solely societal aspects of the system. But, within the anthropocene-related research, the need to address planetary boundaries and tipping points of entire social–ecological systems is imperative to best manage such systems (Rockström et al. 2009). MCES assessments can focus toward developing limits and thresholds on the use and supply of MCES to ensure their sustainability (Österblom et al. 2017), by taking stock on available knowledge. Science, policy and practice should work together to establish novel sets of indicators that integrate social and ecological knowledge on the marine environment and allow decision makers to monitor the proximity to the 'boundaries'.

Enhancing societal literacy and raising awareness

MCES research needs to ensure that the role, functions and benefits derived from marine and coastal ecosystems are acknowledged by the general public and not only the community of policy and practice. For the 'enabling conditions' (point 1) to happen, society needs to be aware of the multi-dimensional value of the marine and coastal ecosystems. The successful application of management policies and regulations heavily relies on people's compliance. But compliance is partly dependent on people's awareness of their reliance on ecosystems for their well-being; thus, there is a strong need to improve the dissemination of scientific knowledge in society. A mix of institutional types promoted by well-structured dialogue involving scientists, resource users and interested publics is needed for this (e.g. the Italian Ocean Literacy program).

Inclusiveness of plural views into the decision-making process is needed to deal with complexities and transparency by giving space to social knowledge, other than scientific evidence (Reed et al. 2014). Ignoring cultural and ethical values into the decision-making process may place further constraints on the acceptability of top-down management decisions (Farber et al. 2006) and reduce the actual limited uptake of fair allocations of appropriated natural resources amongst stakeholders (Barry 2011).

Our 'wish list' for the future

For MCES assessments to reach and influence decision-making, still several aspects need to be considered. Herein, we present a series of desired future actions as they occurred from the workshop discussions, the post-workshop survey (Row 14, appendix) and the authors' viewpoints.

Many of the generated MCES benefit people who are located far from the provision area (e.g. where fish are caught). The routes of trade and shipping lanes facilitate the flow of MCES within and outside Europe, having a key role on the marine and coastal systems state (Österblom et al. 2015). The demand for MCES from distant areas acts as an additional component that puts pressure in natural resources, since the demand does not occur only at the local level, but elsewhere (Kittinger et al. 2015; Drakou et al. 2017), and should be considered in research and practice.

As marine ecosystems are usually large and lay across multiple political jurisdictions, regional assessment is called for to better integrate ES into actual management (Hanley et al. 2015). For example, HELCOM is conducting the Second Holistic Assessment of the Ecosystem Health of the Baltic Sea with the aim to develop regional approach for social and economic analyses where MCES are accounted for (HELCOM 2017). Such regional assessments deal with trans-boundary areas and different socio-economic and ecological conditions across them. In such cases, the flow of MCES between different countries needs to be taken into account for the MCES assessment of the focal area to avoid double-counting in scientific assessments.

MCES assessments in Europe currently make the first steps toward linking scientific research with practice and policy. Significant effort is required from science, policy and practice, across spatial and temporal scales, to achieve integrated management of marine social–ecological systems. We believe that the integration of social–ecological systems approach with sectoral perspectives that focus on one of the social–ecological systems aspects is the basis for a meaningful dialog among stakeholders to be established. This can provide the foundation to shape collective arrangements for overcoming barriers, addressing social challenges and seizing opportunities. The evidence we collected in the assessed case studies, along with our 'wishes' for the future, will hopefully be only the first step toward more integrated, collaborative and robust MCES assessments.

Notes

1. The Convention for the Protection of the Marine Environment of the North-East Atlantic.
2. Baltic Marine Environment Protection Commission – Helsinki Commission.
3. Convention for Protection of the Mediterranean Sea against Pollution.
4. http://ec.europa.eu/maritimeaffairs/policy/blue_growth_en.

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ORCID

Evangelia G. Drakou http://orcid.org/0000-0003-4404-629X
Charlène Kermagoret http://orcid.org/0000-0003-2402-7833
Ana Ruiz-Frau http://orcid.org/0000-0002-1317-2827
Kremena Burkhard http://orcid.org/0000-0003-2843-4591
Ana I. Lillebø http://orcid.org/0000-0002-5228-0329
Alexander P. E. van Oudenhoven http://orcid.org/0000-0002-3258-2565
João Garcia Rodrigues http://orcid.org/0000-0002-0234-5710
Emmi Nieminen http://orcid.org/0000-0002-0727-2039
Elena Gissi http://orcid.org/0000-0002-1666-8772
Kristina Veidemane http://orcid.org/0000-0002-5497-3030
Anda Ruskule http://orcid.org/0000-0003-1580-8304
Anne Böhnke-Henrichs http://orcid.org/0000-0002-6918-0121
Arjen Boon http://orcid.org/0000-0003-2614-5024
Richard Wenning http://orcid.org/0000-0003-3481-0477
Simone Martino http://orcid.org/0000-0002-4394-6475
Berit Hasler http://orcid.org/0000-0003-0433-4086
Mette Termansen http://orcid.org/0000-0003-4875-2810
Herman Hummel http://orcid.org/0000-0001-6902-5773
Plamen Peev http://orcid.org/0000-0002-9361-1980

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Appendix

Question		A	B	C	D	E	F	G	H	I	J	K
1	Name of the area	Mediterranean Sea	Adriatic and Ionian Region (AIR)	Wadden Sea	Marine waters of Latvia	Bulgarian Black Sea coast	Northern Lagoon of Venice (Italy)	Balearic Islands (Spain)	Delfland Coast (Netherlands)	Ria de Aveiro coastal lagoon (Portugal)	Aquitaine coast (France)	Gulf of Morbihan (France)
2	Spatial scale of the assessment	Large Marine Ecosystem	Regional	National	National	Local	Local	Local	Local	Local	Local	Local
3	Corresponding author	Liquete C.	Gissi E., Depellegrin D.	El Serafy G., A. Ziemba	Veidemane K., A. Ruskule	Burkhard K., P. Peev	Böhnke-Henrichs A.	Ruiz-Frau A.	van Oudenhoven A.	Lillebø A.I.	Delangue J.	Ballé-Béganton J.
4	**Aim of the study**	To spatially and temporally assess the sustainable use and supply of five marine and coastal ecosystem services in the Mediterranean Sea.	To map MCES in the AIR in relation to the MSFD Directive, within the general framework of the European Strategy for the Region.	To incorporate the concept of ES in an assessment of both policy and managerial impacts on a protected area.	To provide spatial information on the distribution of areas important for ES provision.	To produce a strategic framework for sustainable use of coastal ecosystems and the relevant resources.	To quantify ES provision by salt marshes and also to understand stakeholder preferences for ES and salt marsh management.	To assess and value the ES derived from *Posidonia oceanica* around the Balearic Islands.	To provide a nature-friendly, sustainable alternative to hard engineering structures.	To provide a tool for integrated management through an increased understanding of land to sea processes and the science-policy-stakeholder interface in the context of climate change.	To understand the functioning of sand dune ecosystem and show how it can represent a relevant and economically interesting solution against coastal erosion.	To assess ES provided by seagrass beds and raise awareness on seagrass conservation to improve their management and identify management options.
5	**Specific policy/ decision-making need for the work**	Promotion of the sustainable use of marine resources for EU Biodiversity Strategy to 2020 and also **MSFD ; MSPD ; CFP.**	Informing the implementation of the **MSP** in relation to the **MSFD** within the general framework of the European Strategy for the Adriatic and Ionian Region (EUSAIR)	Methodology and tools to assess the effectivity and the potential impact of implemented policy on a **Natura 2000** and UNESCO site; Inform the implementation of the **MSP**	Mapping and assessment of marine ecosystem services for the implementation of **MSP** in Latvia	Inform and facilitate the integration of ecosystem services into local, regional and sectoral **planning**	Improve **conservation and restoration** for salt marshes (Natura 2000 habitat)	N/A	Inform policies about innovative solution to **protect** coasts and to provide space for nature and recreation	Increase the connection between research and policy in the context of **WFD**	Local authorities need to have proof that protecting ecosystems was efficient and could answer to erosion issues and justify their management actions.	Inform the implementation of the Scheme for Sea Development in relation to a **Natura 2000** site.
6	**Scale of policy**	Supra-National	National and Supra-National	Local to supra-national	National	Local, regional and sectoral	Local	Local	Local	National	Local	Local
7	**Stakeholder groups involved**	None	None	Local administration ; Regional administration ; Government	Government; Local authorities; NGOs; Sea use sectors	Local administration ; Government ; NGO ; Research ; Tourism sector	Local administration ; Regional administration ; Government ; Civil society ; Fishermen ; Shipping industry	Local administration ; Regional administration ; NGO ; Tourism sector ; Fishermen	Local administration ; Regional administration ; Government ; NGO ; Research	Local administration; Regional administration; NGOs; Research; Tourism sector; Civil society; Fishermen (professional and recreational); Farmers and hunter associations	Regional administration ; Government ; NGOs; Research	Regional administration ; Research ; Tourism sector; Fishermen; Mooring managers; Shellfish farmers; Watershed managers
8	**Stakeholder involvement methods**	None	Only as data input (interviews, participatory workshops)	Participatory workshops; Surveys	Public hearing	Interviews; Participatory workshops; Surveys	Interviews; Surveys	Interviews; Surveys	Interviews; Participatory workshops; Conference/ symposia	Participatory workshops; Focus groups; Citizens jury	Interviews; Focus groups	Interviews; Participatory workshops; Surveys; Focus groups; Conference/ Symposia

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Appendix (Continued).

Question		A	B	C	D	E	F	G	H	I	J	K
9	**Ecosystem services assessed**	Food provision ; Water purification ; Coastal protection ; Lifecycle maintenance (nursery) ; Recreation	All ES listed in CICES 2013	Mass Stabilization and control of erosion rates ; Abiotic services ; Recreation and leisure, Buffering and Attenuation ; Lifecycle maintenance (nursery); Supply of cockles and fish as a provisioning resource	Wild plants, algae and their outputs ; Wild animals and their outputs; Bio-remediation by micro-organisms, algae, plants, and animals; Filtration/ sequestration/ storage by micro-organisms, algae, plants, and animals ; Mass stabilisation and control of erosion rates ; Maintaining nursery populations and habitats ;Global climate regulation by reduction of greenhouse gas concentrations ; Experiential and physical use of plants, animals and landscapes /seascapes	Products from plants, animals, mushrooms, algae; Products from in-situ agriculture; Freshwater supply; Plant and animal based energy sources; Air and water purification; Mass stabilisation and control of erosion rates; Hydrological cycle, water flow maintenance; Maintaining nursery populations and habitats, pollination and seed dispersal; Climate regulation; Experiential use of the natural environment; Scientific, educational activities; Heritage; Recreation; Natural heritage	Climate regulation (carbon dioxide, methane); water treatment (nutrient abatement); erosion prevention/ sediment fixation; lifecycle maintenance/sea food; air purification; moderation of extreme events; nature protection; recreation; artistic inspiration; opportunities for education; aesthetic information; cultural heritage and identity; spiritual experience	Climate regulation; Habitat and lifecycle maintenance -nursery grounds; coastal protection; water quality maintenance; recreation; identity; cognitive oportunities	Coastal erosion prevention; storm surge protection; recreation; life-cycle maintenance; information for cognitive development; aesthetic experience	All ES listed in CICES 2013	Coastline retreat mitigation	All ecosystem services provided by *Zostera noltei* and *Zostera marina* seagrass beds.
10	**Ecosystem services concept used as:**	A method to assess environmental and ecological trends affecting socio-economic benefits, to provide policy recommendations	A tool to generate spatial information	A unit that is mapped and quantified with the final objective to develop a tool for managers; A way to demonstrate the potential trade-off between ES; Input data for an investigatory tool for end-users; The backbone for a serious game for the general public.	A tool to support MSP with spatial information on marine ecosystems and as a method in the strategic environmental assessment (SEA) to assess the impacts of proposed sea uses on supply of ES	A tool for integration of a sustainable ecosystem-based approach into planning	i) A key study objective (to estimate changes in ES availability) and ii) as a tool to understand management preferences of stakeholder	i) A key study objective and ii) as a tool to understand management preferences of stakeholders and general public	Communication and evaluation tool	As a communication tool to reveal stakeholders' management preferences	As a direct policy objective to quantify and assess ES	As a tool to support effective and informed management and planning for seagrass beds.

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Appendix (Continued).

Question		A	B	C	D	E	F	G	H	I	J	K
11	**Conceptual**	(1) Biophysical and socio-economic integration ; (2) Confusion on what is actually measured (within the ES framework)	(1) Use of expert opinion ; (2) Lack of empirical evidence	(1) Term ES was hard to use with people ("benefits derived" as an alternative)	(1) Multi-dimensional nature of marine ES makes it difficult to apply LC based ES mapping method ; (2) Marine ES and cultural services are challenging ; (3) Supply/Demand difference	(1) CICES (too ecology oriented/ hard to adapt to decision-making at such a large scale) ; (2) Links between ES and indicator-based assessment ; (3) Stakeholders not familiar with the concept ; (4) Conflict of interest between sectors (tourism, fisheries, agriculture) ; (5) Stakeholders are not familiar with the EU biodiversity strategy for 2020	(1) Use of terminology of ES framework and translation between a technical and non-technical terminology ; (2) People's lack of trust in local institutions affects the choice of the payment vehicle used to elicit WTP; (3) Difficulty to attach monetary value to ES	(1) Term ES was hard to use with people ("benefits derived" as an alternative)	(1) Vague terms in policy requirements ; (2) disagreement between meaning of specific concepts ; (3) no ES specific framework	(1) Stakeholders uncertainty in the use of CICES ES Classes ; (2) Exclusion of abiotic outputs from ES ; (3) Supply/Demand indicator definition	Difficulty in discerning benefits provided by ecosystem function to those co-produced by society	(1) Habitat types like seagrass, have high regulating or cultural value, which is hard to quantify/measure ; (2) ES classification : time consuming to agree upon ; (3) Inclusion of drivers of change in existing ES frameworks is necessary when we need to inform policy, management (which manage human activities and drivers of change)
12	**Methodological**	(1) Need for training and expertise to use models ; (2) Lack of geospatial socio-econ data, esp. in large spatial scales	(1) Habitat mapping uncertainties ; (2) Data gaps ; (3) Data inconsistencies (no large scale data/ extrapolation needed) ; (4) Patchy dataset (various quality, various scales)	(1) Data harmonization ; (2) Inaccessible or sensitive data ; (3) Time consuming (consultation with stakeholders, esp since the latter don't have time)	(1) Data gaps ; (2) Knowledge gaps on marine ES supply	(1) Data gaps ; (2) Data inconsistencies (no large scale data/ extrapolation needed) ; (3) Scale mismatch between data, study area and results	(1) Scale selection changes research outputs and social perceptions; (2) Data gaps on ecosystem functions ; (3) Knowledge gaps on the ecological interactions between salt marshes and aquatic fishery resources	(1) Stakeholder lack of engagement ; (2) Budget constraints (on stakeholder consultation)	(1) Lack of social scientists in research team	N/A	Lack of data/ information on how much the ecosystem actually contributes to the MCES assessed	(1) Lack of knowledge on impact of human activities on seagrass and associated functions and services ; (2) Lack of quantification methods on sedimentation
13	**Ways the studies overcame them**	Researchers (esp. modellers) with high expertise	Quantification of uncertainty	Translating ES into non-technical description ; Prioritization; Quantification and accurate representation of uncertainty as a measure of data viability to end-users	Adapting the scale	Simplification of CICES names ; Merge CICES classes ; Only monetary quantification ecosystem-based	Payment schemes adapted to local context; Data collection through interviews	Simplification of scientific terms, i.e. change from "services" to benefits"	End-user involvement in research ; Interdisciplinary collaboration ; ES terminology simplification	Practical recommendations on the use of ES to guide decision making ; To improve mapping, knowledge on ES functioning needs to be enhanced	N/A	End-user involvement in research ; Awareness raising

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Appendix (Continued).

Question		A	B	C	D	E	F	G	H	I	J	K
14	**Proposed /Desired solutions**	Integrate biophysical and socio-economic approaches ; invest in communication and awareness raising ; fill the gaps that still exist in the scientific literature ; providing comprehensive information for marine spatial planning ; continue using ecosystem models ; start the analysis of scenarios to support knowledge-based management ; establish links between ES and maritime spatial planning	Define means/ platforms/tools for effective data sharing; bridge shortcomings between basic science and applied research; define methods and procedures for data harmonization	Further collection of in-situ data into a singular functional location; continual dialog with policy makers and managers to ensure that the assessment strategy and hierarchy of needs remains constant or at least continually applicable.	Perform economic valuation ; assess supply and demand of ES	Inform and structure advocacy and communication activities to integrate the results into the local, regional and sectoral planning.	Compare case studies; identify case study-based best practices, develop guidelines, recommendations; communicate challenges to relevant funding agencies	Use of the MEA (2005) framework of drivers (direct and indirect) and impacts on ES to assess of responses to wellbeing (policy, management)	Involve decision makers & end users in research loop ; Combine traditional coastal / marine science with socio-economic and political science ; Do not use the ES concept or classification in communication with decision makers ; Translate policy aims to ES as well as other terms ; Include cultural ES in all phases, especially innovation	Include the provisional accompanying classification table of abiotic outputs from natural systems for the MCES assessment in support of ecosystems management and governance ; Provide practical recommendations on how to use ES to guide decision making ; Mapping needs to be coupled with additional knowledge on the functioning of marine ecosystems	Launch new research projects on the topic	N/A
15	**Associated project (s)**	JRC institutional working programme	ADRIPLAN, RITMARE, SUPREME	ECOPOTENTIAL	National project on MSP; Horizon2020 "ESMERALDA"	All projects related the programme 'BG03 Biodiversity and Ecosystem Services' of the EEA	LIFE VIMINE	OPERAs	NatureCoast	LAGOONS (EU/FP7; contract no. 283157)	French national assessment of ecosystem services (EFESE)	Interreg VALMER
16	**Project time frame**	2014-2016	2013-2015; 2012-2016; 2016-2018	2015-2019	2015-2018	2015-2016 (16 months)	2013-2017	2012-2017	2013-2018	2011-2014	2012-2017	3 years (2 in case study)