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UNIVERSIDADE D COIMBRA

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ANALYSIS AND SPATIAL MAPPING OF MARINE COASTAL ECOSYSTEM SERVICES:

INTEGRATING BIOPHYSICAL AND SOCIOECONOMIC DATA AT DIFFERENT SPATIAL RESOLUTION LEVELS.

Tese no âmbito do Doutoramento em Biociências, ramo de especialização em Ecologia, orientada pelo Professor Doutor João Carlos Marques, coorientada pela Doutora Rute Pinto e a Doutora Zara Teixeira e apresentada ao Departamento de Ciências da Vida da Facultade de Ciências e Tecnologia da Universidade de Coimbra

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Abstract

Ecosystem services (ES) are defined as the final outcomes of the internal structures, processes, and functions derived from ecosystems that contribute to human well-being. It is a growing and valuable concept that supports the achievement of Sustainable Development Goals, facilitating connections between people and nature. Nevertheless, although ES have gained representation in science and policy agendas, a gap remains between ES research and the information required to support management decisions. To fulfil this gap, this thesis contributes to highlight the pathways through which the ES concept can be made usable to decision-makers, adding information and presenting methodological approaches organized in two operationalisation facets: A) Access to reliable datasets (i.e. availability of site-specific spatial datasets), and B) support to management actions (i.e. effects of pressures on the delivery of ES). This work is focused on coastal and marine ecosystems and uses the Atlantic coastal region adjacent to the Mondego River as a case study. This region was selected due to community interest to develop environmental management proposals and the willing of local decision-makers to implement an ecosystem-based management to promote the sustainable development of the area.

The accomplishment of the abovementioned objective was driven by three main research questions: 1) Are current open source spatial databases suitable to informed decision-making related to coastal and marine ecosystem services in Europe?; 2) Can gap analyses based on site-specific databases contribute to the development of ES research and knowledge transfer?; and lastly, 3) How to explore the role of ES supply and demand in spatial explicit habitat risk assessments?

The chapters cover the necessity to gather, systematize and organize information regarding ecosystem services status, trends and gaps (Chapters I, II and III), and the application of conceptual approaches (Chapter III) as well as methodological approaches (Chapters III and IV) to identify the relationships between the ecological characteristics of habitats, the pressures acting on the system, and the role of management actions and decision-making to support the operationalisation of the ecosystem services approach.

Chapter I introduces the ES concept, describes the current state of ES studies, placing emphasis on coastal and marine ecosystems, and presents the needs for information to guide decision-making in terms of current conceptual, methodological, policy and applicability challenges. This chapter also describes the main characteristics of the Atlantic coastal region adjacent to the Mondego River, used as a case study to test our proposals.

Chapter II covers facets A and B and addresses research question 1. It presents a set of useful databases to map European coastal and marine ES with a deep analysis linked to the Common International Classification of Ecosystem Services (CICES) framework, as well as the Driver-Pressure-Status-Impact and Response (DPSIR) management framework and their utility to support the Marine Strategy Framework Directive. 581 open source databases were analysed, but only 193 allowed further work to map ecosystem services. Most of these were related to regulation services and had the ability to report the status of ecosystems and the Marine Strategy Framework Directive (MSFD) descriptors linked with hydrogeological conditions (D7), Eutrophication (D5), and Biodiversity (D1). The results highlight the open source spatial data limitations to be integrated into in-depth study case analyses focused on mapping ecosystem services in Europe, as well as the need to improve the metadata behind the datasets for a better interpretation of the information.

Chapter III is linked to facets A and B and addresses research question 2. It presents a multicriteria decision-making approach to identify ES research hotspots at the local level, based on a literature review of coastal and marine ES. This methodology identified 231 potential and current CICES ecosystem services, linked to 21 EUNIS (European Nature Information System) habitats in the study area. The results highlight the local importance of cultural services and the need to deepen ES research associated to saltworks' habitats. In addition, the results emphasize the value and necessity to establish priority areas for management actions, since it is not possible to manage large areas at the same time with enough efficiency to obtain good results in all of them.

Chapter IV focuses on the operationalisation of facet B and addresses research question 3. This chapter establishes an explicit spatial relationship between habitat risk and the vulnerability of ecosystems in the presence of ES supply, using a modified habitat risk assessment (HRA) model from the InVEST tool. The results indicate that the modified HRA model appears to be more in accordance with the social-environmental realm than a non-modified HRA model, suggesting its usefulness for decision-making processes. For the study area, intertidal habitats, specially seagrasses, were identified to be at risk due to sea level rise and Nitrogen enrichment, however the results also indicate that these habitats are sensitive to management actions, and thus may be positively influenced by actions that tend to reduce their exposure to risk. The findings could be a useful addition to the political management documents that recommend taking precautionary actions to protect potentially vulnerable areas.

Chapter V offers a discussion about the need to manage information and create consensus in operative definitions, promote the legitimization of shared objectives and to prioritize actions to avoid the risk of service loss, taking into account the dynamic and context

dependence of ecosystem services, as well as a friendly communication strategy to ensure the participation of all social actors in the accomplishment of the objectives defined. The study also suggests ways to introduce ES in decision making through understandable and replicable steps, especially in local scales with scarce information.

In summary, this study focuses on the importance of information to describe the spatial heterogeneity that makes it possible to recognize the potential of ecosystems to meet the human demand for services and to improve the understanding and management of ES across scales. Likewise, it stresses the importance of the existence of conceptual and methodological frameworks to provide structure to the real-world, highlighting important avenues for the assessment of ecosystem services and ways to communicate results from the scientific community to policymakers and practitioners.

Keywords: Ecosystem services operationalisation, coastal and marine ecosystems, spatial databases accessibility, research hotspots, multi-criteria analysis, habitat risk assessment.

Resumo

Os serviços dos ecossistemas (SE) podem-se definir como o resultado final das estruturas internas, processos e funções derivados dos ecossistemas, que contribuem para o bem-estar humano. Este é um conceito em ascensão e importante para atingir os Objetivos do Desenvolvimento Sustentável, nomeadamente por facilitar a conexão entre as pessoas e a natureza. Embora os SE tenham ganhado protagonismo nas agendas científica e política, ainda há uma lacuna entre a investigação em SE e a informação necessária para apoiar decisões de gestão. Neste contexto, este trabalho contribui para o processo através do qual o conceito de SE se torna útil para os decisores políticos, por meio da apresentação da informação e propostas metodológicas que têm sido organizadas em duas facetas do processo de operacionalização: A) Acessibilidade a bases de dados confiáveis (i.e., na disponibilidade de dados espaciais), e B) Apoio à gestão (i.e., nos efeitos das pressões no fornecimento de SE). O trabalho foca-se nos ecossistemas marinho-costeiros e utiliza a Região da Costa Atlântica adjacente ao Rio Mondego como caso de estudo. Esta área tem sido escolhida com base no interesse da comunidade para desenvolver propostas de gestão ambiental e pela disponibilidade dos decisores locais para implementar uma gestão na base dos ecossistemas para promover o desenvolvimento sustentável da área.

Para atingir o objetivo acima mencionado o trabalho foi orientado para três questões científicas: 1) Serão as atuais bases de dados espaciais em formato aberto adequadas para apoiar decisões informadas sobre os SE marinho-costeiros na Europa? 2) Poderá a análise de lacunas em bases de dados locais contribuir para o desenvolvimento da investigação em SE e, assim, apoiar a transferência de conhecimento? 3) Como integrar a análise da oferta e da procura em SE numa análise de risco de habitats de forma espacialmente explícita?

Os capítulos cobrem a necessidade de reunir, sistematizar e organizar informação relacionada sobre o status dos serviços dos ecossistemas, as tendências e as lacunas ali existentes (Capítulos I, II e III), e a aplicação de abordagens conceptuais (capítulo III) bem como as propostas metodológicas (Capítulo III e IV) a fim de identificar as relações entre as características ecológicas dos habitats, as pressões que atuam sobre o sistema e o papel das ações de gestão e decisões tomadas para apoiar a abordagem dos serviços dos ecossistemas.

O Capítulo I apresenta o conceito dos SE, descreve o estado da arte do tema, com ênfase nos ecossistemas marinho-costeiros, e apresenta as necessidades de informação em SE para orientar a tomada de decisões, considerando desafios conceituais, metodológicos, políticos e de

aplicação. Este capítulo também descreve as principais características da Região da Costa Atlântica adjacente ao Rio Mondego, usada como estudo de caso para aplicar nossas propostas.

O Capítulo II integra as facetas de operacionalização A e B e responde à questão 1). Apresenta um conjunto de bases de dados úteis para mapear os SE marinho-costeiros na Europa e faz uma análise profunda vinculada à estrutura da Classificação Internacional dos SE (CICES) e à estrutura de gestão DPSIR, assim como à sua utilidade para apoiar a Diretiva-Quadro Estratégia Marinha. 581 bases de dados de código aberto foram analisadas, mas apenas 193 tiveram potencial para ser envolvidas em trabalhos de mapeamento de SE na Europa. A maioria das bases de dados está relacionada com os serviços de regulação e tem capacidade para informar sobre o status dos ecossistemas e sobre os descritores relacionados com as condições hidrogeológicas (D7), de eutrofização (D5) e a biodiversidade (D1) da Diretiva Quadro da Estratégia Marinha (MSFD). Assim, os resultados deste capítulo sublinham as limitações e os desafios das bases de dados de acesso aberto para se integrar em estudos mais profundos sobre mapeamento dos SE na Europa e identificam as lacunas e oportunidades que estas oferecem para a gestão sustentável dos ecossistemas marinho-costeiros.

O Capítulo III integra as facetas A e B e responde à questão 2). Com base em revisão de literatura, apresenta uma abordagem para a tomada de decisões multicritério capaz de identificar *hotspots* de investigação em SE ao nível local. Os resultados permitiram identificar, na área em estudo, 231 SE atuais e potenciais, em conformidade com a CICES, vinculados a 21 habitats EUNIS, com destaque para a importância local dos serviços culturais e a necessidade de uma maior investigação associada aos habitats Salinas. Os resultados deste capítulo sublinham o valor e a necessidade de estabelecer áreas prioritárias para as ações de gestão com base na ideia que não é possível implementar ações em grandes áreas, ao mesmo tempo e com a mesma eficiência, para obter bons resultados em todas elas.

O Capítulo IV foca-se na faceta B e está orientado para a questão 3). Este capítulo estabelece uma relação espacialmente explícita entre o risco a que um habitat está sujeito e a vulnerabilidade dos seus ecossistemas num contexto de usufruto de SE, utilizando um modelo modificado da Análise de Risco de Habitats (HRA) da ferramenta InVEST. Os resultados mostraram que o modelo modificado apresenta uma maior concordância com a realidade, por comparação com um modelo não-modificado, sugerindo que terá utilidade em processos de tomada de decisão. Para a área de estudo, os habitats interditais, nomeadamente as pastagens marinhas, foram identificadas em risco devido ao incremento no nível do mar e ao enriquecimento do nitrogénio. Os resultados também indicaram que esses habitats são sensíveis as ações de manejo para reduzir sua exposição ao risco. Esta proposta fornece um

complemento útil para ser adicionado aos documentos de gestão que recomendam a adoção de ações preventivas para proteger areas potencialmente vulneráveis.

O Capítulo V discute a necessidade de apresentar e usar a informação para criar consenso nas definições operativas, promover a legitimação de objetivos partilhados e priorizar ações para evitar o risco de perder SE, considerando a dinâmica e os contextos dos SE e uma estratégia de comunicação amigável que assegure a participação de todos os atores socias na concretização dos objetivos definidos. Na discussão, esta tese sugere formas para introduzir os SE nas decisões ao longo de passos compreensíveis e replicáveis, nomeadamente em escalas locais com escassa informação.

Em resumo, este estudo focou sua atenção na importância da informação para descrever a heterogeneidade espacial que torna possível reconhecer o potencial dos ecossistemas para satisfazer a demanda humana de serviços e para melhorar a compreensão e gestão dos SE através de diferentes escalas. Da mesma forma, enfatiza a importância da existência de estruturas conceituais e metodológicas para fornecer estrutura ao mundo real, destacando importantes formas de avaliar os SE e maneiras de comunicar os resultados da comunidade científica aos formuladores de políticas e profissionais.

Palavras chave: Operacionalização dos serviços dos ecossistemas, ecossistemas marinho-costeiros, acessibilidade a bases de dados espaciais, *hotspots* de investigação, análise multicritério, analise de risco nos habitats.

Contents

CHAPTER I: GENERAL INTRODUCTION AND THESIS OUTLINE

General Introduction

Motivation

The ability of people to cover their basic necessities as food, medicines, education and recreation, among others, depends largely on the capacity of ecosystems to provide them. Ecosystems are composed of biotic and abiotic structures linked by well-organized processes; whose equilibrium guarantees the ecosystems sustainability and the delivery of outcomes that meet social demands. The match between the final ecosystem outcomes with the social demands is known as ecosystem services (MEA, 2005; Haines-Young and Potschin ,2010). The capacity to deliver such ecosystem services will depend on natural processes and pressures, but also on anthropogenic pressures, as people have an effect in ecosystem structures and processes that underpin the ecosystem services when taking profit of them, potentially compromising the sustainable delivery in the long term. The effect of people on the delivery of ecosystem services is particularly alarming in coastal and marine ecosystems - which contribute to around 43% of the total ecosystem services provided by the biosphere (Levrel et al., 2014). For example, it is known that human impacts have affected around 66% of the ocean, as a result of activities such as fisheries, urbanization and industrialization (Halpern et al., 2015).

Due to the close relationship between ecosystem outcomes and human needs there is a growing interest in the management of ecosystem services from scientists, decision makers and stakeholders in general. Several scientific articles have been published dedicated to different ecosystem services topics like concepts (e.g. Potschin-Young et al., 2018), classification methods (e.g. Liquete et al., 2013), quantification (e.g. Boerema et al., 2017) valuation (e.g. Small et al., 2017), mapping (e.g. Burkhard et al., 2014), monitoring (e.g. van Oudenhoven et al., 2012), modelling (e.g. Pascual et al., 2016) and decision making (e.g. Dunford et al., 2018). Consequently, ecosystem services are gaining representation in the policy agenda, as it is evident in documents such as the European Biodiversity Strategy to 2020 (EC, 2011) and the Marine Strategy Framework Directive (EC, 2008).

To support the operationalisation of the ecosystem services concept in policy and planning (Dick et al., 2018), i.e., "the process by which concepts are made usable by decision makers" (Potschin et al., 2014), several international initiatives have emerged, such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net), the EU-project Operationalisation of Ecosystem Services and Natural Capital (OpenNESS, www.openness-project.eu), the Ecosystem Services Partnership (ESP, https://www.es-partnership.org) , the Mapping and Assessment of Ecosystems and their Services initiative (Maes et al., 2013), the Global Partnership for Wealth Accounting and the Valuation of Ecosystem Services (WAVES, https://www.wavespartnership.org/), the ESMERALDA project (Weibel et al., 2018), and the Economics of Ecosystems and Biodiversity (TEEB, http://www.teebweb.org). However, the gap between research and the information required to support decisions still remains large (Olander et al., 2017) as positive results on effective decision making are yet to be proven (Montgruel et al., 2015; Dick et al., 2018; Saarikoski et al., 2018). This might be due to the fact that going from conceptual development to inclusion of ecosystem services in decision making implies overcoming multiple operational challenges to promote integration and improve the dialog between nature and society (Jax et al., 2018; Saarikoski et al., 2018). Such operational issues are even more challenging for coastal and marine ecosystems due to the lack of information and the limitation of current technology and methodologies to describe all the dimensions of these aquatic ecosystems (Liquete et al., 2013; Hauck et al., 2013; Rao et al,2015), especially when in comparison with terrestrial ecosystems for which the availability of information is higher.

This work contributes to the process by which the Ecosystem Service concept is made usable by decision makers (Potschin et al., 2014) dealing with coastal and marine ecosystems, focusing on the availability of information, specifically spatial datasets and site-specific data; and on the effects of pressures on the delivery of ecosystem services.

The Ecosystem Services approach

The Ecosystem Service Approach (ESA) has evolved from concepts traditionally dominated by ecologists and economists, towards a more multidisciplinary concept to enable greater recognition of social and political issues (MEA, 2005; Chaudhary et al., 2015). The new discourse strengthened robustness of ecosystem services and increased its potential to inform policy makers and underpin action oriented at improved ecosystem management (de Groot et al., 2010; Primmer et al., 2015; Bouwma et al., 2018). Nevertheless, the concept has received some criticisms due its anthropocentrism and its strong connection with market rules (Schröter et al., 2014). However, this apparent weakness is actually being used to support ecosystems conservation by taking advantage of cultural values to encourage financial incentives to address environmental problems (Engel et al., 2008; de Groot et al., 2012).

For the purpose of this work, ecosystem services are defined as the final outcomes of the internal structures, processes and functions, derived from ecosystems, that fulfil social demands, sustaining and enhancing human wellbeing (Müller et al., 2000; Martinez-Harms et al., 2015; Potschin-Young et al., 2018). The concept highlights the existence of limits in nature, as well as restrictions to human activities (Vaissière et al., 2013) that may cause a loss of resilience and therefore a loss on the ecosystems' ability to provide benefits to human welfare (Walker et al., 2004; MEA, 2005; Nahuelhual et al., 2017). The ecosystem service paradigm, linking the benefits with the mechanisms that give rise to ecosystem services, has been commonly represented by diagrams like the one available in Figure I.1.

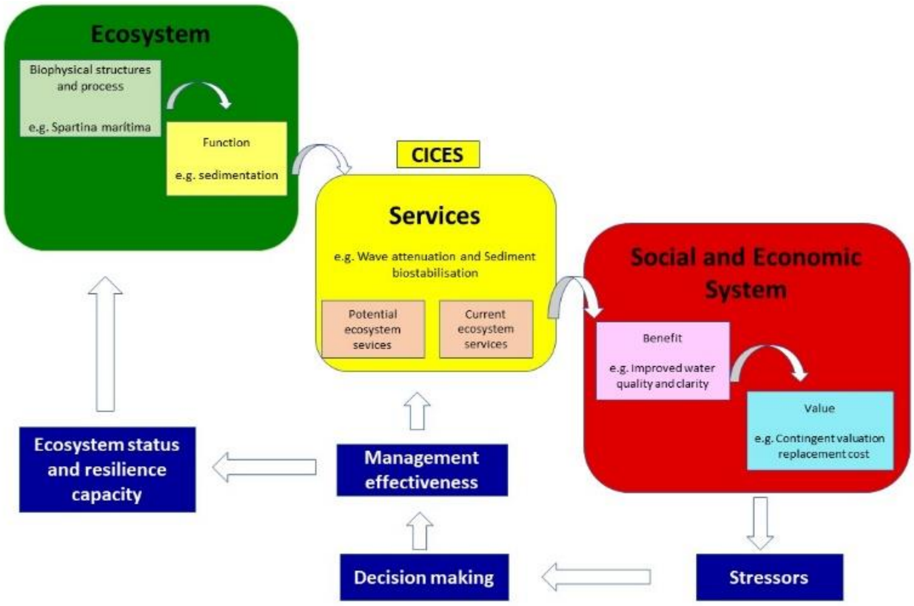


Figure I.1. The ecosystem services cascade model adapted from(Haines-Young and Potschin (2010), Spangenberg et al. (2014) and van Oudenhoven (2015)

To better describe the diagram, saltmarsh habitats (for instance composed of *Spartina* sp.) will be used as an example. Saltmarsh plants ('biophysical structure' box in Figure I.1) have the ability to promote sedimentation ('function' box in Figure I.1) (Couto et al., 2013), contributing to wave energy attenuation ('service' box in Figure I.1), (Jadhav et al., 2013) which may be highly useful from a human point of view as it may mitigate storm damage and act as a coastal buffer (Feagin et al., 2010). But is this service actually considered valuable? It would be reasonable to assume that populations would value more (socially and economically) the potential protection gained ('benefit' box in Figure I.1) from the presence of saltmarsh habitats in urbanized coastal areas, than in non-urbanized areas. It is thus, utterly important, not only to know the ecosystem dynamics, but also to understand the geographical context and the societal choices and values. When there is an actual human interest in the services provided by the ecosystem, its exploitation may introduce pressure in the system, and thus those habitats with greater potential to supply ecosystem services are potentially more vulnerable (Culhane et al., 2019), a condition that may be relieved after the implementation of adequate management measures, which could keep the ecosystem with resilience enough to ensure the continued delivery of services.

A few characteristics of Ecosystem Services should thus be considered to guide an effective decision-making process. The most important are: i) Ecosystem services are context dependent: structures and processes that make possible the delivery of ecosystem services are not homogeneous along time and/or space (Fisher et al., 2009), they are dynamic and, temporally and spatially, change as a function of natural or anthropogenic drivers (Andersson et al., 2015); ii) Ecosystem services are benefit specific: it means that ecosystem services are contingent on particular human activities, being defined by social demands and people interests (Boyd and Banzhaf, 2007); iii) Ecosystem services are influenced by their accessibility, which could explain the way as they are valued and conserved. Some ecosystem services block their availability from some users to others, while some services do not impose restriction in their use or enjoyment (Fisher et al., 2009); iv) Ecosystem services could be bundled: Some areas could deliver a group of ecosystem services that are interdependent, providing multiple benefits for human welfare (Boulton et al., 2016); v) Ecosystem services follow the complexity of biophysical structures that support them: This means that ecosystem services are not a commonly linear phenomenon, by the contrary, they present feedbacks, time lags, and nested phenomena (Biggs et al., 2012).

These characteristics introduce advantages in the ESA that are important to take into account, for example, it: i) acts as a boundary object that facilitates the transversality of the ecosystem services concept to different fields and experts at different scales (Schroter et al., 2014); ii) offers a logical and organized framework with categories (Mongruel et al., 2015); iii) offers an idea of integrity among social and natural sciences, facilitating the interaction and trade-offs (Mongruel et al., 2015).

Despite the recognised advantages, the growing importance of the ESA has highlighted the lack of consensus about the concept, typology, frameworks, tools, research and priorities (de Groot et al., 2002; Nahlik et al., 2012; Newton et al., 2018; Potschin-Young et al., 2018). To overcome these issues several initiatives have been put into action. For instance, the Millennium Ecosystem Assessment (MEA, 2005) and The Economics of Ecosystems & Biodiversity (TEEB, 2010) projects have emerged to clarify topics related with ES evaluation; the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES,2019) has emerged to strengthen the science-policy interface focusing not only on the assessment, but also on policy support, capacity building and outreach; the Common International Classification of Ecosystem Services - CICES (Haines-Young and Potschin, 2011) has emerged as a way to standardize definitions and typologies (Haines-Young and Potschin, 2018). The CICES classification was developed by the European Environment Agency (EEA) and is currently the most accepted classification system, especially in the European realm. More specifically, it has its background in the cascade model (Haines-Young and Potschin, 2010), presents a hierarchical system which distinguishes services from biotic and abiotic realms, and considers three main categories (Haines-Young and Potschin, 2011): i) Provisioning services, which include the products used by humans that are obtained directly from habitats and ecosystems (Lillebø et al., 2016); ii) Regulation & maintenance services, which are related with how living organisms can mediate or moderate the environment and affect human activities and well-being (Lillebø et al., 2016); and iii) Cultural services, which include non-material and/or non-consumptive ecosystem utputs that affect human physical and mental states (Lange and Jiddawi , 2009).

Challenges for the operationalisation of the Ecosystem Services concept

The sustainability of ecosystem services depends on management actions that are socially desirable, environmentally sustainable, economically viable, technologically feasible, administratively achievable, legally permissible, and politically expedient to deal with (Marques et al., 2009). The operationalisation of the ecosystem services concept provides an opportunity to guide sustainable resource management, as it makes the services of nature explicit, allowing the analysis of trade-offs and impacts of different management options.

Operationalising the ecosystem services concept implies: i) raising awareness about the importance of ecosystems' functioning to human welfare (Fisher et al., 2009) and the way human activities impact ecosystems' structures and functions in turn (Halpern et al., 2015); and ii) putting in action conceptual frameworks to go from theory to sustainable management actions, ensuring the delivery of ecosystem services despite disturbances and ongoing changes (Schlüter et al., 2015). Operationalisation involves going beyond from simply highlighting the potential usefulness of the concept of ecosystem services for different social groups, to facilitating its application in real-world decision-making processes to demonstrate its usefulness in addressing real world issues through practical experience (Carmen et al., 2018).

Despite the progress achieved to integrate the ecosystem services concept into management and decision-making, several challenges still remain, which can be divided into four categories: i) Conceptual challenges, ii) Methodological challenges, iii) Policy challenges and iv) Application challenges. Together, these challenges demand the management of information, the establishment of priorities, an analysis of socio-ecological interactions and communication and legitimization of actions.

Conceptual Challenges

The ecosystem services concept offers the opportunity to organise the knowledge about the importance of structures, processes, and functions of ecosystems to human welfare (Fisher et al., 2009). This in an integrate and systematic view, coupling social, economic, and ecological components (Carmen et al., 2018) to deliver information to society and guide its decisions with focus oriented towards sustainability (Ainscough et al., 2019).

However, despite its growing importance (e.g. Erlich and Mooney, 1983, MEA, 2005, Costanza et al., 2017), the ecosystem services concept is still vague and limited (Hauck et al., 2013), and some debates still remain, for example about the limits between the definitions of ‘‘function’’, ‘‘service’’ and ‘‘benefit’’ (de Groot, 2010), the harmonization of classification schemes, avoiding redundancy and improving the process of valuing ecosystem services (Fisher et al., 2009), the definition of indicators to monitor ecosystem services (e.g. Heink et al., 2016; van Oudenhoven et al., 2018a), and the pertinence of considering ecosystem services as a boundary object (Schröter et al., 2014). The lack of common understanding around these and other topics (Dick et al., 2018) could be hindered by integrating a multi-stakeholder perspective (Czúcz et al., 2018; van Oudenhoven et al., 2018b) in consensus building (Altmann and Stanton, 2017; Carmen et al., 2018; Saarikoski et al., 2018; Keenan et al., 2019).

The mismatch between the conceptual understanding of the ES concept in science, and its limited practical application (Lautenbach et al., 2019), could be overcome if the different disciplines involved in the ecosystem services approach are able to consider the following suggested points in consensus building:

i. Work, at the beginning, with ecosystem services as a boundary object to facilitate the communication and cooperation between different groups, scaling up to more specific definitions to ensure the necessary harmonization in nomenclature, typologies and valuation, that facilitate comparisons between experiences (van Oudenhoven et al., 2018b; Ainscough et al., 2019; Weitzman, 2019).
ii. Build a concept with the power to promote shifts in natural resources management, the same that should be addressed with different stakeholders and be able to be adapted to different contexts and worldviews (Schröter et al., 2014; Ainscough et al., 2019; Maczka et al., 2019).
iii. Develop a concept that keeps simplicity, while maintaining its ability to reflect the complexity of ecosystems and to communicate the benefits of ecosystem conservation and highlighting the significance of ecosystems to human societies (Ainscough et al., 2019; Lebreton et al., 2019).

iv. Build a concept that stresses the idea of sustainability (Ainscough et al., 2019), to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need (Saairosky et al., 2018).

Thus, the ecosystem services concept represents an opportunity to develop the interdisciplinarity to go beyond science limits to reach a variety of fields and professional activities (Portman, 2013; Chaudahary et al., 2015) in order to ensure sustainability and, ultimately, human well-being.

Methodological Challenges

To be effective, the application of the ecosystem services concept to decision-making should address the following methodological challenges:

i. Assess the condition of ecosystem services considering particular contexts and scales (Vialatte et al., 2019): Ecosystems have the potential to deliver services based on their biophysical and social heterogeneity (e.g. Burkhard et al., 2009; Salomidi et al., 2012; Moreno et al., 2014). The challenge consists in overcoming the tendency to easily fall in the oversimplification typical of big scales, without considering the complexity of local contexts (Hauck et al., 2013). Overcoming this challenge demands management information to recognize the spatial heterogeneity of a place, both ecologically and socio-economically (Ghermandi et al., 2019). Managing, simultaneously, biophysical and socio-economic information will be possible avoiding the risk of being centered in just one side of the cascade that underpins ecosystem services (Potschin-Young et al., 2018), and promoting approaches that integrate both perspectives (Boerema et al., 2017) for a more sustainable future (Abson et al., 2014). The EUNIS habitat classification (Davies et al., 2004), for instance, which is frequently used to support the assessment of coastal and marine ES, avoids this pitfall by joining the physico-chemical features necessary to ensure the existence of determinate plants or animals' communities, with economic, functional and cultural importance in the ecosystems; organized in a hierarchical structure of up to six levels (Manakos et al., 2016).

ii. Manage information to assess ecosystem services: ES assessment requires the identification and quantification of ES and the characterization of the distribution of biophysical structures able to deliver services in a determinate location. It is thus important to provide ready-available datasets and develop tools that allow the flow of information from researchers to practitioners, in order to explain ecosystem services' trends and integrate the information into public- and private-sector decision-making processes.

With regard to datasets, and despite their importance, there is still a lack of long-term verified datasets that could be used for valuation and decision-making (Keenan et al., 2019), which may be a result of the relative newness of the ES concept in broader environmental management. Some efforts to overcome this challenge are the free available databases published by many research groups and institutions and monitoring manuals that offer information to guide decisions (e.g. Weatherdon et al., 2015). Nevertheless, it is necessary to improve this field for better decision-making related to ecosystem services.

With regard to tools to assess ES several have emerged along the years (Bagstad et al. 2013), and some of which have gained particular relevance in the assessment of ecosystem services. For example:

- Integrated Valuation of Ecosystem Services and Trade-offs (InVEST): This is a well-documented open source tool to model and map changes in a suite of services under different management scenarios (Sharp et al., 2018);
- Artificial Intelligence for Ecosystem Services (ARIES): This is a flexible modelling framework that uses artificial intelligence to select the most appropriate components to map ecosystem services to each context, keeping the necessary simplification to be usable and communicable at a range of spatial scales (Villa et al., 2014);´
- Soil and Water Assessment Tool (SWAT): This is a model developed to predict the impact of management on water and sediments along large basins, (Arnold and Fohrer, 2005) and is thus a tool widely used to provide information to manage provisioning and regulation services, although it could also be sued in the context of cultural services assessment (Francesconi, 2016).
- Costing Nature: This is a web based spatial tool focused in cost analysis to sustain and improve ecosystem services. It incorporates the identification of beneficiaries and the impacts of human activities on the services through scenarios analysis of climate and land use to guide decision-making (Mulligan et al., 2010, http://www.policysupport.org/costingnature).
- Multiscale Integrated Models of Ecosystem Services (MIMES): This is an integrated assessment system that models interactions between the Earth spheres, using a matrix associated with ecosystem services functions and human activities, to visualize how the ecosystems benefits are gained or lost (Boumans et al., 2015);

- Social Values for Ecosystem Services (SolVES): Is a tool for mapping and quantifying non-market values perceived by different groups of stakeholders describing the relationship between social values and ecosystems (Sherrouse et al., 2011);
- Marxan: Software used to identify areas for conservation actions (Possingham, et al., 2000) whose latest version, MARZONE (Watts et al., 2009; Pinto et al; 2019) allows to incorporate multiple conservation measures and their associated costs in a flexible spatial analysis to land-use zoning;
- Global unified metamodel of the biosphere (GUMBO). This is a tool that integrates and simplifies several dynamic global models in a metamodel, working with natural and social sciences to value ecosystem services (Boumans et al., 2002).

iii. Establishment of priorities: Resources are not always enough to manage entire sites. It is necessary to consider the prioritization of certain areas with the highest potential to deliver services, meaning that it may be more useful to consider bundles of ecosystem services rather than isolated or single ones (Costanza et al., 2017). Areas that bundle many ecosystem services, could be considered as ecosystem services' hotspots (Schroter and Remme, 2016). The identification of these areas may help to reduce the resources and efforts required to ensure the maximum benefit in the long-term ability of ecosystems for providing multiple services (Egoh et al., 2008; Cabral et al., 2015; Culhane et al., 2019). However, the identification of hotspots is not always simple (Schröter and Remme, 2016) because, among other reasons, it needs data to confirm the existence of services in quality and quantity enough to meet the social demands, which, in turn, requires improving research, especially in places where there is empirical evidence of the existence of multiple ecosystem services but scarce information.

iv. Ecosystem services valuation: value is what the service represents to people in terms of cost; something that can be quantified and easily communicated. Ecosystem service values can be expressed using social or ecological metrics, but are most often expressed in monetary terms (Adekola et al., 2015). The challenge here is to avoid highlighting the monetization as a unique expression of ecosystem services, because it could reduce the nature of ES to utilitarism (Bekessy et al., 2018). Other challenges in valuation are the extra focus in few ecosystem services at the expense of others (Inostroza et al., 2017). Indeed, valuation should be able to deal with trade-offs of ecosystem services (Lautenbach et al., 2019), favouring the provision of bundles of ecosystem services with higher values (Falk et al., 2018).

v. Communication of results about ecosystem services: Ecosystem services could be seen as a communication vehicle to carry information from researches to end-users and vice-versa (Bekessy et al., 2018). A good communication process allows ensuring the possibility to have the desired effect on society. This requires identifying the target audience, defining the objectives of the communication strategies adapted to specific decision-making contexts (Diehl et al., 2016), as well as defining the indicators to measure the success of the communication process (Bekessy et al., 2018). To cover communication requirements, the communication strategy should be oriented to: i) awareness raising and education, ii) building strategic arguments for policy, and iii) facilitating dialog between different stakeholders (Dick et al., 2018). Achievement of this communication big goals requires counting on interactive communication tools, shared databases and documents focused on different scales and contexts, and robust networks to facilitate the flow of information (de Groot, 2010; Klein et al., 2015).

In this context, maps are seen as one of the most effective instruments to communicate about ecosystem services, by their power to tell stories interconnecting elements in just one image, while improving the visualization capacity and allowing the establishment of comparisons between facts over space and time (Hong, 2014; Kerski, 2015). Ecosystem services' mapping helps to address critical scientific questions including the impact of local or regional policy decisions on biodiversity and ecosystems in a spatially explicit manner. Nevertheless, mapping requires to manage information in quality and quantity enough to answer the challenges that represent the decision making (Maes et al., 2013), including in situ data, remote sensing data and expert opinion (Costello, 2009). The big challenges to map ecosystem services are related to the quality of information and the spatial resolution, which are scarce for water environments (Tyberghein et al., 2012; Mantas et al., 2013;).

Policy Challenges

Policy challenges are related to the implementation of the ecosystem service concept as a normative dimension (Schleyer et al., 2015), to help in the achievement of critical goals addressed to solve the tension between economic development and environmental conservation, as well as to influence the decisions made by the users to align their practices with the interests of the beneficiaries of ecosystem services (Muradian et al., 2012).

Although there is no specific EU policy addressed to govern ecosystem services, this issue has gradually become more integrated in policies that govern natural ecosystems, being generally service specific (Keenan et al., 2019; Bouwma et al., 2018) and closely related to payments to ecosystem services and environmental damage repair (Altmann and Stanton, 2017).

Policy challenges include multiple stakeholders' perceptions (Saarikoski et al., 2018) who have heterogeneous interests that are simultaneously affected (Schleyer et al., 2015). The actual challenge is the translation of these interactions into 1) institutions, (2) actors, (3) knowledge, and (4) processes (Dick et al., 2018) allowing to conceal the economic and ecological goals through a horizontal and vertical policy integration (Saarikoski et al., 2018). This approach guarantees system persistence, the conservation of ecosystems and the enhancement of the human well-being (Abson et al., 2014), while the policies remain credible, salient and legitimate (Keenan et al., 2019).

Another policy challenge is the inclusion of bundles of ecosystem services into governance, rather than single ecosystem governance, raising awareness about the fact that ecosystem governance must simultaneously address different types of ecosystem services and trade-offs between them (Falk et al., 2018) At the same time, policy should be context- and scale-dependent, while also taking into consideration the link of ecosystem services with the notion of sustainability (Abson et al., 2014).

Application challenges

To put in action the ecosystem services concept to guide actions, based on informed decisions, requires easy language and accessible databases, methods, and tools (Dicks et al., 2018; Carmen et al., 2018). The main challenges for the application of ecosystem services concept includes counting on political leadership, governance arrangements and established mechanisms for efficient measurement and reporting of results, which should be a product of the interaction between ecosystem scientists and the public and private sector decision makers (Keenan et al., 2019).

A big challenge during the application of the ecosystem services concept is to guarantee the maintenance and enhancement of ecosystem services resilience (Carpenter et al., 2001; Walker et al., 2004; Biggs et al., 2012), or in other words, to ensure the ecosystems capacity to deliver a desired set of ecosystem services, inclusive during a disturbance moment and under ongoing changes (Schlüter et al.,2015). The accomplishment of this goal could be done through the management of stressors that could induce the loss of ecosystem structures and processes upon which the delivery of services depends on (Stenchion, 1997; Wyatt et al., 2017).

Resilience management requires encouraging the participation of multiple stakeholders not only in the science dimension, but also in the more general arenas as literature, education and government to really become a transformative tool for sustainability (Abson et al., 2014, Schleyer et al., 2015). It is the ultimate tool to make the ecosystem services concept a real boundary object to raise awareness and promote the dialogue between different actors and to guide decision making at advanced stages of the process (Dick et al., 2018; Portman, 2013), supporting ecosystem services' mainstreaming. Mainstreaming ecosystem services allows bringing new information and new methodologies into an established set of rules and procedures and, thus, to include relevant ecosystem services concerns into the decision of institutions that drive national, local and sectorial development of policies (Dalal-Clayton and Bass, 2009). For example, the ecosystem services approach has resulted useful to improve the scoping, make easier the identification of cumulative impacts and enable the analysis of social impacts in impact assessment processes (Sales-Rosa and Sanchez, 2016).

Another challenge for the application of an ecosystem services approach is the development of context-dependent decision models, which should include management variables and economic drivers across scales (de Groot, 2010), as well as uncertainty assessments (Hamel and Bryant, 2017). Likewise, it is important to build a common structure to monitor and evaluate the ecosystem services, as well as report practices with shared standards among the practitioners, and interested public, to ensure comparability and transferability under specific contexts (de Groot, 2010).

Finally, during the application of the ecosystem services approach, it is important to consider the economic aspect, i.e., the financial mechanisms to help policy makers to use cross-sectoral synergies and manage trade-offs (Olander et al., 2017; Bouwma et al., 2018), avoiding to fall in market rules that could guide to a substantial reduction of complexity, concentrating the attention just in certain popular services, forgetting that they are interconnected with others that could be less recognized but equal in importance (Muradian et al., 2012).

Coastal and marine ecosystems

Marine ecosystems represent the source of many benefits for approximately 775 million of people who highly depend on marine ecosystem services (Selig et al., 2018). In fact, Levrel et al. (2014) have estimated that marine ecosystems contribute to around 43% of the total ecosystem services provided by the biosphere, including the provision of food, raw materials, recreation opportunities and climate regulation (Halpern et al., 2015; Salomidi et al., 2012; Thrush et al., 2013), representing a significative contribution to the world economy (Costanza et al., 1997; Maes et al., 2013). To this percentage contribute the coastal areas which are among the most productive around the world (Jacobs et al., 2015) hosting, in their surroundings, one third of the world's population (Rao et al., 2015; Small and Nicholls, 2003). Despite its relevance, coastal and marine ecosystems are subject to continuous perturbations that affect their capacity to deliver services and to contribute to human well-being. For example, land reclamation, pollution, overexploitation of natural resources, alien species invasion and climate change, which are affecting food provision, availability of nursery habitats, waste treatment, and other vital services (Barbier et al., 2011).

Despite their importance and threats, coastal and marine ecosystems face all the above-mentioned ecosystem services operationalisation challenges which make it difficult to address an effective process to implement the ESA in these ecosystems.

From a methodological point of view it should be pointed out the lack of information regarding coastal and marine ES to guide management actions (Yang et al., 2019), as for example, the gap in the availability of datasets linked with the spatial distribution of the structures that underpin ES to different scales, particularly at local scales (Liquete et al., 2013; Lillebo et al., 2016). This shortage in information poses another challenge which is related with the difficulty of the non-academic population to recognize some ES as such, as for example the non-extractive services derived from marine structures and functions (Ruiz-Frau et al., 2013).

Also from a methodological point of view, and considering that ES are not homogeneous across seascapes(Fisher et al., 2009), the location where the services are generated implies an extra methodological challenge in coastal and marine areas relevant for their quantification and valuation (Syrbe and Walz, 2012). The challenge arises specifically from the difficulty in determining the association of a physical space with the variety of species that compose the nekton (very active movement for long distances), the plankton (little movement within a moving water mass) and the benthos (that may never move within their entire life) (Costello, 2009) in a highly dynamic environment and under the current technological limitations (Tempera et al., 2016). Thus, methodologically, one of the most important steps to assess the coastal and marine ES would be to describe the spatial heterogeneity of the study site using an ecosystem classification scheme able to reduce the uncertainties mentioned above (Costello, 2009). Currently, the most accepted classification scheme, at the European level, that supports the identification of service providing areas is based on the EUNIS habitat classification, from the European Environment Agency (Davies et al., 2004), which is frequently integrated with the CICES framework to provide the most comprehensive spatially explicit baseline for the assessment of marine ecosystem services in Europe (Tempera et al., 2016).

Another relevant methodological challenge related to coastal and marine ecosystems is the lack of consensus about indicators to monitor ES in these areas. Despite the efforts (i.e Babcock et al., 2005; Lillebø, et al., 2016:), it is still necessary to create consensus about the definition of these indicators, including those relevant to monitor the good environmental status descriptors mentioned in the Marine Strategy Framework Directive (MSFD; EC, 2008) and those compatible with management frameworks such as the driver-pressure-impact-response (DPSIR) framework (Pinto et al., 2013a). Notice that monitoring will benefit the development of models to assess, for example, the interaction between multiple ecosystem services (Broszeit et al., 2019); integration of multiple criteria in the decision-making under different scenarios (Chakraborty et al., 2020) and evaluation of ES tradeoffs in face of natural and anthropogenic hazards (Willaert et al., 2019). In this context, it is important to be aware that models will improve in the presence of better data quality, ideally georeferenced (Singh et al., 2017; Sousa et al.,2017), which is specially challenging in coastal and marine water due to their biophysical characteristics described before.

With respect to policy, coastal and marine ecosystems also face operational challenges. One of the most known and studied is the challenge related to the demand to go further from political boarders, for instance to conserve marine areas. The establishment of the Regional Sea Conventions covering European seas (i.e. OSPAR - https://www.ospar.org/ and, HELCOM- https://helcom.fi/) (Lillebø, et al., 2016) is an advancement to surpass such challenge, but improvements are still necessary, especially to include more areas, to gain consensus in the common objectives respecting contexts and to in improve the available information through different spatial scales.

The Atlantic coastal region adjacent to the Mondego River

The study area is the Atlantic coastal region adjacent to the Mondego River, located in the central western coast of mainland Portugal. It includes four transitional water bodies (WB1, WB2, WB-HMWB, WB3) and one coastal water body (CWB-1-3), defined under the scope of the Water Framework Directive (WFD; EC, 2000). It has a longitude of 21 Km, a surface area of 83.31 Km^2, and drains approximately 8.5 x 10^9 m^3/year of water from the Mondego River to the Atlantic Ocean in the city of Figueira da Foz (Falcão et al., 2012; Mantas et al., 2013).

The study area has a semidiurnal regime and a tidal variation between 0.35 and 3.80 m and high energy wave hydrodynamics mostly between October to March. The coastline is dominated by sandy beaches that, at south of the river mouth, pass inland to an aeolian dune field and to the estuary (Cunha et al., 2006). The Mondego River mouth is adjacent to the town of Figueira da Foz.

The transitional water bodies conform a mesotidal well-mixed estuary, except during floods and droughts. The last 7 Km close to the mouth of the estuary (with the maximum wide of 3Km) are divided into two subsystems separated by the Morraceira Island (formed by sediments deposition). Each subsystem has specific characteristics that allow to identify different zones based on the substrates, water flow and salinity conditions (Teixeira et al.,2008). The Mondego subsystem (comprising the North branch) is deeper (4-10 m during high tide), has strong salinity changes, and presents medium to coarse sands. This subsystem constitutes the main navigation channel of the estuary (Marques et al., 1993). The Pranto subsystem (comprising the South branch), is shallower (2-4 m during high tide), shows frequent changes in temperature (Flindt et al., 1997) and salinity (Cunha and Dinis, 2002) and organic enrichment as result of the Pranto River water inputs (Baeta et al., 2011) and aquaculture discharges. Due to its low depths, the Pranto subsystem, presents large areas of intertidal mudflats with high percentage of silt and clay, and significant seagrass meadows exposed during low tide (Neto, et al., 2008).

The coastal water body is flanked by two aeolian dune fields, located north of the Serra da Boa Viagem (Almeida, 1997; Danielsen, 2008) and south of the River Mondego (André, 1996; André et al., 2009). The modern shore platform is associated with a coarse sandy, locally gravelly, beach (Cunha and Dinis, 1998a). Classified as Mesotidal Exposed Atlantic Coast (Bettencourt et al., 2004), the coastal waters are characterized by high energy hydrodynamics, struck by storms from the North Atlantic, particularly from October to March. The dominant wave direction is from west and northwest and the wave periods are in the range of 8-12 s and significant heights in the range of 1-3 m (Bettencourt et al., 2004).

The study area climate, which suffers the effects of The North Atlantic Oscillation - NAO (Nytrai, 2013), is characterised by strong seasonal changes with rainfalls from November to May and dry periods from June to October. The mean precipitation is 1136 mm, from which, approximately, 400 mm go to runoff (Teixeira et al., 2008).

The biophysical gradients along the study area offer the necessary heterogeneity to originate different habitats, such as seagrasses (Marques et al., 1993), saltmarshes, (Couto et al., 2013), saltworks, (Múrias et al., 2002), rocks and reefs (Martins et al., 2002), beaches, (Cunha et al., 2006), rivers (Ceia et al., 2013). These habitats have the potential to offer a wide diversity of ecosystem services, such as water provision (Sousa et al., 2008), eco-tourism opportunities (Pinto et al., 2013b), nursery grounds (Marques et al., 2013), food production (Marques et al., 2006), and carbon storage (Couto et al., 2014).

Despite the social benefits that have been obtained from the Atlantic coastal region adjacent to the Mondego River, its present ecosystem services are in danger as a result of multiple pressures from natural and human origin (Teixeira et al., 2014), such as water flow control, through a series of dams and channels (Mantas et al., 2013), water extraction for irrigation projects (Pinto et al., 2013a), organic enrichment from nitrogen and phosphorus (Flindt et al., 1997, Teixeira and Marques, 2016), landfills and dredging/sand extraction (Cunha et al., 1998b; Cunha et al., 2006), fisheries (Pinto et al., 2013a), contaminants and marine litter inputs (Bessa et al., 2018; Botelho et al., 2019), presence of invasive species (Franco et al., 2012), sea level rise (Loureiro et al., 2017) and impacts from navigation and harbor activities, such as noise and contaminants (Ceia et al., 2013; Mantas et al., 2013).

The Atlantic coastal region adjacent to the Mondego River was chosen as a study area due to the long-term assessment that allows us to understand the dynamics of its natural structures and processes (e.g. Baeta et al., 2009; Baptista et al., 2015); the application of management actions to improve its environmental quality (Veríssimo et al., 2017); and the social interest in the development of environmental management proposals (Pinto et al., 2014a, 2016). To this background adds the willing of local decision-makers to assume the challenge of applying an ecosystem based-management to promote social and economic growth (Teixeira et al., 2018); and the recognition of the study area as an 'Area of Outstanding Natural Beauty', a RAMSAR site (https://bit.ly/3cW8SjD), and an Important Bird and Biodiversity Area (http://datazone.birdlife.org/country/portugal/ibas).

Objectives and thesis outline

The ecosystem services approach (MEA, 2005; Beaumont et al., 2017) is an integrated and sustainable strategy that helps building a bridge between the natural world and the human society. It demands the development of adequate communication vehicles to facilitate the decision making (Hauck, et al., 2013). The main goal of this study was to contribute to the process by which the Ecosystem Service concept is made usable by decision makers (Potschin et al., 2014), focusing on two operationalisation facets related to the problem of knowledge availability for implementation of the ES concept (Carmen et al., 2018; Jax et al., 2018; Lautenbach et al., 2019):

i. **Facet A | Access to reliable datasets**

The flow of information from researchers to practitioners relies on data on ecosystem services. For one hand, there is a need for spatial assessments based on accurate mapping of ES (Andrew et al., 2015), for example, for monitoring purposes (e.g. MSFD; EC, 2008). For another, there is a need for site-specific data that more directly represents ecosystem properties and the local realm, in order to increase decision-makers confidence for the development of environmental measures.

ii. **Facet B | Support to management actions**

Understanding the effects of pressures of human activities on ecosystem services delivery is paramount for decision-making, in order to guarantee the sustainability of ES. Several approaches have been used, such as structuring information through established frameworks (e.g. DPSIR - OECD, 1993) and analysing the ecosystem risk through modelling (e.g. InVEST Habitat Risk Assessment model).

To attain our main goal, the following research questions drove our study:

1. Are current open source spatial databases suitable to informed decision-making related to coastal and marine ecosystem services in Europe?
2. Can gap analysis based on site-specific databases contribute to the development of ES research and knowledge transfer?
3. How to explore the role of ecosystem services supply and demand in spatial explicit habitat risk assessments?

Three chapters of the present PhD thesis address the abovementioned research questions (Chapter II, Chapter III and Chapter IV), which constitute three scientific papers currently published. These chapters are preceded by a general introduction (Chapter I) and followed by a general discussion (Chapter V), built on the findings of the tree papers, and final remarks.

Chapter I | General introduction. Introduces the motivation for this work, presents the Ecosystem Services concept and an overview about the state of art in ecosystem services studies with emphasis in marine ecosystems, identifying the necessities of information to guide decision making.

Chapter II | *Use and usefulness of open source spatial databases for the assessment and management of European coastal and marine ecosystem services*. This chapter addresses operationalisation facet A (Datasets) and B (support to management actions) and is oriented towards research question 1. It presents an overview about the existing open source databases available to map marine ecosystem services, establishing a link with the DPSIR management framework and their utility to support the Marine Strategy Framework Directive. It also identifies data gaps and the necessities to improve spatial databases, based on literature review.

Chapter III | *Identifying ecosystem services research hotspots to illustrate the importance of site-specific research: An Atlantic coastal region case study*. This chapter addresses operationalisation facet A (Datasets) and is oriented towards research question 2. It presents a methodology to identify ecosystem services research hotspots at the local level, as a mean to support data gathering and ultimately decision-making.

Chapter IV | *Ecosystem services as a resilience descriptor in habitat risk assessment using the InVEST model.* This chapter addresses operationalisation facet B (support to management actions) and is oriented towards research question 3. It establishes a relationship between impact risk and ecosystem service by accounting for the ecosystem vulnerability based both on exposure and adaptive capacity in the presence of ecosystem services supply and demand.

Chapter V | General discussion. This chapter integrates the information gathered in the previous chapters, discussing the main findings. Final remarks present the main findings that could be used to improve future research.

At last, it is important to mention that this work highlights the importance of raising knowledge about ecosystem services and the possibility to work in places where the information is scarce

Publications

Paper 1

Caro, C., Pinto, R., Marques, J. C. 2018. Use and usefulness of open source spatial databases for the assessment and management of European coastal and marine ecosystem services. Ecological Indicators. 95:41–52. https://doi.org/10.1016/j.ecolind.2018.06.070

Paper 2

Caro, C., Cunha, P.P., Marques, J.C., Teixeira, Z. 2020. Identifying ecosystem services research hotspots to illustrate the importance of site-specific research: An Atlantic coastal region case study. Environmental and Sustainability Indicators. Environmental and Sustainability Indicators. 6:100031. https://doi.org/10.1016/j.indic.2020.100031

Paper 3

Caro, C., Marques, J.C., Cunha, P. P., Teixeira, Z. 2020. Ecosystem services as a resilience descriptor in habitat risk assessment using the InVEST model. Ecological Indicators. 115: 106426. https://doi.org/10.1016/j.ecolind.2020.106426

CHAPTER II: Use and usefulness of open sources databases for the assessment and management of European coastal and marine ecosystem services

Abstract

Assessing the stocks and flows of ecosystem services valued by society is crucial to ensure the sustainable management of marine ecosystems, as required by the European Marine Strategy Framework Directive (MSFD; EC, 2008). The mapping of these ecosystem services enhances the flow of information from researchers to practitioners, contributing to a better management of ecosystem services. The objective of this work is twofold. First, a screening and evaluation of available open source spatial databases was conducted to assess their usefulness to map European coastal and marine ecosystem services. Second, these spatial databases were classified according to the DPSIR (Drivers, Pressures, Status, Impacts, Responses) framework and the MSFD descriptors to assess how this information can inform decision-makers. The supply of explicit spatial information was used as main screening criteria and allowed to identify 581 existing databases. These databases were then categorised according to a set of criteria (including data collection methods and updating frequency) related with their usefulness to be applied to map ecosystem services. The databases that did not meet the selected criteria (e.g. no explicit spatial information) were discarded. This process allowed to identify 329 spatial databases useful for coastal and marine ecosystem services mapping in Europe. The databases were then distinguished based on the ability to work the data on a GIS software, identifying 193 databases that allowed further analysis (hereafter applicable), and 136 databases that do not allow the extraction of data (hereafter non-applicable). The applicable spatial databases were further linked to the i) CICES framework for ecosystem services classification, ii) DPSIR framework and iii) descriptors considered in the MSFD. The obtained results showed that 42% of the spatial databases can be useful to map regulation services, followed by provision (33%) and cultural (21%) services. Considering the DPSIR framework, more than half can be used as proxies to evaluate coastal and marine ecosystems status (66%), followed by proxies of pressures (18%), drivers (8%), responses (4%), and finally impacts (4%). The available databases represent, in a better way, MSFD descriptors related to Hydrogeological conditions (D7), Eutrophication (D5), and Biodiversity (D1), being the Non-indigenous species (D2) and Contaminants in seafood (D9) descriptors somehow underrepresented. The obtained findings highlight the spatial open data limitations and challenges when mapping coastal and marine ecosystem services and contribute to the identification of spatial data gaps and opportunities when aiming for the sustainable management of marine ecosystems.

Keywords: Spatial databases, data accessibility, coastal and marine ecosystem services, Marine Strategy Framework Directive

Introduction

Since the introduction of the ecosystem services concept in the 80´s (Ehrlich and Mooney, 1983) several studies have been conducted aiming to assess and value the services provided by ecosystems, taking into account physical, ecological, economic, social and cultural aspects (MEA, 2005; Wallace, 2007; TEEB, 2008; Martinez-Harms et al., 2015; Costanza et al., 2017). Most of the studies conducted have been, however, focused mainly on terrestrial ecosystems. Knowing that 70.9% of the Earth is covered by oceans (Halpern et al., 2012) and that around 43% of ecosystem services are provided by coastal and marine systems (Levrel et al., 2014), there is still a lack of studies focusing on the assessment and valuation of these natural resources. Marine ecosystem services can be defined as the final outcome of the internal structure, processes and functioning derived from marine systems that contribute to the satisfaction of society demands, sustaining and enhancing human well-being (Müller et al., 2000; Pendleton et al., 2015). Yet, to guarantee the sustainable management of coastal and marine ecosystem services is essential to rely on reliable spatial information (Maes et al., 2013).

Good spatial data is crucial to ensure effective decision-making processes concerning, for example, the protection of a particular area, the assessment of spatial trade-offs between ecosystem services, to inform about species distribution, or even to communicate about policies implementation and targets (Martínez-Harms and Balvanera, 2012; Townsend et al., 2014). In this sense, Europe has conducted some mapping exercises for marine ecosystems to monitor, in a spatially explicit manner, not only the progresses in achieving important objectives related to the Marine Strategy Framework Directive (MSFD; EC, 2008), but also the advances in the Habitats and Species Directive (HSD; EC,1992) and Biodiversity Strategy (BD; EC, 2011). All these European polices target the maintenance and protection of coastal and marine ecosystem services in Europe (Fraschetti et al., 2011; Albert et al., 2016; Bonamano et al., 2016). Likewise, mapping exercises can be useful to recognize the effects of pressures and impacts of human activities on ecosystem services delivery. This analysis requires the integration of both qualitative and quantitative information about the relationships between a systems' biophysical components and the socio-economic activities taking place in a specific area. One approach to structure this information is through the Drivers-Pressures-Status-Impacts-Responses Framework (DPSIR; OECD, 1993). This approach has been used to support decision-making regarding ecosystems' management actions, monitor strategies and determine ecosystem services trade-offs (e.g. Atkins et al., 2011; de Jonge et.al., 2012; Pinto et al., 2013a).

European marine ecosystem services mapping exercises have been mainly focused on the description of ecosystem's status as result of human pressures (Parravicini et al., 2012). From these, regulation related services are the most described, especially carbon sequestration and storage (e.g. Liquete et al., 2013; Levrel et al., 2014) and coastal protection (e.g. Rioja-Nieto et al., 2017). These are closely followed by provision services, particularly food provision, fisheries and aquaculture activities (e.g. Deutsch et al., 2007; Pauly, 2007; Thiault et al., 2017). Finally, cultural services, like stakeholders' preferences related to marine protected areas (Halpern et al., 2012) and education or recreational opportunities (Davis and Darling, 2017) are amongst the least mapped services in coastal and marine ecosystems.

From these mapping exercises four main challenges have been identified. The first challenge is related with the gathering of enough qualitative and quantitative information to describe all the dimensions of marine ecosystems (Hauck et al., 2013). This process might be particularly complex due to i) the vertical component of oceans (depth), that makes harder to represent the benthic and pelagic dynamics across time (Lavorel et al., 2017); ii) the ambiguous boundaries within marine ecosystems; iii) the difficulties to associate species with their marine habitats with enough spatial resolution (Tempera et al., 2016); and finally iv) the social dynamics related with the ocean and the incorporation of associated economic values to these systems (Bergström et al., 2015; Moore et al., 2017).

The second challenge concerns the scale of the mapping exercises. Most studies are performed at the regional or national scale (Martinez-Harms and Balvanera, 2012), while there is the need to improve our knowledge regarding marine ecosystem services using global datasets that have higher resolution (Tyberghein et al., 2012).

The third challenge is linked to the existence of uncertainty sources in the existing maps that could hinder their use. Among them are, for example, the lack of consistency in the definition of the indicators to be used for mapping coastal and marine ecosystem services. The Common International Classification of Ecosystem Services (CICES) framework has been developed to try to fill this gap by creating a standardized framework to describe and categorize ecosystem services (Potschin-Young et al., 2016). Other operational challenges are found such as the i) lack of clear information about the methodology used in the data gathering; ii) scarcity of quantitative information in spatial databases (Levrel et al., 2014; Lavorel et al., 2017); and iii) defined methodology to map marine ecosystem services, resulting in different outputs depending on the methodology used (Schulp et al., 2014).

Finally, the fourth challenge regards the limitations that current technology offer, making difficult the full recognition of all marine habitats (Rao et al., 2015). For example, benthic habitats frequently are not visible with remote-sensing technology (Lavorel et al., 2017), making the mapping of marine ecosystems significantly more costly (Fraschetti et al., 2008) and reducing their elaboration just for those services that have a more direct economic interest (e.g. food production; Liquete et al., 2013).

The main objective of this work is to conduct a review of existing spatial databases that can be used to map coastal and marine ecosystem services in Europe. More specifically, we aim to 1) make an inventory of existing georeferenced open source information for European seas; 2) assess how the available information can be used to map coastal and marine ecosystem services, using the CICES classification as benchmark, and finally 3) infer how the different variables available in those databases can be linked to existing frameworks and policies, such as DPSIR and MSFD descriptors, contributing to the management of coastal and marine ecosystem services.

Methodology

A comprehensive review of available spatial databases for European seas was undertaken, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009). The first step involved the listing of open source databases available in institutional websites, such as European Environmental Agency (EEA; https://www.eea.europa.eu/) or NASA (https://www.nasa.gov/), specific project websites (e.g. Copernicus project; http://www.copernicus.eu/), or even data repositories, such as Web of Science (https://apps.webofknowledge.com/), Scopus (https://www.scopus.com/), or ScienceDirect (http://www.sciencedirect.com/). Additionally, already existing European guides on how to map marine ecosystem services were reviewed (e.g. Tempera et al., 2016). This search only considered databases available in English and using the following keywords, either alone or in combination, 'ecosystem services', 'map', 'spatial data', 'coast', 'marine', 'sea', 'ocean', 'Europe', 'Marine Strategy Framework Directive'.

A total of 443 papers were retained for review, including review (e.g. Liquete et al., 2013), and local mapping (e.g. Hattam et al., 2015) papers, or databases created by research projects (e.g. Harris et al., 2014). A first screening was done to assess the originality of the data sources, to eliminate duplicated information, and to prioritize those with mapping exercises. From this, 205 papers that contained information on marine spatial databases were identified and considered for further analysis. The gathered information resulted in a list of links that helped to build an inventory of available coastal and marine spatial databases.

Based on the initial inventory, a further screening process was conducted considering three main selection criteria: i) access to spatial data; ii) spatial coverage; and iii) ability to work the data in a GIS software. Regarding the first selection criterion (access to spatial data), an effort was done to ensure that only open access databases were included in this review, either by direct download from database repositories (e.g. http://data.unep-wcmc.org/) or downloadable after a form completion (e.g. http://www.marineregions.org/downloads.php). The second selection criterion was related with the spatial coverage of the databases, where the listed links were classified into geographical ranges: local (e.g. http://www.mareano.no), national (e.g. http://atlas.marine.ie), regional (e.g. http://metadata.helcom.fi/geonetwork), European (e.g. http://www.emodnet-seabedhabitats.eu), or even global (e.g. https://podaac-tools.jpl.nasa.gov/soto) databases. Finally, the last selection criterion related to the ability to work the data, which allowed to categorize the databases into four classes: 1) geodatabase, 2) tool, 3) file server, and 4) non-spatial data. Geodatabases and non-spatial data were further divided according to the format in which the information was presented: raster files, shapefiles, viewer tools, images, or CVS, Klm and pdf extensions.

Given the objective to assess the availability and quality of data that could be used to map European marine ecosystem services, only the geodatabases and non-spatial databases were considered for a next screening step. These databases were then classified into five categories: 1) Biodiversity (species, traits, biomass, community and indexes), 2) Environment (climate, water quality, geophysical, environmental quality and habitat), 3) Administrative (limits of scientific, administrative and protected areas), 4) Social (human population impact), and 5) Economic (tourism, energy, fisheries, ports and transport and metallic and non-metallic production). Variables within each category were further explained in terms of i) units of measurement (qualitative categories, quantitative specific variable unit), ii) temporal availability (years of available information), iii) updating frequency (daily, weekly, monthly, yearly, once) iv) spatial resolution (Km, dots, country, pixel), v) biogenic habitat (seagrass, reefs, saltmarsh, mangrove, kelp forest), vi) vertical stratum (surface water, deep water, seabed), and, finally, vii) coordinate system (presence/absence).

The metadata description of the considered variables was also considered, taking into account the i) source of information (academic, government, international agency, NGO/Citizen), ii) data gathering methodology (in situ monitoring, satellite) iii) data conversion requirement (yes/no)), iv) data access (direct, required by form) v) data analysis (descriptive, predictive, both), vi) database creation and vii) metadata explanation. For the latter, three criteria were considered: 1) legends clarity, 2) published papers with clear methodology explaining the database, and 3) instructions about how to use the georeferenced database or how to manage the information. If the database met at least two of those requirements it was considered good; if the database met only one of these characteristics it was considered regular;

and the non-clear accomplishment of the above characteristics classified the database as non-suitable.

Focusing only on the applicable databases (raster files, shapefiles, CVS and Klm extensions), which allow for further analysis using a GIS software, a further analysis was undertaken, establishing the relationships between those databases variables with the i) CICES framework for costal and marine ecosystem services classification, ii) DPSIR framework categories, and iii) Good Environmental Status (GES) descriptors under the European MSFD context. This correspondence aimed to infer which databases could be used to inform regulations and frameworks at the European level. The establishment of the links were based on papers review related with ecosystem services indicators (e.g. Maes et al., 2012, 2016; Liquete et al., 2013), proxies to DPSIR framework analysis (e.g. Atkins et al., 2011; Pinto et al., 2013a) and suggested indicators to evaluate the Good Environmental Status mentioned in the MSFD (e.g. Broszeit et al., 2017).

Results

Spatial databases usefulness to map coastal and marine ecosystem services

From the initial categorization of studies, a total of 581 databases were listed: 545 geodatabases, 1 non-spatial database, 32 file servers, and 3 tools (Figure II.1). File servers (e.g. FishBase, http://fishbase.org/) and tools (e.g. Know seas, https://bit.ly/32wyHUh) were discarded from the next steps since they do not contribute directly with data about marine ecosystems. The file servers offer mainly lists of links to complementary information or data that has already been included in primary geodatabases, while the tools offer platforms to visualize maps through the input of external information sources. The remaining 546 databases (545 geodatabases and 1 non-spatial database) varied greatly in geographical scale covered: 157 databases have global scale, 126 European, 46 regional, 46 bi-national or tri-national, 152 national, and 19 local. These databases were further categorised in two main groups according to their ability to be applicable or not in a GIS software. From here, 374 databases (68%) have potential to be worked in a GIS software (hereafter applicable), while 172 (32%) are viewer tools or figures (hereafter non-applicable).

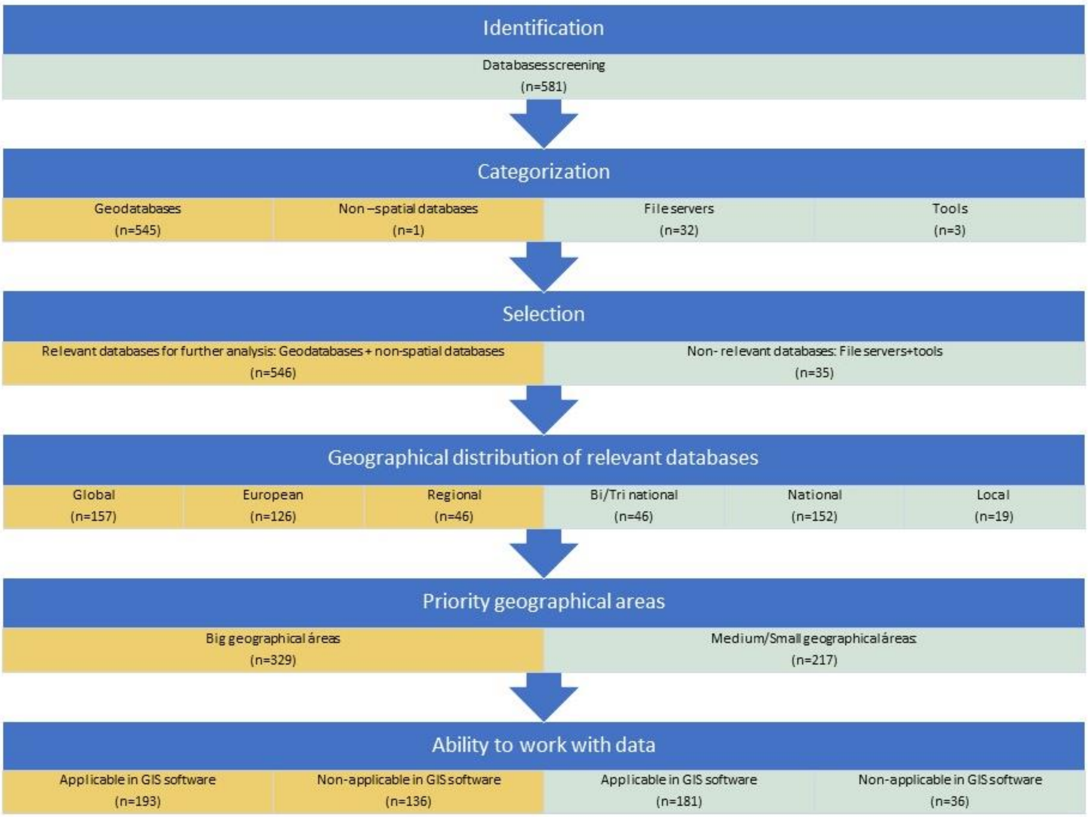
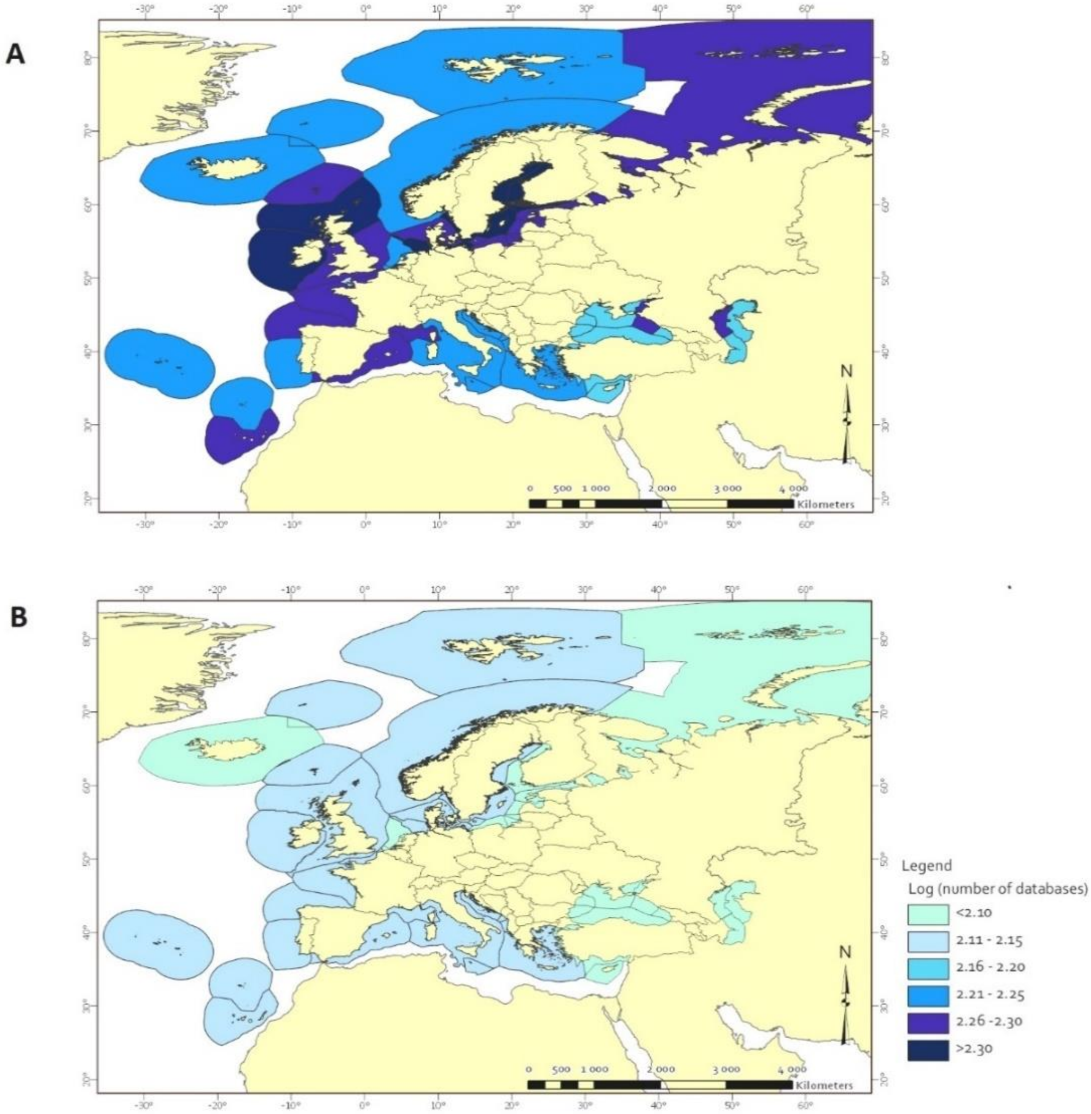


Figure II.1. Diagram of the selection process used in the databases review.

A comparison of the number of databases by European countries, with (Figure II. 2A) and without (Figure II. 2B) ability to be worked in a GIS software, also revealed the predominance of databases that allow incorporation in ecosystem services mapping exercises (e.g. Scotland, Ireland and some Baltic countries; Figure II.2A). Another finding is related to the existing differences among European countries regarding the total number of databases available. In general, the United Kingdom, Ireland and West Baltic countries present a higher number of databases, while the North Black Sea and East Baltic countries show fewer available databases (Figure II.2).



FigureI II. 2. Number of applicable (A) and non-applicable (B) open source spatial databases by Economic Important Zone (EEZ) in European countries.

To ensure a reliable comparison among databases, local, national and few countries databases were discarded, resulting in the analysis of 329 databases that covered regional (e.g. Baltic Sea), European and global scales (Figure II.3). The selected databases were, in a first step, divided into applicable or non-applicable, according to their ability to be worked on a GIS software. A total of 193 spatial databases were considered as applicable (45% raster files, 41% shapefiles, 8% CVS, and 6% Klm), while 136 spatial datasets were classified as non-applicable (71% viewer tools, 28% images, and 1% pdf bases).

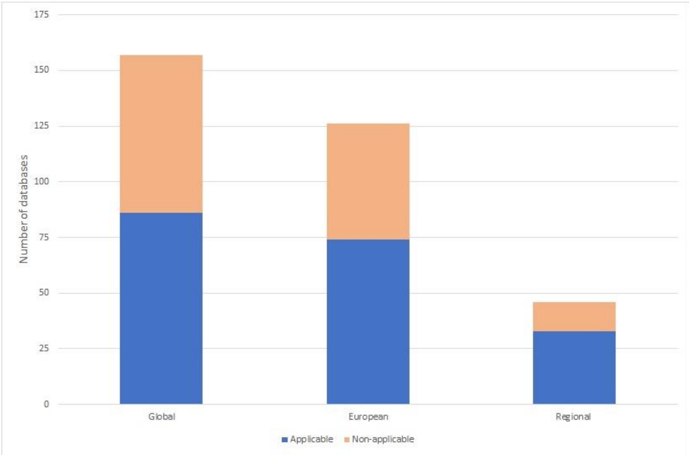


Figure II.3. Number of applicable and non-applicable databases by regional, European and global geographic coverage.

The 329 selected databases were further described according to the five categories of information and their ability to be applicable in a GIS software, allowing to verify that 59 databases were linked to biodiversity, 199 databases were related to environmental variables, 28 databases were about administrative variables, 3 databases concerned social variables and 40 databases covered economic activities. A further analysis revealed that as the spatial resolution increases, there is a reduction in the number of spatial databases that allow the data to be applicable in a GIS software: at the regional scale 72% of the databases are applicable, at the European scale this number reduces to 59%, while at the global scale 55% are applicable (Figure II.4).

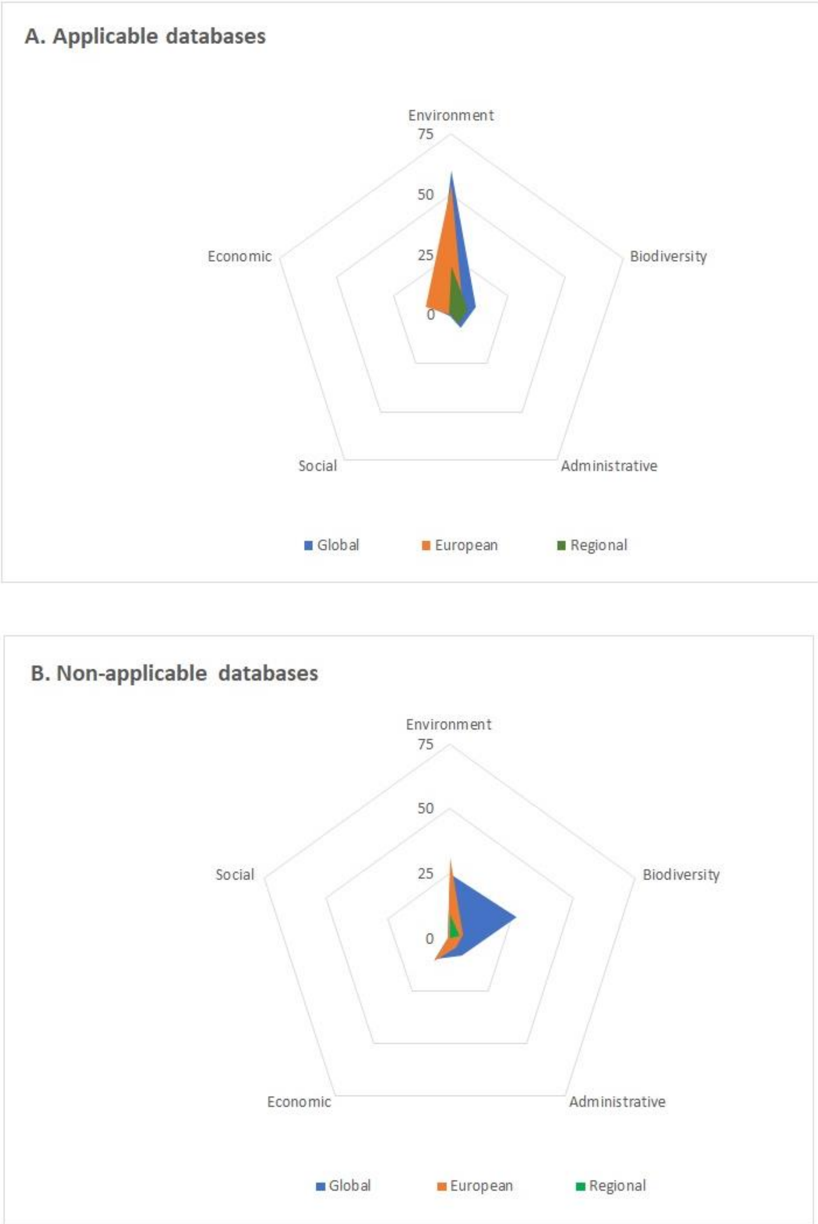


Figure II.4. Distribution of applicable (A) and non-applicable (B) databases by geographic coverage and potential utility in mapping exercises of ecosystem services.

These spatial databases were then classified according to the type of information conveyed (Figure II.5): i) biodiversity (of which 39% are applicable databases), ii) environment (with 67% applicable databases), iii) administrative (of which 57% are applicable databases), iv) social (of which 33% are applicable databases), and v) economic (of which 48% are applicable databases).

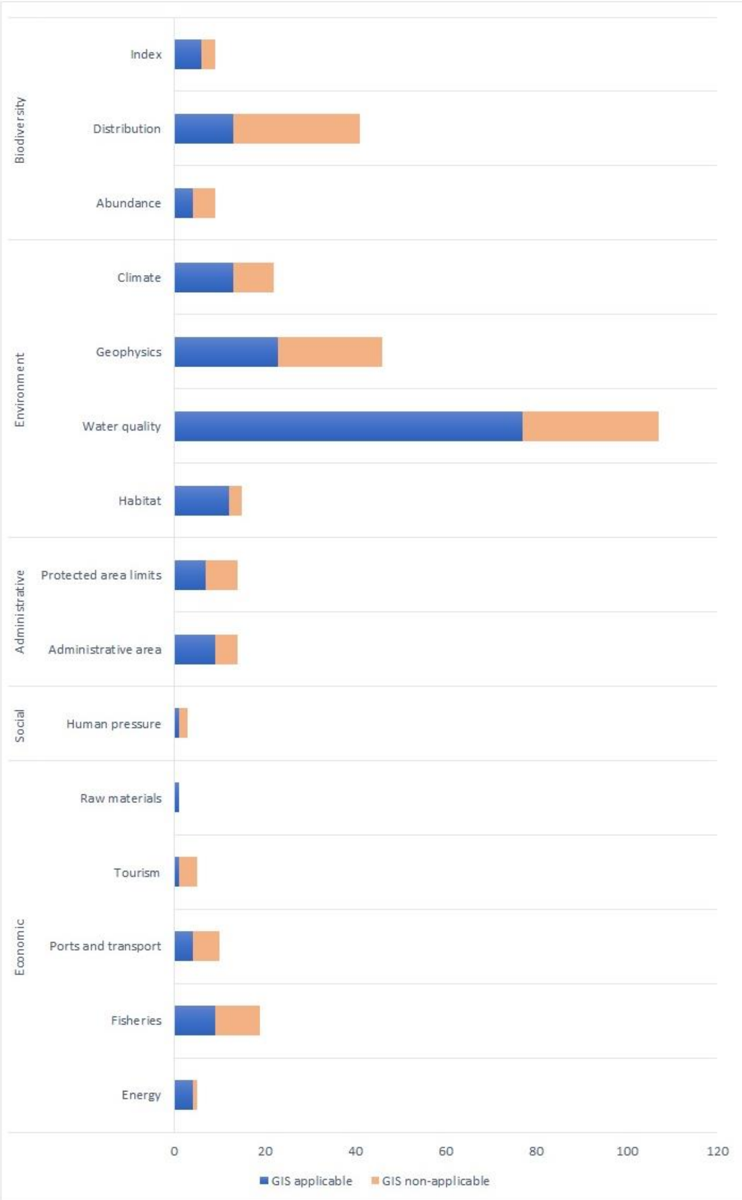


Figure II. 5. Categories of Databases sub-grouped by their main descriptors with potential or not to be used in a GIS Software.

The selected databases were then evaluated according to the established criteria: units of measurement, temporal availability, updating frequency, spatial resolution, biogenic habitat, vertical stratum and presence or absence of coordinate system (Table II.1). It is important to note that 46% of the available information is qualitative and 54% quantitative. Biodiversity and administrative variables are presented mostly as qualitative information (78% and 100%, respectively), while environmental variables are mostly reported as quantitative values (78%). Considering the temporal availability, only 22% of the databases offer information for more than 5 years and 75% of the databases were created but lack further updating. Taking into account the spatial resolution, 51% of the information is represented by data with resolution up to 10 Km (mainly applicable environmental data), while 21% of the information is represented by dots. Regarding the vertical stratum, 64% of the databases cover both surface and deep waters, and 25% cover just surface waters. From these, only 3% includes information explicitly related to one of the five biogenic habitats (Table II.1). Other remarkable findings are related to the fact that 57% of the information did not mention a well-defined coordinate system.

Table II.1. Characteristics used for the comparison and assessment of available spatial data to map marine databases.

		Biodiversity		**Environment**		**Administrative**		**Social**		**Economic**	
		Applicable	Non-applicable	Applicable	Non-applicable	Applicable	Non-applicable	Applicable	Non-applicable	Applicable	Non-applicable
Units of measurement	Qualitative (e.g. presence/absence)	18	27	30	21	16	12	0	0	11	8
	Quantitative (e.g. abundance)	5	9	104	44	0	0	1	2	8	13
Temporal availability	1 year	16	25	58	41	16	9	0	1	10	10
	2 - 5 years	2	3	42	4	0	0	1	0	4	1
	> 5 years	3	6	30	17	0	3	0	0	5	9
Updating frequency	Mean information	2	2	4	3	0	0	0	1	0	1
	Never	19	32	87	53	16	12	1	2	14	12
	Daily	0	0	18	6	0	0	0	0	0	0
	Biweekly	1	0	4	0	0	0	0	0	0	0
	Monthly	0	0	5	1	0	0	0	0	0	1
	Yearly	3	4	20	5	0	0	0	0	5	8
Spatial resolution	0-10 Km	14	1	99	30	8	0	1	0	9	6
	11-150 Km	5	11	6	8	0	2	0	0	0	0
	Dots	1	12	18	16	4	3	0	1	7	8
	Country	0	2	0	3	1	6	0	1	0	4
	No clearly determined	3	10	11	8	3	1	0	0	3	3
Biogenic habitat	Seagrass	1	1	0	0	0	0	0	0	0	0
	Reefs coral	1	3	0	0	0	0	0	0	0	0
	Saltmarsh	1	1	0	0	0	0	0	0	0	0
	Mangrove	1	1	0	0	0	0	0	0	0	0
	Kelp forest	0	1	0	0	0	0	0	0	0	0
	Not mentioned	19	29	134	65	16	12	1	2	19	21
Vertical Stratum	Surface water	0	3	43	18	2	1	0	1	3	11
	Deep waters	0	2	0	3	0	0	0	0	0	1
	Surface and Deep waters	23	30	78	30	14	11	0	1	15	9
	Seabed	0	1	2	5	0	0	0	0	0	0
	Not applicable	0	0	11	9	0	0	1	0	1	0
Coordinate system	Presence	19	0	87	7	12	0	1	0	15	0
	Absence	4	36	47	58	4	12	0	2	4	21

The databases were also described according to the source of information, methodology applied in data gathering, conversion requirements and the easiness to access and understand the underlying data. Likewise, it was determined the type of spatial analysis performed and the date of database creation (Table II. 2). Academic sources provide 77% of the gathered information, including academic research projects, 21% of the information is generated by governmental organizations (e.g. NASA and EEA) and only 2% come from NGO or citizen initiatives. Most of the information (65%) come from *in situ* monitoring and modelled or interpreted information, and 35% come from satellite images. Access, and download, of the databases can be done directly in 88% of the cases, with only 12% requiring the filling of an access form. In addition, 94% of the information can be used directly and the remaining 6% need data conversion to be usable.

Most of databases are descriptive (93%), and a limited number of databases (2%) present scenarios analysis. In relation to the ability to understand the information, 52% of the databases offer good and understandable metadata overview, 35% are reasonably understandable and 13% do not provide enough metadata information. Finally, 74% of the considered spatial databases were created after 2010, 14% between 2000 and 2010, and 12% were created before 2000.

Table II.2. Data source information, according to the type of information provided and categorised as applicable or non-applicable in a GIS software.

		Biodiversity		Environment		Administrative		Social		Economic	
		Applicable	Non-applicable	Applicable	Non-applicable	Applicable	Non-applicable	Applicable	Non-applicable	Applicable	Non-applicable
Source of information	Academic	5	34	109	49	12	12	1	1	16	14
	Government International Agency	18	2	24	15	4	0	0	1	2	5
	NGO/ Citizen	0	0	1	1	0	0	0	0	1	2
Data gathering methodology	Monitoring/modelled	23	36	64	22	16	12	1	2	18	20
	Satellite	0	0	70	43	0	0	0	0	1	1
Data conversion requirement	Yes	1	0	18	0	0	0	0	0	0	0
	No	22	36	116	65	16	12	1	2	19	21
Data access	Direct	22	36	99	64	12	12	1	2	19	21
	Required by form	1	0	35	1	4	0	0	0	0	0
Metadata explanation	Good	19	11	86	30	9	1	0	2	8	6
	Regular	4	17	43	17	6	8	1	0	10	9
	Bad	0	8	5	18	1	3	0	0	1	6
Type of spatial analysis	Descriptive	23	35	117	59	16	12	1	2	19	21
	Predictive	0	0	0	5	0	0	0	0	0	0
	Both	0	1	17	1	0	0	0	0	0	0
Database creation	1980-1990	3	1	13	1	3	0	0	0	1	0
	1991-2000	1	1	2	4	0	0	0	0	1	7
	2001-2010	5	4	20	7	7	1	0	1	1	1
	2011-present	14	30	99	53	6	11	1	1	16	13

Spatial databases: applicable databases

This section only covers the databases classified as applicable in a GIS software (193 databases). A special focus was given to these spatial databases due to their ability to be used to map ecosystem services in coastal and marine systems under the context of European directives, such as the MSFD (Appendix A: Table A.1 Applicable databases analysis)

In a first step, the relations between the databases and the CICES framework for ecosystem services classification were established. According to this analysis, 42% of the databases have potential to map regulation services, 33% can be used to map provision services, 21% are related with cultural services and 4% do not present a direct correspondence with any ecosystem services category (e.g. border areas) (Figure II.6). Both regulation and provision ecosystem services can be mapped with 33% of the databases, especially those that offer information about productivity, pH, dissolved oxygen and species distribution (mainly commercial species). All ecosystem services sections (provisioning, regulation and cultural) could be mapped with 13% of databases. The selected databases also provide useful information to map the maintenance of habitats conditions, storing and cycling of nutrients, climate regulation and natural hazard protection.

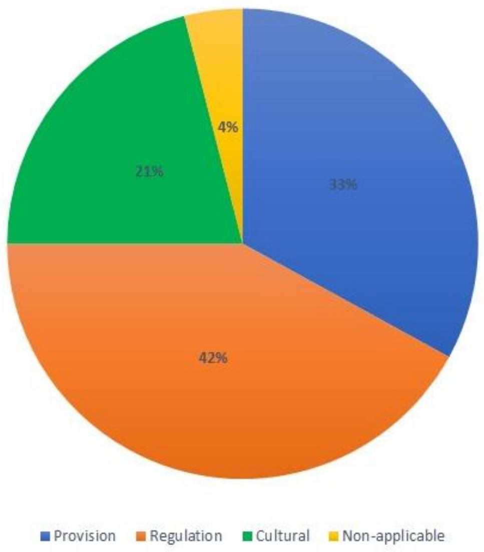


Figure II.6. Relation of Databases with ecosystem services division according CICES.

A second step was performed to establish the utility of the databases to potential mapping exercises of coastal and marine management actions under the DPSIR framework. This analysis shows that 66% of the databases are related with descriptors of ecosystems status, while 18% are useful to monitor pressures, 8% are linked to drivers and only 4% are related with both impact and response variables (Figure II.7).

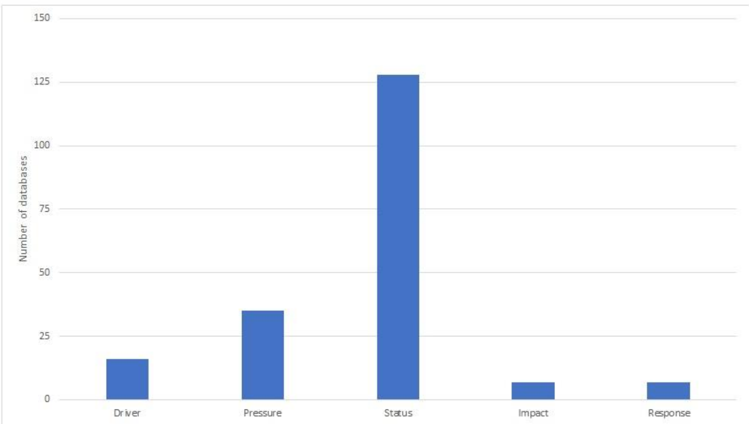


Figure II.7. Relation between number of databases and DPSIR framework descriptors.

Finally, in a third step, the same exercise was performed relating the databases with the descriptions of Good Ecological Status (GES) considered in the EU MSFD (Figure II.8). Most of the applicable databases are related to descriptors 7 (Hydrographical conditions: 29%) and 5 (Eutrophication: 21%), followed by descriptors 1 (Biodiversity: 19%), 8 (Concentration of contaminants: 5%), 10 (Marine litter: 5%), 11 (Introduction of energy: 5%), 6 (Sea-floor integrity: 4%), 4 (Food webs: 4%), and finally descriptors 9 (Contaminants in seafood: 2%) and 2 (Non-indigenous species: 1%).

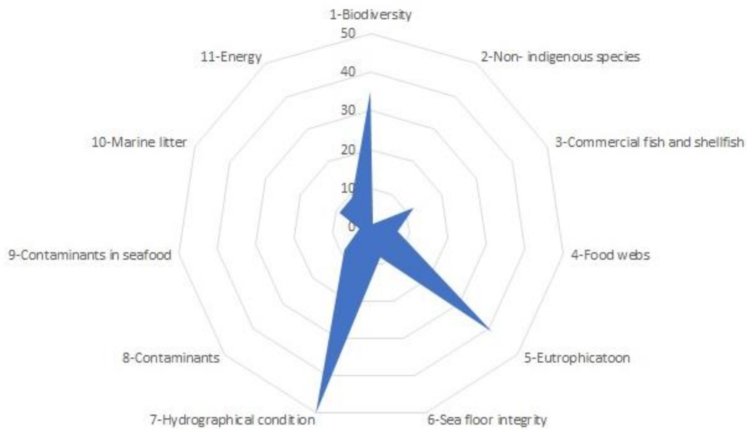


Figure II.8. Number of databases related with Good Ecological Status (GES) descriptors.

Discussion

Oceans provide 43% of global ecosystem services (Levrel et al., 2014). However, coastal and marine ecosystems are increasingly subjected to, and threatened by, a wide array of anthropogenic stressors (Singh et al., 2017) such as overpopulation (Rao et al., 2015) or intense human activities (Hawkins and Popper, 2017). Therefore, it becomes crucial to facilitate the flow of information from academics to policy-makers and practitioners (Drakou et al., 2015) to address critical scientific questions and help to develop new policies aiming at the sustainable management of coastal and marine ecosystem services (Burkhard et al., 2012; Martinez-Harms and Balvanera, 2012; Townsend et al., 2014).

The mapping of coastal and marine ecosystem services has been suggested as an important tool to facilitate the communication and convey the information between scientists and decision-makers (Burkhard et al., 2012; Maes et al., 2012). In Europe some efforts to map marine ecosystem services have been developed by the European Group of Mapping and Assessment of Ecosystems and their Services (MAES) as a method to monitor the European environmental politics application (Maes et al., 2016). Despite the wide offer on marine environmental data, from several sources, some authors claim that there is still a lack of user-friendly and high-resolution global datasets to attain this goal, mainly driven by the difficult and costly data gathering (e.g. Tyberghein et al., 2012). Similar findings were observed in this review where from the initial 581 open-source databases, only 193 proved to be useful to be incorporated in a GIS software to map ecosystem services. This result recalls the first challenge mentioned in the introduction regarding the insufficient qualitative and quantitative information to describe all the dimensions of marine ecosystems.

The geographical coverage of the databases allowed to recognize the existence of many databases with local, national and few countries information (40% of the total databases: both applicable and non-applicable in GIS software). Most of this information is currently scattered, which makes their use and integration on higher spatial scales analysis difficult. This finding, related to the second challenge, previously mentioned, is also in accordance with previous studies which stated that the national scale is the most common geographical scale addressed in mapping exercises (Martínez-Harms and Balvanera, 2012). One way to prevent the loss of data from small geographical areas can be done through its integration into major databases repositories. This integration will then contribute to the process of decision-making, which is not always at the same scale (Hauck et al., 2013). For example, the Mareano website (http://www.mareano.no/kart/mareano_en.html?language=en) offers information on critical reef coral area in Norway which could be integrated or linked to a more complete database focused on the North Sea. Other interesting example of information integration is offered by Baltic Marine Environment Protection Commission - Helsinki Commission (HELCOM; http://www.helcom.fi/baltic-sea-trends/data-maps), which facilitates the finding of spatial information useful for mapping exercises.

Despite the existence of a significant number of databases with a spatial scale equal or higher than the regional level (329 out of 581), 41% of this information does not offer the possibility of integration into maps. Nevertheless, they can be useful to visualize patterns and offer insights into the state of marine ecosystems. Most of this information comes from research projects or some private initiatives that offer interesting data, which utility could improve if this information could be converted into spatially explicit data.

The main problems related to mapping of coastal and marine ecosystem services seems to be related with the lack of geo-referenced data with enough resolution (Liquete et al., 2013; Lavorel et al., 2017) and the scarcity of quantitative studies about marine ecosystem (Levrel et al., 2014). Consequently, most of the information found, excluding the environmental variables, is qualitative (e.g. presence/absence or class value gradient). These result are in line with previous studies (e.g. Lillebø et al., 2016), which show that most of the ecosystem services information is available in more qualitative terms rather than quantitative data. Academic initiatives provided 77% of the analysed databases, most of which were created after 2010, coinciding with the implementation of European policies such as the EU Marine Strategy Framework Directive (MSFD; EC, 2008) and Biodiversity Strategy (EC, 2011).

Previous studies have revealed the existence of sources of uncertainties that can impair coastal and marine ecosystem services mapping. Among the most common problems are the lack of consistency in the definition of ecosystem services indicators and the incomplete understanding and quantification of the socio-economic pressures (Schulp et al., 2014). From the databases evaluation was possible to see that environmental variables, which represent 66% of the applicable databases play a crucial role in the understanding of marine processes. McHenry et al. (2017), for example, revealed that this data could explain a significant portion of variance (37-59%) in benthic species composition and on the distribution of many marine species. Likewise, the temperature on the sea surface has demonstrated to have a high correlation with diversity (Tittensor et al., 2010). Environmental variables such as pH, salinity, wind, clouds, upwelling and dissolved oxygen have proved to be interesting to map fisheries related services (Brander, 2013). Other important variable, which has been studied recently, is the colour of the ocean which gives information about phytoplankton production estimates from surface chlorophyll *a* concentrations through a productivity model (Brewin et al., 2017).

Mapping marine biodiversity is operationally difficult and costly in Europe due the limitations of the current technology (Fraschetti et al., 2008) and some proxies are used to enhance the information on species distribution mapping (Coll et al., 2012), considering essentially marine mammals, marine turtles, seabirds, fishes and commercial invertebrates, as well as large predators (e.g. http://data.unep-wcmc.org/). This process has also resulted in the important mapping of the distribution of threatened or endangered species (Tittensor et al., 2010) and alien species (Beauchard et al., 2014). Other proxies used are biological traits, to link species composition and ecological functions (Mumby et al., 2008; Frid, 2011), benthic macrofauna as food source to other species (Šiaulys et al., 2012), and toxicity to evaluate contamination levels in sediments (Blasco et al., 2015). Biogenic habitats have also been used to map the provision of ecosystem services, namely mangroves (Hutchison et al., 2014), seagrasses (Pu and Bell, 2017), coral reefs (Mumby et al., 2008), estuaries (Liekens et al., 2013), and wetlands (Spencer et al., 2016). Regarding these proxies, only 3% of the applicable databases are directly associated with biogenic habitats. To ensure the accurate assessment of coastal and marine ecosystems, it is recommendable that future monitoring efforts include this type of information in their data provision.

Considering biodiversity, efforts have been conducted to accurately map zones with high biodiversity, using for example number of species (Davis and Darling, 2017) and biomass (Fu et al., 2015) and to prioritize management actions (e.g. Naidoo et al., 2008). There is, however, the need to update and improve databases related with proxies of biodiversity indices or biomass, especially if a sustainable management of provision resources is aimed (e.g. biomass data of commercial species). Among the economic variables, should be highlighted the fisheries production and its economic impact (Pauly, 2007; Townsend et al., 2014), being the FAO data (http://www.fao.org/fishery/topic/16110/en) one of the major information sources used so far (Egoh et al., 2012). However, the databases analysis in this study allowed to observe that there is still not enough information related to economic variables as fisheries, energy and mineral extraction in European seas, and there is still some challenges on how to incorporate the available information into spatially explicit databases. Also, it is necessary to increase the information linked with tourism activities on coastal and marine ecosystems (e.g. dive centres activities) and the impact of those activities on the ecosystems. The administrative variables were represented by databases related to establishment of borders for management, economic activities, and research (e.g. marine regions under the MSFD, https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions-1).

This study also revealed that the information related to social variables is still very limited. These variables require an increase of the availability of information related with coastal populations, as well as more information related with the accessibility to beaches, localization of cultural sites and scenic beauty values (Parravicini et al., 2012).

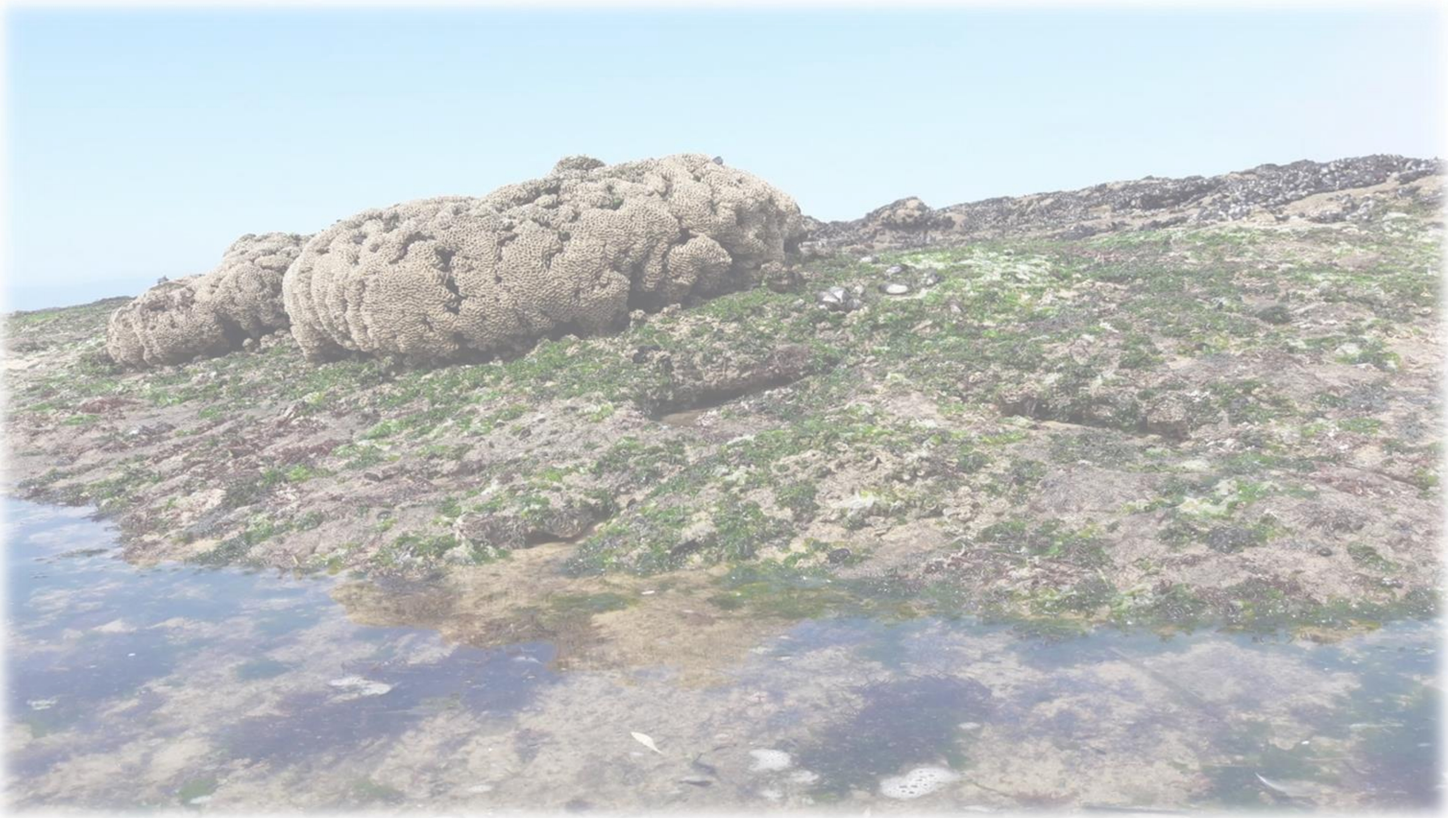
Regarding the ecosystem services classes, ecosystem services proxies for regulation and maintenance are the most common (42%), especially those linked with carbon sequestration, habitat maintenance (e.g. water purification) and coastal protection. These findings are in accordance with previous studies that presented similar results (e.g. Martínez-Harms and Balvanera, 2012; Rioja-Nieto et al., 2017). The second most common group of proxies are related with provision services (33%), especially variables related with fisheries (Deutsch et al., 2007), energy generation and materials extraction (Hattam et al., 2015). Nevertheless, it is necessary to reinforce that this data is mainly related with direct measurements of fish production and raw materials extraction (Lillebø et al., 2016). Finally, cultural services proxies represent just 21% of the analysed databases. These spatial proxies can be used in combination with habitat maps to estimate, for example, ecosystem services values for recreational fisheries (O'Higgins et al., 2010), to determinate preferences stakeholders' values for marine ecosystems (Halpern et al., 2012) , or even educational or recreational opportunities in marine ecosystems (Lillebø et al., 2016). To accomplish this becomes necessary to include more social data in maps, making an effort to add a participatory component in their elaboration (Brown et al., 2014; Thiault, et al., 2017).

The dynamic of marine ecosystems create ambiguity in the definition of boundaries and also in the identification of the existing associations between species and their habitats, especially in pelagic environments where data is often scarce (Roberson et al., 2017). From this study is possible to see that there are already some advances in the gathering this information. The Environmental Marine Information System (http://mcc.jrc.ec.europa.eu/emis/) or EMODnet (http://www.emodnet.eu/) are two examples of data repositories that can be used to map ecosystem services.. Similarly, the EUNIS habitat map (http://www.emodnet-seabedhabitats.eu/) also revealed to be very effective to map ecosystem services according to habitat characteristics (e.g. Fletcher et al., 2011; Galparsoro et al., 2014).

Another important challenge in marine ecosystem services mapping is the current technological limitation (Hamel and Andréfouët, 2010). Although remote sensing offers a great opportunity to collect spatial information about marine ecosystems (e.g. NASA, https://oceancolor.gsfc.nasa.gov/), it should be highlighted the importance of reinforcing *in situ* monitoring to allow the validation of remote sensing data. Another limitation found in this study is related to the lack of good metadata explanations. This becomes especially relevant when ensuring the accurate and reliable use of these databases by end-users.

Conclusions

Coastal and marine ecosystem services maps can serve as a tool to better communicate the pressures and status of these systems at different geographical scales. These exercises can also help to guide decision-making processes regarding marine spatial planning and to monitor advances in the implementation of regulatory measures, such as the EU MSFD. However, the creation of and accessibility to spatial databases can be hindered by the associated cost of data gathering and information scarcity. This study aims to identify the main challenges and gaps encountered when mapping coastal and marine ecosystem services by analyzing 581 open source databases that could potentially be used in these exercises. The findings gathered with this study allowed to see that approximately half of the information made accessible does not allow to work the data in a spatially explicit matter. From the 329 spatial databases (excluding file servers, tools and local or national databases from the original list), 59% allow further incorporation in a GIS software and inclusion in marine ecosystem services mapping. The obtained findings also revealed that even for these applicable databases, the type of information given can be unequally distributed when considering the main ecosystem services classes, with 42% of the spatial databases being related to regulation services, followed by provision services (33%), and lastly cultural services (21%). The same pattern is observed for databases associated with the DPSIR framework classes and MSFD GES descriptors. Still, several databases were identified as having enough quality to contribute to the mapping of coastal and marine ecosystem services in European seas, highlighting databases related with habitats description, such as EMODNET SEA habitats (http://www.emodnet.eu/seabed-habitats), and databases with environmental indicators water quality indicators, such as pH and salinity (e.g. HELCOM or Global Marine Environment Datasets). From the undertaken database analyses, is important to highlight the need for consensus related to the selection of indicators to monitor the MSFD GES descriptors, and to present a set of indicators that can be used under the DPSIR framework. Another key aspect that should be reinforced in future works is to ensure clear and comprehensive spatial metadata. Information such as depth (benthic or pelagic information), geographical scale, coordinate system used, units considered, databases creation dates, or even clear legends to allow the correct information interpretation. This metadata is often missing or not easily accessed, playing a crucial role to guarantee accurate and reliable coastal and marine ecosystem services mapping.



CHAPTER III: Identifying ecosystem services research hotspots to illustrate the importance of site-specific research: An Atlantic coastal region case study

Abstract

The mismatch between the conceptual understanding of the Ecosystem Services (ES) in science, and their practical application, remains. Among the many issues under discussion is the link between knowledge and implementation. Base knowledge built over cases studies exist, but their usefulness for site-specific management purposes is limited. The goal of this work is to illustrate how gap analysis at the local level may contribute to the development of ES research and knowledge transfer. A review of coastal ES was performed, based on peer-reviewed journals, grey literature and other sources, allocating the information per European Nature Information System aquatic habitat coupled with the Common International Classification of Ecosystem Services. Then, a multicriteria decision-making approach was applied to find ES research hotspots, i.e., habitats for which ES research should be prioritized. Three criteria were used: abundance of ES, evidence for the supply of ES, and strength of evidence. The criteria were considered suitable for coastal areas where profound gaps in ES research exist. The Atlantic coastal region adjacent to the Mondego River was used as case study. 231 current and potential ES were listed and mapped for 21 coastal habitats. Cultural services arose as the dominant category. Saltworks emerged as the most recommended habitat for ES research. Results are in accordance with local decision-makers trends of management; we consider the approach to be appropriate as a first step towards the operationalisation of the ES concept and flexible enough to be readapted to focus on critical questions that characterize ES research.

Keywords: Analytic Hierarchy Process, CICES, Decision-making, EUNIS habitats, Multicriteria, Mondego River, Western Iberia

Introduction

Ecosystem Services, i.e., the final outcomes of the internal structures, processes and functions, derived from ecosystems, that fulfil social demands, sustaining and enhancing human wellbeing (Müller et al., 2000; Martinez-Harms et al., 2015; Potschin – Young et al., 2018), are an increasingly used concept (Hamel and Bryant, 2017), mainly due to its potential to link the functioning of ecosystems to human welfare (Fisher et al., 2009). The concept allows building a bridge between economy, ecology and social sciences to communicate the way ecosystems underpin human existence (Keenan et al., 2019), and has thus become a crucial topic incorporated in a broad range of decision – making processes (Fisher et al., 2009).

Efforts have been made to operationalize the Ecosystem Services (ES) concept (European Commission, 2011; Potschin et al., 2014; Donovan et al., 2015;), but the mismatch between the considerable conceptual understanding of the concept in science, and the limited practical application thereof, remains (Díaz et al., 2015; Saarikoski et al., 2018). Operationalisation is "the process by which concepts are made usable by decision makers" (Potschin et al., 2014). This discussion has several strands that can be generally summarized into: (1) need for a common understanding; (2) role of institutions; (3) linking knowledge to implementation; (4) best practice for action (Carmen et al., 2018; Jax et al., 2018; Saarikoski et al., 2018; Lautenbach et al., 2019;). The current work is focused on the available knowledge on ES for pratical implementation of the concept.

Successful knowledge transfer from ES case studies to decision-making processes relies on a significant base knowledge regarding the socio-ecological interrelationships between ecosystems, the benefits society retrieves from the natural capital and human activities and its pressures in the considered area (Lautenbach et al., 2019). Several initiatives aim at providing such a base knowledge (e.g. TEEB, 2010; ELD, 2014; IPBES, 2019; WAVES, https://www.wavespartnership.org/2019) to support high-level policy frameworks, such as the Convention on Biological Diversity[5] and the EU Biodiversity Strategy[6]. But at the local level, leaning on existing databases may lead to unfitted data collection processes, which in turn may lead to additional costs and highly uncertain results (Gómez-Baggethun and Barton, 2013; Jax et al., 2018). As such, at the local level, a clear problem definition and pathways for solution should be framed towards an effective and efficient way of applying the ES concept in a useful manner (Wittmer and Gundimedia, 2012).

Within this process, the contribution of a multistakeholder team is essential to tackle the environmental, social, institutional, economic and cultural issues of these usually complex problems (Jax et al., 2018). Researchers play an important role by identifying problems and partially supporting future work based on previous research (Jax et al., 2018).

The purpose of this work is to illustrate how gap analysis at the local level may contribute to the development of ES research and ultimately to knowledge transfer. To do so, a multicriteria decision-making approach is applied to find those habitats for which research should be prioritized. We assume that prioritizing research will support the delivery of the most relevant ES information for decision-makers (Wright et al., 2017), supporting policy development (McKenzie et al., 2014) and/or allowing the evaluation of alternative policy options (Laurans et al., 2013).

The Atlantic coastal region adjacent to the Mondego River has been selected for a case study. In this region, decision-makers have been struggling to apply an ecosystem approach to foster social and economic growth while guaranteeing the functioning of local ecosystems (Teixeira et al., 2018). The ES concept may have a key role to play in the further development and the functional orientation of such a strategy as it provides knowledge and a rational basis for management decisions (De Lucia, 2018). Despite its potential to support policy development (McKenzie et al., 2014) and the evaluation of alternative policy options (Laurans et al., 2013), limited site-specific research applying explicitly the ES concept has been performed (Pinto et al., 2010, 2013a, 2013b, 2014a, 2014b; Teixeira et al., 2018). We expect the current study to unlock the existing void by guiding future research towards habitats that may represent an added value to the region. Ultimately, the upscaling of the current study, and in particular its methodology, to other habitats and coastal systems worldwide, will have the potential to reveal blindspots in ecosystem services research at the global scale (Lautenbach et al., 2019).

Study Area

The coastal region adjacent to the Mondego River lies at the centre of mainland Portugal, in the Atlantic east coast. The Mondego is the longest river located exclusively on Portuguese territory. It has its source 1425 m above (mean) sea level (a.s.l.) on the northern slopes of the Estrela Mountain Range, the highest mountain range in mainland Portugal. The Mondego River flows for 234 km in a southwestward direction to its mouth into the Atlantic Ocean (Figure 1), next to the town of Figueira da Foz (Western central mainland Portugal). It is a perennial fluvial system with an average annual flow of 79 m^3/s that could increase up to 140 m^3/s in rainy years and drop up to 27 m^3/s in dry years (Teixeira et al., 2008). In the Lower Mondego, located downstream of Coimbra, the river valley has several fluvial and coastal terraces and an alluvial plain (Cunha et al., 1997a; Ramos et al., 2012), the Holocene alluvium, which comprises fluvial gravels and sands that grade downstream into estuarine sands and muds (Cunha et al., 2006).

The study area encompasses one coastal water body (CWB-1-3) and four transitional water bodies (coded as WB1, WB2, WB-HMWB and WB3), from the Atlantic coastal region adjacent to the Mondego River,as defined by the Water Framework Directive (WFD; EC, 2000; https://sniamb.apambiente.pt) (Figure III.1).

The coastal water body is flanked by two aeolian dune fields, located north of the Serra da Boa Viagem (e.g. Almeida, 1997; Danielsen, 2008) and south of the River Mondego (André, 1996; André et al., 2009). The modern shore platform is associated with a coarse sandy, locally gravelly, beach (e.g., Cunha and Dinis, 1998a).Classified as Mesotidal Exposed Atlantic Coast (Bettencourt et al., 2004), the coastal waters are characterized by high energy hidrodynamics, struck by storms from the North Atlantic, particularly from October to March. The dominant wave direction is from west and northwest and the wave periods are in the range of 8 to 12 seconds and significant heights in the range of 1 to 3 m (Bettencourt et al., 2004).

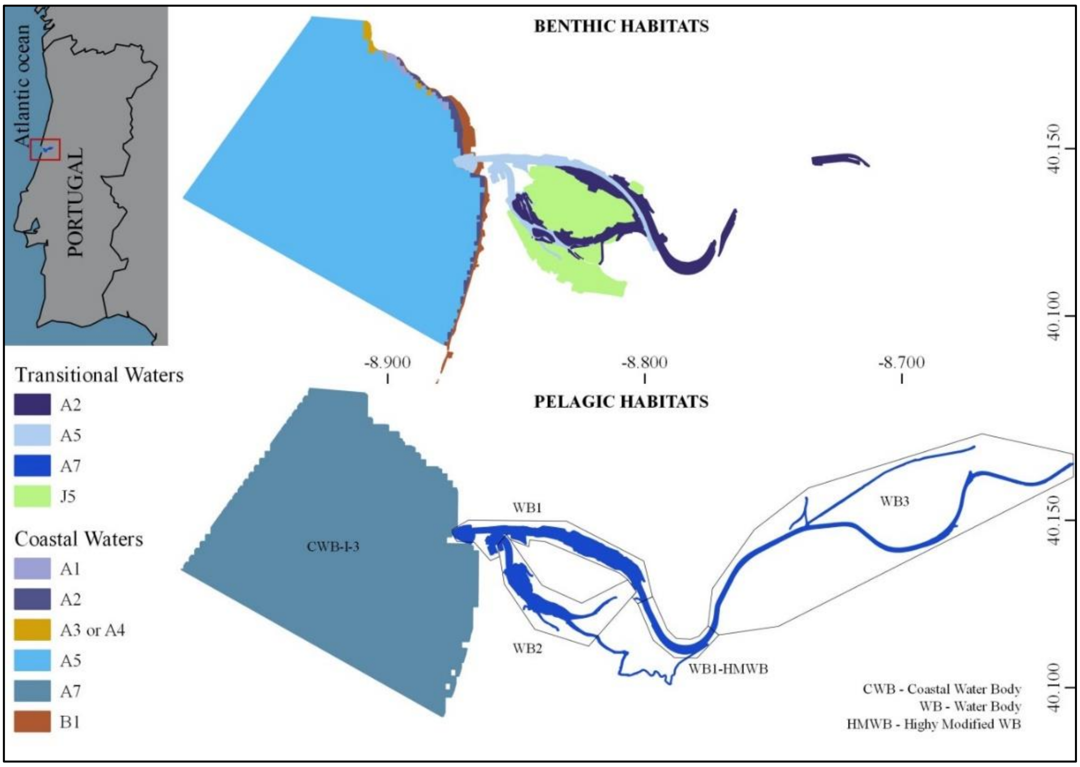


Figure III.1. Map in the upper left shows the location of the study site in the centre of mainland Portugal. The study area is the Atlantic coastal region adjacent to the Mondego River The upper right map shows the benthic habitats, according to EUNIS habitat classification – level 2, for which spatial information was available. The lower map shows the pelagic habitats, according to the EUNIs habitat classification – level 2, for which spatial information was available. A1 - Littoral rocky and other hard substrata; A2 – Sandy littoral; A3 – Infralittoral rocky & other hard substrata; A4 - Circalittoral rocky & other hard substrata; A5 – Sandy sublittoral; A7 – Pelagic water column; B1 – Coastal aeolian dunes and sandy shores; J5 - Highly artificial man-made structures and associated structures

The transitional water bodies that compose the estuary are located c. 26 km downstream the town of Montemor-o-Velho (upper limit of the tide range), totalizing an area of 860 ha. The last 7.5 km of the estuary (the Lower and Middle reaches) are divided into two branches separated by the Morraceira Island (Cunha et al., 1995). The Northern Branch belongs to the Mondego estuary subsystem and the Southern Branch is designated as the Pranto estuary subsystem. The Morraceira island was generated by deposition, fixed by vegetation, and occupied by saltworks (“salinas”) and aquaculture (“fish-farms”) (Cunha et al., 1997b). The Mondego subsystem is deeper (4-10 m during high tide) and characterized by strong salinity changes and the river bed mainly comprises medium to coarse sands (Dinis and Cunha, 1999; Cunha and Dinis, 2002); this Branch is used as the main navigation channel (Marques et al., 1993). The Pranto River subsystem (Southern Branch) is shallower (only 2-4 m depth during high tide) and is characterized by stronger salinity and temperature changes (Dinis and Cunha, 1999; Flindt et al., 1997), and sediments with high percentage of silt and clay (Cunha and Dinis, 2002). During low tide, large areas of intertidal sandflats, mudflats and seagrass meadows are exposed (Cunha and Dinis, 2002; Neto et al., 2008). This polihaline and mesotidal well-mixed estuary, with a tidal variation between 0.35 to 3 m and irregular river discharge (Kenov et al., 2012, Teixeira et al., 2008). Biodiversity in the Mondego Estuary is influenced by seasonal changes and water quality, where salinity (van der Linden et al., 2012), temperature (Ceia et al., 2013; Marques et al., 2018) and sediment texture/composition (Cunha and Dinis, 2002) are determinant for species distribution.

The engineering works carried out in the Figueira da Foz harbour and in the Mondego River drainage basin (damming and fow regulation), mainly since 1960, lead to fast and large scale changes in the dynamics of the Mondego estuary and adjacent coastal area. The sedimentary system responses to artificial sand extraction and mud dredging in the lower estuary were fast. The main impacts of the successive anthropic interventions were (Cunha et al., 1995; Dinis and Cunha, 1998; Baeta et al., 2011): (i) interference with the longshore drift; (ii) increase sand deficit in the coast; (iii) reduction of the tidal prism; (iv) increased upstream penetration of the tide; (v) shoaling and eutrophication of the estuary southern branch; (vi) increase trend to estuarine siltation by marine sediments.

Methodology

Habitats for which ecosystem services’ research should be prioritized were analysed following the methodological steps presented on Figure III.2, which we designated as the SHOT Method - Ecosystem **S**ervices research **HOT**spot . The next subsections explain in detail each stage.

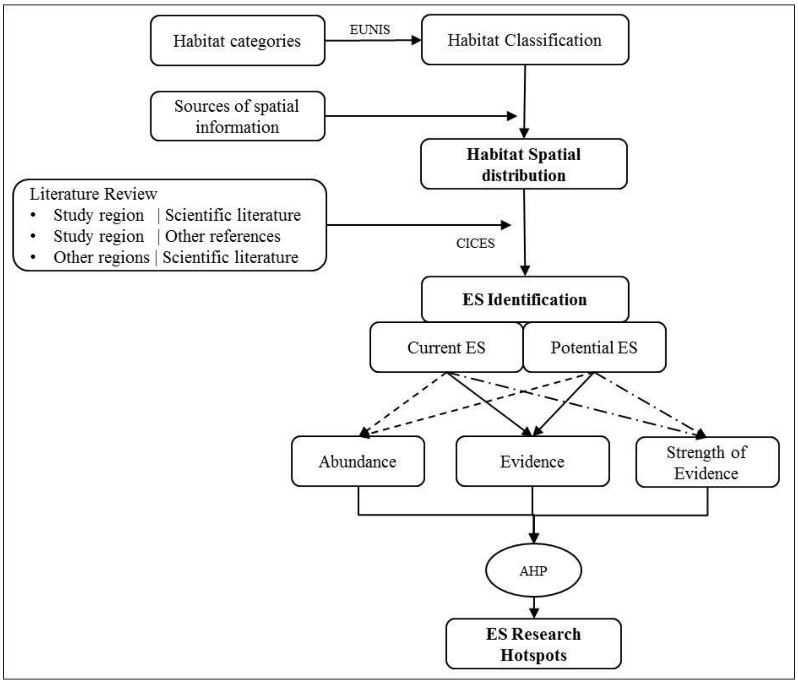


Figure III.2. The SHOT Method - Ecosystem Services Research HOTspot method. Diagram listing the methodological steps to find habitats for which ecosystem services' research should be prioritized. EUNIS - EUNIS habitat classification; CICES - Common International Classification of Ecosystem Services; AHP – Analytic Hierarchy Process.

Habitat spatial distribution

To identify the aquatic ES of the Atlantic coastal area under study, a list of habitat categories was used (Table III.1) and their distribution mapped based on different sources of spatial information (Appendix B. Supplementary tables). A correspondence of these habitats was then established with the EUNIS habitat classification system (Table III.1).

Table III. 1. List of habitats according to the EUNIS habitat classification system and sources of spatial information.

	Habitat ID	Habitat	EUNIS L1	EUNIS L2	EUNIS L3	Source *
Transitional Waters	hab1	Estuarine saltmarshes	A Marine Habitats	A2 Littoral Sediment	A2.5 Coastal saltmarshes and saline reedbeds	Field sampling
	hab2	Aquaculture tanks	J Constructed, industrial and other artificial habitats	J5 Highly artificial man-made waters and associated structures	J5.1 & J5.11 Saline and brackish industrial lagoons and canals J5.11 Saline and brackish industrial lagoons and canals	Teixeira et al., 2018
	hab3	Water ponds	J Constructed, industrial and other artificial habitats	J5 Highly artificial man-made waters and associated structures	J5.1 & J5.11 Saline and brackish industrial lagoons and canals J5.11 Saline and brackish industrial lagoons and canals	Teixeira et al., 2018
	hab4	Saltworks	J Constructed, industrial and other artificial habitats	J5 Highly artificial man-made waters and associated structures	J5.1 & J5.12 Saltworks J5.12 Saltworks	Teixeira et al., 2018
	hab5	Estuarine littoral granule and very coarse to coarse sands	A Marine Habitats	A2 Littoral Sediment	A2.1 Littoral coarse sediment	Cunha and Dinis, 2002

	hab6	Estuarine littoral sandy mud and very fine to medium sands	A Marine Habitats	A2 Littoral Sediment	A2.2 Littoral sand and muddy sand	Cunha and Dinis, 2002
	hab7	Estuarine littoral mud	A Marine Habitats	A2 Littoral Sediment	A2.3 Littoral mud	Cunha and Dinis, 2002
	hab8	Estuarine seagrass bed	A Marine Habitats	A2 Littoral Sediment	A2.6 Littoral sediments dominated by aquatic angiosperms	Field sampling
	hab9	Estuarine sublittoral granule, very coarse to coarse sands	A Marine Habitats	A5 Sublittoral Sediment	A5.1 Sublittoral coarse sediment	Cunha and Dinis, 2002
	hab10	Estuarine sublittoral sandy mud and very fine to medium sands	A Marine Habitats	A5 Sublittoral Sediment	A5.2 Sublittoral sand	Cunha and Dinis, 2002
	hab11	Estuarine sublittoral mud	A Marine Habitats	A5 Sublittoral Sediment	A5.3 Sublittoral mud	Cunha and Dinis, 2002
	hab12	Estuarine pelagic waters of the South Mondego Branch and Pranto River	A Marine Habitats	A7 Pelagic water column	A7.4 Partially mixed water column with reduced salinity and medium or long residence time	SNIAmb (https://bit.ly/3diLfSN)
	hab13	Estuarine pelagic waters of the North Branch of the Mondego River and upstream system	A Marine Habitats	A7 Pelagic Water Column	A7.6 Vertically stratified water column with reduced salinity	SNIAmb (https://bit.ly/3diLfSN)
Coastal Waters	hab14	Sandy beaches	B Coastal Habitat	B1 Coastal dunes and sandy shores	B1.2 Sand beaches above the driftline	IGP, 2010
	hab15	Coastal rocky middle and supralitoral areas	A Marine Habitats	A1 Littoral rock and other hard substrata or Littoral Sediment	---	Ecosystem types of Europe, 2015 (https://bit.ly/2Ybzedu)
	hab16	Coastal supralittoral sedimentary areas	A Marine Habitats	A2 Littoral sediment	---	Ecosystem types of Europe, 2015 (https://bit.ly/2Ybzedu)
	hab17	Infra and circalittoral rocky areas	A Marine Habitats	A3 or A4 Infra&Circa rock&other hard substrata	---	Ecosystem types of Europe, 2015 (https://bit.ly/2Ybzedu)
	hab18	Infralittoral or circalittoral sedimentary areas	A Marine Habitats	A5 Sublittoral Sediment	A5.2 Sublittoral sand (Infrallittoral or Circalittoral)	EUSeamap, 2016 (http://www.emodnet-seabedhabitats.eu/)
	hab18_1	Infralittoral fine sand or infralittoral muddy sand areas	A Marine Habitats	A5 Sublittoral Sediment	A5.23 or A5.24 Infralittoral fine sand or infralittoral muddy sand	EUSeamap, 2016(http://www.emodnet-seabedhabitats.eu/)
	hab18_2	Circalittoral fine sand or muddy sand areas	A Marine Habitats	A5 Sublittoral Sediment	A5.25 or A5.26 Circalittoral fine sand or circalittoral muddy sand	EUSeamap, 2016 (http://www.emodnet-seabedhabitats.eu/)
	hab19	Marine pelagic (0-200) waters	A Marine Habitats	A7 Pelagic water column	A7.3 Completely mixed water column with full salinity	EMODNET bathymetry portal (http://www.emodnet-bathymetry.eu/data-products)

* The methodological approach to define the spatial distribution of the coastal habitats is described in Appendix B. Supplementary tables.

Ecosystem services identification

ES were identified based on literature review and following the CICES hierarchical classification system (CICES) (Haines-Young and Potschin, 2013) (Figure III.2). Literature review encompassed three steps: 1) systematic review of scientific literature focused on the study area; 2) non-exhaustive review of other references focused on the study area; 3) non-exhaustive review of scientific literature focused on other geographic areas with similar habitats. The first step encompassed a systematic search on Web of Science (WoS) to explore references focused on the study area. No data limits were included. Three separate searches were performed to guarantee the three main coastal geographic areas encompassed in this study: 1) "Buarcos" AND "Portugal", which returned 12 studies; 2) "Lavos" AND "Portugal", which returned 4 studies; and 3) "Mondego Estuary", which returned 281 studies. Other known relevant articles, not provided by WoS but focused on the study area, were also included to guarantee a full review of the geographic area. In the end, a total of 292 papers focused on the Atlantic coastal region adjacent to the Mondego River were listed (Appendix B. Supplementary tables). The second step encompassed a non-exhaustive review of grey literature and other references focused on the study area that would allow us to explore empirical evidence of ES supply and/or demand for local services that could stimulate research and discussion on ES assessments. The review includes reports, ongoing scientific projects, online videos, *in* situ observations supported by a long term monitoring program, among other. The third step encompassed a review of scientific literature focused on ES supply at other geographic areas with similar aquatic habitats. In this third step, due to the high diversity of habitats, biological components and types of ecosystem services, we opted for a non-exhaustive review and considered that a minimum of one reference would sustain the evidence for potential ES (Appendix B. Supplementary tables).

For the purpose of this study we used the definition of ES supply from Tallis et al. (2012) and an adapted definition of ES demand from Burkhard et al. (2012). Supply is "the full potential of ecological functions or biophysical elements in an ecosystem to provide a potential ES, irrespective of whether humans actually use or value that function or element currently" (Tallis et al., 2012). Demand is the sum of all ecosystem goods and services currently consumed or used in a particular area over a given time period, considering only those ES that are actually provided within the study area. This definition differs from the one proposed by Burkhard et al. (2012) and others (Wolff et al., 2015) in that it excludes ES that are consumed in the study area but have been provided by ecosystems outside the study area. This adaptation to the definition is necessary to use Demand as a proxy for the provision of ES.

Based on the literature, the ES were then divided into Current and Potential. Current ES include those for which ES supply and/or demand in the study area is confirmed by the scientific literature and/or other references from the study area. This wide definition, including ES not confirmed by scientific literature, allowed us to map ES from empirical evidences, important to analyse gaps in local ES assessment. Potential ES include those for which ES supply of and/or the demand in the study area are not confirmed by any means, but scientific literature suggests the presence of biophysical structures and/or functions in the study area with potential to supply ES, and, at the same time, scientific literature from other geographic areas suggests the supply of ES by those biophysical structures and/or functions (Salomidi et al., 2012; Liquete et al., 2013;

Tempera et al., 2016). This definition allowed us to map ES from evidences at other geographic areas, also important to analyse gaps in local ES assessment.

Ecosystem Services Research Hotspots

An Analytic Hierarchy Process (AHP) approach (Vaidya and Kumar, 2006; Teixeira et al., 2018; de Marinis and Sali, 2020) was followed to find ES Research Hotspots (RH) based on a set of criteria and subcriteria.

Criteria and subcriteria

For the purpose of this study, Ecosystem Services Research Hotspots are aquatic habitats for which research on ES is recommended based on three selected criteria. In order of importance, these are: 1) abundance of ES; 2) evidence for ES; 3) strength of evidence (Table III.2). According to this definition, a highly recommended habitat shows a high abundance of ES, for which there is current evidence for the presence of ES in the geographic area under study, supported by scientific literature. Research Hotspots were identified applying an Analytic Hierarchy Process, which allowed us to prioritize coastal aquatic habitats based on the weighted relevance of the above-mentioned criteria.

The abundance of ES is defined as the percentage of ES encountered at each habitat. The percentage was calculated taking into consideration the maximum number of types of ES (defined by CICES codes) for each habitat and each category (Provisioning, Regulation, Cultural), regardless of whether ES have been classified as current or potential. Currently the CICES classification points to 42 types of provisioning ES, 28 types of regulation ES and 15 types of cultural ES (Haines-Young and Potschin, 2018). This means that if the same type of ES (defined by the CICES code) was provided in the same habitat, but by different biophysical structures (e.g. fish and macroalgae), it was counted only once. This procedure was a necessary simplification to allow calculating abundance percentages. To define abundance subcategories suitable to be included in the AHP calculations, it was necessary to classify the percentage of abundance into abundance intervals (Table III.2). For this purpose, and as a reference, it was considered that high abundance habitats are those with more than 20% of the possible ES. This limit was set upon the average number frequently found in coastal habitats (Hutchinson et al., 2013).

The evidence for ES is defined as the type of proof found for the occurrence of ES. It was calculated as the percentage of current ES in relation to potential ES (Table III.2). For example, if an habitat shows 1 current provisioning ES and 4 potential provisioning ES, we assume it shows 20% of current ES, showing thus evidence that there are less current than potential ES in the habitat under analysis (Moderately Low evidence for ES).

The strength of evidence for each habitat was calculated based on the most frequent type of references found for each habitat (Table III.2). For example, a habitat with strong evidence (score 6) is one for which the most frequent evidence for ES confirms the current presence of an ES and is based on scientific literature that does not have the concept of ES explicitly into account.

Table III.2. Subcategories for the three categories used in the AHP process: abundance; evidence for ES and strength of evidence

Level_id	Level	Description
Category | Abundance of ES		
5	High	More than 50%
4	Moderately High	From 20% up to 50%
3	Moderate	From 10% up to 20%
2	Moderately Low	From 5% up to 10%
1	Low	Less of equal to 5%
0	No ES	Equal to 0. No ES
Category | Evidence for ES		
5	Robust	Evidence that all ES identified are currently occurring
4	Moderately Robust	Evidence that there are more current than potential ES
3	Moderate	Evidence for as many current as potential
2	Moderately Fragile	Evidence that there are less current than potential ES
1	Fragile	There is no evidence for current ES. All evidence is for potential ES
0	No Evidence	There is no evidence for the current or potential occurrence of ES
Category | Strength of Evidence		
6	Strong	Evidence for current ES based on scientific literature that does not have the concept of ES explicitly into account (Current/non-Explicit ES)
5	Moderately Strong	Evidence for current ES based on grey literature (Current/Grey literature)
4	Moderate	Evidence for current ES based on other types of references (Current/other)
3	Moderately Weak	Evidence for potential ES based on scientific literature that has the concept of ES explicitly into account (Potential/Explicit ES)
2	Weak	Evidence for potential ES based on scientific literature that does not have the concept of ES explicitly into account (Potential/non-Explicit ES)
1	Very Weak	Evidence for current ES based on scientific literature that has the concept of ES explicitly into account. Though this is in reality the strongest evidence, it was considered that if a study had already been taken in the geographic area under study, explicitly considering the concept of ES, than there was no urgency in planning a new one (Current/Explicit ES), which is the overall goal of this study, i.e., to plan research based on evidence of occurrence and lack of studies.
0	No Evidence	There is no evidence for ES

Ranked list of factors based on AHP

The absolute measurement method (Saaty, 1990) was applied to determine criteria and sub-criteria priorities. With the absolute approach, the criteria are pairwise compared to derive priorities, and the sub-criteria are rated within the criteria to which they belong (Saaty, 1990). The free web based *BPMSG AHP Online System* (Goepel, 2017, http://bpmsg.com/academic/) was applied to develop the comparison matrices, their consistency ratio (CR) and the weights. The comparison matrices were established using an evaluation scale divided into nine levels, where level 1 represents equal importance between factors, and level 9 represents nine times more importance of one factor compared to another. Four pairwise matrices were created, one for the criteria (Appendix B. Supplementary tables) and three for the subcriteria (Appendix B.

Supplementary tables). The consistency of the matrices' was determined based on the consistency ratio (CR). A CR of 0.10 or less was considered acceptable to continue the AHP analysis (Saaty, 2012). The CR measures the consistency of a given evaluation matrix by comparing its consistency index with a random consistency index (Mu and Pereyra-Rojas, 2017). The priority ranks that set the importance of each factor were obtained multiplying the criteria and the sub-criteria weighted priorities (Saaty, 1990). The highest priority rank of Abundance, for example, was established multiplying the weight of *Abundance* criteria by the weight of *High* sub-criteria.

Research priorities

After defining the importance of each factor, research priority for each habitat was established summing the priorities of the corresponding factors. The highest rank priority was assigned to habitats with *High Abundance* and with *Robust* and *Strong Evidence*, but for which there is a gap in ES research. For this reason these spots are preferred for ES Research. Because the results provide a ranked list of factors that is unmanageable, the overall priority ranks were further classified within intervals of recommendation for ES research. The intervals of recommendation were determined based on the Equal Intervals Method defining *a priori* five classification intervals: highly recommended, very recommended, recommended, little recommended and very little recommended. The distance between classification intervals (*D*) was calculated following Eq. (1).

$$D = (H+L) / 5 \quad (1)$$

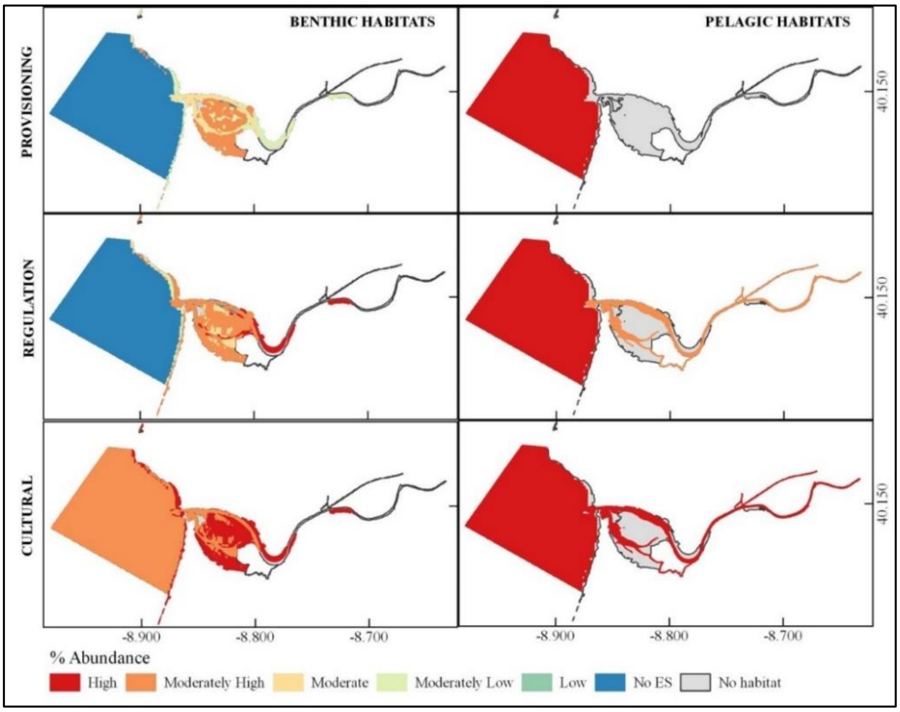
where *H* is the highest rank value and *L* is the lowest rank value. The intervals allowed us to classify habitats (from coastal and transitional waters) based on the ES *Abundance*, *Evidence* for ES and *Strength* of evidence for ES, but also to find the ES Research Hotspots.

Results

Ecosystem Services at the Atlantic coastal region adjacent to the Mondego River

In the habitats of the Atlantic coastal studied area (Figure III.3), the abundance of ES per habitat does not exceed 28% of the possible ES, when considering the CICES classification (Figure III.4a). Saltworks (hab4), coastal rocky middle and supralitoral areas (hab15) and marine pelagic (0-200) waters (hab19) show the highest percentage of ES, higher than 20%. More specifically, and as an example, saltworks show a total of 23 ES, which corresponds to 27.38% in an universe of 84 possible ES (Appendix B. Supplementary tables). Estuarine habitats with sediment bed consisting of granule to coarse sands (hab5 and hab9), sedimentary supralittoral areas (hab16) and sedimentary infralittoral and circalittoral habitats (hab18, hab18_1, hab18_2) reveal the lowest percentage of ES (Figure III.4a), lower than 5%.

Figure III.3. Abundance (% of CICES types) of ecosystem services per categories and type of habitats.



When considering the three ES categories separately (Figure III.4b), the presence of cultural services seems to dominate at almost all habitats. With exception for the marine pelagic waters (hab19), all habitats show more cultural ES than provisioning or regulation, such as saltworks (hab4) which exhibit 93% of the possible CICES cultural ES types, correspondinig to a total of 14 ES out of a total of 15 possible cultural services (Appendix B. Supplementary tables). In fact, for some there is only evidence for cultural ES and not for provisioning and cultural, which is the case for the estuarine littoral granule and very coarse to coarse sands (hab5) and infralittoral to circalittoral sedimentary environments (hab18, hab18_1, hab18_2).

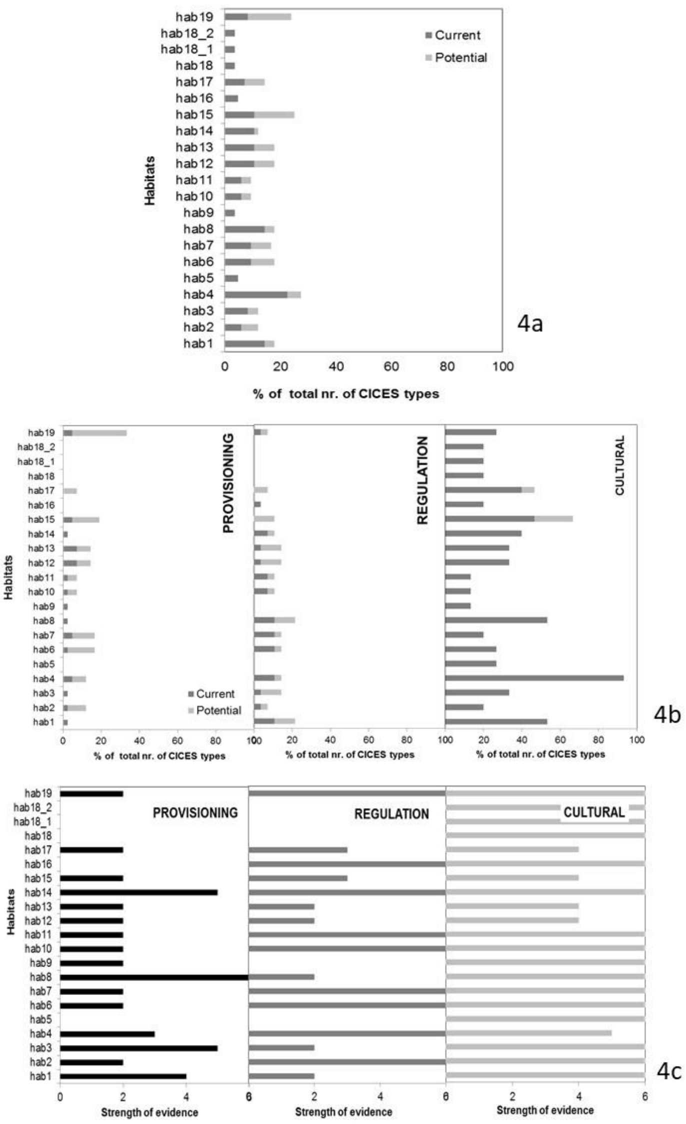


Figure III.4. 4a. Abundance (% of CICES Types) per habitat and type of evidence (Current or Potential; 4b. Abundance (% of CICES Types) per habitat, type of evidence and category (Provisioning, Regulation and Cultural); 4c. Strenght of Evidence per habitat and category. hab1 - Estuarine saltmarshes; hab 2 - Aquaculture tanks; hab3 - Water ponds; hab4 – Saltworks; hab5 - Estuarine littoral granule and very coarse to coarse sands; hab6 - Estuarine littoral sandy mud and very fine to medium sands; hab7 - Estuarine littoral mud; hab8 - Estuarine seagrass bed; hab9 - Estuarine sublittoral granule and very coarse to coarse sands; hab10 - Estuarine sublittoral sandy mud and very fine to medium sands; hab11 - Estuarine sublittoral mud; hab12 - Estuarine pelagic waters of the South Mondego Branch and Pranto River; hab13 - Estuarine pelagic waters of the North Branch of the Mondego River and upstream system; hab14 - Sandy beaches; hab15 - Coastal rocky middle and supralitoral areas; hab16 - Coastal supralittoral sedimentary areas; hab17 - Infra and circalittoral rocky areas; hab18 - Infralittoral or circalittoral sedimentary areas; hab18_1 - Infralittoral fine sand or infralittoral muddy sand areas; hab18_2 - Circalittoral fine sand or muddy sand areas; hab19 - Marine pelagic (0-200) waters.

The evidence for ES in the Atlantic coastal region adjacent to the Mondego River differs among habitats (Figure III.4b). The evidence for ES in coastal rocky middle and supralitoral areas (hab15) and marine pelagic (0-200) waters (hab19) points for more potential ES than for current. On the contrary, estuarine littoral granule and very coarse to coarse sands (hab5), estuarine sublittoral granule and very coarse to coarse sands (hab9), coastal supralitoral sedimentary areas (hab16) and infralittoral and circalittoral sedimentary areas (hab18, hab18_1, hab18_2) show only evidence for current supply of ES and no evidence for potential ES. The remaining habitats show evidence for more current ES than potential.

The strength of evidence seems to be generally stronger for the cultural services than for the regulation or the provisioning services (Figure III.4c). No habitats show weak evidence for the cultural services, whereas up to 11 habitats show weak evidence for provisioning services, when present.

Ranked list of factors

The ranked list of factors obtained when applying the AHP approach (Table III.3) is suitable for any analysis that applies the same criteria and sub-criteria defined in this study. Such list determines the prioritization of habitats for research. The results indicate that the most preferred habitats for ES research have a maximum priority value of 0.378 (0.207+0.114+0.058), which corresponds to habitats with *High Abundance* and with *Robust* and *Strong Evidence* (Table III.3); and that the least preferred habitats for ES research have a priority of 0.034 (0.019+0.010+0.004), which corresponds to habitats for which no evidence of ES has been found (Table III.3).

Table III.3. Rank list of criteria and sub-criteria.

Criteria	Subcriteria	Priorities
Abundance	High	0.207
	Moderately high	0.136
	Moderate	0.087
	Moderately Low	0.053
	Low	0.037
	No ES	0.019
Evidence	Robust	0.114
	Moderately Robust	0.075
	Moderate	0.048
	Moderately Fragile	0.031
	Fragile	0.020
	No Evidence	0.010
Strength of Evidence	Strong	0.058
	Moderately Strong	0.039
	Moderate	0.026
	Moderately Weak	0.017
	Weak	0.011
	Very Weak	0.008
	No Evidence	0.004

When classifying the rank priorities (Table III.3) into intervals of recommendation, a manageable scale of priorities is obtained (Table III.4). Such scale supports data interpretation and ultimately decision-making.

Table III. 4. Classification levels.

riority	Levels	Interval	
		maximum	minimum
Priority 1	Highly recommended	0.378	0.310
Priority 2	Very Recommended	0.310	0.241
Priority 3	Recommended	0.241	0.172
Priority 4	Little Recommended	0.172	0.103
Priority 5	Very Little Recommended	0.103	0.034

Ecosystem Services Research Hotspots

The ES Research Hotspots in the studied area i.e., habitats for which research on ES is recommended, differ if one is considering the three categories of ES altogether (Provisioning, Regulation and Cultural), or one at a time. When considering altogether, saltworks (hab4), for instance, emerges has the habitat most recommended for research (Table III.5) and the remaining habitats are considered either "very recommended" or "recommended". This pattern changes when evaluating one category at a time. If one ought to study provisioning services, Marine pelagic (0-200) waters (hab19) is a "very recommended" habitat, while five other habitats are "very little recommended". If one ought to study regulation services eight habitats are "very recommended", and six other are "little recommended". If one ought to study cultural services, nine habitats are "highly recommended", while the remaining are all "very recommended".

Table III.5. Analytic Hierarchy Process rank priorities after classification..

	Habitat ID	Provisioning	Regulation	Cultural	Total
Transitional Waters	hab1	Recommended	Very Recommended	Highly recommended	Very Recommended
	hab2	Recommended	Recommended	Very Recommended	Recommended
	hab3	Recommended	Recommended	Highly recommended	Very Recommended
	hab4	Recommended	Very Recommended	Highly recommended	Highly recommended
	hab5	Very Little Recommended	Little Recommended	Highly recommended	Recommended
	hab6	Recommended	Very Recommended	Very Recommended	Very Recommended
	hab7	Recommended	Very Recommended	Very Recommended	Very Recommended
	hab8	Recommended	Very Recommended	Highly recommended	Very Recommended
	hab9	Recommended	Little Recommended	Very Recommended	Recommended
	hab10	Little Recommended	Very Recommended	Very Recommended	Recommended
	hab11	Little Recommended	Very Recommended	Very Recommended	Recommended
	hab12	Recommended	Recommended	Highly recommended	Recommended
	hab13	Recommended	Recommended	Highly recommended	Recommended
Coastal Waters	hab14	Recommended	Very Recommended	Highly recommended	Very Recommended
	hab15	Recommended	Recommended	Very Recommended	Very Recommended
	hab16	Very Little Recommended	Recommended	Very Recommended	Recommended
	hab17	Little Recommended	Little Recommended	Very Recommended	Recommended
	hab18	Very Little Recommended	Little Recommended	Very Recommended	Recommended
	hab18_1	Very Little Recommended	Little Recommended	Very Recommended	Recommended
	hab18_2	Very Little Recommended	Little Recommended	Very Recommended	Recommended
	hab19	Very Recommended	Recommended	Highly recommended	Very Recommended

hab1 - Estuarine saltmarshes; hab 2 - Aquaculture tanks; hab3 - Water ponds; hab4 – Saltworks; hab5 - Estuarine littoral granule and very coarse to coarse sands; hab6 - Estuarine littoral sandy mud and very fine to medium sands; hab7 - Estuarine littoral mud; hab8 - Estuarine seagrass bed; hab9 - Estuarine sublittoral granule and very coarse to coarse sands; hab10 - Estuarine sublittoral sandy mud and very fine to medium sands; hab11 - Estuarine sublittoral mud; hab12 - Estuarine pelagic waters of the South Mondego Branch and Pranto River; hab13 - Estuarine pelagic waters of the North Branch of the Mondego River and upstream system; hab14 - Sandy beaches; hab15 - Coastal rocky middle and supralitoral areas; hab16 - Coastal supralittoral sedimentary areas; hab17 - Infra and circalittoral rocky areas; hab18 - Infralittoral or circalittoral sedimentary areas; hab18_1 - Infralittoral fine sand or infralittoral muddy sand areas; hab18_2 - Circalittoral fine sand or muddy sand areas; hab19 - Marine pelagic (0-200) waters.

Discussion

Habitats and Ecosystem services maps

Coastal and marine maps are an essential source of information for resource exploitation and management purposes (Galparsoro et al., 2014; Tempera et al., 2016). At the European level, recent efforts have been made to deliver databases with a spatial component (Caro et al., 2018). However, not all databases are suitable for high resolution analysis, which hampers the ability to perform site-specific research (Tempera et al., 2016; Caro et al., 2018) and the capacity to operationalize the ES concept (Carmen et al., 2018; Jax et al., 2018; Saarikoski et al., 2018; Lautenbach et al., 2019). Despite the challenges associated to the spatial distribution of coastal and marine habitats for local-level research, the current study successfully provides the first comprehensive coastal habitats map of the Atlantic coastal region adjacent to the Mondego River region. The spatial information used was retrieved from a wide variety of sources with different resolutions, data certainty and geographic scope. At least three reasons can be outlined to explain this data diversity: (1) global and regional spatial databases fail to provide extensive high resolution data (Tempera et al., 2016; Caro et al., 2018); (2) spatial information at the national level is scarce, more even for the aquatic realms (Instituto Geográfico Português, 2010), and, when available, frequently not with free access; (3) site-specific spatial information is also scarce and often not publicly available (e.g. the 1/10.000 cartography of Mondego Estuary subsedimentary enviroments presented by Cunha and Dinis, 2002). Spatial analysis is not mandatory for the methodological approach presented in this study, but studies have shown that practitioners and policy makers are increasingly seeking spatially-explicit information to use in decision-making and the implementation of policies (Tempera et al., 2016). Coastal and marine maps are also an important baseline type of information used to produce ES maps (Galparsoro et al., 2014), when primary data (i.e., direct ecosystem function/service measurements) from within the study area is absent (Tempera et al., 2016). For our case study, literature review revealed that providing comprehensive ES maps based solely on primary data is still not possible. On the contrary, using habitats as proxies has proven to be a successful approach to map the distribution of ES in the Atlantic costal region adjacent to the Mondego River. One of the advantages of producing ES maps is the ability to extract quantitative indicators based on the areal extent where the service is suggested to be present (Galparsoro et al., 2014). One must however, bear in mind that aquatic habitats are dynamic, i.e., their spatial distribution and characteristics is likely to change as a result of the hydromorphological conditions of the system, its sedimentary characteristics (Cunha et al., 1995; Dinis and Cunha, 1998; Duarte et al., 2001), and the anthopogenic pressures acting upon the system (Crespo et al., 2010; Baeta et al., 2011; Teixeira et al., 2014; Teixeira and Marques, 2016). This means that habitat maps, at the local level, should be updated as frequently as possible to reflect the most recent conditions (McKerrow, et al., 2014).

Decision-making approach for ES research prioritization

The multicriteria method used in this study is conceptually different from those approaches that explore blindspots in research (e.g. Lautenbach et al., 2019). More than looking for gaps in ES research, our goal was to find those habitats for which research should be prioritized. The criteria were selected from a science management point of view, i.e., 'which habitats show less scientific research', but also from a decision-making point of view, i.e., 'which habitats show less scientific research, despite the number of ES and the evidence for relevant resources?' The number of ES and evidence for relevant resources are proxies for the habitat potential to deliver ecosystem benefits valued by humans (Gos and Lavorel, 2012). The results obtained with the methodology applied seem to be in accordance with the recent efforts of local authorities to mainstream the cultural and social heritage associated to human activities in the coastal Mondego region (Teixeira et al., 2018). Results show that the region is dominated by cultural services and that saltworks should be a priority for research. Teixeira et al. (2018) had already stated that saltworks' conservation and rehabilitation is one of the main goals of local authorities for a number of socio-cultural reasons. If this social meaning, rather than ecological health, is the major factor underpinning cultural ES (Irvine and Herrett, 2018), it may be an indication that decision-makers are depreciating ecosystem characteristics, such as species richness, population dynamics and resilience. If this is the case, the importance assigned to cultural services in the AHP model, as a result of the percentage of cultural ES found, may be arguable from an ecological point of view, as the model is prioritizing habitats based more on social objectives than ecological health. As mentioned, this may be relevant, for decision-making and management purposes, as it is of utmost importance to focus on the most relevant ES, however one should not forget that it is also crucial to consider the relationships between them (e.g., Kandziora et al., 2013), as the selection of the ES to benefit may involve losing one quality or aspect of something in return for gaining another quality or aspect (McShane et al., 2011; Iniesta-Arandia et al., 2014; Martín-López et al., 2014;). In the Atlantic coastal region adjacent to the Mondego River region, social meaning might be behind ES such as 'Area of Outstanding Natural Beauty', while ecological health might be behind ES such as 'Site of special scientific interest: RAMSAR site and Important Bird and Biodiversity Area (IBA)', and 'Site used for conservation activities'. Future work could highlight the public's perceptual characterization of coastal aquatic habitats to understand the values underpinning ES preferences. Regardless of the reason behind the abundance of cultural ES – either social or ecological -, the results indicate that they play an important role in the studied region and thus the best available methods (Cheng et al., 2019) and indicators (Hernández-Morcillo et al., 2013) should be applied in order to not omitt cultural services from ES assessments or limit the capacity of the analysis (Cheng et al., 2019; Zhang et al., 2019). To this matter, the type of evidences found for the presence of cultural ES point to the opportunity of including novel approaches such as the analysis of social networks (Kilonzi and Ota, 2019).

AHP criteria challenges

The maximum abundance of total ES found for the Atlantic coastal region adjacent to the Mondego River region is in line with abundances found for other systems (Barbier et al., 2011; Hutchinson et al., 2013). These findings support the categorization for the abundance criteria implemented in our approach, i.e., any habitat with more than 20% of ES is a highly abundant habitat. This statement is less clear when analyzing the cultural services independently, as their percentage per habitat frequently surpassed the 20% boundary, reaching a maximum of 93.3%. Three causes could explain the high percentages found for cultural services. The first one comes from mathematics. The CICES classification describes 42 provisioning services, 28 regulation services and 14 cultural services, this means that for any cultural ES identified, the percentage is automatically higher. For instance, 2 provisioning ES represent 2.4%, 2 regulation services represent 4.8% and 2 cultural services represent 13.3%. This still means that 20% in an universe of 14 types is a high percentage. Second, cultural ES are relatively easy to spot in the absence of scientific literature by identifying the local ES through other references. For instance, the presence of educational programs as an indicator of sites used for *insitu* teaching (Lovell et al., 2010), the presence of scenic views used for photos as indicators of archive records (Everard et al., 2010) and the existence of bird watching activities (Tzoulas and James, 2010) can be identified through a simple internet searching. Selecting references other than scientific, as for example grey literature, videos and books, has proven useful to spot the current supply and/or demand for ES provided locally, but for which no scientific literature is yet available. In fact, this information can later become good indicators of ES supply (Lovell et al., 2010; Everard et al., 2010; Tzoulas and James, 2010).The third cause, might be associated to the social motivations advanced in the previous section (section 4.2). Highly scored habitats, e.g. saltworks, might be showing high number of cultural ES as a result of the socio-cultural importance given to these habitats. Taking into account the reasons advanced to explain the high percentages of cultural ES, we consider that using the same boundary, to determine abundance scores, for all ES categories remains the best approach as it harmonizes calculations and simplifies interpretations.

The AHP methodology allows limiting the influence of less trustable criteria, by assigning lower weights. In our case, the lowest weight was assigned to the "strength of evidence" criteria. The approach applied to determine the strength of evidence considers only the most frequent types of references found for each habitat and whenever there is a tie the highest score is selected. This means that the methodology ignores weak evidence for some ES if the majority of the ES in the habitat show strong evidence. Because we are aware of the loss of information with the approach followed, we considered it was important to limit the influence of this criteria and, thus, to the strength of evidence a weight of only 16.3% was assigned. Other approaches to calculate the strength of evidence are possible. Namely, calculating the average of the criteria scores by habitat. However, other weaknesses would have been introduced with this approach as it would be ignoring the categorical nature of the score system while treating it as nominal (Stevens, 1946). With this approach one would be assuming that the strength of evidence criteria has interval properties (in the sense of the classification given by Stevens (1946)) and no ordering characteristics, which is not the case.

Conclusion

Ecosystem services (ES) maps using habitats as proxies has, once more, revealed to be a useful approach for ES mapping, but map quality and resolution will depend on the characteristics of the underlying habitat maps used. For this work, a comprehensive map of habitats of the Atlantic coastal region adjacent to the Mondego River was produced, integrating not only inedit 1/10,000 cartography of the sedimentary subenvironments of the study area but other relevant data. To our knowledge it is the first map of its kind, but its production highlighted gaps in the availability of high resolution spatial information for site-specific analysis.

The AHP method applied suggests that saltwork habitats should be a priority for research in the Atlantic coastal region adjacent to the Mondego River and that cultural services play an important role in the studied region. These results are in accordance with decision-makers trends of management, i.e., in line with the recent efforts of local authorities to mainstream the cultural and social heritage associated to human activities in the region, such as traditional salt production. Other recommended habitats for ES research in the study area are Marine pelagic (0-200) waters, Sandy beaches, Estuarine seagrass bed and Estuarine saltmarshes. Analysing ES in these habitats will provide baseline information for decision-making, as it may clarify, and possibly quantify, the potential of these habitats to deliver services and the actual demand by services provided by the region. This information, together with data on the main pressures that could put under risk the ES resilience, could support evaluation with regard to the carrying capacity of the aquatic habitats under study, which is crucial to guarantee the environmental, social and economic sustainability of the region.

The criteria used is suitable for regions where profound gaps in ES research exist. For regions where ES research has already been undertaken, the methodology could be extended or readapted to focus on critical questions that characterize ecosystem services research (Lautenbach et al., 2019). For instance, prioritization could be based on criteria determining whether research on the relationships between ES (i.e. trade-offs, synergies, or no-effects) has already been taken (Lee and Lautenbach, 2016); or on criteria that take into account if a comprehensive integration of ES supply and demand has been assessed (Wei et al., 2017). The approach is appropriate as a first step towards an effective operationalisation of the ES concept (Grêt-Regamey et al., 2017). By finding gaps in site-specific ES research, the work is able to find knowledge breaches that hamper the use of the ES concept by decision-makers. The site-specific ES research that may arise from the analysis performed is of utmost importance not only for decision-makers at the local-level but also at high-level decision processes, as the existence of case studies is crucial to develop sound knowledge bases that support the development of ES research (Lautenbach et al., 2019).

CHAPTER IV: Ecosystem services as a resilience descriptor in habitat risk assessment using the InVEST model

Abstract

Vulnerability of coastal ecosystems has been increasing as a result of human perturbations that compromise the ability to provide multiple ecosystem services. Vulnerability is a function of exposure to stressors and of sensitivity to impact and resilience; it has been suggested as a proxy of a habitat's ability to deliver ecosystem services. Different approaches have been proposed; some assume that vulnerability is lower when habitats provide more ecosystem services, as it increases the ecosystem adaptive capacity, while others assume the opposite, as multiple activities (exploiting multiple services) introduce multiple pressures. To establish a relationship between impact risk and ecosystem service supply potential, while accounting for these two apparently conflicting assumptions, it has been proposed adding ecosystem services' abundance as a resilience descriptor to the habitat risk assessment (HRA) model from the InVEST tool, assigning different weights to provisioning, regulation and cultural services. This study: (i) applies the modified HRA model (HRA_ES-2) to 21 habitats in an Atlantic coastal region; (ii) compares the results with a non-modified HRA model (HRA-1) and with other previous approaches; (iii) and explores management scenarios that could be translated into better environmental conditions for seagrass and saltmarsh habitats and, consequently, into positive impacts in the supply of ecosystem services by these habitats.

Results show that there are significant statistical differences between the HRA-1 model and the HRA_ES-2 model, and between the HRA_ES-2 model and approaches from other authors that also take ES into consideration. In addition, the cumulative risk obtained from the modified HRA_ES-2 model seems to be more in accordance with the social-environmental realm than the risk scores obtained with the HRA-1 model. Finally, the new model approach indicates that avoiding the degradation of saltmarsh and seagrass habitats will be possible with management measures acting upon the two stressors most contributing to habitat risk: sea level changes and organic enrichment due to nitrogen increase.

With this approach the user is able to account not only for the resilience of ecosystems that arises from the presence of ecosystem services, but also for the sensitivity associated to the potential impacts if ecosystem services are in demand, in a spatial explicit manner, which is an advantage compared to other approaches. The resilience component from the InVEST/HRA model is thus flexible to accommodate other variables than those proposed by the developers.

Keywords: Ecosystem services abundance, vulnerability, EUNIS habitats, management, wetlands, Mondego estuary; Portugal

Introduction

Coastal and marine aquatic habitats are amongst the most productive ecosystems around the world, contributing with around 43% of total benefits provided by the biosphere to human well-being (Levrel et al., 2014), or in other words, contributing with a large percentage of ecosystem services. Unfortunately, multiple increasing human perturbations have been felt in these habitats (e.g. Barbier et al., 2011; Rao et al., 2015), such as biological and sedimentary resources exploitation (Islam and Haque, 2004), pollution (e.g. Santos and Andrade, 2009) and anthropization of natural areas, which may compromise the ability to provide provisioning, regulating and cultural services (Muñoz et al., 2018), including food, flood protection, natural environmental conservation and recreation activities. As a result, the vulnerability of marine/coastal aquatic ecosystems has been increasing (Schröter, 2005; Cabral et al., 2015). It is widely accepted, however, that ecosystem vulnerability is not only a function of exposure to stressful uses and pressures, but also a function of impact, measured by sensitivity and adaptive capacity (Arkema et al., 2014; Cabral et al., 2015; Halpern et al., 2015). Sensitivity is the degree to which a human-environment system is affected by environmental change (Cabral et al., 2015); whereas adaptive capacity, or in other words, resilience, is the capacity of an ecosystem to absorb shocks and still maintain function (Folke, 2006).

In an exposure-impact approach to habitat risk assessment, vulnerability is linked to risk (Culhane et al., 2019), i.e., to the exposure to hazards, and has been suggested as a proxy of a habitat's ability, or potential, to deliver ecosystem services (ES) (Cabral et al., 2015). This perspective allows exploring the effects of ecosystem state changes in the supply of ecosystem services, but different approaches have been implemented. Cabral et al. (2015) assume that vulnerability is lower when habitats provide more ecosystem services, as it increases the ecosystem adaptive capacity. Others have also proposed that the capacity of habitats to deliver a large abundance of ecosystem services could be an expression of resilience to the natural variations of their environment (Brock et al., 2018; Arnan et al., 2019). However, Culhane et al. (2019) and Willaert et al. (2019) assume that vulnerability, and inherently impact risk, is more likely to increase with greater potential to supply ecosystem services, as “multiple activities (exploiting multiple services) introduce multiple pressures” (Culhane et al., 2019). These two contrasting assumptions seem counter-intuitive, but it could be argued that their coexistence is possible. Consider, as an example, two equivalent ecosystems with the same pressures. The one with the highest availability of ecosystem services will, in theory, be less vulnerable as it may have a higher capacity to self-organize and retain essentially the same function, structure, identity, and feedbacks, as well as the capacity to adapt to new conditions (Carpenter et al., 2001; Walker et al., 2004; Biggs et al., 2012). Likewise, when considering two habitats with the same ecosystem services, the one suffering the highest pressure as a result of ecosystem services demand will tend to be more vulnerable. In this context, habitats dominated by regulation services are expected to show less vulnerability and lower risk, as they do not require active exploitation (Culhane et al., 2019). Including the abundance of ecosystem services in the habitat risk assessment, highlights the importance of ecosystem services as endpoints in the decision making process (Munns et al., 2015), raising the interest of end-users in order to avoid the loss of habitats that deliver multiple services (Rodríguez-Loinaz et al., 2015), usually subject to multiple stressors (Willaert et al., 2019).

This study aims to find a suitable methodology to establish a relationship between impact risk and ecosystem service supply potential, while accounting for the two apparently conflicting assumptions above-mentioned. Such methodology would greatly improve the ecosystem-based management (EBM) of fully coastal and marine regions (Borja et al., 2016), which is clearly endorsed by the Marine Strategy Framework Directive (MSFD; EC, 2008), which "aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend". To achieve the main goal of this study, a set of three hypotheses have been developed, which also demonstrate the usefulness of combining habitat risk assessment with an ecosystem services approach and spatial planning (Arkema et al., 2015). All three hypotheses rely on a modified habitat risk assessment (HRA) model from the InVEST tool (Sharp et al., 2018), in which ecosystem services abundance is added as a resilience descriptor, introducing a novel approach that deviates from the vision introduced by the current InVEST/HRA which expects four habitat-specific measures of resilience: natural mortality rate, recruitment rate, age at maturity and connectivity. Below are the three hypotheses to be tested:

H1: Adding ES abundance as a resilience descriptor will introduce significant and meaningful changes in the InVEST/HRA risk scores, compared to a model without resilience descriptors.

H2: A HRA model that accounts for ES abundance as an expression of environmental resilience and, at the same time, as a source of environmental stress due to demand, originates habitat risk values significantly different from other approaches that only take one of the assumptions into consideration.

H3: Improving the management effectiveness score of the stressors that most contribute for habitats' risk, will decrease the risk score of a modified HRA model.

The Atlantic coastal region adjacent to the Mondego River mouth (western central mainland Portugal; westernmost sector of the Iberian Peninsula) was used as a case study and scenarios were built to test the potential effect of management improvements that could be translated into better environmental conditions for seagrass and saltmarsh' habitats. This study case was selected because it is under a long-term monitoring program (Marques et al., 2007; Veríssimo et al., 2017), providing a suitable amount of data regarding pressures and their effects on ecosystems (e.g., Marques et al., 1993; Veríssimo et al., 2013a; Couto et al., 2014), which enables the assignment of magnitudes of pressures on habitats, the base of any habitat risk assessment procedure (Duggan et al., 2015). Seagrass and saltmarsh' habitats were selected for the development of future management scenarios due to their importance for local environmental quality and economic development. These habitats act as nursery areas to many species, some with commercial importance (Lillebø et al., 1999), show high carbon sequestration rates (Couto et al., 2013, 2014), contribute with nutrient fixation (Cardoso et al., 2004; Sousa et al., 2008), are efficient in the sedimentation function (promote the deposition of fine particles), buffering the sea level raise effects (Raposa et al., 2016) and reducing the erosion rate (Schoutens et al., 2019), and provide strong cultural benefits (Cullen-Unsworth et al., 2014). Moreover, during the last 25 years, seagrasses in the Mondego estuary have suffered high environmental fluctuations, led mainly by nutrient discharges coupled with hydro-morphological changes determined by anthropic actions, which have significantly reduced the natural diversity of the study area (Dinis and Cunha, 1998; Neto et al., 2010; Veríssimo et al., 2013b). After 1997, when experimental mitigation measures were implemented, the water quality improved significantly with positive impacts on the environmental conditions (Neto et al., 2010). This work is thus assuming that the current stressors that might affect these habitats are different and should be assessed as well as their potential risk to these habitats.

Methodology

The methodology is oriented towards testing the three hypotheses defined in the Introduction section, using the Atlantic coastal region adjacent to the Mondego River as case study (Figure IV.1).

The study area

The study area is the Atlantic coastal region adjacent to the Mondego River, located in the central western coast of mainland Portugal (Figure IV.1). Two subareas are considered, based on water bodies defined under the scope of the Water Framework Directive (WFD) (Gonçalves et al. 2011; WFD; EC, 2000; Ferreira et al., 2006): a) transitional waters, corresponding to the lower and middle sectors of the estuary, which includes four transitional water bodies (here referred as WB1, WB2, WB-HMWB and WB3), and b) coastal waters, corresponding to the adjacent littoral and near part of the marine platform, which includes one coastal water body (CWB-1-3).

The study area has a semidiurnal regime and a tidal variation between 0.35 to 3.80 m and high energy wave hydrodynamics mostly between October to March. Wave direction is generally from West and Northwest with some occurrences from Southwest; wave periods are between 8 to 12 seconds, with wave heights usually between 1 to 3 m that can reach up to 8 m in stormy conditions (Bettencourt et al., 2004). The coastline is dominated by sandy beaches that, at south of the river mouth, pass inland to an aeolian dune field and to the estuary (Cunha et al., 2006). The Mondego River mouth is adjacent to the town of Figueira da Foz.

The transitional waters conform a mesotidal well-mixed to partially mixed estuary, except during floods and droughts, being the two estuary subsystems quite different (Cunha and Dinis, 2002). Being 21 km long and with a surface area of 860 ha, it has an irregular river discharge (Bettencourt et al., 2004), with a mean value of $79m^3/s$ of water from the Mondego River (Falcão et al., 2012; Teixeira et al., 2008). The last 7 km close to the estuary mouth are divided into two subsystems separated by the Morraceira Island. The Mondego subsystem (comprising the North branch and reaching Montemor-o-Velho, that is located c. 26 km upstream of the river mouth) is deeper (4-10 m during high tide), with strong salinity changes and comprising a bed load of medium to coarse sands (Marques et al., 1993; Cunha and Dinis, 2002). The Pranto subsystem (South branch) is shallower (2-4 m during high tide), with frequent changes in temperature (Flindt et al., 1997), salinity (Cunha and Dinis, 2002), but also presence of organic enrichment as a result of the Pranto River water inputs (Baeta et al., 2011) and aquaculture discharges.

Biophysical gradients along the Mondego transitional and coastal waters have originated a total of 21 habitats, where saltmarshes, seagrasses, sandy beaches, marine sedimentary areas, and marine rocky areas are dominant (Gaspar et al., 2017; Caro et al., 2020). All these habitats evidence great capacity to offer services such as water provision, eco-tourism opportunities, biological nursery grounds, food production and carbon storage (e.g., Pinto et al., 2014b). Among the habitats of the Atlantic coastal region adjacent to the Mondego River, seagrass and saltmarsh ecosystems are among the most important. Seagrasses and saltmarshes play a vital role in the accretion of fine sediment and filtration of nutrients (Lillebø et al., 1999; Sousa et al., 2008), as nurseries, and supporting commercially important fisheries (Castro et al., 2016, 2019). With the ongoing climate change trend, the biomass of seagrass and saltmarsh species is expected to increase, fostered by high levels of CO^2 in the atmosphere (Short et al., 2016) and an increment in the temperature (Couto et al., 2014). As result of sea level rise induced by global warming (IPCC, 2018), the area occupied by these habitats is expected to diminish because the sedimentation rate of some species will presumably not be able to keep pace with increases in sea level (Couto et al., 2014; Raposa et al., 2016) and because the lateral migration inland is not allowed due to progressive urbanization towards the estuary area (Cunha et al., 1997a).

Despite the social benefits that have been obtained from the Atlantic coastal region adjacent to the Mondego River, its present ecosystem services are in danger as a result of multiple pressures from natural and human origin (Teixeira et al., 2014), such as water flow control, through a series of dams and channels (Mantas et al., 2013), water extraction for irrigation projects (Pinto et al., 2013a), organic enrichment from nitrogen and phosphorus (Flindt et al., 1997, Teixeira and Marques, 2016), landfills and dredging/sand extraction (Cunha et al., 1998b, 2006), fisheries (Pinto et al., 2013a), contaminants and marine litter inputs (Bessa et al., 2018; Botelho et al., 2019), presence of invasive species (Franco et al., 2012), sea level rise (Loureiro et al., 2017) and impacts from navigation and harbor activities, such as noise and contaminants (Ceia et al., 2013; Mantas et al., 2013).

To overcome challenges posed by the impacts in the study area, a diversity of social responses have been proposed, some focused on management measures and others focused on improving scientific knowledge about the system. Responses focused on management include a) the increase of the Pranto subsystem (South branch) hydrodynamics, through the reconnection of the upstream communication between this subsystem and the Mondego subsystem (North branch), with the consequent improvement of the environmental quality in the Pranto subsystem (Cunha and Dinis, 2002; Veríssimo et al., 2013b); b) spatial planning of aquaculture and salt production activities to minimize the negative impacts on water quality, while reducing competition for space (Teixeira et al., 2018); and c) the definition of socio-economic scenarios to forecast the ecological impacts in the system, as a tool for decision-making (Pinto et al., 2013a). Responses focused on improving scientific knowledge include: a) the development of long-term datasets (around 30 years) through regular monitoring programs in the Mondego estuary, which are a crucial baseline to guide decision making (Pinto et al., 2014a; Veríssimo et al., 2017); and b) the development of tools to report the estuary environmental quality status (Mantas et al., 2016; Neto et al., 2013).

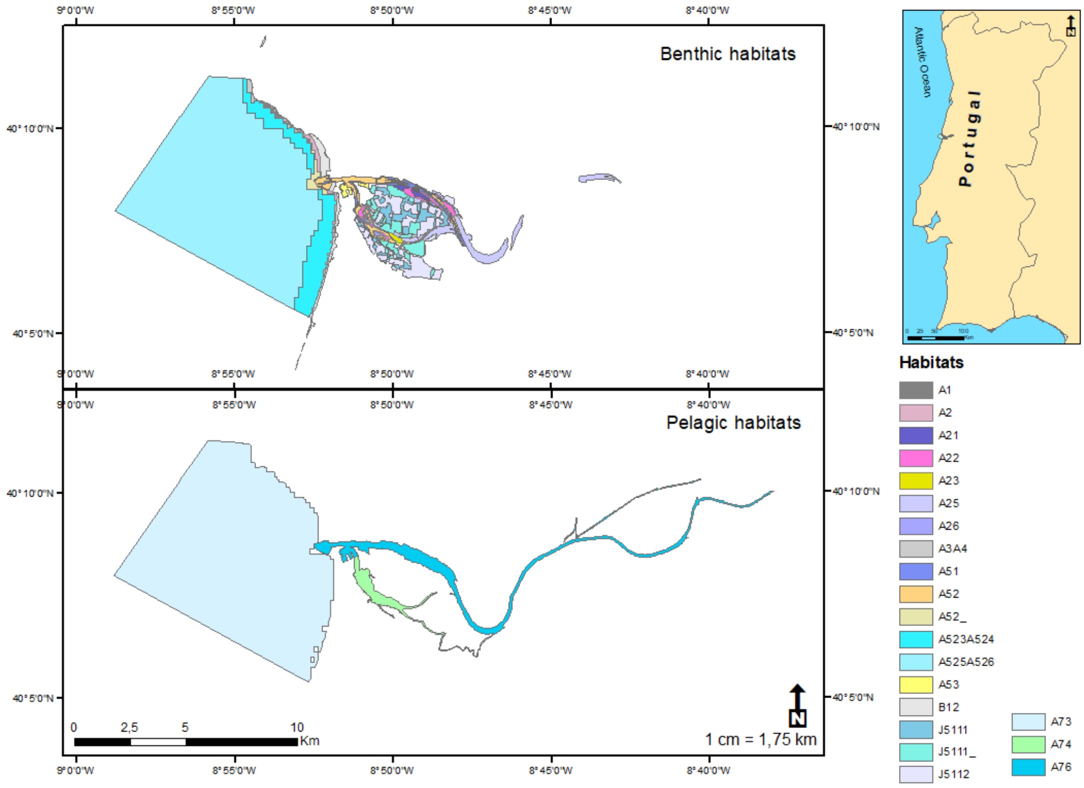


Figure IV.1. Location of the Atlantic coastal region adjacent to the Mondego River. A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 - Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters; A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Testing Hypothesis 1

To test whether *adding ES abundance as a resilience descriptor will introduce significant and meaningful changes in the InVEST/HRA risk scores, compared to a model without resilience descriptors* (Hypothesis 1), two InVEST Habitat Risk Assessment models (HRA) were performed: (1) the HRA-1 model, which was calculated with no adaptations (see section2.2.1 for details); and (2) the HRA_ES-2 model, a modified version of the HRA-1 model, in which the ecosystem services' abundance was added as a resilience descriptor (see section 2.2.2 for details). Then, both models were cross-compared (see section 2.2.3 for details).

The non-modified InVEST Habitat Risk Assessment model (HRA-1)

The InVEST Habitat Risk Assessment (HRA) model is an exposure-consequence framework that allows users to assess the cumulative risk posed to habitats affected by stressors, typically due to human activities, and to explore the consequences for the delivery of ecosystem services (Duggan et al., 2015; Sharp et al., 2018). When coupled with an Overlap Analysis model it allows the assessment of locations where stressors are having an impact on habitats (Wyatt et al., 2017).

The model assumes that the further the habitat is from the stressor, or exposure (E), the less the consequence (C) on it would be. This association follows a model decay that is linear when is applied to environmental studies (Ban et al., 2010). Exposure and consequence are both determined by assigning a rating (typically 1-3, with 0 = no score) to a set of criteria for each attribute (Table IV.1). For this study, scores were assigned to criteria based on information from peer-reviewed literature and expert judgement from researchers of the University of Coimbra with at least five years of research experience in the study area. Data model inputs include spatial explicit data of habitats, stressors and ecosystem services' abundance. In total, 18 benthic habitats, 3 pelagic habitats (Figure IV.1), 13 stressors (Figure IV.2) and 231 ecosystem services (Appendix C – Supplementary data) were analysed. The criteria scores and the data model inputs are fully described in the supplementary material (Appendix C– Supplementary data).

Table IV.1. Score criteria for Exposure and Consequence attributes of InVEST Habitat Risk Assessment models (HRA). HRA-1 – non-modified InVEST/HRA model; HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.

Attribute	Score criteria				Model	
	Low (1)	Medium (2)	High (3)	No score (0)	HRA-1	HRA_ES-2
Exposure						
Temporal overlap	Habitat and stressor co-occur for 0-4 months of the year	Habitat and stressor co-occur for 4-8 months of the year	Habitat and stressor co-occur for 8-12 months of the year	N/A	+	+
Intensity	Low intensity	Medium intensity	High intensity	N/A	+	+
Management effectiveness	Very effective	Somewhat effective	Not effective, poorly managed	N/A	+	+
Consequence – Resilience						
Natural mortality rate	High mortality (e.g., 80% or higher)	Moderate mortality (e.g., 20-50%)	Low mortality (e.g., 0-20%)	N/A	+	+
Natural recruitment rate	Annual or more often	Every 1-2 yrs	More than 2 yrs	N/A	+	+
Age at maturity/recovery time	Less than 1 yr	1-10 yrs	More than 10 yrs	N/A	+	+
Connectivity	Highly connected	Medium connectivity	Low connectivity	N/A	+	+
Ecosystem services abundance	Low number of ecosystem services by habitat (≤5% of the total by CICES class)	Medium number of ecosystem services by habitat (5-10% of the total by CICES class)	High number of ecosystem services by habitat (≥10% of the total by CICES class)	N/A	-	+
Consequence-Sensitivity						
Change in area	Low loss in area (0-20%)	Medium loss in area (20-50%)	High loss in area (50-100%)	N/A	+	+
Change in structure	Low loss in structure (0-20% loss, little to no structural damage)	Medium loss in structure (20-50% loss, partial structural damage)	High loss in structure (50-100% loss, total structural damage)	N/A	+	+
Frequency of similar natural disturbance	Frequent (daily to weekly)	Intermediate (several times per year)	Rare (annually or less often)	N/A	+	+

+: attribute included in the analysis
-: attribute not included in the analysis

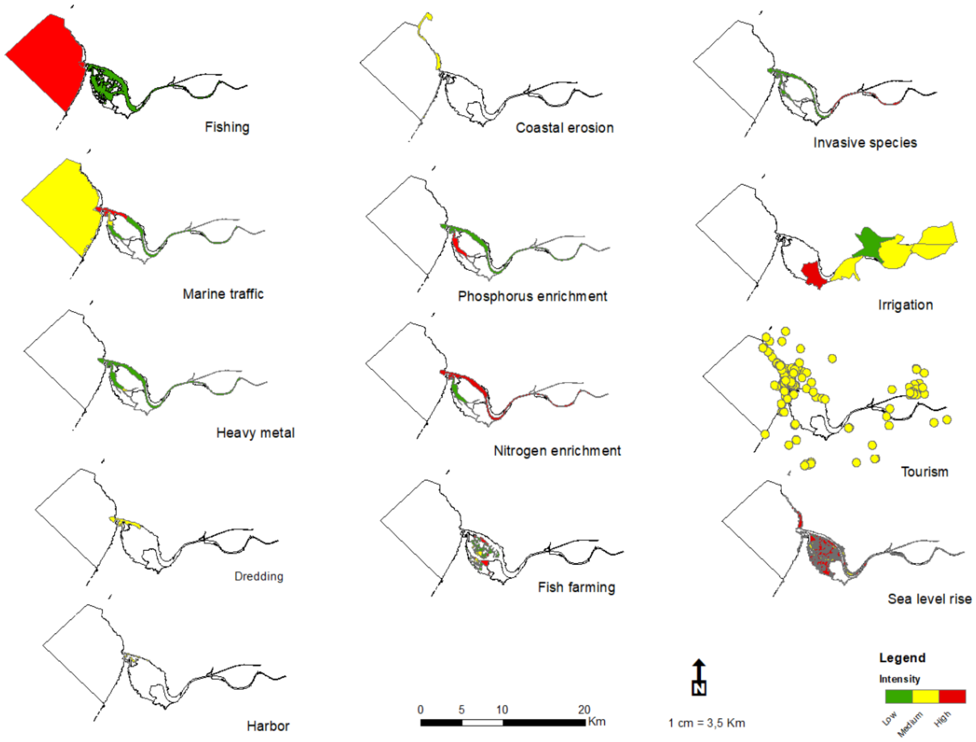


Figure IV.2. Spatial distribution of the thirteen stressors included in the habitat risk assessment, and their intensity, along the Atlantic coastal region adjacent to the Mondego River (see Appendix A – Supplementary data for further details).

The overall exposure *E* (Eq. 1) and consequence *C* (Eq. 2) scores are calculated as weighted averages of the exposure values e_i and consequence values c_i for each criterion *i*, from habitat *j* and stressor *k*.

$$Ejkl = \frac{\sum_{i=1}^{N} \frac{eijkl}{dijkl * wijkl}}{\sum_{i=1}^{N} \frac{1}{dijkl * wijkl}} \qquad \text{(Eq. 1)}$$

$$Cjkl = \frac{\sum_{i=1}^{N} \frac{cijkl}{dijkl * wijkl}}{\sum_{i=1}^{N} \frac{1}{dijkl * wijkl}} \qquad \text{(Eq. 2)}$$

where *Ejkl* is the exposure score specific to habitat *j*, from stressor *k* in location *l*; *Cjkl* is the consequence score, *eijkl* is the exposure rating criterion *i*, specific to habitat *j* and stressor *k* and location *l*; *cijkl* is the consequence rating. *dijkl* represents the data quality rating, *wijkl* represents the importance weighing for criterion. *N* is the number of criteria evaluated for each habitat.

The model also allows assigning weights to score according to data quality and importance of each criterion (Table IV.2).

Table IV.2. Data quality and criteria weights scores.

Data quality	Best data (1)	Adequate data (2)	Limited data (3)
	Supported by scientific published papers that characterize the study area	Information based on data collected outside of the study area, with similar characteristics and published. Data sources published in European Union pages or inferred from studies whose objectives are not specific to measure the variables of the model	Reasonable inferences made by the user in the study area
Weight of criteria	Most important (1)	Moderately important (2)	Less important (3)

After calculating the exposure and consequence scores, their values are combined to produce a risk value for each stressor-habitat combination in each grid cell. For the purpose of this work, risk calculation was based on the Euclidean distance from the origin in the exposure-consequence space (Arkema et al., 2014), where average exposure (*Ejkl*) is on one axis and the average consequence score (*Cjkl*) is on the other (Eq. 3) (Sharp et al., 2018).

$$Rjkl = \sqrt{(Ejkl - 1)^2 + (Cjkl - 1)^2} \qquad \text{(Eq. 3)}$$

where *Rjkl* is the risk to habitat *j* caused by stressor *k* in each location (i.e. cell).

The model then quantifies, in each location, the cumulative risk to each habitat from all stressors (Eq. 4), after which identifies areas of habitats that are risk 'hotspots'.

$$Rjl = \sum_{k=1}^{K} Rjkl \qquad \text{(Eq. 4)}$$

where *Rjl* is the sum of all risk scores by habitat *j*.

Risk 'hotspots' are further identified classifying grid cells as high, medium and low risk, based on the maximum risk score or on the total possible cumulative risk. For this study, the maximum risk score was applied, which assumes that when a stressor is particularly destructive, additional stressors will not further increase the risk of habitat degradation (Sharp et al., 2018). Using the Euclidean risk calculation and a score rank on a scale 1-3, the maximum risk score for an individual habitat-stressor combination is equal to 2.83 (Sharp et al., 2018). As such, high risk corresponds to grid cells with scores greater than 1.87 (66% of 2.83); medium risk corresponds to grid cells with scores between 0.93 and 1.86 (between 33% and 66% of 2.83); and low risk corresponds to grid cells with scores between 0.00 and 0.92 (between 0 and 33%).

To overcome habitats co-occurrence, the HRA model also provides an integrative index of risk across all habitats, i.e. an ecosystem risk, summing each habitat risk scores in a cell, which represents the total risk output of the model. Ecosystem risk increases with an increasing number of co-occurring habitats (Eq. 5).

$$Rl = \sum_{j=1}^{J} Rjl \qquad \text{(Eq. 5)}$$

Where *Rl* is the sum of risk scores across all habitats.

<u>The modified InVEST Habitat risk assessment model (HRA_ES-2)</u>

The Habitat risk assessment (HRA) model, as described in the previous section, was modified to add the ecosystem services' abundance as a resilience attribute to describe the consequences of habitat exposure to a set of stressors (Table 1). As each ecosystem services' category, i.e., provisioning, regulation and cultural, contributes in a different manner to the resilience of ecosystems (Culhane et al., 2019; Liu et al. 2019), different weights have been assigned to each category: provisioning services pose the highest risk as they imply more human activities to get them (weight = 1); regulation services pose the lowest risk as they do not imply invasive activities to be obtained (weight=3); cultural services pose a medium risk, considering that they represent an intermediate human impact (weight =2). As ecosystem services abundance was defined based on a high diversity of literature references - from scientific papers, to grey literature and social media (Caro et al., 2020) - a score of 2 was assigned to the data quality component (Table IV.2).

<u>Comparison between HRA-1 and HRA_ES-2 models</u>

To capture the main differences between the non-modified habitat risk assessment model (HRA-1) and the modified habitat risk assessment model that includes ecosystem services' abundance as a resilience descriptor (HRA_ES-2), it was applied the formula HRA_ES-2 – HRA-1 using the raster calculator tool from ArcGis 10.6.1. A histogram was produced to compare the mean risk values by habitat between the two models and a paired sample t-test between the mean risk scores of both models was performed to determine whether their mean difference is zero, assuming that data comes from related observations. A two-tailed hypothesis and a significance p-value of 0.05 was used. The t-test was selected because, according to a Shapiro-Wilk test, the distribution of the means followed a normal distribution.

In addition, a Principal Component Analysis (PCA) was performed to verify how much variance the two HRA models are able to explain and to understand if the correlation structure in the data was different among the two models. All (mean, max. and min.) exposure, consequence and risk score attributes were included in the analysis. All statistic data was calculated using Past 4.0, a free statistical software developed by a team from the University of Oslo (Hammer, 2001).

Testing Hypothesis 2

To test whether *a HRA model that accounts for ES abundance as an expression of environmental resilience and, at the same time, as a source of environmental stress due to demand, originates habitat risk values significantly different from other approaches that only take one of the assumptions into consideration* (Hypothesis 2), the HRA_ES-2 model was compared to other approaches available in literature which also establish a relationship between habitat risk and ecosystem services. The modified HRA_ES-2 model was compared to the indices proposed by Cabral et al. (2015), Willaert et al. (2019) and Culhane et al. (2019).

To compare the results of the four approaches, first was calculated the influence of ES abundance on habitat risk scores based on the indices described by Cabral et al. (2015), Willaert et al. (2019) and Culhane et al. (2019). As such, the vulnerability index (Vi_C) of Cabral et al. (2015) was calculated based on Eq. 6, the vulnerability index (Vi_W) of Willaert et al. (2019) was calculated based on Eq. 7, and the ecosystem service supply (RESS) of Culhane et al. (2019) was calculated based on (Eq. 8)

$$Vi_C = \frac{Ri}{A} \qquad \text{(Eq. 6)}$$

$$Vi_W = Ri \times A \quad \text{(Eq. 7)}$$

$$RESS = \frac{1}{\sqrt{(Ri-1)^2+(A-1)^2}} \qquad \text{(Eq. 8)}$$

where *Ri* is the cumulative mean risk by habitat obtained from the HRA-1 model and *A* is the total abundance of ecosystem services scores (Caro et al., 2020), normalized to 0-1 by taking the maximum risk score as being equal to one, and the minimum risk score as being equal to 0.

Then, a Friedman test (Pereira et al., 2015) followed by a Wilcoxon Pairwise test (Zimmernan and Zumbo, 1993) with Bonferroni correct p-values (Armstrong, 2014), suitable to compare the medians of more than two non-normal paired samples, was applied to determine whether there were any statistically significant differences between the risk scores of all four approaches. A significance p-value of 0.05 was used. The Friedman-test was selected because, according to a Shapiro-Wilk test, the distribution of the metrics did not follow a normal distribution.

Finally, a Principal Component Analysis (PCA) (Mishra et al., 2017) was applied to enable a different perspective and improve knowledge about the data structure. PCA is more commonly used as a method for feature extraction and dimensionality reduction, i.e., to create 'new' independent variables based on a combination of 'old' independent variables. In this process, researchers get to understand which 'new' variables predict better the dependent variable. This study is assuming that the cumulative mean risk score is the dependent variable, and that the four approaches (HRA_ES-2, Vi_C, Vi_W and RESS) are the independent variables. Performing a PCA will allow understanding whether there is a relationship among the approaches (in the form of 'new' independent variables), what kind of relationship exists, what might distinguish the approaches among themselves and which are more important in predicting the cumulative risk score. To enable the comparison, the results of all four approaches were scaled to 0-1, by subtracting the minimum value and dividing by the difference between the maximum and minimum value (Parravicini et al., 2012). All statistic data was calculated using Past 4.0 (Hammer, 2001).

Testing Hypothesis 3

To test whether *improving the management effectiveness score of the stressors that most contribute for habitats' risk, will decrease the HRA risk score* (Hypothesis 3), management scenarios were tested for seagrass and saltmarsh habitats based on the modified HRA_ES-2 model. To do that, the first step was to describe the influence of stressors on seagrass and saltmarsh habitats' risk based on the area affected by each stressor. This information allowed us to identify the most impacting stressors, which, for the purpose of this study, correspond to those for which more than 10% of the habitat area is under high risk and/or more than 50% is under medium risk (see section 2.2.1 for further details on the definition of high and medium risk). Stressors were selected based on the HRA_ES-2 model results.

Then management scenarios were tested changing the management effectiveness attribute (Exposure) (Table IV.1), in the HRA_ES-2 model, of the stressors that most contribute for seagrass and saltmarsh habitats' risk. Two scenarios – the "one stressor management scenario" and the "multiple stressor management scenario" - were tested for each habitat (Table IV.3).

Table IV.3. Management scenarios built to assess the effect on seagrasses and saltmarshes habitats' risk.

Scenario		Goal	Description
Scenario 1	One stressor management scenario	To assess how a small intensity management change in the most impacting stressor could alter the habitats' risk.	Management effectiveness attribute (Exposure) of the most important stressor was increased by one value. The stressor with the largest area percentage under high risk was selected.
Scenario 2	Multiple stressor management scenario	To assess how a large reduction in human pressures' intensity in the most impacting stressors could alter the habitats' risk.	Management effectiveness attribute (Exposure) of all significant stressors was increased to the maximum effectiveness in order to simulate a reduction of human pressures' intensity to the minimum. All stressors for which more than 10% of the habitat area is under high risk and/or more than 50% is under medium risk, were selected.

Results

Are there differences among the modified and the non-modified InVEST/HRA models?

The t-test, suitable for paired samples and normal distributions, confirms, with 95% confidence, that there are significant statistical differences (p <0.05) between the non-modified HRA-1 model and the modified HRA_ES-2 model (including ecosystem services' abundance as a resilience attribute) (Table IV.4), meaning that the results cannot be explained by random variation only.

Table IV.4. Statistical results for hypothesis 1. Shapiro-Wilk to evaluate whether the populations are drawn from normal distributions. Paired t-test to evaluate differences between two groups (Null hypothesis (H_0): means of the two HRA models are equal).

Shapiro-Wilk normality test				
	Mean	**Stand. Dev.**	**Shapiro-Wilk**	**p-value**
HRA-1	0.6924	0.1981	0.9723	0.7842
HRA_ES-2	0.7781	0.2229	0.9526	0.3817
paired t- test				
	Mean difference	**95% conf.**	**t-value**	**p-value**
	0.0875	0.058267 - 0.11316	-6.5143	2.38E-06*

* p-value <0.05
Note: The normality test shows that both the HRA-1 and the HRA_ES-2 populations do not deviate from nomality (p>0.05), justifying the use of a parametric test (t-test).
HRA-1 – non-modified InVEST/HRA model; HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.

The Principal Component Analysis (Figure IV.3) shows that the correlation structure in the data differs among the two models, confirming that including the abundance of ecosystem services as a descriptor of resilience influences the results. For both models, the mean exposure (E_MEAN) is the variable that most contributes to PC1 (loading score of 0.53 in HRA-1; loading score of 0.55 in HRA_ES-2), whereas the maximum exposure (E_MAX) is the variable that most contributes to PC2 (loading score of -0.66 in HRA-1; loading score of -0.69 in HRA_ES-2) (Appendix C- Supplementary data). As a result, the right and upper-side aggregates habitats with high mean exposure scores and low maximum exposure scores, whereas the left and lower-side aggregates habitats with low mean exposure scores and high maximum exposure scores. Despite the similarities among models, in the HRA-1 model, seagrass habitats (A2.6) are clearly separated from the remaining habitats as a result of a much higher mean exposure, whereas in the HRA_ES-2 model, the number of habitats with similar high mean exposure increases. As the results also show that the mean exposure is highly positively correlated with the mean risk (R = 0.95, p-value = $1.08E^{-11}$) (Appendix C - Supplementary data), it is to expect a higher number of habitats with high mean risk with the HRA_ES-2 model than with the HRA-1 model.

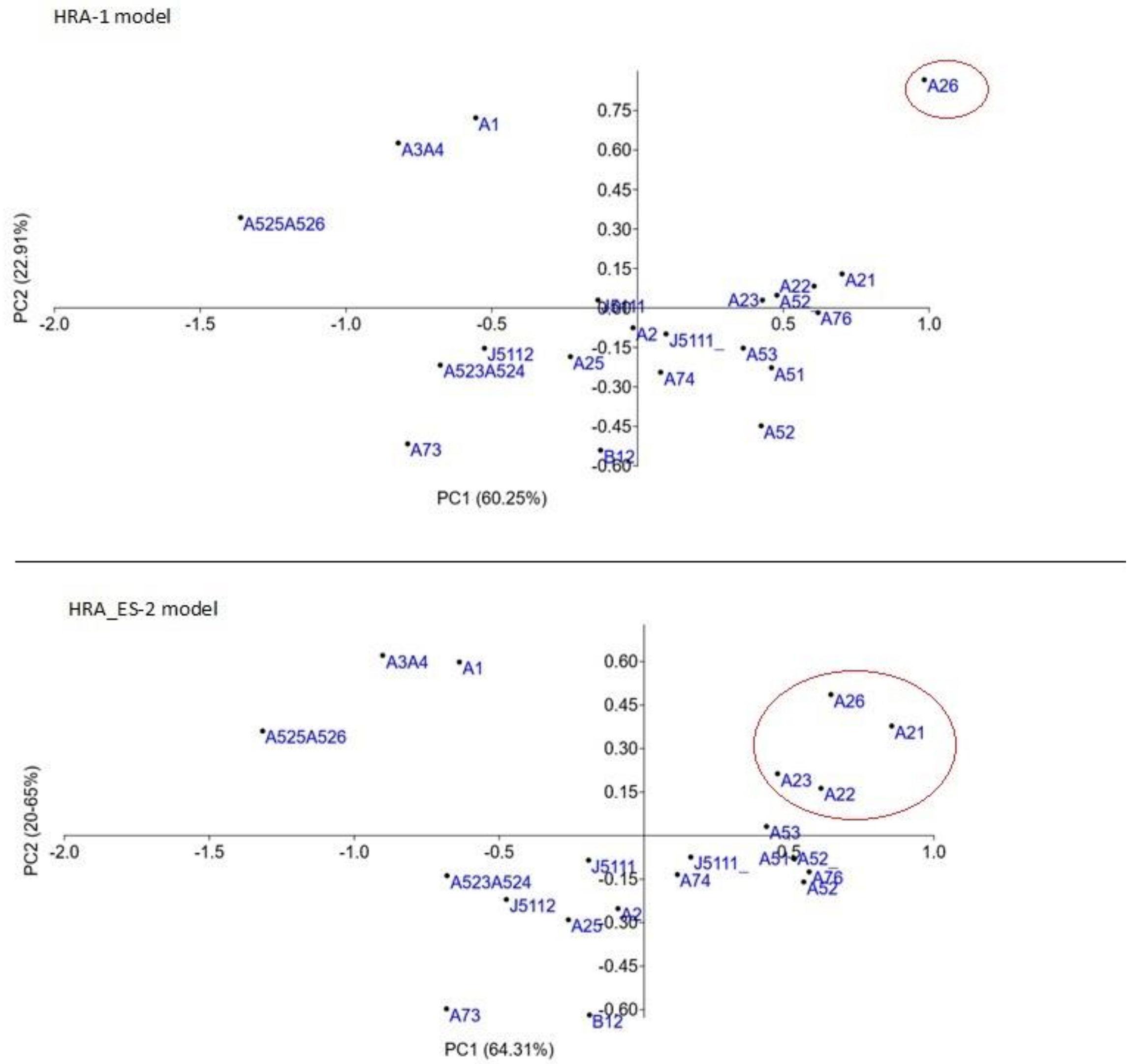


Figure IV.3. Principal Component Analysis (PCA) to analyse the relationship between HRA-1 and HRA_ES-2. The figure shows the first two components for both models, which, in both cases, explain a minimum of 84% of the variance. Distance from axes reveals the coefficient magnitude: the larger the magnitude, the more important the corresponding habitat is in calculating the component. Habitats in the positive quadrants show positive associations with the PCA component. Habitats in the negative quadrants show negative associations with the PCA component. The ellipses show habitats with similar high mean risk score. Legend: Legend: HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A26 - Estuarine seagrass beds.

Analyzing the results in more detail, the cumulative risk score shows that the highest score (*Rmax*) does not exceed the upper medium score limit, i.e. 1.86 for all habitat-stressor combinations (Appendix C - Supplementary data), for both models, considering stressors altogether, which means that the Atlantic coastal region adjacent to the Mondego River does not show areas under high risk. The habitats with the largest area under medium risk differ between models and are located in transitional waters. For the HRA-1 model, two habitats - Estuarine littoral granule, very coarse to coarse sands (A2.1) and Estuarine seagrass bed (A2.6) show more than 40% of their area under medium risk, and thus are the habitats with higher risk. For the HRA_ES-2 model, six habitats are in the same conditions - Estuarine littoral granule, very coarse to coarse sands (A2.1), Estuarine littoral sandy mud and very fine to medium sands (A2.2), Estuarine littoral mud (A2.3), Estuarine seagrass bed (A2.6), Estuarine sublittoral granule and very coarse to coarse sands (A5.1), and Estuarine sublittoral sandy mud and very fine to medium sands (A5.2) (Table IV.5 and Figure IV.4). For all the remaining habitats, their area is classified as low risk (Figure 4). Notice that, with exception for habitats A5.1 and A5.2 in the HRA_ES-2 model, the habitats with higher risk are all intertidal habitats (Figure IV.4 and Appendix C - Supplementary data).

Table IV.5. Cumulative risk scores for all stressors by habitat for medium risk habitats for the non-modified HRA-1 model and the modified HRA_ES-2 model.

Habitat	R_MEAN	R_MIN	R_MAX	R_%HIGH	R_%MEDIUM	R_%LOW
HRA-1 model						
A21	0.943974	0.483739	1.152391	0	40.22989	59.77011
A26	1.061587	0.931535	1.188512	0	86.04651	13.95349
HRA-_ES-2 model						
A21	1.109863	0.714008	1.341436	0	80.23256	19.76744
A22	1.023484	0.317507	1.306909	0	66.80498	33.19502
A23	0.981223	0.464899	1.310804	0	58.59375	41.40625
A26	1.168636	0.601396	1.285765	0	95.83333	4.166667
A51	1.035931	0.293235	1.395215	0	65.66524	34.33476
A52	1.042899	0.293235	1.440711	0	64.83516	35.16484

R – Cumulative risk score; MIN – minimum; MAX – maximum
HRA-1 – non-modified InVEST/HRA model; HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A26 - Estuarine seagrass beds; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands

The results show that the medium risk areas are mainly located in the Mondego subsystem of the estuary (North branch), when running the HRA-1 model, but spread, after running the HRA_ES-2 model, to the Pranto subsystem of the estuary (South branch), as shown by the spatial distribution of the ecosystem risk, i.e., the sum of risk of all habitats in a grid cell, rather than a single habitat (Figure IV.4).

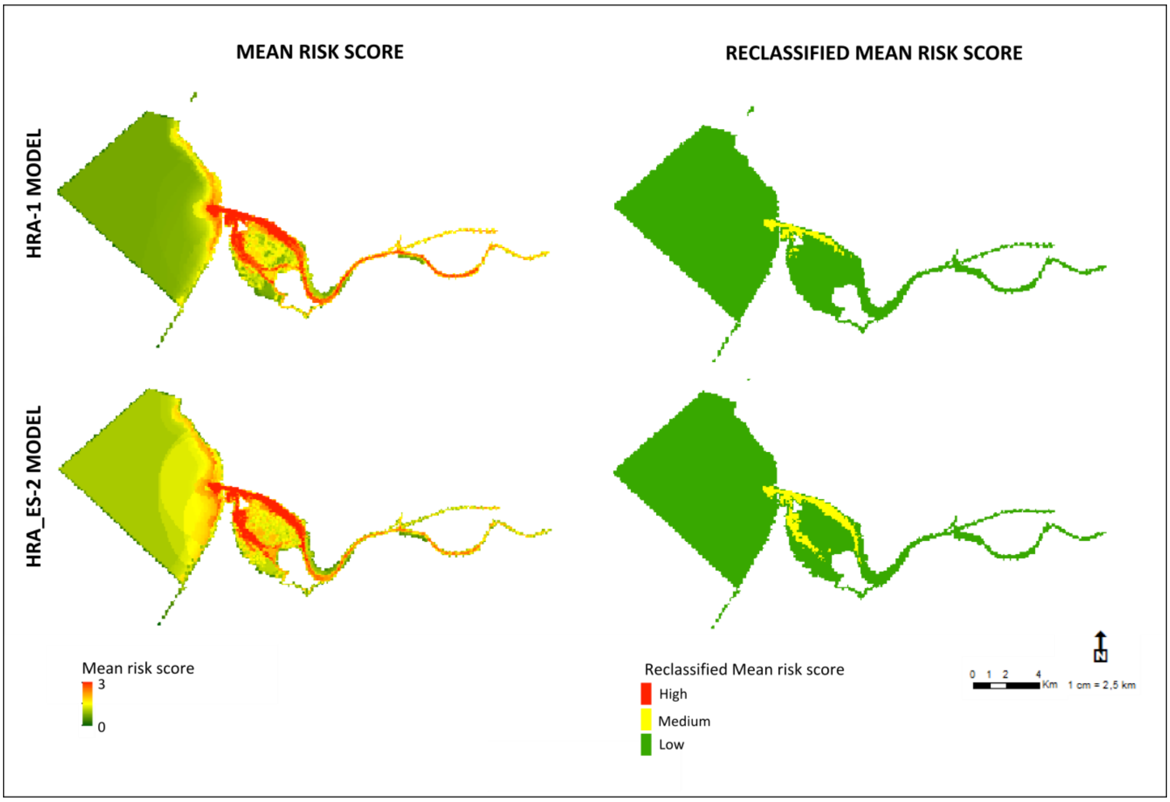


Figure IV. 4. Ecosystem risk map of the study area. The upper left image shows the average cumulative risk scores across all habitats from the HRA-1 model (non-modified InVEST/HRA model). The upper right image shows the reclassified average cumulative risk scores by categories for the HRA-1 model. The lower left image shows the average cumulative risk scores across all habitats from the HRA_ES-2 model (modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience). The lower right image shows the reclassified average cumulative risk scores by categories for the HRA_ES-2 model. Reclassification categories: High risk (red), medium risk, (yellow) and low risk (green).

The spatial differences among the results from the two models are highlighted in Figure IV.5. Positive values, which occupy most of the study area, show areas where the risk has increased from the HRA-1 model to the HRA_ES-2 model. Negative values show the opposite trend. The largest positive differences are seen in the downstream area of the estuary and in the coastal area around the estuarine mouth. Negative differences, indicating a decrease in the cumulative risk score from one model to the other, are more intense in the upstream area of the estuary. Analyzing the cumulative risk scores by habitat (histogram in Figure IV.5), than rather by grid cell, the cumulative risk scores only decrease for two low risk habitats: the *Estuarine saltmarshes* (A2.5), from transitional waters; and the *Sandy beaches* (B1.2) habitats, from coastal waters.

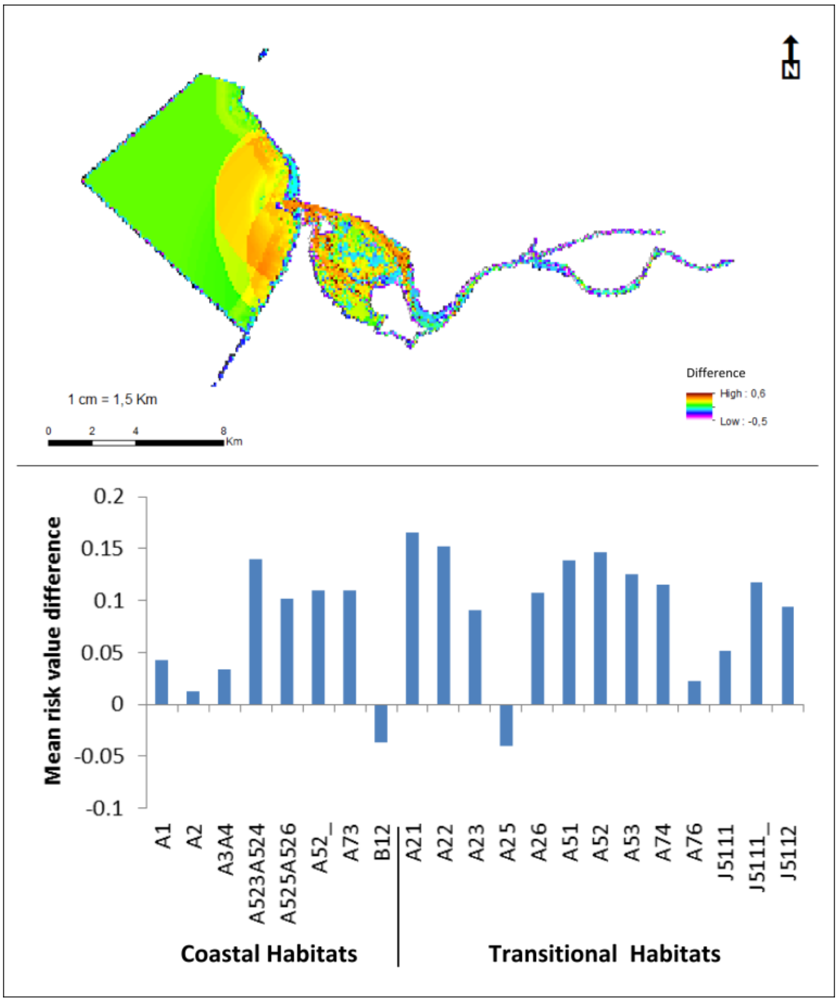


Figure IV. 5. Differences between the cumulative mean risk scores from HRA-1 model (non-modified InVEST/HRA model) and the HRA_ES-2 model (modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience). The upper map shows the spatial distribution of the differences by grid cell. The histogram shows the differences by habitat. A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 - Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters; A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Are there significant statistical differences between the modified HRA_ES-2 model and the approaches from other authors?

The Friedman test, suitable for paired samples drawn from non-normal distributions, confirms, with 95% confidence, that there is a significant difference ($p < 0.05$) between the means of the HRA_ES-2 model, the vulnerability index proposed by Cabral et al. (2015) (Vi_C), the vulnerability index proposed by Willaert et al. (2019) (Vi_w) and the ecosystem service supply (RESS) value proposed by Culhane et al. (2019) (Table IV.6) (see Appendix A - Supplementary data for the risk values of Vi_C, Vi_W and RESS). These results are confirmed by the Wilcoxon pairwise, with Bonferroni corrected p values. In particular, the pairwise test shows that the HRA_ES-2 model is significantly different from Vi_W RESS, but not from Vi_C (although the p-value is very close to 0.05, and thus it is not possible to be entirely sure that the significant difference does not exist) (Table IV.6).

Table IV.6. Statistical results for hypothesis 2. The Shapiro-Wilk results evaluate whether the populations are drawn from normal distributions. The Friedman non-parametric test evaluates differences between groups and the Wilcoxon is used for pairwise comparison (Null hypothesis (H0): medians of the four risk approaches are equal).

Shapiro-Wilk normality test				
	Shapiro-Wilk W	**p-value**	**Mean**	**Stand. dev**
HRA_ES-2	0.9526	0.3817	0.7780952	0.2229489
Vi_C	0.8943	0.02713*	0.579296	0.5012828
Vi_W	0.9006	0.03601*	0.4595304	0.3421495
RESS	0.6642	0.00001*	3.342591	3.681292
Friedman test for equal means				
Chi2	**p-value**			
44.814	1.18E-10*			
Wilcoxon pairwise (above the diagonal) and bonferroni corrected p-values (below the diagonal)				
	HRA_ES-2	**Vi_C**	**Vi_W**	**RESS**
HRA_ES-2		190	224	228
Vi_C	0.05768		3	231
Vi_W	0.00098*	1		231
RESS	0.00055*	0.00036*	0.00036*	

* p-value < 0.05

HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.

Vi_C – vulnerability index proposed by Cabral et al. (2015); Vi_W – vulnerability index proposed by Willaert et al. (2019); RESS – index proposed by Culhane et al. (2019).

Note: A non-parametric test has been chosen because the normality test shows that the HRA_ES-2 population deviates from nomality (p>0.05), and also because the four models show very different standard deviations.

The PCA results confirm the statistically significant differences found with the Friedman test, clarifying the relationship between the HRA_ES-2 model and the approaches proposed by other authors (Figure IV.6). On component 1, all four approaches have similar positive loadings, indicating that this component is measuring habitat's risk, but on component 2, HRA_ES-2 has a very large positive loading, contrary to the other approaches (Table IV.7) indicating that this component is capturing the differentiating feature of the HRA_ES-2 model. The first two principal components explain 85% of the variance (Figure IV. 6 and Appendix C – Supplementary data).

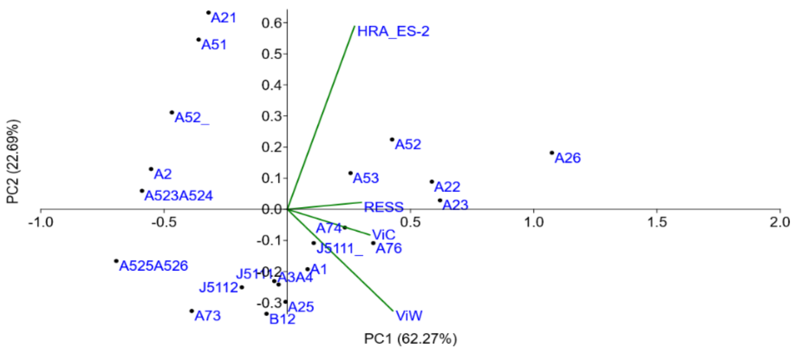


Figure IV.6. Principal Component analysis (PCA) to analyse the relationship between the following risk assessment approaches: HRA_ES-2, ViC, ViW and RESS. The figure shows the first two components, which together explain 85% of the variance. Distance from axes reveals the coefficient magnitude: the larger the magnitude, the more important the corresponding approach is in calculating the component. Approaches in the positive quadrants show positive associations with the PCA component. Approaches in the negative quadrants show negative associations with the PCA component. Legend: HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience; ViC – Vulnerability index proposed by Cabral et al. (2015); ViW – Vulnerability index proposed by Willaert et al. (2019); RESS – index proposed by Culhane et al. (2019).

Table IV.7. Magnitude and direction of PCA coefficients for the following risk assessment approaches: HRA_ES-2, ViC, ViW and RESS. The total variance explained by each component is between brackets. The values indicate the coefficient magnitude: the larger the magnitude, the more important the corresponding approach is in calculating the component. The positive and negative signs indicate the coefficient direction and whether there is a positive or negative association with the PCA component.

	PCA components			
	PC1 (62.2%)	**PC2 (22.8%)**	**PC3 (12.5%)**	**PC4 (2.4%)**
HRA_ES-2	0.404435	0.867085	-0.00077	0.290853
Vi_C	0.492434	-0.12164	-0.7985	-0.32421
Vi_W	0.630359	-0.48217	0.234199	0.561526
RESS	0.443383	0.029679	0.554572	-0.70355

HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience; Vi_C - Vulnerability index proposed by Cabral et al. (2015); Vi_W – Vulnerability index proposed by Willaert et al. (2019); RESS – index proposed by Culhane et al. (2019)

Does the habitat risk score decrease with increasing management effectiveness?

To analyse changes in the habitat risk score within different management scenarios, the management effectiveness score of the HRA_ES-2 model was modified only for those stressors that most impacted saltmarsh and seagrass habitats (Table IV.8). The results show that Estuarine saltmarshes (A2.5) are majorly affected by sea level change, organic enrichment due to nitrogen increase, irrigation and fishing; and that Estuarine seagrass bed (A2.6) are affected by all stressors, except coastal erosion and tourism activities (Table IV.8). Because sea level change is the stressor that contributes to the largest area percentage under high risk, in both habitats, it was selected for management improvement in scenario 1 (see section 2.6). The remaining marked stressors were selected for scenario 2 (see section 2.6).

Table IV. 8. Percentage of saltmarsh and seagrass habitats' area under high, medium and low risk, in the Atlantic coastal region adjacent to the Mondego River, based on the contribution of each stressor, for the HRA_ES-2 model.

	R_%HIGH	R_%MEDIUM	R_%LOW	R_%HIGH	R_%MEDIUM	R_%LOW
Stressor	**Saltmarshes (A2.5)**			**Seagrasses (A2.6)**		
Fishing: recreative, commercial	0.00	62.72**	37.28	0.00	100**	0.00
Coastal erosion	0.00	0.00	100	0.00	0.00	100
Landfill/dredging/sand extraction	0.00	0.00	100	0.00	58.33**	41.67
Pollution by Fish farming	1.72	12.93	85.34	0.00	93.75**	6.25
Harbor activities	0.00	4.96	95.04	0.00	100**	0.00
Contamination by heavy metals	0.00	21.12	78.88	0.00	97.92**	2.08
Invasive species	5.17	28.02	66.81	0.00	56.25**	43.75
Irrigation (loss of freshwater discharge)	5.6	81.90**	12.5	0.00	95.83**	4.17
Marine and estuary navigation traffic	0.00	24.78	75.22	0.00	97.92**	2.08
Organic enrichment due to Nitrogen increase	14.87*	20.47	64.66	25.00*	72.92**	2.08
Organic enrichment due to Phosphorus increase	0.00	33.62	66.38	0.00	97.92**	2.08
Sea level changes	27.37*	58.84**	13.79	39.58*	60.42**	0.00
Tourism activities	0.00	5.17	94.83	0.00	0.00	100

R – Cumulative risk score; HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.
* more than 10% of the habitat area is under high risk
** more than 50% of the habitat area is under medium risk

After modifying the management effectiveness score for the stressors selected, the results indicate that the current situation has the highest cumulative mean risk score, followed by the "one stressor management scenario" (scenario 1). The "multiple stressor management scenario" (scenario 2) shows the lowest cumulative mean risk score. These trends are similar for both habitats (Table IV.9).

Table IV. 9. Cumulative mean risk scores of saltmarsh and seagrass habitats in the current situation and for two management scenarios: the one stressor management scenario (scenario 1) and the multiple stressor management scenario (scenario 2). Results calculated using the HRA_ES-2 model.

Habitat	Current situation (HRA_ES-2)	Scenario 1 "one-stressor"	Scenario 2 "multiple stressor"
Saltmarshes (A2.5)	0.59	0.57	0.52
Seagrasses (A2.6)	1.17	1.15	1.03

HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.

In saltmarsh habitats the increase in management effectiveness induces the disappearance of areas under high risk due to sea level changes and irrigation, and noticeably changes the area under medium risk due to irrigation and fishing to low risk. The same trend is not observed in seagrasses, for which the most noticeable change is the disappearance of areas under high risk due to sea level changes and a slight decrease of areas under medium risk due to fishing (Figure IV.7).

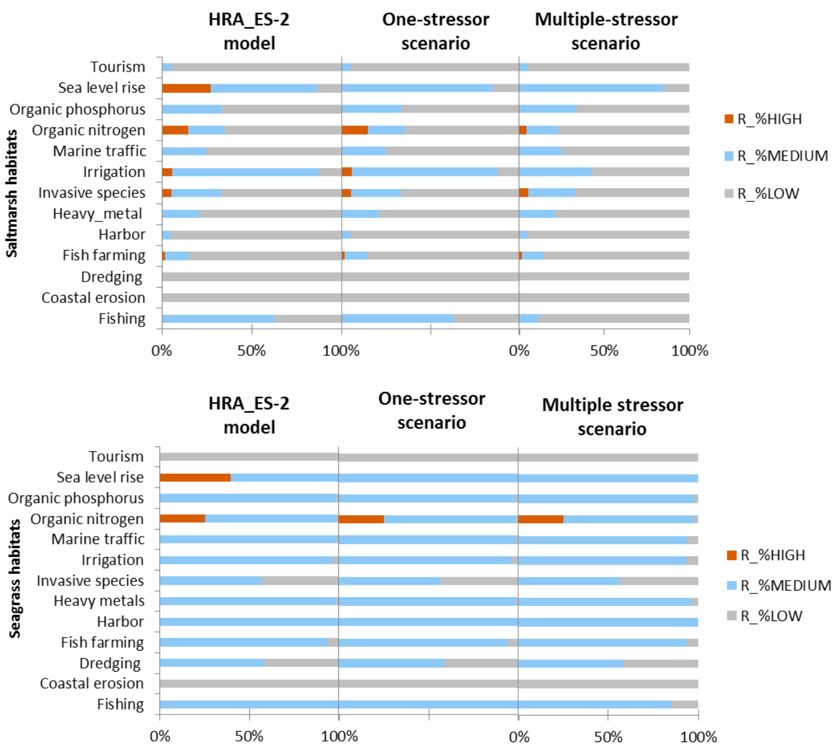


Figure IV.7. Percentage of saltmarsh and seagrass habitats' area with high, medium and low risk under different stressors, for current situation (HRA_ES-2 model), one stressor management scenario (scenario 1) and multiple stressor management scenario (scenario 2). Legend: R – Cumulative risk score; HRA_ES-2 - modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.

Discussion

Ecosystem services' abundance as a resilience descriptor

The cumulative risk seems to be more in accordance with the social-environmental realm after adding ecosystem services' abundance as a resilience descriptor to the InVEST habitat risk assessment model. This is clear when comparing the risk score values of the Pranto subsystem (South branch) of the Mondego estuary from the two models tested: without (HRA-1 model) and with (HRA_ES-2 model) ecosystems services' abundance as a resilience descriptor. Pranto subsystem is one of the most vulnerable sectors of the case study area (e.g. Teixeira et al., 2008; Veríssimo et al., 2013a; Pinto et al., 2014a), as it is highly sensitive to eutrophication (Flint et al., 1997, Dolbeth et al., 2007; Neto et al., 2008, 2010) due to its hydro-morphological characteristics (Duarte et al., 2001; Kenov et al., 2012; Veríssimo et al., 2013a). At the same time, the Pranto subsystem is highly important because it holds the largest and the more consistent patches of saltmarsh and seagrass habitats which provide a wide diversity and abundance of ecosystem services (Caro et al., 2020). Because model HRA-1 only accounts for the exposure-consequence combination without weighting the importance of the habitats for local development and environmental equilibria or, in other words, ecosystem services, it failed to detect the combined social and environmental vulnerability of the Pranto subsystem, i.e., the potential increase in vulnerability that comes from the impacts if ecosystem services are in demand, but also the decrease in vulnerability in habitats that provide higher abundances of ecosystem services. On the contrary, model HRA_ES-2, which took into account the ecosystem services' abundance, successfully detected it. A similar trend occurred for the coastline habitats and nearshore areas around the mouth of the Mondego estuary. These are low risk areas for which the cumulative risk score has increased after adding the ecosystems services' abundance as a resilience descriptor, indicating that in the presence of ecosystem services' demand, the vulnerability of coastline habitats may be higher than expected. This is in accordance with previous studies that show that stability is associated to species abundance rather than species richness (Pinto et al., 2013b), and that coastline and nearshore habitats are rich in species diversity, but low in species abundance (Teixeira et al., 2007).

The cumulative risk scores have, in fact, increased for almost all habitats when the ecosystem services abundance is included in the habitat risk assessment model. This is relevant from a precautionary principle (Kriebel et al., 2001), for four main reasons: 1) though an ecosystem might be capable of providing a service, it does not mean it is actually being used, but might be used in the future; 2) there can be a use of a service, even without an expression of demand, which frequently occurs with regulation services (Villamagna et al., 2013; Geijzendorffer and Roche, 2014); 3) the supply of ecosystem services may be associated to indirect pressures, for instance, road construction to increase value of previously inaccessible locations; and/or occasional low invasive pressures, such as ecosystem visitors for aesthetic/spiritual reasons; and 4) there can be a spatial mismatch between supply and demand (Syrbe and Grunewald, 2017). If, for these reasons, the stressors are overlooked, the exposure-consequence combination of the traditional habitat risk assessment model will not be able to reveal the full social and environmental vulnerability of the ecosystem.

The modified HRA_ES-2 model successfully establishes a relationship between impact risk and ecosystem service supply potential while accounting for two apparently conflicting assumptions: decrease in habitat vulnerability as a result of greater ecosystem adaptive capacity (measured by ecosystem service abundance) (Cabral et al., 2015) and increase in vulnerability as a result of exposure to ecosystem service demand (measured by the different weights assigned to the different categories of ES: provisioning, regulation and cultural) (Culhane et al., 2019). The model is in line with previous approaches (Cabral et al., 2015; Culhane et al., 2019; Willaert et al., 2019), but while these first perform a risk assessment and only then combine it with ecosystem services availability of habitats, the approach presented in this work integrates ecosystem services supply into the risk assessment model, introducing a spatial relationship between the pressures acting upon the system and the supply of ecosystem services, which provides a geographically more accurate risk assessment based on both impactful activities and ecosystem vulnerability.

Counter-intuitive habitat risk results

The Mondego subsystem of the estuary is dominated by medium risk areas, regardless of the model used. These results are counter-intuitive considering that this subsystem has low water residence time, which has a positive impact in eutrophication vulnerability (Duarte et al., 2001). However, they are consistent with the exposure to pressures such as: (a) the presence of the Figueira da Foz harbor, whose good operation depends on maintaining the navigation channel through dredging activities that cause instability of bottom habitats, leading to sediments re-suspension in the water column and turbidity (Ceia et al., 2013); (b) the proximity to the Figueira da Foz town, which contributes to water pollution (Pinto et al., 2013a; Teixeira et al., 2008); and (c) the embankement of the Mondego river channel which has triggered the replacement of natural habitats by artificial hard structures (e.g. harbor facilities, aquaculture farms, saltworks, artificial riverbanks), leading to ecosystem structure impoverishment (Marques et al., 1993; Cunha and Dinis, 2002; Jørgensen et al., 2002; Ceia et al., 2011). In fact, previous studies have shown that the Mondego subsystem benthic communities are more disturbed than the Pranto subsystem communities (Marques et al., 1993; van der Linden et al., 2016) - frequently dominated by opportunistic species, mainly bivalves, polychaetes, amphipods and oligochaetes (Chainho et al., 2006) -; and that there is an incapacity of intertidal areas to recover after big perturbations (Veríssimo et al., 2013a).

Results also indicate that risk mean score decreases for saltmarsh and sandy beaches habitats when adding ecosystem services abundance as a resilience descriptor (HRA_ES-2 model). As the exposure component has remained unchanged from one model (HRA-1) to another (HRA_ES-2), it would be expected a higher risk mean score just like for the remaining habitats, or, at least, the same risk mean score. However, a lower risk mean score is consistent with the type of ecosystem services supplied by these habitats (Caro et al., 2020). They both supply a wide diversity of regulation and cultural services, which indicate a high adaptive capacity to environmental change; and, at the same time, they show a very low number of provisioning services, and thus low human pressure to get them (Culhane et al., 2019), which is consistent with high resilience and low vulnerability.

Stressors in the Atlantic coastal region adjacent to the Mondego River

According to the model that include ecosystem services abundance in to habitat risk assessment, the stressors most contributing to habitat risk in the Atlantic coastal region adjacent to the Mondego River are the sea level change, organic enrichment due to nitrogen increase and, at a lesser extent, the presence of heavy metals. This agrees with previous research that shows that sea level rise is one of the most important threats to coastal environments (e.g. Teck et al., 2010; Almeida et al., 2016; Doubleday et al., 2017), affecting mainly estuaries (Boerema and Meire., 2017). Model-based projections advocate an increment of 0.26 to 0.77 m by 2100 for 1.5°C of global warming (IPCC, 2018), suggesting that areas with elevation lower or equal to 5 m above the sea level have the risk to disappear or to be naturally modified during the next centuries (e.g., Rova et al., 2018). In the Mondego estuary, studies have shown that a sea level rise of 0.50 m would induce a general increase in water depth in the lower areas of the estuary and large flooded areas (Ferreira et al., 2008; Santos et al., 2012). However, the margins of the estuary are already significantly occupied by urbanization and the inland displacement will not be possible. Sea level rise could change the hydrodynamics of coastal habitats, modifying the tidal pattern and inducing, in turn, changes in salinity, temperature, nutrients availability and oxygen demanding (MEA, 2005). In the worst-case scenario the sea level changes could lead to the disappearance of entire habitats as saltmarshes and seagrasses (Couto et al., 2014).

Nitrogen enrichment as a stressor is confirmed by Marques et al. (2007) and Veríssimo et al. (2013a) which have revealed high nitrogen concentrations in the Mondego estuary, due mainly to agricultural areas located around the Mondego River. Nitrogen loading to aquatic ecosystems can lead to eutrophication, changing the ecosystem productivity, water clarity, and food web dynamics (Rhodes et al., 2017). In the Mondego estuary, high levels of eutrophication have been found in the Pranto subsystem favored by a low water residence time (Martins et al., 1997).

Finally, there is evidence of sediment contamination by heavy metals in the Mondego estuarine habitats (Vale et al., 2002), but concentrations are very low (Couto et al., 2013) - below the limits prescribed in the Guidance on the assessment and redevelopment of contaminated land (ICRLC, 1987) - and have a seasonal pattern, being higher in winter as a result of strong river discharges (Pereira et al., 2007). Despite the low concentrations found, heavy metals tend to be accumulated in the above- and belowground tissues of saltmarsh and seagrass plants and exported to the water column during plant release events, indicating that the plants of the ecosystem function not only as a sink for heavy metals, but also as a source of heavy metals to nearby systems, with implications on the ecosystem metal budget (Couto et al., 2013).

Management of seagrass and saltmarsh habitats

The results confirm the initial assumption that management measures to prevent the degradation of saltmarsh and seagrass habitats will be key to avoid the decrease of the environmental quality conditions of the study area and maintain the supply of socially and environmentally important ecosystem services. Since the end of the eighteenth century and until the end of the twentieth century, high-impact, land-based human activities (Doubleday et al., 2017) have caused the reduction of saltmarsh areas in about 20% of the original area (Castro and Freitas, 2011) and the significant reduction of seagrass habitats in the Pranto subsystem (South branch) (Neto et al., 2010). The results from the ES-2 model indicate that, currently, high risk areas in saltmarsh and seagrass habitats from the study area could be largely explained by the effect of sea level change and organic enrichment due to nitrogen increase, whereas medium risk areas can be explained by other stressors (irrigation, fishing, and sea level changes for saltmarshes; fishing, harbor activities, contamination by heavy metals, marine and estuary navigation traffic, organic enrichment due to phosphorus increase, irrigation, pollution by fish farming, organic enrichment due to nitrogen increase , sea level change, landfill/dredging/sand extraction and invasive species for seagrasses).

Scenario building simulating management improvements revealed that it is possible to change the condition of high-risk areas to medium risk and/or low risk sectors of saltmarsh and seagrass habitats exposed to stressors. With exception for the sector under high risk due to sea level changes, the change is more noticeable for saltmarshes than for seagrasses, whose large area under medium risk may hardly change its condition.

To prevent drowning of saltmarsh and seagrass due to sea level rise (Raposa et al., 2016; Sampath and Boski, 2016), adaptation measures should be applied (Leo et al., 2019). In the case study area, studies have shown that *Scirpus maritimus*, a species that accumulates large percentages of total carbon sequestered in the tissues, will disappear from the Mondego estuary if the sea level rise rates are confirmed (Couto et al., 2014). Measures to accommodate restoration and migration of these habitats include mechanisms of physical alteration of the environment; land acquisition and protection; and regulatory or policy interventions. In the case study, and based on its hydro-morphological characteristics and current land reclamation, the potential of the following adaptation measures should be analysed: (a) hydraulic manipulation, which limits tidal flows, is usually used for agriculture, and could also be useful to promote wetlands restoration (Sandi et al., 2018); (b) stimulation of vertical sediment accretion, through the use of green infra structures or plant transplantation (Waycott et al., 2009); (c) promotion of land covenants, whereby a land owner restricts the use of their own property to protect natural resources; and d) land acquisition, in particular of abandoned private lands which may hold a strategic importance for the recovery of coastal processes.

To avoid the effects of nitrogen enrichment, especially in the Pranto subsystem, the water residence time must be maintained or increased (Lillebø et al., 2005), the nitrogen discharges should be avoided (Martins et al., 2001), the use of agricultural fertilizers controlled (Veríssimo et al., 2013b; Teixeira and Marques, 2016) and nitrogen inputs from fish farming activities reduced (Vasconcelos et al., 2007). These measures would prevent eutrophication events similar to those that occurred in the estuary throughout the period from 1986 to 1997 (Martins et al., 2001; Marques et al., 2007; Neto et al., 2010). Moreover, as scenarios analysis indicate that management measures will be insufficient to completely reduce high-risk areas related with this stressor, the better proposal could be coupling management actions focused on nitrogen enrichment with actions focused on enhancing ecosystem resilience, by managing stressors that diminish seagrass and saltmarsh biomass (Gladstone–Gallagher et al., 2018), like increased turbidity (Samper-Villarreal et al., 2016), fishing practices (Waycott et al., 2009), diseases (Hughes and Paramor, 2004) and storms (Cardoso et al., 2008).

Other management actions still need further research in order to analyse the actual effect on saltmarsh and seagrass habitats, such as the establishment of the maximum amount of water that could be extracted from rivers for irrigation before affecting the biotic communities (Pinto et al 2013a); and the control of invasive species, in particular *Ruditapes philippinarum* whose population dynamics, the factors controlling it (Dang, 2009) and the impacts in the Mondego estuary, are still poorly studied. In fact, estuaries are known for their resilience created by Environmental Homeostasis, i.e., their ability to withstand stress, both natural and anthropogenic, that comes from the ability to achieve a stable state by compensating for changes in the environment as a result of a homeostasis response that may operate at any level of biological organization, be it at the individual, population, community or ecosystem (Elliot and Quintino, 2007). This means that although seagrasses and saltmarshes seem to be sensitive to management effectiveness improvements, which is in accordance to historic management measures oriented to improve the habitat quality (Veríssimo et al., 2017), it is important to consider that ecosystems are context dependent and that within a background of high natural variability, it is more difficult to detect changes caused by anthropogenic stress (Veríssimo et al., 2013b). This difficulty is termed the *Estuarine Quality Paradox* (Elliot and Quintino, 2007). In addition, it is important to be aware that models can be improved in the presence of better data quality, ideally georeferenced (Caro et al., 2018), which might be achieved by strengthening monitoring programs (Singh et al., 2017; Sousa et al., 2017), which, in turn, should be considered as the first management action to conserve habitats, as well as the ecosystem services they deliver.

Conclusions

This study introduces a modified InVEST/HRA model that adds ecosystem services (ES) abundance as a resilience descriptor, assigning different weights to provisioning, regulation and cultural ecosystem services, based on whether there is a need for active exploitation. With this approach, the user is able to account not only for the resilience of ecosystems that arises from the presence of ecosystem services, but also for the sensitivity associated to the potential impacts if ecosystem services are in demand. As such, the methodology provides a risk assessment that takes into account not only the exposure-consequence component of risk, but also the importance of the habitats for local development and environmental equilibria.

Adding ES abundance as a resilience descriptor introduces significant and meaningful changes in the InVEST/HRA risk scores, compared to a model without resilience descriptors. This indicates that the resilience component from the InVEST/HRA model is flexible to accommodate other variables than those proposed by the developers, namely mortality rate, recruitment rate, age at maturity and connectivity. More specifically, the results indicate that the modified InVEST/HRA model is a novel approach to explore, in a spatial explicit manner, the influence of ecosystem services supply in habitats' risk, but also the effects of ecosystem state changes in the supply of ES.

A modified HRA model that accounts for ES abundance as an expression of environmental resilience and, at the same time, as a source of environmental stress due to demand, originates habitat risk values significantly different from those calculated applying the approaches suggested by Willaert et al. (2019) and Culhane et al. (2019), which only assume that ES are a source of environmental stress. At the same time, although not showing significant differences from the values calculated using the approach of Cabral et al. (2015), which only assumes ES as an expression of environmental resilience, the results are not strong enough to state a clear similarity between these two models. The results confirm that the modified InVEST/HRA is conceptually different from the approaches of other authors, which may become an advantage, especially if one is particularly interested in its spatial component, which is weak or absent in other approaches. The modified HRA has into consideration the spatial distribution of three important habitat risk components: habitats, exposure and ecosystem services provided by the habitats.

Changing the modified HRA_ES-2 model by increasing the management effectiveness score of the stressors that most contribute for risk of seagrass and saltmarsh habitats, decreases the risk score of these habitats. This is an indication that the approach is also suitable to evaluate management scenarios and the potential impacts on ecosystem services supply. With regard to the Atlantic coastal region adjacent to the Mondego River, the case study addressed in this research, the management scenarios applied, to ensure the sustainability of saltmarsh and seagrass habitats, show that there is still room for management improvement. This study is in line with others that show that tidal marshes and the ecosystem services they provide may be at risk from sea level changes. In the future, in detail studies could evaluate the feasibility of some of the adaptation measures proposed for this case study, either testing mechanisms on site; modeling the wetland habitat response to sea-level-rise or acting based on a precautionary principle implementing regulatory or policy interventions. The results are also in line with past studies in the estuary that show that nitrogen enrichment is one of the most concerning pressures, even though the actual effect of this pressure remains difficult to assess due to the natural variability of transitional systems, and there are no current signs of eutrophication impacts. This may be an indication that, currently, communities are capable to withstand, at some level, the current concentrations of nitrogen, possibly as a result of ecosystem homeostasis, but caution must be taken, as any ecosystem changes, such as those observed in the past, may rapidly cause a change in the Ecological Status of the system.

CHAPTER V: GENERAL DISCUSSION

The results of this work will contribute to the process by which the Ecosystem Service concept is made usable by decision makers in coastal and marine systems management. This study has covered the need to gather, systematize and organize information regarding ecosystem services status, trends and gaps (Chapter I, Chapter II and Chapter III), and the application of conceptual (Chapter III) and methodological (Chapter III and Chapter IV) approaches to identify the relationships between the ecological characteristics of habitats, the pressures acting on the system, and the role of management actions and decision-making.

Information to support ecosystem service-based management approach

Spatial datasets to support the implementation of an ecosystem service approach for ecosystem-based management of coastal and marine ecosystems still need improvement. Our results confirm that the lack of spatially explicit information, especially at scales at which ecosystem processes and functions happen, and where could be managed through the effective engagement of local communities (Lavorel et al., 2017; Liquete et al., 2013; Portman, 2013), remains. Only 32% of freely available data is useful for spatial assessments (Chapter II), which hinders our capacity to overcome the fact that marine services remain the less studied around the world (Hauck et al., 2013), even though marine ecosystems deliver 43% of the biosphere services (Levrel et al., 2014).

Furthermore, the spatial data available is more suitable to map regulation services, than provisioning and cultural services (Chapter II), which may introduce a bias in the spatial assessment of ecosystem services, their status and trends, and hamper our ability to assess highly socially valued services (Daniel et al., 2012: Zoderer et al., 2016), and to identify services relevant for both people and ecosystems (Small et al., 2017). The importance of spatial information arises from its proven capacity to enhance the communication of results from scientific community to policymakers and practitioners (Drakou et al., 2015; Maes et al., 2018); to describe the heterogeneity present in a study area (Burkhard et al., 2009; Schröter and Remme, 2016); to recognize the potential of ecosystems to meet the human demand for services (Ghermandi et al., 2010); and to improve the understanding of ecosystem services across scales (Tyberghein et al., 2012).

Support to regional European policies and local decision-making can be enhanced by increasing information availability. At the European level, and as an example, our results have revealed current spatial information breaches to monitor descriptors defined in the scope of the European Marine Strategy Framework Directive (MSFD; EC, 2008), specifically the non-indigenous species (D2) and contaminants in seafood (D9) descriptors (Chapter II). At the local level, we have shown that ecosystem service research based on case studies could be optimized to simultaneously support research interests and local decision-making, by framing the information in harmonized objectives and criteria (Chapter III) (Cowling et al., 2008). Though one might think that prioritization of research based on site-specific needs might inhibit the capacity to contribute for regional studies, previous research results reveal that this is unreasonable as information can still be applied to support generalization and the understanding of trends across scales, as has happened in habitat risk assessment studies where there is a combination of information from different sources, including local knowledge (Wyatt et al., 2017; Willaert et al., 2019).

Conceptual and methodological approaches to support management actions

Conceptual frameworks help to provide structure to the real-world, highlighting important inter-linkages and possibilities for measurement and assessment. In this work, the conceptual cascade model proposed by Haines-Young and Potschin (2010) was used throughout all thesis chapters as a reference to facilitate the connections between the biophysical structures and process of ecosystems with the social demand for services. The thesis starts with the identification of proxies that measure biophysical structures able to deliver services (Chapter II); then recognizes that the natural heterogeneity of biotic and abiotic structures configures the potential of habitats to deliver services (Chapter III); and establishes a relationship between ecosystem services, stressors, management effectiveness and ecosystem resilience (Chapter IV).

The cascade model also constitutes the basis of the Common International Classification of Ecosystem Services framework CICES (Haines-Young and Potschin, 2018) that describes 42 provisioning services, 28 regulation services and 14 cultural services and which has guided our work. The use of CICES as a classification framework of ecosystem services has been recommended by the European Union (Haines-Young and Potschin 2011) and is growing in use in different studies (e.g. Depellegrin et al., 2016; La Notte et al., 2017; Czúcz et al., 2018).

But linking the conceptual work to real world conditions and situations, helping us to express and use concepts in practice, can be a daunting task (Jax et al., 2018). In this work, we have looked at the conceptual DPSIR framework (OECD, 1993), and our results revealed a need to improve the quality, quantity, spatial resolution and spatial distribution of information to monitor responses, impacts, pressures and drivers in coastal and marine ecosystems (Chapter II). From an Ecosystem Service operationalisation point of view, this lack of information hinders the capacity of decision-makers to identify ecosystem services trade-offs through the impact of shared drivers (Xue et al., 2015). The lack of information related to pressures (exposure) and impacts/responses (consequences) is particularly critical when decisions include a component of risk, as shown by the InVEST Habitat Risk Assessment model (Chapter IV).

Methodological approaches help specifying procedures and/or techniques to analyse information. In this work we present two novel methodological approaches suitable for different management contexts: a) when scientific information is scarce and there is an explicit need to prioritize ecosystem service research to support management decisions (Chapter III); b) when authorities need to know which areas should be prioritized for management considenring natural and anthropogenic pressures that could guide to ES loss (Chapter IV). Both cases suggest the prioritization based on habitats' capability to deliver multiple ecosystem services (Costanza et al., 2017; Falk et al., 2018), which helps avoiding the risk of service loss, which could happen when priorizing only one, or just a few, without understanding completely the mechanisms by which the selected services are bundled with others to keep their resilience (Bennett et al. 2009; Kandziora et al., 2013; Boulton et al., 2016).

The methodological approach to prioritize areas for research (Chapter III) presents four characteristics that, together, turns it unique: a) ecosystem service supply is the core criteria; b) ecosystem service demand is, in some cases, used as a proxy for ecosystem service supply; c) the methodology is flexible to account for other criteria, such as criteria more oriented towards future ecosystem management, for example the social demands across space; d) it is spatial explicit.

The methodological approach presented to prioritize areas for management based on habitats' risk, contributes with a novel vision on how to approach the dual and contraditory role of ecosystem services in nature (Chapter IV). The model presented assumes for one hand that habitats at risk (Rao et al., 2015; Hawkins and Popper, 2017) tend to lose structures and processes that underpin the supply of ecosystem services (Culhane et al., 2019), turning habitats more vulnerable (Willaert et al., 2019); but at the same time, that habitats with multiple services tend to be more resilient (Cabral et al., 2015). The approach is useful to embrace management that recommends to assume the precautionary principle (Kriebel et al., 2001; Ysebaert et al., 2016) to protect areas that could offer an insurance to sustainability, i.e., areas with multiple services (Rodríguez-Loinaz et al., 2015); but also to highlight the role of human activities in changing ecosystem services supply (Culhane et al., 2019).

In the literature, there is not a consensus about how to define priority areas for ecosystem management based on an ecosystem service-based approach. For example, to Wolff et al. (2017) prioritization should be based on the different social demands across space, for Willemen et al. (2017) it should be based on stakeholder preferences and for Dale et al. (2018) priorities should embrace cost efficiency, reliability of service supply, and sustainability. The prioritization methods applied in this work (Chapter III and Chapter IV) rely also on service supply and sustainability, as it is a function of ecosystem service availability and the presence of pressures affecting ecosystem services.

Operationalisation of Ecosystem Services Approach

The two facets addressed in this thesis, related to the problem of knowledge availability for implementation of the ES concept – Datasets and Support to management actions - revealed important elements that should be accounted for in the operationalisation of the ecosystem services approach (Daily et al., 2009; Chan et al.,2012). These elements include information management; establishment of priorities; analysis of social interactions; and communication and legitimization of actions.

i. Information management: flaws in the organizational cycle of information related to marine ecosystem services hampers the ability to implement the ESA. For any governance proposal, we recommend paying attention to the acquisition of information, its distribution and storage. This thesis identified needs related to spatial information and to site-specific ecosystem service indicators and highlighted the necessity to share data and scaling-up marine ecological studies, because as it is stated by Liquete et al. (2013) the absence of information in spatial contexts becomes a bottleneck in the management of coastal and marine ecosystems. In the case of this study, from the analysis of 581 open source databases with potential to map coastal and marine ES in Europe, only 33% showed a capacity to be integrated in further mapping exercises. These results stress the necessity for a deep metadata analysis of these useful databases as well as a gap geographical analysis of the available information, as is also suggested by Astiaso-Garcia et al. (2019). In addition, our findings revealed that most of the available information is linked with regulation services, followed by provisioning services, and only then with cultural services, which is aligned with results from a previous research about gaps in ES mapping performed by Lavorel et al. (2017). These results show the necessity to increase the availability of information regarding cultural services (Martin et al., 2016), as well as related information with regard to social (Liquete et al., 2013; Lopes and Videira , 2019) and management connections which may help assessing the link between the ES with social issues and political shared objectives as those ones mentioned in the MSFD (Mongruel et al., 2015).

It is also important to mention the benefits of working with information from different scales and sources, including local knowledge to support management options in coastal and marine ecosystems (Manea et al., 2019; Willaert et al., 2019) as it was performed along this thesis where spatial information used was retrieved from a wide variety of sources with different resolutions, data certainty and geographic scope. The benefits arise from the following observations: (1) global and regional spatial databases fail to provide extensive high resolution data, and it is not possible to use coarse scale data in small areas (Tempera et al., 2016; Farella et al., 2020); (2) spatial information at the national level is scarce, more even for the aquatic realms (Instituto Geográfico Português, 2010), and, when available, frequently not with free access; and (3) site-specific spatial information, necessary to perform a contextualized analysis, is also scarce and often not publicly available (e.g. the 1/10.000 cartography of Mondego Estuary subsedimentary environments presented by Cunha and Dinis, 2002). All of these reasons make a call to implement open source databases repositories to integrate information from different scales with good metadata explanations for their better use.

ii. Establishment of priorities: in face of a wide variety of choices and scarce resources, decision makers need to prioritize their action areas and activities (Rivero and Villasante, 2016; Verhagen et al., 2018). What, how and when to prioritize may depend on the decision-makers' goals and availability of information. Following an ESA point of view, this thesis unveiled methodologies to prioritize research and habitats for conservation, based on hotspots of multiservice areas. The results are novel in the way that prioritization is focused on unveiling the site-specific research needed to support local management and less on broad conceptual and/or methodological research questions, as in the majority of the published works so far (Lautenbach et al. 2019). The work presented may, for instance, help dealing with human pressure that may guide to overexploitation of a few selected services (MEA, 2005), which have resulted for example in the reduction of regulation services that do not offer apparent direct benefits to society (Bennett et al.,2009).

One of the main problems when establishing priorities concerning ES is to overcome the challenge associated to the spatial distribution of the ecosystem's heterogeneity in the study site. After reviewing some proposals to classify heterogeneity in coastal and marine ecosystems (i.e. Dethier, 1990; Costello, 2009, Allee et al., 2014), the EUNIS (European Union Nature Information System) habitats classification system (Davies et al., 2004; Populus et al., 2017) arose as a successful starting-point for describing ecosystems. EUNIS had already been successfully used in previous research (i.e. Fraschetti, 2008; Galpasoro et al., 2012; Mongruel et al., 2015) and successfully complemented with local-level information (Henriques et al. 2015) I a study at the Luiz Saldanha Marine Park in Portugal.

Though the identification of habitats and the classification of their potential to deliver ecosystem services (i.e. Burkhard et al., 2009; Salomidi et al., 2012) maybe a crucial step in ES operationalisation, the assessment of actual ES supply and demand remains and may become a dauting task if one decides to evaluate the entire variety of ES found in an area. To reduce the amount of work needed this work proposes the definition of hotspots as a method of research prioritization. Previously the concept of ES hotspots has been used to define areas that provide large proportions of selected services (Egoh et al., 2008; Depellegrin et al., 2016; Manea et al., 2019). Our proposal is addressed to multiple services areas in a study site with gaps of information and limited resources for research. Something similar was developed by Armoskaite et al. (2020) for Latvia through a gap assessment of ecosystem services to compensate the absence of information about marine areas.

iii. Analysis of socio-ecological interactions for conservation measurements: successful governance proposals based on an ESA recognize the connection between biophysical offer, social demands and the interactions between human activities and the ecosystem to get its benefits (Fisher et al., 2009; Opdam et al., 2016; Lopes and Videira, 2017). Instruments, such as the DPSIR framework (Chapter II), allow to identify the main drivers and pressures that affect the habitats and put them at risk (Chapter IV). They are key components, already included in European policies (Paavola and Primmer et al 2019), that should also be considered in governance proposals for local and regional studies. such as was described by Mukuvari et al. (2016) who applied the DPSIR framework for assessing the recovery of a degraded large marine ecosystem. Gari et al. (2015) performed an analysis of the DPSIR framework based on marine study cases, arriving to the conclusion that this could be considered a powerful tool for adaptative management, with ability to build a bridge between different social actors making visible the interactions between natural systems and social systems (Atkins et al. 2011). Nevertheless, despite its usefulness, the DPSIR framework demands a good previous knowledge of the system under study, clear objectives and consensus in the terminology used in order to improve its performance to assess policies, as for example the MSFD (Gari et al., 2015; Oesterwind et al., 2016).

Another way to implement an analysis of socio-ecological interactions for conservation measurements, allowing the participation of both researchers and communities to integrate knowledge, was performed in this thesis trough a habitat risk assessment (HRA) using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) tool (Sharp et al., 2018) (Chapter IV). Although this kind of analysis has been performed before (i.e. Arkema et al., 2014; Cabral et al., 2015; Willaert et al., 2019), we included a novel approach in the model by adding the abundance of ES as a resilience descriptor of the ecosystems, highlighting the effect of each ES class (regulation, provision and cultural) to buffer potential threats. This approach differs from previous experiences

(Cabral et al., 2015; Culhane et al., 2019; Willaert et al., 2019) which first performed a risk assessment and only then combine it with ecosystem services availability of habitats to get a risk map, without considering any differences in the ES class contribution to the total scores (Willaert et al., 2019). Results of this novel approach seems to be more in accordance with previous risk descriptions in certain areas of our study site (i.e. Ceia et al., 2013; Veríssimo et al., 2013a; Stratoudakis et al., 2020). Although there are different tools to perform a risk assessment (Hammar et al., 2020; Culhane el al., 2019) the InVEST tool is a good choice for this kind of analysis due to its characteristics such as: i) being an open source tool with a good description about how it works together with application examples (Sharp et al., 2018); ii) requiring a smaller amount of input data sustained by short- term monitoring, which facilitates its application to regions where data is limited (Singh et al., 2017; Willaert et al., 2019; iii) being relatively simple to operate, with good visual representation of results (Cong et al., 2020). Nevertheless, the tool still requires some improvements like the inclusion of temporal dynamics, which could be improved with better availability of information (Singh et al., 2017). For the particular purpose of this study, the HRA model from the InVEST tool turned out to be a successful choice because it allowed the spatial integration of the cumulative impacts with the availability of ecosystem services, supporting the identification of priority areas for conservation (Farella et al., 2020) avoiding ES loss, which is aligned with precautionary principles (Gray and Bewers, 1996), and allows us to understand better our ecosystems and the relationship between humans and the environment (Singh et al., 2017).

iv. Communication and legitimization of actions: Communication tools facilitate the interchange of information between the different stakeholders (Kerski, 2015). Communication increases the awareness of people to detect and react to ecological feedbacks and improve adaptative management of ecosystem services (Birgé et al., 2016). This is important because people are not always aware of the importance of their participation in the governance process, especially along the monitoring activities (Gonçalvez et al., 2011). In fact, governance is only possible based on the collaboration of a diverse set of stakeholders, operating at different levels, often through networks. In this work, when possible, information has been translated into understandable communication instruments such as color charts and maps, which are powerful instruments of communication and management (Kerski, 2015, Klein et al., 2015). We expected that the use of communication tools could improve the understanding of linkages between ES and human well-being and the consequent willingness to manage and conserve, because only people connected with their environment can improve ES management results (Lopes and

Videira, 2019). This suggestion is in accordance with Hutchinson et al. (2013) who developed a work to identify local stakeholder perceptions about coastal ES to create spatial representations of the number of ES provided by habitats and use this information to guide better-informed decisions regarding priority areas for conservation. Also, Burdon et al. (2019) used a participatory GIS mapping to co-produce knowledge addressed to discover community interest at the UK North Sea coast to promote the management and coastal development along this area.

We believe that the elements mentioned above have the ability to support integrated environmental management approaches with focus in the ecosystem services as connectors between the natural and social worlds, whose integration is not always simple to accomplish (Spangenberg et al., 2014), especially considering different stakeholders 'views and knowledge in decision-making processes (Primmer et al., 2015).

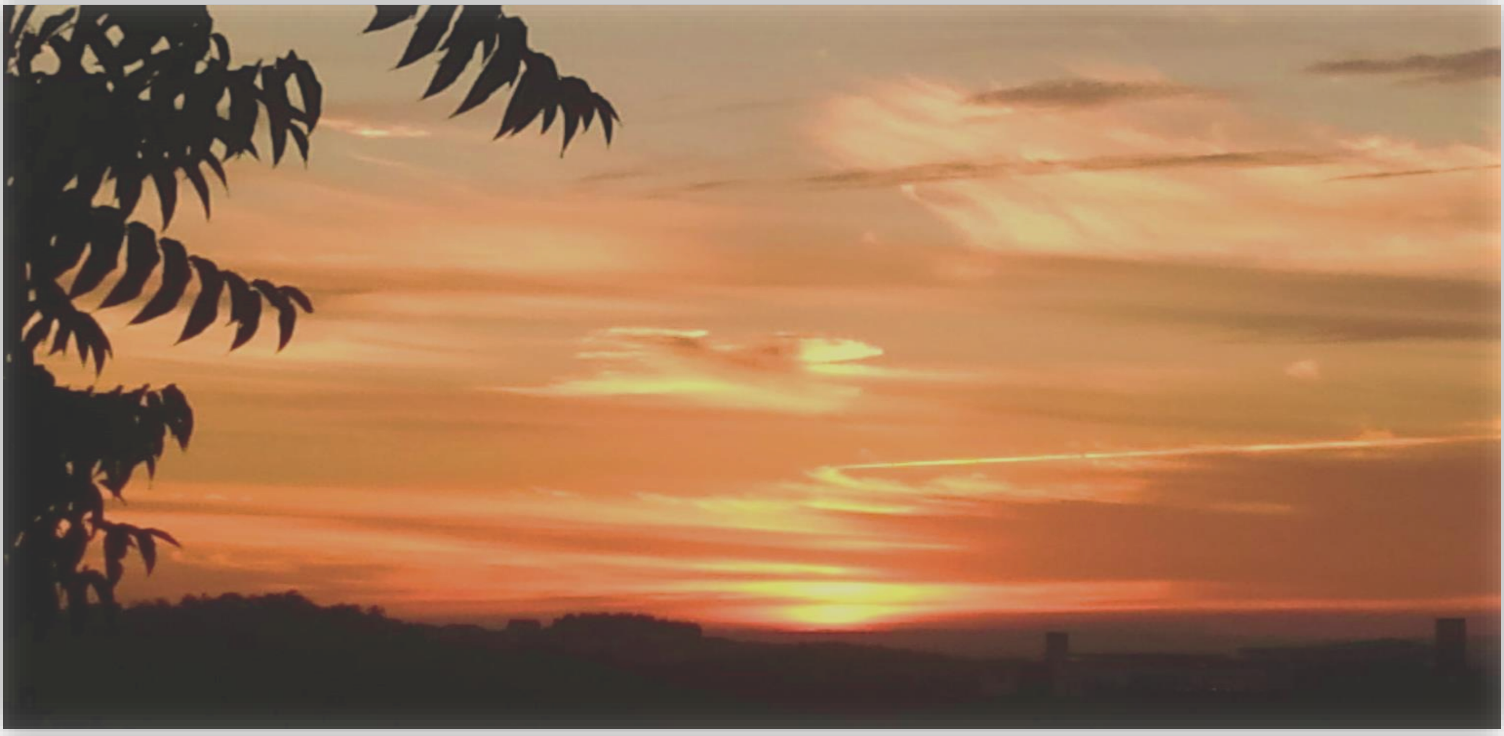
The Atlantic coastal area adjacent to the Mondego River

Despite the historical monitoring programmes and scientific projects in the study site (e.g., Ferreira et al., 2006; Couto et al., 2010; Baptista et al., 2015), our findings suggest the need to improve the availability of local biophysical information, as freely available databases at national and regional scales (e.g. EMODNET, http://www.emodnet.eu/) (Chapter II) do not always offer information at resolutions suitable for site-specific studies (Chapters III and IV). To fulfill this information gap, we consider that the solution should include the improvement of data sharing mechanisms for spatial data (de Groot et al., 2010; Gewin, 2016). The benefits of data sharing have been show in some scientific areas such as neurosciences and genomics (Milham et al., 2018; Bonàs-Guarch et al., 2018), although many researchers in biological sicences remain reluctant to share their own data. In ecology, one of the most impressive examples comes from the Long-Term Ecological Research Network (LTER, https://lternet.edu/) (Michener, 2015), from which are now arising databases supported by large networks of researchers (e.g. The Earth Microbiome Project, http://www.earthmicrobiome.org/).

To our knowledge, this thesis presents the first comprehensive mapping of coastal and marine habitats and ecosystem services in the studied area, at a resolution suitable for local decision-making. A total of 231 potential and current CICES ecosystem services, linked with 21 EUNIS habitats were identified. The number of habitats was close similar to the 28 identified by Willaert et al. (2019) in the Western-Atlantic coast of Portugal and the 26 habitats found in the Portuguese southwest coast identified by Henriques et al. (2015). Nevertheless, the number of potential ecosystem services were determined, for the first the time, to all the identified habitats without a priory selection.

From a management point of view, our work suggests that special attention should be paid to saltwork habitats, due to the abundance of ecosystem services provided by these ecosystems (Chapter III), and to seagrass habitats due to the risk to which the ecosystem services of this habitat are subjected to (effects of sea level change and Nitrogen enrichment) (Chapter IV). Our findings are in accordance with other studies, which have also highlighted the importance of saltworks in the study area (Texeira et al., 2018) and others that have recognized the value of seagrasses as providers of multiple ecosystem services (Waycott et al., 2009; Nordlund et al., 2016), whose value, unfourtunatelly, is under-scored by society, making difficult to ensure the continuty in the delivering of services provided by them (Friess et al., 2020). Likewise, the recognizement of sea leavel change (Teck et al., 2010; Almeida et al., 2016) and Nitrogen enrichment (Marques et al.;2007; Veríssimo et al.,2013b) as the main stressors in coastal and marine ecosystems has been recognized in previous studies (i.e. Singh et al., 2017; Boerema and Meire, 2017).

Our findings suggest also that cultural services, such as recreation, spiritual and aesthetic experiences, inspiration, cognitive development, symbolic representation, heritage and existence values (Haines-Young and Potschin, 2018), play a crucial role in the study area, as also was mentioned by Pinto et al. (2010) when describes an increase of recreation services in the study area, stressing the need for a better understanding of the structures and processes that support them (van Oudenhoven et al., 2018a; Lebreton et al., 2019). It is important to highlight that according to our findings, just 21% of the open source available databases are useful to map cultural ecosystem services (Chapter II), being necessary more work to enhance the knowledge of cultural ES, which are often overlooked (Garcia Rodrigues et al., 2017) and valued lower than provisioning services (Lau et al., 2019). The few exceptions are associated to recreation services which have shown a positive correlation between benefits and the implementation of conservation strategies (i.e. Baulcomb et al., 2015; Spalding et al., 2017), and the existence of iconic species and habitats in the study sites (Ruiz-Frau et al., 2013). Although cultural ES have received little attention, probably due to their intangible nature to be valued (Martin et al., 2016) it is crucial to improve their visibility and increase their importance in coastal and marine ecosystems to take advantage of their ability to create links between the ecosystems with feelings and emotional attitudes from citizens, being more appealing to drive conservation measurements (Chan et al., 2012; Queiroz et al., 2017).



FINAL REMARKS

The operationalisation of the ecosystem services concept in coastal management has guided this manuscript. Because coastal management is a complex process, due to its heterogeneity and the amount of human settlements that have preference for this space, the ecosystem services-based management approach could be seen as an opportunity to raise awareness of people about the importance of ecosystems for their life, and therefore, engage them in conservation initiatives.

The ecosystem services-based management presents some challenges, which need to be overcome in order to have satisfactory results. The main challenges could be explained in terms of limited understanding about the ecosystem properties, from which ecosystem services are derived, and the limited resources of managers and decision makers to endeavor actions related to ecosystems management. A robust ecosystem management, based on ecosystem services, could be accomplished if the governance process included the following elements i) management of information, ii) establishment of priorities, ii) evaluation of socio-economical interactions for conservation measurements and iv) communication and legitimization of actions (see Chapter V). This thesis presents examples and novel approaches that justify the importance of these elements and suggest a path to implement them in the decision making through understandable and replicable steps, especially in local scales with scarce information. It i) analysed the state of available information with potential to be used by decision makers to understand and communicate the state of ecosystem services in a spatially defined way; ii) presented a methodology to prioritize hotspots areas (habitats) to raise information about ecosystem services, based on current and potential evidence of their existence and iii) delimitated the conservation of areas based on their exposure to stressors and their potential to deliver ecosystem services.

As a final remark, it is important to mention that the concept of ecosystem services allows to congregate different social actors and interests with the necessary flexibility to facilitate the collaboration. As such, a key for future research might be focused on the creation of consensus in operative definitions and the legitimization of shared objectives in the study sites and on strengthening the communication about ecosystem services from scientists to practitioners. This would allow to improve not only the flow of information from ecosystems to society, but also the effective inclusion of social measurements to improve ecosystems conditions.

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APPENDIX

Appendix A

Applicable databases analysis

Table A.1 Applicable databases analysis

Cod	DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8	DB9	DB10	DB11
Title	Bathymetry	Bio-Oracle									
Link	http://www.gebco.net/data_and_products/gridded_bathymetry_data/gebco_30_second_grid/	http://www.bio-oracle.org/									
Layers	Bathymetry	Calcite	Chlorophyll a	Cloud cover	Diffuse attenuation coefficient	Dissolved Oxygen	Iron	Nitrate	pH	Phosphate	Photosynthetically Active Radiation
Geographic name	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global
Format	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster
Category	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Big variable group	Water geophysics	Water quality indicator	Water quality indicator	Climate	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Climate
Units (quality/quantitative)	m	mol/m3	mg/m3	Percentage of cover	m	mol/m3	umol/m3	mol/m3	Value	mol/m3	einstein/m²/day
Year	2014	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100
Frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
Spatial resolution	1 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 kM	10 Km
Biogenic habitat	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Vertical stratum	Surface and deep waters	Seabed	Surface and deep waters	Non- applicable	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface water
Coordinate system	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined
Information source	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
Data gather	Satellites	In situ monitoring/Modelled	Satellites	Satellites	Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites
Data conversion	Yes	No	No	No	No	No	No	No	No	No	No
Data access	By required	By required	By required	By required	By required	By required	By required	By required	By required	By required	By required
Type of spatial analysis	Descriptive	Descriptive and predictive	Descriptive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive
Metadata explanation in understandable way	Regular	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
ES-PROVISION	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No
ES-REGULATION	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ES-CULTURAL	No	No	No	No	Yes	No	No	No	No	No	No
DPSIR	S	S	S	S	S	S	S	S	S	S	S
GES - MSFD	D7	D3	D5	D7	D5	D5	D8	D5	D5	D5	D5

DB23	DB22	DB21	DB20	DB19	DB18	DB17	DB16	DB15	DB14	DB13	DB12
Coral Reef Watch Satellite Monitoring		ChloroGIN Europe									
https://coralreefwatch.noaa.gov/satellite/hdf/index.php		http://ocean.ices.dk/Helcom/Helcom.aspx?Mode=1									
Temperature: Sea Surface	Bleaching HotSpot	Salinity	pH	Sea ice concentration	Ice thickness	Currents velocity	Temperature: Sea Surface	Silicate	Salinity	Primary Productivity	Phytoplankton
European seas	European seas	Baltic sea	Baltic sea	Global	Global	Global	European seas	Global	Global	Global	Global
Raster	Raster	CVS	CVS	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster
Environment	Biodiversity	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Water quality indicator	Species distribution	Water quality indicator	Water quality indicator	Water geophysics	Water geophysics	Water geophysics	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator
C	Presence/absence	psu	value	Qualitative class	Cm	m/s	C	umol/m3	psu	gr/m3/day	umol/m3
2013-2018	2013-2018	1990-2016	1990-2016	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100	2012 and 2100
Biweekly	Biweekly	Yearly	Yearly	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
5 Km	5 Km	Dots	Dots	10 Km	10 Km	10 Km	10 Km	10 km	10 Km	10 Km	10 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface water	Surface and deep waters	Surface water	Surface water	Surface water	Surface water	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined
Government/Public authorities/International agency	Government/Public authorities/International agency	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites	Satellites	Satellites	Satellites	In situ monitoring/Model	In situ monitoring/Model	Satellites	Satellites
Yes	Yes	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	By required	By required	By required	By required	By required	By required	By required	By required
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive	Descriptive and predictive
Good	Good	Regular	Regular	Good	Good	Good	Good	Good	Good	Good	Good
Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yes	Yes	No	No	No	No	Yes	Yes	No	No	No	No
S	I	S	S	S	S	S	S	S	S	S	S
D7	D1	D7	D5	D7	D7	D7	D7	D5	D7	D5	D5

DB32	DB31	DB30	DB29	DB28	DB27	DB26	DB25	DB24
EMODnet Human activities	EMODnet Biology	EMODNET Bathymetry	EMIS Europe				Dissolved oxygen	dbSEABED: Information Integration System for Marine Substrates
http://www.emodnet-humanactivities.eu/view-data.php	http://www.emodnet-biology.eu/portal/index.php	http://portal.emodnet-bathymetry.eu/?menu=19	http://emis.jrc.ec.europa.eu/index_fullscreen.php?xml_selection=2km&variable_selection=12&time_selection=YY&month_selection=09&year_selection=2011&extent_selection=-23.42%2020.14%2039.86%2068.82				https://data.giss.nasa.gov/o18data/grid.html	http://instaar.colorado.edu/~jenkinsc/dbseabed/kml/
Aquaculture	Species distribution	Bathymetry	Temperature: Sea Surface	Surface productive layer	Photosynthetically Active Radiation	Chlorophyll a	Dissolved Oxygen	Texture of seabed
European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	Global
Shapefile	Shapefile	Raster	Raster	Raster	Raster	Raster	Raster	Klm
Economic	Biodiversity	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Fisheries	Species distribution	Water geophysics	Water quality indicator	Water quality indicator	Climate	Water quality indicator	Water quality indicator	Water geophysics
Presence/absence	Presence/absence	m	C	m	einstein/m²/d	mg/m3	mol/m3	qualitative class
2018	2017	2014	2000-2012	2002-2018	2002-2018	2002-2015	2006	2018
Non-frequency	Non-frequency	Non-frequency	Monthly	Monthly	Monthly	Monthly	Non-frequency	Non-frequency
1 Km	1 Km	230 m	2 km	2 km	2 km	2 Km	1 Km	10 km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface water	Surface water	Surface and deep waters	Surface and deep waters	Seabed
WGS84	WGS84	WGS84	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	WGS84
Academic	Academic	Academic	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	Yes	Yes	Yes	Yes	Yes	No	No
Direct	By required	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Regular	Regular	Regular	Regular	Regular	Regular
Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No	Yes	No	Yes	No	No	No	No	Yes
P	S	S	S	S	S	S	S	S
D3	D1	D7	D7	D5	D5	D5	D5	D6

DB44	DB43	DB42	DB41	DB40	DB39	DB38	DB37	DB36	DB35	DB34	DB33
EMODNET SEA habitats											
http://www.emodnet-seabedhabitats.eu/default.aspx?page=1953											
Broad-scale habitat map	Sediment extraction	Wind Farms	Waste Disposal	Management areas designation	Ocean Energy Facilities	Main Ports	Hydrocarbon Extraction	First sales of fish	Dredging	Cultural Heritage Zones	Bathing water
European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas
Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile
Environment	Environment	Economic	Environment	Administrative	Economic	Economic	Economic	Economic	Environment	Administrative	Environment
Habitat	Water quality indicator	Energy -economic	Water quality indicator	Protected area limits	Energy -economic	Ports and transport	Raw materials extraction	Fisheries	Water quality indicator	Protected area limits	Water quality indicator
Km2	Qualitative class	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Tons	Presence/absence	Presence/absence	Qualitative class
2016	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	Dots	Dots	1 Km	1 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No
Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	No	No
No	Yes	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
S	P	P	P	R	P	P	P	D	P	R	S
D1	D6	D11	D10	D1	D11	D11	D8	D3	D6	D1	D8

DB52	DB51	DB50	DB49	DB48	DB47	DB46	DB45
FAO	European Environmental Agency						
http://www.fao.org/geonetwork/srv/en/main.home?uuid=ac02a460-da52-11dc-9d70-0017f293bd28	http://ftp.eea.europa.eu/www/msfd/2017/rev1/MarineRegions_shapefile.zip	https://www.eea.europa.eu/data-and-maps/data/sediment-discharges	https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions-1	https://www.eea.europa.eu/data-and-maps/data/geomorphology-geology-erosion-trends-and-coastal-defence-works	https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-corine	https://www.eea.europa.eu/data-and-maps/data/shoreline	https://www.eea.europa.eu/data-and-maps/data/eea-coastline-for-analysis-1
FAO Fishing areas	Marine regions	Sediments discharge from European Rivers	Marine regions and subregions under MSFD	Morpho-sedimentological and geological patterns	Corine land cover	Eurosion Shoreline	Coastline
Global	Global	European seas	European seas	European seas	European seas	European seas	European seas
Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile
Administrative	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Administrative areas	Habitat	Water quality indicator	Habitat	Water geophysics	Habitat	Water geophysics	Water geophysics
Presence/absence	Qualitative class	Presence/absence	Presence/absence	Qualitative class	km2	Presence/absence	Km
2014	2017	2016	2017	2016	1990-2012	2016	2015
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Yearly	Non-frequency	Non-frequency
By country	1 Km	Dots	1 Km	1 Km	10 km	Dots	1 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface water	Surface and deep waters	Surface water	Surface and deep waters	Surface water	Surface water	Surface water	Surface water
WGS84	WGS84	ETRS89	ETRS89	ETRS89	EPSG:3035	ETRS89	ETRS89
Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	satellites	satellites	Satellites	satellites
No	No	No	No	No	No	No	No
Direct	Direct	Direct	By required	By required	By required	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good
Yes	Non- applicable	No	Non- applicable	No	Yes	No	No
No	Non- applicable	Yes	Non- applicable	Yes	Yes	Yes	Yes
No	Non- applicable	Yes	Non- applicable	Yes	No	No	No
D	D	P	D	S	S	S	S
D3	D1	D6	D1	D6	D1	D7	D7

DB64	DB63	DB62	DB61	DB60	DB59	DB58	DB57	DB56	DB55	DB54	DB53
Global Marine Environmental Datasets											
http://gmed.auckland.ac.nz/download.html											
Phosphate	pH	Nitrate	Dissolved Oxygen	Diffuse attenuation coefficient	Chlorophyll a	Calcite	Land distance	Ice cover	Currents velocity	Bathymetry	Wave height
European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas
Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster
Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water geophysics	Water geophysics	Water geophysics	Water geophysics	Water geophysics
mol/m3	Value	umol/m3	mol/m3	m	mg/m3	mol/m3	Km	Percentage of cover	m/s	m	m
2014	2014	2014	2014	2014	2014	2014	2014	2014	2014	2014	2014
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface water	Surface water	Surface water	Surface and deep waters	Surface water
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites	Satellites	In situ monitoring/Modelled	Satellites	Satellites	Satellites	Satellites	Satellites
No	No	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No	No	No	No	Yes	No	No	Yes	No	Yes	No	Yes
S	S	S	S	S	S	S	S	S	S	S	S
D5	D5	D5	D5	D5	D5	D3	D7	D7	D7	D7	D7

DB76	DB75	DB74	DB73	DB72	DB71	DB70	DB69	DB68	DB67	DB66	DB65
HELCOM Map and Data Service	Global Seafloor Geomorphic Features Map										
http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/f18672ef-8040-471d-be81-0998140e3862	http://geonode.grida.no/search/?q=Seafloor+										
Coastal fish key functional groups - cyprinids mesopredators	Geomorphology	Tide average	Slope	Wind	Utilized oxyen	Temperature: Sea Surface	Silicate	Saturated oxygen	Salinity	Primary Productivity	Photosynthetically Active Radiation
Baltic sea	Global	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas
Shapefile	Shapefile	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster
Biodiversity	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Species distribution	Water geophysics	Water geophysics	Water geophysics	Climate	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Climate
Presence/absence	Qualitative class	m	grades	m/s	mol/m3	C	umol/m3	mol/m3	psu	mg/m2/day/cell	einstein/m²/day
2011-2015 (mean)	2014	2014	2014	2014	2014	2014	2014	2014	2014	2014	2014
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
1 Km	1 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	10 Km	5 Km	10 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Non- applicable	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water
WGS84	Non-determined	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Government/Public authorities/International agency	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
In situ monitoring/Modelled	satellites	Satellites	Satellites	Satellites	In situ monitoring/Modelled	Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites	Satellites
No	No	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No	No
S	S	S	S	S	S	S	S	S	S	S	S
D4	D6	D7	D6	D7	D5	D7	D5	D5	D7	D5	D5

DB84	DB83	DB82	DB81	DB80	DB79	DB78	DB77
http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/63f2c36d-b67e-411e-b075-b4f0a65d0ead	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/4e60c259-2965-43fa-8439-8773a743c0ac	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/d27df8c0-de86-4d13-a06d-35a8f50b16fa	http://maps.helcom.fi/website/mapservice/?datasetID=f18672ef-8040-471d-be81-0998140e3862	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/7ce6abce-583f-425e-9ae8-d1d6171e5198	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/cc48a577-4dc6-40bc-aeed-783b48a29adf	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/b018a687-4915-4e25-92a6-f799061c94ad	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0e1714fb-f863-4908-b3e1-57226e3ed25e
Integrated biodiversity status assessment - fish	Integrated biodiversity status assessment - benthic habitats	Helcom areas	Harzard substances	Integrated eutrophication status assessment 2017	Charophyte distribution	Baltic Sea Impact and Pressure Index	Coastal fish key functional groups – piscivores data point
Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea
Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile
Biodiversity	Biodiversity	Administrative	Environment	Environment	Biodiversity	Environment	Biodiversity
Species index	Species index	Administrative areas	Water quality indicator	Water quality indicator	Species distribution	Water quality indicator	Species distribution
Qualitative class	Qualitative class	Presence/absence	Qualitative class	Value	Presence/absence	Value	Presence/absence
2017	2017	2018	2017	2017	2017	2011-2015 (mean)	2011-2015 (mean)
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good
Yes	Yes	Non- applicable	Yes	Yes	Yes	Yes	No
Yes	Yes	Non- applicable	Yes	Yes	Yes	Yes	Yes
No	No	Non- applicable	Yes	Yes	No	Yes	Yes
S	S	D	P	I	S	P	S
D1	D1	D7	D8	D5	D1	D8	D4

DB95	DB94	DB93	DB92	DB91	DB90	DB89	DB88	DB87	DB86	DB85
ICES				Hellenic Center for Marine Research						
http://ocean.ices.dk/helcom/Helcom.aspx?Mode=1	http://ocean.ices.dk/helcom/Helcom.aspx?Mode=1	http://ocean.ices.dk/helcom/Helcom.aspx?Mode=1	http://ecosystemdata.ices.dk/Map/index.aspx?Action=AddLayer&DataSet=663&Param=138949&LatN=&LatS=&LonE=&LonW=&Sdate=&Ed	http://arch.her.hcmr.gr/downl.htm			http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/75f43d41-11cc-4506-ab11-dea2c9cfe347	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/59db825b-d311-4a33-ba36-bcb8fb8865b0	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/4be124be-79c2-42d6-8828-db957ad6f7b5	http://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/a83abaf0-651e-4668-bc4a-ac22adb065d6
Chlorophyll a	Ammonium	Alkalinity	Biological community	Temperature: Sea Surface	Catch on Illex coindetii	Bathymetry	Oil Spills	Overall ecosystem health status coastal area	Integrated biodiversity status assessment - seal	Integrated biodiversity status assessment - pelagic habitats
Baltic sea	Baltic sea	Baltic sea	European seas	Mediterranean	Mediterranean	Mediterranean	Baltic sea	Baltic sea	Baltic sea	Baltic sea
CVS	CVS	CVS	Shapefile	Raster	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile
Environment	Environment	Environment	Biodiversity	Environment	Economic	Environment	Environment	Environment	Biodiversity	Biodiversity
Water quality indicator	Water quality indicator	Water quality indicator	Species abundance	Water quality indicator	Fisheries	Water geophysics	Water quality indicator	Habitat	Species index	Species index
mg/m3	µmol/l	meq/l	Percentage of cover	C	Number	m	tons	Qualitative class	Qualitative class	Qualitative class
1990-2018	1990-2018	1990-2018	2007-2016	1999	1990 and 1999	1997	2008-2009	2011-2015 (mean)	2017	2017
Yearly	Yearly	Yearly	Yearly	Monthly	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	1.6 Km	Non-clearly determined	Dots	1 Km	1 Km	1 Km	1 Km
Non-determined	Non-determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
Non-determined	Non-determined	Non-determined	Non-determined	WGS84	Non-determined	WGS84	WGS84	WGS84	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency
satellites	satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	Satellites	In situ monitoring/Modelled	satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	Yes	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Regular	Regular	Regular	Regular	Regular	Regular	Regular	Good	Good	Good	Good
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
No	No	No	Yes	Yes	No	No	Yes	No	Yes	No
S	S	S	S	S	P	S	P	S	S	S
D5	D5	D5	D1	D7	D3	D7	D8	D1	D1	D1

DB107	DB106	DB105	DB104	DB103	DB102	DB101	DB100	DB99	DB98	DB97	DB96
http://ocean.ices.dk/helcom/Helcom.aspx?Mode=1				http://gis.ices.dk/sf/	http://ocean.ices.dk/helcom/Helcom.aspx?Mode=1	http://gis.ices.dk/sf/	http://gis.ices.dk/sf/	http://ecosystemdata.ices.dk/Map/index.aspx?Action=AddLayer&DataSet=657&LatN=&LatS=&LonE=&LonW=&Sdate=&Edate=	http://ecosystemdata.ices.dk/Map/index.aspx?Action=AddLayer&DataSet=657&LatN=&LatS=&LonE=&LonW=&Sdate=&Edate=	http://ecosystemdata.ices.dk/Map/index.aspx?Action=AddLayer&DataSet=138933&LatN=&LatS=&LonE=&LonW=&Sdate	http://ocean.ices.dk/helcom/Helcom.aspx?Mode=1
Temperature: Sea Surface	Silicate	Salinity	Phosphate	ICES Subregions	Nitrate	ICES Ecoregions	ICES Areas	Fish Trawl survey	Fish predation	Eggs and larvae	Dissolved Oxygen
Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	Baltic sea	European seas	European seas	European seas	Baltic sea
CVS	CVS	CVS	CVS	Shapefile	CVS	Shapefile	Shapefile	CVS	CVS	CVS	CVS
Environment	Environment	Environment	Environment	Administrative	Environment	Administrative	Administrative	Economic	Biodiversity	Biodiversity	Environment
Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Administrative areas	Water quality indicator	Administrative areas	Administrative areas	Fisheries	Species abundance	Species abundance	Water quality indicator
C	μmol/l	psu	μmol/l	Presence/absence	μmol/l	Presence/absence	Presence/absence	Number	Number	Number	ml/l
1990-2018	1990-2018	1990-2018	1990-2018	2018	1990-2016	2018	2018	1965-2017	1980-1991	1962-2015	1990-2018
Yearly	Yearly	Yearly	Yearly	Non-frequency	Yearly	Non-frequency	Non-frequency	Yearly	Yearly	Yearly	Yearly
Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined	Non-clearly determined
Non-determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Yes	Yes	Yes	Yes	Non- applicable	Yes	Non- applicable	Non- applicable	Yes	No	Yes	Yes
Yes	Yes	Yes	Yes	Non- applicable	Yes	Non- applicable	Non- applicable	No	Yes	Yes	Yes
Yes	No	No	No	Non- applicable	No	Non- applicable	Non- applicable	No	No	No	No
S	S	S	S	D	S	D	D	P	S	S	S
D7	D5	D7	D5	D7	D5	D7	D7	D3	D4	D4	D5

DB116	DB115	DB114	DB113	DB112	DB111	DB110	DB109	DB108
Marine Regions				Marine Geoscience Data System	Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas	MAIA WEB GIS Find out more about the Atlantic Arc MPA network		
http://www.marineregions.org/downloads.php				http://www.marine-geo.org/tools/kmls.php	https://www.worldwildlife.org/publications/marine-ecoregions-of-the-world-a-bioregionalization-of-coastal-and-shelf-areas	http://carto.maia-network.org/1/maia.map		
IOS Zooplankton regions	Marine Heritage Zones	IOH seas	EEZ	Ship tracks	Marine regions	Marine protected areas	Total Phosphorus	Total Nitrogen
Global	Global	Global	Global	Global	Global	North Atlantic	Baltic sea	Baltic sea
Klm	Shapefile	Shapefile	Shapefile	Klm	Shapefile	Shapefile	CVS	CVS
Environment	Administrative	Administrative	Administrative	Economic	Environment	Administrative	Environment	Environment
Habitat	Protected area limits	Administrative areas	Administrative areas	Ports and transport	Habitat	Protected area limits	Water quality indicator	Water quality indicator
Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	µmol/l	µmol/l
2016	2013	2017	2016	2009	2007	2010	1990-2018	1990-2018
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Yearly	Yearly
1 Km	1 Km	1 Km	1 Km	Non-clearly determined	1 Km	Dots	Non-clearly determined	Non-clearly determined
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
Non-determined	WGS84	WGS84	WGS84	Non-determined	WGS84	WGS84	Non-determined	Non-determined
Academic	Academic	Academic	Academic	Citizen/NGO	Citizen/NGO	Academic	Academic	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No	No
By required	By required	By required	By required	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Bad	Regular	Bad	Regular	Regular
Yes	No	Non- applicable	Non- applicable	Yes	Non- applicable	No	Yes	Yes
Yes	Yes	Non- applicable	Non- applicable	No	Non- applicable	Yes	Yes	Yes
No	Yes	Non- applicable	Non- applicable	Yes	Non- applicable	Yes	No	No
S	R	D	D	P	D	R	S	S
D1	D1	D7	D7	D11	D1	D1	D5	D5

DB127	DB126	DB125	DB124	DB123	DB122	DB121	DB120	DB119	DB118	DB117
NCEAS: National Center for Ecological Analysis y Synthesis				Fishing effort	Natural Earth	Natural Earth	NASA			
https://knb.ecoinformatics.org/#view/doi:10.5063/F1S180FS				https://data.jrc.ec.europa.eu/dataset/jrc-fad-ais1415	http://www.naturalearthdata.com/downloads/10m-physical-vectors/	http://www.naturalearthdata.com/downloads/10m-physical-vectors/	https://opendap.jpl.nasa.gov/opendap/	https://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am		
Ocean pollution	Ocean acidification	Invasive especies	Demersal destructive fishing	Fisheries	Coastline	Bathymetry	Temperature: Ocean	Chlorophyll a	World 12 and 24 Nautical Miles Zone	Marine and Land Zones
Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global
Raster	Raster	Raster	Raster	Raster	Shapefile	Shapefile	Raster	Raster	Shapefile	Shapefile
Environment	Environment	Biodiversity	Economic	Economic	Environment	Environment	Environment	Environment	Administrative	Environment
Water quality indicator	Water quality indicator	species distribution	Fisheries	Fisheries	Water geophysics	Water geophysics	Water quality indicator	Water quality indicator	Administrative areas	Habitat
qualitative class	Presence/absence	Presence/absence	qualitative class	Tons	Km	m	C	ug/l	Presence/absence	Presence/absence
2008 and 2013	2008 and 2013	2008 and 2013	2008 and 2013	2014-2015	2009	2009	2011-2016	2002-2018	2016	2014
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Daily	Daily	Non-frequency	Non-frequency
1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	Non-determined	Non-determined	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Government/Public authorities/International agency	Government/Public authorities/International agency	Academic	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	satellites	satellites	Satellites	satellites	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	By required	Direct	Direct	By required	By required
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Regular	Regular	Regular	Regular	Good	Regular	Regular	Regular	Regular	Good	Good
Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Non- applicable	Non- applicable
Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Non- applicable	Non- applicable
Yes	No	Yes	No	No	No	No	Yes	No	Non- applicable	Non- applicable
P	S	P	P	P	S	S	S	S	D	D
D8	D5	D2	D3	D3	D7	D7	D7	D5	D7	D7

DB137	DB136	DB135	DB134	DB133	DB132	DB131	DB130	DB129	DB128
Ocean Data Viewer									
http://data.unep-wcmc.org/									
Global distribution of Atlantic spotted dolphinis	Dive centers	Cold water coral reef	Chlorophyll a	Estuary Database	Radiation UV	Shipping	Population in coast	Pelagic fishing	Oil rigs
Global	Global	Global	Global	Global	Global	Global	Global	Global	Global
Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Raster	Raster	Raster	Raster	Raster
Biodiversity	Economic	Biodiversity	Environment	Environment	Environment	Economic	Social	Economic	Environment
Species distribution	Tourism	Species distribution	Water quality indicator	Habitat	Climate	Ports and transport	Human pressure - indicator	Fisheries	Water quality indicator
Presence/absence	Presence/absence	Presence/absence	mg/m3	Presence/absence	mJ/cm2	Presence/absence	Number	Tons	Presence/absence
2013	2015	2018	2009-2013 (mean)	2003	2008 and 2013	2008 and 2013	2008 and 2013	2008 and 2013	2008 and 2013
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
50 km	Dots	Dots	5 Km	1 Km	1 Km	1 Km	1 Km	1 Km	1 Km
Non- determined	Non- determined	Reef	Non- determined	Non- determined	Non-determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Non-applicable	Surface and deep waters	Non- applicable	Surface and deep waters	Surface and deep waters
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Academic	Academic	Academic	Academic	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	satellites	In situ monitoring/Modelled	Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Regular	Regular	Regular	Regular	Regular
No	No	No	Yes	Yes	No	Yes	No	Yes	Yes
Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes
S	P	S	S	S	S	P	D	P	P
D4	D10	D1	D5	D1	D1	D11	D10	D3	D11

DB145	DB144	DB143	DB142	DB141	DB140	DB139	DB138
Shannon Index	Seagrasses	Saltmarshes	Protected areas	Global distribution of mangroves	Hulbert Biodiversty Index	Grey seals	Marine Ecorregions
Global	Global	Global	Global	Global	Global	Global	Global
Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile	Shapefile
Biodiversity	Biodiversity	Biodiversity	Administrative	Biodiversity	Biodiversity	Biodiversity	Environment
Species index	Species distribution	Species distribution	Protected area limits	Species abundance	Species index	Species distribution	Habitat
Value	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Value	Presence/absence	Presence/absence
2014	2017	2017	2016	2015	2014	2013	2015
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
110 Km	1 Km	10 Km	Dots	1 Km	110 Km	50 km	1 Km
Non- determined	Seagrass	Saltmarsh	Non- determined	Mangrove	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good
Yes	Yes	Yes	No	Yes	Yes	No	Non- applicable
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Non- applicable
Yes	No	Yes	Yes	Yes	Yes	Yes	Non- applicable
S	S	S	R	S	S	S	D
D1	D1	D1	D1	D1	D1	D4	D1

DB155	DB154	DB153	DB152	DB151	DB150	DB149	DB148	DB147	DB146
OSPAR comission									
https://odims.ospar.org/layers/?limit=100&offset=0									
Inventory of Offshore Installations	Environmental Radioactive substances -	Environmental radioactive substances - biota	Bottom Fishing Intensity - Surface	Marine Litter Beach Monitoring Areas	Fishing for Litter	Bottom Fishing Intensity - Subsurface	Whales	Global distribution of sea turtles nesting sites	Temperature: Sea Surface
European seas	European seas	European seas	European seas	European seas	European seas	European seas	Global	Global	Global
Klm	Shapefile	Shapefile	Shapefile	Shapefile	Klm	Shapefile	Shapefile	Shapefile	Shapefile
Economic	Environment	Environment	Economic	Environment	Environment	Economic	Biodiversity	Biodiversity	Environment
Energy -economic	Water quality indicator	Water quality indicator	Fisheries	Water quality indicator	Water quality indicator	Fisheries	Species distribution	Species distribution	Water quality indicator
qualitative class	Presence/absence	Presence/absence	value	Presence/absence	Kg.	value	Presence/absence	Presence/absence	C
2001-2015	1995-2013	1995-2013	2009-2015	2017	2016	2009-2015	2013	2015	2009 -2013 (mean)
Yearly	Yearly	Yearly	Yearly	Non-frequency	Non-frequency	Yearly	Non-frequency	Non-frequency	Non-frequency
Dots	Dots	Dots	Dots	Dots	Dots	Dots	50 Km	1 Km	1 Km
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface water
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Government/Public authorities/International agency	Government/Public authorities/International agency	Government/Public authorities/International agency
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	satellites
No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Regular	Regular	Regular	Regular	Regular	Regular	Regular	Good	Good	Good
Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes
No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
P	P	I	P	P	I	P	S	S	S
D11	D8	D9	D3	D10	D10	D3	D4	D1	D7

DB166	DB165	DB164	DB163	DB162	DB161	DB160	DB159	DB158	DB157	DB156
Status and Trends for Heavy Metals in Fish and Shellfish	Seabed Litter - total counts of plastic items caught per	Seabed Litter - total counts of litter items caught per trawl	Relative number of litter items per square km	Plastic Particles in Fulmar Stomachs	Region Boundary	Marine protected areas	Marine Contaminants - Water	Marine Contaminants - Sediment	Marine Contaminants - Biota	Offshore Renewable Energy Developments
European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas	European seas
Klm	Klm	Klm	Klm	Shapefile	Shapefile	Shapefile	Klm	Klm	Klm	Shapefile
Environment	Environment	Environment	Environment	Environment	Administrative	Administrative	Environment	Environment	Environment	Economic
Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Water quality indicator	Administrative areas	Protected area limits	Water quality indicator	Water quality indicator	Water quality indicator	Energy -economic
qualitative class	Number	Number	Number	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence	Presence/absence
2015	2015	2015	2017	2000-2013	2018	2016	2011-2015	2011-2015	2011-2015	2009-2015
Non-frequency	Non-frequency	Non-frequency	Non-frequency	Yearly	Non-frequency	Non-frequency	Yearly	Yearly	Yearly	Yearly
Dots	Dots	Dots	Dots	Dots	Dots	Dots	Dots	Dots	Dots	Dots
Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined	Non- determined
Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters	Surface and deep waters
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled	In situ monitoring/Modelled
No	No	No	No	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Yes	Yes	Yes	Yes	Yes	Non- applicable	No	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	Yes	Non- applicable	Yes	Yes	Yes	Yes	No
No	No	No	Yes	Yes	Non- applicable	Yes	Yes	Yes	Yes	No
I	P	P	P	I	D	R	P	P	I	P
D9	D10	D10	D10	D10	D7	D1	D8	D6	D9	D11

DB180	DB179	DB178	DB177	DB176	DB175	DB174	DB173	DB172	DB171	DB170	DB169	DB168	DB167
Copernicus: Marine Environment Monitoring Service					Copernicus	USGS	Worldclim					World Port Index	World Database on Protected Areas
http://marine.copernicus.eu/services-portfolio/access-to-products/					https://land.copernicus.eu/	https://earthexplorer.usgs.gov/	http://worldclim.org/version2					http://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0015	https://protectedplanet.net/
Chlorophyll a	Ocean Waves Analysis	Radiation UV	Biogeochemical: Oxygen, Nitrate,	Temperature: Bottom	Land cover	Land cover	Wind	Water vapor pressure	Temperature of air	Solar radiation	Precipitation	World ports	Marine protected areas
Global	Global	Global	Global	Global	European seas	Global	Global	Global	Global	Global	Global	Global	Global
Raster	Raster	Raster	Raster	Raster	Shapefile	Raster	Raster	Raster	Raster	Raster	Raster	Shapefile	Shapefile
Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Economic	Administrative
Water quality indicator	Water geophysics	Climate	Water quality indicator	Water quality indicator	Habitat	Habitat	Climate	Climate	Climate	Climate	Climate	Ports and transport	Protected area limits
mg/m3	m	mJ/cm2	Qualitative class	C	km2	km2	m/s	Kpa	C	kJ/ m2/day	mm	Value	Presence/absence
2012- 2018	2016 - 2018	2016- 2018	2012 - 2018	2016 - 2018	2012	2013	1970-2000	1970-2000	1970-2000	1970-2000	1970-2000	2018	2015
Weekly	Daily	Daily	Weekly	Daily	Non-frequency	Biweekly	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency	Non-frequency
111 Km	11 Km	9 Km	111 Km	111 Km	2.5 m	30 m	1 Km	1 Km	1 Km	1 Km	1 Km	Dots	1 Km
Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non- determined	Non- determined
Surface and deep waters	Surface water	Non-applicable	Surface and deep waters	Seabed	Surface water	Surface water	Non-applicable	Non-applicable	Non-applicable	Non-applicable	Non-applicable	Non- applicable	Surface water
ETRS89	WGS84	WGS84	ETRS89	WGS84	ETRS89	WGS84	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Government/Public authorities/International agency	Government/Public authorities/International agency
satellites	satellites	satellites	satellites	satellites	satellites	satellites	Satellites	Satellites	Satellites	Satellites	Satellites	In situ monitoring/Modelled	In situ monitoring/Modelled
Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No	No
Direct	Direct	Direct	Direct	Direct	Direct	By required	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	descriptive	descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Bad	Bad	Bad	Bad	Bad	Regular	Regular
Yes	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	No
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
No	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes
S	S	S	S	S	S	S	S	S	S	S	S	P	R
D5	D7	D1	D5	D7	D1	D1	D7	D7	D7	D7	D7	D11	D1

DB193	DB192	DB191	DB190	DB189	DB188	DB187	DB186	DB185	DB184	DB183	DB182	DB181
Planet	ESA Copernicus: Sentinel Datasets											
https://www.planet.com/	https://scihub.copernicus.eu/dhus/#/home											
Land cover	Land cover	Significant wave heigth	Temperature: Sea Surface	Algal pigment concentration	Ocean Depth	Sea surface height	Wave spectra	Ocean Wind	Temperature: Sea Surface	Sea surface height	Wave height	Wind
Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global
Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster	Raster
Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment	Environment
Habitat	Habitat	Water geophysics	Water quality indicator	Water quality indicator	Water geophysics	Water geophysics	Water geophysics	Climate	Water quality indicator	Water geophysics	Water geophysics	Climate
m	m	m	K	mg/m3	m	m	m	m	K	m	m	m/s
2009-2018	2014 - 2018	2014 - 2018	2014 - 2018	2014 - 2018	2014 - 2018	2014 - 2018	2014 - 2018	2014 - 2018	2014 - 2018	2017- 2018	2017- 2018	2015 - 2018
Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
3m	10 m	300 m	500 m	300 m	300 m	1 Km	300 m	500 m	9 Km	111 Km	7 km	25 km
Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined	Non-determined
Surface water	Surface water	Surface water	Surface water	Surface and deep waters	Surface and deep waters	Surface water	Surface water	Non-applicable	Surface water	Surface water	Surface water	Non-applicable
WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	WGS84	ETRS89	WGS84	WGS84
Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic	Academic
satellites	satellites	satellites	satellites	satellites	satellites	satellites	satellites	satellites	satellites	satellites	satellites	satellites
No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
By required	By required	By required	By required	By required	By required	By required	By required	By required	Direct	Direct	Direct	Direct
Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive	Descriptive
Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Yes	Yes	No	Yes	yes	Yes	Yes	No	No	Yes	Yes	No	No
Yes	Yes	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	No
S	S	S	S	S	S	S	S	S	S	S	S	S
D1	D1	D7	D7	D5	D7	D7	D7	D7	D7	D7	D7	D7

Appendix B

Supplementary tables

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Table B1. Sources of spatial information for coastal habitat distribution and methodological approach.

	Habitat ID	Habitat	Source and methodological approach
Transitional Waters	hab1	Estuarine saltmarshes	Areal cover mapped based on field observations from 2012 (GPS measurements collected on foot). The data is a part of the Mondego estuary monitoring program, in practice since 1986 (Neto et al., 2013). The most abundant species in the low saltmarshes of the Mondego estuary are Scirpus maritimus and Spartina maritima (Couto et al., 2014).
	hab2	Aquaculture tanks	Spatial information obtained from previous studies (Teixeira et al., 2018). Aquaculture tanks, Water ponds and Saltworks, together, constitute the Salgado of the Figueira da Foz system, a traditional solar salt extraction area, whose saltworks are intermixed, nowadays, with extensive (Water ponds) and semi-extensive (Aquaculture tanks) aquaculture farms.
	hab3	Water ponds	
	hab4	Saltworks	
	hab5	Estuarine littoral granule and very coarse to coarse sands	Spatial information obtained from previous studies (Cunha and Dinis 2002; inedit 1/10,000 cartography of the subsedimentary enviroments of the Mondego estuary and adjacent sedimentary systems). The Mondego estuary is a tidal and fluvial dominated system, controlled by periodic phenomena at different time and space scales. The fluvial sediment transport is expressed by a grain-size decrease towards the mouth (gravel to fine sand), but an inverse variation results from the tidal flood currents. Fine sediments, like mud and muddy very fine sand, accumulate on areas of reduced hydrodynamics of the channel margins and in the tidal flats.
	hab6	Estuarine littoral sandy mud and very fine to medium sands	
	hab7	Estuarine littoral mud	
	hab8	Estuarine seagrass bed	Areal cover of meadows mapped based on field observations (GPS measurements collected on foot) (Neto et al., 2013) sampled in September 2016. The data is a part of the Mondego estuary monitoring program, in practice since 1986 (Neto et al., 2013). Seagrasses in the Mondego estuary are occupied by the species Zostera noltii. Its cover is highly variable because it responds to hydromorphology, light intensity, toxic substances and changes in nutrient concentrations (Benedetti-Cecchi et al., 2001; Soltan et al., 2001; Panayotidis et al., 2004; Melville and Pulkownik, 2006; Yuksek et al., 2006; Arévalo et al., 2007; Scanlan et al., 2007; Krause-Jensen et al., 2008).
	hab9	Estuarine sublittoral granule and very coarse to coarse sands	Spatial information obtained from previous studies (e.g., Cunha and Dinis, 2002). The Mondego estuary is a tidal and fluvial dominated system, controlled by periodic phenomena at different time and space scales. The fluvial sediment transport is expressed by a grain-size decrease towards the mouth (gravel to fine sand), but an inverse variation results from the tidal flood currents. Fine sediments, like mud and muddy very fine sand, accumulate on areas of reduced hydrodynamics of the channel margins and in the tidal flats.
	hab10	Estuarine sublittoral sandy mud and very fine to medium sands	
	hab11	Estuarine sublittoral mud	
	hab12	Estuarine pelagic waters of the South Mondego Branch and Pranto River	Obtained from the Mondego estuary limits downloaded from the National System of Environmental Information , specifically the file named «Transitional surface water bodies of mainland Portugal».For the purpose of this study, the habitat categories were characterized based on the water column characteristics during winter, when the fluvial discharge is high (Cunha and Dinis, 2002; Kenov et al., 2012). As such, this study assumes that the estuarine water column from the South arm, the Armazéns channel and the Pranto River is completely mixed and shows reduced salinity due to freshwater inflow and tidal dynamics (Cunha and Dinis, 2002); whereas the estuarine water column from the North arm is stratified (Cunha and Dinis, 2002) with short residence time (1 day in winter) (Kenov et al., 2012).
	hab13	Estuarine pelagic waters of the North Branch of the Mondego River and upstream system	
Coastal Waters	hab14	Sandy beaches	Spatial information obtained from Carta de Ocupação do Solo 2007 (IGP., 2010), corresponding to class 3.3.1.02 - Coastal beaches and dunes, which is equivalent to class 3.3.1 Beaches, dunes, sands from CORINE Land Cover Maps . Includes pre-dune vegetation.
	hab15	Coastal rocky middle and supralitoral areas	Seabed habitat based on the Ecosystem types of Europe raster dataset (version 2.1.)), converted to vector data format. This dataset combines the Copernicus land service portfolio with the non-spatial EUNIS habitat classification for a better biological characterization of ecosystems across Europe.
	hab16	Coastal supralittoral sedimentary areas	
	hab17	Infra and circalittoral rocky areas	
	hab18	Infralittoral or circalittoral sedimentary areas	Seabed habitats based on the EMODnet broad-scale seabed habitat map for Europe (AKA EUSeaMap 2016). The 'AllcombD" field was used for the identification of EUSeamap 2016 habitat types.
	hab18_1	Infralittoral fine sand or infralittoral muddy sand areas	
	hab18_2	Circalittoral fine sand or muddy sand areas	
	hab19	Marine pelagic (0-200) waters	Pelagic habitats are based on the EMODnet bathymetric data. In the study area, only shallow pelagic habitats (0 to 200m) are present.

Table B2. Systematic review of scientific literature focused on the Atlantic coastal region adjacent to the Mondego River

	Biophysical structures															Habitats							
References	Bivalves	Fish	Zooplankton	Phytoplankton	Bacterioplankton	Macroinvertebrates	Birds	Macroalgae	Microalgae	Microfauna	Microbiological	Benthic Foraminiferal	Meiofauna	Macrophytes /Seagrasses	Macrophytes /Saltmarshes	Aquaculture	Saltworks	Coastal Surface Waters	Rocky Shore	Sandy shore	Surface Water	Other	Ecosystem Services
Bessa et al., 2018																					x	x	
Campos and Soares 2018																						x	
Fernandez-Fernandez et al., 2018																					x	x	
Marques et al., 2018			x																		x		
Mesquita et al., 2018	x																						
Neves et al., 2018		x																			x	x	
Primo et al., 2018		x																			x		
Rodrigues et al., 2018																					x	x	
Teixeira et al., 2018																x	x				x		x
Vieira et al., 2018		x																					
Bessa et al., 2017						x														x			
Cruz et al., 2017																							
Gaspar et al., 2017a								x											x				
Gaspar et al., 2017b								x											x				
Gonçalves et al., 2017	x																						
Veríssimo et al., 2017						x																	
Vinagre et al., 2017	x							x											x				
Bento et al., 2016		x																			x		
Castro et al., 2016		x																			x		
Cruzeiro et al., 2016																					x	x	
D'Ambrosio et al., 2016			x																		x		
Dessandier et al., 2016												x											
Filimionova et al., 2016			x	x																	x		
Gonçalves et al., 2016																							
Ojeda et al., 2016																						x	
Rada et al., 2016																						x	
Soares et al., 2016								x															
van der Linden et al., 2016						x																	
Vinagre et al., 2016	x					x		x											x				
Alves et al., 2015													x										
Araújo et al., 2015						x		x	x														
Baptista et al., 2015		x																					
Botelho et al., 2015	x																						
Brito et al., 2015																					x	x	
Gonçalves et al., 2015			x																				
Primo et al., 2105			x																				
Rodrigues and Pardal 2015				x				x						x									

Rodrigues et al., 2015				x				x															
Rossi et al., 2015	x					x			x					x									
Verdelhos et al., 2015	x																						
Verdelhos et al., 2015	x																						
Vinagre et al., 2015						x																	
Zell et al., 2015																						x	
Alves et al., 2014													x										
Bessa et al., 2014						x														x			
Bordalo et al., 2014						x								x									
Carrola et al., 2014		x																					
Couto et al., 2014															x								
Friis et al., 2014																						x	
Guerra et al., 2014						x																	
Kristensen et al., 2014						x																	
Leite et al., 2014						x																	
Marques et al., 2014			x																				
Martins et al., 2014b						x																	
Mota and Pinto 2014																		x					
Niquil et al., 2014														x									
Pinto et al., 2014a																						x	x
Pinto et al., 2014b																						x	x
Rocha et al., 2014																						x	
Teixeira et al., 2014																						x	
Veiga et al., 2014								x															
Verdelhos et al., 2014	x																						
Alves et al., 2013													x										
Baptista et al., 2013a		x																					
Baptista et al., 2013b		x																					
Calves et al., 2013		x																					
Castro and Santos 2013		x																					
Ceia et al., 2013						x																	
Costa et al., 2013a						x																	
Costa et al., 2013b																	x						
Couto et al., 2013a									x						x								
Couto et al., 2013b															x							x	
Friis et al., 2013																						x	
Guinand et al., 2013		x																					
Lança et al., 2013		x																					
Mantas et al., 2013																						x	
Marques et al., 2013						x																	
Martinho et al., 2013		x																					
Modesto et al., 2013	x																						
Neto et al., 2013														x									
Nolasco et al., 2013						x																	
Nyitrai et al., 2013		x																					

Otero et al., 2013																						x	
Pinto et al., 2013a																						x	x
Primo et al., 2013		x																					
Reis-Santos et al., 2013		x																					
Veríssimo et al., 2013a						x																	
Veríssimo et al., 2013b						x																	
Brito et al., 2012				x																			
Duarte et al., 2012															x								
Falcão et al., 2012			x																				
Franco et al., 2012	x																						
Gamito et al., 2012						x																	
Gaspar et al., 2012								x															
Gonçalves et al., 2012b			x																				
Gonçalves et al., 2012c			x																				
Gonçalves et al., 2012a			x																				
Grilo et al., 2012						x								x									
Kenov et al., 2012																						x	
Lillebo et al., 2012																						x	
Neto et al., 2012								x															
Nyitrai et al., 2012		x																					
Patrício et al., 2012								x					x										
Primo et al., 2012c				x																			
Primo et al., 2012a		x	x																				
Primo et al., 2012b		x	x																				
Ramos et al., 2012																						x	
Van der Linden et al., 2012						x																	
Veríssimo et al., 2012						x																	
Viegas et al., 2012						x																	
Baeta et al., 2011						x																	
Bordalo et al., 2011a						x																	
Bordalo et al., 2011b						x																	
Borja et al., 2011						x																	
Dolbeth et al., 2011														x									
Friis et al., 2011																						x	
Grilo et al., 2011						x																	
Lillebo et al., 2011																							
Marques et al., 2011			x																				
Nunes et al., 2011																						x	
Primo et al., 2011		x	x																				
Tavares et al., 2011		x																					
Baptista et al., 2010		x																					
Bessa et al., 2010						x																	
Cardoso et al., 2010														x									
Chaves et al., 2010						x																	
Couto et al., 2010						x																	

Crespo et al., 2010	X																						
Dolbeth et al., 2010		x																					
Gonçalves et al., 2010a			x																				
Gonçalves et al., 2010b			x																				
Martinho et al., 2010		x																					
Neto et al., 2010						x																	
Pinto et al., 2010																						x	x
Sousa et al., 2010															x								
Vasconcelos et al., 2010		x																					
Adão et al., 2009													x										
Alves et al., 2009													x										
Anastacio et al., 2009	x																						
Baeta et al., 2009a								x						x									
Baeta et al., 2009b		x	x			x		x					x	x									
Castro et al., 2009														x	x								
Costa et al., 2009															x								
Crisman et al., 2009																	x						
Duarte et al., 2009a																						x	
Duarte et al., 2009b																						x	
Duarte et al. 2009c																						x	
Garel et al., 2009																						x	
Grilo et al., 2009						x		x						x									
Marques et al., 2009			x																				
Martinho et al., 2009		x																					
Martynova et al., 2009			x																				
Patrício et al., 2009						x																	
Pedro and Ramos 2009							x																
Pinto et al., 2009						x																	x
Primo et al., 2009			x																				
Ribeiro et al., 2009																						x	
Teixeira et al., 2009						x																	
Vasconcelos et al., 2009		x																					
Vinagre et al., 2009		x																					
Cardoso et al., 2008a						x								x									
Cardoso et al., 2008b						x																	
Cardoso et al., 2008c						x																	
Chainho et al., 2008						x																	
Dolbeth et al., 2008a		x																					
Dolbeth et al., 2008b		x																					
Leston et al., 2008								x						x									
Marques et al., 2008			x																				
Martinho et al., 2008a		x																					
Martinho et al., 2008b		x																					
Neto et al., 2008																						x	
Reis-Santos et al., 2008		x																					

Salas et al., 2008						x																	
Sliva-Santos et al., 2008						x	x	x						x	x								
Sousa et al., 2008															x								
Teixeira et al., 2008a						x																	
Teixeira et al., 2008b						x																	
Almeida et al., 2007																						x	
Cabral et al., 2007		x																					
Cardoso et al., 2007a						x																	
Cardoso et al., 2007b														x									
Castro et al., 2007a																						x	
Castro et al., 2007b														x	x								
Chaínho et al., 2007a						x																	
Chaínho et al., 2007b						x																	
Dolbeth et al., 2007a		x																					
Dolbeth et al., 2007b						x																	
Ferreira et al., 2007						x								x									
Leitão et al., 2007		x																					
Lillebo et al 2007a																						x	
Lillebo et al., 2007b															x								
Marques et al., 2007a			x																				
Marques et al., 2007b			x																				
Martinho et al., 2007a		x																					
Martinho et al., 2007b		x																					
Martins et al., 2007								x															
Morgado et al., 2007			x																				
Patrício et al., 2007								x															
Saraiva et al., 2007																						x	
Teixeira et al., 2007						x																	
Vasconcelos et al., 2007		x																					
Viegas et al., 2007						x																	
Wise et al., 2007																						x	
Baeta et al., 2006						x																	
Chainho et al., 2006						x																	
Coelho et al., 2006	x																						
Ferreira et al., 2006																						x	
Francisco et al., 2006		x																					
Leitão et al., 2006		x																					
Lopes et al., 2006							x	x															
Marques et al., 2006		x	x																				
Patrício et al., 2006a	x		x	x		x								x									
Patrício et al., 2006b																						x	
Remerie et al., 2006			x																				
Salas et al., 2006a						x																	
Salas et al., 2006b						x																	
Salas et al., 2006c						x																	

Silva-Santos et al., 2006						x	x	x						x									
Baeta et al., 2005						x																	
Cardoso et al., 2005						x																	
Dolbeth et al., 2005						x								x									
Lillebo et al., 2005																						x	
Lopes et al., 2005							x																
Martins et al . 2005														x									
Pereira et al., 2005																						x	
Santos et al., 2005							x																
Verdelhos et al., 2005	x																						
Cardoso et al., 2004a						x																	
Cardoso et al., 2004b														x									
Coelho et al., 2004																						x	
Ferreira et al., 2004						x																	
Freire et al., 2004																				x		x	
Jensen et al., 2004						x																	
Lillebo et al., 2004																						x	
Pardal et al., 2004						x																	
Pereira and Mesquita 2004								x															
Rydin et al., 2004																						x	
Salas et al., 2004						x																	
Anastacio et al., 2003						x																	
Aprahamian et al., 2003		x																					
Bacelar-Nicolau et al., 2003					x																		
Cabral et al., 2003		x																				x	
Costa et al., 2003						x																	
Cruz et al . 2003						x																	
Dolbeth et al., 2003						x																	
Gonçalves et al., 2003a						x																	
Gonçalves et al., 2003b			x																				
Lillebo et al., 2003															x								
Maranhão and Marques 2003						x																	
Marques et al., 2003a						x																	
Marques et al., 2003b																						x	
Pastorinho et al., 2003a			x																				
Pastorinho et al., 2003b			x																				
Pereira and Mesquita 2003								x															
Vieira et al . 2003a			x																				
Vieira et al., 2003b			x																				
Azeiteiro 2002			x																				
Cardoso et al., 2002						x																	
Domingos et al., 2002		x																				x	
Fonseca et al., 2002						x																	
Jorgensen et al., 2002																						x	
Martins and Marques 2002								x															

Martins et al., 2002						x																	
Neves et al., 2002															x		x						
Correia et al., 2001		x																					
Do Carmo and Marques 2001																						x	
Duarte et al., 2001																						x	
Maranhão et al., 2001						x																	
Martins et al., 2001								x															
Vale and Sampayo 2001	x																						
Friis et al., 2000																						x	
Lopes et al., 2000							x	x															
Pardal et al., 2000						x																	
Schories et al., 2000						x																	
Azeiteiro et al., 1999						x																	
Cabral et al., 1999							x	x															
Friis et al., 1999																						x	
Granja 1999																						x	
Lillebo et al., 1999a						x																	
Lillebo et al., 1999b						x				x			x		x								
Martins et al., 1999								x															
Almeida et al 1998	x																						
Almeida et al 1997	x																						
Flindt et al 1997																						x	
Martins et al 1997								x															
Múrias et al. 1997							x																
Cabral et al. 1996							x	x															
Múrias et al., 1996							x	x															
Ribeiro et al., 1996		x																					
Gonçalves et al., 1995a						x																	
Gonçalves et al., 1995b						x																	
Marques et al., 1994						x																	
Marques et al., 1993						x																	
Baetahall et al., 1989											x												

Table B3. Current and potential provisioning ecosystem services per habitat, in the Atlantic coastal region adjacent to the Mondego River, based on literature review.

	Habitats	CICES Code	Class type	Service	Goods and Benefits	Evidence for Current: Scientific, explicitly analysing the ES concept	Evidence for Current: Scientific	Evidence for Current: Grey Literature	Evidence for Current: Other (observation/expert knowledge/ongoing projects/Media	Evidence for Potential: Scientific, explicitly analysing the ES concept	Evidence for Potential: Scientific	Evidence for Potential: Scientific / grey literature / other
Transitional waters	Estuarine saltmarshes	1.2.1.1	Macrophytes	Population of saltmarsh species used to in breeding programmes	Wild plant replantation for habitat reconstruction				ReSEt project. (Ongoing)		Zhao et al., 2016; Heuner et al., 2016; Carus et al., 2017	Couto et al., 2014
	Aquaculture tanks	1.1.2.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption						Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016; Pereira et al., 2018; Pereira et al., 2003	Gaspar et al., 2017a
		1.1.2.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals						Ahmed et al., 2017; Khalil et al., 2018; Pereira 2018; Vieira et al., 2017; Soares et al., 2016	Gaspar et al., 2017a
		1.1.2.3	Macroalgae	Harvestable surplus of seaweed biomass in situ	Seaweed for bioenergy production						Balina et al., 2017; Bruhn et al., 2011; Romagnoli et al., 2010	Gaspar et al., 2017a
		1.1.4.1	Fish, bivalve	Harvestable stock of reared fishes (*Sparus aurata*, *Dicentrachus labrax*) and bivalves	Fish (Sparus aurata, Dicentrachus labrax) and Seafood (e.g. mussels) for human food consumption	Pinto et al., 2014a; Teixeira et al., 2018					Gadelha et al., 2019; Matias et al., 2013	Teixeira et al., 2018
		1.1.4.3	Fish, Macroalgae, Microalgae	Biogas from aquaculture waste; Animal food (e.g. Artemia sp.) from aquaculture waste	Energy production; Fodder production						Balina et al., 2017; Bikker et al., 2016; Lanari and Franci 1998; Luo et al., 2017; Nnali and Oke 2013; van der Wal et al., 2013; Hughes et al., 2012	Teixeira et al., 2018
	Water ponds	1.1.6.1	Fish	Harvestable surplus of estuarine commercial fish population and/or fish stocking	Fish for human food consumption			Da Rocha 2017		Costa et al., 2013b	Hunt et al., 2017; Rocha et al., 2012	Da Rocha 2017; Teixeira et al., 2018
	Saltworks	1.1.5.1	Macrophytes	Harvestable surplus of macrophytes (e.g. Salicornia and other halophytes) in saltpond habitats	Source of food fibre, protein and minerals for human and animal consumption			Marques et al., 2017		Costa et al., 2013b	Laconsole et al., 2019	Neves et al., 2002; Castro and Freitas 2011
		1.2.1.2	Macrophytes	Population of plant algae or fungi species used to in breeding programmes	Wild plant replantation for commercial sale					Costa et al., 2013b	Laconsole et al., 2019	Neves et al., 2002; Castro and Freitas 2011
		1.2.1.3	Macrophytes	Harvestable share of population of plant species used to extract genes	Development of pharmaceuticals					Costa et al., 2013b	Patel 2016	Neves et al., 2002; Castro and Freitas 2011
		1.1.2.2	Macroalgae	Harvestable surplus of microalgae and halobacteria	Extraction of carotenoids and glycerol					Costa et al., 2013b	Abbes et al., 2013	Couto et al., 2013a
		4.3.1.1	Salt	Salt production	Dietary value	Pinto et al., 2010; Pinto et al., 2014a	Teixeira et al., 2018			Costa et al., 2013b	Rocha et al., 2012	Neves et al., 2002; Teixeira et al., 2018
	Estuarine littoral granule and very coarse to coarse sands											
	Estuarine littoral sandy mud and very fine to medium sands	1.1.5.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption						Li et al., 2018; Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016;	Gaspar et al., 2017a; Patrício et al., 2009
		1.1.5.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals						Khalil et al., 2018; Pereira 2018; Rocha et al., 2019;	Gaspar et al., 2017a; Patrício et al., 2009
		1.1.6.1	Bivalve	Harvestable surplus of estuarine commercial bivalve population	Seafood for human food consumption	Pinto et al., 2014a	Crespo et al., 2010					Mesquita et al., 2018

	1.1.6.2	Wild species (shrimps, crabs, seaworms, bivalves)	Harvestable surplus of animals	Fish baits				Carvalho et al., 2013	Verdelhos et al., 2015; Veríssimo et al., 2017
	1.2.1.1	Macroalgae	Seeds or spores that we can harvest	Wild plant seed for commercial sale				Gupta et al., 2018	Gaspar et al., 2017a; Patrício et al., 2009
	1.2.2.1	Bivalve	Spat for shellfish farms	Reduced costs of production				Brenner and Buck 2010; Walter and Liebezeit 2003; Teixeira et al., 2018	Mesquita et al., 2018
	1.2.2.2	Bivalve	Population of animals used in breeding programmes	Animals with novel characteristics that increase yields or reduce costs by resisting diseases or pests				Rasmussen and Morrissey 2007	Mesquita et al., 2018
Estuarine littoral mud	1.1.5.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption		Pereira et al., 2003		Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016; Pereira et al., 2018;	Gaspar et al., 2017a; Patrício et al., 2009
	1.1.5.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals				Khalil et al., 2018; Pereira 2018; Rocha et al., 2019;	Gaspar et al., 2017a; Patrício et al., 2009
	1.1.6.1	Bivalve	Harvestable surplus of estuarine commercial bivalve population	Seafood for human food consumption	Pinto et al., 2014a	Crespo et al., 2010			Mesquita et al., 2018
	1.1.6.2	Wild species (shrimps, crabs, seaworms, bivalves)	Harvestable surplus of animals	Fish baits				Carvalho et al., 2013	Verdelhos et al., 2015; Veríssimo et al., 2017
	1.2.1.1	Macroalgae	Seeds or spores that we can harvest	Wild plant seed for commercial sale				Gupta et al., 2018	Gaspar et al., 2017a; Patrício et al., 2009; Soares et al., 2016
	1.2.2.1	bivalve	Spat for shellfish farms	Reduced costs of production				Brenner and Buck 2010; Walter and Liebezeit 2003;	Mesquita et al., 2018
	1.2.2.2	Bivalve	Population of animals used in breeding programmes	Wild bivalves' breeding for commercial sale				Rasmussen and Morrissey 2007	Mesquita et al., 2018
Estuarine seagrass bed	1.2.1.1	Macrophytes (Zoostera noltii)	Population of zostera noltii used to in breeding programmes	Wild plant replantation for habitat reconstruction		Martins et al., 2005		Heuner et al., 2016	Neto et al., 2013
Estuarine sublittoral granule and very coarse to coarse sands	4.3.2.2	Sand and gravel	Occurrence of exploitable sand and gravel	Source of sand and gravel for materials				Velegrakis et al., 2006	Cunha et al., 2006
Estuarine sublittoral sandy mud and very fine to medium sands	1.1.6.1	Bivalve	Harvestable surplus of estuarine commercial bivalve population	Seafood for human food consumption		Crespo et al., 2010			Mesquita et al., 2018
	1.2.2.1	Bivalve	Spat for shellfish farms	Reduced costs of production				Brenner and Buck 2010; Walter and Liebezeit 2003;	Mesquita et al., 2018
	1.2.2.2	Bivalve	Population of animals used in breeding programmes	Wild bivalves' breeding for commercial sale				Rasmussen and Morrissey 2007	Mesquita et al., 2018
Estuarine sublittoral mud	1.1.6.1	Bivalve	Harvestable surplus of estuarine commercial bivalve population	Seafood for human food consumption	Pinto et al., 2014a	Crespo et al., 2010			Mesquita et al., 2018
	1.2.2.1	Bivalve	Spat for shellfish farms	Reduced costs of production				Brenner and Buck 2010; Walter and Liebezeit 2003;	Mesquita et al., 2018
	1.2.2.2	Bivalve	Population of animals used in breeding programmes	Wild bivalves' breeding for commercial sale				Rasmussen and Morrissey 2007	Mesquita et al., 2018
Estuarine pelagic waters of the South Mondego Branch and Pranto River	1.1.6.1	Fish	Harvestable surplus of estuarine commercial fish population	Fish for human food consumption		Domingos, 2002	Portaria 164/99	Piet et al., 2017	Vieira et al., 2018; Primo et al., 2018
	1.1.6.2	Zooplankton	Zooplankton – jellyfish used for various purposes	Aquaria and other non-nutritional puposes				Purcell et al., 2013;	D'Ambrosio 2017
	1.2.2.1	Fish	Spat for fish farms	Reduced costs of production		Teixeira et al., 2018			Vieira et al., 2018; Primo et al., 2018
	1.2.2.2	Fish	Population of animals used in breeding programmes	Wild fish species' breeding for commercial sale				Rasmussen and Morrissey 2007	Vieira et al., 2018; Primo et al., 2018
	4.2.1.2	Estuarine Surface Water	Temperature and volume of water that can be used for cooling	Reduced energy costs			EDP 2017	Hoffmeyer et al., 2005	Teixeira et al., 2018
	4.2.1.4	Estuarine Surface Water	Tidal velocity	Tidal power				Angeloudis et al., 2018	Teixeira et al., 2018
Estuarine pelagic waters of the North	1.1.6.1	Fish	Harvestable surplus of estuarine commercial fish population	Fish for human food consumption		Domingos, 2002	Portaria 164/99	Piet et al., 2017	Vieira et al., 2018; Primo et al., 2018

	Branch of the Mondego River and upstream system	1.1.6.2	Zooplankton	Zooplankton – jellyfish used for various purposes	Aquaria and other non-nutritional purposes				Burgess et al., 2018	D'Ambrosio 2017
		1.2.2.1	Fish	Spat for fish farms	Reduced costs of production	Teixeira et al., 2018				Vieira et al., 2018; Primo et al., 2018
		1.2.2.2	Fish	Population of animals used in breeding programmes	Wild fish species' breeding for commercial sale				Rasmussen and Morrissey 2007	Vieira et al., 2018; Primo et al., 2018
		4.2.1.2	Estuarine Surface Water	Temperature and volume of water that can be used for cooling	Reduced energy costs			EDP 2017	Hoffmeyer et al., 2005	Teixeira et al., 2018
		4.2.1.4	Estuarine Surface Water	Tidal velocity	Tidal power				Angeloudis et al., 2018	Teixeira et al., 2018
	Sandy beaches	4.3.2.1	Beaches	Sunlight	Vitamin D		Fernandes, 2015		Sreelatha et al., 2018	Fernandes, 2015; Vinagre etal. 2017; Vinagre et al., 2016
		4.3.2.2	Sand and gravel	Occurrence of exploitable sand and gravel	Source of sand and gravel for materials			Diário de Notícias Lusa, 2019	Velegrakis et al., 2006	Fernandes, 2015; Vinagre etal. 2017; Vinagre et al., 2016
	Coastal rocky middle and supralitoral areas	1.1.5.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption				Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016; Pereira et al., 2018;	Gaspar et al., 2017b; Soares et al., 2016
		1.1.5.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals	Soares et al., 2016			Khalil et al., 2018; Pereira 2018; Rocha et al., 2019;	Gaspar et al., 2017b; Soares et al., 2016
		1.1.5.3	Macroalgae	Harvestable surplus of seaweed biomass in situ	Seaweed for bioenergy production				Balina et al., 2017; Bruhn et al., 2011; Romagnoli et al., 2010	Gaspar et al., 2017b; Soares et al., 2016
		1.1.6.1	Bivalve; Crabs	Harvestable surplus of commercial bivalve population	Seafood for human food consumption	Rius and Cabral 2004; Costa et al., 2003				Costa et al.,2003; Vinagre et al., 2016; Vinagre et al., 2017
Coastal Waters		1.1.6.2	Bivalve	Harvestable surplus of animals	Fish baits				Carvalho et al., 2013; Plicanti et al., 2016;	Vinagre et al., 2016; Vinagre et al., 2017
		1.2.2.1	Bivalve	Spat for shellfish farms	Reduced costs of production				Brenner and Buck 2010; Walter and Liebezeit 2003; Rius and Cabral 2004;	Vinagre et al., 2016; Vinagre et al., 2017
		1.2.2.2	Bivalve	Population of animals used in breeding programmes	Wild bivalves', and/or sea urchins, breeding for commercial sale				Rasmussen and Morrissey 2007; Rocha et al., 2019; Suckling et al., 2018	Vinagre et al., 2016; Vinagre et al., 2017
		1.2.2.3	Echinoderme (Sea Urchin)	Harvestable share of population of a given species used to extract genes	Sea urchins used for the creation of biomimetic products				Lebesgue et al., 2016; Viana and Santos 2018	in situ observations observation
	Coastal supralittoral sedimentary areas	none								
	Infra and circalittoral rocky areas	1.1.5.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption				Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016; Pereira et al., 2018;	Gaspar et al., 2017b; Soares et al., 2016
		1.1.5.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals				Khalil et al., 2018; Pereira 2018; Rocha et al., 2019;	Gaspar et al., 2017b; Soares et al., 2016

	1.1.5.3	Macroalgae	Harvestable surplus of seaweed biomass in situ	Seaweed for bioenergy production		Balina et al., 2017; Bruhn et al., 2011; Romagnoli et al., 2010	Gaspar et al., 2017b; Soares et al., 2016
Infralittoral or circalittoral sedimentary areas	none						
Infralittoral fine sand or infralittoral muddy sand areas	none						
Circalittoral fine sand or muddy sand areas	none						
Marine pelagic (0-200) waters	1.1.2.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption		Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016; Pereira et al., 2018;	Gaspar et al., 2017b; Soares et al., 2016
	1.1.2.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals		Ahmed et al., 2017; Khalil et al., 2018; Pereira 2018; Vieira et al., 2017;	Gaspar et al., 2017b; Soares et al., 2016
	1.1.2.3	Macroalgae	Harvestable surplus of seaweed biomass in situ	Seaweed for bioenergy production		Balina et al., 2017; Bruhn et al., 2011; Fernand et al., 2017; Romagnoli et al., 2010	Gaspar et al., 2017b; Soares et al., 2016
	1.1.4.1	Fish, bivalve	Harvestable stock of reared fishes and molluscs	Fish and Seafood (e.g. mussels) for human food consumption		Ramalho and Dinis 2011; Dumbauld et al., 2009	Baptista et al., 2013a; Vinagre et al., 2016; Vinagre et al., 2017
	1.1.4.3	Fish	Biogas from aquaculture waste; Animal food (e.g. Artemia sp.) from aquaculture waste	Energy production; Fodder production		Balina et al., 2017; Bikker et al., 2016; Lanari and Franci 1998; Luo et al., 2016; Nnali and Oke 2013; Van der wal et al., 2013; Hughes et al., 2012	Baptista et al., 2013a; Cabral et al., 2003
	1.1.5.1	Macroalgae	Harvestable surplus of seaweed biomass in situ	Source of food fibre, protein and minerals for human and animal consumption		Abirami and Kowsalya 2011; Abudabos et al., 2013; Ahmed et al., 2017; Makkar et al., 2016; Pereira et al., 2018;	Gaspar et al., 2017b; Soares et al., 2016
	1.1.5.2	Macroalgae	Harvestable surplus of seaweed biomass in situ	Production of thickening or emulsifying agents (e.g. agar and carrageenan), Cosmeceuticals, Algotherapy, Thalassotherapy; Pharmaceuticals		Khalil et al., 2018; Pereira 2018; Rocha et al., 2019;	Gaspar et al., 2017b; Soares et al., 2016
	1.1.5.3	Macroalgae	Harvestable surplus of seaweed biomass in situ	Seaweed for bioenergy production		Balina et al., 2017; Bruhn et al., 2011; Fernand et al., 2017; Romagnoli et al., 2010	Gaspar et al., 2017b; Soares et al., 2016
	1.1.6.1	Fish	Harvestable surplus of commercial fish population	Fish for human food consumption	Nunes 2005; Cabral et al., 2003	Piet et al., 2017	Baptista et al., 2013a; Cabral et al., 2003
	1.1.6.2	Zooplankton	Zooplankton – jellyfish used for various purposes	Aquaria and other non-nutritional purposes		Burgess et al., 2018	D'Ambrosio 2017
	1.2.2.1	Fish	Spat for fish farms	Reduced costs of production	Cabral et al., 2003		Baptista et al., 2013a; Cabral et al., 2003
	1.2.2.2	Fish	Population of animals used in breeding programmes	Wild fish species' breeding for commercial sale		Pacheco et al., 2018; Rasmussen and Morrissey 2007;	Baptista et al., 2013a; Cabral et al., 2003
	4.2.1.4	Coastal surface waters	Wave intensity	Wave Power		Castro-Santos et al., 2015	Mota and Pinto 2014
	4.3.2.3	Wind	Wind power	Renewable energy source		Lopes 2016	Campos and Soares 2018

Table B4. Current and potential regulation ecosystem services per habitat, in Atlantic coastal region adjacent to the Mondego River based on literature review.

	Habitats	CICES Code	Class type	Service	Goods and Benefits	Evidence for Current: Scientific, explicitly analysing the ES concept	Evidence for Current: Scientific	Evidence for Current: Grey Literature	Evidence for Current: Other (observation/expert knowledge/ongoing projects/Media	Evidence for Potential: Scientific, explicitly analysing the ES concept	Evidence for Potential: Scientific	Evidence for Potential: Scientific / grey literature / other
Transitional Waters	Estuarine saltmarshes	2.2.1.1	Macrophytes and Microphytobenthos	Wave attenuation and Sediment biostabilisation	Improved water quality and clarity					Almeida et al., 2016	Macintyre et al., 1996; Shepard et al., 2011; Castro and Freitas 2011;	Araújo et al., 2015; Couto et al., 2014
		2.2.1.3	Macrophytes	The capacity of saltmarsh macrophytes to retain water and release it slowly	Mitigation of damage as a result of reduced in magnitude and frequency of flood/storm events						McCartney et al., 2013;	Couto et al., 2014
		2.2.2.3	Macrophytes	Important nursery habitat	Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.	Pinto et al., 2014a	Martinho et al., 2007a; Vasconcelos et al., 2007; Dolbeth et al., 2008a			Whitfield et al., 2017		Couto et al., 2014
		2.2.3.1	Macrophytes	Providing a habitat for native pest control agents	Reduction in pest damage to comercially important indigenous species						Secord 2003;	Couto et al., 2014; Chainho et al., 2015
		2.2.5.2	Macrophytes	Nutrient and contaminant absorption	Improved water quality and reduction of human health risks	Pinto et al., 2014a; Pinto et al., 2013	Castro et al., 2007b; Castro et al., 2009;			Pinto et al., 2014a; Wieski et al., 2010		Couto et al., 2014
		2.2.6.1	Macrophytes	Carbon sequestration	Climate regulation resulting in avoided damage costs		Couto et al., 2013a; Sousa et al., 2010			Schaefer et al., 2014	Beaumont et al., 2014	Couto et al., 2014
	Aquaculture tanks	2.2.5.2	Macroalgae, Bivalve	Nutrient and contaminant absorption	Improved water quality and reduction of human health risks					Pinto et al., 2014a; Gray et al., 2019; Clements and Comeau 2019	Leston et al., 2014; Abreu et al., 2011; Elizondo-González et al., 2018; Hadley et al., 2016; Nielsen et al., 2016; Walton et al., 2015;	Gaspar et al., 2017a; Patrício et al., 2009
		2.2.6.1	Macroalgae	Carbon sequestration	Climate regulation resulting in avoided damage costs		Baeta et al., 2009a				Sengupta et al., 2017; Walton et al., 2015	Gaspar et al., 2017a; Patrício et al., 2009
	Water ponds	2.2.2.2	Macrophytes (Water column as dispersal agent)	Natural restoration of saltmarsh beds	Contribution to saltmarsh restoration						Huiskies et al., 1995	Couto et al., 2014; Da Rocha 2017; Teixeira et al., 2018
		2.2.2.3	Water column	Important nursery habitat	Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.	Pinto et al., 2014a	Teixeira et al., 2018					Martinho et al., 2007a; Teixeira et al., 2018; Vasconcelos et al., 2007
		2.2.3.1	Water column	Providing a habitat for native pest control agents	Reduction in pest damage to comercially important indigenous species						Secord 2003;	Chainho et al., 2015; Martinho et al., 2007a; Teixeira et al., 2018; Vasconcelos et al., 2007
		2.2.5.2	Biological components at Water/Sediment interface (autotrophic (benthic algae) and heterotrophic (bacterial community) biofilms)	Transformation processes of Organic matter and nutrients	Improved water quality and reduction of human health risks						Sauvage et al., 2018	Lillebo et al., 1999b
	Saltworks	2.2.1.1	Macrophytes	Wave attenuation and shoreline stabilization	Improved water quality and clarity						Shepard et al., 2011;	Neves et al., 2002; Castro and Freitas 2011
		2.2.2.3	Macrophytes	Habitat for birds	Sustainable populations of useful or iconic species, such as Flamingos, that contribute to a service in another ecosystem.		Múrias et al., 2005		Neves et al., 2002	Costa et al., 2013b	Herbert et al., 2018; Rocha et al., 2012	Neves et al., 2002; Pedro and Ramos 2009
		2.2.5.2	Macrophytes, planktonic communities, halophilic bacteria, benthic communities	Nutrient and contaminant absorption; Water temperature increase; saltwork floor sealing.	Improved water quality and reduction of human health risks. Increased evaporation and increased salt production		Castro et al., 2007a; Castro et al., 2009; Vieira and Bio 2011			Pinto et al., 2014a; Costa et al., 2013b	Rocha et al., 2012	Couto et al., 2014; Neves et al., 2002

	2.2.6.1	Macrophytes	Carbon sequestration	Climate regulation resulting in avoided damage costs		Couto et al., 2013a; Sousa et al., 2010	Neves et al., 2002		Beaumont et al., 2014	Neves et al., 2002
Estuarine littoral granule and very coarse to coarse sands	none									
Estuarine littoral sandy mud and very fine to medium sands	2.1.2.1	Deposit-feeding macrofaunal consumers (Amphipods, bivalves, polychates, gastropods)	Removal of material such as rotting algal mats, which is in the littoral zone but could potentially wash up on shore and produce olfactory and visual impacts	Reduction in nuisance effect of smells from animal lots		Rossi et al., 2015				Martins et al., 2014a; Rossi et al., 2015
	2.2.5.2	Macroalgae; Microphytobenthos ; Microbial communities; Bivalve	Nutrient and contaminant absorption; Source and sink of inorganic nutrients by Microphytobenthos communities regulating the resilience of tidal flats to eutrophication; Microbial communities as biodegradation agents	Higher resilience to eutrophication, improved water quality and reduction of human health risks	Pinto et al., 2014a; Pinto et al., 2013	CC/PP: Baeta et al., 2009a; Baeta et al., 2011		Pinto et al., 2014a; Gray et al., 2019	Harrabi et al., 2019; Henriques et al., 2017; Larson and Sundback 2008; Nielsen et al., 2016	Araújo et al., 2015; Botelho et al., 2019; Gaspar et al., 2017a; Lillebo et al., 1999b
	2.2.1.1	Macroinvertebrates	Sediment biostabilisation	Improved water quality and clarity		Kristensen et al., 2013				Veríssimo et al., 2017
	2.2.6.1	Macroalgae	Carbon sequestration	Climate regulation resulting in avoided damage costs		Baeta et al., 2009a			Sengupta et al., 2017	Gaspar et al., 2017a; Patrício et al., 2009
Estuarine littoral mud	2.1.2.1	Deposit-feeding macrofaunal consumers (Amphipods, bivalves, polychates, gastropods)	Removal of material such as rotting algal mats, which is in the littoral zone but could potentially wash up on shore and produce olfactory and visual impacts	Reduction in nuisance effect of smells from animal lots		Rossi et al., 2015				Martins et al., 2014a; Rossi et al., 2015
	2.2.5.2	Macroalgae; Microphytobenthos ; Microbial communities; Bivalve	Nutrient and contaminant absorption; Source and sink of inorganic nutrients by Microphytobenthos communities regulating the resilience of tidal flats to eutrophication; Microbial communities as biodegradation agents	Higher resilience to eutrophication, improved water quality and reduction of human health risks	Pinto et al., 2014a; Pinto et al., 2013	Baeta et al., 2009a; Baeta et al., 2011		Pinto et al., 2014a; Gray et al., 2019	Harrabi et al., 2019; Henriques et al., 2017; Larson and Sundback 2008; Nielsen et al., 2016	Araújo et al., 2015; Botelho et al., 2019; Gaspar et al., 2017a; Lillebo et al., 1999b
	2.2.1.1	Macroinvertebrates	Sediment biostabilisation	Improved water quality and clarity		Kristensen et al., 2013				Veríssimo et al., 2017
	2.2.6.1	Macroalgae	Carbon sequestration	Climate regulation resulting in avoided damage costs		Baeta et al., 2009a			Sengupta et al., 2017	Gaspar et al., 2017a; Patrício et al., 2009
Estuarine seagrass bed	2.2.1.1	Macrophytes (Zostera noltii) and Microphytobhentos	Sediment biostabilisation	Improved water quality and clarity					Macintyre et al., 1996; Potouroglou et al., 2017; van Katwijk et al., 2010; Widdows et al., 2008	Neto et al., 2013; Rossi et al., 2015
	2.2.1.3	Macrophytes (Zostera noltii)	The capacity of seagrass macrophytes to retain water and release it slowly	Mitigation of damage as a result of reduced in magnitude and frequency of flood/storm events					Fonseca and Calahan 1992; Widdows et al., 2008	Neto et al., 2013
	2.2.2.3	Macrophytes (Zostera noltii)	Important nursery habitat	Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.	Pinto et al., 2014b	Castro et al., 2016; Dolbeth et al., 2008a; França et al., 2009		Whitfield et al., 2017	Polte and Asmus 2006	Neto et al., 2013
	2.2.3.1	Macrophytes (Zostera noltii)	Providing a habitat for native pest control agents	Reduction in pest damage to comercially important indigenous species					Secord 2003	Chainho et al., 2015; Neto et al., 2013

	2.2.5.2	Macrophytes (Zostera noltii)	Nutrient and contaminant absorption	Improved water quality and reduction of human health risks	Pinto et al., 2014a; Pinto et al., 2013	Castro et al., 2007b; Castro et al., 2009;	Pinto et al., 2014a; Wieski et al., 2010	La Nafie et al., 2014	Neto et al., 2013
	2.2.6.1	Macrophytes (Zostera noltii)	Carbon sequestration	Climate regulation resulting in avoided damage costs		Couto et al., 2013b; Sousa et al., 2010	Schaefer et al., 2014	Beaumont et al., 2014	Neto et al., 2013
Estuarine sublittoral granule and very coarse to coarse sands	none								
Estuarine sublittoral sandy mud and very fine to medium sands	2.1.2.1	Deposit-feeding macrofaunal consumers (Amphipods, bivalves, polychates, gastropods)	Removal of material such as rotting algal mats, which is in the littoral zone but could potentially wash up on shore and produce olfactory and visual impacts	Reduction in nuisance effect of smells from animal lots		Rossi et al., 2015			Martins et al., 2014a; Rossi et al., 2015
	2.2.5.2	Macroalgae; Microphytobenthos; Microbial communities; Bivalve	Nutrient and contaminant absorption; Source and sink of inorganic nutrients by Microphytobenthos communities regulating the resilience of tidal flats to eutrophication; Microbial communities as biodegradation agents	Higher resilience to eutrophication, improved water quality and reduction of human health risks	Pinto et al., 2014a; Pinto et al., 2013	Baeta et al., 2009a; Baeta et al., 2011	Pinto et al., 2014a; Gray et al., 2019	Harrabi et al., 2019; Henriques et al., 2017; Larson and Sundback 2008; Nielsen et al., 2016	Araújo et al., 2015; Botelho et al., 2019; Gaspar et al., 2017a; Lillebo et al., 1999b
	2.2.1.1	Macroinvertebrates	Sediment biostabilisation	Improved water quality and clarity		Kristensen et al., 2013			Veríssimo et al., 2017
Estuarine sublittoral mud	2.1.2.1	Deposit-feeding macrofaunal consumers (Amphipods, bivalves, polychates, gastropods)	Removal of material such as rotting algal mats, which is in the littoral zone but could potentially wash up on shore and produce olfactory and visual impacts	Reduction in nuisance effect of smells from animal lots		Rossi et al., 2015			Martins et al., 2014a; Rossi et al., 2015
	2.2.5.2	Macroalgae; Microphytobenthos; Microbial communities; Bivalve	Nutrient and contaminant absorption; Source and sink of inorganic nutrients by Microphytobenthos communities regulating the resilience of tidal flats to eutrophication; Microbial communities as biodegradation agents	Higher resilience to eutrophication, improved water quality and reduction of human health risks	Pinto et al., 2013	Baeta et al., 2009a; Baeta et al., 2011	Pinto et al., 2014a; Gray et al., 2019	Harrabi et al., 2019; Henriques et al., 2017; Larson and Sundback 2008; Nielsen et al., 2016	Araújo et al., 2015; Botelho et al., 2019; Gaspar et al., 2017a; Lillebo et al., 1999b
	2.2.1.1	Macroinvertebrates	Sediment biostabilisation	Improved water quality and clarity		Kristensen et al., 2013			Veríssimo et al., 2017
Estuarine pelagic waters of the South Mondego Branch and Pranto River	2.2.2.1	Macroalgae (Water column as dispersal agent of gametes)	Natural fertilization of Macroalgae	Macroalgae for human use and/or consumption				Cui et al., 2018	Gaspar et al., 2017a; Patrício et al., 2009
	2.2.2.2	Macrophytes (Water column as dispersal agent)	Natural restoration of aquatic macrophyte-based habitats	Contribution to saltmarsh restoration				Huiskies et al., 1995	Couto et al., 2014
	2.2.2.3	Water column	Important nursery habitat	Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.	Pinto et al., 2014b	Martinho et al., 2007a			Martinho et al., 2007a; Teixeira et al., 2018; Vasconcelos et al., 2007
	2.2.5.2	Biological components at Water/Sediment interface (autotrophic (benthic algae) and heterotrophic (bacterial community) biofilms)	Transformation processes of organic matter and nutrients	Improved water quality and reduction of human health risks			Pinto et al., 2014a	Sauvage et al., 2018	Lillebo et al., 1999b
Estuarine pelagic waters of the North	2.2.2.1	Macroalgae (Water column as dispersal agent of gametes)	Natural fertilization of Macroalgae	Macroalgae for human use and/or consumption				Cui et al., 2018	Gaspar et al., 2017a; Patrício et al., 2009

	Branch of the Mondego River and upstream system	2.2.2.2	Macrophytes (Water column as dispersal agent)	Natural restoration of aquatic macrophyte-based habitats	Contribution to saltmarsh restoration				Huiskies et al., 1995	Couto et al., 2014
		2.2.2.3	Water column	Important nursery habitat	Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.	Pinto et al., 2014b	Martinho et al., 2007a			Martinho et al., 2007a; Teixeira et al., 2018; Vasconcelos et al., 2007
		2.2.5.2	Biological components at Water/Sediment interface (autotrophic (benthic algae) and heterotrophic (bacterial community) biofilms)	Transformation processes of organic matter and nutrients	Improved water quality and reduction of human health risks			Pinto et al., 2014a	Sauvage et al., 2018	Lillebo et al., 1999b
Coastal Waters	Sandy beaches	2.1.2.1	Deposit-feeding macrofaunal consumers (Amphipods, bivalves, polychates, gastropods)	Removal of material such as rotting algal mats, which is in the littoral zone but could potentially wash up on shore and produce olfactory and visual impacts	Reduction in nuisance effect of smells from animal lots		Bessa et al., 2014			Bessa et al., 2014
		2.2.2.3	Sandy shore	Foraging habitat for birds	Sustainable populations of bird species that people enjoy		Pereira et al., 2018			Bessa et al., 2014; Bessa et al., 2017
		5.2.1.2	Sandy shore	Flood and erosion protection	Reduction in damage costs		Do Carmo et al., 2010; Reis et al., 2008;		Do Carmo et al., 2018; Stronkhorst et al., 2018	Bessa et al., 2014; Bessa et al., 2017
	Coastal rocky middle and supralitoral areas	2.1.2.1	Deposit-feeding macrofaunal consumers (Amphipods, bivalves, polychates, gastropods)	Removal of material such as rotting algal mats, which is in the littoral zone but could potentially wash up on shore and produce olfactory and visual impacts	Reduction in nuisance effect of smells from animal lots				Vinagre et al., 2015	Bessa et al., 2014; Vinagre et al., 2017
		2.2.6.1	Macroalgae	Carbon sequestration	Climate regulation resulting in avoided damage costs			Geraldi et al., 2014	Sengupta et al., 2017	Gaspar et al., 2017b; Soares et al., 2016
		2.2.5.2	Bivalve	Nutrient absorption	Improved water quality and reduction of human health risks			Pinto et al., 2014a; Gray et al., 2019	Nielsen et al., 2016	Vinagre et al., 2016;Vinagre et al., 2017
	Coastal supralittoral sedimentar y areas	5.2.1.2	Sandy shore	Flood and erosion protection	Reduction in damage costs		Do Carmo et al., 2010; Reis et al., 2008			Bessa et al., 2014; Bessa et al., 2017
	Infra and circalittoral rocky areas	2.2.6.1	Macroalgae	Carbon sequestration	Climate regulation resulting in avoided damage costs			Geraldi et al., 2014	Sengupta et al., 2017	Gaspar et al., 2017b; Soares et al., 2016
		2.2.5.2	Bivalve	Nutrient absorption	Improved water quality and reduction of human health risks			Gray et al., 2019; Clements and Comeau 2019	Nielsen et al., 2016	Vinagre et al., 2016;Vinagre et al., 2017
	Infralittoral or circalittoral sedimentar y areas	none								
	Infralittoral fine sand or infralittoral muddy sand areas	none								
	Circalittoral fine sand or muddy sand areas	none								
	Marine pelagic (0-200) waters	2.2.2.1	Macroalgae (Water column as dispersal agent of gametes)	Natural fertilization of Macroalgae	Macroalgae for human use and/or consumption				Cui et al., 2018	Gaspar et al., 2017b; Soares et al., 2016
		2.2.2.3	Water column	Important nursery habitat	Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.		Cabral et al., 2003			Baptista et al., 2013a; Cabral et al., 2003

Table B5. Current and potential cultural ecosystem services per habitat, in the Atlantic coastal region adjacent to the Mondego River, based on literature review.

						Evidence for Current				Evidence for Potential		
	Habitat	Code	Class type	Service	Goods and Benefits	Scientific, explicitly analysing the ES concept	Scientific	Grey Literature	Other (obervation/expert knowledge/ongoing projects/Media	Scientific, explicitly analysing the ES concept	Scientific	Scientific / grey literature / other
Transitional Waters	Estuarine saltmarshes	3.1.1.2	Macrophytes; Birds; Macroinvertebrates	Species of interest to birdwatchers	de-stressing or mental health; eco-tourism		Lopes et al., 2002	Cruz et al., 2014; Ribeiro et al., 2001		Pinto et al., 2014b		Pedro and Ramos 2009
		3.1.2.1	Wader species	Site of special scientific interest: RAMSAR site and Important Bird and Biodiversity Area (IBA)	Knowledge about the environment and nature		Costa et al., 2013c	BirdLife International, 2019.				
		3.1.2.2	Macrophytes; Birds; Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Lopes et al., 2002; Costa et al., 2013b	Cruz et al., 2014;				
		3.1.2.4	Macrophytes; Birds; Macroinvertebrates	Area of Outstanding Natural Beauty; panorama site	Artistic inspiration		Lopes et al., 2002	Cruz et al., 2014; Ribeiro et al., 2001		Pinto et al., 2014b		
		3.2.1.1	Flamingos	Presence of iconic species: Flamingos	Social cohesion, cultural icon	Pinto et al 2013	Múrias et al., 2002					Múrias et al., 2002
		3.2.1.3	Macrophytes; Birds; Macroinvertebrates	Archive records or collections	Nature films				Mondego documentary, 2011			
		3.2.2.1	Macrophytes; Birds; Macroinvertebrates	Areas designated as wilderness	Mental/Moral well-being	Pinto et al., 2013			Ramsar, 1999		Lefeuvre et al., 2003	Botelho et al., 2019; Couto et al., 2014; Lopes et al., 2002
		3.2.2.2	Macrophytes; Birds; Macroinvertebrates	Near Threatened wader species; Saltmarsh biodiversity	Moral well-being	Pinto et al 2013	Lopes et al., 2005; Couto et al., 2014;	Cruz et al., 2014				
	Aquaculture tanks	3.1.1.1	Fish	Recreational fishery	Recreation; Tourism	Pinto et al., 2016			Fernandes, 2015; Pescódromo de Lavos Facebook Page			Teixeira et al., 2018
		3.1.2.1	Fish, Macroalgae and Bivalves	Site of special scientific interest for two main reasons: 1. to evaluate its relationship with the natural surroundings; 2. to support aquaculture studies for the developmet of more sustainable solutions	Knowledge about the environment and nature		Teixeira et al., 2018; Baptista et al., 2013b				Nunes et al., 2011	Teixeira et al., 2018
		3.1.2.2	Fish, Macroalgae and Bivalves	Site used for *insitu* teaching and conservation activities	Skills or knowledge about technological and environmental management				in situ observations			Teixeira et al., 2018
	Water ponds	3.1.1.1	Fish	Recreational fishery	Recreation; Tourism	Pinto et al., 2016			Fernandes, 2015			Da Rocha, 2017; Teixeira et al., 2018
		3.1.1.2	Water ponds' Biodiversity	Species of interest to birdwatchers	de-stressing or mental health; eco-tourism		Lopes et al., 2002	Cruz et al., 2014; Ribeiro et al., 2001				
		3.1.2.1	Wader species	Site of special scientific interest: RAMSAR site and Important Bird and Biodiversity Area (IBA)	Knowledge about the environment and nature		Costa et al., 2013c	BirdLife International, 2019				
		3.1.2.2	Fish	Site used for *insitu* teaching and conservation activities	Skills or knowledge about		Costa et al., 2013b					Da Rocha 2017; Teixeira et al., 2018

				environmental management							
	3.1.2.3	Fish	Recreational fishery	Tourism, Local Identity	Pinto et al., 2016			Fernandes, 2015			Da Rocha 2017; Teixeira et al., 2018
Saltworks	3.1.1.1	Saltworks' biodiversity	Ecological qualities of saltworks that make it attractive to hiker	Recreation; nature-based recreation		Múrias et al., 2002	Cruz et al., 2014; Ribeiro et al., 2001		Pinto et al., 2014b; Crisman et al., 2009	Gauci et al., 2017	
	3.1.1.2	Saltworks' biodiversity	Species of interest to birdwatchers	de-stressing or mental health; eco-tourism		Múrias et al., 2002	Cruz et al., 2014; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009		
	3.1.2.1	Birds	Site of special scientific interest: RAMSAR site and Important Bird and Biodiversity Area (IBA)	Knowledge about the environment and nature		Múrias et al., 2002	BirdLife International, 2019		Pinto et al., 2014a; Crisman et al., 2009	Millán et al., 2011	Múrias et al., 2002
	3.1.2.2	Birds	Site used for voluntary conservation activities	Skills or knowledge about environmental management				in situ observations	Pinto et al., 2014a; Crisman et al., 2009	Lopes et al., 2005	Múrias et al., 2002
	3.1.2.3	Saltworks	Recreational use and emotional attachment of saltwork areas	Tourism, local identify			Neves et al., 2002; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009		
	3.1.2.4	Saltworks	Area of Outstanding Natural Beauty; panorama site	Artistic inspiration			Neves et al., 2002; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009		
	3.2.1.1	Flamingos	Presence of iconic species: Flamingos	Social cohesion, cultural icon	Pinto et al., 2010	Múrias et al., 2002			Pinto et al., 2014a; Crisman et al., 2009		Múrias et al., 2002
	3.2.1.3	Saltworks	Archive records or collections	Nature films				Mondego documentary, 2011	Pinto et al., 2014a; Crisman et al., 2009		
	3.2.2.1	Wader species	Areas designated as wilderness	Mental/Moral well-being	Pinto et al., 2010	Lopes et al., 2002; Castro and Freitas 2011;			Pinto et al., 2014a; Crisman et al., 2009	Lefeuvre et al., 2003	
	3.2.2.2	Saltworks	Endangered habitat for bird species	Moral well-being		Lopes et al., 2005	Cruz et al., 2014		Pinto et al., 2014a; Crisman et al., 2009		
	6.1.1.1	Saltworks	Recreational use of saltwork areas	Ecotourism			Neves et al., 2002; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009	Crisman et al., 2009; Korovessis and Lekkas 2009; Rodrigues et al., 2011; Walmsley et al., 1999;	
	6.1.2.1	Saltworks	Recreational use and emotional attachment of saltwork areas	Recreation			Neves et al., 2002; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009	Crisman et al., 2009; Korovessis and Lekkas 2009; Rodrigues et al., 2011; Walmsley et al., 1999;	
	6.2.1.1	Saltworks	Emotional attachment of saltwork areas	Identity			Neves et al., 2002; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009		
	6.2.2.1	Saltworks	Emotional attachment of saltwork areas	Cultural meaning			Neves et al., 2002; Ribeiro et al., 2001		Pinto et al., 2014a; Crisman et al., 2009		
Estuarine littoral granule and very coarse to coarse sands	3.1.1.1	Macroinvertebrates	Recreational mollusc harvest	Recreation; nature-based recreation		Crespo et al., 2010					Verdelhos et al., 2015
	3.1.2.1	Macroinvertebrates	Site of special scientific interest	Knowledge about the environment and nature		Verdelhos et al., 2015				Kristensen et al., 2013	Verdelhos et al., 2015
	3.1.2.2	Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Costa et al., 2013b					Verdelhos et al., 2015

	3.1.2.3	Macroinvertebrates	Traditional mollusc harvest	Tourism, local identity		Crespo et al., 2010					Verdelhos et al., 2015
Estuarine littoral sandy mud and very fine to medium sands	3.1.1.1	Macroinvertebrates	Recreational mollusc harvest	Recreation; nature-based recreation		Crespo et al., 2010					Verdelhos et al., 2015
	3.1.2.1	Macroinvertebrates	Site of special scientific interest	Knowledge about the environment and nature		Verdelhos et al., 2015					Verdelhos et al., 2015
	3.1.2.2	Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Costa 2013b					Verdelhos et al., 2015
	3.1.2.3	Macroinvertebrates	Traditional mollusc harvest	Tourism, local identity		Crespo et al., 2010					Verdelhos et al., 2015
Estuarine littoral mud	3.1.1.1	Macroinvertebrates	Recreational mollusc harvest	Recreation; nature-based recreation		Crespo et al., 2010					Verdelhos et al., 2015
	3.1.2.1	Macroinvertebrates	Site of special scientific interest: RAMSAR site and Important Bird and Biodiversity Area (IBA)	Knowledge about the environment and nature		Verdelhos et al., 2015; Costa et al., 2013b	BirdLife International, 2019				Verdelhos et al., 2015
	3.1.2.2	Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Costa et al., 2013b					Verdelhos et al., 2015
Estuarine seagrass bed	3.1.2.1	Zostera noltii	Site of special scientific interest	Knowledge about the environment and nature		Cardoso et al ., 2004b; Lillebø et al., 1999b; Rodrigues et al., 2015					
	3.1.1.2	Seagrasses' biodiversity	Species of interest to birdwatchers	de-stressing or mental health; eco-tourism		Lopes et al., 2002; Cardoso et al ., 2004b;	Cruz et al., 2014				
	3.1.2.2	Zostera noltii	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Costa et al., 2013b					
	3.2.1.3	Macrophytes; Birds; Macroinvertebrates	Archive records or collections	Nature films				Mondego documentary,2011		Freitas, 2014	
	3.1.2.4	Zostera noltii	Area of Outstanding Natural Beauty; panorama site	Artistic inspiration		Lopes et al., 2002; Cardoso et al ., 2004b	Cruz et al., 2014				
	3.2.1.1	Flamingos	Presence of iconic species: Flamingos	Social cohesion, cultural icon	Pinto et al 2010	Múrias et al., 2002					Múrias et al., 2002
	3.2.2.1	Zostera noltii	Areas designated as wilderness	Mental/Moral well-being	Pinto et al., 2010	Lopes et al., 2002; Castro and Freitas 2011;					
	3.2.2.2	Zostera noltii	Endangered species or habitat	Moral well-being		Neto et al., 2013; Leston et al., 2008					
Estuarine sublittoral granule and very coarse to coarse sands	3.1.2.1	Macroinvertebrates	Site of special scientific interest	Knowledge about the environment and nature		Verdelhos et al., 2015					Verdelhos et al., 2015
	3.1.2.2	Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Costa et al., 2013c					Verdelhos et al., 2015
Estuarine sublittoral sandy mud and very fine to medium sands	3.1.2.1	Macroinvertebrates	Site of special scientific interest	Knowledge about the environment and nature		Verdelhos et al., 2015					Verdelhos et al., 2015
	3.1.2.2	Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management		Costa et al., 2013c					Verdelhos et al., 2015
Estuarine sublittoral mud	3.1.2.1	Macroinvertebrates	Site of special scientific interest	Knowledge about the environment and nature		Verdelhos et al., 2015					Verdelhos et al., 2015

		3.1.2.2	Macroinvertebrates	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management	Costa et al., 2013c			Verdelhos et al., 2015
	Estuarine pelagic waters of the South Mondego Branch and Pranto River	3.1.1.1	Fish	Recreational fishery	Recreation; nature-based recreation		Fernandes, 2015		Vieira et al., 2018; Primo et al., 2018
		3.1.2.1	Fish, zooplankton, phytolankton	Site of special scientific interest	Knowledge about the environment and nature	D'Ambrosio et al., 2016; Filimonova et al., 2016; Primo et al., 2018; Vieira et al., 2018			D'Ambrosio et al., 2016; Filimonova et al., 2016; Primo et al., 2018; Vieira et al., 2018
		3.1.2.2	Fish, zooplankton, phytolankton	Site used for *insitu* teaching and conservation activities	Skills or knowledge about environmental management	Costa et al., 2013c			D'Ambrosio et al., 2016; Filimonova et al., 2016; Primo et al., 2018; Vieira et al., 2018
		3.1.2.3	Fish	Recreational fishery	Tourism, local identity		Fernandes, 2015		Vieira et al., 2018; Primo et al., 2018
		3.2.1.3	Macrophytes; Birds; Macroinvertebrates	Archive records or collections	Books		Estorias do Mondego,2019	Freitas, 2014	
	Estuarine pelagic waters of the North Branch of the Mondego River and upstream system	3.1.1.1	Fish	Recreational fishery	Recreation; nature-based recreation		Fernandes, 2015		Vieira et al., 2018; Primo et al., 2018
		3.1.2.1	Fish, zooplankton, phytolankton	Site of special scientific interest	Knowledge about the environment and nature	D'Ambrosio et al., 2016; Filimonova et al., 2016; Primo et al., 2018; Vieira et al., 2018			D'Ambrosio et al., 2016; Filimonova et al., 2016; Primo et al., 2018; Vieira et al., 2018
		3.1.2.2	Fish, zooplankton, phytolankton	Site used for voluntary conservation activities	Skills or knowledge about environmental management	Costa et al., 2013c			D'Ambrosio et al., 2016; Filimonova et al., 2016; Primo et al., 2018; Vieira et al., 2018
		3.1.2.3	Fish	Recreational fishery	Tourism, local identity		Fernandes, 2015		Vieira et al., 2018; Primo et al., 2018
		3.2.1.3	Fish	Archive records or collections	Books		Estorias do Mondego, 2019	Freitas, 2014	
Coastal Waters	Sandy beaches	3.1.2.1	Sand shore Biological and Geomorphological elements	Site of special scientific interest	Knowledge about the environment and nature	Bessa et al., 2014; Bessa et al., 2017; Cunha et al., 2006			Bessa et al., 2014; Bessa et al., 2017; Cunha et al., 2006
		3.1.2.2	Sand shore Biological and Geomorphological elements	Site used for insitu teaching and voluntary conservation activities	Skills or knowledge about environmental management	Bessa et al., 2014; Bessa et al., 2017; Cunha et al., 2006		Cravidão and Santos 2013	Bessa et al., 2014; Bessa et al., 2017; Cunha et al., 2006
		6.1.1.1	Beaches	Qualities of beaches that make them attractive to bathers and coastal tourists	Recreation, fitness; de-stressing or mental health; nature-based recreation		in situ observations		Fernandes, 2015; Vinagre et al., 2017; Vinagre et al., 2016
		6.1.1.1	*Monumento Natural do Cabo Mondego*	Qualities that make it attractive to hikers	Recreation, fitness; de-stressing or mental health; nature-based recreation		in situ observations		Rocha et al., 2012; Trincão et al., 2018
		6.1.2.1	*Monumento Natural do Cabo Mondego*	Site used for insitu teaching outreaching activities	Recreation		in situ observations		Rocha et al., 2012; Trincão et al., 2018
		6.2.2.1	*Monumento Natural do Cabo Mondego*	Distinctive geological formation or geomorphological feature.	Cultural meaning	Rocha et al., 2012; Trincão et al., 2018			Rocha et al., 2012; Trincão et al., 2018
	Coastal rocky middle and supralitoral areas	3.1.1.1	Macroalgae; Macroinvertebrates; Echinodermes	Ecological qualities of rocky platforms that make it attractive to hiker	de-stressing or mental health; nature-based recreation	Vinagre et al., 2017; Cunha et al., 2006; Rodrigues et al., 2015	in situ observations	Depellegrin et al., 2012; Drius et al., 2019	Gaspar et al., 2017b; Vinagre et al., 2017
		3.1.1.2	Macroalgae; Macroinvertebrates; Echinodermes	Mix of species that can be enjoyed by wildlife watchers	de-stressing or mental health; eco-tourism	Vinagre et al., 2017; Cunha et al., 2006;	in situ observations	Depellegrin et al., 2012	Gaspar et al., 2017b; Vinagre et al., 2017

					Rodrigues et al., 2015			
	3.1.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Site of special scientific interest	Knowledge about the environment and nature	Vinagre et al., 2017; Cunha et al., 2006; Rodrigues et al., 2015			Gaspar et al., 2017b; Vinagre et al., 2017
	3.1.2.2	Macroalgae; Macroinvertebrates; Echinodermes	Site used for insitu teaching and voluntary conservation activities	Skills or knowledge about environmental management		in situ observations	Cravidão and Santos 2013	Gaspar et al., 2017b; Vinagre et al., 2017
	3.1.2.3	Macroinvertebrates	Harvestable Fish Bait (Sabellaria sp.)	Tourism, local identity			Plicanti et al., 2016	Vinagre et al., 2016
	3.1.2.4	Macroalgae; Macroinvertebrates; Echinodermes	Area of Outstanding Natural Beauty; panorama site	Artistic inspiration		Guia de Bolso Às Voltas com o MARE,2019.		Gaspar et al., 2017b; Vinagre et al., 2017
	3.2.1.3	Macroalgae; Macroinvertebrates; Echinodermes	Archive records or collections	Nature films		Cabo Mondego Beach - Portugal,2018		Gaspar et al., 2017b; Vinagre et al., 2017
	3.2.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Areas designated as wilderness	Mental/Moral well-being		Guia de Bolso Às Voltas com o MARE,2019.		Gaspar et al., 2017b; Vinagre et al., 2017
	3.2.2.2	Macroalgae; macroinvertebrates	Endangered species or habitat	Moral well-being	Vinagre et al., 2016			Vinagre et al., 2016; Vinagre et al., 2017
	6.1.1.1	Rocky Shores	Qualities of that make it attractive to hikers	Recreation, fitness; de-stressing or mental health; nature-based recreation		in situ observations		Cunha et al., 2006; Trincão et al., 2018
Coastal supralittoral sedimentary areas	3.1.2.1	Talitrus sp.	Site of special scientific interest	Knowledge about the environment and nature	Bessa et al., 2014		Bessa et al., 2017	
	3.1.2.2	Talitrus sp.	Site used for insitu teaching	Skills or knowledge about environmental management	Bessa et al., 2014		Cravidão and Santos 2013	
	6.1.1.1	Sand	Qualities that make it attractive to hikers	Recreation, fitness; de-stressing or mental health; nature-based recreation	Cunha et al., 2006		Drius et al., 2019; Semeoshenkova and Newton 2015	
Infra and circalittoral rocky areas	3.1.1.2	Macroalgae; Macroinvertebrates; Echinodermes	Mix of species that can be enjoyed by wildlife watchers	Recreation, fitness; de-stressing or mental health; eco-tourism	Vinagre et al., 2016; Vinagre et al., 2017			Gaspar et al., 2017b; Vinagre et al., 2017
	3.1.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Site of special scientific interest	Knowledge about the environment and nature	Vinagre et al., 2016; Vinagre et al., 2017			Gaspar et al., 2017b; Vinagre et al., 2017
	3.1.2.2	Macroalgae; Macroinvertebrates; Echinodermes	Site used for insitu teaching	Skills or knowledge about environmental management		in situ observations	Cravidão and Santos 2013	Gaspar et al., 2017b; Vinagre et al., 2017
	3.2.1.3	Macroalgae; Macroinvertebrates; Echinodermes	Archive records or collections	Nature films		Cabo Mondego Beach - Portugal, 2018		Gaspar et al., 2017b; Vinagre et al., 2017
	3.2.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Areas designated as wilderness	Mental/Moral well-being		Guia de Bolso Às Voltas com o MARE,2019.		Gaspar et al., 2017b; Vinagre et al., 2017
	3.2.2.2	Macroalgae; Macroinvertebrates; Echinodermes	Endangered species or habitat	Moral well-being	Vinagre et al., 2016			Gaspar et al., 2017b; Vinagre et al., 2017
	6.1.1.1	Rocky shores	Qualities of rocky shores that make them attractive to	Recreation, fitness; de-stressing or mental health;		Fernades, 2015		Cunha et al., 2006; Trincão et al., 2018

			bathers and coastal tourists	nature-based recreation					
Infralittoral or circalittoral sedimentary areas	3.1.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Site of special scientific interest	Knowledge about the environment and nature	Martins et al., 2013a; Martins et al., 2014b; Sampaio et al., 2016; Martins et al.,2013b			Salominidi et al., 2012; Tempera et al., 2016	Martins et al., 2013a; Martins et al., 2014b; Sampaio et al., 2016; Martins et al.,2013b
	3.1.2.2	Macroalgae; Macroinvertebrates; Echinodermes	Site used for insitu teaching	Skills or knowledge about environmental management			in situ observations	Salominidi et al., 2012; Tempera et al., 2016	Martins et al., 2013a;Martins et al., 2014b,; Sampaio et al., 2016; Martins et al., 2013b
	6.1.2.1	Sediments	Site of special scientific interest	Knowledge about the environment and nature	Fernández-Fernández et al., 2018			Salominidi et al., 2012; Tempera et al., 2016	
Infralittoral fine sand or infralittoral muddy sand areas	3.1.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Site of special scientific interest	Knowledge about the environment and nature	Martins et al.,2013a; Martins et al., 2014b; Sampaio et al., 2016; Martins et al., 2013b			Salominidi et al., 2012; Tempera et al., 2016	Martins et al.,2013a; Martins et al., 2014b; Sampaio et al., 2016; Martins et al., 2013b
	3.1.2.2	Macroalgae; Macroinvertebrates; Echinodermes	Site used for insitu teaching	Skills or knowledge about environmental management			in situ observations	Salominidi et al., 2012; Tempera et al., 2016	Martins et al., 2013a; Martins et al.,2014b; Sampaio et al., 2016; Martins et al.,2013b
	6.1.2.1	Sediments	Site of special scientific interest	Knowledge about the environment and nature	Fernández-Fernández et al., 2018			Salominidi et al., 2012; Tempera et al., 2016	
Circalittoral fine sand or muddy sand areas	3.1.2.1	Macroalgae; Macroinvertebrates; Echinodermes	Site of special scientific interest	Knowledge about the environment and nature	Martins et al 2013a; Martins et al 2014b; Sampaio et al., 2016; Martins et al., 2013b			Salominidi et al., 2012; Tempera et al., 2016	Martins et al.,2013a; Martins et al., 2014b; Sampaio et al., 2016; Martins et al 2013b
	3.1.2.2	Macroalgae; Macroinvertebrates; Echinodermes	Site used for insitu teaching	Skills or knowledge about environmental management			in situ observations	Salominidi et al., 2012; Tempera et al., 2016	Martins et al.,2013a;Martins et al., 2014b; Sampaio et al., 2016; Martins et al., 2013b
	6.1.2.1	Sediments	Site of special scientific interest	Knowledge about the environment and nature	Fernández-Fernández et al., 2018			Salominidi et al., 2012; Tempera et al., 2016	
Marine pelagic (0-200) waters	3.1.1.1	Water	Opportunities for swimming	Recreation, fitness; de-stressing or mental health; nature-based recreation	Carmo, 2013; Mendonça et al., 2012			Drius et al., 2019	
	3.1.2.1	Fish	Site of special scientific interest	Knowledge about the environment and nature	Cabral et al., 2003; Mesquita et al., 2017	De Oliveira, 2015		Braga et al., 2017	Baptista et al., 2013a; Cabral et al., 2003
	3.1.2.2	Fish	Site used for insitu teaching	Skills or knowledge about environmental management		De Oliveira, 2015			Baptista et al., 2013a; Cabral et al., 2003
	3.1.2.3	Fish	Recreational fishery	Tourism, local identity			Fernandes, 2015		Baptista et al., 2013a; Cabral et al., 2003

Table B6. Pairwise comparison matrix for the criteria.

Criteria	Abundance	Evidence	Strength of Evidence	Weight	
Abundance	1	2	3	0.539613	CR = 0.01
Evidence	0.5	1	2	0.296962	
Strength of Evidence	0.333333	0.5	1	0.163425	

CR - Consistency Ratio

Table B7. Pairwise comparison matrix for the subcriteria.

Criteria ABUNDANCE									
Subcriteria	High	Moderately High	Moderate	Moderately Low	Low	No ES		Weight	
5 -High	1	2	3	4	5	7		0.387	CR = 0.023
4 - Moderately high	0.50	1	2	3	4	6		0.252	
3 - Moderate	0.333	0.500	1	2	3	5		0.162	
2 - Moderately Low	0.250	0.333	0.500	1	2	3		0.098	
1 - Low	0.200	0.250	0.333	0.500	1	3		0.068	
0 -No ES	0.143	0.167	0.200	0.333	0.333	1		0.036	
Criteria EVIDENCE									
Subcriteria	5 -Robust	4 - Moderately Robust	3 - Moderate	2 - Moderately Fragile	1 - Fragile	0 -No Evidence		Weight	
5 -Robust	1	2	3	4	5	7		0.383	CR = 0.026
4 - Moderately Robust	0.500	1	2	3	4	6		0.251	
3 - Moderate	0.333	0.500	1	2	3	5		0.161	
2 - Moderately Fragile	0.250	0.333	0.500	1	2	4		0.103	
1 - Fragile	0.200	0.250	0.333	0.500	1	3		0.067	
0 -No Evidence	0.143	0.167	0.200	0.250	0.333	1		0.034	
Criteria STRENGTH OF EVIDENCE									
Subcriteria	Strong	Moderately Strong	Moderate	Moderately Weak	Weak	Very Weak	No Evidence	Weight	
Strong	1	2	3	4	5	6	8	0.354	CR = 0.03
Moderately Strong	0.500	1	2	3	4	5	7	0.240	
Moderate	0.333	0.500	1	2	3	4	6	0.159	
Moderately Weak	0.250	0.333	0.500	1	2	3	5	0.105	
Weak	0.200	0.250	0.333	0.500	1	2	4	0.069	
Very Weak	0.167	0.200	0.250	0.333	0.500	1	3	0.047	
No Evidence	0.125	0.143	0.167	0.200	0.250	0.333	1	0.025	

CR - Consistency ratio

Table B8. Abundance of ecosystem services per habitat, ecosystem service category and type of evidence.

	Habitat ID	Number of ES												% of ES											
		Provisioning			Regulation			Cultural			Total			Provisioning			Regulation			Cultural			Total		
		C	P	T	C	P	T	C	P	T	C	P	T	C	P	T	C	P	T	C	P	T	C	P	T
Transitional Waters	hab1	1	0	1	3	3	6	8	0	8	12	3	15	2.38	0.00	2.38	10.71	10.71	21.43	53.33	0.00	53.33	14.29	3.57	17.86
	hab2	1	4	5	1	1	2	3	0	3	5	5	10	2.38	9.52	11.90	3.57	3.57	7.14	20.00	0.00	20.00	5.95	5.95	11.90
	hab3	1	0	1	1	3	4	5	0	5	7	3	10	2.38	0.00	2.38	3.57	10.71	14.29	33.33	0.00	33.33	8.33	3.57	11.90
	hab4	2	3	5	3	1	4	14	0	14	19	4	23	4.76	7.14	11.90	10.71	3.57	14.29	93.33	0.00	93.33	22.62	4.76	27.38
	hab5	0	0	0	0	0	0	4	0	4	4	0	4	0.00	0.00	0.00	0.00	0.00	0.00	26.67	0.00	26.67	4.76	0.00	4.76
	hab6	1	6	7	3	1	4	4	0	4	8	7	15	2.38	14.29	16.67	10.71	3.57	14.29	26.67	0.00	26.67	9.52	8.33	17.86
	hab7	2	5	7	3	1	4	3	0	3	8	6	14	4.76	11.90	16.67	10.71	3.57	14.29	20.00	0.00	20.00	9.52	7.14	16.67
	hab8	1	0	1	3	3	6	8	0	8	12	3	15	2.38	0.00	2.38	10.71	10.71	21.43	53.33	0.00	53.33	14.29	3.57	17.86
	hab9	1	0	1	0	0	0	2	0	2	3	0	3	2.38	0.00	2.38	0.00	0.00	0.00	13.33	0.00	13.33	3.57	0.00	3.57
	hab10	1	2	3	2	1	3	2	0	2	5	3	8	2.38	4.76	7.14	7.14	3.57	10.71	13.33	0.00	13.33	5.95	3.57	9.52
	hab11	1	2	3	2	1	3	2	0	2	5	3	8	2.38	4.76	7.14	7.14	3.57	10.71	13.33	0.00	13.33	5.95	3.57	9.52
	hab12	3	3	6	1	3	4	5	0	5	9	6	15	7.14	7.14	14.29	3.57	10.71	14.29	33.33	0.00	33.33	10.71	7.14	17.86
	hab13	3	3	6	1	3	4	5	0	5	9	6	15	7.14	7.14	14.29	3.57	10.71	14.29	33.33	0.00	33.33	10.71	7.14	17.86
Coastal Waters	hab14	1	0	1	2	1	3	6	0	6	9	1	10	2.38	0.00	2.38	7.14	3.57	10.71	40.00	0.00	40.00	10.71	1.19	11.90
	hab15	2	6	8	0	3	3	7	3	10	9	12	21	4.76	14.29	19.05	0.00	10.71	10.71	46.67	20.00	66.67	10.71	14.29	25.00
	hab16	0	0	0	1	0	1	3	0	3	4	0	4	0.00	0.00	0.00	3.57	0.00	3.57	20.00	0.00	20.00	4.76	0.00	4.76
	hab17	0	3	3	0	2	2	6	1	7	6	6	12	0.00	7.14	7.14	0.00	7.14	7.14	40.00	6.67	46.67	7.14	7.14	14.29
	hab18	0	0	0	0	0	0	3	0	3	3	0	3	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	20.00	3.57	0.00	3.57
	hab18_1	0	0	0	0	0	0	3	0	3	3	0	3	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	20.00	3.57	0.00	3.57
	hab18_2	0	0	0	0	0	0	3	0	3	3	0	3	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	20.00	3.57	0.00	3.57
	hab19	2	12	14	1	1	2	4	0	4	7	13	20	4.76	28.57	33.33	3.57	3.57	7.14	26.67	0.00	26.67	8.33	15.48	23.81

C - Current; P - Potential; T – Total;
hab1 - Estuarine saltmarshes; hab 2 - Aquaculture tanks; hab3 - Water ponds; hab4 – Saltworks; hab5 - Estuarine littoral granule and very coarse to coarse sands; hab6 - Estuarine littoral sandy mud and very fine to medium sands; hab7 - Estuarine littoral mud; hab8 - Estuarine seagrass bed; hab9 - Estuarine sublittoral granule and very coarse to coarse sands; hab10 - Estuarine sublittoral sandy mud and very fine to medium sands; hab11 - Estuarine sublittoral mud; hab12 - Estuarine pelagic waters of the South Mondego Branch and Pranto River; hab13 - Estuarine pelagic waters of the North Branch of the Mondego River and upstream system; hab14 - Sandy beaches; hab15 - Coastal rocky middle and supralitoral areas; hab16 - Coastal supralittoral sedimentary areas; hab17 - Infra and circalittoral rocky areas; hab18 - Infralittoral or circalittoral sedimentary areas; hab18_1 - Infralittoral fine sand or infralittoral muddy sand areas; hab18_2 - Circalittoral fine sand or muddy sand areas; hab19 - Marine pelagic (0-200) waters.

Table B9. Analytic Hierarchy Process rank priorities per habitat.

		AHP Priorities												AHP Ranks			
	Habitat ID	ahpA_P	ahpA_R	ahpA_C	ahpA_T	ahpEv_P	ahpEv_R	ahpEv_C	ahpEv_T	ahpS_P	ahpS_R	ahpS_C	ahpS_T	Ranking_P	Ranking_R	Ranking_C	Ranking_T
Transitional Waters	hab1	0.05	0.21	0.21	0.14	0.11	0.05	0.11	0.07	0.03	0.01	0.06	0.06	0.19	0.27	0.38	0.27
	hab2	0.14	0.09	0.14	0.14	0.03	0.05	0.11	0.05	0.01	0.06	0.06	0.01	0.18	0.19	0.31	0.20
	hab3	0.05	0.14	0.21	0.14	0.11	0.03	0.11	0.07	0.04	0.01	0.06	0.06	0.21	0.18	0.38	0.27
	hab4	0.14	0.14	0.21	0.21	0.03	0.07	0.11	0.07	0.02	0.06	0.04	0.04	0.18	0.27	0.36	0.32
	hab5	0.02	0.02	0.21	0.05	0.01	0.11	0.11	0.11	0.00	0.00	0.06	0.06	0.03	0.14	0.38	0.22
	hab6	0.14	0.14	0.21	0.14	0.03	0.07	0.01	0.07	0.01	0.06	0.06	0.06	0.18	0.27	0.28	0.27
	hab7	0.14	0.14	0.14	0.14	0.03	0.07	0.11	0.05	0.01	0.06	0.06	0.06	0.18	0.27	0.31	0.24
	hab8	0.05	0.21	0.21	0.14	0.11	0.05	0.11	0.07	0.06	0.01	0.06	0.06	0.22	0.27	0.38	0.27
	hab9	0.05	0.02	0.14	0.05	0.11	0.11	0.11	0.11	0.01	0.00	0.06	0.06	0.18	0.14	0.31	0.22
	hab10	0.09	0.14	0.14	0.09	0.03	0.07	0.11	0.07	0.01	0.06	0.06	0.06	0.13	0.27	0.31	0.22
	hab11	0.09	0.14	0.14	0.09	0.03	0.07	0.11	0.07	0.01	0.06	0.06	0.06	0.13	0.27	0.31	0.22
	hab12	0.14	0.14	0.21	0.14	0.05	0.03	0.11	0.07	0.01	0.01	0.03	0.01	0.20	0.18	0.35	0.22
	hab13	0.14	0.14	0.21	0.14	0.05	0.03	0.11	0.03	0.01	0.01	0.03	0.01	0.20	0.18	0.35	0.18
Coastal Waters	hab14	0.05	0.14	0.21	0.14	0.11	0.07	0.11	0.07	0.04	0.06	0.06	0.06	0.21	0.27	0.38	0.27
	hab15	0.14	0.14	0.21	0.21	0.03	0.02	0.07	0.03	0.01	0.02	0.03	0.01	0.18	0.17	0.31	0.25
	hab16	0.02	0.05	0.14	0.05	0.01	0.11	0.11	0.11	0.00	0.06	0.06	0.06	0.03	0.22	0.31	0.22
	hab17	0.09	0.09	0.21	0.14	0.02	0.02	0.07	0.05	0.01	0.02	0.03	0.03	0.12	0.12	0.31	0.21
	hab18	0.02	0.02	0.14	0.05	0.01	0.11	0.11	0.11	0.00	0.00	0.06	0.06	0.03	0.14	0.31	0.22
	hab18_1	0.02	0.02	0.14	0.05	0.01	0.11	0.11	0.11	0.00	0.00	0.06	0.06	0.03	0.14	0.31	0.22
	hab18_2	0.02	0.02	0.14	0.05	0.01	0.11	0.11	0.11	0.00	0.00	0.06	0.06	0.03	0.14	0.31	0.22
	hab19	0.21	0.09	0.21	0.21	0.03	0.05	0.11	0.03	0.01	0.06	0.06	0.01	0.25	0.19	0.38	0.25

AHP- Analytic Hierarchy Process; A - abundance; Ev - Evidence; S - Strength of Evidence; P - Provisioning; R - Regulation; C - Cultural; T - Total

hab1 - Estuarine saltmarshes; hab 2 - Aquaculture tanks; hab3 - Water ponds; hab4 – Saltworks; hab5 - Estuarine littoral granule and very coarse to coarse sands; hab6 - Estuarine littoral sandy mud and very fine to medium sands; hab7 - Estuarine littoral mud; hab8 - Estuarine seagrass bed; hab9 - Estuarine sublittoral granule and very coarse to coarse sands; hab10 - Estuarine sublittoral sandy mud and very fine to medium sands; hab11 - Estuarine sublittoral mud; hab12 - Estuarine pelagic waters of the South Mondego Branch and Pranto River; hab13 - Estuarine pelagic waters of the North Branch of the Mondego River and upstream system; hab14 - Sandy beaches; hab15 - Coastal rocky middle and supralitoral areas; hab16 - Coastal supralittoral sedimentary areas; hab17 - Infra and circalittoral rocky areas; hab18 - Infralittoral or circalittoral sedimentary areas; hab18_1 - Infralittoral fine sand or infralittoral muddy sand areas; hab18_2 - Circalittoral fine sand or muddy sand areas; hab19 - Marine pelagic (0-200) waters.

Appendix B | References

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Appendix C

Supplementary data

Index

1. Data model inputs

To build the Habitat Risk Assessment models (InVEST/HRA), spatial explicit data of habitats, stressors and ecosystem services' abundance was gathered. In total, 18 benthic habitats, 3 pelagic habitats and 13 stressors were evaluated.

i. **Habitats**. Data based on the habitats classification of the European Nature Information System (EUNIS) level 3 (EMODnet SeaBed Habitats 2016). Information was taken from previous work (Caro et al., 2020), in vector format using WGS 84_UTM projection. Table C.1 presents all habitats of the study site.

ii. **Stressors.** The degree of exposure of a habitat to a stressor and the consequence of this exposure are mandatory for the InVEST Habitat Risk Assessment model (Sharp et al., 2018). The degree of exposure is determined, among other criteria, by spatial overlap and pressure intensity (i.e., Arkema et al., 2014; Sharp et al., 2018). After listing the stressors and matching them with the list of pressures from the Marine Strategy Framework Directive (MFSD; EC, 2008) (Table C.2), stressors were characterized based on previous studies (i.e., Flindt et al., 1997; Pinto et al; 2013a; Teixeira et al., 2014) and expert judgement from researchers of the University of Coimbra with at least five years of research experience in the study area. Whenever the information was absent, standard criteria provided by the InVEST/HRA model was used. The sources of spatial information are available on Table S.2, for which priority to open source databases was given (Caro et al., 2018). The spatial representation of stressors was performed using ARCGis V10.3, WGS 84_UTM projection. The list of stressors used in this study, their influence area (buffer) and their weight according to their importance, are listed in Table C.3.

Table C1. Aquatic habitats of the Atlantic coastal region adjacent to the Mondego River.

	Habitat code	Area (Km2)	Study Area (%)	Description
Transitional Waters	A2.5	2.64	3.17	Estuarine saltmarshes
	J5.1 & J5.11_	2.36	2.83	Aquaculture tanks
	J5.1 & J5.11	2.07	2.48	Water ponds
	J5.1 & J5.12	4.65	5.58	Saltworks
	A2.1	0.29	0.35	Estuarine littoral granule, very coarse to coarse sands
	A2.2	0.82	0.98	Estuarine littoral sandy mud and very fine to medium sands
	A2.3	0.28	0.34	Estuarine littoral mud
	A2.6	0.16	0.19	Estuarine seagrass bed
	A5.1	0.76	0.91	Estuarine sublittoral granule and very coarse to coarse sands
	A5.2	1.99	2.39	Estuarine sublittoral sandy mud and very fine to medium sands
	A5.3	0.41	0.49	Estuarine sublittoral mud
	A7.4	1.9	2.28	Estuarine pelagic waters of the South Mondego branch and Pranto River
	A7.6	5.98	7.18	Estuarine pelagic waters of the North branch of the Mondego River and upstream system
Coastal Waters	B1.2	1.42	1.7	Sandy beaches
	A1	0.21	0.25	Coastal rocky middle and supralittoral areas
	A2	0.74	0.89	Coastal supralittoral sedimentary areas
	A3 or A4	0.27	0.32	Infra and circalittoral rocky areas
	A5.2_	0.54	0.65	Infralittoral or circalittoral sedimentary areas
	A5.23 or A5.24	6.87	8.25	Infralittoral fine sand or infralittoral muddy sand areas
	A5.25 or A5.26	53.61	64.35	Circalittoral fine sand or muddy sand areas
	A7.3	61.29	73.57	Marine pelagic (0-200) waters

Table C2. Sources of information for stressors on the Atlantic coastal region adjacent to the Mondego River and their correspondence to the Marine Strategy Framework Directive (MSFD).

Stressor	Source	Type	MSFD Pressure indicator	Description	Link
Fishing: recreative, commercial	FAO, 2019	Polygon	Physical damage (abrasion and selective extraction, including exploration and exploitation of living and non-living resources on seabed and subsoil)	Area was defined according to FAO fishing areas. (2019) and NCEAS artisanal fishing areas. (NCEAS, 2015) Intensity was based on the fishing statistics from INE (2017).	http://www.fao.org/fishery/statistics/en http://www.fao.org/fishery/area/search/en
	National Center for Ecological Analysis and Synthesis (NCEAS, 2015)	Tiff	Biological disturbance (selective extraction of species, including incidental non-target catches (e.g. by recreative and commercial fishing)		https://www.nceas.ucsb.edu/globalmarine
Marine and estuary navigation traffic	Marine traffic	Polygon	Physical damage (abrasion) Other physical disturbance (underwater noise and marine litter) Contamination by hazardous substances (input of synthetic and non-synthetic substances and compounds)	Area occupied by the Port of Figueira da Foz - COS-2007 (DGT,2019) and ships concentration reported by the Marine traffic live map along the Mondego estuary. Intensity was based on the density of ships shown by Marine traffic (2019). More than five ships (3) between 2-5 ships (2), less than 2 ships (1).	http://mapas.dgterritorio.pt/geoportal/catalogo.html https://www.marinetraffic.com/en/ais/home/centerx:-8.808/centery:40.137/zoom:12
Contamination by heavy metals	Pereira et al., 2007	Point	Contamination by hazardous substances	Area corresponds to the Mondego estuary, along which Pereira et al. (2007) collected heavy metal samples. Intensity was based on heavy metals concentration available on Pereira et al. (2007) determined by the metal/Al ratio.	
Coastal erosion	Cunha and Dinis, 1998	Polygon	Physical damage (remotion of non-living resources on seabed, change in siltation)	Area was based on the Portuguese National Land Cover Map -COS-2007 (DGT,2019). Intensity was based on descriptions performed by Cunha and Dinis (1998). An unique value was assigned to the entire area.	http://mapas.dgterritorio.pt/geoportal/catalogo.html
Harbor activities	COS-2007, DGT,2019	Polygon	Physical damage (abrasion) Other physical disturbance (marine litter) Physical loss (smothering)	Area based on the Portuguese National Land Cover Map -COS-2007 (DGT,2019), selecting the marine and ports category. Intensity was based on the impact of activities of mid-size harbors (NGIA, 2017). An unique value was assigned to the entire area.	http://mapas.dgterritorio.pt/geoportal/catalogo.html
Landfill/dredging /sand extraction	EMODnet,2019; Ceia et al., 2013	Point	Physical damage (selective extraction of living and non-living resources on seabed, changes in siltation). Physical loss (smothering)	Area was based on EMODnet dredging location points from the EMODNET human activities database (2019), Intensity was based on descriptions from Ceia et al. (2013). An unique value was assigned to the entire area.	http://www.emodnet-humanactivities.eu/download-data.php
Invasive species	Franco et al., 2012; Loureiro et al., 2017	Polygon	Biological disturbance (introduction of non-indigenous species and translocations,)	Presence of invasive species per estuarine water body was based on the invasive species list from Loureiro et al. (2017), and information from Franco et al. (2012). Intensity per water body was determined based on expert knowledge, for each of the invasive species identified (Corbicula fluminea, Ruditapes philippinarum). The final intensity score per water body was defined selecting the highest score.	
Organic enrichment due to Nitrogen and Phosphorus increase	Ferreira et al., 2003 Marques et al., 2007	Polygon	Nutrient and organic Matter enrichment	Area corresponds to the Mondego estuary under monitoring program (Marques et al., 2007) Intensity was defined based on Nitrogen and Phosphorus inputs to the North and South arms of the estuary, available from Ferreira et al. (2003). Independent stressor maps were built for Nitrogen and Phosphorus.	
Polution by fish farming	Teixeira et al., 2018	Polygon	Nutrient and organic Matter enrichment Interference with hydrological processes Physical loss (smothering and sealing)	Aquaculture areas and information to describe intensity were taken from Teixeira et al. (2018). Intensity was calculated based on descriptions about the type of activity in the aquaculture area: active and semi-intensive aquaculture ponds (3), active and extensive aquaculture ponds (2), inactive aquaculture ponds (1); water ponds (1).	
Tourism activities	Pinto et al., 2013a PORTDATA, 2017 OpenStreetMap project, 2019 Li et al., 2015	Polygon/ Point	Physical disturbance (marine litter)	Derived from information about points of interest (archeological places, castles, fountains, museums, gardens, pubs), places to eat (restaurants, bars and cafes) and places to sleep (hostel, hotel, guess houses, identified by the OpenStreetMap project (2019). An area of influence of 500 m around the interest points was delimited, roughly equal to 10 m walking distances at an average speed of around 1 m/s (Li et al., 2015). Intensity was based on descriptions from Pinto et al. (2013a). An unique value was assigned to the entire area.	http://forest-gis.com/2012/01/portugal-shapefiles-gerais-do-pais.html/
Irrigation (loss of freshwater discharge)	ABOFHBM, 2018	Polygon	Interference with hydrological processes	Area was determined based on the irrigation blocks presented by the Portuguese Association of Water Resources (Santos and Freitas, 2011) Intensity determined by the amount of water extracted for irrigation purposes (m3/ha), based on information from the 2018 campaign from the Association of Beneficiaries of the Hydro-agricultural Development Work of Baixo Mondego (ABOFHBM). The amount of water extracted was classified in three levels according to its amount 5000-10000 m3/ha (low); 10000- 15000 m3/ ha (medium) and 15000 -20000 m3/ha (high).	http://www.abofhbm.net/relatorioecontas2018.pdf http://www.abofhbm.net/historial.htm
Sea level changes	USGS/NASA SRTM,2019 Kenov et al., 2012	Polygon	Interference with hydrological processes	Area under sea level rise pressure was based on the SRTM 30m digital elevation data derived from USGS/NASA SRTM data and on the Mondego Estuary bathymetry data (Kenov et al., 2012). Intensity: altitude between 0 m and 1 m and areas with altitude below 0 but that are located in supratidal areas (high); altitude between 1 m and 3 m (medium); Low- altitude between 3 m and 5m (low); altitude above 5 m and subtidal areas with bathymetry below 0 (no score).	

Table C3. Weights and buffer distance by stressor.

Stressor	Buffer (m)	Weight	References
Fishing: recreative, commercial	100	1	Bavins et al., 2000
Marine and estuary navigation traffic	4000	2	Cabral et al., 2015
Contamination by heavy metals	80	3	Macfarlane et al., 2014
Coastal erosion	1000	1	UAB, 2002
Harbor activities	4000	3	Cabral et al., 2015
Landfill/dredging/sand extraction	3000	2	Fisher et al., 2015
Invasive species	0	2	Willaert et al., 2019
Organic enrichment due to Nitrogen and Phosphorus increase	80	1	Macfarlane et al., 2014
Polution by Fish farming	3000	2	Cabral et al., 2015
Tourism activities	0	2	Li et al., 2015
Irrigation (loss of freshwater discharge)	22000	2	ABOFHBM, 2018
Sea level changes	10000	1	Teck et al., 2010

iii. **Ecosystem Services abundance.** Data taken from a previous study (Caro et al., 2020), which determined the abundance of ecosystem services by habitat as a percentage of the total services potentially delivered by category (provision, regulation and cultural) according to the CICES framework (Haines-Young and Potschin, 2018) (Table S.4). Caro et al. (2020) present a categorization of ecosystem services abundance based on 5 classes (very low, low, medium, high and very high) that were, for the purpose of this study, reclassified into three classes in order to be comparable to the intensity criteria defined by the HRA (Sharp et al., 2018): very low and low classes were assigned to “low” (value 1); medium class was assigned to “medium” (value 2) and high and very high classes were assigned to “high” (value 3). These three abundance categories of ecosystem services were allocated to habitat building polygons using ArcGis V.10.6 software with WGS 84_UTM projection (Figure S.1.). Where pelagic ecosystems overlap the benthic ecosystems the highest abundance value was considered.

Table C.4. Abundance of ecosystem services types per habitat (% of total possible based on the CICES framework). Adapted from Caro et al. (2020).

	Habitat code	Provisioning	Regulation	Cultural	Total
Transitional waters	A2.5	2.38	21.43	53.33	17.86
	J5.1 & J5.11_	11.90	7.14	20.00	11.90
	J5.1 & J5.11	2.38	14.29	33.33	11.90
	J5.1 & J5.12	11.90	14.29	93.33	27.38
	A2.1	0.00	0.00	26.67	4.76
	A2.2	16.67	14.29	26.67	17.86
	A2.3	16.67	14.29	20.00	16.67
	A2.6	2.38	21.43	53.33	17.86
	A5.1	2.38	0.00	13.33	3.57
	A5.2	7.14	10.71	13.33	9.52
	A5.3	7.14	10.71	13.33	9.52
	A7.4	14.29	14.29	33.33	17.86
	A7.6	14.29	14.29	33.33	17.86
Coastal waters	B1.2	2.38	10.71	40.00	11.90
	A1	19.05	10.71	66.67	25.00
	A2	0.00	3.57	20.00	4.76
	A3 or A4	7.14	7.14	46.67	14.29
	A5.2_	0.00	0.00	20.00	3.57
	A5.23 or A5.24	0.00	0.00	20.00	3.57
	A5.25 or A5.26	0.00	0.00	20.00	3.57
	A7.3	33.33	7.14	26.67	23.81

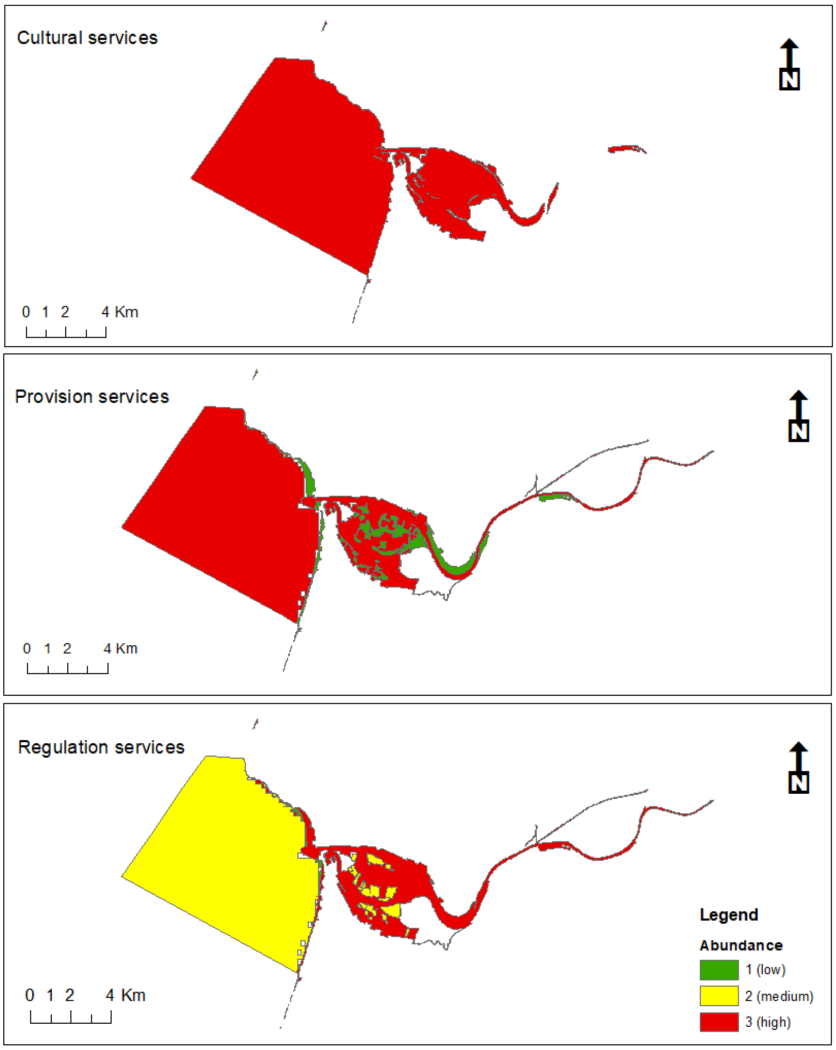

Figure C.1. Abundance and distribution of ecosystem services types per habitat, in the Atlantic coastal region adjacent to the Mondego River. Adapted from Caro et al. (2020).

Table C5. A1. Consequences of exposure scores (resilience attributes).

HABITAT		Recruitment rate	Natural mortality rate	Conectivity rate	Recovery time	Provision services	Regulation services	Cultural services
A1	RATING	1	2	2	3	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A2	RATING	1	2	2	2	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A3A4	RATING	1	2	2	3	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A21	RATING	1	2	3	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A22	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A23	RATING	1	2	3	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A25	RATING	2	2	2	2	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A26	RATING	2	2	3	2	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A51	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A52	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A52_	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A53	RATING	1	2	1	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A73	RATING	1	3	1	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	3	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A74	RATING	1	3	1	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	3	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A76	RATING	1	3	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	3	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A523A524	RATING	1	2	2	2	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
A525A526	RATING	1	2	1	2	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
B12	RATING	1	3	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	3	2	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
J5111	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
J5111_	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
J5112	RATING	1	2	2	1	Provision_servp.shp	Regulation_servp.shp	cultural_servp.shp
	DQ	2	2	3	2	2	2	2
	WEIGHT	2	2	2	2	1	3	2
CRITERIA TYPE	E/C	C	C	C	C	C	C	C
Rating instruction		(3) every 2 + yrs (2) every 1 - 2 yrs (1) every <1yrs (0) no score	(3) 0 - 20% + yrs (2) 20 -50% (1) > 80% mortality (0) no score	(3) <10Km (2) 10 - 100Km (1) > 100Km (0) no score	(3) >10yrs (2) 10 -10yrs (1) < 1yr (0) no score			

DQ- Data Quality; E - Exposure; C - Consequence

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Provision_servp.shp – Geospatial vector data, in shapefile format, of provisioning services from the Atlantic coastal region adjacent to the Mondego River; Regulation_servp.shp - Geospatial vector data, in shapefile format, of regulation services from the Atlantic coastal region adjacent to the Mondego River; cultural_servp.shp - Geospatial vector data, in shapefile format, of cultural services from the Atlantic coastal region adjacent to the Mondego River.

Table C5. B1. Consequences of exposure scores (Sensitivity attributes).

HABITAT		Coastal erosion			Landfill/dredging/sand extraction			Polution by fish farming			Fishing: recreative, commercial			Harbor activities			Contamination by heavy metals		
		fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs
A1	RATING	3	2	2	0	0	0	0	0	0	0	1	2	0	0	0	0	1	1
	DQ	3	3	2	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A2	RATING	2	3	3	0	0	0	0	0	0	0	1	1	0	3	3	0	3	3
	DQ	3	2	2	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A3A4	RATING	2	2	2	0	0	0	0	0	0	0	1	1	0	0	0	0	1	3
	DQ	2	2	2	3	3	3	3	3	3	2	2	2	3	3	3	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A21	RATING	0	0	0	0	2	3	1	1	1	1	2	2	0	2	3	0	1	2
	DQ	3	3	3	3	2	2	2	2	2	3	2	2	3	2	2	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A22	RATING	0	0	0	0	2	3	1	1	1	1	2	2	0	2	3	0	1	2
	DQ	3	3	3	3	2	2	2	2	2	3	2	2	3	2	2	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A23	RATING	0	0	0	0	2	3	1	1	1	1	2	2	0	2	2	0	1	2
	DQ	3	3	3	3	2	2	2	2	2	3	2	2	3	2	2	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A25	RATING	0	0	0	0	1	1	0	1	3	1	1	2	0	0	0	0	3	2
	DQ	3	3	3	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A26	RATING	0	0	0	0	2	3	0	1	1	1	1	1	0	1	1	0	2	2
	DQ	3	3	3	3	2	2	3	2	2	2	3	2	3	2	2	3	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A51	RATING	1	1	2	0	2	2	0	1	1	1	1	1	0	2	3	0	2	3
	DQ	2	2	2	3	2	3	3	2	2	3	2	2	3	2	2	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A52	RATING	1	1	2	0	2	2	0	1	1	1	1	1	0	2	3	0	2	3
	DQ	2	2	2	3	2	3	3	2	2	3	2	2	3	2	2	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A52_	RATING	2	3	3	0	3	3	0	1	2	1	1	2	0	3	3	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	2	2	3	3	3	2	2	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A53	RATING	1	1	2	0	2	2	0	1	1	1	1	1	0	2	3	0	2	3
	DQ	2	2	2	3	2	3	3	2	2	3	2	2	3	2	2	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A73	RATING	0	1	1	0	0	0	0	0	0	1	1	2	0	0	0	0	1	3
	DQ	3	3	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A74	RATING	0	1	1	0	2	2	0	3	2	1	1	2	0	2	2	0	1	3
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A76	RATING	0	1	1	0	2	2	0	3	2	1	1	2	0	2	2	0	1	3
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A523A524	RATING	2	1	2	0	2	2	0	0	0	1	1	1	0	1	1	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	2	2	2	3	3	3	2	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
A525A526	RATING	0	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	3
	DQ	3	3	3	3	3	3	3	3	3	2	2	2	3	3	3	2	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
B12	RATING	2	3	2	0	2	2	0	1	1	0	1	1	0	3	3	0	1	1
	DQ	2	3	2	3	2	2	3	2	2	2	2	2	3	2	2	3	2	2
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
J5111	RATING	0	0	0	0	2	2	0	3	3	2	2	3	0	1	1	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
J5111_	RATING	0	0	0	0	1	2	0	3	3	2	2	3	0	1	1	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
J5112	RATING	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3	3	3	3
CRITERIA TYPE	E/C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

Rating instruction
fd – (3) Anually or less often. (2) Several times per year. (1) Weekly or more often. (0) no score
ca - (3) 50 - 100% loss. (2) 20 - 50% loss. (1) 0 -20% loss. (0) no score
cs - (3) 50 - 100% loss. (2) 20 - 50% loss. (1) 0 -20% loss. (0) no score

fd – frequency of disturbance; ca – change in area rating; cs – change in structure rating; DQ- Data Quality; E - Exposure; C - Consequence

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Table C5. B2. Consequences of exposure scores (Sensitivity attributes). (continuation)

HABITAT		Invasive species			Irrigation (loss of fresh water discharge)			Marine and estuary navigation traffic			Organic enrichment due to Nitrogen increase			Organic enrichment due to Phosphorus increase			Sea level changes			Tourism activities		
		fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs	fd	ca	cs
A1	RATING	1	3	3	0	0	0	0	1	1	2	1	2	2	1	2	2	3	3	0	1	2
	DQ	3	2	2	3	3	3	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A2	RATING	0	1	2	0	0	0	0	3	3	2	2	3	2	2	3	2	3	3	0	1	2
	DQ	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A3A4	RATING	1	1	3	0	0	0	0	2	2	2	2	2	2	2	2	2	3	3	0	1	1
	DQ	3	2	2	3	3	3	3	2	2	2	2	2	2	2	2	3	3	3	2	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A21	RATING	1	2	2	3	2	2	0	2	2	2	2	2	2	2	2	2	2	1	0	1	1
	DQ	2	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A22	RATING	1	2	3	3	2	2	0	2	2	2	2	2	2	2	2	2	2	1	0	1	1
	DQ	2	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A23	RATING	1	2	3	3	2	2	0	2	2	2	2	2	2	2	2	2	2	1	0	1	1
	DQ	2	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A25	RATING	1	2	1	3	1	3	0	1	1	2	2	2	2	2	2	2	2	3	0	1	2
	DQ	3	2	2	2	2	2	2	2	2	3	2	2	3	2	2	2	2	2	2	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A26	RATING	1	2	2	3	1	2	0	1	1	2	2	2	2	2	2	2	2	2	0	1	1
	DQ	2	2	2	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A51	RATING	2	1	2	3	1	1	0	1	0	1	2	2	1	2	2	2	1	1	0	1	1
	DQ	3	2	2	3	3	3	3	2	2	2	2	2	2	2	2	3	3	3	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A52	RATING	2	1	2	3	1	1	0	1	0	1	2	2	1	2	2	2	1	1	0	1	1
	DQ	3	2	2	3	3	3	3	2	2	2	2	2	2	2	2	3	3	3	3	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A52_	RATING	1	1	2	0	0	0	0	2	2	2	2	3	2	2	3	2	3	3	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	2	3	3	2	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A53	RATING	2	1	2	3	1	1	0	1	0	1	2	3	1	2	2	2	1	1	0	1	1
	DQ	3	2	2	3	3	3	3	2	2	2	2	2	2	2	2	3	3	3	2	2	2
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A73	RATING	1	3	3	0	0	0	0	2	2	2	1	2	2	1	2	2	1	1	0	1	1
	DQ	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A74	RATING	1	1	2	3	2	2	0	1	2	2	1	2	2	1	2	2	2	2	0	1	1
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A76	RATING	1	1	2	3	2	2	0	1	2	2	1	2	2	1	2	2	2	2	0	1	1
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A523A524	RATING	3	1	1	0	0	0	0	1	2	2	2	1	2	2	1	2	1	1	0	1	2
	DQ	2	2	2	3	3	3	3	3	3	2	2	2	2	2	2	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
A525A526	RATING	1	1	1	0	0	0	0	3	3	2	1	2	2	1	2	2	1	1	0	1	1
	DQ	2	2	2	3	3	3	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
B12	RATING	1	1	1	0	1	1	0	1	1	2	1	1	2	1	1	2	3	3	0	2	2
	DQ	3	2	2	3	3	3	3	2	2	3	3	2	3	3	2	3	2	2	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
J5111	RATING	1	1	2	3	3	3	0	1	2	2	1	2	2	1	3	2	3	3	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
J5111_	RATING	1	1	2	3	3	3	0	1	2	2	1	3	2	1	3	2	3	3	0	1	2
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
J5112	RATING	1	2	1	3	1	1	0	0	0	2	2	2	2	2	2	2	3	3	0	2	2
	DQ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	WEIGHT	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2
CRITERIA TYPE	E/C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

Rating instruction
fd - (3) Anually or less often. (2) Several times per year. (1) Weekly or more often. (0) no score
ca - (3) 50 - 100% loss. (2) 20 - 50% loss. (1) 0 -20% loss. (0) no score
cs - (3) 50 - 100% loss. (2) 20 - 50% loss. (1) 0 -20% loss. (0) no score

fd – frequency of disturbance; ca – change in area rating; cs – change in structure rating; DQ- Data Quality; E - Exposure; C - Consequence

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Table C5. C1. Exposure scores of habitats to stressors.

		Coastal erosion			Landfill/dredging/sand extraction			Polution by fish farming			Fishing: recreative, commercial			Harbor activities		
HABITAT		to	me	ir	to	me	ir	to	me	ir	to	me	ir	to	me	ir
A1	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A2	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A3A4	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A21	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A22	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A23	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A25	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A26	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A51	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A52	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A52_	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A53	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A73	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A74	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A76	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A523A524	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
A525A526	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
B12	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
J5111	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
J5111_	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
J5112	RATING	2	3	2	1	3	2	3	2	Fish farming.shp	3	2	Fishing.shp	3	3	2
	DQ	2	2	2	1	2	1	1	2	1	2	2	2	1	2	1
	WEIGHT	1	1	1	2	2	2	2	2	2	1	1	1	3	3	3
CRITERIA TYPE	E/C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

Rating instruction
to – (3) co-occur 8-12 mo/year. (2) 4-8 mo/yr. (1) 0 - 4 mo/yr. (0) no score
me – (3) no effective. (2) somewhat effective. (1) very effective. (0) no score
ir – (3) high. (2) medium. (1) low. (0) no score

to – temporal overlap; me – management effectiveness; ir – intensity rating; DQ- Data Quality; E - Exposure; C - Consequence

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Fish farming.shp – Geospatial vector data, in shapefile format, of Polution by fish farming pressure at the Atlantic coastal region adjacent to the Mondego River; Fishing.shp - Geospatial vector data, in shapefile format, of Fishing: recreative, commercial pressure at the Atlantic coastal region adjacent to the Mondego River.

Table C5. C2. Exposure scores of habitats to stressors. (continuation)

HABITAT		Contamination by heavy metals			Invasive species			Irrigation (loss of freshwater discharge)			Marine and estuary navigation traffic		
		to	me	ir	to	me	ir	to	me	ir	to	me	ir
A1	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A2	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A3A4	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A21	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A22	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A23	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A25	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A26	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A51	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A52	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A52_	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A53	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A73	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A74	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A76	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A523A524	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
A525A526	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
B12	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
J5111	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
J5111_	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
J5112	RATING	2	3	heavy_metal.shp	3	3	Invasive_sp.shp	3	2	Irrigation.shp	3	2	Marine traffic.shp
	DQ	2	3	2	2	3	2	2	2	2	2	2	2
	WEIGHT	3	3	3	2	2	2	2	2	2	2	2	2
CRITERIA TYPE	E/C	E	E	E	E	E	E	E	E	E/C	E	E	E

Rating instruction
to – (3) co-occur 8-12 mo/year. (2) 4-8 mo/yr. (1) 0 - 4 mo/yr. (0) no score
me – (3) no effective. (2) somewhat effective. (1) very effective. (0) no score
ir – (3) high. (2) medium. (1) low. (0) no score

to – temporal overlap; me – management effectiveness; ir – intensity rating; DQ- Data Quality; E - Exposure; C - Consequence

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Heavy_metal.shp – Geospatial vector data, in shapefile format, of Contamination by heavy metals pressure at the Atlantic coastal region adjacent to the Mondego River; Invasive_sp.shp - Geospatial vector data, in shapefile format, of invasive species pressure at the Atlantic coastal region adjacent to the Mondego River; Irrigation.shp - Geospatial vector data, in shapefile format, of Irrigation (loss of fresh water discharge) pressure at the Atlantic coastal region adjacent to the Mondego River; Marine traffic.shp - Geospatial vector data, in shapefile format, of Marine and estuary navigation traffic pressure at the Atlantic coastal region adjacent to the Mondego River.

Table S5. C3. Exposure scores of habitats to stressors. (continuation)

		Organic enrichment due to Nitrogen increase			Organic enrichment due to Phosphorus increase			Sea level changes			Tourism activities		
HABITAT		**to**	**me**	**ir**	**to**	**me**	**ir**	**to**	**me**	**ir**	**to**	**me**	**ir**
A1	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A2	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A3A4	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A21	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A22	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A23	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A25	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A26	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A51	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A52	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A52_	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A53	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A73	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A74	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A76	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A523A524	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
A525A526	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
B12	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
J5111	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
J5111_	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
J5112	RATING	3	2	Organic Nitrogen.shp	3	2	Organic Phosphorus.shp	2	3	Sea level changes.shp	2	2	2
	DQ	1	2	1	1	2	1	2	3	2	2	3	2
	WEIGHT	1	1	1	1	1	1	1	1	1	2	2	2
CRITERIA TYPE	E/C	E	E	E	E	E	E	E	E	E	E	E	E

Rating instruction
to – (3) co-occur 8-12 mo/year. (2) 4-8 mo/yr. (1) 0 - 4 mo/yr. (0) no score
me – (3) no effective. (2) somewhat effective. (1) very effective. (0) no score
ir – (3) high. (2) medium. (1) low. (0) no score

to – temporal overlap; me – management effectiveness; ir – intensity rating; DQ- Data Quality; E - Exposure; C – Consequence

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Organic Nitrogen.shp – Geospatial vector data, in shapefile format, of organic enrichment due to Nitrogen increase pressure at the Atlantic coastal region adjacent to the Mondego River; Organic phosphorus.shp - Geospatial vector data, in shapefile format, of organic enrichment due to Phosporus increase pressure at the Atlantic coastal region adjacent to the Mondego River; Sea level changes.shp - Geospatial vector data, in shapefile format, of Sea level changes pressure at the Atlantic coastal region adjacent to the Mondego River; Marine traffic.shp - Geospatial vector data, in shapefile format, of Marine and estuary navigation traffic pressure at the Atlantic coastal region adjacent to the Mondego River.

2. Results

Table C6. Results of the habitat risk assessment (HRA-1 model).

HABITAT	STRESSOR	E_MEAN	E_MIN	E_MAX	C_MEAN	C_MIN	C_MAX	R_MEAN	R_MIN	R_MAX	R_%HIGH	R_%MEDIUM	R_%LOW
A1	All stressors	0.86	0.55	1.03	0.93	0.82	0.95	0.66	0.46	0.75	0.00	0.00	100.00
A1	Fishing: recreative, commercial	2.52	0.00	2.67	1.47	0.00	1.50	1.72	0.00	1.85	0.00	88.46	11.54
A1	Coastal erosion	2.12	0.97	2.33	2.04	1.44	2.15	1.63	0.46	1.87	0.00	94.23	5.77
A1	Landfill/dredging/sand extraction	0.24	0.00	0.84	0.56	0.00	1.33	0.15	0.00	0.35	0.00	0.00	100.00
A1	Polution by fish farming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Harbor activities	0.48	0.00	1.38	0.89	0.00	1.50	0.33	0.00	0.67	0.00	0.00	100.00
A1	Contamination by heavy metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Invasive species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Irrigation (loss of freshwater discharge)	1.04	0.94	1.16	1.33	1.33	1.33	0.36	0.35	0.39	0.00	0.00	100.00
A1	Marine and estuary navigation traffic	2.07	1.58	2.33	1.50	1.49	1.50	1.26	0.80	1.51	0.00	61.54	38.46
A1	Organic enrichment due to Nitrogen increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Organic enrichment due to Phosphorus increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Sea level changes	1.83	1.49	2.63	2.43	2.41	2.43	1.81	1.58	2.29	30.77	69.23	0.00
A1	Tourism activities	2.00	2.00	2.00	1.65	1.65	1.65	1.27	1.27	1.27	0.00	100.00	0.00
A2	All stressors	0.94	0.48	1.70	0.91	0.71	1.68	0.66	0.39	1.13	0.00	1.06	98.94
A2	Fishing: recreative, commercial	2.18	0.00	2.67	1.00	0.00	1.10	1.35	0.00	1.77	0.00	66.14	33.86
A2	Coastal erosion	2.17	0.84	2.33	2.21	1.32	2.32	1.79	0.33	1.99	0.00	92.59	7.41
A2	Landfill/dredging/sand extraction	0.74	0.00	1.80	0.88	0.00	1.17	0.25	0.00	0.87	0.00	0.00	100.00
A2	Polution by fish farming	0.35	0.00	1.07	0.72	0.00	1.17	0.11	0.00	0.19	0.00	0.00	100.00
A2	Harbor activities	1.35	0.00	2.60	1.43	0.00	1.83	0.83	0.00	1.91	0.00	41.27	58.73
A2	Contamination by heavy metals	0.02	0.00	1.50	0.02	0.00	1.83	0.01	0.00	1.03	0.00	1.06	98.94
A2	Invasive species	0.03	0.00	2.25	0.02	0.00	1.43	0.02	0.00	1.40	0.00	1.59	98.41
A2	Irrigation (loss of freshwater discharge)	1.24	0.98	1.38	1.17	1.17	1.17	0.32	0.18	0.44	0.00	0.00	100.00
A2	Marine and estuary navigation traffic	1.93	1.57	2.33	1.85	1.81	1.86	1.36	1.05	1.68	0.00	100.00	0.00
A2	Organic enrichment due to Nitrogen increase	0.02	0.00	1.60	0.02	0.00	2.10	0.01	0.00	1.33	0.00	1.06	98.94
A2	Organic enrichment due to Phosphorus increase	0.02	0.00	1.60	0.02	0.00	2.10	0.01	0.00	1.33	0.00	1.06	98.94
A2	Sea level changes	1.88	1.49	2.63	2.21	2.20	2.21	1.64	1.37	2.15	28.57	71.43	0.00
A2	Tourism activities	1.52	0.00	2.00	1.14	0.00	1.50	0.90	0.00	1.19	0.00	76.19	23.81
A21	All stressors	1.59	0.74	1.83	1.35	0.79	1.51	0.94	0.48	1.15	0.00	40.23	59.77
A21	Fishing: recreative, commercial	1.95	0.00	2.00	1.68	0.00	1.70	1.26	0.00	1.30	0.00	98.85	1.15
A21	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A21	Landfill/dredging/sand extraction	1.15	0.19	1.80	1.45	1.03	1.74	0.60	0.03	1.15	0.00	20.69	79.31
A21	Polution by fish farming	1.64	1.33	2.80	1.33	1.28	1.35	0.78	0.46	1.94	0.00	10.34	89.66
A21	Harbor activities	1.80	0.74	2.51	1.53	1.28	1.69	1.06	0.29	1.76	0.00	54.02	45.98
A21	Contamination by heavy metals	1.70	0.00	1.88	1.38	0.00	1.47	0.93	0.00	1.05	0.00	75.86	24.14
A21	Invasive species	0.80	0.00	2.25	0.64	0.00	1.65	0.51	0.00	1.49	0.00	39.08	60.92
A21	Irrigation (loss of freshwater discharge)	1.55	1.45	1.67	1.83	1.77	1.89	1.05	0.95	1.18	0.00	78.16	21.84
A21	Marine and estuary navigation traffic	1.99	1.63	2.67	1.58	1.56	1.58	1.22	0.89	1.87	0.00	78.16	21.84
A21	Organic enrichment due to Nitrogen increase	2.42	0.00	2.80	1.75	0.00	1.85	1.81	0.00	2.11	75.86	18.39	5.75
A21	Organic enrichment due to Phosphorus increase	1.51	0.00	1.60	1.75	0.00	1.85	1.04	0.00	1.11	0.00	94.25	5.75
A21	Sea level changes	2.39	1.50	2.63	1.63	1.63	1.63	1.63	0.85	1.85	0.00	88.51	11.49
A21	Tourism activities	0.71	0.00	2.00	0.45	0.00	1.26	0.39	0.00	1.10	0.00	35.63	64.37
A22	All stressors	1.53	0.69	1.83	1.36	0.77	1.50	0.87	0.41	1.11	0.00	10.74	89.26
A22	Fishing: recreative, commercial	1.99	1.67	2.00	1.64	1.64	1.64	1.25	0.98	1.26	0.00	95.87	4.13
A22	Coastal erosion	0.00	0.00	0.25	0.02	0.00	0.75	0.00	0.00	0.00	0.00	0.00	100.00
A22	Landfill/dredging/sand extraction	0.84	0.10	1.80	1.25	0.94	1.65	0.31	0.00	1.09	0.00	2.07	97.93
A22	Polution by fish farming	1.59	1.33	2.80	1.26	1.21	1.29	0.69	0.42	1.93	0.00	7.44	92.56
A22	Harbor activities	1.67	0.67	2.60	1.41	1.19	1.62	0.90	0.20	1.82	0.00	43.80	56.20
A22	Contamination by heavy metals	1.75	0.00	2.25	1.32	0.00	1.38	0.92	0.00	1.38	0.00	79.34	20.66
A22	Invasive species	1.20	0.00	2.25	0.99	0.00	1.71	0.80	0.00	1.53	0.00	57.85	42.15
A22	Irrigation (loss of freshwater discharge)	1.56	1.43	2.67	1.74	1.67	1.80	0.99	0.85	1.96	0.00	37.19	62.81
A22	Marine and estuary navigation traffic	1.96	1.63	2.33	1.50	1.49	1.50	1.15	0.84	1.51	0.00	78.51	21.49
A22	Organic enrichment due to Nitrogen increase	2.21	0.00	2.80	1.73	0.00	1.79	1.57	0.00	2.08	42.98	53.72	3.31
A22	Organic enrichment due to Phosphorus increase	1.55	0.00	1.60	1.73	0.00	1.79	1.01	0.00	1.05	0.00	96.69	3.31
A22	Sea level changes	2.32	1.50	2.63	1.57	1.57	1.57	1.54	0.81	1.83	0.00	85.54	14.46
A22	Tourism activities	0.38	0.00	2.00	0.23	0.00	1.20	0.21	0.00	1.08	0.00	19.01	80.99
A23	All stressors	1.41	0.56	1.71	1.33	0.60	1.51	0.89	0.41	1.14	0.00	15.50	84.50
A23	Fishing: recreative, commercial	1.92	0.00	2.00	1.71	0.00	1.75	1.27	0.00	1.33	0.00	97.67	2.33
A23	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A23	Landfill/dredging/sand extraction	0.63	0.06	1.42	1.31	1.07	1.64	0.34	0.08	0.81	0.00	0.00	100.00
A23	Polution by fish farming	1.67	1.41	2.80	1.42	1.38	1.43	0.85	0.59	1.96	0.00	13.18	86.82
A23	Harbor activities	1.54	0.76	2.47	1.48	1.35	1.65	0.86	0.37	1.70	0.00	37.21	62.79
A23	Contamination by heavy metals	1.62	0.00	2.25	1.39	0.00	1.56	0.95	0.00	1.45	0.00	58.14	41.86
A23	Invasive species	1.44	0.00	2.25	1.32	0.00	1.86	1.01	0.00	1.61	0.00	71.32	28.68
A23	Irrigation (loss of freshwater discharge)	1.59	1.44	2.67	1.89	1.83	1.95	1.14	1.00	2.03	3.10	95.35	1.55
A23	Marine and estuary navigation traffic	1.90	1.63	2.33	1.65	1.64	1.65	1.19	0.95	1.57	0.00	58.14	41.86
A23	Organic enrichment due to Nitrogen increase	1.67	0.00	2.00	1.70	0.00	1.89	1.19	0.00	1.42	0.00	89.92	10.08
A23	Organic enrichment due to Phosphorus increase	1.44	0.00	1.60	1.70	0.00	1.89	1.03	0.00	1.14	0.00	89.92	10.08
A23	Sea level changes	2.45	1.50	2.63	1.68	1.68	1.68	1.71	0.89	1.87	0.00	95.35	4.65
A23	Tourism activities	0.08	0.00	2.00	0.05	0.00	1.35	0.04	0.00	1.12	0.00	3.88	96.12
A25	All stressors	0.88	0.28	1.71	0.97	0.58	1.43	0.63	0.27	1.11	0.00	5.41	94.59
A25	Fishing: recreative, commercial	1.55	0.00	2.00	1.28	0.00	1.59	0.93	0.00	1.23	0.00	60.39	39.61
A25	Coastal erosion	0.05	0.00	1.49	0.06	0.00	0.96	0.01	0.00	0.52	0.00	0.00	100.00
A25	Landfill/dredging/sand extraction	0.17	0.00	1.42	0.48	0.00	1.34	0.08	0.00	0.57	0.00	0.00	100.00
A25	Polution by fish farming	0.91	0.00	2.80	1.21	0.00	1.70	0.55	0.00	2.05	1.73	3.90	94.37
A25	Harbor activities	0.46	0.00	2.16	0.73	0.00	1.40	0.27	0.00	1.31	0.00	4.11	95.89
A25	Contamination by heavy metals	0.66	0.00	2.25	0.74	0.00	1.88	0.47	0.00	1.62	0.00	39.18	60.82
A25	Invasive species	0.72	0.00	3.00	0.58	0.00	1.74	0.49	0.00	2.26	5.19	28.35	66.45
A25	Irrigation (loss of freshwater discharge)	1.89	1.49	2.67	2.14	2.04	2.15	1.56	1.22	2.15	16.45	83.55	0.00
A25	Marine and estuary navigation traffic	1.68	1.50	2.00	1.39	1.37	1.40	0.84	0.66	1.14	0.00	17.32	82.68
A25	Organic enrichment due to Nitrogen increase	0.80	0.00	2.80	0.79	0.00	2.00	0.62	0.00	2.18	12.55	27.06	60.39
A25	Organic enrichment due to Phosphorus increase	0.63	0.00	1.60	0.79	0.00	2.00	0.49	0.00	1.24	0.00	39.61	60.39
A25	Sea level changes	2.10	1.49	2.63	2.21	2.19	2.21	1.77	1.37	2.15	30.52	69.48	0.00
A25	Tourism activities	0.11	0.00	2.00	0.08	0.00	1.55	0.07	0.00	1.21	0.00	5.41	94.59
A26	All stressors	1.53	1.37	1.65	1.32	1.25	1.38	1.06	0.93	1.19	0.00	86.05	13.95
A26	Fishing: recreative, commercial	1.98	1.67	2.00	1.54	1.54	1.54	1.19	0.91	1.20	0.00	95.35	4.65
A26	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A26	Landfill/dredging/sand extraction	0.84	0.43	1.15	1.70	1.53	1.83	0.74	0.56	0.90	0.00	0.00	100.00
A26	Polution by fish farming	1.52	1.43	1.60	1.64	1.62	1.65	0.87	0.80	0.94	0.00	0.00	100.00
A26	Harbor activities	1.93	1.35	2.47	1.73	1.68	1.78	1.27	0.81	1.76	0.00	76.74	23.26
A26	Contamination by heavy metals	1.87	1.50	1.88	2.02	2.02	2.02	1.42	1.20	1.42	0.00	100.00	0.00
A26	Invasive species	1.16	0.00	2.25	1.12	0.00	2.00	0.87	0.00	1.70	0.00	55.81	44.19
A26	Irrigation (loss of freshwater discharge)	1.52	1.45	1.60	2.03	2.00	2.07	1.23	1.17	1.30	0.00	100.00	0.00
A26	Marine and estuary navigation traffic	1.98	1.67	2.33	1.65	1.65	1.65	1.25	0.99	1.57	0.00	93.02	6.98
A26	Organic enrichment due to Nitrogen increase	2.20	1.60	2.80	2.10	2.10	2.10	1.74	1.33	2.24	25.58	74.42	0.00
A26	Organic enrichment due to Phosphorus increase	1.60	1.60	1.60	2.10	2.10	2.10	1.33	1.33	1.33	0.00	100.00	0.00

A26	Sea level changes	2.38	1.50	2.63	2.10	2.10	2.10	1.89	1.28	2.08	48.84	51.16	0.00
A26	Tourism activities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	All stressors	0.78	0.46	0.98	0.78	0.66	0.82	0.59	0.36	0.74	0.00	0.00	100.00
A3A4	Fishing: recreative, commercial	2.41	0.00	2.67	1.12	0.00	1.20	1.58	0.00	1.78	0.00	85.25	14.75
A3A4	Coastal erosion	2.04	0.84	2.33	1.85	1.23	2.00	1.44	0.25	1.77	0.00	78.69	21.31
A3A4	Landfill/dredging/sand extraction	0.10	0.00	0.78	0.46	0.00	1.33	0.12	0.00	0.35	0.00	0.00	100.00
A3A4	Polution by fish farming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Harbor activities	0.25	0.00	1.32	0.54	0.00	1.50	0.19	0.00	0.63	0.00	0.00	100.00
A3A4	Contamination by heavy metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Invasive species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Irrigation (loss of freshwater discharge)	0.97	0.86	1.16	1.33	1.33	1.33	0.36	0.35	0.39	0.00	0.00	100.00
A3A4	Marine and estuary navigation traffic	2.05	1.61	2.33	1.80	1.78	1.80	1.42	1.05	1.65	0.00	100.00	0.00
A3A4	Organic enrichment due to Nitrogen increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Organic enrichment due to Phosphorus increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Sea level changes	1.60	1.49	2.63	2.33	2.32	2.33	1.58	1.49	2.23	8.20	91.80	0.00
A3A4	Tourism activities	1.64	0.00	2.00	1.17	0.00	1.43	0.95	0.00	1.15	0.00	81.97	18.03
A51	All stressors	1.62	0.59	2.01	1.10	0.45	1.30	0.90	0.33	1.17	0.00	26.29	73.71
A51	Fishing: recreative, commercial	1.96	0.00	2.67	1.20	0.00	1.21	1.06	0.00	1.78	0.00	85.78	14.22
A51	Coastal erosion	0.20	0.00	2.33	0.21	0.00	1.40	0.06	0.00	1.48	0.00	2.59	97.41
A51	Landfill/dredging/sand extraction	1.16	0.00	1.80	1.19	0.00	1.47	0.53	0.00	0.99	0.00	0.00	100.00
A51	Polution by fish farming	1.39	0.40	2.80	1.15	0.98	1.20	0.48	0.00	1.92	0.00	3.88	96.12
A51	Harbor activities	1.87	0.00	2.60	1.45	0.00	1.62	1.17	0.00	1.82	0.00	64.66	35.34
A51	Contamination by heavy metals	1.75	0.00	2.25	1.50	0.00	1.56	1.01	0.00	1.45	0.00	79.74	20.26
A51	Invasive species	1.98	0.00	2.25	1.42	0.00	1.55	1.25	0.00	1.45	0.00	91.81	8.19
A51	Irrigation (loss of freshwater discharge)	1.60	1.27	2.67	1.50	1.42	1.56	0.85	0.53	1.86	0.00	10.34	89.66
A51	Marine and estuary navigation traffic	2.12	1.63	2.67	1.05	1.05	1.05	1.19	0.66	1.77	0.00	78.88	21.12
A51	Organic enrichment due to Nitrogen increase	2.42	0.00	2.80	1.55	0.00	1.60	1.67	0.00	2.01	68.10	11.64	20.26
A51	Organic enrichment due to Phosphorus increase	1.55	0.00	1.60	1.55	0.00	1.60	0.87	0.00	0.90	0.00	0.00	100.00
A51	Sea level changes	1.77	1.49	2.63	1.42	1.41	1.42	0.95	0.67	1.78	0.00	25.86	74.14
A51	Tourism activities	1.06	0.00	2.00	0.64	0.00	1.20	0.57	0.00	1.08	0.00	53.02	46.98
A52	All stressors	1.64	0.41	2.10	1.11	0.33	1.30	0.90	0.25	1.24	0.00	26.75	73.25
A52	Fishing: recreative, commercial	1.99	0.00	2.67	1.17	0.00	1.19	1.08	0.00	1.78	0.00	86.18	13.82
A52	Coastal erosion	0.35	0.00	2.33	0.29	0.00	1.38	0.14	0.00	1.47	0.00	7.24	92.76
A52	Landfill/dredging/sand extraction	1.19	0.00	1.80	1.20	0.00	1.44	0.52	0.00	0.97	0.00	0.00	100.00
A52	Polution by fish farming	1.34	0.28	2.80	1.10	0.90	1.16	0.44	0.00	1.92	0.00	3.29	96.71
A52	Harbor activities	1.96	0.00	2.60	1.44	0.00	1.59	1.20	0.00	1.81	0.00	67.98	32.02
A52	Contamination by heavy metals	1.77	0.00	2.25	1.49	0.00	1.53	1.01	0.00	1.44	0.00	80.92	19.08
A52	Invasive species	1.95	0.00	2.25	1.39	0.00	1.53	1.22	0.00	1.44	0.00	91.01	8.99
A52	Irrigation (loss of freshwater discharge)	1.55	1.25	2.67	1.46	1.38	1.53	0.77	0.48	1.85	0.00	7.46	92.54
A52	Marine and estuary navigation traffic	2.15	1.61	2.67	1.00	0.99	1.00	1.22	0.64	1.77	0.00	77.63	22.37
A52	Organic enrichment due to Nitrogen increase	2.33	0.00	2.80	1.55	0.00	1.59	1.57	0.00	2.01	54.82	26.10	19.08
A52	Organic enrichment due to Phosphorus increase	1.56	0.00	1.60	1.55	0.00	1.59	0.87	0.00	0.89	0.00	0.00	100.00
A52	Sea level changes	1.91	1.49	2.63	1.39	1.38	1.39	1.07	0.66	1.77	0.00	40.35	59.65
A52	Tourism activities	1.01	0.00	2.00	0.59	0.00	1.16	0.54	0.00	1.07	0.00	50.66	49.34
A523A524	All stressors	0.80	0.34	1.67	0.57	0.36	1.14	0.48	0.16	0.92	0.00	0.00	100.00
A523A524	Fishing: recreative, commercial	2.61	0.00	2.67	1.29	0.00	1.30	1.74	0.00	1.80	0.00	95.57	4.43
A523A524	Coastal erosion	1.44	0.00	2.33	1.38	0.00	1.71	0.73	0.00	1.60	0.00	37.06	62.94
A523A524	Landfill/dredging/sand extraction	0.41	0.00	1.80	0.70	0.00	1.61	0.23	0.00	1.07	0.00	0.47	99.53
A523A524	Polution by fish farming	0.25	0.00	1.07	0.56	0.00	1.17	0.09	0.00	0.19	0.00	0.00	100.00
A523A524	Harbor activities	0.88	0.00	2.51	1.06	0.00	1.47	0.49	0.00	1.68	0.00	15.15	84.85
A523A524	Contamination by heavy metals	0.00	0.00	1.50	0.00	0.00	1.50	0.00	0.00	0.75	0.00	0.00	100.00
A523A524	Invasive species	0.00	0.00	1.88	0.00	0.00	1.71	0.00	0.00	1.20	0.00	0.12	99.88
A523A524	Irrigation (loss of freshwater discharge)	1.21	0.84	1.37	1.17	1.17	1.17	0.31	0.18	0.43	0.00	0.00	100.00
A523A524	Marine and estuary navigation traffic	2.27	1.58	2.33	1.50	1.48	1.50	1.45	0.80	1.51	0.00	90.44	9.56
A523A524	Organic enrichment due to Nitrogen increase	0.00	0.00	1.60	0.00	0.00	1.70	0.00	0.00	0.98	0.00	0.00	100.00
A523A524	Organic enrichment due to Phosphorus increase	0.00	0.00	1.60	0.00	0.00	1.70	0.00	0.00	0.98	0.00	0.00	100.00
A523A524	Sea level changes	1.53	1.49	2.63	1.54	1.54	1.54	0.81	0.77	1.82	0.00	2.45	97.55
A523A524	Tourism activities	0.58	0.00	2.00	0.43	0.00	1.50	0.34	0.00	1.19	0.00	28.79	71.21
A525A526	All stressors	0.56	0.24	1.03	0.54	0.40	0.62	0.33	0.13	0.60	0.00	0.00	100.00
A525A526	Fishing: recreative, commercial	2.65	0.00	2.67	1.20	0.00	1.20	1.76	0.00	1.78	0.00	98.32	1.68
A525A526	Coastal erosion	0.07	0.00	2.00	0.09	0.00	1.04	0.01	0.00	1.06	0.00	0.02	99.98
A525A526	Landfill/dredging/sand extraction	0.15	0.00	1.72	0.24	0.00	1.00	0.02	0.00	0.76	0.00	0.00	100.00
A525A526	Polution by fish farming	0.02	0.00	0.77	0.07	0.00	1.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Harbor activities	0.24	0.00	2.14	0.33	0.00	1.13	0.08	0.00	1.22	0.00	0.54	99.46
A525A526	Contamination by heavy metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Invasive species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Irrigation (loss of freshwater discharge)	0.98	0.62	1.32	1.00	1.00	1.00	0.07	0.00	0.34	0.00	0.00	100.00
A525A526	Marine and estuary navigation traffic	2.32	1.63	2.33	1.71	1.69	1.71	1.59	0.99	1.60	0.00	99.91	0.09
A525A526	Organic enrichment due to Nitrogen increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Organic enrichment due to Phosphorus increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Sea level changes	1.50	1.49	1.50	1.42	1.41	1.42	0.69	0.67	0.69	0.00	0.00	100.00
A525A526	Tourism activities	0.03	0.00	2.00	0.02	0.00	1.22	0.01	0.00	1.09	0.00	1.36	98.64
A52_	All stressors	1.12	0.88	1.94	1.08	0.88	1.72	0.73	0.54	1.21	0.00	11.96	88.04
A52_	Fishing: recreative, commercial	2.66	1.67	2.67	1.41	1.41	1.41	1.81	0.83	1.82	0.00	98.91	1.09
A52_	Coastal erosion	1.79	0.65	2.33	1.76	1.08	2.09	1.18	0.09	1.82	0.00	68.48	31.52
A52_	Landfill/dredging/sand extraction	1.56	0.84	1.80	1.55	1.27	1.65	0.85	0.29	1.09	0.00	25.00	75.00
A52_	Polution by fish farming	0.28	0.00	0.81	0.88	0.00	1.12	0.02	0.00	0.13	0.00	0.00	100.00
A52_	Harbor activities	1.97	1.38	2.54	1.47	1.35	1.59	1.15	0.55	1.74	0.00	76.09	23.91
A52_	Contamination by heavy metals	0.22	0.00	1.88	0.17	0.00	1.27	0.10	0.00	0.97	0.00	0.00	100.00
A52_	Invasive species	0.29	0.00	2.25	0.20	0.00	1.41	0.17	0.00	1.40	0.00	14.13	85.87
A52_	Irrigation (loss of freshwater discharge)	1.25	1.16	1.33	0.94	0.94	0.94	0.26	0.17	0.35	0.00	0.00	100.00
A52_	Marine and estuary navigation traffic	2.22	1.63	2.67	1.41	1.40	1.41	1.37	0.79	1.82	0.00	81.52	18.48
A52_	Organic enrichment due to Nitrogen increase	0.27	0.00	2.80	0.25	0.00	1.92	0.21	0.00	2.14	5.43	7.61	86.96
A52_	Organic enrichment due to Phosphorus increase	0.21	0.00	1.60	0.25	0.00	1.92	0.15	0.00	1.16	0.00	13.04	86.96
A52_	Sea level changes	1.59	1.50	2.63	2.09	2.09	2.09	1.33	1.27	2.07	5.43	94.57	0.00
A52_	Tourism activities	1.59	0.00	2.00	1.03	0.00	1.29	0.88	0.00	1.11	0.00	79.35	20.65
A53	All stressors	1.50	0.71	1.98	1.05	0.46	1.31	0.78	0.36	1.10	0.00	17.42	82.58
A53	Fishing: recreative, commercial	1.86	0.00	2.00	1.07	0.00	1.11	0.96	0.00	1.07	0.00	75.48	24.52
A53	Coastal erosion	0.39	0.00	2.10	0.27	0.00	1.22	0.13	0.00	1.19	0.00	1.94	98.06
A53	Landfill/dredging/sand extraction	1.02	0.04	1.80	1.09	0.80	1.32	0.38	0.00	0.91	0.00	0.00	100.00
A53	Polution by fish farming	1.51	0.87	2.80	1.02	0.91	1.05	0.55	0.00	1.91	0.00	11.61	88.39
A53	Harbor activities	1.89	0.62	2.60	1.29	1.00	1.44	1.02	0.00	1.76	0.00	51.61	48.39
A53	Contamination by heavy metals	1.53	0.00	2.25	1.18	0.00	1.39	0.81	0.00	1.39	0.00	58.06	41.94
A53	Invasive species	1.68	0.00	2.25	1.13	0.00	1.40	0.99	0.00	1.39	0.00	80.65	19.35
A53	Irrigation (loss of freshwater discharge)	1.51	1.32	2.67	1.33	1.27	1.39	0.65	0.45	1.82	0.00	1.94	98.06
A53	Marine and estuary navigation traffic	2.02	1.63	2.67	0.90	0.90	0.90	1.08	0.66	1.77	0.00	56.13	43.87
A53	Organic enrichment due to Nitrogen increase	1.80	0.00	2.80	1.47	0.00	1.70	1.20	0.00	2.05	23.23	34.84	41.94
A53	Organic enrichment due to Phosphorus increase	1.38	0.00	1.60	1.30	0.00	1.50	0.72	0.00	0.83	0.00	0.00	100.00
A53	Sea level changes	2.12	1.48	2.63	1.29	1.28	1.29	1.24	0.59	1.75	0.00	58.71	41.29
A53	Tourism activities	0.77	0.00	2.00	0.39	0.00	1.00	0.41	0.00	1.06	0.00	38.71	61.29
A73	All stressors	0.60	0.24	1.91	0.48	0.31	1.20	0.33	0.11	1.02	0.00	0.02	99.98
A73	Fishing: recreative, commercial	2.64	0.00	2.67	1.38	0.00	1.38	1.79	0.00	1.81	0.00	97.92	2.08

A73	Coastal erosion	0.26	0.00	2.33	0.17	0.00	1.00	0.09	0.00	1.41	0.00	4.21	95.79
A73	Landfill/dredging/sand extraction	0.19	0.00	1.80	0.24	0.00	0.87	0.02	0.00	0.85	0.00	0.00	100.00
A73	Polution by fish farming	0.05	0.00	1.06	0.10	0.00	0.87	0.00	0.00	0.06	0.00	0.00	100.00
A73	Harbor activities	0.32	0.00	2.54	0.35	0.00	1.00	0.08	0.00	1.63	0.00	2.00	98.00
A73	Contamination by heavy metals	0.00	0.00	1.88	0.00	0.00	1.38	0.00	0.00	1.01	0.00	0.02	99.98
A73	Invasive species	0.00	0.00	1.88	0.00	0.00	1.84	0.00	0.00	1.29	0.00	0.06	99.94
A73	Irrigation (loss of freshwater discharge)	1.01	0.62	1.37	0.87	0.87	0.87	0.09	0.00	0.40	0.00	0.00	100.00
A73	Marine and estuary navigation traffic	2.31	1.63	2.67	1.44	1.43	1.44	1.47	0.80	1.83	0.00	97.19	2.81
A73	Organic enrichment due to Nitrogen increase	0.00	0.00	2.80	0.00	0.00	1.57	0.00	0.00	2.00	0.02	0.00	99.98
A73	Organic enrichment due to Phosphorus increase	0.00	0.00	1.60	0.00	0.00	1.57	0.00	0.00	0.88	0.00	0.00	100.00
A73	Sea level changes	1.51	1.49	2.63	1.36	1.36	1.36	0.66	0.64	1.77	0.00	0.75	99.25
A73	Tourism activities	0.12	0.00	2.00	0.07	0.00	1.13	0.06	0.00	1.07	0.00	5.80	94.20
A74	All stressors	1.32	0.29	1.84	1.14	0.52	1.34	0.72	0.21	1.05	0.00	4.09	95.91
A74	Fishing: recreative, commercial	1.80	0.00	2.00	1.29	0.00	1.36	0.98	0.00	1.13	0.00	68.39	31.61
A74	Coastal erosion	0.05	0.00	0.86	0.08	0.00	0.77	0.00	0.00	0.00	0.00	0.00	100.00
A74	Landfill/dredging/sand extraction	0.56	0.00	1.80	0.79	0.00	1.37	0.13	0.00	0.94	0.00	0.00	100.00
A74	Polution by fish farming	1.49	0.15	2.80	1.42	0.93	1.50	0.75	0.00	1.98	0.00	11.17	88.83
A74	Harbor activities	1.33	0.00	2.60	0.99	0.00	1.38	0.68	0.00	1.74	0.00	36.24	63.76
A74	Contamination by heavy metals	1.50	0.00	2.25	1.16	0.00	1.38	0.79	0.00	1.39	0.00	52.04	47.96
A74	Invasive species	1.17	0.00	2.25	0.77	0.00	1.37	0.68	0.00	1.38	0.00	56.13	43.87
A74	Irrigation (loss of freshwater discharge)	1.74	1.39	2.67	1.69	1.60	1.75	1.11	0.76	1.94	0.00	39.51	60.49
A74	Marine and estuary navigation traffic	1.88	1.63	2.33	1.25	1.24	1.25	0.97	0.71	1.44	0.00	52.32	47.68
A74	Organic enrichment due to Nitrogen increase	1.56	0.00	2.80	1.31	0.00	1.55	0.91	0.00	1.99	0.00	52.04	47.96
A74	Organic enrichment due to Phosphorus increase	1.35	0.00	1.60	1.31	0.00	1.55	0.73	0.00	0.86	0.00	0.00	100.00
A74	Sea level changes	2.19	1.49	2.63	1.73	1.72	1.73	1.51	0.92	1.89	0.00	68.39	31.61
A74	Tourism activities	0.28	0.00	2.00	0.16	0.00	1.13	0.15	0.00	1.07	0.00	14.17	85.83
A76	All stressors	1.39	0.82	2.10	1.18	0.92	1.38	0.81	0.43	1.30	0.00	20.45	79.55
A76	Fishing: recreative, commercial	1.77	0.00	2.67	1.35	0.00	1.45	1.01	0.00	1.83	0.00	61.46	38.54
A76	Coastal erosion	0.21	0.00	2.33	0.15	0.00	1.09	0.08	0.00	1.42	0.00	3.50	96.50
A76	Landfill/dredging/sand extraction	0.57	0.00	1.80	0.57	0.00	1.50	0.29	0.00	1.00	0.00	20.74	79.26
A76	Polution by fish farming	0.60	0.00	2.80	0.78	0.00	1.63	0.31	0.00	2.02	0.76	0.47	98.77
A76	Harbor activities	0.85	0.00	2.60	0.62	0.00	1.52	0.52	0.00	1.79	0.00	28.88	71.12
A76	Contamination by heavy metals	1.71	0.00	1.88	1.52	0.00	1.52	0.95	0.00	1.08	0.00	56.72	43.28
A76	Invasive species	1.38	0.00	3.00	0.91	0.00	1.50	0.89	0.00	2.19	12.50	48.11	39.39
A76	Irrigation (loss of freshwater discharge)	1.88	1.25	2.67	1.83	1.66	1.88	1.31	0.74	2.00	0.00	74.62	25.38
A76	Marine and estuary navigation traffic	1.95	1.61	2.67	1.37	1.36	1.38	1.09	0.75	1.81	0.00	56.25	43.75
A76	Organic enrichment due to Nitrogen increase	2.28	1.60	2.80	1.64	1.64	1.64	1.55	0.93	2.02	56.63	0.09	43.28
A76	Organic enrichment due to Phosphorus increase	1.60	1.60	1.60	1.64	1.64	1.64	0.93	0.93	0.93	0.00	0.00	100.00
A76	Sea level changes	1.79	1.48	2.63	1.82	1.80	1.82	1.25	0.99	1.93	0.00	96.78	3.22
A76	Tourism activities	0.59	0.00	2.00	0.37	0.00	1.25	0.32	0.00	1.09	0.00	29.26	70.74
B12	All stressors	0.88	0.28	2.10	0.92	0.55	1.40	0.58	0.14	1.29	0.00	6.43	93.57
B12	Fishing: recreative, commercial	1.02	0.00	2.67	0.47	0.00	1.03	0.59	0.00	1.77	0.00	25.44	74.56
B12	Coastal erosion	2.21	0.84	2.33	1.93	1.15	2.00	1.62	0.16	1.77	0.00	95.03	4.97
B12	Landfill/dredging/sand extraction	0.77	0.00	1.80	0.91	0.00	1.58	0.35	0.00	1.05	0.00	7.89	92.11
B12	Polution by fish farming	0.36	0.00	1.16	0.66	0.00	1.18	0.05	0.00	0.25	0.00	0.00	100.00
B12	Harbor activities	1.31	0.00	2.60	1.24	0.00	1.84	0.82	0.00	1.92	0.00	44.15	55.85
B12	Contamination by heavy metals	0.14	0.00	1.88	0.11	0.00	1.35	0.07	0.00	1.00	0.00	0.00	100.00
B12	Invasive species	0.16	0.00	2.25	0.11	0.00	1.37	0.10	0.00	1.38	0.00	7.89	92.11
B12	Irrigation (loss of freshwater discharge)	1.24	0.79	1.39	1.23	1.17	1.25	0.37	0.18	0.49	0.00	0.00	100.00
B12	Marine and estuary navigation traffic	1.66	0.49	2.67	1.24	1.04	1.26	0.77	0.04	1.79	0.00	14.91	85.09
B12	Organic enrichment due to Nitrogen increase	0.19	0.00	2.80	0.12	0.00	1.44	0.13	0.00	1.97	0.00	5.26	94.74
B12	Organic enrichment due to Phosphorus increase	0.13	0.00	1.60	0.12	0.00	1.44	0.06	0.00	0.79	0.00	0.00	100.00
B12	Sea level changes	1.88	1.42	2.63	2.29	2.20	2.30	1.71	1.35	2.20	29.53	70.47	0.00
B12	Tourism activities	1.47	0.00	2.00	1.13	0.00	1.53	0.88	0.00	1.20	0.00	73.68	26.32
J5111	All stressors	0.86	0.51	1.65	1.03	0.72	1.53	0.57	0.34	0.99	0.00	0.00	100.00
J5111	Fishing: recreative, commercial	1.79	0.00	2.00	1.83	0.00	1.91	1.29	0.00	1.44	0.00	95.62	4.38
J5111	Coastal erosion	0.00	0.00	0.12	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	100.00
J5111	Landfill/dredging/sand extraction	0.80	0.00	1.74	1.03	0.00	1.40	0.23	0.00	0.89	0.00	0.00	100.00
J5111	Polution by fish farming	1.83	1.55	2.80	1.65	1.62	1.65	1.13	0.88	2.03	2.07	51.38	46.54
J5111	Harbor activities	1.56	0.44	2.54	1.17	1.10	1.24	0.67	0.10	1.65	0.00	24.42	75.58
J5111	Contamination by heavy metals	0.14	0.00	1.88	0.12	0.00	1.33	0.07	0.00	0.99	0.00	0.00	100.00
J5111	Invasive species	0.14	0.00	2.25	0.09	0.00	1.41	0.08	0.00	1.40	0.00	6.68	93.32
J5111	Irrigation (loss of freshwater discharge)	1.56	1.43	2.67	1.93	1.85	2.00	1.15	1.01	2.06	0.23	99.77	0.00
J5111	Marine and estuary navigation traffic	1.53	1.31	2.00	1.26	1.22	1.29	0.63	0.40	1.11	0.00	3.92	96.08
J5111	Organic enrichment due to Nitrogen increase	0.15	0.00	2.80	0.13	0.00	1.57	0.09	0.00	2.00	1.15	1.84	97.00
J5111	Organic enrichment due to Phosphorus increase	0.13	0.00	1.60	0.14	0.00	1.74	0.08	0.00	1.01	0.00	8.29	91.71
J5111	Sea level changes	2.40	1.49	2.63	2.09	2.07	2.09	1.90	1.25	2.07	62.44	37.56	0.00
J5111	Tourism activities	0.10	0.00	2.00	0.06	0.00	1.29	0.05	0.00	1.11	0.00	4.84	95.16
J5111_	All stressors	0.99	0.49	1.81	1.11	0.73	1.59	0.65	0.36	1.13	0.00	1.25	98.75
J5111_	Fishing: recreative, commercial	1.87	0.00	2.00	1.85	0.00	1.91	1.34	0.00	1.44	0.00	96.75	3.25
J5111_	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
J5111_	Landfill/dredging/sand extraction	0.74	0.00	1.80	0.99	0.00	1.29	0.21	0.00	0.90	0.00	0.00	100.00
J5111_	Polution by fish farming	2.11	1.55	2.80	1.65	1.62	1.65	1.39	0.88	2.03	25.00	36.50	38.50
J5111_	Harbor activities	1.48	0.00	2.60	1.13	0.00	1.24	0.65	0.00	1.72	0.00	30.75	69.25
J5111_	Contamination by heavy metals	0.43	0.00	2.25	0.33	0.00	1.33	0.21	0.00	1.37	0.00	4.75	95.25
J5111_	Invasive species	0.27	0.00	2.25	0.19	0.00	1.41	0.15	0.00	1.40	0.00	13.25	86.75
J5111_	Irrigation (loss of freshwater discharge)	1.61	1.42	2.67	1.93	1.84	2.00	1.19	0.99	2.06	4.75	94.75	0.50
J5111_	Marine and estuary navigation traffic	1.63	1.31	2.67	1.28	1.22	1.29	0.74	0.41	1.80	0.00	10.50	89.50
J5111_	Organic enrichment due to Nitrogen increase	0.46	0.00	2.80	0.43	0.00	1.74	0.30	0.00	2.06	1.50	23.50	75.00
J5111_	Organic enrichment due to Phosphorus increase	0.40	0.00	1.60	0.43	0.00	1.74	0.25	0.00	1.01	0.00	25.00	75.00
J5111_	Sea level changes	2.42	1.50	2.63	2.09	2.09	2.09	1.91	1.27	2.07	63.75	36.25	0.00
J5111_	Tourism activities	0.11	0.00	2.00	0.07	0.00	1.29	0.06	0.00	1.11	0.00	5.25	94.75
J5112	All stressors	0.82	0.38	1.73	0.65	0.56	1.15	0.46	0.23	1.02	0.00	0.25	99.75
J5112	Fishing: recreative, commercial	1.25	0.00	2.00	0.47	0.00	0.70	0.60	0.00	1.06	0.00	34.34	65.66
J5112	Coastal erosion	0.00	0.00	0.51	0.01	0.00	0.70	0.00	0.00	0.00	0.00	0.00	100.00
J5112	Landfill/dredging/sand extraction	0.62	0.00	1.80	0.69	0.00	0.94	0.10	0.00	0.85	0.00	0.00	100.00
J5112	Polution by fish farming	1.71	1.33	2.80	1.40	1.33	1.41	0.87	0.50	1.96	0.00	26.54	73.46
J5112	Harbor activities	1.32	0.00	2.60	1.01	0.00	1.07	0.52	0.00	1.70	0.00	21.89	78.11
J5112	Contamination by heavy metals	0.27	0.00	2.25	0.21	0.00	1.33	0.13	0.00	1.37	0.00	2.26	97.74
J5112	Invasive species	0.18	0.00	2.25	0.13	0.00	1.41	0.10	0.00	1.40	0.00	8.93	91.07
J5112	Irrigation (loss of freshwater discharge)	1.60	1.42	2.67	1.49	1.44	1.53	0.83	0.65	1.85	0.00	3.27	96.73
J5112	Marine and estuary navigation traffic	1.57	1.26	2.67	0.94	0.94	0.94	0.60	0.27	1.77	0.00	6.92	93.08
J5112	Organic enrichment due to Nitrogen increase	0.29	0.00	2.80	0.27	0.00	1.74	0.19	0.00	2.06	1.51	14.21	84.28
J5112	Organic enrichment due to Phosphorus increase	0.25	0.00	1.60	0.27	0.00	1.74	0.16	0.00	1.01	0.00	15.72	84.28
J5112	Sea level changes	2.35	1.49	2.63	2.09	2.07	2.09	1.87	1.25	2.07	59.25	40.75	0.00
J5112	Tourism activities	0.12	0.00	2.00	0.08	0.00	1.41	0.07	0.00	1.15	0.00	5.79	94.21

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

E_MEAN – Mean exposure value; E_MIN - Minimum exposure value; E_MAX – Maximum exposure value; C_MEAN – Mean consequence value; C_MIN – Minimum consequence value; C_MAX – Maximum consequence value; R_MEAN - Cumulative mean risk value; R_MIN – Cumulative minimum risk value; R_MAX – Cumulative maximum risk value; R_%HIGH – Percentage of area under high risk; R_%MEDIUM – Percentage of area under medium risk; R_%LOW – Percentage of area under low risk.

Table C7. Results of the habitat risk assessment including the abundance of ecosystem services (HRA_ES-2 model).

HABITAT	STRESSOR	E_MEAN	E_MIN	E_MAX	C_MEAN	C_MIN	C_MAX	R_MEAN	R_MIN	R_MAX	R_%HIGH	R_%MEDIUM	R_%LOW
A1	All stressors	0.85	0.51	1.06	0.99	0.71	1.06	0.70	0.28	0.92	0.00	0.00	100.00
A1	Fishing: recreative, commercial	2.49	0.00	2.67	1.57	0.00	1.77	1.76	0.00	1.95	0.00	88.68	11.32
A1	Coastal erosion	2.07	0.97	2.33	1.99	1.32	2.24	1.58	0.78	1.93	0.00	92.45	7.55
A1	Landfill/dredging/sand extraction	0.23	0.00	0.84	0.69	0.00	1.76	0.27	0.00	0.80	0.00	0.00	100.00
A1	Polution by fish farming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Harbor activities	0.46	0.00	1.35	1.03	0.00	1.89	0.47	0.00	1.01	0.00	3.77	96.23
A1	Contamination by heavy metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Invasive species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Irrigation (loss of freshwater discharge)	1.05	0.95	1.17	1.56	0.83	1.76	0.62	0.00	0.82	0.00	0.00	100.00
A1	Marine and estuary navigation traffic	2.07	1.58	2.33	1.65	0.96	1.84	1.35	0.62	1.67	0.00	71.70	28.30
A1	Organic enrichment due to Nitrogen increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Organic enrichment due to Phosphorus increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A1	Sea level changes	1.81	1.49	2.63	2.29	1.73	2.44	1.68	0.93	2.30	26.42	64.15	9.43
A1	Tourism activities	2.00	2.00	2.00	1.75	1.06	1.94	1.36	1.06	1.45	0.00	100.00	0.00
A2	All stressors	0.95	0.43	1.79	0.96	0.59	1.68	0.68	0.20	1.27	0.00	3.23	96.77
A2	Fishing: recreative, commercial	2.19	0.00	2.67	1.15	0.00	1.46	1.39	0.00	1.83	0.00	66.13	33.87
A2	Coastal erosion	2.16	0.84	2.33	2.02	0.94	2.36	1.66	0.00	2.02	14.52	79.03	6.45
A2	Landfill/dredging/sand extraction	0.78	0.00	1.80	1.01	0.00	1.66	0.39	0.00	1.10	0.00	1.61	98.39
A2	Polution by fish farming	0.37	0.00	1.12	0.85	0.00	1.66	0.23	0.00	0.70	0.00	0.00	100.00
A2	Harbor activities	1.37	0.00	2.54	1.43	0.00	2.05	0.88	0.00	1.90	0.00	45.70	54.30
A2	Contamination by heavy metals	0.02	0.00	1.50	0.03	0.00	2.07	0.02	0.00	1.25	0.00	0.54	99.46
A2	Invasive species	0.02	0.00	2.25	0.01	0.00	1.41	0.01	0.00	1.39	0.00	1.08	98.92
A2	Irrigation (loss of freshwater discharge)	1.25	0.99	1.38	1.31	0.72	1.66	0.49	0.00	0.80	0.00	0.00	100.00
A2	Marine and estuary navigation traffic	1.92	1.57	2.33	1.75	1.19	2.06	1.27	0.65	1.81	0.00	53.76	46.24
A2	Organic enrichment due to Nitrogen increase	0.03	0.00	1.60	0.03	0.00	2.20	0.02	0.00	1.42	0.00	1.61	98.39
A2	Organic enrichment due to Phosphorus increase	0.03	0.00	1.60	0.03	0.00	2.20	0.02	0.00	1.42	0.00	1.61	98.39
A2	Sea level changes	1.86	1.49	2.63	2.00	1.51	2.29	1.47	0.74	2.20	8.06	70.97	20.97
A2	Tourism activities	1.53	0.00	2.00	1.13	0.00	1.86	0.93	0.00	1.40	0.00	76.34	23.66
A21	All stressors	1.60	0.84	1.84	1.43	0.91	1.58	1.11	0.71	1.34	0.00	80.23	19.77
A21	Fishing: recreative, commercial	1.95	0.00	2.00	1.88	0.00	1.92	1.39	0.00	1.44	0.00	98.84	1.16
A21	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A21	Landfill/dredging/sand extraction	1.15	0.19	1.80	1.80	1.15	2.00	0.93	0.16	1.36	0.00	39.53	60.47
A21	Polution by fish farming	1.66	1.33	2.80	1.70	1.31	1.74	1.05	0.52	2.07	10.47	12.79	76.74
A21	Harbor activities	1.79	0.74	2.51	1.87	1.31	2.00	1.31	0.33	1.92	0.00	75.58	24.42
A21	Contamination by heavy metals	1.73	0.00	1.88	1.79	0.00	1.88	1.20	0.00	1.32	0.00	93.02	6.98
A21	Invasive species	0.78	0.00	2.25	0.73	0.00	1.94	0.56	0.00	1.66	0.00	38.37	61.63
A21	Irrigation (loss of freshwater discharge)	1.55	1.46	1.67	2.03	1.66	2.10	1.24	0.91	1.36	0.00	97.67	2.33
A21	Marine and estuary navigation traffic	1.98	1.63	2.67	1.88	1.50	1.90	1.41	0.88	2.01	8.14	88.37	3.49
A21	Organic enrichment due to Nitrogen increase	2.45	0.00	2.80	1.94	0.00	2.03	1.91	0.00	2.20	75.58	17.44	6.98
A21	Organic enrichment due to Phosphorus increase	1.54	0.00	1.60	1.94	0.00	2.03	1.20	0.00	1.26	0.00	90.70	9.30
A21	Sea level changes	2.37	1.50	2.63	1.85	1.55	1.87	1.73	1.06	1.95	0.00	100.00	0.00
A21	Tourism activities	0.74	0.00	2.00	0.62	0.00	1.70	0.48	0.00	1.29	0.00	37.21	62.79
A22	All stressors	1.53	0.68	1.84	1.42	0.71	1.57	1.02	0.32	1.31	0.00	66.80	33.20
A22	Fishing: recreative, commercial	1.97	0.00	2.00	1.81	0.00	1.87	1.36	0.00	1.41	0.00	97.51	2.49
A22	Coastal erosion	0.00	0.00	0.25	0.03	0.00	1.29	0.01	0.00	0.30	0.00	0.00	100.00
A22	Landfill/dredging/sand extraction	0.85	0.13	1.74	1.62	0.62	1.92	0.69	0.00	1.25	0.00	9.13	90.87
A22	Polution by fish farming	1.55	1.33	2.80	1.61	0.80	1.69	0.89	0.35	2.04	2.90	1.66	95.44
A22	Harbor activities	1.68	0.71	2.54	1.75	0.73	1.93	1.15	0.00	1.90	0.00	61.41	38.59
A22	Contamination by heavy metals	1.76	0.00	2.25	1.68	0.00	1.81	1.16	0.00	1.58	0.00	90.87	9.13
A22	Invasive species	1.23	0.00	2.25	1.13	0.00	1.97	0.89	0.00	1.68	0.00	58.51	41.49
A22	Irrigation (loss of freshwater discharge)	1.56	1.44	2.67	1.93	1.12	2.03	1.17	0.58	2.08	0.41	85.89	13.69
A22	Marine and estuary navigation traffic	1.96	1.63	2.33	1.78	0.96	1.84	1.32	0.66	1.67	0.00	89.63	10.37
A22	Organic enrichment due to Nitrogen increase	2.22	0.00	2.80	1.85	0.00	1.97	1.66	0.00	2.17	43.98	48.55	7.47
A22	Organic enrichment due to Phosphorus increase	1.53	0.00	1.60	1.85	0.00	1.97	1.13	0.00	1.21	0.00	86.31	13.69
A22	Sea level changes	2.33	1.50	2.63	1.77	1.13	1.82	1.65	0.55	1.93	0.00	98.34	1.66
A22	Tourism activities	0.37	0.00	2.00	0.29	0.00	1.65	0.23	0.00	1.26	0.00	18.67	81.33
A23	All stressors	1.40	0.55	1.71	1.38	0.73	1.57	0.98	0.46	1.31	0.00	58.59	41.41
A23	Fishing: recreative, commercial	1.95	0.00	2.00	1.83	0.00	1.95	1.36	0.00	1.46	0.00	97.66	2.34
A23	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A23	Landfill/dredging/sand extraction	0.67	0.12	1.42	1.60	1.07	1.93	0.64	0.08	1.08	0.00	4.69	95.31
A23	Polution by fish farming	1.63	1.41	2.80	1.65	1.19	1.78	0.98	0.52	2.08	3.13	42.19	54.69
A23	Harbor activities	1.54	0.76	2.47	1.72	1.15	1.96	1.05	0.16	1.86	0.00	50.78	49.22
A23	Contamination by heavy metals	1.61	0.00	2.25	1.57	0.00	1.93	1.09	0.00	1.65	0.00	75.00	25.00
A23	Invasive species	1.46	0.00	2.25	1.39	0.00	2.06	1.06	0.00	1.74	0.00	71.88	28.13
A23	Irrigation (loss of freshwater discharge)	1.59	1.45	2.67	1.96	1.54	2.13	1.22	0.90	2.14	0.78	85.94	13.28
A23	Marine and estuary navigation traffic	1.90	1.63	2.33	1.81	1.35	1.94	1.30	0.80	1.73	0.00	78.91	21.09
A23	Organic enrichment due to Nitrogen increase	1.65	0.00	2.00	1.71	0.00	2.05	1.22	0.00	1.54	0.00	85.94	14.06
A23	Organic enrichment due to Phosphorus increase	1.40	0.00	1.60	1.71	0.00	2.05	1.05	0.00	1.28	0.00	85.94	14.06
A23	Sea level changes	2.43	1.50	2.63	1.80	1.44	1.90	1.75	0.82	1.97	0.00	98.44	1.56
A23	Tourism activities	0.05	0.00	2.00	0.04	0.00	1.74	0.03	0.00	1.32	0.00	2.34	97.66
A25	All stressors	0.88	0.27	1.75	0.99	0.54	1.50	0.59	0.16	1.34	0.00	7.97	92.03
A25	Fishing: recreative, commercial	1.53	0.00	2.00	1.22	0.00	1.83	0.91	0.00	1.38	0.00	62.72	37.28
A25	Coastal erosion	0.05	0.00	1.49	0.05	0.00	1.44	0.01	0.00	0.55	0.00	0.00	100.00
A25	Landfill/dredging/sand extraction	0.18	0.00	1.38	0.53	0.00	1.73	0.14	0.00	0.87	0.00	0.00	100.00
A25	Polution by fish farming	0.92	0.00	2.80	1.17	0.00	1.97	0.53	0.00	2.17	1.72	12.93	85.34
A25	Harbor activities	0.46	0.00	2.13	0.73	0.00	1.84	0.28	0.00	1.49	0.00	4.96	95.04
A25	Contamination by heavy metals	0.65	0.00	2.25	0.66	0.00	2.11	0.42	0.00	1.77	0.00	21.12	78.88
A25	Invasive species	0.74	0.00	3.00	0.56	0.00	2.00	0.49	0.00	2.25	5.17	28.02	66.81
A25	Irrigation (loss of freshwater discharge)	1.90	1.50	2.67	1.83	1.34	2.26	1.34	0.67	2.21	5.60	81.90	12.50
A25	Marine and estuary navigation traffic	1.68	1.49	2.00	1.35	0.88	1.77	0.84	0.52	1.34	0.00	24.78	75.22
A25	Organic enrichment due to Nitrogen increase	0.81	0.00	2.80	0.72	0.00	2.13	0.59	0.00	2.26	14.87	20.47	64.66
A25	Organic enrichment due to Phosphorus increase	0.61	0.00	1.60	0.72	0.00	2.13	0.43	0.00	1.36	0.00	33.62	66.38
A25	Sea level changes	2.10	1.49	2.63	1.95	1.59	2.28	1.57	0.81	2.19	27.37	58.84	13.79
A25	Tourism activities	0.10	0.00	2.00	0.07	0.00	1.87	0.06	0.00	1.41	0.00	5.17	94.83
A26	All stressors	1.51	0.86	1.66	1.38	0.79	1.45	1.17	0.60	1.29	0.00	95.83	4.17
A26	Fishing: recreative, commercial	1.97	1.67	2.00	1.78	1.49	1.79	1.32	1.10	1.35	0.00	100.00	0.00
A26	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A26	Landfill/dredging/sand extraction	0.84	0.48	1.13	1.95	1.58	2.05	1.00	0.62	1.12	0.00	58.33	41.67
A26	Polution by fish farming	1.53	1.43	2.00	1.90	1.54	1.94	1.11	0.77	1.45	0.00	93.75	6.25
A26	Harbor activities	1.91	1.31	2.45	1.99	1.60	2.04	1.45	1.09	1.90	0.00	100.00	0.00
A26	Contamination by heavy metals	1.82	0.00	1.88	2.13	0.00	2.19	1.51	0.00	1.57	0.00	97.92	2.08
A26	Invasive species	1.17	0.00	2.25	1.21	0.00	2.16	0.94	0.00	1.81	0.00	56.25	43.75
A26	Irrigation (loss of freshwater discharge)	1.52	1.46	1.60	2.16	1.79	2.21	1.35	1.00	1.43	0.00	95.83	4.17
A26	Marine and estuary navigation traffic	1.99	1.67	2.33	1.91	1.55	1.94	1.43	0.92	1.73	0.00	97.92	2.08
A26	Organic enrichment due to Nitrogen increase	2.14	0.00	2.80	2.14	0.00	2.20	1.76	0.00	2.29	25.00	72.92	2.08
A26	Organic enrichment due to Phosphorus increase	1.57	0.00	1.60	2.14	0.00	2.20	1.38	0.00	1.42	0.00	97.92	2.08
A26	Sea level changes	2.37	1.50	2.63	2.18	1.90	2.20	1.93	1.37	2.14	39.58	60.42	0.00
A26	Tourism activities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	All stressors	0.79	0.44	0.95	0.85	0.63	0.93	0.62	0.21	0.83	0.00	0.00	100.00

A3A4	Fishing: recreative, commercial	2.45	0.00	2.67	1.29	0.00	1.54	1.65	0.00	1.86	0.00	86.44	13.56
A3A4	Coastal erosion	2.07	0.84	2.33	1.82	1.24	2.12	1.47	0.31	1.85	0.00	86.44	13.56
A3A4	Landfill/dredging/sand extraction	0.10	0.00	0.78	0.55	0.00	1.76	0.23	0.00	0.80	0.00	0.00	100.00
A3A4	Polution by fish farming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Harbor activities	0.23	0.00	1.29	0.59	0.00	1.89	0.27	0.00	0.99	0.00	0.00	100.00
A3A4	Contamination by heavy metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Invasive species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Irrigation (loss of freshwater discharge)	0.97	0.86	1.16	1.48	0.83	1.76	0.55	0.00	0.82	0.00	0.00	100.00
A3A4	Marine and estuary navigation traffic	2.08	1.58	2.33	1.77	1.14	2.03	1.43	0.64	1.79	0.00	72.88	27.12
A3A4	Organic enrichment due to Nitrogen increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Organic enrichment due to Phosphorus increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A3A4	Sea level changes	1.59	1.49	2.63	2.14	1.59	2.37	1.39	0.81	2.26	5.08	71.19	23.73
A3A4	Tourism activities	1.69	0.00	2.00	1.32	0.00	1.78	1.07	0.00	1.35	0.00	84.75	15.25
A51	All stressors	1.61	0.58	2.02	1.16	0.42	1.38	1.04	0.29	1.40	0.00	65.67	34.33
A51	Fishing: recreative, commercial	1.97	0.00	2.67	1.46	0.00	1.56	1.17	0.00	1.87	0.00	86.27	13.73
A51	Coastal erosion	0.19	0.00	2.33	0.28	0.00	1.68	0.09	0.00	1.59	0.00	3.43	96.57
A51	Landfill/dredging/sand extraction	1.14	0.00	1.80	1.45	0.00	1.83	0.78	0.00	1.23	0.00	35.19	64.81
A51	Polution by fish farming	1.39	0.34	2.80	1.49	0.71	1.65	0.74	0.05	2.03	1.72	2.15	96.14
A51	Harbor activities	1.85	0.00	2.60	1.69	0.00	1.94	1.36	0.00	1.97	0.00	69.10	30.90
A51	Contamination by heavy metals	1.72	0.00	1.88	1.69	0.00	1.90	1.15	0.00	1.33	0.00	81.97	18.03
A51	Invasive species	1.92	0.00	2.25	1.58	0.00	1.87	1.33	0.00	1.62	0.00	84.98	15.02
A51	Irrigation (loss of freshwater discharge)	1.61	1.27	2.67	1.73	0.91	1.90	1.07	0.40	2.01	6.87	63.52	29.61
A51	Marine and estuary navigation traffic	2.11	1.63	2.67	1.42	0.68	1.55	1.29	0.66	1.86	0.00	78.54	21.46
A51	Organic enrichment due to Nitrogen increase	2.37	0.00	2.80	1.67	0.00	1.83	1.70	0.00	2.10	62.23	24.03	13.73
A51	Organic enrichment due to Phosphorus increase	1.53	0.00	1.60	1.67	0.00	1.83	0.98	0.00	1.09	0.00	78.97	21.03
A51	Sea level changes	1.81	1.49	2.63	1.63	0.97	1.74	1.15	0.51	1.90	0.00	29.18	70.82
A51	Tourism activities	1.04	0.00	2.00	0.78	0.00	1.65	0.64	0.00	1.26	0.00	51.93	48.07
A52	All stressors	1.63	0.52	2.10	1.17	0.40	1.38	1.04	0.29	1.44	0.00	64.84	35.16
A52	Fishing: recreative, commercial	1.98	0.00	2.67	1.42	0.00	1.55	1.18	0.00	1.86	0.00	86.59	13.41
A52	Coastal erosion	0.34	0.00	2.33	0.36	0.00	1.68	0.17	0.00	1.59	0.00	9.23	90.77
A52	Landfill/dredging/sand extraction	1.19	0.00	1.80	1.50	0.00	1.83	0.81	0.00	1.22	0.00	35.38	64.62
A52	Polution by fish farming	1.33	0.24	2.80	1.46	0.61	1.63	0.70	0.00	2.02	1.10	1.76	97.14
A52	Harbor activities	1.95	0.00	2.60	1.69	0.00	1.94	1.39	0.00	1.97	0.00	75.38	24.62
A52	Contamination by heavy metals	1.77	0.00	2.25	1.72	0.00	1.89	1.18	0.00	1.63	0.00	82.42	17.58
A52	Invasive species	1.92	0.00	2.25	1.57	0.00	1.87	1.32	0.00	1.61	0.00	85.27	14.73
A52	Irrigation (loss of freshwater discharge)	1.55	1.25	2.67	1.70	0.85	1.89	1.01	0.30	2.01	3.74	53.41	42.86
A52	Marine and estuary navigation traffic	2.15	1.63	2.67	1.39	0.63	1.53	1.32	0.66	1.86	0.00	77.58	22.42
A52	Organic enrichment due to Nitrogen increase	2.32	0.00	2.80	1.69	0.00	1.83	1.64	0.00	2.10	49.01	38.24	12.75
A52	Organic enrichment due to Phosphorus increase	1.57	0.00	1.60	1.69	0.00	1.83	0.99	0.00	1.08	0.00	77.58	22.42
A52	Sea level changes	1.92	1.49	2.63	1.61	0.94	1.74	1.23	0.51	1.89	0.00	40.88	59.12
A52	Tourism activities	0.99	0.00	2.00	0.73	0.00	1.63	0.60	0.00	1.26	0.00	49.67	50.33
A523A524	All stressors	0.80	0.33	1.67	0.69	0.33	1.11	0.62	0.11	1.00	0.00	0.12	99.88
A523A524	Fishing: recreative, commercial	2.60	0.00	2.67	1.55	0.00	1.61	1.82	0.00	1.88	0.00	95.44	4.56
A523A524	Coastal erosion	1.45	0.00	2.33	1.67	0.00	1.94	0.99	0.00	1.73	0.00	47.31	52.69
A523A524	Landfill/dredging/sand extraction	0.42	0.00	1.80	0.91	0.00	1.92	0.43	0.00	1.25	0.00	8.76	91.24
A523A524	Polution by fish farming	0.26	0.00	1.11	0.78	0.00	1.66	0.31	0.00	0.70	0.00	0.00	100.00
A523A524	Harbor activities	0.87	0.00	2.47	1.33	0.00	1.87	0.74	0.00	1.80	0.00	26.87	73.13
A523A524	Contamination by heavy metals	0.00	0.00	1.50	0.00	0.00	1.23	0.00	0.00	0.58	0.00	0.00	100.00
A523A524	Invasive species	0.00	0.00	1.88	0.00	0.00	1.41	0.00	0.00	1.02	0.00	0.12	99.88
A523A524	Irrigation (loss of freshwater discharge)	1.21	0.86	1.38	1.60	0.72	1.66	0.71	0.00	0.80	0.00	0.00	100.00
A523A524	Marine and estuary navigation traffic	2.27	1.58	2.33	1.81	0.93	1.86	1.60	0.66	1.68	0.00	92.06	7.94
A523A524	Organic enrichment due to Nitrogen increase	0.00	0.00	1.60	0.00	0.00	1.46	0.00	0.00	0.80	0.00	0.00	100.00
A523A524	Organic enrichment due to Phosphorus increase	0.00	0.00	1.60	0.00	0.00	1.46	0.00	0.00	0.80	0.00	0.00	100.00
A523A524	Sea level changes	1.52	1.49	2.63	1.78	1.05	1.83	1.01	0.52	1.93	0.00	91.82	8.18
A523A524	Tourism activities	0.58	0.00	2.00	0.51	0.00	1.86	0.39	0.00	1.40	0.00	29.21	70.79
A525A526	All stressors	0.56	0.24	1.03	0.69	0.36	0.76	0.43	0.09	0.76	0.00	0.00	100.00
A525A526	Fishing: recreative, commercial	2.64	0.00	2.67	1.52	0.00	1.54	1.83	0.00	1.86	0.00	97.96	2.04
A525A526	Coastal erosion	0.07	0.00	2.10	0.13	0.00	1.49	0.04	0.00	1.28	0.00	0.09	99.91
A525A526	Landfill/dredging/sand extraction	0.15	0.00	1.68	0.36	0.00	1.55	0.14	0.00	0.93	0.00	0.00	100.00
A525A526	Polution by fish farming	0.02	0.00	0.81	0.10	0.00	1.55	0.04	0.00	0.59	0.00	0.00	100.00
A525A526	Harbor activities	0.23	0.00	2.14	0.48	0.00	1.67	0.22	0.00	1.40	0.00	2.06	97.94
A525A526	Contamination by heavy metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Invasive species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Irrigation (loss of freshwater discharge)	0.98	0.62	1.33	1.53	0.62	1.55	0.59	0.00	0.68	0.00	0.00	100.00
A525A526	Marine and estuary navigation traffic	2.32	1.63	2.33	1.95	1.11	1.97	1.73	0.67	1.75	0.00	98.63	1.37
A525A526	Organic enrichment due to Nitrogen increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Organic enrichment due to Phosphorus increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
A525A526	Sea level changes	1.50	1.49	1.50	1.73	0.97	1.74	0.94	0.51	0.95	0.00	0.00	100.00
A525A526	Tourism activities	0.03	0.00	2.00	0.02	0.00	1.69	0.02	0.00	1.29	0.00	1.32	98.68
A52_	All stressors	1.11	0.88	1.98	1.16	0.92	1.78	0.84	0.50	1.45	0.00	10.99	89.01
A52_	Fishing: recreative, commercial	2.67	2.67	2.67	1.60	1.24	1.71	1.89	1.79	1.92	0.00	100.00	0.00
A52_	Coastal erosion	1.75	0.65	2.33	1.85	1.14	2.21	1.25	0.15	1.91	0.00	71.43	28.57
A52_	Landfill/dredging/sand extraction	1.56	0.84	1.80	1.76	1.09	1.96	1.04	0.10	1.33	0.00	61.54	38.46
A52_	Polution by fish farming	0.28	0.00	0.81	1.27	0.00	1.63	0.41	0.00	0.67	0.00	0.00	100.00
A52_	Harbor activities	1.94	1.38	2.47	1.72	1.12	1.93	1.30	0.42	1.73	0.00	91.21	8.79
A52_	Contamination by heavy metals	0.20	0.00	1.88	0.19	0.00	1.74	0.12	0.00	1.22	0.00	4.40	95.60
A52_	Invasive species	0.29	0.00	2.25	0.22	0.00	1.82	0.18	0.00	1.59	0.00	10.99	89.01
A52_	Irrigation (loss of freshwater discharge)	1.25	1.17	1.34	1.39	0.89	1.54	0.55	0.18	0.67	0.00	0.00	100.00
A52_	Marine and estuary navigation traffic	2.22	1.63	2.67	1.67	1.17	1.82	1.49	0.69	1.97	0.00	82.42	17.58
A52_	Organic enrichment due to Nitrogen increase	0.26	0.00	2.80	0.23	0.00	2.08	0.20	0.00	2.23	5.49	4.40	90.11
A52_	Organic enrichment due to Phosphorus increase	0.19	0.00	1.60	0.23	0.00	2.08	0.14	0.00	1.31	0.00	9.89	90.11
A52_	Sea level changes	1.57	1.50	2.63	2.08	1.68	2.21	1.33	0.89	2.15	1.10	83.52	15.38
A52_	Tourism activities	1.58	0.00	2.00	1.24	0.00	1.75	0.99	0.00	1.33	0.00	79.12	20.88
A53	All stressors	1.51	0.72	1.96	1.12	0.54	1.38	0.91	0.37	1.27	0.00	29.61	70.39
A53	Fishing: recreative, commercial	1.88	0.00	2.00	1.32	0.00	1.49	1.04	0.00	1.18	0.00	72.37	27.63
A53	Coastal erosion	0.37	0.00	2.10	0.29	0.00	1.49	0.15	0.00	1.17	0.00	2.63	97.37
A53	Landfill/dredging/sand extraction	1.03	0.09	1.80	1.40	0.77	1.73	0.68	0.00	1.15	0.00	23.68	76.32
A53	Polution by fish farming	1.49	0.81	2.80	1.34	0.58	1.55	0.72	0.00	2.00	0.00	11.18	88.82
A53	Harbor activities	1.89	0.62	2.60	1.54	0.85	1.84	1.22	0.00	1.91	0.00	59.21	40.79
A53	Contamination by heavy metals	1.57	0.00	2.25	1.42	0.00	1.79	0.98	0.00	1.57	0.00	53.95	46.05
A53	Invasive species	1.66	0.00	2.25	1.25	0.00	1.77	1.07	0.00	1.56	0.00	69.74	30.26
A53	Irrigation (loss of freshwater discharge)	1.51	1.32	2.67	1.56	0.79	1.79	0.87	0.34	1.81	0.00	26.97	73.03
A53	Marine and estuary navigation traffic	2.01	1.63	2.67	1.27	0.58	1.45	1.15	0.66	1.83	0.00	53.95	46.05
A53	Organic enrichment due to Nitrogen increase	1.85	0.00	2.80	1.57	0.00	1.90	1.30	0.00	2.14	19.74	57.89	22.37
A53	Organic enrichment due to Phosphorus increase	1.41	0.00	1.60	1.44	0.00	1.76	0.83	0.00	1.02	0.00	65.79	34.21
A53	Sea level changes	2.12	1.49	2.63	1.49	0.88	1.66	1.35	0.51	1.86	0.00	63.16	36.84
A53	Tourism activities	0.74	0.00	2.00	0.43	0.00	1.50	0.42	0.00	1.19	0.00	36.84	63.16
A73	All stressors	0.59	0.24	1.93	0.63	0.28	1.30	0.44	0.09	1.26	0.00	0.08	99.92
A73	Fishing: recreative, commercial	2.64	0.00	2.67	1.68	0.00	1.70	1.89	0.00	1.92	0.00	98.21	1.79
A73	Coastal erosion	0.26	0.00	2.33	0.28	0.00	1.48	0.14	0.00	1.50	0.00	5.06	94.94
A73	Landfill/dredging/sand extraction	0.19	0.00	1.80	0.40	0.00	1.52	0.15	0.00	1.01	0.00	0.06	99.94
A73	Polution by fish farming	0.05	0.00	1.06	0.18	0.00	1.52	0.06	0.00	0.55	0.00	0.00	100.00

A73	Harbor activities	0.31	0.00	2.47	0.56	0.00	1.64	0.26	0.00	1.69	0.00	3.93	96.07
A73	Contamination by heavy metals	0.00	0.00	1.88	0.00	0.00	1.85	0.00	0.00	1.30	0.00	0.08	99.92
A73	Invasive species	0.00	0.00	2.25	0.00	0.00	2.07	0.00	0.00	1.74	0.00	0.08	99.92
A73	Irrigation (loss of freshwater discharge)	1.01	0.62	1.38	1.49	0.52	1.52	0.55	0.00	0.68	0.00	0.00	100.00
A73	Marine and estuary navigation traffic	2.31	1.63	2.67	1.80	0.89	1.83	1.64	0.66	1.82	0.00	97.65	2.35
A73	Organic enrichment due to Nitrogen increase	0.00	0.00	2.80	0.00	0.00	1.82	0.00	0.00	2.10	0.02	0.06	99.92
A73	Organic enrichment due to Phosphorus increase	0.00	0.00	1.60	0.00	0.00	1.82	0.00	0.00	1.08	0.00	0.06	99.94
A73	Sea level changes	1.51	1.49	2.63	1.71	0.90	1.73	0.93	0.51	1.89	0.00	0.67	99.33
A73	Tourism activities	0.12	0.00	2.00	0.09	0.00	1.67	0.07	0.00	1.27	0.00	5.86	94.14
A74	All stressors	1.31	0.29	1.84	1.19	0.47	1.43	0.84	0.15	1.29	0.00	38.15	61.85
A74	Fishing: recreative, commercial	1.81	0.00	2.00	1.45	0.00	1.73	1.09	0.00	1.31	0.00	77.38	22.62
A74	Coastal erosion	0.05	0.00	0.86	0.12	0.00	1.32	0.02	0.00	0.34	0.00	0.00	100.00
A74	Landfill/dredging/sand extraction	0.57	0.00	1.74	1.12	0.00	1.80	0.45	0.00	1.16	0.00	2.18	97.82
A74	Polution by fish farming	1.48	0.16	2.80	1.57	0.56	1.89	0.90	0.00	2.13	4.09	51.77	44.14
A74	Harbor activities	1.32	0.00	2.60	1.28	0.00	1.85	0.89	0.00	1.92	0.00	46.59	53.41
A74	Contamination by heavy metals	1.51	0.00	2.25	1.35	0.00	1.85	0.94	0.00	1.61	0.00	65.12	34.88
A74	Invasive species	1.15	0.00	2.25	0.92	0.00	1.81	0.76	0.00	1.58	0.00	52.32	47.68
A74	Irrigation (loss of freshwater discharge)	1.73	1.39	2.67	1.73	0.96	2.04	1.21	0.43	2.08	1.63	76.84	21.53
A74	Marine and estuary navigation traffic	1.88	1.63	2.33	1.47	0.74	1.74	1.12	0.66	1.62	0.00	72.75	27.25
A74	Organic enrichment due to Nitrogen increase	1.55	0.00	2.80	1.38	0.00	1.85	0.98	0.00	2.11	0.54	64.85	34.60
A74	Organic enrichment due to Phosphorus increase	1.33	0.00	1.60	1.38	0.00	1.85	0.81	0.00	1.10	0.00	52.86	47.14
A74	Sea level changes	2.18	1.49	2.63	1.75	1.14	1.97	1.52	0.54	2.01	34.60	44.14	21.25
A74	Tourism activities	0.28	0.00	2.00	0.20	0.00	1.67	0.17	0.00	1.27	0.00	14.17	85.83
A76	All stressors	1.39	0.82	2.10	1.19	0.84	1.47	0.83	0.29	1.52	0.00	31.52	68.48
A76	Fishing: recreative, commercial	1.76	0.00	2.67	1.32	0.00	1.79	1.03	0.00	1.96	0.00	64.57	35.43
A76	Coastal erosion	0.21	0.00	2.33	0.18	0.00	1.55	0.10	0.00	1.53	0.00	4.67	95.33
A76	Landfill/dredging/sand extraction	0.57	0.00	1.80	0.68	0.00	1.89	0.40	0.00	1.27	0.00	20.10	79.90
A76	Polution by fish farming	0.61	0.00	2.80	0.88	0.00	1.96	0.42	0.00	2.17	0.76	22.38	76.86
A76	Harbor activities	0.85	0.00	2.60	0.73	0.00	1.93	0.61	0.00	1.96	0.00	32.48	67.52
A76	Contamination by heavy metals	1.71	0.00	1.88	1.43	0.00	1.93	0.97	0.00	1.36	0.00	52.10	47.90
A76	Invasive species	1.40	0.00	3.00	0.93	0.00	1.89	0.94	0.00	2.20	12.95	39.33	47.71
A76	Irrigation (loss of freshwater discharge)	1.88	1.25	2.67	1.62	1.00	2.11	1.25	0.32	2.12	1.62	81.24	17.14
A76	Marine and estuary navigation traffic	1.95	1.61	2.67	1.35	0.81	1.81	1.14	0.64	1.97	0.00	61.05	38.95
A76	Organic enrichment due to Nitrogen increase	2.28	1.60	2.80	1.53	1.09	1.91	1.51	0.64	2.14	45.33	16.86	37.81
A76	Organic enrichment due to Phosphorus increase	1.60	1.60	1.60	1.53	1.09	1.91	0.90	0.64	1.16	0.00	33.14	66.86
A76	Sea level changes	1.80	1.49	2.63	1.65	1.20	2.03	1.15	0.56	2.04	9.05	40.76	50.19
A76	Tourism activities	0.58	0.00	2.00	0.41	0.00	1.74	0.35	0.00	1.32	0.00	28.95	71.05
B12	All stressors	0.86	0.27	2.07	0.92	0.50	1.47	0.54	0.06	1.49	0.00	5.85	94.15
B12	Fishing: recreative, commercial	1.03	0.00	2.67	0.53	0.00	1.43	0.62	0.00	1.82	0.00	26.32	73.68
B12	Coastal erosion	2.20	0.84	2.33	1.66	0.81	2.13	1.48	0.00	1.85	0.00	93.57	6.43
B12	Landfill/dredging/sand extraction	0.76	0.00	1.80	0.85	0.00	1.90	0.34	0.00	1.28	0.00	6.73	93.27
B12	Polution by fish farming	0.36	0.00	1.21	0.68	0.00	1.63	0.12	0.00	0.67	0.00	0.00	100.00
B12	Harbor activities	1.28	0.00	2.60	1.09	0.00	2.07	0.76	0.00	1.99	0.00	40.35	59.65
B12	Contamination by heavy metals	0.12	0.00	1.88	0.11	0.00	1.79	0.07	0.00	1.25	0.00	3.22	96.78
B12	Invasive species	0.15	0.00	2.25	0.11	0.00	1.77	0.09	0.00	1.56	0.00	6.14	93.86
B12	Irrigation (loss of freshwater discharge)	1.25	0.80	1.39	1.15	0.71	1.72	0.40	0.00	0.86	0.00	0.00	100.00
B12	Marine and estuary navigation traffic	1.66	0.47	2.67	1.16	0.66	1.70	0.78	0.00	1.92	0.00	17.25	82.75
B12	Organic enrichment due to Nitrogen increase	0.16	0.00	2.80	0.11	0.00	1.75	0.10	0.00	2.07	2.63	2.34	95.03
B12	Organic enrichment due to Phosphorus increase	0.11	0.00	1.60	0.11	0.00	1.75	0.06	0.00	1.02	0.00	3.80	96.20
B12	Sea level changes	1.85	1.42	2.63	1.92	1.57	2.34	1.38	0.74	2.24	21.05	49.71	29.24
B12	Tourism activities	1.46	0.00	2.00	0.99	0.00	1.89	0.85	0.00	1.42	0.00	73.10	26.90
J5111	All stressors	0.86	0.45	1.67	1.11	0.66	1.58	0.62	0.20	1.17	0.00	3.66	96.34
J5111	Fishing: recreative, commercial	1.75	0.00	2.00	1.77	0.00	2.09	1.25	0.00	1.57	0.00	91.53	8.47
J5111	Coastal erosion	0.00	0.00	0.18	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	100.00
J5111	Landfill/dredging/sand extraction	0.82	0.00	1.74	1.29	0.00	1.81	0.48	0.00	1.17	0.00	3.20	96.80
J5111	Polution by fish farming	1.83	1.52	2.80	1.73	0.99	1.96	1.21	0.58	2.17	1.37	85.35	13.27
J5111	Harbor activities	1.55	0.44	2.51	1.46	0.64	1.75	0.87	0.00	1.79	0.00	35.93	64.07
J5111	Contamination by heavy metals	0.15	0.00	1.88	0.15	0.00	1.81	0.09	0.00	1.26	0.00	6.18	93.82
J5111	Invasive species	0.13	0.00	2.25	0.10	0.00	1.82	0.09	0.00	1.59	0.00	6.18	93.82
J5111	Irrigation (loss of freshwater discharge)	1.56	1.44	2.67	1.90	1.13	2.17	1.14	0.50	1.94	0.00	63.39	36.61
J5111	Marine and estuary navigation traffic	1.53	1.29	2.00	1.50	0.74	1.75	0.79	0.36	1.33	0.00	14.87	85.13
J5111	Organic enrichment due to Nitrogen increase	0.17	0.00	2.80	0.15	0.00	1.85	0.11	0.00	2.11	0.92	5.95	93.14
J5111	Organic enrichment due to Phosphorus increase	0.14	0.00	1.60	0.16	0.00	1.97	0.10	0.00	1.21	0.00	5.72	94.28
J5111	Sea level changes	2.40	1.49	2.63	2.01	1.40	2.21	1.85	0.67	2.15	30.21	67.05	2.75
J5111	Tourism activities	0.08	0.00	2.00	0.06	0.00	1.75	0.05	0.00	1.33	0.00	4.12	95.88
J5111_	All stressors	0.99	0.49	1.82	1.21	0.88	1.67	0.76	0.34	1.30	0.00	13.40	86.60
J5111_	Fishing: recreative, commercial	1.88	0.00	2.00	1.96	0.00	2.09	1.43	0.00	1.57	0.00	95.04	4.96
J5111_	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
J5111_	Landfill/dredging/sand extraction	0.77	0.00	1.80	1.43	0.00	1.75	0.61	0.00	1.16	0.00	11.91	88.09
J5111_	Polution by fish farming	2.09	1.55	2.80	1.88	0.99	1.96	1.53	0.58	2.17	22.83	68.73	8.44
J5111_	Harbor activities	1.46	0.00	2.60	1.57	0.00	1.76	0.96	0.00	1.88	0.00	37.97	62.03
J5111_	Contamination by heavy metals	0.43	0.00	2.25	0.44	0.00	1.81	0.28	0.00	1.58	0.00	23.82	76.18
J5111_	Invasive species	0.25	0.00	2.25	0.22	0.00	1.82	0.17	0.00	1.59	0.00	12.41	87.59
J5111_	Irrigation (loss of freshwater discharge)	1.62	1.42	2.67	2.06	1.12	2.18	1.32	0.47	2.17	2.73	87.10	10.17
J5111_	Marine and estuary navigation traffic	1.63	1.31	2.67	1.66	0.77	1.75	0.99	0.52	1.94	0.00	48.64	51.36
J5111_	Organic enrichment due to Nitrogen increase	0.46	0.00	2.80	0.48	0.00	1.97	0.34	0.00	2.17	1.74	22.33	75.93
J5111_	Organic enrichment due to Phosphorus increase	0.40	0.00	1.60	0.48	0.00	1.97	0.29	0.00	1.21	0.00	21.34	78.66
J5111_	Sea level changes	2.42	1.50	2.63	2.14	1.41	2.21	1.95	0.69	2.15	53.35	45.41	1.24
J5111_	Tourism activities	0.09	0.00	2.00	0.07	0.00	1.75	0.06	0.00	1.33	0.00	4.71	95.29
J5112	All stressors	0.82	0.38	1.73	0.77	0.51	1.27	0.56	0.15	1.21	0.00	2.24	97.76
J5112	Fishing: recreative, commercial	1.24	0.00	2.00	0.77	0.00	1.26	0.62	0.00	1.10	0.00	34.00	66.00
J5112	Coastal erosion	0.00	0.00	0.45	0.01	0.00	1.26	0.00	0.00	0.28	0.00	0.00	100.00
J5112	Landfill/dredging/sand extraction	0.64	0.00	1.80	1.04	0.00	1.54	0.37	0.00	1.02	0.00	0.37	99.63
J5112	Polution by fish farming	1.70	1.33	2.80	1.66	0.81	1.82	1.07	0.35	2.10	2.37	71.73	25.90
J5112	Harbor activities	1.31	0.00	2.60	1.41	0.00	1.65	0.80	0.00	1.83	0.00	30.51	69.49
J5112	Contamination by heavy metals	0.27	0.00	2.25	0.27	0.00	1.81	0.17	0.00	1.58	0.00	13.20	86.80
J5112	Invasive species	0.17	0.00	2.25	0.14	0.00	1.82	0.11	0.00	1.59	0.00	7.97	92.03
J5112	Irrigation (loss of freshwater discharge)	1.61	1.43	2.67	1.72	0.88	1.89	1.04	0.47	2.01	1.12	73.97	24.91
J5112	Marine and estuary navigation traffic	1.57	1.25	2.67	1.38	0.57	1.54	0.77	0.27	1.86	0.00	6.48	93.52
J5112	Organic enrichment due to Nitrogen increase	0.29	0.00	2.80	0.30	0.00	1.97	0.21	0.00	2.17	1.49	11.71	86.80
J5112	Organic enrichment due to Phosphorus increase	0.25	0.00	1.60	0.30	0.00	1.97	0.18	0.00	1.21	0.00	11.58	88.42
J5112	Sea level changes	2.35	1.49	2.63	2.08	1.40	2.21	1.86	0.67	2.15	43.59	51.18	5.23
J5112	Tourism activities	0.12	0.00	2.00	0.09	0.00	1.82	0.07	0.00	1.37	0.00	5.85	94.15

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

E_MEAN – Mean exposure value; E_MIN - Minimum exposure value; E_MAX – Maximum exposure value; C_MEAN – Mean consequence value; C_MIN – Minimum consequence value; C_MAX – Maximum consequence value; R_MEAN - Cumulative mean risk value; R_MIN – Cumulative minimum risk value; R_MAX – Cumulative maximum risk value; R_%HIGH – Percentage of area under high risk; R_%MEDIUM – Percentage of area under medium risk; R_%LOW – Percentage of area nder low risk.

Table C8. Spearman correlation among variables for the HRA-1 model (non-modified InVEST/HRA model). R values are listed below the diagonal. P-values are listed above the diagonal.

	E_MEAN	E_MIN	**E_MAX**	C_MEAN	C_MIN	C_MAX	R_MEAN	R_MIN	R_MAX
E_MEAN		0.00	0.01	0.00	0.23	0.03	0.00	0.01	0.00
E_MIN	0.67 *		0.55	0.00	0.00	0.04	0.00	0.00	0.02
E_MAX	0.52 *	0.14		0.15	0.35	0.25	0.12	0.60	0.00
C_MEAN	0.87 *	0.71 *	0.32		0.01	0.01	0.00	0.00	0.00
C_MIN	0.27	0.72 *	-0.21	0.54 *		0.02	0.06	0.00	0.18
C_MAX	0.46 *	0.44 *	0.26	0.57 *	0.50 *		0.05	0.02	0.00
R_MEAN	0.95 *	0.77 *	0.34	0.87 *	0.41	0.42		0.00	0.00
R_MIN	0.54 *	0.90 *	-0.12	0.66 *	0.88 *	0.48 *	0.70 *		0.08
R_MAX	0.74 *	0.48 *	0.71	0.62 *	0.29	0.58 *	0.68 *	0.38	

* p-value < 0.05

E_MEAN – Mean exposure value; E_MIN - Minimum exposure value; E_MAX – Maximum exposure value; C_MEAN – Mean consequence value; C_MIN – Minimum consequence value; C_MAX – Maximum consequence value; R_MEAN - Cumulative mean risk value; R_MIN – Cumulative minimum risk value; R_MAX – Cumulative maximum risk value.

Table C9. Spearman correlation among variables for the HRA_ES-2 model (modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience. R values are listed below the diagonal. P-values are listed above the diagonal.

	E_MEAN	**E_MIN**	**E_MAX**	**C_MEAN**	**C_MIN**	**C_MAX**	**R_MEAN**	**R_MIN**	**R_MAX**
E_MEAN		0.00	0.01	0.00	0.09	0.02	0.00	0.00	0.00
E_MIN	0.74 *		0.22	0.00	0.00	0.06	0.00	0.00	0.04
E_MAX	0.57 *	0.27		0.17	0.92	0.08	0.17	0.48	0.00
C_MEAN	0.87 *	0.75 *	0.30		0.00	0.00	0.00	0.00	0.00
C_MIN	0.37	0.72 *	-0.02	0.65 *		0.00	0.02	0.00	0.17
C_MAX	0.50 *	0.41	0.39	0.59 *	0.61 *		0.08	0.03	0.00
R_MEAN	0.91 *	0.85 *	0.30	0.88 *	0.49 *	0.38		0.00	0.02
R_MIN	0.74 *	0.93 *	0.16	0.80 *	0.75 *	0.47 *	0.87 *		0.07
R_MAX	0.72 *	0.44 *	0.83 *	0.58 *	0.31	0.60 *	0.49 *	0.40	

* p-value <0.05

E_MEAN – Mean exposure value; E_MIN - Minimum exposure value; E_MAX – Maximum exposure value; C_MEAN – Mean consequence value; C_MIN – Minimum consequence value; C_MAX – Maximum consequence value; R_MEAN - Cumulative mean risk value; R_MIN – Cumulative minimum risk value; R_MAX – Cumulative maximum risk value.

Table C10. Magnitude and direction of PCA coefficients for the HRA-1 model. The total variance explained by each component is between brackets. The values indicate the coefficient magnitude: the larger the magnitude, the more important the corresponding approach is in calculating the component. The positive and negative signs indicate the coefficient direction and whether there is a positive or negative association with the PCA component.

	PCA components			
	PC1 (60.8%)	PC2 (22.6%)	PC3 (10.2%)	PC4 (4.5%)
E_MEAN	0.53 *	0.00	-0.62 *	0.05
E_MIN	0.33	0.39	0.18	0.53 *
E_MAX	0.33	-0.66 *	0.13	0.42
C_MEAN	0.41	0.13	-0.10	-0.53 *
C_MIN	0.20	0.39	0.43	0.04
C_MAX	0.32	-0.25	0.53 *	-0.47
R_MEAN	0.31	0.12	-0.20	-0.09
R_MIN	0.20	0.32	0.17	0.13
R_MAX	0.24	-0.24	0.17	0.11

* variables with the highest loading coefficients (>0.50)

E_MEAN – Mean exposure value; E_MIN - Minimum exposure value; E_MAX – Maximum exposure value; C_MEAN – Mean consequence value; C_MIN – Minimum consequence value; C_MAX – Maximum consequence value; R_MEAN - Cumulative mean risk value; R_MIN – Cumulative minimum risk value; R_MAX – Cumulative maximum risk value.

Table C11. PCA scores from the first two components for the HRA-1 model. High factor scores in each compnent are associated to variables with high loadings in the same component, meaning that the habitats will tend to score higher on those variables.

Habitat	PC 1	PC 2
A1	-0.52	0.74
A2	0.01	-0.07
A21	0.73	0.13
A22	0.63	0.09
A23	0.46	0.04
A25	-0.21	-0.18
A26	1.02	0.85
A3A4	-0.78	0.65
A51	0.48	-0.22
A52	0.44	-0.44
A523A524	-0.66	-0.20
A525A526	-1.33	0.38
A52_	0.50	0.04
A53	0.38	-0.15
A73	-0.78	-0.50
A74	0.10	-0.24
A76	0.64	-0.03
B12	-0.11	-0.54
J5111	-0.11	0.04
J5111_	0.12	-0.10
J5112	-0.51	-0.14

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

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Table C12. Magnitude and direction of PCA coefficients for the HRA_ES-2 model. The total variance explained by each component is between brackets. The values indicate the coefficient magnitude: the larger the magnitude, the more important the corresponding approach is in calculating the component. The positive and negative signs indicate the coefficient direction and whether there is a positive or negative association with the PCA component.

	PCA components			
	PC1 (64.6%)	PC2 (20.6%)	PC3 (9.5%)	PC4 (3.1%)
E_MEAN	0.55 *	0.20	-0.53 *	-0.09
E_MIN	0.27	0.25	0.17	0.67 *
E_MAX	0.37	-0.69 *	-0.12	0.28
C_MEAN	0.37	0.23	0.11	-0.50 *
C_MIN	0.18	0.23	0.57 *	0.11
C_MAX	0.31	-0.28	0.51 *	-0.37
R_MEAN	0.33	0.23	-0.21	-0.07
R_MIN	0.22	0.25	0.16	0.24
R_MAX	0.26	-0.35	0.06	0.05

***** variables with the highest loading coefficients (>0.50)

E_MEAN – Mean exposure value; E_MIN - Minimum exposure value; E_MAX – Maximum exposure value; C_MEAN – Mean consequence value; C_MIN – Minimum consequence value; C_MAX – Maximum consequence value; R_MEAN - Cumulative mean risk value; R_MIN – Cumulative minimum risk value; R_MAX – Cumulative maximum risk value.

Table C13. PCA scores from the first two components for the HRA_ES-2 model. High factor scores in each compnent are associated to variables with high loadings in the same component, meaning that the habitats will tend to score higher on those variables.

Habitat	PC 1	PC 2
A1	-0.60	0.62
A2	-0.08	-0.24
A21	0.89	0.37
A22	0.63	0.16
A23	0.49	0.22
A25	-0.25	-0.27
A26	0.68	0.48
A3A4	-0.87	0.65
A51	0.53	-0.07
A52	0.57	-0.15
A523A524	-0.66	-0.12
A525A526	-1.28	0.40
A52_	0.54	-0.09
A53	0.44	0.03
A73	-0.67	-0.58
A74	0.14	-0.12
A76	0.59	-0.13
B12	-0.17	-0.61
J5111	-0.17	-0.08
J5111_	0.18	-0.06
J5112	-0.46	-0.20

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

Table C14. Habitat risk values for different approaches: HRA_ES-2 (modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience), ViC (Vulnerability index based on the formulation proposed by Cabral et al. (2015); ViW (Vulnerability index based on the formulation proposed by Willaert et al. (2019) and RESS (Risk to ecosystem service supply based on the formulation proposed by Culhane et al. (2019).

Habitat	Raw data				Normalized data			
	HRA_ES-2	Vi_C	Vi_W	RESS	HRA_ES-2	Vi_C	Vi_W	RESS
A1	0.70	0.66	0.66	2.91	0.36	0.37	0.62	0.13
A2	0.68	0.00	0.00	0.95	0.34	0.00	0.00	0.01
A21	1.11	0.00	0.00	1.00	0.92	0.00	0.00	0.01
A22	1.02	0.87	0.87	7.77	0.80	0.49	0.82	0.45
A23	0.98	0.89	0.89	9.12	0.74	0.50	0.84	0.54
A25	0.59	0.63	0.63	2.68	0.22	0.35	0.59	0.12
A26	1.17	1.06	1.06	16.24	1.00	0.59	1.00	1.00
A3A4	0.62	0.59	0.59	2.42	0.26	0.33	0.55	0.10
A51	1.04	0.00	0.00	0.99	0.82	0.00	0.00	0.01
A52	1.04	1.79	0.45	1.96	0.82	1.00	0.42	0.07
A523A524	0.62	0.00	0.00	0.89	0.26	0.00	0.00	0.00
A525A526	0.43	0.00	0.00	0.83	0.00	0.00	0.00	0.00
A52_	0.84	0.00	0.00	0.97	0.55	0.00	0.00	0.01
A53	0.91	1.56	0.39	1.83	0.65	0.87	0.37	0.06
A73	0.44	0.33	0.33	1.49	0.01	0.18	0.31	0.04
A74	0.84	0.72	0.72	3.59	0.55	0.40	0.68	0.18
A76	0.83	0.81	0.81	5.17	0.54	0.45	0.76	0.28
B12	0.54	0.58	0.58	2.38	0.15	0.32	0.55	0.10
J5111	0.62	0.57	0.57	2.31	0.26	0.32	0.53	0.10
J5111_	0.76	0.65	0.65	2.83	0.45	0.36	0.61	0.13
J5112	0.56	0.46	0.46	1.87	0.18	0.26	0.44	0.07

A1 - Coastal rocky middle and supralittoral areas; A2 - Coastal supralittoral sedimentary areas; A21 - Estuarine littoral granule, very coarse to coarse sands; A22 - Estuarine littoral sandy mud and very fine to medium sands; A23 - Estuarine littoral mud; A25 - Estuarine saltmarshes; A26 - Estuarine seagrass bed; A3A4 - Infra and circalittoral rocky areas; A51 - Estuarine sublittoral granule and very coarse to coarse sands; A52 - Estuarine sublittoral sandy mud and very fine to medium sands; A52_ - Infralittoral or circalittoral sedimentary areas; A523A524 -- Infralittoral fine sand or infralittoral muddy sand areas; A525A526 - Circalittoral fine sand or muddy sand areas; A53 - Estuarine sublittoral mud; B12 – Sandy beaches; J51511 - Water ponds; J5111_ – Aquaculture tanks; J5112 – Saltworks; A73 - Marine pelagic (0-200) waters;A74 - Estuarine pelagic waters of the South Mondego branch and Pranto River; A76 - Estuarine pelagic waters of the North branch of the Mondego River and upstream system.

HRA_ES-2 – modified InVEST/HRA model to include ecosystem services' abundance as a descriptor of resilience.
ViC - model proposed by Cabral et al. (2015); ViW – model proposed by Willaert et al. (2019); RESS – model proposed by Culhane et al. (2019).

Table C15. Scenarios analysis. Habitat risk assessment results based on management scenarios for saltmarsh (A2.5) and Seagrass (A2.6) habitats.

		Cumulative mean risk (R-Mean)			% High risk area			% Medium risk area			% Low risk area		
HABITAT	STRESSOR	Current	Scenario 1	Scenario 2	Current	Scenario 1	Scenario 2	Current	Scenario 1	Scenario 2	Current	Scenario 1	Scenario 2
Saltmarshes (A2.5)	All stressors	0.59	0.57	0.52	0.00	0.00	0.00	7.97	7.33	5.60	92.03	92.67	94.40
	Fishing: recreative, commercial	0.91	0.91	0.68	0.00	0.00	0.00	62.72	62.72	11.64	37.28	37.28	88.36
	Coastal erosion	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00	100.00
	Landfill/dredging/sand extraction	0.14	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00	100.00
	Polution by fish farming	0.53	0.53	0.53	1.72	1.72	1.72	12.93	12.93	12.93	85.34	85.34	85.34
	Harbor activities	0.28	0.28	0.28	0.00	0.00	0.00	4.96	4.96	4.96	95.04	95.04	95.04
	Contamination by heavy metals	0.42	0.42	0.42	0.00	0.00	0.00	21.12	21.12	21.12	78.88	78.88	78.88
	Invasive sp	0.49	0.49	0.49	5.17	5.17	5.17	28.02	28.02	28.02	66.81	66.81	66.81
	Irrigation (loss of fresh water discharge)	1.34	1.34	1.13	5.60	5.60	0.00	81.90	81.90	42.67	12.50	12.50	57.33
	Marine and estuary navigation traffic	0.84	0.84	0.84	0.00	0.00	0.00	24.78	24.78	24.78	75.22	75.22	75.22
	Organic enrichment due to Nitrogen increase	0.59	0.59	0.54	14.87	14.87	4.31	20.47	20.47	18.75	64.66	64.66	76.94
	Organic enrichment due to Phosphorus increase	0.43	0.43	0.43	0.00	0.00	0.00	33.62	33.62	33.62	66.38	66.38	66.38
	Sea level changes	1.57	1.40	1.26	27.37	0.00	0.00	58.84	84.91	84.91	13.79	15.09	15.09
	Tourism activities	0.06	0.06	0.06	0.00	0.00	0.00	5.17	5.17	5.17	94.83	94.83	94.83
Seagrasses (A2.6)	All stressors	1.17	1.15	1.03	0.00	0.00	0.00	95.83	95.83	72.92	4.17	4.17	27.08
	Fishing: recreative, commercial	1.32	1.32	1.07	0.00	0.00	0.00	100.00	100.00	85.42	0.00	0.00	14.58
	Coastal erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00	100.00
	Landfill/dredging/sand extraction	1.00	1.00	1.00	0.00	0.00	0.00	58.33	58.33	58.33	41.67	41.67	41.67
	Polution by fish farming	1.11	1.11	1.02	0.00	0.00	0.00	93.75	93.75	93.75	6.25	6.25	6.25
	Harbor activities	1.45	1.45	1.26	0.00	0.00	0.00	100.00	100.00	100.00	0.00	0.00	0.00
	Contamination by heavy metals	1.51	1.51	1.28	0.00	0.00	0.00	97.92	97.92	95.83	2.08	2.08	4.17
	Invasive sp	0.94	0.94	0.77	0.00	0.00	0.00	56.25	56.25	56.25	43.75	43.75	43.75
	Irrigation (loss of fresh water discharge)	1.35	1.35	1.25	0.00	0.00	0.00	95.83	95.83	93.75	4.17	4.17	6.25
	Marine and estuary navigation traffic	1.43	1.43	1.19	0.00	0.00	0.00	97.92	97.92	93.75	2.08	2.08	6.25
	Organic enrichment due to Nitrogen increase	1.76	1.76	1.62	25.00	25.00	25.00	72.92	72.92	72.92	2.08	2.08	2.08
	Organic enrichment due to Phosphorus increase	1.38	1.38	1.30	0.00	0.00	0.00	97.92	97.92	97.92	2.08	2.08	2.08
	Sea level changes	1.93	1.74	1.58	39.58	0.00	0.00	60.42	100.00	100.00	0.00	0.00	0.00
	Tourism activities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00	100.00

Current – HRA_ES-2 model; Scenario 1 - One stressor management scenario; Scenario 2 - Multiple stressor management scenario.

3. Appendix C | References

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