Universidade de Aveiro
2021

MARIA DA LUZ BANDEIRA RODRIGUES FERNANDES

MODELOS DE PADRÕES ESPACIAIS COMO APOIO AO ORDENAMENTO DO ESPAÇO MARÍTIMO PORTUGUÊS

SPATIAL PATTERNS MODELS TO SUPPORT THE PORTUGUESE MARITIME SPATIAL PLANNING

Universidade de Aveiro
2021

MARIA DA LUZ
BANDEIRA
RODRIGUES
FERNANDES

MODELOS DE PADRÕES ESPACIAIS COMO APOIO AO ORDENAMENTO DO ESPAÇO MARÍTIMO PORTUGUÊS

SPATIAL PATTERNS MODELS TO SUPPORT THE PORTUGUESE MARITIME SPATIAL PLANNING

Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Ciência, Tecnologia e Gestão do Mar, realizada sob a orientação científica da Doutora Maria de Fátima Lopes Alves, Professora Auxiliar com Agregação do Departamento de Ambiente e Ordenamento da Universidade de Aveiro e sob coorientação científica do Doutor Francisco Javier Sanz Larruga, Professor Catedrático da Universidade da Corunha.

Apoio financeiro da FCT e do FSE no âmbito do III Quadro Comunitário de Apoio através da Bolsa de Doutoramento com a referência PD/BD/113485/2015 e apoio no âmbito do Protocolo celebrado entre a Direção Geral dos Recursos Naturais e Marítimos (DGRM), para a elaboração do projeto de Avaliação Ambiental do Plano de Situação do Ordenamento do Espaço Marítimo Nacional.

o júri

presidente	Doutor Nuno Miguel Gonçalves Borges de Carvalho Professor Catedrático, Universidade de Aveiro
vogais	Doutor Javier Garcia Onetti Professor Sustituto Interino, Universidad de Cádiz
	Doutora Lia Maldonado Teles de Vasconcelos Professora Associada, Universidade Nova de Lisboa
	Doutora Cristina Brice Pita Investigadora Principal, Universidade de Aveiro
	Doutora Catarina Frazão da Fonseca Ribeiro dos Santos Investigadora, Universidade de Lisboa
	Doutora Maria de Fátima Lopes Alves Professora Auxiliar Convidada Com Agregação, Universidade de Aveiro (orientadora)

agradecimentos

Agradeço em primeiro lugar à Professora Fátima Alves que me trouxe para este desafio há já 8 anos e que sempre me motivou e incentivou a ter um olhar positivo e confiante sobre a investigação e sobre a vida! Agradeço a orientação, e a disponibilidade constante (sempre no seu gabinete com a porta aberta para nós), a liberdade para investigar, os desafios, a inspiração e entusiasmo que se sempre me trouxe. Agradeço também ao Professor Francisco Sanz Larruga por ter aceite este desafio e por me ter recebido na Corunha sempre com toda a disponibilidade.

Agradeço ao consórcio Campus Do*Mar por tornarem este programa doutoral possível e à FCT pela concessão da bolsa para produzir esta investigação.

Também a todos os colegas da 313 e do COPING; Lisa, Eduardo, Adriano, Márcia, Cristina, Tereza, aos que por lá passaram em determinados momentos da tese, em especial Tanya, Sílvia, Fábio, Johnny, Isabel, André e para os que chegaram mais recentemente ou que já saíram há mais algum tempo… muito obrigada por partilharem os bons momentos, mas também os de frustração e desespero, e por terem sempre um café, tempo disponível e uma palavra amiga para dar.

Agradeço à família Flor de Sal, a Carla, o Rubi e Anita pela amizade e por me ouvirem e porque no fundo temos crescido juntos ao longo destes anos e nas (in)decisões desta vida.

Agradeço ao meu tio Manelzinho por me ter introduzido à ciência e me ter mostrado como pode ser divertida e inteligível.

Um agradecimento especial ao meu irmão e aos meus pais. Ao meu irmão por me acompanhar sempre. Aos meus pais que por tudo o que fizeram por nós tornaram este doutoramento possível; obrigada por me terem apoiado e respeitado sempre as minhas decisões.

Por último obrigada ao Nuno por estar ao meu lado e me aturar, sempre com bom humor. Por me incentivar e apoiar em todos os momentos. Ao Miguel que apareceu algures no capítulo 3, tornando tudo mais difícil, mas também bem mais maravilhoso e gratificante.

palavras-chave

Ordenamento do Espaço Marítimo, Atividades e Usos, Avaliação Ambiental, Ferramentas de Apoio à Decisão.

resumo

O espaço marinho está cada vez mais ocupado conduzindo a pressões crescentes sobre as espécies e habitats. O quadro político marinho e costeiro está a reconhecer este facto e a utilizar o Ordenamento do Espaço Marítimo (OEM) como um instrumento para alcançar uma melhor gestão e planeamento integrados dos espaços marítimos. A Diretiva Europeia sobre Ordenamento do Espaço Marítimo (Diretiva 2014/89/UE) visa alcançar uma abordagem integrada da governação marinha, assegurando e mantendo simultaneamente o estado saudável das águas marinhas e costeiras, seguindo uma abordagem de Gestão Baseada em Ecossistemas (GBE). Além disso, os Estados Membros devem produzir planos até 2021. Em 2014, Portugal promulgou a lei que estabelece a Base do Espaço Marítimo Nacional e em 2015 seguiu-se o quadro para a elaboração do Plano de Ordenamento do Espaço Marítimo Nacional, denominado Plano de Situação. O Plano de Situação Português desenvolvido para o Continente, Madeira e Subdivisões da Plataforma Alargada foi aprovado em dezembro de 2019.

A principal contribuição desta tese é o desenvolvimento de um conjunto de padrões espaciais para abordar espaços costeiros e marinhos com informação comparável, afastando-se da abordagem sectorial ao mar. Os padrões são utilizados para classificar os espaços marítimos e recolher informações sobre potenciais oportunidades e desafios para o desenvolvimento das regiões. Esta tese desenvolve abordagens metodológicas para planeadores para apoiar o processo do OEM num contexto limitado de tempo e recursos, utilizando a Subdivisão Portuguesa do Continente como um estudo de caso. As abordagens são fáceis de utilizar, acessíveis e facilmente compreendidas por planeadores e decisores políticos. A maioria dos resultados foram produzidos sob a forma de mapas mostrando informação combinada, e em alguns casos, mostrando diferentes cenários para seleção das melhores opções disponíveis. O foco foi atribuído à conservação dos impactos ambientais e à avaliação sócio-ecológica, em linha com uma abordagem GBE. As ferramentas apresentadas nesta tese são úteis para fornecer ao OEM informações relevantes para apoiar uma abordagem GBE para a gestão dos oceanos.

keywords

Maritime Spatial Planning, Activities and Uses, Environmental assessment, Decision Support Tools.

abstract

Sea space is increasingly occupied and leading to rising pressures on species and habitats. Marine and coastal policy framework is acknowledging this fact and using Maritime Spatial Planning (MSP) as a tool for achieving a better integrated management and planning of maritime spaces. The European Directive on Maritime Spatial Planning (Directive 2014/89/EU) aims to achieve an integrated approach to marine governance, whilst securing and maintaining the healthy status of marine and coastal waters, following an Ecosystem Based Management Approach (EBM). Moreover, Member States must produce plans until 2021. In 2014, Portugal enacted the law establishing the Basis of the National Maritime Space and in 2015 followed the framework for elaboration of the national Maritime Spatial Plan, named as Situation Plan. The Portuguese Situation Plan, developed for Mainland, Madeira and Extended Platform Subdivisions was approved in December 2019.

This thesis' main contribution is the development of a set of spatial patterns for addressing coasts and seas with comparable information, moving away from the sectorial approach to the sea. The patterns are used to classify maritime spaces and gather evidence on potentials opportunities and challenges for the development of regions. Therefore, this thesis develops methodological approaches for planners and managers to support the MSP process in a time and resource data limited setting using the Portuguese Mainland Subdivision as a case study. The approaches are easy to use, accessible and easily understood by planners and decision-makers. Most of the outputs were produced in the forms of maps showing combined information, and in some cases, different scenarios for selection of best available options. The focus was given to environmental impacts conservation and socio-ecological assessment in line with an EBM approach. The tools presented in this thesis can be of value in the years to come to provide MSP with relevant information to support an EBM approach to the sea management of ocean uses.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SUPPLEMENTARY MATERIAL

LIST OF ACRONYMS

AML	Área Metropolitana de Lisboa
APA	Portuguese Environment Agency (Agência Portuguesa do Ambiente)
BLM	Boundary Length Modifier
BS	Best Solution
CBD	Convention on Biological Diversity
CIM	Cumulative Impacts Model
CZ	Contiguous Zone
CZPM	Coastal Zone Management Plans
DGRM	Directorate General for Natural Resources, Safety and Maritime Services (Direcção-Geral de Recursos Naturais, Segurança e Serviços Marítimos)
DST	Decision Support Tools
EBM	Ecosystem-Based Management
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ETRS 89	European Terrestrial Reference System 1989
EU	European Union
GES	Good Environmental Status
GIS	Geographic Information System
GVA	Gross Value Added
HCA	Hierarchical Cluster Analysis
ICNF	Institute for Nature Conservation and Forestry (Instituto da Conservação da Natureza e das Florestas)
ICZM	Integrated Coastal Zone Management

IMP	Integrated Maritime Policy
IPMA	Portuguese Institute for Sea and Atmosphere (Instituto Português do Mar e da Atmosfera)
LBOGEM	Basis for the Spatial Planning and Management of the National Maritime Space (Lei de Bases para o Ordenamento do Espaço Marítimo)
LBOGEM	Law for the Maritime Spatial Planning Framework (Lei de Bases do Ordenamento e Gestão do Espaço Marítimo Nacional)
MCL	Marine Clusters
MPA	Marine Protected Areas
MSEC	Marine Socio-Ecological Categories
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning
MSPD	Maritime Spatial Planning Directive
NOS	National Ocean Strategy
nMDS	non-Metric Multidimensional Scaling
NUTS	Nomenclature of Territorial Units for Statistical Purposes
PCA	Principal Component Analysis
PNPOT	National Land Use Policy Programme (Programa Nacional da Política d de Ordenamento do Território)
POEM	Plano de Ordenamento do Espaço Marítimo
PROT	Planos Regionais de Ordenamento do Território
PSOEM	Plano de Situação do Ordenamento do Espaço Marítimo
PU	Planning Units
RBMP	River Basin Management Plans
SCI	Sites of Community Importance

SCL	Socioeconomic Clusters
SEA	Strategic Environmental Assessment
SES	Social-Ecological Systems
SES	Socio-Ecological Systems
SPA	Special Protected Areas
SS	Summed Solution
SST	Sea Surface Temperature
TS	Territorial Sea
TUPEM	Private use Permit of the Maritime Space (Título de Utilização Privativa de Espaço Marítimo)
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
WFD	Water Framework Directive

1. INTRODUCTION

1.1. Background

MSP, a paradigm shift and the challenges ahead

With more than 70 countries pursuing initiatives on Maritime Spatial Planning (MSP) and with over 60 plans being developed at the national level, MSP is now a worldwide process (IOC-UNESCO, 2018). MSP is most commonly defined as "a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process". The concept evolved in the last decades since its notion was first advanced in the 1980s, at the Australian Great Barrier Reef, where zoning plans were created to accommodate conflicting uses and ensure the conservation of the ecosystems (Day, 2002; Ehler and Douvere, 2009). Its origins are rooted in nature conservation and the realization of the importance of marine ecosystem management due to the increasing awareness of the degradation and destruction the natural world was facing. More recently, already in the 2000s as seas were becoming more crowded with a growing interest in marine resources, it developed to an effective process to deal with conflicting uses to achieve both environmental, social and economic objectives. Several experiences took place around the world expanding from the marine protected areas management to multi-objective management of activities (Douvere, 2008). On the numbers from UNESCO in 2017, MSP is currently under development in over 66 countries around the world and is already in place (i.e., approved by the government) in 22 countries (Frazão Santos et al., 2018). In the coming years, it is expected that the remaining 44 will have their plans approved. Nevertheless, only a small part of these initiatives has been effectively implemented at the Exclusive Economic Zone (EEZ) and/or territorial sea (TS). Most of the countries rely on existing legislation to implement the plans and only a few have legislation that explicitly authorizes MSP (IOC-UNESCO, 2017).

At the European Union (EU) level, the EU Green Paper on Maritime Policy: ''*Toward a Future Maritime Policy for the Union: A European Vision for the Oceans and Seas*,' was the first document to address issues of reconciling the economic, social and environmental dimensions of the exploitation of the seas and oceans (Suárez de Vivero, 2007). The EU vision for an Integrated Maritime Policy (IMP) the Blue Growth Strategy and the EU "*Roadmap for MSP: Achieving Common Principles in the EU*" followed the lead, addressing the economic opportunities at sea but replacing the compartmentalized resource management with a holistic and integrated Ecosystem-Based Management (EBM) approach to human activities (Fernandes et al., 2013). The approach in EU was characterized by maximizing the economic opportunities of traditional uses, such as fishing and navigation, combined with the new emergent blue sectors, as renewable energies and aquaculture (Jay et al., 2013). It had in the Good Environmental Status (GES) launched by the Marine Strategy Framework Directive (MSFD, EU, 2008) its environmental pillar. Finally, in 2014, the MSP Directive was adopted by the EU Member States (Directive 2014/89/EU, EU, 2014) as a cross-cutting policy of IMP, to develop the integrated planning and management, embodied with the EBM. It establishes that coastal Member States must develop a national MSP by 2021 (EU, 2014).

The EBM approach, established before the emergence of MSP, has been present since its inception, in the marine conservation in Australia. It is its overarching principle in the EU Roadmap for MSP and has become widely accepted as a key framework for delivering sustainable development in both terrestrial, coastal and marine environment (Douvere and Ehler, 2009; EC, 2008). It is a paradigm shift from other traditional approaches focused on individual species on a small spatial scale and based on a short term-perspective (Ansong et al., 2017). EBM explicitly accounts for the interconnectedness within systems, recognizing the importance of interactions between many target species or key services, different scales (…) and integrates ecological, social, economic, and institutional perspectives (Mcleod et al., 2005). After all, sustainable development and management of global and regional resources are not an ecological problem, nor an economic or a social one. They are a combination of all three (Berkes et al., 2003). This is a fundamental principle of EMB, the individual ecosystem components (biological, physical, chemical, social, cultural, economic) are intrinsically linked to others within a coupled socio-ecological system (SES). EBM is fitting the approach at sea, as this is a different experience from terrestrial planning. As often pointed out, the sea is dynamic, due to its mobile physical and ecological characteristics, less constrained nature of human activities and weaker patterns of ownership of marine space and no human permanence or settlements (Jay, 2018).

After all, we are moving from individual species to ecosystems; from sectoral management agencies, we are now forward-looking to network of institutions, from separated management of research and static fixed plans we are evolving to soft spaces approaches and adaptive management based on monitoring, research, and continuous changes in plans according to state of the art knowledge. On the same basis we are no longer looking to individual activities but to use patterns, both in space and time (Blenckner et al., 2015; Kannen, 2014). Use patterns may be considered as various sea uses resulting in complexing patterns leading to preferences in resource use (Lange et al., 2010).

After the enormous progress made on MSP, a lot remains to be done. Charles Ehler, at the 2nd International Conference on Marine/Maritime Spatial Planning, in 2017 (IOC-UNESCO, 2017) highlighted the most relevant challenges ahead:

1. Integration of MSP into planning: namely on coordination and cooperation with authorities responsible for land use planning, and with sectoral management authorities and private sector;
2. Improving the sustainable economic development of activities: by restoring and maintaining ecosystem services that support it;
3. Planning for the future: thinking on spatial scenarios, where we want to go and how to get there;
4. Monitoring and evaluation of MSP plans: through improving indicators and definitions for measuring equity of the plans; Most often management objectives are often poorly specified and management actions are not linked to objectives making evaluation difficult;
5. Transboundary MSP: management actions in one jurisdiction affect others but there are not many experiences of transboundary MSP. EU encourages its approach at regional and sea basin level (see for example TPEA and SIMNORAT project in the Atlantic Basin, and Jay et al., 2016).
6. Climate change is opening new perspectives also to MSP: in the Arctic Ocean new pressures are arising from new development opportunities as hydrocarbon exploitation, shipping and fisheries. Integrated and transboundary MSP can help to improve the environmental and economic outcomes (Edwards and Evans, 2017).
7. Developing MSP as an effective area-based management process in the High Seas: as of 60% of the ocean lies outside of maritime jurisdiction MSP can be a practical tool for securing the sustainable exploitation of its resources while ensuring its environmental protection.

Indeed, MSP's major underlying challenge is ensuring the right balance between socioeconomic development and environmental protection. Frazão Santos et al. (2018) highlights "it needs a deep understanding of ecological processes, functions, interconnectivity, and the delivery of services and thus values". Research can play a major role in providing information to guide and support the decision-making process.

Decision Support Tools and MSP

To overcome the challenges mentioned by Ehler (IOC-UNESCO, 2017) and to assist the development of MSP, planners need to have accessible knowledge representing the different characteristics of the zones at stake, current and potential uses and their possible impacts on ecosystems and towards each other. In many cases, this means having spatially explicit tools that can help incorporate data from social, ecological and economic systems and transparently assess alternatives, trade-offs or evaluate progress towards management objectives (COC, 2011). Decision Support Tools (DST) are considered software-based instruments that provide support in the decision-making process (Pınarbaşı et al., 2017a). In general terms, these tools also save planners time, energy and resources (Gee et al., 2019), when the planning process is most often time and resource limited.

The operationalization of EBM in MSP is far from simple. The sea is dynamic and three dimensional, it remains a public good, where no people reside, but appreciated and valued by the public (Ansong et al., 2017; Domínguez-Tejo et al., 2016). It requires a deep understanding of how these ecosystems function and a better understanding of how humans use and value these environments (Noble et al., 2019). Also, the inclusion of DSTs to support it within the MSP process remains a challenge. A recent survey on practitioners on the use of DSTs acknowledged that practitioners have not used them. While "most respondents judged the use of DSTs positively, such tools were not used in the majority of the reviewed MSP processes. In particular, authorities and stakeholders were said to be skeptical of DSTs. These tools were perceived as being of no avail, overly complex or not trustworthy" (Janßen et al., 2019). Several recommendations were provided in the same review for improving the integration of DSTs among the MSP processes. Along with the need to become comprehensible to nonprofessionals, to create confidence into the DST outcomes, better communication, improving financial resources to use them and lastly the usability of DSTs should be further improved. Most of the recommendations fall into the advantages of providing "higher degrees of multifunctionality and integrity while they need to seek solutions to reduce their complexity".

1.2. Research questions

Moving away from the sector approach to the sea, this thesis main contribution is the development of a set of sea patterns for addressing coasts and seas with comparable information. They are used to classify maritime spaces and gather evidence on potentials and challenges, focusing on opportunities for the development of regions. The aim of this thesis is therefore to develop methodological approaches to support the MSP process in a time-bound and resource limited setting. It aims to create a set of data informed tools for the sea, provide scientific knowledge and to contribute to the sustainable ocean planning and management. Using the Portuguese Mainland Subdivision as a case study, five main research questions were formulated:

(1) How can cumulative impact assessment models be used to aid the Environmental Assessment in MSP? (Chapter 3)
(2) How can foreseen activities and uses that may significantly affect Natura 2000 be assessed in a Maritime Strategic Environmental Assessment of an MSP process? (Chapter 4)
(3) To what extent can marine assets and resources be best incorporated into planning to improve the distribution of activities and uses while avoiding the less impacted natural areas? (Chapter 5)
(4) How do socioeconomic and marine environmental characteristics differ in coastal marine areas? How can this information be used to improve the spatial planning process? (Chapter 6)
(5) Can mapping of different patterns of maritime uses, activities and functions with the aim of characterizing different types of seas, be used to guide and improve MSP processes to produce better maritime management and planning? (Chapter 3,4,5 and 6)

1.3. Thesis structure

This research is composed of seven chapters, three of which are published in international peer-reviewed scientific journals:

- **Fernandes** M.L., Esteves T.C., Oliveira E.R., Alves F.L. (2017) How does the cumulative impacts approach support Maritime Spatial Planning? Ecological Indicators. 73, 189-202.10.1016/j.ecolind.2016.09.014 (Chapter 3)
- **Fernandes** M.L, Sousa L.P., Quintela A., Marques M., Reis J., Simão A.P., Castro A.T., Marques J.M., Alves F.L. (2020) Mapping the future: Pressures and impacts in the Portuguese maritime spatial planning. Science of The Total Environment, 715 13686 (Chapter 4)
- **Fernandes**, M.L., Quintela A., Alves F.L. (2018) Identifying conservation priority areas to inform maritime spatial planning: A new approach. Science Of The Total Environment. 639, 1088-1098 10.1016/j.scitotenv.2018.05.147 (Chapter 5)

One more scientific paper is in progress to publish the findings presented in chapter six:

- Fernandes, M.L. et al, (working paper) Spatial characterization of marine socio-ecological systems.

Other publications were produced during the period of development of this dissertation and contributed to the reflection on the management and planning of ocean spaces:

- Jay S., Alves F.L., O'Mahony C., Gomez M., Rooney A., Almodovar M., Gee K., de Vivero J.L.S., Goncalves J.M.S., **Fernandes** M.D., Tello O., Twomey S., Prado I., Fonseca C., Bentes L., Henriques G., Campos A. (2016) Transboundary dimensions of marine spatial planning: Fostering inter-jurisdictional relations and governance. Marine Policy. 65, 85-96 10.1016/j.marpol.2015.12.025
- **Fernandes** M.L., Antunes I.C., Oliveira E.R., Alves F.L. (2016) Design Policy Options supported by Marine and Coastal Ecosystem Services Assessment and Valuation: a Case Study in Portugal. Journal of Coastal Research, 977-981. 10.2112/SI75-196.1

Chapter 1 is the general introduction and **Chapter 2** provides a conceptual analysis of the concepts addressed in this research, setting the context for MSP, EBM and the research developed on the following chapters. Chapters 3 to 6 explore different aspects of tools to support the MSP process.

Chapter 3 assesses the cumulative impacts on the Portuguese Mainland subdivision. It aims to understand how impacts from multiple threats affect marine and coastal ecosystems. The developed approach provides a framework to support impact assessment on the MSP process and contributes with relevant information to improve the management process. The following **chapter 4** explores this topic of environmental assessment from a different perspective, with focus on a particular stage of the Strategic Environmental Assessment (SEA) of PSOEM regarding the assessment of the activities/uses that may significantly affect Natura 2000 marine network. It aims to show how real dilemmas were surpassed when integrating impact assessment in the Portuguese MSP process, a real case study, bound to be developed under knowledge constraints, data-gaps and time limitations.

Chapter 5 uses systematic conservation planning to combine ecological meaningful information with anthropogenic impacts, sea uses and activities to develop several scenarios for selection of high priority areas for conservation. This case study illustrates how ecological goals can be better included to contribute to the MSP process in Portugal.

Finally, **chapter 6** uses a spatial methodology to assess socio-ecological meaningful information. It explores how coastal-marine areas differ in socioeconomic and marine environmental characteristics and create different categories for each stretch. This categorization aims to support management and planning policies focused on sustainable land-sea interfaces.

Chapter 7 that resumes the key findings and main results obtained concludes this thesis. It develops by demonstrating the application of the spatial tools addressed in previous chapters in supporting the MSP decision-making process. Future works and some recommendation on main issues for improving EBM approach are also pointed out.

References

Ansong, J., Gissi, E., Calado, H., 2017. An approach to ecosystem-based management in maritime spatial planning process. Ocean Coast. Manag. 141, 65–81. https://doi.org/10.1016/j.ocecoaman.2017.03.005

Berkes, F., Colding, J., Folke, C., 2003. Navigating Social-Ecological Systems. Building Resilience for Complexity and Change. Cambridge University Press.

Blenckner, T., Kannen, A., Barausse, A., Fischer, C., Heymans, J.J., Luisetti, T., Todorova, V., Valman, M., Mee, L., 2015. Past and future challenges in managing European seas. Ecol. Soc. 20. https://doi.org/10.5751/ES-07246-200140

COC, 2011. Decision Guide: Selecting decision support tools for marine spatial planning. Center for Ocean Solutions. Woods Inst. Environ. 56.

Day, J.C., 2002. Zoning—lessons from the Great Barrier Reef Marine Park. Ocean Coast. Manag. 45, 139–156. https://doi.org/10.1016/S0964-5691(02)00052-2

Domínguez-Tejo, E., Metternicht, G., Johnston, E., Hedge, L., 2016. Marine Spatial Planning advancing the Ecosystem-Based Approach to coastal zone management: A review. Mar. Policy 72, 115–130. https://doi.org/10.1016/j.marpol.2016.06.023

Douvere, F., 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Mar. Policy 32, 762–771. https://doi.org/10.1016/j.marpol.2008.03.021

Douvere, F., Ehler, C.N., 2009. New perspectives on sea use management: initial findings from European experience with marine spatial planning. J. Environ. Manage. 90, 77–88. https://doi.org/10.1016/j.jenvman.2008.07.004

EC, 2008. Roadmap for Maritime Spatial Planning : Achieving Common Principles in the EU. COM(2008) 791 final. Communication 12.

Edwards, R., Evans, A., 2017. The challenges of marine spatial planning in the Arctic: Results from the ACCESS programme. Ambio 46, 486–496. https://doi.org/10.1007/s13280-017-0959-x

Ehler, C., Douvere, F., 2009. Marine spatial planning - A step by Step Approach.

EU, 2014. Directive 2014/89/EU of the European Parliment and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Offical Journal of the European Union. European Commission.

EU, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). European Commission.

Fernandes, M. da L., Sousa, L.P., Lillebø, A.I., Alves, F.L., 2013. Establishment of a Guidance Framework for Cross-border Maritime Spatial Planning. Proc. TWAM2013 - Transbound. water Manag. across borders interfaces Present Futur. challenges 1–5.

Frazão Santos, C., Ehler, C.N., Agardy, T., Andrade, F., Orbach, M.K., Crowder, L.B., 2018. Marine spatial planning, Second Edi. ed, World Seas: An Environmental Evaluation Volume III: Ecological Issues and Environmental Impacts. Elsevier Ltd. https://doi.org/10.1016/B978-0-12-805052-1.00033-4

Gee, K., Blazauskas, N., Dahl, K., Göke, C., Hassler, B., Kannen, A., Leposa, N., Morf, A., Strand, H., Weig, B., Zaucha, J., 2019. Can tools contribute to integration in MSP? A comparative review of selected tools and approaches. Ocean Coast. Manag. 179, 104834. https://doi.org/10.1016/j.ocecoaman.2019.104834

IOC-UNESCO, 2018. Status of MSP by phase of planning [WWW Document]. URL http://msp.ioc-unesco.org/world-applications/status_of_msp/ (accessed 5.6.20).

IOC-UNESCO, 2017. 2nd International Conference on Marine/Maritime Spatial Planning, 15-17 March 2017, Paris, France - UNESCO Digital Library.

Janßen, H., Göke, C., Luttmann, A., 2019. Knowledge integration in Marine Spatial Planning: A practitioners' view on decision support tools with special focus on Marxan. Ocean Coast. Manag. 168, 130–138. https://doi.org/10.1016/j.ocecoaman.2018.11.006

Jay, S., 2018. The shifting sea: from soft space to lively space. J. Environ. Policy Plan. 0, 1–18. https://doi.org/10.1080/1523908X.2018.1437716

Jay, S., Alves, F.L., O’Mahony, C., Gomez, M., Rooney, A., Almodovar, M., Gee, K., de Vivero, J.L.S., Gonçalves, J.M.S., da Luz Fernandes, M., Tello, O., Twomey, S., Prado, I., Fonseca, C., Bentes, L., Henriques, G., Campos, A., 2016. Transboundary dimensions of marine spatial planning: Fostering inter-jurisdictional relations and governance. Mar. Policy 65, 85–96. https://doi.org/10.1016/j.marpol.2015.12.025

Jay, S., Flannery, W., Vince, J., Liu, W.-H., Xue, J.G., Matczak, M., Zaucha, J., Janssen, H., Tatenhove, J. van, Toonen, H., Morf, A., Olsen, E., Vivero, J.L.S. de, Mateos, J.C.R., Calado, H., Duff, J., Deanm, H., 2013. International Progress in Marine Spatial Planning. Ocean Yearb. 27, 171–212.

Kannen, A., 2014. Challenges for marine spatial planning in the context of multiple sea uses, policy arenas and actors based on experiences from the German North Sea. Reg. Environ. Chang. 14, 2139–2150. https://doi.org/10.1007/s10113-012-0349-7

Lange, M., Burkhard, B., Garthe, S., Gee, K., Kannen, A., Lenhart, H., Windhorst, W., 2010. Analyzing Coastal and Marine Changes - Offshore Wind Farming as a Case Study - Zukunft Küste - Coastal Futures. LOICZ No. 36 general, coastal futures, North Sea, HZG-general,.

Mcleod, K.L., Lubchenco, J., Palumbi, S., Rosenberg, A.A., 2005. Scientific Consensus Statement on Marine Ecosystem-based management. Communication Partnership for Science and the Sea (COMPASS) 1–5.

Noble, M.M., Harasti, D., Pittock, J., Doran, B., 2019. Linking the social to the ecological using GIS methods in marine spatial planning and management to support resilience: A review. Mar. Policy 108, 103657. https://doi.org/10.1016/j.marpol.2019.103657

Pınarbaşı, K., Galparsoro, I., Borja, Á., Stelzenmüller, V., Ehler, C.N., Gimpel, A., 2017. Decision support tools in marine spatial planning: Present applications, gaps and future perspectives. Mar. Policy 83, 83–91. https://doi.org/10.1016/j.marpol.2017.05.031

Suárez de Vivero, J.L., 2007. The European vision for oceans and seas—Social and political dimensions of the Green Paper on Maritime Policy for the EU. Mar. Policy 31, 409–414. https://doi.org/10.1016/j.marpol.2006.10.005

2. CONCEPTUAL FRAMEWORK

2.1. The institutional context for the emergence of Maritime Spatial Planning

A systems perspective for marine governance

"The impacts of humanity on the ocean are parts of our inheritance and future. They have helped to shape our present and will shape not only the future of the ocean and its biodiversity as an integral physical and biological system, but also the ability of the ocean to provide the services that we use now, that we will increasingly need to use in the future and that are vital to each of us and to human well-being overall." The extract belongs to the summary of the First Global Integrated Marine Assessment published in 2016 (UN, 2016) addressing how ocean ecosystems are unable to cope with the impact of multiple anthropogenic stressors, placing the life-supporting services that the ocean provides to humankind in imminent danger.

The increased footprint of human actions on oceans is long known. By the 1950s, after the 2nd World War ending, globalization, technological advances and population growth led to increased human use of the oceans. At the time, governance of the marine environment was an iterative process, heavily influenced from terrestrial experiences, using the traditional permit-by-permit approach to land planning (Wright, 2015). Major issues were addressed on a sector-by-sector basis when problems arose for example due to increasing regulatory controls over offshore oil and gas as this sector increased in significance from the 1960s (Alexander and Haward, 2019). This provided the impetus for a widening of state jurisdiction, leading to the beginning of the discussions that led to the United Nations Convention on the Law of the Sea, UNCLOS, as is commonly abbreviated.

UNCLOS is the unified regime that shapes the modern legal framework for maritime zones and is the starting point of discussions on ocean governance (UN, 1982). Maritime Spatial Planning (MSP) has neither developed nor it operates in a legal vacuum. UNCLOS is the international marine law regulating the rights and duties of State Parties and regulates several maritime uses and activities such as the rights of passage, freedom of navigation, fishing and the laying of submarine cables or pipelines (Maes, 2008; Douvere and Ehler, 2009). It establishes a legal order promoting international communication, the equitable and efficient utilization of seas and oceans resources, conservation, protection and preservation of the marine environment (UN, 1982; Maes, 2008). The process towards UNCLOS represented a milestone and is widely considered to be one of the longest and most complex treaty processes in the history of international law, as negotiations lasted almost a decade, from 1973 to 1982 (Wright, 2015). Opened for signature in 10th December 1982 in

Montego Bay, Jamaica, it finally came into force in 16th November 1994, one year after the signature of the 60th country.

“Conscious that the problems of ocean space are closely interrelated and need to be considered as a whole” is a well-known statement on the preamble of UNCLOS (UN, 1982). It addresses one of the most significant key features of the convention, the endorsement of a systems perspective for marine governance, paving the way to an integrated and holistic perspective, away from the single-sector form of management regime. As Juda (2003) points out, UNCLOS was relevant at the international level, but also at the national level on two other key features. First, on the recognition of the rights of the states in the different parts of the ocean, increasing the scale of national jurisdiction and management of ocean space providing interest on the states for effective management (Juda, 2003; Wright et al., 2015). Secondly, the Convention established the responsibilities for the management of the marine environment, by ratifying, states accept obligations to “protect and preserve the marine environment” and to undertake a range of actions to achieve this. UNCLOS second implementing agreement—the 1995 Fish Stocks Agreement—establishes the obligation of states to protect marine biodiversity, including through their duty to cooperate in regional fisheries management organizations (RFMOs) or Arrangements (Diz, 2018).

The Earth Summit’s legacy for MSP

A few years later after Montego Bay signature, the United Nations Conference on Environment and Development (UNCED) also called Earth Summit, held in Rio de Janeiro, Brazil in 1992, was a milestone at the environmental level and was the major agreement on sustainable development. Major outcomes of the conference were the Rio Principles, Agenda 21, and a side event of the conference, the Convention on Biological Diversity (CBD). They were fundamental on the establishment of two relevant innovations on ocean governance and influenced the environmental policies all over the world, including MSP, they were Integrated Coastal Zone Management (ICZM) and the Ecosystem Approach.

Chapter 17 of Agenda 21 concerns the Protection of the oceans and coastal zones, setting out a framework programme for achieving protection and sustainable development of the marine environment and its resources. It first coined the term ICZM, an integrated approach for achieving sustainable resource management in coastal areas. A dynamic, multi-disciplinary and iterative process that seeks to balance economic development and use of the coastal zone (Gopnik et al., 2012). ICZM was a relevant achievement on marine governance and on the path that eventually led to MSP; it offered integrated spatial planning at the coastal zone and near-shore marine environment with a sustainable development focus.

European Union (EU) supported this approach and developed a formal agreement on eight principles of good practice, outlined in the EU ICZM recommendation (2002/413/EC). Based on these principles, the recommendation invited coastal Member States to develop national strategies for ICZM implementation (Alves et al., 2013).

In the UNCED, where the CBD was also adopted, main goals were the conservation of biological diversity and the sustainable use of its components and the fair and equitable sharing of benefits arising from the use of genetic resources (UN, 1992; Douvere and Ehler, 2009). It was the first time that the concept of an Ecosystem approach was addressed in a policy context. In 1995, at the Conference of the Parties (COP) of the CBD, held in Jakarta, was adopted as the primary framework for action.

The Ecosystem approach or the Ecosystem-Based Management (EBM) as is often called as well, is defined by the CBD (2004) as "*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way*". EBM is an environmental management approach that recognizes the full array of interactions within a (marine) ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation (Ansong et al., 2017; Christensen et al., 1996). Its goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. EBM is not marine oriented, but as most marine ecosystems are threatened, an EBM approach has been called for in marine planning as well (Portman, 2016).

The CBD defined 12 principles (Figure 2.1) to guide the implementation of the Ecosystem Approach into planning and policy practices for the achievement of sustainable. EBM requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. As ecosystem processes are often non-linear, the outcome of such processes often shows time lags. Management must be adaptive to be able to respond to such uncertainties and contain elements of "learning-by-doing" or research feedback (CBD, 2004).

Scientific research provides an understanding of the functioning of the ecosystem, its component parts and their connectivity. Oriented towards the information needs of management, it will ensure that management decisions are based on the best available science in the context of the precautionary approach.

The 12 Principles of the ecosystem approach

1. *Management objectives are a matter of societal choice.*
2. *Management should be decentralized to the lowest appropriate level.*
3. *Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems.*
4. *Recognizing potential gains from management there is a need to understand the ecosystem in an economic context, considering e.g. mitigating market distortions, aligning incentives to promote sustainable use, and internalizing costs and benefits.*
5. *A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning.*
6. *Ecosystems must be managed within the limits to their functioning.*
7. *The ecosystem approach should be undertaken at the appropriate scale.*
8. *Recognizing the varying temporal scales and lag effects which characterize ecosystem processes, objectives for ecosystem management should be set for the long term.*
9. *Management must recognize that change is inevitable.*
10. *The ecosystem approach should seek the appropriate balance between conservation and use of biodiversity.*
11. *The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.*
12. *The ecosystem approach should involve all relevant sectors of society and scientific disciplines.*

Figure 2.1. The Ecosystem approach principles (CBD, 2004)

Agenda 21 launched at the Earth Summit was a comprehensive plan of action to build a global partnership for sustainable development to improve human lives and protect the environment. In 2000 United Nations (UN) has created an agenda for sustainable development achievement based on goals (Sustainable Development Goals, SDGs). First were eight Millennium Development Goals (MDG) to reduce extreme poverty by 2015. At the UN Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil, in June 2012, Member States adopted the outcome document

"The Future We Want" in which they decided, inter alia, to launch a process to develop a set of SDGs to build upon the MDGs. In 2015 Sustainable Development Summit, held in New York, put forth the "2030 Agenda for Sustainable Development", with the protection of the natural environment at the foundation of sustainable development. The Agenda established seventeen sustainable development goals – one of them, goal 14 to "Conserve and sustainably use the oceans, seas and marine resources" (UN, 2020) commits governments to conserve and sustainably use the oceans, seas and marine resources for sustainable development, giving this important source of food and biodiversity a standalone goal for the first time. Moreover, as SDGs have targets and indicators, they bring together the necessary components to enable action on a given goal (Houghton, 2014). Several targets from goal 14 are related to the Strategic Plan for Biodiversity 2011-2020, Aichi Biodiversity Targets. These targets were the outcome of the CBD meeting in Nagoya (UNEP, 2010). Target 14.5 for example, establishes a clear indicator, "to conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information".

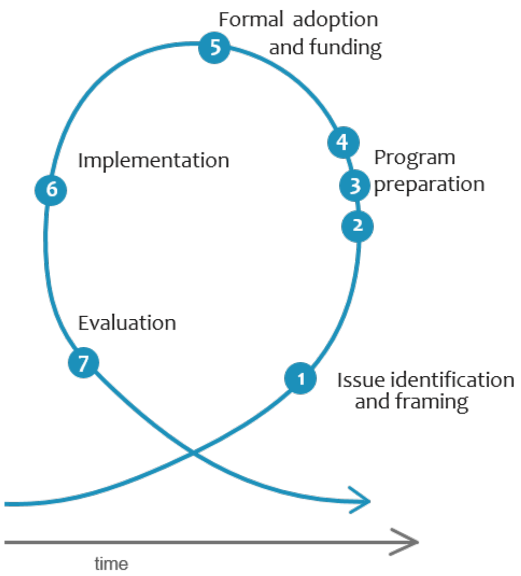
2.2. What is Maritime Spatial Planning?

MSP is defined by IOC-UNESCO as a "public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process" (Ehler & Douvere, 2009). At present, the MSP Directive (MSPD, Directive 89/2014/EC) provides the most frequently used definition in Europe. It describes MSP as "a process by which the relevant Member State's authorities analyze and organize human activities in marine areas to achieve ecological, economic and social objectives. This definition narrows down the process to one conducted by public administrations (Ehler et al., 2019), as this is put forward by the EU Directive, that urges Member States (MS) to produce plans by 2021. Also, the terms used between the two entities show the different understanding, as IOC-UNESCO term *marine* focus in the ecological and environmental issues incorporated into planning, while the EU, using the term *maritime* focus on minimizing conflicts between maritime sectors (Ehler et al., 2019). Simply put, MSP is a form of organizing the ocean space and the interactions among human uses, users and the marine environment.

The MSP Process

As a process, MSP entails several key phases, steps and tasks. The IOC-UNESCO produced a guide that provides a comprehensive overview of MSP for practitioners on describing a logical sequence of steps that are all required to achieve desired goals and objectives for marine areas (Ehler and Douvere, 2009).

The process (Figure 2.2) begins with a **Pre-planning** where the goals, principles are SMART objectives (i.e., specific, measurable, achievable, relevant, and time bound) are defined. It is in this stage that the planning boundaries and horizon are also identified.



1 Pre-Planning

Authority identified; Financing obtained; Work Plan drafted;
Stakeholders engaged;
Initial problems identified;
Principles and Goals defined;
SMART objectives specified;
Planning boundaries defined;
Planning horizon defined

2 Analysis for Planning

Data collection and organization initiated;
Analysis of existing conditions;
Analysis of future conditions;
Spatial/temporal conflicts/compatibilities;
Data atlas/data portal development;

3 Management Plan Development

Preliminary management actions identified;
performance indicators identified;
performance
monitoring and evaluation plan completed;

4 Management Plan Completion

Management plan completed, but not yet approved

5 Management Plan Approval

Management plan approved by relevant level of government

6 Management Plan Implementation

Management plan actions put in place;
performance monitoring and evaluation underway

7 Management Plan Revision

Management plan revised, amended, adapted

Figure 2.2. MSP Phases of the planning process as defined by IOC-UNESCO (2018) and adapted to the Management Cycle from GESAMP (1996), following Olsen et al. (2011).

Ideally, the goals and objectives shall be derived from particular problems or conflicts encountered in the marine area and will reflect a set of MSP that will guide the process (Ehler and Douvere, 2009). It is also during this phase that a plan indicating who, when and how to involve stakeholders throughout the process should be delineated. In the following stage occurs the **Analysis for planning**, besides the usual inventory and collection of data of human activities, oceanographic, physical environmental features and biological and ecological distributions it is also pertinent to consider information regarding specific ecological characteristics, specific economic and social factors, main pressures on the management area and any particular threats. An analysis of the future conditions should also be considered with the main forces likely to shape marine development in the near future (Ehler and Douvere, 2009). In this stage, alternative spatial sea use scenarios (visions that project the future use of the space) should be put in place, when human activities are redistributed based on the new goals and objectives. After this analysis, a preferred future spatial vision is selected.

The next stage, **Management plan development** is the spatial plan itself. Here, spatially explicit management actions or measures are identified to lead to the desired spatial vision for the use of the ocean. A spatial (and temporal) management measure is a means of producing desired goods and services from a marine management area. It specifies how, where, and when human activities should occur (Ehler and Douvere, 2009). Zones are usually defined using a combination of maps and regulations and Decision Support Tools (DST) are available to support zoning (Frazão Santos et al., 2018). At this stage, performance indicators to evaluate the management plan and institutional arrangements (what institutions have the authority to implement specified management measures). In this phase of MSP, performance criteria, or indicators, should be defined to evaluate the management actions.

From this point onwards is in the **Plan completion** and **Plan approval** stages, and only afterwards it should be implemented and monitored. **Plan's implementation** is the process of converting MSP plans into actual operating programs. The responsible entities shall ensure compliance with the plan. Monitoring and evaluation of the plan will allow accessing the performance of the management measures of the plan. It provides managers and stakeholders with indications of the extent of progress toward the achievement of management goals and objectives.

The last stage corresponds to the **Plan's revision**, where proposals for adapting management goals, objectives, outcomes and strategies for the next round of planning are identified. Also, issues for future applied research may be put forward to be developed in the next planning cycle.

Adaptive management, as an iterative process is therefore achieved as knowledge is gathered within the process, baseline circumstances or even preferences may change, producing the need to refine and propose new management objectives (Alves et al., 2013; Douvere and Ehler, 2011; Olsen et al., 2011; Sousa, 2017).

European policy context

Over the last 20 years, MSP has gained a strong political presence in Europe and elsewhere. In Europe efforts begun in 2002 in the Baltic sea, as part of an EU-funded BaltCoast project, involving several Member States (MS) around the Baltic (Zaucha and Gee, 2019). After the European Union (EU) developed an intensive agenda on Marine Policy. It started with the EU Green Paper on Maritime Policy: ‘‘*Toward a Future Maritime Policy for the Union: A European Vision for the Oceans and Seas*,’ and followed with the Integrated Maritime Policy (IMP) the Blue Growth Strategy and the EU “*Roadmap for MSP: Achieving Common Principles in the EU*”. The Blue Growth characterized the approach in EU, a strategy developed to support the sustainable growth in the maritime sectors as a whole. EU put forward a set of principles for MSP to influence the development of a common approach within MS (EC, 2008). The principles had as overarching principle the Ecosystem Approach (Figure 2.3).

MSP Key Principles, MSP Roadmap (EC COM(2008) 791)

The Ecosystem Approach

1. *Using MSP according to area and type of activity*
2. *Defining objectives to guide MSP*
3. *Developing MSP in a transparent manner*
4. *Stakeholder participation*
5. *Coordination within MS– simplifying decision processes*
6. *Ensuring the legal effect of national MSP*
7. *Cross-border cooperation and consultation*
8. *Incorporating monitoring and evaluation in the planning process*
9. *Achieving coherence between terrestrial and maritime spatial planning – relation with ICZM*
10. *A strong data and knowledge base*

Figure 2.3. MSP key principles, according to the MSP Roadmap (EC COM(2008)791)

The Marine Strategy Framework Directive (MSFD; EU, 2008) is the environmental pillar of the MSP in Europe. It is focused on securing and maintaining the healthy status of marine and coastal waters, requiring MS to make assessments not only on pressures and impacts but also on the state of the marine environment and then take measures towards reaching a Good Environmental Status (GES) by 2020. Each coastal MS is obliged to produce a monitoring programme for the assessment and progress, and programmes of measures to achieve or maintain GES in their marine waters.

In 2013, and embodying the Blue Growth Strategy was published the Action Plan for the Atlantic Sea Basin Strategy (EU, 2013). In its own words “it sets out priorities for research and investment to drive the ‘blue economy’ forward in the Atlantic area, and the regions from the five Atlantic Member States can draw on the Action Plan to help create sustainable and inclusive growth in coastal areas”.

Finally, in 2014, the directive establishing a framework for MSP (Directive 2014/89/EC) was enacted. It “aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas, and the sustainable use of marine resources” (EU, 2014). The directive sets forward the objectives and establishes minimum requirements to be observed in the plan, such as giving considering to land-sea interactions, environmental, economic, social and safety aspects, ensuring coherence between MSP and other processes such as ICZM, ensuring the involvement of stakeholders and transboundary cooperation between member states and with third countries. Moreover, MS must have plans in place by 2021 and they should be revised at least every 10 years.

MSP policy context in Portugal

The Portuguese maritime space occupies a unique strategic position facing the Atlantic Ocean, with vast potential in natural resources and heritage. This urges the country to meet the challenges of promoting and developing a maritime economy. Portugal had important developments in marine policy in the last years. Since 2006 two National Ocean Strategies (NOS) have been developed and approved for Portugal – the NOS 2006–2016, and more recently, the NOS 2013–2020 (Frazão Santos et al., 2014). Two MSFD's strategies were developed for Portugal (MAMAOT, 2012a, 2012b), the transposition to the national law of the MSP Directive and the creation of an entirely new legal regime for the Portuguese maritime space. At the same time, the Portuguese government started MSP. The process begun in 2008, with a task force to develop the first Portuguese approach to MSP, named Plano de Ordenamento do Espaço Marítimo (POEM). The project was carried out for the entire Portuguese mainland exclusive economic zone by a multidisciplinary team (Calado et al., 2010). It included a spatial characterization and diagnosis of the marine resources, activities and uses and the potential future activities for a mid to long term assessment. The POEM was subject to public consultation in 2010 and, in 2012 was published (Ruling 14449/2012) without being legally binding or enforceable, but useful as an exercise for further developing the new Portuguese legal framework for MSP (Becker-Weinberg, 2015; Ferreira et al., 2015).

The new basis of the policy for Marine Spatial Planning and Management (MSP Law) was enacted by Law no. 17/2014, published in April 2014. Afterwards, the Decree-Law no. 38/2015, published in March 2015, further develops key aspects of the Law and transposed the EU MSP Directive. It defines two types of maritime spatial planning instruments, the Situation Plan (PSOEM - *Plano de Situação do Ordenamento do Espaço Marítimo*) and the Allocation Plan (AP - *Planos de Afetação*). The PSOEM identifies the spatial and temporal distribution of existing and potential uses and activities to be developed under a private use permit and the natural and cultural values (DGRM, 2019), while the AP is a supplementary planning tool, which can be developed to allocate new areas to existing or new uses and activities that are not included in PSOEM. PSOEM's elaboration was committed, by the Ruling nº. 11494/2015 and was approved in the Mainland, Extended Continental Shelf and Madeira subdivisions in December 2019 by the Resolution of the Council of Ministers n.º 203-A/2019. In parallel to the development of PSOEM, a SEA was carried out, to identify the potential effects arising from its implementation (Ministry of Agriculture and the Sea, 2011).

2.3. Decision Support tools in MSP

Decision Support Tools (DST) are considered software-based instruments that provide support in the decision-making process (Pınarbaşı et al., 2017a). DSTs that use interactive software including maps, models, communication modules, and additional components can help solve problems that are too complex and multi-faceted to solve using human intuition or conventional approaches alone(COC, 2011). Tools used in MSP are necessarily different. Apart from the sea being dynamic and three dimensional, marine space remains a public good, remote from, but valued by, the public (Potts et al. 2016) and requires effective public representation in the processes of decision-making and trading off of multiple competing objectives. Also, the spatial resolutions are different from the traditional marine management requirements; the national dimension of MSP processes including territorial seas and EEZ is different from the more local approaches of using DSTs in the past (Lombard et al., 2019).

The Stanford's Center for Ocean Solutions (COC) developed a decision guide to help experts, resource planners, managers, practitioners of MPS to select properly the DST to use. According to COC (2011) the tools are useful to spatially incorporate 1) ecological, social or economic data into the process; 2) transparently assess management alternatives and trade-offs; 3) involve stakeholders and 4) evaluate progress towards management objectives. Used properly, planning tools can:

- Save time, energy, and resources;
- Guide users through difficult steps of decision-making processes so they can efficiently move from data analysis to final decisions;
- Repeat analyses with relative ease and reduce redundancy by leveraging the work of others;
- Reduce requirements for human expertise;
- Help users explore a wider range of alternatives;
- Document decisions about inputs and parameters; and
- Increase the understanding of planning requirements and limitations for multiple sectors in the planning process.

Many of the tools were developed for operationalizing EBM concepts on management areas such as conservation planning or more sectorial approaches, for example, focused on fisheries modelling. Web databases on DSTs can be assessed to understand the different uses of tools (good examples are MESMA Project inventory http://mesmacentralexchange.eu/tools.html and EBM Tools Network, now hosted at OpenChannels website, https://meam.openchannels.org/tools). A recent review from Pınarbaşı et al. (2017) focuses on existing MSP implementation processes and summarizes the current use, gaps, and expected development trends of DSTs. The review analyzed and classified DSTs according to the MSP stages they are used. From the 34 tools assessed from 29 MSP experiences, most of the tools were used for gathering data and definition of current conditions (21%) and Identifying issues, constraints and future conditions (36%). Both these steps correspond to the **Analysis for planning** process, as presented in Figure 2.1 of this chapter. Only 10% of the applications were for Monitoring and Evaluation and 7% were for evaluating alternative management measures. 5% of the applications were for defining of goals and objectives or could also be used for refinement of goals and objectives, at the **Management plan revision**.

The most common DSTs used in MSP so far are conservation tools (such as Marxan/Marxan with Zones or Zonation), Cumulative Effects/Impacts Tools, Ecosystem services assessment (such as InVEST, Aries), sectorial management, such as fisheries stock management or numerical modeling (such as Atlantis, Ecospace). Other types of tools that have developed in the past few years are used for participatory approaches that improve the communication between stakeholders and planners, such as Seasketch, MSP Challenge simulation game. Also, atlas, data portals and marine cadasters are used with more frequency mostly because they are useful for stakeholders engagement and practitioners to collect and easily assess and view data (COC, 2011; Janßen et al., 2019; Pınarbaşı et al., 2017a; Stelzenmüller et al., 2013). There are already a few practical examples of tools that are arising from specific case-studies that address stakeholders and knowledge integration perspectives (Gee et al., 2019; Lombard et al., 2019) or sets of multifunctional tools (Depellegrin et al., 2017).

In general, each tool focuses on different purposes, using different application methods and achieving, therefore, different results depending on the goals for their implementation. Therefore, clarity of purpose is essential to ensure the right tool is chosen for the right task in the right context. This must include an understanding of the capacity of the tool (what it is designed to do), application requirements (what resources are needed to apply it) and the limitations of the tool (what outcomes can be realistically expected). It must also include an understanding of which tool is useful at which stage of the planning or management process (Gee et al., 2019). Review on the usage of DSTs by practitioners found out that their usage is still hindered by several gaps. One of its major drawbacks is functionality for usage. Most of the tools only address one issue, while MSP planners are dealing with multi-objective planning. Pınarbaşı et al. (2017b) review found that most of the tools are used on environmental issues and in the first stages of the MSP process, on site identification, analysis of existing conditions and on environmental assessments. Other deficit found in reviews analyzed indicated the high technical skills needed for the tools, most due to the high learning curve to use them, highly time-consuming and most often demanding large amounts of information for implementation (Janßen et al., 2019; Lombard et al., 2019; Pınarbaşı et al., 2017a). Although tools are mainly built for practitioners, their usage must have outputs easily understood by stakeholders, otherwise, they will not have confidence on the results limiting their interest and increasing distrust in the process (Janßen et al., 2019).

Finally, DSTs must be easy to use and available, provide higher degrees of multifunctionality and integrity, improve the balance between ecological, social and economic objectives, focus on public participation and integrate future scenarios specially with climate change challenges ahead (Janßen et al., 2019; Lombard et al., 2019; Pınarbaşı et al., 2017b)

References

Alexander, K.A., Haward, M., 2019. The human side of marine ecosystem-based management (EBM): 'Sectoral interplay' as a challenge to implementing EBM. Mar. Policy 101, 33–38. https://doi.org/10.1016/j.marpol.2018.12.019

Alves, F.L., Sousa, L.P., Almodovar, M., Phillips, M.R., 2013. Integrated Coastal Zone Management (ICZM): A review of progress in Portuguese implementation. Reg. Environ. Chang. 13, 1031–1042. https://doi.org/10.1007/s10113-012-0398-y

Ansong, J., Gissi, E., Calado, H., 2017. An approach to ecosystem-based management in maritime spatial planning process. Ocean Coast. Manag. 141, 65–81. https://doi.org/10.1016/j.ocecoaman.2017.03.005

Becker-Weinberg, V., 2015. Portugal's legal regime on marine spatial planning and management of the national maritime space. Mar. Policy 61, 46–53. https://doi.org/10.1016/j.marpol.2015.06.014

Calado, H., Ng, K., Johnson, D., Sousa, L., Phillips, M., Alves, F., 2010. Marine spatial planning: Lessons learned from the Portuguese debate. Mar. Policy 34, 1341–1349. https://doi.org/10.1016/j.marpol.2010.06.007

CBD, 2004. Secretariat of the Convention on Biological Diversity. The Ecosystem Approach (CBD Guidelines).

Christensen, N.L., Bartuska, A.M., Brown, J.H., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J.F., MacMahon, J.A., Noss, R.F., Parsons, D.J., Peterson, C.H., Turner, M.G., Woodmansee, R.G., 1996. The report of the ecological society of america committee on the scientific basis for ecosystem management. Ecol. Appl. 6, 665–691. https://doi.org/10.2307/2269460

COC, 2011. Decision Guide: Selecting decision support tools for marine spatial planning. Center for Ocean Solutions. Woods Inst. Environ. 56.

Depellegrin, D., Menegon, S., Farella, G., Ghezzo, M., Gissi, E., Sarretta, A., Venier, C., Barbanti, A., 2017. Multi-objective spatial tools to inform maritime spatial planning in the Adriatic Sea. Sci. Total Environ. 609, 1627–1639. https://doi.org/10.1016/j.scitotenv.2017.07.264

DGRM, 2019. Volume V - Plano de Situação do Ordenamento do Espaço Marítimo Nacional. Relatório Ambiental PSOEM.

Diz, D., 2018. Marine Biodiversity: Opportunities for Global Governance and Management Coherence, in: Handbook on Marine Environment Protection. Springer International Publishing, Cham, pp. 855–870. https://doi.org/10.1007/978-3-319-60156-4_45

Douvere, F., Ehler, C.N., 2011. The importance of monitoring and evaluation in adaptive maritime spatial planning. J. Coast. Conserv. 15, 305–311. https://doi.org/10.1007/s11852-010-0100-9

EC, 2008. Roadmap for Maritime Spatial Planning : Achieving Common Principles in the EU. COM(2008) 791 final. Communication 12.

Ehler, C., Douvere, F., 2009. Marine spatial planning - A step by Step Approach.

Ehler, C., Zaucha, J., Gee, K., 2019. Maritime/Marine Spatial Planning at the Interface of Research and Practice, in: Maritime Spatial Planning. Springer International Publishing, Cham, pp. 1–21. https://doi.org/10.1007/978-3-319-98696-8_1

EU, 2014. Directive 2014/89/EU of the European Parliment and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Offical Journal of the European Union. European Commission.

EU, 2013. Action Plan for a Maritime Strategy in the Atlantic area delivering smart, sustainable and inclusive growth COM(2013) 279. European Commission.

EU, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). European Commission.

Ferreira, M.A., Calado, H., Pereira da Silva, C., Abreu, A.D., Andrade, F., Fonseca, C., Gonçalves, E.J., Guerreiro, J., Noronha, F., Pereira, M., Pinto Lopes, C., Ribeiro, M.C., Stratoudakis, Y., Vasconcelos, L., 2015. Contributions towards maritime spatial planning (MSP) in Portugal – Conference report. Mar. Policy 59, 61–63. https://doi.org/10.1016/j.marpol.2015.04.017

Frazão Santos, C., Domingos, T., Ferreira, M.A., Orbach, M., Andrade, F., 2014. How sustainable is sustainable marine spatial planning? Part I-Linking the concepts. Mar. Policy 49, 59–65. https://doi.org/10.1016/j.marpol.2014.04.004

Frazão Santos, C., Ehler, C.N., Agardy, T., Andrade, F., Orbach, M.K., Crowder, L.B., 2018. Marine spatial planning, Second Edi. ed, World Seas: An Environmental Evaluation Volume III: Ecological Issues and Environmental Impacts. Elsevier Ltd. https://doi.org/10.1016/B978-0-12-805052-1.00033-4

Gee, K., Blazauskas, N., Dahl, K., Göke, C., Hassler, B., Kannen, A., Leposa, N., Morf, A., Strand, H., Weig, B., Zaucha, J., 2019. Can tools contribute to integration in MSP? A comparative review of selected tools and approaches. Ocean Coast. Manag. 179, 104834.

https://doi.org/10.1016/j.ocecoaman.2019.104834

GESAMP, 1996. The contributions of science to integrated coastal management.GESAMP Reports and Studies No.61. Rome, Italy. [WWW Document]. URL http://www.fao.org/3/contents/dc824e26-b1b7-568d-8770-1f9347ecb063/W1639E00.HTM#CONTRIBUTIONS (accessed 5.14.20).

Gopnik, M., Fieseler, C., Cantral, L., McClellan, K., Pendleton, L., Crowder, L., 2012. Coming to the table: Early stakeholder engagement in marine spatial planning. Mar. Policy 36, 1139–1149. https://doi.org/10.1016/j.marpol.2012.02.012

Houghton, K., 2014. A Sustainable Development Goal for the Ocean : Moving from Goal Framing Towards Targets and Indicators for Implementation.

IOC-UNESCO, 2018. Status of MSP by phase of planning [WWW Document]. URL http://msp.ioc-unesco.org/world-applications/status_of_msp/ (accessed 5.6.20).

Janßen, H., Göke, C., Luttmann, A., 2019. Knowledge integration in Marine Spatial Planning: A practitioners' view on decision support tools with special focus on Marxan. Ocean Coast. Manag. 168, 130–138. https://doi.org/10.1016/j.ocecoaman.2018.11.006

Juda, L., 2003. Changing National Approaches to Ocean Governance: The United States, Canada, and Australia. Ocean Dev. Int. Law 34, 161–187. https://doi.org/10.1080/00908320390209627

Lombard, A.T., Ban, N.C., Smith, J.L., Lester, S.E., Sink, K.J., Wood, S.A., Jacob, A.L., Kyriazi, Z., Tingey, R., Sims, H.E., 2019. Practical Approaches and Advances in Spatial Tools to Achieve Multi-Objective Marine Spatial Planning. Front. Mar. Sci. 6, 1–9. https://doi.org/10.3389/fmars.2019.00166

MAM, 2011. Ruling n.o 11494/2015. Diário da República, 2.a série — N.° 201 — 14 de outubro de 2015. Ministry of the Agriculture and Sea.

MAMAOT, 2012a. Maritime Strategy for Continent Subdivision (Estrategia Marinha para a Divisão do Continente). Ministry of Agriculture, Sea, Environment and Spatial Planning 930.

MAMAOT, 2012b. Maritime Strategy for Extended Continental Shelf Subdivision (Estratégia Marinha para a subdivisão da Plataforma Continental Estendida). Ministry of Agriculture, Sea, Environment and Spatial Planning. 214.

Olsen, S.B., Olsen, E., Schaefer, N., 2011. Governance baselines as a basis for adaptive marine spatial planning. J. Coast. Conserv. 15, 313–322. https://doi.org/10.1007/s11852-011-0151-6

Pınarbaşı, K., Galparsoro, I., Borja, Á., Stelzenmüller, V., Ehler, C.N., Gimpel, A., 2017a. Decision support tools in marine spatial planning: Present applications, gaps and future perspectives. Mar. Policy 83, 83–91. https://doi.org/10.1016/j.marpol.2017.05.031

Pınarbaşı, K., Galparsoro, I., Borja, Á., Stelzenmüller, V., Ehler, C.N., Gimpel, A., 2017b. Decision support tools in marine spatial planning: Present applications, gaps and future perspectives. Mar. Policy 83, 83–91. https://doi.org/10.1016/j.marpol.2017.05.031

Portman, M.E., 2016. Environmental Planning for Oceans and Coasts. https://doi.org/10.1007/978-3-319-26971-9

Resolution of the Council of Ministers n.o 203-A/2019, 2019. Resolution of the Council of Ministers n.o 203-A/2019. Resolução do Conselho de Ministros de 30 de Dezembro. Diário da República, 1a série no 250.

Sousa, L., 2017. Modelo de integração dos Serviços dos Ecossistemas no processo de planeamento. Univ. Aveiro.

Stelzenmüller, V., Lee, J., South, A., Foden, J., Rogers, S.I., 2013. Practical tools to support marine spatial planning: A review and some prototype tools. Mar. Policy 38, 214–227. https://doi.org/10.1016/j.marpol.2012.05.038

UN, 2020. Sustainable Development Goals .:. Sustainable Development Knowledge Platform [WWW Document]. URL https://sustainabledevelopment.un.org/?menu=1300 (accessed 5.13.20).

UN, 2016. First global integrated marine assessment (First World Ocean Assessment).

UN, 1982. United Nations Convention on the Law of the Sea. United Nations, Montego Bay, pp. 7–208.

UNEP, 2010. Conference of the Parties to the Convention on Biological Diversity UNEP/CBD/COP/DEC/X/2. Strateg. Plan Biodivers. 2011-2020 13.

Wright, G., 2015. Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. Mar. Policy 52, 77–84. https://doi.org/10.1016/j.marpol.2014.10.021

Wright, G., Ardron, J., Gjerde, K., Currie, D., Rochette, J., 2015. Advancing marine biodiversity protection through regional fisheries management: A review of bottom fisheries closures in areas beyond national jurisdiction. Mar. Policy 61, 134–148. https://doi.org/10.1016/j.marpol.2015.06.030

Zaucha, J., Gee, K., 2019. Maritime Spatial Planning past, present, future, Maritime Spatial Planning. https://doi.org/10.1007/978-3-319-98696-8_

3. HOW THE CUMULATIVE IMPACTS APPROACH SUPPORTS MARITIME SPATIAL PLANNING?

Abstract

Maritime Spatial Planning (MSP) needs to incorporate spatial information on human impacts. As human activities and uses increase in marine and coastal waters around the world, pressures in ecosystems are also increasing, leading to multiple adverse effects on different species and habitats. The European Directive on MSP aims to achieve an integrated approach to marine governance, whilst securing and maintaining the healthy status of marine and coastal waters, in accordance with the Marine Strategy Framework Directive. The latter requires Member States to develop assessments not only on pressures and impacts, but also on the state of the marine environment and then take measures towards reaching a Good Environmental Status by 2020.

The Portuguese Maritime Spatial Plan - Plano de Ordenamento do Espaço Marítimo (POEM) was developed between 2009 and 2012. In 2014 a law establishing the Basis for the Spatial Planning and Management of the National Maritime Space was enacted and in 2015 the framework for the elaboration of a new national Maritime Spatial Plan, named Situation Plan, was established. Portugal will face, in the next five years, the challenge of planning and managing its marine space, whilst promoting its sustainable use and protection.

This study adapted a cumulative effects assessment model to understand how the impacts from multiple threats affect the marine and coastal ecosystems and, how this information can be used to improve the management process. Information was gathered on intensity and distribution of activities and uses for the Portuguese continental subdivision marine area. Their cumulative impacts in marine ecosystems were quantified and mapped. After they were overlapped with the POEM. Results show that impacts are spreading from the coast up to the Contiguous Zone. Higher scores appear in Transitional and Coastal Waters in the north (Viana do Castelo/Figueira da Foz), centre (Peniche/Setúbal) and south (Lagos/Faro). In some areas with higher ranks, statutes of nature conservation are already in place, but potential activities may still occur on top of existing ones. This study shows that the adapted model is a helpful tool to clarify ocean planning, identify areas of potential conflicts among users and support the decision making process.

Keywords: ocean activities and uses, conflicts, ecosystem-based management, ocean management, Portugal

3.1. Introduction

Human activities and uses cause multiple pressures on ecosystems. These pressures may produce multiple adverse effects, which can have various degrees on different species and habitats and, can act cumulatively (MA, 2005). By definition, we are considering cumulative effects (the terms impacts and effects are used interchangeably) as a result from the incremental, accumulating, and/or interacting impacts of an activity or uses and its stressors on habitats (Judd et al., 2015; Korpinen et al., 2012; WWF, 2014). Marine management approaches used to be rather sectoral and focused on conflicts among multiple activities and uses. Nowadays, however, the emphasis is shifting towards an ecosystem approach to sustainable management of natural resources (Douvere et al., (Douvere et al., 2007; Stelzenmüller et al., 2008). In 2007, the European policy initiated a new approach to marine management focused on the Integrated Maritime Policy (EU, 2007) and through Maritime Spatial Planning (MSP). In 2014, the Maritime Spatial Planning Directive (MSPD, EU, 2014a) was created and prior to that, in 2002 the Recommendation on Integrated Coastal Zone Management (EC, 2002) was established. The Marine Strategy Framework Directive (MSFD,EU, 2008) focused in securing and maintaining the healthy status of marine and coastal waters, requiring Member States to make assessments not only on pressures and impacts but also on the state of the marine environment and then take measures towards reaching a Good Environmental Status by 2020. With the MSPD, Member States must implement maritime plans to ensure that human activities are developed within an Ecosystem-Based Management (EBM) approach and taking into account the carrying capacity of the ecosystem. The MSPD asserts the need to assess environmental effects of spatial plans in accordance with the Strategic Environmental Assessment (SEA) Directive 2001/42/EC and in Natura 2000 sites, the assessment can be combined with the requirements of Directive 92/437EEC (EEC, 1992).

The Portuguese maritime space occupies a unique strategic position facing the Atlantic Ocean, with a vast potential in natural resources and heritage. This urges the country to meet the challenges of promoting and developing a maritime economy, in line with the strategic framework developed at the European and global level. In 2008, a task force was created by Ruling 32277/2008 December, 18, to develop the first Portuguese approach to MSP, named Plano de Ordenamento do Espaço Marítimo (POEM). The project was carried out for the entire Portuguese mainland exclusive economic zone by a multidisciplinary team (Calado et al., 2010). It included a spatial characterization and diagnosis of the marine resources, activities and uses and the potential future activities for a mid to long term assessment. It also produced a preliminary plan proposal, which included the allocation of space to different uses (POEM's 'spatialization'), management guidelines, an action program and a monitoring program (Frazão Santos et al., 2014). The POEM was subject to public consultation in 2010 and, in 2012 was published (Ruling 14449/2012) without being legally binding or enforceable, but useful as an exercise for further developing the new Portuguese legal framework for MSP (Becker-Weinberg, 2015; Ferreira et al., 2015a). In April 2014, a law establishing the Basis for the Spatial Planning and Management of the National Maritime Space (LBOGEM, Law 17/2014) was enacted and in March 2015 a Decree-Law was published, introducing the implementation aspects of the LBOGEM (Decree-Law 38/2015). The Decree-Law defines two sets of MSP instruments; the situation plan and the allocation plan. The situation plan identifies the distribution of the existing and potential uses and activities. According to the Decree-Law, this plan may or may not be subject to SEA. The allocation plans intend to allocate space to new uses and activities that are not included in the situation plan, and they are subject to Environmental Impact Assessment (EIA). However, Portuguese legislation is not specifically designed for carrying out EIA in the marine environment (Ferreira et al., 2015a; Frazão Santos et al., 2015). Throughout this scenery, Portugal now appears to be facing the challenge of planning, managing and enforcing a huge maritime area, whilst having to promote a sustainable use and protection of its marine waters by 2020 (Ferreira et al., 2015b).

The development of spatial plans in the maritime space requires information, not only on present and potential activities, uses and its pressures, but also on current impacts, that can effectively inform marine policy over the upcoming years (Halpern et al., 2009; Kelly et al., 2014; Parravicini et al., 2012). The analysis of human activities, uses and related pressures can indicate how many and how often human threats occur simultaneously in marine environments(Ban et al., 2010; Crain et al., 2009; Halpern et al., 2009). Attempts have been made to address cumulative impacts and how to use this information in marine management (Ban et al., 2010; Batista et al., 2014; Halpern et al., 2009; Henriques et al., 2014; Judd et al., 2015; Kelly et al., 2014; Korpinen et al., 2012). It is necessary to understand the relationships between multiple human activities, the ecosystems and their health status within the territory and at the appropriate scale. The spatial visualization of these issues have an important role to play on planning and environmental management (Stelzenmüller et al., 2013) .

The aim of this study is to adapt a model for cumulative impacts (hereafter Cumulative Impacts Model-CIM) for the Portuguese maritime space and analyse to which extent such models can be used to effectively aid its spatial planning. We used the methodology applied by Halpern et al.

(2008) to assess the cumulative effects of human activities and uses in the sea. This method takes into account the pressures and their impacts on specific ecosystems using expert judgment for each pressure and ecosystem. Afterwards, the resulting index scores of cumulative impacts are overlapped with the synthesis maps of the POEM showing the distribution of existing and potential activities and uses and within the POEM's 'spatialization' (hereafter called MSP Proposal).

3.2. Material and Methods

3.2.1. The study area

Portugal has a large marine jurisdiction of 1.720.560 km^2, which corresponds to 18 times its terrestrial area. In Figure 3.1, the maritime space was divided into Transitional and Coastal Waters, as defined in the Water Framework Directive (WFD) (EU, 2000). It was also classified as Territorial Sea (TS), Contiguous Zone (CZ) and Economic Exclusive Zone (EEZ), as defined by UNCLOS (UN, 1982).The Portuguese continental coast is mostly sandy shore, prone to erosion, with some rocky and cliffed stretches. The wave climate is highly energetic with wave direction frequently between West and Northwest. The continental platform is quite narrow, extending from 5 km to 80 km. It has a regular soft relief with prominent canyon features, such as Nazaré, Cascais and Setúbal-Lisbon (Lastras et al., 2009). About 75 % of the population lives on the coast and, by 2010, ocean economy represented directly around 2.5% of the gross added value and 2.3% of national employment (MAM/DGPM, 2014). Larger cities of the country are located in river mouths and hold important ports connected to the whole of the Atlantic basin and are part of important highways of the sea connecting to Europe. Most relevant activities supporting sea economy nowadays are tourism, shipbuilding, fisheries and related industry, marine infrastructures and transports. Potential activities of living and non-living resource extraction are expected to increase in the coming years (MAMAOT, 2012).

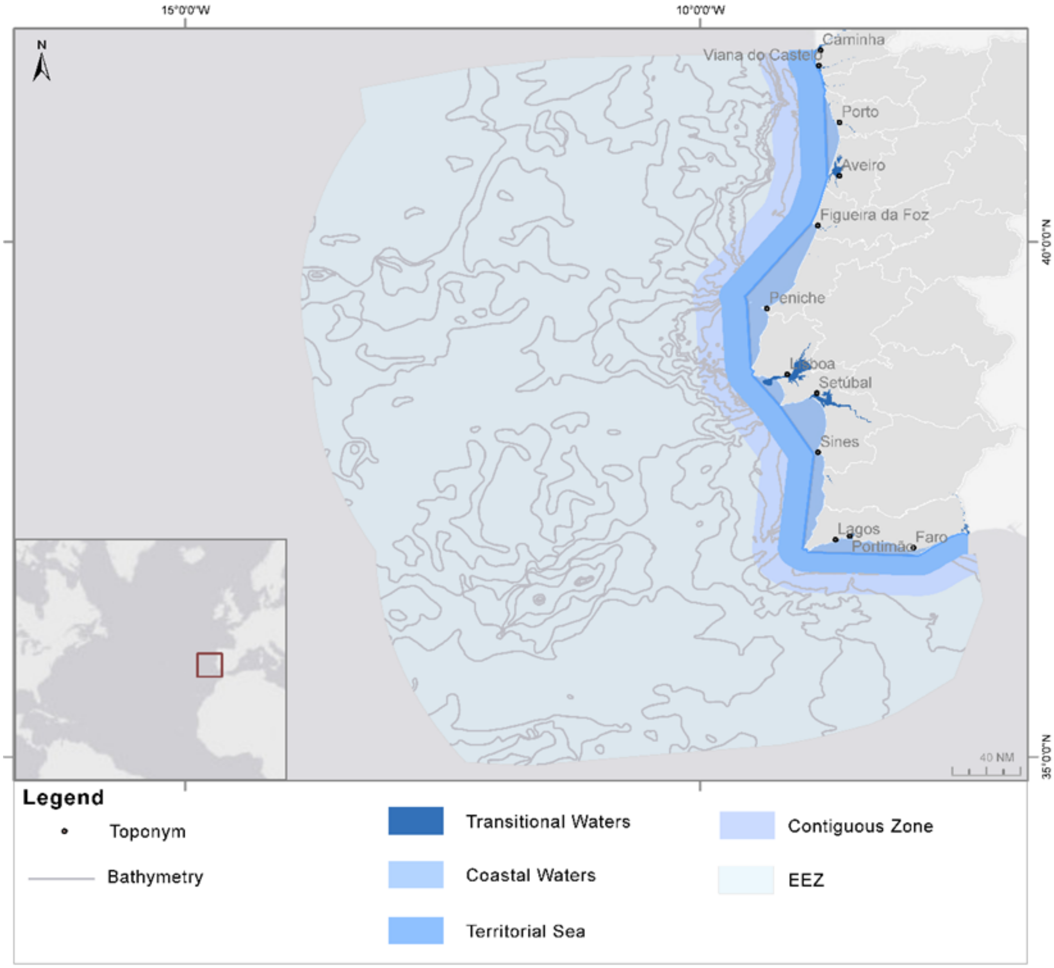


Figure 3.1. Map of the Portuguese maritime space (continental subdivision); (source: ESRI, DeLorme, HERE, MapmyIndia)

3.2.2. Compatibilities between activities, uses and nature conservation

During the development of the POEM an analysis was carried out of the likely interactions between a range of marine uses, activities and functions. Within the scope of this study POEM was reviewed in order to identify and analyse the individual interactions between the different uses and activities with the marine environment. This included an examination of compatibilities and necessary restrictions with important marine species, habitats and protected areas that were appearing in the Portuguese continental subdivision.

3.2.3. Cumulative Impacts Model

The CIM adapted the overall methodology used in other works (Ban and Alder, 2008; Halpern et al., 2008; Korpinen et al., 2012; Micheli et al., 2013a). A Geographic Information System (GIS) software was used for data analysis (ESRI, ArcGIS 10.2 Desktop) with the Spatial Analyst extension and the spatial reference system adopted was the European Terrestrial Reference System 1989 (ETRS89) with Transverse Mercator Projection (PT-TM06). For each anthropogenic driver and each ecosystem, information was collected on their distribution and their related spatial data. Data from activities and uses was adapted as a proxy to define anthropogenic drivers. Each activity, use and ecosystem dataset was converted into layers composed of 25 km^2 presence/absence grid cells. The selection of the grid size of 5 km per 5 km was selected in accordance with the available data and it was similar to other studies developed in the European space, such as in Korpinen et al. (2012) although the latter was defined in an enclosed sea, i.e. the Baltic Sea.

For each cell, we multiplied each anthropogenic driver (Di) layer with each ecosystem (Ej) layer to create driver-by-ecosystem combinations, and then multiplied these combinations by the appropriate weighting variable (Uij). Only the cells with both values of ecosystems and anthropogenic drivers produced a Cumulative Impact (CI) score within the study area.

CI = $\sum_{i=1}^{i}\sum_{j=1}^{i} Di * Ei * Uij$

Data used as the weighing variable was adapted from the work of Halpern et al. (2007) on ecosystem vulnerability to each anthropogenic threat. In this system, vulnerability was measured by spatial scale, frequency and functional impact of each threat in each marine ecosystem, the resistance of the ecosystem to disturbance by each threat and the recovery time of the ecosystem following such disturbance. The information used for the weighing variable is presented in Table 1 of Supplementary Material A. As previously stated in other works (Halpern et al., 2008; Micheli et al., 2013b) this value represents the relative impact of an anthropogenic driver on an ecosystem within a given cell when both exist in that cell and does not represent the relative global impact of a driver or the overall status of an ecosystem.

3.2.4. Used data and information

As anthropogenic drivers, 22 spatial datasets of activities and uses were used, based on the best available data. More information can be viewed in Table 3.1, where activities and uses were grouped into themes. These drivers provoking pressures on the marine environment were classified in accordance with the designation used by the MSFD (Annex III, Table 2 of MSFD). In order to account for these pressures, and similarly to other studies, each pressure was defined as a negative impact in the marine environment (Ban et al., 2010; Batista et al., 2014; Korpinen et al., 2012). The spatial data for drivers was selected based on its relevance, its quality and coverage of the study area, being then classified based on the existing metrics available for determining its intensity. Following the approach used by Ban et al. (2010), the distance to which the effect of the activities or uses is likely distributed (influence distance) was included in the analysis, as its impacts often extend beyond their boundaries. A stressor distance category (Buffer) was added following the definition: Short (S=200m), Short-Medium (SM =500-1000m), Medium (M =2km), Medium Long (ML =10 k), Long (L =30km) and Very Long (VL > 30 km). Some activities and uses are already defined with delimited buffer areas and therefore no buffer was added to the layer (N/A) (see Supplementary Material A, Table 1). The intensity of the activities and uses was categorized (see column "Indicator" in Table 3.1) and were log [X+1]-transformed and rescaled between 0-1 to put them on a single scale that allows direct comparison. Some activities and uses were treated as binary data, in the cases where there was a presence/absence influence. This was the case of several infrastructures such as defence works or submarine cables, but also with the fisheries (the input data available for the study was the spatial distribution subdivided by fishing type).

Table 3.1. List of activities and uses, pressures and indicators used in CIM.

	Activities/uses	**Pressures**	**Indicator**
Coastal Infrastructures			
1	Harbours and Marinas	Physical damage Contamination by hazardous substances	Number of anchor places
2	Defence works	Physical damage/loss	Presence/absence
Shipping			
3	Traffic at ports and marinas	Physical loss and disturbance Contamination by hazardous substances	Cargo movements (ton/year)
4	Traffic Separation Schemes	Physical loss and disturbance Contamination by hazardous substances	Presence/absence
5	Compulsory navigation area	Physical loss and disturbance Contamination by hazardous substances	Presence/absence
Benthic structures			
6	Submarine cables	Physical damage and disturbance	Presence/absence
7	Anchorages	Physical damage	Presence/absence
Offshore Energy			
8	Renewable Energies	Physical damage and disturbance	Presence/absence
9	Oil Prospection	Physical loss, disturbance Contamination by hazardous substances	Presence/absence
Fisheries			
10	Areas per fishing Trawling / Crustaceans	Physical damage Biological and Physical disturbance	Presence/absence
11	Areas per type of fishing Trawling/Fish	Physical damage Biological disturbance	Presence/absence
12	Areas per type of fishing- Purse Seine	Biological and Physical disturbance	Presence/absence
13	Areas per type of fishing Multi-gear	Physical damage Biological and Physical disturbance	Presence/absence

Tourism			
14	Regatta sites	Physical damage and disturbance	Presence/Absence
15	Surf spots	Physical disturbance /contamination by hazardous substances	Presence/Absence
Pollutants input			
16	Discharges	Contamination by hazardous substances; Biological disturbance Nutrient and organic matter enrichment	Discharges combined with type of treatment
17	Beach water quality	Contamination by hazardous substances and Biological disturbance	Beach water quality categories in accordance with the Bathing Water Directive (2006/7/EC)
18	Water quality	Contamination by hazardous substances and Biological disturbance	Good ecological/chemical status, in accordance with the WFD
19	Marine litter	Contamination by hazardous substances Physical Disturbance	Quantity of litter found in beaches
20	Dredging Deposition	Physical damage and loss	Quantity Deposited in the sea
21	Population Density	Contamination by hazardous substances; Physical disturbance	Number of inhabitants /m^2

Due to the coarse resolution of the cell grid (25 km^2), when in comparison with other studies it was accepted to have several ecosystems in the same cell. Benthic habitats were selected to match the habitats used in Halpern et al. (2007), based on the availability of data and handling treatment. Information available from the Habitats Directive (EEC, 1992) and EUNIS habitat database (EEA, 2014) was used, matching the biological zone, bottom-substrate type and depth range (Figure 3.2 and Supplementary Material A, Table 2).

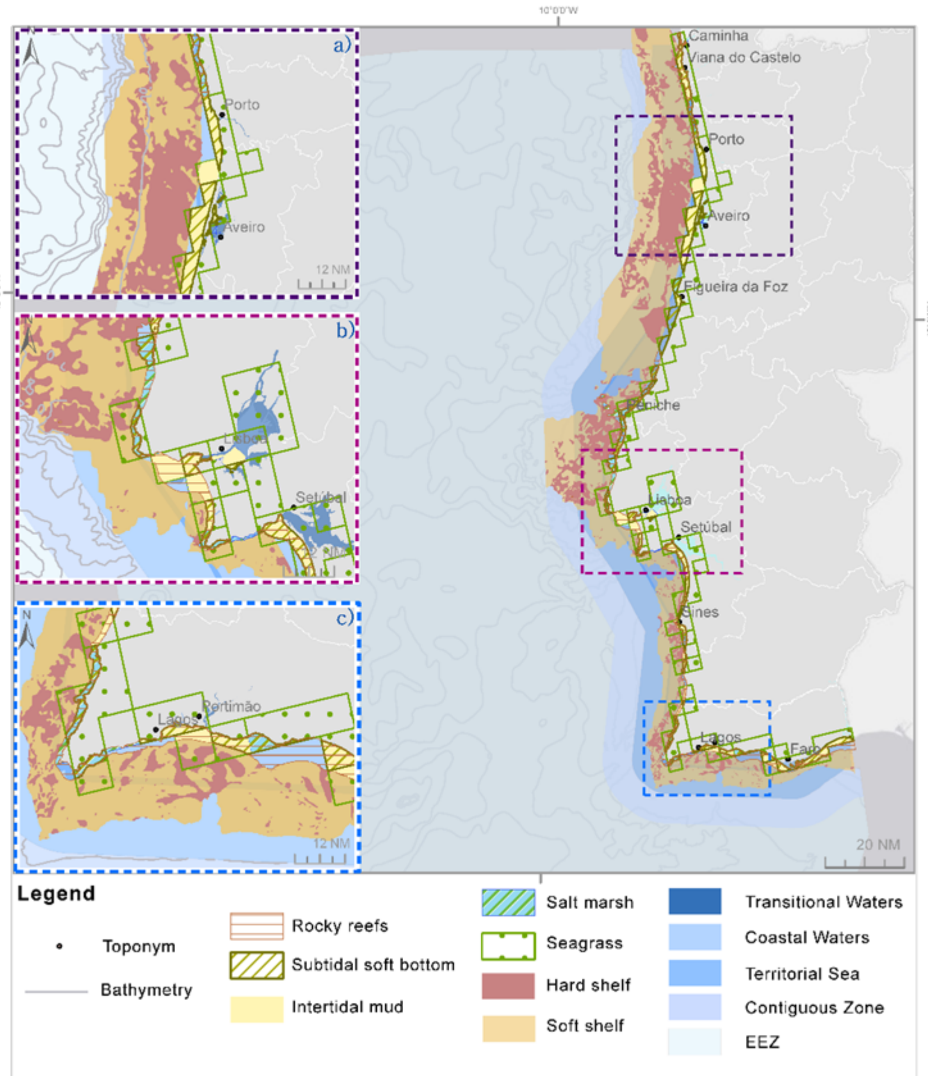


Figure 3.2. Ecosystems used in the CIM, with details from a) north; b) centre; c) south).

3.2.5. Overlapping CIM with MSP

To analyze the outputs of the model and to establish relations with the management process, the CIM map was overlapped with the outcome synthesis maps of Existing activities and uses (Figure 3.3a), with Potential activities and uses (Figure 3.3b) and with the MSP proposal from POEM (INAG, 2012a, 2012b) (Figure 3.3c).

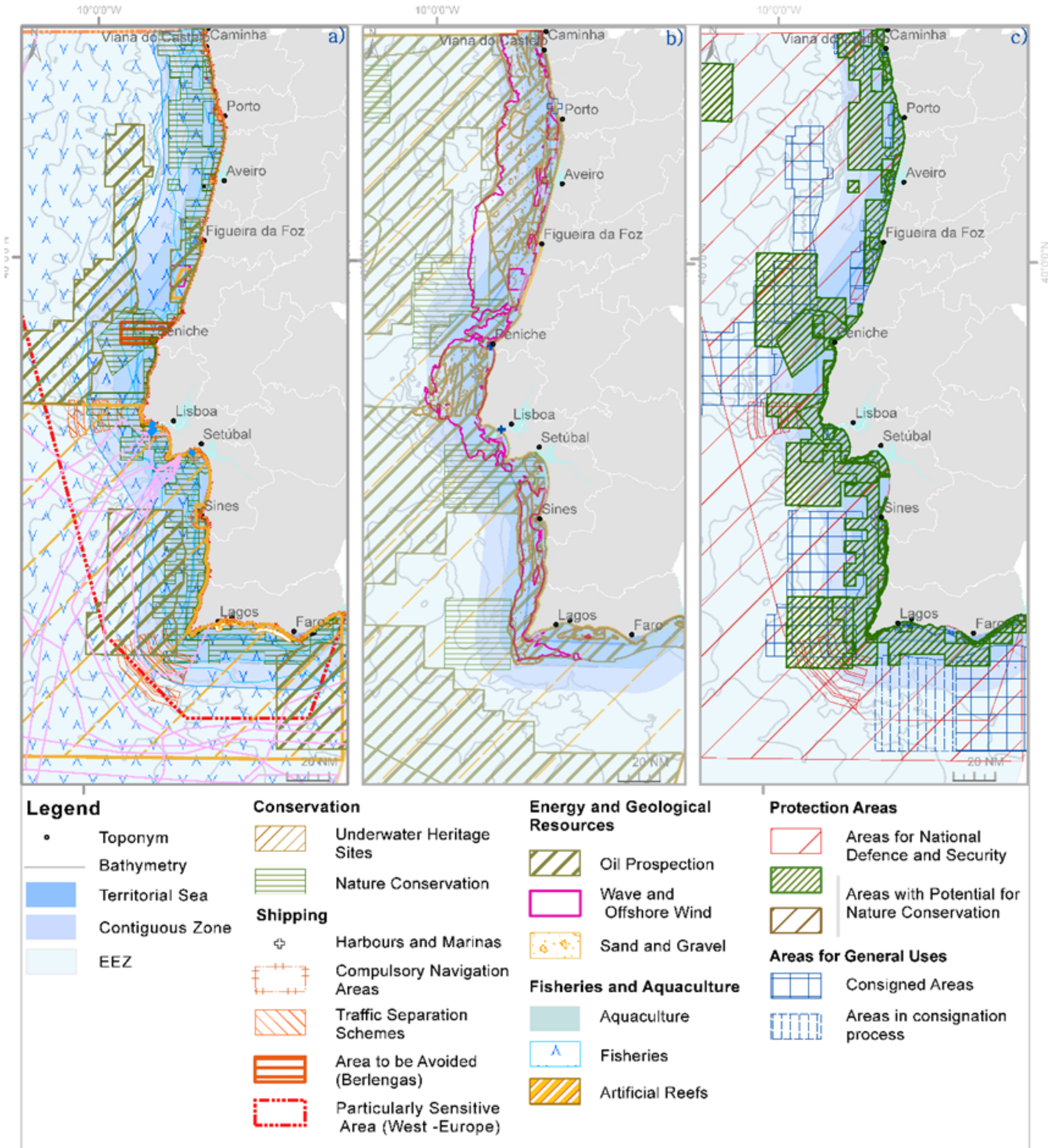


Figure 3.3. POEM maps: a) Existent Situation; b) Potential Situation and c) MSP Proposal (INAG, 2012a).

3.3. Results

3.3.1. Compatibilities between activities, uses and nature conservation

The information presented in Table 3.2 is divided into Compatibility/Incompatibility and Exclusion between activities, uses and important species and habitats. Compatible activities or uses that require protection measures are assigned and security perimeters or nesting periods are identified. The gaps in the table are assumed to have harmless interactions and therefore, are compatible with nature conservation features.

Table 3.2. Compatibility matrix between activities/uses and important species and habitats according with the POEM (I not compatible; E Exclusion; RPM requires protection measures; RPM SP security perimeter; RPM N nesting period forbiddance; R/D Substantial Limit

Activities/ uses	MPA (Total)	MPA (Partial – P Complem–C)	SIC	ZPE	MIBA	Specific occurrence;[1]	Partial/total submerged caves[2]	Reefs[3]	Sandbanks[4]	River mouths submarine canyons;	Underwater heritage
Energy Production	I		RPM							I	I*
Offshore Wind Parks	I	I		I	I						
Wave energy Parks		RPM	RPM	RPM	RPM						
Mineral resources exploration prospection		RPM	RPM	RPM	RPM	RPM	RPM	I		I	I*
Oil Prospection Exploration	I	RPM	RPM	RPM	RPM/N	RPM	RPM	RPM		RPM SP	
Carbon Sequestration	I	I(P)/ RPM (C)	RPM	RPM	RPM	RPM	RPM	I		I	I
Coastal Defence	I							I			I
Navigation Channels Pilotage areas	I						R/D	R/D	R/D		I*
Infrastructures	I										RPM**
Harbours Port works	I						R/D	R/D	R/D		
Dredging	I						I	I			RPM**
Commercial harbours							R/D	R/D	R/D		
Fishing harbours	E						E		E		
Fishing Trawling						I					RPM**
Aquaculture Floating							I		I		RPM**
Tourism											I*/RPM **
Defence											RPM**
Submarine cables											RPM**

* not compatible in the same space; requires a security perimeter around the heritage.
** requires consultation to the appropriate bodies
1- Areas with occurrence of Harbour Porpoise (Phocoena phocoena); Bottlenose dolphin (Tursiops truncates)
2- 8330 Submerged or partially submerged sea caves
3- 1170 Reefs
4- 1110 Sandbanks which are slightly covered by sea water all the time

3.3.2. Cumulative Impacts Model outputs

The Portuguese territorial continental waters are affected by multiple impacts, as suggested by the multiple activities and uses presented in Figure 3.3 and shown by the output of CIM map, in Figure 3.4.

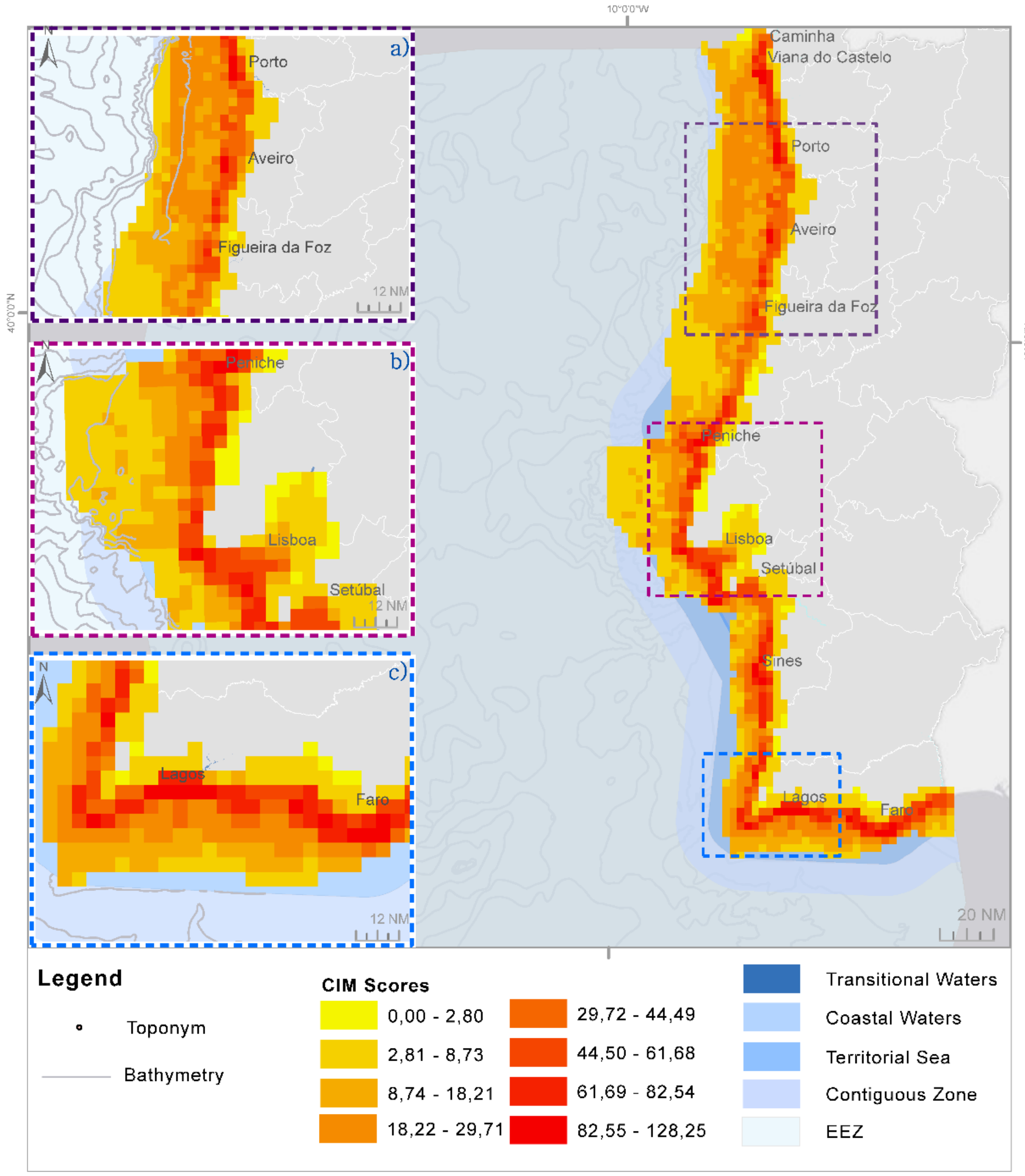


Figure 3.4. CIM Scores with details from a) north; b) centre; c) south.

The values in each cell varied from 0 to 128. The CIM values were grouped into distinct levels using the standard classification method 'Natural Breaks (Jenks)' (ESRI, 2016), where the class breaks are identified with the best group of similar values and maximizing the variances between classes. We divided the scores into the following classes (Figure 3.5): Low (scores 1 to 6); Medium (scores 7 to 31); High (scores 32 to 68) and Very High (scores higher than 69). The areas classified within each level were calculated as: 24% Low, 53% Medium, 17 % High and 6% Very High. The outputs from the CIM model are in line with results from similar studies in other marine areas (Ban and Alder, 2008; Batista et al., 2014; Korpinen et al., 2012; Micheli et al., 2013a) and with the results for the Portuguese maritime space according to Batista et al. (2014). Higher impact scores appear in the north stretch between Viana do Castelo/Figueira da Foz (Figure 3.5a), in the centre stretch between Peniche/Setúbal (Figure 3.5b) and in the south stretch between Lagos/Faro (Figure 35c) All areas with higher ranks are located in the coastal zone, mainly in the land-sea interface. This is the case for areas near urban centres with higher populations, such as Lisbon, Faro or the stretch Viana do Castelo/Figueira da Foz.

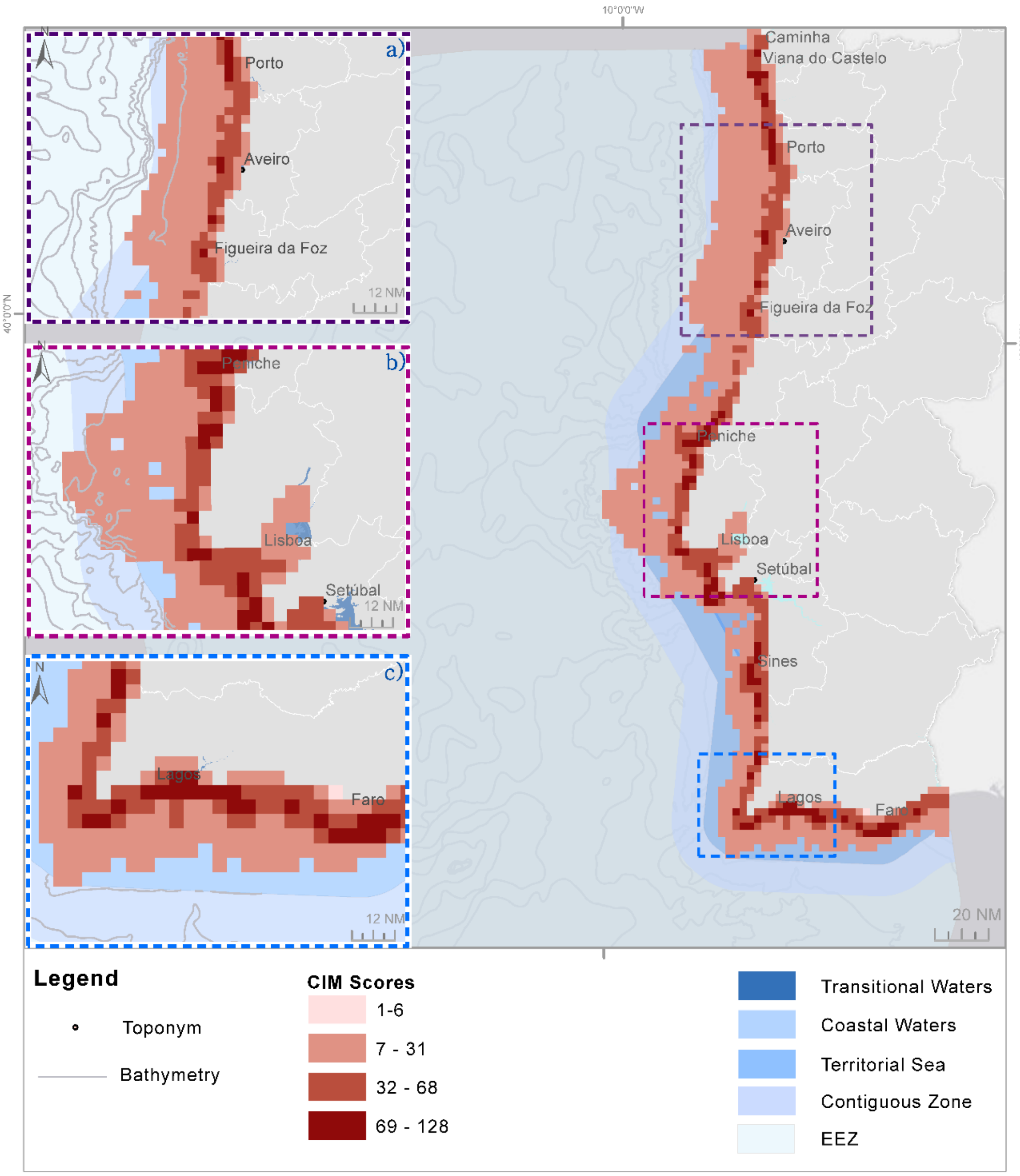


Figure 3.5. CIM Scores divided into classes, with details from a) north; b) center; c) south.

The maximum number of activities and uses that are simultaneous presented in a grid cell was between 13 to 15. However, this only occurred in a small percentage of areas (about 2% of the total occupied space). Higher percentages of simultaneously activities were observed in the classes of 4 to 6 and 7 to 9 (around 33 % and 26% of total occupied space, respectively), as seen in Figure 3.6. In ecosystems occurring beyond the 30m bathymetry (namely, Soft Shelf and Hard Shelf), the number of activities and uses that occur simultaneously is smaller, generally 1 to 6 (together, these two classes correspond in total to 82% of the occupied space).

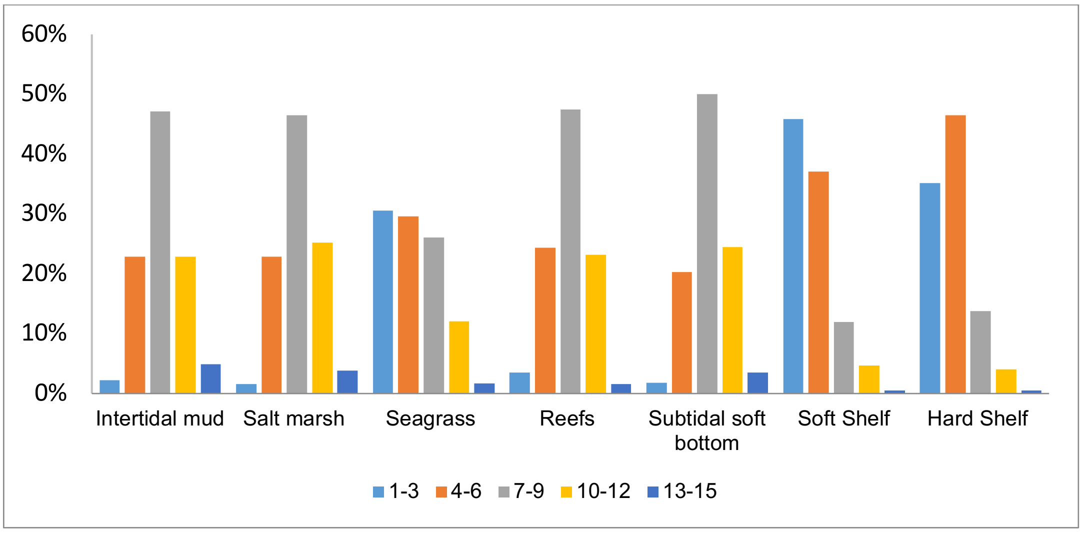


Figure 3.6. Number of activities and uses occurring within each ecosystem

The information presented in Figures 3.4, 3.5 and 3.6 is supported by the scores obtained when dividing the CIM by Territorial Sea and Contiguous Zone limits as defined in UNCLOS (UN, 1982) as well as by the limits of water bodies, as defined in the WFD, namely, Transitional Waters and Coastal Waters (EU, 2000, see also Table 3.3). Highest variability for Transitional and Coastal Waters (represented by the higher SD values) displays the variety of CIM scores occurring throughout these spaces. Coastal Waters appear as the most impacted space while the Contiguous Zone/EEZ is the least impacted.

Table 3.3. Summary statistics of CIM results (only cells with positive CI values were considered) according to the space division defined by WFD and UNCLOS.

Limits	**Min**	**Max**	**Average**	**SD**
Transitional Waters	3.53	128.24	27.4	25.9
Coastal Waters	3.82	128.24	41.38	25.09
Territorial Sea	3.00	121.58	23.69	19.97
Contiguous Zone/EEZ	3.00	26.58	11.44	7.14

All the considered activities and uses seem to be causing impacts on marine/coastal ecosystems. However, fisheries present the highest average impact score (namely 13.8) while affecting. 72% of the impacted space (Table 3.4). The second highest average scores were in pollutants input (9.49%), followed by coastal infrastructures (9.24%). Benthic coastal structures, tourism and emerging offshore energies appear with much lower impact scores and influence area. Some activities with specific location, such as coastal infrastructures, have impacts that spread to long distances (expressed as buffers distances), therefore resulting in high percentages of impacted space.

Table 3.4. Summary statistics of CIM results according to activity groups. Maximum, Average impact scores and SD values found for each grid cell (only cells with a positive CI value were considered), as well as the percentage of occupied space.

Activities/uses	Max	Average	SD	% Space
Fisheries	44.53	13.81	8.16	72%
Pollutants Input	44.04	9.49	9.37	51%
Coastal Infrastructures	27.07	9.24	7.06	32%
Benthic Structures	14.20	3.94	2.73	6%
Shipping	19.00	3.63	3.29	34%
Tourism	6.80	2.57	1.17	13%
Offshore Energies	4.60	2.11	0.73	4%

3.3.3. Overlapping CIM with MSP

Figure 3.7 and 3.8 show the overlap between the CIM and the POEM's Existent situation, Potential situation and MSP Proposal. In Figure 3.7, CIM scores are divided by classes and overlapped with the activities and uses existing in the maritime space (Figure 3.7a), the ones predicted for the future, i.e. potential activities and uses (Figure 3.7b), and the MSP Proposal for allocating the maritime space (Figure 3.7c), as defined in the POEM. In both the Existing and Potential situation, activities and uses are divided by thematic areas, namely Defence, Shipping, Fisheries and Aquaculture, Infrastructures, Energy and Geological Resources. The MSP Proposal defined Protection Areas, as the ones reserved for Nature Conservation, Defence and Heritage, and also Areas for General Use. These Areas are subdivided by spaces already in place for certain activities and uses (Consigned Areas) and others that may be allocated upon licensing (Areas in Consignation Process). Figure 3.8 shows the overlap between CIM scores with parts of both Potential situation and the MSP Proposal from POEM. The detailed view from the north and centre zone (Figure 3.8a and 3.8b) shows nature conservation areas suffering high impacts. Moreover, these are still prone to the occurrence of new potential activities, namely, oil prospection, wave or offshore wind or sand and gravel extraction.

The same happens in the south, where areas considered for protection purposes can be exposed to additional aquaculture and oil exploration activities (Figure 3.8c).

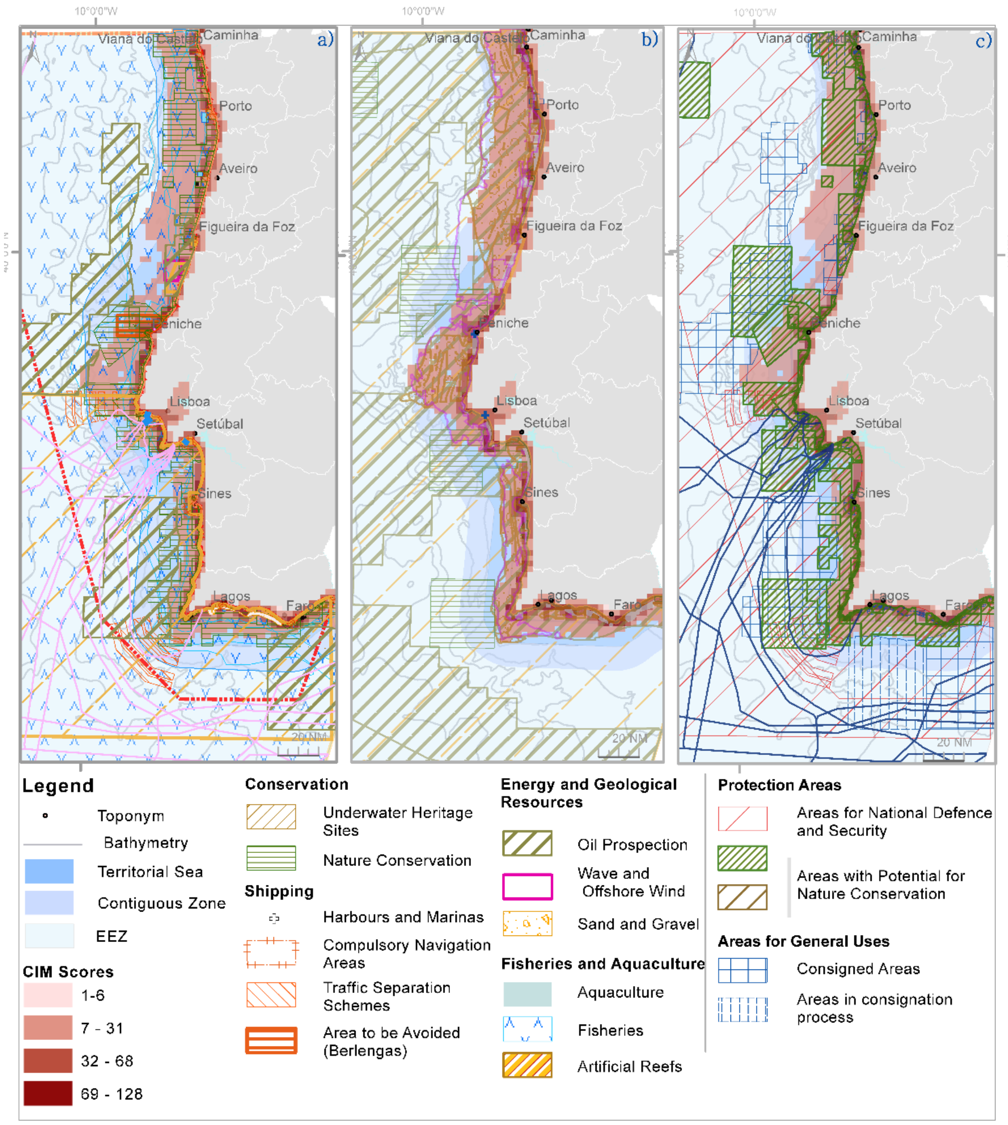


Figure 3.7. CIM and POEM a) Existent Situation; b) Potential Situation and c) MSP Proposal (INAG, 2012a)

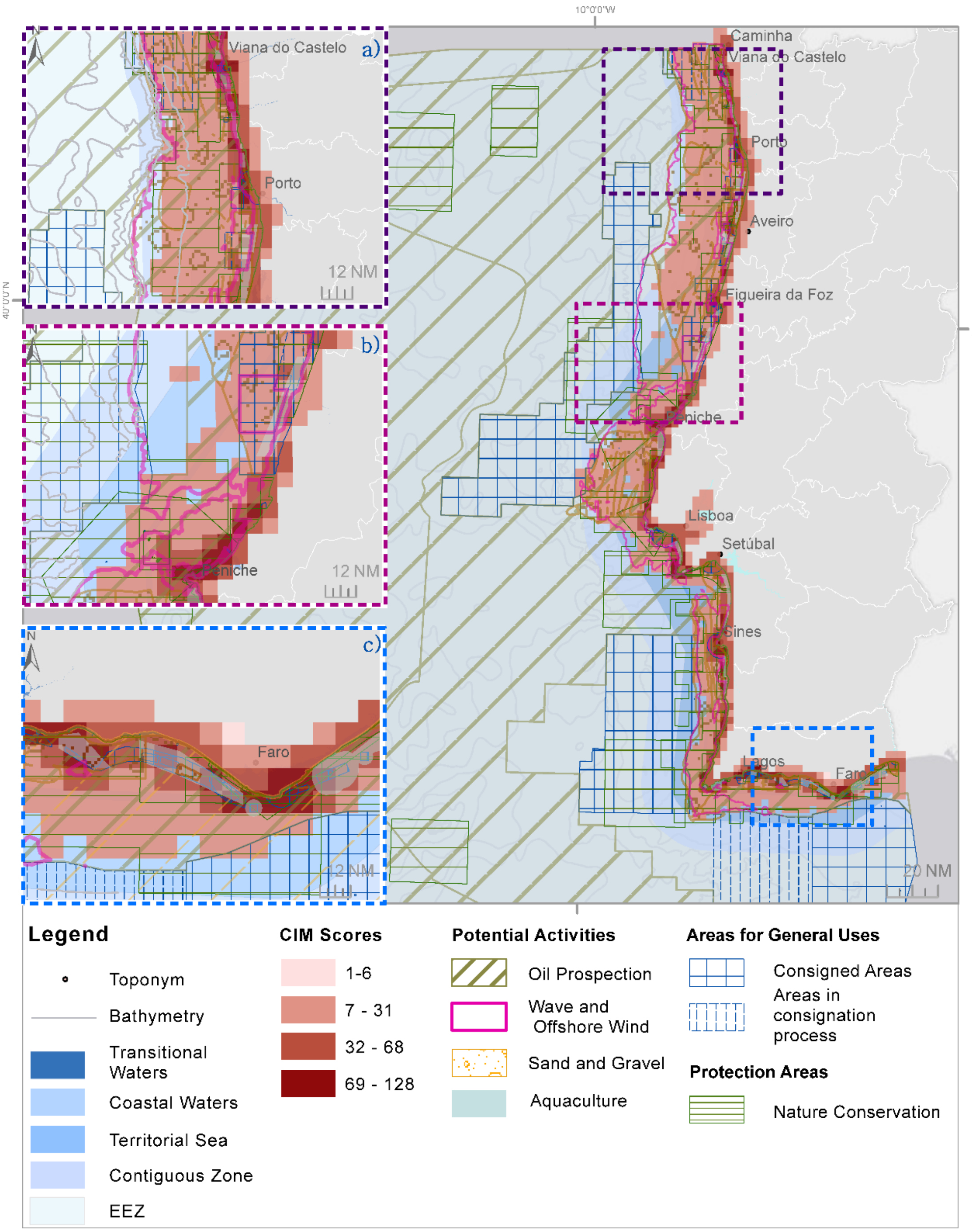


Figure 3.8. CIM and parts of both MSP Proposal and Potential activities that may occur, details from a) north; b) centre; c) south (INAG, 2012a).

3.4. Discussion

The ranking and mapping of cumulative impacts illustrates a quantitative approach to assess how ecosystems respond to anthropogenic impacts. The CIM overlapped with the MSP Proposal of POEM allows for an enhanced understanding of the relationships between potential human activities and uses and their impacts in ecosystems within the territory. At the appropriate scale, it can contribute significantly to the spatial planning process.

3.4.1. Spatial analysis of the CIM model results

All areas with higher ranks are located in the coastal zone, mainly in the land-sea interface near cities with high population density. All mapped impacts occur from the coastline to the Contiguous Zone limit (the 24 nm). In addition, the ecosystems suffering higher impacts are located within the coastal area and are exposed to a high number of simultaneous activities and uses (from 7 to 9). The lower average scores and high SD values obtained for the Territorial Sea suggests variable patterns of space occupation.

The activities and uses that are affecting more space and producing more impacts are fisheries and pollution inputs from human coastal activities. When overlapping the CIM scores with the POEM maps of existing and potential situations (Figure 3.7a and 3.7b), the amount of activities already occurring in the maritime space and the potential activities and uses that may still be overlayed are visible. When visualizing the details from Figure 3.8, it is noticeable that some areas have a protection status due to nature conservation, although oil prospection, wave or wind farms and sand and gravel exploration (in Figures 3.8a and 3.8b) or aquaculture installations (in Figure 3.8c) can be placed in these areas. The management strategy on the POEM's MSP Proposal requires several protection measures for installing new activities in protected areas, as shown in the compatibility matrix (Table 3.2). This is helpful for some activities nonetheless; there are several blank spaces on the table providing no clue on the level of restrictions occurring on these spaces.

3.4.2. CIM as a support to the Management Process

The environmental report of POEM (INAG, 2011) refers the importance to monitor the maritime space and the cumulative impacts, but it also adds as well that the only specified form of addressing the cumulative impacts is through the EIA of each project, where it still may not be enough. When reading the LGBOEM, it appears that the EIA may or may not even occur for new allocation projects (Ferreira et al., 2015a; Frazão Santos et al., 2015). The conflict/compatibilities analysis presented in Table 3.2 is common practice for addressing planning issues. As part of the POEM management guidelines, its purpose is showing the environmental compatibility of activities and uses and the appropriate protection measures that need to be implemented. Considering the activities that may occur in the future, as depicted in Figure 3.8, there are severe restrictions and incompatibilities for their allocation in areas with conservation status, except for aquaculture. However, more than analyzing the interactions between a certain activity and the nature conservation features, it is important to take into account the impacted status of that feature in order to more accurately assess the restrictions that activities or uses may be subject to on those specific habitats and species. The use of CIM scores may significantly improve management guidelines. It can support the conflicts and compatibility analyses by adding consideration to the already impacted ecosystems and the prospective impacts of new activities or uses. Combining the information provided by conflicts and compatibilities with the CIM scores will improve management either within space (also considering the overlaying in the water column) and in time.

The results from this model show that this type of information can be valuable for the MSP process, assisting the management of activities and uses within the maritime space. It is important to clearly evaluate what is the carrying capacity, i.e. the level of impact that a particular area may support. This means assessing how much, when and how infrastructures can be accommodated in a particular location. This is difficult even when submitting allocation plans to the EIA, not only when considering scenarios for one sector, such as how many wind farms should be built (Gilliland et al., 2004; Kannen, 2014; Lange et al., 2010), but even more when considering the full range of activities and uses occurring or predicted to occur over a foreseeable timescale in a given Area of General Use (Figure 3.7c).

Several limitations to this model have already been recognized by other authors (Halpern et al., 2008; Korpinen et al., 2012; Micheli et al., 2013a) and were perceived in our research, namely:

- Available data was characterized by using indicators for measuring pressures, relying on the available information.
- Cumulative Impacts may not be addible, even if activities and uses overlap on top of each other. Actually, one or multiple activities may provoke pressures which have effects on a single or on multiple receptors and relate differently with each other (Judd et al., 2015). In this model, pressures were always assumed as addible, however, this may not be the case, as they can act in other forms (Crain et al., 2008) leading to a completely different result of impacts.
- We have not considered the temporal scale of some activities that occur in specific seasons of the year.
- Ecosystem vulnerability values are what make these maps different from just human use intensity. In the model we used the data developed by Halpern et al. (2007), but for improved replication of the real conditions experienced in the Portuguese maritime space,

vulnerability values should be developed by experts with a good knowledge base, specifically for the Portuguese space.

- Using a grid size of 25 km^2 may represent a good compromise in the open ocean, in accordance with the available data, but the outputs suggest that in some Portuguese coastal areas, this grid size is too large, as there were occurrences of all the 7 ecosystems in some grid cells. For calculating the CIM scores, we used the sum of the ecosystem impact scores within each grid cell, representing them as present/absent for each one ecosystem, which distorted the reality of the marine space. Moreover, the available ecosystems to use in the study were all characterized the benthic structures, leaving behind the water column and the surface waters.
- Considering the bulk of information used in this study, and despite the limitations on obtaining information for the correct characterization of the activities, one of the most limiting factors of this study was the lack of detailed and usable information on ecosystems. Addition of habitats data and species distribution can improve the accuracy and use of such a model.

3.5. Conclusions

The CIM model is a valuable tool for informing patterns of impacts in particular areas and for providing inputs on the carrying capacity of the ecosystems. The CIM shows that the continental Portuguese maritime space is experiencing high cumulative impacts, particularly near the coasts, caused by current activities and uses. Furthermore, several other activities can be allocated to some high impacting areas. To be more effective, the conflict/compatibility analysis and environmental assessment tools must be improved. Information on cumulative impacts, such as the CIM maps provide are useful to support decisions, identifying those ecosystems that are most impacted overall. Additionally, it works as a catalogue of data for the region. When used in combination with other instruments, such as MSP and SEA, it provides valuable insights on specific management measures for potential activities and uses. It can also inform where reductions in anthropogenic pressures should be an explicit goal, and it is also a flexible tool that can be used for managing and monitoring the measures already in place. CIM will not contribute to reduce uncertainty on MSP, but it improves the ability to make more informed management decisions.

References

Ban, N., Alder, J., 2008. How wild is the ocean? Assessing the intensity of anthropogenic marine activities in British Columbia, Canada. Aquaric Conserv. Mar. Freshw. Ecosyst. 18, 671–675. https://doi.org/10.1002/aqc.816

Ban, N.C., Alidina, H.M., Ardron, J.., 2010. Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. Mar. Policy 34, 876–886. https://doi.org/10.1016/j.marpol.2010.01.010

Batista, M.I., Henriques, S., Pais, M.P., Cabral, H.N., 2014. Assessment of cumulative human pressures on a coastal area: Integrating information for MPA planning and management. Ocean Coast. Manag. 102, 248–257. https://doi.org/10.1016/j.ocecoaman.2014.09.020

Becker-Weinberg, V., 2015. Portugal's legal regime on marine spatial planning and management of the national maritime space. Mar. Policy 61, 46–53. https://doi.org/10.1016/j.marpol.2015.06.014

Calado, H., Ng, K., Johnson, D., Sousa, L., Phillips, M., Alves, F., 2010. Marine spatial planning: Lessons learned from the Portuguese debate. Mar. Policy 34, 1341–1349. https://doi.org/10.1016/j.marpol.2010.06.007

Crain, C., Halpern, B.S., Beck, M., Kappel, C., 2009. Understanding and managing human threats to the coastal marine environment. Ann. N. Y. Acad. Sci. 1162, 39–62. https://doi.org/10.1111/j.1749-6632.2009.04496.x

Crain, C.M., Kroeker, K., Halpern, B.S., 2008. Interactive and cumulative effects of multiple human stressors in marine systems. Ecol. Lett. 11, 1304–1315. https://doi.org/10.1111/j.1461-0248.2008.01253.x

Douvere, F., Maes, F., Vanhulle, a., Schrijvers, J., 2007. The role of marine spatial planning in sea use management: The Belgian case. Mar. Policy 31, 182–191. https://doi.org/10.1016/j.marpol.2006.07.003

EC, 2002. Recommendation of the European Parliament and of the Council concerning the implementation of Integrated Coastal Zone Management in Europe (2002/413/EC). Off. J. Eur. Communities L 148, 24–27.

EEA, 2014. EUNIS habitat classification 2007 - Revised descriptions 2012. http://eunis.eea.europa.eu/ (acessed 13.03.2015).

EEC, 1992. Council Directive 92/43/EEC of 21 May 1992 published in the OJEC Nº L206/7 44.

ESRI, 2016. Classifying numerical fields for graduated symbology—Help | ArcGIS for Desktop [WWW Document]. URL http://desktop.arcgis.com/en/arcmap/10.3/map/working-with-layers/classifying-numerical-fields-for-graduated-symbols.htm (accessed 8.19.16).

EU, 2014. Directive 2014/89/EU of the European Parliment and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Offical Journal of the European Union. European Commission.

EU, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). European Commission.

EU, 2007. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. An Integrated Maritime Policy for the European Union COM(2007) 575 final. European Commission.

Ferreira, M.A., Calado, H., Pereira da Silva, C., Abreu, A.D., Andrade, F., Fonseca, C., Gonçalves, E.J., Guerreiro, J., Noronha, F., Pereira, M., Pinto Lopes, C., Ribeiro, M.C., Stratoudakis, Y., Vasconcelos, L., 2015a. Contributions towards maritime spatial planning (MSP) in Portugal – Conference report. Mar. Policy 59, 61–63. https://doi.org/10.1016/j.marpol.2015.04.017

Ferreira, M.A., Silva, C.P., Campbell, H. V., Conway, F., Andrade, F., Johnson, D., 2015b. Gold Rush or Pandora's Box? Toward a Transparent and Measured Approach to Marine Spatial Planning in Portugal. Int. J. Mar. Coast. Law 30, 1–27. https://doi.org/10.1163/15718085-12341365

Frazão Santos, C., Domingos, T., Ferreira, M.A., Orbach, M., Andrade, F., 2014. How sustainable is sustainable marine spatial planning? Part II - The Portuguese experience. Mar. Policy 49, 48–58. https://doi.org/10.1016/j.marpol.2014.04.005

Frazão Santos, C., Orbach, M., Calado, H., Andrade, F., 2015. Challenges in implementing sustainable marine spatial planning: The new Portuguese legal framework case. Mar. Policy 61, 196–206. https://doi.org/10.1016/j.marpol.2015.08.010

Gilliland, P.M., Rogers, S., Hamer, J.P., Crutchfield, Z., 2004. The practical implementation of marine spatial planning – understanding and addressing cumulative effects. Report of a Workshop held 4 December 2003, Stansted. English Nature Research Reports, No. 599, Peterborough: English Nature., English.

Halpern, B.S., Kappel, C., Selkoe, K., Micheli, F., Ebert, C., Kontgis, C., Crain, C.M., Martone, R.G., Shearer, C., Teck, S.J., 2009. Mapping cumulative human impacts to California Current marine ecosystems. Conserv. Lett. 2, 138–148. https://doi.org/10.1111/j.1755-263X.2009.00058.x

Halpern, B.S., Selkoe, K., Micheli, F., Kappel, C., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conserv. Biol. 21, 1301–1315. https://doi.org/10.1111/j.1523-1739.2007.00752.x

Halpern, B.S., Walbridge, S., Selkoe, K. a, Kappel, C. V, Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., 2008. A global map of human impact on marine ecosystems. Science 319, 948–952. https://doi.org/10.1126/science.1149345

Henriques, S., Pais, M.P., Batista, M.I., Teixeira, C.M., Costa, M.J., Cabral, H., 2014. Can different biological indicators detect similar trends of marine ecosystem degradation? Ecol. Indic. 37, 105–118. https://doi.org/10.1016/j.ecolind.2013.10.017

INAG, 2011. POEM—Plano de Ordenamento do Espaço Marítimo, Volume 3: Relatório Ambiental.

Judd, A., Backhaus, T., Goodsir, F., 2015. An effective set of principles for practical implementation of marine cumulative effects assessment. Environ. Sci. Policy 54, 254–262. https://doi.org/10.1016/j.envsci.2015.07.008

Kannen, A., 2014. Challenges for marine spatial planning in the context of multiple sea uses, policy arenas and actors based on experiences from the German North Sea. Reg. Environ. Chang. 14, 2139–2150. https://doi.org/10.1007/s10113-012-0349-7

Kelly, C., Gray, L., Shucksmith, R.J., Tweddle, J.F., 2014. Investigating options on how to address cumulative impacts in marine spatial planning. Ocean Coast. Manag. 102, 139–148. https://doi.org/10.1016/j.ocecoaman.2014.09.019

Korpinen, S., Meski, L., Andersen, J.H., Laamanen, M., 2012. Human pressures and their potential impact on the Baltic Sea ecosystem. Ecol. Indic. 15, 105–114. https://doi.org/10.1016/j.ecolind.2011.09.023

Lange, M., Burkhard, B., Garthe, S., Gee, K., Kannen, A., Lenhart, H., Windhorst, W., 2010. Analyzing Coastal and Marine Changes - Offshore Wind Farming as a Case Study - Zukunft Küste - Coastal Futures. LOICZ No. 36 general, coastal futures, North Sea, HZG-general,.

Lastras, G., Arzola, R.G., Masson, D.G., Wynn, R.B., Huvenne, V.A.I., H??hnerbach, V., Canals, M.,

2009. Geomorphology and sedimentary features in the Central Portuguese submarine canyons, Western Iberian margin. Geomorphology 103, 310–329. https://doi.org/10.1016/j.geomorph.2008.06.013

MA, 2005. Ecosystems and Human Well-being Island Press, Washington, DC., Millenium Assessments. World Resources Institute. https://doi.org/10.1196/annals.1439.003

MAMAOT, 2012. Maritime Strategy for Continent Subdivision (Estrategia Marinha para a Divisão do Continente). Ministry of Agriculture, Sea, Environment and Spatial Planning 930.

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A. a., 2013a. Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: Assessing current pressures and opportunities. PLoS One 8. https://doi.org/10.1371/journal.pone.0079889

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A. a, 2013b. Supplementary Online Materials Methods Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities 1–29.

Parravicini, V., Rovere, A., Vassallo, P., Micheli, F., Montefalcone, M., Morri, C., Paoli, C., Albertelli, G., Fabiano, M., Bianchi, C.N., 2012. Understanding relationships between conflicting human uses and coastal ecosystems status: A geospatial modeling approach. Ecol. Indic. 19, 253–263. https://doi.org/10.1016/j.ecolind.2011.07.027

Stelzenmüller, V., Lee, J., South, A., Foden, J., Rogers, S.I., 2013. Practical tools to support marine spatial planning: A review and some prototype tools. Mar. Policy 38, 214–227. https://doi.org/10.1016/j.marpol.2012.05.038

Stelzenmüller, V., Rogers, S.I., Mills, C.M., 2008. Spatio-temporal patterns of fishing pressure on UK marine landscapes, and their implications for spatial planning and management. ICES J. Mar. Sci. 65, 1081–1091. https://doi.org/10.1093/icesjms/fsn073

UN, 1982. United Nations Convention on the Law of the Sea. United Nations, Montego Bay, 7–208.

WWF, 2014. Cumulative Eff ects in Marine Ecosystems : Scientifi c Perspectives on its Challenges and Solutions.WWF-Canada and Center For Ocean Solutions. 60.

4. MAPPING THE FUTURE: PRESSURES AND IMPACTS IN THE PORTUGUESE MARITIME SPATIAL PLANNING

Abstract

Maritime Spatial Planning (MSP) is bringing new challenges to planning and management in the marine realm, namely on the environmental assessment of the new plans and projects. Portugal is developing its first MSP instrument, PSOEM (*Plano de Situação do Ordenamento do Espaço Marítimo*), since 2015 and published it on December 2019. This paper focuses on a particular stage of the Strategic Environmental Assessment (SEA) of PSOEM regarding the assessment of the activities/uses that may significantly affect Natura 2000 marine network during the Plan's implementation in the Mainland subdivision. Over the years, progress has been made in researching and assessing the environmental impacts of maritime activities/uses. However, its application to practice raised several challenges and limitations. The methodological approach presented in this paper was developed to overcome knowledge, data and time constraints. Some of the limitations are a consequence of the MSP approach itself adopted in Portugal, namely the low technical detail on future uses and activities, which is required and desirable at this level of planning. Others relate with the lack of spatially explicit data on marine habitats and species distribution preserved under Natura 2000 network, which is not fully established in the marine environment. The adopted methodology started with the characterization and mapping of the conservation values and the pressures arising from the potential activities/uses. It followed with the assessment of their impacts and finally with the identification of mitigation measures, which were then adopted by the PSOEM as good practices. As new knowledge is generated and more information is collected, this tailor-made approach can be easily adapted and improved to keep supporting decision-making throughout PSOEM's implementation. The method can be easily adapted and transferred to other contexts, not only within the Portuguese maritime area, and could be made available to stakeholders that wish to invest in blue growth.

Keywords: SEA; Natura 2000; MSP; Portugal; Activities and Uses; Environmental assessment

4.1. Introduction

Impact assessment rose from public demand due to serious environmental damages caused by increasing human activities. The United States was the first nation to address public concerns over the protection of the environment and enacted in 1969 the National Environmental Policy Act (NEPA, 1969). The latter is based on the premise that sustainable development is desirable, but consequences and environmental implications of plan or projects should be taken into account before decisions are made (Jay et al., 2007; Willsteed et al., 2017). Assessments can be carried out either for individual projects (EIA – Environmental Impact Assessment) or for public plans or programmes (SEA-Strategic Environmental Assessment (European Union, 2017). The

European SEA Directive (Directive 2001/42/EC), required by legislative, regulatory or administrative provisions, aims to provide the integration of environmental considerations into the preparation and adoption of plans and programmes.

When plans or programmes may cause significant effects on the integrity of Natura 2000 sites, an appropriate assessment of their potential implications is required, in line with the site's conservation objectives. Natura 2000 is a European ecological network of sites (terrestrial, coastal and marine) for the conservation of natural habitats and wild fauna and flora, listed under Habitats and Birds Directives (Directive 92/43/EEC and Directive 2009/147/EC). Supported by these two Directives, which envisage spacially targeted and enhanced conservation provisions and measures, the Natura 2000 network was designed to protect the common heritage of the European Community (Möckel, 2017). Along with the Marine Strategy Framework Directive (MSFD Directive 2008/56/EC), these two directives are the environmental pillar of the wider Integrated Maritime Policy (IMP), which aims to provide a more coherent approach to maritime issues in Europe. Concepts as the Ecosystem-Based Approach (EBA) and Maritime Spatial Planning (MSP) were developed to decrease fragmentation and sectoral approaches, aiding the implementation of IMP (Altvater and Passarello, 2018; Katsanevakis et al., 2011; Sousa et al., 2016). EBA explicitly considers the interdependence of all ecosystem components, including species both human and nonhuman, and the environments in which they live (Christensen et al., 1996; Levin and Lubchenco, 2008). The MSP Directive was adopted by the EU Member States in 2014 (Directive 2014/89/EU, EU, 2014) as a cross-cutting policy of IMP, to develop the integrated planning and management, embodied with the EBA (Douvere, 2008). MSP is defined, within the Directive, as a public process of analysing and organising human activities in marine areas to achieve ecological, economic and social objectives (EU, 2014). It establishes that coastal Member States must develop a national MSP by 2021.

One of the most pressing challenges of MSP implementation is how to address the impacts of multiple activities, and their various associated pressures (Frazão Santos et al., 2018; Fernandes et al., 2018; Judd et al., 2015; Kannen, 2014; Katsanevakis et al., 2011; Stelzenmüller et al., 2009). Attempts to address these issues have been made, with different purposes and contexts, either by the scientific community (Fernandes et al., 2017; Halpern et al., 2008; Knights et al., 2013) or at institutional bodies as part of their attributions to perform national or regional marine environmental assessments (Andersen and Stock, 2013; Kelly et al., 2014; Kruk-Dowgiallo et al., 2011; SSMEI, 2010). They follow a common framework, which includes characterizing the baseline conditions, the activities and describing their pressures and impacts. Various criteria have been used for the impact assessment, such as intensity, direction, spatial extent, duration, frequency, reversibility, or probability (Andersen and Stock, 2013; Beanlands and Duinker, 1983; Halpern et al., 2007; Willsteed et al., 2017). The Swedish SEA for the MSP proposal for the Baltic Sea, for instance, adopted Symphony, a quantitative tool to assess cumulative environmental impacts from different planning options (SwAM, 2018). This tool integrates the distribution of ecosystem components, the spatial extent of pressures and the sensitivity of ecosystems to the pressures, based on expert opinion. Since Symphony is based on spatial data, which is often scarce, other models have been used for extrapolation and to overcome data limitations. At the pilot SEA for the Western Gulf of Gdansk, within the BaltSeaPlan project, an impact assessment framework was developed in a prospective outlook for the plan (Kruk-Dowgiallo et al., 2011). In this study, the typology of each impact was defined and divided according to three criteria: direction of influence, type of relation to the influenced object, and time of influence. The impact of each activity, defined at the start of the analysis, on all components of the environment was accessed. In the Scottish National Marine Plan, a Habitat Appraisal report was developed where the potential generic effects of the activities of each marine sector on the qualifying interests of Natura 2000 sites were identified but no significance assessment was pursued due to the generic nature of the plan (Scottish Government, 2015).

When applying an impact assessment framework to actual MSP processes, relevant knowledge, data and information gaps are one of the most cited impediments (Douvere and Ehler, 2011). These constraints/factors, together with the adopted MSP approach itself and time restrictions, contribute to shaping the framework of impact assessment. Nevertheless, one of the major benefits of developing impact assessment at the beginning of the planning process, embedded in a SEA, is the early environmental awareness, leading to better informed, efficient and focused project-level assessments and decisions. It requires starting the environmental assessment on a high strategic level and following it across sequential decision-making levels (Partidário, 2012; SSMEI, 2010; Tamis et al., 2016).

In Portugal, the Law no. 17/2014, published in April 2014, establishes the basis of the policy for Marine Spatial Planning and Management (MSP Law) of the national maritime space (Becker-Weinberg, 2015). Afterwards, the Decree-Law no. 38/2015, published in March 2015, further develops key aspects of the Law and transposed the EU MSP Directive. It defines two types of maritime spatial planning instruments, the Situation Plan (PSOEM - *Plano de Situação do Ordenamento do Espaço Marítimo*) and the Allocation Plan (AP - *Planos de Afetação*). The PSOEM is the first line instrument in MSP. It identifies the spatial and temporal distribution of existing and potential uses and activities to be developed under a private use permit, as well as the natural and cultural values of strategic importance for environmental sustainability and intergenerational solidarity (DGRM, 2019a). The AP is a supplementary planning tool, which can be developed to allocate new areas to existing or new uses and activities that are not included in PSOEM (Frazão Santos et al., 2015). PSOEM's elaboration was committed, by the Ruling nº. 11494/2015, to Directorate General for Natural Resources, Safety and Maritime Services (DGRM) in the Mainland and Extended Continental Shelf subdivisions. It was approved in December 2019 by the Resolution of the Council of Ministers n.º 203-A/2019. In parallel to the development of PSOEM, a SEA was carried out, in order to identify the potential effects arising from its implementation (MAM, 2011).

This paper focuses on a particular stage of the work developed within the SEA of PSOEM regarding the assessment of the activities/uses that may significantly affect Natura 2000 marine network, within the Mainland subdivision. It aims to show how real dilemmas were surpassed when integrating impact assessment in the Portuguese MSP process, a real case study, bound to be developed under knowledge constraints, data-gaps and time limitations.

4.2. Material and methods

4.2.1. Study area

PSOEM covers the entire Portuguese maritime space, which is divided into four subdivisions: Mainland, Azores, Madeira, and Extended continental shelf (Figure 4.1). This paper narrows its approach to the Mainland subdivision, in particular to the Natura 2000 marine network areas and to the potential maritime activities/uses that are spatially explicit, foreseen within PSOEM.

The Mainland subdivision encompasses the Interior Waters (6 508 km^2), the Territorial Sea (16 460 km^2) and the Economic Exclusive Zone (EEZ, 287 521 km^2) (Bessa Pacheco, 2013).

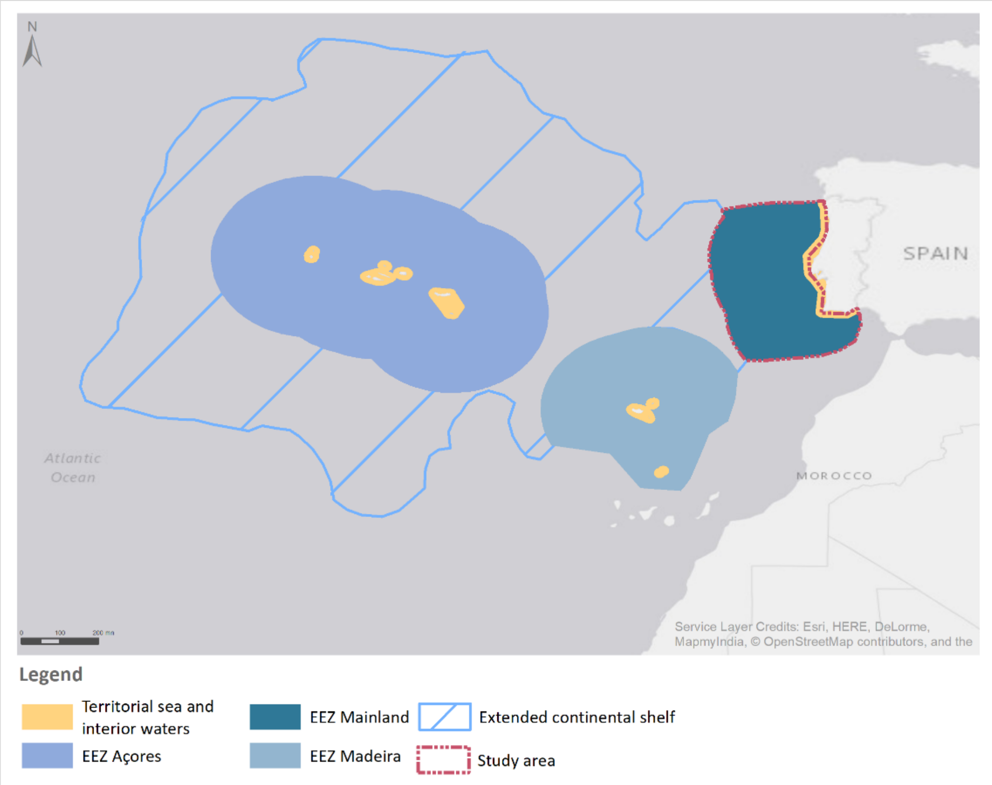


Figure 4.1. Functional units of the Portuguese maritime space

PSOEM defines a development model for the maritime space through the definition of areas where new private uses and activities can take place (DGRM, 2019b). These areas are spatially explicit and can be observed in the PSOEM geoportal, which was created to support and display the spatial data (http://www.psoem.pt/geoportal_psoem/, (DGRM, 2019a). According to Decree-Law no. 38/2015, these activities will require a private use permit to take place (*TUPEM - Título de Utilização Privativa de Espaço Marítimo*). Consequently, it is expected that the Territorial Sea of the Mainland subdivision will experience an increase in the demand for space for maritime activities. It is also within the Territorial Sea that most of the common uses (e.g. artisanal fisheries or recreational vessels), as well as port and navigation easements (e.g. port access corridors), take place (DGRM, 2019b). Therefore, this is the most challenging area for the coexistence of multiple uses.

In the Mainland subdivision, the Natura 2000 network comprises 19 sites, from which 11 are Special Protected Areas (SPA) and 8 are Sites of Community Importance (SCI) (Figure 4.2 and Table 4.1). From these, only 2 SCIs and 3 SPAs are entirely marine, with their overall marine area representing only 3% of the total Natura 2000 network. The remaining SCIs and SPAs pertain to coastal areas with marine stretches, 5 of them occupy only marine interior waters, from which only one is located exclusively in the EEZ (Banco de Gorringe).

Table 4.1. SCI and SPA with marine areas classified under Natura 2000 within the Mainland subdivision (source: Environmental Report PSOEM, (DGRM, 2019a))

Name	Code	Total area (km²)	Marine area (%)	Location
Sites of Community Importance (SCI)				
Litoral Norte	PTCON0017	27.97	33	Marine interior waters / Territorial sea
Maceda/Praia da Vieira	-	5025.382	100	Marine interior waters / Territorial sea
Ria de Aveiro	PTCON0061	331.27	7	Marine interior waters / Territorial sea
Peniche/Santa Cruz	PTCON0056	82.86	66	Marine interior waters
Sintra/Cascais	PTCON0008	166.32	51	Marine interior waters / Territorial sea
Arrábida/Espichel	PTCON0010	206.62	27	Marine interior waters / Territorial sea
Costa Sudoeste (extension)	PTCON0012	2633.95	62	Marine interior waters / Territorial sea
Banco Gorringe	PTCON0062	22927.78	100	EEZ
Special Protection Areas (SPA)				
Estuários dos rios Minho e Coura	PTZPE0001	33.93	10	Marine interior waters
Ria de Aveiro	PTZPE0004	514.46	40	Marine interior waters / Territorial sea
Aveiro/Nazaré	PTZPE0060	2929.29	100	Marine interior waters / Territorial sea
Ilhas Berlengas	PTZPE0009	1026.63	100	Marine interior waters / Territorial sea
Cabo Raso	PTZPE0061	1335.47	100	Marine interior waters / Territorial sea
Cabo Espichel	PTZPE0050	164.28	95	Marine interior waters / Territorial sea
Lagoa de Santo André	PTZPE0013	21.65	30	Marine interior waters
Lagoa da Sancha	PTZPE0014	4.09	52	Marine interior waters
Costa Sudoeste	PTZPE0015	1006.85	53	Marine interior waters / Territorial sea
Leixão da Gaivota	PTZPE0016	0.0016	24	Marine interior waters
Ria Formosa	PTZPE0017	232.69	36	Marine interior waters / Territorial sea

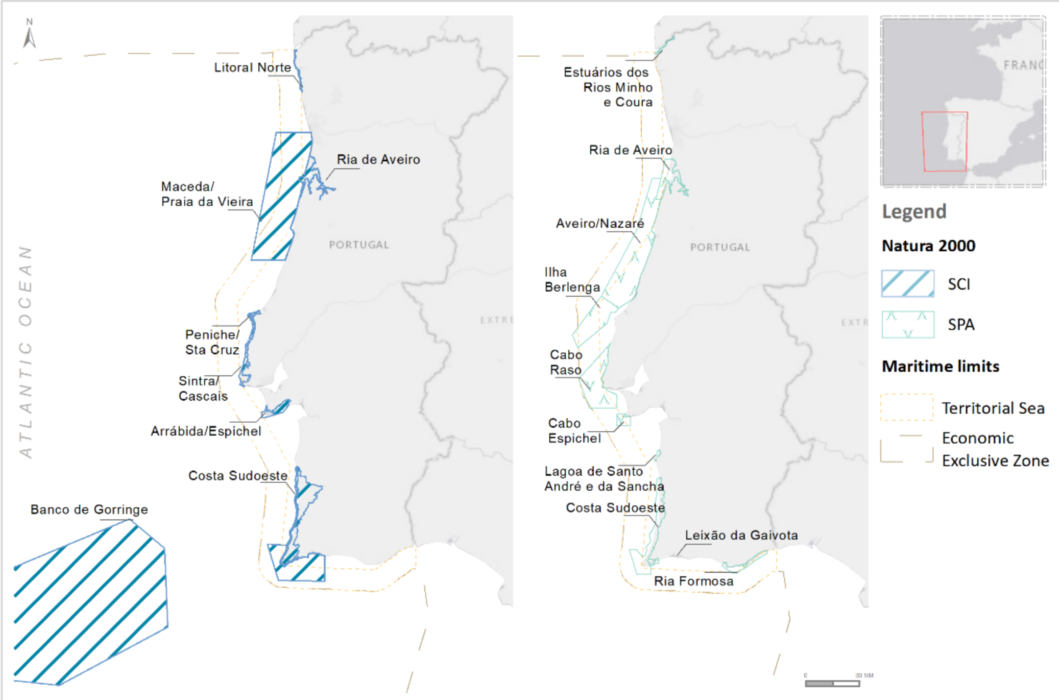


Figure 4.2. SPAs and SCIs classified under Natura 2000 within the Mainland subdivision, as defined at the time of the study, December 2018 (Data source: ICNF “Natura 2000 — ICNF,”2019)

4.2.2. Methodology

A semi-quantitative approach was developed to assess, and respond to, the likely significant impacts of PSOEM’s implementation in the Natura 2000 marine network. It followed four major steps. The first step was the identification of the conservation values to protect, followed by the identification and mapping of the pressures arising from the potential activities/uses foreseen in the PSOEM and the assessment of their impacts. Afterwards, the necessary mitigation measures were identified and integrated into the plan. Figure 4.3 displays a scheme with the overall steps and a description of each step is provided in the following sections.

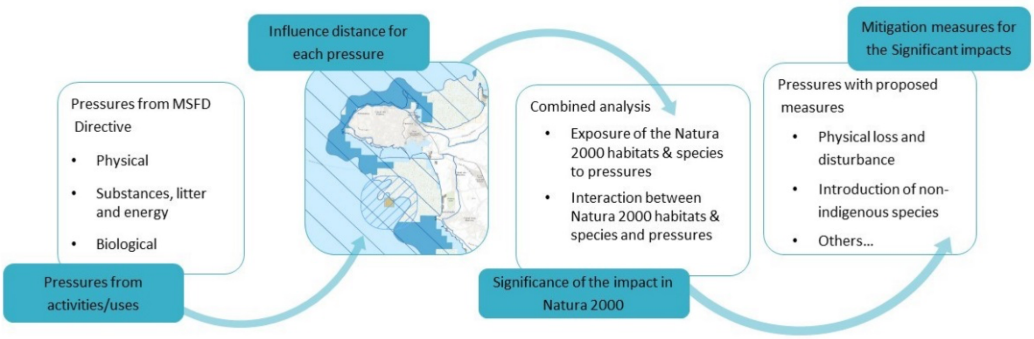


Figure 4.3. Schematic methodology applied

This methodology was discussed with and validated by the national authorities responsible for the MSP (DGRM), nature conservation (Instituto da Conservação da Natureza e das Florestas -

ICNF) and environmental assessment (Agência Portuguesa do Ambiente – APA). It involved desktop analysis, expert judgment and spatial analysis. A Geographic Information System (GIS) software was used for data preparation and analysis (ESRI, ArcGIS 10.5 Desktop) with the Spatial Analyst extension and the spatial reference system adopted was the European Terrestrial Reference System 1989 (ETRS89) with Transverse Mercator Projection (PT-TM06).

Spatial information on existing and potential activities/uses was provided by DGRM. Spatial information regarding habitats and species distribution, as well as Natura 2000 classified areas, were provided by the ICNF. For some SCIs the habitats distribution was obtained from the EMODnet website ("EMODnet Seabed Habitats - Homepage," 2019). Table 1 in Supplementary Material B1 summarizes the spatial information used in the study and the respective sources of information.

4.2.2.1. Conservation values

The aim of this stage was to analyze the marine conservation values (habitats and species) preserved under Natura 2000 network, particularly their distribution, conservation goals and major threats. This sets the baseline for assessing the likely significant impacts and establishing mitigation measures.

A compilation of this information was performed and for each protected area were selected the marine conservation values (marine habitats and species) to be the focus of the analysis. The National Sectorial Plan of Natural 2000 (ICNF, 2008), habitats and species characterization sheets ("Natura 2000 — ICNF," 2019), as well as management plans of the SCI and SPA were the major sources of information.

4.2.2.2. Pressures and impacts

For the purpose of characterizing and mapping the pressures, the maritime uses and activities integrated into the PSOEM were first analyzed in terms of their pressures and possible impacts on the conservation values, establishing a relationship framework between activities/uses-pressures-impacts (for detailed information see Table 2 to 16 of the Supplementary Material B1). The identification of the pressures acting on the marine environment followed the pressures' typologies defined at Annex III of the MSFD, which is the environmental pillar for MSP (EC, 2017). Several sources of information were used to support this task, namely the Marlin database, the OSPAR literature of reference, and the MSFD Report of the Mainland subdivision (MAMAOT, 2012; "MarLIN - The Marine Life Information Network - Home,"2019; OSPAR

Commission, 2009). This work was done in close relation with DGRM, which is also the competent authority for the MSFD implementation.

The lack of knowledge on the potential activities/uses increased the challenge of assessing their effects on natural values. As so, activities/uses were analyzed in order to understand the different types of technologies that can be implemented and explored. Maritime activities may either produce effects at local scale or may spread and originate effect several kilometers away from the source. For instance, aquaculture can cause local sealing and smothering in the seabed where its located, but can also be a source of microbial pathogens, which may be transported for kilometers from their origin (Ban et al., 2010). For this reason, this study quantified the limiting distance at which pressures ceased to have impacts, following other studies approaches (Andersen and Stock, 2013; Ban et al., 2010). For each pairwise activity/use-pressure, an influence distance radius was assigned (see Table 17 of the Supplementary Material B1), using information from the regional study of marine impacts assessment in the eastern North Sea (Andersen and Stock, 2013), and information from other scientific and technical documents, such as Ban et al. (2010), DGRM (2019b), and OSPAR Commission (2009). The pressures' influence distance ranged from local to a maximum of 50 km. Based on the influence distance, each pressure was mapped and then overlapped with Natura 2000 marine areas. Only the pressures that overlapped with protected areas were considered for further analysis.

4.2.2.3. Impact assessment

A critical part of the assessment of impacts is the spatial and temporal extent of pressures, and their magnitude (Judd et al., 2015). Several authors (Ban et al., 2010; Halpern and Fujita, 2013; Micheli et al., 2013) map the intensity of the pressures on each habitat type and apply a vulnerability weight that translates the intensity of the pressure into the predicted impact on the habitat. Within the scope of the planning in SEA, due to the uncertainty of the expected development scenarios, detailed information such as the extent, intensity or seasonality of potential activities and, consequently, their effects on the natural values is unknown. Therefore, within the scope of SEA, impacts were assessed based on the combination of two factors: i) exposure of the natural values (habitats and species) to the pressures within each SCI and SPA, and ii) potential interaction between the pressures and the natural values.

The degree of exposure was derived from the guidelines for the establishment of the Natura 2000 network in the marine environment (EEA, 2007). This document indicates relative surface thresholds to represent adequately the habitat in the Natura 2000. The degree of exposure to each pressure varied according to the relative area of pressure incidence on: (i) the spatial distribution of the protected habitat/species within the SCI/SPA (when it was available); or (ii) the entire marine area of the SCI/SPA (when detailed spatial information did not exist or was not available). The degree of exposure varied between:

- **High (H):** when the percentage of the habitat/species (or marine area of the SCI/SPA) area overlapped by the pressure was higher than 15%;
- **Medium (M)**: when the percentage of the habitat/species (or marine area of the SCI/SPA) area overlapped by the pressure was higher than 2% and lower than or equal to 15%;
- **Low (L)**: when the percentage of the habitat/species (or marine area of the SCI/SPA) area overlapped by the pressure was lower than or equal to 2%.

The potential links between the pressures and their potential impacts on the conservation values identified in the first step “Conservation values” were classified (Table 4.2) according to the work from the N2K group (N2K, 2017), which provide a relationship between marine Natura 2000 habitats and species and pressures (terminology similar to MSFD). The research study of Morel *et al*. (2018), was also used as it included a compilation of pressures and impacts from maritime activities in the study area.

The interaction between pressures and natural values was categorized as:

- **Probable (A)** when the pressure is known to change the habitat type and/or affect the individuals of species in most instances;
- **Possible (B)** when the pressure may change the habitat and/or affect the individuals of species in some cases or particular locations or situations;
- **Unlikely (C)** when the pressure is unlikely to affect habitat and/or individuals of species;
- **Unknown (D)** when there is not enough information available.

Table 4.2. Interaction among pressures and conservation values (Source: (N2K, 2017); Morel et al., 2018 when marked with *; by recommendation from ICNF as a result of the expert meeting when marked with **)

Pressures		**Interaction between pressure and habitat/species**				
		1110	**1170**	**8330**	**cetaceans**	**Sea birds**
Physical	Physical disturbance to the seabed (temporary or reversible)	A	A	A	B	B
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)	A	A	A	B**	B
	Changes to hydrological conditions	B	B	B	C	C

Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition	B	B	D	D	B
	Input of organic matter — diffuse sources and point sources	B	B	D	C*	B
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events	B	B	B	A	A
	Input of litter (solid waste matter, including micro-sized litter)	B*	B*	B*	B*	A*
	Input of anthropogenic sound (impulsive, continuous)	C	C	B	A	B*
	Input of other forms of energy (including electromagnetic fields, light and heat)	C	C	C	B*	D
Biological	Input of microbial pathogens	D	D	D	B	B
	Input or spread of non-indigenous species	D	B	C	D	B
	Input of genetically modified species and translocation of native species	D	D	D	D	D
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species	D	D	D	D	D
	Disturbance of species (e.g. where they breed, rest and feed) due to human presence	C*	B*	B*	B*	A
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	A	A	B	A	A

The impact assessment resulted from the combined analysis between the two criteria: exposure of habitat/species to pressures, and level of interaction between pressures and habitat/species. Figure 4.4 shows the evaluation matrix and the resulting degree of impact: High (H), Medium (M) or Low (L). High degree of impact means that a certain pressure caused by a certain activity will likely cause a significant effect on Natura 2000 habitat or species.

Figure 4.4. Impact evaluation matrix

In order to validate the methodology for the impact assessment, an expert meeting was held on the 8th November of 2018, at the DGRM premises. This meeting was attended by experts from ICNF, APA, IPMA (Instituto Português do Mar e da Atmosfera) and DGRM. The intervals that set the degree of exposure; the interaction between the pressures and their potential impacts on Natura 2000 habitats and species; as well as the matrix to evaluate impacts, were presented, discussed and accepted by all attendees at the meeting.

4.2.2.4. Mitigation measures

This step aimed to identify which activities/uses could need additional measures to minimize or even cancel potential significant impacts. PSOEM includes a set of informative forms for each activity and use, which cover several parameters (e.g. current and potential areas for such activity/use, good practices for the activity/use in light of sustainable use and management of the maritime space, and compatibility measures) (DGRM, 2019b). The pressures that were causing significant impacts (classified as high) were analyzed in detail. Information on good practices was examined to understand if measures to minimise potentially significant impacts were already identified in the document. Otherwise, additional measures were proposed to be included in the plan. The same approach was followed for the pressures with unknown interaction with the Natura 2000 habitats and species, with the aim of adopting a precautionary approach and avoiding serious or irreversible damage.

4.3. Results

4.3.1. Conservation values

The SCIs in the Mainland subdivision comprise three marine habitat types and two species for which marine site designation is required, according to the Habitats Directive (EEC, 1992; ICNF, 2018): reefs (1170), sandbanks which are slightly covered by seawater all the time (1110), submerged or partially submerged sea caves (8330), common bottlenose dolphin (*Tursiops* *truncatus)* and harbor porpoise *(Phocoena phocoena).* From the review of the National Sectorial Plan of Natural 2000 and the SPA, SCI and the habitats and species characterisation sheets, the most common goals of conservation on SCIs were the maintenance, restoration or improvement of marine habitats, cetacean populations, their feeding and migratory routes. The spatial distribution of the habitats was assessed following the literature at ICNF (2008). As submerged marine caves (8330) was not available, and, it was assumed to be the same as reefs (ICNF, 2008).

SPAs conservation values in Mainland subdivision pertain to wild marine birds that have regular migratory routes through the northeast Atlantic. The SPAs' marine areas are a place of resting, feeding, breeding and wintering of migratory birds. The importance of the northeast Atlantic for migratory water birds is recognized through the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA), to which Portugal has been a contracting party since 2004 (McInnes R., 2018). As spatial information of sea bird populations' was not available, the entire area of the SPA was used as a proxy for its distribution. The lack of spatial distribution information on birds revealed knowledge gaps on SPAs conservation values.

4.3.2. Pressures and impacts

Assessing pressures and their potential impacts depends on the sources of the pressures, i.e. the potential activities/uses. Figure 4.5 synthesizes the pressures associated with each activity/use (considering both the construction and operation phases). Pressures categorised as "substances, litter and energy" were the most frequent within the studied activities/uses. The "input of anthropogenic sound" was associated with all activities, followed by "physical loss" (which is only absent for marine cultural heritage). Aquaculture and deep-sea mining were the activities/uses likely to produce a higher number of pressures.

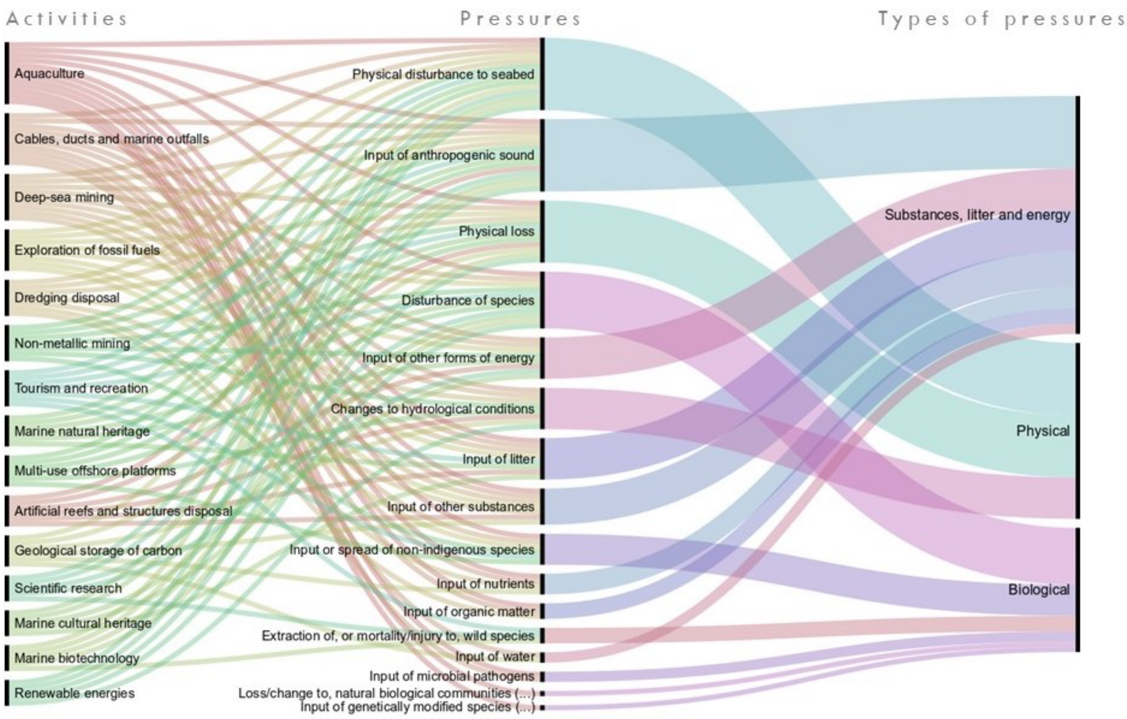


Figure 4.5. Sankey diagram (Mauri et al., 2017) illustrating the relationship between activities/uses and pressures. Pressures and types of pressures are described according to MSFD and activities/uses refers to potential activities or uses of PSOEM

The pressures associated with the potential activities/uses (spatially defined in the PSOEM; its location is shown in Figure 1 of the Supplementary Material B2) were mapped according to their distance of influence. Figure 4.6 shows an illustrative example of how the pressures produced by aquaculture could affect the SCI Peniche/Santa Cruz. While “physical pressures” only have a localised influence and do not affect the SCI, others may extend further and reach it, such as “biological pressures”, which are frequently related to aquaculture activities.

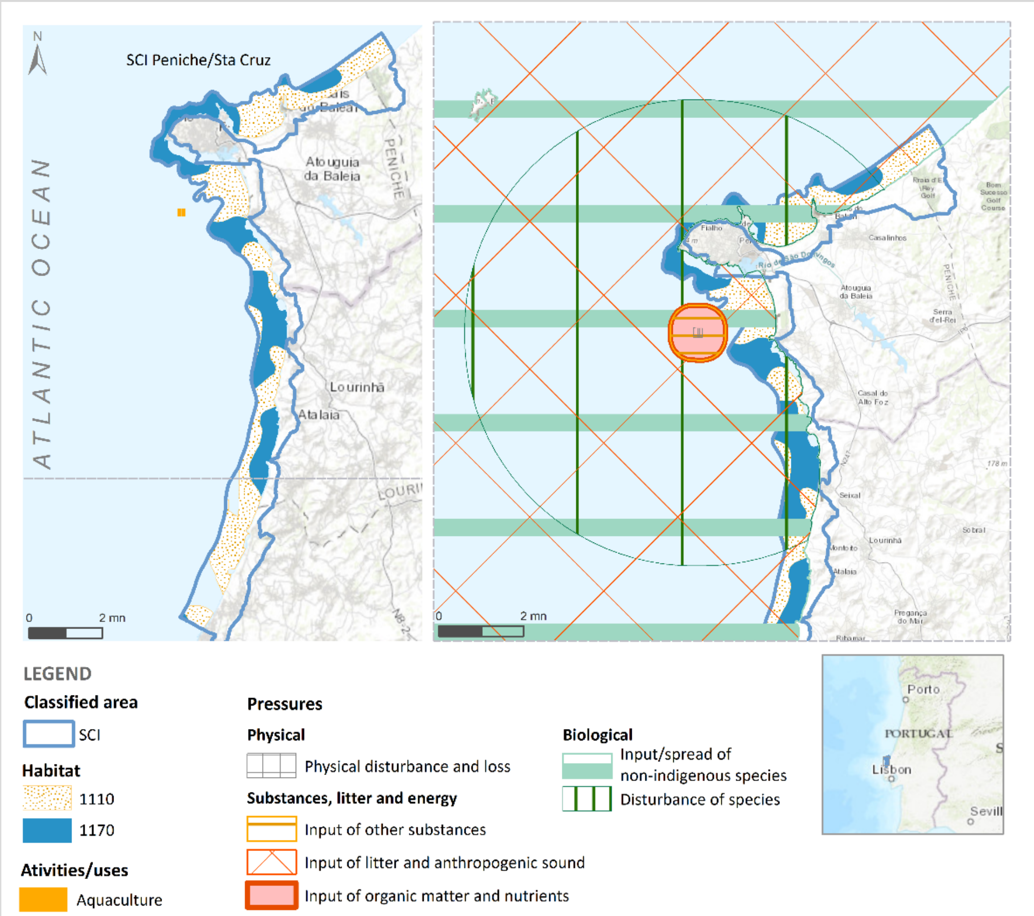


Figure 4.6. Example of the spatial analysis of the pressures resulting from aquaculture in the SCI Peniche/Santa Cruz (Sources of the spatial data: ESRI, 2019, ICNF, 2018; "Natura 2000 — ICNF," 2019).

This spatial analysis was performed for all the pressures associated with the potential activities/uses mapped in the PSOEM. The results were presented by type of pressure, namely, "physical", "substances, energy and litter" and "biological" and by protected area in order to simplify its interpretation. Figure 4.7 shows how the combined analysis of the pressures was performed for the north and central part of Mainland subdivision. It shows the cumulative layer of pressures associated with "substances, litter and energy" for SCIs Litoral Norte, Maceda/Praia da Vieira and Ria de Aveiro. While the "input of organic matter" and "input of nutrients" caused by dredging disposal is highly localized, the "input of litter" and "input of sound" results from different activities and its effect may spread to longer distances. At the middle and right side are shown the pressures and protected habitats, within Natura 2000 and a detailed view of some locations (Detail A).

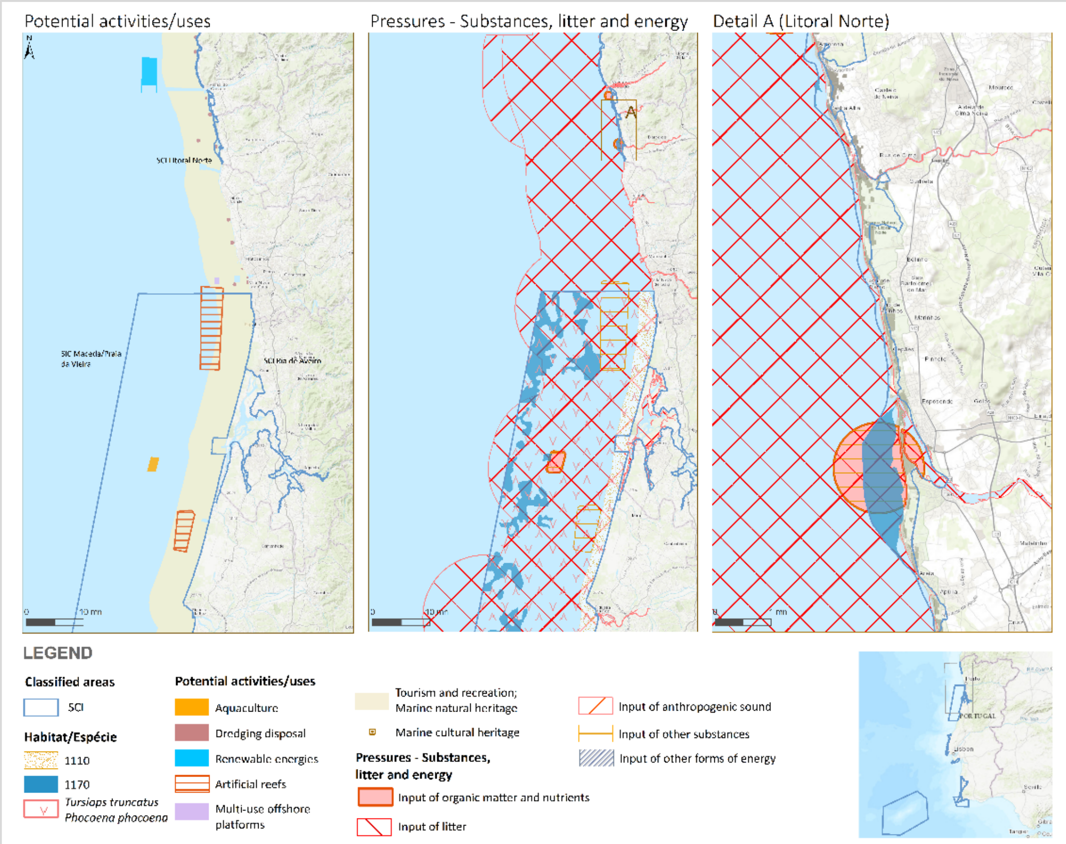


Figure 4.7. Potential activities/uses, their resulting pressures (associated to substances, litter and energy) that may affect the SCIs Litoral Norte, Maceda/Praia da Vieira and Ria de Aveiro and the habitats and species that were spatially assessed (Sources of the spatial data: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018; “Natura 2000 — ICNF,” 2019).

Figures 2 to 22 in Supplementary Material B2 show the maps with the overall analysis for all types of pressures in the SCIs and SPAs. Regarding private uses and activities for which no potential areas have been defined, such as marine biotechnology, geological storage, exploration of CO_2, exploitation of oil and deep-sea mining, their development will depend on the approval of APs, under the terms established by Decree-Law no. 38/2015. Therefore, they were not part of the spatial analysis and impact assessment

4.3.3. Impact assessment

The level of exposure was obtained from the spatial analysis of the mapped pressures. This information was combined with the interaction between pressures and natural values relevant to conservation within each SCI and SPA (see Table 4.2). From this analysis, it was possible to assess the significant impacts arising from the potential activities/uses of PSOEM. Table 4.3 shows an example of the impact assessment for SCI Arrábida/Espichel. In this site, the relevant habitats are sandbanks (1110), reefs (1170), submerged or partially submerged sea caves (8330) and common bottlenose dolphins (*Tursiops truncatus*). Habitats may suffer significant impacts from “physical pressures” (“physical disturbance to seabed” and “physical loss”) and from “extraction of, or mortality/injury to, wild species” (see also Figure 4.5). Activities causing these pressures were marine natural heritage and tourism and recreation. Common bottlenose dolphin (*Tursiops truncatus*) can be significantly affected by “extraction or mortality/injury to wild species” (caused by tourism and recreation) and “input of anthropogenic sound”. This last one was a result of the disposal of ships/structures, artificial reefs, dredging disposal, marine cultural and natural heritage, multi-use offshore platforms and tourism and recreation.

In the overall assessment, significant impacts caused by “physical pressures” were always resulting from marine natural heritage, tourism and recreation except for dredging disposal (Figure 4.7) in Litoral Norte. In this SCI, the activity is potentially overlapping the natural habitat reefs (1170). The overall impact assessment for SCIs and SPAs is shown in the Supplementary Material-A, Tables 18 and 19).

Activities related to marine natural heritage or tourism and recreation, such as touristic parks, underwater itineraries, regattas or surf competitions, need a reserve of space and consequently a TUPEM. These activities can occur in any location of a wide stretch covering the range of maritime space that extends from the coast up to 6 nm. When analysing the impacts arising from these activities, it is important to bear in mind that they refer to “physical pressures” occurring only during construction and are mainly local pressures, whereas this layer shows the potential space than is available for these activities.

Table 4.3. Impact assessment at SCI Arrábida/ Espichel. Exposure: H- High. Interaction: A-Probable; B-Possible; C-Unlikely; D-Unknown. Impact scale: H-High; M–Medium; L- Low. na–not applicable since it is not a target habitat/species of SCI or pressure does not affect the habitat/species)

Pressures		Activity/uses	Exposure				Interaction Pressure/Habitat/Species				Degree of Impact			
			1110	1170	8830	*Tursiops truncatus*	1110	1170	8830	*Tursiops truncatus*	1110	1170	8830	*Tursiops truncatus*
Physical	Physical disturbance to seabed (temporary or reversible)	Tourism and recreation	H	H	H	H	A	A	A	B	H	H	H	M
		Marine natural heritage	H	H	H	H	A	A	A	B	H	H	H	M
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)	Tourism and recreation	H	H	H	H	A	A	A	B	H	H	H	M
		Marine natural heritage	H	H	H	H	A	A	A	B	H	H	H	M
Substances, litter and energy	Input of litter (solid waste matter, including micro-sized litter)	Marine natural and cultural heritage	H	H	H	H	B	B	B	B	M	M	M	M
		Artificial reefs and structures disposal	H	H	H	H	B	B	B	B	M	M	M	M
		Tourism and recreation	H	H	H	H	B	B	B	B	M	M	M	M
	Input of anthropogenic sound (impulsive, continuous)	Dredging disposal	H	H	H	H	C	C	B	A	L	L	M	H
		Marine natural and cultural heritage	H	H	H	H	C	C	B	A	L	L	M	H
		Artificial reefs and structures disposal	H	H	H	H	C	C	B	A	L	L	M	H
		Multi-use offshore platforms	H	H	H	H	C	C	B	A	L	L	M	H
		Tourism and recreation	H	H	H	H	C	C	B	A	L	L	M	H
	Input of other forms of energy	Marine natural heritage	H	H	H	H	C	C	C	B	L	L	L	M
Biolo	Input or spread of non-indigenous species	Tourism and recreation	H	H	H	H	D	B	D	C	D	M	D	L

		Multi-use offshore platforms	H	H	H	H	D	B	D	C	D	M	D	L
	Disturbance of species	Tourism and recreation	H	H	H	H	C	B	B	B	L	M	M	M
		Multi-use offshore platforms	H	H	H	na	C	B	B	B	L	M	M	na
		Marine natural heritage	H	H	H	H	C	B	B	B	L	M	M	M
		Marine cultural heritage	H	H	H	na	C	B	B	B	L	M	M	na
	Extraction of, or mortality/injury to, wild species	Tourism and recreation	H	H	H	H	A	A	B	A	H	H	M	H

4.3.4. Mitigation measures

The relative distribution of the significant and unknown impacts per activity/use was calculated using the information from the impact assessment (see Supplementary Material B1, Tables 17 and 18). Tourism, leisure, and fruition of marine natural heritage were the activities with the highest number of significant impacts as in SCIs as well as in SPAs (accounting for 87% of all significant impacts on SCIs and 65% on SPAs, see Figure 4.8). Aquaculture was the activity accounting for the highest percentage of unknown impacts in SCIs as well as in SPAs.

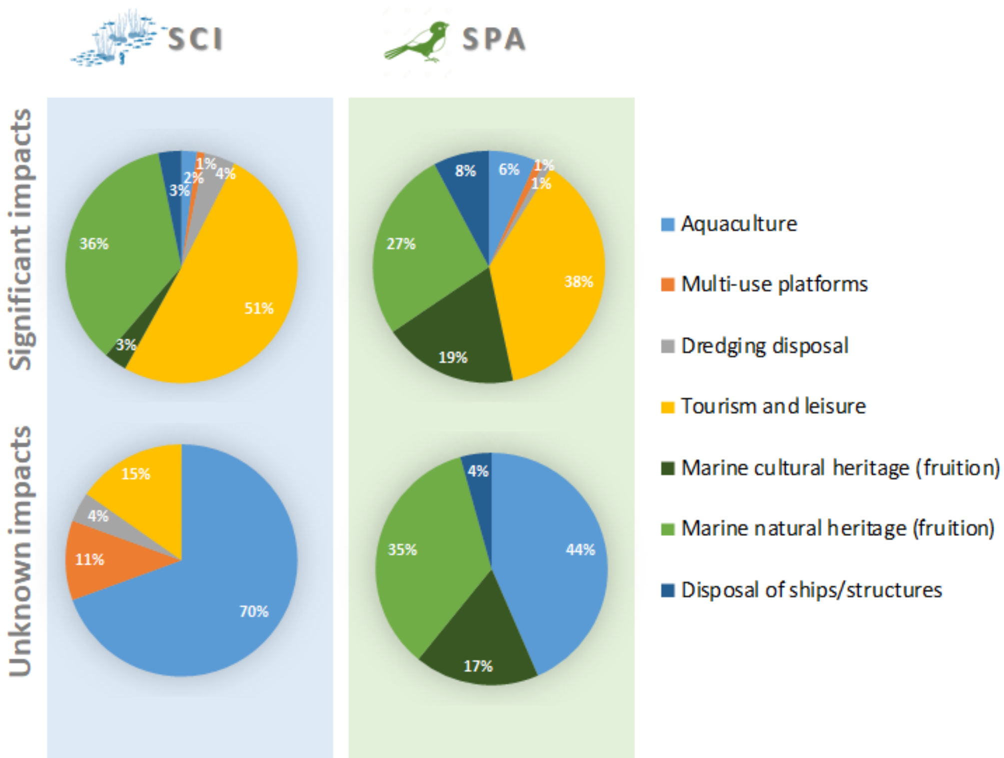


Figure 4.8. Relative distribution of the significant and unknown impacts per activity/use

In the SCIs significant impacts were mostly caused by "physical pressures" (both "physical disturbance" and "physical loss") and in the SPAs were the "input of waste" and "disturbance of species". The SCIs with more significant impacts were Costa Sudoeste and Arrábida/Espichel with 21 entries for pressure/activity pairs. SPAs that have highest impacts were Ria Formosa with 11 entries and Leixão da Gaivota, Cabo Espichel, Ria de Aveiro and Costa Sudoeste, all with 9 entries.

Within the SCIs, from the 10 types of pressures listed and causing impacts, 4 may cause significant and 6 may cause unknown effects. Mitigation measures in these cases were necessary but only 3 pressures implied the incorporation of additional measures to the plan. Two of these pressures were due to unknown interaction between pressures and natural values: “input of nutrients” and “input or spread of non-indigenous species” (Table 4.4).

Table 4.4. Pressures and activities/uses requiring additional mitigation measures to be included in PSOEM regarding SCIs and SPAs

	Pressures	**Activities/uses**	**Mitigation measures**
SCIs	Input of anthropogenic sound	Disposal of ships/structures Artificial reefs Dredging disposal Marine natural heritage Marine cultural heritage Multi-use offshore platforms Tourism and recreation Aquaculture	Projects must consider mitigation measures, as defined by OSPAR (2014) and ACCOBAMS (2008)
	Input or spread of non-indigenous species	Tourism and recreation Multi-use offshore platforms	The project should include the measures set out in Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October on the prevention and management of the introduction and spread of invasive alien species.
	Input of nutrients	Dredging disposal	Assess the area's ability to disperse or assimilate excess nutrients.
SPAs	Input of litter	Aquaculture	Ensure that all wastes produced in the activity, such as packaging waste and residues resulting from maintenance operations, must be properly packed, transported to land and sent to the final destination appropriate to their type.
		Marine cultural heritage Tourism and recreation	Under no circumstances should this activity be an intentional or negligent cause of marine litter. The materials used in the promotion and dissemination of journeys and visits should be biodegradable. The practice of this activity should contribute to the good state of the marine environment, promoting the collection of marine litter that is found in places of interest.
		Disposal of structures and installation of artificial reefs	Ensure that all wastes produced in the activity must be properly packed, transported to land and sent to the final destination appropriate to their type.
	Disturbance of species	Marine natural heritage Marine cultural heritage Tourism and recreation	Promote awareness meetings and campaigns on the conservation of the natural values present in the SPAs should be held before activity enters into practice, namely on how to avoid the disturbance of species.
		Marine cultural heritage Multi-use offshore platforms	A marine area study including biodiversity, physical and chemical characteristics and an evaluation of the main impacts should be developed.
		Marine cultural heritage Tourism and recreation	Interactions with wildlife should be avoided, as well as the capture, manipulation or collection of biological material or elements of natural or cultural heritage, according to what is stipulated in article 4 of Law nº 24/2013, March 20.
	Extraction or mortality/injury of wild species	Tourism and recreation	Interactions with wildlife should be avoided, and the capture, manipulation or collection of biological material or elements of natural or cultural heritage, according to what is stipulated in article 4 of Law nº 24/2013, March 20.
	Input of other forms of energy	Disposal of structures and installation of artificial reefs Marine natural heritage Marine cultural heritage	New projects requesting permits (TUPEM) should include, whenever applicable to the activity in question, measures to mitigate the impact of the introduction of other forms of energy defined in the OSPAR guidelines.

In SPAs 9 pressures were found to cause either significant or unknown impacts. Pressures that may cause significant impacts requiring additional measures (Table 4.4) were the “input of litter", “disturbance of species” and “extraction of, or mortality/injury to, wild species”. Additional mitigation measures were included when the interaction between pressure and natural values was unknown in order to follow a precautionary approach. In SPAs this happened only for the “input of other forms of energy” due to activities related to the marine natural and cultural heritage, disposal of structures and installation of artificial reefs.

4.4. Discussion

Overall, this assessment provided a prospective outlook of the activities/uses with a defined location and in need of a privative license (TUPEM). This work took into account the information available for Natura 2000 areas at the government body for nature conservation (ICNF). Within this study, the most significant impacts derived from the fruition of the marine natural space and tourism and recreation activities, due to their spatial demand on the plan and ubiquitous nature. Aquaculture was the activity, which generated most unknown impacts, and therefore a precautionary approach must be taken into account. Nevertheless, the plan included several measures for mitigating most of the significant and unknown impacts. The SCIs Costa Sudoeste and Arrábida/Espichel and SPA Ria Formosa were the protected areas more exposed to significant impacts occurring from the potential activities/uses assessed within this study.

MSP plans have been dealing with the assessment of significant impacts within their SEAs or in dedicated studies (Government of Ireland, 2019; Kru k-Dowgiallo et al., 2011; Scottish Government, 2013; SSMEI, 2010). Although significant progress has been made on this subject, its application in practice raises several challenges and limitations, which shape the impact assessment framework adopted in each case study.

The impact assessment performed in the Mainland subdivision faced several constraints. Some were intrinsic to the MSP process, such as the level of uncertainty associated with technical details of future maritime uses and activities. For example, within renewable energies, different types of resource extraction can be applied, such as wind, wave, tidal, etc., and dimensions of farms can greatly vary. This information was lacking in the majority of the cases, as well as the seasonality or extent of activities. Therefore, a quantitative exercise as the Swedish or Polish was not feasible. Other constraints were related to data scarcity (particularly spatial data) on environmental components, or insufficient knowledge on the effects that certain pressures have on natural values, for instance. The methodology applied within this study aimed to surpass data, time and knowledge constraints and to be as comprehensive as possible in the identification of pressures and impacts. It moves from other quantitative approaches due to the lack of data available (Kruk-Dowgiallo et al., 2011; SwAM, 2018), but explores further the options presented as in the Scottish pilot project (SSMEI, 2010). On that note, at this level of planning, the impact assessment should be assumed as strategic, resulting in early environmental awareness and better-informed decisions, which serve as a reference for project-level developments (Tamis et al., 2016).

Another characteristic of this framework is its adaptive nature. It can easily be adapted to incorporate new knowledge and refine the interaction between pressures and natural values, as new information and finer-scale data become available. Effective management of the marine environment is dependent on adequate knowledge, information and data concerning the area to be managed. Monitoring of the marine environment is inherently more difficult than in terrestrial environments and can be prohibitively expensive. Therefore the current state of knowledge (represented by available data and information) of marine areas may not represent the complete picture. However, as the appreciation and recognition of the value of marine areas increases, there is better awareness of the data gaps and data limitations. A more coherent strategy for marine data collection and organization is needed. This could be accomplished with cooperative research, as Stratoudakis et al. (2019) suggest to overcome pressing timelines and spatially uneven level of information.

4.5. Concluding remarks

This study was produced within the scope of the SEA of PSOEM and therefore was developed within the knowledge constraints on the development options and the conservation values to be protected. Future planning on these areas must take into account not only the existing activities already producing adverse effects but also a cumulative detailed study of the activities to be placed in the vicinity of the protected areas. It is essential to improve the knowledge of the natural values to be protected. The impact assessment shall consider not only its exposure, but also, for example, their state of conservation, and their sensitivity or recovery rate to specific impacts.

This assessment foresees significant effects from future activities/uses to be placed in the Natura 2000 marine sites. It showed, however, that PSOEM good practices is prepared in most cases to deal with these impacts, as only a few needed additional mitigation measures. This work was a first assessment that should be part of an adaptive approach to MSP, strongly linked to monitoring, evaluation of the plan outcomes and future impacts assessment of particular projects (Bidstrup et al., 2016; Douvere and Ehler, 2011; Tamis et al., 2016).

Natura 2000 network in Portuguese Mainland subdivision is taking the first steps in the marine realm, as the appointed areas for the protection of marine mammals indicate (ICNF, 2016). Natura 2000 information on threats is mostly regarding terrestrial activities and it is not coherent with the terminology used at MSFD, which is the standard at the European level. Also, the habitats classification used is too broad and needs to be harmonized with EUNIS habitats classification (EEA, 2014), allowing to refine the assessment. This would facilitate as well, the use of information gathered nowadays on research, which is mainly being conducted with EUNIS classification. This is an effort that the Natura 2000 network should accomplish to update its framework. This would enable a better coherence between the marine protected areas management plans', MSFD and MSP.

References

Altvater, S., Passarello, C., 2018. Policy Brief: Implementing the Ecosystem-Based Approach in Maritime Spatial Planning. Version 25.10.2018, European MSP Platform.

Andersen, J.H., Stock, A., 2013. Human Uses , Pressures and Impacts in the Eastern North Sea. Aarhus University,DCE—Danish Centre for Environment and Energy. Technical Report fromDCE—Danish Centre for Environment and Energy No. 18.

Ban, N.C., Alidina, H.M., Ardron, J.., 2010. Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. Mar. Policy 34, 876–886. https://doi.org/10.1016/j.marpol.2010.01.010

Beanlands, G.E., Duinker, P.N., 1983. Ecological Framework for Environmental Impact Assessment in Canada. https://doi.org/10.1016/0004-6981(83)90241-x

Becker-Weinberg, V., 2015. Portugal's legal regime on marine spatial planning and management of the national maritime space. Mar. Policy 61, 46–53. https://doi.org/10.1016/j.marpol.2015.06.014

Bessa Pacheco, M., 2013. Medidas da Terra e do Mar. Instituto Hidrográfico. Lisboa.

Bidstrup, M., Kørnøv, L., Partidário, M.R., 2016. Cumulative effects in strategic environmental assessment: The influence of plan boundaries. Environ. Impact Assess. Rev. 57, 151–158. https://doi.org/10.1016/j.eiar.2015.12.003

Christensen, N.L., Bartuska, A.M., Brown, J.H., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J.F., MacMahon, J.A., Noss, R.F., Parsons, D.J., Peterson, C.H., Turner, M.G., Woodmansee, R.G.,

1996. The report of the ecological society of america committee on the scientific basis for ecosystem management. Ecol. Appl. 6, 665–691. https://doi.org/10.2307/2269460

DGRM, 2019a. Volume V - Plano de Situação do Ordenamento do Espaço Marítimo Nacional. Relatório Ambiental PSOEM.

DGRM, 2019b. Volume III - A. Plano de Situação do Ordenamento do Espaço Marítimo Nacional - Espacialização de servidões, usos e atividades (Continente e Plataforma continental estendida).

Douvere, F., 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Mar. Policy 32, 762–771. https://doi.org/10.1016/j.marpol.2008.03.021

Douvere, F., Ehler, C.N., 2011. The importance of monitoring and evaluation in adaptive maritime spatial planning. J. Coast. Conserv. 15, 305–311. https://doi.org/10.1007/s11852-010-0100-9

EC, 2017. Commission Directive (EU) 2017/845 of 17 May 2017 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies. Off. J. Eur. Union L 125/27-33. https://doi.org/http://eur-lex.europa.eu/pri/en/oj/dat/2003/l_285/l_28520031101en00330037.pdf

EEA, 2014. EUNIS habitat classification 2007 - Revised descriptions 2012. http://eunis.eea.europa.eu/ (acessed 13.03.2015).

EEA, 2007. Guidelines for the establishment of the Natura 2000 network in the marine environment . Application of the Habitats and Birds Directives 112.

EEC, 1992. Council Directive 92/43/EEC of 21 May 1992 published in the OJEC Nº L206/7 44.

EMODnet Seabed Habitats - Homepage [WWW Document], n.d. URL https://www.emodnet-seabedhabitats.eu/ (accessed 1.18.19).

ESRI, 2019. "Topographic" [basemap]. "World Topographic Map" Topographic (Local Language) [WWW Document]. URL https://www.arcgis.com/home/item.html?id=19bf4648d3c2491d832ec67b404613d8 (accessed 2.15.19).

EU, 2014. Directive 2014/89/EU of the European Parliment and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Offical Journal of the European Union.

European Commission.

European Union, 2017. Environmental Assessment of Plans, Programmes and Projects: Rulings of the Court of Justice of the European Union 124.

Fernandes, M. da L., Quintela, A., Alves, F.L., 2018. Identifying conservation priority areas to inform maritime spatial planning: A new approach. Sci. Total Environ. 639, 1088–1098. https://doi.org/10.1016/j.scitotenv.2018.05.147

Fernandes, M.L., Esteves, T.C., Oliveira, E.R., Alves, F.L., 2017. How does the cumulative impacts approach support Maritime Spatial Planning? Ecol. Indic. 73. https://doi.org/10.1016/j.ecolind.2016.09.014

Frazão Santos, C., Agardy, T., Andrade, F., Crowder, L.B., Ehler, C.N., Orbach, M.K., 2018. Major challenges in developing marine spatial planning. Mar. Policy 1–3. https://doi.org/10.1016/J.MARPOL.2018.08.032

Frazão Santos, C., Orbach, M., Calado, H., Andrade, F., 2015. Challenges in implementing sustainable marine spatial planning: The new Portuguese legal framework case. Mar. Policy 61, 196–206. https://doi.org/10.1016/j.marpol.2015.08.010

Government of Ireland, 2019. Irish National Marine Planning Framework. Natura Impact Statement. Prepared by the Department of Housing, Planning and Local Government.

Halpern, B.S., Selkoe, K., Micheli, F., Kappel, C., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conserv. Biol. 21, 1301–1315. https://doi.org/10.1111/j.1523-1739.2007.00752.x

Halpern, B.S., Walbridge, S., Selkoe, K. a, Kappel, C. V, Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., 2008. A global map of human impact on marine ecosystems. Science 319, 948–952. https://doi.org/10.1126/science.1149345

Halpern, B.S.B.S., Fujita, R., 2013. Assumptions, challenges, and future directions in cumulative impact analysis. Ecosphere 4, art131. https://doi.org/10.1890/ES13-00181.1

ICNF, 2018. Relatório de base do plano de gestão da área marinha de cinco SIC: Costa sudoeste, Litoral norte, Arrábida/Espichel, Peniche/Santa Cruz e Sintra/Cascais.

ICNF, 2016. Processo de extensão da Diretiva Habitats ao meio marinho: Prposta técnica de Sítios de Importância Comunitária a designar em Portugal continental.

ICNF, 2008. Plano Setorial da Rede Natura 2000 (PSRN2000) - Resolução do Conselho de Ministros n.º 115-A/2008, de 21 de julho.

Jay, S., Jones, C., Slinn, P., Wood, C., 2007. Environmental impact assessment: Retrospect and prospect. Environ. Impact Assess. Rev. 27, 287–300. https://doi.org/10.1016/j.eiar.2006.12.001

Judd, A., Backhaus, T., Goodsir, F., 2015. An effective set of principles for practical implementation of marine cumulative effects assessment. Environ. Sci. Policy 54, 254–262. https://doi.org/10.1016/j.envsci.2015.07.008

Kannen, A., 2014. Challenges for marine spatial planning in the context of multiple sea uses, policy arenas and actors based on experiences from the German North Sea. Reg. Environ. Chang. 14, 2139–2150. https://doi.org/10.1007/s10113-012-0349-7

Katsanevakis, S., Stelzenmüller, V., South, A., Sørensen, T.K., Jones, P.J.S., Kerr, S., Badalamenti, F., Anagnostou, C., Breen, P., Chust, G., D’Anna, G., Duijn, M., Filatova, T., Fiorentino, F., Hulsman, H., Johnson, K., Karageorgis, A.P., Kröncke, I., Mirto, S., Pipitone, C., Portelli, S., Qiu, W., Reiss, H., Sakellariou, D., Salomidi, M., van Hoof, L., Vassilopoulou, V., Vega Fernández, T., Vöge, S., Weber, A., Zenetos, A., Hofstede, R. Ter, 2011. Ecosystem-based marine spatial management: Review of concepts, policies, tools, and critical issues. Ocean Coast. Manag. 54, 807–820. https://doi.org/10.1016/j.ocecoaman.2011.09.002

Kelly, C., Gray, L., Shucksmith, R.J., Tweddle, J.F., 2014. Investigating options on how to address cumulative impacts in marine spatial planning. Ocean Coast. Manag. 102, 139–148. https://doi.org/10.1016/j.ocecoaman.2014.09.019

Knights, A.M., Koss, R.S., Robinson, L.A., 2013. Identifying common pressure pathways from a complex network of human activities to support ecosystem-based management. Ecol. Appl. 23, 755–765. https://doi.org/10.1890/12-1137.1

Kruk-Dowgiallo, L., Opiola, R., Michalek, M., 2011. Developing a Pilot Strategic Environmental Assessment for the Western Gulf of Gdansk, BaltSeaPlan Report 11.

Levin, S.A., Lubchenco, J., 2008. Resilience , Robustness , and Marine Ecosystem-based Management 58, 27–32.

MAM, 2011. Ruling n.º 11494/2015. Diário da República, 2.ª série — N.° 201 — 14 de outubro de 2015. Ministry of the Agriculture and Sea.

MAMAOT, 2012. Maritime Strategy for Continent Subdivision (Estrategia Marinha para a Divisão do Continente). Ministry of Agriculture, Sea, Environment and Spatial Planning 930.

MarLIN - The Marine Life Information Network - Home [WWW Document], n.d. URL https://www.marlin.ac.uk/ (accessed 1.18.19).

Mauri, M., Elli, T., Caviglia, G., Uboldi, G., Azzi, M., 2017. RAWGraphs: A visualisation platform to create open outputs. ACM Int. Conf. Proceeding Ser. Part F1313. https://doi.org/10.1145/3125571.3125585

McInnes R., 2018. African-Eurasian Waterbird Agreement (AEWA) and Wetland Management, in: Finlayson, C.M., Milton, G.R., Prentice, R.C., Davidson, N.C. (Eds.), The Wetland Book. Springer.

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A. a., 2013. Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: Assessing current pressures and opportunities. PLoS One 8. https://doi.org/10.1371/journal.pone.0079889

Möckel, S., 2017. The European ecological network "Natura 2000" and the appropriate assessment for projects and plans under Article 6(3) of the Habitats Directive. Nat. Conserv. 23, 1–29. https://doi.org/10.3897/natureconservation.23.13599

Morel, C., Gimard, A., Alloncle, N., Quintela, A., Lloret, A., Lopes Alves, F., Gomez Ballesteros, M., Buceta, J.-L., Giret, O., Marques, M., Silva, A., Plaza, M., Sousa, L., 2018. Annex 2 to Initial Assessment: Pressures/Impacts. EU Project Grant No.: EASME/EMFF/2015/1.2.1.3/03/SI2.742089. Supporting Implementation of Maritime Spatial Planning in the European Northern Atlantic (SIMNORAT). https://doi.org/10.5281/zenodo.260914

N2K, T., 2017. The N2K Group Overview of the Potential Interactions and Impacts of Activities apart from Fishing on Marine Habitats and Species Protected Under the EU Habitats Directive 23.

Natura 2000 — ICNF [WWW Document], n.d. URL http://www2.icnf.pt/portal/pn/biodiversidade/rn2000 (accessed 1.18.19).

OSPAR Commission, 2009. Trend analysis of maritime human activities and their collective impact on the OSPAR maritime area.

Partidário, M.R., 2012. Strategic Environmental Assessment Better Practice Guide - methodological guidance for strategic thinking in SEA. Lisbon.

Resolution of the Council of Ministers n.º 203-A/2019, 2019. Resolution of the Council of Ministers n.º 203-A/2019. Resolução do Conselho de Ministros de 30 de Dezembro. Diário da República, 1ª série nº 250.

Scottish Government, 2015. Scotland's National Marine Plan.Habitats Regulations Appraisal.

Scottish Government, 2013. National Planning Framework 3 Scottish Planning Policy. Strategic Environmental Assessment. Environmental Report.

Sousa, L.P., Sousa, A.I., Alves, F.L., Lillebø, A.I., 2016. Ecosystem services provided by a complex coastal region: challenges of classification and mapping. Nat. Publ. Gr. 1–14. https://doi.org/10.1038/srep22782

SSMEI, 2010. Sound Of Mull Marine Spatial Plan. Strategic Environmental Assessment (SEA) Environmental Report. Scottish Sustainable Marine Environment Initiative.

Stelzenmüller, V., Lee, J., South, a., Rogers, S.I., 2009. Quantifying cumulative impacts of human pressures on the marine environment: A geospatial modelling framework. Mar. Ecol. Prog. Ser. 398, 19–32. https://doi.org/10.3354/meps08345

Stratoudakis, Y., Hilário, A., Ribeiro, C., Abecasis, D., Gonçalves, E.J., Andrade, F., Carreira, G.P., Gonçalves, J.M.S., Freitas, L., Pinheiro, L.M., Batista, M.I., Henriques, M., Oliveira, P.B., Oliveira, P., Afonso, P., Arriegas, P.I., Henriques, S., 2019. Environmental representativity in marine protected area networks over large and partly unexplored seascapes. Glob. Ecol. Conserv. e00545. https://doi.org/10.1016/j.gecco.2019.e00545

SwAM, 2018. Strategic Environmental Assessment of the Marine Spatial Plan proposal for the Baltic Sea. Swedish Agency Mar. Water Manag. 170.

Tamis, J.E., de Vries, P., Jongbloed, R.H., Lagerveld, S., Jak, R.G., Karman, C.C., Van der Wal, J.T., Slijkerman, D.M., Klok, C., 2016. Toward a harmonized approach for environmental assessment of human activities in the marine environment. Integr. Environ. Assess. Manag. 12, 632–642. https://doi.org/10.1002/ieam.1736

Willsteed, E., Gill, A.B., Birchenough, S.N.R., Jude, S., 2017. Assessing the cumulative environmental effects of marine renewable energy developments: Establishing common ground. Sci. Total Environ. 577, 19–32. https://doi.org/10.1016/j.scitotenv.2016.10.152

5. IDENTIFYING CONSERVATION PRIORITY AREAS TO INFORM MARITIME SPATIAL PLANNING: A NEW APPROACH

Abstract

Accommodating sea uses while protecting the ecosystems is a challenge of the marine planning and management process. The European Directive on Maritime Spatial Planning calls for Maritime Spatial Plans until 2021 developed within an Ecosystem-Based Management approach. The main goal of this study is to support the Maritime Spatial Planning process with ecological meaningful information, namely identifying priority areas for conservation that are facing less anthropogenic impacts. We developed a new approach for selection of high priority areas for conservation using Marxan software and Cumulative Impacts decision support tools.

We identified four main areas prone to conservation in Portuguese mainland subdivision, namely the areas of Figueira da Foz/Peniche, south Cabo Espichel/Sines, Cabo Sardão/Faro and Lagos/Faro. The outputs from this study show the valuable input when allocating space to activities and uses in the marine realm supporting the planning process in the development of management alternatives. This case study also illustrates how ecological goals can be better included to contribute to the Maritime Planning process in Portugal. Systematic planning can be applied to support the connection between Marine Strategy Framework and Maritime Spatial Planning European Directives. This is highly relevant in the time being for Portugal, as the 2nd cycles of both directives are ongoing.

Keywords: Ecosystem-Based Management approach; Cumulative Effects Assessment; Decision Support Tools; Marine Protected Areas; Marxan; Portugal

5.1. Introduction

The state of our oceans and coasts is at jeopardy as human activities and uses continue to grow resulting in even more impacts in marine and coastal ecosystems (EEA, 2015; UN, 2016). Many of the species and habitats are already in poor condition leading to a continuous degradation on ocean health (EEA, 2015; Jackson et al., 2001; MEA, 2005).

Maritime Spatial Planning (MSP) was identified by Douvere (2008), as a “mechanism for strategic and integrated plan-based approach for marine management (…)” of “current and potential conflicting uses, the cumulative effects of human activities, and marine protection”. Afterwards, in 2014, European Union (EU) approved the MSP Directive (MSPD) where MSP was defined “as a process by which the relevant Member State’s authorities analyze and organize human activities in marine areas to achieve ecological, economic and social objectives” (EU, 2014). MSP is perceived as a tool to support sustainable development whilst implementing the Ecosystem-Based

Management (EBM) approach (Brennan et al., 2014; EC, 2016; Flannery and Ó Cinnéide, 2012; Frazão Santos et al., 2014a; Maes, 2008; Schaefer and Barale, 2011), achieving the Good Environmental Status (GES) required within Marine Strategy Framework Directive (MSFD).

MSP experiences worldwide have shown that a critical component to its efficacy is comprehensive ecological and social data to support the process (Ban et al., 2013; Foley et al., 2010) but in reality features of EBM are difficult to be included (Domínguez-Tejo et al., 2016). Data on ecological features are necessary to identify areas of importance for biodiversity conservation. Its combination with human use data and its impacts allows for explicit identification of conflicts between activities, uses and conservation. (Ban et al., 2013; Klein et al., 2013; Martín-García et al., 2015). Information such as Cumulative Impacts (or effects) Assessment (CIA) may provide valuable inputs on which areas are in best state of conservation. Planners can use this information to prioritize the approach to select locations with best conditions to protect natural values (Fernandes et al., 2017; Halpern and Fujita, 2013; Kappel et al., 2009; Klein et al., 2013).

In Portugal, major advances are occurring in MSP (Becker-Weinberg, 2015; Calado et al., 2010; Frazão Santos et al., 2014b). In 2014 was published the National Ocean Strategy (NOS) 2013-2020 (DR, 2014) and the law establishing the Basis for the Spatial Planning and Management of the National Maritime Space (LBOGEM, Law nº 17/2014) was enacted. The law developed by Decree-Law nº 38/2015 defines two sets of MSP instruments, the Situation Plan (SP) and the Allocation Plans (AP). The SP identifies the distribution of the existing and potential uses and activities, the AP aims to assign space to new uses and activities that are not included in the SP (Ferreira et al., 2015; Frazão Santos et al., 2014b). These juridical tools adopt the sustained development model of EU's Blue Growth Strategy, aiming to deliver a smart, inclusive and sustainable growth for the European ocean (EC, 2012; Ferreira et al., 2018). Debate is rising regarding the alignment of these strategies and real achievement of its goals while increasing exploration of the seas brings new challenges to management of conflicting uses, cumulative effects and marine protection (Ansong et al., 2017; Douvere, 2008; Flannery et al., 2016; Jay et al., 2016).

The main goal of this study is to provide information to the MSP process in Portugal, namely by identifying priority areas for conservation that are facing less anthropogenic impacts. We aim to develop a tool to support the decision making process of distributing activities and uses in space. We argue that such tool will provide information for the authorities with responsibility on the Portuguese SP when assigning space, having into account the need to avoid less impacted natural values.

5.2. Material and Methods

5.2.1. The study area

Portugal mainland subdivision has a large marine jurisdiction of 287 521 km2. In Figure 5.1, the marine space was classified as Territorial Sea (TS) (16 460 km2), Contiguous Zone (CZ) (17 286 Km2) included in the Economic Exclusive Zone (EEZ) (287 521 Km2) (Bessa Pacheco, 2013). These marine areas were defined by United Nations Convention on the Law of the Sea (UNCLOS) (UN, 1982).TS expands from the normal baseline up to 12 nautical miles (nm) and CZ extends offshore from the TS exterior limit up to 24 nm. This study focused its approach from the normal baseline until the CZ exterior limit (24 nm), including the territorial waters of the mainland subdivision.

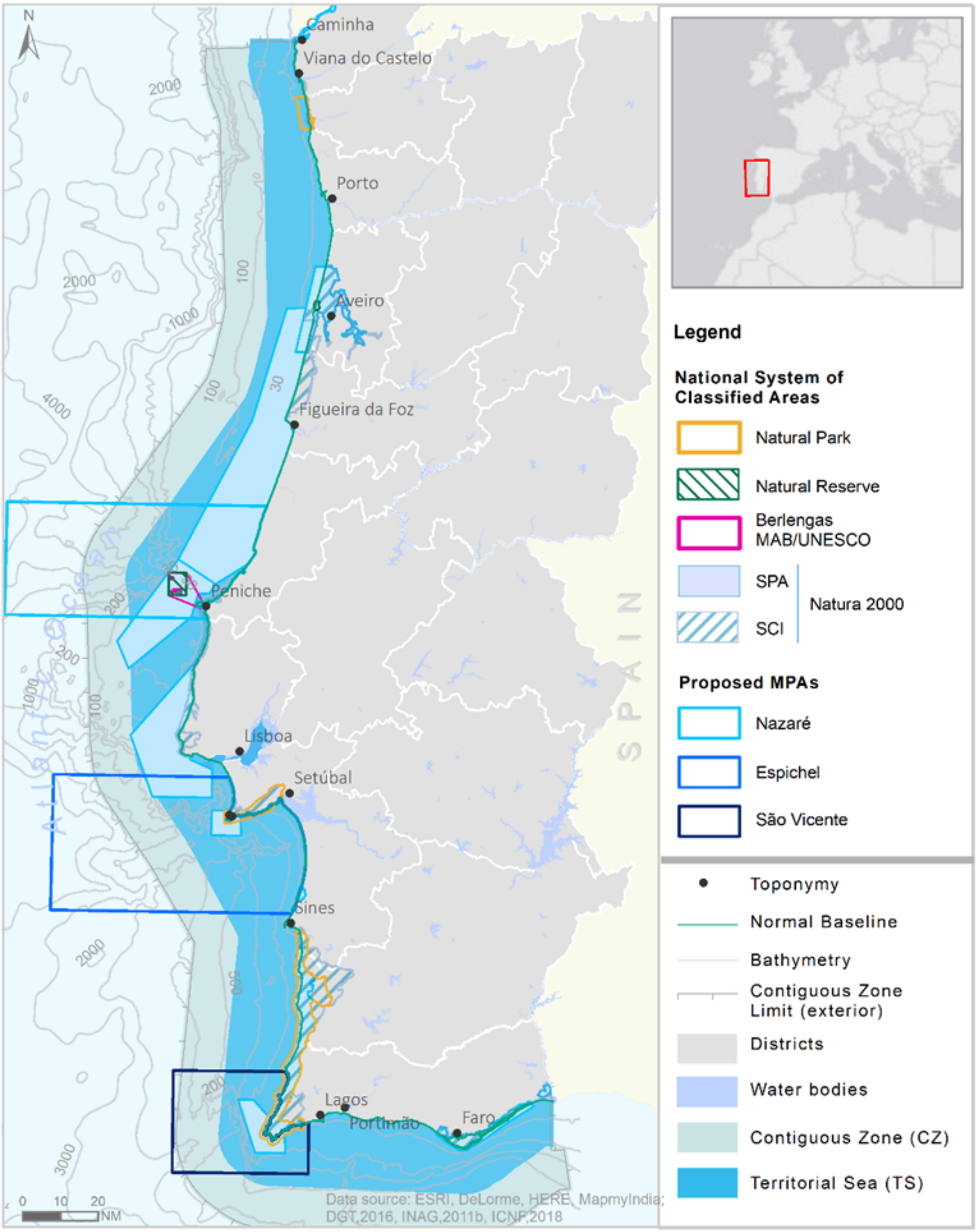


Figure 5.1. Study area, UNCLOS marine areas, National System of Classified Areas (with marine area) and Proposed Marine Protected Areas (MPAs).

There are a few protected areas with marine waters in the mainland subdivision, which are part of the National Network of Protected Areas (APA, 2017). These appear in Figure 5.1 from North to South as:

- Litoral Norte Natural Park
- Dunas de São Jacinto Natural Reserve
- Berlengas Natural Reserve
- Arrábida Natural Park

- Lagoa de Santo André e Sancha Natural Reserve
- Sudoeste Alentejano Natural Park

In accordance with the EU legislation, Habitats (92/43/CE) and Birds Directive (79/409/CE), there are also several marine natural conservation status in place (ICNF, 2018), namely Special Protection Areas (SPA) and Sites of Community Importance (SCI) with marine area (see Figure 5.2).

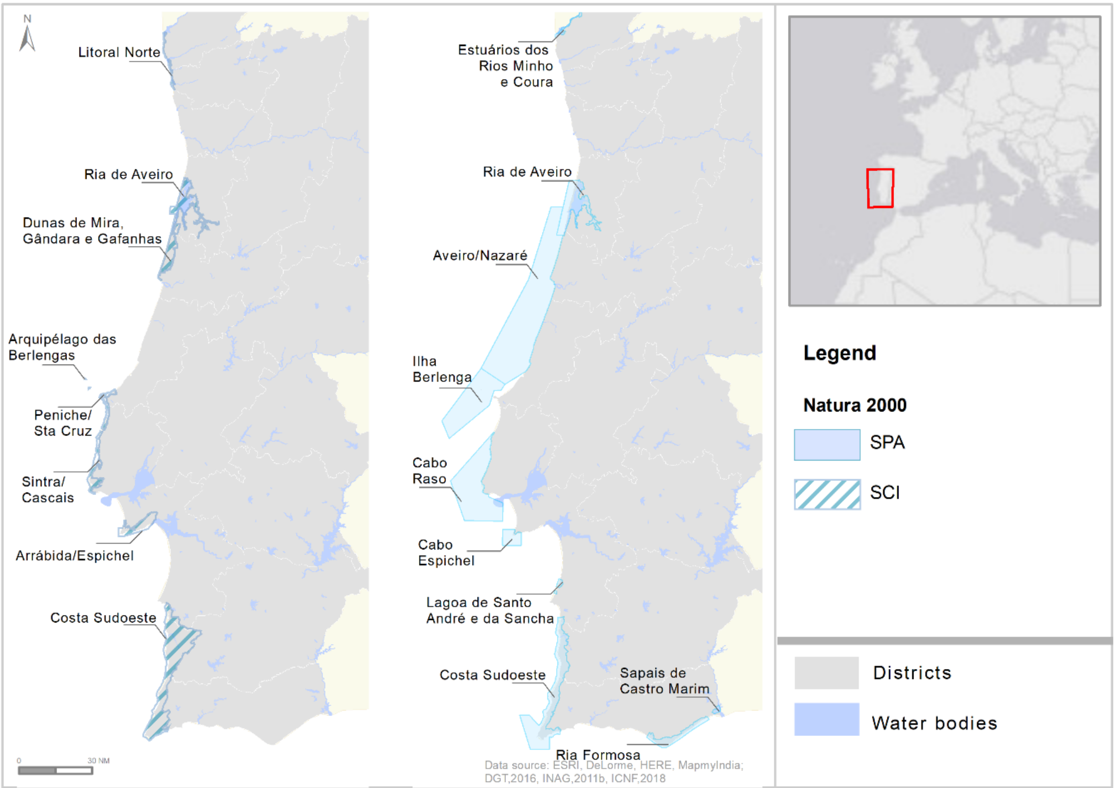


Figure 5.2. SPA and SCI within marine waters in mainland Portugal.

In 2014, MPAs were proposed (Garcia, 2014) to increase the conservation of marine mammals within the scope of MSFD (MAMAOT, 2014). These areas are part of the spatial protection measures network of MPA and, if created, would be located in the region of Nazaré Canyon, Cabo Espichel and Cabo de São Vicente (see Figure 5.1).

According to Fernandes et al. (2017) the most relevant activities and uses occurring in the coastal and marine space are fisheries and aquaculture, tourism, shipbuilding and shipping, marine infrastructures and offshore energies. Some of these activities and uses depend on fixed structures and cannot occur in other spaces, such as aquacultures, shipping, ports, offshore wind, wave energy and coastal infrastructures. Others are quite moveable, despite being dependent of specific habitats or substrata, they can adjust to spaces such as fisheries and some touristic uses of the sea (INAG, 2011).

5.2.2. Software Marxan

Marxan software is a decision-support tool (DST) for the identification of a network of areas that combine to satisfy a number of ecological, social and economic goals (Ball and Possingham, 2000). Marxan can be used to offer planning scenarios on conservation needs that are alternatives to existing protected area networks. Initially the objective was to project systematic conservation planning but it has also been used for the entire zoning process as it provides scenarios including ecological information as well as human activities and uses (Ban et al., 2013; Ekebom and Jäänheimo, 2008; Game and Grantham, 2008; Henriques et al., 2017).

To select priority areas for conservation we used the conservation planning software Marxan software v2.4.3 (Ball and Possingham, 2000). Marxan includes several algorithms for reserve selection but primarily uses simulated annealing, a randomization method that seeks a minimum value of an objective function. The objective function is formulated to represent the reserve selection problem (Lewis et al., 2003). Marxan finds a near-optimal solution that achieves the predetermined conservation goals while keeping the cost of including Planning Units (PUs) as low as possible. The objective function is the combination of the cost of the planning units within the selected area; the length of the protected area boundaries (optional); and a penalty to pay when the conservation characteristics are inadequately represented. The relative importance of the boundary length is weighed by a variable called Boundary Length Modifier (BLM). BLM controls the importance of minimizing the overall reserve system boundary length relative to the reserve system cost. Higher BLM values will produce a more compact reserve system, but the cost is likely greater (Game and Grantham, 2008).

Conservation features represent biological (e.g. spawning areas, highly-suitable habitats) or geographical (e.g. habitat types, depth ranges) characteristics to be protected and their conservation targets are usually percentages of the total amount available (Carvalho et al., 2010).

5.2.3. Conservation features

We compiled information on the spatial distribution of species and habitats designated for conservation in accordance with Natura 2000 network (EEA, 2007). Within the Habitats and Birds Directives, EU identified and classified a number of marine habitats types that should be represented in a network of MPAs – the Natura 2000. The Portuguese Institute for Nature

Conservation and Forests (Instituto da Conservação da Natureza e Florestas - ICNF) is the responsible body to assess the conservation status of species and habitats and to inform towards nature conservation policies and natural resource management.

Table 5.1 displays species and habitats selected as priority within this study, due to its status within Natura 2000. Priority was assessed based on information from European Nature Information System (EUNIS) and ICNF. When information from these entities was lacking, we used information available at the IUCN Red List of Threatened Species™. Using the satellite imaging it was possible to obtain information on seasonal spring data of Net Primary Production (NPP). NPP is an oceanographic variable used as a surrogate for the ecosystem productivity (Pauly et al., 2005). More information supplied in Table 1 of the Supplementary Material C. Coverage was calculated as percentage (presence/absence in a number of PUs from the total number of PUs). Due to coarse nature of some data, several habitats and species appear in the same PU.

Table 5.1. Selected species, habitats, and relative conservation status (more information supplied in Supplementary Material).

Code	**Species/Habitats**	**Priority Level**	**Coverage (%)**
1110	Sandbanks	Medium	26%
1130	Estuaries	Medium	10%
1140	Mud	Low	15%
1150	Coastal lagoons	High	6%
1160	Large shallow inlets and bays	Medium	3%
1170	Reefs	Medium	62%
8330	Submerged caves	Medium	4%
2618	*Balaenoptera acutorostrata*	High	50%
2621	*Balaenoptera physalus*	High	1%
1350	*Delphinus delphis*	Medium	10%
5686	*Lepidorhombus boscii*	Low	2%
5715	*Merluccius merluccius*	Low	8%
1351	*Phocoena phocoena*	High	2%
1340	*Tursiops truncatus*	Medium	1%
2034	*Stenella coeruleoalba*	Medium	1%
2029	*Globicephala melas*	Medium	38%
2030	*Grampus griseus*	Medium	16%
2035	*Ziphius cavirostris*	Medium	3%
3022	*Isurus oxyrinchus*	High	19%
5707	*Lophius piscatorius*	Low	23%
	Sardina pilchardus	Medium	38%
-	Sea-pen an burrowing megafauna communities	High	0,3%
-	*Lophelia pertusa* reefs	High	0,3%
-	Net Primary Production	Medium	21%

5.2.4. Conservation costs

For solving the minimum set problem, Marxan seeks to meet the biodiversity objectives whilst minimizing the costs. We used two different approaches for considering costs: ecosystem condition and area. We used Cumulative human Impacts Model (CIM) on the marine environment, as illustrated in Figure 5.3, developed by Fernandes et al. (2017) as surrogate for ecosystem condition (Hermoso et al., 2016; Linke et al., 2012; Venegas-Li et al., 2017). The goal was to prioritize places that are less impacted by people and therefore, in a better state for conservation, needing less actions for improving the general status of the area.

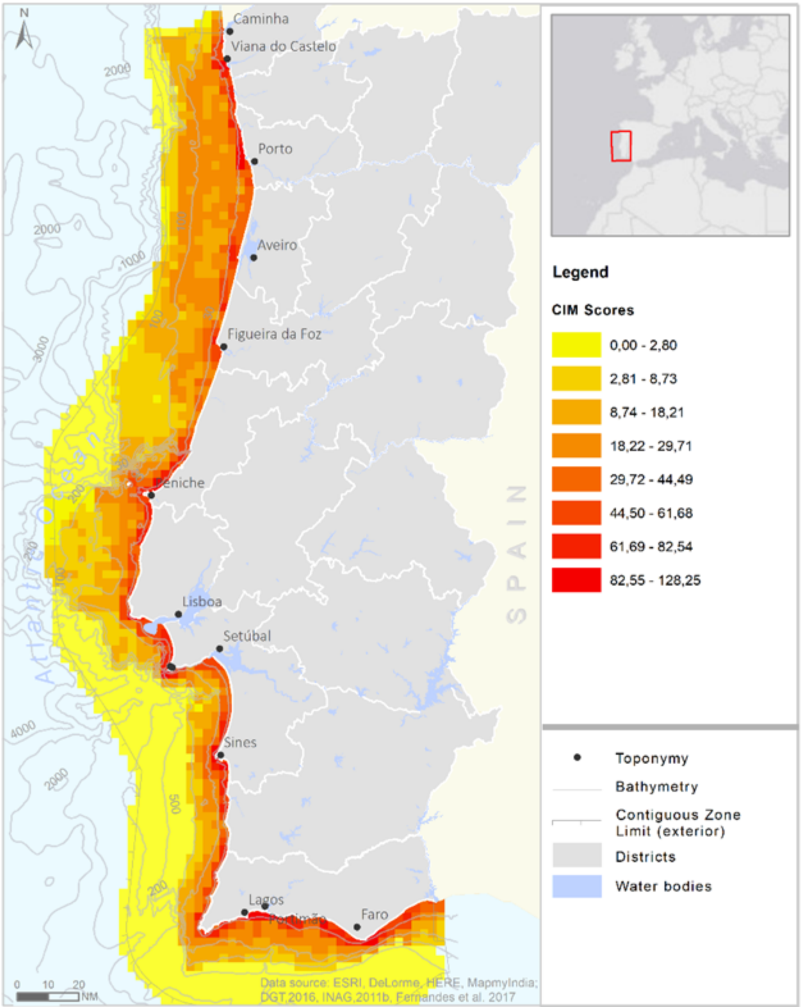


Figure 5.3. CIM Assessment for the study area. Adapted from Fernandes et al., (2017).

5.2.5. Planning scenarios

In this study, six scenarios were designed to test different prioritization approaches composed out of different combinations of status of PUs, costs and targets. Status is a model parameter providing information on the initial and final state of the PU in the reserve system. It can assume several different values ranging:

Status Meaning

0: The PU is not guaranteed to be in the initial (or seed) reserve system, however, it still may be.

1: The PU will be included in the initial reserve system but may or may not be in the final solution.

2: The PU is fixed in the reserve system (“locked in”). It is in the initial reserve system and cannot be removed.

3: The PU is fixed outside the reserve system (“locked out”). It is not included in the initial reserve system and cannot be added.

Cells status assumed different values in order to replicate existing classified areas or activities. CIM was used as a surrogate for costs as explained in 2.4. Targets used were based in the information on the conservation status of habitats and species (see Table 5.1). Scenario C1 was a baseline set up with CIM as costs, and no other restrictions. Targets differed between 10 and 60% as features were divided into 3 categories (low, medium and high) of priority (see Table 5.2 and also Table 1 in Supplementary Material C). Each feature was assigned a proportion of conservation (levels of 0.1, 0.3 and 0.6). Scenario C2 and C3 were designed similarly to C1 but with different targets. They were designed as test scenarios to understand the response of the model to the prioritization approach. As so, in Scenario C2, the goal was to select at least 10% of all features and in scenario C3, this target was raised to 30%. In order to account the reality of the Portuguese MSP, we developed two scenarios (C4 and C5) similar to C1 but with use restrictions (locking cells in status). On Scenario C4, we used the established existing National System of Classified Areas within marine waters (presented in Figure 5.1 and 5.2) as inputs to the model”. This was done to understand if they were relevant for conservation purpose within the Marxan model. Scenario C5 limited the reserve system to areas without fixed activities and uses. This meant that PUs with aquacultures, shipping lanes, offshore wind, wave energy and pipelines were locked out of the reserve system. This scenario aimed to test the achievement of the conservation targets, considering existing activities and uses in the study area. C6 was a control scenario, similar to C1 but without considering CIM as costs.

Table 5.2. Targets for each scenario. Species and Habitats included in the study and the corresponding targets attributes within each Scenario. Scenario C1, C2, C3, C4 and C5 used CIM as costs. C1, C2 and C3 have no restrictions. C4 considered protected areas as inputs to the model and C5 locked out PUs with human activities and uses. C6 had no restrictions and no costs.

<table>
<tr><th rowspan="2">Species/Habitats</th><th colspan="3">Targets</th></tr>
<tr><th>Scenario C1,C4,C5,C6</th><th>Scenario C2</th><th>Scenario C3</th></tr>
<tr><td>Coastal lagoons
Balaenoptera acutorostrata
Balaenoptera physalus
Phocoena phocoena
Isurus oxyrinchus
Sea-pen and burrowing megafauna communities
Lophelia pertusa reefs</td><td>0.6</td><td rowspan="3">0.1</td><td rowspan="3">0.3</td></tr>
<tr><td>Sandbanks
Reefs
Estuaries
Large shallow inlets and bays
Submerged caves
Delphinus delphis
Tursiops truncatus
Stenella coeruleoalba
Globicephala melas
Grampus griseus
Ziphius cavirostris
Sardina pilchardus
Net Primary Production</td><td>0.3</td></tr>
<tr><td>Mud
Lepidorhombus boscii
Merluccius merluccius
Lophius piscatorius</td><td>0.1</td></tr>
</table>

5.2.6. Marxan analysis

The study area was divided into grid cells with 2500 ha of area, in order to follow the previous development of CIM by Fernandes et al. (2017). Each cell of this grid is a PU. A Geographic Information System (GIS) software was used for data preparation and analysis (ESRI, ArcGIS 10.2 Desktop) with the Spatial Analyst extension and the spatial reference system adopted was the European Terrestrial Reference System 1989 (ETRS89) with Transverse Mercator Projection (PT-TM06). We applied Marxan (v.2.4.3) software using QMarxan complement for preparation of data in QGIS (v.2.14) environment, Zonae Cogito (v.1.74) interface for calibration and previewing of results and R software (v.3.4.2) for calculation on statistics.

Calibration was performed in accordance with Marxan Good Practice Guide (Ardron, J.A., Possingham, H.P., and Klein, 2010). For BLM a series of trial analysis was performed and the value was attuned to provide a more compact result. A BLM of 0.1 was used for all scenarios to ensure solutions produced were sufficiently compacted. The Species Penalty Factor (SPF) was unaltered at

1 for all features with 100 repetitions and 1000000 Iterations. The algorithm simulated annealing was used in all analyses followed by iterative improvement.

Main outputs analyzed extracted from Marxan were the summed solution (SS) maps, which shows the selection frequency of each PU i.e. the number of times that PU was selected in the final solution across all repeated runs. This was used as a priority for conservation index, divided into 5 categories using the standard classification method 'Natural Breaks (Jenks)' (ESRI, 2016), which was then adjusted to fit all scenarios equally: no priority: 1–20 selections; low priority: 21–40; medium priority: 41–60; high priority: 61-80; very high priority: 81-100. An additional category was added to select PUs with highest priority of conservation with values above 90% (Kark et al., 2009; Schmiing et al., 2015). These cells were designated as Irreplaceable due to its high value of Irreplaceability (Carwardine et al., 2007).They were extracted from each scenario and overlapped, allowing to spatially analyze key areas emerging from the different scenarios. Other data analyzed was the Best Solution (BS) outputs. BS is the solution with the lowest objective function value (BS Score) achieved within all runs. This data was not spatially assessed, but information regarding achievement of targets, missing values and total costs was analyzed.

5.3. Results

Table 5.3 presents the information withdrawn from the BS of each scenario. The analysis of this information shows the high performance concerning the achievement of targets. From the 24 conservation features, only two did not achieve the targets in one scenario (C5), namely Coastal Lagoons and Large Shallow inlets and Bays and another (Lepidorhombus boscii) in one scenario (C3). In all scenarios with targets ranging from 10-60% the selected area for conservation was high, between 45 until 55%.

Table 5.3. Results from Marxan for each scenario.

	Scenario	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Inputs	Status	None	None	None	Existing classified areas	Existing activities & uses	None
	Cost	CIM	CIM	CIM	CIM	CIM	No Cost
	Targets	10-60 %	10% all	30% all	10-60%	10-60%	10-60%
Results	BS Score	86473	45060	76606	86903	2014490	74597

	Scenario	C1	C2	C3	C4	C5	C6
	Protected area initially	0	0	0	20%	0	0
	Selected area from total area	51%	10%	31%	46%	45%	55%
	Achievement of targets	100%	100%	96%	100%	88%	100%

BS Scores, Table 5.3, increased in line with the protection target levels in scenarios with CIM costs and without restrictions (C1, C2 and C3). Scenario C5 presented the worse performance, with lowest achievement of targets and highest BS score.

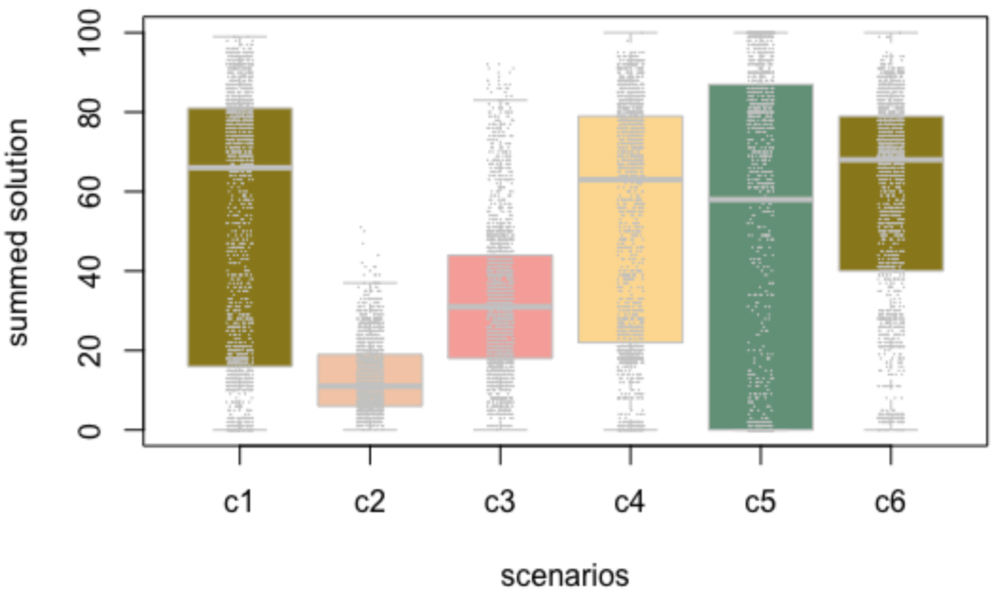


Figure 5.4. Boxplot of SS with data points (in grey) for each scenario.

Figure 5.4 illustrates the SS statistics for each scenario. Scenario C1 and C4 display a similar dispersion of data with median values around 60 and higher dispersion of values in the first quartile. In scenario C5 values are mostly in the first and fourth quartile, with higher selection frequencies in both ends of the spectrum. Scenario C2 and C3 have the lowest median values, as they were the ones with lowest targets. The higher dispersion of solutions is also visible in the maps in Figure 5.5, as percentages of selections were in general lower than 50%. In scenario C5 the majority of SS are in the extremes.

Figure 5.5 displays the spatial results of the solutions provided by Marxan. Each map represents for each scenario the collection of solutions after 100 runs classified over 5 categories representing priority of conservation. Figure 5.5a) depicts the baseline scenario (C1), where three areas with higher conservation priorities stand out (selection class from 81 to 100%).

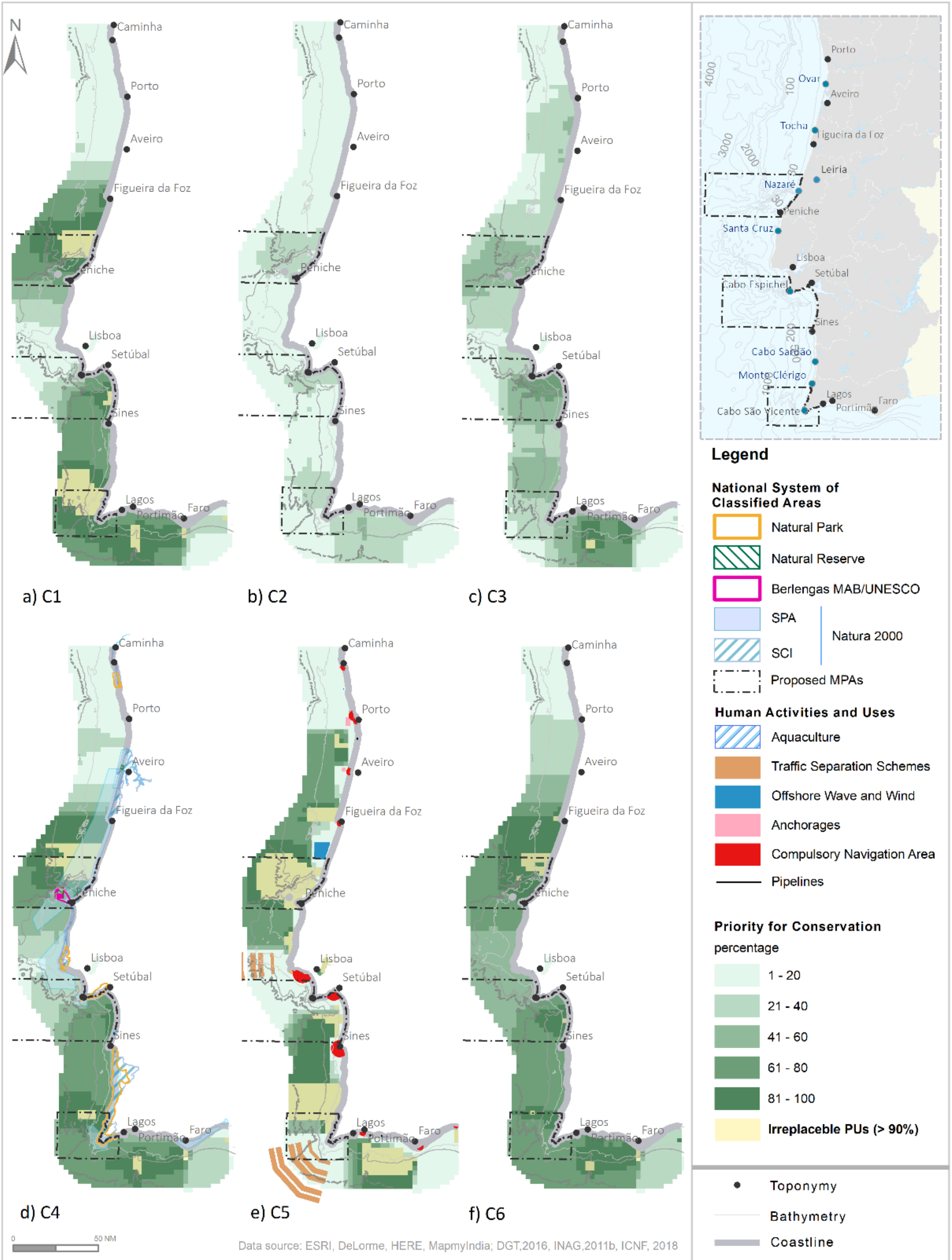


Figure 5.5. Spatial results of the selection frequency provided by Marxan for each scenario (a) C1 targets 10-60%; CIM as costs; b) C2 targets 10%; CIM as costs; c) C3 targets 30%; CIM as costs; d) C4 targets 10-60%; CIM as costs; MPA as inputs to model; e) C5 targets 10-60%; CIM as costs; Activities and uses locking PUs out of the model; e) C6 targets 10-60%; no costs.

The first spreads from the coastal area in Tocha/Peniche. It ranges from 20 to 70 km wide offshore, incorporating the Nazaré Canyon. The second higher priority area is the smallest one. Located south of Lisbon metropolitan area between Cabo Espichel/Sines with 35 km wide to offshore. The third area is located in the Portuguese south coast near Cabo de São Vicente between Cabo Sardão/Faro. Within this stretch, from Cabo São Vicente to Faro, the coastal area is not in the higher priority class.

In the lowest target (10%) scenario (C2), the SS map shows the variability of the outputs (Figure 5.5b). The selection frequency of PU across all runs was lower than 50% and on average was 10%. Highest values are in the class of 21-60% (Figure 5.4). The spatial outputs for this scenario generally match scenario C1, being smaller and more patched in shape (Figure 5.5b).

Scenario C3 is an intermediate target scenario (30%) whose outputs are consistent with the tendencies shown in the previous scenarios (see Figure 5.5c). Only at the south coast, the selection frequency was higher than 80% in two small areas, one offshore Portimão and other at the coast of Faro. Areas selected between 41 to 80% are located in Ovar, Nazaré/Peniche, Cabo Espichel, Cabo Sardão/Monte Clérigo and Cabo São Vicente/Faro.

Scenario C4 (Figure 5.5d) considered classified areas as included in the reserve system a priori. As the grid was encompassing terrestrial as well as marine area, the overall initial protected space considering both areas was 20% of the total study area. To achieve the proposed targets for the scenario, Marxan selected in the BS output 46% of the study area. When considering the SS, i.e. the map shown in the higher percentage of conservation priority, outputs are consistent with the ones presented in C1 (Figure 5.5a). The most distinctive difference is in the stretch of Cabo Sardão/Faro, where the higher priority class does not cover the area of São Vicente.

The scenario C5 (Figure 5.5e) considered activities which are already in place in the marine space (ports and aquacultures) and uses that are part of international agreements (such as shipping lanes) or whose nature is also difficult to relocate (such as pipelines). Several areas subject to these constraints are located near estuaries and high-populated areas, mainly due to Port activities. The model treated these PUs as untouchables, meaning they could never become part of a conservation area. In this scenario, areas with higher conservation value appear less connected with the coast, spreading to the exterior limit of CZ. More outstandingly, appear the areas north of Ovar between Tocha/Figueira da Foz, Leiria/Peniche, Santa Cruz/Sintra, Lisbon, south of Setúbal/Cabo São Vicente and lastly Lagos/Faro.

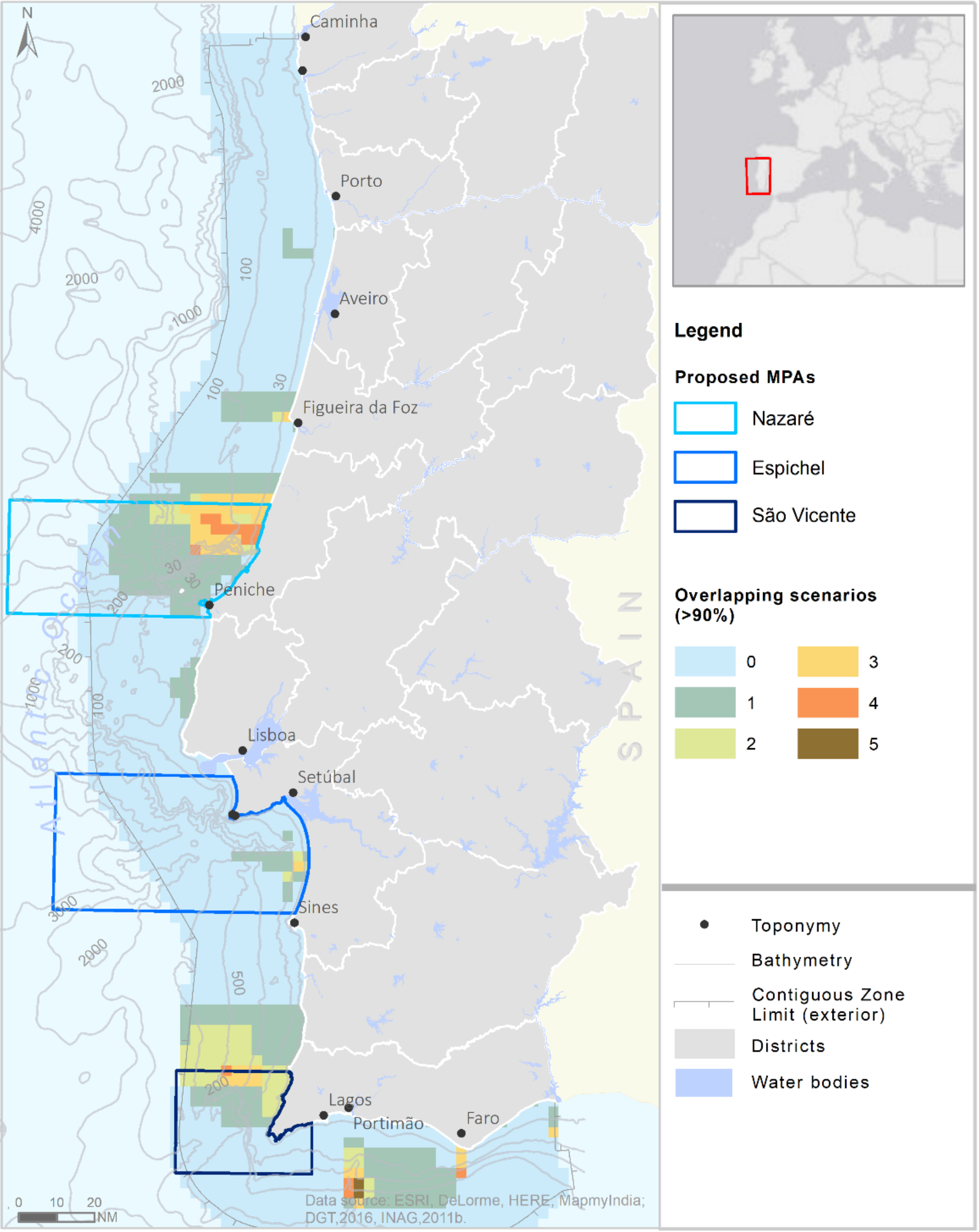


Figure 5.6. Overlapping of Irreplaceable PUs (above 90%) output of all scenarios.

Finally, the last scenario (C6) run in Marxan excluded costs and worked with targets ranging from 10 to 60 % as presented in Table 5.2. In general, the outputs, shown in Figure 5.5f) are also consistent with the areas appearing in the baseline scenario (C1). The first area appearing from the north is more clumped. The patch representing the Setubal region is larger, stretching from south Setúbal to Sines and extending wider offshore in comparison with C1 and C4. The patch in the south coast is divided in Cabo São Vicente. Appearing one small area in Monte Clérigo and other between Lagos/Faro, which spreads connected to land in some locations.

Through the exercise of overlapping the Irreplaceable class (above 90%) of all scenarios, was withdrawn a hot-spot analysis, showing the locations that were consistently selected on all scenarios. Figure 5.6 illustrates the output of this analysis. The location that showed less spatial variability was a small patch located offshore of Portimão. It was selected across 5 out of the 6 scenarios. A small area north of Nazaré, extending from the coast along the canyon, until 30 km offshore appeared in 4 scenarios. Areas selected in two or three scenarios appeared north of São Vicente MPA, a small coastal patch at the north of Sines and other small patch offshore Faro.

5.4. Discussion

This study demonstrates how to combine conservation objectives and cumulative impacts to support the decision-making process when allocating space to uses and activities. The spatial analysis here experienced is useful to inform where important ecological values are less impacted and provides inputs to sound management actions. This approach can be used as first step on the decision making framework for developing management alternatives, in line with the approach of Gregory et al. (2012) applied by Tulloch et al. (2015). By exploring alternative actions, managers may be in a better condition to evaluate the pros and cons of different solutions. This information supports the MSP framework with ecological meaningful information, in line with the EBM approach, as defined in the article 5 of the MSP Directive.

From the analysis of the maps, displayed in Figure 5.5, four main areas appear with higher percentages of selection, even in lower targets scenarios: Area between Figueira da Foz/Peniche including Nazaré Canyon, south Cabo Espichel/Sines, Cabo Sardão/Faro and Lagos/Faro. The lack of selected areas for conservation in the north part of the Portuguese waters is evident. This may occur due to the scarcity of data and the high cumulative impacts occurring in this region, namely due to coastal fisheries and the high density of urban areas. Interestingly, the Litoral Norte Natural Park was never included in the high priority areas, even in scenario C4 where it was included as a priori. The high cumulative impacts in this area, together with a smaller amount of diversity in comparison with other areas, justifies the absence of this area in the output solutions.

In the Centre region, in Nazaré, the large patch consistently selected varies significantly in format and area. However, the connection to land in Nazaré is kept through the scenarios. Also, the Nazaré canyon is always selected, reaffirming its importance for structural and functional biodiversity supporting many Ecosystem Services as stated by several authors (Cunha et al., 2011). This assumption may be expanded to the small patch between Cabo Espichel/Sines, where Setúbal canyon occurs. This selection is also relevant due to the resident marine mammal populations in

Sado Estuary and the spreading of the existent protected area from the estuary to offshore (ICNF, 2016) as a way to ensure the land-sea continuum.

In the south of Algarve, the large patch of high priority area is crossing a navigation channel in scenario C1, but in all others, the higher conservation priority class appears divided between the north of this navigation channel and between Lagos/Faro. Even in the scenario C4, where conservation areas are inputs to the model this division occurs. This fact suggests that the focus of conservation value is in the area offshore Portimão, as confirmed by Figure 5.6, which is not in line with the proposed area of MPA São Vicente. In these areas occur unique habitats of *Lophelia pertusa* and Sea-pen and burrowing megafauna communities which explain the high conservation level attributed.

When considering the scenario C5 that combines existing impacts with existing activities and uses (Figure 5.4 and 5.5e), it is noticeable that several areas have a higher selection frequency (above 90%). The comparison of this scenario with C4 outputs highlights the mismatch of the existing Protected Areas and the higher priority levels extracted from the model. The new proposed MPA in São Vicente also shows this mismatch. The outputs from the model lead to the idea that the MPA in São Vicente is not adequately placed and conservation efforts should be moved, having into consideration the ecological and human data in order to accomplish a better spatial outcome. Results from the model suggest that conservation priorities should instead be placed in Alentejo coast, from Setúbal to Cabo São Vicente and in the south coast of Algarve from Lagos to Faro. This solution would better accommodate the existing activities (the navigation channel in São Vicente) and protect a low impacted space (Alentejo coast) and the Algarve coast, which despite the existing pressures, have unique irreplaceable conservation features. The overlapping methodology used allowed to enhance the higher priority classes locations and to spatially assess its convergence regardless the scenarios' assumptions. This method allows analyzing spatial data from all scenarios in a simple and easily explainable way to stakeholders, planners and decision makers.

The high percentage of selected area for conservation presented in Table 5.3 and Figure 5.4, mainly for scenarios with targets ranging from 10 to 60% reveals that for its achievement there is a high area demand (from 45 to 55%). This may lead to more conflicts occurring between human activities and conservation. This fact leads to the assumption that for some species and habitats the targets may have been too ambitious in light of the data available. In addition, considering the high conflict of uses, activities and functions occurring near the coast, this suggests the need to consider different levels of protection with zoning schemes.

As seen in Figure 5.2, the CIM model applied in this study shows a clear disparity in the impact scores, presenting vast offshore areas without any values. Despite knowing offshore areas are less impacted, this does not reflects reality. Several activities are known to occur in the area, as well as coastal impacts that spread offshore. This influences the outputs of Marxan, naturally suggesting areas that have lower impacts. Therefore, it usually tends to exclude areas on coastal water, which are more prone to have higher impacts than areas in open waters. Results regarding existing protected areas need to be carefully interpreted. On one hand, the conservation features of the model are obviously only a brief spectrum of the conservation features that require protection in the entire Portuguese waters. In addition, the existent protected areas were defined with a whole set of features that fall out of the scope of this paper. On the other hand, high cumulative impacts have also been found in areas with protection status (Fernandes et al., 2017) leading to the exclusion of these areas.

The results obtained though this analysis bring new inputs to the conservation efforts in Portuguese marine waters, to the existing and proposed MPAs (Figure 5.6), developed in accordance with MSFD measures. This advocates the usefulness of this methodology in supporting the MSP process. Nevertheless, to improve the use of such methods, ecological and human activities information must be continuously improved and updated in order to reduce its uncertainties. Species distribution and habitats suitability models could assist with filling the gaps in data. Moreover, such models should be fed with expert judgment and stakeholders inputs. Methodologies applied to CIA must also be improved in order to account the seasonality of activities and uses, its occupation through the water column, which suggests the urgent need to classify pelagic habitats according to EUNIS (EEA, 2014).

5.5. Conclusions

This research is timely relevant as Portuguese large sea jurisdiction combined with the national strategy to develop and increase economic growth supported by sea-based activities, makes expectable the increase of stress in the environmental values provoked by anthropogenic activities. The use of DST aids the achievement of GES whilst ensuring the development of Blue Growth initiative, enabling a sound connection between MSFD and MSPD. The systematic conservation planning is a key point to minimize the effects of these factors ensuring sustainable growth and future societal well-being especially as the second cycles of MSPD and MSFD are ongoing.

The outputs from this model can be a valuable input when allocating space to activities and uses in the marine realm. This information supports the planning process in the development of management alternatives, incorporating at the same time the national strategy conservation priorities.

Information withdrawn from this study would highly benefit from improved definition of conservation features carrying capacity, especially for the ones whose contribution to ecosystem services is less studied.

References

Ansong, J., Gissi, E., Calado, H., 2017. An approach to ecosystem-based management in maritime spatial planning process. Ocean Coast. Manag. 141, 65–81. https://doi.org/10.1016/j.ocecoaman.2017.03.005

APA, 2017. Relatório do Estado do Ambiente Portugal 2016. Agência Portuguesa do Ambiente. Lisboa, Portugal.

Ardron, J.A., Possingham, H.P., and Klein, C.J., 2010. Marxan Good Practices Handbook, Version 2. Pacific Marine Analysis and Research Association, Victoria, BC, Canada.

Ball, I., Possingham, H., 2000. Marxan v1. 8.2: Marine reserve design using spatially explicit annealing. The Great Barrier Reef Marine Park Authority, Townsville, Australia.

Ban, N.C., Bodtker, K.M., Nicolson, D., Robb, C.K., Royle, K., Short, C., 2013. Setting the stage for marine spatial planning: Ecological and social data collation and analyses in Canada's Pacific waters. Mar. Policy 39, 11–2012. https://doi.org/10.1016/j.marpol.2012.10.017

Becker-Weinberg, V., 2015. Portugal's legal regime on marine spatial planning and management of the national maritime space. Mar. Policy 61, 46–53. https://doi.org/10.1016/j.marpol.2015.06.014

Bessa Pacheco, M., 2013. Medidas da Terra e do Mar. Instituto Hidrográfico. Lisboa, Portugal.

Brennan, J., Fitzsimmons, C., Gray, T., Raggatt, L., 2014. EU marine strategy framework directive (MSFD) and marine spatial planning (MSP): Which is the more dominant and practicable contributor to maritime policy in the UK? Mar. Policy 43, 359–366. https://doi.org/10.1016/j.marpol.2013.07.011

Calado, H., Ng, K., Johnson, D., Sousa, L., Phillips, M., Alves, F., 2010. Marine spatial planning: Lessons learned from the Portuguese debate. Mar. Policy 34, 1341–1349. https://doi.org/10.1016/j.marpol.2010.06.007

Carvalho, S.B., Brito, J.C., Pressey, R.L., Crespo, E., Possingham, H.P., 2010. Simulating the effects of using different types of species distribution data in reserve selection. Biol. Conserv. 143, 426–438. https://doi.org/10.1016/j.biocon.2009.11.010

Carwardine, J., Rochester, W.A., Richardson, K.S., Williams, K.J., Pressey, R.L., Possingham, H.P., 2007. Conservation planning with irreplaceability: Does the method matter? Biodivers. Conserv. 16, 245–258. https://doi.org/10.1007/s10531-006-9055-4

Cunha, M.R., Paterson, G.L.J., Amaro, T., Blackbird, S., de Stigter, H.C., Ferreira, C., Glover, A., Hilário, A., Kiriakoulakis, K., Neal, L., Ravara, A., Rodrigues, C.F., Tiago, Á., Billett, D.S.M., 2011. Biodiversity of macrofaunal assemblages from three Portuguese submarine canyons (NE Atlantic). Deep. Res. Part II Top. Stud. Oceanogr. 58, 2433–2447. https://doi.org/10.1016/j.dsr2.2011.04.007

DGT, 2016. Carta Administrativa Oficial de Portugal. http://www.dgterritorio.pt/cartografia_e_geodesia/cartografia/carta_administrativa_oficial_de_portugal__caop_/caop__download_/carta_administrativa_oficial_de_portugal___versao_2016. Lisboa, Portugal.

Domínguez-Tejo, E., Metternicht, G., Johnston, E., Hedge, L., 2016. Marine Spatial Planning advancing the Ecosystem-Based Approach to coastal zone management: A review. Mar. Policy 72, 115–130. https://doi.org/10.1016/j.marpol.2016.06.023

Douvere, F., 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Mar. Policy 32, 762–771. https://doi.org/10.1016/j.marpol.2008.03.021

EC, 2016. Joint Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: International ocean governance: an agenda for the future of oceans. JOIN(2016) 49 final. Com/2016/352 17.

EC, 2012. Communication from the Commission to the European Parliament, the Council, the European Economic and Social committee and the Committee of the Regions. Blue Growth opportunities for marine and maritime sustainable growth. COM(2012) 494 final.

EEA, 2015. State of Europe's seas. EEA Report No. 2/2015. doi:10.2800/0466. Copenhagen, Denmark.

EEA, 2014. EUNIS habitat classification 2007 - Revised descriptions 2012. http://eunis.eea.europa.eu/ (last accessed 13.03.2017).

Ekebom, J., Jäänheimo, J., Reker, J., 2008. Towards Marine Spatial Planning in the Baltic Sea. BALANCE Technical Summary Report 4.

ESRI, 2016. Classifying numerical fields for graduated symbology—Help | ArcGIS for Desktop. http://desktop.arcgis.com/en/arcmap/10.3/map/working-with-layers/classifying-numerical-fields-for-graduated-symbols.htm (accessed 8.19.16).EU, 2014. Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning. Off. J. Eur. Union 2014, 135–145.

Fernandes, M.L., Esteves, T.C., Oliveira, E.R., Alves, F.L., 2017. How does the cumulative impacts approach support Maritime Spatial Planning? Ecol. Indic. 73. https://doi.org/10.1016/j.ecolind.2016.09.014

Ferreira, M.A., Calado, H., Pereira da Silva, C., Abreu, A.D., Andrade, F., Fonseca, C., Gonçalves, E.J., Guerreiro, J., Noronha, F., Pereira, M., Pinto Lopes, C., Ribeiro, M.C., Stratoudakis, Y., Vasconcelos, L., 2015. Contributions towards maritime spatial planning (MSP) in Portugal - Conference report. Mar. Policy 59, 61–63. https://doi.org/10.1016/j.marpol.2015.04.017

Ferreira, M.A., Johnson, D., Pereira, C., Ramos, T.B., 2018. Developing a performance evaluation mechanism for Portuguese Marine Spatial Planning using a participatory approach. https://doi.org/10.1016/j.jclepro.2018.01.183

Flannery, W., Ellis, G., Ellis, G., Flannery, W., Nursey-Bray, M., van Tatenhove, J.P.M., Kelly, C., Coffen-Smout, S., Fairgrieve, R., Knol, M., Jentoft, S., Bacon, D., O'Hagan, A.M., 2016. Exploring the winners and losers of marine environmental governance/Marine spatial planning: Cui bono?/"More than fishy business": epistemology, integration and conflict in marine spatial planning/Marine spatial planning: power and scaping/Surely not all. Plan. Theory Pract. 17, 121–151. https://doi.org/10.1080/14649357.2015.1131482

Flannery, W., Ó Cinnéide, M., 2012. A roadmap for marine spatial planning: A critical examination of the European Commission's guiding principles based on their application in the Clyde MSP Pilot Project. Mar. Policy 36, 265–271. https://doi.org/10.1016/j.marpol.2011.06.003

Foley, M.M., Halpern, B.S., Micheli, F., Armsby, M.H., Caldwell, M.R., Crain, C.M., Prahler, E., Rohr, N., Sivas, D., Beck, M.W., Carr, M.H., Crowder, L.B., Emmett Duffy, J., Hacker, S.D., McLeod, K.L., Palumbi, S.R., Peterson, C.H., Regan, H.M., Ruckelshaus, M.H., Sandifer, P.A., Steneck, R.S., 2010. Guiding ecological principles for marine spatial planning. Mar. Policy 34, 955–966.

https://doi.org/10.1016/j.marpol.2010.02.001

Frazão Santos, C., Domingos, T., Ferreira, M.A., Orbach, M., Andrade, F., 2014a. How sustainable is sustainable marine spatial planning? Part I-Linking the concepts. Mar. Policy 49, 59–65. https://doi.org/10.1016/j.marpol.2014.04.004

Frazão Santos, C., Domingos, T., Ferreira, M.A., Orbach, M., Andrade, F., 2014b. How sustainable is sustainable marine spatial planning? Part II - The Portuguese experience. Mar. Policy 49, 48–58. https://doi.org/10.1016/j.marpol.2014.04.005

Game, E.T., Grantham, H.S., 2008. Marxan User Manual for Marxan version 1.8.10. St. Lucia, Queensland, Australia and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Garcia, R., 2014. Portugal vai ter 400 mil quilómetros quadrados de áreas marinhas protegidas. Público 1–6. Article published in Jornal Público on 3 de julho de 2014 [in portuguese].

Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., Ohlson, D., 2012. Structured Decision Making: A Practical Guide to Environmental Management Choices. Wiley-Blackwell. Oxford, UK.

Halpern,B.S., Fujita, R., 2013. Assumptions, challenges, and future directions in cumulative impact analysis. Ecosphere 4, art131. https://doi.org/10.1890/ES13-00181.1

Henriques, N. S., Monteiro, P., Bentes, L., Oliveira, F., Afonso, C. M. L., and Gonçalves, J. M. S. (2017). Marxan as a zoning tool for development and economic purposed areas - Aquaculture Management Areas (AMAs). Ocean Coast. Manag. 141, 90–97. doi:10.1016/j.ocecoaman.2017.03.016.

Hermoso, V., Filipe, A.F., Segurado, P., Beja, P., 2016. Catchment zoning to unlock freshwater conservation opportunities in the Iberian Peninsula. Divers. Distrib. 1–10. https://doi.org/10.1111/ddi.12454

ICNF, 2016. Processo de extensão da Diretiva Habitats ao meio marinho: Proposta técnica de Sítios de Importância Comunitária a designar em Portugal continental [in portuguese].

ICNF, 2018. Sistema Nacional de Áreas Classificadas. Rede Natura 2000. http://www2.icnf.pt/portal/pn/biodiversidade/snac (last accessed 18.04.2018) [in portuguese]

INAG, 2011a. POEM—Plano de Ordenamento do Espaço Marítimo, Volume 5 Tomo1: Estudos de Caracterização [in portuguese].

INAG, 2011b. POEM—Plano de Ordenamento do Espaço Marítimo, Volume 5 Tomo 2: Caracterização Cartográfica [in portuguese].

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., John, M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical Overfishing and the Recent Colllapse of Coastal Ecosystems. Science (80). 293, 629–638. https://doi.org/10.1126/science.1059199

Jay, S., Alves, F.L., O'Mahony, C., Gomez, M., Rooney, A., Almodovar, M., Gee, K., de Vivero, J.L.S., Gonçalves, J.M.S., da Luz Fernandes, M., Tello, O., Twomey, S., Prado, I., Fonseca, C., Bentes, L., Henriques, G., Campos, A., 2016. Transboundary dimensions of marine spatial planning: Fostering inter-jurisdictional relations and governance. Mar. Policy 65, 85–96. https://doi.org/10.1016/j.marpol.2015.12.025

Kappel, C. V., Halpern, B.S., Martone, R.G., Micheli, F., Selkoe, K.A., 2009. In the Zone: Comprehensive Ocean Protection. Issues in Science and Technology. Spring 1–8.

Kark, S., Levin, N., Grantham, H.S., Possingham, H.P., 2009. Between-country collaboration and consideration of costs increase conservation planning efficiency in the Mediterranean Basin. Proc. Natl. Acad. Sci. 106, 15368–15373. https://doi.org/10.1073/pnas.0901001106

Klein, C.J., Tulloch, V.J., Halpern, B.S., Selkoe, K.A., Watts, M.E., Steinback, C., Scholz, A., Possingham, H.P., 2013. Tradeoffs in marine reserve design: habitat condition, representation, and socioeconomic costs. Conserv. Lett. 6, https://doi.org/10.1111/conl.12005

Lewis, A., Slegers, S., Lowe, D., Muller, L., 2003. Use of Spatial Analysis and GIS techniques to Re-Zone the Great Barrier Reef Marine Park. Coastal GIS Workshop, July 7-8 2003, University of Wollongong, Australia.

Linke, S., Kennard, M.J., Hermoso, V., Olden, J.D., Stein, J., Pusey, B.J., 2012. Merging connectivity rules and large-scale condition assessment improves conservation adequacy in river systems.

J. Appl. Ecol. 49, 1036–1045. https://doi.org/10.1111/j.1365-2664.2012.02177.x

Maes, F., 2008. The international legal framework for marine spatial planning. Mar. Policy 32, 797–810. https://doi.org/10.1016/j.marpol.2008.03.013

MAMAOT, 2014. Estratégias marinhas para as águas marinhas Portuguesas. Diretiva-Quadro Estratégia Marinha. Programa de monitorização e programa de medidas [in portuguese].

Martín-García, L., Sangil, C., Brito, A., Barquín-Diez, J., 2015. Identification of conservation gaps and redesign of island marine protected areas. Biodivers. Conserv. 24, 511–529. https://doi.org/10.1007/s10531-014-0833-0

MEA, 2005. Ecosystems and Human Well-being: Synthesis. Millennium Ecosystem Assessment. In: Island Press, Washington, DC.

Pauly, D., Alder, J., Bakun, A., Heileman, S., Kock, K.-H., Mace, P., Perrin, W., Stergiou, K., Sumaila, U.R., Vierros, M., Freire, K., Sadovy, Y., Christensen, V., Kaschner, K., Palomares, M.-L., Tyedmers, P., Wabnitz, C., Watson, R., Worm, B., Baker, J., Casasola, P.M., Lugo, A., Rodriguez, A.S., Dan, L., Tang, L., 2005. Marine fisheries systems, in: Ecosystems and Human Well-Being: Current State and Trends. pp. 477–511.

Schaefer, N., Barale, V., 2011. Maritime spatial planning: opportunities & challenges in the framework of the EU integrated maritime policy. J. Coast. Conserv. 15, 237–245. https://doi.org/10.1007/s11852-011-0154-3

Schmiing, M., Diogo, H., Serrão Santos, R., Afonso, P., 2015. Marine conservation of multispecies and multi-use areas with various conservation objectives and targets. ICES J. Mar. Sci. 72, 851–862. https://doi.org/10.1093/icesjms/fst176

Tulloch, V.J.D., Tulloch, A.I.T., Visconti, P., Halpern, B.S., Watson, J.E.M., Evans, M.C., Auerbach, N.A., Barnes, M., Beger, M., Chadès, I., Giakoumi, S., McDonald-Madden, E., Murray, N.J., Ringma, J., Possingham, H.P., 2015. Why do We map threats? Linking threat mapping with actions to make better conservation decisions. Front. Ecol. Environ. 13, 91–99. https://doi.org/10.1890/140022

UN, 2016. A Regular process for global reporting and assessment of the state of the marine environment, including socioeconomic aspects (Regular process). First global integrated marine assessment (First World Ocean Assessment).

UN, 1982. United Nations Convention on the Law of the Sea. United Nations, Montego Bay, pp. 7–208.

Venegas-Li, R., Levin, N., Possingham, H., Kark, S., 2017. 3D spatial conservation prioritisation: Accounting for depth in marine environments. Methods Ecol. Evol. 2017, 1–12. https://doi.org/10.1111/2041-210X.12896

6. SPATIAL CHARACTERIZATION OF MARINE SOCIO-ECOLOGICAL SYSTEMS

Abstract

There is a lack of available methods to understand the associations between land and sea in social and ecological systems. This work adapts a methodology used in the south Mediterranean Coast to explore how coastal-marine areas in the Portuguese Mainland Subdivision differ in socioeconomic and marine environmental characteristics. The outputs of this work, Marine Socio-Ecological Categories mapped along the coast, show contrasting ecological and societal conditions across the coastal municipalities and are valuable to understand how different conditions may be dealt with at regional and national context in future management and planning policies. Mapping socio-ecological systems aids the sustainable economic development, but further research is needed to improve the categorization. This study shows that there is no land-sea divide as these complex systems are closely interlinked and the connections between both systems as well as their socioeconomic impacts should be reflected in the existent policy framework.

Keywords: Maritime Spatial Planning; Land-Sea interface; Socioeconomic; Portugal

6.1. Introduction

Marine or Maritime Spatial Planning (MSP) aims to contribute to a more balanced and sustainable use of ocean resources by defining priority or restricted areas to decide which outputs are to be produced from a marine area over time (Gee et al., 2017). While the ecological and economic evidence base for MSP tends to be relatively well developed, this cannot be said for the social dimension of the sea. Incorporation of social data into ocean plans or information on social-ecological linkages has not received sufficient attention (Cornu et al., 2014).

The MSP Directive (2014/89/EU) at European level identifies MSP as a process to organize human activities in marine areas to achieve ecological, economic and social objectives urges the Member States to have plans in place until 2021 and within an Ecosystem-Based Management (EBM) approach, social aspects shall be taken into account. EBA as "an approach which integrates the connections between land, air water and all living things including human beings and their institutions" must incorporate spatial consideration to manage human uses and requires an understanding of social processes and human preferences (Mee et al., 2015). One of the identified aims of the Directive is to deliver social cohesion, along with economic growth and sustainable development. The way or form how to take them into the plan is left to Member States definition (Hassler et al., 2019). But authors as Flannery et al. (2016) are concerned with the lack of attention to social aspects given in MSP plans that embody the blue economy developments. A review on coastal and ocean planning processes showed that less than 50% included social data and only 10.8% of social data were spatially characterized (Cornu et al., 2014). Noble et al. (2019) suggests for MSP Plans that socially based spatial information shall be integrated concerning environmental information in a way that supports both social and ecological resilience. In a recent review of socio-ecological MSP case studies, Noble et al. reported the need to develop innovative predictive modelling techniques to understand how social uses change over time and how marine ecosystems may respond to potential direct and indirect disturbances. This means understanding the human linkages to the ecosystem within adaptive management plans.

MSP is still in its early stage of developments and several approaches of how to implement it are emerging. There have been explorations of how to ensure sustainable development of the seas while ensuring the restoration of marine environments, but the operationalization of EBM in MSP is far from simple. Besides the sea dynamics, the marine space is a public good, and requires the inclusion of public representation into the MSP process. Coupled social-ecological systems (SES) concept emerged from the realization that human and ecological systems shall be viewed as inextricably linked. SES are complex adaptive systems in which social and biophysical components are interacting at multiple temporal and complex scales (Berkes et al., 2003; Liu et al., 2007; Martín-López et al., 2017; Ostrom, 2009). However, the dynamic nature of SES, resulting from the interdependencies of socio-cultural, economic and biophysical variables makes it difficult to understand the complex feedbacks between variables. The way as human actions are affected and have effects on the ecosystems is difficult to assess and are varied at different scales (Martín-López et al., 2017). There is nowadays a consensus over the need to reverse the fragmentation of knowledge and promote a holistic approach to management and planning is desired (Crowder et al., 2006; Douvere, 2008; Katsanevakis et al., 2011; Mee et al., 2015).

Several works have focused on the social-ecological associations but assessing the spatial configuration of the social-ecological system remain a challenge (Lazzari et al., 2019a; Martín-López et al., 2017). Few studies have developed tools spatially assessing SES and their potential for informing management and planning. Alessa et al. (2008) identified geographical areas (SES hotspots) where human-perceived landscape values and biophysical values converged to identify areas of high concern and to the components of the system that lend resilience or vulnerability. Castellarini et al. (2014) developed a framework to build socio-ecoregions using ecoregions and human development index. The information on location and extent of different eco-regions would support federal or state level policy design. Hanspach et al. (2016) identified social-ecological units that represent different types of villages with distinct species diversity patterns to inform biodiversity conservation. However, all these exercises were on land. Lazzari et al. (2019b) updated a framework developed by Martín-López et al. (2017) to identify and characterize socio-ecological associations at the land-sea interface in the Mediterranean Coast of Andaluzia. The framework used information on socioeconomic characteristics and marine environmental data to characterize coastal regions for efficient management of coastal resources and improvement of relevant policies.

In Portugal was recently approved in December 2019 by the Resolution of the Council of Ministers n.º 203-A/2019, the first line instrument in MSP, PSOEM (*Plano de Situação do Ordenamento do Espaço Marítimo*). It identifies the spatial and temporal distribution of existing and potential uses and activities to be developed under a private use permit, as well as the natural and cultural values of strategic importance for environmental sustainability (DGRM, 2019). PSOEM would benefit from increased socio-ecological knowledge, such as the exploration of how the land-sea systems, which are rather complex, interface and connect between the social and ecological systems. Moreover, the application of PSOEM, which is in its early stages has considerable options of incorporating new information, improvement and adaptation. This study adapts the methodology Lazzari et al. (2019b; Martín-López et al., 2017) to the mainland coast of Portugal to explore how coastal-marine areas differ in socioeconomic and marine environmental characteristics. This categorization aims to support management and planning policies to improve sustainable land-sea interfaces.

6.2. Materials and methods

6.2.1. Study area

Mainland Portugal is divided into 4 NUTS (Nomenclature of territorial units for statistical purposes), a hierarchical system that divides the territory into regions (DGT, 2018a), they are called Norte, Centro, Alentejo, Algarve and Área Metropolitana de Lisboa (AML). There are 51 municipalities (see Figure 6.1) that share a boundary with coastal waters (EU, 2000). This territory has a wide variety of land and sea uses, including natural protected areas, urban and industrial centers, intensive farming and fishing areas. The gross majority of the population lives on coastal municipalities (around 75%) and larger cities are located in river mouths hosting ports, which are an important part of the highways of the sea. Latest available data indicated that maritime economy accounted for 3.1% of the Gross Value Added (GVA) and 3.8% of national employment and trend (INE, 2016), showing a growth dynamic above the national average (Mateus et al., 2019). Most relevant activities supporting sea economy nowadays are tourism, shipbuilding, fisheries and related industry, marine infrastructures and transports (Mateus et al., 2019). The average unemployment rate on coastal municipalities, in 2018, was 4.7% with a monthly average base salary of 816 euros, with highest income around 1400 euros in Oeiras.

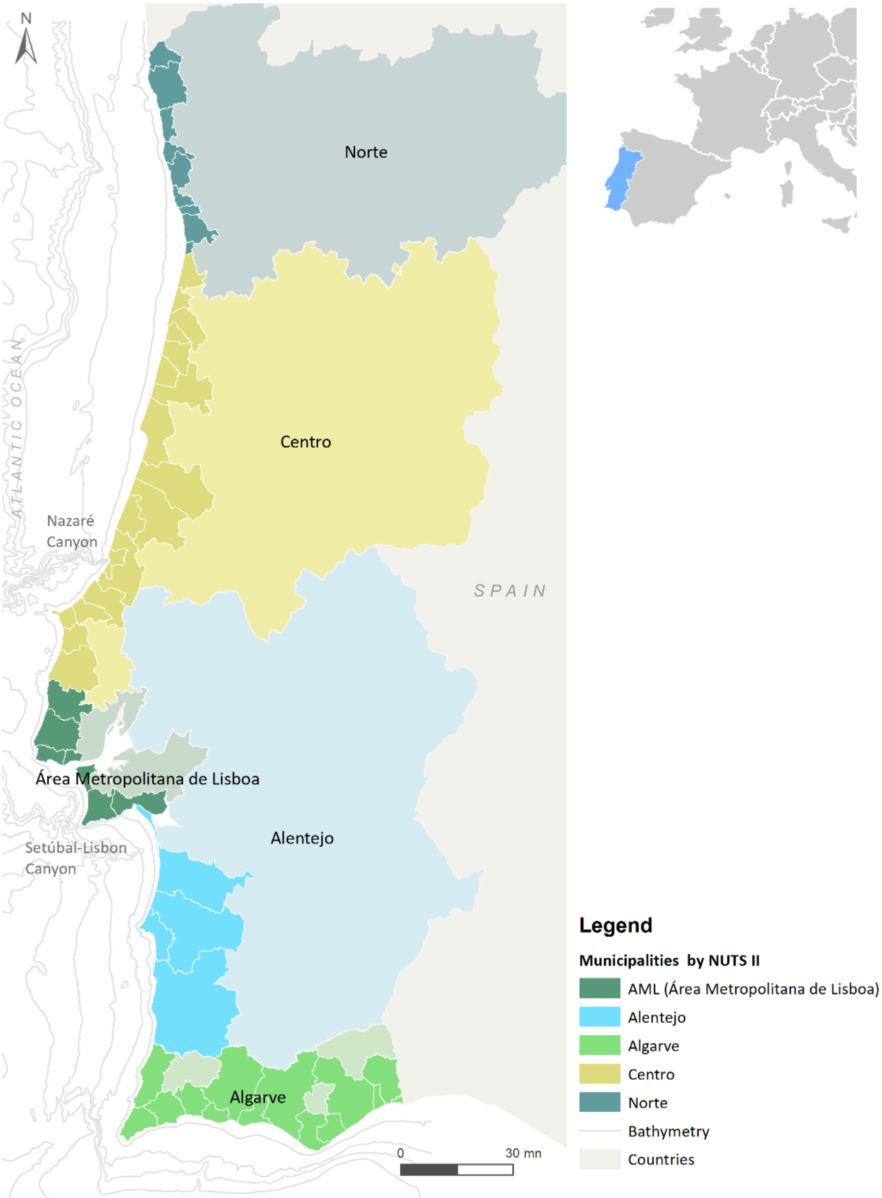


Figure 6.1. Map of the study area, illustrating the geographical location of the municipalities in the coastline of Mainland Portugal. Municipalities are divided by NUTS II Area Metropolitana de Lisboa (7 municipalities), Alentejo (4 municipalities), Algarve (13 municipalities), Centro (18 municipalities) and Norte (9 municipalities).

Highest population densities are occurring in Lisbon and Porto metropolitan areas (941,9 and 843,1), quite above the national average of 111.5 inhabitants per km^2 (PORDATA, 2019)

The Portuguese continental coast is mostly sandy shore with some rocky and cliffed stretches. It has a regular soft relief with prominent canyon features, such as Nazaré and Setúbal-Lisbon promoting the occurrences of coastal upwelling that support high productivity (Lastras et al., 2009; Relvas et al., 2007). Highest anthropogenic pressures, mapped on previous research, appear in the transitional and coastal areas in the north (Norte), center (Centro) and in western Algarve (Fernandes et al., 2017).

The Spatial Planning and Urban Development Law of 1998 (Law 48/1998) set the beginning of the spatial planning organization in Portugal. The law was amended in 2014 (Law 31/2014) to integrate soil, spatial planning and urban principles under the same legal regime. Together with the Decree-Law 80/2015 that sets the Legal Framework of Territorial Management Tools, these documents establish the basis of the territorial planning instruments, their articulation and tools.

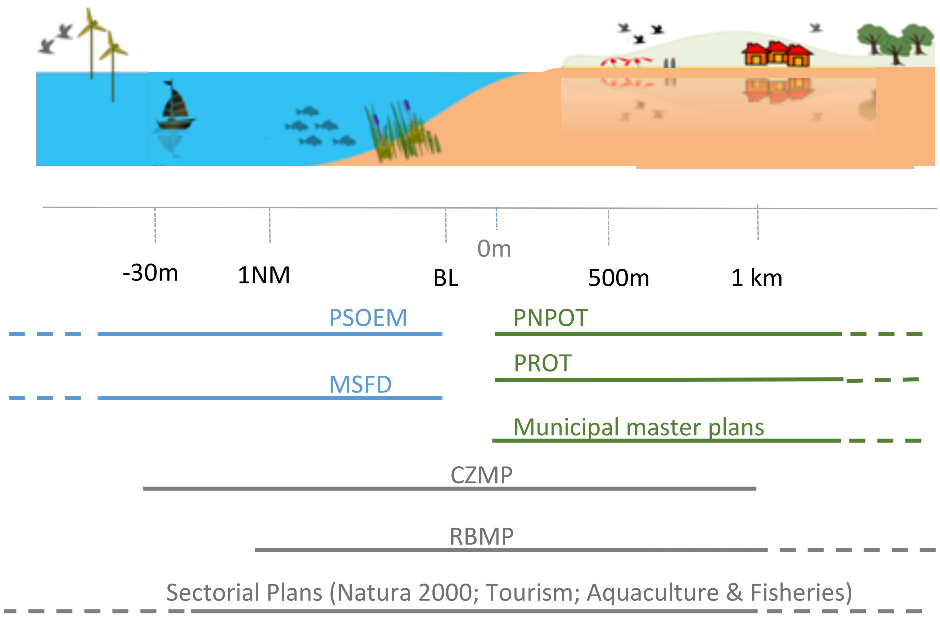


Figure 6.2. Policy tools of relevance in the study area context

The territorial system in force is divided into 4 areas: national, regional, inter-municipal and municipal. At the regional, intermunicipal and municipal level instruments can be programmes or plans, such as regional programmes (PROT – Planos Regionais de Ordenamento do Territorio), intermunicipal urbanization programmes or municipal master plans). At the national level instruments can be sector programmes (Tourism, Energy, Nature, etc…), special programmes (Coastal Zone Management Plans - CZMP, protected areas management, estuaries and public water reservoir programmes) and strategic, embodied in the National Land Use Policy Programme

(PNPOT), a figure that was already created already in 1998's Law but which was only produced in 2007. The programme faced a revision in 2016 (Resolution of the Council of Ministers n. 44/2016 of August 23) and was finally published in 2019 through Law 99/2019.

Regarding the water resources legislation, two documents are relevant to analyze within this scope. Marine Strategy Framework Directive (MSFD - transposition into Portuguese Law by Decree-Law 108/2010) urges the attainment or maintenance of the Good Environmental Status of marine waters and the Water Framework Directive (transposed by Law 58/2005) implemented by the River Basin Management Plans (RBMP) for each of the 8 river basins in Portugal aims to achieve a Good Ecological Status.

The National framework for MSP was also enacted in 2014, through Law 17/2014 which establishes the basis of the policy for MSP and Management (MSP Law) of the national maritime space (Becker-Weinberg, 2015). Afterwards, the Decree-Law no. 38/2015, published in March 2015, further develops key aspects of the Law and transposed the EU MSP Directive. It defines two types of maritime spatial planning instruments, the PSOEM (identifying the spatial and temporal distribution of existing and potential uses and activities to be developed under a private use permit) and the Allocation Plan (AP - *Planos de Afetação*). PSOEM was approved so far for the Mainland, Madeira, and Extended continental shelf subdivisions in December 2019. With the new terrestrial and marine laws of 2014, there is a distinct separation between both regimes. While it is ensured effective articulation and compatibility of territorial programmes and plans with the national maritime spatial planning it creates two separate systems. Figure 6.2 shows the spatial extent of the different policy tools referred to as relevant within the study scope.

6.2.2. Data collection

We followed the methodological approach developed previously for terrestrial systems and afterwards adapted to marine areas (Lazzari et al., 2019b; Martín-López et al., 2017). We collected marine environmental and socioeconomic data to identify and characterize marine environmental and socioeconomic classes.

For the marine environmental data, as in Lazzari et al. (2019), we used the satellite database, BIO-ORACLE (Assis et al., 2018). We extracted values of nine variables from ocean pixels contiguous to the coastline using the maximum resolution available at BIO-ORACLE. The nine variables are selected due to their relevance for marine biodiversity: inorganic carbon (calcite concentration), primary productivity (minimum chlorophyll a and mean chlorophyll a), nutrients (nitrate and phosphate concentrations), salinity, and sea surface temperature (SST; maximum SST, mean SST and SST range). We averaged the pixel values for each municipality for each variable to obtain an environmental value per municipality. A buffer to each municipality was performed, considering a marine offshore limit. Initially, this offshore limit was to the 30 m bathymetry, as this is the limit of the CZMP in Portugal. However, this limit would deprive some municipalities of having data, as it was too near the coast in some locations. As so, a metric distance of 6 km from the coast was settled. This was a compromise to guarantee there was satellite data for all municipalities and a conservative approach to the 30 m bathymetry all over the Portuguese coast. We added two more variables to characterize the benthic habitats, reefs and sand, using information from EMODNET (Galparsoro et al., 2012) and followed the same procedure of obtaining an average value for each municipality.

We collected the socioeconomic information from public access databases, PORDATA (2019), INE (2018) and spatial data from DGT (2018a). We selected the municipality level, as it is the most disaggregated with statistical information available for all the variables. Demographic information included population density, age classes (people below 25 and above 65), education level (people with a university degree and illiterate). Economic variables included average monthly income, employment in primary, secondary and tertiary economic sectors, unemployment, touristic accommodations and gross value added by tourism. Fisheries information included the percentage of fishers in the overall population and gross value added by fisheries and aquaculture. Land use information included information on urban and industrial areas, agriculture, forests and wetlands/water bodies. Finally, we also considered the level of environmental protected surface. All the variables collected and their details are listed in Table 1 of Supplementary Material D.

6.2.3. Data analysis

We used a combined analytical approach to characterize the Portuguese Marine Socio-Ecological Categories (MSEC, see Figure 6.3). All the analyses were conducted using R software (R Development Core Team, 2011). First, we performed a principal component analysis (PCA) with varimax rotation on the socioeconomic data. This was done to simplify the dimensions of the socioeconomic variables and to understand the dominant relationships. We used the Kaiser criterion (Kaiser, 1960) in combination with the scree test to select the number of the principal components to use (Cattell, 1966).

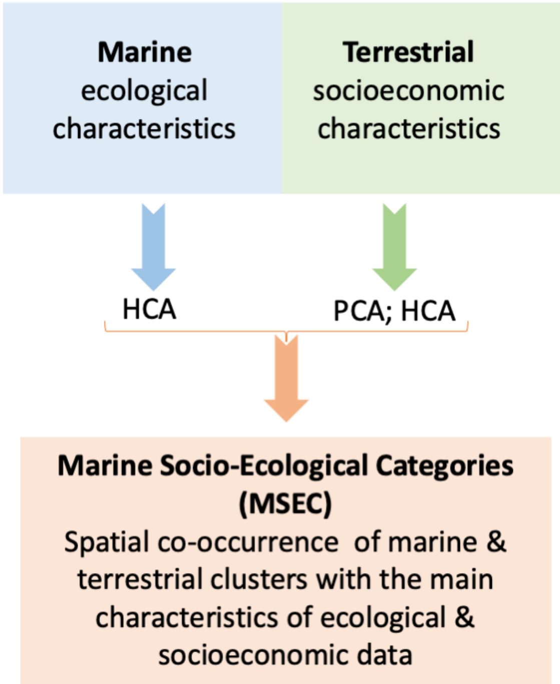


Figure 6.3. Schematic methodological approach used to identify the Marine Socio-Ecological Categories (MSEC) in Portugal

After we carried out the hierarchical cluster analysis (HCA). On the socioeconomic data, we used the selected PCA components to identify the homogeneous classes. The PCA and HCA analyses were performed in R using the packages 'FactoExtra' and 'FactoMiner' (Lê et al., 2008). On the marine variables, we performed the HCA after standardizing data with a mean of 0 and a standard deviation of 1. We used the Euclidean distance and Ward's linkage method. To identify the suitable number of clusters, we used the package NBclust for determining the best number of clusters and propose the best clustering scheme (Charrad et al., 2014). Third, we conducted ANOVA and Kruskal-wallis tests for the differences in the variables among the clusters. We used Shappiro-wilk test to check normality for all the variables used. When ANOVA or Kruskal Wallis was significant (p-value <0.05), we used post hoc pairwise comparisons t-test and Dunn's multiple comparisons tests, respectively, to assess differences between clusters.

Finally, we used the spatial co-occurrence between socio-ecological and marine classes in order to understand their level of relationship creating MSEC. To graphically visualize the difference between categories we conducted a non-metric multidimensional scaling (nMDS), following Lazzari et al. (2019) approach using the Euclidean similarity and taking its stress value as an indicator of the goodness of the representation. We used radar charts to represent the influence of each variable in each MSEC.

6.3. Results

6.3.1. Socioeconomic classifications

The PCA aims to reduce the number of variables to be used. The first 6 principal components (PC) are selected due to the combination of the eigenvalue (higher or approximate to 1) and explained 80 % of the variance in the socioeconomic data (see Table 2 of Supplementary Material D). The first PC1 (33.87%) represented by its positive scores municipalities with high population densities, university degrees, tertiary sector workers and urban and industrial areas with high touristic income. PCA2 (14.91%) shows the highest values of people above 65 years, illiterate, unemployed and a high spatial cover of forests and semi natural areas. PCA3 (12.01%) highest gradients are on the variables of tertiary employment, agricultural and protected areas. PCA4 (8.33 %) is related to agricultural areas and touristic establishments. PCA5 (6.12%) covers variables representing fishing activity (fishers, VAB from fisheries and aquaculture) and also high primary sector employment. Finally, PCA6 (4.83%) represents municipalities with low percentages of fisheries activities, unemployment and high rates of young people (below 25). Using these 6 PCA components we identify 3 socioeconomic clusters (SCL) (Figure 6.4a and Figure A.2 of the Supplementary Material D). The most relevant variables for the separation among the three clusters are population density, urban and industrial land cover (see Table 6.1), due to the lack of association between clusters in pairwise comparisons test. The municipalities within SCL3 have the highest population density (3000 inhabitants per km^2), an outstanding value considering the average in Portugal of 111.5 inhabitants per km^2 (PORDATA, 2019). The highest income values and high urban and industrial cover also characterize SCL3. This cluster represents the most developed municipalities in Portugal, which are part of the metropolitan areas of Lisbon and Porto, and hence are the economic cores of development in the country. It has the highest percentages of tertiary workers, university degree holders, touristic development, but also the highest unemployment rates, which is more evident in the northern municipalities. It shows also the lowest percentage of primary workers and illiterate people. SCL1 and SCL2 both represent municipalities with higher percentages of primary workers, including fishers, with lower education level and lowest monthly incomes.

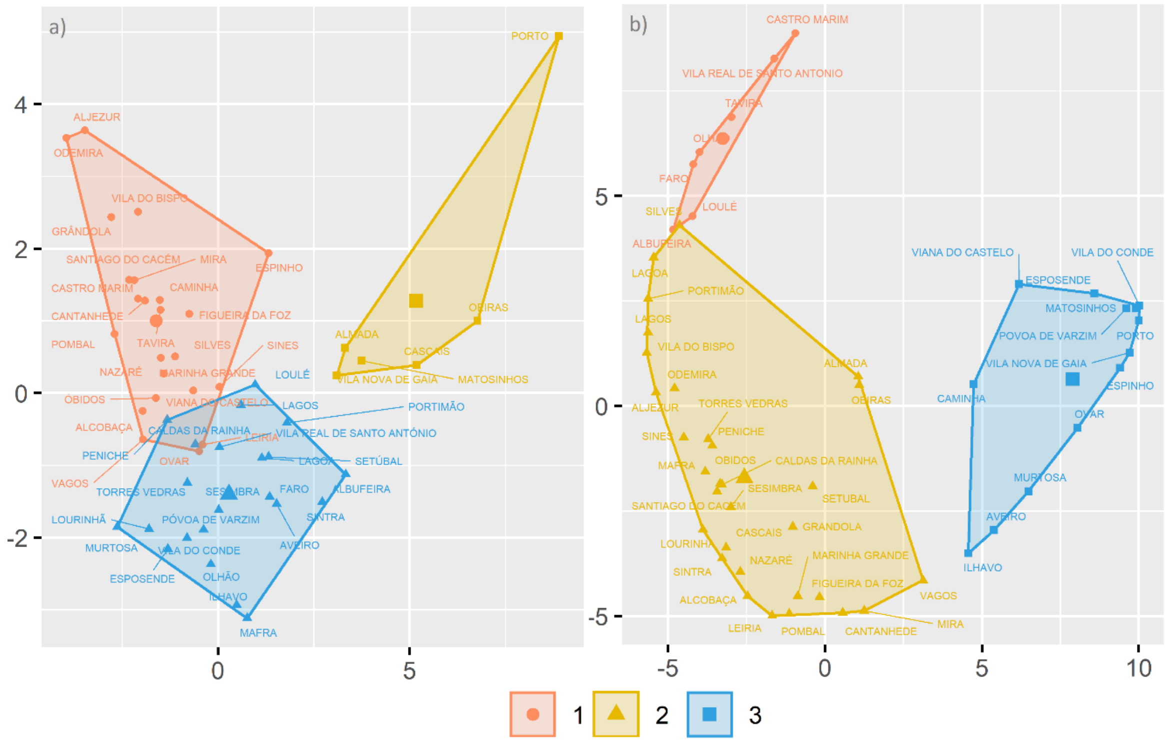


Figure 6.4. Visualization of partitioning results a) Socioeconomic clusters after the PCA and the HCA; b) Marine results after HCA. Final positions in the figure are influenced by all three dimensions of principal components but visually represented here from a two-dimensional perspective (hence perceived overlap).

The most distinct differences on these clusters are the lower level of illiterate people and highest revenues on tourism and fishing related activities on SCL2, although employment in fisheries is similar between SCL1 and SCL2 (around 0.95 %). In addition, SCL2 shows a younger ageing profile (highest percentage of young and lowest on older people), the highest percentage of agricultural areas, wetlands and water bodies. As stated, SCL1 shows highest levels of illiterate, oldest people (above 65) and highest average primary and secondary workers. This cluster has the highest percentages of forests and semi natural areas. It also has the lowest population density, average monthly income and revenues from fisheries, aquaculture and tourism.

Overall, the social and economic variables are showing younger and more educated municipalities among SCL2 than SCL1. SCL2 and SL3 shared the variables associated with high VAB from tourism and lower level of illiterate people. However, they are distinct on monthly incomes and university graduates, which are highest in SCL3 and on the percentage of employment in the primary sector and fishers, showing the higher averages for SCL2, SCL1 and SCL3 are the most distinct clusters.

Table 6.1. Mean values of the socioeconomic variables in each socioeconomic class (Cluster SCl, F-value, and X2 statistic for the significant differences among the socioeconomic classes. The SCls sharing superscript letters (a, b or c) do not differ (pairwise comparison t−tests or Dunn's multiple comparison tests after Bonferroni correction). The bold values point to the cluster with the highest mean value for each variable. * $p < 0.05$).

						Pairwise comparisons		
Variables	**SCl1**	**SCl2**	**SCl3**	**F**	**X2**	**1-2**	**1-3**	**2-3**
Population density (hab/km^2)	165.88a	360.12b	**3030.07c**		29.35*	0.0003*	0*	0.0188*
Illiterate people (%)	**7.37a**	4.46b	2.87b		26.87*	0.0004*	0*	0.0364
People with university degree (%)	10.39a	12.56a	**21.87b**		18.42*	0.0417	0*	0.0089*
People younger than 25 (%)	22.42a	**26.04a**	24.50a	24.07*		7.42E-11	6.73E-03	0.064615
People older than 65 (%)	**24.56a**	19.70a	22.55a	12.37*		1.32E-07	0.261548	0.051711
People employed in primary sector (%)	**5.79a**	4.67a	0.45b		15.69*	0.4341	0.0001*	0.0017*
People employed in secondary sector (%)	27.93a	**23.20a**	16.93a	10.14*		0.019841	0.013496	0.29093
People employed in tertiary sector (%)	66.28a	72.14a	**82.62a**	18.02*		0.074971	0.000348	0.030224
Unemployed (%)	4.41a	4.45a,b	**6.80b**		7.31*	0.9558	0.0112*	0.0277
Touristic accommodations	23.09	40.00	**65.50**		2.37			
Monthly income per inhabitant (Euro/hab)	783.15a	792.05a	**1030.15b**		12.67*	0.6746	0.0006*	0.0036*
Urban and industrial areas (%)	8.77a	14.31b	**64.97c**		23.29*	0.0072*	0*	0.0086*
Agricultural (%)	33.19	**49.99**	20.63	0.07				
Forests and semi-natural areas (%)	**55.51a**	27.04a	12.84a	69.09*		1.55E-08	2.90E-08	0.078856
Wetlands and water bodies (%)	2.53	**8.65**	1.56		1.84			
Fishers (%)	0.95a	**0.95a**	0.10b		11.13*	0.7863	0.0056*	0.0014*
Gross added value of Fisheries (Euro)	1 292 214	**4 673 252**	1 624 753		3.68	-	-	-
Gross added value of Tourism (Euro)	16 772 896a	52 192 166 b	**156 039 064b**		20.44*	0.0052*	0*	0.0332
Protected Areas	7.62	**10.19**	8.18		2.45			

6.3.2. Marine environmental classifications

Through the HCA we identify 3 marine clusters (MCL) that are spatially separated as Figure 6.4b (and the dendrogram in Figure 3 of Supplementary Material D) shows. All the northern municipalities are associated in MCL3, which is significantly different from the other clusters (in 9 out of 11 variables). MCL3 shows the highest average values for Mean Calcite, Mean and Minimum Chlorophyll a, Mean Nitrate and Phosphate (see Table 6.2). MCL1 and MCL2 have only significant differences on the variables associated with Sea Surface Temperature (maximum SST, mean SST and SST range). MCL2 has lower SST variables and salinity, higher chlorophyll (mean and min), higher nitrate and covers all the Continental Atlantic Coast (from Vagos to Silves). MCL1 appears in west Algarve, from Albufeira to Vila Real de Santo António. The bottom substrate analysis, of sand and reefs did not provide significant differences among clusters.

Table 6.2. Mean values of the marine variables in each marine class (Cluster MCL, F-value, and X2 statistic for the significant differences among the socioeconomic classes. The MCLs sharing superscript letters (a, b or c) do not differ (pairwise comparison with Dunn's multiple comparison tests after Bonferroni correction). The bold values point to the cluster with the highest mean value for each variable. * p < 0.05).

					Pairwise comparisons		
Variables	**MCl1**	**MCl2**	**MCl3**	**X2**	**1-2**	**1-3**	**2-3**
Mean calcite (mol/m^3)	0.0022a	0.0026a	**0.0037b**	9.5448	0.9178	0.0209*	0.0067*
Mean chlorophyll a (mg/ m^3)	0.1988a	0.3403a	**0.9877b**	30.727*	0.1755	0.0000*	0.0000*
Min chlorophyll a (mg/m^3)	0.0681 a	0.0839 a	**0.2092 b**	29.144*	0.6336	0.0000*	0.0000*
Mean nitrate (mol/m^3)	0.0961 a	0.1115 a	**0.6535 b**	28.572*	1.0000	0.0002*	0.0000*
Mean phosphate (mol/ m^3)	0.0606 a	0.0654 a	**0.0820 b**	26.034*	0.2787	0.0000*	0.0000*
Surface salinity (PSS)	**35.7700** a	35.3822 a	34.2055 **b**	34.158*	0.0261	0.0000*	0.0000*
Maximum SST (ºC)	**23.4713a**	20.7390b	19.7859 **c**	37.828*	0.0034*	0.0000*	0.0000*
Mean SST (ºC)	**18.5277a**	16.9041b	15.7924c	37.828*	0.0034*	0.0000*	0.0000*
Range SST (ºC)	**8.8140a**	7.0890b	7.5272c	23.585*	0.0000*	0.0208*	0.0238*
Sand (%)	0.3737	0.4633	**0.6221**	4.6504			
Reefs (%)	0.0736	**0.1818**	0.1240	3.0356			

6.3.3. Characterization of Marine Socio-Ecological Categories (MSEC)

The MCL and the SCL clusters are associated by their spatial co-occurrence and form the Marine Socio-Ecological Categories (MSEC, see Figure 6.5). The category C, composed by SCL3 and MCL1 is not observed.

The nMDS analysis performed with a multivariate dispersion p-value of 0.02 (<0.05 and analysis of variance table 0.7436 > 0.05 meaning there are no problems with the assumption) shows that the MSEC groups are different from each other. Figure 6.6 shows the two-dimensional dispersion of the nMDS results of the MSEC. Categories that share the same MCL and are either SCL 1 or 2 are closer, as the MSEC A and B, D and E show. MSEC G and H are grouped as well. Only F and I are distant from all other categories. Figure 6.7a and 6.7b show the spatial representation of the Marine (MCL), Socioeconomic (SCL) clusters and the composition of the resulting MSEC. Figure 6.8 shows radar charts representing the scaled average values from the municipalities composing each category.

MCL \ SCL	1	2	3
1	A	B	C
2	D	E	F
3	G	H	I

Figure 6.5. Matrix of the resulting MSEC

Each chart shows the different 4 groups of variables: social, economic, land cover and ecological. MSEC A and B sharing the MCL 1 are found in Algarve coast between Albufeira and Vila Real de Santo António (see Figure 6.7b). Higher temperature waters and high incidence of agricultural areas are common in both categories. MSEC A shows a rural profile (SCL1), with low average economic variables and higher rates of older and illiterate people while MSEC B shows a higher average on economic sectors and higher rates of young people.

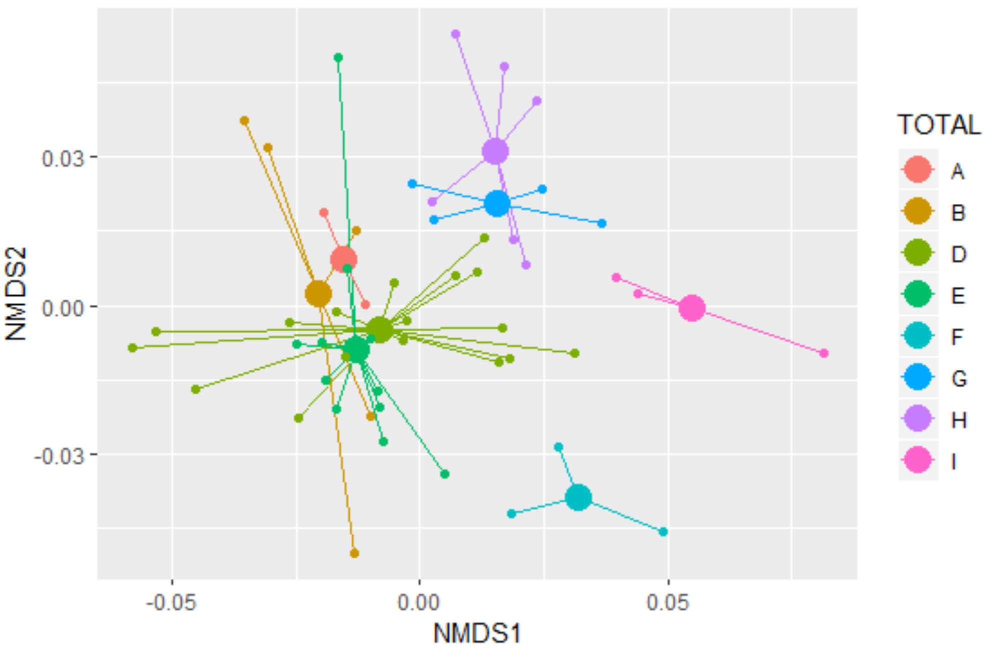


Figure 6.6. Two-dimensional nMDS of the MSEC

In the Atlantic coast three MSEC D, E and F share the same marine cluster, MCL2. Although it's the same cluster, its ecological variables have differences within each category. MSEC F is showing lowest average values of productivity (Chlorophyll related variables) and Nitrates, with highest values of Inorganic carbon, while MSEC D shows higher levels of nutrients. MSEC E is characterized by rocky coastline municipalities, most on them northern of Lisbon. Regarding socioeconomic variables, MSEC F shows an urban profile, appearing in municipalities from AML region and closer to Lisbon (Oeiras, Cascais and Almada) with the highest indicators on urban and industrial area, population density, highest average graduated people, tertiary workers and highest national average income. It also shows the 2nd highest revenues from tourism. MSEC D is characterized by older, illiterate and primary sector workers, while MSEC E shows the highest level of young people, higher levels of population density and higher incomes from tourism and fisheries.

Regarding land cover, MSEC D holds the coastal municipalities with the highest superficial area and it shows the highest forest occupation in the coastal municipalities, while both categories, D and E having lower levels of urban and industrial areas.

MSEC G, H and I share the same MCL3, all located on the Northern part of the country. They share the highest levels of productivity and nutrients in the water, with the lowest salinity and temperatures. On socioeconomic levels, these categories all have higher population densities with high percentages of urban and industrial land cover. MSEC I occurs in 3 municipalities Porto, Vila Nova de Gaia and Matosinhos. It has the highest national averages of population density, unemployment levels, touristic accommodations and tourism VAB. Besides, it shows the highest urban and industrial land cover. It is the second-best ranking category on monthly incomes and an average of graduates in the population, only behind category F (covering the municipalities around Lisbon, as Oeiras, Cascais and Almada).

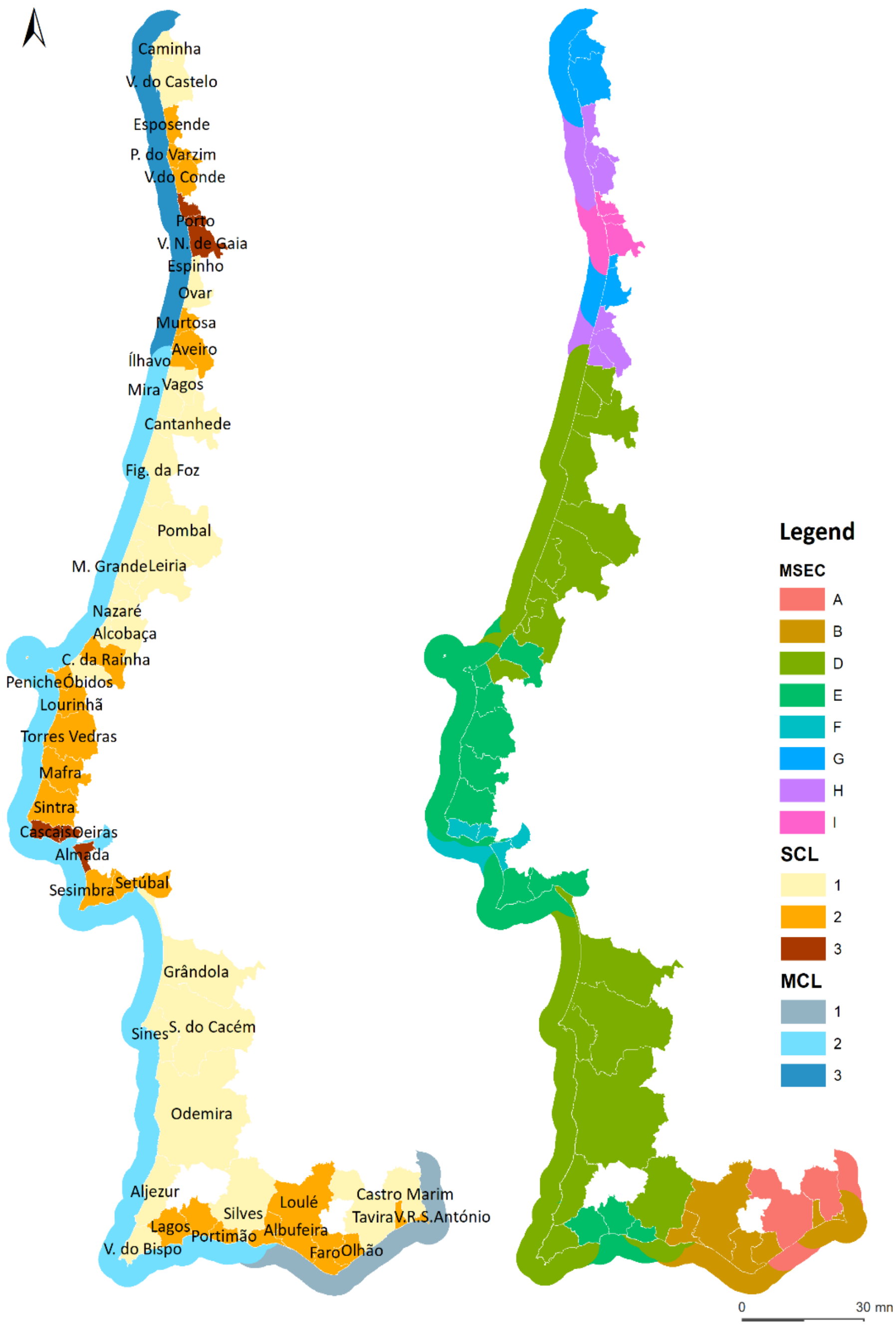


Figure 6.7. a) Marine (MCL) and Socioeconomic (SCL) clusters; b) Combined 8 categories of Marine Socio-ecological Categories (MSEC)

MSEC H appears in the boundary areas of MSEC I, with highest average values on fishery related categories, incomes and fishers, and the highest national average of workers in the primary and secondary sector. In opposition, it shows the lower levels of unemployment, older people (above 65 years) and a lower number of touristic accommodations. Regarding land cover, this category shows the highest average occupation within each municipality of wetlands and water bodies and sand benthic habitats. Finally, MSEC G is characterized by the lower levels of income, percentage of graduates among the population, low added value from tourism or fishing activities and higher illiterate and older people (above 65 years) when compared with H and I. It also shows a higher area covered by forests and semi natural areas within its municipalities. Alike MSEC H, also G has low levels of unemployment and high levels of workers on the secondary sector.

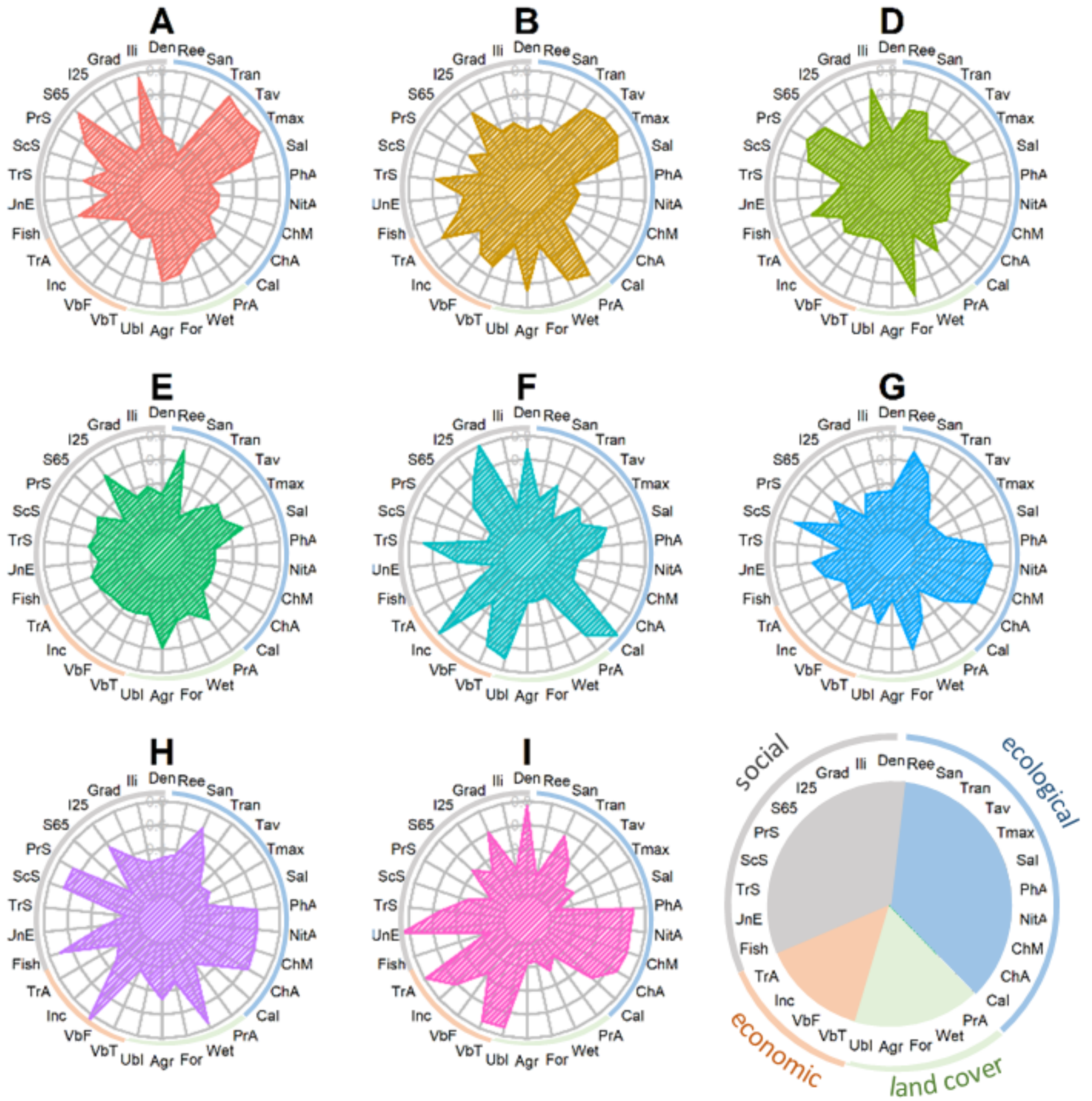


Figure 6.8. Marine and Socioeconomic variables that characterize each category of MSEC. **Social variables**: Den - population density; Ili - Illiterate people; Grad - People with university degree; I25 - People younger than 25; S65 - People older than 65; PrS - People employed in primary sector; ScS - People employed in secondary sector; TrS – People employed in tertiary sector; UnE – Unemployed; Fish – Fishers. **Economic variables**: TrA – Touristic accommodations; Inc – Monthly income per inhabitant; VbF – Gross added value of Fisheries; VbT – Gross added value of Tourism. **Land cover variables**: Ubl – Urban and industrial areas; Agr – Agricultural areas; For – Forests and semi-natural areas; Wet – Wetlands and water bodies; PrA – Protected areas. **Ecological variables**: Ree – Reefs; San – Sand; Tran – SST range; Tav – Mean SST; Tmax- Maximum SST; Sal – Mean salinity; PhA – Mean phosphate; NitA – Mean nitrate; ChM- Minimum chlorophyll a; ChA – Mean chlorophyll a; Cal – Mean calcite

6.4. Discussion

6.4.1. Implications for management and planning policies

We followed a methodology developed in terrestrial systems and later adapted to marine systems (Lazzari et al., 2019b; Martín-López et al., 2017). Through the application of the method, we identified several MSEC showing different marine socio-ecological patterns along the Portuguese coast. This study allowed identifying specific factors either socioeconomic or ecological behind the similarities and differences within MSEC, essential to better understand the specificities of each region and improve design policy-making decisions and management measures.

Municipalities within MSEC F and I represent the urban municipalities part of the metropolitan areas of Lisbon and Porto respectively (INE, 2014), being the most economically developed categories, with highest percentages of income and tertiary workers but also the highest unemployment rates. Unemployment is particularly evident within the MSEC I, representing the northern municipalities. This inequality was identified in the social vulnerability outlook of the PNPOT (DGT, 2018) where northern unemployment was associated with highest rates of elderly people and higher insecurity in labor market, while in the south, MSEC F was related with migrant communities.

Northern territories related with MSEC G,H and I exhibit a profile with highest maritime pollution (level of nutrients, mainly nitrogen), higher inorganic carbon and lower marine temperatures, in a territory with a high industrial profile (APA, 2017; DGT, 2018b), mainly evident in MSEC H and I. This aspect was already identified in the analysis of chemical water quality report of the WFD (RBMP of Cávado Ave and Leça, APA, 2017), where streams in Cávado, Ave and Leça faced high nitrate concentration. It's worth mention that other streams also had high concentrations, however, the northern rivers are known for extensive rivers runoff with short transit time within the estuaries, which may lead to more nutrients achieving the coastal area (Saraiva et al., 2007). MSEC H appears as transition territory, highly related with fisheries (on the employment of fishers and VAB from fisheries), but also with a strong component of agriculture, corresponding to territories with a strong tradition of fishing, such as Póvoa do Varzim, Vila do Conde, Esposende, Ílhavo and Aveiro (DGT, 2018b). Territories already facing higher marine pollution, such as MSCE G, H and I indicate they will be dealing with higher human pressures and higher resources demands, as they also have higher rates of young people. In this sense, it will be relevant to develop policies that promote the control of chemicals used in agriculture and to develop supporting structures to cope with the urbanization of the territories.

MSEC D correspond to the central region, the coastal stretch between Vagos and Óbidos (with the exception of Caldas da Rainha) and at the south of Lisbon, the Alentejo coast (between Grândola and Vila do Bispo, see Figure 6.6b). The maritime cluster MCL 2 that originates it has lower levels of pollution than MCL3. Within this maritime category, which extends from Vagos to Silves, differences arise on the higher Chlorophyll parameters and lower SST than the average of the MCL2 cluster. At the socioeconomic level, MSEC D shows the least developed profile of the Atlantic coast. This is in line with the territorial diagnostic at PNPOT (DGT, 2018b) where these stretches are characterized as relevant in the food production and agroforestry systems. Exception in the Leiria-Marina Grande and Sines, with are relevant hubs at a regional economic level (DGT, 2018c), but do not appear so in this categorization, perhaps due to its focus on tourism and fisheries economic activities only. The demographic challenge in these territories is obvious, with high rates of older people and lower rates of youngsters, being vulnerable to depopulation. Different challenges arise on the contiguous MSEC E, which has a semi urban profile (population densities above 100 and below 500 hab/km^2, see INE, 2014), but with a younger population and better economic conditions. It includes peripheric municipalities of Lisbon area, as Sintra, Setúbal and even Mafra and Algarve cities with highest population density. It combines a fishery and touristic aspects, not showing revenues as high as of the urban core municipalities (MSEC I and F) but relevant at the national scale (Mateus et al., 2019). It includes Peniche a well renowned hub for fisheries and tourism, Portimão and Sesimbra, traditional artisanal fishery ports (Mateus et al., 2019). Interestingly, MSEC D and E spread pass thru regional boundaries, namely MSEC E between Região Centro and AML and MSEC D between Alentejo and Algarve, indicating that national policies will be more relevant to tackle the issues, than regional ones. Although both D and E have the same MCL they differ on socioeconomic characteristics and their management measures and policies should target their challenges accordingly. For example, in MSEC E with higher population densities and rates of younger people, more economic activity as tourism, policies shall target specific human pressures (due to increased resources consumption, urbanization and urban sprawl). On the contrary MSEC D with higher rates of older people and an economic profile focused on agricultural and forestry systems, shall target policies to develop sustainable growth and education, although considering as well to foster development and preserving the ecosystems at the same time.

MSEC A and B appeared in Algarve coast related to MCL 1 and SCL1 and 2 respectively. Both MSEC were showing higher temperatures, lowest levels of nutrients and B had also the lowest levels of chlorophyll. Cabo São Vicente in Vila do Bispo municipality is known as an upwelling event location where it conveys cold SST into the inshore waters of Algarve eventually reaching Faro municipality in some cases (Cardeira et al., 2013; Relvas et al., 2007). The main differences arise where B is showing higher population density, income and higher economic indicators on tourism and fisheries. It is the third best category on tourism VAB and the second highest on touristic accommodations. Also, in this category occurs the protected area of Ria Formosa with anthropogenic pressures on ecological values (Fernandes et al., 2020, 2017). Algarve coast is divided between 4 categories, showing the dissimilarities and the fragmentation of the territory. Locations as Faro, Portimão, Lagos and Albufeira (MSEC E and B) are more developed and dynamic than Castro Marim and Tavira (DGT, 2018b). In three of the categories (MSCE A, B and E) there are high rates of tertiary workers and in two MSEC A and D are the highest percentages of illiterates, the lowest population densities and highest average of older people. This unbalanced growth between neighboring municipalities in Algarve is a challenge for management and planning, where some municipalities show the relevance of the primary sector and the incidence of agricultural tradition, with ageing and depopulation as the main challenge alongside territories more economically developed but focused mainly in tourism services activities (Turismo de Portugal, 2017). Mainly for MSEC E and B, the two clusters more economically developed but with average lower primary production indicators in Algarve management and policies measures should focus on environmental education oriented on promoting sustainable fisheries and diversified touristic activities, to reduce the pressures on ecosystems.

The MSEC provide valuable inputs to characterize and expose specific vulnerabilities of the territory. The policy tools shown in Figure 6.2 can acknowledge the MSEC to design more efficient management actions and policies at different spatial scales. At the national level with PNPOT, and at a regional level PROTs that present a strategic regional vision may benefit from this cluster analysis as a means to reduce disparities between levels of development among clusters and improve cohesion over the different territories. Accessibilities, Tourism, Fisheries and CZMP programmes can also incorporate items from the analysis. Also, the new MSP Plan, PSOEM may incorporate information from the analysis by exploring the most resilient municipalities to changes in fisheries and tourism activities, relevant within the maritime sector, but also to explore the differences on demographic and socioeconomic conditions on coastal municipalities.

This work can support a better definition of MSP working scales, by defining spatial patterns associated with marine and land–sea interfaces. It identified a lack of social characterization of Portuguese mainland coastal areas at the municipal level, which may be further studied in future, especially in the time being that new census will be through in 2021. In future, such studies can be improved with more detailed information at the coastal municipality level on other maritime activities, such as maritime transport, shipbuilding, improved fishing and tourism indicators.

6.4.2. Limitations and further research

Several limiting constraints were already acknowledged in the study of Lazzari et al., (2019). In our study we identified several limiting factors. On the socioeconomic characterization, there was mainly a lack of information on data inputs by years. We used only specific years from the last census, 2011 and when available data that is recent or official estimates. This may be improved in future studies with more information. The socioeconomic analysis may also in future encompass neighboring municipalities that although do not have waterfront are near to be exposed to maritime influence.

The three marine clusters were identified based on the SST variables, mean, range and maximum. The clusters on the Iberian coast MCL 2 and 3 showed lower SST temperatures, higher chlorophyll levels and low salinity levels. The Iberian coast, in Nazaré, but also around Lisbon, Setubal and Cabo São Vicente is known to be prone to upwelling events, which transport cold and nutrient rich upwelled water, typically occurring between Spring to Autumn (Moita, 1993; Relvas et al., 2007). To understand these events and specifies is beyond the scope of this work, neither the data used allows it. However, this does show that some trends may appear related with known trends of the Western Iberian coast and therefore, the indicators used for the accessing ecological system can be improved. We used the database of Bio-Oracle with derived metrics that were not accounting for inter-annual and seasonal differences, which characterize ecological systems. In future, species richness, abundance or functional biodiversity (Foley et al., 2010) would be a valuable addition. Hanspach et al., (2016) included in his study species richness models to develop a typology of terrestrial socio-ecological units. Also the study of Gomes et al., (2018) identified several areas of marine biological value which are a good proxy for ecological characterization which can be useful to support the categorization in a future implementation.

6.5. Conclusion

The characterization of marine socio-ecological systems can support policy design by displaying a comparative research on the contrasting ecological and societal conditions across the Portuguese coastal municipalities. Socio-ecological regional mapping characterization exercises are still in an early phase and were mainly focused inland. We adapted a methodology developed for marine coastal socio-ecological characterization in Andaluzia. Despite some limitations and shortcomings on the information applied, this exercise showed that the spatial information extracted from the categories was valuable to understand how different conditions along the territory may be dealt with at regional and national context in future management and planning policies. Mapping socio-ecological systems aid the sustainable economic development, but further research is needed to improve the categorization. Nevertheless, such studies make clear that there is no land-sea divide as these complex systems are closely interlinked. Therefore, the connections between both systems as well as their socioeconomic impacts should be reflected in the existent policy framework.

References

Alessa, L. (Naia), Kliskey, A. (Anaru), Brown, G., 2008. Social-ecological hotspots mapping: A spatial approach for identifying coupled social-ecological space. Landsc. Urban Plan. 85, 27–39. https://doi.org/10.1016/j.landurbplan.2007.09.007

APA, 2017. Relatório do Estado do Ambiente Portugal 2016. Agência Portuguesa do Ambiente 82.

Assis, J., Tyberghein, L., Bosch, S., Verbruggen, H., Serrão, E.A., De Clerck, O., 2018. Bio-ORACLE v2.0: Extending marine data layers for bioclimatic modelling. Glob. Ecol. Biogeogr. 27, 277–284. https://doi.org/10.1111/geb.12693

Becker-Weinberg, V., 2015. Portugal's legal regime on marine spatial planning and management of the national maritime space. Mar. Policy 61, 46–53. https://doi.org/10.1016/j.marpol.2015.06.014

Berkes, F., Colding, J., Folke, C., 2003. Navigating Social-Ecological Systems. Building Resilience for Complexity and Change. Cambridge University Press.

Cardeira, S., Rita, F., Relvas, P., Cravo, A., 2013. Chlorophyll a and chemical signatures during an upwelling event off the South Portuguese coast (SW Iberia). Cont. Shelf Res. 52, 133–149. https://doi.org/10.1016/j.csr.2012.11.011

Castellarini, F., Siebe, C., Lazos, E., Tejera, B. De, Cotler, H., Pacheco, C., Boege, E., Moreno, A.R., Saldívar, A., Larrazábal, A., Galán, C., Casado, J.M., Balvanera, P., 2014. A social-ecological spatial framework for policy design towards sustainability : Mexico as a study case A social-ecological spatial framework for policy design towards sustainability : Mexico as a study.

Cattell, R.B., 1966. The scree test for the number of factors. Multivariate Behav. Res. 1, 245–276. https://doi.org/10.1207/s15327906mbr0102_10

Charrad, M., Ghazzali, N., Boiteau, V., Niknafs, A., 2014. NbClust : An R Package for Determining the. J. Stat. Softw. 61, 1–36. https://doi.org/10.18637/jss.v061.i06

Cornu, E. Le, Kittinger, J.N., Koehn, J.Z., Finkbeiner, E.M., Crowder, L.B., 2014. Current practice and future prospects for social data in coastal and ocean planning. Conserv. Biol. 28, 902–911. https://doi.org/10.1111/cobi.12310

Crowder, L.B., Osherenko, G., Young, O.R., Airamé, S., Norse, E.A., Baron, N., Day, J.C., Douvere, F., Ehler, C.N., Halpern, B.S., Langdon, S.J., Mcleod, K.L., Ogden, J.C., 2006. Resolving Mismatches in U.S. Governance. Science (80-.). 617–618.

DGRM, 2019. Volume V - Plano de Situação do Ordenamento do Espaço Marítimo Nacional. Relatório Ambiental PSOEM.

DGT, 2018a. Carta Administrativa Oficial de Portugal [WWW Document]. URL http://www.dgterritorio.pt/cartografia_e_geodesia/cartografia/carta_administrativa_oficial_de_portugal__caop_/caop__download_/carta_administrativa_oficial_de_portugal___versao_2016/

DGT, 2018b. Programa Nacional da Politica de Ordenamento do Território (PNPOT) Diagnóstico Territorial. Direcção Geral do Território 39.

DGT, 2018c. Programa Nacional da Politica de Ordenamento do Território (PNPOT) Estratégia e Modelo Territorial. Direcção Geral do Território 29.

Douvere, F., 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Mar. Policy 32, 762–771. https://doi.org/10.1016/j.marpol.2008.03.021

EU, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. European Commission.

Fernandes, M.L., Esteves, T.C., Oliveira, E.R., Alves, F.L., 2017. How does the cumulative impacts approach support Maritime Spatial Planning? Ecol. Indic. 73. https://doi.org/10.1016/j.ecolind.2016.09.014

Fernandes, M.L., Sousa, L.P., Quintela, A., Marques, M., Reis, J., Simão, A.P., Castro, A.T., Marques, J.M., Alves, F.L., 2020. Mapping the future: Pressures and impacts in the Portuguese maritime spatial planning. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2020.136863

Flannery, W., Ellis, G., Ellis, G., Flannery, W., Nursey-Bray, M., van Tatenhove, J.P.M., Kelly, C., Coffen-Smout, S., Fairgrieve, R., Knol, M., Jentoft, S., Bacon, D., O'Hagan, A.M., 2016. Exploring the winners and losers of marine environmental governance/Marine spatial planning: *Cui bono* ?/"More than fishy business": epistemology, integration and conflict in marine spatial planning/Marine spatial planning: power and scaping/Surely . Plan. Theory Pract. 17, 121–151. https://doi.org/10.1080/14649357.2015.1131482

Foley, M.M., Halpern, B.S., Micheli, F., Armsby, M.H., Caldwell, M.R., Crain, C.M., Prahler, E., Rohr, N., Sivas, D., Beck, M.W., Carr, M.H., Crowder, L.B., Emmett Duffy, J., Hacker, S.D., McLeod, K.L., Palumbi, S.R., Peterson, C.H., Regan, H.M., Ruckelshaus, M.H., Sandifer, P.A., Steneck, R.S., 2010. Guiding ecological principles for marine spatial planning. Mar. Policy 34, 955–966. https://doi.org/10.1016/j.marpol.2010.02.001

Galparsoro, I., Connor, D.W., Borja, Á., Aish, A., Amorim, P., Bajjouk, T., Chambers, C., Coggan, R., Dirberg, G., Ellwood, H., Evans, D., Goodin, K.L., Grehan, A., Haldin, J., Howell, K., Jenkins, C., Michez, N., Mo, G., Buhl-Mortensen, P., Pearce, B., Populus, J., Salomidi, M., Sánchez, F., Serrano, A., Shumchenia, E., Tempera, F., Vasquez, M., 2012. Using EUNIS habitat classification for benthic mapping in European seas: Present concerns and future needs. Mar. Pollut. Bull. 64, 2630–2638. https://doi.org/10.1016/j.marpolbul.2012.10.010

Gee, K., Kannen, A., Adlam, R., Brooks, C., Chapman, M., Cormier, R., Fischer, C., Fletcher, S., Gubbins, M., Shucksmith, R., Shellock, R., 2017. Identifying culturally significant areas for marine spatial planning. Ocean Coast. Manag. 136, 139–147. https://doi.org/10.1016/j.ocecoaman.2016.11.026

Gomes, I., Pérez-Jorge, S., Peteiro, L., Andrade, J., Bueno-Pardo, J., Quintino, V., Rodrigues, A.M., Azevedo, M., Vanreusel, A., Queiroga, H., Deneudt, K., 2018. Marine biological value along the Portuguese continental shelf; insights into current conservation and management tools. Ecol. Indic. 93, 533–546. https://doi.org/10.1016/j.ecolind.2018.05.040

Hanspach, J., Loos, J., Dorresteijn, I., Abson, D.J., Fischer, J., 2016. Characterizing social–ecological units to inform biodiversity conservation in cultural landscapes. Divers. Distrib. 22, 853–864. https://doi.org/10.1111/ddi.12449

Hassler, B., Blažauskas, N., Gee, K., Luttmann, A., Morf, A., Piwowarczyk, J., Saunders, F., Stalmokaitė, I., Strand, H., Zaucha, J., 2019. New generation EU directives, sustainability, and the role of transnational coordination in Baltic Sea maritime spatial planning. Ocean Coast. Manag. 169, 254–263. https://doi.org/10.1016/j.ocecoaman.2018.12.025

INE, 2018. Portal do INE - Instituto Nacional de Estatística [WWW Document]. URL https://www.ine.pt/xportal/xmain?xpgid=ine_main&xpid=INE&xlang=pt (accessed 3.25.20).

INE, 2016. Satellite Account for the Sea - Press Release. June, 3rd 2016.

INE, 2014. Portal do INE - Divisões estatísticas : Tipologias de áreas urbanas, 2014 [WWW Document]. URL https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_cont_inst&INST=6251013&xlang=pt (accessed 3.2.20).

Kaiser, H.F., 1960. The Application of Electronic Computers to Factor Analysis. Educ. Psychol. Meas. 20, 141–151. https://doi.org/10.1177/001316446002000116

Katsanevakis, S., Stelzenmüller, V., South, A., Sørensen, T.K., Jones, P.J.S., Kerr, S., Badalamenti, F., Anagnostou, C., Breen, P., Chust, G., D'Anna, G., Duijn, M., Filatova, T., Fiorentino, F., Hulsman, H., Johnson, K., Karageorgis, A.P., Kröncke, I., Mirto, S., Pipitone, C., Portelli, S., Qiu, W., Reiss, H., Sakellariou, D., Salomidi, M., van Hoof, L., Vassilopoulou, V., Vega Fernández, T., Vöge, S., Weber, A., Zenetos, A., Hofstede, R. Ter, 2011. Ecosystem-based marine spatial management: Review of concepts, policies, tools, and critical issues. Ocean Coast. Manag. 54, 807–820. https://doi.org/10.1016/j.ocecoaman.2011.09.002

Lastras, G., Arzola, R.G., Masson, D.G., Wynn, R.B., Huvenne, V.A.I., H??hnerbach, V., Canals, M., 2009. Geomorphology and sedimentary features in the Central Portuguese submarine canyons, Western Iberian margin. Geomorphology 103, 310–329. https://doi.org/10.1016/j.geomorph.2008.06.013

Lazzari, N., Becerro, M.A., Sanabria-Fernandez, J.A., Martín-López, B., 2019a. Appendix A. Spatial characterization of coastal marine social-ecological systems: Insights for integrated management. Supplement for Methods section Table S1. Type and specific marine environmental variables used in this study with arguments for their sel. Environ. Sci. Policy 1–5.

Lazzari, N., Becerro, M.A., Sanabria-Fernandez, J.A., Martín-López, B., 2019b. Spatial characterization of coastal marine social-ecological systems: Insights for integrated management. Environ. Sci. Policy 92, 56–65. https://doi.org/10.1016/j.envsci.2018.11.003

Lê, S., Josse, J., Husson, F., 2008. FactoMineR: An R package for multivariate analysis. J. Stat. Softw. 25, 1–18. https://doi.org/10.18637/jss.v025.i01

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., Taylor, W.W., 2007. Complexity of coupled human and natural systems. Science (80-.). 317, 1513–1516. https://doi.org/10.1126/science.1144004

Martín-López, B., Palomo, I., García-Llorente, M., Iniesta-Arandia, I., Castro, A.J., García Del Amo, D., Gómez-Baggethun, E., Montes, C., 2017. Delineating boundaries of social-ecological systems for landscape planning: A comprehensive spatial approach. Land use policy 66, 90–104. https://doi.org/10.1016/j.landusepol.2017.04.040

Mateus, A., Costa, D., Martins, D.R., Rodrigues, H., Oliveira, H., Ferreira, R., 2019. A Economia do Mar em Portugal. EY -AM&A.

Mee, L., Cooper, P., Kannen, A., Gilbert, A.J., O'Higgins, T., 2015. Sustaining Europe's seas as coupled social-ecological systems. Ecol. Soc. 20. https://doi.org/10.5751/ES-07143-200101

Moita, M.T., 1993. Spatial variability of Phytoplankton communities in the upwelling region of Portugal. Int. Counc. Explor. Sea L 64, 20.

Noble, M.M., Harasti, D., Pittock, J., Doran, B., 2019. Linking the social to the ecological using GIS methods in marine spatial planning and management to support resilience: A review. Mar. Policy 108, 103657. https://doi.org/10.1016/j.marpol.2019.103657

Ostrom, E., 2009. A general framework for analyzing sustainability of Social-ecological systems. Science (80-.). 325. https://doi.org/10.5055/jem.2013.0130

PORDATA, 2019. PORDATA Base de dados de Portugal contemporâneo [WWW Document]. URL https://www.pordata.pt/ (accessed 12.4.19).

R Development Core Team, R., 2011. R: A Language and Environment for Statistical Computing. R

Found. Stat. Comput., R Foundation for Statistical Computing. https://doi.org/10.1007/978-3-540-74686-7

Relvas, P., Barton, E.D., Dubert, J., Oliveira, P.B., Peliz, Á., da Silva, J.C.B., Santos, A.M.P., 2007. Physical oceanography of the western Iberia ecosystem: Latest views and challenges. Prog. Oceanogr. 74, 149–173. https://doi.org/10.1016/j.pocean.2007.04.021

Resolution of the Council of Ministers n.º 203-A/2019, 2019. Resolution of the Council of Ministers n.º 203-A/2019. Resolução do Conselho de Ministros de 30 de Dezembro. Diário da República, 1ª série nº 250.

Saraiva, S., Pina, P., Martins, F., Santos, M., Braunschweig, F., Neves, R., 2007. Modelling the influence of nutrient loads on Portuguese estuaries. Hydrobiologia 587, 5–18. https://doi.org/10.1007/s10750-007-0675-9

Turismo de Portugal, 2017. Estratégia Turismo 2027: Liderar o Turismo do Futuro, 66.

7. GENERAL DISCUSSION

7.1. Key findings

The overarching contribution of this thesis is the development of methodological approaches to support Maritime Spatial Planning (MSP) process in a time and resource data limited setting. To do so, I created a set of data informed tools for the sea to support the MSP process using the Portuguese Mainland Subdivision as a case study. Managers in several contexts within MSP can use these tools on different phases of the process, but mostly for Analysis for planning (within the tasks of gathering data and definition of current conditions, identifying issues, constraints and future conditions) and in the Plan revision phase (when evaluating alternative management measures, refinement of goals and objectives). The tools were developed with the focus on Ecosystem-Based Management approach (EMB) coupled with MSP and have an adaptive management nature. They encompass the possibility of including additional or different data to improve its results and be easily adaptable to future management decisions. Besides, the tools are easy to use, accessible and easily understood by planners and decision-makers. Most of the outputs were produced in the forms of maps showing most of the times combined information, and in some cases, showing different scenarios for selection of best available options.

Chapters 3, 4 and 5 explored how to improve the integration of human activities and uses, its distribution and impacts with ecological values. Chapter 6 focused on social-ecological issues in the land-sea interface. Main findings of this thesis are summarized in the following paragraphs.

Chapter 3 developed a Cumulative Impacts Model (CIM) for informing patterns of impacts in particular areas and for providing inputs on the carrying capacity of the ecosystems. CIM shows that the continental Portuguese maritime space is experiencing high cumulative impacts, particularly near the coasts, caused by current activities and use. The results also show that impacts are spreading from the coast up to the Contiguous Zone and higher scores appeared in Transitional and Coastal Waters in the north (Viana do Castelo/Figueira da Foz), centre (Peniche/Setúbal) and south (Lagos/Faro). Most interestingly, in some areas with higher ranks, statutes of nature conservation are already in place. This study developed before enacting MSP Law (Law 17/2014) and when the first Portuguese approach to MSP - Plano de Ordenamento do Espaço Marítimo (POEM) exercise was already published, used POEMs' proposal as MSP plan. According to the distribution of activities/uses in POEM, it showed that potential activities could still occur in high impacted places.

Finally, it showed that when used in combination with other instruments, such as MSP and Strategic Environmental Assessment (SEA), it can provide valuable insights on specific management measures for potential activities and uses. It can also inform where reductions in anthropogenic pressures should be an explicit goal, and it is a flexible tool that can be used for managing and monitoring the measures already in place.

Chapter 4 approached the assessment of the activities/uses that may significantly affect the Natura 2000 marine network during the MSP implementation. It used a real case study, the development of SEA of the MSP Situation Plan - Plano de Situação do Ordenamento do Espaço Marítimo (PSOEM) of the Mainland Subdivision. The methodological approach developed in this study aimed to overcome knowledge, data and time constraints. This assessment foresees significant effects from future activities/uses to be placed in the Natura 2000 marine sites. It showed, however, that PSOEM good practices are prepared in most cases to deal with these impacts, as only a few needed additional mitigation measures. This work was a first assessment, part of an adaptive approach to MSP, strongly linked to monitoring, evaluation of the plan outcomes and future impacts assessment of particular projects. This study also highlighted that future planning on these areas must take into account not only the existing activities already producing adverse effects but also a cumulative detailed study of the activities to be placed in the vicinity of the protected areas, having in mind the study developed in chapter 3. It is essential to improve the knowledge of the natural values to be protected. The impact assessment shall consider not only its exposure, but also, for example, their state of conservation, and their sensitivity or recovery rate to specific impacts.

Finally, this work also showed as Natura 2000 network in Portuguese Mainland subdivision is taking the first steps in the marine realm, as the appointed areas for the protection of marine mammals indicate (ICNF, 2016). To accomplish this change, Natura 2000 information on threats must be adapted to the marine reality, as it is mostly regarding terrestrial activities and it is not coherent with the terminology used at MSFD, which is the standard at the European level. Also, the habitats classification used is too broad and needs to be harmonized with EUNIS habitats classification (EEA, 2014b), allowing to refine the assessment.

The integration of ecological meaningful information in the MSP process was the focus of **Chapter 5**. To provide a different perspective to planners and managers when developing management alternatives and for allocating activities or uses, this tool was developed to select the areas more prone to conservation that are also facing less anthropogenic impacts. The aim was not to select areas for nature conservation per se but to indicate the areas within the maritime space which, if allocated with activities would provoke less impact on nature conservation values.

In the study four main areas prone to conservation in Portuguese mainland subdivision, namely the areas of Figueira da Foz/Peniche, south Cabo Espichel/Sines, Cabo Sardão/Faro and Lagos/Faro. It shows as well, that systematic conservation planning is a valuable tool to support the MSP process. In this case, it was used to minimize the effects of anthropogenic pressures improving the connection between EBM and Blue Growth strategy.

The results obtained through this study brings new inputs to the conservation efforts in Portuguese marine waters, to the existing and proposed MPAs in PSOEM. Through the hot-spot analysis, it was possible to acknowledge that the locations that were consistently selected on all scenarios were in the vicinity or overlapping the proposed MPAs.

Chapter 6 was motivated by MSP Directive aims at improving social cohesion along with economic growth and sustainable development. It focused on the acknowledged need to develop innovative predictive modelling techniques to understand how social uses change over time (Noble et al., 2019) and how marine ecosystems may respond to potential direct and indirect disturbances. This meant understanding the human linkages to the ecosystem within adaptive management plans.

To achieve it, this chapter explored a new methodological approach spatially assessing social-ecological systems (SES) and their potential of informing management and planning. It displays comparative research on the contrasting ecological and societal conditions across the Portuguese coastal municipalities. Through the application of the method developed by Lazzari et al (2019b) were identified several Marine Socio-Ecological Categories (MSEC) showing different marine socio-ecological patterns along the Portuguese coast. This study allowed identifying specific factors either socioeconomic or ecological behind the similarities and differences within MSEC, essential to better understand the specificities of each region and improve design policy-making decisions and management measures.

Despite some limitations and shortcomings on the information applied, this exercise showed that the spatial information extracted from the categories was valuable to understand how different conditions along the territory may be dealt with at regional and national level. Mapping socio-ecological systems aid the sustainable economic development, but further research is needed to improve the categorization. Nevertheless, such studies make clear that there is no land-sea divide as these complex systems are closely interlinked. Therefore, the connections between both systems as well as their socioeconomic impacts should be reflected in the existent policy framework.

After the work performed through chapters 3 to 6, I performed a compilation of the most relevant spatial outputs from each chapter. Each one was presenting a different tool that spatially explored the different dynamics, showing different spatial patterns, according to the topic of study. Figure 7.1 shows the compilation of CIM, Priority for Conservation and a new metric, named Sea Use Intensity, that was the summing up of activities and uses, as presented in PSOEM in the same grid cell format used throughout this thesis (5x5 km).

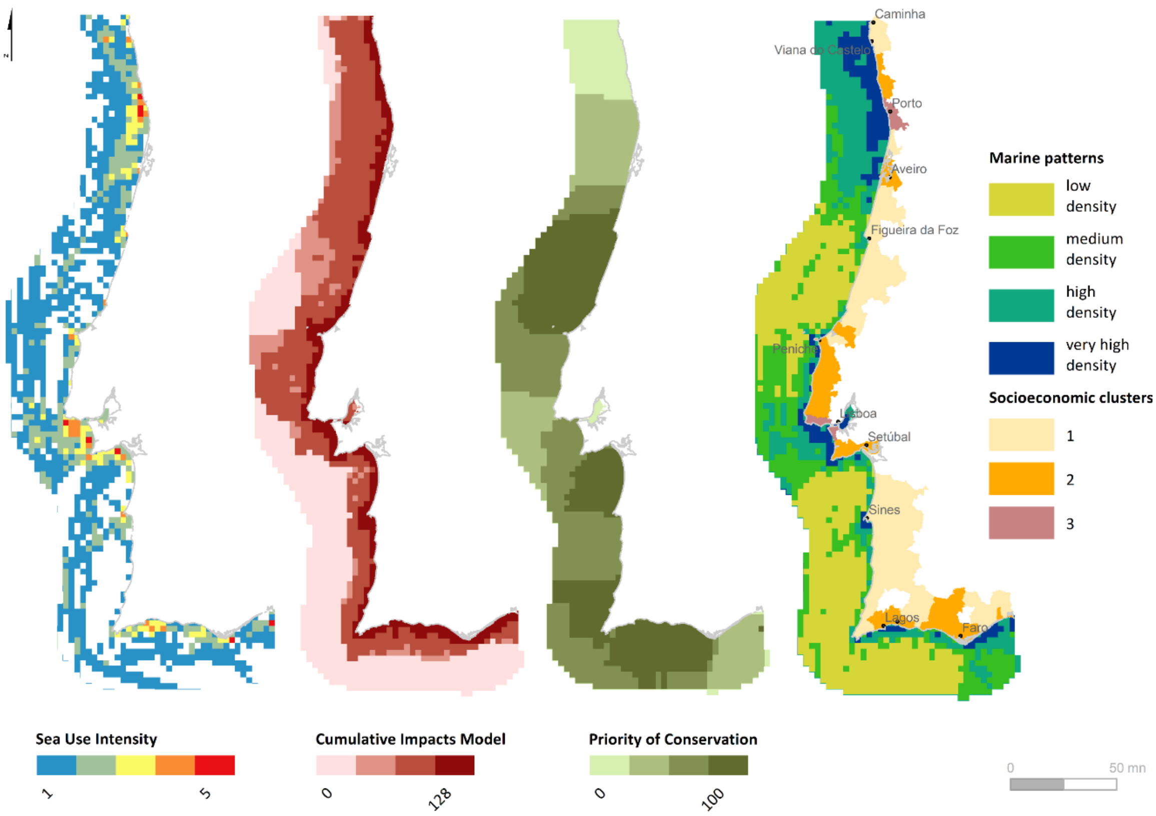


Figure 7.1. Compilation of the main spatial outputs of chapters 3 to 6, and its resulting Marine Patterns (terminology of the typologies used followed the EU ESPON approach to the Sea, developed at the ESATDOR project (Espon, 2013). See Supplementary Material E for more information.

This figure shows a summary of the research chapters main outputs offered in this thesis. Patterns were divided into very high to low density. Very high density depicts a level of use of the ocean space by activities, their subsequent impacts coupled with low priority for conservation. Low density areas depict the contrary with areas of low intensity of uses and impacts with the higher priority of conservation status. Finally, the compilation map shows the socioeconomic cluster inland developed within chapter 6.

Coastal areas are considered as very high-density areas, with several uses and activities occurring, most of it around big city hubs as Lisbon and Porto. The region at the north of Figueira da Foz until the border is medium to high density territory, showing high levels of cumulative impacts and low priorities of conservation. This region is a place for many activities, with relevant ports as sea hubs (Mateus et al., 2019) and they also **have** the most urban and industrial territory inland, as the Socioeconomic clusters have shown. Besides, the region around Lisbon, expanding from Peniche to Setubal is medium to high density, showing this trend of higher development and sea use intensity in the region, coupled with the Socioeconomic cluster 2 and 3 with corresponding to the more developed municipalities. The marine region between Figueira da Foz and Peniche is of low density, as well as the region south of Setubal and the west part of Algarve (with exceptions around the port of Sines and Lagos, important ports for transportation and fisheries and tourism respectively). This sums up a trend explored already in chapters 3, 5 and 6 showing these areas have good potential for nature conservation and sustainable tourism activities. This could also improve the low development of the municipalities inland that are near this territory, as the Socioeconomic cluster 1 points out.

Outputs of this analysis are in line with the previously mentioned in each chapter, the mapping of marine patterns and dynamics improved the definition of the spatial scales of analysis. This shows that different spatial categories exist in the Mainland Subdivision on a macro-regional level. It was possible to split the sea into a lower intensity use to higher intensity, clearly showing the existence of regional hubs around very high density marine pattern. As shown in this thesis the development of different marine spatial patterns relates to population patterns inland and is also reflected in economic development in coastal areas and may allow to the easier establishment and connection between the land-sea interface as well.

7.2. Fields for future research

The development of the tools to support the decision-making process in MSP is only in its beginnings. The methodological approaches developed in this thesis show the scientific developments in the field, but research gaps remain. The following topics are suggested as future work for research. Although identified within the development of the tools presented, they are valuable within the overall development of DSTs to support MSP research and practice:

- Improve the data collection methods available to characterize activities/uses and also habitats and species, its distribution and overall condition. A harmonization between Habitats Directive framework and EUNIS would be of enormous advantage when studying threats and impacts.

- Improve Cumulative Impacts methods to associate future scenarios, introduce climate change and become more dynamic and easier to use.
- SES methodological approach should be improved with the inclusion of more data, municipalities and more years available for the study;
- The approach presented in this thesis could be extended to produce a maritime region typology encompassing both land and sea, including sea use economic impacts inland and also offshore;
- The use of stakeholders and expert judgment within the development of the tools would be a major benefit for the overall improvement of the tools;

Considering the newly implemented PSOEM, monitoring, assessment and evaluation will be key to inform scientist and managers about the process performance, to support an adaptive management approach to MSP. The tools presented in this thesis can be of value on this part of the process in the years to come to provide MSP with relevant information to support an EBM approach to the sea management of ocean uses.

References

Bidstrup, M., Kørnøv, L., Partidário, M.R., 2016. Cumulative effects in strategic environmental assessment: The influence of plan boundaries. Environ. Impact Assess. Rev. 57, 151–158. https://doi.org/10.1016/j.eiar.2015.12.003

Douvere, F., Ehler, C.N., 2011. The importance of monitoring and evaluation in adaptive maritime spatial planning. J. Coast. Conserv. 15, 305–311. https://doi.org/10.1007/s11852-010-0100-9

EEA, 2014. EUNIS habitat classification 2007 - Revised descriptions 2012. http://eunis.eea.europa.eu/ (acessed 13.03.2015).

Espon, 2013. European Seas and Territorial Development , Opportunities and Risks Governance Case Studies : Mediterranean Sea. ESaTDOR 45.

ICNF, 2016. Processo de extensão da Diretiva Habitats ao meio marinho: Prposta técnica de Sítios de Importância Comunitária a designar em Portugal continental.

Lazzari, N., Becerro, M.A., Sanabria-Fernandez, J.A., Martín-López, B., 2019. Spatial characterization of coastal marine social-ecological systems: Insights for integrated management. Environ. Sci. Policy 92, 56–65. https://doi.org/10.1016/j.envsci.2018.11.003

Mateus, A., Costa, D., Martins, D.R., Rodrigues, H., Oliveira, H., Ferreira, R., 2019. A Economia do Mar em Portugal. EY -AM&A.

Noble, M.M., Harasti, D., Pittock, J., Doran, B., 2019. Linking the social to the ecological using GIS methods in marine spatial planning and management to support resilience: A review. Mar. Policy 108, 103657. https://doi.org/10.1016/j.marpol.2019.103657

Tamis, J.E., de Vries, P., Jongbloed, R.H., Lagerveld, S., Jak, R.G., Karman, C.C., Van der Wal, J.T., Slijkerman, D.M., Klok, C., 2016. Toward a harmonized approach for environmental assessment of human activities in the marine environment. Integr. Environ. Assess. Manag. 12, 632–642. https://doi.org/10.1002/ieam.1736

8. SUPPLEMENTARY MATERIAL

Supplementary Material A

Table 1. Data used for calculation of CIM. The activities and uses were grouped into 7 themes: Coastal infrastructures, Shipping, Benthic Structures, Offshore Energies, Fisheries, Tourism and Pollutants input.(Legend: Short (S=200m), Short-Medium (SM =500-1000m), Medium (M =2km), Medium Long (ML =10 k), Long (L =30km), Very Long (VL > 30 km), Not Attributed (N/A))

	Activities/ uses	Pressure	Indicator	Source	Intensity	Buffer	Weighing values for ecosystem vulnerability adapted from Halpern et al. (2007)						
							Intertidal mud	Salt Marsh	Seagrass	Reef	Subtidal soft bottom	Soft Shelf	Hard Shelf
Coastal Infrastructures													
1	Harbours and Marinas	Physical damage Contamination by hazardous substances	Number of anchor places, 2015	POEM (INAG, 2012, 2011) National Statistics Institute (INE, 2015)	Log-normalized values between 0 e 1	ML	2.1	2.3	2.4	1.9	2.3	1.2	1.5
2	Defence works	Physical damage/loss	Presence/absence	National Water Resources Information System (SNIRH, 2015)	1 or 0	SM	2.1	2.3	2.4	1.9	2.3	1.2	1.5
Shipping													
3	Traffic at ports and marinas	Physical loss and disturbance Contamination by hazardous substances	Cargo movements (ton/year), 2007-2013	National Statistics Institute (INE, 2015)	Log-normalized values between 0 e 1	ML	1.9	1.4	1.9	1.4	0.3	1.7	0.9

4	Traffic Separation Schemes	Physical loss and disturbance Contamination by hazardous substances	Presence/absence	POEM (INAG, 2012, 2011)	1 or 0	N/A	1.9	1.4	1.9	1.4	0.3	1.7	0.9
5	Compulsory navigation area	Physical loss and disturbance Contamination by hazardous substances	Presence/absence	POEM (INAG, 2012, 2011)	1 or 0	N/A	1.9	1.4	1.9	1.4	0.3	1.7	0.9
Benthic structures													
6	Submarine cables	Physical damage and disturbance	Presence/absence	POEM (INAG, 2012, 2011)	1 or 0	SM	0.9	0.9	1.6	1.7	0.1	0.5	2.3
7	Anchorages	Physical damage	Presence/absence	POEM (INAG, 2012, 2011)	1 or 0	SM	0.9	0.9	1.6	1.7	0.1	0.5	2.3
Offshore Energies													
8	Renewable Energies	Physical damage and disturbance	Presence/absence	POEM (INAG, 2012, 2011)	1 or 0	N/A	0	0.7	0	0.7	0	1.2	1.1

9	Oil Prospection	Physical loss, disturbance Contamination by hazardous substances	Presence/absence	POEM (INAG, 2012, 2011)	1 or 0	SM	0	0.7	0	0.7	0	1.2	1.1
Fisheries													
10	Areas per type of fishing - Crustaceans	Physical damage Biological and Physical disturbance	Presence/absence	POEM (INAG, 2012, 2011)	0 and 1	N/A	1.4	1.0	0.2	2.7	2.1	3	3.1
11	Areas per type of fishing Trawling	Physical damage Biological disturbance	Presence/absence	POEM (INAG, 2012, 2011)	0 and 1	N/A	1.4	1.0	0.2	2.7	2.1	3	3.1
12	Areas per type of fishing- Purse Seine	Biological and Physical disturbance	Presence/absence	POEM (INAG, 2012, 2011)	0 and 1	N/A	0.0	0.5	0	2.6	0.0	1.1	2.8
13	Areas per type of fishing. Multi-gear	Physical damage Biological and Physical disturbance	Presence/absence	POEM (INAG, 2012, 2011)	0 and 1	N/A	1.4	1.0	0.2	2.7	2.1	3	3.1
Tourism													
14	Regatta sites	Physical damage and disturbance	Presence/absence	POEM (INAG, 2012, 2011)	0 and 1	ML	0	1.3	1.5	1.7	0.2	1.3	1.8

15	Surf spots	Physical disturbance /contamination by hazardous substances	Presence/absence	POEM (INAG, 2012, 2011)	0 and 1	S	0	1.3	1.5	1.7	0.2	1.3	1.8
Pollutant input													
16	Discharges	Contamination and Biological disturbance Nutrient and organic matter enrichment	Discharges combined with type of treatment ,2015	National Water Resources Information System (SNIRH, 2015)	Log-normalized values between 0 e 1	ML	2.1	1.5	1.9	2.1	2.6	2.3	1.6
17	Beach water quality	Contamination and Biological disturbance	Beach water quality categories in accordance with the Bathing Water Directive (2006/7/EC), 2014	National Water Resources Information System (SNIRH, 2015) European Bathing water quality in 2014 (EEA, 2015)	Log-normalized values between 0 e 1	S	2.1	1.5	1.9	2.1	2.6	2.3	1.6
18	Water quality	Contamination and Biological disturbance	Good ecological/chemical status in accordance with WFD, 2015	National Water Resources Information System (SNIRH, 2015)	Log-normalized values between 0 e 1	N/A	2.1	1.5	1.9	2.1	2.6	2.3	1.6

19	Dredging Deposition	Physical damage (abrasion seabed) Physical loss	Quantity of sand deposited in the sea (m^3/year), data from 1990 until 2010	POEM (INAG, 2012, 2011) Report on Coastal Zone Management (Santos et al., 2014)	Log-normalized values between 0 e 1	M	2.0	2.2	2.9	2.0	1.5	2.8	1.7
20	Marine litter	Contamination Physical Disturbance	Quantity of litter found in beaches (items found per event), data gathered between 2002 to 2014	Marine Litter Beach monitoring (OSPAR, 2016)	Log-normalized values between 0 e 1	ML	2.2	1.6	2.5	2.5	23	1.2	1.5
21	Population Density	Contamination	Number of inhabitants, 2006	Urban morphological zones (EEA, 2014a)	Log-normalized values between 0 e 1	M	2.9	2.8	3.3	2.5	2.4	1.8	3.8

Table 2. Ecosystems classification used in CIM

Ecosystems (Halpern, 2007)	Ecosystems according with Habitats directive and EUNIS classification
Reefs	1170 Reefs[1]
Intertidal mud	1140 Mudflats and sandflats not covered by seawater at low tide[1]
Seagrass	1140 Mudflats and sandflats not covered by seawater at low tide[1] 1210 Annual vegetation of drift lines[1]
Salt marsh	1310 Salicornia and other annuals colonizing mud and sand[1] 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae) [1] 1410 Mediterranean salt meadows (*Juncetalia maritimi*) [1] 1420 Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*) [1] 1430 Halo-nitrophilous scrubs (*Pegano-Salsoletea*) [1] 1510 Mediterranean salt steppes (*Limonietalia*) [1]
Subtidal soft bottom	1110 Sandbanks which are slightly covered by sea water all the time[1] 1140 Mudflats and sandflats not covered by seawater at low tide[1] 1210 Annual vegetation of drift lines[1]
Soft Shelf (30-200m)	Mud, Muddy Sand, Sand and Sandy mud substrate type in the circalittoral and deep circalittoral region[2]
Hard Shelf (30-200m)	Rock, coarse and mixed sediment substrate type in the circalittoral and deep circalittoral region[2]

[1]Habitats Directive code (EEC, 1992)

[2]EUNISHabitats. MESH Atlantic: Predicted broad-scale EUNIS habitats - Atlantic area. (EEA, 2014b)

References

EEA,2014a. Urban morphological zones 2006 Data and maps. Accessible at http://www.eea.europa.eu/data-and-maps/data/urban-morphological- zones-2006-1

EEA, 2014b. EUNIS habitat classification 2007 - Revised descriptions 2012. http://eunis.eea.europa.eu/ (acessed 13.03.2015).

EEA, 2015. European bathing water quality in 2014. European Environmental Agency, European Environment Agengy Reports. doi:10.2800/1804

EEC, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, published in the OJEC Nº L206/7

Halpern, B.S., Selkoe, K., Micheli, F., Kappel, C., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation Biology 21, 1301–1315. doi:10.1111/j.1523-1739.2007.00752.

INAG, 2012. POEM—Plano de Ordenamento do Espaço Marítimo, Volume 2 Tomo 1: Espacialização [in Portuguese].

INAG, 2011. POEM—Plano de Ordenamento do Espaço Marítimo, Volume 5 Tomo1: Estudos de Caracterização [in Portuguese].

INE, 2015. National Statistics Institute. Online at https://www.ine.pt (acessed 13.03.2015).

OSPAR, 2016. Beach Litter Database, Online at **http://www.mcsuk.org/ospar/** (accessed 07.12.2016)

Santos, F.D., Lopes, A.M., Moniz, G., Taborda, R., Ramos, L., 2014. Gestão da Zona Costeira O Desafio da Mudança: Relatório do Grupo de Trabalho do Litoral [in Portuguese].

SNIRH, 2015. National Water Resources Information System, Online at **http://snirh.pt/** (accessed 03.12.2015)

SUPPLEMENTARY MATERIAL B.1

SPATIAL DATA USED IN THE STUDY

Table 1. Spatial data used in the study

Data	Type	Source	Reference
Activities/Uses			
Aquaculture	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Dredging disposal	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Renewable energies	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Artificial reefs	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Structures disposal	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Tourism and recreation	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Multi-use offshore platforms	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Marine natural heritage	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Marine cultural heritage	Shapefile	DGRM	(“Plano de Situação – Ordenamento do Mar Português,” n.d.)
Natura 2000 information			

Natural values – habitats (1110 and 1170) for SCIs Maceda/Praia da Vieira, Ria de Aveiro and Costa Sudoeste	shapefile	EMODnet	(“EMODnet Seabed Habitats - Homepage,” n.d.)
Natural values – habitats (1110 and 1170) for SCIs Costa Sudoeste, Litoral Norte, Arrábida/Espichel, Peniche/Sta Cruz and Sintra/Cascais	shapefile	ICNF	(ICNF, 2018a)
Natural values – *Tursiops truncatus and Phocoena Phocoena*	PDF	ICNF	(ICNF, 2018a, 2018b)
Natura 2000 SICs and SPAs	Shapefile	ICNF	(“Natura 2000 — ICNF,” n.d.)

PRESSURES AND IMPACTS IN THE MARINE REALM

Several sources from literature were used to compile the following tables. Below we enumerate the different references used for Tables 1-15.

- Human uses, pressures and impacts in the eastern North Sea. Andersen et al. (2013). (Andersen and Stock, 2013);
- Options for Delivering Ecosystem-based Marine Management. Koss et al. (2011). (Koss et al., 2011);
- UK Marine Pressures-Activities Database. Robson et al. (2018) (Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J. & Matear, 2018);
- Marine Life Information Network. Plymouth: Marine Biological Association of the United Kingdom. MarLIN, 2016 ("MarLIN - The Marine Life Information Network - Home," n.d.);
- Relatório de Avaliação do Programa Medidas DQEM. MAM, 2014, (MAM, 2014);
- Relatório de Base do Plano de Gestão da área marinha de cinco SIC. ICNF, 2018 (ICNF, 2018a);
- Plano Setorial da Rede Natura 2000 ICNF,2008 (ICNF, 2008)
- Volumes do Plano de Situação. DGRM, 2018 (DGRM, 2019)
- Estratégia Marinha para a Subdivisão Continente. MAMAOT, 2012 (MAMAOT, 2012)
- OSPAR Guidance on Environmental Considerations for Offshore Wind Farm Development OSPAR, 2008 (OSPAR, 2008)
- Assessment of construction or placement of artificial reefs. OSPAR, 2009 (OSPAR, 2009a)
- Assessment of impacts of offshore oil and gas activities in the North-East Atlantic. OSPAR, 2009 (OSPAR, 2009b)
- Trend analysis of maritime human activities and their collective impact on the OSPAR maritime area. OSPAR, 2009 (OSPAR Commission, 2009)
- Guidelines on Best Environmental Practice (BEP) in Cable Laying and Operation. OSPAR, 2012 (OSPAR, 2012)

Aquaculture

Table 2. Description of the pressures and potential impacts on the marine environment associated with aquaculture

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Construction:** - Physical loss	**Natural habitats:** - Local loss of habitat due to the placement of anchoring structures in the substrate. **Biodiversity (flora and fauna):** - Changes in benthic communities.
	Operation: - Physical disturbance to seabed - Physical loss	**Natural habitats:** - Local loss or disturbance of habitat due to the anchoring of vessels of exploration and maintenance work. **Biodiversity (flora and fauna):** - Changes of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Construction:** - Input of anthropogenic sound (impulsive, continuous)	**Biodiversity (flora and fauna):** - Disturbance of behaviour of marine fauna through noise, especially marine mammals.
	Operation (Finfish aquaculture): - Input of nutrients – diffuse sources, point sources, atmospheric deposition. - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events. - Input of organic matter – diffuse sources and point sources - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous)	**Natural habitats:** - Habitat disturbance, due to deposition of solid waste, organic matter and nutrients. **Biodiversity (flora and fauna):** - Disturbance or changes in the food web due to the introduction of chemical substances used in production control, improvement of anabolic efficiency, survival rate and disease and pathogens control. - Disturbance of behaviour of marine fauna through noise, especially marine mammals.
BIOLOGICAL	**Operation (Finfish and bivalve aquaculture):** - Input or spread of non-indigenous species. - Input of microbial pathogens. - Input of genetically modified species and translocation of native species. - Loss of, or change to, natural biological communities due to cultivation of animal or plant species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Biodiversity (flora and fauna):** - Increase of diseases. - Degradation of the genetic pool. - Disturbance or changes in the food web. - Reduction of reproductive success and survival rate.

Marine biotechnology

Table 3. Description of the pressures and impacts associated with marine biotechnology

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical disturbance to seabed - Physical loss	**Natural habitats:** - Physical disturbance to seabed through extraction procedures. - Local disturbance of benthic habitats. **Biodiversity (flora and fauna):** - Reduction of food availability. - Disturbance of marine organisms. - Disturbance or changes in the food web
SUBSTANCES, LITTER AND ENERGY	**Operation:** - Input of anthropogenic sound (impulsive, continuous).	**Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals.
BIOLOGICAL	**Operation:** - Disturbance of species (e.g. where they breed, rest and feed) due to human presence. - Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	**Biodiversity (flora and fauna):** - Loss and disturbance of marine organisms. - Reduction of food availability. - Disturbance or changes in the food web.

Deep-sea mining

Table 4. Description of the pressures and impacts associated with deep-sea mining

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Survey and research:** - Physical disturbance to seabed	**Natural habitats:** - Physical disturbance to seabed through survey and research procedures. - Local disturbance of benthic habitats. **Biodiversity (flora and fauna):** - Disturbance of benthic communities.

Theme	Pressure description	Potential impacts on natural values
	Operation: - Physical loss - Changes to hydrological conditions	**Natural habitats:** - Loss, fragmentation or disturbance of benthic habitat, due to modification of substrate, seabed morphology and mineral extraction. - Loss, fragmentation or disturbance of benthic habitat, due to particles deposition and compaction of sediment, due to extraction procedures. - Changes to hydrologic conditions. - Degradation of water quality through turbidity increase and consequent disturbance of pelagic habitat, due to resuspension. **Biodiversity (flora and fauna):** - Changes of benthic communities. - Changes in the food web due to the reduction of food availability. - Extraction of, or mortality/injury to, wild species and/or benthic communities, due to substrate removal.
SUBSTANCES, LITTER AND ENERGY	**Survey and research:** - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Decrease of water quality, due to introduction chemical substances needed in the research procedure and vessel operations. - Disturbance of habitats, due to introduction of substances or waste. **Biodiversity (flora and fauna):** - Disturbance of benthic and pelagic habitats, including marine birds. - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals.
	Operation: - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Decrease of water quality, due to introduction chemical substances needed in the research procedure and vessel operations. - Disturbance of habitats, due to introduction of substances or waste. **Biodiversity (flora and fauna):** - Disturbance of benthic and pelagic habitats, including marine birds. - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals. - Bioaccumulation in marine organisms and consequent adverse effects in reproductive success and survival rate. - Changes in the food web.

Theme	Pressure description	Potential impacts on natural values
BIOLOGICAL	**Survey and research:** - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Introduction of diseases in marine organisms and reduction of organism resilience to pathologies. - Reduction of reproductive success and survival rate.
	Operation: - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Introduction of diseases in marine organisms and reduction of organism resilience to pathologies. - Reduction of reproductive success and survival rate. - Changes in the food web.

Non-metallic mining

Table 5. Description of the pressures and impacts associated with non-metallic mining

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Survey and research:** - Physical disturbance to seabed.	**Natural habitats:** - Physical disturbance to seabed through survey and research procedures. - Disturbance of benthic and pelagic habitats due to the resuspension and deposition of particles due to research procedures (sampling). - Decrease of water quality (increase of turbidity and resuspension of pollutants contained in the sediments). **Biodiversity (flora and fauna):** - Disturbance of benthic communities.

Theme	Pressure description	Potential impacts on natural values
	Operation: - Physical loss. - Changes to hydrological conditions.	**Natural habitats:** - Loss, fragmentation or disturbance of benthic habitats due to the substrate change, seabed morphology and mineral extraction. - Loss, fragmentation or disturbance of benthic habitats due to the particle precipitation and sediment compaction due to extraction procedures. - Coastal erosion and/or silting due to changes in the sediment dynamics, bathymetry and water flow. - Decrease of water quality (increase of turbidity and resuspension of pollutants contained in the sediments) and consequent pelagic habitats disturbance. **Biodiversity (flora and fauna):** - Mortality/injury of organisms and/or benthic communities sue to substrate removal. - Changes in benthic communities. - Changes in the food web due to the decrease of food availability.
SUBSTANCES, LITTER AND ENERGY	**Survey and research:** - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Local loss of habitats. **Biodiversity (flora and fauna):** - Disturbance of benthic and pelagic communities. - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals.
	Operation: - Input of anthropogenic sound (impulsive, continuous).	**Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals due to extraction procedures, vessel operations and machinery.
BIOLOGICAL	**Survey and research:** - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Introduction of diseases in marine organisms and reduction of organism resilience to pathologies. - Reduction of reproductive success and survival rate.

Theme	Pressure description	Potential impacts on natural values
	Operation: - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Introduction of diseases in marine organisms and reduction of organism resilience to pathologies. - Reduction of reproductive success and survival rate. - Changes in the food web.

Exploration of fossil fuels

Table 6. Description of the pressures and impacts associated with the exploration of fossil fuels

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Survey and research:** - Physical disturbance to seabed	**Natural habitats:** - Physical disturbance to seabed through survey and research procedures. - Disturbance of benthic and pelagic habitats due to the resuspension and deposition of particles due to research procedures (sampling). **Biodiversity (flora and fauna):** - Disturbance of benthic communities.
	Operation: - Physical loss	**Natural habitats:** - Local loss of habitat due to installation of infrastructures.
SUBSTANCES, LITTER AND ENERGY	**Survey and research:** - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Decrease of water quality, due to introduction chemical substances needed in the research procedure and vessel operations. - Disturbance of habitats, due to introduction of substances or waste. **Biodiversity (flora and fauna):** - Disturbance of benthic, pelagic and marine birds communities due to noise and vibrations of seismic survey, specially marine mammals, leading to behaviour changes.

Theme	Pressure description	Potential impacts on natural values
	Operation: - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Decrease of water quality, due to introduction chemical substances needed in the extraction procedure and vessel operations. - Disturbance of habitats, due to introduction of substances or waste used in the extraction procedures. - Surface, water column and seabed contamination due to accidental oil spills. **Biodiversity (flora and fauna):** - Disturbance of benthic, pelagic and marine birds communities - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals. - Contamination of benthic, marine birds and marine mammals due to accidental oil spills.
BIOLOGICAL	**Survey and research:** - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Reduction of reproductive success and survival rate.
	Operation: - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Reduction of reproductive success and survival rate.

Renewable energies

Table 7. Description of the pressures and impacts associated with renewable energies (wind and waves)

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Construction:** - Physical loss.	**Natural habitats:** - Local loss of habitat due to the placement of anchoring structures in the substrate. **Biodiversity (flora and fauna):** - Changes in benthic communities.

Theme	Pressure description	Potential impacts on natural values
	Operation: - Physical disturbance to seabed. - Physical loss. - Changes to hydrological conditions.	**Natural habitats:** - Local loss or disturbance of the habitat, due to the dragging of infrastructure cables and anchors of vessels used in maintenance operations. - Decrease of water quality. - Changes in hydrological conditions due to changes of local currents regimes in the surroundings of infrastructures. - Coastal erosion and silting (wave energy). **Biodiversity (flora and fauna):** - Changes of benthic communities.
SUBSTANCES, LITTER AND	**Construction and exploration:** - Input of anthropogenic sound (impulsive, continuous). •	**Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through, especially marine mammals.
BIOLOGICAL	**Operation:** - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Biodiversity (flora and fauna):** - Mortality/injury of marine birds (especially migratory species) due to collision with wind turbines.
POSITIVE	- Installation of infrastructures with fishing activities restrains.	- Increase of biomass and biodiversity due to the artificial reef effect.

Cables, ducts and marine outfalls

Table 8. Description of the pressures and impacts associated with cables, ducts and marine outfalls

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation :** - Physical disturbance to seabed. - Physical loss. - Changes to hydrological conditions.	**Natural habitats:** - Local loss or disturbance of habitats. - Fragmentation of habitats. - Topographic change. - Local changes in erosion and silting rates. - Decrease of water quality (increase of turbidity). **Biodiversity (flora and fauna):** - Changes in benthic, epibenthic and infauna communities.

SUBSTANCES, LITTER AND ENERGY	**Construction:** - Input of anthropogenic sound (impulsive, continuous).	**Biodiversity (flora and fauna):** Disturbance of marine fauna behaviour through noise, especially marine mammals.
	Operation (marine outfalls): - Input of nutrients – diffuse sources, point sources, atmospheric deposition. - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) - Diffuse or circumstantial sources, atmospheric deposition, accidental episodes. - Input of organic matter – diffuse sources and point sources - Input of litter (solid waste matter, including micro-sized litter). Input of water - circumstantial sources (e.g. brine) - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Disturbance or change of habitats due to deposition of solid waste, organic matter, nutrients, increase of temperature and salinity change. - Decrease of water quality due to input of chemicals, nutrients, organic matter and micro-particles due to the discharge of effluents, despite being regulated to emission limit values. **Biodiversity (flora and fauna):** - Disturbance or change of food web due to input of chemicals, nutrients, organic matter and micro-particles due to the discharge of effluents, despite being regulated to emission limit values. - Disturbance or change of food web due to increase of temperature and salinity changes. - Algal blooms. - Ingestion of litter and entanglement by marine organisms (fish, turtles, marine mammals and birds). - Toxic bioaccumulation. - Eutrophication. - Adverse effects in reproductive success and survival rate.
	Operation (cables and ducts): - Input of other forms of energy (including electromagnetic fields, light and heat).	**Biodiversity (flora and fauna):** - Changes of behaviour and migration patterns of sensitive species (e.g. sharks and rays) due to input of electromagnetic fields.
BIOLOGICAL	**Operation (marine outfalls)**: - Input of microbial pathogens	**Biodiversity (flora and fauna):** - Increase of pathologies due to the discharge of effluents, despite being regulated to emission limit values.

Multi-use offshore platforms

Table 9. Description of the pressures and impacts associated with multi-use offshore platforms

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Construction:** - Physical loss.	**Natural habitats:** - Local loss of habitat due to the placement of anchoring structures in the substrate.

Theme	Pressure description	Potential impacts on natural values
		Biodiversity (flora and fauna): - Changes in benthic communities.
	Operation: - Physical disturbance to seabed. - Physical loss. - Changes to hydrological conditions.	**Natural habitats:** - Local loss or disturbance of the habitat, due to the dragging of infrastructure cables and anchors of vessels used in maintenance operations. - Decrease of water quality. - Changes in hydrological conditions due to changes of local currents regimes in the surroundings of infrastructures. - Coastal erosion and silting if located near the shore. **Biodiversity (flora and fauna):** - Changes in benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Construction:** - Input of anthropogenic sound (impulsive, continuous).	**Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise, especially marine mammals.
	Operation: - Input of anthropogenic sound (impulsive, continuous).	
BIOLOGICAL	**Operation:** - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Introduction of diseases in marine organisms and reduction of organism resilience to pathologies. - Mortality/injury of marine birds (especially migratory species) due to collision with wind turbines
POSITIVE	- Installation of infrastructures, allowing shelter and settlement of marine species.	- Increase of biomass and biodiversity. •

Scientific research

Table 10. Description of the pressures and impacts associated with scientific research

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical disturbance to seabed.	**Natural habitats:** - Physical disturbance of the seabed due to research procedures and oceanographic vessels anchorage. - Local disturbance of benthic habitats. **Biodiversity (flora and fauna):** - Disturbance of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Operation:** - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise and vibrations, especially marine mammals.
BIOLOGICAL	**Operation:** - Disturbance of species (e.g. where they breed, rest and feed) due to human presence. - Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	**Biodiversity (flora and fauna):** - Disturbance of marine fauna. - Local loss of marine organisms.

Tourism and recreation

Table 11. Description of the pressures and impacts associated with tourism and recreation

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical disturbance to seabed. - Physical loss.	**Natural habitats:** - Local disturbance of habitats due to anchorage and mooring of recreational crafts. - Local loss of habitat due to the placement of anchoring structures in the substrate. **Biodiversity (flora and fauna):** - Disturbance of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Operation:** - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous).	**Natural habitats:** - Accumulation of litter in coastal areas. - Decrease of water quality. **Biodiversity (flora and fauna):** - Disturbance of marine fauna due to the noise of recreational activities and motorized water sports. - Ingestion of litter and entanglement by marine organisms (fish, turtles, marine mammals and birds).

Theme	Pressure description	Potential impacts on natural values
BIOLOGICAL	**Operation:** - Input or spread of non-indigenous species. - Disturbance of species (e.g. where they breed, rest and feed) due to human presence. - Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities) •	**Natural habitats:** - Disturbance of habitats due to the introduction or dispersion of non-indigenous species fixed the vessel structure. **Biodiversity (flora and fauna):** - Reduction of reproductive success and survival rate. - Disturbance of marine fauna. - Decrease of marine organisms (e.g. fishes and cephalopods).

Marine cultural heritage

Table 12. Description of the pressures and impacts associated with marine cultural heritage

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical disturbance to seabed.	**Natural habitats:** - Local disturbance of habitats due to anchorage and mooring of vessels. - Local disturbance of benthic habitats. **Biodiversity (flora and fauna):** - Disturbance of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Operation:** - Input of anthropogenic sound (impulsive, continuous). - Input of litter (solid waste matter, including micro-sized litter). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Accumulation of litter in coastal areas. - Decrease of water quality. **Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise, especially marine mammals. - Disturbance of benthic and pelagic communities. - Ingestion of litter and entanglement by marine organisms (fish, turtles, marine mammals and birds).
BIOLOGICAL	**Operation:** - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Biodiversity (flora and fauna):** - Disturbance of benthic and pelagic communities

Dredging disposal

Table 13. Description of the pressures and impacts associated with dredging disposal

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical disturbance to seabed. - Physical loss. - Changes to hydrological conditions.	**Natural habitats:** - Local loss or disturbance of the habitat. - Fragmentation of habitats. - Topographic change. - Decrease of water quality (increase of turbidity and resuspension of pollutants contained in the dredge material) **Biodiversity (flora and fauna):** - Local loss of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Operation:** - Input of nutrients – diffuse sources, point sources, atmospheric deposition. - Input of organic matter – diffuse sources and point sources - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events - Input of anthropogenic sound (impulsive, continuous).	**Natural habitats:** - Decrease of water quality due to input of contaminants, despite regulation of limit values. - Increase of nutrients and organic matter, although in low concentrations. **Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise, especially marine mammals. - Increase of eutrophication. - Development of algal blooms.
POSITIVE	- Introduction of sediments in the littoral drift.	- Mitigation of coastal erosion.

Artificial reefs and structures disposal

Table 14. Description of the pressures and impacts associated with artificial reeds and structures disposal

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical loss - Changes to hydrological conditions	**Natural habitats:** - Local loss of habitat. - Topographic change. - Local change of currents regime (velocity and direction) and waves in the surrounding of the infrastructures. **Biodiversity (flora and fauna):** - Changes in benthic communities.

Theme	Pressure description	Potential impacts on natural values
SUBSTANCES, LITTER AND ENERGY	**Construction (sinking with the use of explosives):** - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events. - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Habitats disturbance **Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise, especially marine mammals.
POSITIVE	- Installation of infrastructures, allowing shelter and settlement of marine species.	**Natural habitats:** - Creation of new habitats - Increase of water quality. **Biodiversity (flora and fauna):** - Increase of biomass and biodiversity. - Restoration of threatened biologic communities.

Geological storage of carbon

Table 15. Description of the pressures and impacts associated with geological storage of carbon

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Construction:** - Physical disturbance to seabed. - Physical loss. - Changes to hydrological conditions.	**Natural habitats:** - Local loss, fragmentation or disturbance of habitats due the pipeline installation and anchoring of vessels. - Topographic change and changes of erosion and silting rates. - Decrease of water quality (turbidity) due to the installation of pipelines resulting in sediment resuspension. **Biodiversity (flora and fauna):** - Change of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Construction:** - Input of anthropogenic sound (impulsive, continuous).	**Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise, especially marine mammals.
	Operation : - Input of nutrients – diffuse sources, point sources, atmospheric deposition. - Input of other substances (e.g. synthetic, non-synthetic compounds, radionuclides) - Diffuse or circumstantial sources, atmospheric deposition, accidental episodes. - Input of water - point sources (e.g. brine)	**Natural habitats:** - Decrease of water quality due to CO2 leakage – ocean acidification. - Disturbance or change of habitats due to CO2 leakage. - Salinity changes. **Biodiversity (flora and fauna):** - Disturbance or changes in the food web due to CO2 leakage and salinity change. - Development of algal blooms. - Increase of eutrophication.

		- Descaling of bivalves, echinoderms, calcareous plankton and deep-sea corals, among others

Marine natural heritage

Table 16. Description of the pressures and impacts associated with marine natural heritage

Theme	Pressure description	Potential impacts on natural values
PHYSICAL	**Operation:** - Physical disturbance to seabed. - Physical loss.	**Natural habitats:** - Local disturbance of habitats due to anchorage and mooring of recreational crafts. - Local loss of habitat due to the placement of anchoring structures in the substrate. **Biodiversity (flora and fauna):** - Disturbance of benthic communities.
SUBSTANCES, LITTER AND ENERGY	**Operation:** - Input of litter (solid waste matter, including micro-sized litter). - Input of anthropogenic sound (impulsive, continuous). - Input of other forms of energy (including electromagnetic fields, light and heat).	**Natural habitats:** - Accumulation of litter in coastal areas. - Decrease of water quality. **Biodiversity (flora and fauna):** - Disturbance of marine fauna behaviour through noise, especially marine mammals. - Disturbance of benthic and pelagic communities. - Ingestion of litter and entanglement by marine organisms (fish, turtles, marine mammals and birds).
BIOLOGICAL	**Operation:** - Disturbance of species (e.g. where they breed, rest and feed) due to human presence.	**Biodiversity (flora and fauna):** - Disturbance of marine fauna.

PRESSURES AND INFLUENCE DISTANCE

Table 17. Pressures and their influence distance for each activity (sources (a) Ban *et al.*, 2010 (Ban et al., 2010) (b) Andersen *et al.*, 2013 (Andersen and Stock, 2013) (c) OSPAR Commission, 2009 (OSPAR Commission, 2009) (d) PSOEM – Volume III, 2019 (DGRM, 2019b); (e) PSOEM – Volume IV, 2019. (DGRM, 2019a))

Pressures		**Influence distance**	**Aquaculture**	**Dredging disposal**	**Renewable energies**	**Artificial reefs & structures disposal**	**Tourism and recreation**	**Offshore platforms**	**Marine natural heritage**	**Marine cultural heritage**	**Source**
Physical	Physical disturbance to seabed (temporary or reversible)	1km		x							(b,c)
		local	x		x		x	x	x	x	(b)
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)	1km		x							(c)
		local	x		x	x	x	x	x		(b)
	Changes to hydrological conditions	1km		x	x	x		x			adapted from (b)
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition	1km	x	x							(a,b)
	Input of organic matter — diffuse sources and point sources	1km	x	x							(a,b)
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events	1km	x	x		x					(a,b)
	Input of litter (solid waste matter, including micro-sized litter)	20km	x			x	x		x	x	Defined by the authors
	Input of anthropogenic sound (impulsive, continuous)	20km	x	x	x	x	x	x	x	x	(d)
	Input of other forms of energy (including electromagnetic fields, light and heat))	local				x			x	x	(b,c)

Biological	Input of microbial pathogens	20km	x								(a)
	Input or spread of non-indigenous species	50km	x				x	x			(b)
	Input of genetically modified species and translocation of native species	50km	x								(b)
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species	50km	x								(b)
	Disturbance of species (e.g. where they breed, rest and feed) due to human presence	10km	x		x		x	x	x	x	(c)
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	local					x				Defined by the authors

ASSESSMENT OF THE SIGNIFICANCE OF THE IMPACT ON NATURA 2000 NETWORK

Table 18. Assessment of the significance of the impact on SCI (Legend: H-High; M–Medium; L- Low; D- Unknown; na–not applicable since it is not a target habitat/species of SIC or pressure does not affect the habitat/species)

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
LITORAL NORTE	Renewable energies	Input of anthropogenic sound	na	L	na	na
	Dredging disposal	Physical disturbance to seabed	na	H	na	na
		Physical loss	na	H	na	na
		Changes to hydrological conditions	na	M	na	na
		Input of nutrients	na	M	na	na
		Input of organic matter	na	M	na	na

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Input of other substances	na	M	na	na
		Input of anthropogenic sound	na	L	na	na
	Marine cultural heritage	Input of litter	na	M	na	na
		Input of anthropogenic sound	na	L	na	na
	Marine natural heritage	Physical disturbance to seabed	na	H	na	na
		Physical loss	na	H	na	na
		Input of litter	na	M	na	na
		Input of anthropogenic sound	na	L	na	na
		Input of other forms of energy	na	L	na	na
		Disturbance of species	na	M	na	na
	Multi-use offshore platforms	Input or spread of non-indigenous species	na	M	na	na
	Tourism and recreation	Physical disturbance to seabed	na	H	na	na
		Physical loss	na	H	na	na
		Input of litter	na	M	na	na
		Input of anthropogenic sound	na	L	na	na
		Input or spread of non-indigenous species	na	M	na	na
		Disturbance of species	na	M	na	na
		Extraction of, or mortality/injury to, wild species	na	H	na	na
MACEDA/PRAIA DA VIEIRA	Aquaculture	Physical disturbance to seabed	na	na	na	L
		Physical loss	na	na	na	L
		Input of nutrients	na	L	na	D
		Input of organic matter	na	L	na	L
		Input of other substances	na	L	na	L
		Input of litter	M	M	na	M
		Input of anthropogenic sound	L	L	na	H
		Input of microbial pathogens	D	D	na	M
		Input or spread of non-indigenous species	D	M	na	D
		Input of genetically modified species and translocation of native species	D	D	na	D

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Disturbance of species	na	M	na	M
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D	D	na	D
	Artificial reefs and structures disposal	Physical loss	na	na	na	M
		Changes to hydrological conditions	na	L	na	L
		Input of other substances	na	L	na	M
		Input of litter	M	M	na	M
		Input of anthropogenic sound	L	L	na	H
		Input of other forms of energy	na	na	na	M
	Dredging disposal	Input of anthropogenic sound	L	L	na	M
	Multi-use offshore platforms	Input of anthropogenic sound	L	L	na	M
		Input or spread of non-indigenous species	D	M	na	D
		Disturbance of species	L	na	na	M
	Marine natural heritage	Physical disturbance to seabed	H	na	na	M
		Physical loss	H	na	na	M
		Input of litter	M	M	na	M
		Input of anthropogenic sound	L	L	na	E
		Input of other forms of energy	L	na	na	M
		Disturbance of species	L	M	na	M
	Marine cultural heritage	Physical disturbance to seabed	na	L	na	L
		Input of litter	M	M	na	M
		Input of anthropogenic sound	L	L	na	H
		Input of other forms of energy	na	L	na	L
		Disturbance of species	L	M	na	M
	Tourism and recreation	Physical disturbance to seabed	H	na	na	M
		Physical loss	H	na	na	M

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Input of litter	M	M	na	M
		Input of anthropogenic sound	L	L	na	H
		Input of other forms of energy	D	M	na	D
		Disturbance of species	L	M	na	M
		Extraction of, or mortality/injury to, wild species	H	na	na	H
RIA DE AVEIRO	Aquaculture	Input of litter	M	na	na	na
		Input of anthropogenic sound	L	na	na	na
		Input of microbial pathogens	D	na	na	na
		Input or spread of non-indigenous species	D	na	na	na
		Input of genetically modified species and translocation of native species	D	na	na	na
		Extraction of, or mortality/injury to, wild species	D	na	na	na
		Disturbance of species	L	na	na	na
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D	na	na	na
	Artificial reefs and structures disposal	Input of litter	M	na	na	na
		Input of anthropogenic sound	L	na	na	na
	Marine natural heritage	Physical disturbance to seabed	H	na	na	na
		Physical loss	H	na	na	na
		Input of litter	M	na	na	na
		Input of anthropogenic sound	L	na	na	na
		Input of other forms of energy	L	na	na	na
		Disturbance of species	L	na	na	na
	Multi-use offshore platforms	Input or spread of non-indigenous species	D	na	na	na

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
	Tourism and recreation	Physical disturbance to seabed	H	na	na	na
		Physical loss	H	na	na	na
		Input of litter	M	na	na	na
		Input of anthropogenic sound	L	na	na	na
		Input or spread of non-indigenous species	D	na	na	na
		Disturbance of species	L	na	na	na
		Extraction of, or mortality/injury to, wild species	H	na	na	na
PENICHE/SANTA CRUZ	Aquaculture	Input of nutrients	L	na	na	na
		Input of organic matter	L	na	na	na
		Input of other substances	L	na	na	na
		Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Input of microbial pathogens	D	D	D	na
		Input or spread of non-indigenous species	D	M	M	na
		Input of genetically modified species and translocation of native species	D	D	D	na
		Extraction of, or mortality/injury to, wild species	D	D	D	na
		Disturbance of species	L	M	M	na
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D	D	D	na
	Renewable energies	Physical disturbance to seabed	M	M	M	na
		Physical loss	M	M	M	na
		Changes to hydrological conditions	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Disturbance of species	L	M	M	na
	Dredging disposal	Physical disturbance to seabed	M	M	M	na
		Physical loss	M	M	M	na
		Changes to hydrological conditions	M	M	M	na

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Input of nutrients	M	M	M	na
		Input of organic matter	M	M	M	na
		Input of other substances	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
	Marine cultural heritage	Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
	Marine natural heritage	Physical disturbance to seabed	H	H	H	na
		Physical loss	H	H	H	na
		Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Input of other forms of energy	L	L	L	na
		Disturbance of species	L	M	M	na
	Tourism and recreation	Physical disturbance to seabed	H	H	H	na
		Physical loss	H	H	H	na
		Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Input or spread of non-indigenous species	D	M	M	na
		Disturbance of species	L	M	M	na
		Extraction of, or mortality/injury to, wild species	H	H	H	na
SINTRA/CASCAIS	Aquaculture	Input or spread of non-indigenous species	D	M	M	na
		Input of genetically modified species and translocation of native species	D	D	D	na
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D	D	D	na
	Marine cultural heritage	Physical disturbance to seabed	L	L	L	na
		Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Input of other forms of energy	L	L	L	na
		Disturbance of species	L	M	M	na
	Marine natural heritage	Physical disturbance to seabed	H	H	H	na
		Physical loss	H	H	H	na

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Input of other forms of energy	L	L	L	na
		Disturbance of species	L	M	M	na
	Multi-use offshore platforms	Input or spread of non-indigenous species	D	M	M	na
	Tourism and recreation	Physical disturbance to seabed	H	H	H	na
		Physical loss	H	H	H	na
		Input of litter	M	M	M	na
		Input of anthropogenic sound	L	L	L	na
		Input or spread of non-indigenous species	D	M	M	na
		Disturbance of species	L	M	M	na
		Extraction of, or mortality/injury to, wild species	H	H	H	na
ARRÁBIDA/ESPICHEL	Artificial reefs and structures disposal	Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	L	H
	Dredging disposal	Input of anthropogenic sound	L	L	L	H
	Marine cultural heritage	Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	L	H
		Disturbance of species	L	M	M	L
	Marine natural heritage	Physical disturbance to seabed	H	H	H	M
		Physical loss	H	H	H	L
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	L	H
		Input of other forms of energy	L	L	L	M
		Disturbance of species	L	M	M	L
	Multi-use offshore platforms	Input of anthropogenic sound	L	L	L	H
		Input or spread of non-indigenous species	D	M	M	L
		Disturbance of species	L	M	M	na
	Tourism and recreation	Physical disturbance to seabed	H	H	H	M
		Physical loss	H	H	H	M
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	L	H

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Input or spread of non-indigenous species	D	M	M	L
		Disturbance of species	L	M	M	M
		Extraction of, or mortality/injury to, wild species	H	H	H	H
COSTA SUDOESTE	Aquaculture	Physical disturbance to seabed	na	L	L	M
		Physical loss	na	L	L	M
		Input of nutrients	L	L	D	D
		Input of organic matter	L	L	D	L
		Input of other substances	B	L	L	M
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	L	E
		Input of microbial pathogens	D	D	D	M
		Input or spread of non-indigenous species	D	M	D	D
		Input of genetically modified species and translocation of native species	D	D	D	na
		Disturbance of species	L	M	L	na
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D	D	D	na
	Dredging disposal	Physical disturbance to seabed	na	na	na	L
		Physical loss	na	na	na	L
		Changes to hydrological conditions	na	na	na	L
		Input of nutrients	na	na	na	D
		Input of organic matter	na	na	na	L
		Input of other substances	na	na	na	L
		Input of anthropogenic sound	L	L	L	H
	Artificial reefs and structures disposal	Physical loss	na	L	L	L
		Changes to hydrological conditions	na	L	L	L
		Input of other substances	na	L	L	L

SCI	Activity	Pressure	Impact Significance			
			1110	1170	8830	Cetaceans
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	M	H
		Input of other forms of energy	L	L	L	L
		Disturbance of species	L	M	M	M
	Marine cultural heritage	Physical disturbance to seabed	L	L	L	L
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	L	H
		Input of other forms of energy	L	L	L	L
		Disturbance of species	L	M	M	M
	Marine natural heritage	Physical disturbance to seabed	H	H	H	M
		Physical loss	H	H	H	M
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	M	H
		Input of other forms of energy	L	L	L	M
		Disturbance of species	L	M	M	M
	Tourism and recreation	Physical disturbance to seabed	H	H	H	M
		Physical loss	H	H	H	M
		Input of litter	M	M	M	M
		Input of anthropogenic sound	L	L	M	H
		Input or spread of non-indigenous species	D	M	D	D
		Disturbance of species	L	M	M	M
		Extraction of, or mortality/injury to, wild species	H	H	M	H

Table 19. Assessment of the significance of the impact on SPA (Legend: H-High; M–Medium; L- Low; D- Unknown; na–not applicable since it is not a target habitat/species of SIC or pressure does not affect the habitat/species)

SPA	Activity	Pressure	Impact Significance
AVEIRO/NAZARÉ	Aquaculture	Input of nutrients	L
		Input of organic matter	L
		Input of other substances	L

SPA	Activity	Pressure	Impact Significance
		Input of litter	M
		Input of anthropogenic sound	M
		Input of microbial pathogens	M
		Input or spread of non-indigenous species	M
		Input of genetically modified species and translocation of native species	D
		Disturbance of species	M
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Artificial reefs and structures disposal	Physical loss	M
		Changes to hydrological conditions	L
		Input of other substances	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
	Renewable energies	Input of anthropogenic sound	M
		Disturbance of species	L
	Dredging disposal	Physical disturbance	L
		Physical loss	L
		Changes to hydrological conditions	L
		Input of nutrients	L
		Input of organic matter	L
		Input of other substances	L
		Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	M
		Input of anthropogenic sound	M
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Multi-use offshore platforms	Input or spread of non-indigenous species	L
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H

SPA	Activity	Pressure	Impact Significance
		Extraction of, or mortality/injury to, wild species	H
CABO ESPICHEL	Artificial reefs and structures disposal	Input of litter	H
		Input of anthropogenic sound	M
	Dredging disposal	Input of anthropogenic sound	M
	Marine cultural heritage	Physical disturbance	L
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Multi-use offshore platforms	Disturbance of species	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
CABO RASO	Aquaculture	Input or spread of non-indigenous species	M
		Input of genetically modified species and translocation of native species	D
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Artificial reefs and structures disposal	Input of litter	M
		Input of anthropogenic sound	M
		Physical disturbance	L

SPA	Activity	Pressure	Impact Significance
	Marine cultural heritage	Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Multi-use offshore platforms	Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	M
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
COSTA SUDOESTE	Aquaculture	Physical disturbance	M
		Physical loss	M
		Input of nutrients	M
		Input of organic matter	M
		Input of other substances	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of microbial pathogens	M
		Input or spread of non-indigenous species	M
		Input of genetically modified species and translocation of native species	D
		Disturbance of species	H
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Dredging disposal	Input of anthropogenic sound	L
	Marine cultural heritage	Physical disturbance	L
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H

SPA	Activity	Pressure	Impact Significance
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
ESTUÁRIOS DOS RIOS MINHO E COURA	Renewable energies	Input of anthropogenic sound	M
	Dredging disposal	Physical disturbance	M
		Physical loss	M
		Changes to hydrological conditions	L
		Input of nutrients	M
		Input of organic matter	M
		Input of other substances	H
		Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	H
		Input of anthropogenic sound	M
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H

SPA	Activity	Pressure	Impact Significance
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
ILHAS BERLENGAS	Aquaculture	Input of litter	H
		Input of anthropogenic sound	M
		Input of microbial pathogens	M
		Input or spread of non-indigenous species	M
		Input of genetically modified species and translocation of native species	D
		Disturbance of species	M
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Renewable energies	Input of anthropogenic sound	M
		Disturbance of species	M
	Dredging disposal	Input of anthropogenic sound	M
	Marine cultural heritage	Physical disturbance	L
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
LAGOA DA SANCHA	Artificial reefs and structures disposal	Input of litter	H
		Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	H
		Input of anthropogenic sound	M
		Disturbance of species	H
	Marine natural heritage	Input of litter	H
		Input of anthropogenic sound	M

SPA	Activity	Pressure	Impact Significance
		Disturbance of species	H
	Tourism and recreation	Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
LAGOA DE SANTO ANDRÉ	Artificial reefs and structures disposal	Input of litter	H
		Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	H
		Input of anthropogenic sound	M
		Disturbance of species	H
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
LEIXÃO DA GAIVOTA	Aquaculture	Input of litter	H
		Input of anthropogenic sound	M
		Input of microbial pathogens	M
		Input or spread of non-indigenous species	M
		Input of genetically modified species and translocation of native species	D
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Artificial reefs and structures disposal	Input of litter	H
		Input of anthropogenic sound	M
	Dredging disposal	Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	H
		Input of anthropogenic sound	M
		Disturbance of species	H
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D

SPA	Activity	Pressure	Impact Significance
		Disturbance of species	H
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
RIA DE AVEIRO	Aquaculture	Input of litter	H
		Input of anthropogenic sound	M
		Input of microbial pathogens	M
		Input or spread of non-indigenous species	M
		Input of genetically modified species and translocation of native species	D
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Artificial reefs and structures disposal	Input of litter	H
	Artificial reefs and structures disposal	Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	L
		Input of anthropogenic sound	L
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Multi-use offshore platforms	Input or spread of non-indigenous species	M
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H
RIA FORMOSA	Aquaculture	Input of litter	H
		Input of anthropogenic sound	M
		Input of microbial pathogens	M
		Input or spread of non-indigenous species	M

SPA	Activity	Pressure	Impact Significance
		Input of genetically modified species and translocation of native species	D
		Loss/change to, natural biological communities due to cultivation of animal or plant species	D
	Artificial reefs and structures disposal	Changes to hydrological conditions	L
		Input of other substances	M
		Input of litter	H
		Input of anthropogenic sound	M
	Marine cultural heritage	Input of litter	H
		Input of anthropogenic sound	M
		Disturbance of species	H
	Marine natural heritage	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input of other forms of energy	D
		Disturbance of species	H
	Multi-use offshore platforms	Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	M
	Tourism and recreation	Physical disturbance	M
		Physical loss	M
		Input of litter	H
		Input of anthropogenic sound	M
		Input or spread of non-indigenous species	M
		Disturbance of species	H
		Extraction of, or mortality/injury to, wild species	H

References

Andersen, J.H., Stock, A., 2013. Human Uses , Pressures and Impacts in the Eastern North Sea. Aarhus University,DCE—Danish Centre for Environment and Energy. Technical Report fromDCE—Danish Centre for Environment and Energy No. 18.

DGRM, 2019. Volume III - A. Plano de Situação do Ordenamento do Espaço Marítimo Nacional -

Espacialização de servidões, usos e atividades (Continente e Plataforma continental estendida).

EMODnet Seabed Habitats - Homepage [WWW Document], n.d. URL https://www.emodnet-seabedhabitats.eu/ (accessed 1.18.19).

ICNF, 2018a. Relatório de base do plano de gestão da área marinha de cinco SIC: Costa sudoeste, Litoral norte, Arrábida/Espichel, Peniche/Santa Cruz e Sintra/Cascais.

ICNF, 2018b. Proposta de planos de gestão para a área marinha abrangida pelos Sítios Maceda - Praia da Vieira e Costa Sudoeste (revisão) 66.

ICNF, 2008. Plano Setorial da Rede Natura 2000 (PSRN2000) - Resolução do Conselho de Ministros n.º 115-A/2008, de 21 de julho.

Koss, R.S., Knights, A.M., Eriksson, A., Robinson, L.A., 2011. Options for Delivering Ecosystem-Based Marine Management.

MAM, 2014. Estratégias marinhas para as águas marinhas Portuguesas. Diretiva-Quadro Estratégia Marinha. Programa de monitorização e programa de medidas.

MAMAOT, 2012. Maritime Strategy for Continent Subdivision (Estrategia Marinha para a Divisão do Continente). Minist. Agric. Sea, Environ. Spat. Planning.

MarLIN - The Marine Life Information Network - Home [WWW Document], n.d. URL https://www.marlin.ac.uk/ (accessed 1.18.19).

Natura 2000 — ICNF [WWW Document], n.d. URL http://www2.icnf.pt/portal/pn/biodiversidade/rn2000 (accessed 1.18.19).

OSPAR, 2012. Guidelines on Best Environmental Practice (BEP) in Cable Laying and Operation - Agreement 2012-2. OSPAR 12/22/1, Annex14.

OSPAR, 2009a. Assessment of construction or placement of artificial reefs Biodiversity Series.

OSPAR, 2009b. Assessment of impacts of offshore oil and gas activities in the North-East Atlantic Offshore Industry Series.

OSPAR, 2008. OSPAR Guidance on Environmental Considerations for Offshore Wind Farm Development.

OSPAR Commission, 2009. Trend analysis of maritime human activities and their collective impact on the OSPAR maritime area.

Plano de Situação – Ordenamento do Mar Português [WWW Document], n.d. URL http://www.psoem.pt/geoportal_psoem/ (accessed 1.18.19).

Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J. & Matear, L., 2018. UK Marine Pressures-Activities Database "PAD": Methods Report, JNCC Report No. 624, JNCC, Peterborough. Peterborough.

SUPPLEMENTARY MATERIAL B.2

FORESEEN ACTIVITIES/USES ON THE STUDY

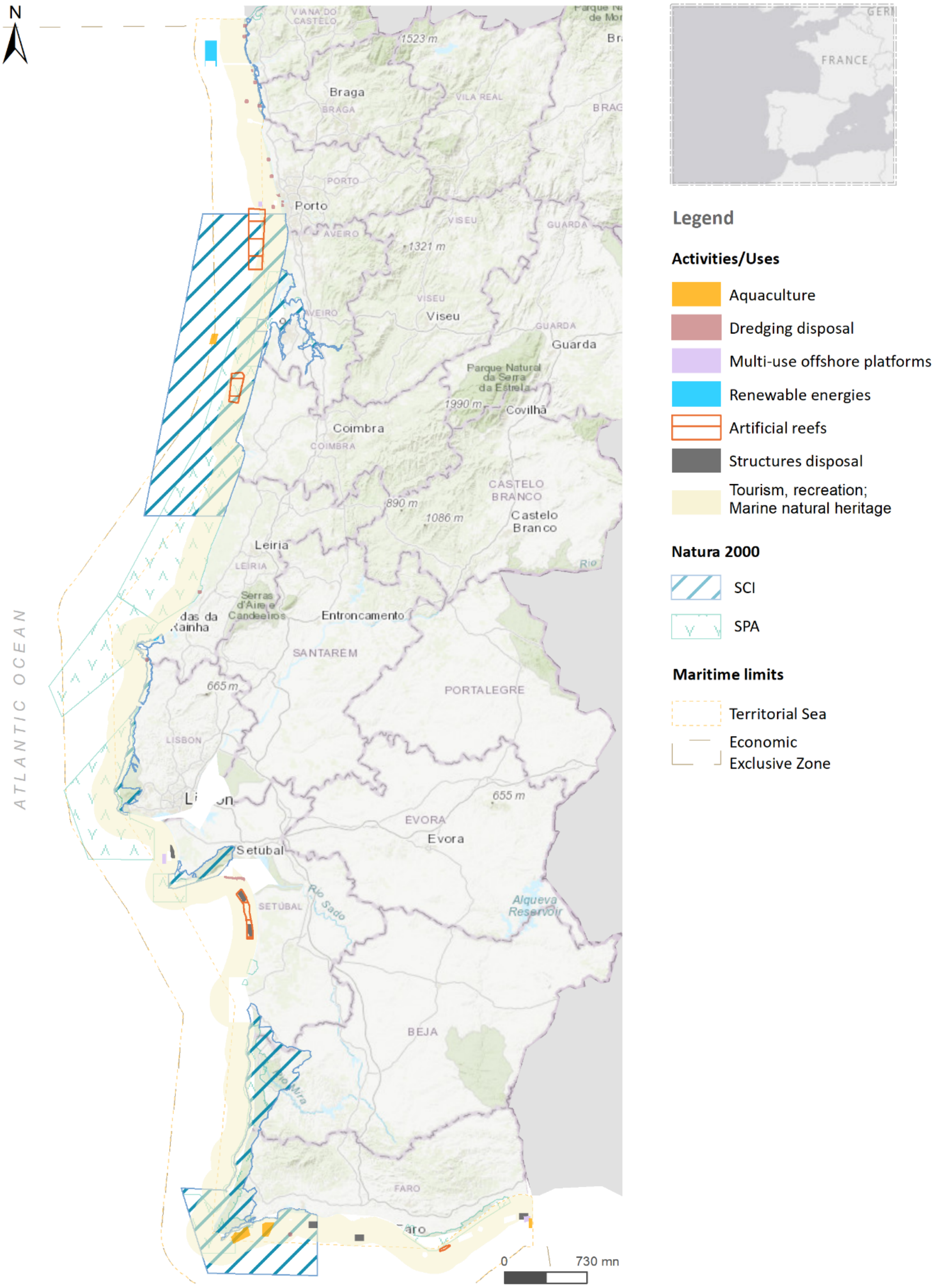


Figure 1. Activities/uses used in the study (Data sources: ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019)

PRESSURES' INFLUENCE ON THE SITES OF COMMUNITY IMPORTANCE (SCI)

Physical pressures

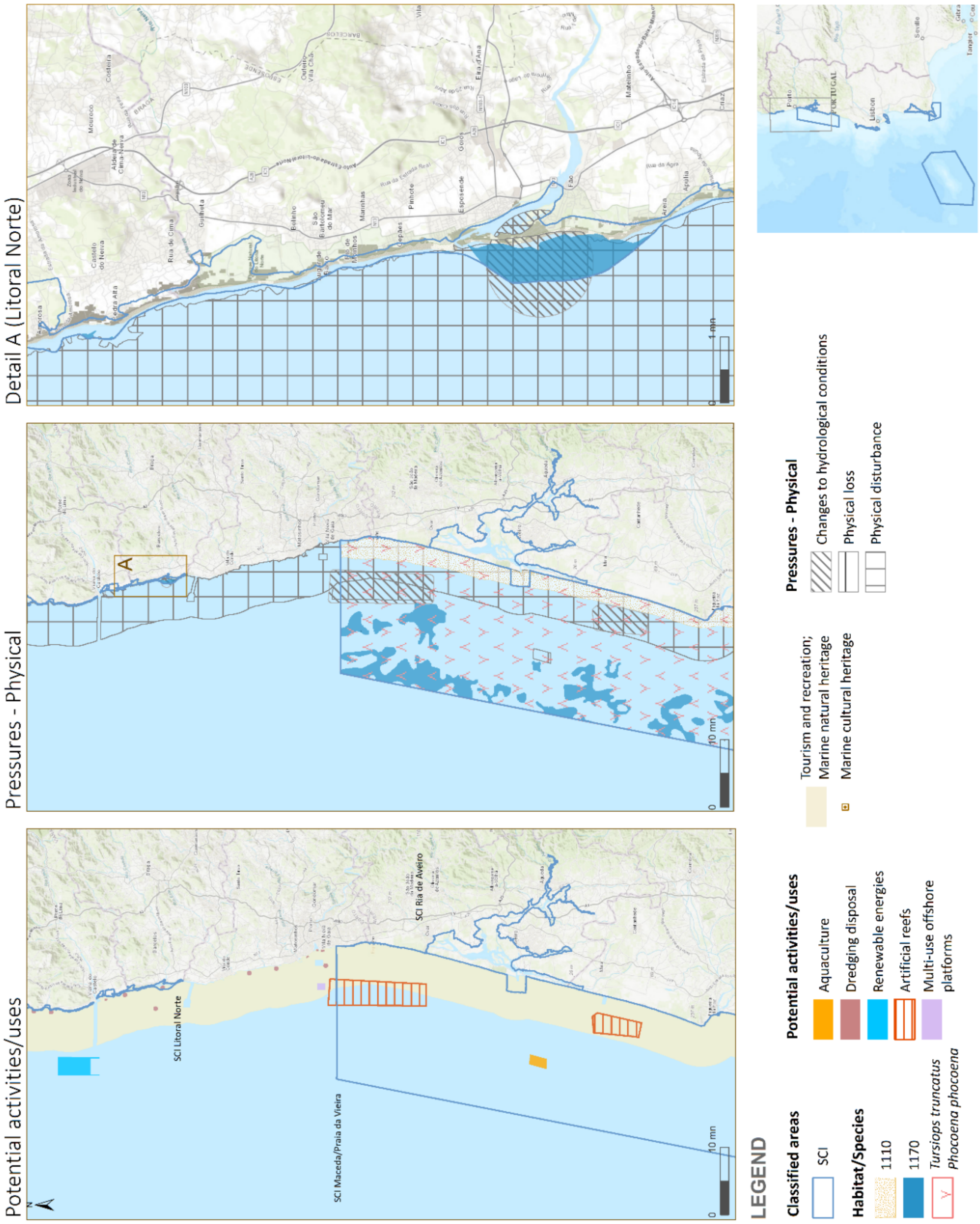


Figure 2. Spatial visualization of the range of influence of the physical pressures that may affect the SCI Litoral Norte, SCI Maceda/Praia da Vieira and Ria de Aveiro (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

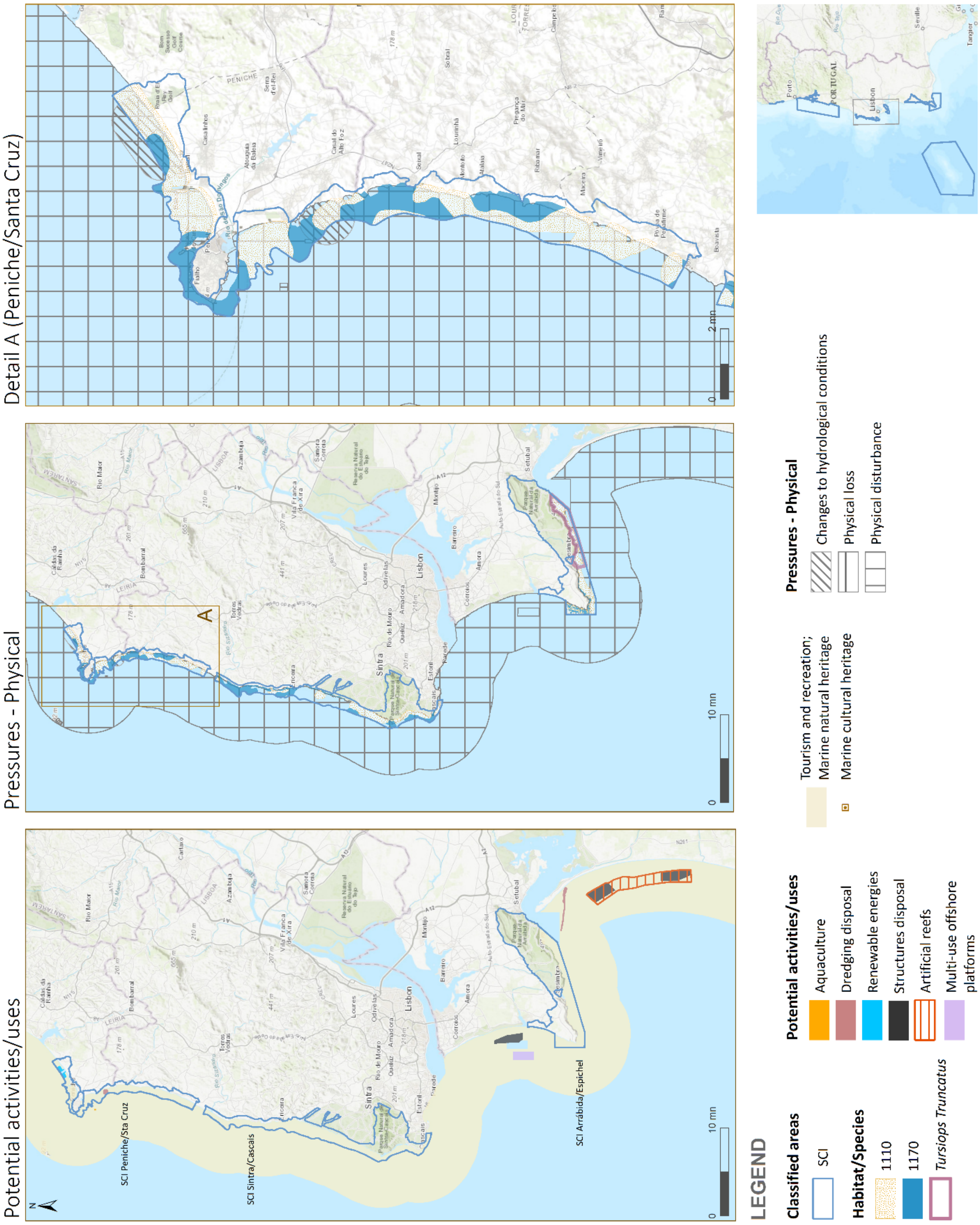


Figure 3. Spatial visualization of the range of influence of the physical pressures that may affect the SCI Peniche/Santa Cruz, Sintra/Cascais, and Arrábida/Espichel (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

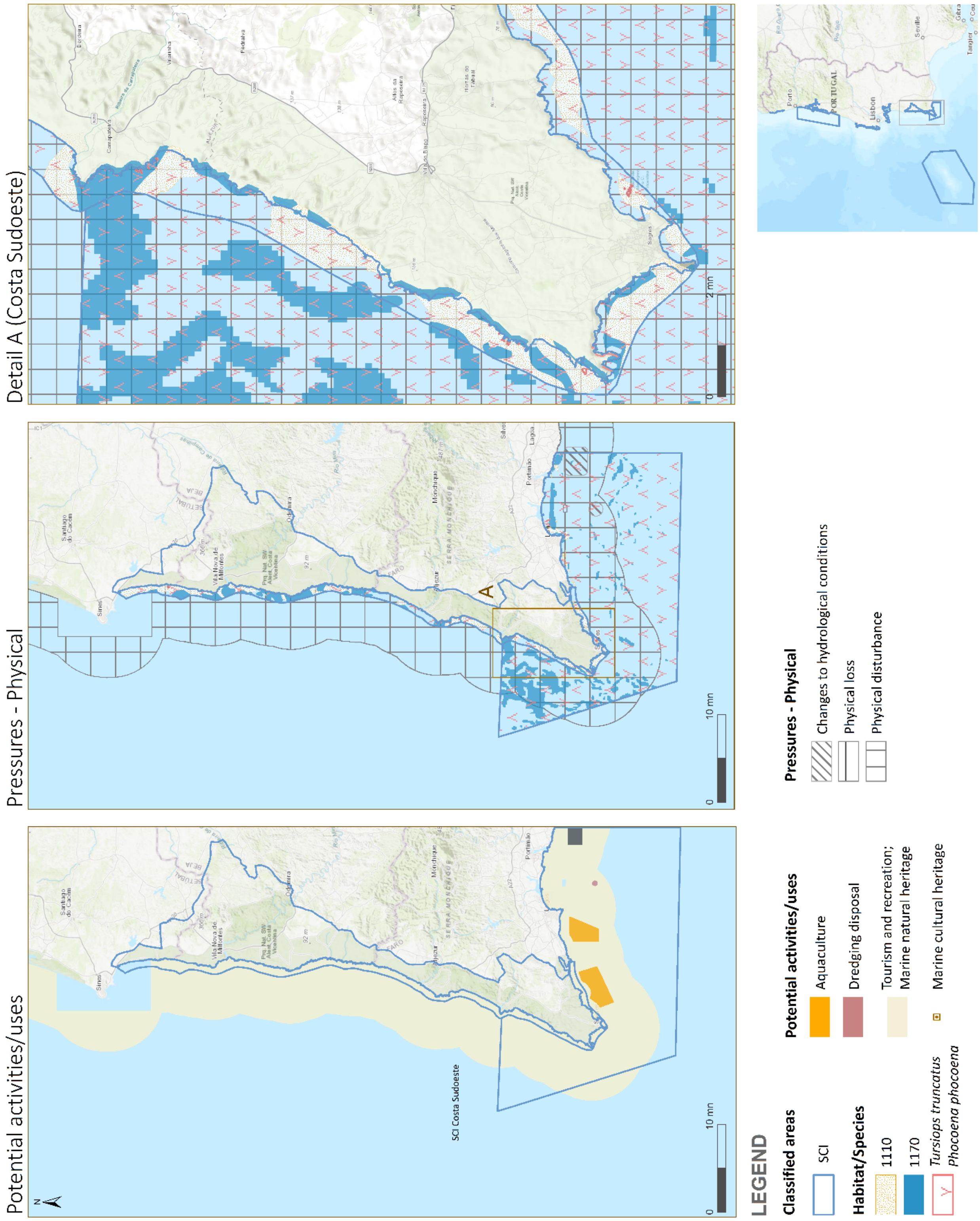


Figure 4. Spatial visualization of the range of influence of the physical pressures that may affect the SCI Costa Sudoeste (Data sources: (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

Substances, litter and energy pressures

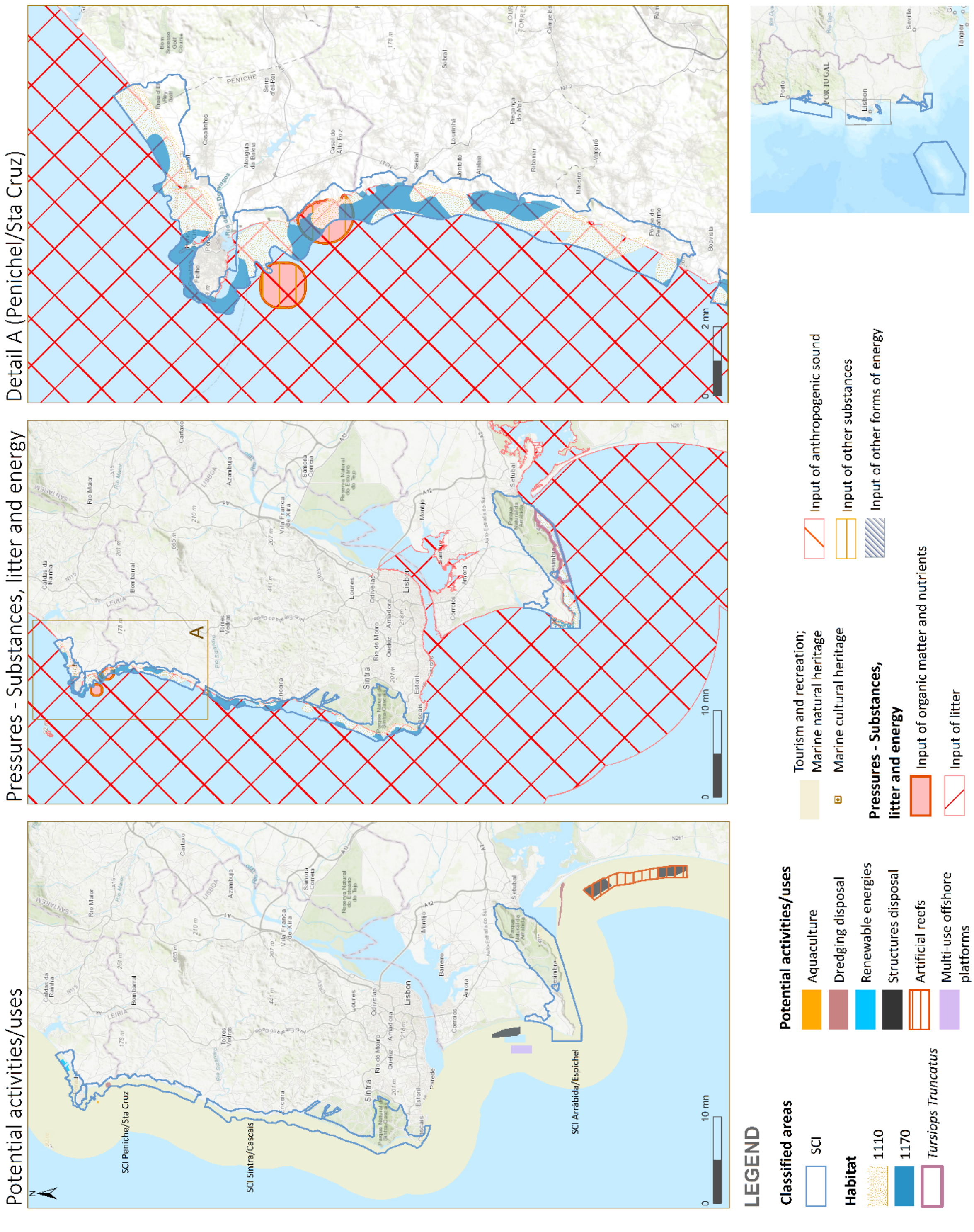


Figure 5. Spatial visualization of the range of influence of the substances, litter and energy pressures that may affect the SCI Peniche/Santa Cruz, Sintra/Cascais and Arrábida/Espichel (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019)..

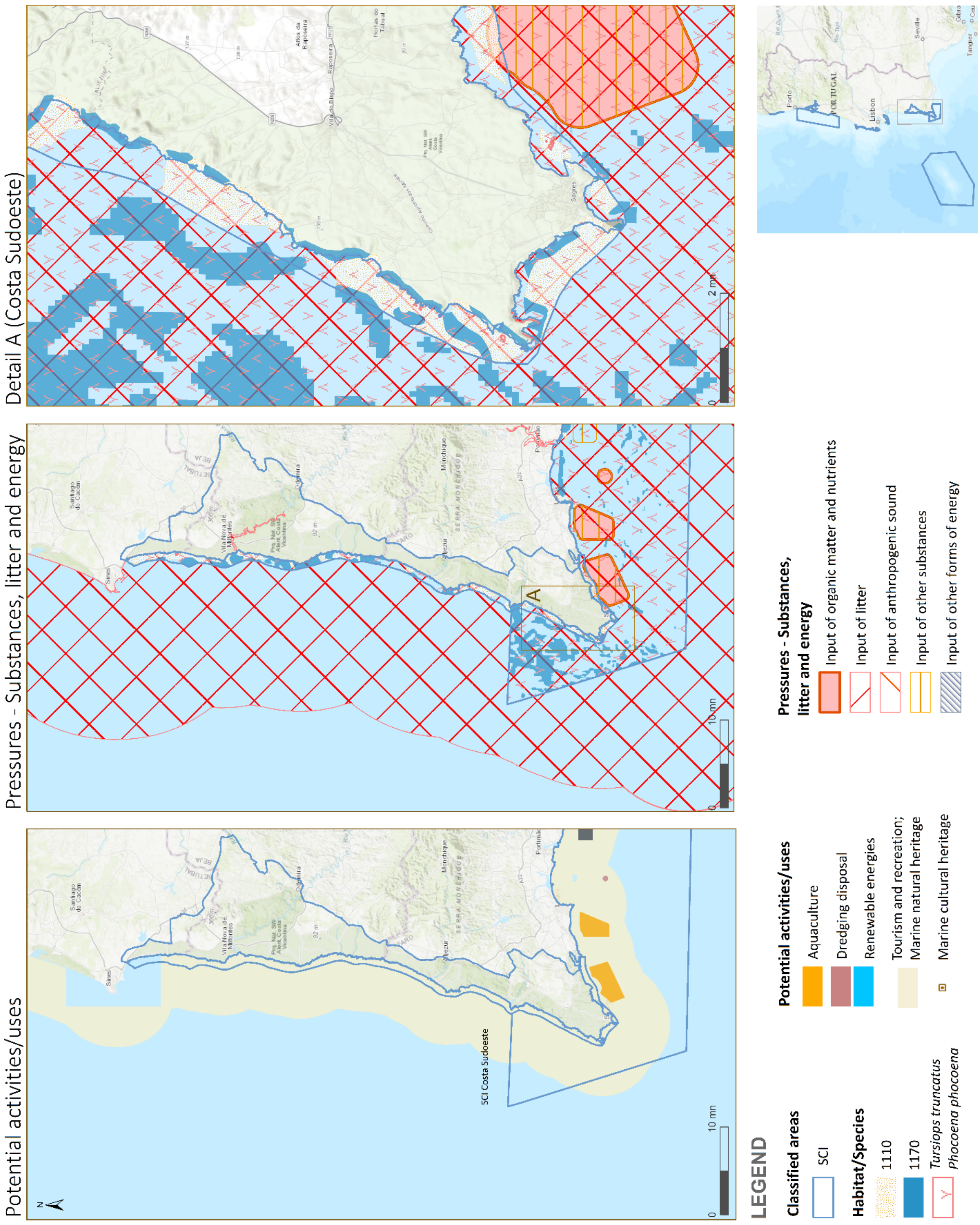


Figure 6. Spatial visualization of the range of influence of the substances, litter and energy pressures that may affect the SCI Costa Sudoeste (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

Biological pressures

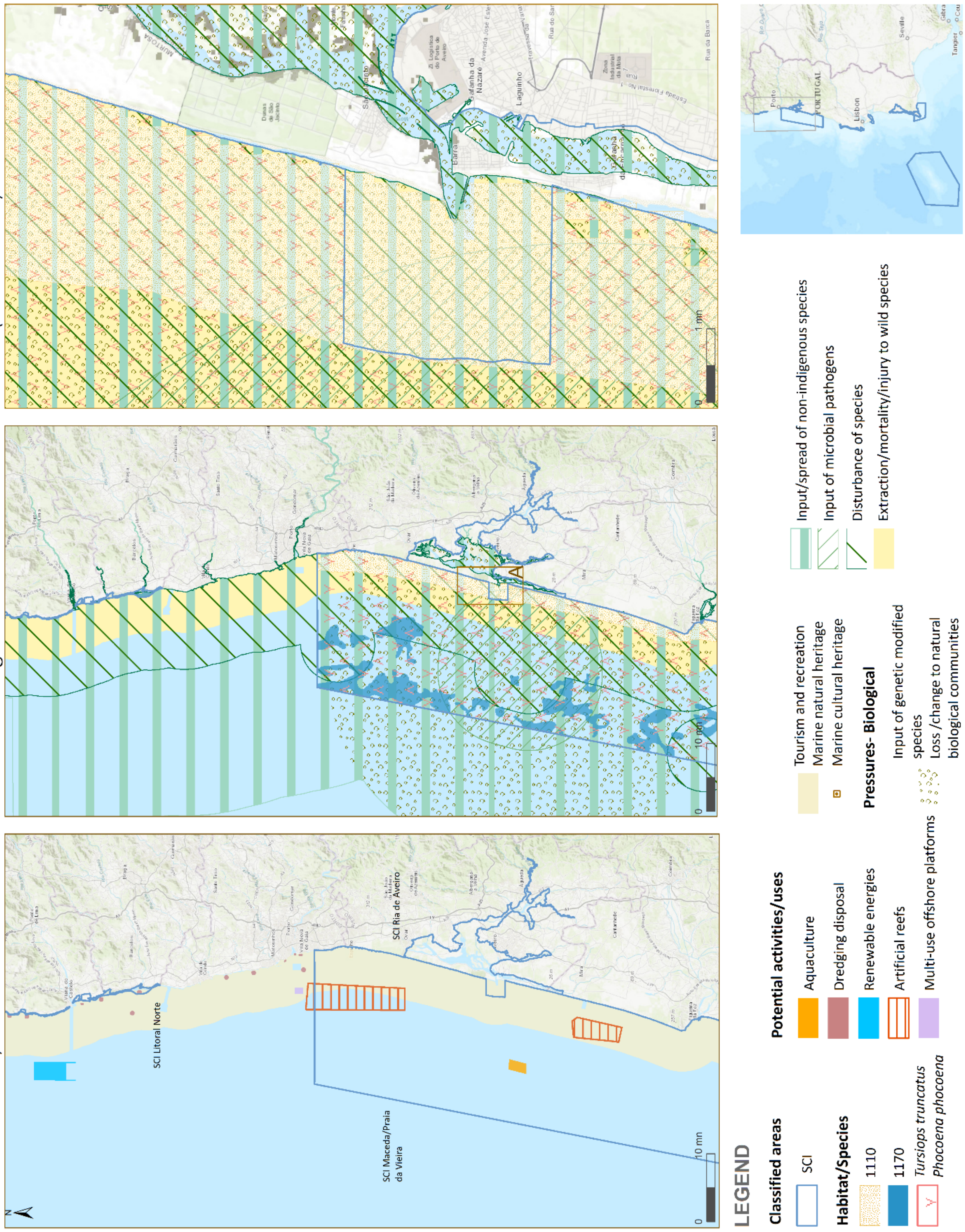


Figure 7. Spatial visualization of the range of influence of the biological pressures that may affect the SCI Litoral Norte, SCI Maceda/Praia da Vieira and Ria de Aveiro (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

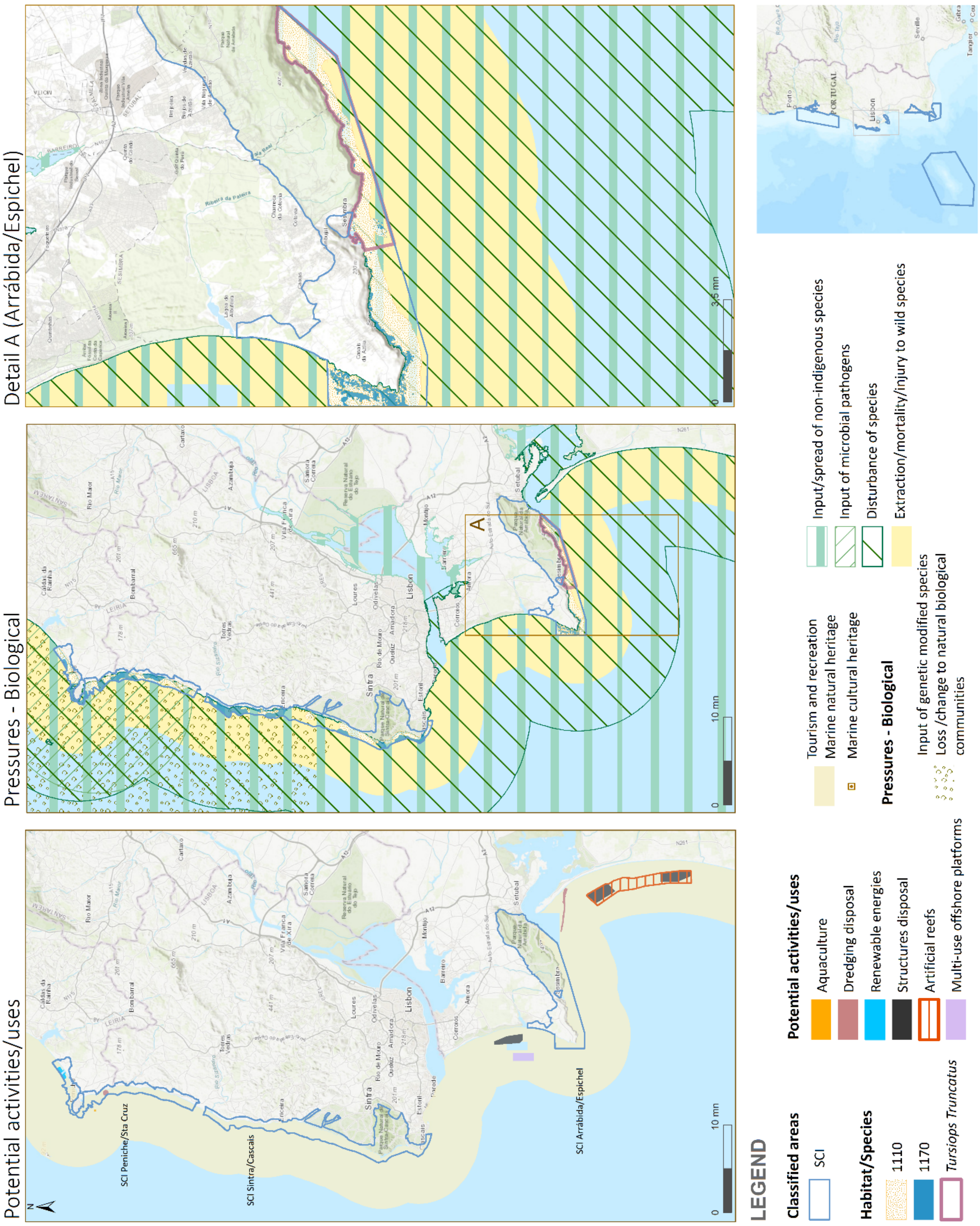


Figure 8. Spatial visualization of the range of influence of the biological pressures that may affect the SCI Peniche/Sta Cruz, Sintra/Cascais and Arrábida/Espichel (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

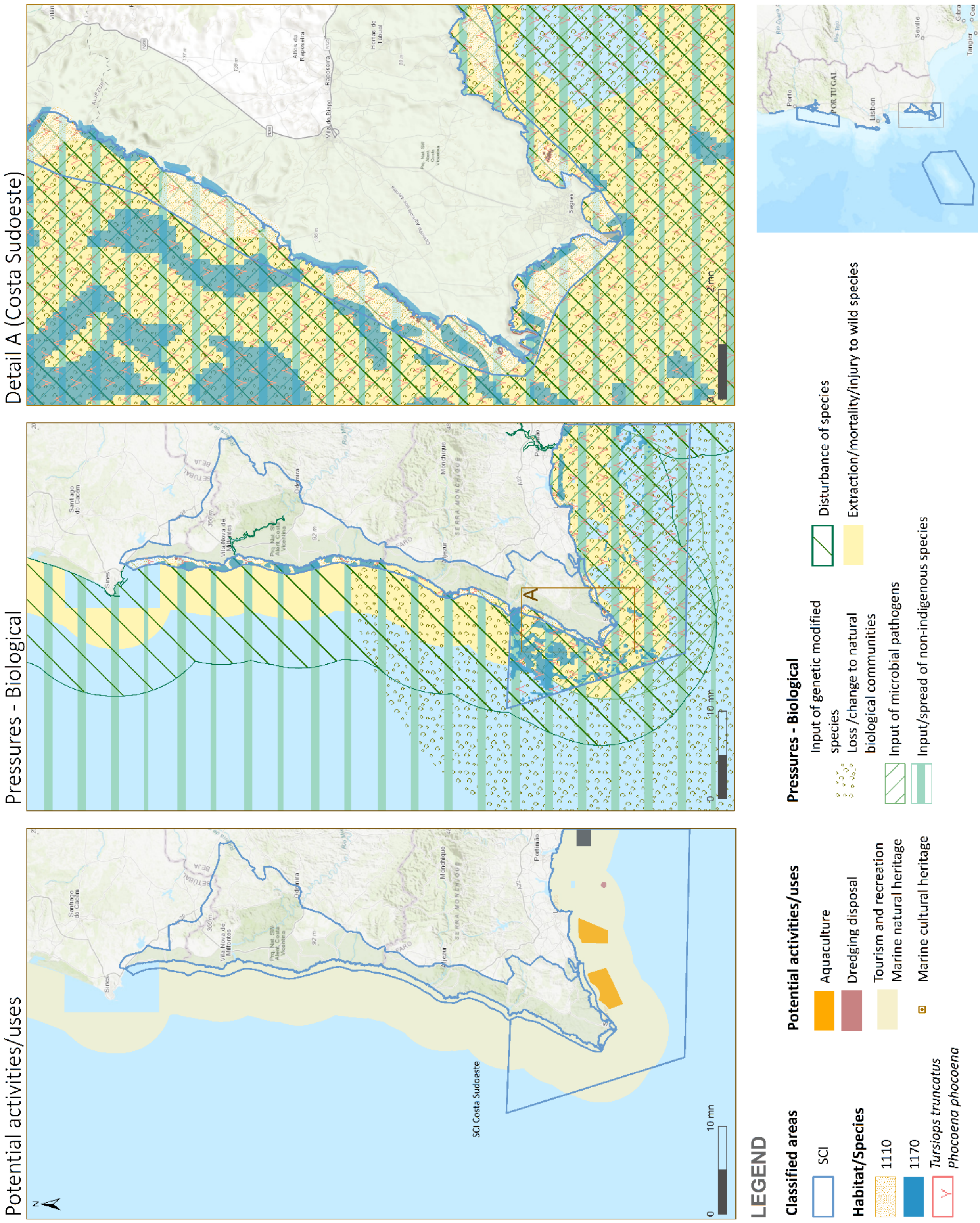


Figure 9. Spatial visualization of the range of influence of the biological pressures that may affect the SCI Costa Sudoeste (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

Banco de Gorringe

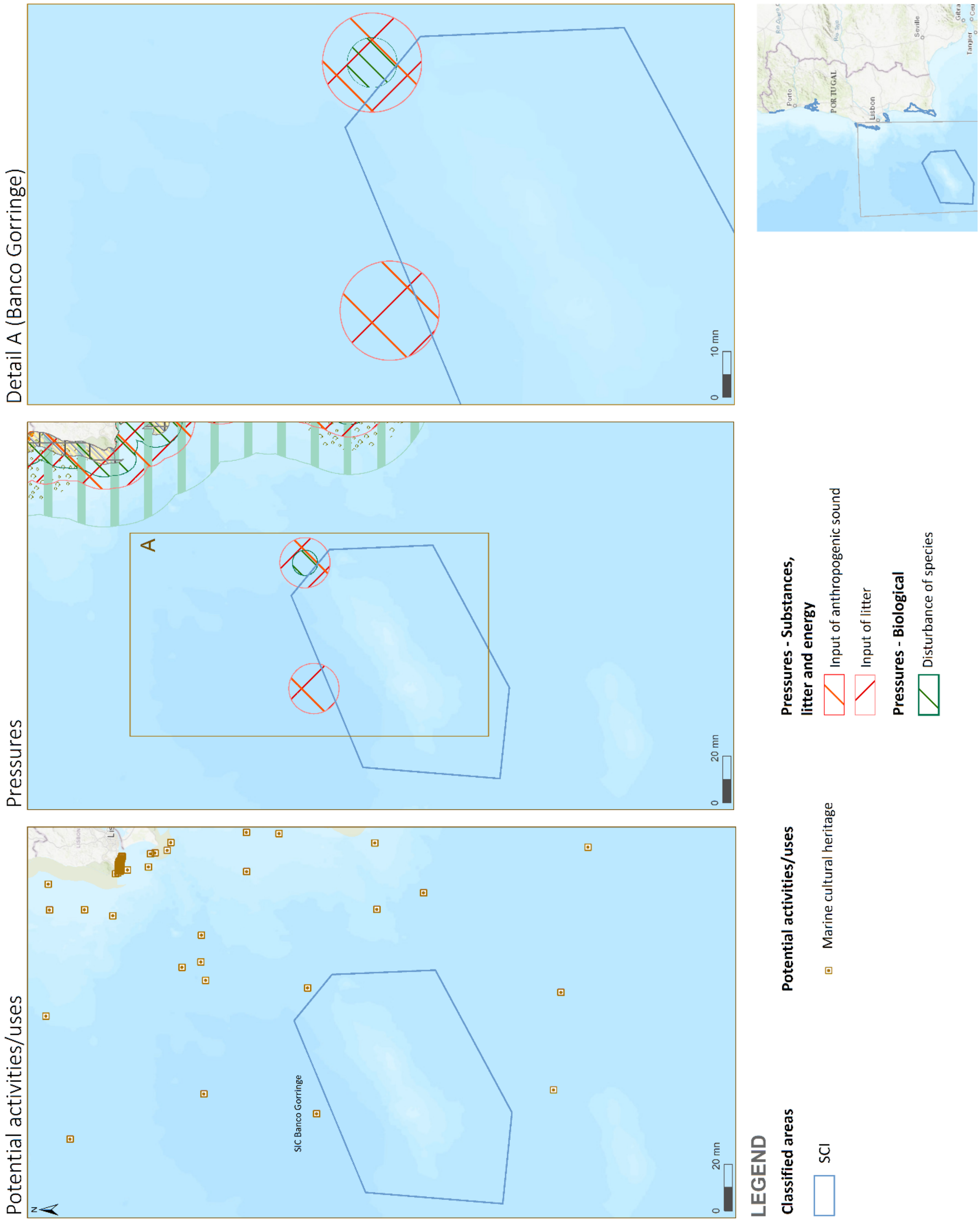


Figure 10. Spatial visualization of the range of influence of the biological, substances, litter and energy pressures that may affect the SCI Banco de Gorringe (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

PRESSURES' INFLUENCE ON THE SPECIAL AREAS OF CONSERVATION (SPA)

Physical pressures

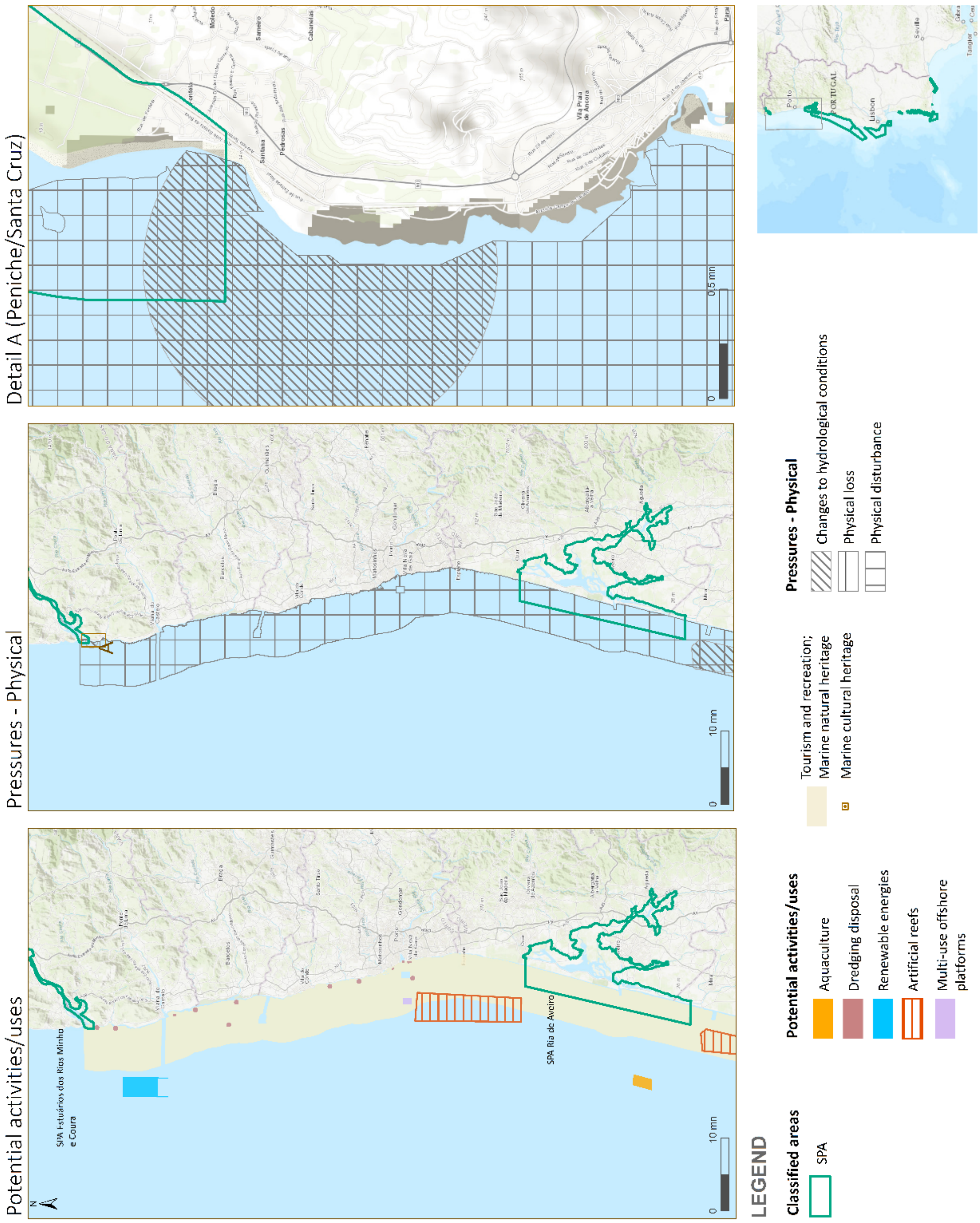


Figure 11. Spatial visualization of the range of influence of the physical pressures that may affect the SPA Estuário dos rios Minho e Coura and Ria de Aveiro (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

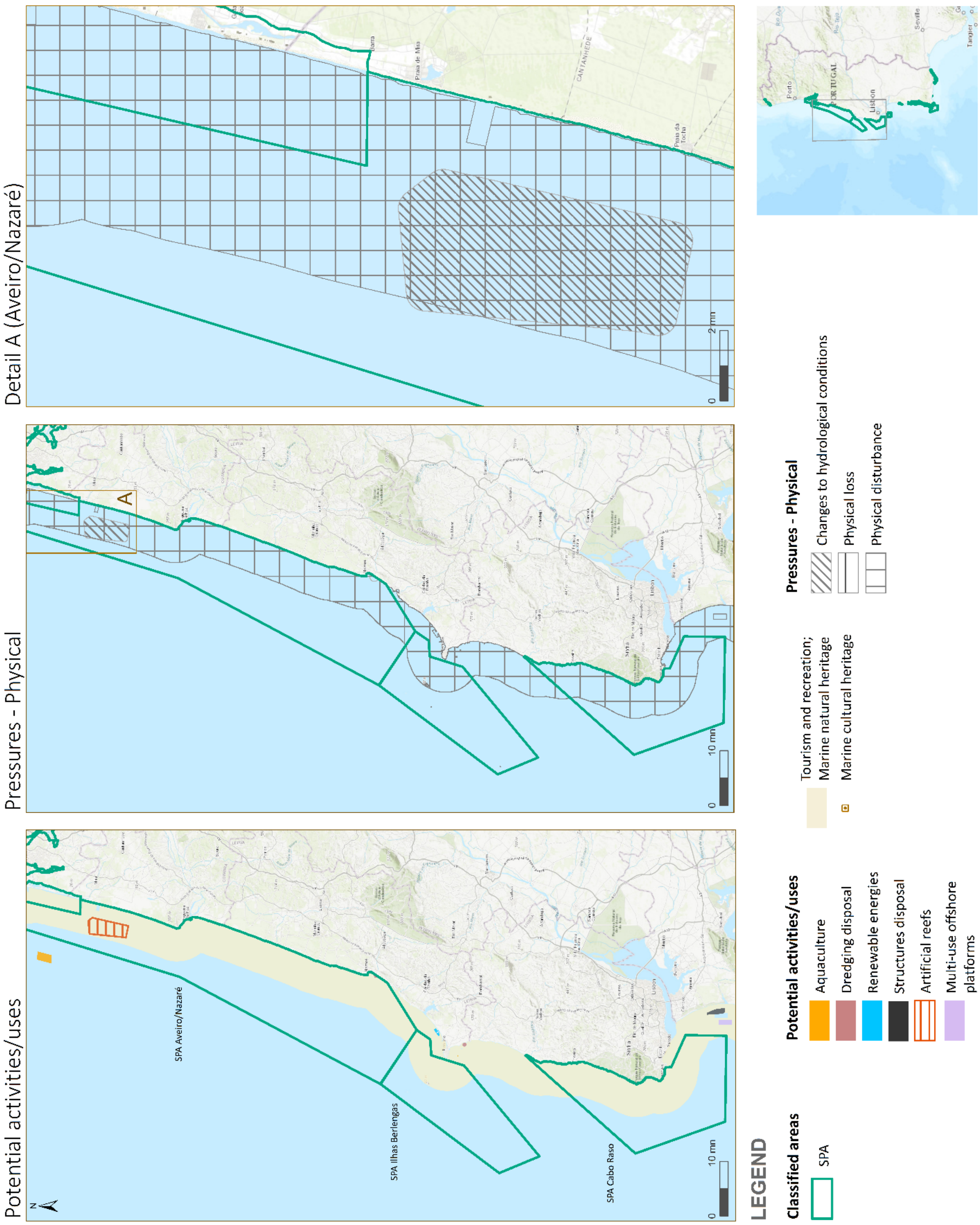


Figure 12. Spatial visualization of the range of influence of the physical pressures that may affect the SPA Aveiro / Nazaré, Ilhas Berlengas and Cabo Raso (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

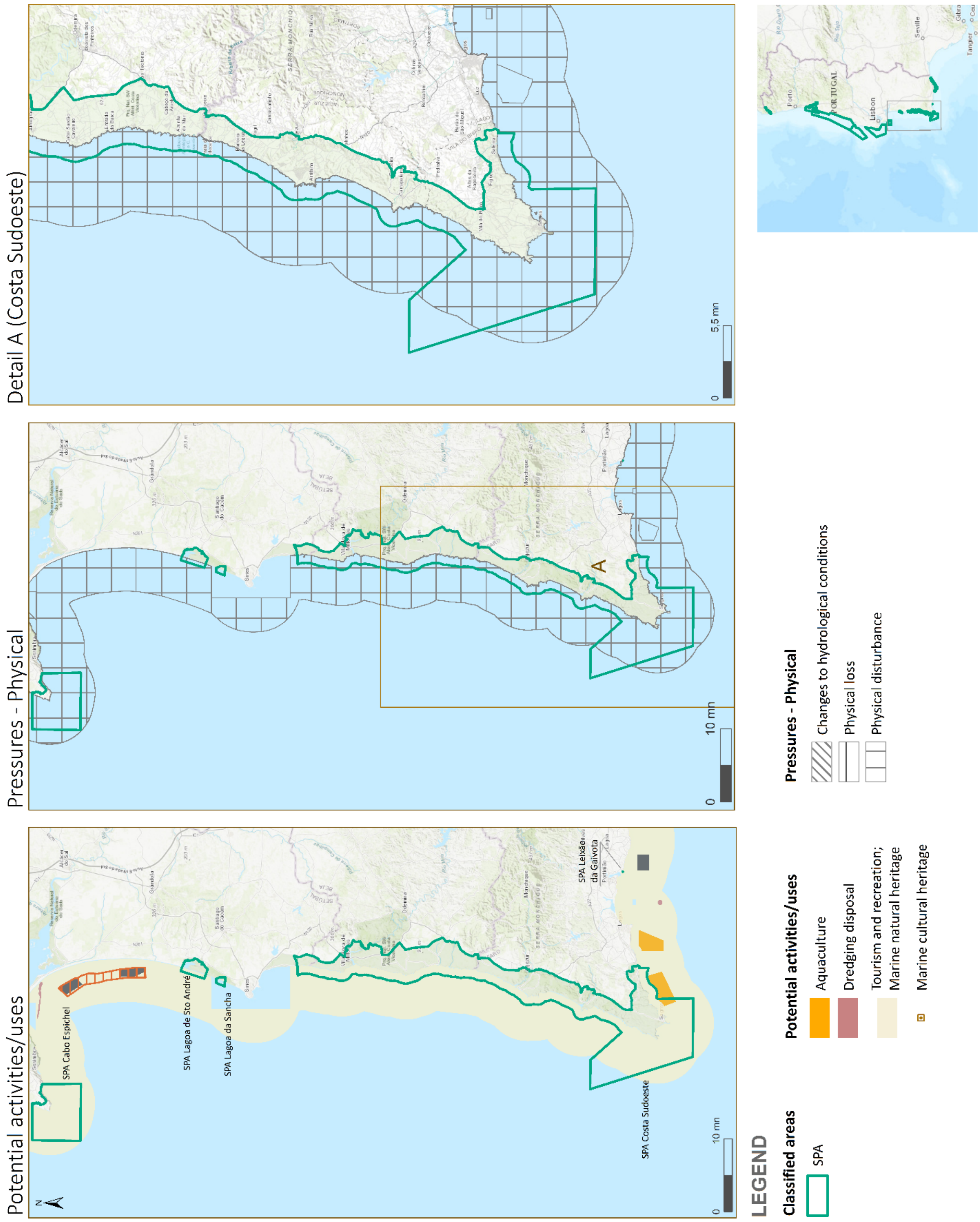


Figure 13. Spatial visualization of the range of influence of the physical pressures that may affect the Cabo Espichel, Lagoa de Santo André, Lagoa da Sancha, Costa Sudoeste and Leixão da Gaivota (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

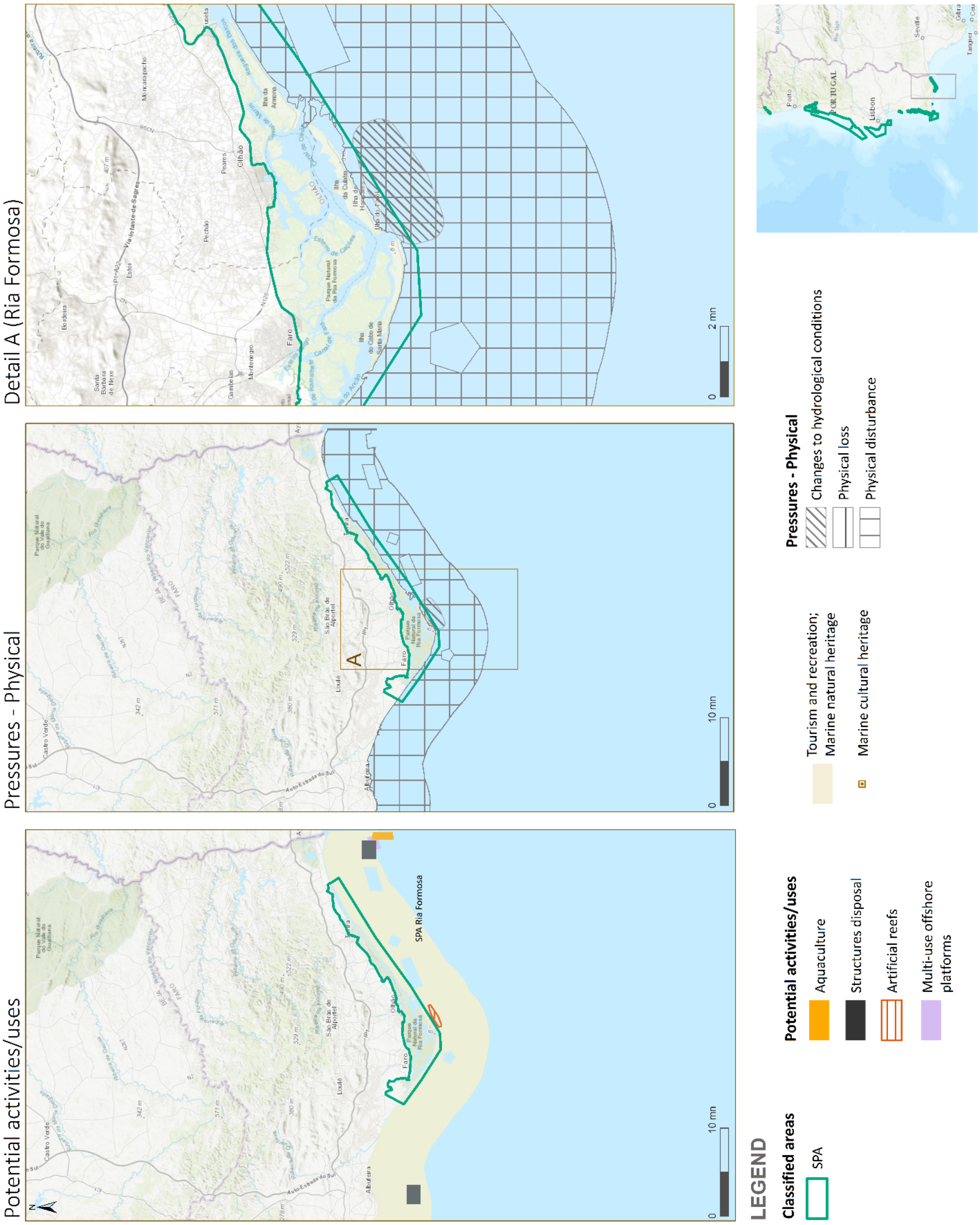


Figure 14. Spatial visualization of the range of influence of the physical pressures that may affect the SPA Ria Formosa (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

Substances, litter and energy pressures

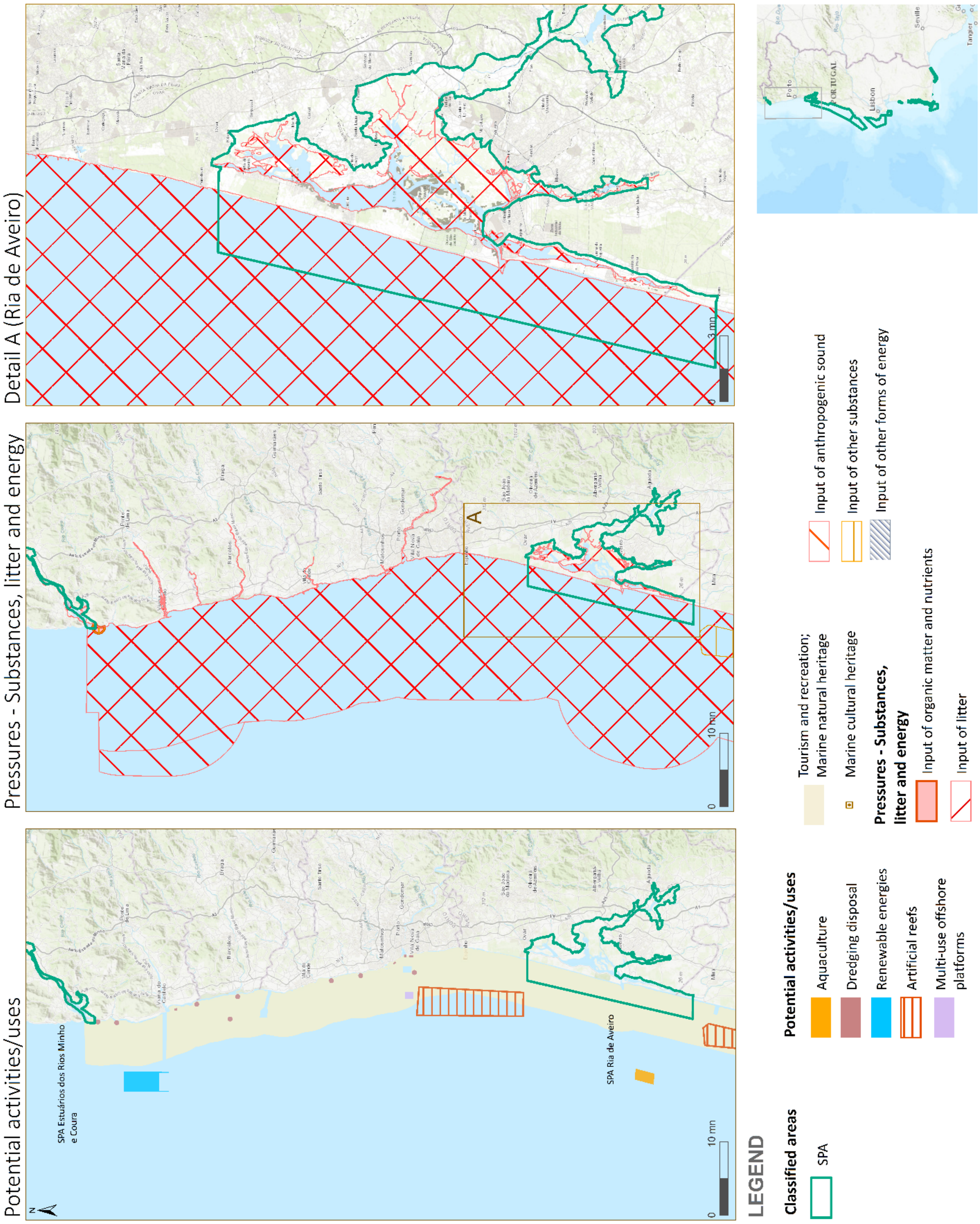


Figure 15. Spatial visualization of the range of influence of the substances, litter and energy pressures that may affect the SPA Estuário dos rios Minho e Coura and Ria de Aveiro (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

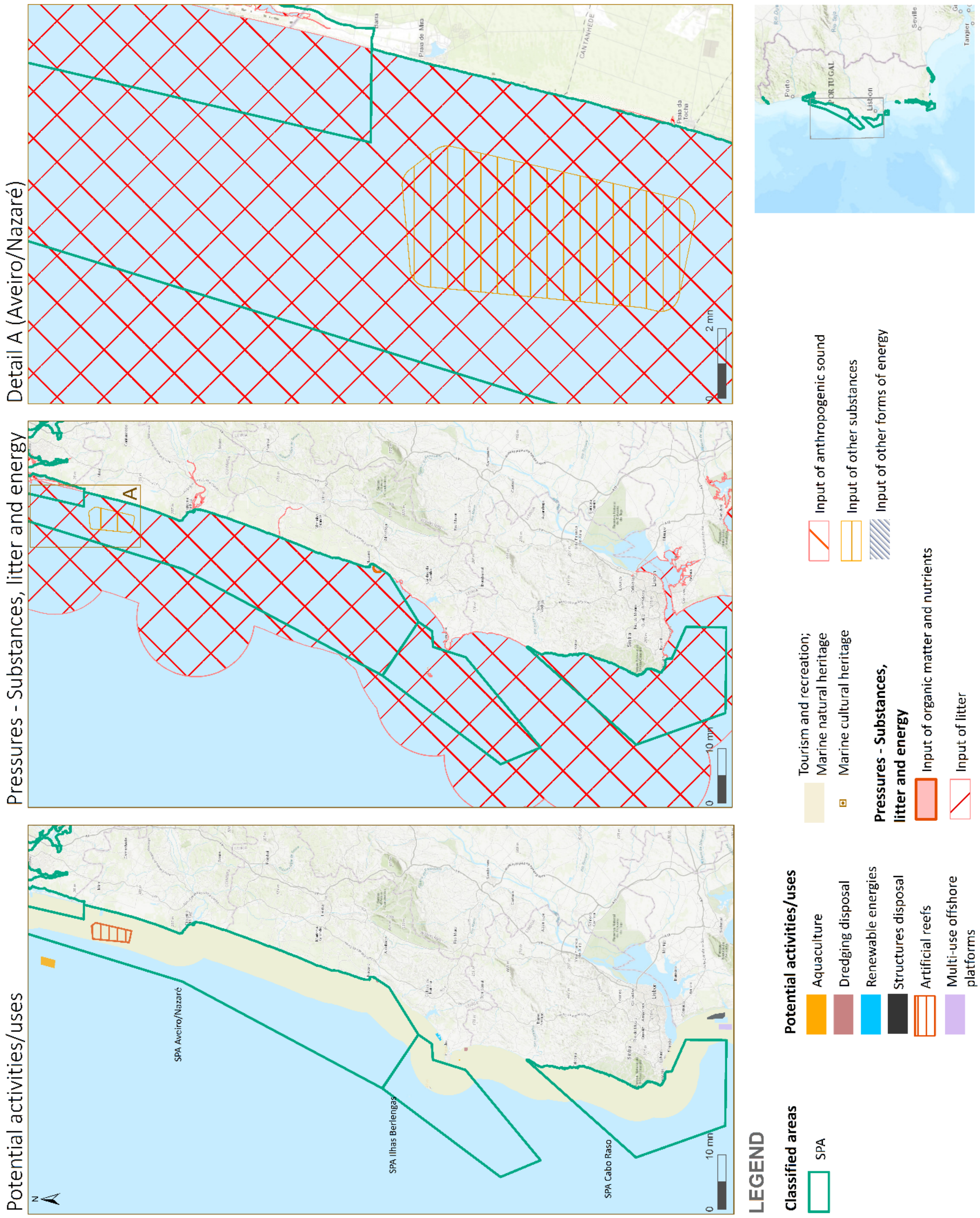


Figure 16. Spatial visualization of the range of influence of the substances, litter and energy pressures that may affect the SPA Aveiro/ Nazaré, Ilhas Berlengas and Cabo Raso (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

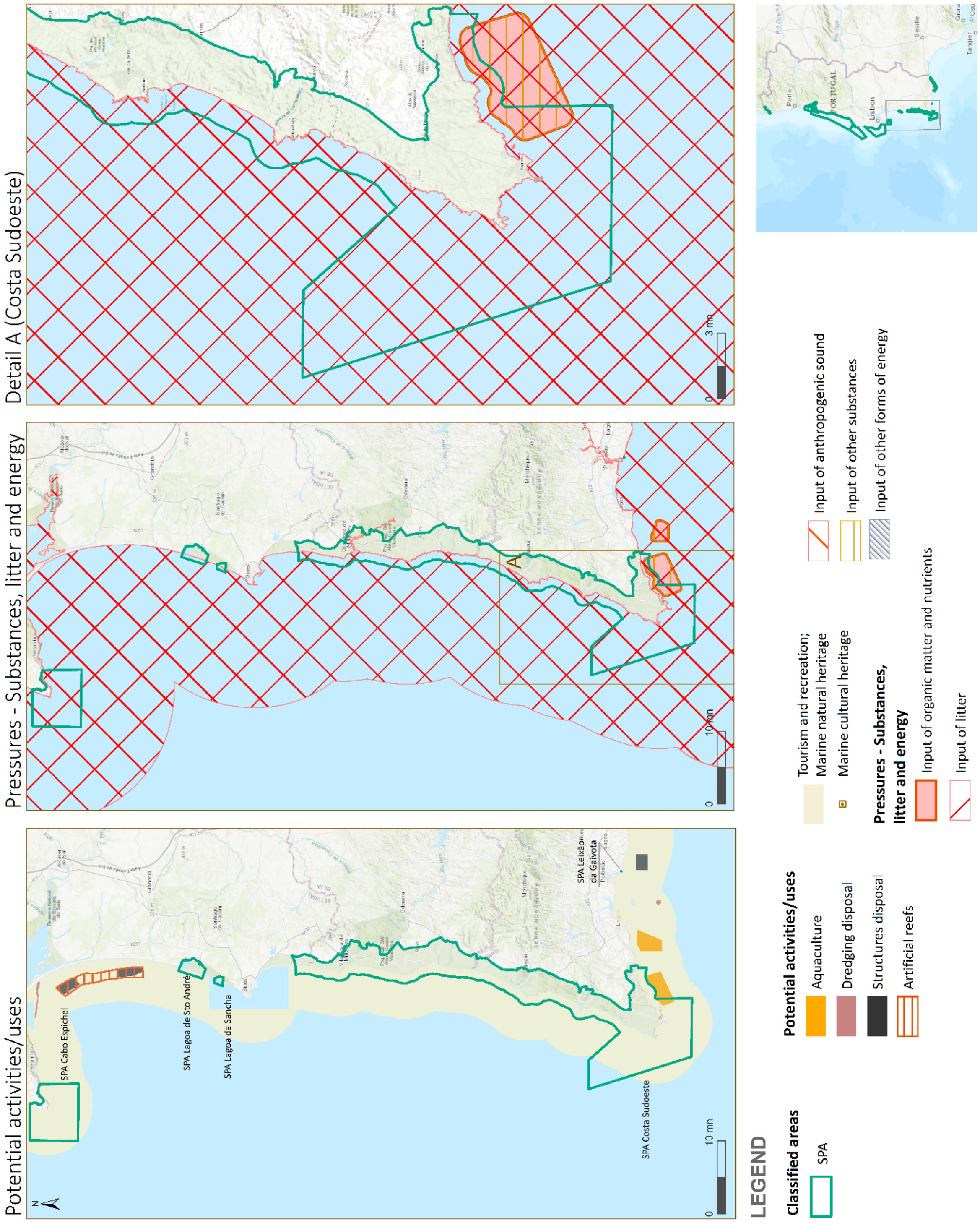


Figure 17. Spatial visualization of the range of influence of the substances, litter and energy pressures that may affect the SPA Cabo Espichel, Lagoa de Santo André, Lagoa da Sancha, Costa Sudoeste and Leixão da Gaivota (Data

sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

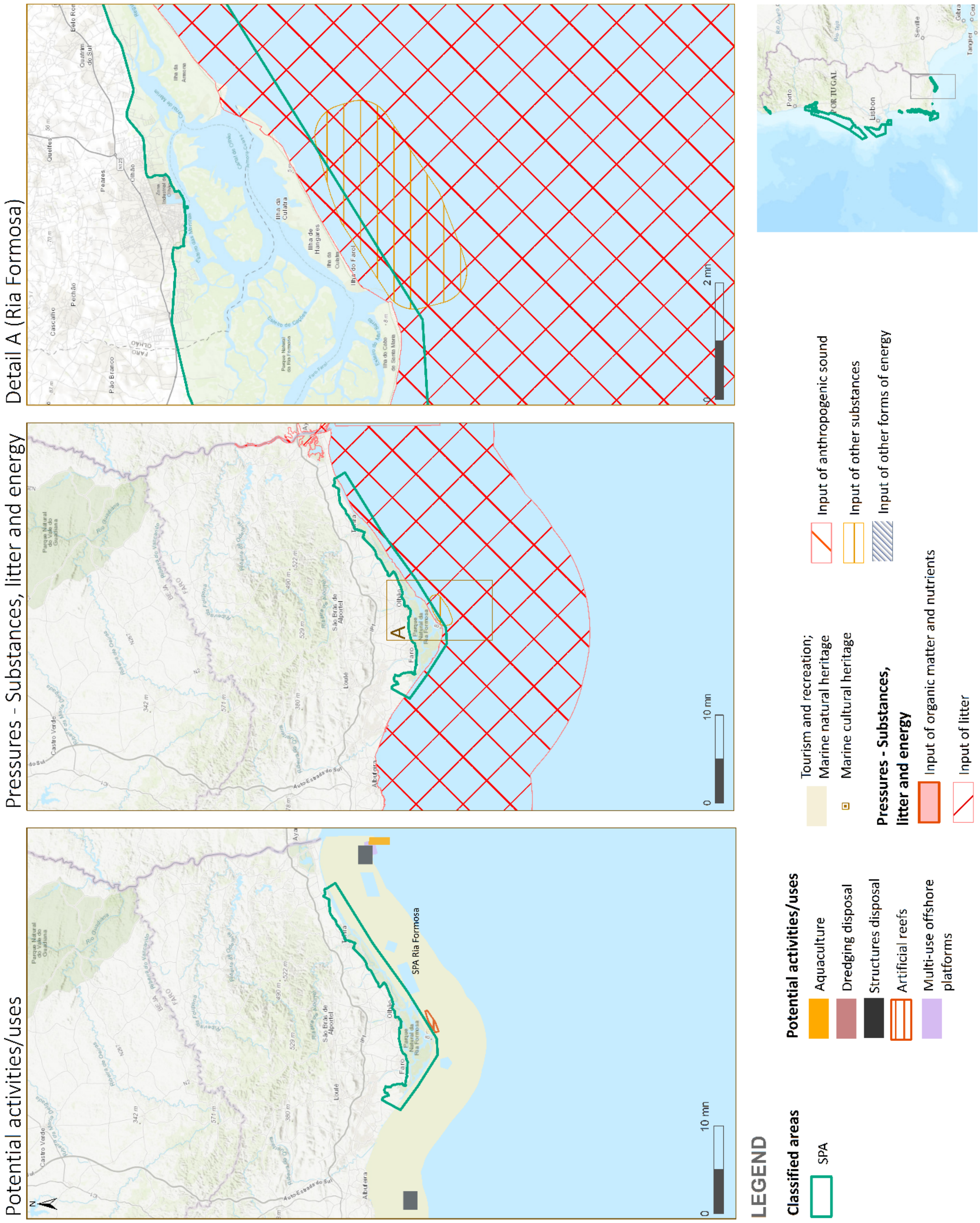


Figure 18. Spatial visualization of the range of influence of the substances, litter and energy pressures that may affect the SPA Ria Formosa (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

Biological pressures

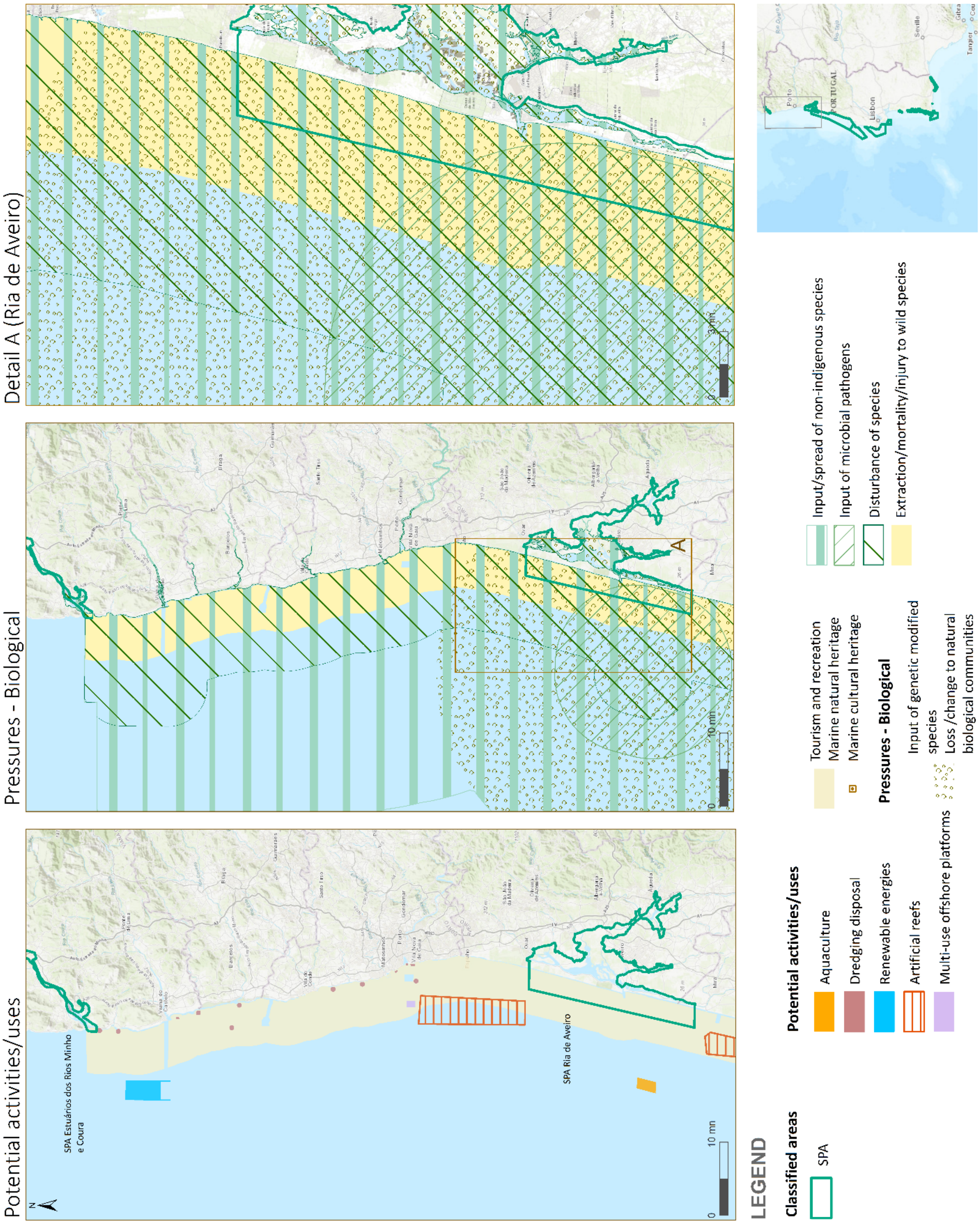


Figure 19. Spatial visualization of the range of influence of the biological pressures that may affect the SPA Estuário dos rios Minho e Coura and Ria de Aveiro (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

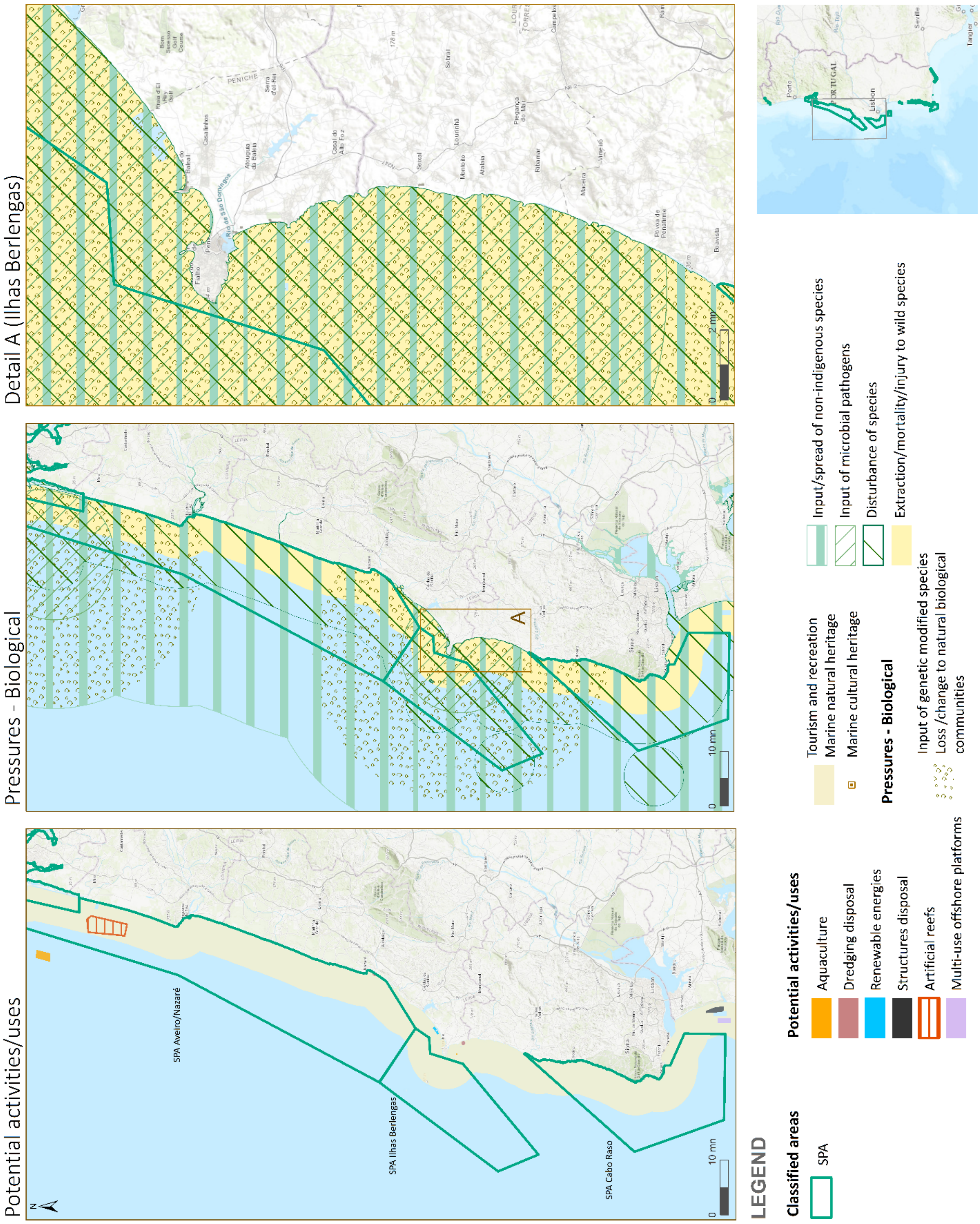


Figure 20. Spatial visualization of the range of influence of the biological pressures that may affect the SPA Aveiro/Nazaré, Ilhas Berlengas and Cabo Raso (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

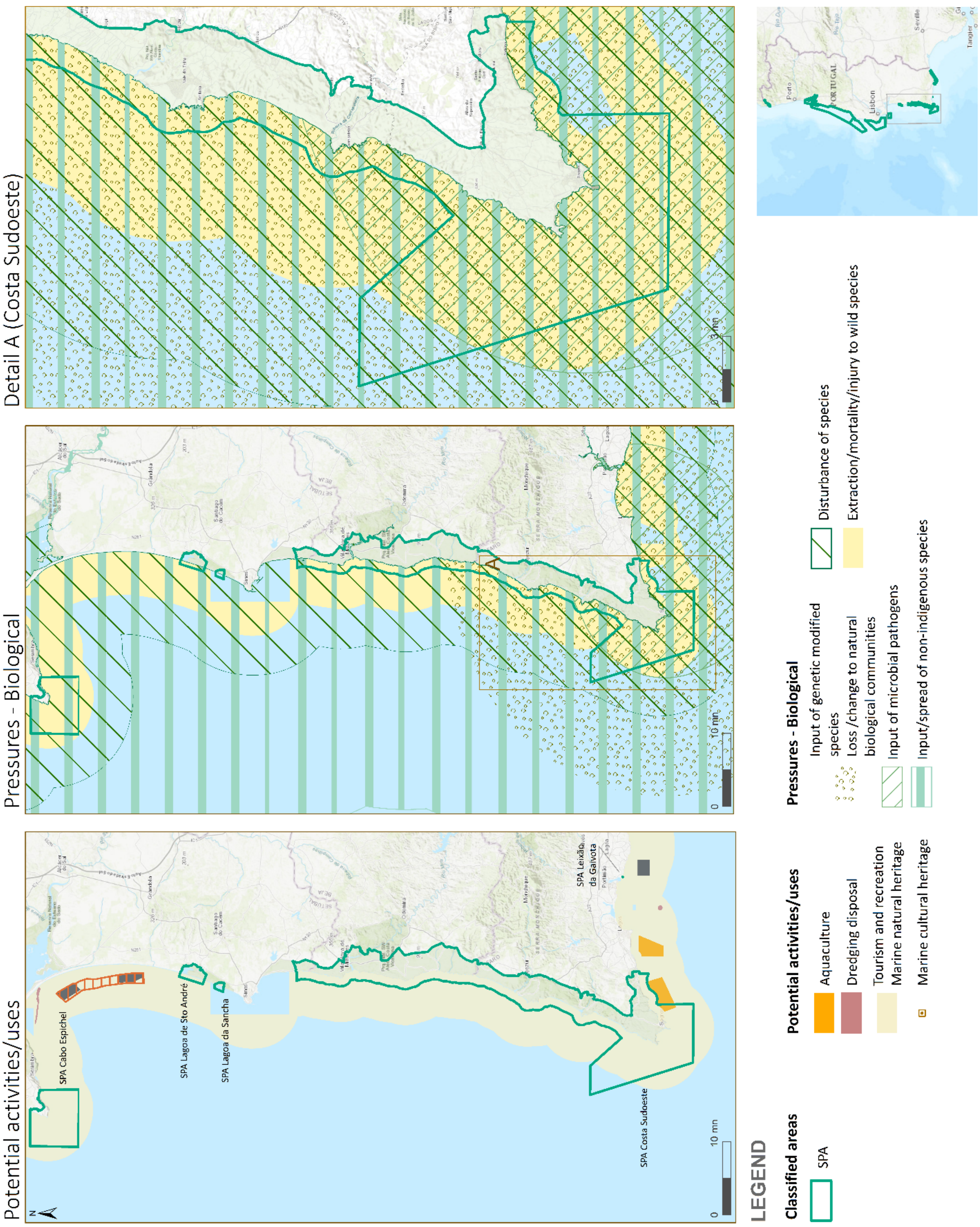


Figure 21. Spatial visualization of the range of influence of the biological pressures that may affect the SPA Cabo Espichel, Lagoa de Santo André, Lagoa da Sancha, Costa Sudoeste and Leixão da (Data sources: "EMODnet Seabed Habitats - Homepage,"2019, ESRI, 2019, ICNF, 2018a, 2018b; "Natura 2000 — ICNF," 2019).

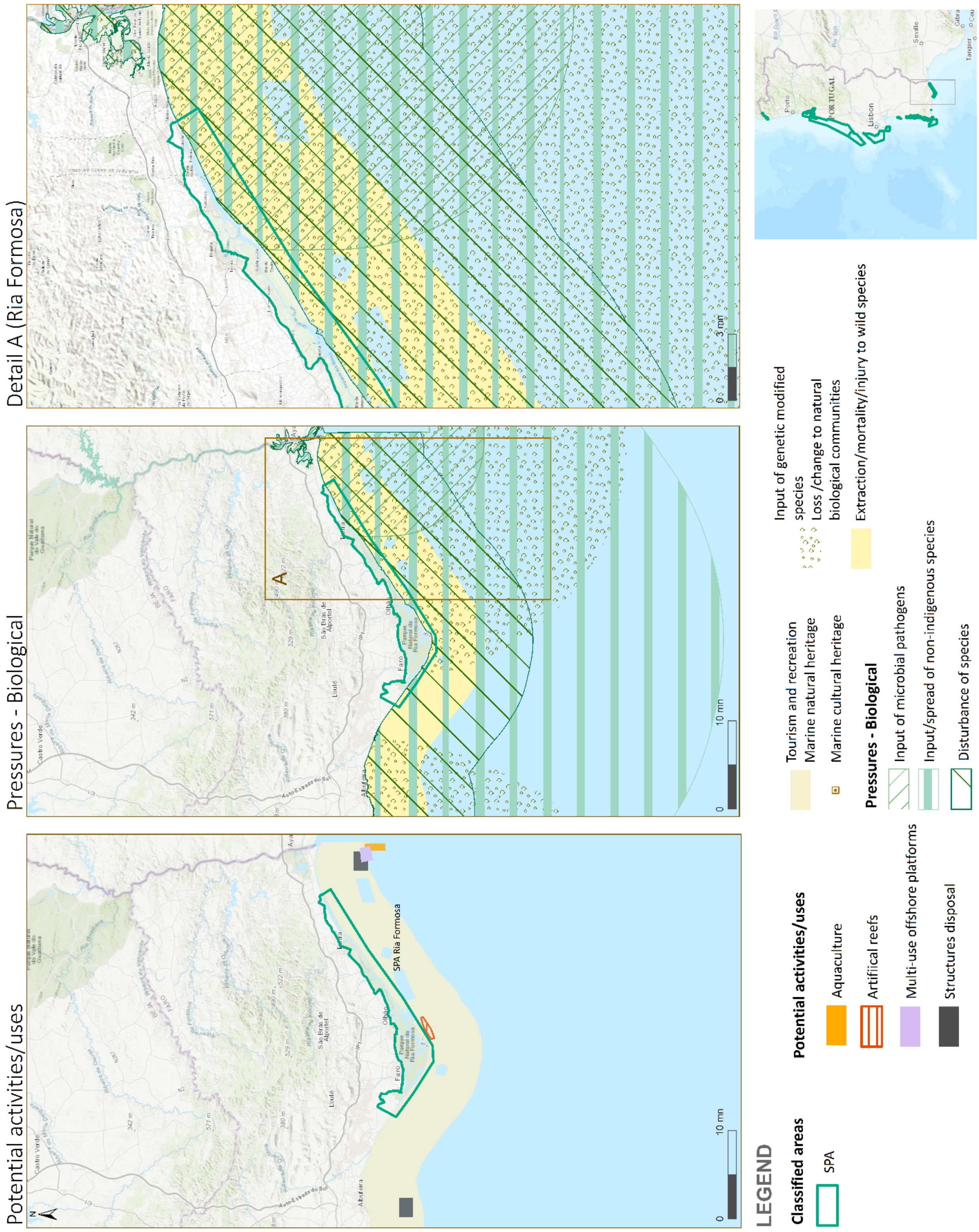


Figure 22. Spatial visualization of the range of influence of the biological pressures that may affect the SPA Ria Formosa (Data sources: “EMODnet Seabed Habitats - Homepage,”2019, ESRI, 2019, ICNF, 2018a, 2018b; “Natura 2000 — ICNF,” 2019).

REFERENCES

EMODnet Seabed Habitats - Homepage [WWW Document], 2019. URL https://www.emodnet-seabedhabitats.eu/ (accessed 1.18.19).

ESRI, 2019 “Topographic” [basemap]. “World Topographic Map” Topographic (Local Language) [WWW Document]. URL https://www.arcgis.com/home/item.html?id=19bf4648d3c2491d832ec67b404613d8 (accessed 2.15.19).

ICNF, 2018a. Relatório de base do plano de gestão da área marinha de cinco SIC: Costa sudoeste, Litoral norte, Arrábida/Espichel, Peniche/Santa Cruz e Sintra/Cascais.

ICNF, 2018b. Proposta de planos de gestão para a área marinha abrangida pelos Sítios Maceda - Praia da Vieira e Costa Sudoeste (revisão) 66.

Natura 2000 — ICNF [WWW Document], 2019. URL http://www2.icnf.pt/portal/pn/biodiversidade/rn2000 (accessed 1.18.19).

SUPPLEMENTARY MATERIAL C

Table 1. Information used as conservation features and their level of protection (CS: Conservation Status, **Low**: LC (Low Concern), Unfavorable; **Medium**: NT (Neat Threatened), Bad; **High**: VU (Vulnerable); EN (Endangered), Threatened. CS obtained from EUNIS, 2018, ICNF, 2013 and IUCN, 2018.

EUNIS Code	Species/Habitats	Period	CS EUNIS	CS ICNF	CS IUCN	Level	Source	Obs.
1110	Sandbanks	N/A	unfavourable-bad	Bad		Medium	ICNF,2013	
1130	Estuaries	N/A	unfavourable-bad	Bad		Medium	ICNF,2013	
1140	Mud	N/A	unfavourable-bad	Unfavourable		Low	ICNF,2013	
1150	Coastal lagoons*	N/A	unfavourable-inadequate	Very bad		High	ICNF,2013	
1160	Large shallow inlets and bays	N/A	unfavourable-bad	Bad		Medium	ICNF,2013	
1170	Reefs	N/A	unfavourable-bad	Moderate-bad		Medium	ICNF,2013	
8330	Submerged caves	N/A	Unknown	Unknown		Medium	ICNF,2013	4)
2618	*Balaenotoptera acutorostrata*	1951-2010	LC	VU		High	Halpin, 2009 ICNF,2013	1)
2621	*Balaenotoptera physalus*	1925-2013	NT	EN		High	Halpin, 2009	1)
1350	*Delphinus delphis*	1967-2013	DD	LC		Medium	Halpin, 2009 INAG, 2011	1)
5686	*Lepidorhombus boscii*	2009-2011	LC	-	-	Low	Halpin, 2009	2)
5715	*Merluccius merluccius*	2009-2011	LC	-		Low	Halpin, 2009	2)
1351	*Phocoena phocoena*	1974-2010	VU	VU	-	High	INAG, 2011	1)
1349	*Tursiops truncatus*	1905-2012	DD	LC		Medium	INAG, 2011 Halpin, 2009	1)
2034	*Stenella coeruleoalba*	1968-2014	DD	LC		Medium	Halpin, 2009	1)
2029	*Globicephala melas*	1992-2010	DD	DD	LC	Medium	Halpin, 2009 ICNF,2013	1)
2030	*Grampus griseus*	1975-2013	DD	DD	LC	Medium	Halpin, 2009 ICNF,2013	1)
2035	*Ziphius cavirostris*	N/A	DD	DD	LC	Medium	Halpin, 2009 ICNF,2013	1)
3022	*Isurus oxyrinchus*	N/A	DD	-	VU	High	Aquamaps, 2017a	2) 5)
5707	*Lophius piscatorius*	N/A	LC	-		Low	Aquamaps, 2017b	2) 5)

EUNIS Code	Species/Habitats	Period	CS EUNIS	CS ICNF	CS IUCN	Level	Source	Obs.
-	*Sardina pilchardus*	2012	NT	-		Medium	INAG, 2011	2) 3)
-	Sea-pen an burrowing megafauna communities	2012	Threatened (OSPAR)			High	OSPAR,2017	
-	*Lophelia pertusa* reefs	2006	Threatened (OSPAR)			High	OSPAR,2017	
-	Net Primary Production (NPP)	Spring data 2010-2014				Medium	EUCMS, 2017	6)

*priority habitat in accordance with Natura 2000 guidelines (EEA, 2007)

1) All Cetacean species are part of the Berna and Bona Convention and listed in ACCOBAMS agreement and CITES (ANEXX 2A). Due to this fact, were all considered at least as medium level or higher.
2) Species added due to reference on the report from Marine Strategy Framework Directive (MAMAOT, 2012). There were 5 species considered with low environmental state, namely: *Sardina pilchardus, Lophius piscatorius*, *Merluccius merluccius*, *Lepidorhombus boscii*, *Isurus oxyrinchus*.
3) Management plan of *Sardina pilchardus* (2012-2015) (DGRM,2018)
4) Despite unknown status its identified in as a biodiversity refuge and important for genetic resource supply (ICNF, 2013).
5) We used data from a predicted reviewed distribution map with modelled native range map. This information provides probabilities of occurrences. From this information, we extracted the locations with probability of occurrence higher than 85% and used it as distribution map of the species (Aquamaps, 2017).
6) Information on NPP was obtained from EU Copernicus Marine Service, 2016. Data from literature allowed to select levels of primary production on spring and summer months as the most intense for the ecosystem production on Portuguese waters (FCG, 2014; ICES, 2008). From this assumption, Net Primary Production was obtained from 2010 to 2014 Spring months. From this data we calculated the average value for each location and selected the top 30% values to be used in the model.

-

•

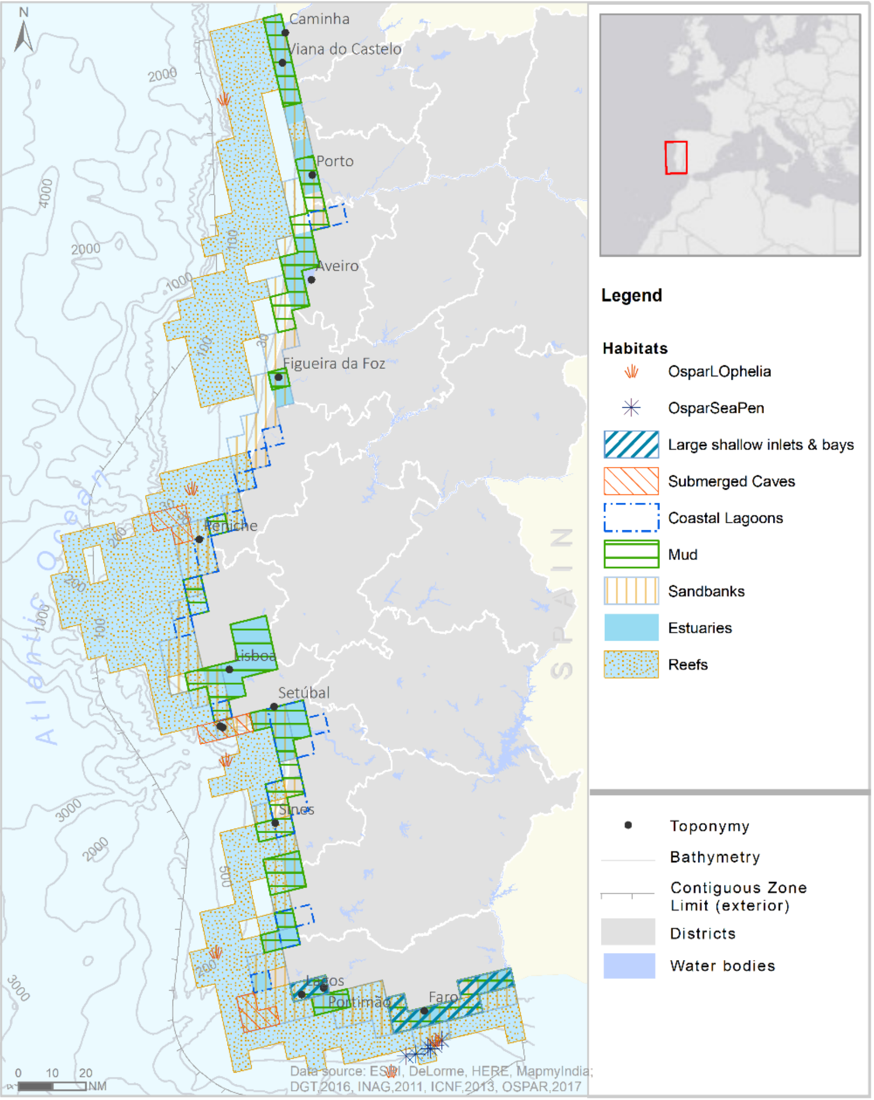


Figure 1. Habitats distribution used in the model

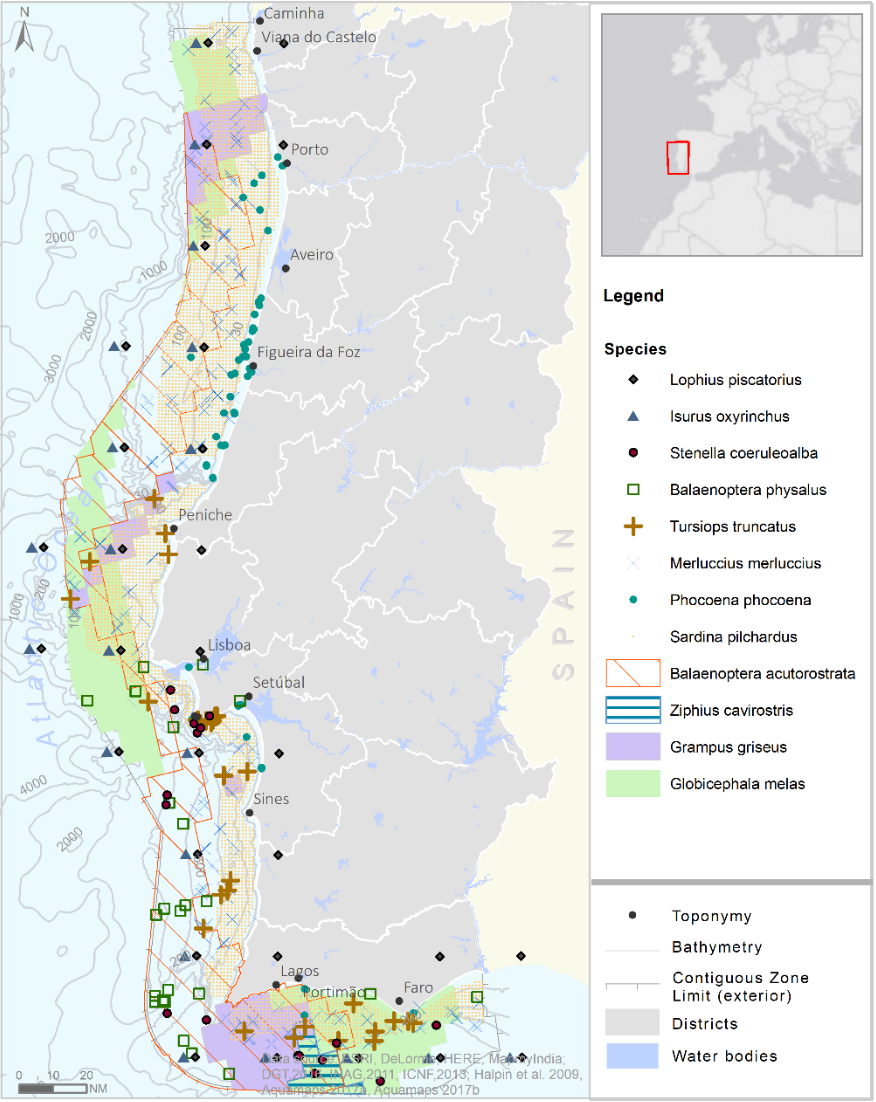


Figure 2. Species distribution used in the model

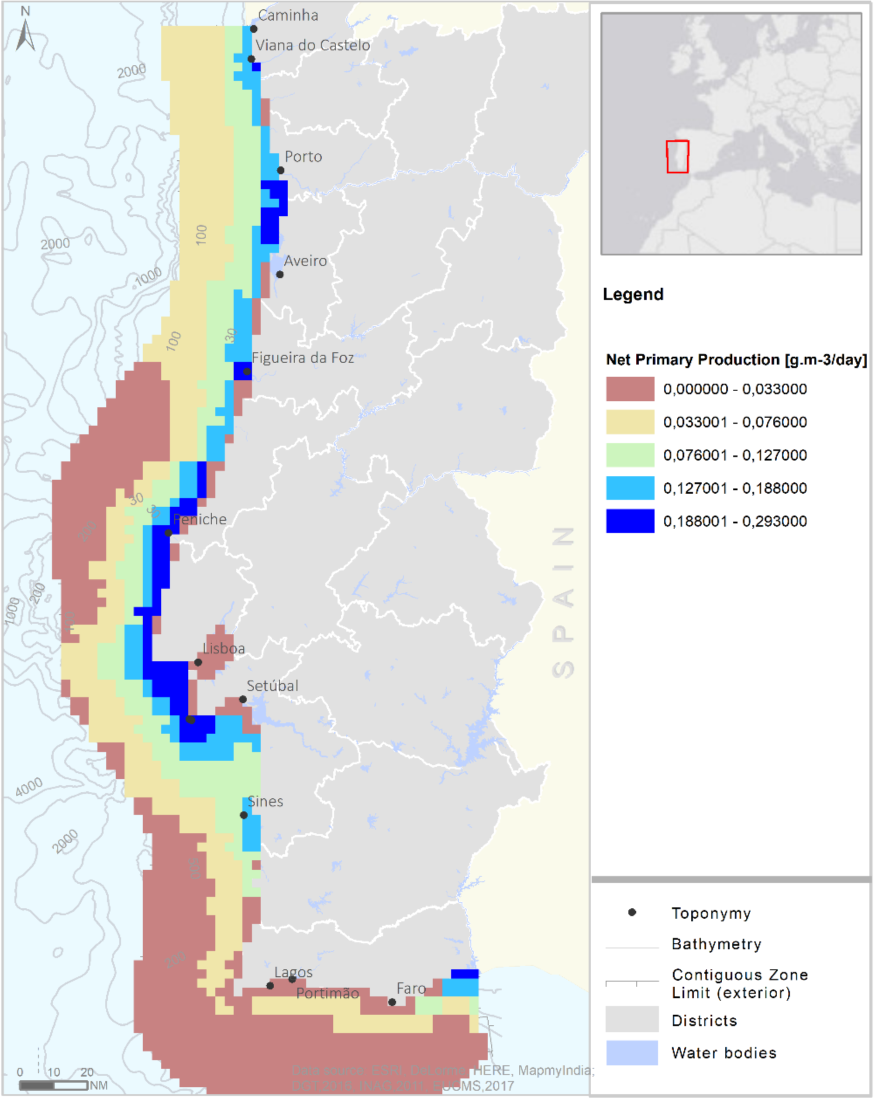


Figure 3. Net Primary Production average from spring data 2010-2014

References

Aquamaps, 2017a. Reviewed distribution maps for *Isurus oxyrinchus* native range map. Aquamaps, 2017. www.aquamaps.org, version of Aug. 2016 (last accessed 15 march 2018).

Aquamaps, 2017b. Reviewed distribution maps for Lophius piscatorius, native range map. www.aquamaps.org, version of Aug. 2016. Web. Last accessed 16 march 2018.

DGRM,2018. Sardine Fishery Management Plan. Available at: https://www.dgrm.mm.gov.pt/plano-de-gestao-da-sardinha (last accessed 19 april 2018)

EEA, 2007. Guidelines for the establishment of the Natura 2000 network in the marine environment . Application of the Habitats and Birds Directives. 112. Available at: http://ec.europa.eu/environment/nature/natura2000/marine/index_en.htm.

EUCMS, 2016. CMEMS-IBI-PUM-005-003.Atlantic IBerian Biscay Irish Ocean Biogeochemistry non assimilative hindcast (2002-2014) Ibi_ Reanalysis_Bio_005_003. EU Copernicus Marine

Service.

EUNIS, 2018. EUNIS: The European Nature Information System Available at: https://eunis.eea.europa.eu/ (last accessed 19 april 2018)

FCG, 2014. The Economic Value of Oceans and in Portugal Policy Brief the Gulbenkian Oceans.

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird and sea turtle distributions. Oceanography 22(2):104-115.

ICES, 2008. ICES advice 2008. Report of the ICES Advisory Committee, Bay of Biscay and Western Iberian Seas.

ICNF, 2013. Rede Natura 2000 – 3º Relatório Nacional de Aplicação da Diretiva Habitats. (2007-2012) Avaliação Global do Estado de Conservação das Espécies [in portuguese].

IUCN, 2018. The IUCN Red List of Threatened Species. http://www.iucnredlist.org/ (last accessed 18/03/2018)

MAMAOT, 2012. Estratégia Marinha para a subdivisão do Continente. Ministério da Agricultura, Mar, Ambiente e Ordenamento do Território; 2012. p. 906 [in Portuguese].

INAG, 2011. POEM—Plano de Ordenamento do Espaço Marítimo, Volume 5 Tomo1: Estudos de Caracterização [in portuguese].

OSPAR, 2017. OSPAR's Data & Information Management System. Mapping habitats on the OSPAR List of Threatened and/or Declining Species and Habitats. https://www.ospar.org/work-areas/bdc/species-habitats/mapping-habitats-on-the-ospar-list-of-threatened-or-declining-species-and-habitats (last accessed 18/03/2018).

SUPPLEMENTARY MATERIAL D

Table.1. Sources, units and years of marine and socioeconomic variables used in the study.

Type		Variables	Unit	Year	Source
Marine		Mean calcite	mol/m³	2002-2009	Bio-ORACLE
		Mean chlorophyll a	mg/m³	2002-2009	Bio-ORACLE
		Minimum chlorophyll a	mg/m³	2002-2009	Bio-ORACLE
		Mean nitrate Mean phosphate	mol/m³	interpolation in-situ measurements	Bio-ORACLE
		Mean salinity	PSS	interpolation in-situ measurements	Bio-ORACLE
		Maximum SST	°C	2002-2009	Bio-ORACLE
		Mean SST	°C	2002-2009	Bio-ORACLE
		SST range	°C	2002-2009	Bio-ORACLE
		Mean phosphate	mol/m³	interpolation in-situ measurements	Bio-ORACLE
		Reefs	% of coverage	2016	EMODNET
		Sand	% of coverage	2016	EMODNET
Socioeconomic	Social	Population density	Ind./km²	2018	INE, 2018b
		Illiterate people	% of inhabitants	2011	INE, 2012
		People with university degree	% of inhabitants	2011	INE, 2012
		People younger than 25	% of inhabitants	2018	INE, 2018
		People older than 65	% of inhabitants	2018	INE, 2018
		People employed in primary sector	% of inhabitants	2011	INE, 2012
		People employed in secondary sector	% of inhabitants	2011	INE, 2012
		People employed in tertiary sector	% of inhabitants	2011	INE, 2012
		Unemployed	% of inhabitants	2018	PORDATA,2018
		Fishers[1]	% of inhabitants	2018	INE,2018

[1] Fishers data was obtained by Port and divided by kilometers of coastline of each municipality

	Economic	Touristic accommodations		2017	INE,2018
		Monthly income per inhabitant	(Euro/hab)	2013	PORDATA,2018
		Gross added value of Fisheries	Euro	2017	INE,2018
		Gross added value of Tourism	Euro	2017	INE,2018
	Land-cover	Urban and industrial areas	% of coverage	2018	DGT,2018
		Agricultural	% of coverage	2018	DGT,2018
		Forests and semi-natural areas	% of coverage	2018	DGT,2018
		Wetlands and water bodies	% of coverage	2018	DGT,2018
		Protected Areas	% of coverage	2018	DGT,2018 ICNF,2018

Table.2. Summary of the socioeconomic PCA showing the eigenvalues and total variance and the factor loadings from the six principal components.

Variables	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Population density	0.34	0.17	-0.10	-0.04	0.19	-0.04
Illiterate people	-0.28	0.32	0.15	0.10	0.07	0.19
People with university degree	0.34	0.01	-0.12	-0.18	-0.02	0.21
People younger than 25	0.15	-0.47	0.16	0.02	-0.18	-0.20
People older than 65	-0.11	0.52	0.02	-0.11	0.11	0.23
People employed in primary sector	-0.26	0.09	0.19	0.01	0.43	0.03
People employed in secondary sector	-0.17	-0.14	-0.52	0.03	0.02	-0.16
People employed in tertiary sector	0.26	0.08	0.38	-0.03	-0.21	0.13
Unemployed	0.23	0.22	-0.07	0.08	0.25	-0.32
Touristic accommodations	0.22	0.18	0.22	0.31	0.07	-0.11
Monthly income per inhabitant	0.27	0.05	-0.16	-0.19	-0.12	0.15
Urban and industrial areas	0.34	0.10	-0.15	-0.06	0.19	-0.14
Agricultural	-0.09	-0.30	0.36	0.33	0.16	0.14
Forests and semi-natural areas	-0.26	0.23	-0.18	-0.04	-0.40	-0.16
Wetlands and water bodies	0.01	-0.20	0.04	-0.46	0.22	0.45
Fishers[2]	-0.15	0.08	0.28	-0.32	0.14	-0.57

[2] Fishers data was obtained by Port and divided by kilometers of coastline of each municipality

Gross added value of fisheries	0.00	-0.21	-0.06	-0.22	0.50	-0.13
Gross added value of tourism	0.33	0.13	0.14	0.20	-0.03	-0.07
Protected areas	0.00	0.05	0.33	-0.54	-0.25	-0.17
eigenvalue	6.44	2.83	2.28	1.58	1.16	0.92
variance	33.87	14.91	12.01	8.33	6.12	4.83
Cumulative variance	33.87	48.77	60.78	69.12	75.23	80.06

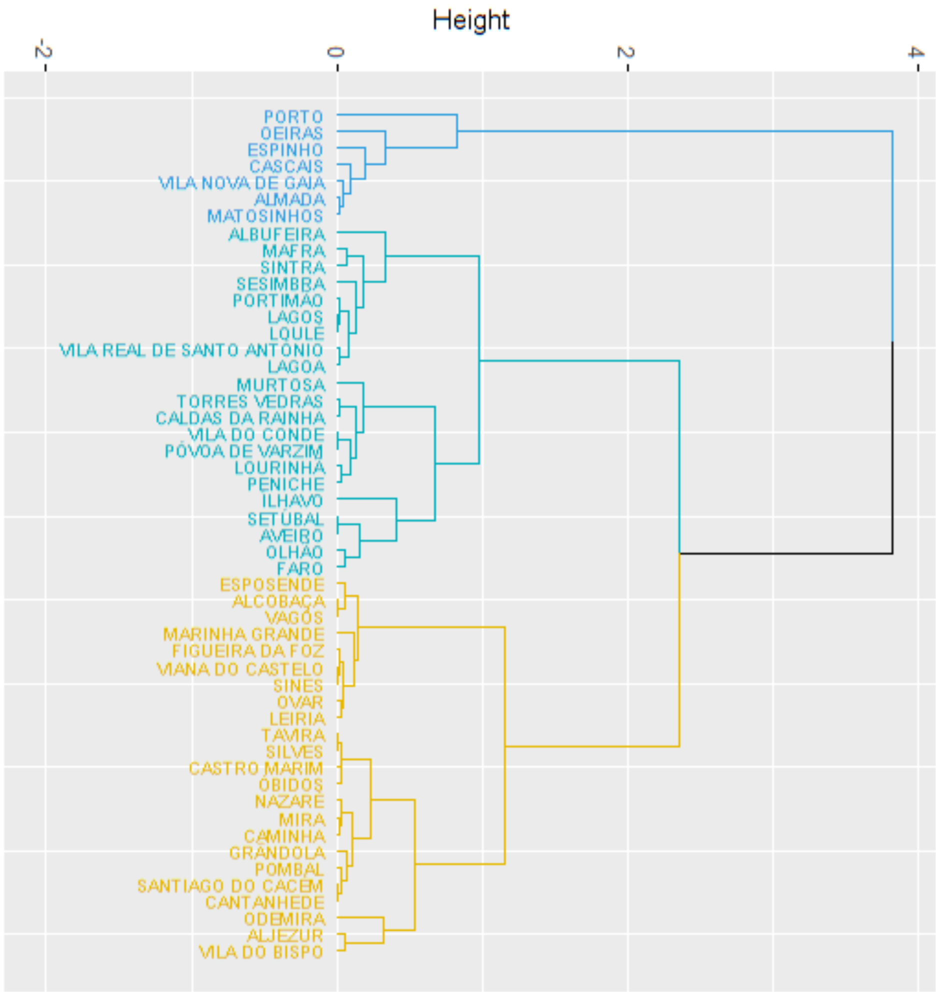


Figure.1. Dendrogram with the municipalities included in each socioeconomic class (SCL)

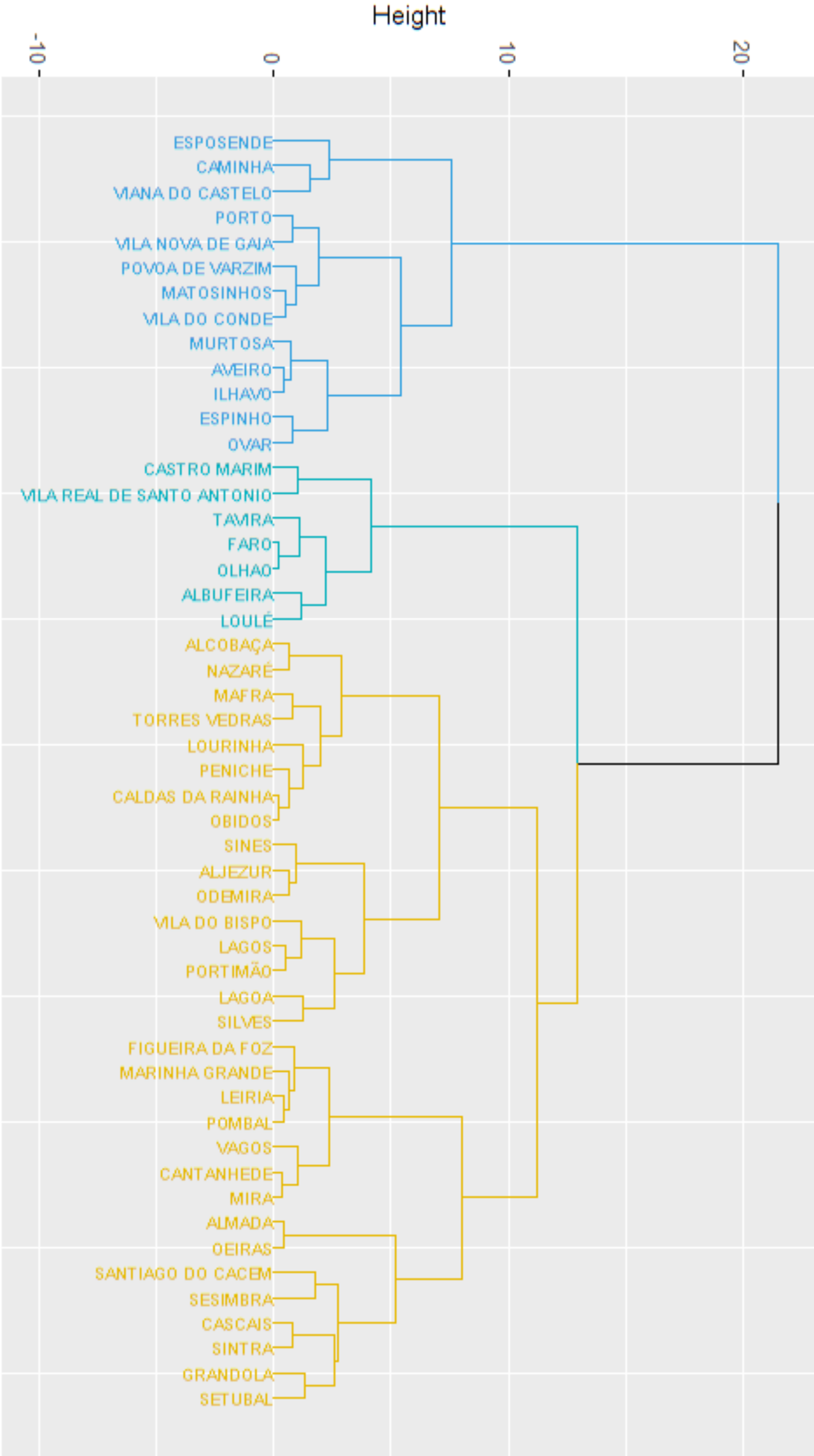


Figure.2. Dendrogram with the municipalities included in each Marine class (MCL)

References

BIO-ORACLE. INE, 2018. Densidade populacional (N.º/ km²) por Local de residência (NUTS - 2013) [WWW Document]. URL https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&contecto=pi&indOcorrCod=0008337&selTab=tab0 (accessed 3.25.20).

INE, 2012. Censos 2011- Resultados Definitivos Portugal. Instituto Nacional de Estatística. Lisboa.

DGT, 2018. Carta Administrativa Oficial de Portugal [WWW Document]. URL http://www.dgterritorio.pt/cartografia_e_geodesia/cartografia/carta_administrativa_oficial_de_portugal__caop_/caop__download_/carta_administrativa_oficial_de_portugal___versao_2016/

INE, 2018. Instituto Nacional de Estatística. https://www.ine.pt/. acessed (14/11/2019)

PORDATA, 2018. Pordata - Estatísticas, gráficos e indicadores de Municípios, Portugal e da Europa. https://www.pordata.pt/. acessed (14/11/2019)

ICNF, 2018. Rede Nacional de Áreas Proegidas (RNAP). Áreas Protegidas de Portugal continental. www2.icnf.pt/portal/ap. acessed (14/11/2019)

SUPPLEMENTARY MATERIAL E

Methodology followed to produce Figure 7.1

The study area was divided into a grid of 5x5 km, as the grid presented in Chapter 3 and 5 (used in the CIM and in Priority of Conservation areas).

- Sea use intensity (Act) was obtained from the addition of each activity dataset, converted into presence/absence grid cells. Each presence in a data cell was counted as 1. The only information used was the footprint of the activities, which was considered as the area where they occurred. Most of the activities were derived from information available at PSOEM (see table E-1), with exception of the activities Shipping and Fishing, where the vessel density information was derived from EMODNET data portal. Density was expressed in hours per square kilometer per month. The lowest interval was excluded to avoid unnecessary noise in the data, due to the low level of expression.

Table -1. List of the activities used to create the variable Sea use Intensity (Act)

Activity	**Source**
Structures disposal	PSOEM (DGRM, 2019a, 2019b)
Aquaculture	
Artificial reefs	
Submarine cables	
Dredging disposal	
Outfalls	
Renewable energies	
Multiuse platforms	
Recreation and tourism (with reserve of space)	
Shipping – Cargo Fishing	Vessel density – Human activities (EMODNET, 2019)

- Cumulative Impact Model (CIM) was derived from the information obtained in Chapter 2, as Figure 3.4 and 3.5 shows.
- Priority of Conservation (PrC) outputs were withdrawn from the model of Chapter 5. The scenario C6 of figure 5.5 was used, where priority of conservation was modeled using

Marxan with cost function as area of the planning unit (meaning no cost). Targets for protection of habitats and species were ranging from 10 to 60(ESRI, 2016)%.

The variables were afterwards normalized between 0 and 1 to bring all the values of the dataset into a common scale and compiled using the following equation:

$$MP = \sum_{i=1}^{i} Act_i + CIM_i - PrC_i$$

The resulting values called here as Marine Patterns (MP) were grouped into distinct levels using the standard classification method 'Natural Breaks (Jenks)', where the class breaks are identified with the best group of similar values and maximizing the variances between classes.

Finally, the resulting variable MP was spatially combined with the outputs of Chapter 6, Socioeconomic Clusters (see figure 6.7a).

References

DGRM, 2019a. Volume III - A. Plano de Situação do Ordenamento do Espaço Marítimo Nacional - Espacialização de servidões, usos e atividades (Continente e Plataforma continental estendida).

DGRM, 2019b. Plano de Situação – Ordenamento do Mar Português [WWW Document]. URL http://www.psoem.pt/geoportal_psoem/ (accessed 1.18.19).

EMODNET, 2019. Vessel Density | EMODnet Human Activities [WWW Document]. URL https://www.emodnet-humanactivities.eu/search-results.php?dataname=Vessel+Density+ (accessed 4.21.20).

ESRI, 2016. Classifying numerical fields for graduated symbology—Help | ArcGIS for Desktop [WWW Document]. URL http://desktop.arcgis.com/en/arcmap/10.3/map/working-with-layers/classifying-numerical-fields-for-graduated-symbols.htm (accessed 8.19.16).