

Review

The role of legislation, policy and regulation in estuarine management: from an international to a regional scale

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ABSTRACT

Estuaries are increasingly populated due to urbanisation, leading to shoreline alteration, and increase of waste discharge and water extraction. Managing an estuary involves taking into consideration the governance framework, which includes a set of policies and legislation at the international and country level. However, current governance systems do not reflect this which limits their ability to manage competing interests, such as tourism, shipping and conservation. Economic activity often drives estuary governance, but continuous loss of biodiversity and habitats highlights the need for more inclusive governance systems that preserve both, natural and socio-economic capital. Reviewing current governance systems can identify challenges and promote solutions. This study reviews the legislation applied to estuarine systems from an international to a regional scale, using Portugal as a reference case. A 'horrendogram' was created to assess legislation which was categorised by the following topics: biodiversity, land planning, water management, marine governance, aquaculture and fisheries, waste management, economic policy, forest management, and climate change. Key challenges include limited coordination between maritime and land planning systems, difficulties in incorporating EU legislation into national frameworks, and fragmented administrative responsibilities. To improve estuarine governance, this study recommends enhancing coordination between administrative bodies, promoting stakeholder engagement throughout decision-making processes, and adopting ecosystem service-based approaches. This approach aligns with the sustainability goals by supporting ecosystem health, enhancing human well-being and promoting sustainable economic growth. The insights developed are applicable to estuarine systems globally, and future research should focus on testing governance systems that integrate ecological, social and economic priorities, while promoting collaboration across administrative bodies and stakeholders.

1. Introduction

In spatial planning terms, estuaries are partially enclosed coastal systems where fresh and salt water mix. These systems encompass several ecosystem components including land, water, fauna and flora, which are under the influence of estuarine flooding and human developments. Estuaries are particularly important for human communities due to their economic and social values, for example, 14 out of 20 of the largest cities in the world are situated near estuaries (Laruelle et al., 2024; Rodrigues and Fidélis, 2021). From an ecological standpoint, estuaries typically exhibit habitat diversity, strong temporal

cycles, and high productivity. While they may have low species diversity due to rigorous ecological conditions, this is often offset by high species abundances (Elliott and McLusky, 2002). They benefit from a high resilience to change due to the species being particularly hardy to the high-stress environmental conditions commonly present in transitional systems (Elliott and Whitfield, 2011).

Estuaries comprise public goods (e.g., seawater), private goods (e.g., salt pans), and common-pool resources (e.g., freshwater; Schumacher, 1973). Unlike public goods which are freely accessible without being depleted by individual use, common-pool resources consumption by one user reduces their availability to others, which may cause conflicts

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(Deneulin and Townsend, 2007; Ostrom, 2002). Therefore, managing estuarine assets is inherently challenging and requires balancing diverse users and types of goods. These issues have significant governance implications for sustainably meeting user needs and mitigating over-exploitation of common-pool resources (e.g., overuse of freshwater for irrigation). However, to achieve equitable management, we must consider the social context and its particularities (Kubiszewski et al., 2024). In this study, governance or governance framework represents the system ruling each country and regions within them, including all legislation and policies (Elliott et al., 2025a; Glavovic, 2024). Governance is a crucial part of the management of ecosystems, and includes the economic, political and social realms (Glavovic, 2024). The operationalisation of these legislation and policies is done through public management (Beaumont and Glavovic, 2024).

Estuaries offer numerous recreational opportunities, often linked to cultural identity, and function as trading hubs linking land and sea through ports (O'Leary et al., 2023). Despite these values, estuaries face significant pressures from urbanisation and industrialisation, leading to habitat loss, pollution, and biodiversity decline (Kennish, 2002). These conflicting interests reinforce the need for effective spatial planning to ensure equitable resource distribution while safeguarding environmental integrity (Geneletti, 2015; Rodrigues and Fidélis, 2021).

Governance systems, including policies, politics and legislation, play a pivotal role in the process and success of spatial planning, and mitigate impacts of anthropogenic pressures (Lonsdale et al., 2018). They define rules, allocate responsibilities, and facilitate collective management actions (Roux et al., 2023). However, current spatial management often fails to account for estuaries as unique terrestrial and environmental units, due to conflicting legal definitions (Carvalho and Fidélis, 2013; Daniell et al., 2020). Current governance systems are typically managed through centralised sectoral approaches without sufficient coordination across sectors, leading to ineffective management (Fidélis and Carvalho, 2015; Næsje et al., 2023). Portuguese estuaries exemplify these challenges, where economic priorities coupled with an insufficient management framework, have driven resource transformation and disturbance (Fidélis and Carvalho, 2015), such as construction of industrial facilities that remove natural habitat and tourist resorts in close proximity to natural reserves.

Generally, the governance structure operates across two dimensions: vertically, by integrating international and national frameworks; and horizontally, by facilitating the engagement of diverse stakeholders, including policymakers and local communities (Lonsdale et al., 2022; see Glossary for description of governance terms). At any scale, governance is ruled by law. At the international level, UN conventions provide sovereignty and independence for each state and associated political systems, therefore, the conventions must address transboundary issues (Cormier et al., 2022; Elliott et al., 2023). Without collaboration between nations, a state can only address damaging activities happening within their sovereignty area (Cormier et al., 2022). Within the European Union, governance is based on actions driven by treaties democratically ratified by all member states (European Commission, 2014a). At the national level, legislation translates these commitments into actionable legal frameworks to fulfil international obligations (Lonsdale et al., 2022).

Several scholars have addressed the multi-scale governance challenges, usually focused on sectoral areas (e.g., climate change; Pahl-Wostl et al., 2021), however, there is a knowledge gap in assessing the multi-scale characteristics of governance arrangements for estuaries, especially considering the challenges previously mentioned. Thus, this study proposes a multi-scale analysis focused on: (1) understanding the influence and contribution of legislation to efficient management of estuaries, and (2) assessing how vertical integration is delivered in each governance level. An “horrendogram” (see Glossary for description) tool (Boyes and Elliott, 2014) was used to fulfil the second goal by visually relating the different scales of governance. Thus, this study proposes a review and update of the ‘horrendogram’ to the estuarine context, by

using Portugal as a reference case. Although previous studies have advanced discussions on estuarine management, including in Portugal (Carvalho and Fidélis, 2013; Fidélis and Carvalho, 2015; Rodrigues and Fidélis, 2021), this is the first study to holistically examine the influence of legislative frameworks across multiple scales in Portugal.

2. Navigating estuarine law: a comprehensive review

The ‘horrendogram’ framework categorises governance instruments according to their scale of intervention: the central circle represents international and European instruments; the intermediate circle includes national instruments (and their linkages to broader scales) while the outermost layer encompasses regional and local instruments (with their corresponding linkages) as applied to Portugal (Fig. 1). To enhance analytical clarity, national and local legislation were classified into thematic categories (adapted from Taljaard et al., 2019), according to the reviewed legal frameworks. The analysis prioritised sustainable use of estuaries and their environmental protection, therefore, categories are based on instruments that (1) have legal jurisdiction over estuaries and/or (2) activities happening in the estuaries and/or (3) assess the environmental condition of estuaries’ resources (fresh- and saltwater, sediments, biodiversity). The thematic categories are: biodiversity and conservation management; land planning; water management; marine governance; aquaculture and fisheries policy; waste management; economic policy; forest management; climate change and energy. By organising the legal landscape in this way, the framework seeks to streamline the identification of key instruments and their relationships. The following sections will detail the specific instruments within each scale, with a particular focus on land planning, water management, and marine and conservation policies given their importance to estuarine management.

2.1. International scale

At an international scale, estuary management is shaped by key United Nations (UN) treaties and conventions, such as the Paris Agreement on Climate Change, the UN 2030 Agenda for Sustainable Development and the Convention for Biodiversity. These frameworks prioritise sustainable practices and environmental protection.

Additionally, the use of estuaries for trade requires compliance with other international agreements, such as the Cartagena Protocol (focused on biosafety), CITES (regulating introduction of endangered species by trade), MARPOL (regulating marine pollution), SOLAS (regulating safety at sea) and OSPAR (focused on protecting the North-East Atlantic marine environment; Supplementary Material). Table S1 summarises important information about each element in Fig. 2, and details international and European directives summarised in Fig. 2. Together, these international agreements set standards for balancing economic activity and environmental protection at sea, and are implemented by several international organisations, such as the United Nations Environment Programme.

EU legislation harmonises with numerous international frameworks, integrating them into directives (e.g., OSPAR integrated into Maritime Spatial Planning directive). The European directives are key regulatory instruments, and each Member State is required to transpose those into national law, alongside other European policies (e.g., the EU Biodiversity Strategy, 2030). Over the past years, EU policy has shifted from sector-specific directives, such as the Nitrates Directive, to framework directives, such as the Water Framework Directive (Boyes and Elliott, 2015). This evolution marks the “third wave” of EU legislation, which emphasises the use of a holistic and integrated ecosystem-based approach, that grants Member States greater flexibility in achieving objectives (Boyes and Elliott, 2014; Holt et al., 2011; Moran and Dann, 2008).

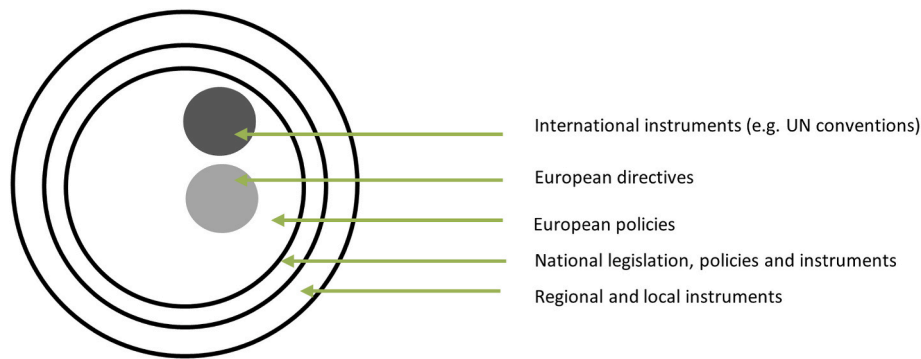


Fig. 1. ‘Horrendogram’ structure by scale of intervention.

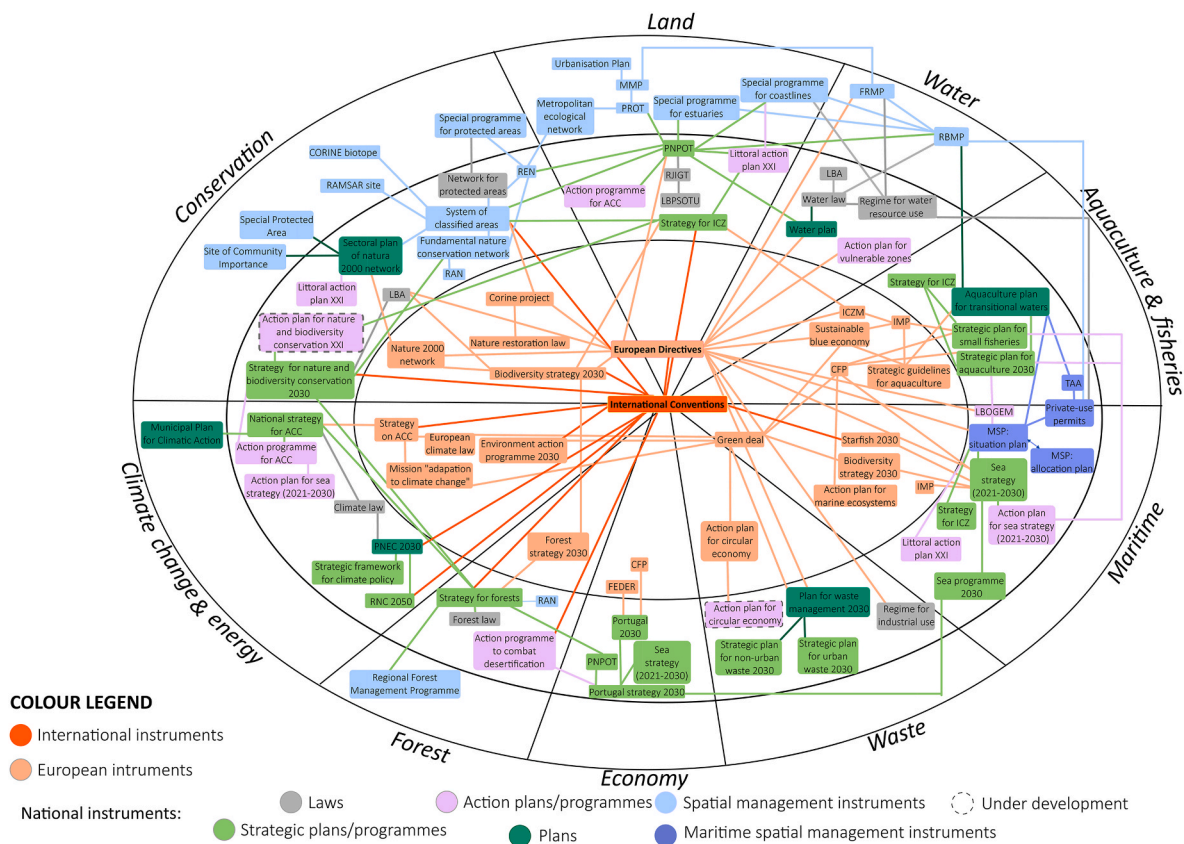


Fig. 2. ‘Horrendogram’ of legislation and instruments influencing estuary management in Portugal. All national strategies are connected, however, to facilitate visualisation they are presented separately (e.g., Sea Programme, 2030; Portugal, 2030). Details about connections among International instruments and European Directives in Supplementary Material. ACC – Adaptation to climate change; CFP – Common fisheries policy; FEDER - European Regional Development Fund; FRMP – Flood risk management plan; ICZ – Integrated coastal zone; ICZM – Integrated coastal zone management; IMP – Integrated maritime policy; LBA – Environmental law; LBOGEM – Basic law on policy and management on national maritime areas; LBPSOTU – Basic law on spatial development and urban planning; MMP – Municipal master plan; MSP – Maritime spatial planning; PNEC – National energy and climate plan; PNPOI – National programme for spatial planning; PROT – Regional spatial development plan; RAN – National agricultural reserve; RBMP – River basin management plan; REN – National ecological reserve; RJGT – Legal regime of territory management instruments; RNC – Roadmap for carbon neutrality; TAA – Titles for aquaculture activities.

2.1.1. Land management instruments

Land regulation of their sovereign physical areas is a direct competence of the Member States while taking into consideration the EU land development goals (Faludi, 2009; Tulumello et al., 2018).

2.1.2. Water management instruments

Key EU directives relevant to estuary management include: the

Water Framework Directive (WFD)¹, the Floods Directive,² the Marine Strategy Framework Directive (MSFD)³, and the “Nature Directives”⁴ (see Section 2.1.3. and 2.1.4 for details). The WFD was considered a

¹ WFD, Directive 2000/60/EC.

² Floods Directive, Directive 2007/60/EC.

³ MSFD, Directive 2008/56/EC.

⁴ Habitat Directive, Directive 92/43/EC; Bird Directive, Directive 2009/147/EC.

groundbreaking directive as it was the first policy to address transitional waters while aiming for comprehensive water management (Carvalho et al., 2019). In addition, it was the first initiative to shift to a holistic approach, thus, the first legal instrument to prioritise hydrological units over administrative boundaries and to integrate other sectoral policies, including the Nitrates Directive (European Commission, 2003; O'Hagan et al., 2020). The WFD requires Member States to establish a Programme of Measures comprising a set of actions, interventions and regulatory tools to achieve the environmental objectives of the Directives, thereby, supporting its implementation within national legal and management frameworks. The WFD feeds into the OSPAR convention objective to reduce pollution of water bodies (including estuaries; see Supplementary Material for multi-level connections). The implementation of the WFD happens through river basin management (Section 2.2.2.). The Floods Directive complements the WFD by requiring member states to assess flood risks, map flood extents and identify vulnerable areas (Jacobs et al., 2013). Their implementation is done through Flood Risk Management Plans at the river basin level (Section 2.2.2.)

2.1.3. Maritime management instruments

The EU Integrated Maritime Policy (IMP⁵) ensures coordination between all-sea related EU policies, including the MSFD, the Maritime Spatial Planning (MSP⁶) Directive, and the Integrated Coastal Zone Management (ICZM⁷; Breuer and Twisk, 2025; see Supplementary Material for connection with estuary management). The MSFD defines the environmental objectives to be applied across all European Seas. Application of the MSFD aims to achieve or maintain good environmental status of European marine waters (*i.e.*, covering territorial sea, exclusive economic zones and internal waters) and promote sustainable growth of maritime economies (Paramana et al., 2023). The implementation of the MSFD is supported by a Programme of Measures, similar to the WFD, which aims to achieve all the environmental objectives of the Directive. The area of jurisdiction of the MSFD excludes estuaries, yet there are cases where the WFD does not address priority issues of concern within MSFD, including non-indigenous species, litter and underwater noise (Borja et al., 2010). Some authors, such as Borja et al. (2010) and Louropoulou et al. (2025) suggest an integration of MSFD and WFD to complement each other and fill the gaps in each framework, as umbrella policies for European aquatic systems. Additionally, both relate to the goals of the OSPAR convention to reduce pollution in the marine environment (Supplementary Material to see multi-level connections). Therefore, any alteration in water quality at the European or Member State scale will feed into the OSPAR targets. Additionally, the MSFD and the CBD⁸ are interconnected since they both aim to protect marine biodiversity and share principles to achieve their goals (Supplementary Material to see multi-level connections). The MSP is used to arrange the spatial distribution of activities in the maritime space, whereas the management of coastal zones falls under the authority of ICZM (Ehler and Douvère, 2009; Ehler, 2012; Frazão Santos et al., 2019). Both include coastal waters, as defined by WFD, but exclude transitional waters, such as estuaries (DEFRA, 2014; European Commission, 2014b). The MSP directive is also related with the UNCLOS⁹, since the MSP builds on the jurisdictional framework provided by UNCLOS (Supplementary Material to see multi-level connections). Implementation of EU maritime instruments by member states depends on how the measures are integrated into the existing national policies and governance frameworks.

2.1.4. Instruments for conservation management

The EU designed several directives concerning the conservation of natural resources, and the Bird and Habitat Directives hold significant positions. Together, these directives establish the Natura 2000 network, a comprehensive conservation initiative that designates protected areas across Europe (Sundseth, 2018). As the 'cornerstone of the EU conservation policy', these directives play a critical role in preserving biodiversity by safeguarding habitats and species of European significance (Kenig-Witkowska, 2017; Fig. 2). The implementation of Natura 2000 network depends on the site selection and monitoring of the areas to guarantee the conservation status. Each Member State must be responsible for defining appropriate management measures. The protected areas created under the Natura 2000 can be nominated as Special Areas of Conservation or as Special Protected Areas to protect the most vulnerable species and habitats. Projects that likely can cause impacts on these protected areas must be subject to an Appropriate Assessment (Amorim and Elliott, 2026).

2.2. National scale

The national planning systems across countries are heterogeneous, influenced by system maturity, power distribution, legal frameworks, and the roles of the public and private sectors (CEC, 1997). In Europe, most land planning systems have constitutional roots, aligning with one of the major 'families' of planning frameworks that have evolved post-World War II, in articulation with local and regional development policies (Newman and Thornley, 1996). Southern European regions, such as Portugal, are typically characterised by having less mature spatial planning systems, which contrasts with North-Western regions' more advanced, efficient, and well-developed plans (CEC, 1997; Nadin and Stead, 2013; Tulumello et al., 2018).

Spatial planning in our case study, Portugal, lagged behind the rest of Europe until the end of the 20th century when significant advances began, supported by the democratisation of local governance and integration into the EU. The latter was key in providing financial resources essential for infrastructure development (Cabral, 2018). The late arrival of spatial planning in Portugal is confirmed by the international lists of governance. According to the World Bank Group, Portugal's government effectiveness and rule of law are measured as being fairly high (80.2 and 83.5 in 2023, respectively), similar to other countries in southern Europe (Spain – 77.0 and 78.0, respectively). However, there is a larger difference between the southern and northern European countries (average northern countries; Government effectiveness 89.3 and Rule of Law 93.4). While Portuguese values show elevated quality in the implementation and formulation of laws, there are still areas that can be improved.

2.2.1. Land management instruments

This analysis concerns land that affects estuaries, thus, vicinities and estuary margins. In 2015, the Portuguese basic law for spatial development and urban planning (LBPSOTU¹⁰) underwent structural amendments to address rapid urban expansion, particularly on rural lands. While these changes aimed to facilitate interventions by the central and local administrations, full implementation remains incomplete. Additionally, the transfer of estuarine management from local to central administration under the amended law diminishes the role of private stakeholders, creating challenges and conflicts (Table 1; Fidélis, 2018).

Under the Legal Regime of Territorial Management Instruments¹¹, spatial and urban planning in Portugal operates at three hierarchical levels: national, regional and local. At the national level, the National

⁵ IMP, COM(2007)575.

⁶ MSP, Directive 2014/89/EU.

⁷ ICZM, Directive 2002/413/EC.

⁸ CBD, United Nations Convention on Biological Diversity.

⁹ UNCLOS, United Nations Convention on the Law of the Sea.

¹⁰ LBPSOTU, Decree Law no. 80/2015, May 30th.

¹¹ Legal Regime of Territorial Management Instruments, Decree-Law no. 80/2015, May 14th.

Table 1

Intervention scale of spatial planning instruments and type of administration (adapted from Cabral, 2018). PNPOT - National programme for spatial planning, PROT - Regional spatial development plan, MMP - Municipal master plan, UP - Urbanisation plan. Empty cells indicate no instrument with this scale and administration.

Administration	National	Regional	Local
Central	PNPOT	Sectoral Programmes	Special Programmes
Regional		PROT	
Municipality		Intermunicipal plan	MMP, UP

Programme for Spatial Planning (PNPOT¹²) is the first step of the LBPSOTU (Fig. 2) implementation and serves as a strategic instrument which connects various planning scales, ensuring consistency across sectoral policies (Maia and Marques, 2019). This law was the first national instrument designed to coordinate policies and foster collaboration among different actors (Cossu, 2020). The Regional Spatial Development Plans (PROT) and local plans – Municipal Master Plan (MMP) and Urbanisation Plan (UP) - provide more localised guidelines (Fig. 2). Regional, special and sectoral programmes establish principles and measures to guide specific policies (Table 1). Special programmes prevail over MMPs and focus on unique environments, such as coastlines (Coastline programmes), estuaries (Estuary management programmes, POE), protected areas and reservoirs (Campos and Ferrão, 2015). Similarly, sectoral programmes are crucial for managing specific environmental and territorial concerns, such as flood risk management plans and conservation sites. These programmes align with EU directives and are integrated into broader spatial planning frameworks (Law no. 31/2014).

2.2.2. Water management instruments

Portugal's water planning system comprises the National Water Plan, River Basin Management Plans (RBMP) and Specific Water Management Plans (Cardoso et al., 2019; Fig. 2). The National Water Plan is a sectoral programme elaborated under the scope of the Water law and defines the strategy for the water policy applied in every river basin (APA, 2021). The Water law (Decree-Law No. 130/2012) transposes the WFD into national legislation, promoting the achievement of WFD objectives into all water bodies, including estuarine zones (Rodrigues and Fidélis, 2021). The WFD goals are also promoted at a regional scale, through the RBMPs, which integrate terrestrial and water management approaches (Grizzetti et al., 2016). Additionally, the Floods Directive proposes the identification of high-risk flood zones, which have been identified on a regional scale to enable proactive planning and mitigation (Decree-Law No. 115/2010). The Portuguese Agency for Environment (APA) is the main entity responsible for overseeing water resource management and protection (Decree-law no. 115/2010; Table 2).

2.2.3. Maritime management instruments

Portugal has the third largest EU exclusive economic zone (see Glossary), covering over 1.7 million km², which accounts for nearly 50% of the EU's maritime area (Guerreiro et al., 2021; Leitão et al., 2014). As an EU Member state, the country followed the guidelines of the EU MSP Directive (European Commission, 2014b) to develop and adopt a systematic approach responsible for allocating activities at sea and promoting the sustainable use of marine resources. Nonetheless, compared to countries like Norway, which have had MSP systems in place for decades, Portugal's MSP plans were only approved between 2019 and 2024 (Frazão Santos et al., 2019; Resolution of the Council of Ministers No. 203-A/2019; Resolution of the Council of Ministers No. 136/2024).

The Portuguese MSP includes marine waters under national jurisdiction of four subdivisions (the Mainland, Azores, Madeira, and the

Table 2

State organisations with responsibility about several areas of importance. APA - Portuguese Environmental Agency; DGPM - Directorate-General for Maritime Policy; DGRM - Directorate-General for Nature Resources, Safety and Maritime Services; ICNF - Conservation Institute for Nature and Forests; IH - Hydrographic Institute; IPMA - Portuguese Institute for Sea and Atmosphere.

Area of responsibility	Organisation	Management Responsibility
Biodiversity and Nature conservation	ICNF	Public institute under indirect administration of the State. Under management of Ministry of Environment and Energy.
Climate and sea research	IPMA	State laboratory. Under management of Ministry of Environment and Energy and Ministry of Education, Science and Innovation.
Defence of marine environment	IH	State laboratory. Under management of Ministry of National Defence.
Environmental impacts	APA	Public institute under indirect administration of the State. Under management of Ministry of Environment and Energy.
Flood protection and coastal protection	APA	-
Food quality and health	IPMA	-
Integrated coastal zone management	APA	-
MSFD and MSP	DGPM; DGRM	Central service for direct administration of the State. Under management of the Ministry of the Economy. DGRM also engages with the Ministry of Agriculture and Fisheries.
Shipping, ports and pollution prevention	DGRM	-
Water quality	APA	-

Extended Continental Shelf), from the baselines of its territorial waters to the outer limit of the continental shelf and is composed by two different instruments: the situation plan and allocation plans (Fig. 2; Calado et al., 2024). The situation plan identifies relevant areas for conservation and protection and outlines the temporal and spatial distribution of activities across Portuguese maritime space, covering sectors like aquaculture, renewable energy and tourism (Calado et al., 2024; Decree-Law No. 38/2015). The allocation plans identify and authorise new uses of the maritime space not initially foreseen, integrating them into the situation plan (Decree-law no. 38/2015). Complementary to these MSP instruments, private-use permits are issued for activities that exceed common utilisation and require the reservation of an area or volume of the ocean space for the exploration of its resources (Fig. 3; Decree-Law No. 38/2015). The MSP instruments are under the responsibility of the Directorate-General for Nature Resources, Safety and Maritime Services (DGRM), together with regional coordination by the Regional Directorate for Maritime Policies in Azores, and the Regional Directorate for the Environment and the Sea in Madeira (Table 2). Directorate-General for Maritime Policy (DGPM) is the entity responsible for monitoring and evaluating MSP instruments. Since 2017, private aquaculture operations have been subject to new guidelines, as new installations need to acquire “titles for aquaculture activity” instead of the above-mentioned private-use permits (Decree-Law No. 40/2017). The DGRM is responsible for the emission and enforcement of these titles

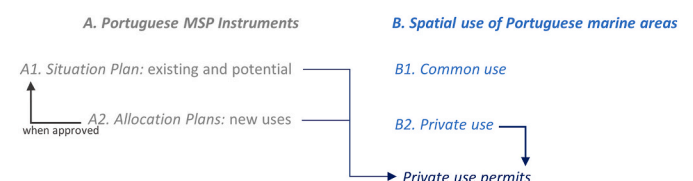


Fig. 3. Marine Spatial Planning (MSP) instruments and complementary legislation (adapted from Calado et al. (2024)).

¹² PNPOT, Law no. 99/2019, September 5th.

for the marine area, while the Conservation Institute for Nature and Forests (ICNF) is responsible for the emission and enforcement for inland waters. Although the importance of land-sea interactions for the MSP process is recognised, estuaries management and planning are not considered in Portuguese MSP (Calado et al., 2024; European Commission, 2014b). Even though the MSP has no jurisdiction over estuarine waters, it is responsible for managing all maritime activities happening in national waters (e.g., aquaculture and renewable energy), which also can influence estuaries and their development.

2.2.4. Instruments for conservation management

The Basic Environmental Law¹³ enshrines the right to a balanced ecological environment, ensuring sustainable use of natural resources (Campos and Ferrão, 2015). This law underpins environmental policy across various domains, intersecting with landscape and spatial planning (Campos and Ferrão, 2015). Unlike spatial planning, environmental protection is a formal competence of the EU, which influences the national framework significantly (Campos and Ferrão, 2015). EU regulations aim to ensure protection and conservation of biodiversity (Biodiversity Strategy 2030), and to provide environmental impact assessments of projects or developments (Environmental Impact Assessment Directive). In Portugal, the ICNF is the institute responsible for biodiversity and nature conservation (Table 2). This includes responsibilities related to protected areas, such as Natura 2000 sites, which integrate national and EU objectives for environmental sustainability.

Different entities bear responsibility for spatial planning instruments. For example, POE usually falls under the APA's jurisdiction (Table 2). However, in cases where estuaries overlap with protected areas, the jurisdiction is shared with ICNF (Fidélis and Carvalho, 2015). This layered governance reflects the complexity of integrating environmental protection with spatial planning in Portugal's multi-level administrative system.

3. Discussion

3.1. Estuary management in a fragmented legal landscape

Sustainable estuarine management relies on active stakeholder involvement in governance (Lonsdale et al., 2018). There is no unique and global governance model due to varying political, economic, and social contexts (Ruhl and Craig, 2011). However, holistic approaches are needed for effective estuarine management. Moreover, stakeholder participation in the legislative process ensures better uptake of such legislation by social actors, because it fosters inclusivity and recognition of diverse perspective (Kraan et al., 2014).

A common threat to estuaries is upstream water extraction (e.g., for irrigation), drastically affecting the hydrology of the systems by reducing the freshwater input (Donázar-Aramendía et al., 2024). Additionally, downstream activities (e.g., dredging) can escalate due to activities happening upstream (e.g., deforestation), that have environmental (e.g., increase in sediment loads) and also economic impacts (e.g., increase in associated costs; O'Leary et al., 2023). Addressing such downstream impacts requires integrated planning that defines ecosystem boundaries based on ecological processes rather than jurisdictional limits. Despite progress in Europe, fragmented governance remains a persistent barrier to implementing these strategies, as compartmentalised data collection and integration prevents informed decision-making (Boyes and Elliott, 2014).

In coastal transitional waters, both WFD and MSFD apply, and aim to achieve "good ecological/environmental status" for water and seabed ecosystems respectively. While the WFD takes primacy to meeting ecological and chemical status objectives, the MSFD is complementary

by addressing additional pressures not covered by WFD (e.g., marine litter, underwater noise). Yet, the implementation of these two Directives often occurs individually, with minimal integration across sectors (Holt et al., 2011; Moss, 2008; Wakefield, 2010). This issue is not exclusive to Europe. For instance, Australia faces similar challenges with fragmented estuarine policies, given that estuaries are managed by a wide array of national acts and policies with no clear integration (Hallett et al., 2016). Other consequences of the fragmented nature of European legislation is policy conflicts, such as initiatives that try to reduce the use of fertilisers (European Green Deal; see details in Supplementary Material) whilst others promote the increase of agriculture production (Common Agriculture Policy; https://agriculture.ec.europa.eu/common-agricultural-policy_en). Another example is the simultaneous creation of marine protected areas and promotion of sustainable fishing (CFP and MSFD; see details in Supplementary Material), at the same time as investing to deliver policies that encourage the development and expansion of fishing (European Maritime, Fisheries and Aquaculture Fund; https://oceans-and-fisheries.ec.europa.eu/funding/emfaf_en). Ambitious EU Directives such as the WFD and MSFD often set broad objectives to facilitate national implementation. Programmes of Measures play a key role in translating these objectives into specific actions or regulatory instruments, supporting Member States in achieving the goals of the directives. Nevertheless, implementation challenges persist in other frameworks, for example the EU MSP directive that promotes an ecosystem-based approach, but in practice for most member states tends to prioritise political and economic factors over environmental goals (Frazão Santos et al., 2019; Qiu and Jones, 2013; Stelzenmüller et al., 2013). These examples highlight the difficulty of aligning ambitious legal frameworks with national decision-making. Environmental goals are often sidelined over other priorities, this is evident in the inconsistent enforcement of the Natura 2000 Network, which leads to member states being penalised for non-compliance, including non-definition of conservation areas or unsuitable measures (Beunen, 2006).

Elliott et al. (2025a) conclude that management success is dependent on two factors: (1) competent authorities (i.e., entities responsible to administer legislation according to scientific knowledge), and (2) comprehensive instruments, which may be vertically integrated from bottom-up - local to global levels - and horizontally integrated across sectors (Elliott et al., 2025a). The present study has mostly focused on integration of global legislation into national legislation, but vertical integration is also required in transboundary management (Elliott et al., 2023). For example, the transboundary management of three European estuaries (Ems, Elbe and Weser) that all discharge into Wadden Sea requires a trilateral agreement across Denmark, Germany and the Netherlands. All three countries fall within the EU legislation, thus all aim to achieve the same outcomes, even if using different means to achieve these goals (Elliott and Whitfield, 2025). In these cases, transboundary management is facilitated, however, challenges may rise when conflicting national priorities hinder cooperation.

Portugal serves as an example of these challenges, with its spatial planning framework reflecting significant imbalances between coastal and interior zones. Globally, coastal zones are densely populated and driven by economic activities like maritime transportation, while the interior regions face depopulation and ageing demographics (Cossu, 2020). This is also the case of Portugal. The National Programme for Spatial Planning (PNPOT) has attempted to address these disparities, proposing initiatives to valorise unused land (Cossu, 2020). However, despite legislative reforms, such as amendments to Portuguese basic law for spatial development and urban planning (LBPSOTU), Portugal often faces criticism for disorganised management and inadequate stakeholder engagement (APA, 2008; Baptista, 2008; Ferrão, 2014; Maia and Marques, 2019; Schmidt, 2008). A prominent example is the lack of Geographic Information System (GIS) data integration for MMPs, important to clearly and undoubtedly define the boundaries and location of activities developed, highlighting the urgent need for improved data integration in spatial planning. To address these issues, Lonsdale

¹³ Basic environmental law, Law no. 19/2014, April 14th.

et al. (2018) proposed an Estuarine Planning Support System (EPSS) tool created to aid decision-makers and stakeholders in integrating legislation, receptors and impacts in the Humber Estuary. These issues may be further exacerbated in estuarine environments due to their transitional nature. The legal framework for Special Programmes for Portuguese Estuaries restricts the definition to “transitional waters, and their beds and banks” (Decree-Law no. 129/2008, July 21st). However, this study adopts a wider perspective that includes areas influenced by estuarine dynamics, particularly during flooding or other extreme events (see Introduction section). Adopting this broader perspective is critical, as it enables management frameworks to account for the full spatial extent of estuarine processes, thereby supporting more robust and effective management tools. Especially important in the context of climate change and the need to mitigate potential impacts.

Another persistent issue lies in the limited coordination between maritime and terrestrial planning systems. In 2014, the LBPSOTU and *Basic law on policy and management on national maritime areas* were written and reformulated simultaneously, however, no integration was found (Campos and Ferrão, 2018). While EU driven initiatives like the MSP and Water Law aim for cohesion, based on holistic and integrated approaches, in Portugal the PNPTOT operates largely in isolation, based on a sectoral approach, complicating estuarine management (Campos and Ferrão, 2015). Maritime and terrestrial approaches work independently, however, this is not true in coastal areas and estuaries where management must comprehend both frameworks, since they fall under maritime and terrestrial jurisdictions. The MSP (situation plan), for example, governs maritime activities that develop part of their activities in estuarine waters, but estuaries are excluded from its jurisdiction (Fidélis and Carvalho, 2015). Future revision cycles of the process should promote new initiatives, and revised instruments, that explore such relation. Further, the amendment to the LBPSOTU introduced Estuary Management Programmes (POEs) representing a step forward in addressing estuarine governance. However, the slow drafting and approval of POEs mean that estuary management remains largely reliant on MMPs, which lack target guidelines for estuaries (Rodrigues and Fidélis, 2021). On a positive note, the amendment also integrated estuarine management into the national strategies, reducing fragmentation in areas previously managed by local authorities alone. Nonetheless, excessive centralisation of legal and regulatory frameworks coupled with the lack of guidelines is leading to conflicts in decision-making and exacerbates governance challenges in Portugal (Chamusca, 2021). The prevailing “one-size-fits-all” approach often fails to account for the unique dynamics of each ecosystem, limiting the flexibility needed to address multi-scale environmental issues (Cumming et al., 2006). Additionally, future efforts must align MSP instruments with the PNPTOT to provide cohesive guidance on the private use of maritime space, however, no indication has been presented on how to do this (Calado et al., 2024).

Portugal is not the only country struggling with coastal and transitional systems management. Lawlor and Depellegrin (2023) compared coastal and marine governance in European countries, and noted that similarly to Portugal, Ireland and Romania have a centralised and sectoral governance systems. While in Portugal there are specific land plans for coastal zones managed at a regional scale, Ireland and Romania's regional and local authorities have limited or no responsibilities regarding the coastal and marine zones. Particularly in Ireland, there is a strong division between land and sea governance, similarly to Portugal, due to the conflicting approaches used in each. In Spain, the governance is also centralised, and marine and coastal areas are managed nationally, however, when focused on resource management, fisheries and aquaculture, these are managed at a regional level.

The Basque country offers a successful case of integrated management (Elliott et al., 2025a). In the Nervión estuary, intense industrialisation led to a significant loss of intertidal habitats (Cearreta et al., 2004; Borja et al., 2006). Several actions were taken to improve environmental health and recover the ecosystem services and societal benefits. These

actions were taken through 31 tiers, including: diversification of discharges, water treatment by using physical and biological methods, and closing of some companies (Borja et al., 2016; Elliott et al., 2025a). Over the years, water and sediment pollution decreased significantly (Elliott et al., 2025a). Another case of recognised good and effective management is recognised in the Scheldt Estuary, a transboundary ecosystem located between the Netherlands and Belgium. Its success was due to the use of innovative governance models (e.g., decision making through interactive governance, introduction of adaptive management principles), transboundary coordination and creation of solutions to complex conflicts (e.g., nature-based solutions; Slinger, 2023).

3.2. Integrating climate change adaptation into estuary governance

Estuaries are highly vulnerable to climate change and Sea-Level Rise (SLR), which exacerbate pre-existing anthropogenic pressures, further destabilising these ecosystems (e.g., Biguino et al., 2024; O'Leary et al., 2023). Although estuarine resilience allows for a range of adaptive responses to climate change, industrialisation and urbanisation can limit their adaptive capacity and exceed their ecological thresholds, leading to significant biodiversity loss, and reducing resilience (Basset et al., 2013; Paerl et al., 2001). The socio-economic impacts are equally concerning, as vulnerable communities face disproportionate risks and greater social disparities due to limited adaptive capacity to tackle climate change (IPCC, AR5). These challenges highlight the urgency of integrated management strategies, essential to support ecosystem adaptation and equip communities with tools to mitigate these impacts (Hulme, 2005; West et al., 2009). For example, restoring coastal vegetation to enhance coastal protection (O'Leary et al., 2023).

Yet estuaries are highly dynamic and variable. Global studies have reported an increase of water temperatures in estuaries (0.014–0.2 °C per year; Preston, 2004; Scanes et al., 2020). Yet, for example, the Sado Estuary in Portugal appears to have low sensitivity to atmospheric and oceanic warming, as water temperatures do not demonstrate a positive trend in the past 40 years (Biguino et al., 2024). One possible explanation is the prevalence of drought events in the region, which have reduced freshwater input and enhanced the intrusion of oceanic water (Biguino et al., 2024). These shifts have caused an increase in salination, within the estuary (Biguino et al., 2024) and in the estuarine aquifer (Rodrigues, 2024). Excessive water abstraction is a global challenge, as upstream interventions (e.g., dam construction and irrigation) can substantially diminish freshwater delivery to estuaries. This reinforces the need for watershed-focused management strategies that consider cumulative impacts across the entire system.

In transitional systems, SLR can have significant impacts on the intertidal communities causing the migration of these communities landwards, the so-called ‘coastal squeeze’ (Elliott et al., 2014). Moreover, SLR can lead to greater marine incursion in estuaries, resulting in alterations in bathymetry, salinity and sediment cycles, which can cause significant changes to estuarine community structure (Elliott et al., 2015). Maintenance dredging requirements are likely to increase with the increase in sediment transport due to SLR, consequently increasing the associated costs. The creation of an *Integrated Sediment Management Plan* at a watershed scale includes stakeholder participation and coordination with other policies, which may help to address impacts of sediment on water quality, particularly as both would be implemented at a watershed level (CIS, 2022). Whilst such plans are not explicitly required, in the future they could be included in the Programme of Measures of WFD for ecological status and of MSFD descriptors related to seafloor integrity.

The European Commission has strongly advocated for the creation of adaptation measures, especially regarding water policies (Fanzeros, 2024). An adaptation plan should consider reducing social vulnerability to climate change impacts and creating capacity to deal with uncertainty (Sondermann and Proença de Oliveira, 2022). For example, Lisbon council has prompted several municipalities to advance with climate

change adaptation plans. These initiatives illustrate a shift towards localised, actionable strategies that could tackle broader national policies.

Fanzeres (2024) interviewed water management specialists of the Tagus estuary (Portugal), who highlighted Tagus vulnerability to climate change due to pursuit of continued economic growth, especially in agricultural policies and lack of consideration of drought risks. Moreover, participants showed concerns regarding the lack of awareness of the public about these discussions (Fanzeres, 2024). In contrast, in the Hunter estuary (Australia) several strategies have been proposed to promote effective adaptation to changing environmental conditions, such as blue-green corridors, habitat restoration, and re-naturalisation (Lopez et al., 2024). Integration could drive a more cohesive national spatial policy, overcoming the historical fragmentation of environmental protection, economic development and urban planning (Cossu, 2020). While Portugal's climate change adaptation remains fragmented and sectoral, (Swart et al., 2009), collaborative efforts across governance levels and robust environmental monitoring are essential for providing accurate data to inform decision-making, enabling policy-makers to prioritise measures that safeguard both coastal ecological integrity and human livelihoods (Carvalho et al., 2019).

3.3. Lessons and resolutions for sustainable management of estuaries

Different socio-economic, political and ecological contexts limit the creation of unique governance and management approaches that provide win-win situations applicable to every system in the same way. However, some principles can be taken in consideration to move to a sustainable and equitable management of estuaries. One of the baseline principles of environmental policy is the *polluter pays principle*, which gives responsibility to whom causes harms to the environment (e.g., pollution of waters ; Nash, 2000) by increasing their responsibility (Costanza et al., 1998). This principle could guarantee funds to monitor estuary health, and to invest in solutions to mitigate damages caused by the polluters/payers. Additionally, using the best data available – informed by ongoing academic efforts to comprehensively understand the system – is fundamental. Decision-makers should be able to indicate what data are actually needed for management, before starting the process, so that the data collected is fit-for-purpose (Elliott et al., 2020). Usually, management decisions can be done even with few data. In environmental policy, the focus is on the quality of the data, instead of the quantity of the data (Ruhl and Craig, 2011). However, it must be clear that informed decision-making is the best path possible. The *precautionary principle* allows decision-makers to accept a hypothesis if the evidence is credible, even if not completely conclusive. Scientists have also an important role in the governance process, especially with regard to data that are needed. Therefore, scientists must start combining evidence-based information with society engagement (Borja et al., 2025).

To address several of the challenges of governance, the multi-level nature of the governance systems cannot be ignored (Pahl-Wostl et al., 2021). The central question must be to understand how the different actors from multi-levels should interact to produce desirable outcomes. Ostrom's *polycentricity* theory includes a multi-scale governance system that involves collective management based at the local and community levels (Ostrom, 2010). The main aim of this theory is to use a pluralistic framework that balances the potential costs of including multiple and frequently overlapping domains of governance (Gillard et al., 2017). Therefore, having governing authorities at different levels, functioning across overlapping jurisdictions, operating with autonomy, and implementing rules within a specific domain diverges from more traditional frameworks which usually have a central authority governed by rule of law and a series of overarching regulations (Contipelli, 2018). This framework can improve the fit between governance and natural resource system processes (Lebel et al., 2013). For example, studies on water resources' management suggest that polycentric systems with

multi-level governance arrangements often perform better than decentralised or centralised arrangements (Pahl-Wostl and Knieper, 2014).

Current governance systems often lack the necessary mechanisms to comprehensively protect natural capital assets. Conservation efforts tend to focus primarily on resources with direct economic value, frequently neglecting broader ecosystem functions and services (Holt et al., 2011). This issue is evident in this study's multi-level analysis, demonstrating the fragmented and inconsistent management of estuaries in Portugal, as discussed in section 3.1. Although estuaries fall under regulations for water bodies (e.g., RBMP), land planning, and maritime spatial planning, these frameworks rarely account for both the unique ecological processes and the socio-economic characteristics of estuarine ecosystems.

Effective, long-term environmental protection requires a holistic framework that evaluates all ecosystem functions and diverse benefits provided to communities (Holt et al., 2011). An ecosystem service-based approach as a fundamental component of decision-making offers a systematic method to address these gaps. By identifying synergies and trade-offs among ecosystem services, this approach enhances management efficiency and sustainability (Hornung et al., 2019). Moreover, it promotes social sustainability by incorporating stakeholder perspectives and fostering their active involvement in the decision-making processes.

In Portugal stakeholder involvement is notably weak during the elaboration of legislation, plans or instruments, as stakeholders are typically included only during the final stages of public consultation (Carvalho and Fidélis, 2013). Even though some participation is available in processes of Environmental Impact Assessment (EIA - in projects according to the EIA Directive and in plans/programmes according to the Strategic and Regional Environmental Assessment), the public consultation is limited to two phases: (i) scoping phase, and (ii) after the draft and impact assessment report. In the 1st phase, the consultation is not mandatory and is targeted to environmental conservation entities (in Portugal APA and ICNF), while the 2nd phase is mandatory and is open for the broader public for 30 days (Decree-law no. 232/2007; Decree-law no. 151-B/2013). This delayed engagement diminishes the potential for meaningful contributions to policy development.

Additionally, greater integration of stakeholder knowledge can facilitate proactive management, enabling anticipation of ecological and socio-economic changes rather than relying on reactive measures to mitigate damage. In recent years, member states have made an effort to use holistic approaches, but there are still further measures that could be taken into consideration for spatial management, such as defining precautionary buffers surrounding water bodies to accommodate simulations for SLR (MacDonell et al., 2025). However, existing European and Portuguese legislation frequently adopts a reactive approach, *i.e.*, acting in response to an issue rather than controlling the issues in early stages, resulting in disjointed frameworks that address environmental damage *post hoc*.

The integration of an ecosystem service-based approach into spatial planning can optimise sustainable planning models, under different scenarios, while considering ecological, economic, and social priorities (Wang et al., 2018). Such measures are essential to implement sustainable management strategies that protect the full range of ecosystem services, thus underpinning resilient estuarine ecosystems. Moreover, putting in practice an ecosystem-based approach at the watershed scale could aid in managing several pressures that act from beyond the limits of the estuary (e.g., water extraction upstream), integrating upstream and downstream management in the same instrument. However, Elliott et al. (2025a) review showed that despite the known advantages of ecosystem-based management, there are still challenges in integrating the different components, such as stakeholder engagement, technology and data, and communication and marketing.

Future directions could include pilot projects to test governance systems using ecosystem service-based approaches that are adaptive, participatory and deliberative. This could be similar to the Marine Pioneer Project developed in the UK coastal and marine ecosystems,

where a decision support tool was implemented based on natural capital asset and risk assessment to understand the risk to ecosystem service supply in relation to implementation of management decisions (Rees et al., 2022). In this way, it would allow a flexible governance focused on co-management decisions and collective discussion for sustainable management of estuaries without impacting people that depend on benefits from these systems (Beaumont and Glavovic, 2024). The framework could be guided by the ten tenets of marine management (Elliott et al., 2025b), which aim to achieve ecologically sustainable goals while ensuring that other tenets are respected. The pilot study would put this governance framework into action through a single management programme applied to a unique estuarine system, at a watershed scale. This programme would have higher authority than adjacent instruments and be managed at a regional scale by a single entity – including people with different expertise and interests in the estuary, ideally with experience in developing legislation. GIS tools would be used to facilitate the integration of ecological, social and economic priorities, while promoting collaborative work among administrative bodies and stakeholders. Such approaches not only address current challenges but also provide scalable solutions for managing estuaries as dynamic and interconnected systems. Moreover, environmental monitoring would be used initially to understand the ecosystem requirements and carrying capacity, and along the way to understand if the management is effective in defining sustainable limits for each activity (e.g., industrial discharges, aquaculture). Although this programme would be based on an innovative approach, it would also incorporate traditional principles, such as the *precautionary principle* or *polluter pays principle*, to simplify and strengthen regional management.

4. Conclusions

Understanding how legislation and policies are implemented and effectively enforced is crucial to understand their impact on ecosystems. Historically, Portuguese estuaries have been absent from most planning instruments, leading to insufficient data collection to support informative management (Daniell et al., 2020). Making decisions without information poses a risk, however, policies that overlook their actual impact in estuaries is even more so. While recent initiatives, such as the creation of special programmes for estuaries and their integration into national strategies represent progress, persistent challenges hinder comprehensive governance. These challenges stem from an estuaries' overlapping jurisdictions of river catchment and coastal areas, leading to fragmented governances, conflicting guidelines, and a lack of standardised protocols to ensure coordinated decision-making (Daniell et al., 2020). These fundamental governance gaps result from: limited coordination between maritime and land planning systems; challenges in integrating and implementing the EU legislation into national frameworks; fragmentation of administrative responsibilities across estuarine regions. Therefore, studies similar to this one provide insight into the challenges and propose ways to overcome them.

Given the complexity of these systems and the identified challenges, several recommendations could improve estuarine governance, such as enhancing the coordination between administrative bodies. For example, in Portugal, the coordination between Maritime Spatial Planning and the National Programme for Spatial Planning would be a significant improvement in managing coastal and estuary zones more effectively. In addition, developing clear actionable guidelines for integrating EU legislation, such as Water Framework Directive, into regional and local contexts can provide a more consistent implementation. Moreover, fostering stakeholder engagement in governance initiatives, from the initial planning to the implementation and monitoring, can lead to more inclusive decision-making and greater compliance. Employing ecosystem service-based approaches can also be a way to improve estuarine management. Ecosystem service-based approaches inherently align with the main pillars of sustainability by supporting ecosystem health (environmental pillar), enhancing human well-being

(societal pillar) and promoting sustainable economic growth (economic pillar).

CRedit authorship contribution statement

F. Afonso: Writing – original draft, Visualization, Software, Investigation, Data curation, Conceptualization. **M. Fernandes:** Writing – review & editing, Visualization, Validation, Data curation. **M.C. Austen:** Writing – review & editing, Visualization, Conceptualization. **S. Broszeit:** Writing – review & editing, Visualization, Conceptualization. **A.C. Brito:** Writing – review & editing, Visualization, Conceptualization.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ocecoaman.2026.108184>.

Data availability

No data was used for the research described in the article.

References

- Amorim, E., Elliott, M., 2026. 'Marine space oddities'-overlapping conservation designations—do we need all the different local, national, regional and global categories? *Mar. Pol.* 185, 106960. <https://doi.org/10.1016/j.marpol.2025.106960>.
- APA, 2008. *Relatórios do Estado do Ambiente E do Ordenamento do Território em Portugal. 20 anos.* Agência Portuguesa do Ambiente [in Portuguese].
- APA, 2021. Plano Nacional da água [Online post]. <https://apambiente.pt/agua/plano-nacional-da-agua>. (Accessed 11 December 2024) [in Portuguese].

- Baptista, I., 2008. O Programa POLIS e o País 'Desordenado'. In: Cabral, M.V., Silva, F.C. D. (Eds.), *Cidade & Cidadania*. Instituto de Ciências Sociais, pp. 131–176 [in Portuguese].
- Basset, A., Barbone, E., Elliott, M., Li, B.-L., Jorgensen, S.E., Lucena-Moya, P., Pardo, I., Mouillot, D., 2013. A unifying approach to understanding transitional waters: fundamental properties emerging from ecotone ecosystems. *Estuar. Coast Shelf Sci.* 132, 5–16. <https://doi.org/10.1016/j.ecss.2012.04.012>.
- Beaumont, N.J., Glavovic, B.C., 2024. Introduction to the values and governance of estuaries and coasts. In: Baird, D., Elliott, M. (Eds.), *Treatise on Estuarine and Coastal Science*, Second 7. Academic Press, Oxford, pp. 1–13.
- Beunen, R., 2006. European nature conservation legislation and spatial planning: for better or for worse? *J. Environ. Plann. Manag.* 49 (4), 605–619. <https://doi.org/10.1080/09640560600747547>.
- Biguino, B., Antunes, C., Dias, J.M., Haigh, I.D., Cruz, J.P.C., Borges, C., Palma, C., Pereira, H., Picado, A., Ferreira, A., Brito, A.C., 2024. Long-term trends (1986–2019) in the physicochemical properties of the Sado Estuary (Portugal) driven primarily by changes in river flow and influenced by marine upwelling. *Mar. Pollut. Bull.* 207, 116806. <https://doi.org/10.1016/j.marpolbul.2024.116806>.
- Borja, Á., Adarraga, I., Bald, J., Belzunce-Segarra, M.J., Cruz, I., Franco, J., Garmendia, J. M., Larreta, J., Laza-Martínez, A., Manzanos, A., Marquiegui, M.A., Martín, I., Martínez, J., Menchaca, I., Pouso, S., Revilla, M., Rodríguez, J.G., Ruiz, J.M., Sagarmínaga, Y., et al., 2025. Marine biodiversity and environmental data: an AI-ready, open dataset from the long term (1995–2023) Basque Country monitoring network. *Front. Ocean Sustain.* 2, 1528837. <https://doi.org/10.3389/focsu.2024.1528837>.
- Borja, Á., Chust, G., Rodríguez, J.G., Bald, J., Belzunce-Segarra, M.J., Franco, J., Garmendia, J.M., Larreta, J., Menchaca, I., Muxika, I., Solaun, O., Revilla, M., Uriarte, A., Valencia, V., Zorita, I., 2016. 'The past is the future of the present': learning from long-time series of marine monitoring. *Sci. Total Environ.* 566, 698–711. <https://doi.org/10.1016/j.scitotenv.2016.05.111>.
- Borja, A., Elliott, M., Carstensen, J., Heiskanen, A.S., van de Bund, W., 2010. Marine management – towards an integrated implementation of the European marine strategy framework and the water framework directives. *Mar. Pollut. Bull.* 60, 2175–2186. <https://doi.org/10.1016/j.marpolbul.2010.09.026>.
- Borja, Á., Galparsoro, I., Solaun, O., Muxika, I., Tello, E.M., Uriarte, A., Valencia, V., 2006. The European water framework directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status. *Estuar. Coast Shelf Sci.* 66 (1–2), 84–96. <https://doi.org/10.1016/j.ecss.2005.07.021>.
- Boyes, S.J., Elliott, M., 2014. Marine legislation—The ultimate 'horrendogram': international law, European directives & national implementation. *Mar. Pollut. Bull.* 86 (1–2), 39–47. <https://doi.org/10.1016/j.marpolbul.2014.06.055>.
- Boyes, S.J., Elliott, M., 2015. The excessive complexity of national marine management systems – has this decreased in England since the introduction of marine and coastal access act 2009. *Mar. Pol.* 51, 57–65. <https://doi.org/10.1016/j.marpol.2014.07.019>.
- Breuer, M.E.G., Twisk, D.D., 2025. Integrated Maritime Policy of the European Union. Fact Sheets on the European Union. <https://www.europarl.europa.eu/factsheets/en>.
- Cabral, J., 2018. The urban dimension in European territorial planning – the case of Portugal. *Jornadas Internacionais Sobre Los Nuevos Crecimientos Urbanos 12–27*.
- Calado, H., Santos, C.F., Quintela, A., Fonseca, C., Gutierrez, D., 2024. The ups and downs of maritime spatial planning in Portugal. *Mar. Pol.* 160, 105984. <https://doi.org/10.1016/j.marpol.2023.105984>.
- Campos, V., Ferrão, J., 2015. O ordenamento do território: uma perspectiva genealógica. In: *ICS Working Papers*, 1. Instituto de Ciências Sociais Da Universidade de Lisboa, Lisboa. http://www.ics.ul.pt/flipping/wp2015_1/index.html.
- Campos, V., Ferrão, J., 2018. Spatial planning in Portugal: a genealogical approach. In: Farinós, J., Peiró, E., Territorio, y Estados (Eds.), *Elementos Para la Coordinación de las Políticas de Ordenación del Territorio en el Siglo XXI*, p. 563.
- Cardoso, P.G., Dolbeth, M., Sousa, R., Relvas, P., Santos, R., Silva, A., Quintino, V., 2019. *The Portuguese Coast*. In: Sheppard, C. (Ed.), *World Seas: an Environmental Evaluation*, 2nd. Elsevier Ltd, pp. 189–208. 1.1016/C2015-0-04330-1.
- Carvalho, L., Mackay, E.B., Cardoso, A.C., Baattrup-Pedersen, A., Birk, S., Blackstock, K. L., Borics, G., Borja, A., Feld, C.K., Ferreira, M.T., Globovnik, L., Grizzetti, B., Hendry, S., Hering, D., Kelly, M., Langaas, S., Meissner, K., Panagopoulos, Y., Penning, E., et al., 2019. Protecting and restoring Europe's waters: an analysis of the future development needs of the water framework directive. *Sci. Total Environ.* 658, 1228–1238. <https://doi.org/10.1016/j.scitotenv.2018.12.255>.
- Carvalho, T.M., Fidéls, T., 2013. The relevance of governance models for estuary management plans. *Land Use Policy* 34, 134–145. <https://doi.org/10.1016/j.landusepol.2013.02.007>.
- Cearreta, A., Irabien, M.J., Pascual, A., 2004. Human activities along the Basque coast during the last two centuries: geological perspective of recent anthropogenic impact on the coast and its environmental consequences. In: Borja, A., Collins, M. (Eds.), *Elsevier Oceanography Series*, 70, pp. 27–50. [https://doi.org/10.1016/S0422-9894\(04\)00040-0](https://doi.org/10.1016/S0422-9894(04)00040-0). ISBN 9780444515810.
- CEC, 1997. *The EU Compendium of Spatial Planning Systems and Policies*. Luxembourg: Office for Official Publications of the European Communities. Commission of the European Communities.
- Chamusca, P., 2021. Urban planning and policy in Portugal an overview. *Urban Res. Pract.* 16 (1), 44–65. <https://doi.org/10.1080/107535069.2021.1980607>.
- CIS, 2022. *Integrated sediment management: guidelines and good practices in the context of the water framework directive*. Common Implementation Strategy for the Water Framework Directive (2000/60/EC).
- Contipelli, E., 2018. Multi-level climate governance: polycentricity and local innovation. *Revista Catalana de Dret Ambiental* 9 (2). <https://raco.cat/index.php/rcda/article/view/348623>.
- Cormier, R., Elliott, M., Borja, Á., 2022. Managing marine resources sustainably—the 'Management response-footprint pyramid' covering policy, plans and technical measures. *Front. Mar. Sci.* 9, 869992. <https://doi.org/10.3389/fmars.2022.869992>.
- Costanza, R., Andrade, F., Antunes, P., van den Balt, M., Boersma, D., Boesch, D.F., Catarino, F., Hanna, S., Limburg, K., Low, B., Molitor, M., Pereira, G., Rayner, S., Santos, R., Wilson, J., Young, M., 1998. Principles for sustainable governance of the oceans. *Science* 281, 198–199.
- Cossu, M., 2020. *Spatial Planning and Climate Change Adaptation in Mainland Portugal*. Master Thesis. Politecnico di Torino. Available in Politecnico di Torino Repository. <https://webthesis.biblio.polito.it/16172/1/tesi.pdf>.
- Cumming, G.S., Cumming, D.H.M., Redman, C.L., 2006. Scale mismatches in social-ecological systems: causes, consequences, and solutions. *Ecol. Soc.* 11 (1), 1–20. <https://www.jstor.org/stable/26267802>.
- Daniell, K.A., Plant, R., Pilbeam, V., Sabinot, C., Paget, N., Astles, K., Steffens, R., Barreteau, O., Bouard, S., Coad, P., Gordon, A., Ferrand, N., Le Meur, P.Y., Lejars, C., Maurel, P., Rubio, A., Rougier, J.E., White, I., 2020. Evolutions in Estuarine governance? Reflections and lessons from Australia, France and New Caledonia. *Mar. Pol.* 112. <https://doi.org/10.1016/j.marpol.2019.103704>.
- Decree-Law No. 38/2015. Decreto-Lei n.º 38/2015, de 12 de Março. Diário da República n.º50/2015, Série I, 1523-1549. Ministério da Agricultura e do Mar. [in Portuguese].
- Decree-Law No. 40/2017. Decreto-Lei n.º 40/2017, de 4 de Abril. Diário da República n.º67/2017, Série I, 1712-1724. [in Portuguese].
- Decree-Law No. 115/2010. Decreto-Lei n.º 115/2010, de 22 de Outubro de 2010, Portugal: Diário da República n.º206/2010, Série I, 4757-4764. Ministério do Ambiente e do Ordenamento do Território. [in Portuguese].
- Decree-Law No. 129/2008. July 21st. Decreto-Lei n.º 115/2010, de 21 de Julho. Diário da República n.º206/2010, Série I, 4757-4764. Ministério do Ambiente e do Ordenamento do Território. [in Portuguese].
- Decree-Law No. 130/2012. Decreto-Lei n.º 130/2012, de 22 de Junho de 2012, Portugal: Diário da República n.º120/2012, Série I, 3109-3139. Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território. [in Portuguese].
- Decree-law no. 151-B/2013. Decreto-Lei n.º 151-B/2013 de 31 de Outubro. Diário da República n.º 211/2013, 2º Suplemento, Série I de 2013-10-31, Páginas 6328-(6) a 6328-(31). Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território. [in Portuguese].
- Decree-law no. 232/2007. Decreto-Lei n.º 232/2007 de 15 de Junho. Diário da República n.º 114/2007, Série I de 2007-06-15, 3866 - 3871. Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional. [in Portuguese].
- DEFRA, 2014. *Marine Strategy Part Two: UK Marine Monitoring Programmes*. Department for Environment Food & Rural Affairs, p. 86. <https://assets.publishing.service.gov.uk/media/5a7efecded915d74e6227ca0/msfd-part-2-final.pdf>. (Accessed 18 February 2025).
- Deneulin, S., Townsend, N., 2007. Public goods, global public goods and the common good. *Int. J. Soc. Econ.* 34 (1–2), 19–36. <https://doi.org/10.1108/03068290710723345>.
- Donázar-Aramendia, I., Megina, C., Miró, J.M., Florido, M., Reyes-Martínez, M.J., Olaya-Ponzono, L., García-Gómez, J.C., 2024. Environmental effects of maintenance dredging works in a highly modified estuary: a short-term approach. *Ocean Coast Manag.* 258, 107394. <https://doi.org/10.1016/j.ocecoaman.2024.107394>.
- Ehler, C., Douvère, F., 2009. *Marine Spatial Planning: a step-by-step Approach*. UNESCO, Paris, France, p. 99. <https://doi.org/10.25607/OBP-43> (IOC Manuals and Guides 53), (ICAM Dossier 6).
- Ehler, C.N., 2012. 13 myths of marine spatial planning. *Marine Ecosys. Manag.* 5, 5–7.
- Elliott, M., Borja, Á., Cormier, R., 2020. Managing marine resources sustainably: a proposed integrated systems analysis approach. *Ocean Coast Manag.* 197, 105315. <https://doi.org/10.1016/j.ocecoaman.2020.105315>.
- Elliott, M., Borja, Á., Cormier, R., 2023. Managing marine resources sustainably—ecological, societal and governance connectivity, coherence and equivalence in complex marine transboundary regions. *Ocean Coast Manag.* 245, 106875. <https://doi.org/10.1016/j.ocecoaman.2023.106875>.
- Elliott, M., Borja, Á., Cormier, R., 2025a. Managing marine resources sustainably—but how do we know when marine management has been successful? *Ocean Coast Manag.* 265, 107623. <https://doi.org/10.1016/j.ocecoaman.2025.107623>.
- Elliott, M., Borja, Á., McQuatters-Gollop, A., Mazik, K., Birchenough, S., Andersen, J.H., et al., 2015. Force majeure: will climate change affect our ability to attain good environmental status for marine biodiversity? *Mar. Pollut. Bull.* 95 (1), 7–27. <https://doi.org/10.1016/j.marpolbul.2015.03.015>.
- Elliott, M., Cormier, R., Borja, Á., 2025b. Making sense of marine management – the tenets revisited. *Mar. Pollut. Bull.* 221, 118580. <https://doi.org/10.1016/j.marpolbul.2025.118580>.
- Elliott, M., Cutts, N.D., Trono, A., 2014. A typology of marine and estuarine hazards and risks as vectors of change: a review for vulnerable coasts and their management. *Ocean Coast Manag.* 93, 88–99. <https://doi.org/10.1016/j.ocecoaman.2014.03.014>.
- Elliott, M., McLusky, D.S., 2002. The need for definitions in understanding estuaries. *Estuar. Coast Shelf Sci.* 55 (6), 815–827. <https://doi.org/10.1006/ecss.2002.1031>.
- Elliott, M., Whitfield, A.K., 2011. Challenging paradigms in estuarine ecology and management. *Estuar. Coast Shelf Sci.* 94 (4), 306–314. <https://doi.org/10.1016/j.ecss.2011.06.016>.
- Elliott, M., Whitfield, A.K., 2025. Science and management achieving connectivity, coherence and equivalence to ensure the health of estuarine fish communities. *Estuar. Coast Shelf Sci.*, 109133 <https://doi.org/10.1016/j.ecss.2025.109133>.
- European Commission, 2003. *Common Implementation Strategy for the Water Framework Directive (2000/60/EC)*. Guidance Document No. 5. *Transitional and Coastal Waters—Typology, Reference Conditions and Classification Systems*. European Commission.

- European Commission, 2014a. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL. A new EU framework to strengthen the role of law. <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52014DC0158>.
- European Commission, 2014b. Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014, Establishing a Framework for Maritime Spatial Planning. Official Journal of the European Union, Brussels.
- Faludi, A., 2009. A turning point in the development of European spatial planning? The 'Territorial Agenda of the European Union' and the 'First Action Programme'. *Prog. Plann.* 71 (1), 1–42. <https://doi.org/10.1016/j.progress.2008.09.001>.
- Fanzeres, D.S., 2024. Drought Challenges in the Tagus River Basin: Transboundary Water Management Through Climate Change Adaptation and Cooperation Strategies. Master thesis. Delft University of Technology. Available in Delft University of Technology repository. https://repository.tudelft.nl/file/File_5d27ef52-b86e-4962-8117-8fa731490562.
- Ferrão, J., 2014. O Ordenamento Do Território Com Política Pública, 2nd. Fundação Calouste Gulbenkian.
- Fidélis, T., 2018. A articulação entre o planeamento territorial e sectorial: uma reflexão crítica sobre os recursos hídricos. TPU: Território, Planeamento e Urbanismo: Teoria e Prática 1 (13) [in Portuguese].
- Fidélis, T., Carvalho, T., 2015. Estuary planning and management: the case of Vouga Estuary (Ria de Aveiro), Portugal. *J. Environ. Plann. Manag.* 58 (7), 1173–1195. <https://doi.org/10.1080/09640568.2014.918874>.
- Frazão Santos, C., Ehler, C.N., Agardy, T., Andrade, F., Orbach, M.K., Crowder, L.B., 2019. Marine spatial planning. In: *World Seas – an Environmental Evaluation*. <https://doi.org/10.1016/3978-0-12-805052-1.00033-4>.
- Geneletti, D.A., 2015. Conceptual approach to promote the integration of ecosystem services in strategic environmental assessment. *J. Environ. Assess. Pol. Manag.* 17, 1550035. <https://doi.org/10.1142/S1464333215500350>.
- Gillard, R., Gouldson, A., Paavola, J., van Alstine, J., 2017. Can national blockages accelerate the development of polycentric governance? Evidence from climate change policy in the United Kingdom. *Glob. Environ. Change* 45, 174–182. <https://doi.org/10.1016/j.gloenvcha.2017.06.003>.
- Glavovic, B., 2024. Governance experiences and prospects in estuarine and coastal communities. In: Baird, D., Elliott, M. (Eds.), *Treatise on Estuarine and Coastal Science, Second 7. Academic Press, Oxford*, pp. 411–447.
- Grizzetti, B., Liqueste, C., Antunes, P., Carvalho, L., Geamăna, N., Giucă, R., Leone, M., McConnell, S., Preda, E., Santos, R., Turkelboom, F., Vădineanu, A., Woods, H., 2016. Ecosystem services for water policy: insights across Europe. *Environ. Sci. Pol.* 66, 179–190. <https://doi.org/10.1016/j.envsci.2016.09.006>.
- Guerreiro, J., Carvalho, A., Casimiro, D., Bonnin, M., Calado, H., Toonen, H., Fotso, P., Ly, I., Silva, O., da Silva, S.T., 2021. Governance prospects for maritime spatial planning in the tropical atlantic compared to EU case studies. *Mar. Pol.* 123, 104294. <https://doi.org/10.1016/j.marpol.2020.104294>.
- Hallett, C.S., Valesini, F., Elliott, M., 2016. A review of Australian approaches for monitoring, assessing and reporting estuarine condition: international context and evaluation criteria. *Environ. Sci. Pol.* 66, 260–269. <https://doi.org/10.1016/j.envsci.2016.07.014>.
- Holt, A., Godbold, J.A., White, P.C.L., Slater, A.M., Pereira, E.G., Solan, M., 2011. Mismatches between legislative frameworks and benefits restrict the implementation of the ecosystem approach in coastal environments. *MEPS* 434, 213–228. <https://doi.org/10.3354/meps09260>.
- Hornung, L.K., Podschun, S.A., Pusch, M., 2019. Linking ecosystem services and measures in river and floodplain management. *Ecosyst. People* 15 (1), 214–231. <https://doi.org/10.1080/26395916.2019.1656287>.
- Hulme, P.E., 2005. Adapting to climate change: is there scope for ecological management in the face of a global threat? *J. Appl. Ecol.* 42, 784–794. <https://doi.org/10.1111/j.1365-2664.2005.01082.x>.
- Jacobs, S., Vandenbrunaw, W., Vrebos, D., Beauchard, O., Boerema, A., Wolfstein, K., Maris, T., Saathoff, S., Meire, P., 2013. Ecosystem service assessment of TIDE estuaries. *Tidal River Dev.*
- Kenig-Witkowska, M.M., 2017. Natura 2000—The European Union mechanism for nature conservation. Some legal issues. *J. Comparat. Urban Law Pol.* 2 (1), 198–214. Available in: https://readingroom.law.gsu.edu/jculp/vol2/iss1/10?utm_source=readingroom.law.gsu.edu%2Fjculp%2Fvol2%2Fiss1%2F10&utm_medium=PDF&utm_campaign=PDFCoverPages.
- Kennish, M.J., 2002. Environmental threats and environmental future of estuaries. *Environ. Conserv.* 29 (1), 78–107. <https://doi.org/10.1017/S0376892902000061>.
- Kraan, M., Hendriksen, A., Van Hoof, L., Van Leeuwen, J., Jouanneau, C., 2014. How to dance? The tango of stakeholder involvement in marine governance research. *Mar. Pol.* 50, 347–352. <https://doi.org/10.1016/j.marpol.2014.05.010>.
- Kubiszewski, I., Ward, C., Pickett, K.E., Costanza, R., 2024. The complex relationships between economic inequality and biodiversity: a scoping review. *Anthropocene Rev.* 11 (1). <https://doi.org/10.1177/20530196231158080>.
- Laruelle, G.G., Rosentreter, J.A., Regnier, P., 2024. Extrapolation-based regionalized Re-evaluation of the global estuarine surface area. *Estuaries Coasts* 48 (2), 34. <https://doi.org/10.1007/s12237-024-01463-3>.
- Law no. 31/2014. Lei N.º 31/2014, de 30 de Maio. *Lei de Bases Gerais da Política Pública de Solos, de Ordenamento do Território e de Urbanismo*. Diário da República n.º 104/2014, Série I de 2014-05-30, pp. 2988 – 3003. Assembleia da República. [in Portuguese].
- Lawlor, P., Depellegrin, D., 2023. Managing land sea interactions: case studies of coastal governance in four EU member states. In: Partelow, S., Hadjimichael, M., Hornidge, A., Governance, Ocean (Eds.), *Knowledge Systems, Policy Foundations and Thematic Analyses*. Springer, ISBN 978-3-031-20740-2, pp. 209–230. <https://doi.org/10.1007/978-3-031-20740-2>.
- Lebel, L., Nikitina, E., Pahl-Wostl, C., Knieper, C., 2013. Institutional fit and river basin governance: a new approach using multiple composite measures. *Ecol. Soc.* 18 (1), 1. <https://doi.org/10.5751/ES-05097-180101>.
- Leitão, F., Baptista, V., Erzini, K., Iritani, D., Zeller, D., 2014. Reconstruction of mainland Portugal fisheries catches 1950–2010. *Univ. Br. Columbia Work.* 40 (2), 143–145. <https://doi.org/10.1111/birt.12047>.
- Lonsdale, J.A., Leach, C., Parsons, D., Barkwith, A., Manson, S., Elliott, M., 2022. Managing estuaries under a changing climate: a case study of the humber Estuary, UK. *Environ. Sci. Pol.* 134, 75–84. <https://doi.org/10.1016/j.envsci.2022.04.001>.
- Lonsdale, J., Nicholson, R., Weston, K., Elliott, M., Birchenough, A., Sühling, R., 2018. A user's guide to coping with estuarine management bureaucracy: an Estuarine Planning Support System (EPSS) tool. *Mar. Pollut. Bull.* 127, 463–477. <https://doi.org/10.1016/j.marpolbul.2017.12.032>.
- Lopez, I.P., Carrasco, S., Madrigal, C.M., 2024. Cartographic analysis as spatial determinant for climate change adaptation in the hunter river Estuary, Australia. *Cities* 125, 105162. <https://doi.org/10.1016/j.cities.2024.105162>.
- Louropoulou, E., Alonso Aller, E., Cardoso, A.C., Carravieri, A., Druon, J.N., Magliozzi, C., Martini, E., Mendes, C., Palma, M., Piroddi, C., Ruiz-Orejón, L.F., Zupan, M., Hanke, G., 2025. Programmes of Measures Under the Marine Strategy Framework Directive to Achieve or Maintain Good Environmental Status. Publications Office of the European Union, Luxembourg. Available in: <https://data.europa.eu/doi/10.2760/7769294,JRC139180>.
- MacDonell, C., Langlands, C., Keith, L., Naylor, L.A., Hurst, M.D., 2025. Southeast Scotland Coastal Risk Assessment: Dynamic Coast Analysis to Inform Climate Ready Southeast Scotland (CRSES). Final Report 11/04/2025. University of Glasgow, School of Geographical & Earth Sciences.
- Maia, A.C., Marques, T.S., 2019. Collaborative processes and spatial planning: the national spatial planning policy in Portugal. In: *Planning for Transition: Book of papers/venice AESOP Annual Congress*. <https://hdl.handle.net/10216/125460>.
- Moran, D., Dann, S., 2008. The economic value of water use: implications for implementing the water framework directive in Scotland. *J. Environ. Manag.* 87, 484–496. <https://doi.org/10.1016/j.jenvman.2007.01.043>.
- Moss, B., 2008. The water framework directive: total environment or political compromise? *Sci. Total Environ.* 400, 32–41. <https://doi.org/10.1016/j.scitotenv.2008.04.029>.
- Nadin, V., Stead, D., 2013. Opening up the compendium: an evaluation of international comparative planning research methodologies. *Eur. Plan. Stud.* 21 (10), 1542–1561. <https://doi.org/10.1080/09654313.2012.722958>.
- Næsje, T.F., Rivers, N., Wood, A.D., Andersen, O., Mishi, S., Murray, T.S., Snow, B., Strand, M., Bøoi, S., Nonyane, C.L., Cowley, P.D., 2023. Benchmarking Knowledge-based Adaptive Management of Estuarine Fisheries in South Africa for Sustainable Development (NINA Report 2312; P. 122). South African Institute for Aquatic Biodiversity, Norwegian Institute for Nature Research and Institute for Coastal and Marine Research. Nelson Mandela University.
- Nash, J.R., 2000. Too much market? Conflict between tradable pollution allowances and the 'polluter pays' principle. *Harv. Environ. Law Rev.* 24 (2), 465–535.
- Newman, P., Thornley, A., 1996. *Urban Planning in Europe: International Competition, National Systems and Planning Projects*, 1st. Routledge. <https://doi.org/10.4324/9780203427941>.
- O'Hagan, A.M., Paterson, S., Tissier, M.L., 2020. Addressing the tangled web of governance mechanisms for land-sea interactions: assessing implementation challenges across scales. *Mar. Pol.* 112, 103715. <https://doi.org/10.1016/j.marpol.2019.103715>.
- O'Leary, J.K., Bockmon, E.E., Goodman, M., Grimsditch, G., Madej, M.A., Mohammed, A., Tyburczy, J., 2023. Conserving and managing estuaries during climate change. In: *Climate Change and Estuaries*, first ed. CRC Press, Taylor & Francis Group. <https://doi.org/10.1201/978103126096>.
- Ostrom, E., 2002. Property-rights regimes and common goods: a complex link. In: *Common Goods: Reinventing European Integration Governance*. Rowman and Littlefield, pp. 29–58.
- Ostrom, E., 2010. Beyond markets and states: policentric governance of complex economic systems. *Am. Econ. Rev.* 100, 641–672.
- Paerl, H.W., Bales, J.D., Ausley, L.W., Buzzelli, C.P., Crowder, L.B., Eby, L.A., Fear, J.M., Go, M., Peierls, B.L., Richardson, T.L., Ramus, J.S., 2001. Ecosystem impacts of three sequential hurricanes (Dennis, Floyd, and Irene) on the United States' largest lagoonal estuary, Pamlico Sound, NC. *Proc. Natl. Acad. Sci. USA* 98 (10), 5655–5660. <https://doi.org/10.1073/pnas.10109739>.
- Pahl-Wostl, C., Gorris, P., Jager, N., Koch, L., Lebel, L., Stein, C., Venghaus, S., Withanachchi, S., 2021. Scale-related governance challenges in the water–energy–food nexus: toward a diagnostic approach. *Sustain. Sci.* 16 (2), 615–629. <https://doi.org/10.1007/s11625-020-00888-6>.
- Pahl-Wostl, C., Knieper, C., 2014. The capacity of water governance to deal with the climate change adaptation challenge: using fuzzy set qualitative comparative analysis to distinguish between polycentric, fragmented and centralized regimes. *Glob. Environ. Change* 29, 139–154. <https://doi.org/10.1016/j.gloenvcha.2014.09.003>.
- Paramana, Th., Dassenakis, M., Bassan, N., Dallangelo, C., Campostrini, P., Raicevich, S., Ronchi, F., Giorgi, G., Murillas-Maza, A., Uyerra, M.C., Papadopoulou, N., Smith, C., Jarni, K., Koren Bačovnik, Š., Klančík, K., Pavičić, M., Skejić, S., Vidjak, O., Cadiou, J.F., et al., 2023. Achieving coherence between the marine strategy framework directive and the maritime spatial planning directive. *Mar. Pol.* 155, 105733. <https://doi.org/10.1016/j.marpol.2023.105733>.
- Preston, B.L., 2004. Observed winter warming of the Chesapeake Bay estuary (1949–2002): implications for ecosystem management. *Environ. Manag.* 34 (1), 125–139. <https://doi.org/10.1007/s00267-004-0159-x>.

- Qiu, W., Jones, P.J.S., 2013. The emerging policy landscape for marine spatial planning in Europe. *Mar. Pol.* 39, 182–190. <https://doi.org/10.1016/j.marpol.2012.10.010>.
- Rees, S.E., Ashley, M., Cameron, A., Mullier, T., Ingle, C., Oates, J., Lannin, A., Hooper, T., Attrill, M.J., 2022. A marine natural capital asset and risk register – towards securing the benefits from marine systems and linked ecosystem services. *J. Appl. Ecol.* 59 (4), 1098–1109. <https://doi.org/10.1111/1365-2664.14121>.
- Resolution of the Council of Ministers No. 136/2024, Resolução do Conselho de Ministros n.º 136/2024, de 16 de Outubro. Diário da República n.º 201/2024, Série I, Presidência do Conselho de Ministros. [in Portuguese].
- Resolution of the Council of Ministers No. 203-A/2019, Resolução do Conselho de Ministros n.º 203-A/2019, de 30 de Dezembro. Diário da República n.º 250/2019, Série I, 2-391, Presidência do Conselho de Ministros. [in Portuguese].
- Rodrigues, A.G.M., 2024. Exploração de Aquíferos Estuarinos, em Contexto de Alterações Climáticas: O Caso do Estuário do Sado. Master Thesis. Universidade de Lisboa. Available in Universidade de Lisboa Repository. <http://hdl.handle.net/10451/65206>.
- Rodrigues, C., Fidélis, T., 2021. Distinctive features of spatial planning nearby estuaries – an exploratory analysis of water-related rules in municipal master plans in Portugal. *Estuar. Coast Shelf Sci.* 255, 107352. <https://doi.org/10.1016/j.ecss.2021.107352>.
- Roux, D.J., Taplin, M., Smit, I.P.J., Novellie, P., Russell, I., Nel, J.L., Freitag, S., Rosenberg, E., 2023. Co-Producing narratives and indicators as catalysts for adaptive governance of a common-pool resource within a protected area. *Environ. Manag.* 72, 1111–1127. <https://doi.org/10.1007/s00267-023-01884-z>.
- Ruhl, J.B., Craig, R.K., 2011. New sustainable governance institutions for estuaries and coasts. In: McLusky, D., Wolanski, E. (Eds.), *Treatise on Estuaries and Coastal Science*, pp. 239–270. ISBN 978-0-12-374711-2.
- Scanes, E., Scanes, P.R., Ross, P.M., 2020. Climate change rapidly warms and acidifies Australian estuaries. *Nat. Commun.* 11, 1803. <https://doi.org/10.1038/s41467-020-15550-z>.
- Schmidt, L., 2008. Ambiente e Políticas Ambientais: escalas e Desajustes. In: Cabral, M. V., Wall, K., Aboim, S., Silva, F.C. (Eds.), *Itinerários. A Investigação Nos 25 Anos Do ICS*. Instituto de Ciências Sociais, pp. 285–314.
- Schumacher, D., 1973. *Small is Beautiful. Blond&Briggs*.
- Slinger, J.H., 2023. Developing the transboundary long term vision of the scheldt Estuary—an untold story. *Water Int.* 48 (8), 1046–1067. <https://doi.org/10.1080/02508060.2023.2264668>.
- Sondermann, M., Proenca de Oliveira, R., 2022. Climate adaptation needs to reduce water scarcity vulnerability in the Tagus river basin. *Water* 14, 2527. <https://doi.org/10.3390/w14162527>.
- Stelzenmüller, V., Breen, P., Stamford, T., Thomsen, F., Badalamenti, F., Borja, Á., Buhl-Mortensen, L., Carlstöm, J., D'Anna, G., Dankers, N., Degraer, S., Dujin, M., Fiorentino, F., Galparsoro, I., Giakoumi, S., Gristina, M., Johnson, K., Jones, P.J.S., Katsanevakis, S., et al., 2013. Monitoring and evaluation of spatially managed areas: a generic framework for implementation of ecosystem based marine management and its application. *Mar. Pol.* 37, 149–164. <https://doi.org/10.1016/j.marpol.2012.04.012>.
- Sundseth, K., 2018. *Natura 2000: Protecting Europe's Biodiversity*. Information Press. Available in: <https://op.europa.eu/en/publication-detail/-/publication/e4d56202-545d-43d8-972c-6be52cc8fec3>.
- Swart, R., Biesbroek, R., Binnerup, S., Carter, T.R., Cowan, C., Henrichs, T., Loquen, S., Mela, H., Morecroft, M., Reese, M., Rey, D. (Eds.), 2009. *Europe Adapts to Climate Change: Comparing National Adaptation Strategies*. PEER.
- Taljaard, S., van Niekerk, L., Weerts, S.P., 2019. The legal landscape governing South Africa's coastal marine environment – helping with the 'horrendogram'. *Ocean Coast Manag.* 178, 104801. <https://doi.org/10.1016/j.ocecoaman.2019.05.003>.
- Tulumello, S., Cotella, G., Othengrafen, F., 2018. Spatial planning and territorial governance in Southern Europe between economic crisis and austerity policies. *Int. Plan. Stud.* 25 (1), 72–87. <https://doi.org/10.1080/13563475.2019.1701422>.
- Wakefield, J., 2010. Undermining the integrated maritime Policy. *Mar. Pollut. Bull.* 60, 323–333. <https://doi.org/10.1016/j.marpolbul.2009.12.023>.
- Wang, Y., Li, X., Zhang, Q., Li, J., Zhou, X., 2018. Projections of future land use changes: multiple scenarios-based impacts. *Ecol. Indic.* 94 (1), 430–445. <https://doi.org/10.1016/j.ecolind.2018.06.047>.
- West, J.M., Julius, S.H., Kareiva, P., Enquist, C., Lawler, J.J., Petersen, B., Johnson, A.E., Shaw, M.R., 2009. U.S. natural resources and climate change: concepts and approaches for management adaptation. *Environ. Manag.* 44, 1001–1021. <https://doi.org/10.1007/s00267-009-9345-1>.