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Mapping the governance landscape of the blue bioeconomy: A systems approach to understanding innovation barriers and enablers

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ABSTRACT

The blue bioeconomy offers promising pathways for sustainable marine resource management, yet its development faces significant governance challenges. This study examines how governance structures can enable or hinder innovation in emerging blue bioeconomy systems, focusing on the valorisation of fishery side-streams and microalgae development. Using a novel Governance of Innovation Systems (GOIS) framework adapted from Technological Innovation Systems theory, we analyse governance structures across four European regions: Sicily (Italy), Saaremaa (Estonia), Greenland and West Jutland (Denmark). Through desk research and 18 stakeholder interviews, we identify key barriers and enablers within six governance functions: knowledge development, direction of search, legitimacy creation, resource mobilisation, market formation and entrepreneurial experimentation. Our findings reveal that while market formation shows promise across regions, significant challenges persist in legitimacy creation and knowledge development. Regulatory complexity and fragmented responsibilities emerge as primary barriers to innovation, particularly affecting small and medium-sized enterprises. Resource constraints manifest differently across regions, from infrastructure limitations in Sicily to workforce shortages in Denmark and Estonia. Based on these insights, we propose three key policy interventions: regulatory process simplification through sandboxes and administrative one-stop shops, innovative financing mechanisms including blue bonds and accelerator programs, and enhanced collaborative frameworks through regional networks and public-private partnerships. This study contributes to innovation systems theory and practice by demonstrating how systematic analysis of governance functions can inform targeted interventions to support sustainable blue bioeconomy development.

1. Introduction

The fishing industry plays a vital role in ensuring global food security and is often essential to the local economy in coastal regions. However, with growing overexploitation, increasing competition for marine space, climate change, pollution and resource depletion, oceans and coastal regions face significant ecological, economic, and social challenges (Christie et al., 2014; Pauly et al., 2002; Racioppo et al., 2021; Voyer et al., 2018; Yan and Chen, 2015). To tackle these challenges and deliver on Sustainable Development Goal 14 'Life below water': "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" as well as the Ocean Decade's priorities (UNESCO Intergovernmental Oceanographic Commission, 2021; United Nations, n.d.), the concept of the blue bioeconomy has emerged as a promising pathway.

The blue bioeconomy emphasises the promotion of sustainable marine resource management by valorising parts of fish or seafood that are typically discarded during processing (Ligtvoet et al., 2019; Voyer et al., 2018). Still, it is a concept which have often been overlooked as a commercial opportunity (European Commission, n.d.). The blue bioeconomy sets itself apart from the broader bioeconomy and the blue economy by concentrating specifically on aquatic and marine ecosystems. The general bioeconomy encompasses all economic activities based on biological resources. In contrast, the blue economy concerns any economic activity related to seas and oceans, including offshore renewable energy, maritime transport, fisheries and coastal tourism (European Commission, 2021). Within this context, the blue bioeconomy represents a distinct segment that specifically focuses on

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marine environments and geography. It encompasses fisheries, aquatic biomass, marine biotechnology and coastal tourism, with the primary aim of leveraging marine biodiversity for sustainable economic development (Bugge et al., 2016). The blue bioeconomy seeks to maximise the value derived from marine resources by leveraging innovation, while also aiming to foster ecological and regional sustainability (European Commission et al., 2021; Mirabella et al., 2014). This includes promoting advanced waste processing strategies to transform waste into valuable products, and valorising by-products from the fishing industry. Thus, the blue bioeconomy allows for adopting strategies to improve and develop the use of marine resources. This may pave the way for ecological sustainability and socioeconomic growth in oceans and coastal regions (Ligtvoet et al., 2019; Roy et al., 2023; Stevens et al., 2018; Yan and Chen, 2015).

While the blue bioeconomy presents considerable potential, its development is not without significant challenges. For example, there is an uneven distribution of power and resources, conflicts between short-term economic objectives and long-term environmental sustainability, fragmented multilateral cooperation and low local implementation capacity, which pose substantial barriers to its effective realisation (Li et al., 2025). This paper addresses these challenges by examining how the existing governance structures enable or hinder innovation in emerging blue bioeconomy systems.

To understand the emergence of the blue bioeconomy and how it can be developed through improved governance structures, this study draws on the innovation systems literature, specifically the technological innovation systems (TIS) framework (Bergek et al., 2008; Carlsson and Stankiewicz, 1991). By this framework, we conceptualise the blue bioeconomy through the lens of a 'socio-technical' system, meaning that society and technology are deeply intertwined by a close interconnection between technologies, actors, networks and institutions. Using a case study approach, this study explores the conditions for the governance of the blue bioeconomy to develop through socio-technical functions, such as knowledge development, resource mobilisation and entrepreneurial experimentation. The approach allows us to identify governance interventions supporting the blue bioeconomy development in the case study regions and beyond.

Advancing the blue bioeconomy requires a comprehensive approach to identifying, understanding and addressing both failures and structural weaknesses in the functions that support the socio-technical system. The TIS approach has previously been applied to study the blue bioeconomy, such as the development and diffusion of biorefinery technologies (Bauer et al., 2017), and the use of algae as a feedstock for various applications (Berg et al., 2019; Haase et al., 2013). However, the valorisation of fish and seafood by-products remains unexplored in the TIS literature. These by-products, which are often discarded during processing, present a broader spectrum of alternative pathways for fostering a bioeconomy tailored to marine and coastal contexts. For these products to come to fruition, a more in-depth examination of the innovation system's preconditions, and particularly the socio-technical functions of the emerging blue bioeconomy, is warranted.

Various innovation system failures constituting barriers to the development of the local blue bioeconomy in Europe can be identified in the literature. For example, markets for valorised fishery by-catch products, as well as micro- and macroalgae harvesting or cultivation, are still very small in Europe (Araújo et al., 2021; Caruso et al., 2020). This may be attributed to innovation system failures. Moreover, fragmented regulatory frameworks and administrative processes across sectors and levels of governance (Pender et al., 2024; Permani et al., 2024; Thompson et al., 2024), along with challenges related to the impending impacts of climate change, population decline and ageing in many European coastal communities (Fischer, 2018), represents significant barriers to development. Collectively, these system failures, along with their opportunities, span various societal levels and processes, highlighting the need for joint governance efforts to sustain healthy, productive and resilient oceans and ecosystem services (Diz et al., 2019). Therefore, focusing on understanding the governance landscape of the blue bioeconomy and its barriers to innovation is key to unlocking its potential.

1.1. Governance of the blue bioeconomy

The emergence of a sustainable blue bioeconomy cannot be directed solely through a top-down approach. Nor can it emerge from a strict bottom-up advancement. Instead, just like any innovation system evolution, the blue bioeconomy requires institutional development involving learning and change practices across a diverse range of actors, including national, regional and local governments, established firms, entrepreneurs and citizens (Lundvall, 1992; Nelson and Winter 1982). These actors must navigate uncertainty, and the most suitable interventions may evolve as the innovation system progresses through different phases (Grin et al., 2010). By acknowledging the multi-actor nature of innovation system development and the shared principles underpinning their actions, it becomes possible to govern transitions of emerging innovation systems, such as the blue bioeconomy (Kooiman, 2003).

Scholars have looked at the role of policy and institutions in shaping emerging innovation systems (Boon et al., 2022; Kern, 2011), how institutional logics shape development and transition processes (Fuenfschilling and Truffer, 2014), and the role of practice-oriented actor arenas (Jørgensen, 2012). In the context of developing the European blue bioeconomy, research shows it is essential to establish local-level governance mechanisms that connect to national and EU levels (Berkowitz, 2020). These mechanisms serve two primary purposes: enabling the initiation of experiments and innovation, and ensuring their sustainability, monitoring, and broader dissemination (ibid). Therefore, an exclusive focus on technology as a source of growth and employment risks overlooking critical socio-political factors that can ultimately hinder the development of innovation (Bednarsek et al., 2023). A broader understanding of innovation systems in terms of existing governance structures for supporting development in the blue bioeconomy is thus necessary.

Governing the emergence of the blue bioeconomy in Europe involves numerous complex challenges. This includes fragmented responsibilities, multi-level and cross-sectoral governance, historical and spatial contexts (Bednarsek et al., 2023) and persistent mismatches between policy narratives and local development (Albrecht and Lukkarinen, 2020). To support the development of the blue bioeconomy, a systemic and integrated governance, involving a wide range of stakeholders to foster sustainable innovation capabilities, has been suggested as necessary (Albrecht and Lukkarinen, 2020; Berkowitz, 2020).

This paper aims to explore how the governance of an emerging innovation system can be strengthened to enable blue bioeconomy innovation. We adopt Konrad and Böhle's (2019) broad understanding of the governance of innovation. Their conceptualisation emphasises the different ways individuals, organisations, societal groups and states coordinate, ranging from hierarchies to networks, communities, associations and market-like systems, all guided by both formal and informal rules (Konrad and Böhle, 2019).

By mapping the current governance structures for blue bioeconomy innovation systems across four European regions: Sicily (Italy), Saaremaa (Estonia) Greenland and West Jutland (Denmark), the study elucidates how governance structures anticipate and support the development of innovation systems for the valorisation of fishery sidestreams and the emerging microalgae industry. The paper proposes a framework of functional elements in the governance of innovation systems. The framework is applied to the blue bioeconomy and demonstrates enablers and barriers for the development of innovation systems around the European blue bioeconomy. In turn, this may help improve ecological, economic, and social sustainability governance efforts in the studied regions and beyond.

2. Methodology

This study systematically evaluates governance structures influencing blue bioeconomy innovation, building on preliminary research conducted within the Horizon Europe BlueRev project (Mattisson et al., 2024). The methodology includes the empirical analysis of side-stream valorisation across three European regions and one self-governing territory. The analysis is primarily related to the valorisation of side-streams from the fishing and aquaculture industries. The study also analyses the functional elements of the governance of innovation systems in the blue bioeconomy. The paper contributes to the academic literature on governance of innovation systems by offering insights into its mechanisms through the case of the upscaling of by-products in the blue bioeconomy.

Employing an analytical framework based on Technological Innovation System (Carlsson and Stankiewicz, 1991; Johnson and Jacobsson, 2001), the study critically examines governance functions that mediate innovation and sustainable development dynamics (Bergek et al., 2008a). The following sections describe the research design and characteristics of the regions studied, the data collection approach, and the analytical framework.

2.1. Research design and approach

For this study, we have employed a case study approach to gain an understanding of the governance challenges facing four geographically distinct European regions in the upscaling and utilisation of side-streams in the blue bioeconomy. The case study methodology enables a nuanced and contextually grounded exploration of governance mechanisms' impact on local innovation dynamics (Flyvbjerg, 2006, 2011). In addition to analysing the regional cases individually, a comparative approach was used to identify patterns, challenges and best practices. This led to the development of actionable recommendations for enhancing governance structures for innovation within the blue bioeconomy across Europe (Eisenhardt, 1989).

The case studies include Sicily (Italy), Saaremaa, (Estonia), Greenland and West Jutland (Denmark). The cases were selected according to their geographical distribution across Europe, providing examples from different cultural and spatial contexts, as well as different governance structures (see e.g. Flyvbjerg, 2006, 2011). This contributes to deeper insights into the governance challenges individual regions are facing, as well as challenges beyond local and regional cases that may be generalisable (Flyvbjerg, 2006). For an overview of the case study regions, see Table 1. While we acknowledge the distinct governance structures and relative asymmetrical powers vested in Danish mainland regions versus the autonomous territory of Greenland, they are analysed together as they are both part of the Danish Realm ("Rigsfællesskabet"). Moreover, Denmark and Greenland share a long history and both belong to the Nordic macro-region, which suggests similarities in perspectives and attitudes, and – to some extent – their overarching vision for the future of the Nordic region, while simultaneously maintaining very different relationships with the EU. The analysis highlights both similarities and differences between these two entities within the same realm.

2.2. Data collection methods

A mixed-methods approach was used for the data collection, combining semi-structured stakeholder interviews with desk research. Eighteen in-depth interviews were conducted across the regions, each lasting 60–90 min. Interviewees represented diverse stakeholder groups, including businesses, NGOs and government agencies (see Appendix A). An interview guide was used, structured around six key governance functions identified in our analytical framework, with questions adapted to each stakeholder's specific role and expertise. Interviews were conducted online between June and December 2024. They were recorded with permission and transcribed for analysis. A snowball sampling approach was employed to select interviewees, initiated by the BlueRev case study coordinators in each region. In this method, initial participants recommend other individuals relevant to the study, generating a chain of referrals that expands the sample like a 'snowball'. This approach is commonly used in qualitative case study research to broaden the participant pool.

The desk research encompassed academic publications, grey literature and policy documents at both regional, national and supranational levels. The desk research was focused on governance structures and innovation systems within the blue bioeconomy sector.

Table 1
Overview of the case study regions.

Country	Region(s)	Description
Italy	Trapani, Sicily	The Italian case study focuses on the region around Trapani in Sicily, which has a rich maritime heritage and diverse coastal resources. In the BlueRev project, the focus of the Italian case study was to understand how marine bioactive compounds and ingredients from fish processing residuals and algae can be valorised and used for industrial applications, e.g., cosmetics and nutraceuticals.
Denmark	West Jutland & Greenland	The Danish case consist of both West Jutland on the Danish mainland, and Greenland, a self-governing territory, providing two distinct cases within The Danish Realm, with differing challenges and varied contexts and governance powers. For both cases, however, the focus is to increase the use of fish side-streams for nutraceutical, food and feed applications. The challenges in these regions are similar, all standing in the way of upscaling a blue bio-based economy, are related to a lack of skilled personnel, logistic infrastructures, and in the case of Greenland being an outermost region.
Estonia	Saaremaa	The Estonian case centres around the island of Saaremaa off the west coast of the Estonian mainland. The value chain in focus for the analysis is the use of red algae biomass for food, nutraceuticals and compounds in the cosmetic industry. Red algae have been an important resource in Saaremaa since the 1960s when they started being processed into furcellaran gelling agent. While historically prominent in Eastern Europe confectionery, some enterprises in Saaremaa now aim to diversify red algae utilisation into food, nutraceuticals, and cosmetics. To achieve this there is a need for a transition from traditional technologies for processing red algae to modern technologies to extract substances that could be valuable inputs for other industries.

2.3. Analytical framework

This study employs an integrated analytical framework built upon the Technological Innovation System (TIS) analysis approach (Bergek et al., 2005; Bergek, Hekkert et al., 2008) while introducing novel elements to the TIS framework to analyse governance structures and functions. The Governance of Innovation Systems (GOIS) framework adapts the TIS methodology to specifically examine how governance structures mediate innovation and sustainable development dynamics (Markard et al., 2012). Where TIS traditionally focuses on technological development (Jacobsson and Bergek, 2011), GOIS redirects attention to the governance mechanisms that enable or constrain innovation across the system. This adaptation is particularly relevant for emerging sectors like the blue bioeconomy, where governance challenges often exceed purely technological barriers.

Developed through iterative application in multiple EU research

projects (RUGGEDISED,[1] MOVE21,[2] BlueRev[3]), the analytical approach of the GOIS framework has been progressively refined. The GOIS framework assesses the governance of innovation systems using six system functions from the TIS framework: knowledge development and dissemination, direction of search, legitimacy creation, resource mobilisation, market formation and entrepreneurial experimentation (see Table 2 for definitions of the functions). The analysis is divided into structural and functional parts, following the analytical procedures of a TIS analysis (Bergek et al., 2005; Oltander and Perez Vico, 2005). Relevant governance actors in the studied regions are mapped in a structural analysis, while the functional analysis is focused on the six functional dimensions above to uncover how governance systems perform in developing the blue bioeconomy.

By drawing on the analytical structure of TIS, the GOIS framework adds an additional and more in-depth understanding of how governance structures influence innovation in the blue bioeconomy. It also helps elucidate how policy interventions can create more dynamic and sustainable innovation systems. Interviews and desk research were coded using the descriptions of the six system functions and the guiding questions in Table 2. The coded interviews and desk research were used to assess each function's strength and effectiveness in the regions. These six system functions were rated on a scale from *very weak* to *very strong* in each region (Table 3).

3. Analysis and results

The results are listed below according to the structural and functional analyses of the case studies, providing perspectives on the actors in the governance systems and how the system operates in the regions.

3.1. Structural analysis: mapping the governance landscape

The structural analysis reveals distinct multilevel governance arrangements across the regions, each characterised by unique institutional configurations and stakeholder interactions. Table 4 provides a comparative overview of key governance structures across regions.

3.1.1. Sicily, Italy

Sicily provides an interesting case for Italy's governance structure. The region has an autonomous status, featuring strong vertical integration from the EU to local levels. The multilevel governance arrangement enables Sicily to pass region-specific legislation while operating within the broader framework of EU and national policies. The Fisheries Department of Sicily maintains overarching responsibility for critical functions, including encouraging cooperation, conservation and optimal exploitation of marine biological resources. This is complemented by a network of specialised organisations: cooperatives provide administrative support through 44 consortia gathered under the General Association of Italian Cooperatives Sicily (AGCI Pesca); producer organisations and trade associations represent industry interests in institutional interactions; and the Sicilian Consortium for the Management of Artisanal Fishery implements local resource management plans. The District of Fishing and Blue Growth (DFBG) and Sicindustria emerge as particularly significant in facilitating industry-institutional interactions, supporting competitiveness, market expansion and technological advancement.

3.1.2. Greenland and West-Jutland, Denmark

The Jutlandic and Greenlandic cases present an instructive contrast in EU relationship dynamics. Companies in Denmark's West Jutland operate within the EU's Common Fisheries Policy framework,

[1] https://ruggedised.eu/legacy/.
[2] https://move21.eu/.
[3] https://www.bluerevproject.eu/.

Table 2
Definitions of system functions, drawn from the TIS framework with the questions used to guide the initial functional analysis.

System functions	Definition	Diagnostic questions
Knowledge development and dissemination	Generation and spread of knowledge and expertise within an innovation system. Includes activities such as research and development (R&D), training, and education. The development aspect focuses on creating new technological know-how, while dissemination involves spreading this knowledge among various actors within the system, such as firms, research institutions, and government bodies. Effective dissemination ensures that the knowledge developed is accessible and can be utilised for further innovations.	- What is the current knowledge situation around the by-product? - What are the current knowledge-gaps in relation to the by-product? - What initiatives currently exist in the region that aim to create and disseminate knowledge across relevant actor groups in the region?
Direction of search	The process of setting and influencing the trajectory of innovation activities. It involves guiding the focus of research and development efforts towards specific areas, technologies, or problems. This direction can be shaped by various factors, including policy decisions, market demands, societal needs, and scientific and technological advancements. Effectively directing the search can lead to more targeted and efficient innovation efforts.	- What arenas or forums for dialogue and collaboration currently exist in the region? - Are there shared perspectives among actors in the region over how the value-chain and by-product can and should be developed/scaled? - How can solutions be scaled and optimised over time to ensure success?
Legitimacy creation	Building social acceptance and support for new technologies or innovation practices. Legitimacy is crucial for the successful diffusion of technology, as it influences public opinion, government policy, and the willingness of stakeholders to invest in and adopt new technologies. Creating legitimacy often involves engaging with various stakeholders, including the public, policymakers, and industry players, to address concerns and build trust in the innovation.	- Are there existing policies and/or regulations currently in place that can work as incentives or restrictions for the by-products market demand? - Are there any potential risks associated with repurposing the by-product, such as health and safety concerns or negative impacts on the environment or other industries? - Is there currently acceptance for the use of the by-product from environmental, economic and social perspectives in the region? Any barriers?
Resource mobilisation	Acquiring and allocating necessary resources to support the innovation process. Resources can include financial investment, human capital, and infrastructural support. Mobilising resources is crucial for driving R&D efforts, supporting entrepreneurial activities, and building necessary infrastructures to enable innovation. The accessibility	- What is the quantity of the by-product generated during the manufacturing process, and how does this vary over time? - What are the major resource constraints that are likely to limit or hinder use of the by-product? (spatial/physical resources, financial resources, human capital and knowledge)

(*continued on next page*)

Table 2 (*continued*)

System functions	Definition	Diagnostic questions
	of these resources and the efficiency with which they are allocated can significantly influence the pace and direction of technological development.	- Are there sufficient financial resources for the use and up-scaling of the by-product?
Market formation	Creating demand and developing markets for new technologies. It includes activities such as setting standards and regulations, providing subsidies or incentives for adopting new technologies, and developing infrastructures that facilitate market growth. Market formation is essential to ensure that technological innovations find a viable commercial application and are adopted broadly.	- What are the potential markets for, and buyers of, the by-product, and what are their requirements, specifications, and levels of demand? - What is the potential for growth or expansion of the market demand for the by-product, and what are the factors that could influence this? - What current policies (e.g. related to public procurement, guaranties, subsidies) are in place that are drivers or barriers for the market development?
Entrepreneurial experimentation	Highlights the role of entrepreneurs in the innovation system. It involves the testing, development, and implementation of new ideas, products, or processes. Entrepreneurs are vital in innovation systems as they often initiate the commercialisation of new technologies, take risks to bring novel concepts to the market, and adapt to emerging opportunities and challenges within the innovation landscape.	- Can partnerships with other organisations or suppliers be explored to develop the value chain around the by-product? - Can the by-product be used in other industries, and are there any potential markets for it? - What are the potential risks or challenges associated with entering the market for the by-product, such as regulatory barriers or changing market conditions?

Table 3
Scale used in the functional assessment of the system functions.

Scale	Description used for assessment
Very weak	No activity observed. The function is not present or has no discernible impact within the innovation system. There is a complete lack of resources, structures, or participants supporting this function.
Weak	Minimal activity with weak impact. There is some evidence of the function, but it is stochastic, informal, or poorly organised. Efforts are often isolated or lack significant resources or commitment, resulting in very limited influence on the system.
Moderate	Moderate activity with some impact. The function has a noticeable presence and some dedicated resources. Activities are somewhat organised and have a modest but tangible effect on the innovation system, though they may still lack scale, reach, or consistency.
Good	Well-established activity with strong impact. The function is well-represented, with organised and consistent activities supported by adequate resources. Efforts are coordinated and widely recognised, contributing significantly to the progress and performance of the innovation system.
Excellent	Highly developed activity with substantial impact. The function is fully integrated into the system and operates at a high level of efficiency and effectiveness. Activities are comprehensive, well-resourced, and influential, with a strong and sustained positive impact on the innovation system.

implementing detailed marketing standards and labelling requirements. On the other hand, Greenland, though exiting the EU in 1985 and with a status as a self-governing territory in the Kingdom of Denmark, maintains association agreements with the EU that balance autonomy with market access.

Policies for marine businesses in Denmark's West Jutland region are developed by the Danish Ministry of Food, Agriculture and Fisheries. The Danish Spatial Planning Act, however, delegates significant responsibilities to municipalities to design and formulate guidelines for the administration of valuable nature areas (Bentsen et al., 2019).

Greenland's natural resource policies are developed by the Greenlandic Ministry for Fisheries, Hunting, Agriculture and Self-sufficiency. Moreover, the Greenlandic Fisheries Council exemplifies an innovative approach to stakeholder governance, mandated by the Fisheries Act to advise on policy and quota matters. The Council's composition integrates industry representatives (Greenland Business Association), resource users (Fishers' and Hunters' Association), and non-voting members from government ministries, municipalities, trade unions and environmental organisations. This structure facilitates knowledge exchange between scientific expertise, particularly through the Greenland Institute of Natural Resources, and traditional ecological knowledge (Long and Jones, 2021).

3.1.3. Saaremaa, Estonia

Estonia's governance of the algae value chain in Saaremaa exemplifies the challenges of coordinating emerging blue bioeconomy sectors. Primary oversight is divided between the Ministry of Regional Affairs and Agriculture, which is responsible for blue bioeconomy development and fisheries policy, and the Ministry of Climate, which oversees environmental protection and marine resource management. The involvement of additional ministries further complicates this dual leadership: Economic Affairs and Communication (maritime industry and infrastructure), Education and Research (research programs) and Finance (maritime spatial planning). At the local level, Saaremaa municipality's authority is primarily limited to land-based facilities, creating a distinct division between terrestrial and marine governance. While municipalities can influence enterprises through planning permissions, broader marine activities such as trawling quotas remain under national jurisdiction. This complex arrangement reflects the challenges of developing coherent governance frameworks for emerging marine industries while balancing local and national interests.

3.2. Functional analysis: identifying innovation barriers

The functional analysis is presented here, examining the performance of key processes or functions for the governance structures to support the innovation system in the case study regions. Like the structural analysis, the functional analysis is structured by case study regions, under which the performance of the six dimensions from the GOIS framework is presented.

3.2.1. Sicily, Italy

The analysis of Sicily reveals significant systemic challenges in the governance system's support for innovation in the fishing sector. The functional analysis demonstrates that the majority of analytical factors exhibit weak performance, indicating only marginal activity with limited systemic impact (Fig. 1). This pattern suggests fundamental structural barriers to innovation system development that require targeted interventions across multiple governance dimensions.

3.2.1.1. Knowledge development. Knowledge development exhibits substantial weakness, characterised by two primary functional constraints. First, marine by-products are predominantly conceptualised as waste requiring disposal rather than potential resources for valorisation. This perception indicates a fundamental gap in understanding the

Table 4
Comparative overview of governance structures in pilot regions.

Region	Primary governance bodies	Regulatory frameworks	Stakeholder integration mechanisms	Vertical coordination approaches
Trapani, Italy	Fisheries Department of Sicily, Ministry of Agriculture, Food and Forestry Policies	EU Common Fisheries Policy, Regional autonomous status regulations	Cooperatives (44 consortiums under AGCI Pesca), Producer organisations, DFBG, Sicindustria	Multilevel structure (EU-national-regional-local), Regional autonomy enabling local lawmaking
West Jutland/ Greenland, Denmark	Ministry of Food, Agriculture and Fisheries, Greenland Fisheries License Control	EU CFP (West Jutland), Fisheries Act of 1996 (Greenland), EU association agreements	Fisheries Council (Greenland), Industry-regulator dialogue forums	Municipal delegation (West Jutland), Consultative obligations with Fisheries Council (Greenland)
Saaremaa, Estonia	Ministry of Regional Affairs and Agriculture, Ministry of Climate, Ministry of Economic Affairs and Communication	Maritime spatial planning regulations, National fisheries policy, Environmental protection frameworks	Association of Saaremaa Entrepreneurs, Saarte Kalandus, Kuressaare College collaboration platforms	Division between national oversight of marine activities and local management of land-based facilities

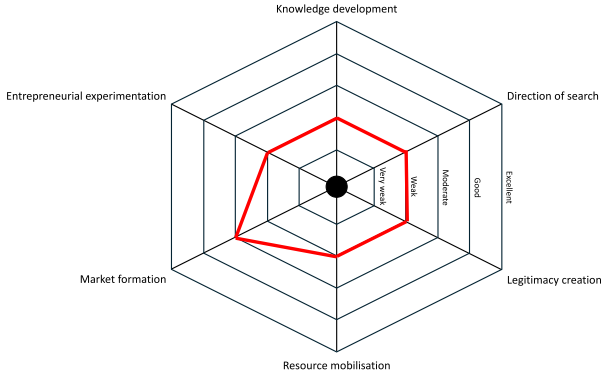

Fig. 1. Results for the functional analysis for the Sicily case study.

economic and environmental potential of these resources, stifling innovation potential. Second, while initiatives like the Blue Sea Land Expo exist to raise industry awareness and improve market appeal, interviews indicate limited awareness among industry actors about initiatives promoting by-product valorisation. This gap between existing initiatives and industry engagement suggests barriers in knowledge transfer and dissemination mechanisms within the innovation system.

3.2.1.2. Direction of search. The direction of search function demonstrates significant weakness, stemming from limitations in shared visions, goals, and development trajectories. While initiatives like the Blue Sea Land Expo represent efforts to establish arenas for dialogue and collaboration, their impact appears limited in fostering systemic change. The uncertainty surrounding how products and solutions can be scaled or optimised suggests a critical gap in strategic planning within Sicily's fishing and bioactive compound industries (Raicevich et al., 2020). This absence of strategic planning and clear directionality indicates a need for more comprehensive development approaches to ensure that innovations can be effectively developed, scaled and integrated into the broader industry landscape. The lack of coordinated direction particularly affects the ability to optimise solutions over time, suggesting a systemic barrier to long-term innovation.

3.2.1.3. Legitimacy creation. Legitimacy creation faces two primary barriers that contribute to its weak assessment. First, there is insufficient engagement with local and regional communities to build support for marine by-product utilisation within the innovation system. While the region demonstrates strong support for local produce due to its perceived high quality and authenticity, this remains underutilised in promoting by-product valorisation. The absence of public awareness campaigns, educational programs, or systematic communication efforts suggests a missed opportunity to leverage positive perceptions of local production. Second, there is a significant knowledge gap regarding regulatory frameworks governing side-stream utilisation in the fishing industry. While specific legislation like D.lgs. 152/2006 ITA and REG 1069/2009 EU provide guidelines for the sustainable utilisation of marine by-products, and the insufficient dissemination of regulatory information acts as a deterrent for sector actors. This regulatory uncertainty reduces the legitimacy of innovative practices around marine by-products and diminishes the willingness to invest in new product development, as the risk-reward balance appears unfavourable given the unclear regulatory landscape.

3.2.1.4. Resource mobilisation. Resource mobilisation confronts two fundamental challenges that significantly impact innovation system development: financial constraints and infrastructure limitations. Interviewees consistently highlight financial constraints as a key barrier for developing side-stream valorisation in the region, expressing significant uncertainty regarding the availability and adequacy of financial support for industry development. This indicates a critical need for improved resource allocation strategies to support sustainable growth and innovation in the sector. Infrastructure limitations, particularly storage facilities for by-products, create barriers to handling and processing resources efficiently. The fundamental question of infrastructure investment responsibility remains unresolved, requiring a collaborative approach from regional actors. These resource constraints create a self-reinforcing cycle that inhibits both current operations and future development, suggesting a systemic barrier to innovation system development.

3.2.1.5. Market formation. Market formation achieves a moderate assessment, though significant challenges persist in developing robust market structures. The region demonstrates low experience in utilising marine by-products, including fundamental aspects such as collection, storage, sales and management practices. Industry respondents consistently indicate scepticism about market potential, highlighting a prevailing pessimism about market opportunities. However, this pessimism contrasts sharply with the knowledge base of regional research actors, who demonstrate significant understanding of the potential for valorisation of marine by-products, including their Technological Readiness Level (TRL). Despite this academic knowledge base, there is a notable shortage of research resources to participate in accelerators, facilitate knowledge and technology transfer, and support start-ups in Sicily's blue economy. This disconnection between research capabilities and market implementation highlights a systemic gap in the innovation system's ability to translate technical knowledge into market opportunities.

3.2.1.6. Entrepreneurial experimentation. Entrepreneurial experimentation is assessed as weak, primarily due to insufficient support and involvement from committed individuals in government agencies. Interviewees indicate that a lack of support from government actors significantly hinders innovation and development, citing unclear

regulatory frameworks and insufficient funding as key factors limiting entrepreneurs' willingness to experiment in the sector. Enhanced partnerships between private and public organisations emerge as a critical requirement for encouraging entrepreneurial experimentation and exploration of cross-industry applications. Supporting initiatives that investigate the commercial use of marine by-products, including the identification of risks and challenges, would be important to enable entrepreneurial experimentation.

3.2.2. West Jutland/Greenland, Denmark

The analysis of West Jutland and Greenland reveals similar performance across innovation system functions and is thus merged into one case study (Fig. 2). While market formation and entrepreneurial experimentation demonstrate relative strength, persistent challenges in areas such as knowledge development and legitimacy creation suggest systemic barriers to innovation diffusion that require targeted interventions.

3.2.2.1. Knowledge development. The knowledge development function exhibits weaknesses across both West Jutland and Greenland, particularly regarding by-product valorisation strategies. In Greenland, current practices involve direct disposal of potentially valuable by-products at sea. This is exemplified by the discarding of Atlantic Cod liver and stomach, components historically valued in traditional cuisine. This indicates a disconnect between traditional knowledge systems and contemporary industrial operations. Businesses in West Jutland face parallel challenges, though primarily centred on process water management and protein recovery. A significant cross-regional barrier emerges in the categorisation of new products as novel foods. The ambiguity in regulatory definitions provides insufficient guidance for determining novel food status, while EU approval processes for human consumption create additional procedural complexity. Despite these systemic challenges, evidence of innovation emerges through initiatives for nutrient recovery. This includes, for example, protein and phosphorus extraction from processing water, and new applications for solid side-streams through partnerships with biorefinery operations.

3.2.2.2. Direction of search. The direction of search function demonstrates significant weakness in both West Jutland and Greenland, primarily due to collaboration barriers within the highly competitive fishing industry. Industry actors express marked reluctance to share business information in collaborative projects, contributing to an innovation-inhibiting culture. In West Jutland, this manifests particularly in the relationship between industry and the Danish Veterinary and Food Administration (DVFA). While industry stakeholders perceive gaps in inspectors' expertise regarding side-stream management, the DVFA actively encourages early engagement during pilot production phases to facilitate approval processes. In Greenland, actors have articulated a need for enhanced collaboration, citing a perceived lack of understanding regarding the circumstances of different actors within the value chain. It is noted that this limited awareness is contributing to an absence of local products for sale, which in turn affects the valorisation of side-streams in the industry (Departement for LandbrugSelvforsyningEnergi og Miljø, 2024). These dynamics highlight the need for enhanced dialogue mechanisms and trust-building initiatives between regulatory bodies and industry stakeholders (Refsgaard et al., 2021).

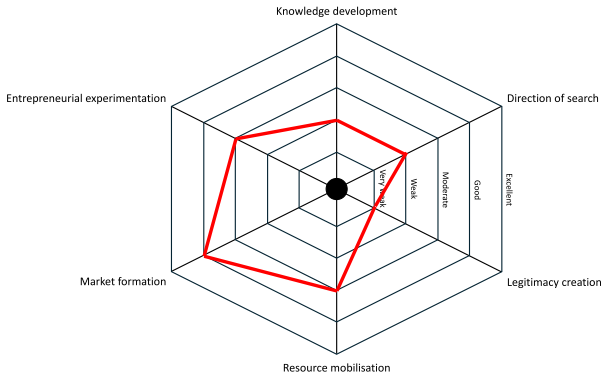

Fig. 2. Results for the functional analysis for the West Jutland and Greenland case studies.

3.2.2.3. Legitimacy creation. Legitimacy creation emerges as the system's weakest function in both Greenland and West Jutland, rated as 'Very weak' due to complex regulatory frameworks that impede innovation potential. The regulatory environment simultaneously drives and constrains market development for fish processing by-products. In West Jutland, smaller enterprises, particularly SMEs and startups with limited specialised staff, find DVFA requirements particularly challenging and time-consuming. A notable example of regulatory constraints is found in Danish facilities' inability to simultaneously produce products for human and animal consumption, a restriction not found in, for example, comparable Norwegian operations. This regulatory uncertainty significantly reduces businesses' willingness to invest in innovation, highlighting the systemic nature of legitimacy barriers in Denmark, which are also prevalent in Greenland.

3.2.2.4. Resource mobilisation. Resource mobilisation achieves a 'Moderate' rating despite facing distinct regional challenges in input resources, infrastructure and workforce availability. Both West Jutland and Greenland experience resource pressure, with Greenland particularly constrained by freshwater scarcity for side-stream processing. Both regions confront diminishing fish stocks and rising energy costs. However, these pressures have catalysed innovation, driving increased interest in side-stream valorisation for profitability enhancement. Infrastructure limitations manifest differently across regions: Greenland's smaller settlements lack freezing capacity for by-product market access, while the West Jutland region faces a shortage of large-scale facilities for higher-value product processing. A critical workforce shortage spans both operational roles (boat crews, processing facilities) and specialised professions (electricians, maintenance technicians), creating inter-industry competition, notably with construction in Greenland and life sciences in West Jutland.

3.2.2.5. Market formation. Market formation represents a significant systemic strength, with substantial activities supporting side-stream product development. However, processing costs present ongoing challenges, while raw materials are typically inexpensive, complex processing requirements like freezing or labour-intensive meat recovery impact profitability. Greenland faces additional logistical complexities due to geographical dispersion, with 36 processing plants across remote settlements lacking road connectivity. Despite these constraints, market opportunities persist. Greenland demonstrates, for example, demand for products incorporating side-streams in products like dog food, while West Jutland has adapted to market shifts following the termination of the mink industry (Kevany, 2020), previously a major by-product consumer. Companies like Biomega exemplify successful market adaptation through nutraceutical development, while potential exists for expanded Asian market access following established Icelandic models in the 100 % Fish initiative (Iceland Ocean Cluster, 2024).

3.2.2.6. Entrepreneurial experimentation. Entrepreneurial experimentation achieves a 'Moderate' rating, with ongoing activities demonstrating impact despite scaling and consistency challenges. Current initiatives align with market formation efforts, indicating active product development from side-streams. However, regulatory barriers, particularly around novel food classification in Denmark, constrain investment in

product development due to uncertain approval timelines. Early regulatory engagement, particularly with DVFA, offers potential pathways for reducing uncertainty, though EU-level decision-making processes continue to present significant challenges for rapid innovation cycles.

3.2.3. Saaremaa, Estonia

The governance functions in Saaremaa demonstrate relatively robust performance in supporting blue bioeconomy innovation compared to other regions in this case study (Fig. 3). However, no function achieves an 'Excellent' rating, indicating significant room for systemic improvement. The analysis reveals great contrasts between legitimacy creation (Very weak) and market formation (Good), suggesting uneven development of the innovation system.

3.2.3.1. Knowledge development. Knowledge development achieves a 'Moderate' rating, characterised by active commitment from commercial actors to technological advancement and knowledge exchange beyond immediate geographical and industrial boundaries. Ongoing partnerships between commercial actors and research institutions, including collaborations with the Estonian Marine Institute and the Estonian University of Life Sciences, demonstrate focused exploration of innovative applications in nutraceuticals, bio-stimulants and cosmetics. However, the algae-related blue bioeconomy remains a niche field, with only a few micro-enterprises engaged in algae valorisation and a limited number of specialised scientists. This concentration of expertise creates potential vulnerabilities in the knowledge infrastructure. While committed actors provide important platforms for collaborative learning, broader societal awareness regarding the full scope of blue bioeconomy sustainability practices remains constrained, indicating a systemic limitation in knowledge diffusion.

3.2.3.2. Direction of search. The direction of search function demonstrates mixed performance, with some impact from ongoing collaborative activities and regional visions, though lacking a consistent structure. A notable systemic gap exists in dedicated forums for communication between the municipality, blue bioeconomy businesses and the community. Current information sharing primarily occurs through informal channels and existing organisational structures like the Association of Saaremaa Entrepreneurs, Saaremaa Development Centre, Kuressaare College and Saarte Kalandus. Fragmented governance at the national level, combined with regulatory gaps and insufficient sectoral coordination, creates additional barriers. Interviewees particularly emphasise the absence of a holistic vision for blue bioeconomy planning at the national level, encompassing permits, regulations, planning processes, infrastructure development, and educational and research funding policies.

3.2.3.3. Legitimacy creation. Legitimacy creation emerges as the weakest function, which is hampered by fragmented responsibilities between public and regulatory agencies. The division of aquaculture and fisheries governance between two ministries, coupled with additional ministerial responsibilities for the blue economy and maritime topics, creates coordination challenges. Each ministry's tendency to regulate within its specific domain results in a lack of unified oversight of the blue economy and maritime sector. Interview results further indicate a governmental preference for maintaining status quo approaches, suggesting systemic resistance to governance innovation. Public acceptance presents an additional challenge, with growing resistance to offshore wind farms potentially signalling broader opposition to marine resource utilisation initiatives. This necessitates improved maritime spatial planning processes, particularly regarding macroalgae cultivation and co-location opportunities (Armoškaitė et al., 2021).

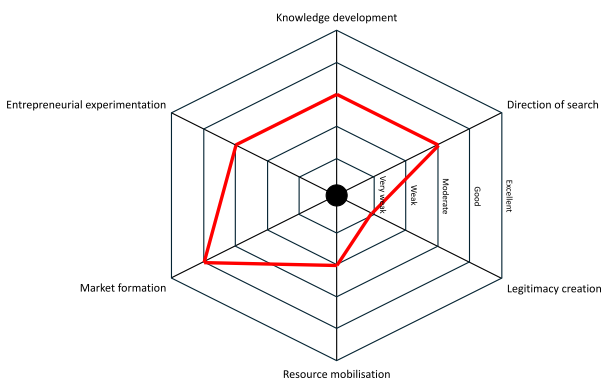

Fig. 3. Results for the functional analysis for the Saaremaa case study.

3.2.3.4. Resource mobilisation. Resource mobilisation is rated as 'Weak', with informal activity yet to achieve a significant regional impact. While commercial actors have invested in human resources, including researchers, technology specialists and production workers, current red algae extraction remains below environmental permit levels of 2000 tons annually (Kepp et al., 2022). The emerging nature of the field and its capital-intensive characteristics create barriers to infrastructure development and investment. Financial, material and human resources are essential for systemic change, yet gaps in regional innovation support structures, particularly in commercialisation funding and research partnerships, constrain development. The region's low population density exacerbates workforce challenges, while the concentration of expertise in a few R&D actors creates potential vulnerabilities. Cross-border grants and international project participation currently serve as critical resource mobilisation mechanisms.

3.2.3.5. Market formation. Market formation represents a systemic strength, supported by the EU's recognition of the Baltic Sea Region's circular bioeconomy potential (European Commission, 2021; Polityka Insight, 2019). Current red algae processors actively explore diverse applications, including plastic replacement alternatives. Regulatory frameworks for sustainable harvesting practices, including permit and quota management systems, provide a foundational market structure. However, significant challenges persist in cost-effectiveness, market trends for hydrocolloids and gelling agents, and attracting substantial investment capital for infrastructure development and large-scale pilot testing. Financial incentives and market development support emerge as potential mechanisms for establishing new market norms and industry standards.

3.2.3.6. Entrepreneurial experimentation. Entrepreneurial experimentation achieves a 'Moderate' rating, reflecting ongoing market testing and product development initiatives, such as organic fertiliser from red algae by-products. Commercial actors demonstrate substantial commitment through investments in human resources and research capacity. Notable examples include Est-Agar's development of a pilot plant for powdered furcellaran in collaboration with French partners, and Vetik's research investments in phycoerythrin extraction for cosmetic applications (Kepp et al., 2022). However, entrepreneurial development faces constraints from limited skilled worker availability, concentrated expertise, and insufficient pilot production facilities. These systemic barriers suggest the need for enhanced support structures to facilitate business development and innovation scaling.

3.3. Case study insights

The results from the case studies indicate that there are shared patterns in the functions, both in terms of strengths and weaknesses in the governance of the respective innovation systems. Strengths include 'moderate' to 'good' function of market formation in the regions where activities supporting demand creation and new product development

are underway. However, generally low scores for legitimacy creation demonstrate weak market formation and limited development and implementation of regulations and permit issuance.

The functions of the governance systems differ across the regions studied in this paper. While it is difficult to conclude that the functions perform overall better in one region compared to another due to structural differences in the governance system, the analysis indicates that governance functions support innovation better in Saaremaa than in Sicily at present, whereas the situation in West Jutland and Greenland falls somewhere in-between. There is no single function where one case study region clearly stands apart from the other. Instead, we are seeing marginally stronger governance functions in some regions, such as better performing market formation in the West Jutland and Saaremaa cases, or conversely, a somewhat better legitimacy function in Sicily.

Similarities between the case study regions instead indicate that the geographically and culturally disparate regions are facing similar governance challenges, which could potentially generalise to other European regions and beyond. The regions studied are all facing governance challenges in the legitimacy creation, knowledge development, and resource mobilisation functions. The barriers in the legitimacy function relate to a perceived lack of regulatory support for the valorisation of side streams or complex permission processes that hinder businesses from investing in product development and infrastructure. This, in turn, will have an impact on market formation, as fewer products are likely to enter the market due to the legislative uncertainty surrounding the use of side streams.

4. Discussion and policy implications

This paper makes three key contributions to the literature on innovation systems and blue bioeconomy governance. First, following the GOIS framework and the case study results, the paper demonstrates the value of applying a governance-focused analytical innovation systems perspective to the emerging bio-based sectors, extending traditional TIS approaches. The GOIS framework enables researchers and policymakers to better understand the potential strengths and weaknesses of the governance functions that propel the development of a regional blue bioeconomy forward. Applying the GOIS framework thus allows for identifying key interventions and governance aspects to strengthen emerging regional innovation systems.

Second, the paper provides empirical evidence of how governance functions can vary across different regional contexts, while identifying common challenges that transcend geographical boundaries. Considering the richness of the empirical data gathered along the six dimensions of the GOIS framework, the results in this paper show relevance for blue bioeconomy development in regions beyond the case studies. Complementing previous studies on the development and diffusion of biorefinery technologies (Bauer et al., 2017) and the algae feedstock for various applications (Berg et al., 2019; Haase et al., 2013), this paper casts new light on challenges in the sector. Namely, the uneven distribution of power and resources, conflicts between short-term economic objectives and long-term environmental sustainability, fragmented multilateral cooperation, and low local implementation capacity (Li et al., 2025). The generalisable findings, including the challenges connected to legitimacy creation, knowledge development and resource mobilisation, provide lessons for policymakers and funding authorities in the way that funding schemes and policies can be developed. Some of these lessons are outlined in sections 4.1.1–4.1.3, and include recommendations for innovative funding schemes that draw inspiration from blue bonds, as well as policies that streamline permit processes and emphasise cooperative practices. Additional lessons for government authorities include recognising the complexity of governing the blue bioeconomy and invest in capacity and capability training in local authorities to better support entrepreneurs in the space; emphasise building trust among stakeholders to strengthen innovation capacity and identify new collaborations and products; and engaging in novel governance approaches, involving relevant stakeholders in decision making processes and utilising the emerging concept of anticipatory innovation governance to shape the future through governance mechanisms (Tõnurist and Hanson, 2020).

Third, applying the GOIS framework allows for establishing a clear link between governance functions and innovation outcomes in the blue bioeconomy sector. The innovation outcomes are dependent on the way in which the governance functions in the specific cases are structured, and the ability of the governance structure to address system failures. Thus, this paper joins the literature highlighting the need for joint and regional governance efforts to sustain healthy, productive, and resilient oceans and ecosystem services (Albrecht and Lukkarinen, 2020; Bednarsek et al., 2023; Diz et al., 2019).

While this study offers valuable insights into current governance conditions, the evolving nature of the blue bioeconomy (Ligtvoet et al., 2019; Pisarović, 2022) calls for a more forward-looking governance perspective. Thus, we suggest that future GOIS approaches builds on the concept of *anticipatory innovation governance*, which views governance as a broad-based capacity among many actors to actively explore options with the hopes of shaping innovative practice and a particular aim of spurring innovation (novel to the context, implemented and value-shifting products, services and processes) for uncertain futures (OPSI, 2019). Such methodological development could amount to establishing anticipatory governance of innovation systems as a novel concept, studying how current governance structures support innovation, where potential future developments are taken into consideration. For example, this could include how climate or demographic changes affect the blue bioeconomy, and what governance structures are needed to support innovation in light of these changes.

There are many interconnected challenges that constitute barriers to an emerging blue bioeconomy (Diz et al., 2019). Our analyses reveal how improved governance structures could address key blue bioeconomy system failures, such as market formation challenges (Araújo et al., 2021; Caruso et al., 2020), fragmented regulatory frameworks (Pender et al., 2024; Thompson et al., 2024), and workforce shortages (Fischer, 2018).

Some limitations should be acknowledged. The study focuses on three European regions and one self-governing territory. While providing valuable insights, this study may not capture the full diversity of governance challenges in other geographical contexts. Additionally, the rapidly evolving nature of the blue bioeconomy sector means that some findings may require regular updating as new governance mechanisms emerge. However, we believe that the case studies provide an instructive narrative of the state of play in coastal regions, aiming to develop their local areas and the blue bioeconomy. Hence, the paper has might be relevant for impeding fragmented governance, legitimacy challenges and innovation bottlenecks in emerging blue bioeconomies beyond Europe, including, but not limited, regions in the Global South and small island developing states.

4.1. Implications for ocean and coastal management

Our findings indicate that, despite geographical and cultural differences, the case study regions face similar governance challenges related to the legitimacy creation, knowledge development and resource mobilisation functions identified through the GOIS analysis. Three policy areas emerge as generally important for ocean and coastal management in a European context to strengthen the valorisation of sidestreams in the fishing and aquaculture industries: *simplifying regulatory processes, developing innovative financing mechanisms* and *enhancing collaboration*. While additional weaknesses in the regional innovation systems were identified in our analysis, such as in entrepreneurial experimentation and direction of search, we expect that some of these weaknesses will be addressed by interventions in the identified functions and through the selected policy areas. For example, direction of search is hampered by a lack of collaboration across regions, whereas

entrepreneurial experimentation is constrained by unclear regulatory frameworks. Based on the analysis, the three aforementioned policy areas were chosen as they are likely to provide the overall greatest benefit to the blue bioeconomy as a whole. Subsequently, we will discuss each area and illustrate how our results and other examples from across Europe support these governance strategies at the coastal and marine level.

4.1.1. Simplify regulatory processes

Regulatory complexity is a barrier across the studied regions, inhibiting innovation and market entry through undermining institutional legitimacy for side-stream valorisation. Our results indicate that enhancing coordination and oversight from a governance perspective would contribute to a more strategic approach to the blue bioeconomy and may, in turn, help create a less complex and more predictable and flexible regulatory environment. Two concrete policy mechanisms may help address regulatory challenges in this field: regulatory sandboxes and administrative one-stop shops. First, regulatory sandboxes might enable businesses to test innovative valorisation processes for marine side-streams under controlled conditions with temporary regulatory exemptions (Alaassar et al., 2020), generating evidence for both technical feasibility and appropriate oversight mechanisms while reducing institutional barriers to scaling. Thus, regulatory sandboxes can serve a dual purpose: they provide empirical evidence of regulatory barriers while simultaneously offering protected spaces for testing novel solutions.

Second, administrative one-stop shops represent another emerging approach, streamlining complex regulatory processes by providing businesses with a single point of contact for navigating multi-agency requirements. These initiatives aim to reduce administrative burden while accelerating permit issuance through enhanced inter-agency coordination (see, e.g. Art. 8 in *The Aquaculture Act*, Lovdata, 2020). One-stop shops for the novel food industry have been implemented in Norway and Sweden, showing promising results (Swedish Agency for Economic and Regional Growth, 2024; Osmund and Schei Olsen, 2025). In the case of Norway, the county municipalities have held the authority to allocate aquaculture licenses since 2010, serving as the coordinating body throughout the application process and acting as the ultimate decision-maker. This marked a transfer of responsibility from the Directorate of Fisheries to the regional level, driven by three objectives: bringing decision-making closer to the aquaculture sites, enhancing cooperation between regional authorities and aquaculture stakeholders, and strengthening regional governance capabilities (Osmund and Schei Olsen, 2025). In response to their expanded role, the county municipalities recognised the importance of inter-regional cooperation and subsequently established an expert network – FAKS – to consolidate and advance their collective expertise (Osmund and Schei Olsen, 2025; Kyst.no, 2018). In a recent evaluation, the county municipalities' role as coordinators has been seen as positive, and they have been commended for their efforts to streamline processes. The coordination meetings facilitated by the county municipalities are regarded as crucial forums for fostering collaboration and knowledge-sharing among stakeholders (Osmundsen and Schei Olsen, 2025).

4.1.2. Innovative financing and support mechanisms

The analyses of resource mobilisation in the case study regions have revealed that the present financial constraints are characterised by systemic risk aversion and inadequate support mechanisms. One way to address this is by leaning into novel financing models to support risk-taking and market entry. Emerging financing mechanisms that could have a positive impact on the blue bioeconomy include blue bonds and business accelerator programs. Blue bonds represent an emerging financing mechanism for sustainable ocean-related projects. While these instruments can attract significant capital, their implementation requires careful consideration of debt sustainability, particularly for smaller states. Their design often entails high transaction costs and rigid, pre-determined terms that can prioritise commercial interests and external standards over local needs, thereby marginalising small-scale communities and entrenching dependency on export commodities in the absence of sufficient alternative climate finance (Kılıç, 2024). However, the success of initiatives like the Seychelles Blue Bond demonstrates both the potential and complexities of this approach. Blue Bonds can aid the development of the blue bioeconomy by attracting private capital to finance ocean conservation and sustainable development projects, aligning with global goals like SDG 14 and facilitating mechanisms such as debt-for-nature swaps. However, they are complex due to their ambiguous thematic scope, posing a risk of 'blue-washing', and issues of geographical inequity in fund distribution (Thompson, 2022).

Business accelerator programs provide structured support combining mentorship, resources and funding, which can be particularly effective in fostering innovation in smaller communities. They can act as catalysts for wider ecosystem development, specifically designed to attract entrepreneurs to a locale, promising job creation and cultural transformation via startup growth. These programs often achieve this by facilitating the coordination of resources from multiple stakeholders in a nascent ecosystem, including investors, corporations, universities, and existing entrepreneurs (Cohen et al., 2019). The EU-backed BlueInvest Accelerator exemplifies how such programs can be tailored to the blue bioeconomy sector. BlueInvest offers a range of actions geared towards creating a vibrant community of entrepreneurs in the blue bioeconomy, while assisting in realising their businesses, including events, knowledge centres, capacity building, fundraising assistance, and creating project portfolios for investors (European Commission, n.d). Their investor report from 2023 shows an increased interest from investors and how BlueInvest is helping them navigate opportunities in the blue bioeconomy space (Directorate-General for Maritime Affairs and Fisheries, 2023). The financing and support mechanisms mentioned here can also serve to bring collaborative elements to the blue bioeconomy, through business accelerators, which were identified as a need based on weaknesses in the knowledge development function of the analysis. Ways of increasing collaboration in the sector will be discussed further in the section below.

4.1.3. Enhancing stakeholder collaboration

The development of an innovation system is supported by inter-stakeholder collaboration (Westman et al., 2022). Therefore, emphasising integrated governance approaches, involving a variety of stakeholders, could help marry an otherwise fragmented policy landscape, assisting in creating a more consistent, timely and appropriate innovation system. For example, the case studies show that collaboration among committed actors is key for increased understanding of the blue bioeconomy value chain, knowledge transfer and innovation.

We highlight two collaborative mechanisms for ocean and coastal management to support enhanced collaboration: First, Collaborative Councils and Regional Networks support local knowledge sharing and best practice exchange. Work by Rossoni et al. (2024) has shown that success factors for setting up and running successful collaborative councils include dedicated interaction offices, targeted government incentives such as tax exemptions for collaborative projects and sustained public funding for their operation. These factors will have to be interwoven in the governance structures across levels – national, regional, and local – for collaboration to succeed. Second, Public-Private Partnerships (PPPs) offer a structured approach to combining public resources with private sector innovation capabilities. These partnerships are particularly valuable for high-risk, high-reward areas such as marine biotechnology and sustainable seafood production (OECD). However, research has also identified risks in PPPs that can make them fragile. For example, partnerships can become fragmented due to changing industrial priorities, while the programmes simultaneously need to be cost-effective for it to be financially attractive for food industry actors to participate (Rouvière and Royer, 2017).

Although presented as three distinct policy domains, these policy areas are deeply interconnected. Ocean and coastal management addressing any of these recommendations would most likely be able to unlock some institutional weaknesses, such as fragmented responsibilities, weak multi-level and cross-sectoral governance structures (Bednarsek et al., 2023), while still maintaining sensitivities towards the geographically rooted historical and spatial contexts.

Addressing these aspects through a novel model perspective may not only serve as a springboard for blue bioeconomy businesses but also attract investments and, consequently, revitalise local coastal communities by creating new jobs that demand skilled labour, and unlocking economic opportunities aligned with the needs of blue bioeconomy developments (see e.g., Refsgaard et al., 2021). Therefore, to support the emergence and growth of the blue bioeconomy across Europe, ocean and coastal management, along with future governance research, should focus on these interconnected policy areas.

5. Conclusions

By systematically analysing three European coastal regions and one self-governing territory, this paper has advanced the understanding of innovation system governance and how it might strengthen the emerging blue bioeconomy. The uneven distribution of power and resources, conflicting goals and objectives, fragmented cooperation, and varying capacity levels for implementing actionable policies are significant hurdles to overcome to ensure a booming blue bioeconomy sector. Addressing the underlying governance structures is paramount to solving these issues.

Through the GOIS framework, which sets out to explain the interconnections between individuals, organisations, states and societal groups as well as the formal and informal rules that guide innovation systems, we revealed how governance functions impact innovation potential differently across geographical and institutional contexts. Our findings demonstrate that while market formation shows promise in our cases, persistent challenges in legitimacy creation and regulatory fragmentation continue to impede blue bioeconomy development.

The paper makes two key theoretical contributions: it extends traditional innovation systems theory by incorporating governance-specific analysis, and it provides empirical evidence for how governance functions mediate innovation in emerging bio-based sectors. For practitioners and policymakers specifically, our analysis offers concrete pathways for governance improvements through regulatory simplification, innovative financing, and collaborative frameworks. Beyond the European context, these case studies offer a potentially generalisable foundation for investigating the factors that enable or constrain the development of the blue bioeconomy in other regions. Moreover, they provide insight into how these challenges might be addressed within specific contexts. By applying the GOIS framework, new light is shed on both formal and informal structures that may help or hinder innovation.

Future research in this area could explore how anticipatory governance approaches can enhance actors' capabilities to address emerging innovation systems challenges related to climate adaptation and resource management within the blue bioeconomy sector.

CRediT authorship contribution statement

Björn Persson: Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Niklas Fernqvist:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Mari Wøien Meijer:** Methodology, Formal analysis. **Daniel Bengtsson:** Methodology, Funding acquisition, Conceptualization. **Daniel Mattisson:** Formal analysis, Conceptualization.

Data statement

The data that support the findings of this study are available from the corresponding author in anonymised form upon reasonable request.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Bjorn Persson reports financial support was provided by Horizon Europe. Niklas Fernqvist reports financial support was provided by Horizon Europe. Mari Woien Meijer reports financial support was provided by Horizon Europe. Daniel Bengtsson reports financial support was provided by Horizon Europe. Daniel Mattisson reports financial support was provided by Horizon Europe. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

A. List of interviewees in the studied regions

ID	Perspective	Region
D1	Government agency	Denmark
D2	Business	Denmark
D3	Business	Denmark
D4	Interest organisation	Denmark
G1	Business	Greenland
G2	Business	Greenland
G3	Interest organisation	Greenland
E1	Business	Estonia
E2	Municipality	Estonia
E3	Research	Estonia
E4	Research/Teaching	Estonia
E5	Interest organisation	Estonia
E6	Government agency	Estonia
I1	Business	Italy

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(*continued*)

ID	Perspective	Region
I2	Producer organisation	Italy
I3	Producer organisation	Italy
I4	Interest organisation	Italy
I5	Business	Italy

Data availability

Data will be made available on request.

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