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Assessing the role and functioning of Science-Policy-Society Interfaces in EU Green Deal-related marine policies

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ABSTRACT

The European Green Deal (EGD) proposes a transformative agenda that depends on the coherent design and implementation of environmental policies, including those related to the marine environment. Science-Policy-Society Interfaces (SPSIs) are central to this process, but show uneven performance and sometimes fragmented operation. This paper uses a methodology from the Horizon Europe CrossGov project to assess SPSIs in various policy and governance contexts, focusing on their role in promoting coherence in EU marine policies (Marine Strategy Framework Directive - MSFD, Water Framework Directive - WFD, Maritime Spatial Planning Directive - MSPD) and in delivering EGD objectives. The analysis finds SPSIs are often institutionalised and effective in supporting evidence-based policy-making, yet challenges persist: data integration gaps, inconsistent knowledge transfer, limited societal involvement, and strong sectoral compartmentalisation. Nevertheless, SPSIs show strong potential to support evidence uptake and adaptive governance, especially with collaborative, participatory approaches. Based on these findings, the paper presents recommended actions: cross-cutting measures to strengthen governance models, competence frameworks, and long-term funding, as well as targeted actions for WFD, MSFD, and MSPD. Together, these recommendations can enhance SPSIs' role in evidence-informed policy-making, improve policy coherence, and foster adaptive, legitimate ocean governance, supporting the ambitions of the European Green Deal.

1. Introduction

The European Green Deal (EGD) (European Commission, 2019) calls for deeply transformative policies across all relevant sectors to tackle climate and environmental challenges, creating a fair and prosperous society where economic growth is decoupled from resource use, natural ecosystems are protected and restored, and human health is improved. These ambitions also have direct implications for policies affecting the marine domain, including framework directives and sectoral policies.

Effective governance of the marine domain requires coherence, which can ensure that policies across sectors and governance levels align, so that achieving one target does not undermine another - an imperative for delivering the EGD's integrated goals on biodiversity, climate adaptation, and pollution reduction (Platjouw et al., 2026). Tackling interconnected challenges such as biodiversity loss and climate change requires governance approaches that identify synergies and foster cooperation rather than conflict. However, achieving this is not only a matter of policy design; it also depends on robust Science-Policy-Society Interfaces (SPSIs) that can translate complex knowledge into actionable strategies, handle uncertainty systematically, and integrate diverse perspectives (Balvanera et al., 2020; Ramírez-Monsalve et al., 2016). Within this framework, science is not only a

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source of evidence but also responsive to societal values, concerns, and forms of engagement, recognising society's role as a contributor to data, information, and knowledge (Hansson and Polk, 2018; Shaikh Khatibi et al., 2021; Mach and Kraan, 2021). Strengthening SPSIs is critical to building legitimacy, inclusiveness, and evidence-based decision-making, ensuring that coherence moves from principle to practice. The Ocean Pact (European Commission, 2025a) has underscored the need for coherent, knowledge-informed ocean governance in line with the EGD's transformative ambitions.

The delivery of the EGD's ambitious and interconnected targets depends on various directives, including the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD), and the Maritime Spatial Planning Directive (MSPD), formulated and implemented by different authorities, at different times, and with different institutional logics, monitoring cycles, and implementation pathways (Boteler et al., 2024; Platjouw et al., 2026). This fragmentation makes it difficult for any single policy to deliver its objectives without either depending on or interfering with the others (Nilsson et al., 2016; Kyrönviita et al., 2024). Knowledge, moreover, is unevenly distributed across actors, sectors, and governance levels: natural science perspectives dominate, while socio-economic expertise, local knowledge, and civil society inputs remain underrepresented in many policy processes (European Commission, 2022; Van Leeuwen et al., 2025). As a result, SPSIs often operate in policy-specific silos, limiting their capacity to support the cross-sectoral, multi-level knowledge integration that coherent EGD implementation requires (Barbanti et al., 2023).

Since 2015, the European Commission (EC) has launched, directly or through its Joint Research Centre (JRC), a series of initiatives to connect policy-making with research and promote evidence-informed policy-making (European Commission, 2022; Šucha and Sienkiewicz, 2020), including the Horizon Europe Policy Support Facility and the Knowledge4Policy Platform (European Commission, 2024a), and funding specific research projects such as CrossGov, to study how better SPSIs can contribute to effective ocean governance. At Member State level, several public administrations have strengthened their science advisory structures and set up new boundary organisations (European Commission, 2022; Guston, 2001; Cash et al., 2003).

A substantial body of literature recognises that well-functioning SPSIs contribute to more effective and legitimate policy and decision-making processes (Wagner et al., 2023; European Commission, 2022; Cvitanovic et al., 2015; 2021; Kettle et al., 2017), including enhanced coherence of EGD-related marine policies. Nevertheless, there is limited understanding of factors that deliver or strengthen the effectiveness of SPSIs (Wagner et al., 2023; Koetz et al., 2012; Capano and Malandrino, 2022; Cvitanovic et al., 2016; Kano and Hayashi, 2021). This is particularly relevant when multiple policy objectives should contribute coherently to the same ambitious and transformative vision, as in the case of EU marine policies and the EGD.

The present study, building on research conducted in the Horizon Europe CrossGov project (Capurso et al., 2025), aims to advance knowledge of effective SPSIs development and deepen research on policy design and implementation. The approach entails a systematic and comprehensive investigation of key aspects of SPSIs' functioning to inform the design and implementation of EU marine and EGD-related policies addressing ocean sustainability, with a particular focus on EGD goals for biodiversity, climate adaptation, and pollution reduction. The research identifies barriers, needs, and recommendations for effective SPSIs that support policy coherence in both its vertical and horizontal dimensions (Platjouw et al., 2026).

Building on investigations in selected case studies, the research addressed the following questions:

1. What are the characteristics of SPSIs in the analysed governance contexts, and what common patterns emerge in terms of their functioning and their contribution to policy coherence? (Section 4)
2. What needs emerge as critical to improve the performance of SPSIs, and what recommendations can enhance their contribution to evidence-informed and coherent marine policy-making? (Section 5)

The paper is structured as follows. Section 2 provides the conceptual framework. Section 3 presents the methodology developed and applied to assess SPSIs. Section 4 presents the results of the assessment, addressing the first research question by characterising the Science-Policy-Society Ecosystems (SPSEs) and the practices and impacts identified for each Building Block (BB) across the seven case studies (see Section 3 for definitions of BB and SPSEs). Section 5 addresses the second research question through a discussion of cross-cutting and policy-specific recommendations, followed by an assessment of the methodology's strengths and limitations, and concluding considerations.

2. Conceptual framework

2.1. Science-Policy-Society Interfaces

SPSIs are defined as social processes encompassing interactions among the actors involved in the policy process, enabling the exchange, co-evolution, and joint construction of knowledge to inform decision-making (Van Den Hove, 2007). Research distinguishes between linear models in which knowledge flows unidirectionally from researchers to policymakers, and collaborative models involving iterative, multi-directional exchanges among scientists, decision-makers, and societal actors (Koetz et al., 2012; Sokolovska et al., 2019). Collaborative models are increasingly preferred, as they integrate diverse knowledge types, accommodate uncertainty, and build legitimacy through inclusive deliberation (Gluckman et al., 2021; Strand, 2022). SPSI effectiveness can be evaluated along three dimensions: relevance (the salience of knowledge to decision-makers' needs), credibility (the scientific adequacy of the evidence), and legitimacy (the transparency and inclusiveness in knowledge production) (Cash et al., 2003). Boundary organisations, institutions operating at the interface of science and policy to facilitate knowledge exchange, play a crucial role in maintaining these qualities across institutional contexts (Gustafsson and Lidskog, 2017; Cvitanovic et al., 2018). When well-designed and implemented effectively, SPSIs can improve policy coherence, enhance legitimacy of policy decisions, and support adaptive governance to evolving knowledge and societal needs (Wesselink et al., 2013; Maas et al., 2022; Turnhout, 2024).

Despite growing recognition of their importance, the factors determining SPSI effectiveness remain only partly understood (Wagner et al., 2023; Koetz et al., 2012). Existing frameworks tend to focus on specific policy domains or single aspects of the interface, without providing an integrated tool for assessing SPSIs across multiple policies and governance levels simultaneously. The methodology developed within CrossGov (Barbanti et al., 2023) was designed to offer a structured yet flexible framework that captures the main constituent elements of SPSIs and their contribution to policy coherence in the marine governance context.

2.2. Policy coherence and its relationship with SPSIs

Policy coherence refers to the extent to which policies strengthen each other by promoting synergies or reducing conflicts between their objectives and measures, both in design and during implementation (Platjouw et al., 2026). It can be assessed horizontally, between policies at the same governance level, or vertically, between governance levels (Platjouw et al., 2026). Policy coherence has been studied extensively in the context of sustainable development governance (Nilsson et al., 2012; Stafford-Smith et al., 2017) and, more recently, in relation to the EU environmental policy landscape (Platjouw et al., 2026; Kyrönviita et al., 2024). Both dimensions of coherence in policy design and in implementation are relevant to this study: while EU marine directives may be coherent in design intent, incoherence frequently emerges at the implementation stage, where institutional fragmentation, misaligned monitoring cycles, and sectoral knowledge silos produce divergent outcomes (Boteler et al., 2024).

SPSIs are potential critical enablers of policy coherence. By generating and transferring integrated, cross-sectoral knowledge, they can make policy interactions visible, reduce the risk that one policy's objectives undermine another's, and build the shared understanding needed for coherent implementation (Cash et al., 2003; Barbanti et al., 2023; Wagner et al., 2023). Collaborative, multi-actor knowledge production also builds the mutual trust and legitimacy needed for coherent implementation across governance levels (Koetz et al., 2012; Gluckman et al., 2021). The analysis of SPSIs' contribution to coherence forms a specific attribute within the CrossGov Policy Coherence Evaluation Framework (Boteler et al., 2024; Platjouw et al., 2026), underscoring the recognition that SPSI performance is not separate from, but constitutive of, policy coherence.

3. Methods

3.1. Setting up a methodology for SPSIs analysis

We developed a novel methodology (Barbanti et al., 2023) to assess SPSIs' role in formulating and implementing marine and EGD-related policies, capitalising on a large body of literature. The methodology responds to the needs of being: (i) operational, (ii) flexible, adaptable and applicable to different policies and across policies, to various phases of the policy cycle and geographic scopes, (iii) comprehensive, to capture the many aspects influencing SPSIs' functioning and effectiveness, (iv) targeted to the analysis of SPSIs' capacity in promoting policy coherence. The methodology is operationalised through a step-by-step procedure (see Fig. 1) and is intended to provide a replicable process for any user interested in analysing the role and function of SPSIs in policy formulation and implementation.

3.1.1. Step 1: inception phase - scope and problem definition

In Step 1, the user defines: (i) the scope of the analysis (e.g., a self-assessment or an external assessment to identify actions on governance, use of resources, capacity building); (ii) the geographical scope (local, regional, national, sea basin, EU-level, and the time frame of the analysis); (iii) the policies and the stages of the policy process under analysis (i.e., policy design and formulation, implementation, evaluation, and adaptation; (iv) the main research questions for the analysis, e.g., addressing the type of knowledge needed, its current provision, and its contribution to horizontal and vertical policy coherence (detailed in Supplementary material (A)).

Based on the above points, the user defines the sources of information to be used, ranging from documentation (e.g., websites, scientific publications, project reports, policy and legal documents, communications and reports, environmental assessments) to stakeholder inputs (e.g., questionnaires, interviews, workshops).

3.1.2. Step 2: mapping the Science-Policy-Society Ecosystem

Step 2 aims to define the Science-Policy-Society Ecosystem (SPSE) under analysis, which provides the structural context for the overall SPSI analysis. While an SPSE refers to the set of actors, including civil society, and the connections through which knowledge is acquired, synthesised, translated, presented for use, and applied in the policy-making process (adapted from Oliver, 2022, and European Commission, 2022), SPSIs refer to the relational processes, the actual exchanges, co-evolution, and joint knowledge construction, occurring within and across that ecosystem. Mapping the SPSE (Step 2) is therefore a prerequisite for the Building Blocks (BBs) analysis (Step 3): understanding who the actors are, what roles they play, and how they are connected provides the structural context within which SPSI practices, impacts, and needs can be identified and interpreted. A conceptual map can be developed to visualise the SPSE, organised in eight compartments (Fig. 2; Supplementary material (A)), to visualise the SPSE, distinguishing evidence generators, evidence users, and hybrid actors. An example map is presented in Section 4.1, focusing on the Northern Adriatic Sea and a policy cluster composed of WFD, MSFD, MSPD, fisheries, aquaculture, and biodiversity policies.

3.1.3. Step 3: analysis of SPSI Building Blocks

The analytical framework is grounded in six Building Blocks that represent the core elements of SPSIs relevant to EGD-related marine policies (Table 1). These six BBs were identified through a review of the literature on SPSI and science-to-policy processes (reported in Table 1), and through iterative discussion with CrossGov project partners and Advisory Board Members (Barbanti et al., 2023). The selected BBs represent the main constituent elements of SPSI that are relevant to EGD-related marine policies, i.e., those elements whose characteristics determine whether SPSIs can effectively support evidence-based, coherent policy-making. Step 3 deals with the analysis of such BBs, grouped as Outputs of SPSIs (BB-A and BB-B), Methods or tools through which SPSIs operate (BB-C and BB-D), or Inputs (BB-E and BB-F) to SPSIs functioning. 'Outputs' refer to the knowledge products generated by SPSIs that feed into policy-making processes, i.e., data, knowledge and assessments. 'Methods' refer to the mechanisms and organisational structures through which knowledge is transferred and exchanged between science, policy, and society actors, i.e., models of scientific policy advice and knowledge transfer mechanisms and SPSI platforms. 'Inputs' refer to the enabling conditions, i.e., human capacities and financial resources, that sustain the functioning of the whole system. To guide and facilitate the analysis, attributes have been identified for each BB (Table 1), with associated specific guiding questions (reported in Supplementary material (A)). While all BBs can contribute to the analysis, the inception phase (Step 1) can identify the most relevant ones based on the analysis's scope and its guiding questions.

3.2. Applying the methodology

Within CrossGov, specific policies or policy areas for the application of the methodology were not pre-identified; instead, they were identified in Step 1 for each of the seven case studies considered across different EU sea basins (see Fig. 3 and Table 2).

The seven case studies were selected in the project on the basis of three criteria: (i) geographic diversity, covering four distinct European sea basins (Adriatic-Mediterranean, North Sea, Baltic Sea, and Norwegian waters); (ii) diversity in governance context, including cases at

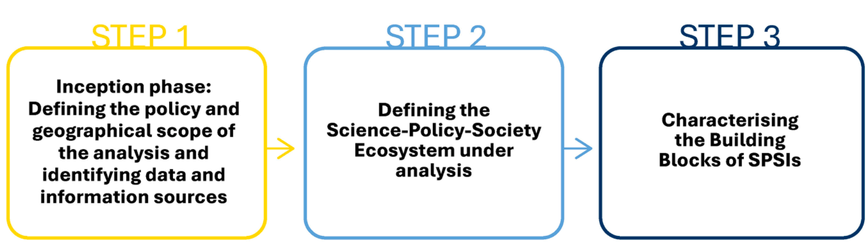

Fig. 1. Schematic overview of the step-by-step procedure. It illustrates the three steps proposed by the methodology.

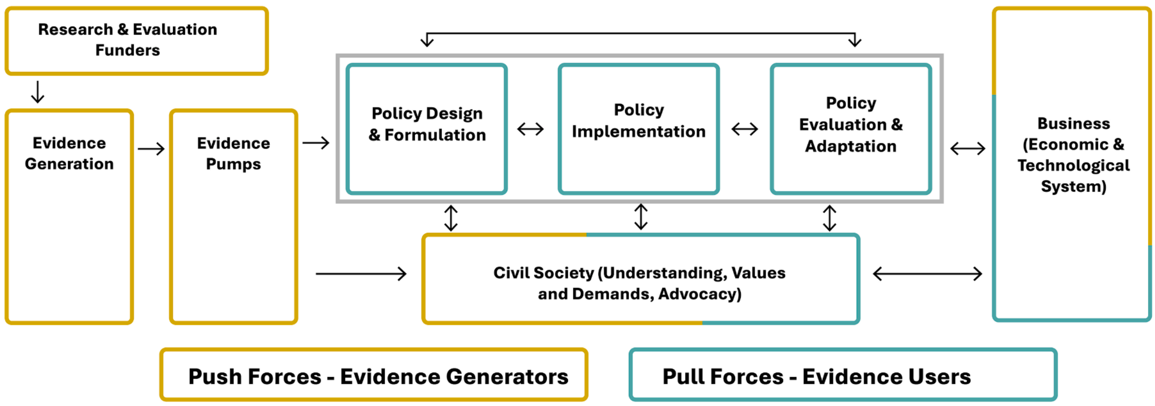

Fig. 2. Conceptual map of the Science-Policy-Society Ecosystem (SPSE). It illustrates the eight compartments that can be used to organise the actors of the SPSE and their connections. The colours differentiate between evidence generators (yellow), evidence users (green), and hybrid actors (both colours).

Table 1
The six Building Blocks analysed in Step 3.

Building Block	Typology	Description	Key Attributes	Refs.
A - Data & knowledge	Outputs	How data and knowledge are made available and used in the policy-making and decision-making process.	Availability and access to data; Gaps and uncertainty; Problem framing.	Oliver et al., 2021; Böcher and Krott, 2014; Breuer et al., 2019; Brugnach et al., 2007; Stafford-Smith et al., 2017; Sokolovska et al., 2019; Cvitanovic et al., 2015
B - Assessments	Outputs	How assessments assemble the best knowledge available in a form useful for decision-making.	Credibility, Relevance, and Legitimacy; Data and knowledge providers; Problem framing.	UNEP and IOC-UNESCO, 2009; Cash et al., 2003; Edenhofer and Kowarsch, 2015; Zeigermann, 2021; Oliver, 2022; Strand, 2022; Wagner et al., 2023; Nilsson et al., 2016, 2018; Mach and Kraan, 2021
C - Models of scientific policy advice and knowledge transfer mechanisms	Methods	Models and transfer mechanisms used and their effectiveness.	Type of model; Credibility, Relevance and Legitimacy; Type of transfer mechanisms; Utilisation.	Koetz et al., 2012; Kettle et al., 2017; Sokolovska et al., 2019; United Nations Department of Economic and Social Affairs, 2021; Böcher and Krott, 2014; Cvitanovic et al., 2015; Oliver et al., 2021, 2022; Wagner et al., 2023; Strand, 2022; European Commission, 2022; Maas et al., 2022; Gluckman et al., 2021; Cvitanovic et al., 2015; Fazey et al., 2020
D - Permanent SPSI platforms	Methods	Permanent platforms (e.g., expert panels, Communities of Practice, SPSI networks, research outreach associations, co-developed web platforms) and their role in SPS and in implementing knowledge transfer mechanisms.	Type and role of platforms; Participants; Problem framing.	European Commission, 2021, 2022; Wagner et al., 2023; Cvitanovic et al., 2018; Hrabanski and Pesche, 2016; Gustafsson and Lidskog, 2017
E - Competence framework for researchers and policy-makers	Inputs	How competence frameworks (i.e., interdisciplinary knowledge, skills, and attitudes) and related capacity-building activities influence the SPS process.	Type of competence; List of competences; Training & capacity building activities and targets.	Hrabanski and Pesche, 2016; Schwendinger et al., 2022; Penca et al., 2024; Wagner et al., 2023; European Commission, 2022; Topp et al., 2018; Maas et al., 2022; Blythe and Cvitanovic, 2020
F - Funding & resources	Inputs	How funding and availability of infrastructures and human resources affect the multiple dimensions of SPSIs.	Type of funding; Drivers for funding; Level and adequacy of funding and resources (including human resources).	Dale et al., 2019; Oliver et al., 2021; Pereira et al., 2006; Wagner et al., 2023

different stages of policy implementation and with different combinations of institutional arrangements; and (iii) policy mix relevance, i.e., involving the three directives under analysis (WFD, MSFD, MSPD) and/or relevant sectoral policies (fisheries, agriculture, climate change or offshore wind energy). Together, the seven cases provide sufficient variation to identify both case-specific dynamics and cross-cutting patterns in SPSI functioning and policy coherence challenges.

The analysis focuses on three EU directives that constitute the core framework for marine environmental governance in the context of the EGD: the WFD (2000/60/EC), the MSFD (2008/56/EC), and the MSPD (2014/89/EU). The WFD establishes a framework for the protection and improvement of aquatic ecosystems, aiming at 'good ecological status' for all surface and coastal water bodies, implemented through River Basin Management Plans (RBMPs). The MSFD requires Member States to achieve and maintain 'good environmental status' (GES) of their marine waters through programmes of measures and related monitoring programmes. The MSPD requires Member States to establish maritime spatial plans that integrate and balance different sea uses with environmental objectives. These three directives were selected because they collectively address the marine components of the EGD's core environmental streams (biodiversity, zero pollution, and climate resilience), they share overlapping geographical scopes and implementation timelines, and they are central to the EGD's ambitions for coherent ocean governance (Boteler et al., 2024).

The methodological approach was adapted to the specific characteristics of each case study, focusing on the BBs and guiding questions identified as relevant for that case in Step 1. The research integrated document and policy analysis with semi-structured interviews conducted between June 2023 and March 2025. These interviews engaged a range of experts and stakeholders, from local to EU levels, to validate and expand the findings (see Table 3).

The analysis highlighted the diversity of SPSEs and their components

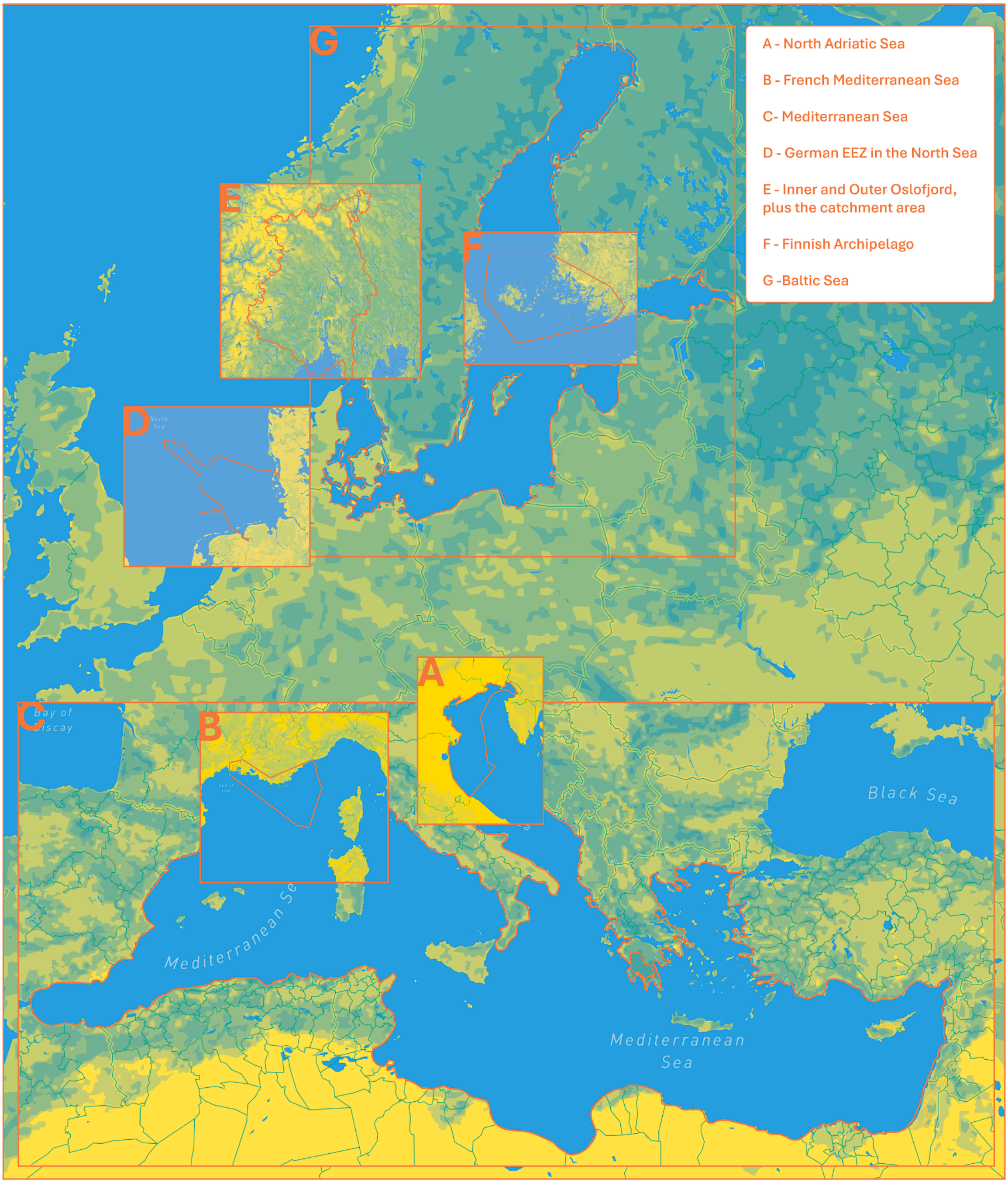

Fig. 3. Map of the seven case studies included in the analysis. The red lines indicate case study boundaries. Rectangles indicate the letters used in the legend to identify each case study. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

(Section 4.1) and enabled us to identify, for each BB, a set of recurrent practices, i.e., observable patterns in how SPSIs function across cases, and their related impacts on evidence-based policy-making and policy coherence. Practices were characterised per BB attribute, and their positive or negative implications for coherence were assessed (see Section 4.2). On this basis, we derived a set of preliminary needs: the types of science, knowledge, interactions, and structural conditions required to improve SPSI performance and support more coherent policy implementation. These needs, which emerge directly from practices identified as insufficient or absent, and from impacts assessed as negative or coherence-limiting, are listed in Supplementary material (C).

The preliminary needs were then validated, refined, and co-developed into recommended actions through two rounds of expert focus groups involving EU-level SPSI experts (see Table 3). The first round (November 2024) focused on consolidating the needs derived from the case study analysis. The second round (February 2025) translated those needs into concrete recommended actions (listed in Supplementary material (D)). This iterative co-creation process ensured that the recommendations are practically grounded, context-sensitive, and aligned with the perspectives of the actors engaged in EU marine governance.

4. Results

This section addresses the first research question by presenting the results of the SPSI assessment across seven case studies. Section 4.1

Table 2
List of seven case studies with corresponding short descriptions and objectives, and policies under analysis.

Case study	Short description/ objective	Policies under analysis
North Adriatic Sea	The case study examines two interrelated objectives: (i) the degree of integration among WFD, MSFD, and MSPD planning processes and their contribution to EGD goals; and (ii) the extent to which EGD biodiversity objectives are mainstreamed into fisheries, aquaculture, and biodiversity policies, identifying opportunities and barriers to this integration.	WFD, MSFD, MSPD, fisheries, aquaculture, and biodiversity policies (including EGD goals on this)
French Mediterranean Sea	The case study investigates the coherence of WFD river basin management, MSFD strategies, and maritime spatial plans at the land-sea interface in the French Mediterranean. It further examines how the implementation of sectoral policies in fisheries and offshore wind energy interact with marine framework objectives and EGD targets.	MSFD, WFD, MSPD, fisheries, energy, and biodiversity policies (including EGD goals on these)
Mediterranean Sea	The case study analyses the integration of biodiversity and climate change policy goals into fisheries management at the scale of the entire Mediterranean basin, extending beyond the EU policy context to include the Barcelona Convention, General Fisheries Commission for the Mediterranean (GFCM), and International Commission for the Conservation of Atlantic Tunas (ICCAT). It examines alignment between EU and regional policy frameworks and identifies options for strengthening cross-scale integration.	Fisheries, biodiversity, and climate change policies (including EGD goals on these)
German Exclusive Economic Zones (EEZ) in the North Sea	The case study analyses how Strategic Environmental Assessments (SEAs) contribute to balancing offshore wind energy expansion targets under the Renewable Energy Directive (RED III) with biodiversity conservation obligations under MSFD in the German North Sea EEZ. It examines the strengths and weaknesses of SEAs in practice, including the treatment of cumulative impacts, transboundary effects, and long-term policy coherence towards EGD 2030 and 2050 objectives.	SEA role in offshore wind farms (OWF), MSPD, MSFD, and biodiversity policies (including EGD goals on these)
Inner and Outer Oslofjord plus the catchment area	The case study examines horizontal coherence among River Basin Management Plans, municipal spatial plans, and Norwegian Integrated Ocean Management Plans in the Oslofjord area, including the catchment area. It assesses how the interplay between these cross-sectoral instruments addresses cumulative impacts and contributes to EGD biodiversity and water quality objectives, with particular attention to the role of the government's Oslofjord Plan as an additional governance layer.	WFD, Ocean Management Plan for the North Sea, Governmental action plan for the Oslofjord (including EGD goals on biodiversity)
Finnish Archipelago	The case study focuses on the implementation and integration of WFD, MSFD, and MSPD planning processes in the Archipelago Sea, a Baltic Sea hotspot for eutrophication. It examines coherence challenges between water, agriculture, and aquaculture policies in achieving the EGD Zero Pollution objective, combining a regional focus with national and transnational policy analysis.	WFD, MSFD, MSPD (including EGD goals on pollution)
Baltic Sea	The case study examines the vertical and horizontal coherence of EU and regional instruments, including WFD, MSFD, MSPD, the Helsinki Convention, and the Baltic Sea Action Plan, in addressing eutrophication, biodiversity loss, and offshore wind energy development in the Baltic Sea. It analyses how coherence among these instruments and policies affects the implementation of EGD objectives, with a focus on the Zero Pollution Action Plan, Biodiversity Strategy 2030, and Sustainable Blue Economy Strategy.	WFD, MSFD, MSPD, agriculture, and OWE policies (including EGD goals on pollution, climate adaptation, sustainable blue economy, and biodiversity)

characterises the SPSEs identified in the analysed governance contexts, providing the structural basis for understanding how actors and knowledge flows are configured. Section 4.2 presents the analysis of the six BBs, identifying recurrent practices and their impacts on policy coherence across cases.

4.1. Structure and configuration of Science-Policy-Society Ecosystems across case studies

The analysis across the different case studies identified a complex, multi-layered configuration of actors within the SPSEs, each performing distinct yet sometimes overlapping roles in relation to evidence production, transfer, and use for evidence-based policy-making. The North Adriatic case is used here as an illustrative example, given its particularly articulated SPSE configuration encompassing multiple overlapping

Table 3
Number of stakeholders and experts involved in the different steps of the analysis process.

Phase of the analysis	Case study	Policy-makers	Researchers and technical advisors/agencies	Civil society (non-governmental organisations - NGOs)	Sectors' operators	Total number of stakeholders and experts involved
Case studies analyses	North Adriatic Sea	5 (sub-national level)	2	2	\	9
Case studies analyses	French Mediterranean Sea	9 (sub-national level)	2	2	3	16
Case studies analyses	Mediterranean Sea	14 (8 at the international level and 6 at the EU-level)	3	3	\	20
Case studies analyses	German North Sea	3 (at the national level)	1	4	2	11
Case studies analyses	Oslofjord	11 (5 at the national level and 6 at the sub-national level)	\	2	2	15
Case studies analyses	Finnish Archipelago and Baltic Sea	7 (1 at the international level, 2 at the national level, and 4 at the sub-national level)	\	1	1	9
Focus groups: discussion of case study practices, identification of needs, formulation of recommendations	\	9 (2 at the international level and 7 at the EU-level)	3	1	\	14

policies (WFD, MSFD, MSPD, fisheries, biodiversity) and a diverse set of actor types across all governance levels, making it representative of complex multi-policy governance conditions (see Fig. 4).

Research and evaluation funders, operating at international, EU, and national levels, shape demand for policy-relevant research and are potentially transformative actors within the ecosystem (Oliver, 2022). Evidence generators include academic and research institutions, environmental agencies, public authorities, and societal actors such as NGOs and private consultancies. Many of these actors also function as evidence pumps, synthesising and transferring evidence to policymakers and the public; agencies such as the National System for Environmental Protection (SNPA) in Italy and EU-level organisations such as the European Environment Agency (EEA) and JRC exemplify this dual role.

Evidence users are distributed across all phases of the policy cycle. In the policy design and formulation phase, governmental institutions at all governance levels set strategic objectives and translate EU directives into operational priorities. In the implementation phase, national and regional administrations, supported by research institutions, manage planning, monitoring, and technical coordination. The evaluation and adaptation phase engages a broad set of actors already active in earlier phases, relying on evidence feedback loops for adaptive governance.

Beyond formal policy actors, the business sector and civil society emerged as hybrid components of the SPSE, acting both as evidence generators and users. Civil society actors, including NGOs, advocacy organisations, and community groups, variably contribute to transparency, public trust, and inclusive decision-making (Oliver, 2022).

Overall, the analysis highlights the hybrid and dynamic nature of the SPSE, in which many actors perform multiple roles across the SPSI.

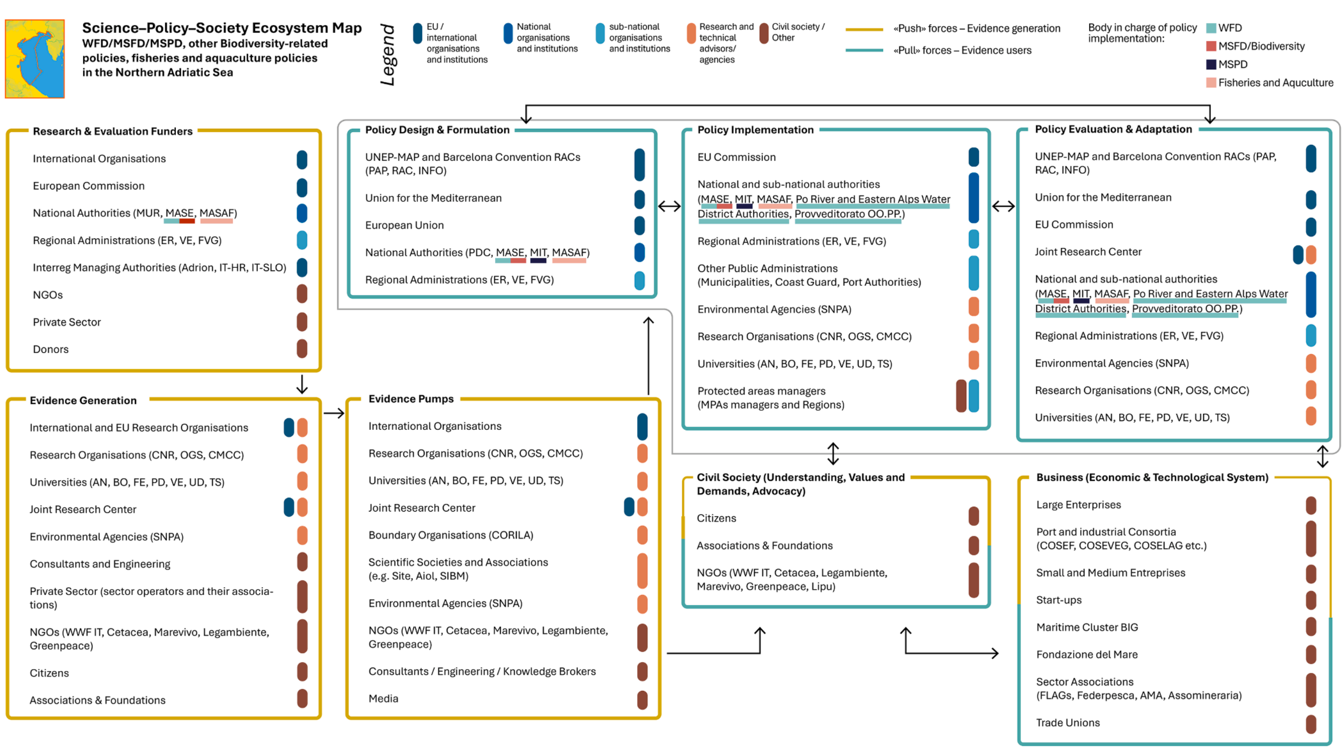

Fig. 4. Science-Policy-Society Ecosystem of the North Adriatic case study. It illustrates the SPSE resulting from the analysis conducted in the North Adriatic case study, focused on WFD, MSFD, MSPD, and other biodiversity-related policies, fisheries, and aquaculture sectoral policies.

Together, these overlapping functions contribute to the robustness of the SPSE but require coordination mechanisms to ensure coherence and trust among actors. The characterisation of the SPSEs provides the analytical context for the BBs analysis presented in Section 4.2. The actor configurations, roles, and relational patterns identified here, can condition the practices, gaps, and coherence implications identified for each BB.

4.2. SPSI Building Blocks: practices, impacts, and implications for policy coherence

This section presents the results of the analysis of the six SPSI BBs, grouped into Outputs, Methods, and Inputs. Across these dimensions, we identified twelve recurrent practices, each associated with impacts of the functioning of SPSI on policy coherence and policy-making processes. The results draw on both case-specific and cross-cutting elements of the BB analysis. The main text identifies patterns observed across multiple cases and provides illustrative examples to anchor findings in concrete evidence. Tables 4–6 summarise the practices and impacts identified for each BB. Additional details, including case extracts per practice, are available in the Supplementary Material (B).

4.2.1. Outputs Building Blocks

In terms of data availability, the North Adriatic benefits from national and regional databases covering WFD, MSFD, MSPD, and biodiversity policies, although fragmentation and differing temporal and spatial policy scales may constrain coherence. Similarly, the French Mediterranean has mature monitoring infrastructures for directives (e.g., WFD, Habitat and Birds Directives, MSFD), while sectoral policies requiring socio-economic integration or impact assessments, such as offshore wind development, face less timely or complete data availability. In the Finnish Archipelago and Baltic Sea cases, the RBMPs and Baltic Sea Action Plan enhance data availability on nutrient loading and eutrophication, cross-border coordination, and policy coherence, also through open-access databases. Nevertheless, relevant gaps remain in biodiversity monitoring, field-specific agricultural data, and the integration of land-based pressures. Advanced open-access systems exist in the Oslofjord for the coast (WFD-based) and the ocean, and the German North Sea EEZ cases (on SEAs and OWE impacts on biodiversity), but full data availability is hindered by structural barriers. In the Oslofjord, these knowledge systems are separated, feeding into the RBMPs and the Norwegian oceans management plans, respectively. The two types of plans do not overlap as in EU coastal states, where MSFD implementation often overlaps with RBMPs (Sander et al., 2026). In the German North Sea, confidentiality and companies' privacy constraints limit access to fine-scale data.

Knowledge gaps and uncertainties are a recurring barrier across all cases. In the North Adriatic case, some examples include biodiversity, marine litter, sediment loads, and cumulative impacts. In the Mediterranean case, biodiversity and climate change data are only partially developed, while major gaps remain in fish stock assessments. In the Oslofjord case, key gaps include weak linkages between the state of the fjord and the need to reduce inputs of nutrients from the catchment area, and ecological connectivity between the coast and the open ocean. In the German case, SEAs identify persistent knowledge gaps regarding long-term and cumulative ecological impacts of OWE. Similarly, the French case highlights persistent knowledge gaps regarding methodological thresholds for MSFD indicator assessment and limited data availability on certain species, habitats, and pressures. Across cases, uncertainties in the data are often recognised but only partially quantified, while differences in measurement methods, misaligned data collection timelines, and limited integration across policy sectors further complicate the interpretation and use of available information.

Assessments are generally credible and legitimate, often combining public agencies and institutions' mandates with research contributions and, in some cases, private consultancy and companies' inputs. The broader public (e.g., NGOs and other societal actors) remains involved only through the formal consultation processes. Cross-sectoral and multidisciplinary approaches are increasingly adopted; for instance, in Finland and the Baltic Sea cases, where RBMPs and the Baltic Sea Action Plan (BSAP) integrate freshwater, marine, and climate considerations with the agricultural and aquaculture sectors. In the Mediterranean Sea case, assessments increasingly integrate fisheries, biodiversity, and climate considerations, although integration of socio-economic factors remains limited. In the North Adriatic, French Mediterranean, and the German North Sea EEZ cases, assessments are robust and policy-relevant, but temporal misalignment and partial policy integration reduce the effectiveness of cross-sectoral decision-making. Efforts to communicate findings to non-specialists exist, e.g., through policy briefs, workshops, or visualisation tools, but are often isolated or constrained by data complexity.

Overall, while data collection and assessment systems are generally well established, challenges persist in fully integrating environmental and socio-economic information, aligning temporal and spatial policy scales, and bridging sectoral divides. These structural limitations, together with restricted data access and incomplete civil society engagement, constrain integrated marine management and policy coherence. Where data systems are interoperable and assessments cross-sectoral, SPSIs support horizontal coherence by enabling shared understanding of WFD, MSFD, and MSPD interdependencies. Conversely, data fragmentation, siloed assessments, and limited civil society engagement undermine both horizontal and vertical coherence: they may prevent policymakers from acknowledging policy interactions, reduce the legitimacy of decisions, and weaken the translation of EU-level commitments into nationally coherent implementation.

4.2.2. Methods Building Blocks

Collaborative knowledge transfer is well developed in several regions. In the North Adriatic and French Mediterranean cases, WFD, MSFD, and MSPD processes rely on standing technical committees and scientific coordination bodies where monitoring strategies, assessment methodologies, and planning approaches are co-produced between researchers and administrations. Similar dynamics occur in the German North Sea case, where SEAs for offshore wind development, embedded in MSP processes, institutionalise formal consultation stages and ongoing exchanges among regulatory agencies, research organisations, environmental authorities, NGOs, and industry actors. In both cases, integrating scientific input into planning and monitoring enhances the relevance and credibility of assessments, though broader societal engagement typically remains limited to consultation phases.

In the Oslofjord case, responsibility for SPSI in the coastal zone is decectralised to the regions responsible for preparing the RBMPs, with limited scientific support. In contrast, ocean management is a national responsibility, supported by strong advisory bodies that regularly deliver assessments as input for the Norwegian ocean management plans' revisions, enabling adaptive governance and ensuring strong legitimacy. Likewise, in the Finnish case, RBMP and MSP processes rely on formal cooperation groups, but translating knowledge into effective measures is constrained by limited involvement of agricultural stakeholders and sector-specific consultation logics.

At the Mediterranean regional scale, knowledge transfer mechanisms often follow more linear models, particularly in fisheries and climate governance. Scientific advice is channeled through regional fora (e.g., the Barcelona Convention, GFCM), and the Mediterranean Experts on Climate and Environmental Change (MedECC)), but co-production mechanisms are less consistently embedded in national policy cycles, leading to discontinuities in uptake and implementation. Collaborative initiatives exist but often depend on project-based funding, limiting continuity.

SPSI platforms operate as the main organisational structures through which these knowledge exchange processes are enacted. Their forms and mandates vary, from international coordination bodies and national

Table 4
List of practices and related impacts identified on BB-A and BB-B (Outputs), extracted from the analysis conducted across seven case studies and classified per attributes.

BB-A – Data & Knowledge
Attribute: Collection, availability, accessibility
Practice: Data production and monitoring activities are well developed, but access and usability still vary among policy domains. Limitations arise from incomplete datasets, confidentiality constraints, differences in data resolution, and misaligned spatial and temporal policy scales.
Impact: Although policy decisions increasingly rely on the best available knowledge, persistent difficulties with data access and availability may constrain the ability to fully support evidence-based decision-making.
Attribute: Aggregation, databases, knowledge gaps
Practice: Significant progress has been made toward shared databases and joint information systems, but notable knowledge gaps persist, even if/when explicitly acknowledged in assessments.
Impact: Acknowledging gaps fosters transparency; however, unresolved scientific uncertainty may reduce the robustness and effectiveness of policy decisions.
Attribute: Integration across policies, sectors, and actors
Practice: Initiatives to integrate data across policies, sectors, and actor groups are increasing; however, significant barriers persist. In particular, environmental datasets are generally more developed and routinely employed in assessments, while socio-economic data remain comparatively limited and less systematically incorporated. Moreover, misalignments in spatial and temporal policy scales continue to hamper effective cross-policy data integration.
Impact: Despite the efforts, these structural barriers may hamper fully integrated marine management and limit coherence and alignment across policies.
BB-B – Assessments
Attribute: Relevance, legitimacy, credibility
Practice: Assessments generally hold a good degree of relevance, legitimacy, and credibility, though limited data availability, transparency issues, and uneven resources occasionally constrain them.
Impact: Policy-making is broadly supported by credible, trusted assessments, yet existing limitations may affect the quality and effectiveness of resulting decisions.
Attribute: Approach (cross-policy/sector or siloed)
Practice: Assessments can support coherence across sectors and policies, and several cross-domain examples exist; however, siloed assessment practices remain widespread.
Impact: When assessments fail to adequately account for interdependencies among policies and sectors, they may overlook crucial interactions, risking the undermining of policy coherence.
Attribute: Involvement of data and knowledge providers
Practice: While many assessments include contributions from key scientific and institutional actors, the engagement of civil society often remains limited to formal consultation procedures.
Impact: Insufficiently inclusive participation may reduce opportunities for knowledge exchange, shared understanding, and higher-quality decisions, and may also weaken the share of policy outcomes.

technical working groups to regional networks. In the North Adriatic and French Mediterranean cases, platforms support coordination and data exchange, but engagement beyond public authorities and research institutions remains selective. In the German North Sea case, platforms facilitate structured dialogue among regulators, researchers, NGOs, and industry, but centralised decision-making limits the extent to which deliberation shapes outcomes. In Finland and the broader Baltic Sea cases, long-standing platforms, including HELCOM-VASAB (Vision and Strategies around the Baltic Sea) working groups, support transboundary monitoring and planning. However, key sectoral actors, such as agriculture stakeholders, remain insufficiently represented.

Taken together, knowledge transfer mechanisms and SPSI platforms contribute positively to the circulation of scientific evidence and to the horizontal and vertical policy coherence of marine governance. Their effectiveness in supporting integrated policies and management, however, depends on continuity of interaction, stable institutional and financial support, and inclusiveness of actor participation. Where platforms remain sector-specific, episodic, or primarily expert-driven, opportunities to integrate diverse forms of knowledge and address cross-policy interdependencies are reduced, limiting their capacity to support coherent and adaptive marine management.

4.2.3. Inputs Building Blocks

In the North Adriatic case, interdisciplinary competence development is supported through cross-policy initiatives and projects (e.g., MEDREGION, ADRION), which facilitate coordination across WFD, MSFD, MSPD, and biodiversity-related processes. Training activities incorporate environmental science, regulatory implementation, economic analysis, and stakeholder engagement. However, SPSI-specific expertise and skills for synthesising and communicating complex information remain only partially developed. Similar patterns occur in the German North Sea case study, where capacity-building focuses on

Table 5
List of practices and related impacts identified on BB-C and BB-D (Methods), extracted from the analysis conducted across seven case studies and classified per attributes.

BB-C – Knowledge Transfer Models and Mechanisms
Attribute: Type (linear, collaborative), functioning
Practice: Knowledge transfer is predominantly organised through collaborative models between scientific institutions, administrative authorities, and sectoral agencies, rather than through linear one-directional advisory models. However, the continuity of these interactions and the systematic involvement of non-institutional knowledge holders (e.g., civil society organisations, professional associations, local communities) remains uneven across policies and governance levels.
Impact: The co-production of knowledge generally enhances the policy relevance and usability of scientific inputs. Nonetheless, restricted stakeholder involvement, participation, and discontinuous engagement may limit the diversity of knowledge integrated into SPSI processes and, consequently, the robustness of resulting policy outputs.
Attribute: Effectiveness
Practice: The models of scientific policy advice and knowledge transfer mechanisms are frequently institutionalised and embedded in established policy procedures, yet their effectiveness depends on political commitment, the availability of financial and human resources, and enforcement capacities.
Impact: The frequent institutionalisation of the nature and mandate of scientific policy advice and knowledge transfer mechanisms tends to enhance the relevance, legitimacy, and credibility of the research supporting policy-making. Despite this, the challenges mentioned above may affect the level and adequacy of information in the policy-making process. These mechanisms tend to remain confined to a specific policy and may not consider or promote coherence with other policies.
BB-D – SPSI Platforms
Attribute: Type, role, and effectiveness
Practice: Many SPSI platforms are in place, each with distinct characteristics. SPSI platforms generally play an efficient role in knowledge transfer. However, challenges remain, e.g., regarding the continuity of activities and the extent to which they consider interlinkages across sectors, societal actors, disciplines, and geographical levels.
Impact: SPSI platforms have a rather positive impact on the policy-making process through their role in knowledge transfer, but the challenges they face regarding sectoriality and continuity may hamper their effectiveness in boosting policy coherence and broad participation.

offshore wind planning and marine environmental management. However, technical, ecological, and regulatory knowledge is only partially integrated due to data-sharing limitations, methodological gaps, and fragmented institutional responsibilities.

In the Baltic Sea and Finnish Archipelago cases, long-standing regional cooperation frameworks (e.g., under HELCOM and BSAP) provide several established mechanisms for integrating systemic and cross-sectoral knowledge. Nevertheless, gaps persist in agricultural expertise and operational tools for translating interdisciplinary assessments into implementable measures, particularly at the land-sea interface.

In the French Mediterranean, interdisciplinary capacity is mainly embedded through periodic technical meetings between the Maritime Authorities and the Water Agencies, which support MSFD implementation and manage funding for coastal restoration and pollution control. Coordination with biodiversity and MSFD authorities enhances cross-policy coherence, though sectoral policies remain strongly siloed and lack interdisciplinarity.

Funding and resource arrangements further shape the operational capacity of SPSI processes. Across cases, financing is primarily public and often project-based, with occasional cross-policy schemes that support coordination among policy domains. In the North Adriatic, EU and national funding support cross-policy collaborations, though limited human resources and discontinuous financing hamper long-term planning capacity. In the Mediterranean more broadly, funding constraints and uneven distribution across countries restrict knowledge generation and cross-sectoral alignment. In the German North Sea case, both public and private funding support assessment and planning activities. In the Oslofjord, the planning for a first version of the governmental action plan relied heavily on knowledge produced by WFD-related activities (Trubbach et al., 2025). In the preparation for the 2026 update, the government commissioned a report on the necessary reductions of nutrient inflows to the Fjord. In the Baltic Sea and Archipelago Sea case studies, MSFD offered greater flexibility than WFD in allocating funding to projects that improve environmental status.

Taken together, competence development and funding arrangements provide essential support to SPSI processes across the policy cycle. However, gaps in interdisciplinary skills and in the adequacy and continuity of resources and funding affect how knowledge is acquired and shared across policy domains. Where interdisciplinary competences are lacking, actors cannot effectively navigate cross-sectoral interactions; where funding lacks continuity, the knowledge production and transfer needed for coherent implementation across policies risk to be compromised.

5. Discussion

Our analysis demonstrates that, despite notable progress over the last few years in strengthening SPSIs' effective and efficient contribution to evidence-based policy-making, several structural and operational needs still hinder SPSIs' full contribution to the ambitious objectives of the EGD. These needs are grounded in the practices and impacts identified in Section 4, which reveal persistent gaps in data integration (BB-A, BB-B), fragmented knowledge transfer mechanisms and sector-specific SPSI platforms (BB-C, BB-D), and insufficient competences and funding continuity (BB-E, BB-F). Together, these needs undermine policy coherence by limiting the cross-sectoral knowledge integration and multi-level governance alignment that coherent EGD implementation requires. The needs derived from these findings (listed in Supplementary material (C)) form the basis for the recommendations presented here (listed in Supplementary material (D)), which were co-developed and validated with stakeholders through two rounds of expert focus groups. The following discussion presents these recommendations, addressing the second research question of this study. Cross-cutting recommendations (Section 5.1) are relevant to all EGD-related marine policies and are directly traceable to the cross-case patterns identified in Section 4.2. Policy-specific recommendations (Section 5.2) address challenges documented for WFD, MSFD, and MSPD, drawing on empirical findings of Section 4, and supplemented where necessary by the broader scientific and policy literature on the implementation of these directives.

5.1. From SPSI needs to recommendations: cross-cutting aspects

Our analysis reveals persistent gaps in data accessibility, standardisation, and cross-policy integration. Science, policy, and society engage with data differently, and heterogeneous knowledge types, including socio-economic and local knowledge, remain underrepresented in policy processes (Böcher and Krott, 2014; Brugnach et al., 2007). Strengthening SPSIs requires not just interoperable data systems, but transparent provenance and collaborative production across science, policy, and society (Cvitanovic et al., 2015; Stafford-Smith et al., 2017). A key recommendation is to develop open-access knowledge catalogues at both EU and national levels (building on existing platforms such as EMODnet), integrating cross-policy data, knowledge gaps, and sectoral interlinkages. This can help in overcoming the data fragmentation that undermines horizontal coherence between policies, which depend on compatible infrastructures for joint assessment and adaptive management.

Effective assessments must integrate ecological and socio-economic dimensions, include diverse knowledge holders, and function as iterative learning processes (UNEP and IOC-UNESCO, 2009; Cash et al., 2003; Edenhofer and Kowarsch, 2015). Our analysis shows persistent challenges across cases, e.g., data gaps, limited transparency, resource constraints. Cross-policy assessment guidelines, defining shared principles for credibility, legitimacy, and stakeholder inclusion at different governance levels, are needed. When environmental and

Table 6
List of practices and related impacts identified on BB-E and BB-F (Inputs), extracted from the analysis conducted across seven case studies and classified per attributes.

BB-E – Competence Framework

Attribute: Interdisciplinarity, knowledge gaps

Practice: Interdisciplinary competence frameworks are increasingly recognised as essential for effective policy-making and research. However, existing frameworks often remain incomplete, with uneven coverage of relevant skills and expertise across disciplines.

Impact: While awareness of the need for interdisciplinary capacities supports more comprehensive and systemic approaches, persistent gaps in skills and expertise may limit the efficient and effective integration of knowledge in policy-making.

Attribute: Capacity-building

Practice: Capacity-building initiatives aimed at strengthening actors' knowledge, skills, and attitudes are implemented in some contexts, but the depth and reach of these activities vary. Expert knowledge and sectoral focus often dominate, limiting cross-sectoral collaboration.

Impact: These activities enhance the expertise of participating actors, supporting evidence-informed policy-making. Nevertheless, compartmentalisation of knowledge and limited integration across sectors can constrain collaborative policy design and operational effectiveness.

BB-F – Funding & Resources

Attribute: Drivers, type, and adequacy

Practice: Funding schemes supporting SPSI activities are heterogeneous and may include cross-policy instruments. However, financial, human, and infrastructural resources are frequently insufficient in quantity, continuity, or allocation.

Impact: Adequate and coordinated resources facilitate policy coherence and integrated management. Conversely, funding and support constraints can reduce the operational capacity of SPSI initiatives, hindering short- and long-term policy effectiveness.

socio-economic conditions are assessed in an integrated manner across directives, trade-offs and synergies become visible and actionable, directly strengthening horizontal coherence (Cash et al., 2003; Nilsson et al., 2016).

Knowledge transfer models are increasingly shifting from linear models towards collaborative approaches that emphasise iterative exchanges, inclusivity, and knowledge co-production (Koetz et al., 2012; Gluckman et al., 2021; Strand, 2022). Yet, our analysis shows persistent gaps in the translation of collaborative models into practice: research outputs are not always operationalised, continuity of exchanges remains fragile, and societal actors are insufficiently involved. Advice mechanisms often remain confined within policy silos. Clearer principles and procedures for knowledge transfer, systematic effectiveness evaluation, and stronger societal engagement are needed. Where knowledge transfer remains directive-specific, cross-policy interdependencies remain invisible to decision-makers, limiting their capacity to identify trade-offs and synergies (Boteler et al., 2024; Barbanti et al., 2023).

SPSI platforms have been widely recognised as key mechanisms for fostering sustained engagement, co-production of knowledge, and cross-sectoral cooperation (Cvitanovic et al., 2018; Gustafsson and Lidskog, 2017; Wagner et al., 2023). Our analysis confirms the crucial role of SPSI platforms across governance levels in facilitating technical advice, knowledge exchange, and stakeholder dialogue, yet challenges persist in continuity, cross-sectoral scope, and stakeholder inclusiveness. Strengthening platforms, by broadening their scope to include under-represented actors and supporting boundary organisations, would enhance coherence, legitimacy, and integrated governance (European Commission, 2022; Gustafsson and Lidskog, 2017; Wagner et al., 2023). Multi-actor platforms operating across policy boundaries can create shared spaces for problem framing, evidence exchange, and coordinated implementation, constituting effective mechanisms for horizontal and vertical policy coherence.

The literature highlights that technical, scientific, institutional, and relational skills and capacities are essential for navigating complex interlinkages, managing trade-offs, and fostering trust in multi-actor environments (Hrabanski and Pesche, 2016; Topp et al., 2018; Blythe and Cvitanovic, 2020; Schwendinger et al., 2022). In our analysis, we found that significant gaps remain in competence frameworks, particularly in communication, synthesis, socio-economic expertise, and stakeholder engagement skills. These limitations risk perpetuating siloed knowledge and reducing the effectiveness of cross-sectoral collaboration. Targeted training initiatives addressing inter- and transdisciplinary skills, combined with recognition of researchers' science-to-policy contributions in evaluation systems, are needed. Such boundary-spanning competences are essential for enabling effective SPSIs and for the cross-sectoral coordination that coherent marine governance demands (Penca et al., 2024).

Finally, effective SPSIs also rely on adequate, stable, and equitably distributed funding and resources. The literature shows that funding and infrastructure directly affect collaborative models, knowledge production and transfer, and the functioning of SPSI platforms (Dale et al., 2019; Oliver et al., 2021). In our analysis, we found that while various funding mechanisms exist (EU schemes, national and private initiatives), financial and human resources remain sometimes insufficient, unevenly distributed across regions and sectors, and often project-bound rather than long-term. Such limitations hinder continuity, cross-sectoral coordination, and ultimately policy coherence. A dual approach is here needed: ensuring long-term institutional funding for all SPSI actors, and targeted investment in research that improves SPSI functioning and strengthens science-to-policy culture. Project-bound financing produces episodic engagement and fragmented knowledge systems, whereas long-term resources enable the coordination and continuity that policy coherence requires.

5.2. From SPSI needs to recommendations: policy-specific aspects

In addition to cross-cutting considerations, some policy-specific challenges emerged for WFD, MSFD, and MSPD. These frameworks are pivotal to implementing the EGD, but their effectiveness is sometimes hampered by gaps in knowledge, data integration, and governance arrangements. Addressing these barriers is essential to ensure policy coherence across these directives and to support compliance with the EGD objectives.

For MSFD and MSPD, incomplete GES threshold values limit their usability within ecosystem-based MSP. Although threshold values for several descriptors have been developed (European Commission, 2024b, 2025b), many remain incomplete or inconsistently applied (Vasilakopoulos et al., 2022). Improving and completing threshold methods and ensuring their systematic use in spatial planning is a prerequisite for horizontal coherence between the two directives: without agreed ecological reference points, MSFD knowledge cannot be meaningfully integrated into MSP. Coherence between their data repositories (e.g., EMODnet and MSFD Wise-Marine, managed by different actors) is also limited. Therefore, shared and coordinated data facilities at EU and national levels are needed.

MSFD also suffers from persistent knowledge gaps on ecosystem functioning and pressure-state relationships, as many habitats and species are not systematically monitored, and uncertainties remain particularly high, e.g., in deep-sea ecosystems (European Commission, 2020; EEA, 2019). More precise determinations of pressures, cumulative impacts and GES thresholds are needed, supported by quantitative indicators and robust scientific baselines for coherent implementation of MSPD and other biodiversity-related directives.

At the land-sea interface, WFD, MSFD, and MSPD operate with different, sometimes disconnected information bases, which may undermine the effectiveness of management measures, especially where land-based pressures affect coastal and marine systems (Tocco et al., 2024). Interconnected repositories across land and sea, starting from metadata catalogues, would strengthen integration. Initiatives such as the Digital Twin of the Ocean and GreenData4All provide useful foundations.

Moreover, climate change knowledge remains insufficiently integrated into MSFD and MSPD processes. While research on past trends, projections, and impacts has advanced (European Environment Agency, 2024), significant knowledge gaps remain across biogeographic regions and regarding vulnerable habitats, species, and cumulative effects (Bednar-Friedl et al., 2023). Science-to-policy mechanisms should better translate available evidence into actionable knowledge for planning and threshold-setting (Frazão Santos et al., 2020). As climate change alters the baselines for GES and MSP targets, the two directives must evolve in a coordinated way, drawing on shared and regularly updated evidence.

For MSPD, current plans rarely integrate robust qualitative-quantitative socio-economic analyses, due to limitations in methodologies and the availability of spatially explicit data (Santiago et al., 2023). This weakens the assessment of alternative planning scenarios and the ability to capture both market and non-market values. Strengthening socio-economic analyses would improve the evidence base and legitimacy of spatial planning decisions (Gambino et al., 2024; Santiago et al., 2023). Equally important is the establishment of stable multi-actor platforms and structured consultation mechanisms, which can provide transdisciplinary knowledge and enhance coherence across policies. While platforms and working groups are already emerging at the sea-basin level (e.g., the Community of Practice on MSP in the Mediterranean (MED-MSP-CoP) and the working group on MSP of the Mediterranean Action Plan under the United Nations Environment Programme), they require consolidation and capacity-building to effectively support collaborative and inclusive policy-making.

Finally, the Nature Restoration Regulation (NRR) requires restoration targets to be integrated with MSFD and MSPD. Restoration planning faces substantial knowledge gaps, particularly regarding the condition of marine habitats and the pressures preventing their recovery (Council of the European Union, 2023). MSP has the potential to play a central role in supporting NRR obligations by incorporating restoration targets into zoning and reducing conflicts with other maritime activities (as also claimed by Agardy et al., 2025). This underscores the need for shared knowledge systems, integrated planning processes and coordination across authorities and policies, ensuring that restoration measures are science-based and embedded within ecosystem-based management approaches.

5.3. Strengths and limitations of the methodology

The methodology applied in this study provides a structured and systematic approach to analysing SPSIs. Its architecture, comprising an inception phase, SPSE mapping and the characterisation of six BBs, proved effective in capturing the complexity and variability of SPSI configurations across policies, governance levels, and geographical areas. Nevertheless, some limitations should be acknowledged.

The analysis relies on document review, semi-structured interviews, and expert focus groups. This qualitative approach ensured contextual depth and interpretative richness regarding governance processes, institutional practices, and knowledge flows. However, differences in data availability across cases introduce a degree of heterogeneity that had to be acknowledged in the analysis phase. Although applied to clearly defined case studies, SPSEs often extend beyond formal geographical and governance boundaries. Interactions shaping SPSIs may operate at higher (EU or international) or more local scales, which cannot be fully captured within a single case. To mitigate this limitation, the study ensured broad stakeholder involvement from case study areas and from EU and international experts.

The methodology demonstrates several strengths. Its adaptable structure allows application across heterogeneous policy domains and analytical scales, supporting system-level diagnostics and targeted assessments. By explicitly focusing on coherence within evidence-informed policymaking, the framework enables a systematic examination of how SPSIs affect policy coherence and the implementation of marine-related directives and EGD objectives. It also offers a transparent and replicable self-assessment tool: the SPSE, BBs, and guiding questions can support public authorities, research organisations, and intermediaries in identifying bottlenecks and strengthening knowledge flows and evidence uptake in policy-making. Iterative stakeholder engagement further enhanced the framework's relevance across academic and operational contexts, increasing its potential uptake in future SPS analyses.

5.4. Conclusions

This paper applies a flexible methodology to assess SPSIs, identifying barriers and enablers to their efficiency and effectiveness, their impact on policy coherence, and recommendations to improve their functioning. The assessment focused on EGD-related marine policies across different phases of the policy cycle and geographical scopes, making its outcomes relevant across governance levels and contexts.

The analysis showed that SPSIs are often institutionalised across all stages of the policy cycle, yet their performance is systematically constrained by data fragmentation, policy-specific silos in knowledge transfer, limited civil society engagement, and insufficient long-term funding. These constraints reduce their capacity to support horizontal and vertical policy coherence, particularly at the interfaces between WFD, MSFD, and MSPD, and limit the adaptive, cross-sectoral governance that EGD implementation demands. The recommendations presented in this paper, cross-cutting and policy-specific, provide a concrete, evidence-based pathway for strengthening SPSIs. Their practical relevance is reinforced by the co-creation process through which they were developed.

Two broader implications emerge from this work. First, SPSI assessment should be embedded systematically within the policy cycle. Periodic SPSI self-evaluation would strengthen accountability and enable adaptive approaches, allowing these mechanisms to evolve in response to emerging challenges and remain effective in supporting transformative goals. Second, the methodology developed and applied here offers a replicable tool for such assessments, applicable by public authorities, research organisations, and boundary institutions seeking to improve evidence uptake and policy coherence in complex governance contexts.

As the international community advances commitments such as the EU Ocean Pact and the upcoming EU Ocean Act, which calls for a robust, credible and legitimate marine knowledge framework and strengthened SPSI, the evidence from this study suggests that investing in effective, inclusive, and well-resourced SPSIs is necessary for translating policy ambition into coherent, adaptive ocean governance.

CRediT authorship contribution statement

Andrea Barbanti: Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Ginevra Capurso:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Emiliano Ramieri:** Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization. **Folco Soffietti:** Writing – original draft, Visualization. **Paulina Ramírez-Monsalve:** Writing – original draft, Methodology. **Pierre Strosser:** Writing – original draft, Methodology. **Froukje Maria Platjouw:** Writing – original draft, Funding acquisition. **Laura Bastide:** Writing – original draft, Formal analysis. **Sašo Gorjanc:** Writing – original draft, Formal analysis. **Eerika Albrecht:** Writing – original draft, Formal analysis. **Cristian Passarello:** Writing – original draft, Formal analysis. **Gunnar Sander:** Writing – original draft, Formal analysis.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: PS, SG and LB were employed by ACTeon SARL. The remaining author (s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2026.104450.

Data availability

Data will be made available on request.

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