Universidade de Aveiro Departamento de Ambiente e Ordenamento
2017

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MODELO DE INTEGRAÇÃO DOS SERVIÇOS DOS ECOSSISTEMAS NO PROCESSO DE PLANEAMENTO

MODEL TO INTEGRATE ECOSYSTEM SERVICES INTO THE PLANNING PROCESS

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Ciências e Engenharia do Ambiente, 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 da Doutora Ana Isabel Lillebø, Investigadora Principal da Universidade de Aveiro, e do Doutor Geoffrey D. Gooch, Professor da University of Dundee.

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“Parecia-lhe que a vida era aprender, saber sempre mais
e mudar para aceitar sempre mais.”

Valter Hugo Mãe, O Filho de Mil Homens

o júri

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"O coração de um homem não está apenas dentro do seu peito, está também dentro das pessoas que ama, dentro da família, dentro dos amigos."

Afonso Cruz

palavras-chave

mapeamento dos serviços de ecossistemas, abordagem baseada no ecossistema, Programa de Estuário, participação dos atores chave, sistemas socio-ecológicos, Ria de Aveiro

resumo

Os serviços de ecossistemas têm vindo a assumir um papel central na investigação científica, observando-se um crescimento exponencial no número de publicações científicas nas últimas duas décadas. Impulsionado por um conjunto de publicações influentes, designadamente a avaliação global do *Millennium Ecosystem Assessment*, este conceito tem vindo a ser adotado por várias disciplinas no sentido de responder, individual ou conjuntamente, aos desafios decorrentes da complexidade dos sistemas socio-ecológicos. Paralelamente, a nível político, tem-se observado um aumento significativo de iniciativas internacionais e europeias com enfoque nos serviços de ecossistemas, como a criação da *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, a adoção do Plano Global Estratégico para a Biodiversidade, e a adoção da Estratégia Europeia para a Biodiversidade. Vários argumentos têm motivado a sua apropriação, nomeadamente a convicção de que a integração dos serviços de ecossistemas permitirá melhorar o processo de tomada de decisão no desenho e implementação das políticas ambientais, salientando o papel basilar dos ecossistemas no bem-estar humano.

Estes aspetos são particularmente relevantes para as zonas costeiras, uma vez que estas são sistemas socio-ecológicos complexos caracterizados, simultaneamente, por um elevado valor ecológico e elevada vulnerabilidade. Esta circunstância desafia as práticas tradicionais de planeamento e apela a uma gestão mais integradora, adaptativa, inclusiva e fortemente baseada nos ecossistemas. Não obstante o crescente volume de investigação desenvolvido nesta área, a integração dos serviços de ecossistemas no processo de planeamento e tomada de decisão é considerada, ainda, limitada e desafiante, em particular nestes territórios de interface – as zonas costeiras.

Assim, e tendo em consideração os constrangimentos da sua aplicação prática, são objetivos específicos desta investigação: i) desenvolver e discutir uma abordagem, orientada para a gestão do território, que permita identificar, classificar e mapear os serviços de ecossistemas; ii) desenvolver um estudo aprofundado dos serviços de ecossistemas presentes na Ria de Aveiro e zona costeira adjacente, bem como as principais pressões e potenciais impactos; iii) propor um modelo de integração dos serviços de ecossistemas no processo de planeamento espacial, aplicado aos Programas de Estuário.

A figura de Programa de Estuário – por ser um programa de natureza especial, por incidir sobre um sistema socio-ecológico complexo, e por ainda não estar devidamente explorada – foi encarada como uma oportunidade única para investigar esta temática. Criado em 2009, o Programa de Estuário do Vouga não foi, à data, elaborado. Neste contexto real, antevê-se como uma excelente oportunidade de futuro para testar as metodologias e abordagem desenhadas ao longo desta investigação. Apesar do âmbito territorial da investigação ter incidência na Ria de Aveiro e zona costeira adjacente, a abordagem, os resultados e o modelo desenvolvido podem ser replicados noutros sistemas socio-ecológicos que vão para além dos estuários e do território nacional.

A complexidade da área de estudo evidenciou constrangimentos de ordem biofísica, técnica e de gestão territorial. Através deste estudo demonstra-se que é possível, com base na informação existente, mapear múltiplos serviços de ecossistemas e incorporar este tipo de informação no processo de planeamento através da adaptação das práticas correntes (inclusivamente de participação). À medida que novos dados vão surgindo, que os métodos e técnicas vão sendo padronizados, e que as competências técnicas vão evoluindo, a abordagem e metodologias propostas podem ser gradualmente melhoradas, seguindo a lógica da gestão adaptativa.

Constata-se a necessidade de o processo de planeamento envolver várias disciplinas das ciências naturais e sociais, bem como ter em consideração múltiplos tipos de informação, não só relativa aos serviços prestados pelos ecossistemas, mas também às pressões, aos cenários alternativos, e às preferências e preocupações dos atores chave. Finalmente, identificam-se quatro princípios fundamentais que devem orientar a integração dos serviços de ecossistemas no processo de planeamento e gestão territorial: holístico, adaptação, inclusão, integração.

Esta investigação evidencia, de modo inequívoco, a viabilidade e relevância de integração dos serviços de ecossistemas na configuração técnica dos Programas de Estuário, e dos processos de planeamento em geral. Demonstra, ainda, o modo como a integração destes conceitos inova e fortalece o processo de planeamento ambiental e gestão do território, numa ótica de sustentabilidade, coesão territorial e social, respondendo aos atuais desafios societais e contribuindo para o bem-estar humano.

keywords

ecosystem services mapping, ecosystem-based management, Estuary Programme, stakeholder participation, socio-ecological systems, Ria de Aveiro

abstract

Triggered by the Millennium Ecosystem Assessment, among other seminal publications, ecosystem services research has experienced an almost exponential growth over the past two decades. Since then, ecosystem services have become widespread and the concept has been used in different disciplines, separately and in collaboration, to address complex socio-ecological problems. These efforts were accompanied at political level with a number of international and European initiatives, such as the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services, the adoption of the Strategic Plan for Biodiversity of the Convention on Biological Diversity, and the adoption of the EU Biodiversity Strategy. Driving the uptake of ecosystem services is the argument that its integration can lead to better environmental decision-making. Moreover, by emphasizing the ecosystems' central role on human well-being it provides anthropocentric-oriented argumentation for biodiversity and nature conservation.

This is particularly relevant for coastal regions which are complex social-ecological systems with high ecological value but simultaneously under significant pressure. This challenges traditional forms of management and calls for a more integrative, adaptive, inclusive, and ecosystem-based management. Despite of the growing body of work, the actual uptake of ecosystem services into policy and decision-making processes is still limited and challenging.

On this basis, and considering the constraints when putting ecosystem services into practice, this research aims to: i) develop and discuss a management-oriented approach to identify, classify and map the ecosystem services provided by a complex social-ecological system; ii) develop an in-depth study of the ecosystem services present in Ria de Aveiro coastal region, as well as the main pressures and potential impacts; iii) explore the potential of integration of the ecosystem services on spatial planning process, particularly on Estuary Programmes.

Estuary Programmes were seen as a unique opportunity to investigate these issues, since they are special programmes, are focused on complex social-ecological systems, and can be further explored. Though Vouga Estuary Programme was created in 2009, it has not been developed yet, which presents an opportunity for testing the proposed approach and methodologies in the future.

Although it uses Ria de Aveiro costal region as case study, the lessons learned and the proposed model can be used in other social-ecological systems beyond the estuary level or Portugal.

Despite of the identified biophysical, technical and management constraints, this research proved that it is possible to map multiple ecosystem services using available data, and that ecosystem services knowledge can be incorporated in spatial planning process by adapting current planning practices (including participation). As new data becomes available, ecosystem services' assessment methods become standardized, and technical skills evolve, the proposed approach and methodologies can be gradually improved, following the adaptive management rationale.

This research suggests that spatial planning processes need to bring together various disciplines from natural and social sciences, and be informed by multiple layers of information regarding the provision of ecosystem services, pressures, alternative futures and stakeholders' preferences and concerns. Principles such as comprehensive, adaptive, inclusive, and integrative were considered key for guiding ecosystem services integration into spatial planning process.

Additionally, it highlights the viability and relevance of integrating ecosystem services into the technical configuration of Estuary Programs and spatial planning processes, in general. It also demonstrates how the integration of these concepts helps to innovate and strengthen the process of environmental planning and management towards sustainability, territorial and social cohesion, responding to current societal challenges and contributing to human well-being.

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APA I.P.	Portuguese Environment Agency (*Agência Portuguesa do Ambiente*, in Portuguese)
BAU	Business As Usual
BVL	*Baixo Vouga Lagunar* (in Portuguese)
CAP	Common Agricultural Policy
CAOP	Official Administrative Boundaries for Portugal (*Carta Administrativa Oficial de Portugal*, in Portuguese)
CBD	Convention on Biological Diversity
CCDR	Regional Coordination and Development Commission (*Comissão de Coordenação de Desenvolvimento Regional*, in Portuguese)
CCDRC	Regional Coordination and Development Commission of the Centre (*Comissão de Coordenação de Desenvolvimento Regional do Centro*, in Portuguese)
CICES	Common International Classification of Ecosystem Services
CFP	Common Fisheries Policy
CIRA	Inter-municipal Community of the Aveiro Region (*Comunidade Intermunicipal da Região de Aveiro*, in Portuguese)
CNA	Water National Commission (*Conselho Nacional da Água*, in Portuguese)
COS	Land Use/ Land Cover map for Portugal (*Carta de Uso e Ocupação do Solo de Portugal Continental*, in Portuguese)
CW	Coastal Waters
CZP	Coastal Zone Programme
DGPM	Directorate General of Marine Policy (*Direção-Geral de Política do Mar*, in Portuguese)
DGRM	Directorate General for Natural Resources, Safety and Maritime Services (*Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos*, in Portuguese)
DGT	Directorate General for the Territorial Development (*Direção-Geral do Território*, in Portuguese)
DL	Decree-Law (*Decreto-Lei*, in Portuguese)
EBM	Ecosystem-Based Management
EC	European Commission
EEZ	Exclusive Economic Zone

EMODnet	European Marine Observation and Data Network
ENAAC	National Strategy for Climate Change Adaptation (*Estratégia Nacional de Adaptação à Alterações Climáticas*, in Portuguese)
ENCNB	National Strategy for Nature Conservation and Biodiversity (*Estratégia Nacional da Conservação da Natureza e da Biodiversidade*, in Portuguese)
ENGIZC	National Strategy for Integrated Coastal Zone Management (*Estratégia Nacional para a Gestão Integrada da Zona Costeira*, in Portuguese)
ENM	National Ocean Strategy (*Estratégia Nacional para o Mar*, in Portuguese)
ERPVA	Structure for environmental protection and enhancement (*Estrutura Regional de Proteção e Valorização Ambiental*, in Portuguese)
ES	Ecosystem Services
ETRS	European Terrestrial Reference System
EU	European Union
EUNIS	European Nature Information System
FG	Focus Groups
FW	Freshwaters
G	Global
GIS	Geographic Information System
GNP	Gross National Product
ICNF, I.P.	Institute for Nature Conservation and Forestry (*Instituto para a Conservação da Natureza e Florestas,* in Portuguese)
ICZM	Integrated Coastal Zone Management
IGP	Portuguese Geographic Institute
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
L	Local
LBOGEM	Law for the Maritime Spatial Planning Framework (*Lei de Bases do ordenamento e Gestão do Espaço Marítimo Nacional*, in Portuguese)
LBPPSOTU	Law For The Public Policy Of Soil, Spatial Planning And Urbanism (*Lei de Bases Gerais da Política Pública de Solos, de Ordenamento do Território e de Urbanismo*, in Portuguese)
LU/LC	Land Use/ Land Cover
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MSFD	the Maritime Strategy Framework Directive

MSP	Marine Spatial Planning
N	National
NA	Non Applicable
NS	Not Specified
NUTS	Nomenclature of Territorial Units for Statistics
OMG	Ovar – Marinha Grande
PAPVL	Action Plan for Littoral Protection and Enhancement (*Plano de Ação de Proteção e Valorização do Litoral*, in Portuguese)
PDM	Municipal Master Plan (*Plano Diretor Municipal*, in Portuguese)
PE	Estuary Programme (*Programa de Estuário*, in Portuguese)
PES	Payment for Ecosystem Services
PGBH	River Basin Management Plan (*Plano de Gestão das Bacias Hdrográficas*, in Portuguese)
PGRI	Flood Risk Management Plan (*Plano de Gestão dos Riscos de Inundações*, in Portuguese)
PNA	Water National Plan (*Plano Nacional da Água*, in Portuguese)
PNAC	National Programme for Climate Change (*Programa Nacional para as Alterações Climáticas*, in Portuguese)
PNPOT	National Programme For Land Use Policy (*Programa Nacional da Política de Ordenamento do Território*, in Portuguese)
POOC	Coastal Zone Management Plan (*Plano de Ordenamento da Orla Costeira*, in Portuguese)
POC	Coastal Zone Programme (*Programa para a Orla Costeira*, in Portuguese)
PORNDSJ	São Jacinto Dunes Nature Reserve Spatial Plan (*Plano da Área Protegida Reserva Natural das Dunas de S. Jacinto*, in Portuguese)
PROT-C	Regional Spatial Plan for Centre (*Plano Regional do Ordenamento do Território do Centro*, in Portuguese)
PSRN2000	Sectoral Plan for Natura 2000 Network (*Plano Sectorial da Rede Natura 2000*, in Portuguese)
R	Regional
RCM	Council of Ministers' Resolution (*Resolução do Conselho de Ministros*, in Portuguese)
REN	National Ecological Reserve (*Reserva Ecológica Nacional*, in Portuguese)
SCI	Site of Community Importance
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SWOT	Strengths, Weaknesses, Opportunities, and Threats

T	Task
TE	Terrestrial Ecosystems
TEEB	The Economics of Ecosystems and Biodiversity
TW	Transitional Waters
UNIR@RIA	Ria de Aveiro Inter-municipal Master Plan (*Plano Intermunicipal de Ordenamento da Ria de Aveiro*, in Portuguese)
WFD	Water Framework Directive
WP	Work Package

1 Introduction

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Sousa L.P., Lillebø A.I., Gooch G.D., Soares J.A., Alves F.L., 2013. Incorporation of Local Knowledge in the Identification of Ria de Aveiro Lagoon Ecosystem Services (Portugal). *Journal of Coastal Research*, SI 65: 1051-1056. DOI: 10.2112/SI65-178.1

Alves F.L., Sousa L.P., Almodovar M., Phillips M.R., 2013. Integrated Coastal Zone Management (ICZM): a review of progress in Portuguese implementation. *Regional Environmental Change*, 13: 1031-1042. DOI: 10.1007/s10113-012-0398-y

1.1. Setting the scene

Over the last two decades there has been an almost exponential growth in scientific research concerning ecosystem services (ES, Figure 1) and related concepts, such as natural capital, triggered by the seminal publications of (i) Daily (1997), which provides the first definition of ES and highlights that *"(...) failure to foster the continued delivery of ecosystem services undermines economic prosperity, forecloses options, and diminishes other aspects of human well-being"*, and (ii) Costanza *et al.* (1997), in which the value of world's natural capital and ecosystem services was estimated, stressing the importance of ES for human well-being and boosting the assessment and valuation of ES worldwide.

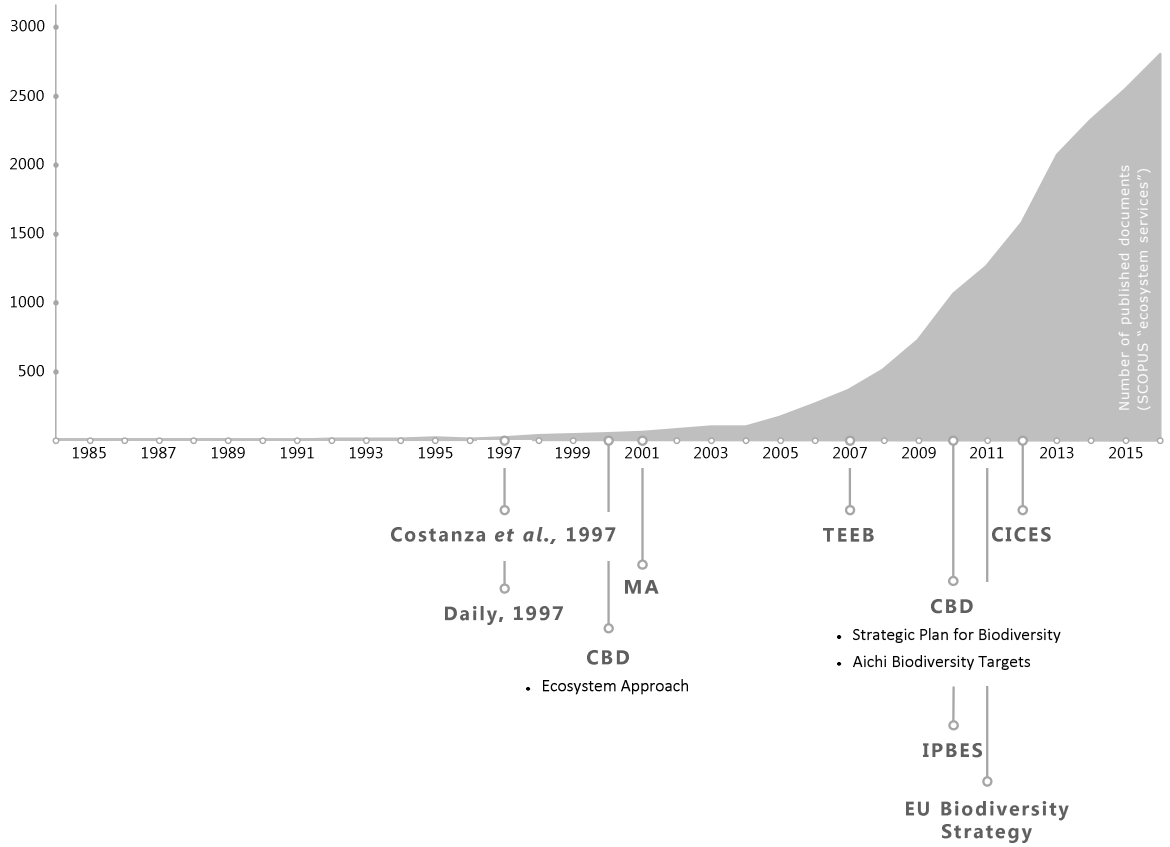


Figure 1. Milestones in ecosystem services and related concepts research and policy agreements.

Another milestone contributing to the mainstream of ES concept was the Millennium Ecosystem Assessment study on the consequences of ecosystems change for human well-being (MA, 2005a), which alerted for the decline of ecosystems services worldwide, promoted the use of ES to inform decision-makers, and called for more research on measuring, modelling, and mapping ES, as well as assessing changes in their supply in relation to human well-being (Martin-Ortega *et al.,* 2015; Häyhä and Franzese,

2014). The Economics of Ecosystems and Biodiversity (TEEB) was another important initiative, launched to draw attention to the global economic benefits of biodiversity and the costs of biodiversity loss (Häyhä and Franzese, 2014; Portman, 2013; TEEB, 2010).

Since then, the notion of ecosystem services has become widespread. It inspired collaboration and enhanced communication between scientists from different disciplines to address complex social-ecological problems (Martin-Ortega *et al.,* 2015). As result, a number of studies, projects and pilots have been developed (e.g., OpenNESS - Operationalisation of Natural Capital and Ecosystem Services; ESMERALDA - Enhancing Ecosystem Services Mapping for Policy and Decision Making; OPERAs - Ecosystem Science for Policy & Practice; EKLIPSE – Knowledge and Learning Mechanism on Biodiversity and Ecosystem Services; MAES - Mapping and Assessment of Ecosystems and their Services; AQUACROSS - Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies), leading the research on ES to different directions – from theoretical conceptualizations to practical applications (La Notte *et al.,* 2017).

These efforts were accompanied by the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) in 2010, dedicated to assess the state of biodiversity and ecosystem services in order to strengthen the science-policy interface for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development; and by the incorporation of the ecosystem services notion into a number of policy agreements and initiatives, including:

- [2010] The Strategic Plan for Biodiversity of the Convention on Biological Diversity (CBD) and the commitment to reach its Aichi Biodiversity Targets for the period 2011-2020. While these targets cover a wide range of conservation concerns, four of them (Targets 1, 2, 14 and 15) are particularly important when addressing ecosystem services:
    - › increasing public awareness of the values and sustainable use of biodiversity (Target 1);
    - › integrating biodiversity values into national development and poverty reduction action plans (Target 2);
    - › safeguarding ecosystems and essential services (Target 14); and
    - › restoring ecosystems and enhancing resilience (Target 15).
- [2011] The European Union's (EU) Biodiversity Strategy, which aims to halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020. It includes six targets (and 20 associated actions), one of which is specifically focused on ES:
    - › maintaining and restoring ecosystems and their services (Target 2).

Ecosystem service is a relatively young but rapidly developing interdisciplinary research field. What started as a concept from the fields of applied ecology and ecological economics evolved (by expanding the scope, the approach, and developing the methods) and is now commonly addressed in different disciplines (e.g., geography, landscape planning) within science, policy and practice. Driving the uptake of ES concept is the argument that ES can lead to better environmental decision-making (Bennett, 2017) as it offers a framework improvement in:

- understanding the links between ecosystems and human well-being (Grizzetti *et al.,* 2016; MA, 2003) as well as forecast how management decisions might affect the provision of services in the future (Bennett, 2017; Albert *et al.,* 2014a);
- highlighting the essential role of ecosystems in the support of human well-being;
- communicating environmental issues to engage science–policy–society (Partelow and Winkler, 2016); and
- promoting the horizontal (e.g., ministries, agencies and other governmental bodies) and vertical (e.g., international, national and subnational actors) policy integration (Mann *et al.*, 2015).

This is particularly relevant for coastal regions, which are complex social-ecological systems in the interface between marine and fluvial, terrestrial and aquatic environments that provide a wide range of services that contribute to the mankind growth and development (MAOTDR, 2009), but are simultaneously among the most threatened in the world (MA, 2003). These ecosystems and the services they provide are becoming increasingly vulnerable (Agardy, 2010), experimenting biological, physical, chemical and social transformations, mostly forced by external pressures resulting from anthropogenic actions that can be exacerbated by climate change (IPCC, 2014). Therefore, there is a need for improvement of convectional management practices, through a more integrated, adaptive, inclusive and ecosystem-based approach (Li *et al.*, 2016; Long *et al.*, 2015: Alves *et al.*, 2013a). Despite of the growing body of work, the actual integration of such principles into policy and decision-making processes particularly the ES concept is poor and presents some challenges such as:

- the compartmentalization of services (Muradian and Rival, 2013), i.e., decisions are frequently interdisciplinary and involve multiple services, meaning that disciplinary, static and single-service knowledge might not be enough to decision-makers (Bennett, 2017);
- balancing the diverse interests of different actors on different scales when negotiating trade-offs (Loft *et al.*, 2015);

- the gap between knowledge generation and knowledge application (Muradian and Rival, 2013; Opdam *et al.*, 2002);
- difficulties in incorporating the ES concept into existing planning processes, regulations, and management programmes (Mann *et al.*, 2015; Rall *et al.*, 2015; Portman, 2013);
- the sectoral organization of environmental administrations (Mann *et al.*, 2015);
- crossing landscape units: marine as opposed to terrestrial (Portman, 2013);
- the additional amount of planners' workload and financial resources for data collection and assessment (Albert *et al.* 2014b).

This research aims to address some of these challenges and to contribute to the conversion of such concepts into actual actions.

1.2. Aim and objectives

The central assumption of this research is that the governance process of complex social-ecological systems, such as coastal regions, towards sustainability can be improved by incorporating the ecosystem services notion into its current framework, given that ecosystem services concept is understood as providing numerous opportunities to move towards a better policy-making and decision-making process, a more integrated and inclusive management, and ultimately towards sustainable development. Nevertheless, the actual uptake of ES into policy and decision-making processes is still limited and challenging. Moreover, the ES information needs to be adapted to specific context and meet the strategic goals in order to be beneficial for practice (Albert *et al.*, 2014a). Based on this premise, and considering the constraints when putting ES on practice, this research aims to explore the potential of using ES knowledge to inform policy and decision-making in the context of complex social-ecological systems, and to suggest a model to integrate ES into the planning process.

Although it uses Ria de Aveiro costal region as case study, the lessons learned and the proposed model in this study can be used in other social-ecological systems beyond the estuary level or Portugal, by adapting the approach to the available data and scale of analysis.

The specific goals of this research are:

- to develop and discuss a management-oriented approach to identify, classify and map the ecosystem services provided by a complex social-ecological system (Chapter 3);

- to develop an in-depth study of the ecosystem services present in the Ria de Aveiro coastal region, as well as the main pressures acting on this region and the potential impacts on the provision of services (Chapter 4, Chapter 5);
- to explore the potential of integration of the ES concept into planning and governance process of complex social-ecological systems, and propose a conceptual approach for ES integration in Estuary Programmes (Chapter 6; Chapter 7).

1.3. Research design and outline

1.3.1. Territorial scope

Coastal territories are considerably diverse and complex, particularly those integrating estuaries or coastal lagoons as they are transition areas between freshwater and marine systems, and between aquatic and terrestrial systems (Sousa *et al.,* 2015). These are ecosystems of strategic importance as they play a crucial role in almost all biogeochemical processes that sustain the biosphere and provide a variety of goods and services that have greatly contributed to the mankind growth and development (MAOTDR, 2009). As already highlighted by several authors (e.g. MAOTDR, 2009; MA, 2005b; Emerton and Bos, 2004; Stuip *et al.*, 2002; Daily *et al.*, 1997), they play, for instance, a fundamental role in the hydrological cycle by storing, regulating and recharging both surface and sub-surface water supplies, as well groundwater.

By acting as reservoirs for holding water, coastal lagoons delay and even out peak flow releases (attenuating downstream flooding) as well as release water in the dry season to maintain flows. Biotic and abiotic components of coastal lagoons also absorb, filter, process and reduce the availability of nutrients, pollutants and wastes. They tend to have a high primary production, providing a rich source of energy for all forms of life, including fish, and are favoured breeding grounds and nurseries for both freshwater and marine species. Also, a wide range of products is harvested from coastal lagoons such as fish and other aquatic species, construction materials, fuel, wild foods and medicines, fodder and pasture. Their biological components play an important role in the global carbon cycle, acting as sinks for carbon and reducing its emission. Furthermore, coastal lagoons provide protection from natural hazards by acting as a protection strip on the coast, mitigating the vulnerability of coastal areas to rising sea levels and erosion.

Coastal areas are highly dynamic natural systems characterized by an intense human presence and activity, being subject to powerful and growing pressures and impacts (Alves *et al.,* 2014; Agardy, 2010;

Martí *et al.*, 2007). Point and non-point source pollution, overfishing, infrastructures (e.g., dams), changing coastlines due to coastal erosion, storm surge and sea level rise, as well as management and policy decisions are among the pressures that threaten these interface systems (Bennett *et al.*, 2016; Dolbeth *et al.*, 2016; Pittman and Armitage, 2016; Carpenter *et al.*, 2009). As human population and consumption increase, drivers of ecosystem change intensify and feedbacks among ecosystem services and human well-being become stronger and more complex (Carpenter *et al.*, 2009; MA, 2003).

The strategic importance of coastal regions, at environmental, economic, social, cultural, and recreational levels is widely recognized, which has been reflected in the initiatives of international organizations, as well as in European policies and national legislation and initiatives (Sousa and Alves 2014; Alves *et al.,* 2013a; MAOTDR 2007a). In 1992, at the United Nations Conference on Environment and Development, it was approved the Agenda 21, which has a chapter entirely dedicated to oceans, seas and coastal areas, as well as to the protection, use and rational development of living marine resources. At this conference, coastal nations have committed themselves to sustainably develop coastal areas and implement Integrated Coastal Zone Management (ICZM) strategies (MAOTDR, 2007a, 2007b; EEA, 2006). Subsequently, from 1996 to 1999, the European Commission (EC) operated an ICZM Demonstration Programme for the purpose of providing technical information on ICZM, and launching a wide-ranging debate among the different actors involved in the planning, management and use of European coastal areas (Pickaver and Ferreira 2008; CEC, 2007). The Programme contributed to a formal agreement on eight principles of good practice[1], outlined in the EU ICZM Recommendation (2002/413/EC), and ICZM Strategy (2000/547/EC) (Smith *et al.*, 2011; Ballinger *et al.,* 2010; Gibson 2003). Based on these principles, the Recommendation invited coastal Member States to develop national strategies for ICZM implementation (Calado *et al.* 2009), guaranteeing the protection and re-qualification of the coast, its economic and social development, as well as the coordination of sectoral policies affecting coastal areas. In 2007, an intensive debate began on the creation of a European maritime policy, resulting in the adoption of the Blue Paper - An Integrated Maritime Policy for the European Union (COM(2007)575 final), and the Maritime Strategy Framework Directive (MSFD, 2008/56/EC). Coastal zones are also addressed in other European legislation, such as the Environmental Impact Assessment Directive (2001), the Water Framework Directive (WFD, 2000), the Quality of Bathing Water Directive (2005), the EU Strategy on Adaptation to Climate Change (2013).

[1] ICZM principles: a broad overall perspective; a long-term perspective; adaptive management; local specificity; working with natural processes and respecting the carrying capacity of ecosystems; involving all the parties concerned in the management process; support and involvement of relevant administrative bodies at national, regional and local level; and use of a combination of instruments.

Having an extensive coastline and Exclusive Economic Zone (EEZ), Portugal realised its strategic importance and followed the international and European trends through the adoption of strategies and management tools which aim to safeguard and promote the sustainable development of coastal and marine areas. Among them are (Sousa and Alves, 2014; Alves *et al.,* 2013a):

- the creation, in 1971, of the Maritime Public Domain;
- the adoption, in 1990, of Coastal Zone Land Use Principles;
- the creation, in 1993, of Coastal Zone Management Plans;
- the adoption, in 2005, of the Water Law, which is the Portuguese legal instrument for the WFD;
- the adoption, in 2006, of the National Ocean Strategy;
- the creation, in 2008, of Estuary Management Plans;
- the creation, in 2008, of the Maritime Spatial Plan;
- the adoption, in 2009, of the National Strategy for Integrated Coastal Zone Management;
- the adoption, in 2010, of the Marine Strategy, which is the Portuguese legal instrument for the MSFD;
- the adoption, in 2014, of the national maritime policy;

The case study of Ria de Aveiro coastal region

Ria de Aveiro coastal region is located in the northwest coast of Portugal (40º38'N, 08º45'W) and is integrated in the catchment of Vouga River (368,521 ha). The study area comprises the Ria de Aveiro coastal lagoon, the corresponding coastal zone (including the marine space), and the lagoon's margins (Figure 2).

Ria de Aveiro is a shallow coastal lagoon with 45 km long and 10 km wide and covers an area of 83 km^2 at high water (spring tide), which is reduced to 66 km^2 at low water (Dias and Lopes, 2006). It is characterized by narrow channels and inner bays, and by large areas of sand and mud flats, and salt marshes that become exposed during low tide.

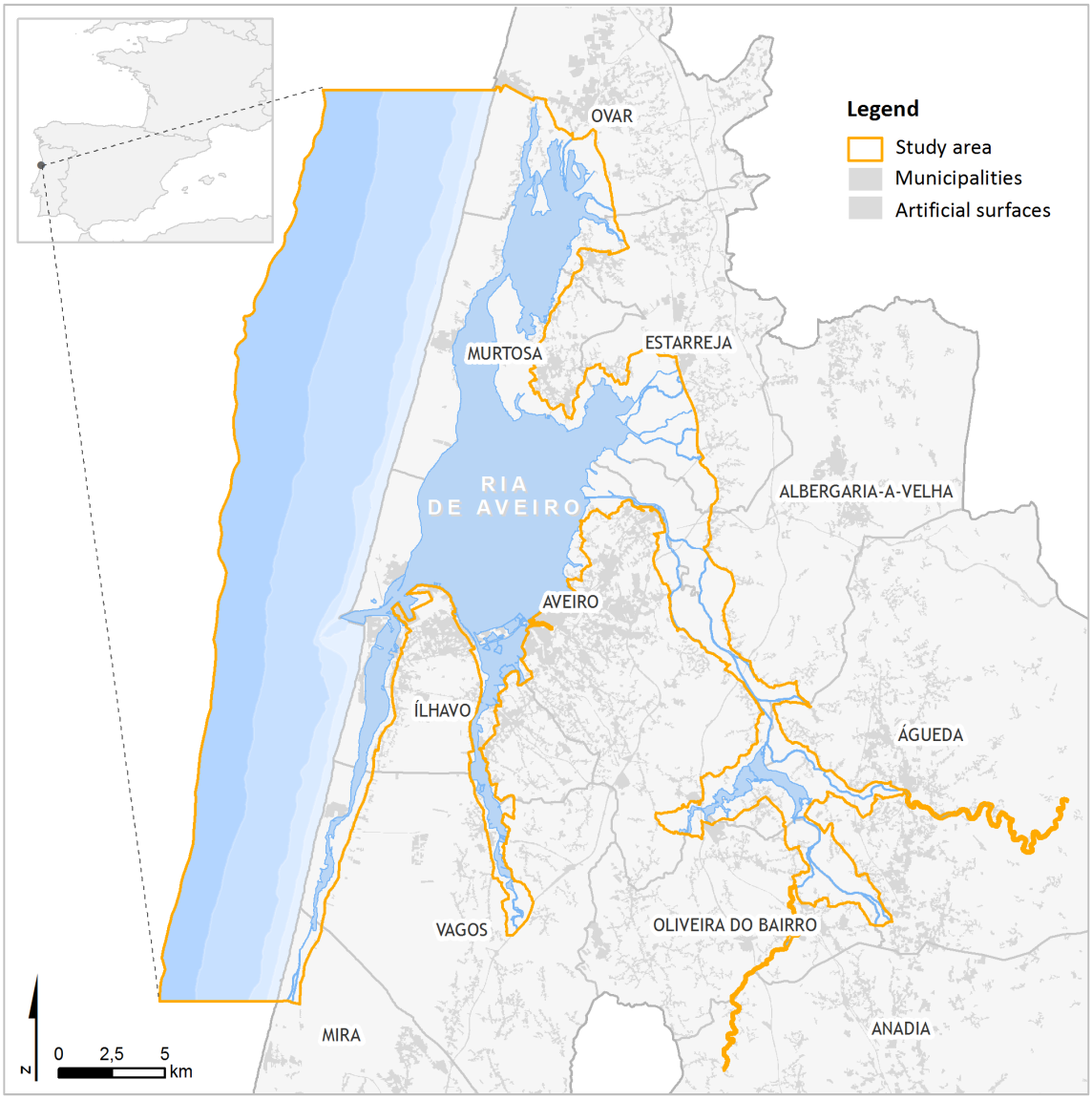


Figure 2. Location of the case study – Ria de Aveiro coastal region – and surrounding municipalities

Ria de Aveiro coastal lagoon has 158740 inhabitants (INE, 2011) in the adjoining parishes and plays a crucial role on the regional and national economy, contributing directly to more than 12% of the overall added value of the Baixo Vouga region (DHV/PLRA, 2011). It houses the Aveiro's Harbour, industrial parks in the margins, fishing, aquaculture and tourism activities. In addition to this, it also supports traditional activities, such as salt-production, artisanal fishing, shellfish collecting and sport fishing. The sport activities in the lagoon (*e.g.* kitesurf, surf and sailing) are also very important for the local community, contributing to the local tourism growth. The high productivity of the lagoon also contributes to the local economy through the commercial exploration of vegetal and animal species of high commercial value, *e.g.* bivalves, crustaceans and fish (Lillebø *et al.*, 2011).

From the ecological point of view, Ria de Aveiro coastal region is a significant area in the national context, being the habitat of several species of flora and fauna that are supported by the dynamics of the lagoon. Its landscape is characterized by the presence of the coastal lagoon, plain and open territories, with few vertical elements, extensive areas of agriculture (both open fields and smallholdings), dunes, and pine forests fixing the dunes along the extensive coastline that separates the lagoon from the Ocean (DHV/PLRA, 2011; ICNB, 2006). A number of habitats can be found here, including seagrass beds, salt marshes including extended areas of reeds, intertidal mudflats, salt pans, and rice fields (AMBIECO/PLRA, 2011). These wide ranges of habitats are used as nursery areas for many valuable species that include bivalves, crustaceans, fish and birds. Due to the great diversity in habitats and bird species, the study area has been integrated in the Nature 2000 network as a Special Protection Area (SPA) and a Site of Community Importance (SCI). It also incorporates the São Jacinto Dunes Nature Reserve, the Ramsar Site Pateira de Fermentelos Lake, and Águeda and Cértima Valleys. Moreover, from the conservational point of view, this system is considered a high priority since it is a fundamental step in the migration of aquatic birds and an ideal place for winter shelter and nesting (ICNB, 2006).

The governance framework of Ria de Aveiro coastal region is characterized by the involvement of a variety of government organizations (e.g., Portuguese Environment Agency – APA I.P.; Regional Coordination and Development Commission of the Centre – CCDRC; Inter-municipal Community of the Aveiro Region – CIRA), non-governmental agencies and other stakeholders (e.g. land-owners, fishermen associations, sports associations). In addition, 11 municipalities have jurisdiction over different parts of the case study (Sousa *et al.,* 2015; Fidélis and Roebeling, 2014). The spatial planning and management of Ria de Aveiro coastal region is performed by programmes and plans of national, regional, inter-municipal and municipal levels (see Chapter 6 for more detailed information).

Concerning both coastal and water management, APA, I.P. plays a major role in the study area. However, because the entire lagoon is classified as Special Protection Area in the scope of the Natura 2000 Network and incorporates a small area of Nature Reserve (Sao Jacinto dunes), the Institute for Nature Conservation and Forestry (ICNF I.P.) plays an important role in assuring the conservation and sustainable management of the lagoon.

Given its territorial complexity and the diversity of uses and activities, there are several sector-based entities in which APA, I.P. delegates planning, management, licensing or supervision responsibilities. Figure 3 summarizes the main thematic areas of management in the Ria de Aveiro and the respective institutional articulation. The articulation between spatial planning tools, Water Law and cross environmental policies is assured by the Regional Coordination and Development Commissions (CCDR).

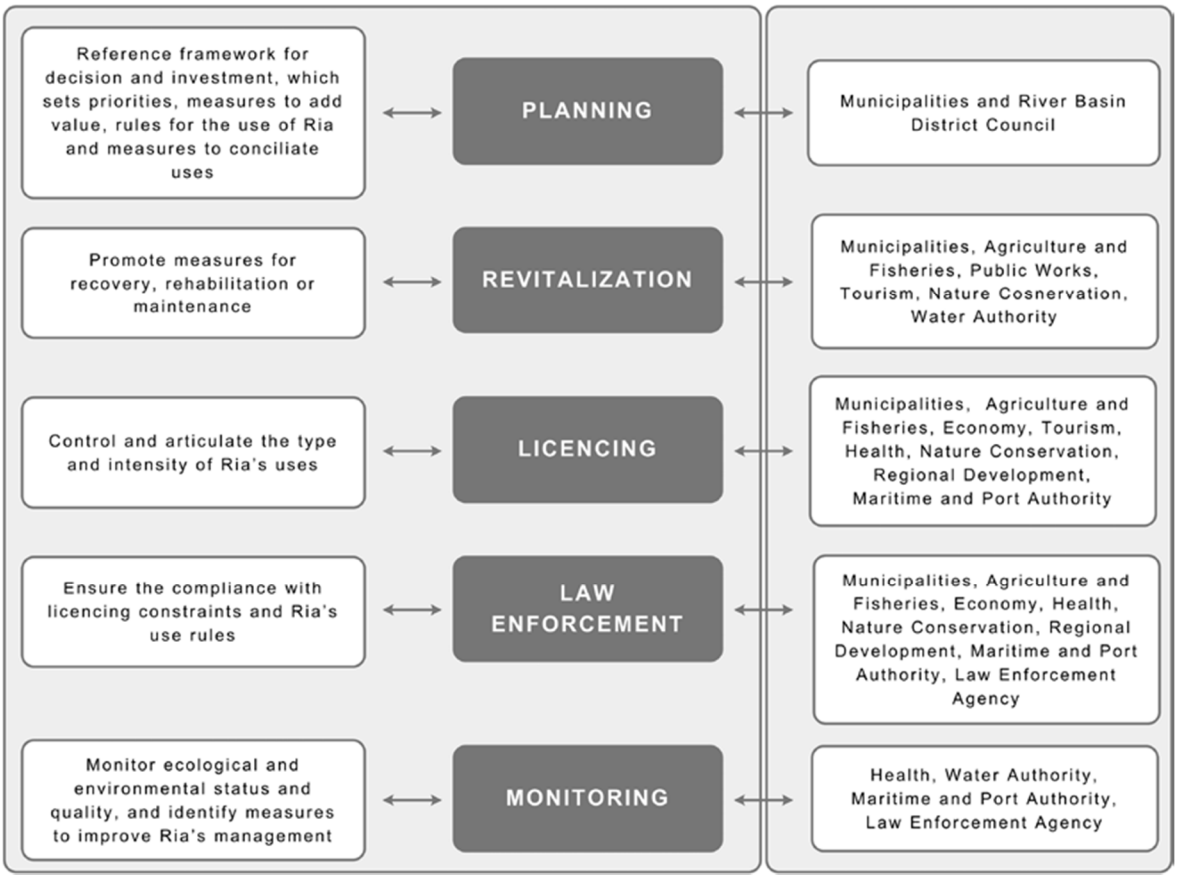


Figure 3. Responsibilities of the water authority and articulation with sector-based institutions. Source: Sousa *et al.*, 2015

1.3.2. Projects and studies

The complexity of this territory, its dynamic character, the biological diversity, the variety of economic and cultural activities, aligned with the multiplicity of risks, its complex institutional framework and management system make the Ria de Aveiro coastal region attractive and challenging for interdisciplinary research. As result, this territory has been the centre of several research and technical studies in a diversity of scientific fields at the University of Aveiro, namely at the group of Environmental Instruments (*Instrumentos Ambientais*) of the Department of Environment and Planning.

Figure 4 presents some of these research projects and technical studies in which I was involved, since 2007, and that contributed, to some extent, to this research by:

- addressing a number of pressing issues such as governance, integrated management, spatial planning and management of natural resources, risk assessment and management, stakeholders engagement;

- focusing on challenging territories from the management point of view: coastal, marine, estuarine;
- promoting the contact with multidisciplinary and international teams, contributing to a multi- and trans-disciplinary view of Ria de Aveiro coastal region.

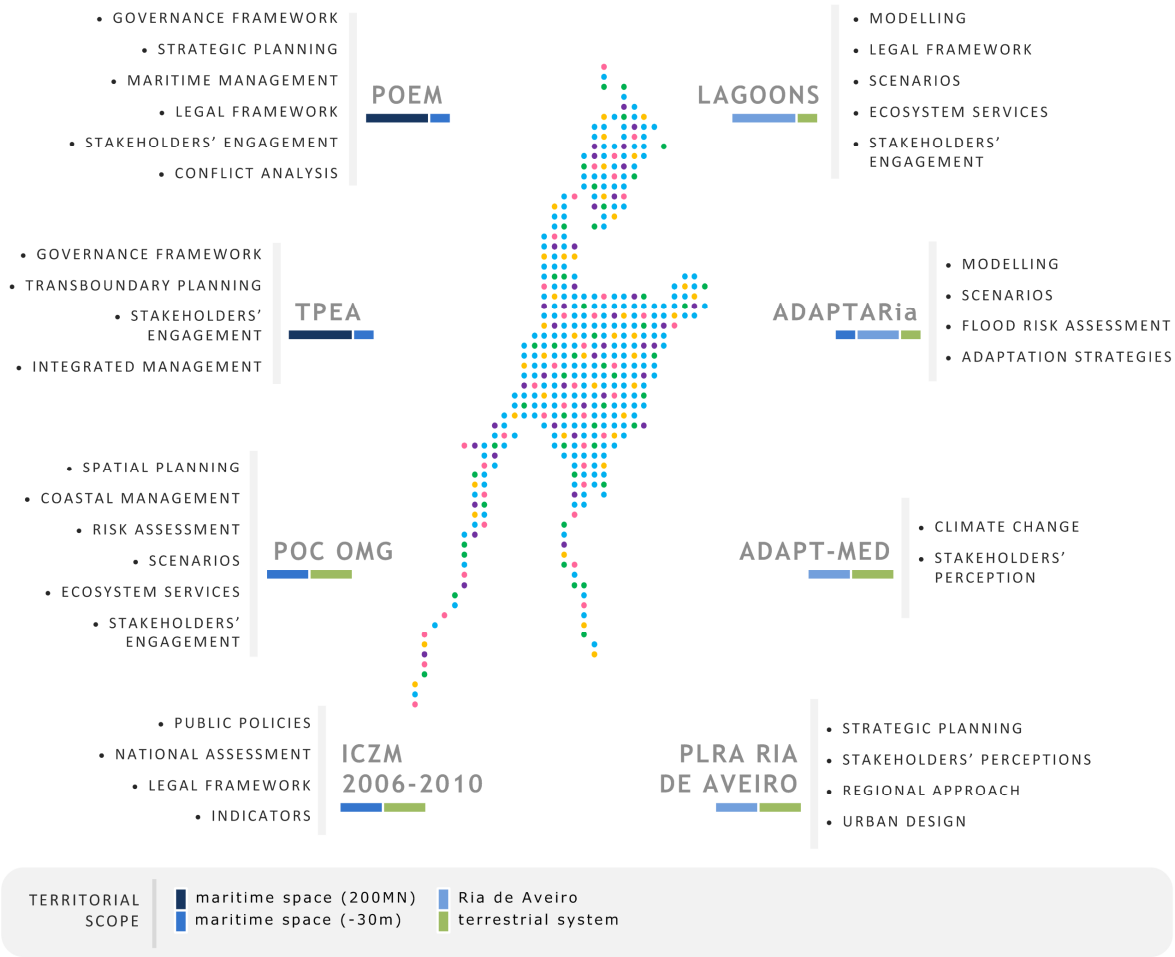


Figure 4. Projects overview

Apart from the knowledge and experience obtained through the participation in these range of projects, the present research was predominantly embedded in two research projects entitled LAGOONS (Integrated water resources and coastal zone management in European lagoons in the context of climate change), and ADAPTARia (Climate Change Modelling on Ria de Aveiro Littoral - Adaptation Strategy for Coastal and Fluvial Flooding), to which this research contributed, and from which it benefited with the integration in multidisciplinary teams, discussions and results.

LAGOONS was a three-year project (2011-2014) funded under the EU's Seventh Framework Programme (contract no. 283157). It brought together the expertise of nine research institutes from eight countries

with the aim of developing science-based strategies and a decision support framework for the integrated management of coastal lagoons and its drainage area. LAGOONS focused on an increased understanding of land to sea processes and of science, policy and stakeholders (including the citizens) interface, all in the context of climate change (Lillebø *et al.*, 2016; Lillebø and Stålnacke, 2015). Four case studies were selected to integrate this research: Ria de Aveiro Lagoon in the Atlantic Ocean (Portugal), Mar Menor in the Mediterranean Sea (Spain); Vistula Lagoon in the Baltic Sea (Poland/Russia); and Tylygulskyi Lagoon in the Black Sea (Ukraine). The project consisted of seven work packages (Lillebø *et al.*, 2015a): WP1 - Project management and dissemination; WP2 - Knowledge base and gap analysis; WP3 - Problem based science analysis; WP4 - Stakeholder participation and qualitative scenarios; WP5 - Quantitative drainage basin scenario modelling in the context of climate and land use change; WP6 - Quantitative lagoons modelling (climate and hydrobiogeochemistry); WP7 - Strategies and decision support framework and pan-European dissemination.

The present research was mainly incorporated in the fourth and seventh work packages and benefited from discussions, international and multidisciplinary context and from stakeholders' participation. Specifically:

- contributed to the discussion on ES classification systems, to the identification of ES in Ria de Aveiro coastal lagoon and to the identification of ES indicators, which were then integrated in the Marine Ecosystem Pilot Exercise – a pilot study carried out by the MAES Working Group;
- contributed to the stakeholders' engagement in Ria de Aveiro case study through the involvement in the organization, preparation, performance and posterior analysis of nine focus groups, one citizens' jury, and a final workshop;
- developed a characterization of the Ria de Aveiro management framework;
- contributed to the discussion, layout and selection of data to be incorporated in the integrated scenarios presented to stakeholders;
- contributed to the discussion and application of the SWOT analysis;
- collected data on the Ria de Aveiro case study for posterior integration in the eco-hydrological model;
- prepared spatially explicit material to be included in the LAGOONS reports, dissemination material and interactive platform (http://webgis.no/openlagoons);
- contributed to the design and writing of dissemination material (e.g., flyers, briefs, posters, booklet).

ADAPTARia was a three and a half year (national) project (2010-2013) funded by the *Fundação para a Ciência e Tecnologia* (PTDC/AAC-CLI/100953/2008). The aim of this project was to (i) study the impact of climate change on flooding events and shoreline retreat in the Ria de Aveiro coastal lagoon and adjacent coastal strip (from Esmoriz to Mira), and (ii) design mitigation and adaptation strategies. The project consisted of eight tasks: T1 - Project management and coordination; T2 - Review of the state of the art and data collection and analysis; T3 – Meteorological and hydrological contributions to flooding in the Ria de Aveiro littoral, for present climate and future climate scenarios; T4 – Wave hindcast and forecast for the Aveiro littoral; T5 - Risk assessment and mapping of Aveiro littoral; T6 - Flood risk assessment and mapping of Ria de Aveiro; T7 - Formulation of adaptation strategies; T8 - End-users participation and dissemination.

The present research benefited from ADAPTARia results, particularly from the flood extent maps that were incorporated in the analysis of the pressures, and contributed to tasks 2, 5, 6, 7 and 8, specifically to the:

- review of policies and strategies on flood risk management;
- elaboration of flood and shoreline retreat vulnerability and risk maps under climate change scenarios;
- definition of adaptation strategies;
- preparation of dissemination material (e.g., booklet).

1.3.3. Thesis outline

This research is composed by eight chapters, one of which is already published in an international peer-reviewed scientific journal:

- 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. *Scientific Reports*, 6: 22782. DOI: 10.1038/srep22782 (Chapter 3, and partially Chapter 2)

Two more scientific papers are in progress with the purpose of publishing the findings presented in the remaining chapters (4 to 7):

- Sousa L.P., Lillebø A.I., Alves F.L., *(working paper)*. Spatial patterns of ecosystem services in complex social-ecological systems: a management-oriented approach (Chapter 4 and 5)
- Sousa L.P., Lillebø A.I., Alves F.L., *(working paper)*. A model to integrate ecosystem services into the planning process: the case study of Estuary Programmes (Chapter 6 and 7)

Other publications produced during this period contributed to the reflection and critical thinking on the territory and governance, and to the writing of the thesis:

- Sousa L.P., Lillebø A.I., Soares J.A., Alves F.L., 2015. The management story of Ria de Aveiro. *In:* Lillebø A.I., Stålnacke P. & Gooch G.D. (Eds.), Coastal Lagoons in Europe: Integrated Water Resource Strategies. IWA Publishers, London, pp. 31-38. ISBN: 9781780406282; eISBN: 9781780406299 (Chapter 1, Chapter 6)
- Sousa L.P., Lillebø A.I., Gooch G.D., Soares J.A., Alves F.L., 2013. Incorporation of Local Knowledge in the Identification of Ria de Aveiro Lagoon Ecosystem Services (Portugal). *Journal of Coastal Research*, SI 65: 1051-1056. DOI: 10.2112/SI65-178.1 (Chapter 1, Chapter 4)
- Alves F.L., Sousa L.P., Almodovar M., Phillips M.R., 2013. Integrated Coastal Zone Management (ICZM): a review of progress in Portuguese implementation. *Regional Environmental Change,* 13: 1031-1042. DOI: 10.1007/s10113-012-0398-y (Chapter 1)

Subsequent to this introductory chapter, Chapter 2 provides a conceptual analysis of the core concepts addressed in this research, setting the ground for the following chapters. From nature sciences to social and political sciences, these concepts are analysed from an interdisciplinary perspective.

Chapter 3 builds on existing ES frameworks for discussing and proposing three key steps for ES identification, classification and mapping at regional level. The framework comprises the definition of the exact geographic boundaries of the study area; the use of CICES (Common International Classification of Ecosystem Services) for ecosystem services identification and classification; and the definition of qualitative indicators that will serve as basis to map the ecosystem services. Methodological aspects as well as the main challenges of implementing such approach to complex coastal regions are discussed in this chapter.

The indicators established in Chapter 3 are applied in Chapter 4 to Ria de Aveiro coastal region, resulting in 11 thematic maps and a detailed description of the ES classes and abiotic outputs. This in-depth analysis is complemented with the identification of multifunctional areas, as well as an analysis of the stakeholders' perception on ES.

Chapter 5 uses multiple sources of information and different methodologies to discuss the expected changes of current pressures and future trends on Ria de Aveiro ecosystem services, as well as the relevance of integrating participatory methods.

Chapter 6 analysis the conceptual uptake of the ES and related concepts in Portuguese policy documents and spatial planning tools.

Chapter 7 uses the existing administrative and governance structures in Ria de Aveiro coastal region and builds on previous chapters to propose a model for integrating ES into spatial planning process, more specifically Estuary Programmes.

The purpose of Chapter 8 is to present the key findings, as well as the limitations and challenges, derived from the previous chapters in justifying and demonstrating the practical application of the ecosystem services notion/concept for achieving a more effective management of coastal regions (including coastal lagoons). This chapter aims to support environmental decision-makers and practitioners in incorporating the ecosystem services into their management practices, particularly at the regional level.

Figure 5 provides an outline of the thesis structure and relates its chapters to the main research questions and objectives.

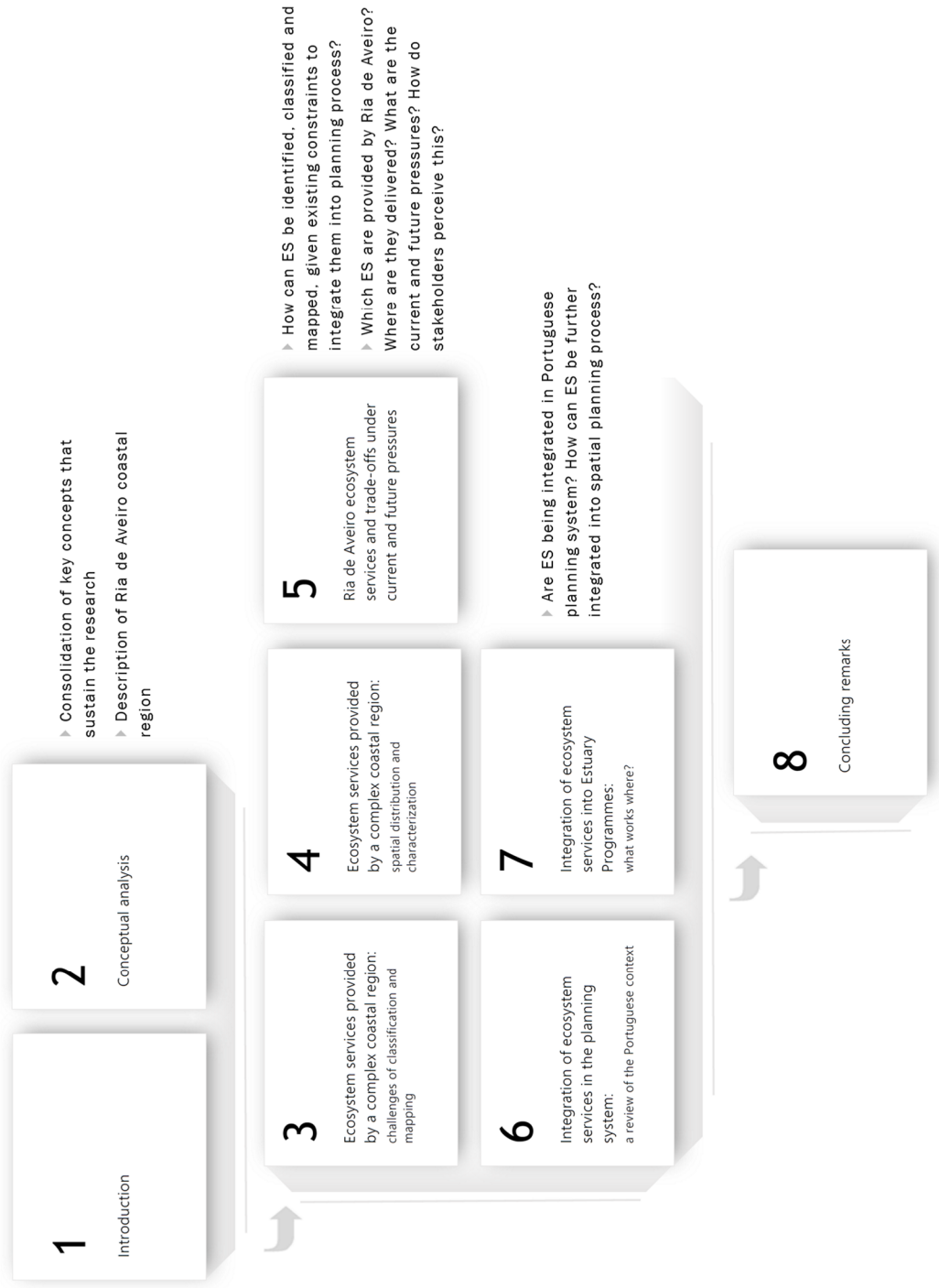


Figure 5. Thesis structure and relation between chapters and main research questions

2 Conceptual framework

The material in this chapter is published in:

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. *Scientific Reports*, 6: 22782. DOI: 10.1038/srep22782

The governance of coastal areas and estuaries needs to deal with a complex interplay of social and ecological systems (Giebels *et al.*, 2013). At the one hand, social systems tend to be characterized by the involvement of a variety of institutions, occasionally overlapping jurisdictions, and conflicting interests. Coastal ecological systems, which lay at the interface between marine and terrestrial ecosystems, are dynamic, multifunctional, and tend to be characterized by its natural and human-induced variability (Giebels *et al.*, 2013). The abundance of natural resources and economic opportunities make these territorial units attractive areas but also place them under significant pressure (Dolbeth *et al.,* 2016; Karrasch *et al.*, 2014). This challenges traditional forms of management, calling for a more integrated, adaptive, inclusive and ecosystem-based management. Following this line of thinking, this chapter brings together key ecological and social concepts that underpin ecosystem-based management of complex social-ecological systems. It synthetizes the current state of knowledge and sets the ground for the subsequent chapters.

2.1. Social-ecological systems

Social-ecological systems are systems that involve both natural/ecological and human/social components that interact and co-evolve at a range of spatial and temporal scales to affect system dynamics (Koontz *et al.*, 2015; Haines-Young and Potschin, 2010). Social-ecological systems provide a theoretical framework that conceptualizes the environment as an open system consisting of ecological and social processes and components, which are integrated through interactions (e.g., management practices, adaptation, and resource use) that occur on multiple scales and through cycles (Figure 6). Being an open system, these processes and interactions are influenced by broad scale drivers, such as political and economic conditions, and large scale biogeochemical conditions (Virapongse *et al.*, 2016). Social-ecological systems has increasingly been used in literature to emphasise that ecological and social systems are highly connected (Haines-Young and Potschin, 2010).

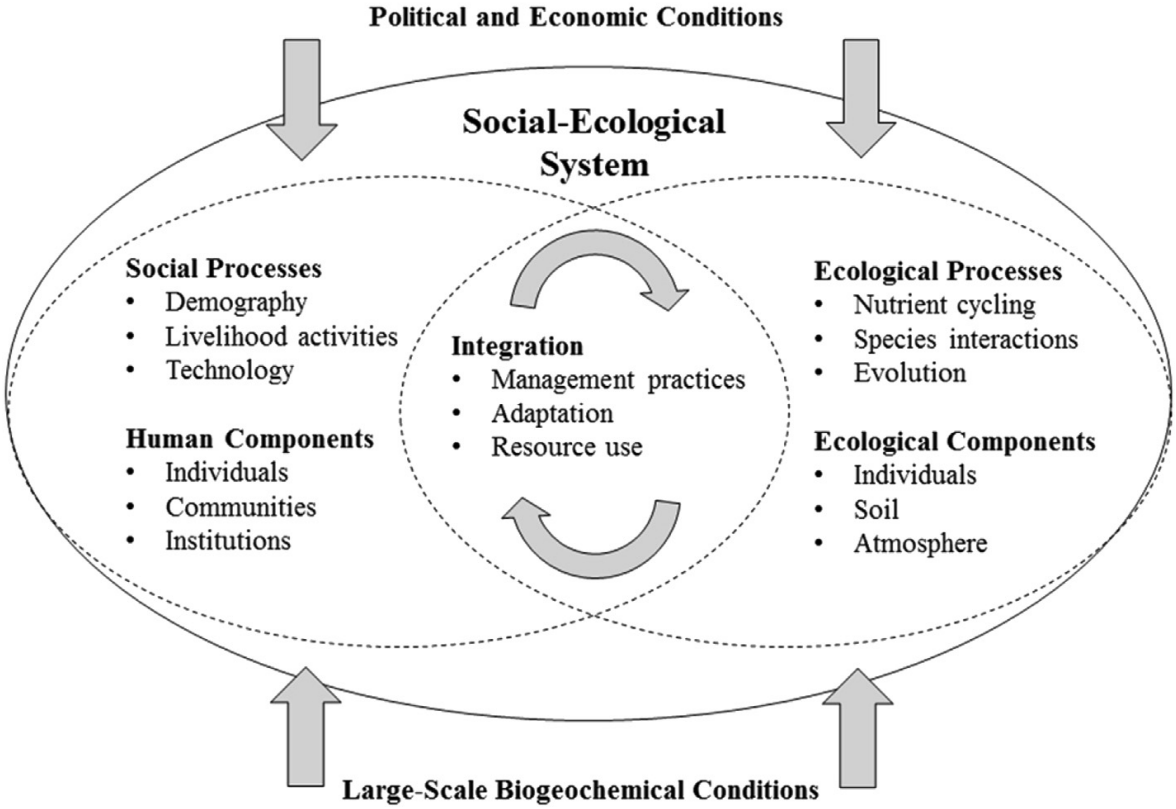


Figure 6. Depiction of a social-ecological system. Source: Virapongse *et al.*, 2016

2.2. Ecosystem services

Ecosystem Services (ES) is a bridging concept that highlights the link between nature and human systems, and the implications of ecosystems functioning for human well-being (MA, 2005a; Daily, 1997). This dependence on nature has been debated since the late 1960s (Häyhä and Franzese, 2014), but is in the early 1980s that the term "ecosystem services" is introduced by Ehrlich and Ehrlich (1981). Since then, the concept has been evolving (Portman, 2013; Braat and de Groot, 2012), and several definitions have been proposed over the years (BOX 1).

BOX 1. DEFINITIONS OF ECOSYSTEM SERVICES

- *"The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life",* Daily, 1997
- *"The benefits human populations derive, directly or indirectly, from ecosystem functions",* Costanza *et al.,* 1997
- *"The benefits people obtain from ecosystems",* MA, 2003
- *"Components of nature, directly enjoyed, consumed, or used to yield human well-being",* Boyd and Banzhaf, 2007
- *"The aspects of ecosystems utilized (actively or passively) to produce human well-being",* Fisher *et al.,* 2009
- *"The direct and indirect contributions of ecosystems to human well-being",* TEEB, 2010
- *"The contributions that ecosystems make to human well-being",* Haines-Young and Potschin, 2013

Despite of being considered broad and ambiguous by some authors (*e.g.* Fisher *et al.*, 2009; Boyd and Banzhaf, 2007), the definition proposed by the Millennium Ecosystem Assessment (MA) is widely adopted. However, there is still an ongoing debate both on ES definition and on ES classification. For instance, Boyd and Banzhaf (2007) present a definition, which only considers the final services or end-products of nature that are directly enjoyed or used by people. They argue that although ecosystem processes and functions contribute to the production of end-products, they are not an output themselves. Therefore, they are considered intermediate products and not final services. In turn, Fisher *et al.* (2009) considers that ecosystem functions and processes can become services if they are directly or indirectly consumed or utilized by people. In both cases benefits are considered distinct from services. Haines-Young and Potschin (2010) propose a conceptual framework that illustrates the pathway from ecosystems to human well-being: the ES cascade model (Figure 7). This model makes clear the distinction, as well as the linkages, between ecosystem structure, function, services and benefit concepts (Saarikoski *et al.,* 2015; Turkelboom *et al.*, 2014; Braat and de Groot, 2012; TEEB*,* 2010). Here, only final services (i.e., *"the contributions that ecosystems make to human well-being",* Haines-Young and Potschin, 2013, p.8) are considered. Nevertheless, its connection to the underlying ecosystem functions, processes and structures is acknowledged.

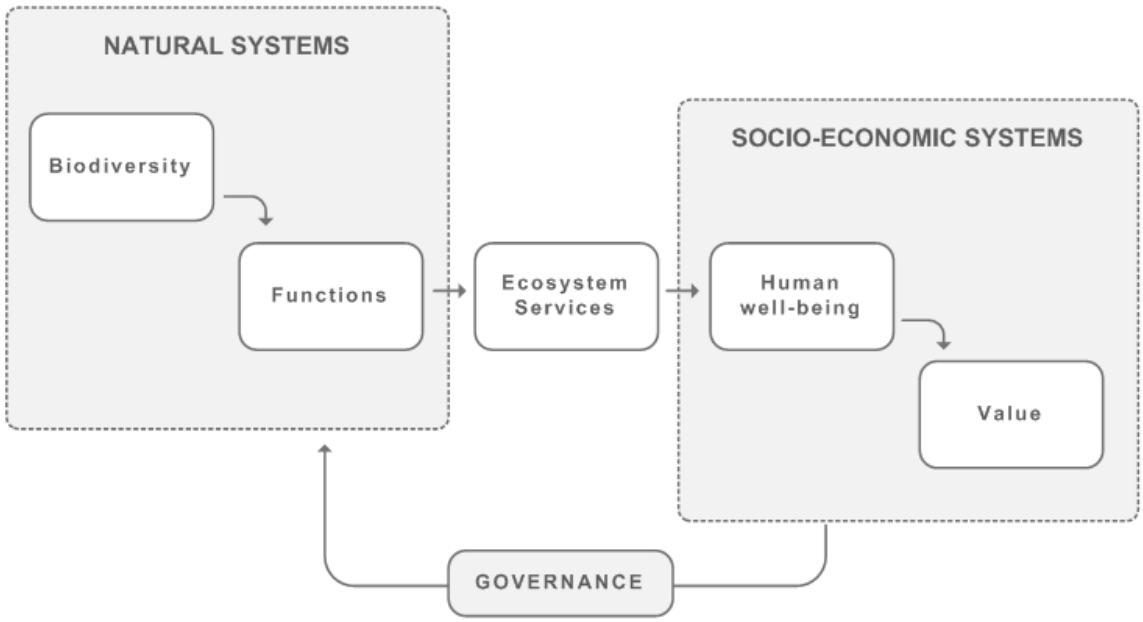


Figure 7. The pathway from ecosystems and biodiversity to human well-being. Source: Adapted from Haines-Young and Potschin, 2010; TEEB, 2010

Not all ecosystem functions have a positive impact on human well-being, such as pest damages, animal attacks, allergenic and poisonous organisms, nutrient runoff, erosion, or floods (Friess, 2016; Döhren and Haase, 2015; Lele *et al.*, 2013). These are called ecosystem disservices.

Ecosystem Services Classification Systems

Ecosystem services have been classified in different ways. According to Haines-Young and Potschin (2014), the lack of agreement on a common definition of the ES concept, together with the variety of purposes, applications (e.g. environmental accounting, ES mapping, ES valuing) and disciplines involved (e.g. ecology, sociology, economy, geography), make the ES classification conceptually and technically challenging. From the available range of ES classification systems, the most widely used are the Millennium Ecosystem Assessment (MA, 2005a), The Economics of Ecosystems and Biodiversity (TEEB, 2010), and the Common International Classification of Ecosystem Services – CICES (Haines-Young and Potschin, 2013). The MA organizes the ES in four classes: provisioning, regulating, cultural and supporting services; TEEB uses a typology of 22 ES grouped in four classes: provisioning, regulating, habitat, and cultural and amenity services; and CICES organizes the ES in three main categories: provisioning, regulating and maintenance, and cultural services. The Table 1 synthetized by Haines-Young and Potschin (2014) provides a comparison of the CICES, MA and TEEB classification systems.

Table 1. Comparison of CICES, the MA and TEEB Classifications. Source: Haines-Young and Potschin, 2014.

CICES v4.3				MA	TEEB
Section	Division	Group	Class		
PROVISIONING	Nutrition	Biomass	Cultivated crops	Food	Food
			Reared animals and their outputs		
			Wild plants, algae and their outputs		
			Wild animals and their outputs		
			Plants and algae from in-situ aquaculture		
			Animals from in-situ aquaculture		
		Water	Surface water for drinking	Water	Water
			Ground water for drinking		
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Fibre, Timber, Ornamental, Biochemical	Raw materials, medicinal resources
			Materials from plants, algae and animals for agricultural use		
			Genetic materials from all biota	Genetic materials	Genetic materials
		Water	Surface water for non-drinking purposes	-	-
			Ground water for non-drinking purposes	-	-
		Energy	Plant-based resources	-	-
			Animal-based resources	-	-
			Animal-based energy	-	-
REGULATION & MAINTENANCE	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	Water purification and water treatment, air quality regulation	Waste treatment (water purification), air quality regulation
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals		
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems		
			Dilution by atmosphere, freshwater and marine ecosystems		
			Mediation of smell/noise/visual impacts		
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	Erosion regulation	Erosion prevention
			Buffering and attenuation of mass flows		
		Liquid flows	Hydrological cycle and water flow maintenance	Water regulation	Regulation of water flows, regulation of extreme events
			Flood protection		
		Gaseous / air flows	Storm protection		
			Ventilation and transpiration		
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Pollination	Pollination
			Maintaining nursery populations and habitats		

CICES v4.3				MA	TEEB
Section	Division	Group	Class		
		Pest and disease control	Pest control	Pest regulation	Biological control
			Disease control	Disease regulation	
		Soil formation and composition	Weathering processes	Soil formation (supporting services)	Maintenance of soil fertility
			Decomposition and fixing processes		
		Water conditions	Chemical condition of freshwaters	-	-
			Chemical condition of salt waters	-	-
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	Atmospheric regulation	-
			Micro and regional climate regulation	Air quality regulation	Air quality regulation
CULTURAL	Physical and intellectual interactions with biota, ecosystems, and landscapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	Recreation and ecotourism	Recreation and tourism
			Physical use of land-/seascapes in different environmental settings		
		Intellectual and representative interactions	Scientific	Knowledge systems and educational values	Inspiration for culture, art and design, aesthetic information
			Educational		
			Heritage, cultural		
			Entertainment		
			Aesthetic		
	Spiritual, symbolic and other interactions with biota, ecosystems, and landscapes	Spiritual and/or emblematic	Symbolic	Spiritual and religious values	Information and cognitive development
			Sacred and/or religious		
		Other cultural outputs	Existence		
			Bequest		

CICES – coordinated by the University of Nottingham and promoted by the European Environment Agency in 2009 – resulted from the need to develop a consistent classification of ES, compatible with the design of the Integrated Environmental and Economic Accounting methods, and that provides a "common base" for comparison across Europe (Haines-Young and Potschin, 2010). CICES classification system has been adopted by the MAES working group and will be used through Europe, by Member States during the implementation of the EU Biodiversity Strategy targets (Maes *et al.,* 2014, 2013a).

CICES follows a hierarchical structure as a way to allow its users to select the most appropriate level of detail required to their application. At the highest hierarchical level (called 'Sections') there are three broad categories (Haines-Young and Potschin, 2013):

- Provisioning services: includes all the nutritional, material and energetic outputs (biomass and water) from natural and semi-natural ecosystems.
- Regulating and maintenance services: relates to the capacity of living organisms to mediate or moderate the environment that affects human performance (e.g. degradation of wastes and toxic substances; mediation of flows in solids, liquids and gases; physic-chemical and biological regulation).
- Cultural services: comprises all non-material and non-consumptive outputs from the ecosystem that affect physical and mental states of people, which result from physical, experiential and intellectual interactions with nature, and also from spiritual and symbolic values.

Below these major 'Sections' are nested a series of 'Divisions', 'Groups' and 'Classes'. CICES considers the outputs of ecosystems dependent on living processes. Abiotic outputs are classified separately and are hierarchically divided in 'Sections', Divisions' and 'Groups'. CICES V4.3 no longer includes abiotic materials and renewable abiotic energy, however it was considered in this study.

Ecosystem Services Critique

In recent years there has been debate and criticism regarding the use of ES concepts for decision-making (e.g., Schröter *et al.,* 2014; McCauley, 2006), particularly around the monetisation of the value of ecosystem services (Martin-Ortega *et al.,* 2015). According to Schröter *et al.* (2014) review there are seven points of critique:

- environmental ethics – ES has a anthropocentric focus and excludes the intrinsic value of nature;
- human-nature relationship – ES might promote an exploitive human-nature relationship;
- conflicts with the concept of biodiversity – ES might replace biodiversity protection as a conservation goal;
- ES valuation – ES comprises economic framing and usually involves economic valuation;
- commodification and Payment for Ecosystem Services (PES) – ES is based on the assumption that PES will ensure the provision of ES;
- vagueness – ES has become a "catch-all" phrase because of its vague definitions;
- optimistic assumptions and normative aims – ES is too optimistic and ecosystem some outputs can be harmful to humans.

2.3. The processes of policy-making and the policy cycle

Policy-making is a process of identifying a problem and setting public policy priorities, goals and objectives, which then leads to the design and adoption of alternative courses of action. This cycle (Figure 8) is closed with the monitoring and evaluation to determine if the effectiveness of the actions and if there is need for change or adaptation (Cormier *et al.*, 2017; Opdam *et al.*, 2002).

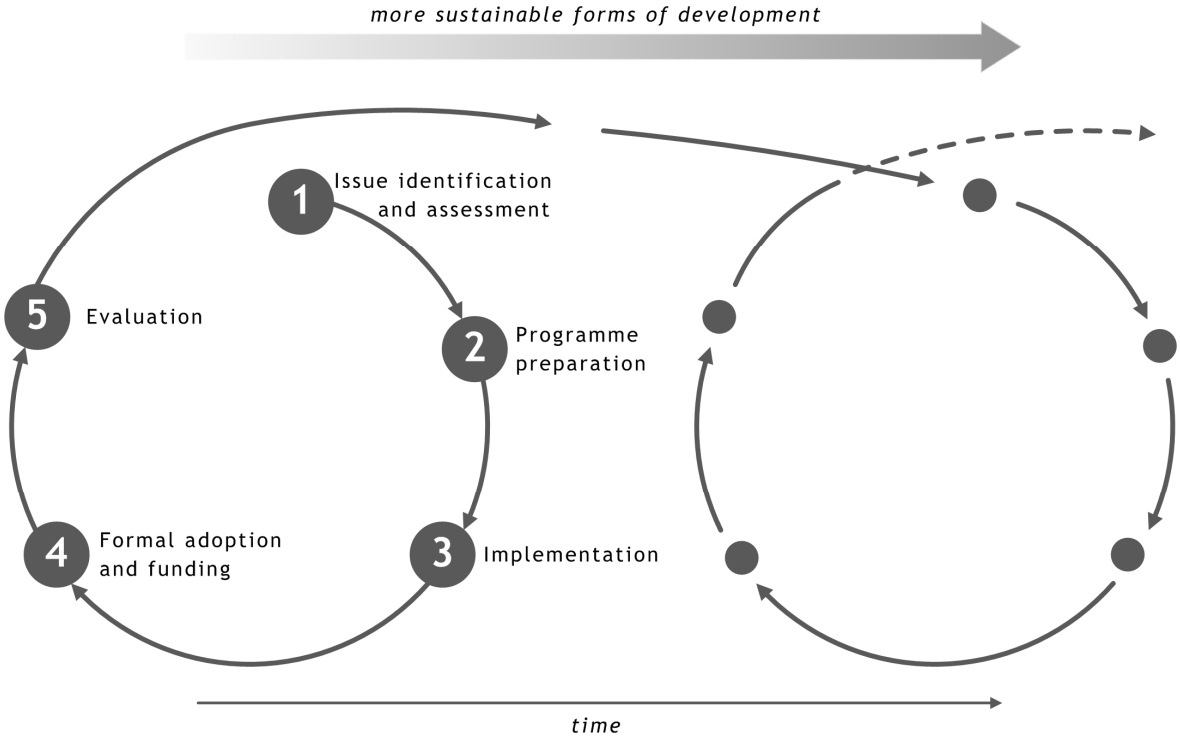


Figure 8. The policy cycle towards sustainable development. Adapted from Olsen *et al.*, 2011 and GESAMP, 1996

The public policy-making is typically a top down process, where the government sets a number of long-term goals for conservation, sustainability and development in line with the national and international agreements (e.g., Water Framework Directive; Aichi Biodiversity Targets; United Nations Sustainable Development Goals). Then administrations do cross-sectoral planning and set regional objectives within these goals. Planning uses decision support tools and stakeholder participation to facilitate the adoption of a specific course of action.

2.4. Governance

The concept of governance is widely used in environmental sciences and policy-making, and represents a shift in the way political processes and decision-making are pursued (Loft *et al.*, 2015; Mann *et al.*, 2015). Rather than decisions falling entirely on the government, they are taken in collaboration with a

wider range of stakeholders. This means that decisions are not necessarily limited to formal governmental institutions or policy-makers, but involve a broader and more inclusive range of perspectives. Governance refers to social processes of acting and interacting in decision-making throughout the different stages of the policy-making cycle (Keune *et al.*, 2015). Regarding ecosystem services, governance requires engaging actors who understand, manage and benefit from the services (Mascarenhas *et al.*, 2014). Rival and Muradian (2013) define governance of ES as *"the institutionalisation of mechanisms for collective decision-making and collective action with respect to natural resource management"*. It is suggested in literature that governance of social-ecological systems can benefit from institutional diversity across scales and from the acknowledgement of the diversity of ecological and social dynamics on the scale in which they are used (Loft *et al.*, 2015; Gómez-Baggethun *et al.*, 2013; Gatzweiler, 2006)

2.5. Stakeholders involvement

The failures of top-down approaches together with international and European initiatives (e.g., Brundtland report in 1987; Agenda 21 in 1992; Aarhus Convention in 1998), and citizens demands through social groups, led to the increase of stakeholders' involvement in environmental management and planning decisions (Valente, 2013).

There is a variety of participatory approaches, methodologies and techniques that require different participatory levels (Durham *et al.*, 2014):

- Inform – lowest level of engagement, where stakeholders have a passive role, designed to simply share information to those that may be affected (e.g., talks and lectures)
- Consult – middle level of engagement, designed to meet the stakeholders' needs (e.g., questionnaires and surveys);
- Involve – middle level of engagement, designed to involve the stakeholders and obtain information, resources or data from them (e.g., individual meetings and interviews, workshops);
- Collaborate – higher level of engagement where stakeholders are closely involved with the team, driving the direction of the decisions (e.g., focus groups, citizens' juries; role-playing; participatory mapping).

Stakeholders' involvement in the decision-making process and environmental management can bring a set of benefits, such as strengthening decision legitimacy and implementation; empowering

communities; developing social equity; improving the quality of decisions; promoting social learning; providing locally-adapted decisions (Sousa *et al.*, 2013a; Valente, 2013).

2.6. Ecosystem Approach and Ecosystem-Based Management

The Ecosystem Approach was first addressed in a policy context at the Earth Summit in Rio de Janeiro (1992). In 1995 it was adopted as the primary framework for action by the Convention on Biological Diversity (CBD), on its second meeting held in Jakarta. Traditional sectoral approach to natural resource and environmental management was seen as insufficient for addressing human impacts on the environment, and a holistic Ecosystem Approach started to be understood as key in delivering sustainable development (Laffoley *et al.,* 2004). Nowadays, it is an integral component of environmental policy, e.g., Marine Spatial Planning, Water Framework Directive (Harrington *et al.*, 2011).

The Ecosystem Approach has been defined by the CBD (Decision V/6, 2000) as *"(…) a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way"*. It is seen as a holistic process for integrating and delivering in a balanced way the three key objectives of the Convention: conservation, sustainable use and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources (Maltby, 2000). The CBD also defined 12 principles to guide the implementation of the Ecosystem Approach into planning and policy practices for the achievement of sustainable management (BOX 2).

The Ecosystem Approach requires adaptive management to deal with the complex and dynamic nature of ecosystems, but also with uncertainty and absence of complete knowledge; and integrated management and holistic thinking.

BOX 2. THE 12 PRINCIPLES OF THE ECOSYSTEM APPROACH

1 | The objectives of management of land, water and living resources are a matter of societal choices.

2 | Management should be decentralized to the lowest appropriate level.

3 | Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

4 | Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should: (i) reduce those market distortions that adversely affect biological diversity; (ii) align incentives to promote biodiversity conservation and sustainable use; (iii) internalize costs and benefits in the given ecosystem to the extent feasible.

5 | Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

6 | Ecosystem must be managed within the limits of their functioning.

7 | The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

8 | Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

9 | Management must recognize the change is inevitable.

10 | The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

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.

Convention on Biological Diversity, 2000

2.7. Adaptive management

The governance of social-ecological systems has to deal with a great amount of complexity and uncertainty, as well as with the fact that equilibrium situations both in social and ecological systems are only temporary and fragile (Giebels *et al.*, 2013).

The adaptive management concept emerges as an attempt to deal with continuous change (Giebels *et al.*, 2013). Here, learning is viewed as a product of management (Stojanovic and Ballinger 2009). Decisions are supported by the best available multi-disciplinary knowledge (historical, traditional, or scientific) and by plausible scenarios of how the social-ecological system might behave under different management options (Mee, 2005). The most favourable pathway for a specific period of time is adopted and closely monitored. As knowledge is gathered, baseline circumstances or preferences change, the governance model can be further refined and new management objectives set (Alves *et al.*, 2013a; Giebels *et al.*, 2013). Consequently, it is expected that governance systems become more resilient and flexible (Giebels *et al.*, 2013).

Adaptive management has become a principle adopted by a number of environmental and transversal policies, such as Integrated Coastal Zone Management (ICZM), Marine Spatial Planning (MSP). It is also inherent to the concepts of integrated management and ecosystem-based management (Directive 2014/89/EU on MSP; Recommendation 2002/413/EC on ICZM).

3 Ecosystem services provided by a complex coastal region: challenges of classification and mapping

The material in this chapter is published in:

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. *Scientific Reports*, 6: 22782. DOI: 10.1038/srep22782

3.1. Introduction

The mapping and assessment of ecosystem services is one of the core actions (Action 5) of the European Union's Biodiversity Strategy, which aims at *"halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss"* (EC, 2011). To support the implementation of Action 5 a working group on Mapping and Assessment of Ecosystems and their Services (MAES) was established (Maes *et al.,* 2014, 2012). These efforts place the European Union on the course to achieve its global commitments under the Convention on Biological Diversity, particularly the Aichi Target 11 on conservation of biodiversity and ES of terrestrial, inland water, coastal and marine areas through the expansion of protected areas; and the Target 14 on restoring and safeguarding essential ES.

Approaches to ES mapping are abundant and vary on aim and rational, type of ES analysed, spatial scale, and source of information (Maes *et al.,* 2012; Martínez-Harms and Balvanera, 2012; Burkhard *et al.,* 2009). Several mapping methodologies' reviews are available in literature (e.g., Malinga *et al.,* 2015; Liquete *et al.,* 2013; Egoh *et al.,* 2012; Martínez-Harms and Balvanera, 2012; Eigenbrod *et al.,* 2010; Burkhard *et al.,* 2009). According to Martínez-Harms and Balvanera (2012) review, which focus on social-ecological assessments of ES, the most commonly mapped ES are carbon storage, carbon sequestration, food production and recreation. The most frequently used method is the causal relationships based on the understanding of ES and readily available information. Other methods for mapping ES are extrapolation of primary data (e.g., field data, surveys, and census data), expert knowledge, regression models and look-up tables. Regional (10^3 – 10^5 km^2) and national (10^5 – 10^6 km^2) spatial scales are the most common analysed; and land cover variables, topographical information and spectral vegetation indices are frequently used as source of information (Martínez-Harms and Balvanera, 2012).

When applied to complex coastal regions, such as Ria de Aveiro coastal region, the selected mapping and classification approaches must be adapted to the case study's biophysical and sociocultural characteristics, governance framework and to the scale of analysis. With the purpose of contributing to the discussion on ES classification and mapping at regional scale, this chapter suggests and debates a set of tools: i) to define the exact geographic boundaries of the study area; ii) to identify and classify the ES provided; and iii) to map the ES delivered by a complex coastal region. Initially, the criteria used to define the exact boundaries (as it involves various ecosystem typologies and a complex governance framework) are determined and discussed. The ES currently provided by the case study are identified, described and classified. Ultimately, a set of indicators that will serve as basis to map ES are established

(Figure 9). This approach follows the principles of integrated and ecosystem-based management approaches, acknowledging the complexity and the interspecies relationship within ecological systems, but also accounting for social and governance objectives (Long *et al.,* 2015). It aims to contribute to the discussion on ES classification and mapping at regional scale.

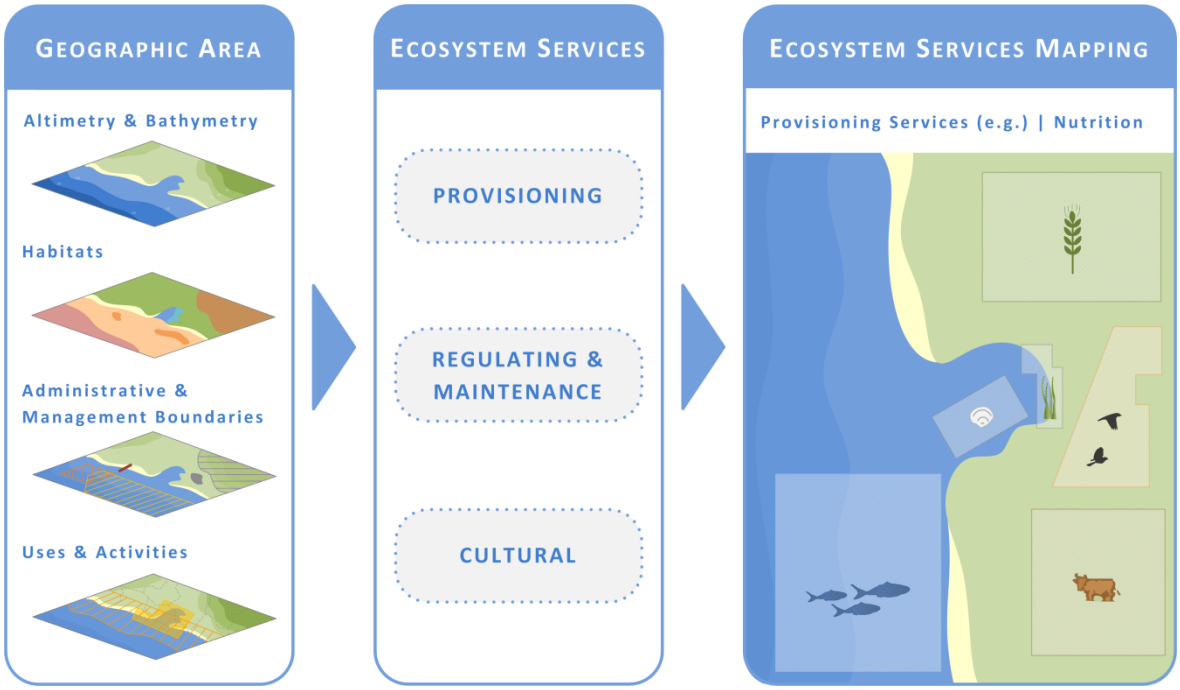


Figure 9. Overview of the conceptual approach: From the boundaries definition to the ecosystem services classification and mapping. Source: Sousa *et al.*, 2016

3.2. Material and methods

3.2.1. Definition of the geographic area

Geographic boundaries are frequently defined by administrative boarders, (e.g. county, municipality, parish), statistical units (e.g. NUTS - Nomenclature of Territorial Units for Statistics) or by jurisdictional boundaries of planning and management tools through plans and programmes (e.g. strategic planning, land/maritime development, environmental planning). Nevertheless, these boundaries do not always correspond to the geography of human uses, ecosystem processes or boundaries, such as those based on biogeography, oceanography and/or bathymetry (Beck *et al.*, 2009). In addition, in the context of an integrated and ecosystem-based management approaches, such boundaries should be taken into account, and a balance between ecological, social and jurisdictional factors should be achieved (Crowder and Norse, 2008; Gilliland and Laffoley, 2008).

Therefore, the criteria for defining the study area include:

- Analysis of the territory elements (e.g. land cover, topography, bathymetry) and identification of the physical boundaries of the main studied ecosystems and its interfaces, in order to include significant connective structures of the landscape (i.e., physical relationships that facilitate the link between different elements in the landscape or spatial settings across multiple scales, such as blue and green infrastructures) and thus adopt a system-wide approach (UNEP-WCMC, 2008);
- Spatial planning and management tools that focus on the study area, particularly at regional or municipal level for land/maritime development, spatial planning, and/or environmental planning;
- Designated areas for nature conservation under international, supranational or national protected areas network (e.g. Ramsar Convention, Natura 2000 network, Nature Parks);
- Administrative and statistical boundaries (e.g. parish, municipality, NUTS III), depending on the detail of the assessment as well as the available information;
- Existence, availability and scale of spatial data, which may condition the enforcement of previous criteria.

3.2.2. Ecosystem services identification and classification

As discussed in Chapter 2, the ES concept has evolved over time, with varying attention for the ecosystem basis or the economic use (Table 2). Concerning the ES classification, CICES not only is the classification adopted by the MAES working group but also the one that will be used by Member States during the implementation of the EU Biodiversity Strategy (Maes *et al.,* 2014). For this reason, and given that CICES is consistent with existing and accepted typologies of ES (such as MA, 2005a and TEEB, 2010), and establishes a basis for comparison between ES assessments in different ecosystems and countries (Turkelboom *et al.,* 2013), the final version of CICES (V4.3) is the classification system used in this research.

Table 2. Ecosystem services definitions. Source: Adapted from Häyhä and Franzese, 2014; Braat and de Groot, 2012; Vandewalle *et al.*, 2008.

Source	ES definition	Ecosystems	Economic
Daily, 1997	*"The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life"*	•	
Costanza *et al.,* 1997	*"The benefits human populations derive, directly or indirectly, from ecosystem functions"*		•
MA, 2003	*"The benefits people obtain from ecosystems"*	•	•
Boyd and Banzhaf, 2007	*"Components of nature, directly enjoyed, consumed, or used to yield human well-being"*		•
Fisher *et al.,* 2009	*"The aspects of ecosystems utilized (actively or passively) to produce human well-being"*		•
TEEB, 2010	*"The direct and indirect contributions of ecosystems to human well-being"*	•	•
Haines-Young and Potschin, 2013	*"The contributions that ecosystems make to human well-being"*	•	•

3.2.3. Ecosystem services mapping

From the variety of ES mapping methodologies consulted, the methodology adopted relates to Burkhard *et al.* (2009) and Medcalf *et al.* (2012) methodologies. Similarly to Burkhard *et al.* (2009), the adopted mapping approach relies on the principle that ecosystems differ in their capacity to provide ES. Besides, as Medcalf *et al.* (2012), it assumes that there is a significant set of available information that can be used to either map a given ES or provide a proxy for the service so that it can be mapped. Like Burkhard *et al.* (2009), this approach uses existing spatial data on habitats and land use/land cover (LU/LC) to demonstrate ecosystems' capacity to provide ES in a spatial manner. This is complemented with alternative data on management plans, administrative procedures and legal instruments (e.g., designated areas for, or areas restricted to, certain activities), biophysical aspects (e.g., soil typology, evapotranspiration rates, position in the landscape, like next to a watercourse), and human activities (e.g., recreational areas, shellfish collecting areas), similarly to Medcalf *et al.* (2012), enabling to reduce the uncertainty associated and provide maps of actual ES. This approach uses a set of qualitative indicators that are assigned to each ES and abiotic outputs to indicate its presence. A Geographic Information System (GIS) based approach is used to map these ecological, biophysical and socioeconomic features that illustrate provisioning, regulating and maintenance, and cultural services. These maps can be organized by 'Division' or 'Group' (under CICES classification) depending on their

complexity in order to obtain clear and visually attractive maps, easily understandable by technicians, planners and other stakeholder groups.

3.2.4. Data acquisition

An important phase in ES mapping is data acquisition, database development, and quality assessment (Peña *et al.,* 2015; Medcalf *et al.,* 2012). In order to implement the proposed methodology, several data needs to be collected and analysed regarding physical, ecological, socioeconomic, territorial and structural aspects of the study area and its surroundings. Because ecosystems are one of the primary landscape units that provide ES, it is important to analyse their spatial distribution (Nemec and Raudsepp-Hearne, 2013). Other features that contribute to the study area characterization and the accuracy of ES maps are: morphology of the territory (elevation and bathymetry); river network and water bodies; geology; soil typology; LU/LC; and social and economic data (e.g., population density, buildings and infrastructures), which provide information regarding the major demands alongside the main drivers of change and pressures (WRT, 2014). Therefore, the resulting geodatabase is composed by multi-source geospatial data in GIS format, which needs to be assessed regarding its spatial coverage, data projections, suitability, date and frequency of updates (Peña *et al.,* 2015).

3.3. Results

3.3.1. Case study boundaries

Ecosystem-based management is an integrated approach to management that recognises that human uses and ecosystem health are interdependent. Although it considers ecological, social and cultural objectives, ecological sustainability is the primary goal of management (CBD, 2009; McLeod *et al.,* 2008). To act in accordance with the objectives of this approach, the delineation of the case study boundaries took into account the concepts of structural connectivity and complementarity between the different natural and semi-natural systems (Figure 10) – marine, transitional, riverine, and terrestrial, including human-shaped ecosystems (agro-ecosystems). Structural connectivity is based entirely on landscape structure (Kindlmann and Burel, 2008), i.e. not considering, for now, the functional responses. However, authors acknowledge the importance of functional connectivity, which is of paramount importance when considering habitats sensitivity and vulnerability, on risk assessment and management.

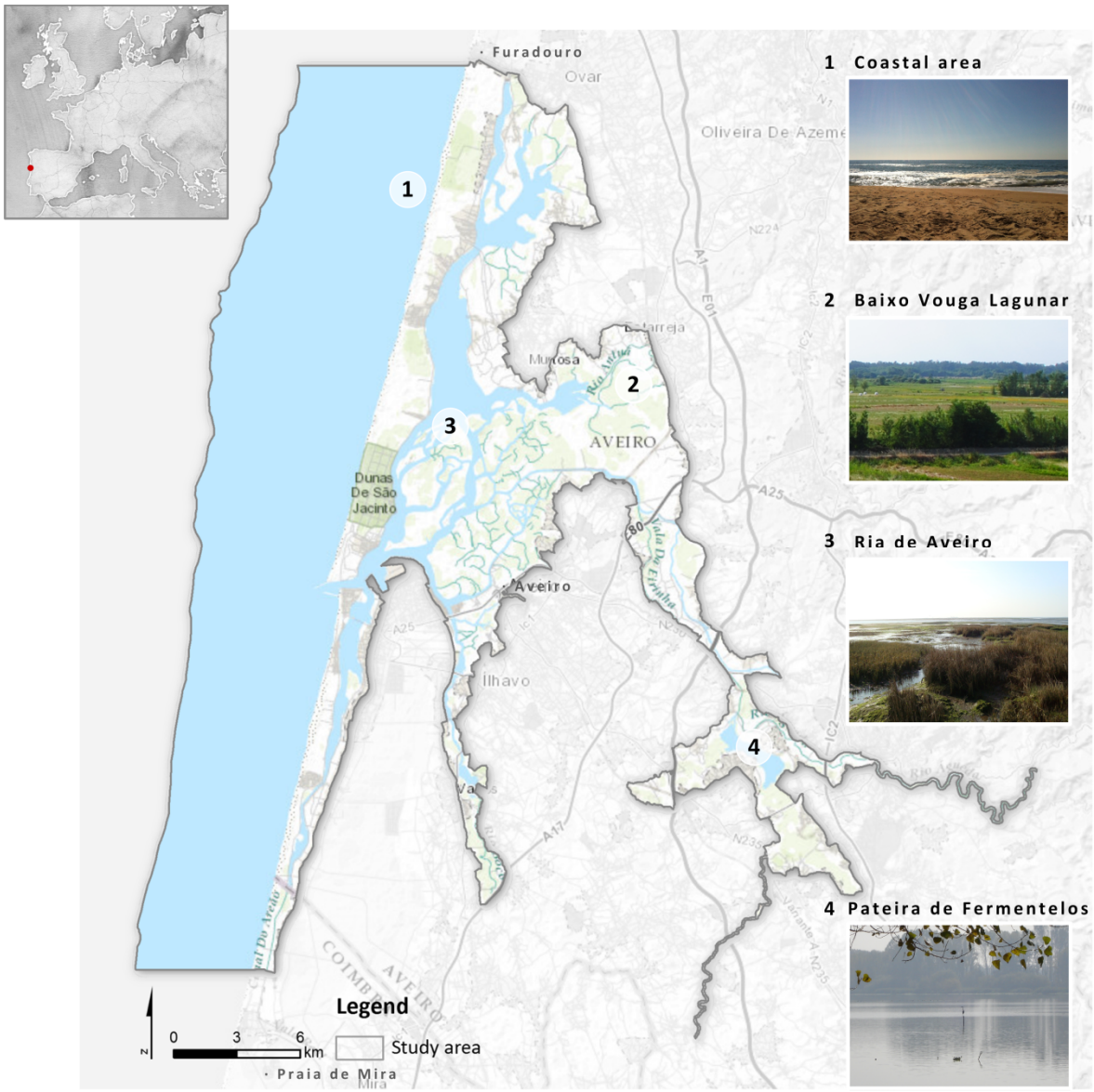


Figure 10. Ria de Aveiro coastal region and its main territorial elements. Map tiles by Stamen Design (http://stamen.com) under CC BY 3.0 (http://creativecommons.org/licenses/by/3.0/). Data by OpenStreetMap (http://openstreetmap.org), licensed under CC BY-SA. The license terms can be found on the following link: http://creativecommons.org/licenses/by-sa/3.0/. Sources of ESRI World Topographic Map: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, {copyright, serif} OpenStreetMap contributors, GIS User Community. Pictures copyright: 1 ©Lisa Sousa, 2 ©Nuno Rodrigues, 3 ©Ana Lillebø, 4 ©Célia Laranjeira. Source: Sousa *et al.*, 2016

To comply with the considered concepts, the study area includes, besides the Ria de Aveiro coastal lagoon (the focus of this research):

- the ecological structures considered complementary to the lagoon – e.g., the coastal strip between Furadouro (in the North) and Praia de Mira (in the South) and the lagoon's margins, responsible for its shape; and the Pateira de Fermentelos freshwater lake, an important wetland from the conservation point of view; and
- the connective structures – e.g., rivers that flow into the lagoon, riparian corridors, and agricultural fields (such as *bocage*) between the lagoon and the Pateira de Fermentelos, which are components of the landscape that can facilitate the biological flows, i.e., which provide important functional connectivity.

Nevertheless, adjustments to the marine and terrestrial boundaries were made in order to match the existing management and spatial planning framework (Sousa *et al.,* 2015; Alves *et al.,* 2013a) (Figure 33), namely the Vouga Estuary Programme[2] and the Coastal Zone Programme (CZP) for the stretch Ovar – Marinha Grande:

- inclusion of the estuary margins (50m measured from the limit of the water body);
- adjustments in the marine boundary up to a depth of 30m in order to include the marine area covered by the CZP.

Additionally, adjustments were made to include the limits of the SPA Ria de Aveiro, the SCI Ria de Aveiro, the Ramsar Site Pateira de Fermentelos Lake, and Águeda and Cértima Valleys.

As result of the adjustments, the study area comprises a total area of 62,535ha of which 30,779ha are marine and 31,756ha are terrestrial. Its elevation ranges between 0-20m in most of the study area, reaching 80m in the proximity of Pateira de Fermentelos.

3.3.2. Ecosystem services in Ria de Aveiro: identification and classification

A total of 59 ES and abiotic outputs were initially considered in this analysis, following the CICES system for both ES and abiotic outputs. The identification of the ES provided by the study area was based on Lillebø *et al.,* 2015b; ADAPT-MED, 2013; Liquete *et al.,* 2013; Sousa *et al.,* 2013a; Salomidi *et al.,* 2012; Maltby *et al.,* 2011; and Barbier *et al.,* 2011.

[2] DL no. 129/2008, July 21st creates the planning figure of "Estuary Management Plan" and Ruling no. 22550/2009 determines its elaboration for the Vouga Estuary; however, the Plan was never developed. Currently, these Plans have a new framework and are called Estuary Programmes (DL no. 80/2015 of May 14th).

For the purpose of presenting the ES identified both in a concise way and without losing detailed information, the study area was divided in four major ecosystem typologies, similar to those defined by Maes *et al.,* 2014: coastal waters, transitional waters, freshwaters, terrestrial ecosystems (including agro-ecosystems). ES related to green infrastructures within urban areas were not considered in this study since the current spatial scale does not allow the degree of detail required for that type of analysis.

The ES and abiotic outputs delivered by the Ria de Aveiro coastal region were identified and briefly described in Table 3 (a detailed description is given in Table A. 1 and Table A. 2 of Appendix I). Regarding abiotic outputs, it was identified the provision of mineral nutritional substances (e.g. marine salt), associated to transitional waters; non-metallic materials (e.g. sand and gravel), associated to coastal waters; and weather regulation, both associated to transitional and freshwaters.

Table 3. Summary of the ES provided by Ria de Aveiro coastal region. CW denotes coastal waters; TW denotes transitional waters; FW denotes freshwaters; TE denotes terrestrial ecosystems (including agro-ecosystems); ● denotes presence of the ES; *stands for adaptations of CICES V4.3 during the mapping process. Source: Sousa *et al.*, 2016

Section	Division	Group	Class	CW	TW	FW	TE
PROVISIONING	Nutrition	Biomass	Cultivated crops				●
			Reared animals and their outputs				●
			Wild plants, algae and their outputs		●	●	
			Wild animals and their outputs	●	●	●	
			Plants and algae from in-situ aquaculture		●		
			Animals from in-situ aquaculture		●		
		Water	Surface water for drinking				
			Ground water for drinking				
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing		●	●	●
			Materials from plants, algae and animals for agricultural use		●	●	●
			Genetic materials from all biota				●
		Water	Surface water for non-drinking purposes		●	●	
			Ground water for non-drinking purposes			●	

Section	Division	Group	Class	CW	TW	FW	TE
	Energy	Biomass-based energy sources	Plant-based resources				
			Animal-based resources				
		Mechanical energy	Animal-based energy				●
REGULATION & MAINTENANCE	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	●	●	●	●
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals*	●	●	●	●
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	●	●	●	●
			Dilution by atmosphere, freshwater and marine ecosystems	●	●	●	
			Mediation of smell/noise/visual impacts				●
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates		●	●	●
			Buffering and attenuation of mass flows	●	●	●	
		Liquid flows	Hydrological cycle and water flow maintenance		●	●	●
			Flood protection		●	●	●
		Gaseous / air flows	Storm protection				
			Ventilation and transpiration				●
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal			●	●
			Maintaining nursery populations and habitats	●	●	●	●
		Pest and disease control	Pest control*	●	●	●	●
			Disease control				
		Soil formation and composition	Weathering processes				●
			Decomposition and fixing processes	●	●	●	●
		Water conditions	Chemical conditions of freshwaters*	●	●	●	
			Chemical conditions of salt waters*	●	●	●	
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	●	●	●	●

Section	Division	Group	Class	CW	TW	FW	TE
			Micro and regional climate regulation				●
CULTURAL	Physical and intellectual interactions with biota, ecosystems, and landscapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings		●	●	●
			Physical use of land-/seascapes in different environmental settings	●	●	●	
		Intellectual and representative interactions	Scientific	●	●	●	●
			Educational		●	●	●
			Heritage, cultural		●	●	●
			Entertainment		●	●	●
			Aesthetic	●	●	●	●
	Spiritual, symbolic and other interactions with biota, ecosystems, and landscapes	Spiritual and/or emblematic	Symbolic				
			Sacred and/or religious				
		Other cultural outputs	Existence*	●	●	●	●
			Bequest*	●	●	●	●

3.3.3. Ecosystem services in Ria de Aveiro: spatial distribution

A set of qualitative indicators, summarized in Table 4, were identified and assigned to each ES and abiotic outputs. This selection took into account the existence and accessibility of spatial data, which serves as a proxy of the service so it could be mapped. Only the ES and abiotic outputs identified in Table 3 were considered in Table 4. However, not all have an assigned indicator due to the lack of spatial data (e.g. hunting, under the ES class *'wild animals and their outputs'*) or due to the nature of the ES (e.g. inspiration and sense of place under *'aesthetic'* ES class, and traditional boats under *'heritage, cultural'*). Additionally, during the ES and abiotic outputs mapping exercise, some issues were identified regarding the application of the CICES (see 3.4. Discussion), resulting in small adaptations of CICES V4.3 table, highlighted in Table 3 with an asterisk. The full list of indicators used to map the ES and abiotic outputs delivered by Ria de Aveiro coastal region, along with the typology and source of data used are given in Table A. 1 and Table A. 2 of Appendix I.

Table 4. Summary of the indicators used to map the ES and abiotic outputs provided by Ria de Aveiro coastal region. NA denotes not applicable. Source: Sousa *et al.*, 2016

Section	Division	Group	Class	Indicator
PROVISIONING	Nutrition	Biomass	Cultivated crops	Presence of annual crops, rice fields and *bocage*
			Reared animals and their outputs	Presence of pastures and *bocage*
			Wild plants, algae and their outputs	Presence of authorized collecting areas
			Wild animals and their outputs	Presence of fishing zones, shellfish collecting areas, hunting areas
			Plants and algae from in-situ aquaculture	Presence of active units
			Animals from in-situ aquaculture	Presence of active units
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Presence of reed marshes along Ria de Aveiro, mudflats, and forested habitats
			Materials from plants, algae and animals for agricultural use	Presence of *Zostera noltei* bed habitat subgroup and rush marsh
			Genetic materials from all biota	Presence of *bocage*
		Water	Surface water for non-drinking purposes	Presence of rivers, ditches, freshwater lakes, aquaculture, active salt pans, transitional waters, and water scooper operation areas
			Ground water for non-drinking purposes	Presence of groundwater abstraction points
	Energy	Mechanical energy	Animal-based energy	Presence of pastures and *bocage*
REGULATION & MAINTENANCE	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	All the considered habitats (e.g. intertidal flats, soils, aquatic and terrestrial vegetated areas)
		Mediation by ecosystems	Filtration/ sequestration/ storage/ accumulation by biota and ecosystems	Presence of salt marshes, reed marshes, intertidal flats (including *Zostera noltei* beds), coastal waters, riparian and alluvial forests
			Dilution by atmosphere, freshwater and marine ecosystems	Presence of coastal waters, transitional waters and freshwaters
			Mediation of smell/ noise/ visual impacts	Presence of *bocage*
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion	Presence of coastal dunes, salt marshes, reed marshes, *Zostera noltei* beds, forests

Section	Division	Group	Class	Indicator
			rates	(including alluvial and riparian forest), natural grassland, and shrubland
			Buffering and attenuation of mass flows	Presence of salt marshes, reed marshes, *Zostera noltei* beds, coastal waters, transitional waters, and freshwaters
		Liquid flows	Hydrological cycle and water flow maintenance	Presence of riparian forest, salt marshes and other areas with high evapotranspiration
			Flood protection	Presence of coastal dunes, salt marshes, reed marshes, riparian forest, and *bocage*
		Gaseous / air flows	Ventilation and transpiration	Presence of *bocage*
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Presence of forests (including alluvial and riparian forest), and *bocage* along low lands of Vouga river
			Maintaining nursery populations and habitats	Presence of rivers, freshwater lakes, transitional waters, salt pans, salt marshes, reed marshes, intertidal flats (including *Zostera noltei* beds), coastal waters, *bocage*, fixed dunes with herbaceous vegetation, and dunes with Salix, and forests (including alluvial and riparian forest)
		Soil formation and composition	Weathering processes	Presence of fluvisols combined with forests and floodplain areas
			Decomposition and fixing processes	All the considered habitats (e.g. intertidal flats, soils, aquatic and terrestrial vegetated areas)
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	Presence of coastal waters, forests (including alluvial and riparian forest), forested dunes, salt marshes, reed marshes, and *Zostera noltei* beds
			Micro and regional climate regulation	Presence of *bocage*
CULTURAL	Physical and intellectual interactions with biota, ecosystems, and landscapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	Designated places for birdwatching and land-/ seascape appreciation
			Physical use of land-/seascapes in different environmental settings	Area of activity (e.g. sailing, canoeing, surfing)
		Intellectual and representative interactions	Scientific	Territory subject of scientific research
			Educational	Location of eco-museums, and environmental interpretative centres
			Heritage, cultural	Designated subaquatic archaeological sites, location of buildings with traditional

Section	Division	Group	Class	Indicator
				architecture, and location of traditional activities
			Entertainment	Location of the festivals and fairs
			Aesthetic	Location of permanent artistic exhibitions
ABIOTIC OUTPUTS	Nutritional abiotic substances	Mineral	NA	Presence of active salt pans
	Abiotic materials	Non-metallic	NA	Designated areas for sand and gravel exploitation
	Maintenance of physical, chemical, abiotic conditions	By natural chemical and physical processes	NA	Presence of transitional waters, rivers, and freshwater lakes

Whenever possible and appropriate, data on administrative processes and legal instruments were used in combination with spatial data as a mean to achieve more accurate maps and consistent with the case study reality. This was especially the case of provisioning and cultural services (e.g. *Salicornia* sp. harvesting, fishing and shellfish collecting, archaeological sites, protected areas). The class *'wild plants, algae and their outputs'* within division *'nutrition'*, for instance, refers to wild glasswort *Salicornia* sp., which is present in almost all salt pans; however, only one of them is certified and authorized to commercialize it. Thus, only this salt pan was mapped (Figure 11). Another example is the class *'wild animals and their outputs'* under the same division. The entire coastal lagoon has potential for fishing; however, this activity is forbidden in certain areas within Aveiro harbour jurisdiction to ensure the safety of navigation, people and goods (Legal Notice no. 01/2012). This results in the exclusion of these areas from the map (Figure 11).

The proposed indicators for mapping regulating and maintenance services are dominantly based on the presence and distribution of functional geographical units[3]. However, in the case of the ES classes *'hydrological cycle and water flow maintenance'* (within the division *'mediation of flows'*) and *'weathering processes'* (within the division *'maintenance of physical, chemical, biological conditions'*) complementary data was considered to achieve a more accurate representation of the ES. Therefore, for the *'hydrological cycle and water flow maintenance'* case, areas with higher evapotranspiration rates were considered beyond the riparian and alluvial habitats. For the *'weathering processes'* case, the type of soil was combined with the land cover and floodplain areas (Figure 12), i.e. the ES is represented by the areas which integrates both fluvisols and forests, or both fluvisols and floodplain areas. Although

[3] See the Discussion section of this chapter for the definition of functional geographical units.

the climate and topography have influence in the weathering processes, they were not considered since these factors are quite regular within the study area.

A significant number of cultural services are geometrically represented by points, not only because of the reduced area (even at this scale) occupied by the ES (e.g. subaquatic archaeological sites), but also due to the nature of the ES. The ES class *'entertainment'*, for instance, refers to ex-situ experiences of the Ria de Aveiro coastal region through festivals and fairs. The location of such festivals and fairs is mapped despite the fact that the service is provided by the existence of salt pans in the coastal lagoon, for example, or the existence of a long tradition of fishing and shellfish collecting in the lagoon. Another example of this technical detail is the use of points to map birdwatching and landscape enjoyment under the *'experiential use of plants, animals and land-/seascapes in different environmental settings'* class. The locations that allow a better enjoyment of the ES are mapped, despite the fact that is the landscape characteristics, or the birds' diversity that provide the service (Figure 13).

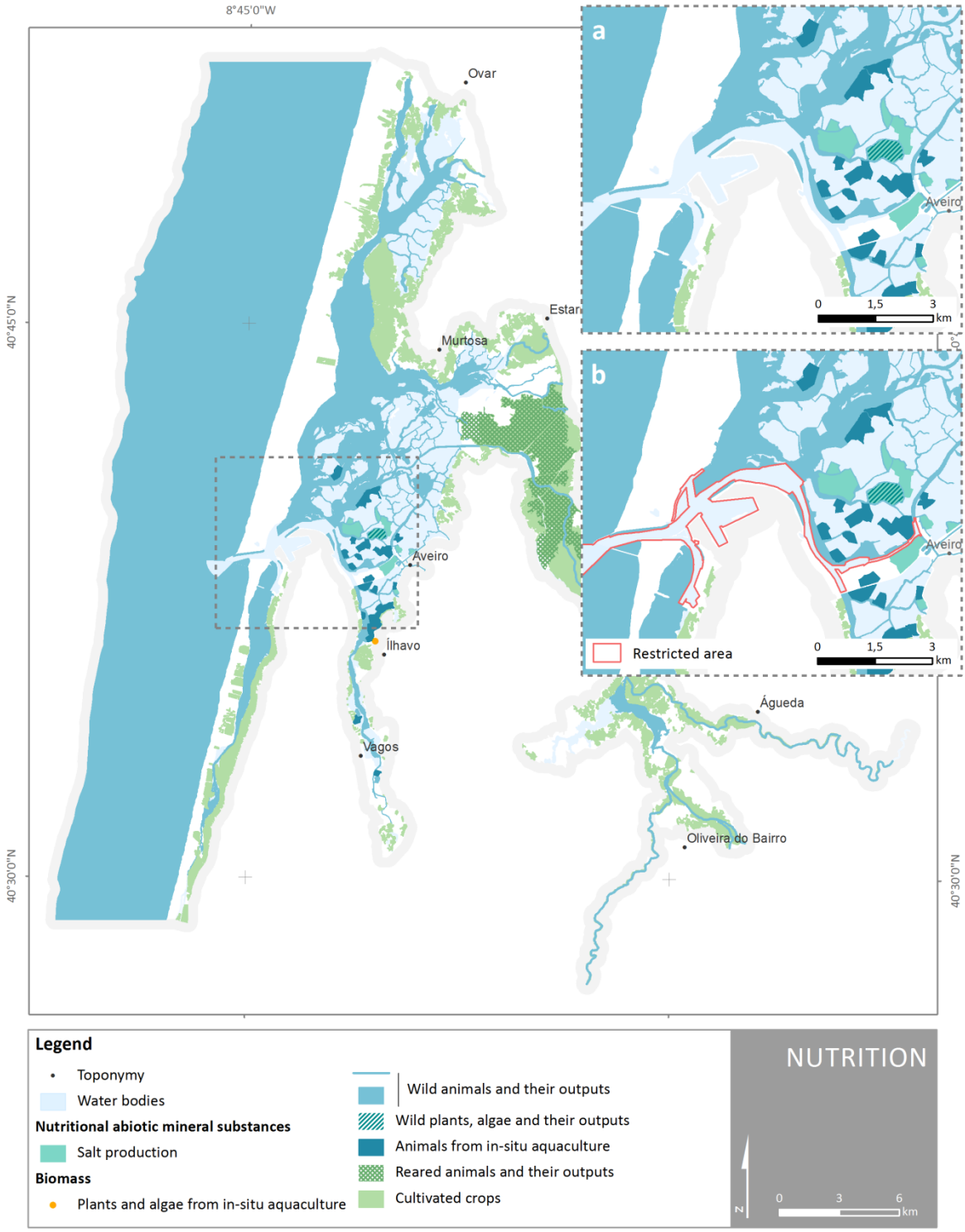


Figure 11. Spatial distribution of ES classes and abiotic outputs present in Ria de Aveiro coastal region under the division 'nutrition'. A – Detail of Ria de Aveiro central area. B – Fishing restricted area (Public Notice no. 01/2012). Source: Sousa *et al.*, 2016

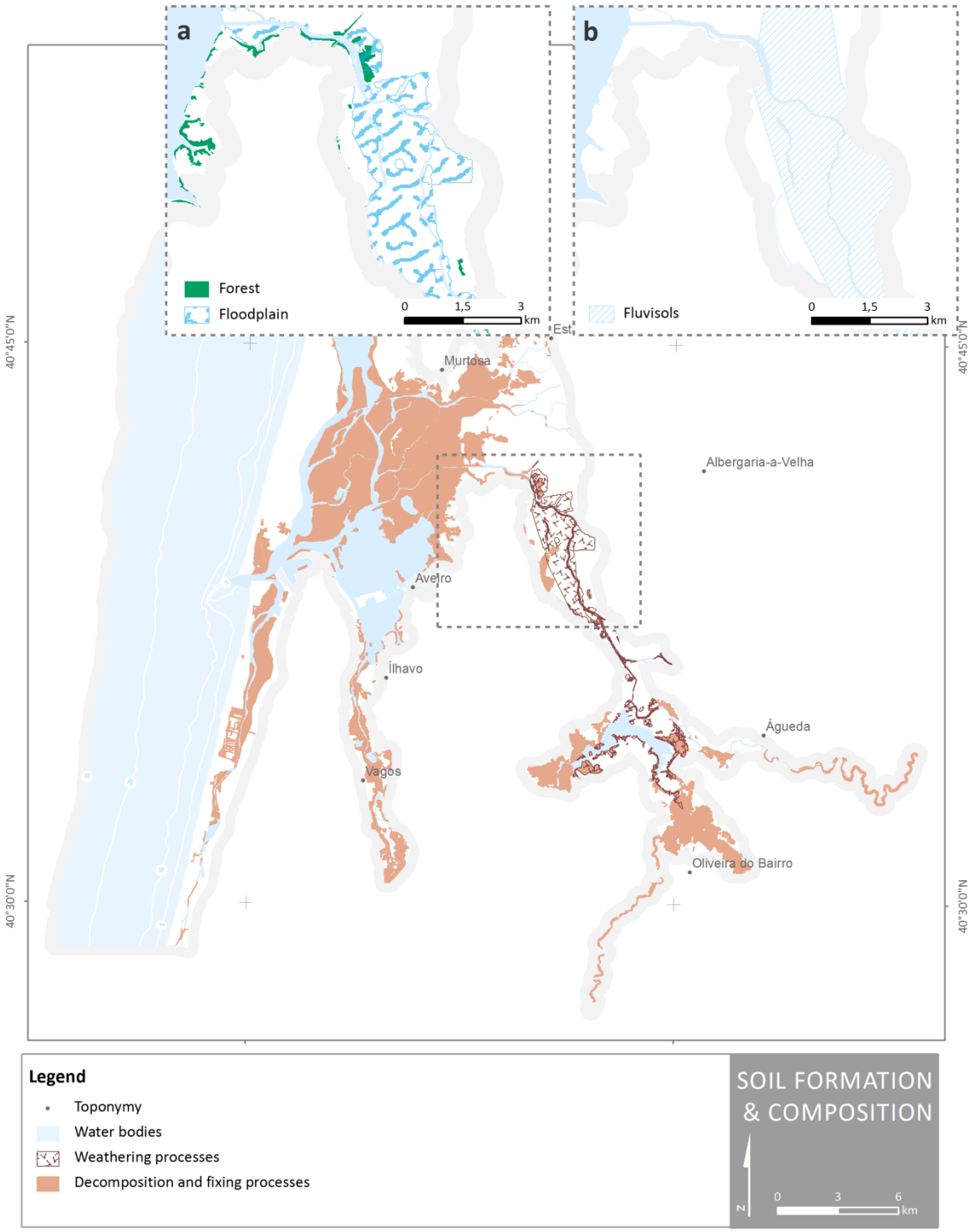


Figure 12. Spatial distribution of ES classes present in Ria de Aveiro coastal region under the group 'soil formation and composition'. A – Detail of the spatial distribution of forest and floodplain areas. B – Detail of the spatial distribution of fluvisols. Source: Sousa *et al.*, 2016

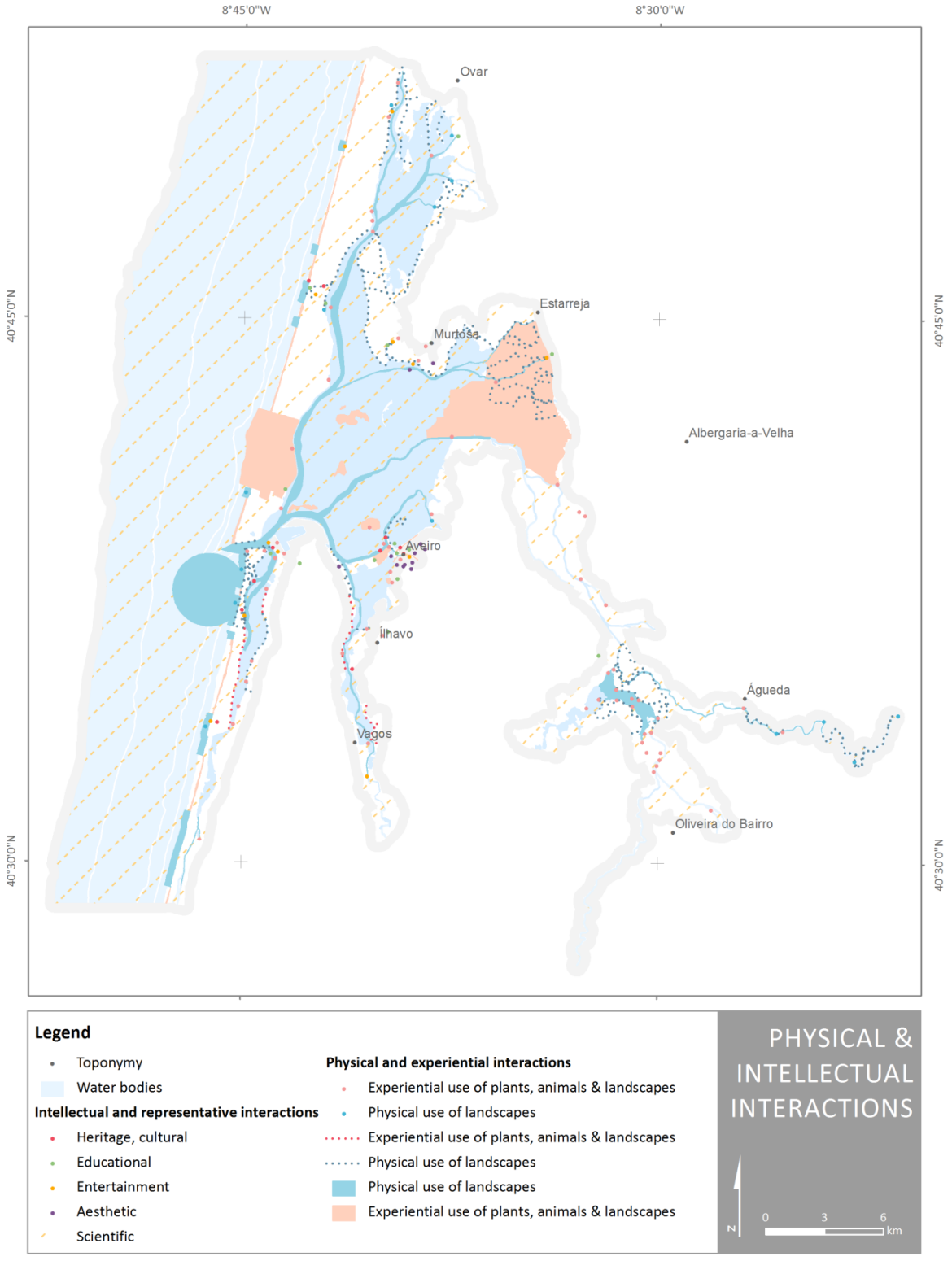


Figure 13. Spatial distribution of ES classes present in Ria de Aveiro coastal region under the division 'physical and intellectual interactions with biota, ecosystems, and landscapes'. Source: Sousa *et al.*, 2016

3.4. Discussion

The process of defining the study area boundaries, identifying and mapping the ES raised some challenges. The fact that coastal lagoons are interface ecosystems hampers the definition of strict boundaries, essential for the scope of this research. Therefore, there was the need to ensure the link between marine, transitional and riverine systems without losing focus on the main feature of this study, the Ria de Aveiro coastal lagoon. Boundaries definition is a crucial step for the identification and classification of ES, since it enables the understanding on the type of ecosystems present. This is particularly important when considering the existence of land-based recreation activities, for instance, driven by the coastal lagoon (e.g. bird watching, angling, walking), or for example the role of coastal dunes in contributing to the lagoon's integrity. Moreover, the compliance of the study area with the legal framework is considered an advantage since it enables the integration of these results in the spatial planning and management tools, and facilitates funding acquisition for its implementation or development.

CICES reveals to be suitable to classify ES of complex coastal regions, with minor adjustments according to the scale of analysis, data availability, and its biophysical and sociocultural characteristics. While establishing a common typology of ES – underpinned on clear concepts and principles – CICES is flexible enough to be adapted to different realities, conditions, scales (e.g. Belgium (Turkelboom *et al.*, 2013), Ria de Aveiro - this study), and purposes (e.g. mapping, economic valuation). This is possible because: i) CICES is based on clear and well defined concepts; ii) it follows a hierarchical structure that allows the adoption of different levels of detail according to the user's interest; iii) each level of the hierarchical structure has been designed in a way that there is no overlapping nor redundancy; and iv) it is focused on "final" services or outputs from ecosystems that people use or value, in order to avoid double counting (Haines-young and Potschin, 2014; Turkelboom *et al.*, 2013). However, the *'regulation and maintenance'* section is relatively specific and requires scientific in-depth knowledge about biological and physic-chemical processes, which can be a constraint to its use by decision-makers, technicians, planners, or even by the public.

During the mapping exercise, some issues arose driven by different reasons, which led to minor adaptations to the CICES V4.3 in order to better integrate the case study conditions, scale of analysis and available data:

- Lack of spatially detailed information to distinguish the biota (micro-organisms, algae, plants, and animals) from the ecosystem. This is the case of the ES classes *'filtration/ sequestration/ storage/ accumulation by microorganisms, algae, plants and animals'* and *'filtration/*

sequestration/ storage/ accumulation by ecosystems' within the division *'mediation of waste, toxics and other nuisances'*. Thus, the ES was spatially represented by the ecosystem components and referred as *'filtration/ sequestration/ storage/ accumulation by biota and ecosystems'*. Examples of these ecosystem components are salt marshes, reed marshes, intertidal flats, coastal waters, riparian and alluvial forests.

- Lack of supporting information for the ES group *'water conditions'* regarding the underlying service to achieve such state. In the mapping exercise, this group was excluded since it was considered that the proposed indicators (Maes *et al.,* 2014) reflect an ecosystem status based on chemical indicators, specifically the indicators for the trophic status, and not the provided service. Therefore, it reflects the status due to environmental pressures (eutrophication) instead of the provided service. On the other hand, *'water conditions'* in the scope of the WFD includes also the biological indicators and the priority substances.
- Insufficient knowledge (particularly about the species and their distribution) regarding "natural" biological control has led to the use of the abundance and distribution of alien species or host-species as proxy indicators for the *'pest control'* (e.g. Maes *et al.,* 2014). Again, the proposed indicator reflects the resistance to the environmental pressure (alien species) and not the provided service. However, despite of acknowledging the existence of alien species in the case study (Table 3), this service was not mapped to avoid its misinterpretation or undermine the communication with the technicians, the public and other stakeholder groups. Nevertheless, authors acknowledge that the spatial distribution of the alien species, and its monitoring, is of paramount importance for the management of ecosystems, and should be considered during a vulnerability assessment.
- Ambiguity and subjectivity associated to the group *'other cultural outputs'* of the division *'spiritual, symbolic and other interaction with biota, ecosystems, and land-/seascapes [environmental settings]'*. In line with the CICES adaptation to Belgium (Turkelboom *et al.*, 2013), this ES group was perceived as part of a valuation analysis and therefore it was excluded from the mapping.

The varying quality, scale and accuracy of the collected data created a barrier, requiring data refinement, reclassification, and projection. Data preparation involved projection to the same coordinate system (in this case ETRS 89 - European Terrestrial Reference System 1989), and data refinement, particularly regarding data on habitat distribution, LU/LC, and seabed benthic habitats, which were collected for the study area from regional, national, and European sources, covering the years 2011, 2007, and 2014,

respectively. These pre-existing, but scattered, data was used as starting point to display ecosystems' spatial distribution, since they are the primary landscape unit that provide ES. Whenever possible, preference was given to more detailed information.

For the terrestrial area overlapping the SPA Ria de Aveiro it was used the habitat map produced by AMBIECO/PLRA (2011) in the scope of the Characterization Study on Ria de Aveiro Ecological Quality for the Polis Litoral Ria de Aveiro. The habitat map production was based on rectified orthophoto images (from 2005 with spatial resolution of 0.5-1m) from the Portuguese Geographic Institute (IGP), and complemented with latest information from Bing (2009) and GoogleEarth (2009, 2010, 2011). For the remaining terrestrial area it was used the second level (15 classes) of LU/LC for Continental Portugal (COS2007), produced by IGP (2010). COS2007 was produced based on visual interpretation of rectified and high resolution (50cm) orthophoto images. COS2007 is in vector format and has a minimum mapping unit of 1ha.

For the marine part of the study area (up to 30m depth) it was used the benthic habitat map from MESHAtlantic project (last updated in February 2014), available in the European Marine Observation and Data Network (EMODnet) website (http://www.emodnet-hydrography.eu/). The MESHAtlantic project covers over 356,000 km^2 of seabed habitats of the European North Atlantic Ocean and used a broad-scale mapping method, proposed within the INTERREG MESH project, which is based on available information or on data derived from mathematical models of the marine environment. The broad-scale map is a map of the physical characteristics of the habitats with a 250m grid resolution (which is roughly equivalent to a scale of 1:1,000,000) and uses the level 4 of the European Nature Information System (EUNIS) classification habitat types (MESHAtlantic, 2013).

In order to combine these three sources of information – Ria de Aveiro habitats from AMBIECO/PLRA (2011), LU/LC from IGP (2010) and benthic habitats from MESHAtlantic (2014) – the habitats classification and the LU/LC nomenclatures needed to be harmonized and reclassified (Figure 14). The resulting nomenclature is presented in Table A. 3 of Appendix II, and will be referred from now on as functional geographical units, as these are units that based on specific attributes and functions (such as habitat, land cover) establish the limits of the territory.

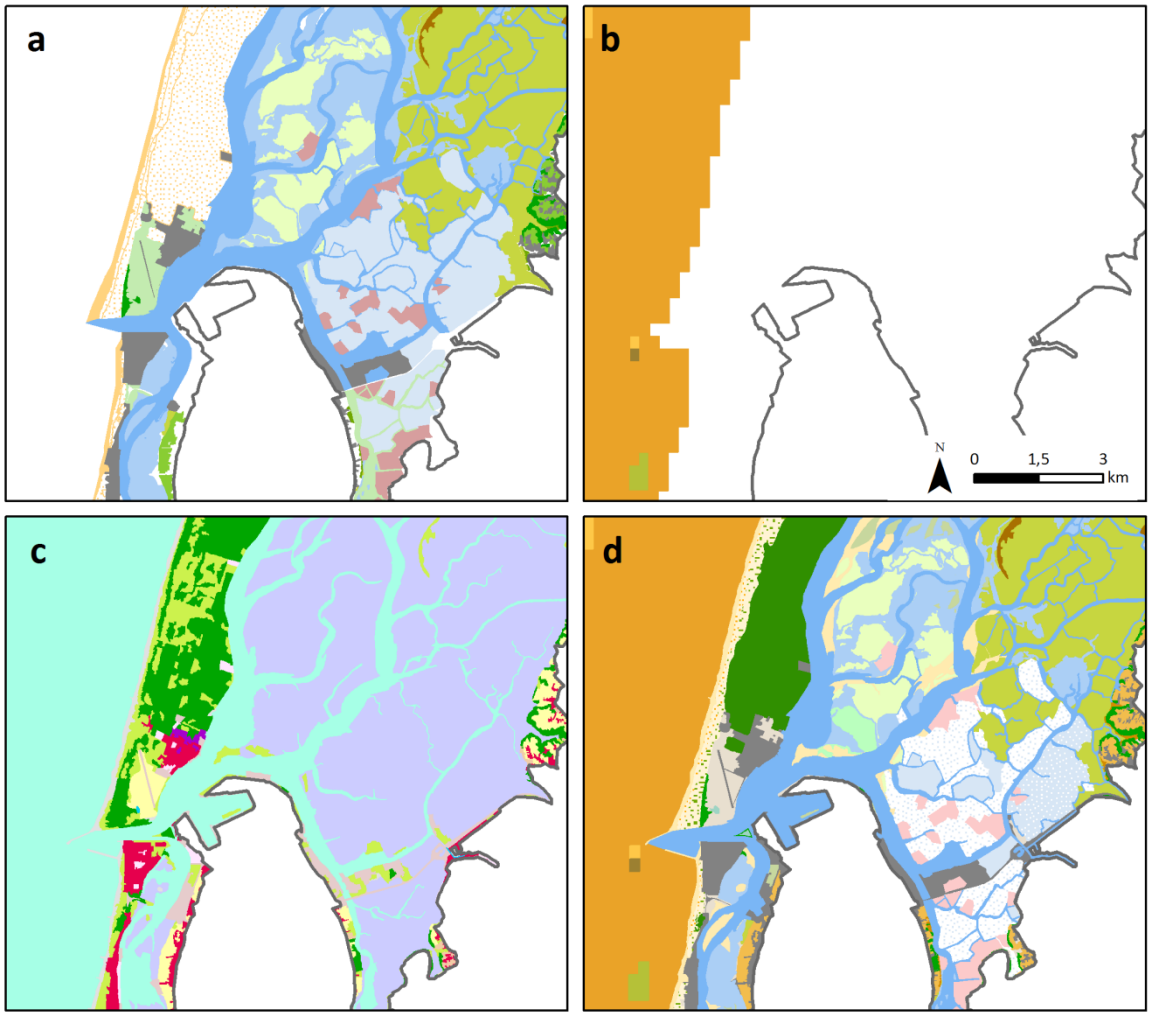


Figure 14. Detail of sources/typologies of data (A – Habitats from AMBIECO/PLRA, 2011; B - Benthic habitats from MESHAtlantic, 2014; C - COS2007 from IGP, 2010) used to obtain the final map of functional geographical units (D) for the Ria de Aveiro coastal region. Source: Sousa *et al.*, 2016

All of these challenges, along with the significant complexity of social-ecological systems and the scientific attempts to cope with that complexity (Schulp *et al.,* 2014; Hou *et al.,* 2013; Carpenter *et al.,* 2006), contribute to a certain degree of uncertainty that must be internalized when using and communicating the results. Bellow we identify some of the sources of uncertainty:

- Generalization and categorization used to reduce complex landscapes into a limited number of LU/LC, or habitat classes (Hou *et al.,* 2013). In the case study of Ria de Aveiro coastal region, whenever possible, it was given preference to habitat data, which was the most accurate available information. In the absence of more detailed information, the second level of COS2007 and the MESHAtlantic benthic habitat were used.

- Another source of uncertainty is the spatial and temporal mismatches of different sources of data. For example, in Ria de Aveiro coastal region, spatial data from different years and with different spatial resolutions had to be combined in order to fill the spatial gaps in habitat map. Moreover, even the most recent available data has more than five years.
- The ES classification system itself can be a source of uncertainty because of the ambiguity present in some classes, as previously referred. Some ES are difficult to assign to specific spatial units. For example, *'aesthetic'* class and *'other cultural outputs'* group within cultural services are appreciated in a very subjective manner and related to the landscape compositions (Hou *et al.,* 2013) and other social factors (e.g., cultural).
- Assumptions made in the course of the mapping, for example regarding the ecological status of the biotope and its ability to provide a certain ES.

3.5. Conclusion

The proposed framework proved to be suitable for addressing ES in complex coastal regions. On the one hand, it uses clear and objective criteria for delineating the geographic area, respecting the connectivity of natural systems but also the complexity of the governance framework, usual in these systems. Therefore, the analysis at a regional scale and the integration of several ecosystem typologies is seen as crucial for such social-ecological systems. The use of the internationally accepted CICES classification, although adapted to the case study reality and scale, is perceived as an advantage, allowing comparisons with other studies. On the other hand, the fact that the mapping approach is based on existing and available data, considers a wide range of ES and abiotic outputs, and uses mainstream software, means that this approach should be somehow easily replicable by technicians, and planners without investing large amounts of human and economic resources.

Exploring the application of CICES and an ES mapping approach based on qualitative indicators to Ria de Aveiro coastal region also allowed the identification of a number of pertinent issues. For instance, because the classes within regulation and maintenance services are relatively specific and require scientific-specific knowledge about biological and physic-chemical processes, CICES application by decision-makers, technicians, and planners can be demanding. Regarding the mapping approach, inspiration, and sense of place services within the ES class *'aesthetic'* provided by the Ria de Aveiro coastal region, which is deeply present in the region (Sousa *et al.*, 2015), still remains a challenge. Additionally, the mapping approach assumes that every part of a given ecosystem is of equal value with regard to its capacity to provide ES, without taking into consideration the ecosystems' health, or the fact

that certain habitats might have comparatively higher or lower potential to provide a certain service. The integration and analysis of additional information (e.g., ecosystem quality status data, the design of rules that could help grade the importance of different habitats capacity in providing ES) in the mapping process opens further opportunities.

4 Ecosystem services provided by a complex coastal region: spatial distribution and characterization

The contents of this chapter will be published in:

Sousa L.P., Lillebø A.I., Alves F.L., (working paper). Spatial patterns of ecosystem services in complex social-ecological systems: a management-oriented approach.

Part of the material in this chapter is published in:

Sousa L.P., Lillebø A.I., Gooch G.D., Soares J.A., Alves F.L., 2013. Incorporation of Local Knowledge in the Identification of Ria de Aveiro Lagoon Ecosystem Services (Portugal). *Journal of Coastal Research*, SI 65: 1051-1056. DOI: 10.2112/SI65-178.1

4.1. Introduction

The assessment of ecosystems and their services is increasingly being undertaken worldwide at a variety of scales: i) regional and global assessments (e.g., biodiversity and ES assessments carried out by IPBES); ii) European (e.g., pilot studies carried out by MAES working group to support the implementation of the EU Biodiversity Strategy to 2020, action 5); iii) national (e.g., MA, 2009; UK-NEA, 2011); and iv) sub-national (e.g., Grizzetti *et al.*, 2016; Guerra *et al.,* 2016). Mapping and assessment of marine ecosystems seems to be less advanced than for terrestrial ecosystems (Lavorel *et al.*, 2017; Liquete *et al.*, 2013; Maes *et al.*, 2012). The main reasons identified are the lack of high-resolution spatially explicit information for marine ecosystems; and incomplete understanding of ecosystem processes and functions in a highly dynamic three-dimensional fluid environment (Lavorel *et al.*, 2017; Liquete *et al.*, 2013; Maes *et al.*, 2012).

Despite of the growing knowledge, ES studies tend to focus on a small set of ES rather than having a comprehensive overview of social-ecological systems. Regarding coastal and marine ecosystems, food provision (fisheries), water purification, coastal protection, life cycle maintenance, and climate regulation are the ES most commonly studied (Liquete *et al.*, 2013).

The framework presented in the previous chapter tries to deal with some of these constraints by considering a wide range of ES and abiotic outputs, and by including not only terrestrial ecosystems, but also freshwater, estuarine and marine ecosystems in all its spatial dimensions (seabed, water column, and surface). This promotes an integrated and comprehensive view of the system. Additionally, it uses existing and available data, as well as mainstream software with the aim of enabling the uptake of the produced information, as well as the approach itself, by spatial planners and technicians.

This chapter provides a comprehensive analysis of the ES currently provided by Ria de Aveiro coastal region and their spatial distribution, which resulted from the application of the mapping methodology presented in the previous chapter. This study was complemented with the identification of multifunctional areas, and with the analysis of stakeholders' perception on ES provided by Ria de Aveiro coastal lagoon.

4.2. Data and methods

4.2.1. Spatial distribution of ecosystem services and multifunctional areas

The approach used to map the ES is described and discussed in the previous chapter. It uses a set of indicators (see Table 4, Table A. 1 and Table A. 2 of Appendix I) that indicate the presence of ES and allows the association of most of the ES classes to the functional geographical units.

Once each ES class has been mapped a spatial analysis was then undertook in ArcGIS 10.0 to identify multifunctional areas, i.e. areas that simultaneously perform multiple functions and provide multiple ES (Berry *et al.*, 2015). Individual layers of ES classes were overlaid and the number of overlapping polygons, lines and/or points was calculated through the use of a series of geoprocessing tools in ArcGIS 10. Values of 0 indicate the absence of ES; values of 1 indicate the presence of a single ES; and values higher than 1 indicate the presence of multiple ES.

4.2.2. Stakeholders' perception of Ria de Aveiro ecosystem services

The stakeholders' perception on Ria de Aveiro ES was inferred from the results of a deliberative and participatory study, so-called Focus Groups (FG), performed in the scope of the EU-FP7 LAGOONS research project (Baggett and Gooch, 2015; Sousa *et al.,* 2013a; Appendix 3). FG were held in different places around Ria de Aveiro coastal lagoon (from April 2012 to January 2013) in order to capture the local knowledge, specificities and perceptions in the different marginal parishes and by different stakeholders' groups. A total of nine FG were conducted, involving 74 stakeholders, mostly end-users, residents, local decision-makers, and some university students and researchers. The aim was to initiate the contact with local stakeholders and to explore their views, concerns and expectations regarding the coastal lagoon (Lillebø *et al.,* 2016; Baggett and Gooch, 2015; Sousa *et al.*, 2013a).

Although FG did not have the identification of ES as primary objective, we used this privileged contact and proximity with local population to analyse the ES that participants indirectly identified during the discussions.

4.3. Ecosystem services of Ria de Aveiro costal region

Following the approach discussed in Chapter 3, the ES provided by the Ria de Aveiro costal region were mapped. A total of 11 thematic maps (presented in the following sub-sections) were produced in accordance with the CICES classification system. Depending on its complexity, each map displays a

CICES' division or group (including abiotic outputs) in order to obtain clear and visually attractive maps, easily understandable by technicians, planners and other stakeholder groups (Sousa *et al.,* 2016).

The analysis of the ES (including abiotic outputs) spatial distribution reveals that provisioning, regulation and maintenance, and cultural services are spread across the study area: provisioning services are present in 83% of the case study area; regulating and maintenance services in 97%; and cultural services in 100%.

The following ES classes are the most representative in terms of areal extent (covering more than 50% of the case study area; see Table A. 4 of Appendix IV): 'scientific'; 'bio-remediation by micro-organisms, algae, plants, and animals'; 'decomposition and fixing processes'; 'maintaining nursery populations and habitats'; 'global climate regulation by reduction of greenhouse gas concentrations'; 'buffering and attenuation of mass flows'; 'filtration/ sequestration/ storage/ accumulation by ecosystems'; 'wild animals and their outputs'; and 'dilution by atmosphere, freshwater and marine ecosystems'. Note that some ES were represented by lines and points, which can give the impression that their contribution is reduced. This is particularly frequent in cultural services (e.g., 'physical use of landscapes' is represented with polygons - such as regatta; lines - as cycling routes; and points - as surf beaches), though it also happens with provisioning, and regulation and maintenance services (e.g., 'dilution by atmosphere, freshwater and marine ecosystems' is represented by a line – river; 'plants and algae from in situ aquaculture' are represented with a point due its reduced size). This can lead to a misinterpretation of the capability of the study area to provide cultural and other services.

4.3.1. Spatial distribution and characterization of provisioning services

Nutrition

Regarding nutrition (Figure 15), over 23% of the study area land is used for crop production, of which 28% is also used for grazing. A large part of this area is called *Baixo Vouga Lagunar* (BVL), and is characterized by its alluvial plain/soils, and three main landscape units: open fields, wetlands, and *bocage* (a characteristic man-shaped landscape of BVL consisting of smallholdings divided by living hedges and draining ditches, providing shelter for cattle and crops) (ADAPT-MED, 2013). Here, the main crop production is soy, beans, corn, wheat, rice and forage, and there is only an indigenous cattle species: the certified *marinhoa* breed (ADAPT-MED, 2013; Andresen *et al.*, 2002). Over half of the entire case study area (59%) is used for fisheries. A wide range of fish and shellfish populations of commercial interest are harvested in the coastal lagoon, in the Vouga, Águeda and Levira rivers, and in the coastal waters. Fishery is a relevant sector for the region in terms of employment, wealth creation and socio-

cultural identity (Sousa *et al.*, 2015). With smaller expression in terms of covered area but not less important are the marine fish and shellfish production in aquaculture farms (approximately 326 ha), and the salt production (approximately 209 ha) (AMBIECO/PLRA, 2011; APA/ARH-Centro, 2011). The harvesting of wild plants such as common samphire (*Salicornia*) to be sold as a *gourmet* product is an emerging activity, as well as the production of marine macroalgae (*Gracilaria verrucosa, Chondrus crispus, Ulva lactuca, Porphyra spp., Codium tomentosum*) in aquaculture for human consumption (AlgaPlus, 2014).

Materials

Concerning the materials division (Figure 16), woodland is estimated to cover approximately 5397 ha, which represents 17% of the land area. During low tide the solitary tube worm (*Diopatra neapolitana*), the ragworm (*Hediste diversicolor*) and the catworm (*Nephthys hombergii*) are collected in intertidal mudflats (approximately 2206 ha) to be use as bait for fishing (Lillebø *et al.,* 2015b; Cunha *et al.*, 2005; Aleixo *et al.*, 2014). The harvesting of plant material for direct use, processing, or agricultural use was once an important activity in the Lagoon: rush marshes were used as animal bedding and afterwards as fertilizer; it was also used as raw materials for mats and for protecting salt mounds from wind and rain; seagrasses and macroalgae were used as fertilizers in agriculture; and reeds were used for traditional products/handcraft, such as mats. Currently, the use of seagrasses, reeds and rush marshes is done in a small scale (covering approximately 647 ha.), mostly for handcraft. Also, a small amount of macroalgae is collected for in-situ macroalgae farming. Concerning genetic materials, *marinhoa* cattle, registered as Protected Designation of Origin, is bred in Central region of Portugal, particularly in the BVL. Surface water is abstracted from the coastal lagoon, lakes, rivers and ditches for aquaculture and salt production, crops irrigation, livestock consumption, forest-fire control, and industrial use (e.g., pulp and paper industry). Groundwater is abstracted for public supply. Regarding abiotic materials, approximately 54% of the marine area is composed by sand and gravel which can be exploited for artificial beach nourishment (DGPM, 2012).

Ria provides the ideal conditions for exploring in-situ aquaculture farms of marine fish (e.g. gilthead seabream - *Sparus aurata*, seabass - *Dicentrarchus labrax* and turbot - *Psetta maxima*) and shellfish (Japanese oyster - *Crassostrea gigas*, clams - *Ruditapes decussates*) (Lillebø *et al.,* 2015b; Sousa *et al.,* 2015).

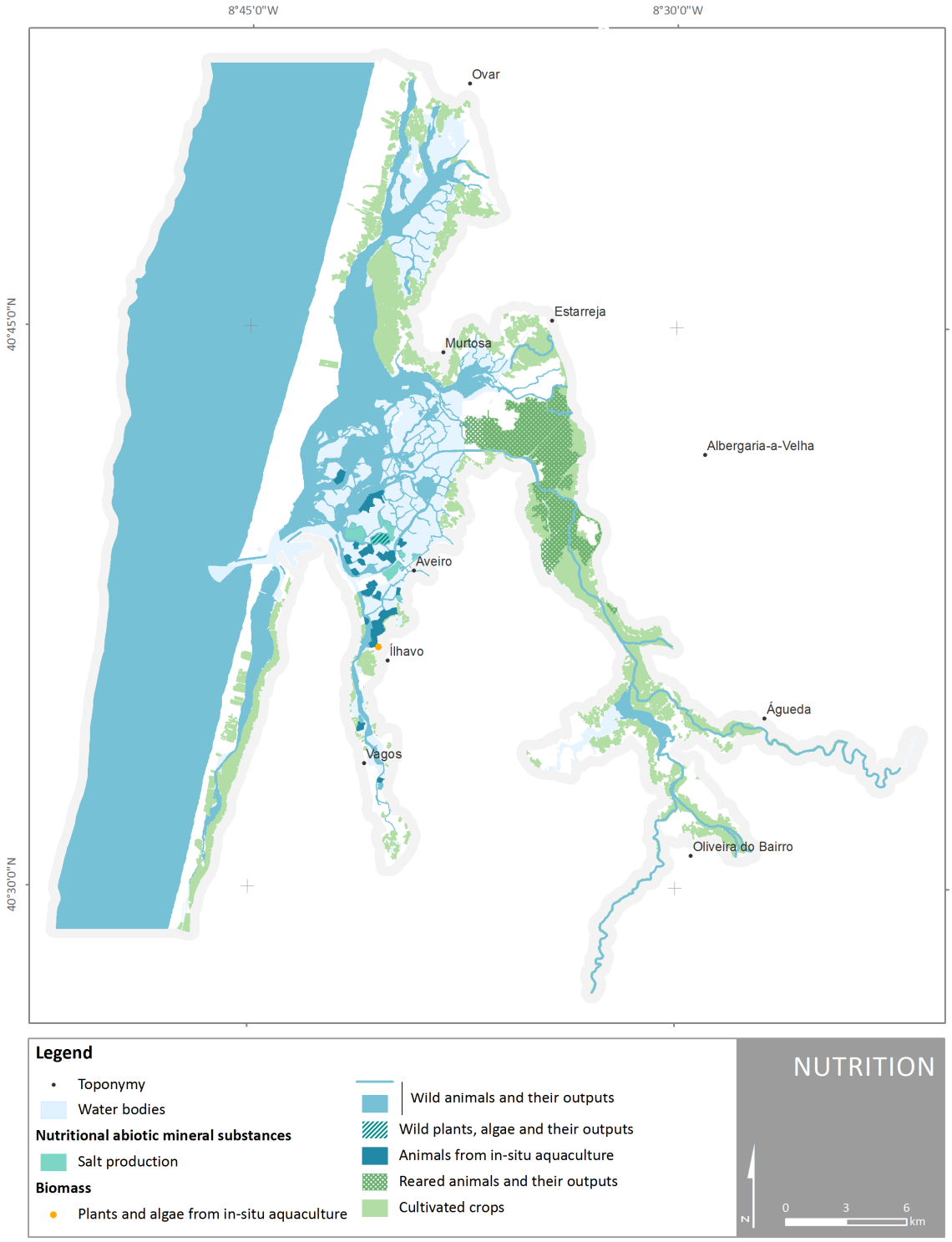


Figure 15. Spatial distribution of ES classes and abiotic outputs under the division 'nutrition'

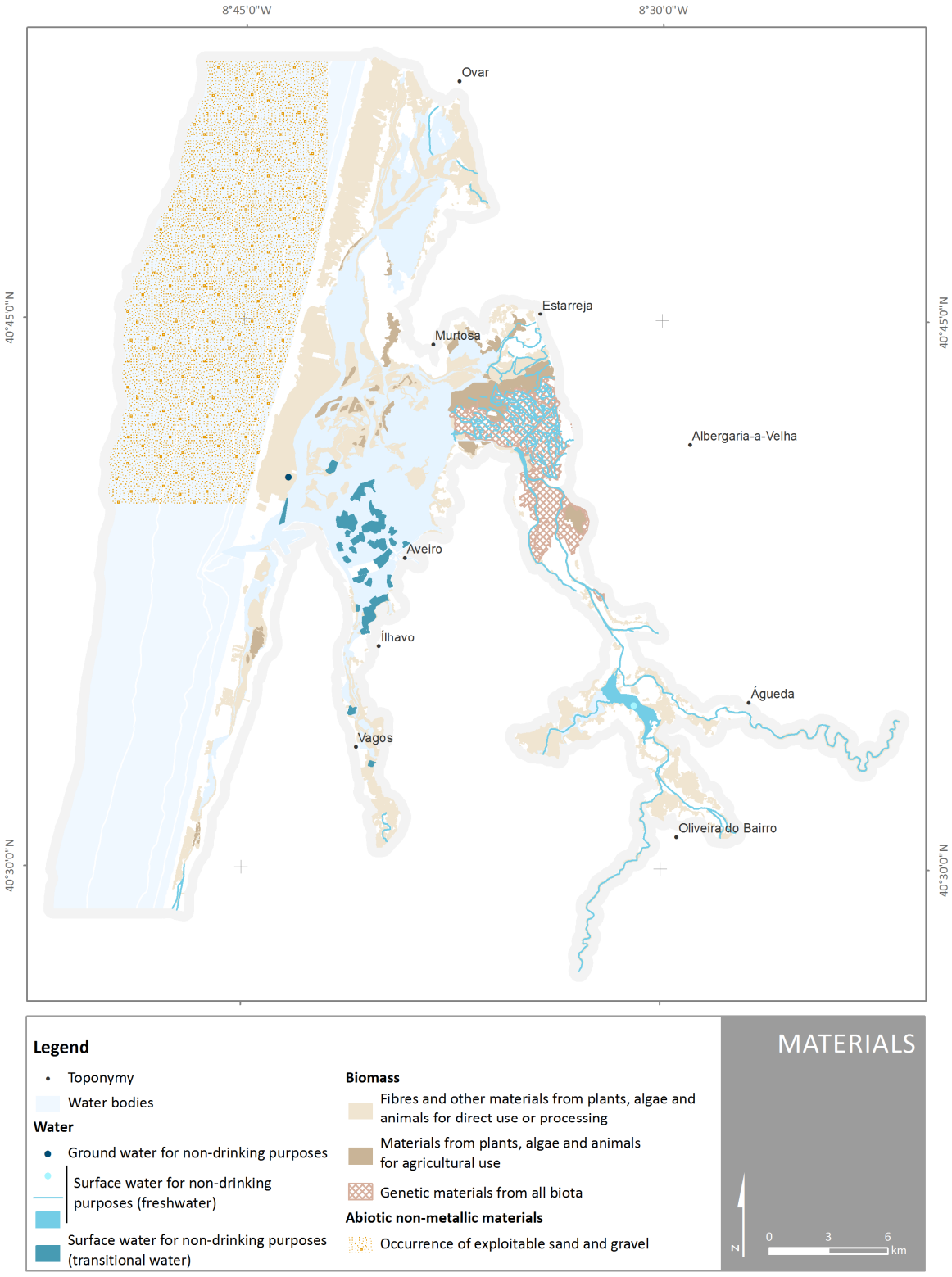


Figure 16. Spatial distribution of ES classes and abiotic outputs under the division 'materials'

Energy

Regarding the energy division (Figure 17), the use of *marinhoa* cattle in the agriculture was identified in the case study as animal-based energy.

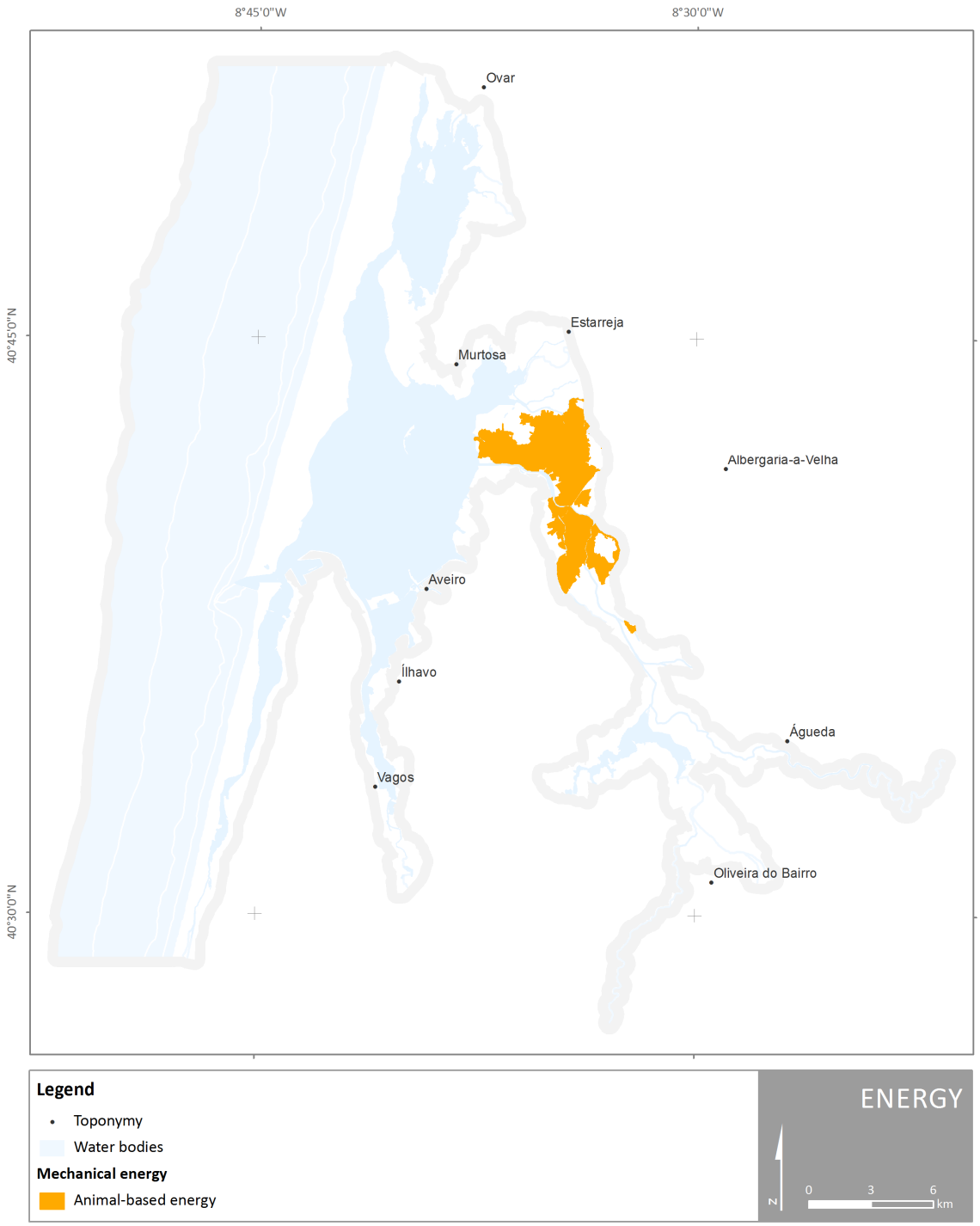


Figure 17. Spatial distribution of ES classes and abiotic outputs under the division 'energy'

4.3.2. Spatial distribution and characterization of regulating and maintenance services

Mediation of waste, toxics and other nuisances

The micro-organisms, algae, plants and animals that live in Ria de Aveiro and the ecosystem itself have the ability to purify the water and regulate air quality through biochemical and physicochemical processes (e.g., filtration, absorption, decomposition, dilution). These services are grouped in the CICES' division 'mediation of waste, toxics and other nuisances', which covers 97% of the study area (Figure 18). For instance, macrophytes, filter organisms (e.g., oysters, clams and mussels) and microorganisms have the ability to reduce the availability of nutrients and potentially toxic elements (e.g., metals, organic pollutants) in the sediment and water column through storage/accumulation, biological filtration and decomposition; salt marshes and seagrass meadows have the ability to promote the retention of pollutants; riparian areas maintain water quality by capturing and filtering water through their soils before it gets to the streams. Rivers, lakes, transitional waters and the ocean have the capacity to dilute gases, wastewater and solid waste through bio-physicochemical processes. *Bocage* landscape helps minimize the visual impact and the odour from the pulp mill industry.

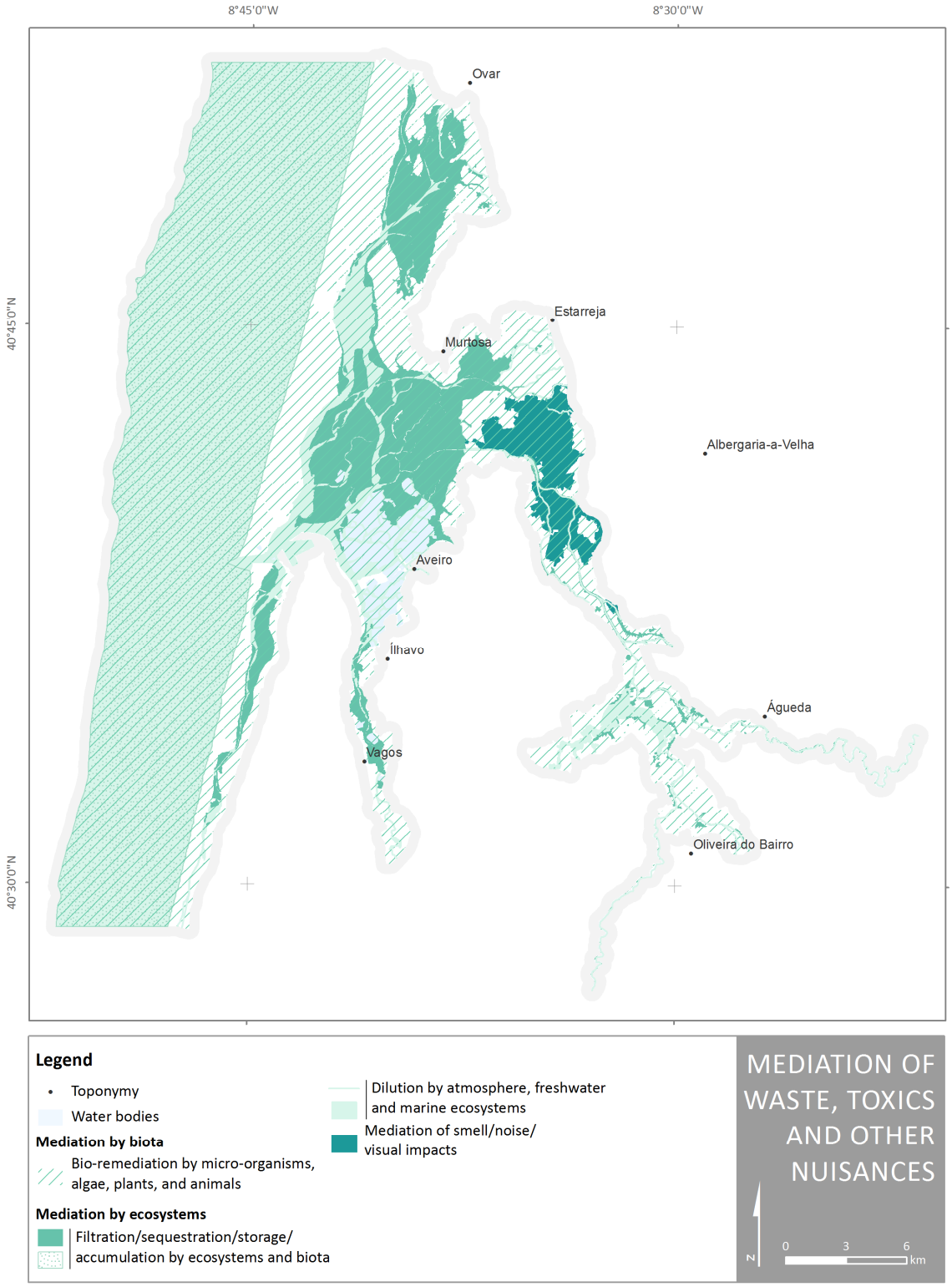


Figure 18. Spatial distribution of ES classes and abiotic outputs under the division 'mediation of waste, toxics and other nuisances'

Mediation of flows

Of the 'mediation of flows' division, 'buffering and attenuation of mass flows' together with 'mass stabilization and erosion control rates' and 'flood protection' are the most representative ES classes in terms of the covered area (39200 ha, 14634 ha and 10974 ha, respectively).

Overall vegetation cover helps to stabilise terrestrial ecosystems and control erosion rates. This service covers approximately 46% of the land (or 23% of the study area) and is mostly provided by vegetated dunes, crucial for its formation and for coastline stabilisation; by riparian areas, essential for riverbanks' stabilisation; but also by forests and natural grassland. Moreover, dunes, salt marshes and seagrass meadows help to maintain the lagoon's integrity. In addition, seagrass meadows and salt marshes reduce sediment re-suspension and turbidity in the water column, contributing to increase the light availability in the water column; rivers, lakes, transitional waters and coastal waters have the ability to transport and storage sediment (Figure 19). Concerning the 'mediation of liquid flows' group (Figure 20), functional geographical units as salt marshes, sand dunes, *bocage*, riparian and alluvial forests provide resilience to extreme weather events, act as physical buffering of climate change, and provide protection from floods. For instance, salt marsh vegetation attenuates wave energy; sand dunes provide direct coastal protection; sand beaches dissipate wave energy by absorbing it; and riparian areas and *bocage* have the ability to slow/reduce the water flow. The class 'hydrological cycle and water flow maintenance' was considered to be present/relevant in the areas where evapotranspiration is higher (see LAGOONS, 2013) – which in this case coincide with *bocage*, woodland and salt marshes – and in riparian areas, which have the capacity to store water for its future use, maintaining the water flow. Regarding 'mediation of gaseous/ air flows' group (Figure 21), the only ES class identified was air ventilation and evapotranspiration enabled by living hedges of *bocage*.

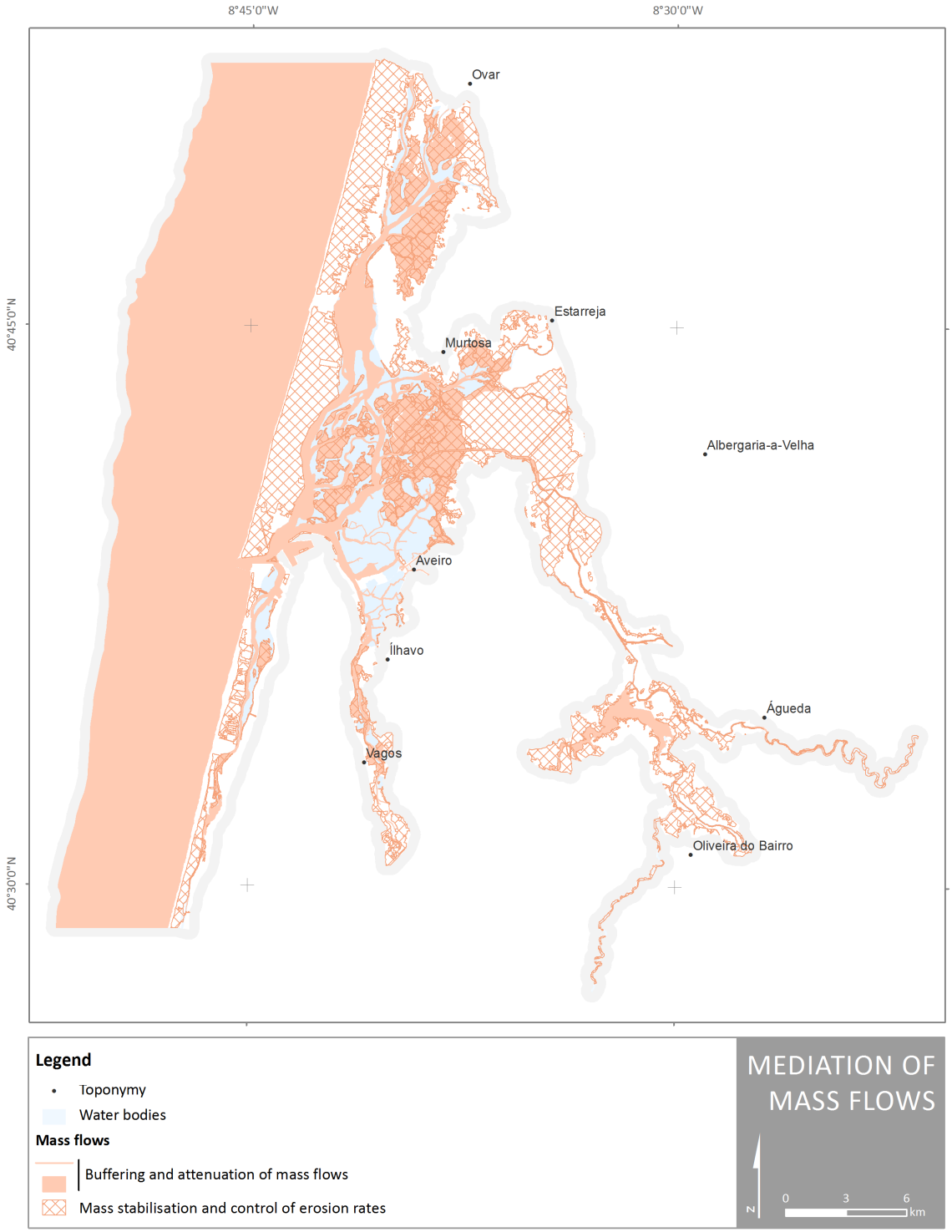


Figure 19. Spatial distribution of ES classes and abiotic outputs under the group 'mediation of mass flows'

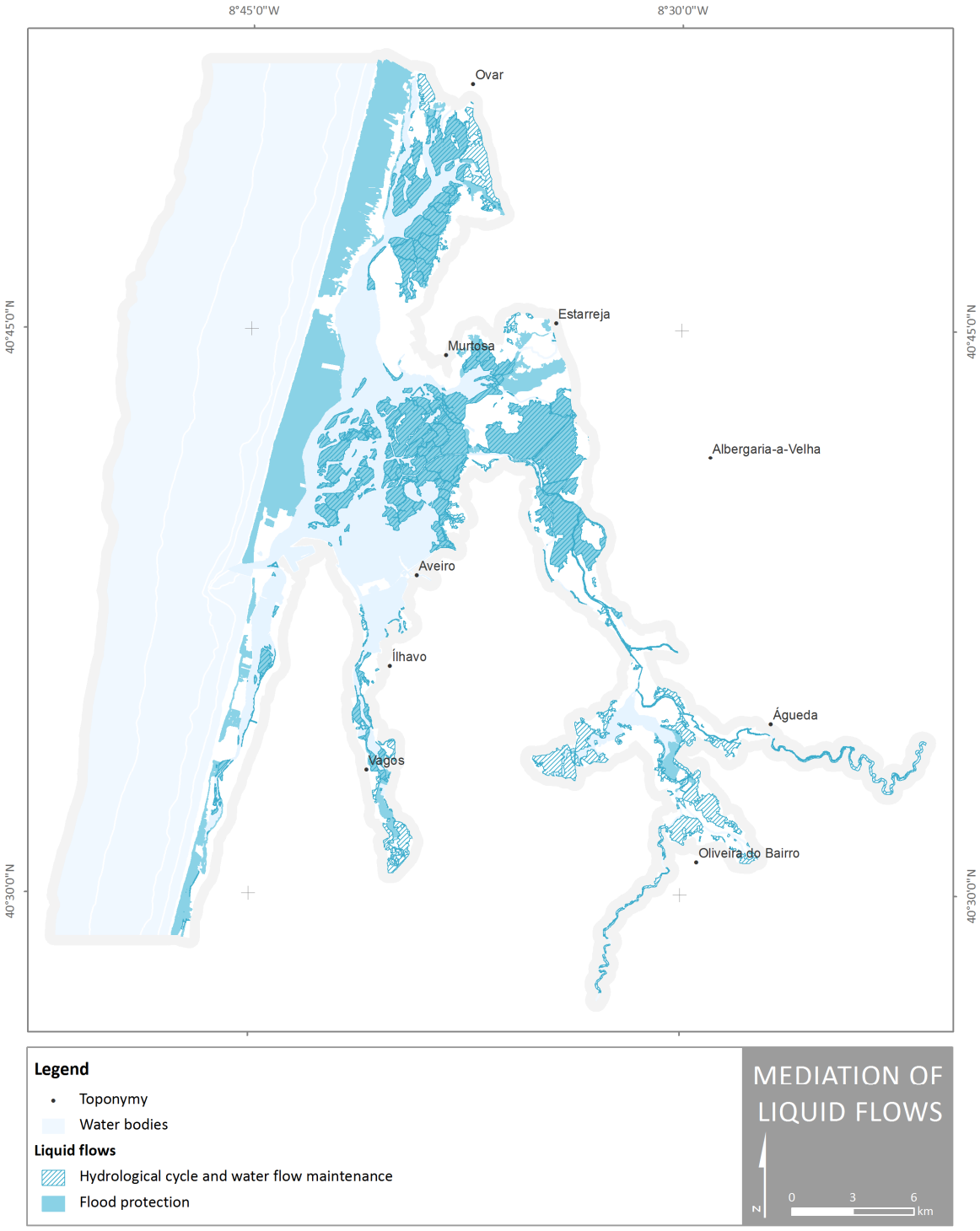


Figure 20. Spatial distribution of ES classes and abiotic outputs under the group 'mediation of liquid flows'

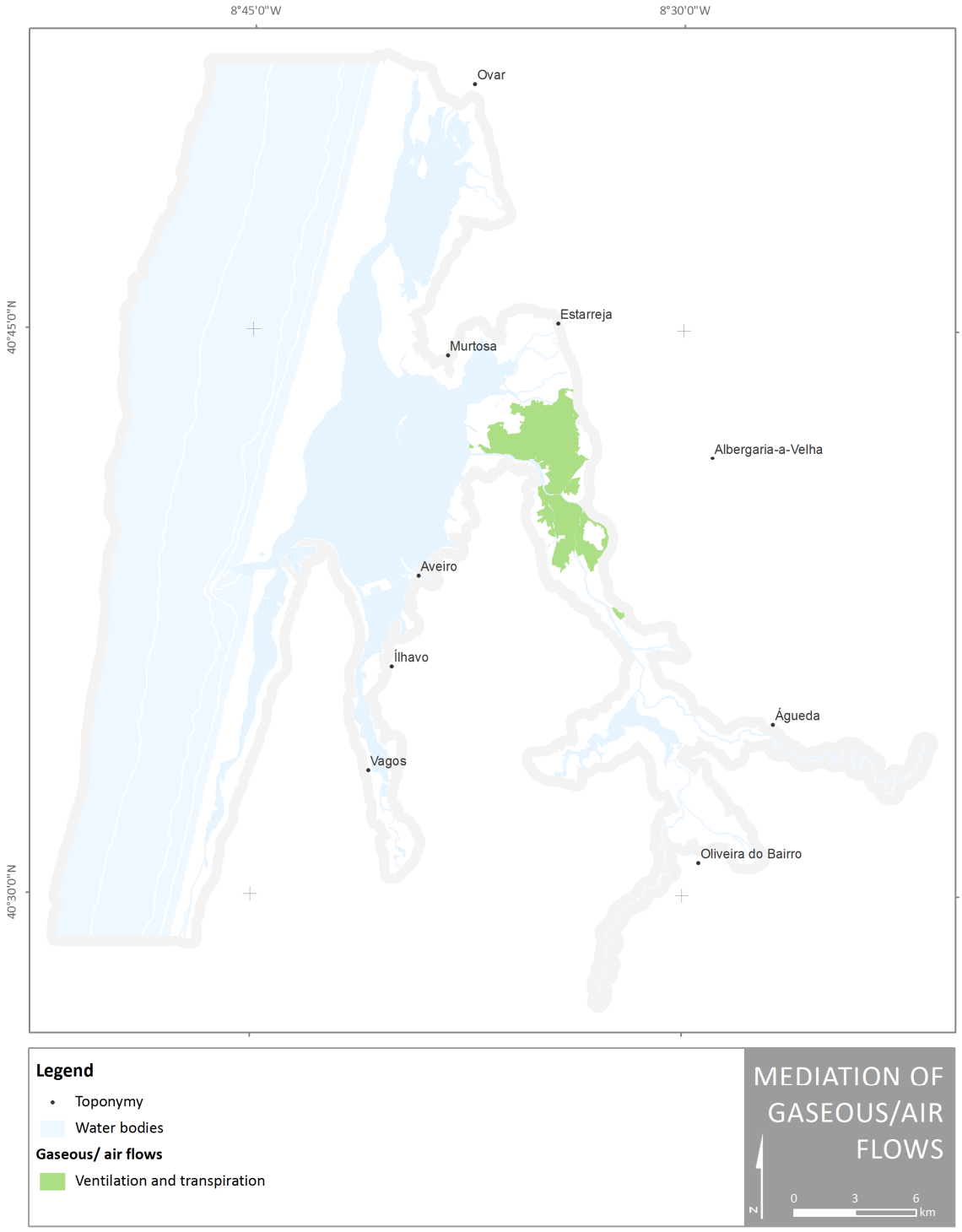


Figure 21. Spatial distribution of ES classes and abiotic outputs under the group 'mediation of gaseous/air flows'

Lifecycle maintenance, habitat and gene pool protection

The study area provides a wide variety of habitats (Figure 22), some of them classified under Habitats Directive (92/43/CEE). From the diversity of habitats we highlight the extensive areas of salt marshes (habitats 1310pt1, 1320, and 1330), intertidal flats (habitats 1140pt1, and 1140pt2), estuaries (habitat 1130),

salt pans, coastal dunes (habitats 2120, 2130, and 2170), forests (including habitats 91E0pt1, 91E0pt3, and 91F0), *bocage* landscape, rush marshes, reed marshes, rivers and freshwater lakes (ICNF, 2012; AMBIECO/PLRA, 2011; RCM no. 1125-A/2008 of July 21st). The most representative benthic habitats present in the marine area of the case study are infralittoral fine sand (EUNIS A5.23) and circalittoral fine sand (EUNIS A5.25), which cover 55% and 44% of the total area, respectively (MESHAtlantic, 2014). The habitats present in the coastal lagoon and in the BVL are important feeding and breeding areas for a variety of bird species (approximately 175 species), particularly aquatic and migratory bird species (ICNF, 2012; RCM no. 1125-A/2008 of July 21st). Vouga, Levira and Águeda rivers are important spawning grounds for anadromous migratory species (as *Petromyzon marinus* Linnaeus, A*losa alosa*, and *Alosa fallax*) and *Lampetra planeri.* Infralittoral and circalittoral fine sand provide feeding and nursery grounds for several commercially exploited species (ICNF, 2012).

Hedgerows, within *bocage* landscape, and woodlands along agricultural fields support a wide range of pollinators. Therefore, its spatial distribution was used as an indicator of the presence of pollination and seed dispersal services, covering an area of 3496 ha.

Soil formation and composition

Fourteen percent of the study area is composed by fluvisols, accordingly to the World Reference Base for Soil Resources classification system (Atlas do Ambiente, 1982), which are the type of soils with higher content of organic matter. Since agricultural fields do not favour the soil formation and the topography is quite regular (ranging between 0 and 80 m), the spatial distribution of the weathering service (Figure 23) resulted from the combination of spatial data on soil type (fluvisols) and land cover (woodlands and floodplains). Hence, this service covers approximately 4% of the land area.

Soil composition covers 38% of the land and is maintained by intertidal mudflats, seagrass meadows and saltmarshes that play an important role in the nitrogen cycling (nitrogen fixing, denitrification, decomposition); and by terrestrial ecosystems, such as woodlands, natural grasslands and some crops (e.g., corn, rice) that contribute to the maintenance of bio-geochemical conditions of soils by decomposition/mineralisation of dead organic material, nitrification and denitrification.

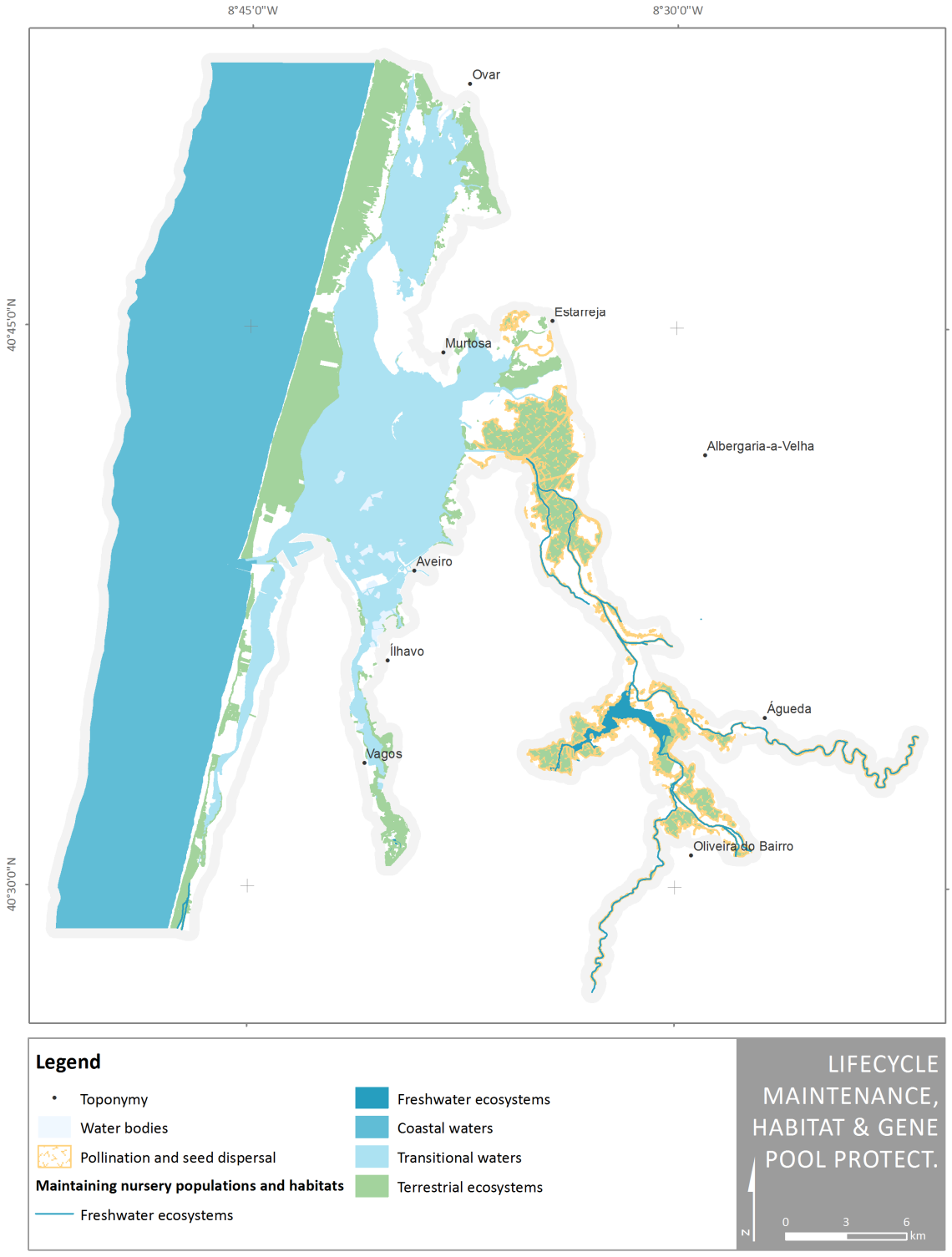


Figure 22. Spatial distribution of ES classes and abiotic outputs under the group 'lifecycle maintenance, habitat and gene pool protection'

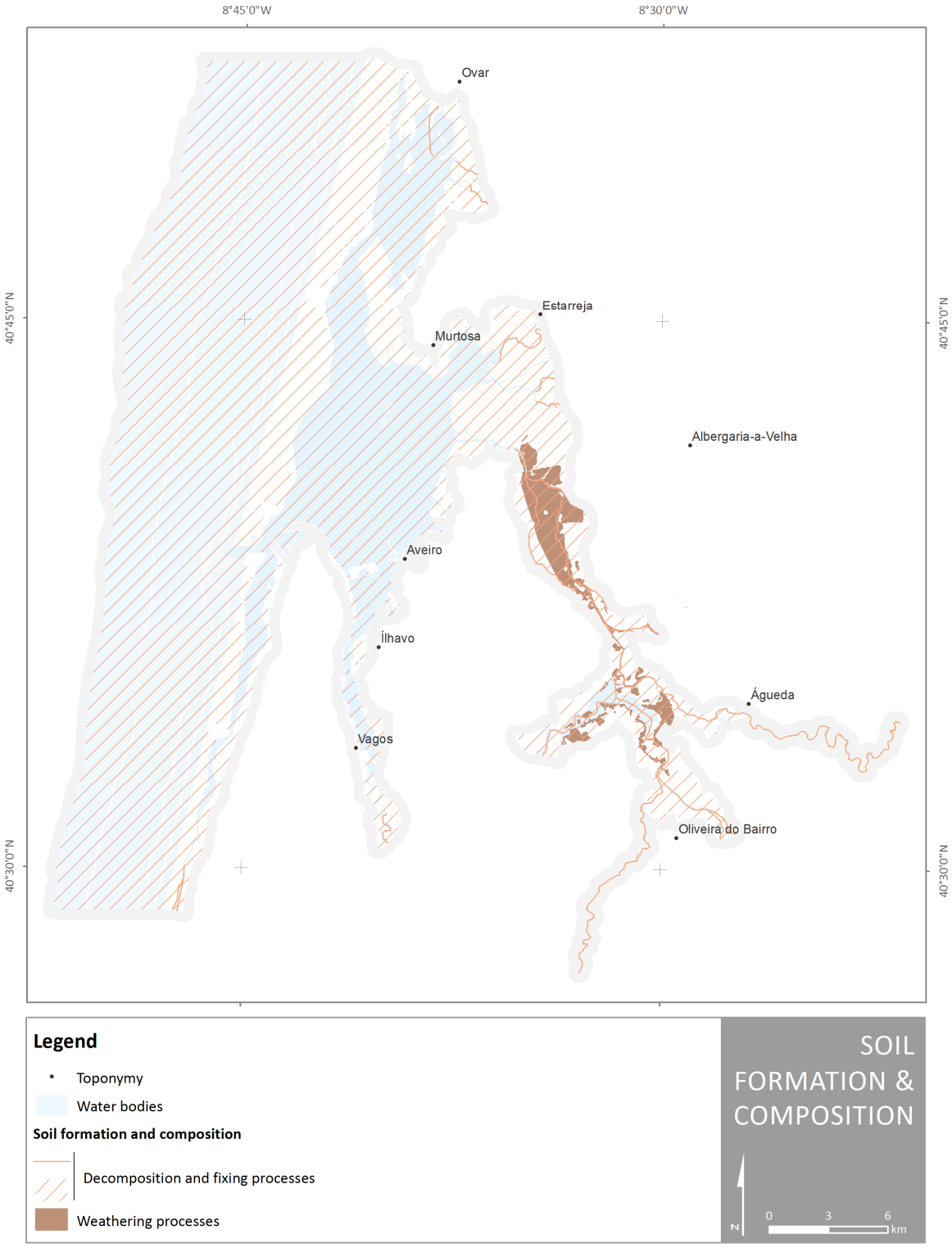


Figure 23. Spatial distribution of ES classes and abiotic outputs under the group 'soil formation and composition'

Atmospheric composition and regulation

Atmospheric carbon is sequestrated by, and stored in, ocean through oceanic algae, woodlands, and macrophytes (e.g., salt marshes, seagrass meadows). These habitats contribute to the global climate regulation by reduction of greenhouse gas concentration (Figure 24), and cover approximately 66% of the study area. Micro and regional climate is regulated by green infrastructures, but also blue infrastructures (through abiotic processes), that contribute to the control of atmospheric conditions. For instance, *bocage* constitutes a barrier to the wind; freshwater ecosystems can moderate extreme temperature; wetlands, due to higher evaporation, can increase relative humidity (Maltby *et al.*, 2011).

4.3.3. Spatial distribution and characterization of cultural services

Physical and intellectual interactions

Cultural services provided by the region of Ria de Aveiro are extensive from both physical and intellectual point of view (Figure 25). For instance, natural and semi-natural beaches, salt pans, quays, public gardens along rivers and lakes, city channels, Ria's islands, São Jacinto dunes Nature Reserve and BVL are some places favoured for landscape appreciation and birdwatching. Maritime and fluvial beaches are ideal for swimming; pathways along Lagoon's margins, lakes, rivers and ditches are used for walking and cycling; watercourses are used for sailing, canoeing, rowing, surfing, kitesurfing, paddling, but also for angling. The marine and coastal area, the Ria de Aveiro and the Vouga river basin (which cover the entire study area) are subject matter for scientific research, as well as a source for education through environmental interpretative centres and museums. Areas such as archaeological sites (e.g., shipwrecks, ship hull); traditional fisherman and salt workers neighbourhoods (e.g., Beira-Mar); traditional architecture (e.g., *Palheiros* in Costa Nova); and the traditional activities related with the lagoon and the sea (e.g., *Arte Xávega* - an ancient fishing gear; salt production; seagrass and rush collecting) have significant cultural and heritage value. The ecosystems and biodiversity are also enjoyed/appreciated ex-situ through festivals (e.g., gastronomic fairs, Vagueira surf festival, Ria de Aveiro Weekend, ObservaRia – Birdwatching fair, *moliceiro* festival, *N.ª S.ª dos Navegantes* religious festival); provide artistic inspiration for writers and painters; and provide sense of place and identity.

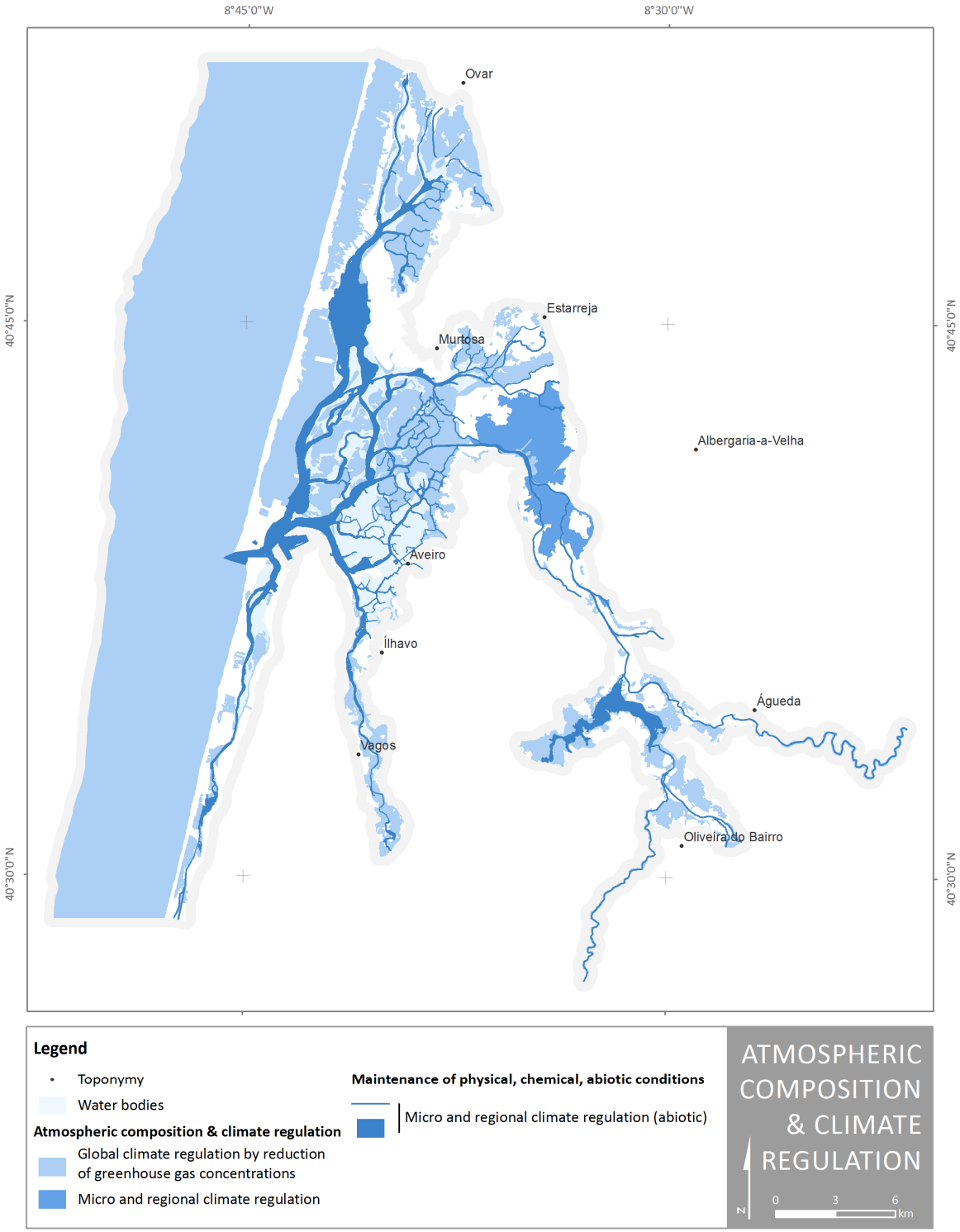


Figure 24. Spatial distribution of ES classes and abiotic outputs under the group 'atmospheric composition and climate regulation'

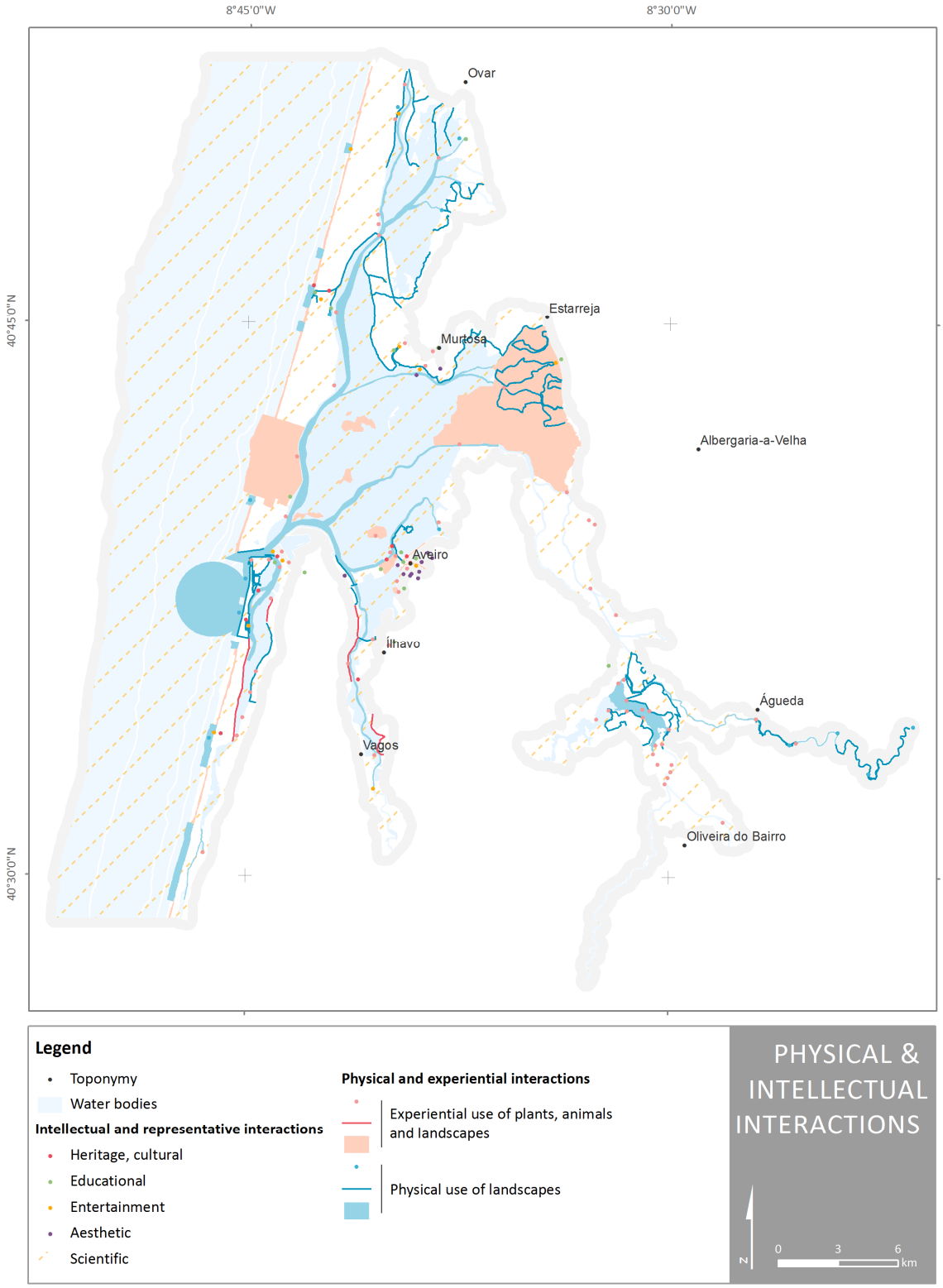


Figure 25. Spatial distribution of ES classes and abiotic outputs under the division 'physical and intellectual interactions with biota, ecosystems and land-/seascapes'

4.4. Multifunctional areas

Multifunctional areas were obtained in the ArcGIS 10.0 through a sequence of geoprocessing tools to overlay the individual ES classes and count the overlapping polygons, lines and/or points. This resulted in (i) three section maps (one map for each CICES' section), representing the multifunctional areas with different overlapping degrees; and (ii) a synthesis map combining the ES classes from all CICES' sections (Figure 26).

Regarding provisioning services (Figure 26 - a), 12 of 16 ES CICES' classes and two of six abiotic outputs were identified and mapped. *Bocage* has the higher number of multiple provisioning services, combining four ES classes: cultivated crops, reared animals and their outputs, genetic materials from all biota, and animal-based energy.

From the 21 ES CICES' classes plus three abiotic outputs under the regulating and maintenance section, 20 were identified and 16 (including one abiotic output) were mapped (Figure 26 - b). The number of overlaying ES classes ranged from a minimum of two to a maximum of 11. The results show that *bocage* landscape holds the higher number of ES classes: 11 ES provided by 29% of the *bocage* area, and 10 ES by 71%. Riparian forests, *Zostera noltei* beds, salt marshes, forests and alluvial forests, coastal waters, transitional waters, forested dunes and freshwater habitats are also associated to a high number of regulating and maintenance classes (over six ES classes).

Concerning cultural services nine of the 11 ES CICES' classes were identified and seven were mapped (Figure 26 - c). Of these seven ES classes, four were represented through point features. The results show that watercourses, walking and cycling pathways in the BVL, and some of the Aveiro city's channels congregate the higher number of cultural services (3 ES classes). The coastal strip together with the waterways, lakes and green areas come next with 2 ES classes. Point features are mostly condensed in the built-up areas (particularly in the surroundings of the Aveiro city's channels, Torreira, Gafanha da Nazaré), in *Pateira de Fermentelos*, along the Águeda and Vouga rivers, and in the Lagoon's margins.

The synthesis map (Figure 26 - d) reveals that the most representative multifunctional areas in terms of areal extent are the polygons with 10, 9, 4, 8, and 7 overlapping ES classes, which cover 36%, 24%, 11%, 9%, and 5% of the case study's area, respectively. When combined this information with the spatial distribution the functional geographical units (Figure 27) the *bocage* stands out, presenting the higher number of multiple services: 15 to 17 ES classes. *Zostera noltei* beds follow with 12 ES classes; riparian forests with 11 to 12 ES classes; salt marshes, coastal waters, freshwater lakes, and alluvial forests provide around 10 ES classes.

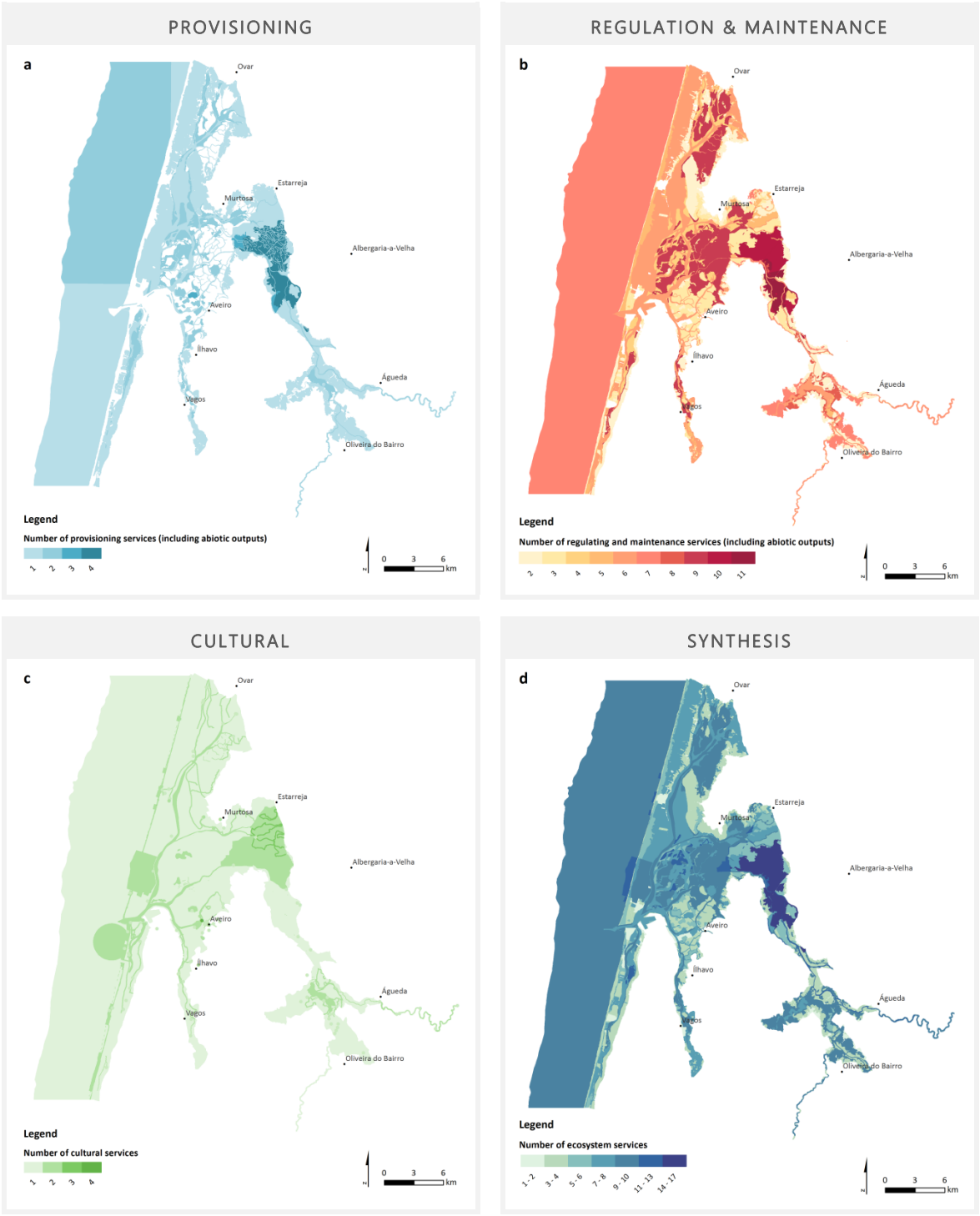


Figure 26. Multifunctional areas (a, b, c) by ES section (provisioning, regulating and maintenance, and cultural), and a synthesis map combining all the ES classes (d).

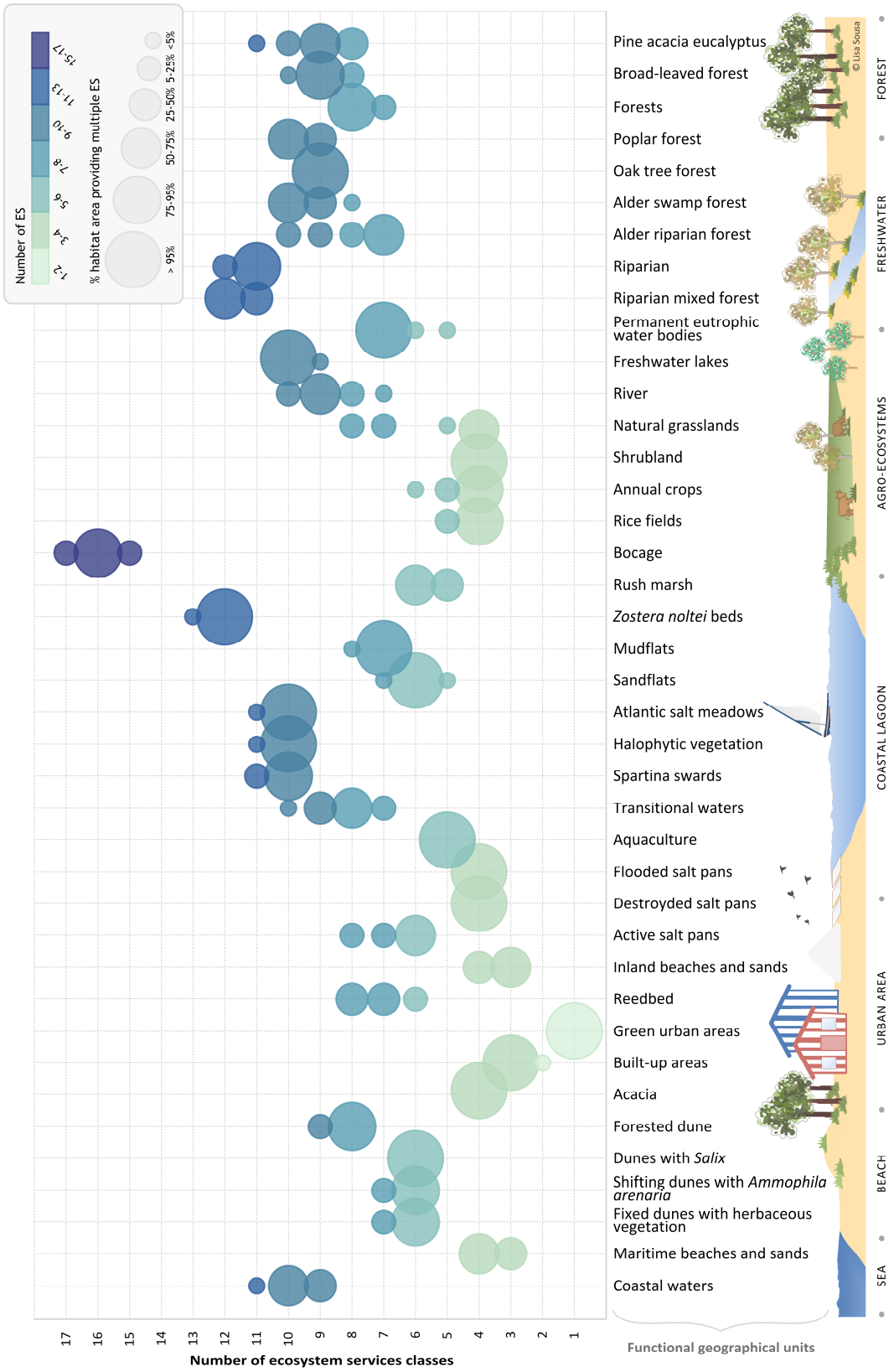


Figure 27. Distribution of the multiple ES through the functional geographical units, by number of ES classes identified and by relative area in percentage (i.e. % of functional geographical unit's area providing multiple ES in relation to its total area)

As mentioned, *bocage* gathers the higher number of ES classes identified, and covers approximately 3% of the study area (6% of the land part). This agroecosystem differs from other agricultural areas of the region due to the presence of living hedges and draining ditches. This feature, besides providing shelter for cattle and crops favouring the delivery of provisioning services (such as cultivated crops, reared animals and their outputs, genetic materials from all biota, and animal-based energy), provides a significant number of regulating and maintenance services (such as bio-remediation, mediation of visual and smell impacts, mass stabilisation and erosion control, hydrological cycle and water flow maintenance, flood protection, ventilation and transpiration, pollination and seed dispersal, maintaining nursery populations and habitats, soil formation and composition, micro and regional climate regulation). Moreover, from the cultural point of view it is equally significant due to its singular and attractive landscape and fauna.

Approximately 99% of *Zostera noltei* beds (corresponding to 171 ha) gather a set of 12 ES classes, most of them regulating and maintenance services. Riparian forests also provide a high number of ES; however it covers a considerable reduced area (approximately 99 ha, which corresponds to 0.5% of the terrestrial ecosystems). This functional geographical units provides mainly regulating and maintenance services: bio-remediation; filtration, sequestration, storage, and accumulation; mass stabilisation and erosion control; hydrological cycle and water flow maintenance; flood protection; pollination and seed dispersal; maintaining nursery populations and habitats; soil formation and composition; and global climate regulation by reduction of greenhouse gas concentrations.

Coastal waters cover a significant part of the study area (49%) and are responsible for the provision of multiple ES (mostly regulating and maintenance services): 10 ES classes were identified in approximately 59% of the coastal waters area, and 9 ES classes in 40%.

More than 90% of salt marshes gather a set of 10 ES classes, most of them regulating and maintenance services. In the remaining area 11 ES classes were identified due to the presence of cultural services.

Freshwater lakes also have the ability to provide a high number of multiple services (10 ES classes were mapped), which vary from provisioning (wild animals and their outputs; and surface water for non-drinking purposes), regulating and maintenance (bio-remediation; dilution by atmosphere, freshwater and marine ecosystems; buffering and attenuation of mass flows; maintaining nursery populations and habitats; decomposition and fixing processes), including abiotic outputs (micro and regional climate regulation by physical structures), and cultural services (physical use of landscapes; and scientific).

Similarly to riparian forest and *Zostera noltei* beds, alder swamp and alder riparian forests cover a very reduced area of the case study (approximately 329 ha, which corresponds to 2% of the terrestrial

ecosystems) but provide a high number of ES (which may reach 10 ES classes). The remaining forest types deliver around 8 to 11 ES classes. All these functional geographical units provide mostly regulating and maintenance services.

4.5. Stakeholders' perception of Ria de Aveiro ecosystem services

As stated in Sousa *et al.* (2013) ecosystem services provided by Ria de Aveiro coastal lagoons are especially important for the local/regional community. During the Focus Groups, participants mentioned several services provided by Ria de Aveiro coastal lagoon, such as the navigability of lagoon channels, allowing the transportation of people and goods and the communication through public transport (ferry and speedboats), touristic transport (traditional boat *moliceiro*), private vessels and traditional boats (such as *bateiras*, *mercanteis* and *moliceiros* formerly used to transport raw materials and now mostly used for tourism). Harvesting of raw materials such as seagrasses, reeds to be used as fertilizers in agriculture, sludge to enrich soils and sand was once a common activity that is currently done on a very small scale. Fishing and shellfish collecting were mentioned as important activities for the local economy, being the income of several families. They reported the diversity of fish and shellfish of commercial value (such as lamprey, eel, bass, bream, sole, cuttlefish, crucian carp, flounder, crab, cockles, oysters and clams). Salt production was once an important economic activity; however at present only a few saltpans are working, having been replaced by aquaculture that is an emerging economic activity in the region. During low tide some users harvest the solitary tube worm (*Diopatra neapolitana*, *casulo*) to use as bait for fishing. Hunting was also referred as a leisure activity. In the lagoon there are several small ports for local fishermen, population and recreational users, and a commercial harbour that plays a crucial role in the regional economy and whose activity has a strong influence in the lagoon's system, namely on bathymetry, tides, currents and water velocity. There are several uses related with leisure, recreation and sport activities such as landscape appreciation, walking and biking on the banks, swimming, sailing, rowing, kayaking, windsurfing, kitesurfing, recreational fishing and others that contribute to the local economy and identity. In some areas of the lagoon, the land is used for agriculture and livestock, where the certified *marinhoa* breed (indigenous specie) is produced. According with some participants, rice and flax production was a common practice in the lagoon's islands, however is no longer the case.

The educational value associated to traditional activities (e.g., salt production) and the local and scientific knowledge (through the existence of museums and guided tours) was stressed out, attracting visitors from schools and others. Additionally, the role of research in the study, monitoring and management of the lagoon was mentioned. Furthermore, some participants showed theoretical interest for the history

of the lagoon and their elements/components (e.g., traditional boats), emphasizing the Ria's inspirational value from which resulted some books, such as *"A Ria de Aveiro – Um olhar resvés"*.

Several traditional products (including food and cosmetics) and handcraft were mentioned, such as salt soap, salt foam, salt exfoliating, flavouring and aromatic salt, flower of salt, samphire, fish and shellfish.

The scenic value of Ria de Aveiro was constantly mentioned in the sessions by the participants, to which the traditional architecture (e.g. *palheiros*), boats, activities and biodiversity also contributes.

Also, the local knowledge and the sense of place were emphasized, in part because of participants' nostalgia for the traditional activities that are vanishing, remaining almost only for tourism and educational purposes.

Religious values were mentioned in association to the uses of the lagoon and to the drawings in traditional boats (*moliceiro*). Some festivals were referred in association to the start and end of salt production, and to the *moliceiros* summer regatta.

A set of these ecosystem services, such as gastronomy, traditional products and handcraft, traditional architecture, activities and boats, the semi-natural landscape and the conditions for navigation and recreation attracts tourism for this region, contributing to the economic growth.

Although most services identified are provisioning and cultural, the participants recognized the importance of vegetation, e.g. reeds and salt marshes for soil-sediment retention/erosion control in the banks. In addition, they value the plant and animal biodiversity of the lagoon and refer the importance of Ria as habitat, nursery and nesting ground (e.g. seagrasses and saltmarshes) for birds, fish and shellfish species.

4.6. Conclusion

This chapter provides a detailed analysis of the ecosystem services provided by Ria de Aveiro coastal region. Results show that ES are widespread across the case study, and that 79% of its area provides a high number of ES (7 or more ES classes identified and mapped). *Bocage*, *Zostera noltei* beds, riparian areas, salt marshes, coastal waters, and freshwater lakes are among the ecosystems that provide the higher number of ES, namely maintaining good water quality, reducing patterns of erosion, flood protection, maintaining nursery populations and habitats, landscape and scenic quality, recreation, education, and research.

Stakeholders showed to be aware of the ecosystem services provided by Ria de Aveiro coastal lagoon. Although they identified more tangible services (provisioning and cultural services) than intangible

(regulating and maintenance services), they clearly recognized the social importance and the regional economic dependence of a healthy ecosystem. In order to maintain the lagoon's ability to provide ecosystem services, essential for the lagoon's uses and activities, participants identified the need to preserve/protect the ecosystem. Participants identified both emerging services (e.g. tourism and recreational activities such as kitesurf and windsurf) and declining services (e.g. navigability, salt production, harvesting of seagrasses and reeds, fish diversity, use of traditional boats, e.g. *moliceiro*), showing a clear concern with the future of some activities in Ria de Aveiro coastal lagoon.

5 Ria de Aveiro ecosystem services and trade-offs under current and future pressures

The contents of this chapter will be published in:

Sousa L.P., Lillebø A.I., Alves F.L., (working paper). Spatial patterns of ecosystem services in complex social-ecological systems: a management-oriented approach.

5.1. Introduction

Complex social-ecological systems and the services they provide are constantly being shaped by society's demands and development priorities (Pittman and Armitage, 2016), particularly in coastal regions where human presence and activity is intense (Martí *et al.*, 2007). Point and non-point source pollution, overfishing, infrastructures (e.g., dams), changing coastlines due to coastal erosion, storm surge and sea level rise, as well as management and policy decisions are among the pressures that threaten these transition systems (Bennett *et al.*, 2016; Dolbeth *et al.*, 2016; Pittman and Armitage, 2016; Carpenter *et al.*, 2009). In Portugal, as in most European countries, 75% of the population lives along the coast and 85% of the national GNP is generated by these coastal metropolitan areas (Alves *et al.,* 2014). Yet, 18% of the national protected areas (e.g. Ramsar Convention, Natura 2000 network, Nature Parks) are within a buffer of 10 km sea- and landwards (ICNF, 2015). Therefore, any strategy or management process based on principles of sustainability, integration, adaptation and ecosystem-based management requires the understanding of social, economic and ecological processes and their relationships (Ai *et al.,* 2015). The ecosystem service concept offers a framework for revealing and better understanding the links between ecosystems and human well-being (Grizzetti *et al.*, 2016; Folke *et al.*, 2011; MA, 2003), helping to assess how ecosystems benefit humanity and how planning options impact ecosystems and the services they provide (Li *et al.,* 2016).

The design of alternative scenarios is also recognized as a useful tool for planning and ecosystem management, as it provides a picture of possible future states of the social-ecological system and allows the analysis of trade-offs and synergies (Martinez-Harms *et al.*, 2017; Bryan *et al.*, 2016; O'Neill *et al.*, 2008). In addition, by making these trade-offs visible, the decisions can be better understood by stakeholders and local/regional community in general (PSI-connect, 2012).

This chapter uses multiple sources of information and different methodologies to discuss the expected changes of current pressures and future trends on Ria de Aveiro ecosystem services. The importance of combining the use of spatial information on ES with alternative scenarios and participatory methods is discussed.

5.2. Materials and methods

Different sources of information and methodologies are brought together in order to discuss how current pressures and future trends can influence the provision of ES, which beneficiaries are affected, and how stakeholders can be involved.

5.2.1. Current Pressures

The identification of these pressures was based on different sources of knowledge, including local knowledge, which resulted from a set of approaches conducted in the scope of the EU-FP7 LAGOONS research project (see Dolbeth *et al.*, 2016; Lillebø *et al.*, 2016, 2014; Baggett and Gooch, 2015; Sousa *et al.,* 2013a for more detailed information on methods and results):

- Stakeholders' concerns, expressed during Focus Groups (FG) and Citizens' Jury with local users of the coastal lagoon; and
- SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis developed by the Portuguese LAGOONS' team.

The main pressures identified are: coastal erosion, floods, change in hydrodynamic regime, overfishing and use of non-authorized fishing gears, abandonment of traditional activities, and invasive species. A database composed by multi-source geospatial data in GIS was compiled (Table 5) and a schematic representation of these pressures was prepared, based on literature review, indicating the approximate location where its intensity in higher.

Table 5. Summary of collected spatial data

Designation	Description	Scale	Data source
Pressures			
Ria de Aveiro marginal flood	Marginal flood extent considering present climate conditions for a return period of 2 years	Local/ Regional	Lopes, 2016; Dias *et al.,* 2014, 2013
Fluvial flood (Águeda)	Fluvial flood extent considering a return period of 20 years	Local/ Regional	APA, 2014
Coastal erosion/ Shoreline retreat	Main areas exposed to shoreline retreat considering its evolution in the period of 1984-2011	Local/ Regional	Cenci *et al.,* 2013
Changes in hydrodynamic regime	Areas where tidal range and water velocity are higher	Local/ Regional	SENER/PLRA, 2012
Overfishing and use of non-authorized fishing gears	Preferential areas for shellfish collecting and type of fishing gear; Location of local fishermen communities (arte Xávega)	Local/ Regional	APA, 2012; AMBIECO/PLRA, 2011
Abandonment of traditional activities	Location of abandoned salt pans	Local/ Regional	AMBIECO/PLRA, 2011
Basemap			
Mean tide	Flooded area during the lagoon's tide of medium tidal range	Local/ Regional	Lopes, 2016; Dias *et al.,* 2014

Designation	Description	Scale	Data source
CAOP 2014	Administrative boundaries regarding the Portugal (mainland), districts, municipalities and parishes	National	DGT, 2014
Bathymetry	Bathymetry	National	APA, 2012
River network	River network mapped in the scope of Water Framework Directive	National	INAG, 2011
Transitional waters	Transitional waters mapped in the scope of Water Framework Directive	National	INAG, 2011

5.2.2. Integrated scenarios for 2030

Four scenarios for Ria de Aveiro coastal lagoon, with the timescale 2013-2030, were developed in the scope of the LAGOONS project (Lillebø *et al.*, 2016; Baggett and Gooch, 2015). These scenarios present four different perspectives of the effects of environmental and economic factors on human well-being and livelihoods, as described by Baggett and Gooch (2015):

- *"Business as Usual (BAU) – attempts to describe how the future could develop based on known changes and past trends, without any major deviation from present arrangements regarding economic growth or environmental quality.*
- *Managed Horizons – provides an alternative future where both economic and environmental factors are positively used to provide tangible human benefits but are co-managed in a way that not only does no harm but may also benefit the environment.*
- *Set Aside – may not provide direct tangible increases in benefits to the residents of the case study but may provide indirect economic and environmental benefits to the area predominately through the value of and payment for ecosystem services and through ecological conservation.*
- *Crisis – where both economic decline and environmental degradation of the study area impact on the well-being and livelihoods of the case study residents and severely affect any economic, social and environmental recovery of the lagoon."*

The definition of the scenarios was based on i) the driving forces identified by stakeholders during the participatory process (Focus Groups and Citizens' Jury) and combined with expert judgement; and ii) on statistical compilations on socioeconomic and environmental factors (e.g., population size, agricultural practices, land use patterns, sewage treatment). Some of these variables were used as new inputs in the eco-hydrological SWIM model at the Vouga river catchment level (see Stefanova *et al.*, 2015). Outputs from SWIM model were then used as inputs in the hydrodynamic and water quality Delft3D model at the Ria de Aveiro coastal lagoon level (see Bielecka *et al.*, 2015). The aim was to estimate the impacts of

such socioeconomic and environmental changes on water quality and quantity. Expected changes in the lagoon's navigability were also estimated (see Lillebø *et al.*, 2014). The modelling results were then combined with qualitative assumptions of each scenario in a poster format (Figure 28[4]) – the so-called integrated scenarios – and presented to the stakeholders.

5.2.3. Stakeholders' recommendations

The presentation of integrated scenarios and its discussion with stakeholders, during the LAGOONS final workshop, resulted in a set of recommendations made by them in order to achieve the desirable future for Ria de Aveiro coastal lagoon and avoid unfavourable/unwanted future situations. These are, in short (LAGOONS, 2014; Lillebø *et al.*, 2014):

[1] Reinforce and elevate the lagoon's banks where needed;

[2] Encourage the use of good agricultural practices and implement a payment for ecosystem services scheme;

[3] Optimize the forest area through the use of native species rather than monocultures;

[4] Maintain the density of life hedges in Baixo Vouga Lagunar;

[5] Develop programmes to protect and recover natural habitats and endemic species in the lagoon (e.g. reintroduction of threatened native species);

[6] Create closed season areas;

[7] Supervise fishing, bivalve and bait harvesting activities;

[8] Dredge, timely and adequate, the channels in order to maintain its navigability, without damaging the natural habitats;

[9] Protect saltpans and saltmarshes from inundation;

[10] Recover traditional activities (e.g. salt production);

[11] Finish the Baixo Vouga dike.

[4] Integrated scenarios are presented in the same way they were presented to the stakeholders, in the original language (Portuguese). *Tendência Atual* stands for Business as Usual; *Gestão Integrada* for Managed Horizons; *Crise Alargada* for Crisis, and *Tendência Ambiental* for Set Aside.

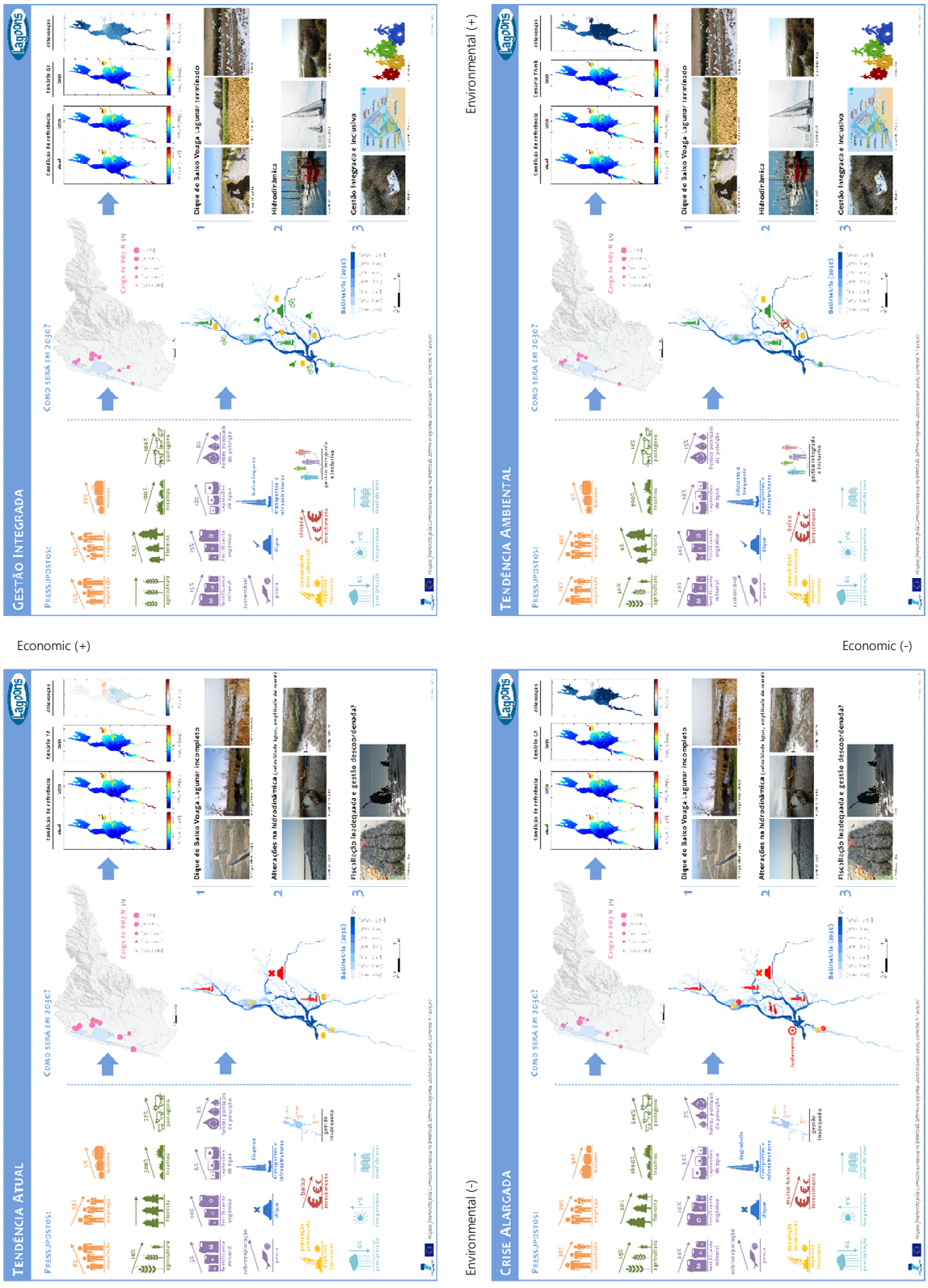


Figure 28. Integrated scenarios for Ria de Aveiro coastal lagoon (2030) discussed with stakeholders. Source: Lillebø *et al.*, 2014

5.2.4. Key ecosystem services

The key ES for Ria de Aveiro stakeholders were inferred from the results of a questionnaire performed in the scope of the LAGOONS project to the stakeholders engaged during the Project (see Lillebø *et al.*, 2015c and Appendix V).

The stakeholders' questionnaire included a set of five closed questions regarding the importance of the benefits obtained from Ria de Aveiro coastal lagoon, the beneficiaries, and the aspirations regarding the provision of those benefits in the near future (2030) (Lillebø *et al.,* 2015c). This questionnaire was printed and distributed among the participants of the LAGOONS' final workshop, which took place in May 2014 at the University of Aveiro. From a total of 32 participants representing nine categories of stakeholders (national, regional and local authorities, business and industry, research organisations, professional, cultural and recreational groups/associations, civil society, and tourists), 26 answered questionnaires were obtained.

This research only uses the results from the first three questions (see Table A. 6, Table A. 7, and Table A. 8 of Appendix V), which aimed to gain a better understanding of the benefits that stakeholders perceive as deriving from Ria de Aveiro. For each section of ES – provisioning, regulating and maintenance, and cultural services – a list of benefits was provided, and respondents had to score each benefit as: very important, moderately important, not important, or don't know (Lillebø *et al.,* 2015c). Only the ES classified as very important by more than 70% of the respondents were considered as key ES. In order to facilitate the stakeholders' interpretation, ES were translated into benefits and therefore do not follow the CICES terminology, which is the one used in the ES maps. To overcome this issue at the results analysis, a link between both terminologies was established.

5.3. Main pressures acting on Ria de Aveiro coastal region

In view of case study's social and ecological relevance, it is important to improve our understanding on the pressures that drive environmental and social changes in Ria de Aveiro coastal region (Dolbeth *et al.*, 2016). The main pressures identified are: coastal erosion, floods, changes in hydrodynamic regime, overfishing and use of non-authorized fishing gears, abandonment of traditional activities, and invasive species. Figure 29 displays, in a simple and schematic manner, the main pressures identified and the locations where they are more pressing, based on the best available information. Each pressure is described and analysed regarding its impacts on ecosystems and the services they provide, as well as the main affected beneficiaries.

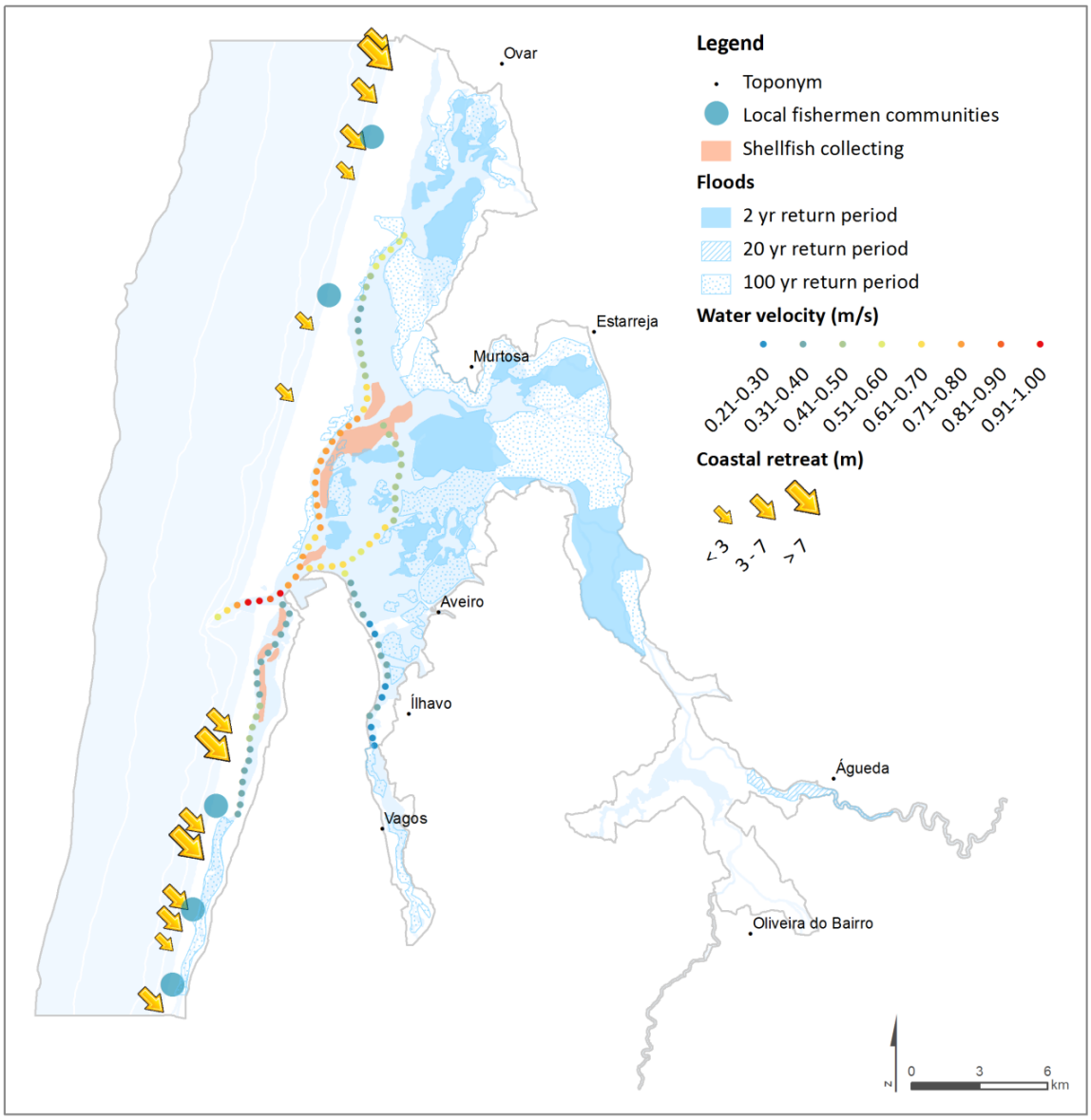


Figure 29. Schematic representation of the pressures addressed in this study

Coastal erosion

The coastal stretch between Furadouro and Mira – particularly in the municipalities of Ovar, Ílhavo, and Vagos – is well-known for its coastal erosion problems (Alves *et al.*, 2014; Dias *et al.*, 2014; Santos *et al.*, 2014; Cenci *et al.*, 2013; Pereira and Coelho, 2013; Coelho *et al.,* 2009; Pinto *et al.*, 2009; EEA, 2006) driven by a very energetic maritime wave climate allied to its sedimentary nature and a reduced river sediment supply (Pereira and Coelho, 2013; Coelho *et al.,* 2009). Following the results of the geomatic approach for shoreline change analysis, developed by Cenci *et al.* (2013) and validated for the coastal stretch between Ovar and Marinha Grande, it was possible to identify the main areas in the case study that are exposed to shoreline retreat (Figure 29). Coastal erosion affects mostly natural territories such as sand

beaches and dunes systems (particularly white and grey dunes), resulting in the decrease, or even loss, of the sandy beaches, and leading to dune destruction. These systems play a significant role in the mediation of mass and liquid flows. Additionally, they are extremely valued by people – not only locals or from neighbouring municipalities, but from other countries, particularly the Spain (LAGOONS, 2012) – for leisure and recreation, land/seascape appreciation; as well as an economic booster, wealth and job creator.

Events of overtopping are reported predominantly in the region of Vagueira (Praia do Labrego) where the land strip is very narrow. These events occasionally lead to the disruption of the "dune system", consequently connecting the Atlantic Ocean to the Lagoon (Alves and Sousa, 2013). Apart from weakening the dune system, it damages the infrastructures and floods the territory, which in this area is mainly composed by agriculture fields and natural grasslands. This situation causes a decline in the soil fertility and its capacity for being used for crops cultivation.

Note that the approach adopted by Cenci *et al.* (2013) does not take into consideration the urban settlements since these areas have always been protected through coastal defence structures (e.g. groin fields and seawalls). For that reason and considering the scope of this paper, settlements, such as Barra, Costa Nova and Vagueira, that are significantly exposed to the sea wave action and that have required a number of interventions over the years (Pereira and Coelho, 2013) are not highlighted in the Figure 29 nor analysed in this section.

Floods

The Ria de Aveiro coastal region is frequently exposed to both fluvial and coastal flood events with increasing environmental and socio-economic effects due to the frequency and magnitude of these events (Alves *et al.,* 2013b). Due to its importance to the region, several scientific and technical studies have been performed in order to assess the flood risk (Lopes, 2016; Dias *et al.*, 2014; Alves and Sousa, 2013; Fortunato *et al.*, 2013; Coelho *et al.*, 2007). This research uses the flood extent results obtained in the scope of the ADAPTARia project for the coastal lagoon area, and obtained from the Flood Risk Management Plan (PGRI, *Plano de Gestão dos Risco de Inundações*) for the Águeda municipality (which was not included in study area of ADAPTARia project). The first one applied the 2D hydrodynamic model ELCIRC (Zhang *et al.*, 2004) to the Ria de Aveiro lagoon in order to determine the lagoon's flood extent under different conditions of tide (mean, spring and equinoctial), storm surge (return period of 2, 10 and 100 years), mean sea level rise (of 0.42m and 0.64m), and fluvial flow (return period of 2, 10 and 100 years) (Lopes, 2016; Dias *et al.,* 2013, 2014; Sousa *et al.,* 2013b). The second uses the MOHID Land model

(APA, 2014). The spatial and integrated analysis of these results (flood extent, considering no changes in the mean sea level) in ArcGIS environment indicate four major typologies of impact:

- flooding in urban areas along the margins of Ria de Aveiro and Águeda River, affecting mostly road infrastructures, but also residential, commercial and industrial buildings (Lopes, 2016; Alves and Sousa, 2013);
- fluvial flooding in agriculture fields, particularly in the BVL along the Vouga River, which to some extent can benefit the agriculture activity by enriching the soil with nutrients, but when is too intense and frequent it might affect the agricultural production (Rodrigues *et al.*, 2016);
- saltwater flooding in agriculture fields, namely at the North part of BVL, at the Murtosa municipality, but also at the end of Mira and Ílhavo channels (Lopes, 2016; Alves and Sousa, 2013). This causes soil salinization, death of *bocage* living-hedges, and affects the soil fertility, leading to the establishment of halophytes (e.g., *Salicornia ramosissima* and the sea rush *Juncus maritimus*) in the areas where the soil salinity is increasing (ADAPT-MED, 2013; Pinho, 2010), and consequently changing the landscape;
- potential loss/migration of medium and high salt marshes, reeds and rush marshes habitats due to the increase in flooding frequency and duration, which is expected to be further pronounced with climate change (Dias *et al.*, 2014).

Land use/cover transferences have been observed in the last years as result of the advance of saltwater driven not only by flood events but also by the increase of tidal range (Silva *et al.*, 2011). Areas that were once used for agriculture and pasture are suffering changes and being gradually occupied by salt tolerant species (Pinho, 2010). This is particularly prominent in the BVL where a dike was partially constructed to control the saltwater intrusion, but the failure to complete the dike prevented the full control of the saltwater intrusion (Rodrigues *et al.*, 2016). There are records of reeds and rush marshes being replaced by mudflats (Pinho, 2010), and agricultural fields by rush marshes. Similar land use/cover changes are expected in the future in other regions of the lagoon if one considers the climate change effects, namely sea level rise and extreme weather events. Also, Atlantic salt meadows may be replaced by other habitats due to the increase in the number and duration of floods (Cui *et al.*, 2015).

Changes in hydrodynamic regime

Changes in the system's hydrodynamics, as a result of the geomorphologic changes in the lagoon (e.g., deepening of the mouth and main channels), have induced the increase of tidal range and water velocity (SENER/PLRA, 2012; Picado *et al*, 2010). These changes contribute to the erosion of the lagoon's banks

and channels and consequent loss of salt marsh and seagrass habitats, particularly in Espinheiro and São Jacinto/Ovar channels and in the central region of the lagoon, where water velocity is higher (SENER/PLRA, 2012; Silva *et al.*, 2004). These habitats provide a high number of ES (between 10 and 11 ES classes were identified), predominantly regulating and maintenance services, that contribute to the mediation of waste, toxics and other nuisances; mediation of mass and liquid flows; and maintenance of physical, chemical, biological conditions. Changes in tidal range contribute to the increase of the inundation periods, resulting in transferences on land use/cover (see the impacts of floods) and flooding of the lagoons' margins and agricultural fields. In addition, it affects the navigability of secondary channels during low tide, which have a negative impact on economic and recreational activities (e.g., fishing, sailing), but also on landscape appreciation.

Overfishing and use of non-authorized fishing gears

The case study area has specific features that make it particularly relevant for the fisheries sector, namely the extensive coastline, the coastal lagoon, the Aveiro's harbour, and the presence of a number of fishing communities, which is significantly associated with the local/regional culture and economy (APA, 2012). Both purse-seine and multipurpose fisheries occur in marine waters of the study area (DGPM, 2012). Shellfish harvesting and bait digging are common activities in the shallow subtidal and intertidal flats of the lagoon (Sousa *et al.,* 2015). The main effects associated to overfishing and the use of destructive fishing gears are the selective extraction of species and abrasion (ICES, 2016; Vasconcelos *et al.,* 2007). The first one has impact on commercial stocks such as small pelagics (e.g., sardine) present in coastal waters, but also diadromos species that use the Lagoon and rivers to complete their reproductive cycle (namely European eel *Anguilla Anguilla*, sea lamprey *Petromyzon marinus*, allis shad *Alosa alosa*, and twait shad *Alosa fallax*) (LAGOONS, 2013; ICNF, 2012). Additionally, it can have impact on foodwebs, and potentially on seabirds and marine mammals due to bycatch (ICES, 2016). Abrasion is associated to the disturbance of the seabed substrate as result of the use of trawling, shellfish harvesting (ICES, 2016), and bait digging. In the lagoon, this is particularly evident in the São Jacinto – Ovar channel, where shellfish collecting is performed with vessels and trawl nets (AMBIECO/PLRA, 2011).

Abandonment of traditional activities

Another pressure stressed by stakeholders is the abandonment of traditional activities, such as salt production, harvesting of seagrass and seaweed, shipbuilding and repair, traditional fishing, agriculture in the lagoon margins, and open-air dried codfish, which gave way to the development of new activities or expansion/modernization of already existing activities, e.g., aquaculture, tourism, and port activity (DHV/PLRA, 2011).

In the particular case of salt production, in 1970, approximately 270 salt pans were active, covering 1661 ha and producing approximately 60000 tons of salt per year (Bastos, 2009). In 2013, only eight salt pans were active. Part of the salt pans still remains with its structure intact, but the walls of most abandoned salt pans are destroyed. According to AMBIECO/PLRA (2011) destroyed salt pans function in a similar way as mudflats and might evolve over time to other habitats such as salt marshes, maintaining some regulating and maintenance services (e.g., providing food, shelter and nesting conditions). The same does not happen in the flooded salt pans, where water renewal is scarce and temperatures are high (AMBIECO/PLRA, 2011). Some of the abandoned salt pans were converted into fish aquaculture. In 2010, 65 licenses for aquaculture were registered in the municipalities of Ílhavo and Aveiro (APA, 2012). Shellfish aquaculture is also an emergent activity in the lagoon, particularly in the Mira and São Jacinto – Ovar channels (Sousa *et al.,* 2016).

These changes become apparent in the landscape, particularly the abandonment of salt pans, the disappearance of the agricultural fields and the open-air dried codfish (DHV/PLRA, 2011), which can contribute to the loss of cultural heritage and local/regional identity.

Invasive species

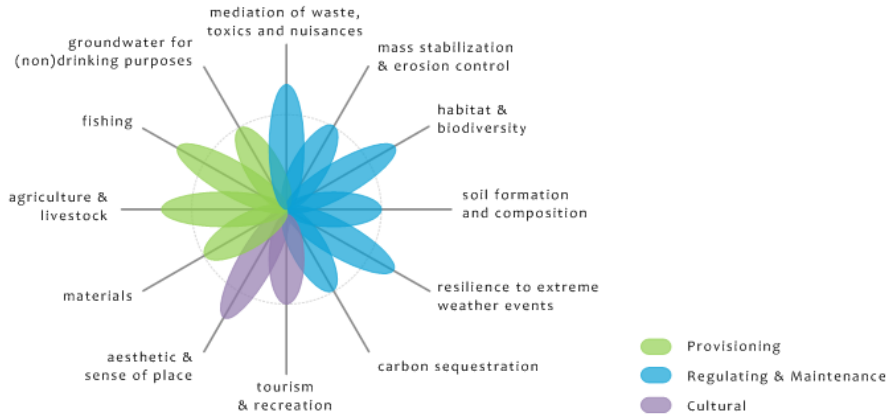
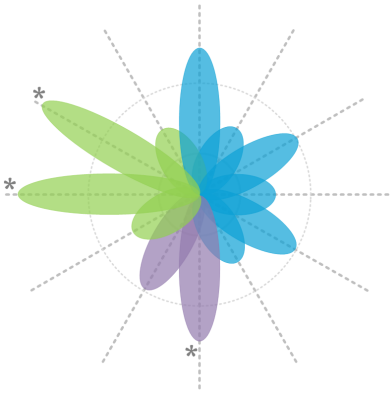
There are records of invasive species of macroinvertebrates (e.g., manila clam *Ruditapes philippinarum*; sand gaper *Mya arenaria*; Asian clam *Corbicula fluminea*), halophyes (e.g., cordgrass *Spartina versicolor*), hydrophytes (e.g., water hyacinth *Eichhornia crassipes*), and angiosperms (e.g., acacia *Acacia longifolia*; sour fig *Carpobrotus edulis*; giant reed *Arundo donax*; pampas grass *Cortaderia selloana*) in the study area (Lillebø *et al.,* 2014, 2015b; LAGOONS, 2013; Laranjeira and Nadais, 2008). For instance, water hyacinths are frequently present in *Pateira de Fermentalos* freshwater lagoon (Laranjeira and Nadais, 2008; Martins *et al.,* 2006) and causes ecological problems with significant socioeconomic repercussions (Téllez *et al.,* 2008). In addition to the changes in physico-chemical characteristics of the water (e.g., temperature, pH, oxygen and nutrient levels), it interferes with navigability, recreational uses (e.g., fishing, water sports, bathing), and aesthetics of the freshwater lagoon (Laranjeira and Nadais, 2008; Téllez *et al.,* 2008). The LAGOONS project identified a lack of knowledge regarding the Manila clam and its ecological and socioeconomic impact on Ria de Aveiro coastal lagoon (LAGOONS, 2014, 2013).

The gathered information on pressures was synthetized in Figure 30, indicating the way each pressure affects the provision of ES, as well as the affected beneficiaries.

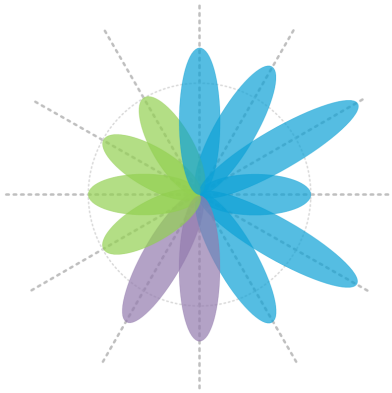
Figure 30. The impact of pressures on ecosystem services of Ria de Aveiro coastal region.

5.4. Expected changes on ecosystem services (2030)

In order to illustrate how expected changes on ES provision, as well as trade-offs, under alternative scenarios can be presented to stakeholders, this section follows the conceptual framework of Foley *et al.* (2005) – which uses a qualitative flower diagram for analysing trade-offs of ES under different land-use regimes.

<table>
<tr><td>PRESENT CONDITION</td><td> 
</td></tr>
<tr><td>BAU 2030</td><td> 

* It is expected that fishing stocks, agricultural fields and tourism (which are the ES with higher investment) will decrease over time as result of the decrease of all other ES that support them.

If present trends continue until 2030, without new management interventions, the following impacts are expected:
• decrease of mass stabilization and erosion control due to the increase in water velocity and consequent erosion of salt marshes and salt pans;
• loss of habitats and biodiversity due to erosion, increased inundation periods, saltwater intrusion, and overexploitation of bait and shellfish;
• decrease of weathering and decomposition processes as result of intensive agriculture and saltwater intrusion;
• diminution of resilience to extreme weather events due to loss of salt marshes;
• reduction of carbon sequestration due to loss of salt marshes and living edges in BVL;
• decline on aesthetic and sense of place due to loss of habitats, biodiversity and abandonment of traditional activities;
• reduction of materials, namely salt as result of flooded salt pans and abandonment salt production;
• decrease groundwater availability due to significant increase of water abstraction for agriculture and livestock</td></tr>
<tr><td>PARTICIPATORY SCENARIO</td><td> 
When considered the aforementioned recommendations proposed by stakeholders:
• recommendations 1, 5 and 9 contribute to the increase of mass stabilization and erosion control;
• 3 to 9 and 10 contribute to the maintenance of habitats and biodiversity;
• 5 and 9 may improve resilience to extreme weather events;
• 3, 4, 9 and 11 contribute to increase carbon sequestration;
• 4, 8 and 9 provide conditions to expand tourism and recreation;
• 11 allows the maintenance of existing agricultural fields and 2 promotes more sustainable agricultural practices;
• 5 to 7 promote a more controlled fishing activity.

Nevertheless, some identified pressures continued overlooked, namely changes in the hydrodynamic regime, invasive species, and dredging.</td></tr>
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Figure 31. Expected changes on ecosystem services and exemplification of how trade-offs could be presented to stakeholders.

A set of 12 ES were selected and used to illustrate the present condition. Then, considering the assumptions made at BAU scenario (see Appendix VI) as well as the expected changes on Ria de Aveiro

coastal lagoon ecosystems, the expected impacts on ES provision were qualitatively analysed (for a potential increase or decrease relative to the baseline) and presented in Figure 31. Additionally, the stakeholders' recommendations were analysed in order to understand how these could change (positively or negatively) the provision of ES.

5.5. Key ecosystem services

In order to take advantage of stakeholders' experiences, values and knowledge about the territory, the results of a questionnaire were used to infer the key ES for stakeholders, i.e. ES that were considered as very important by more than 70% of the respondents. This questionnaire was performed in the scope of the LAGOONS project and more information can be found in Lillebø *et al.*, 2015c and Appendix VI.

Although not representative of the population, due to the reduced sample size (26 responses), but valuable for methodological purposes, the benefits and corresponding ES classes identified as key by the stakeholders are summarized in Table 6. The results analysis indicates that ES from the cultural and regulation and maintenance sections are the most important for Ria de Aveiro stakeholders.

Table 6. Key ecosystem services identified by Ria de Aveiro stakeholders

Benefits	% of responses as 'very important'	Corresponding CICES classes
Landscape and scenic quality	88%	• Experiential use of plants, animals and land-/seascapes in different environmental settings
Maintaining good water quality	85%	• Bio-remediation by micro-organisms, algae, plants, and animals • Filtration/ sequestration/ storage/ accumulation by biota and ecosystems • Dilution by atmosphere, freshwater and marine ecosystems • Buffering and attenuation of mass flows
Habitats and wildlife	81%	• Maintaining nursery populations and habitats
Reducing the patterns of erosion	81%	• Mass stabilisation and control of erosion rates
Nesting areas for birds	77%	• Maintaining nursery populations and habitats
Research	77%	• Scientific
Reducing the incidence and severity of flooding	73%	• Flood protection
Education and knowledge	73%	• Educational
Recreation & leisure: birdwatching	73%	• Experiential use of plants, animals and land-/seascapes in different environmental settings

Employment was a benefit classified as 'very important' by 77% of respondents. However, it does not have a corresponding ES class in CICES and can be associated to a diversity of activities related with the lagoon and its surroundings (e.g., commercial fishing, tourism, agriculture, port activity). Therefore, it was not included as a key ES. Provisioning services were not considered priority by stakeholders. Only agriculture (54%) commercial fishing of fish (54%) and shellfish (62%) were classified as very important by more than 50% of the respondents. Regarding the ES classified as not important, the stakeholders identified timber and forestry (42%), recreation & leisure: hunting (38%), and spiritual and religious values (38%).

5.6. Discussion and conclusion

Ria de Aveiro coastal region is facing a number of pressures that drive ecosystem change in various ways. These changes, in turn, may affect the provision of ES and threat human well-being. Local and regional population are the most likely affected, but these changes can also have influence at national and global level if one considers the loss of protected species and habitats, alteration of the landscape and loss of cultural identity.

The study of alternative scenarios, whether addressing environmental, socioeconomic or management factors, allows to acknowledge uncertainty and to address multiple options for the future. The analysis of the BAU scenario shows that if no measures are taken, several regulating and maintenance services may decline. As in this scenario management is driven mainly by the demands of particular provision and cultural services that provide marketable goods (fishing, agriculture & livestock, and tourism & recreation), it is expected that in the longer run the decrease of ES that sustain these economic activities lead to the decrease of the ES that were being valued in the first place.

By addressing current and future pressures and analysing their potential impact on ecosystems and the services they provide, possible trade-offs and synergies become clear. For instance, the land use/cover transferences expected to occur as result of hydrodynamic changes and increased frequency and magnitude of floods can be seen from different angles. On the one hand the loss of agricultural fields and pastures has a negative impact on local economy; the changes in the landscape, particularly in *bocage* (which is singular and specific of this region), have a negative impact on cultural identity, landscape appreciation and consequently on tourism. On the other hand the increase of salt marshes has also positive impacts since they provide a significant number of regulation and maintenance services. Therefore, these trade-offs need to be analysed and addressed by decision-makers and discussed with stakeholders when defining strategies and implementing measures for climate change

adaptation, protection of people and goods, or conservation, for instance. The identification of both trade-offs and synergies is an important step in the ecosystem-based management since it sets the ground for a more informed dialog, and a more transparent and rigorous decision-making (PSI-connect, 2012).

When analysed the key ES identified by stakeholders one can notice their direct relation with the issues that currently concern local/regional community. For instance, maintaining good water quality was a benefit identified for more than 85% as very important. On the other hand, the presence, with some frequency, of marine biotoxins in Ria de Aveiro waters is seen as concerning since it has social and economic impacts both because it affects the shellfish collecting, as might cause public health problems. Other examples are:

- Reducing the patterns of erosion *versus* severe coastal erosion which has been causing significant damages in maritime beaches, dunes and infrastructures, and threatening the lagoons stability;
- Reducing the incidence and severity of flooding *versus* damages caused by maritime and fluvial flooding, such as flooding of agricultural fields and urban areas; breaches in river banks; and saltwater intrusion in agricultural fields (e.g., in the BVL);
- Habitats and wildlife *versus* overfishing, potentially leading to periodic collapses, as well as to abrasion of the substrate due to destructive fishing (e.g. trawling, shellfish harvesting, and other invasive/intrusive practices).

We argue that data produced and approaches discussed, not only in this chapter but also throughout chapters 3 and 4 (Figure 32), should be brought together when debating and choosing the most appropriate course of action. The identification of multifunctional areas that are vulnerable to certain pressures as result of human activities, management options and/or climate change, for instance, may contribute to the identification of trade-offs, which should support ecosystem-based management.

In addition, the incorporation of stakeholders' perceptions on significant ES and concerns regarding the main pressures improves the degree of policy and social relevance, meeting the real needs of local population and potentially improving the acceptability of future decisions by the community. Moreover, as pointed by Valente (2013), stakeholders' involvement promotes social learning among participants and helps bridging scientific, technical and traditional knowledge.

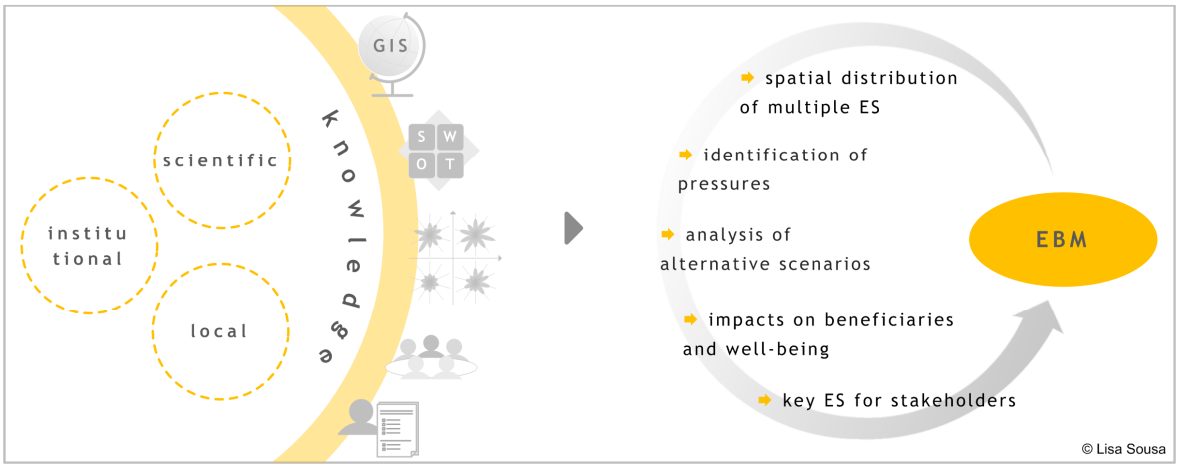

Figure 32. Schematic representation of the knowledge integration to support strategic planning

This multidisciplinary approach contributes to the design of local/regional strategies supported by principles of integration, ecosystem-based management and public engagement. This approach also provides knowledge basis to help decision makers to establish future management actions, determine priority areas for intervention (e.g., protection, recovery, development) and guide public investment.

6 Integration of ecosystem services in the planning system: a review of the Portuguese context

The contents of this chapter will be published in:

Sousa L.P., Lillebø A.I., Alves F.L., (working paper). A model to integrate ecosystem services into the planning process: the case study of Estuary Programmes.

Part of the material in this chapter is published in:

Sousa L.P., Lillebø A.I., Soares J.A., Alves F.L., 2015. The management story of Ria de Aveiro. *In:* Lillebø A.I., Stålnacke P. & Gooch G.D. (Eds.), Coastal Lagoons in Europe: Integrated Water Resource Strategies. IWA Publishers, London, pp. 31-38. ISBN: 9781780406282; eISBN: 9781780406299

6.1. Introduction

Integrating ecosystem services into sectoral policies, strategic planning, practices and decision-making has been advocated as an opportunity to promote sustainable development (e.g., Mann, 2015; Runhaar, 2015; Albert *et al.*, 2014a). Not only can provide anthropocentric-oriented argumentation for nature conservation, also can stimulate a more holistic, system-based thinking, and encourage interdisciplinary cooperation (Rall *et al.*, 2015). Existing EU policies – such as Birds and Habitats Directives; Common Agricultural Policy (CAP); Common Fisheries Policy (CFP); WFD; MSFD; cohesion and regional development policy – support the conservation and sustainable use of ES (Schleyer *et al.*, 2015; Kettunen *et al.*, 2014), which is an important step for ES integration (Maes *et al.*, 2013b). For instance, both WFD and MSFD implicitly underpin ES. The first by supporting ecosystem-based approaches and the second by pursuing the good environmental status of marine areas (Kettunen *et al.*, 2014). CAP, under the 2013 reform, promotes "greening measures" through direct payment to farmers that adopt practices that help meet environment and climate goals; as well as the ecosystems' preservation, restoring and enhancement (Maes *et al.*, 2013b). The EU regional and cohesion policy explicitly recognises ES and measures such as green infrastructures and nature-based solutions are a legitimate part of the EU regional development (Kettunen *et al.*, 2014). However, the majority of these instruments are primarily focused on single ES and may neglect the consequences of their implementation on other ES (Kettunen *et al.*, 2014). Additionally, ES are perceived as being poorly integrated into the information and the decision-support framework underpinning the development, implementation and assessment of EU policies (Kettunen *et al.*, 2014; Matzdorf and Meyer, 2014).

ES integration can take multiple forms and take place at different moments of the planning process (Runhaar, 2015; Opdam *et al.*, 2002). ES can be incorporated as a principle or policy rationale that guide the process of policy making, spatial planning or decision-making. An example is the adoption of an ecosystem-based management approach, or having the maintenance or even expansion of multifunctional areas as specific goal. ES integration can also have a more pragmatic role in the design of specific actions and in the definition of the course of action. This can be materialized through the adoption of nature-base solutions. For instance, the use of green infrastructures to minimize flood risk while promoting multiple other regulation services, but also enabling the enjoyment of this area. Another way might be through cost-benefit analysis or the assessment of monetary or social value of a set of ES provided by certain area in order to support a decision regarding the maintenance of that landscape or its transformation for economic exploitation, for instance.

The goal of this chapter is to analyse how ES are framed in Portuguese policy documents and spatial planning tools. It starts by providing an overview of the planning system in Portugal. In addition to the description of relevant plans and programmes for the case study area, the main authorities responsible for their design, monitoring and enforcement, as well as other stakeholders with interest in the region, are described. Following that, the materials and methods used to select and analyse the documents are specified. Lastly, the results regarding the conceptual integration of ES into these plans and programmes are presented and discussed.

6.2. Governance framework

6.2.1. Spatial planning context in Portugal

In view of the new spatial planning policy (adopted by the Law no. 31/2014 of March 30th and regulated by Decree-Law no. 80/2015 of May 14th), the Portuguese spatial planning system is organized across four spatial scales: national, regional, inter-municipal, and municipal. On the national level, principles and rules are defined through the (i) national programme for land use policy (*Programa Nacional da Política de Ordenamento do Território* – PNPOT), (ii) sectoral programmes, and (iii) special programmes. PNPOT is a strategic instrument of territorial development that defines the main options for the national territory; establishes the framework for all the other spatial planning tools; and is a tool for cooperation with other Member States regarding territorial organization of the European Union. Sectoral programmes develop strategies and programmes that set sectoral options, goals and actions to be achieved, within the national framework, by the various sectors of the central administration (e.g., defence, public safety, environment, water, nature conservation and biodiversity, energy, transports, tourism, agriculture, forestry). Special programmes aim the protection of natural resources, and have a spatial incidence on coastal zone, protected areas, public reservoirs, and estuaries. Within the new spatial planning frame special programmes are only binding for public administration. Therefore, their norms must be integrated in the inter-municipal and municipal plans, which are the only ones that are also binding for private entities, due to their regulatory nature. The guiding principles and rules established at national level are then operationalized at regional level through regional programmes. Inter-municipal and municipal plans develop and put in practice the guidelines established in the pre-existing programmes of national and regional levels. Municipal plans are regulatory instruments that establish the land-use regime, ensuring the compatibility between the various functions: protection, regulation, recreation and leisure, and population's well-being.

In turn, national marine policy and maritime spatial planning is defined separately from the spatial planning policy by the Law no. 17/2014 of April 10th, and is operationalized through two specific instruments: the situation plans and the allocation plans. Situation plans identify the spatial and temporal distribution of current and future uses and activities in the maritime space, as well as the natural and cultural values. Allocation plans proceed to the allocation of new uses and activities that were not included as potential uses in situation plans (Santos *et al.,* 2015).

6.2.2. Spatial planning tools and institutional responsibilities in Ria de Aveiro

As mentioned in Chapter 1 Ria de Aveiro coastal region is subject to a set of policies, plans and programmes with different spatial scales and scopes, summarized in Table 7. Figure 33 presents a schematic representation of the spatial incidence (marine and terrestrial) and governance framework of the relevant plans and programmes for the study area.

Table 7. Existing plans and programmes with territorial incidence on Ria de Aveiro coastal region. Source: Compiled by the author

Spatial scale	Spatial planning instrument	Responsible institution
National	**National Programme for Land Use Policy** *Programa Nacional da Política Pública de Ordenamento do Território* (PNPOT)	DGT Directorate General for the Territorial Development
	Maritime Spatial Plan Plano de Situação e Plano de Afetação	DGPM and DGRM Directorate General of Marine Policy; Directorate General for Natural Resources, Safety and Maritime Services
	Sectoral Programmes	
	Sectoral Plan for Natura 2000 Network *Plano Sectorial da Rede Natura 2000* (PSRN2000)	ICNF, I.P. Institute for Nature Conservation and Forestry
	River Basin Management Plan for Vouga, Mondego and Lis *Plano de Gestão das Bacias Hdrográficas dos rios Vouga, Mondego e Lis* (PGBH Vouga, Mondego e Lis)	APA, I.P. Portuguese Environment Agency
	Flood Risk Management Plan for Vouga, Mondego and Lis *Plano de Gestão dos Riscos de Inundações para a Região Hidrográfica 4 - Vouga, Mondego e Lis* (PGRI)	APA, I.P. Portuguese Environment Agency

	Special Programmes	
	Coastal Zone Management Plan Ovar – Marinha Grande section* *Plano de Ordenamento da Orla Costeira Ovar – Marinha Grande* (POOC OMG)	APA, I.P. Portuguese Environment Agency
	São Jacinto Dunes Nature Reserve Spatial Plan *Plano da Área Protegida Reserva Natural das Dunas de S. Jacinto* (PORNDSJ)	ICNF, I.P. Institute for Nature Conservation and Forestry
	Vouga Estuary Programme** *Programa do Estuário do Vouga* (PE Vouga)	APA, I.P. in collaboration with ICNF, I.P. Portuguese Environment Agency; Institute for Nature Conservation and Forestry
Regional	**Regional Spatial Plan for Centre** *Plano Regional do Ordenamento do Território do Centro* (PROT-C)	CCDR-C Regional Coordination and Development Commission for Centre
Inter-municipal	**Ria de Aveiro Inter-municipal Master Plan** *Plano Intermunicipal de Ordenamento da Ria de Aveiro* (UNIR@RIA)	CIRA Inter-municipal Community of the Aveiro Region
Municipal	**Municipal Master Plan of Ovar** *Plano Diretor Municipal de Ovar* (PDM Ovar)	Ovar municipality
	Municipal Master Plan of Murtosa *Plano Diretor Municipal da Murtosa* (PDM Murtosa)	Murtosa municipality
	Municipal Master Plan of Estarreja *Plano Diretor Municipal de Estarreja* (PDM Estarreja)	Estarreja municipality
	Municipal Master Plan of Albergaria-a-Velha *Plano Diretor Municipal de Albergaria-a-Velha* (PDM Albergaria-a-Velha)	Albergaria-a-Velha municipality
	Municipal Master Plan of Águeda *Plano Diretor Municipal de Águeda* (PDM Águeda)	Águeda municipality
	Municipal Master Plan of Aveiro *Plano Diretor Municipal de Aveiro* (PDM Aveiro)	Aveiro municipality
	Municipal Master Plan of Ílhavo *Plano Diretor Municipal de Ílhavo* (PDM Ílhavo)	Ílhavo municipality
	Municipal Master Plan of Vagos *Plano Diretor Municipal de Vagos* (PDM Vagos)	Vagos municipality

Municipal Master Plan of Oliveira do Bairro *Plano Diretor Municipal de Oliveira do Bairro* (PDM Oliveira do Bairro)	Oliveira do Bairro municipality
Municipal Master Plan of Mira *Plano Diretor Municipal de Mira* (PDM Mira)	Mira municipality
Municipal Master Plan of Anadia *Plano Diretor Municipal de Anadia* (PDM Anadia)	Anadia municipality

* revised in 2015, waiting for legal publication (Coastal Zone Programme, POC OMG) ** not yet developed

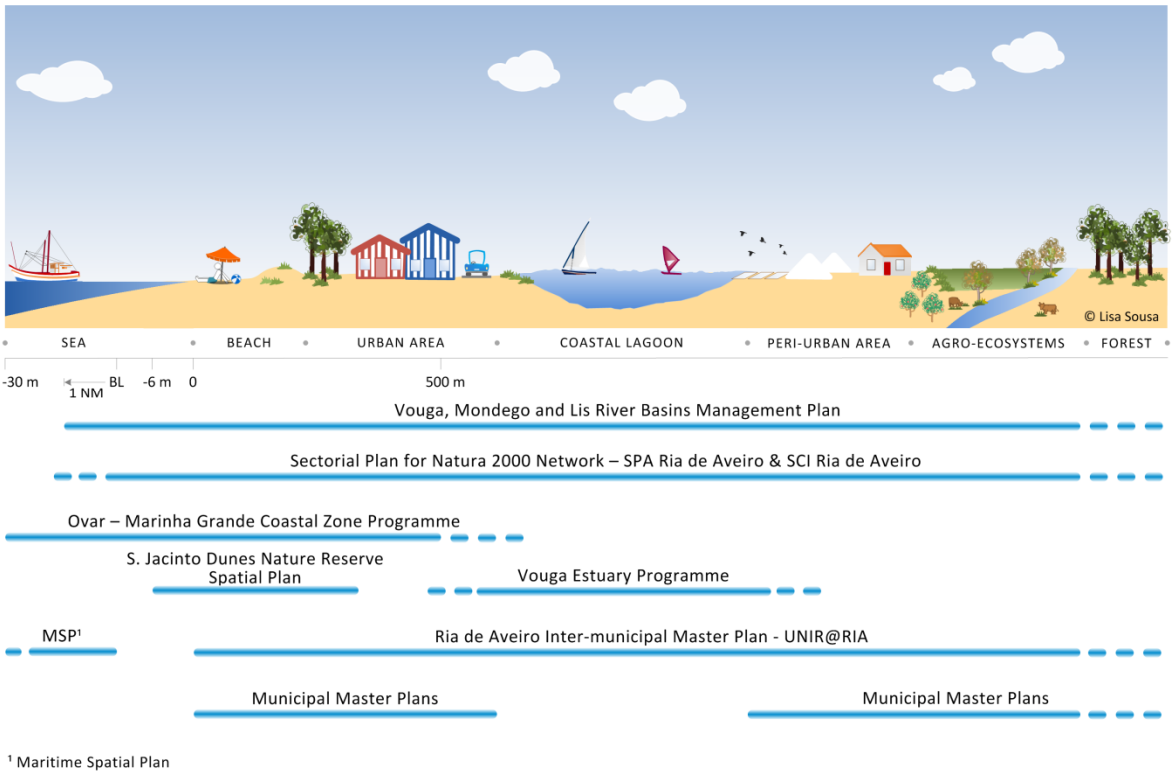

Figure 33. Territorial incidence of case study's relevant planning instruments for both terrestrial and marine space.
Source: Adapted from Sousa *et al.,* 2016

Besides, Ria de Aveiro is embedded in a complex institutional framework, characterized by the involvement of a variety of institutions and organizations, including non-governmental agencies and other stakeholders (Sousa *et al.,* 2015). Government authorities have different types and levels of responsibilities regarding water, coastal and maritime space management, spatial planning, and nature conservation. The Portuguese Environment Agency (APA, I.P.), for instance, plays a major role in the development and monitoring of environmental policies, namely water management, integrated coastal zone management, and climate change, among others. As national water authority, APA I.P. is

responsible for ensuring the management of the Portuguese water resources; for representing the Portuguese State in water issues at international level and for reporting to the European Commission regarding water related directives. Regarding the integrated management of coastal zone, APA I.P. is responsible for promoting, preparing and implementing the National Strategy for Integrated Coastal Zone Management and ensuring its implementation at national, regional and local levels (DL no. 55/2016 of august 26th). Because Ria de Aveiro coastal lagoon is classified as SPA and SCI under Nature 2000 Network and the study area integrates the São Jacinto Dunes Nature Reserve, the Institute for Nature Conservation and Forestry (ICNF, I.P.) plays an important role, as national authority for nature conservation and biodiversity, in assuring the conservation and sustainable management of the lagoon (Law no. 242/2015 of October 15th). The maritime policy – including the development and monitoring of the National Ocean Strategy – is responsibility of the Directorate General of Marine Policy (DGPM). The maritime spatial planning and management of marine protected areas is responsibility of the Directorate General for Natural Resources, Safety and Maritime Services (DGRM). The latter, in articulation with ICNF, I.P.. Several responsibilities concerning environmental policy, spatial planning, and regional development are delegated in the Regional Coordination and Development Commissions, in this case for Centre Region (CCDRC), which are responsible for coordinating the decentralized services and supporting the local authorities and their associations. Composed by 11 municipalities of the NUT III Baixo Vouga, the Inter-municipal Community of the Aveiro Region (CIRA) is an inter-municipal entity that aims at planning and managing the economic, social and environmental development strategy; articulating municipal investments; participating in the management of regional development support programmes; and ensuring the coordination of actions between municipalities and the central administration, namely in the field of spatial planning, nature conservation and natural resources, economic, social and cultural development (Notice no. 72/2014 of March 20th).

In addition to the government authorities, with legal competences to intervene in this region, there is a large number of stakeholders and social groups with direct or indirect interests on Ria de Aveiro such as the Port Authority, scientific research centres, municipalities, and users' associations (e.g., fishing, salt producers, farming, hunting, industry, nautical sports) (Sousa *et al.,* 2015).

6.3. Material and methods

A set of planning documents of different nature (strategic, spatial planning, management), scales, territorial scopes (e.g. sea, coastal zone, estuaries), and policy sectors (e.g. spatial planning, climate change, nature conservation and biodiversity) were selected and analysed regarding the conceptual integration of ES (as defined by Kettunen *et al.*, 2014). The aim was to identify explicit or implicit

references to the ES notion into the overall premises and objectives of strategic and spatial planning tools that influence the development and protection of Ria de Aveiro coastal region. *'Explicit references'* mean that the term *ecosystem services* is unambiguously referred while *'implicit references'* mean that ES related concepts are referred (Kabisch, 2015), such as *benefits*, *goods and services*, *environmental services*, *well-being*, *ecosystem approach*, and *natural capital*. Whenever these terms were mentioned, the content was further analysed in order to confirm the establishment of a relationship between nature and humans, and to assess the extent to which the *ecosystem services* and related concepts were addressed.

The selection process included:

- Documents of strategic nature within varied policy domains considered relevant, which set the scope and objectives for the sustainable management of natural resources, such as policies and strategies related with spatial planning, environment, water, nature conservation and biodiversity, climate change, coastal zone, and marine space; and
- Spatial planning tools that directly affect the case study: PNPOT; PSRN2000; PORNDSJ; PGBH Vouga, Mondego and Lis; POOC OMG (2000); POC OMG (2015); PE Vouga; PROT-C; UNIR@RIA.

The documents were collected between October and November of 2015 through the ministries official websites. A considerable part of the documents had been under public consultation and were still waiting for legal publication. In those cases, both the document in force and the technical reports prepared for their revision were analysed.

Similarly to Baker *et al.* (2012) and Geneletti and Zardo (2016) the content of the analysed programmes and plans was divided into four components that represent different stages of the planning process:

- Information base – includes the characterization of the current conditions, diagnosis and analysis of future trends, which supports the subsequent planning stages.
- Vision, principles and objectives – includes the definition of the plan's long-term vision and the specific objectives to achieve it.
- Strategic lines/ actions – includes the strategies (or strategic lines) that are proposed to guide decisions and achieve the plan's objectives.
- Implementation and monitoring – includes the specific measures defined to achieve a successful plan's implementation and the indicators that allow its evaluation.

Despite of the differences in structure, particularly in sectoral policies, it was possible to divide all analysed documents in these four generic components.

Data regarding the presence or absence of ES related terms were collected and organized in a table. Quotes from the planning documents, together with the corresponding stage in which key terms were mentioned, were also gathered. The notations were supplemented with three coding categories (Geneletti and Zardo, 2016; Baker *et al.,* 2012) to assess the level of integration of the ES notion in the different planning components (Table 8).

Table 8. Coding categories considering various levels of ES conceptual integration in the different planning components. Adapted from Geneletti and Zardo, 2016; Baker *et al.*, 2012

Code	Plan/Programme components			
	Information base	Vision, principles & objectives	Strategic lines/ actions	Implementation & monitoring
0	No evidence of information related to ES	No evidence of objectives related to ES	No evidence of actions related to ES	No evidence of implementation provisions related to ES
1	Acknowledges ES only generally	Mentions ES-related objectives, but lacks further definition	Mentions ES-related (subjective) actions, but lacks further definition	Mentions implementation provisions related to ES, but lacks further definition
2	Acknowledges and describes the ES present, and the potential impacts on ES resulting from different drivers of change	Includes ES in the objectives, provides details on their content and how to pursue them	Includes ES in the actions and provides details on their application and activities, including locally-specific details	Include ES-related implementation provisions and provides details on their application, including details on budget, responsible bodies, etc.

6.4. Conceptual integration of ecosystem services

A total of 32 documents was analysed regarding the conceptual integration of ES, 18 of which are strategic and concern a range of political domains: spatial planning, environment, water, nature conservation and biodiversity, climate change, coastal zone, and maritime space. The remaining documents analysed are plans and programmes that directly affect the case study's development. The results summarized in Table 9 and Table 10 show that *ecosystem services* and related concepts are acknowledged in several sectoral policies and spatial planning tools. However, the degree of the concepts' integration varies across documents, planning components, and year of publication.

6.4.1. Sectoral policies of national scope

Regarding water, nature conservation and biodiversity sectors one can notice an evolution over time concerning the integration of the ES concept.

While in 2005 the Water Law only mentioned the ecosystems functionality as indicator of ecological quality, the revised document (published in 2012) stresses the need for incorporating the subject "*water and ecosystem services*" into the water national plan (PNA). In turn, the revised document of PNA (not published at the time of this analysis) calls for deeper knowledge about "*ecosystem-based approaches*" and "*ecosystem services assessment*". PNA incorporates the ES concept on its strategic objectives, as it aims to "*Protect and restore natural ecosystems, in order to ensure the conservation of natural capital and the provision of aquatic ecosystem services and their dependent terrestrial ecosystems*". Moreover, establishes ES related measures to achieve the mentioned objective, namely "*maintenance and restoration of ecosystems' global processes and functions*", and "*economic valuation of ecosystems' benefits to support public policies*".

The revised document (in 2015) of the National Strategy for Nature Conservation and Biodiversity (ENCNB, not published at the time of this analysis) undoubtedly incorporates the ES concept. Its vision calls for the integration of biodiversity and ES into the various sectors of activity and national economy. "*Maintaining, restoring and enhancing ecosystems and their services*" is one of the five strategic lines, which is further divided into four goals and seven targets. These include:

- "*mapping ecosystems and relevant ecosystem services and assessing their status*";
- "*defining and implementing priority actions for the recovery of ecosystems and their services*";
- "*establishing the economic value of key ecosystem services at national level*";
- "*promoting the investment in natural capital through the development of (i) green, coastal, rural and urban infrastructures; (ii) biodiversity credit systems; and (iii) payment for ecosystem services*".

The Law for the Environmental Policy (approved in 2014) establishes a relationship between the importance of adopting a sustainable management of the ecosystems and natural resources with the human well-being and life quality. Additionally, it foresees the use of compensation instruments, such as fees, prices or rates, to promote rational and efficient use of environmental resources, and suggests that environmental goods should be weighted equally with other goods and values to ensure their compatibility.

Concerning the coastal zone, the occurrence of key terms was found in the National Strategy (ENGIZC, adopted in 2009) several times across the document. ENGIZC assumes a planning and development model for the coastal zone based on an ecosystem approach. Some of the planned measures, also based on an ecosystem approach, promote the ES integration and public awareness.

The National Strategy for Climate Change adaptation (ENAAC, adopted in 2010) appoints biodiversity as one of the strategic sectors to which climate change adaptation measures will be developed. Moreover, it recognizes not only the impacts that climate change has on biodiversity, but also the role that biodiversity and ecosystem services might have on the minimization of such impacts.

Regarding spatial planning, the Law for the Public Policy of Soil, Spatial Planning and Urbanism (LBPPSOTU, approved in 2014) stresses in its goals the need of safeguarding the quality of the soil's environmental functions. Additionally, it states that municipalities must create a municipal fund for environmental and urban sustainability in order to promote the ecosystems' sustainability and the provision of environmental services, among others. The Nacional Ecological Reserve (REN) itself is of critical importance for ecosystems' protection as it is a biophysical structure that comprises fundamental areas which are subject of special protection. These are areas of significant ecological value or sensitivity, or areas exposed to natural risks (e.g., beaches; salt marshes; transitional waters; areas of high risk of soil erosion). Moreover, REN identifies the main ecological functions of each area.

The first National Ocean Strategy (ENM, approved in 2006) already promoted an ecosystem-based approach as well as the maintenance of coastal and marine ecosystem services. The revised Strategy (approved in 2014) goes further in proposing a set of actions to uncover the main ecosystem services and their value (e.g., data acquisition to improve the modelling capacity of ecosystems' functions). Also the Law for the Maritime Spatial Planning Framework (LBOGEM, adopted in 2014) promotes an ecosystem-based approach, and the sustainable use of marine resources and ES.

Table 9. Results of the analysis of the conceptual integration of ES in sectoral policies (* denotes not published at the time of the analysis; N.A. - not applicable). Source: Compiled and analysed by the author

Plan/ Programme	Year	Plan/ Programme main components								Scope	
		Information base	Code	Vision, Principles & Objectives	Code	Strategic lines/ options	Code	Implementation & Monitoring	Code	Spatial	Temporal
SPATIAL PLANNING											
Law for the public policy of soil, spatial planning and urbanism (LBPPSOTU) Law no. 31/2014, May 30th	2014		0	Environmental functions; Ecosystems' production	1	Environmental services	1		0	National	N.A.
Legal regime of the national ecological reserve (REN) * DL no. 166/2008, August 22nd	2008		0	Environmental goods and services	1		0		0	National	N.A.
ENVIRONMENT											
Law for the environmental policy Law no. 19/2014, April 14th	2014		0	Ecosystems' production capacity	1		0	Ecosystem goods and services; Environmental services; Environmental functions; Environmental goods	1	National	N.A.
WATER											
Water law Law no. 58/2005, December 29th	2005	Ecosystems' functions	1		0		0		0	National	N.A.
Water law – revised DL no. 130/2012, June 22nd	2012	Ecosystems' functions	1		0	Ecosystem services	1		0	National	N.A.
Water national plan (PNA 2002) DL no. 112/2002, April 17th	2002	Human well-being; Ecosystems & environmental functions	1		0		0		0	National	2012

Plan/ Programme	Year	Plan/ Programme main components								Scope	
		Information base	Code	Vision, Principles & Objectives	Code	Strategic lines/ options	Code	Implementation & Monitoring	Code	Spatial	Temporal
Water national plan – in revision (PNA 2015) Public discussion: August 2015	*		0	Ecosystem services; Natural capital; Ecosystem approach	1	Ecosystem services; Natural capital; Benefits; Ecosystem functions	2		0	National	2021 (vision for 2027)
NATURE CONSERVATION & BIODIVERSITY											
National strategy for nature conservation and biodiversity (ENCNB) RCM no. 152/2001, October 11st	2001	Natural processes	0		0		0		0	National	2010
National strategy for nature conservation and biodiversity – in revision (ENCNB 2015/2020) Public discussion: July 2015	*	Ecosystem services; Natural capital; Human well-being; Benefits; Goods and services	2	Ecosystem services; Human well-being	2	Ecosystem services	2	Ecosystem services; Natural capital	2	National	2020 (vision for 2050)
CLIMATE CHANGE											
National strategy for climate change adaptation (ENAAC 2010) RCM no. 24/2010, April 1st	2010		0		0	Ecosystem services	1		0	National	Does not specify
National strategy for climate change adaptation – in revision (ENAAC 2020) Public discussion: June 2015	*		0		0	Ecosystem services	1		0	National	2020
National programme for climate change (PNAC 2006) RCM no. 104/2006, August 23rd	2006		0		0		0		0	National	2010/ 2020

Plan/ Programme	Year	Plan/ Programme main components								Scope	
		Information base	Code	Vision, Principles & Objectives	Code	Strategic lines/ options	Code	Implementation & Monitoring	Code	Spatial	Temporal
National programme for climate change – in revision (PNAC 2020/ 2030) Public discussion: June 2015	*		0		0		0		0	National	2020/ 2030
COASTAL ZONE											
National strategy for integrated coastal zone management (ENGIZC) RCM no. 82/2009, September 8th	2009	Goods and services; Functions	1	Ecosystem services	1	Ecosystem-based approach	2	Ecosystem-based approach; Ecosystem services	1	National	2029
Action plan for littoral protection and enhancement (PAPVL 2012-2015)	2012		0		0		0		0	National	2015
MARITIME SPACE											
National ocean strategy (ENM 2006-2016) RCM no. 163/2016, December 12th	2006	Ecosystem-based approach	1	Ecosystem-based approach; Ecosystem services	1		0		0	National	2016
National ocean strategy – revised (ENM 2013-2020) RCM no. 14/2014, February 12th	2014	Ecosystem-based perspective; Functions; Cultural services	1	Ecosystem services	1	Ecosystem function; Functions and services; Benefits; Ecosystem-based approach	2		0	National	2020
Law for the maritime spatial planning framework (LBOGEM) Law no. 14/2014, April 10th	2014		0	Ecosystem-based approach; Ecosystem services	1		0		0	National	N.A.

6.4.2. Spatial planning tools

The content analysis of the documents that set the spatial planning framework of Ria de Aveiro coastal region (Table 10) reveals that the *ecosystem services* concept is acknowledge in almost all documents, with exception for the PORNDSJ. The occurrence of key terms was typically found in the *information base* component of the plans/programmes. These were mostly general affirmations (e.g., *"Soil is essentially a non-renewable resource and a very dynamic system which performs several functions and delivers vital services to human activities and to ecosystems"* – p.174 CCDRC, 2011), without presenting a definition of the terms, nor specifying the ES at scope, or potentially impacted from different drivers of change.

As opposition, the PSRN2000 and the POC OMG integrate the concept of *ecosystem services* in the planning process. For instance, the habitats' technical sheets that complement/integrate the PSRN2000 present a list of the ES provided by each natural habitat of the Appendix I of the Habitats Directive. The technical reports of POC OMG – publicly available for consultation in November 2015 and still waiting for legal publication – provide several references to ES related concepts across all planning components, such as multi-functionality, environmental/ecological functions, well-being, goods and services, environmental/ecosystem services. Moreover, POC OMG identifies the ES that are at risk due to coastal erosion, and analysis the expected implications of alternative scenarios (of coastal intervention) on ES provision.

Table 10. Results of the analysis of the conceptual integration of ES in spatial planning tools (* denotes not published at the time of the analysis; N.A. - not applicable; N.S. - not specified). Source: Compiled and analysed by the author

Plan/ Programme	Year	Plan/ Programme main components								Scope	
		Information base	Code	Vision, Principles & Objectives	Code	Strategic lines/ options	Code	Implementation & Monitoring	Code	Spatial	Temporal
National programme for land use policy (PNPOT 2007) Law no. 58/2007, September 4th	2007		0		0	Ecosystems' functions	1		0	National	2025
Sectoral plan for Natura 2000 network (PSRN2000) RCM no. 115-A/2008, July 21st plus ZPE Ria de Aveiro (PTZPE0004) and SIC Ria de Aveiro (PTCON0061) sheets	2008	Functions	2		0	Functions	1		0	National	First assessment after 5 years
Regional spatial plan for Centre (PROT-C) Technical reports (2011)	*	Ecosystems' functions	1		0	Ecosystems' functions	1		0	Regional	N.S.
Ria d Aveiro inter-municipal master plan (UNIR@RIA) Avisio no. 19308/2008, July 3rd plus technical reports	2008	Goods and services; Multifunctionality	1		0		0	Benefits	0	Inter-municipal	N.S.
River basin management plan for Vouga, Mondego and Lis (PGBH Vouga) RCM no. 16-B/2013, March 22nd plus technical reports	2013	Environmental services	1		0		0		0	National	First revision in 2015
Coastal zone management plan Ovar – Marinha Grande section (POOC OMG) RCM no. 142/2000, October 20th	2000	Functions	1	Function	1		0		0	National	2010
Coastal zone programme Ovar – Marinha Grande (POC OMG) Technical reports from the public discussion (November 2015)	*	Multifunctionality; Environmental functions; Functions; Environmental services	2	Ecological function; Environmental services	1	Ecosystem services; Environmental services; Goods and services	2	Ecosystem services; Functions	1	National	10 years after legal publication

Plan/ Programme	Year	Plan/ Programme main components								Scope	
		Information base	Code	Vision, Principles & Objectives	Code	Strategic lines/ options	Code	Implementation & Monitoring	Code	Spatial	Temporal
São Jacinto Dunes nature reserve spatial plan (PORNDSJ) RCM no. 76/2005, March 21st	2005		0		0		0		0	National	N.S.
Vouga estuary programme (PE Vouga) DL no. 129/2008, June 21st - stablishes the legal regime of Estuary Plans Ruling no. 22550/2009, October 13th - stablishes the elaboration of Vouga Estuary Plan	N.A.		0	Ecosystems' functions	1		0		0	National	N.A.

6.5. Discussion and conclusion

The review of strategic and spatial planning instruments that direct or indirectly influence the management of Ria de Aveiro coastal region show an evolution over time in the conceptual integration of ES. Plans and programmes recently revised are those in which ES integration is more evident, and detailed. Differences in the uptake of ES concept between policy domains are also evident. Water and Nature Conservation realms are two examples of this progress, particularly the Water National Plan (PNA 2015) and the National Strategy for Nature Conservation and Biodiversity (ENCNB 2015), which were both recently revised and were under public discussion at the time of this analysis. The first clearly states the need to guarantee the provision of ES and provides specific measures to achieve this goal. The second defines specific actions to map and assess ES, and identifies instruments that can be used to promote the investment into natural capital or compensate impacts, such as Payments for Ecosystem Services (PES) or biodiversity offsetting schemes. Policies concerning coastal zone and maritime space show a special concern with ecosystem-based management.

This progress seems to be motivated by the increasing efforts (described in Chapter 2) made not only at international level (e.g., Aichi Biodiversity Targets, in 2010; IPBES, in 2010), but also at European level (e.g., EU Biodiversity Strategy, in 2011; MAES Working Group, in 2012) and at national level (e.g., Portuguese MA sub-global assessment, in 2009). Nevertheless, most of the analysed plans and programmes lack of detail and specificity regarding ES knowledge utilization, which may be an obstacle for its actual implementation. For instance, the ES concept is hardly integrated as an objective itself, or as part of an action.

It is important to note that the lack or low level of explicit references to ES does not necessarily mean that they are not being addressed, protected or valued. The creation of a regional structure for environmental protection and enhancement (ERPVA, *Estrutura Regional de Protecção e Valorização Ambiental*) in the scope of PROT-C is an example of this. ERPVA comprises areas with important natural values (including classified areas and ecological corridors) and aims to ensure physical continuity and ecological connectivity; increase habitats and species resilience to climate change and other risks/pressures; and ensure the ecological functions of the territory. Another example is the use of soft measures such as vegetation, artificial sand nourishment, wicker palisades and footbridges to restore and protect the dunes against coastal erosion. These examples reveal that there are current practices that promote multi-functionality, biological diversity and contribute to ES governance, even without giving explicit attention to the 'word' ES. Yet, we argue that planning systems would benefit from a more explicit and deep use of the ES concept, as it is a powerful tool for communicating nature and

biodiversity values to different groups of stakeholders; and to address the impacts (positive or negative) of planning alternatives on ES and human well-being, which are not being fully considered.

7 Integration of ecosystem services into Estuary Programmes: what works where?

The contents of this chapter will be published in:

Sousa L.P., Lillebø A.I., Alves F.L., (working paper). A model to integrate ecosystem services into the planning process: the case study of Estuary Programmes.

7.1. Introduction

Several authors argue that ES should inform decision-making and policy design for governance of complex social-ecological systems (e.g., EEA, 2016, 2015; Geneletti, 2015; Guerry *et al.*, 2015; Albert *et al.,* 2014a; Harrison *et al.,* 2010; Vasconcelos *et al.,* 2007). However, the actual implementation of ES into practice is still limited (Mascarenhas *et al.*, 2015; Albert *et al.,* 2014b; Koschke *et al.*, 2012). The complexity involving ES related studies, alongside the need to adapt to specific decision contexts and scales, and the lack of integration of social and administrative processes in such studies are some of the issues that may potentially limit the integration of ES (Albert *et al.,* 2014b; Primmer and Furman, 2012). Another reason might be the expected additional amount of planners' workload and financial resources for data collection and assessment, which poses already a problem since environmental data is often outdated and there is a lack of resources to conduct more complex ES assessment and valuation studies (Albert *et al.* 2014b).

Various assessments have been performed in order to identify, quantify, map, and value ecosystem services (e.g., García-Nieto *et al.*, 2015; Costanza *et al.*, 2014; Liquete *et al.*, 2013; Burkhard *et al.*, 2009). However, as stressed by Martínez-Harms *et al.* (2015), it is not clear how the information gathered in such assessments could be used to inform decision-making. Recognizing this gap, this chapter proposes a model for integrating ES into spatial planning process. Similarly to Geneletti (2015), the present research looks to the planning stages and discusses how and where ES related information could be further incorporated to better inform decision-making. While Geneletti (2015) proposes a conceptual model for Strategic Environmental Assessment (SEA), this research aims to introduce ES concerns into spatial planning tools, having Estuary Programmes as starting point.

Estuary Programmes are special programmes (i.e. aims at protecting natural resources) of strategic nature that focus on the estuary and estuary banks, which are the core of the case study area. Despite of having a legal framework since 2009, the Vouga Estuary Programme has not been developed yet, which was perceived as an opportunity for improving traditional practices and adapting them to new methodologies and approaches.

7.1.1. From Estuary Plans to Estuary Programmes

Following the Water Framework Directive the Portuguese government approved the Water Law, which introduced a new planning instrument to the national juridical and management system: the Estuary Plans (Sousa *et al.,* 2011). The plans' intervention area, objectives and contents were further developed

by the DL no. 129/2008 of July 21st. The main goal of these plans is to protect estuary's waters, waterbeds, banks and associated ecosystems while increasing the social, economic and environmental value of estuary's surrounding areas. The new spatial planning framework (mentioned in Chapter 6) introduced some changes, namely in special plans, which are now called special programmes. This means that the Estuary Programmes are only binding for public administration, and no longer have a regulatory nature. The directives and rules established in these programmes must be operationalized through inter-municipal or municipal plans. Also, the content of special programmes was updated, comprising now i) the directives for the protection and enhancement of natural resources and values; ii) the implementing rules; and iii) the cartographic elements considered necessary. Additionally, special programmes are complemented with the programme's report; the environmental report; the implementation programme; the financing plan; and the indicators that support the programmes' evaluation. Table 11 highlights the major modifications which resulted from the adoption of Law no. 31/2014 of March 30th, regulated by DL no. 80/2015 of May 14th.

Table 11. Differences between special plans and special programmes

	Special Plans (DL no. 46/2009, February 20th)	Special Programmes (DL no. 80/2015, May 14th)
Scope	National	National
Nature	Regulatory	Strategic
Legal bind	Public and private entities	Public entities
Contents	› Regulation and cartographic elements necessary to represent the regulation's spatial incidence Special Plans are complemented with: › Plan's report › Environmental report › Constraints Map – identifies the easements and restrictions of public utility	› Directives for the protection and enhancement of natural resources and values › Implementing rules › Cartographic elements considered necessary Special Programmes are complemented with: › Programme's report › Environmental report › Implementation Programme and Financing Plan › Qualitative and quantitative indicators for evaluation

7.2. Ecosystem services integration model for Estuary Programmes

Taking advantage of the existing planning framework on Ria de Aveiro coastal region, this section discusses ways of integrating ES related information within the key stages of Vouga Estuary Programme. In view of the recent legislative changes aforementioned, the planning process has been decomposed into three main operational moments or stages: i) characterization and diagnosis; ii) preliminary proposal; iii) action and financing programme. This division was based on the technical norms established in DL no. 129/2008 of June 21st, but also on the report developed by the Water National Commission (see CNA, 2012) and the new legal framework. In parallel to the planning process there are the processes of SEA, as well as the public participation. As mentioned by Geneletti (2011, 2015), each successive stage builds on previous work but they are often not organized in a linear sequence and may be subject of changes across the planning process due to a number of reasons, such as new inputs from public consultation and discussion, or SEA. This is a cyclic process (Olsen *et al.*, 2011; Opdam *et al.*, 2002), meaning that the different stages of the Programme may be revised in case evaluation and monitoring results show significant changes in the baseline condition, if the measures are not been effective, or if the underlying objectives alter.

Figure 34 provides a synthesis of the main operational moments of the planning process, as well as the actions to include ES related information, which are further discussed below.

7.2.1. Characterization and Diagnosis (Stage 1)

The first planning stage includes the definition of physical boundaries of the intervention area; the characterization of the reference condition regarding the biophysical, territorial, socioeconomic, and governance systems (not only on the intervention area but also of the adjacent area); and a prospective diagnosis, which identifies the major trends, as well as the major threats and opportunities. This stage reviews the current situation and sets the ground for the design of the strategic framework.

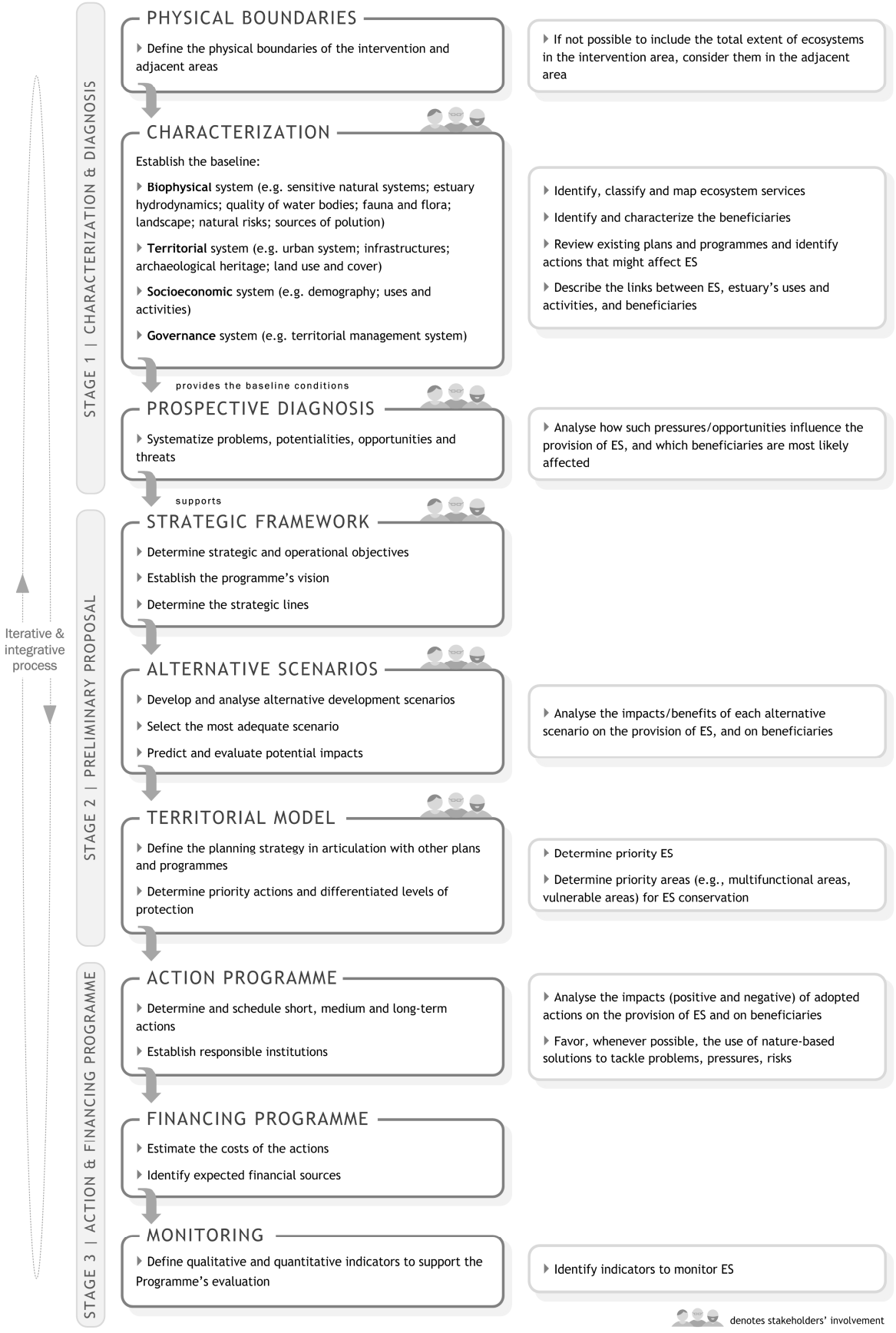

Figure 34. Integration of ecosystem services knowledge in different stages of the Estuary Programmes cycle

Definition of physical boundaries

As discussed in Chapter 3 the delimitation of geographic boundaries should take into consideration not only administrative limits and jurisdictional factors, but also ecological and social factors. In the case of Estuary Programmes the intervention area comprises the estuary (composed by its transitional waters, water beds and margins) and the estuarine shoreline. The latter corresponds to the terrestrial protection zone whose width can go up to 500m measured from the margin. Therefore, in order to set coherent boundaries one should analyse the territory features (regarding the land use/cover, topography, presence of connective structures, for instance), the existing (or non-existing) governance framework, the existing uses and activities, and only then assess the need to go up to 500m. As mentioned by Sousa *et al.* (2011) the delimitation must be done on a similar scale to that used in urban planning, and a set of criteria is proposed: i) urban areas should be excluded from the intervention area once they have their own management tools; ii) areas already managed under a territorial management tool (e.g. CZP) should be excluded; iii) the maximum limit should be respected in the cases where natural values (connective structures) that should be protected, enhanced or recovered are present.

While avoids overlapping objectives, guidelines and management responsibilities, this approach guarantees that important ecosystems and the services they provide, connective structures, as well as estuary related activities are integrated in the intervention area of the programme. In addition, an adjacent area, which may influence the estuary's conditions and development trends, should also be defined and analysed.

Characterization of the reference condition

In this phase, a documentation and analysis of biophysical, territorial, socioeconomic, and governance context is provided (APA, 2015). Usually, due to time restrictions, this results from the systematization of existing information produced in other plans or programmes, technical or scientific studies. Results can be presented as a cartographic atlas accompanied by a descriptive memory and complemented by a synthesis report. This phase is particularly relevant as it establishes the baseline, i.e. the current condition within which the strategic framework will be developed and implemented (Geneletti, 2015), and against which future changes can be tracked (Ehler, 2014). Therefore, it should be supplemented with ES related information, such as:

- Complement the biophysical analysis with the identification, classification and spatial distribution of the ecosystem services present in the intervention area;

- Complement the socioeconomic analysis with the identification and characterization of the beneficiaries of those ES, paying special attention to the most vulnerable groups in terms of geographical location and socioeconomic conditions (Geneletti, 2015);
- Analyse the link between ecosystem services, uses and activities and beneficiaries;
- Complement the governance analysis with the identification of potential actions/goals of plans and programmes that may influence positively or negatively the provision of ES and human well-being.

Cartographic, graphical elements and tables are considered valuable as they allow a quick understanding of the information (CNA, 2012; Olsen *et al.*, 2011).

There are a diversity of approaches available in literature to classify and map ES (e.g., qualitative approaches, GIS analysis, modelling, and participatory mapping). The selection of the most appropriate method will rely on various factors, such as the scale of analysis, information availability, and technicians' expertise/skills. Considering that time and resources constraints might be significant one can take advantage of expert opinion and local knowledge (by complementing the approach with participatory tools/ stakeholders' consultation), particularly in a first attempt to integrate ES in the planning process (Geneletti, 2015). Nevertheless, at this stage it is considered vital to include as many ES as possible in order to have a comprehensive and integrated view of the study area.

Prospective diagnosis

The prospective diagnosis aims to identify the main trends that might affect the estuary and its margins. Therefore it is common to implement a SWOT analysis, where strengths, weaknesses, opportunities and threats are analysed and systematized. This analysis highlights a number of issues acting on the estuary but also vocations, which are crucial to support the design of the strategic framework and the territorial model.

This phase can be complemented with an analysis of:

- How pressures influence the ecosystems' condition and their ability to provide ES;
- Opportunities for improving the provision of ES;
- Which beneficiaries are most likely affected (positive and negatively) by those pressures.

7.2.2. Preliminary Proposal (Stage 2)

Based on the outcomes of the previous stage, the preliminary proposal aims to design the programme's strategy and territorial model.

Strategic framework

At first, a common vision for the programme is established in close relation with stakeholders. Then, building on the diagnosis, the strategic and operational objectives together with the strategic lines to achieve the common vision are determined.

Alternative scenarios

Taking into account the main trends, pressures and vocations previously identified, alternative scenarios can be developed in order to support the delineation of the territorial model. The idea is to anticipate how the system might respond to a given management option or pressure, for instance. The expected impacts or benefits on ecosystems, ecosystem services and beneficiaries should also be acknowledge. By exploring possible futures, scenario planning allows the identification of potential trade-offs and synergies and helps planners to prepare for the major changes ahead and develop robust measures (PSI-connect, 2012).

Territorial model

Finally, the territorial model and planning strategy are defined in articulation with other plans and programmes but also in articulation with different levels of governance (central and local). This multilevel governance is motivated by the new legal framework that requires a dialogue between special programmes and municipal plans (Barroso, 2017). Here the rules for using the estuary and its margins are established; the fundamental areas for nature conservation and biodiversity are identified; and the preferential, conditioned, or prohibited uses and activities are identified.

The definition of such rules and the identification of conservation areas should take in account the ES distribution, condition and importance for stakeholders and beneficiaries. To facilitate this task priority ES can be selected in close relation with stakeholders. Priority ES should include not only ES that are more beneficial for stakeholders, but also those that are the most vulnerable, rare or that play a major role in supporting other ES, for instance.

7.2.3. Action and Financing Programme (Stage 3)

The final stage of Estuary Programme comprises the definition of the actions, corresponding costs and funding required for its implementation; and the selection of indicators to monitor and evaluate the programme's implementation.

Action programme

The action programme brings together a set of actions to be implemented at short, medium or long-term in order to meet the programme's vision and objectives. These can aim i) the preservation of estuary's biophysical integrity and conservation of environmental and landscape values; ii) the enhancement of the estuary resources for public enjoyment; iii) the protection and mitigation of risks; and iv) the creation of conditions for sustainable economic development (APA, 2015). Additionally, it identifies the institutions responsible for the implementation of each action, and specifies the impact (positive and negative) each action might have on the intervention area. ES should be considered when analysing the consequences of proposed actions. Both ES and beneficiaries positively or negatively affected should be identified, so that adopted actions are those that best contribute to the enhancement of opportunities and benefits, or mitigation of risks and negative impacts (Geneletti, 2015).

Whenever possible, proposed actions should favour the use of nature-based solutions and promote the multifunctional areas, instead of grey infrastructures, to tackle potential problems, pressures or risks.

Financing Programme

The financing programme estimates the cost of each proposed action and identifies potential sources for funding their implementation.

Monitoring

Monitoring is an essential step to achieve an effective and efficient Estuary Programme, or any planning process. However, it is also considered one of the greatest weaknesses of Portuguese spatial planning, particularly on coastal zone (Barroso, 2017). Therefore, it is fundamental to define a set of clear and objective indicators to assess the state-of-the-system, the progress and the success of the programme. These indicators should (Barroso, 2017; MAOTDR, 2007a):

- Monitor the territorial context, i.e., monitor the environmental, social and economic evolution of the estuary, in a systematic and updated way;

- Monitor the planned actions regarding their degree of implementation and their performance, i.e., if they led to the expected outcome;
- Monitor the results of the Estuary Programme by evaluating if its objectives are being achieved, namely protection of estuary's ecosystems; safeguarding estuary's waters; and compatibility of estuary's activities, uses and functions.

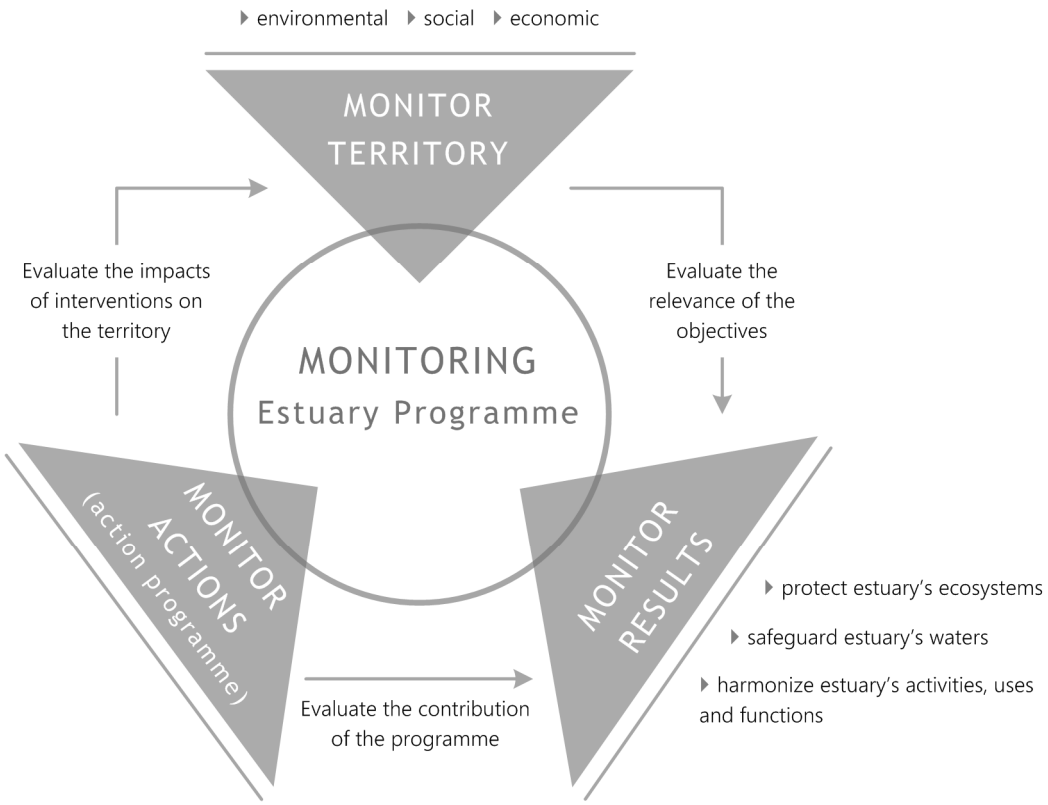

Figure 35. Monitoring System of the Estuary Programme. Source: Adapted from Barroso, 2017

7.2.4. Stakeholders' involvement

The spatial planning process should be iterative, with several small loops resulting from stakeholders' involvement and public participation (von Haaren *et al.*, 2016), since planning becomes more effective if the people affected by the plan are an integral part of the process (PSI-connect, 2012). Maintaining an inclusive process that involves multiple stakeholders and transdisciplinary knowledge is critical for an effective mediation of interests, social learning, and negotiation across scales (Campos *et al.*, 2016). Participation is relevant not only in the end – during public comment period – but along the entire planning process (Virapongse *et al.*, 2016).

For Estuary Programmes and ES integration, this is particularly important in the first two stages:

- Characterization and Diagnosis – local knowledge and expert judgment can be an asset not only for building and validating the baseline, but also for the identifying the strengths, weaknesses, opportunities and threats.
- Preliminary Proposal – stakeholders' involvement is crucial for developing a shared vision of the plan and for the estuary and for co-delineating the way forward.

7.3. Discussion and conclusion

The need to bring ecosystem services into strategic decisions, such as policies, plans and programmes is consensual among scientific and political community, so that i) potential effects of a given planning option on ecosystems and the services they provide can be anticipated and addressed; ii) synergies can be found and encouraged; iii) beneficiaries become aware of their dependence on nature; and iv) multifunctionality of landscapes become a key goal (ECOPLAN, 2016; Geneletti, 2015; Albert *et al.*, 2014a; Lawler *et al.*, 2014; Mascarenhas *et al.*, 2014; McKenzie *et al.*, 2014; Maes *et al.*, 2013b). The survey performed by Mascarenhas *et al.* (2014) to Portuguese regional planners reinforces the importance of integration of ES into the national planning process.

Since that spatial planning is where a set of decisions are taken (for instance, that influence the distribution of people and activities in the territory, the location of infrastructures, the areas to be conserved, protected and recovered) (Barroso *et al.*, 2015), it is also at this level that an effort should be made to incorporate ecosystem services.

Although approaches to spatial planning vary in accordance to the scope, scale, sector and level of decision-making, most of these processes go through the phases of analysis/scoping, vision building, plan design and implementation. In this chapter these planning stages were adapted to the existing governance framework in Ria de Aveiro, and additional tasks were added providing a robust (conceptual) model of how planners and practitioners might incorporate ecosystem services into their current practices and planning processes.

Even though there is not always agreement in the direction marine and coastal management should take, the need for improvement of convectional management practices – specifically through the better acknowledge and incorporation of biodiversity, trade-offs, complexity of social-ecological systems, stakeholders concerns and expectations – is clear and consensual (Li *et al.*, 2016; Long *et al.*, 2015; Alves

et al., 2013a). The integration of ES into the planning process is not an easy task and one needs to be aware of the existing constraints, namely:

- Time constraints for programmes or plans' elaboration. Most of the times, planners have a restrict time to develop the characterization and diagnosis studies, meaning that there is not enough time to develop in-depth studies. Information usually comes from existing studies and reports, and takes advantage from expert opinion by involving the Universities, for example. This can be complemented by additional studies considered vital to minimize significant knowledge gaps.
- Technical skills. Integration of ES adds another layer of complexity (Geneletti, 2015) for which most technicians are not prepared. In addition, the lack of standard methods for ES assessment together with its "novelty" hampers the incorporation of ES knowledge in its full extent.
- Data availability. Systematic data does not always exist or is not available due to financial constraints.
- State of scientific knowledge. Research on ES classification, mapping and assessment has grown substantially but still lacks scientific agreement on standard methods.

All these factors influence the integration of ES into policy and practice, and the selection of the most appropriate method will, to some extent, depend on them. Furthermore, ES integration can be done at different scales and different moments of the planning process (Runhaar, 2015); can consider various types of information (McKenzie *et al.*, 2014); and might be driven by different goals. In spite of that, we argue that these four principles should be considered when incorporating ES into any planning process:

- Comprehensive. The diversity of ecosystems should be acknowledged, as well as the multiplicity of services they provide. The territory should be considered as a whole and the full range of ES should be addressed rather than focusing on single ES or a small set of ES (Martínez-Harms *et al.*, 2015; Liquete *et al.*, 2013).
- Adaptive. The planning process needs to be adaptive in order to accommodate estuary's complexity and dynamism (both in natural and social systems), knowledge evolution, uncertainty, or whenever territorial reality evolves significantly (CNA, 2012; Douvere and Ehler, 2011; Sousa *et al.*, 2011; Calado *et al.*, 2010; Day, 2008).
- Inclusive. People are an essential part of complex social-ecological systems, such as estuaries. The incorporation of local knowledge as well as the stakeholders' involvement is crucial for the

success of planning design, implementation and management (Sousa *et al.*, 2013a; Espinosa-Romero *et al.*, 2011; Richards *et al.*, 2004; Beierle and Konisky, 2000).

- Integrative. Ecosystem services should be incorporated across sectors (Mann *et al.*, 2015) and considered in all policies that might be impacted by decisions relating ES or have a direct or indirect impact on the provision of multiple ES (e.g. agriculture, forest, climate change).

Although the design of the proposed model was based on Estuary Programmes objectives and structure, it is flexible enough to be adapted to other scales of analysis and landscapes. Figure 36 provides a more broad representation of the model, which is divided thought three major planning stages: analysis, plan, and implementation. The methods used in this research are only an example of the methods that can be used to assess ES, identify the pressures and engage stakeholders. Their application to Ria de Aveiro coastal region contributed to a learning process which culminated with the design of the model. However, the selection of the most appropriate methods – either simple concepts or rigorous quantitative tools (Opdam *et al.*, 2002) – will depend on the type of plan or programme, on the stage of the planning process and on the available resources and skills. An interdisciplinary team to carry out the model is seen advantageous to reflect both the biophysical and socioeconomic nature of ES (Landsberg *et al.*, 2011).

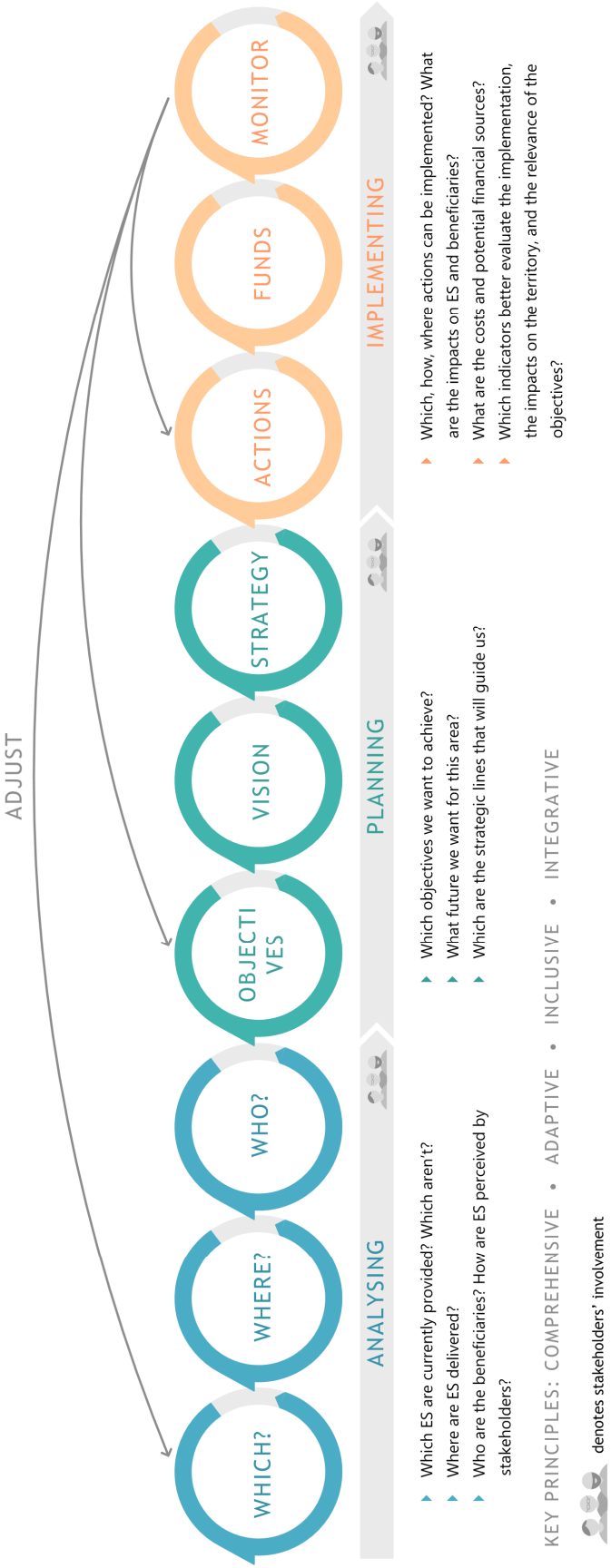

Figure 36. Model to integrate ES into the planning process

8 Concluding remarks

8.1. Key findings

The main goal of this research was to explore the potential of using ES knowledge to inform policy and decision-making in the context of complex social-ecological systems, and to suggest a model to integrate ES into the planning process, using Ria de Aveiro coastal region as case study. Three main research questions were to be answered, and corresponding key findings are summarized below.

I. How ES provided by a complex social-ecological system can be identified, classified and mapped, given the existing constraints to integrate them into spatial planning process?

As ES integration into spatial planning process faces a range of challenges (from lack of data, to restrictions on time and financial resources, and complexity of ES related studies, among others), it was identified a need to adopt an approach which, on the one hand, is in line with the planning procedures and rationale, and, on the other hand, overcomes the existing biophysical, technical, and management constraints. This question was mainly addressed in Chapter 3 and resulted into the following findings:

- The delineation of geographic boundaries that complies with both connectivity of natural systems and complexity of the governance framework was considered a crucial step to initiate ES assessment. A set of criteria were identified and discussed, namely:
    - Analysis of the territory elements (e.g. land cover, topography, bathymetry) and ecosystems' physical boundaries;
    - Incidence of spatial planning and management tools;
    - Distribution of designated areas for nature conservation;
    - Limits of the administrative and statistical boundaries;
    - Existence, availability and scale of spatial data.
- CICES revealed to be suitable to classify ES of complex coastal regions that gather several ecosystems typologies: coastal waters, transitional waters, freshwaters, and terrestrial ecosystems. In addition, its use has advantages in the sense that is a classification system internationally accepted, flexible, that follows a hierarchical structure, and has been designed in a way that focus on "final" services and avoids redundancy. However, the use of CICES by decision-makers, technicians and planners can be demanding due to the complexity and specificity of the ES classes comprising the section regulation and maintenance. Moreover, the

exclusion of abiotic outputs from CICES was perceived as disadvantageous given their relevance for understanding the system as a whole, and the need to be considered in management practices. Finally, the application of CICES to Ria de Aveiro coastal region and posterior mapping exercise raised some issues that led to specific alterations to the CICES V4.3 table. These were driven by:

  - The lack of spatial data detailed enough to distinguish between biota and ecosystems, for instance;
  - The inadequacy of the group *'water conditions'*;
  - The insufficient knowledge regarding "natural" biological control;
  - The ambiguity and subjectivity associated to the group *'other cultural outputs'*.

- The use of qualitative indicators and the use of various sources and types of data allowed to map a number of ES that otherwise wouldn't be possible. The use of multiple sources of information, including data on administrative processes and legal instruments, contributed to achieve more accurate maps and consistent with the case study's reality.
- The concentration of various ecosystems types in the case study brought out the differences in quality, scale and accuracy of data. Marine ecosystems, uses and activities have considerably less information available and less spatial detail than terrestrial ones. The same was observed for transitional waters, especially regarding official data (for example on fisheries), which was managed through the use of scientific and technical studies on Ria de Aveiro coastal lagoon (for example on habitats' distribution).
- ES mapping is always associated to a degree of uncertainty that cannot be ignored and its communication to those that are going to use these maps is essential. This uncertainty might result from different sources, namely:
  - Generalization and categorization used to reduce complex landscapes into a limited number of LU/LC, or habitat classes;
  - Spatial and temporal mismatches of different sources of data;
  - The ES classification system itself can be a source of uncertainty because of the ambiguity present in some classes;
  - Assumptions made in the course of the mapping, for example regarding the ecological status of the biotope and its ability to provide a certain ES.

II. Which ES are provided by Ria de Aveiro? Where are they delivered? What are the current and future pressures? How do stakeholders perceive this?

These questions were addressed in Chapters 4 and 5, which provided an in-depth study of Ria de Aveiro coastal region. A variety of methodological approaches were in the basis of this analysis – ranging from geoprocessing tools to stakeholder engagement methods, and strategic planning tools – in order to understand: i) the presence and distribution of ES; ii) the distribution of multiple services and the identification of multi-functional areas; iii) stakeholders perception on Ria de Aveiro ES and key ES; iv) the main (current and future) pressures and their impact on ecosystems and human well-being. The application of these methodologies to the case study was crucial to deepen the knowledge regarding the ES provided by Ria de Aveiro coastal region. But above all, it allowed the identification of underlying challenges of putting ES into practice, particularly those concerning ES mapping (aforementioned), and the acknowledgement of the relevance of stakeholders' involvement. Not only stakeholders proved to be aware of most of the ES provided by Ria de Aveiro and the main pressures, but also they provided valuable insights for addressing forthcoming pressures and delineating an intervention strategy. Stakeholders' involvement is considered vital as it bridges scientific, technical and traditional knowledge and promotes social learning. The study of current pressures and alternative scenarios proved to be useful as it helps anticipating potential trade-offs and synergies, which can be then addressed in the formulation of decisions. This is an important step in the ecosystem-based management as it promotes a more informed dialog, and more transparent and rigorous decision-making.

The combination of methods form different disciplines offered an opportunity to cope with the lack of data, and to bring together multiple layers of information that should be jointly addressed to support ecosystem-based management.

III. Are ES being integrated in Portuguese planning system? How can ES be further integrated into spatial planning process?

The review of the Portuguese strategic and spatial planning tools (Chapter 6) show an evolution over time in the conceptual integration of ES. Plans and programmes recently revised (e.g., the Water National Plan, the National Strategy for Nature Conservation and Biodiversity, the Coastal Zone Programme Ovar - Marinha Grande) are those in which ES integration is more evident, probably motivated by the mainstreaming of the ES concept worldwide, including some EU policies. Despite of that, most of the analysed plans and programmes lack of detail regarding ES knowledge utilization, and the potential associated to ES thinking is not being fully exploited to inform decision-making.

Recognizing this gap, and having as starting point the technical configuration of Estuary Programmes, a model for integrating ES into spatial planning process was discussed (Chapter 7). The proposed model is divided thought three major planning stages – analysis, plan, and implementation – and is flexible enough to be adapted to other scales of analysis and landscapes. The model, as well as the utilized methods, were designed in a way that allowed to overcome a number of existing constraints to ES integration, namely: i) limited time for programmes' elaboration; ii) lack of technical skills; iii) lack of data availability; and iv) current state of scientific knowledge. All these factors influence the integration of ES into policy and practice, and despite of the methodologies used in this research, the selection of the most appropriate method to use in the various planning stages will, to some extent, depend on them. The involvement of an interdisciplinary team to carry out ES integration was considered crucial, so that the different natures of ES (biophysical and socioeconomic; scientific and practical) are considered. In addition, four key principles considered indispensable for guiding ES integration towards sustainability, territorial and social cohesion were established: comprehensive; adaptive; inclusive; and integrative.

8.2. Limitations and challenges

The lack of quantitative data to support ES mapping and assessment is often mentioned as an obstacle. In this research we decided to have a comprehensive and spatially detailed approach rather than a quantitative one. We argue that in a first effort to integrate ES into spatial planning such comprehensive and spatial explicit approaches, with occasional quantitative or semi-quantitative analysis, is sufficient. As methods and technical skills evolve, as data quality improves and new data becomes available, this approach can be gradually improved. This is one of the reasons why adaptive management is vital.

Despite of the massive work and progress made in ES research worldwide, the application of ES methodologies, particularly mapping methodologies, as well as the used of their results must be done with caution. The uncertainty associated to this methodologies and results, which is underlying to the complexity of social-ecological systems, the weaknesses of data, and the methods itself needs to be communicated and addressed.

8.3. Added value of this research

The research undertaken for this thesis has a considerable added value as it results from a transdisciplinary work and bridges two fundamental pillars in ES research: science and policy. It contributes to a large existing literature on integrating ES into practice in two different ways. First, it suggests a set of management-oriented approaches to address, map and analyse ES, in a first stage

where standardized methods, technical skills, time and data availability are limited but there is a need to start integrating ES into decisions and spatial planning. Second, it proposes a model, which is in line with the planning process, to support decision-makers/planners in the process of incorporating ES knowledge into their practices.

Considering the current and pressing challenge of integrating ES into the planning process, intermediate results of this research can be used, in the short run, to inform local/regional decision-making towards sustainable and ecosystem-base management. More specifically, results can be used in Ria de Aveiro coastal region to inform the elaboration of Vouga Estuary Programme, which poses an opportunity for testing the proposed approach and methodologies in the future.

Despite of the results heading for complex coastal regions, the discussion and key findings could also contribute to the ongoing discussion at national level, in the scope of the PNPOT revision, on how ecosystem services can be integrated in the planning process, for instance.

In the longer run, the results of this research could contribute to current academic debates about ES operationalization and offer a basis for discussion.

8.4. Fields for future research

Despite the considerable scientific progress in the field of ES and their integration on spatial planning process, a number of research gaps remain. The following topics are suggested as future work on ES research and practice:

- Complementing the ES assessment with quantitative indicators or modelling, in order to obtain a graded scale of ES provision;
- Study the cumulative impacts of uses and activities on the ecosystems and the services they provide;
- Identify specific situations where ES valuation would be an asset in supporting decision-making;
- Reduce the uncertainty associated to ES mapping by employing interdisciplinary and multiple/mixed-methods, including participatory methods;
- Identify opportunity areas and define an ES governance strategy, in close relation with stakeholders;
- Explore ways of visualizing and communicating ecosystem services and alternative scenarios to stakeholders and society.

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Appendixes

Appendix I. Indicators used for ES mapping

Table A. 1. Summary of the indicators used for mapping the ES provided by Ria de Aveiro coastal region (LU/LC denotes land use/land cover; NA denotes not applicable)

ES Class (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
Provisioning				
Cultivated crops	Annual crops (e.g., soy, beans, corn, wheat, rice), fruits, vegetables, and forage	Presence of annual crops, rice fields and *bocage*	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Reared animals and their outputs	Meat (e.g., "marinhoa" cattle) and dairy products (milk, cheese, yogurt)	Presence of pastures and *bocage*	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011[2]
Wild plants, algae and their outputs	Wild glasswort *Salicornia* sp.	Presence of authorized collecting area	Administrative and legal processes	
Wild animals and their outputs	Fisheries: freshwater (e.g., lamprey, allis shad, twaite shad); brackishwater (e.g., lamprey, european eel, allis shad, cuttlefish); seawater (e.g., atlantic horse mackerel, sardine); shellfish (e.g., spinous spider crab, clams, cockle, mussels)	Presence of fishing zones, shellfish collecting areas	Habitat units; Administrative and legal processes	AMBIECO/PLRA, 2011; APAveiro, 2012
	Game: wild ducks, quails and doves	Presence of hunting areas	(No spatial data available)	-
Plants and algae from in-situ aquaculture	In-situ macroalgae farming (*Gracilaria verrucosa, Chondrus crispus, Ulva lactuca, Porphyra* spp.*, Codium tomentosum*)	Presence of active units	Location of the activity	AlgaPlus, 2014
Animals from in-situ aquaculture	In-situ aquaculture farms of marine fish (e.g. gilthead seabream - *Sparus aurata*, seabass - *Dicentrarchus labrax,* and turbot - *Psetta maxima*) and shellfish (Japanese oyster - *Crassostrea gigas*, clams - *Ruditapes decussates*)	Presence of active units	Habitat units	AMBIECO/PLRA, 2011; Aerial photograph (ESRI basemap)
Surface water for drinking	NA	NA	NA	NA
Ground water for drinking	NA	NA	NA	NA
Fibres and other materials from plants, algae and animals for direct use or processing	Reeds are harvested and used for traditional products/handcraft (e.g. mats/dunnage)	Presence of reed marshes along Ria de Aveiro	Habitat units	AMBIECO/PLRA, 2011
	Solitary tube worm (*Diopatra neapolitana*, "casulo"), ragworm (*Hediste diversicolor*) and catworm (*Nephthys hombergii*)	Presence of mudflats	Habitat units	AMBIECO/PLRA, 2011

ES Class (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
	are collected to be use as bait for fishing			
	Wood and timber for industrial use (e.g. cellulose for paper)	Presence of forested habitats	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Materials from plants, algae and animals for agricultural use	Seagrasses and macroalgae ("moliço") are harvested to be used as fertilizers in agriculture	Presence of *Zostera noltei* bed	Habitat units	AMBIECO/PLRA, 2011
	Rush marshes (*Juncus maritimus*) are harvested and used as cattle bedding and afterwards as fertilizer, as raw materials for mats, and for protecting salt mounds from wind and rain	Presence of rush marsh	Habitat units	AMBIECO/PLRA, 2011
Genetic materials from all biota	"Marinhoa" cattle (registered as Protected Designations of Origin - PDO)	Presence of *bocage*	Habitat units	AMBIECO/PLRA, 2011
Surface water for non-drinking purposes	Surface water is abstracted from the coastal lagoon, Pateira de Fermentelos lake and freshwater systems for forest-fire control, crops irrigation and livestock consumption, aquaculture and salt production, and for industrial use	Presence of rivers, ditches, freshwater lakes, aquaculture, active salt pans, transitional waters, and water scooper operation areas	Habitat units; legal instruments	AMBIECO/PLRA, 2011; INAG, 2011; ADAPT-MED, 2013; APAveiro, 2012; CM Águeda, 2014
Ground water for non-drinking purposes	Groundwater abstraction for public supply from the "Cretácico de Aveiro" and "Quaternário de Aveiro"	Presence of groundwater abstraction points	Legal instruments	RCM 95/2007, 23 July
Plant-based resources	NA	NA	NA	NA
Animal-based resources	NA	NA	NA	NA
Animal-based energy	Use of "Marinhoa" cattle in the agriculture	Presence of pastures and *bocage*	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Regulation and Maintenance				
Bio-remediation by micro-organisms, algae, plants, and animals	Biological filtration by micro-organisms, algae, plants, and animals (e.g. oysters, clams and mussels)	All the considered habitats (e.g. intertidal flats, soils, aquatic and terrestrial vegetated areas)	Habitat units	AMBIECO/PLRA, 2011
Filtration/ sequestration/ storage/ accumulation by biota and ecosystems	Bio-physicochemical filtration/ sequestration/ storage/ accumulation of pollutants by macrophytes; adsorption and binding of metals and organic compounds in ecosystems, as a result of combination of biotic and abiotic factors	Presence of salt marshes, reed marshes, intertidal flats (including *Zostera noltei* beds), and coastal waters	Habitat units	AMBIECO/PLRA, 2011

ES Class (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
	Riparian areas maintain/protect water quality by capturing and filtrating water through their soils before it gets to streams	Presence of riparian and alluvial forests	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Dilution by atmosphere, freshwater and marine ecosystems	Bio-physicochemical dilution of gases, fluids and solid waste, wastewater in sea, rivers, lakes and the lagoon	Presence of coastal waters, transitional waters and freshwaters	Habitat units	AMBIECO/PLRA, 2011; INAG, 2011
Mediation of smell/noise/visual impacts	*Bocage*, as green infrastructure, reduces the visual impact and the smell from a pulp mill industry	Presence of *bocage*	Habitat units	AMBIECO/PLRA, 2011
Mass stabilisation and control of erosion rates	Dunes, saltmarshes and seagrass beds help to maintain the lagoon integrity. Dune vegetation is crucial to its formation and coastline stabilisation	Presence of coastal dunes (also with *Acacia* sp.), salt marshes (including rush marshes), reed marshes, *Zostera noltei* beds	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
	Riparian areas are essential for bank stabilisation and erosion protection. *Bocage* contributes to erosion reduction	Presence of riparian and alluvial forests, *bocage*	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
	Overall vegetation cover helps to stabilise terrestrial ecosystems	Presence of forests, natural grassland, and shrubland	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Buffering and attenuation of mass flows	Seagrass meadows and salt marshes reduce sediment re-suspension and turbidity in the water column, contributing to increase the light availability in the water column.	Presence of salt marshes, reed marshes, and *Zostera noltei* beds	Habitat units	AMBIECO/PLRA, 2011
	Transport and storage of sediment by rivers, lakes, coastal lagoons and the ocean	Presence of coastal water, transitional water, and freshwater	Habitat units	AMBIECO/PLRA, 2011; INAG, 2011
Hydrological cycle and water flow maintenance	Riparian areas have the capacity to slow/reduce the water flow and store it for future use	Presence of riparian forest	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
	Salt marshes have a significant influence on the hydrological cycle	Presence of salt marshes habitat units	LU/LC; Habitat units	AMBIECO/PLRA, 2011
	Present in the areas where evapotranspiration is higher, which in this case coincide with *bocage* and forest (excluding transitional grass habitats)	Areas with high evapotranspiration	Evapotranspiration	LAGOONS, 2013
Flood protection	Appropriate land coverage provide resilience to extreme weather events and act as physical buffering of climate change	Presence of coastal dunes, salt marshes, reed marshes, riparian forest, and *bocage*	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011

ES Class (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
Storm protection	NA	NA	NA	NA
Ventilation and transpiration	*Bocage* enables air ventilation	Presence of *bocage*	Habitat units	AMBIECO/PLRA, 2011
Pollination and seed dispersal	Vegetation features supporting pollination	Presence of forests (including alluvial and riparian forest), and *bocage* along low lands of Vouga river	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Maintaining nursery populations and habitats	Vouga, Águeda and Levira rivers are relevant spawning areas for anadromous migratory species and *Lampetra planeri*	Presence of rivers and freshwater lakes	Habitat units	AMBIECO/PLRA, 2011; INAG, 2011; RCM no. 1125-A/2008, 21 July; MESHAtlantic, 2014
	Ria de Aveiro is a nursery habitat for fisheries and invertebrates	Presence of transitional waters, salt pans, salt marshes, intertidal flats (including *Zostera noltei* beds)		
	Coastal waters is an important habitat for fisheries	Presence of coastal waters		
	Bocage and salt pans are important area for birds feeding and breeding	Presence of *bocage*	Habitat units	AMBIECO/PLRA, 2011
	Fixed coastal dunes with herbaceous vegetation provide shelter for biodiversity	Presence of fixed dunes with herbaceous vegetation, and dunes with Salix	Habitat units	AMBIECO/PLRA, 2011
	The study area provides other important habitats such as reeds, riparian, alluvial, and other forests.	Presence of forests (including alluvial and riparian forest), and reed marshes	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Pest control	Note: see discussion section of the manuscript	-	-	-
Disease control	NA	NA	NA	NA
Weathering processes	Fluvisols are the type of soils with higher level/content of organic matter. Floodplains constitute important sinks of river nutrients and sediments (transported during flood events), which contribute to the maintenance of soil fertility and nutrient storage	Presence of fluvisols combined with forests and floodplain areas	LU/LC; Soil map	IGP, 2010; Atlas do Ambiente, 1982
Decomposition and fixing processes	Nitrogen cycling (nitrogen fixing, denitrification, decomposition) in intertidal mudflats, seagrass meadows and salt marshes.	All the considered habitats (e.g. intertidal flats, soils, aquatic and terrestrial vegetated areas)	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
	Terrestrial ecosystems contribute to the maintenance of bio-geochemical conditions of soils by decomposition/mineralisation			

ES Class (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
	of dead organic material, nitrification and denitrification			
Chemical conditions of freshwaters	Note: see discussion section of the manuscript	-	-	-
Chemical conditions of salt waters	Note: see discussion section of the manuscript	-	-	-
Global climate regulation by reduction of greenhouse gas concentrations	Fixation of atmospheric carbon by oceanic algae and its eventual deposition in deep water represents an important part of the global carbon cycle and thus influences climate trends	Presence of coastal water	Habitat units	INAG, 2011
	Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota	Presence of forests (including alluvial and riparian forest), forested dunes, salt marshes, reed marshes and *Zostera noltei* beds	LU/LC; Habitat units	IGP, 2010; AMBIECO/PLRA, 2011
Micro and regional climate regulation	Green infrastructures contribute to the control of atmospheric conditions (e.g., temperature, humidity and wind)	Presence of *bocage*	Habitat units	AMBIECO/PLRA, 2011; INAG, 2011
Cultural				
Experiential use of plants, animals and land-/seascapes in different environmental settings	Birdwatching and land-/seascape appreciation (e.g. natural and semi-natural beaches, salt pans, quays, public gardens along rivers and lakes, city channels, Ria's islands, São Jacinto dunes Nature Reserve and Baixo Vouga Lagunar)	Designated places for birdwatching and land-/seascape appreciation	Viewpoints, birdwatching points, protected areas	AMBIECO/PLRA, 2011; Turismo Centro de Portugal, 2015; PLRA, 2010; ICNF, 2014; POC OMG, 2015; CM Ílhavo, 2015; CM Albergaria-a-Velha
Physical use of land-/seascapes in different environmental settings	Sailing, canoeing, rowing, swimming, surfing, windsurfing, kitesurfing, cycling, walking, leisure fishing and hunting	Area of activity	Leisure and sports data	POEM, 2012; POC OMG, 2015; PLRA, 2010; Turismo Centro de Portugal, 2015; CCDRC, 2015; CM Águeda, 2015; CM Ílhavo, 2015; CM Estarreja, 2015; CM Murtosa, 2015; CM Aveiro, 2015; BIORIA, 2014; APAveiro, 2014
Scientific	The entire study area in subject matter of research	Territory subject of scientific research	Study areas	FCT, 2015; Research Centres; WOS, 2015
Educational	Natural and cultural heritage of the study area are subject matter of education	Location of eco-museums, and environmental interpretative centres	Museological infrastructures; environmental interpretative centres	CCDRC, 2015; Turismo Centro de Portugal, 2015

ES Class (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
Heritage, cultural	Subaquatic archaeological sites in the lagoon (e.g. shipwrecks, ship hull, and other isolated findings)	Designated subaquatic archaeological sites	Legal instruments	DGPC, 2014
	Traditional architecture (e.g. "palheiros", "Gafanhoa"), traditional boats (e.g. "moliceiro", "bateira", "mercantel") and traditional activities (e.g. salt production, "arte Xávega")	Location of buildings with traditional architecture, and location of traditional activities	Vernacular heritage, and Intangible cultural activities	Turismo Centro de Portugal, 2015
Entertainment	Ex-situ experiences through festivals related with the activities and products of the study area (e.g. gastronomic fairs, Vagueira surf festival, Ria de Aveiro Weekend, ObservaRia, "moliceiro" feast, NªSª Navegantes fair)	Location of the festivals and fairs	Intangible cultural heritage	CM Águeda, 2015; CM Ílhavo, 2015; CM Estarreja, 2015; CM Murtosa, 2015; CM Aveiro, 2015; CM Vagos; CM Ovar; BIORIA, 2014
Aesthetic	Artistic representations of nature and related activities (e.g. public monuments, statues, tile murals, ceramic tiles, painted shells)	Location of permanent artistic exhibitions	Cultural heritage	CM Ílhavo, 2015; CM Murtosa, 2015; CM Aveiro, 2015
	Inspiration for some painters and writers, interested in the history and heritage of the lagoon and its users	-	-	-
	Sense of place	-	-	-
Symbolic	NA	NA	NA	NA
Sacred and/or religious	NA	NA	NA	NA

Table A. 2. Summary of the indicators for mapping the abiotic outputs provided by Ria de Aveiro coastal region

(NA denotes not applicable)

ES Division (CICES)	ES Group (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
Abiotic provisioning					
Nutritional abiotic substances	Mineral	Salt production	Presence of active salt pans	Habitat units	AMBIECO/ PLRA, 2011
	Non-mineral	NA	NA	NA	NA
Abiotic materials	Metallic	NA	NA	NA	NA
	Non-metallic	Occurrence of exploitable sand and gravel	Designated areas for sand and gravel exploitation	Legal instruments	POEM, 2012
Energy	Renewable abiotic energy sources	NA	NA	NA	NA

ES Division (CICES)	ES Group (CICES)	Ria de Aveiro ES description	Indicator	Typology of data	Data source
	Non-renewable energy sources	NA	NA	NA	NA
Regulation & Maintenance by natural physical structures and processes					
Mediation of waste, toxics and other nuisances	By natural chemical and physical processes	NA	NA	NA	NA
Mediation of flows by natural abiotic structures	By solid (mass), liquid and gaseous (air)flows	NA	NA	NA	NA
Maintenance of physical, chemical, abiotic conditions	By natural chemical and physical processes	Blue infrastructures contribute to weather regulation	Presence of transitional waters, rivers, and freshwater lakes	Habitat units	AMBIECO/ PLRA, 2011
Cultural settings dependent on abiotic structures					
Physical and intellectual interactions with land-/seascapes [physical settings]	By physical and experiential interactions or intellectual and representational interactions	NA	NA	NA	NA
Spiritual, symbolic and other interactions with land-/seascapes [physical settings]	By type	NA	NA	NA	NA

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Appendix II. Functional geographical units

Table A. 3. Functional geographical units (* indicates the habitat confirmed by field work by AMBIECO/PLRA, 2011)

Functional geographical units		Habitat code
Group	Subgroup	
Freshwater	Permanent eutrophic water bodies	3150
	Freshwater lakes	
	River	
Coastal lagoons	Transitional waters	1150
Low salt marsh	*Spartina* swards	1320*
	Halophytic vegetation	1310pt1*
Medium & hight salt marsh	Atlantic salt meadows	1330+1320*
Intertidal flats	Sandflats	1140pt1*
	Mudflats	1140pt1*
	Zostera noltei beds	1140pt2*
Salt pans	Active salt pans	
	Destroyed salt pans	
	Flooded salt pans	
Rush marsh	Rush marsh	1410
Reed marsh	Reed marsh	
Beaches and sands	Maritime beaches and sands	1110
	Inland beaches and sands	
Coastal dunes	Dunes with *Salix*	2170*
	Forested dune	2180, 2270
	Fixed dunes with herbaceous vegetation ('grey dunes')	2130*
	Shifting dunes with *Ammophila arenaria* ('white dunes')	2120*
Coastal waters	Infralittoral fine sand	A5.23
	Circalittoral fine sand	A5.25
	Infralittoral mixed sediments	A5.43
	Circalittoral mixed sediments	A5.44
	Infralittoral muddy sand	A5.24
Acacia	*Acacia*	
Forests	Oak tree forest	9230
	Poplar forest	
	Other forests	

Functional geographical units		Habitat code
Group	Subgroup	
	Broad-leaved forest	
	Pine, Eucalyptus, Acacia	
Alluvial forests	Alder riparian forest	91E0pt1*
	Alder swamp forest	91E0pt3*
Riparian forest	Riparian mixed forest	91F0*
	Other riparian areas	
Natural grassland	Shrubland	
	Natural grasslands	
Aquaculture	Aquaculture	NA
Agricultural areas	Rice fields	NA
	Bocage	NA
	Annual crops	NA
Artificial surfaces	Built-up areas	NA
	Green urban areas	NA

Appendix III. Focus Groups

As described in Sousa *et al.* (2013), 9 Focus Groups (FG) were conducted between April 2012 and January 2013 with the purpose of initiating the communication with the Ria end-users and identifying relevant issues, conflicts, concerns and existing responses to change. A few open questions were structured to lead the discussion into the field of interest. These questions focused on the uses of the lagoon, most important aspects, changes on the lagoon, lagoon's management, tourism and recreation, development in/around the lagoon and desired future wishes. The moderator was asked to leave the development of the discussion to the participants and only slightly control the discussion by keeping them on subject and helping them along when they get stuck (Gooch, 2012). The idea behind this is that participants can react and discuss freely around a general question and then, by the help of the script, are lead in more focused way to the key subject of the study (Gooch, 2012).

The groups were small, between 8-10 participants, in order to have a better group dynamic, to encourage a close connection to the discussion and to provide a better opportunity to give voice to ones opinion (Gooch, 2012). A snowball approach or the identification of a contact person, were two proposed methods of participant selection. In the second one, a contact person is recruited as a participant and through that person new participants are then recruited. The snowball method is similar: a participant is recruited and is responsible for recruiting a new participant, which recruits another one and so on (Gooch, 2012).

FG involved 74 participants (80% men and 20% women): 6 with local citizens of coastal parishes (Torreira, Murtosa, Vera Cruz, São Jacinto, Glória, and Gafanha da Encarnação); 1 with Gloria parish staff/council; 1 with students, technicians and researchers of University of Aveiro; 1 with members of hunters and fishermen's association of Avanca Parish (Figure A. 1). The idea was to capture the local knowledge, specificities and perceptions in the different coastal parishes, because it is noted that, in spite of a shared identity, local traditions, uses and activities vary according to the spatial distribution of habitats, species and physical characteristics of the lagoon.

The number of participants and their background varied in the different Focus Groups:

- **FG1 – Glória Parish (I).** This was the first session and it had the particularity of having all members of the governing body of the parish council. The four participants were found to be users of the lagoon for many years through recreational fishing and admires of the landscape.

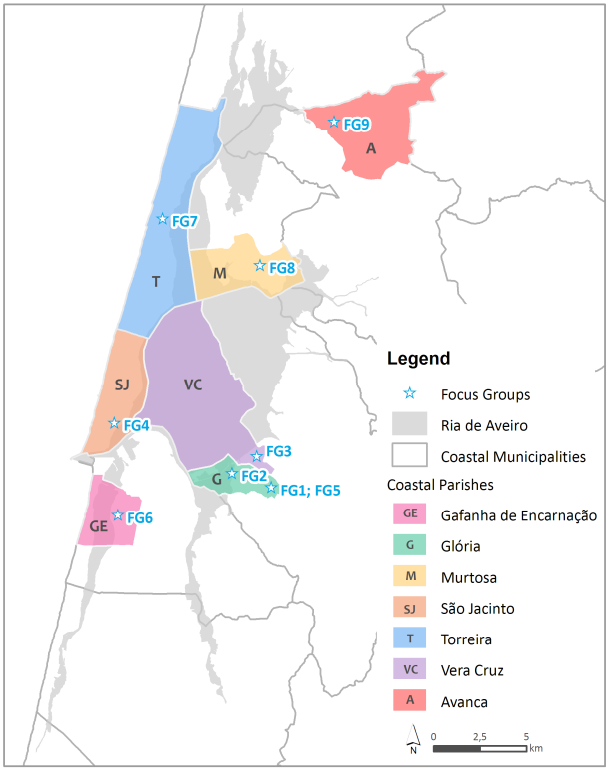


Figure A. 1. Distribution of the Focus Groups in Ria de Aveiro (Sousa *et al.*, 2013)

- **FG3 – Vera Cruz Parish.** This session was attended by three amateur fishermen and one marketing student of University of Aveiro, who admires the landscape. It was marked by the dominant participation of one participant.
- **FG2 – University of Aveiro.** The majority of the participants (7 in 8) were not born in Aveiro, but were studying or working at the University of Aveiro (from 3 to 12 years). Their use of the lagoon was mainly in the Aveiro city channels related with recreation, leisure, landscape appreciation and also research work.
- **FG4 – São Jacinto Parish.** The majority of participants (6 in 7, being the other one the mayor of the parish council) belong to the local community of fishermen with significant knowledge of the lagoon.
- **FG5 – Glória Parish (II).** This session was the second one in the Glória parish, but with different participants (2 members of the parish council and 9 members of the community). Their use of the lagoon was diverse, e.g. exploitation of saltpans, harvesting of reeds and seagrasses, hunting and fishing, transport, nautical and sport activities. Furthermore, some participants demonstrate interest for the theoretical and scientific study of the lagoon.
- **FG6 – Gafanha da Encarnação Parish.** In this session there were eight participants with a long and direct contact with the lagoon. The professional activity of most participants was directly related with the lagoon, e.g. fishermen, shellfish exploitation, boat building and transport of tourists in the lagoon. Others used the lagoon for recreation, such as sport fishing and sailing.

Appendix IV. Ecosystem services covered area

Table A. 4. Area covered by each ecosystem service class.

	DIVISION	GROUP	CLASS	AREA (ha)
PROVISIONING	Nutrition	Biomass	Cultivated crops	7340
			Reared animals and their outputs	2050
			Wild plants, algae and their outputs	43
			Wild animals and their outputs	36697
			Plants and algae from in-situ aquaculture	*point*
			Animals from in-situ aquaculture	326
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	8248
			Materials from plants, algae and animals for agricultural use	1104
			Genetic materials from all biota	2050
		Water	Surface water for non-drinking purposes	898
ABIOTIC	Energy	Mechanical energy	Animal-based energy	2050
	Nutritional abiotic substances	Mineral	[Nutritional abiotic mineral: salt]	210
	Abiotic materials	Metallic	[Non-metalic abiotic mateirals: sand and gravel]	17248
REGULATION & MAINTENANCE	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	60555
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems and biota	38173
			Dilution by atmosphere, freshwater and marine ecosystems	34666
			Mediation of smell/noise/visual impacts	1845
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	14633
			Buffering and attenuation of mass flows	39201
		Liquid flows	Hydrological cycle and water flow maintenance	8535
			Flood protection	11147
		Gaseous/ air flows	Ventilation and transpiration	1845
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	3496
			Maintaining nursery populations and habitats	52196
		Soil formation and composition	Weathering processes	1305
			Decomposition and fixing processes	60555

	DIVISION	GROUP	CLASS	AREA (ha)
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	41492
			Micro and regional climate regulation	1845
ABIOTIC	Maintenance of physical, chemical, abiotic conditions	By natural chemical and physical processes	[Micro and regional climate regulation by physical structures]	3940
CULTURAL	Physical and intellectual interactions with biota, ecosystems, and landscapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	4207
			Physical use of land-/seascapes in different environmental settings	2920
		Intellectual and representative interactions	Scientific	62535
			Educational	*point*
			Heritage, cultural	*point*
			Entertainment	*point*
			Aesthetic	*point*

Appendix V. Stakeholders' Questionnaire

Date: 22/05/2014

Location: University of Aveiro, at the end of the Final Workshop of the FP7 LAGOONS Project

Number of participants in the workshop: 32 (7 female and 25 male)

Number of answered questionnaires: 26

Table A. 5. Stakeholder categorisation

Stakeholder category	No. of participants
Local authority	15
Regional authority	2
National authority	1
Business and industry	4
Research organisations	4
Professional associations	1
Cultural and recreational groups	3
Civil society	1
Tourist	1

Table A. 6. Question 1: How important to you is the Lagoon in terms of the following kinds of benefit?

	Very	Moderate	Not important	Don't know
Recreational Fishing:				
• Fish				
• Shellfish				
Commercial Fishing:				
• Fish				
• Shellfish				
Aquaculture:				
• Fish				
• Shellfish				
• Algae				
Bait digging				
Agriculture - cropping				
Agriculture - livestock				

Timber and Forestry				
Raw materials - gravel, sand				
Raw materials - reeds, sea grasses, algae				
Salt production				
Port and Harbour facilities				
Industries				
Other Economic activities				
Employment				
Reducing the incidence and severity of flooding				
Reducing the patterns of erosion				
Maintaining good water quality				
Shaping the local climate				
Helping store carbon in vegetation and soils				
Source of water supply				
Source of bio-chemicals and medicines				

Table A. 7. Question 2: Thinking about the way in which the lagoon supports plant and animal life, how important are the following types of benefit?

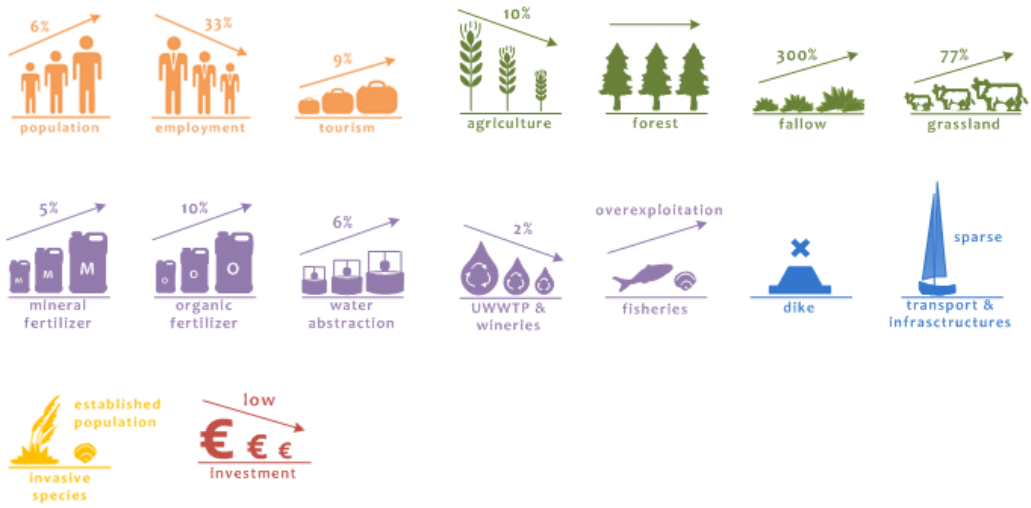
	Very	Moderate	Not important	Don't know
Habitats and wildlife (as a habitat and home for animal and plant communities)				
Nesting areas for birds (as a breeding ground for different species)				
Nursery and migration habitats for fish (as a location for young fish and migratory species)				
Primary production (vegetation growth and production of oxygen through photosynthesis)				
Nutrient cycling (accumulation and recycling of chemical nutrients, essential for life)				
Water cycling (cycling of water resources through rainfall, run-off, rivers & lakes and evaporation)				
Supporting populations of pollinating insects				

Table A. 8. Question 3: How important is the lagoon to you in other kinds of ways?

	Very	Moderate	Not important	Don't know
Education and knowledge				
Sense of Place				
History and archaeological heritage				
Spiritual and religious values				
Recreation & leisure:				
• birdwatching				
• hunting				
• boating				
• swimming				
• walking				
Tourism				
Health (mud, clay, balneary)				
Landscape and scenic qualities				
Local culture and customs				
Traditional products				
Genetic resources				
Research				

Appendix VI. Business as Usual Scenario

Table A. 9. Main assumptions of BAU scenario. Adapted from LAGOONS, 2014 and Lillebø *et al.*, 2014

Business as Usual Scenario	 • 10% of existing agricultural fields are replaced by fallow and grassland • Intensive agriculture (increase use mineral and organic fertilizers and water abstraction) • Abandonment of traditional activities (salt production, seagrass collecting) • Erosion of the lagoon's banks, increase of inundation periods, loss of navigability in secondary channels due to changes in hydrodynamic regime (increase of water velocity and tidal prism) • Saltwater intrusion in agricultural fields • Use of illegal fishing gears and overexploitation of fish, shellfish and bait • Established population of invasive species