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INTERACTIVE GOVERNANCE OF FISHERIES AND AQUACULTURE: TRANSDISCIPLINARY CHALLENGES AND STAKEHOLDER INVOLVEMENT IN COASTAL ZONE MANAGEMENT

Mbachi Ruth MSOMPHORA*

Department of Health and Care Sciences, UiT The Arctic University of Norway, NORWAY

Mbachi Ruth MSOMPHORA: mbachi.msomphora@uit.no, https://orcid.org/0000-0003-3094-5577

**Corresponding author: Mbachi Ruth MSOMPHORA, mbachi.msomphora@uit.no, +47-77623155*

Abstract
This paper examines the interactions between fisheries and aquaculture in Northern Norway, with a particular focus on environmental impacts and governance frameworks. The increasing overlap between aquaculture facilities and critical fisheries, such as cod spawning grounds, has raised concerns regarding habitat degradation and ecosystem sustainability. This study evaluates stakeholder perspectives through a 2020 survey, exploring the challenges of governance, stakeholder engagement, and compliance with environmental regulations. We analyzed how national, regional, and local governance structures interact and how these multi-layered frameworks are crucial for mitigating conflicts between aquaculture and fisheries. The findings underscore the need for enhanced monitoring systems, more transparent decision-making processes, and an integrated governance approach that incorporates both scientific knowledge and local insights to ensure the sustainable development of coastal zones.

Keywords: Coastal zone management, governance framework, aquaculture, fisheries, sustainability, stakeholder engagement

Introduction
Fish is a vital source of animal protein worldwide, especially in developing countries (SOFIA, 2018). However, natural fisheries have faced significant declines, prompting the growth of aquaculture to meet future seafood demands. The expansion of aquaculture has raised societal concerns, particularly regarding its environmental impacts on coastal ecosystems (MARINFORSK, 2018). The discharge of nitrogen (N) and phosphorus (P) from aquaculture

waste into marine environments can exceed the assimilation capacity of these ecosystems, leading to negative effects (Taranger et al., 2015, Msomphora, 2000; Naylor et al., 2000; Eng et al., 1989). These impacts include alterations in sediment composition and benthic communities due to fish-feed losses and larger faeces particles, as well as effects on pelagic communities and euphotic waters from dissolved nutrients and smaller faeces particles (Olsen et al., 2008). The resulting conflicts between fish farmers and fishers underscore the need for improved governance and waste management in aquaculture (Sanchez-Jerez et al., 2016). A nuanced understanding of aquaculture's impacts on ecosystems, stakeholder dynamics, and the integration of food security, safety, and sovereignty into governance is essential for informing policy and practice, particularly in coastal zones where both aquaculture and fisheries are integrated. Coastal zone governance is critical not only for ecological balance but also for the economic and social well-being of dependent communities. In regions where fisheries and aquaculture industries thrive, resource management becomes complex due to the overlapping interests of environmental sustainability and economic viability. Norway, with its extensive coastline and significant reliance on these industries, faces unique challenges exacerbated by climatic changes and evolving demographic patterns. This article aims to develop an evidence-based theoretical framework using Interactive Governance theory (Jentoft & Chuenpagdee, 2015; Kooiman, 2003; Kooiman, 2008; Kooiman, 2013) for interactive governance in such settings, emphasizing the integration of both natural and social sciences to address these challenges holistically. Coastal zones are among the most productive yet vulnerable areas on Earth, crucial for biodiversity, providing significant economic goods and services, and supporting large human populations. Globally, managing these zones is challenged by issues such as pollution, resource depletion, and climate change impacts. Effective coastal governance is essential to balance human development needs with environmental conservation (Stenseth et al., 2020).

Norway's coastal management is particularly challenging due to its long coastline, which hosts diverse marine ecosystems and human activities. The fisheries and aquaculture sectors are vital to the national economy but pose sustainability challenges, including habitat destruction, overfishing, and user group conflicts. These challenges are compounded by climate change (Ottersen et al., 2023), which affects fish populations and distributions, thereby impacting fisheries management and aquaculture practices. Coastal zone planning, implemented in Norway as part of the governance frameworks for interactive coastal zone management, seeks to address these issues by integrating ecological, economic, and social dimensions. This article explores these complexities and proposes an interactive governance model to manage both fisheries and aquaculture sustainably in coastal regions.

Material and Method

Scope of the article

This article focuses on the governance of fisheries and aquaculture within Norway's coastal zones. It seeks to establish a theoretical framework incorporating the principles of interactive governance, emphasizing stakeholder involvement and the integration of multiple disciplinary perspectives. The framework aims to address the complex socio-ecological dynamics of coastal zones, focusing on sustainable management practices.

Research questions and objectives

This article seeks to address critical questions related to the management of fisheries and aquaculture within coastal zones. Central to this inquiry is the exploration of interactive

governance frameworks and their efficacy in navigating the multifaceted challenges inherent in these environments. The primary research questions guiding this study are as follows:

1. How can interactive governance frameworks be effectively applied to manage fisheries and aquaculture in coastal zones?
2. What role do ecological and socio-economic aspects play in the sustainable management of these industries?
3. How can knowledge and practices from Norway be transferred to other regions facing similar challenges?

The objectives of this research are designed to provide a structured approach to answering these questions and contributing valuable insights to the field. First, the study aims to develop a comprehensive understanding of both the challenges and opportunities present in coastal zone management, with a particular emphasis on fisheries and aquaculture. This involves analyzing the socio-ecological dynamics and pinpointing areas where management strategies can be optimized. Furthermore, the article seeks to propose an evidence-based framework for interactive governance that bridges natural and social science perspectives. Such an integrated approach is crucial for fostering sustainable practices that are not only ecologically sound but also socially and economically viable. Lastly, the study aspires to explore how this proposed framework can inform global coastal management practices. Emphasis will be placed on the implications for sustainability, with the aim of promoting adaptable strategies that can be applied in various regions confronting similar challenges. By pursuing these objectives, the article contributes to the discourse on effective governance models that support sustainable resource use, stakeholder inclusion, and the overall well-being of coastal communities. The findings are intended to guide policymakers, stakeholders, and researchers in the development and implementation of frameworks that ensure balanced, long-term management of coastal resources.

Existing frameworks and theories

The literature on coastal zone management is extensive, reflecting the complexity and diversity of issues associated with these areas. Key frameworks such as Integrated Coastal Zone Management (ICZM) and Ecosystem-Based Management (EBM) have been widely discussed. ICZM uses an integrated approach for coastline management, aiming at sustainability by balancing environmental, economic, social, cultural, and recreational objectives (Cicin-Sain & Knecht, 2013). EBM maintains ecosystems in a healthy, productive, and resilient condition to provide the services humans want and need (McLeod & Leslie, 2009; Msomphora, 2016). Despite their widespread adoption, these frameworks often fall short in integrating the specific needs and challenges of fisheries and aquaculture within coastal zones. Traditional management practices frequently fail to account for the socio-economic dynamics characterizing fishing communities (Chuenpagdee & Jentoft, 2009; Jentoft & Chuenpagdee, 2009). Furthermore, the literature suggests a gap in addressing the transdisciplinary nature of coastal challenges, where both natural and social sciences must interact to produce effective governance (Msomphora & Jentoft, 2019). This interaction should also integrate local knowledge from coastal communities and practitioners, who bring invaluable insights into sustainable practices and historical data critical for comprehensive management strategies (Berkes, 2010, 2017).

Integration of fisheries and aquaculture management

Fisheries and aquaculture are critical components of coastal economies but are often managed separately despite their interrelated impacts on ecosystems. Studies have shown that integrating these sectors through policies and governance frameworks can lead to better resource management and sustainability outcomes (FAO, 2011). However, achieving this integration in

practice is challenging due to differing objectives, stakeholder conflicts, and complex regulatory environments (Bremer & Glavovic, 2013; Msomphora, 2016b, 2018).

Gaps in current research

The review of literature highlights significant gaps in frameworks that effectively integrate the ecological, economic, and social dimensions of coastal zone management, particularly in contexts where fisheries and aquaculture coexist. There is also a noted deficiency in frameworks that actively involve stakeholders throughout the governance process, crucial for ensuring that management strategies are both effective and equitable (Reed, 2008; Msomphora, 2016; Jentoft & Chuenpagdee, 2022). Some nations, however, have implemented management frameworks that contribute to effective interactive management of fisheries and aquaculture in coastal zones. In Norway, coastal zone planning is implemented as one of the governance frameworks for interactive coastal zone management.

Transdisciplinary research approach

This study adopts a transdisciplinary research approach, integrating knowledge from natural sciences (e.g., marine biology, environmental science) and social sciences (e.g., sociology, economics), but more so from local knowledge of users and practitioners. This approach is essential for developing a holistic understanding of the socio-ecological systems involved in coastal zone management, enabling governance frameworks that are both scientifically robust and socially acceptable (Lang et al., 2012). The complexity of managing fisheries and aquaculture in coastal zones necessitates this integration, as it provides insights into both ecological impacts and the human dimensions of these industries.

Stakeholder involvement

Stakeholder involvement was emphasized from the beginning to ensure diverse perspectives and interests were integrated into the study. Stakeholders included local fishers, aquaculture operators, community leaders, policymakers, and scientists. A survey was conducted, and in-depth interviews with key informants from marginalized groups, such as small-scale fishers, provided qualitative data about their observations and experiences with integrated coastal zone planning. These engagements helped identify conflicts, governance challenges, and areas where cooperation could be strengthened, contributing significantly to the development of an inclusive framework for fisheries and aquaculture management (Reed et al., 2009).

Qualitative and quantitative methods

Qualitative and quantitative methods were used to gather data. Qualitative data was collected through surveys and interviews to understand stakeholder perspectives on governance, conflicts, and community dynamics. Quantitative data included fisheries and aquaculture production statistics, and environmental impact assessments. A thematic analysis was applied to the qualitative data, identifying key themes such as governance conflicts, stakeholder engagement, and the environmental impact of aquaculture. Statistical analysis was employed on the quantitative data to assess trends and relationships, providing a solid foundation for the proposed governance framework (Creswell & Creswell, 2018).

Case Study: Northern Norway Coastal Communities

A case study focused on Northern Norway's coastal communities was selected for the in-depth application of the governance framework. Northern Norway, with its extensive coastline, provides a unique setting for studying the integration of fisheries and aquaculture (Institute of Marine Research, 2021). The region's reliance on marine resources, coupled with its dynamic ecosystems, offers a practical example of the socio-ecological challenges faced in coastal zones

globally (Petersen at al., 2018; MARINFORSK, 2018). In this region, innovative regulatory frameworks like the "trafikklyssystemet" (traffic light system) for aquaculture are already in place to adapt management strategies to environmental feedback, providing a foundation for adaptive governance (Michaelsen-Svendsen, 2019; Hersoug, 2015). The 'traffic light system' is a color-coded system that categorizes coastal areas into green, yellow, or red zones based on the level of environmental health, particularly focusing on sea-lice infestation levels. Green zones permit continued or increased aquaculture production, yellow indicates moderate impact where caution is needed with potential restrictions, and red mandates reduced production to mitigate ecological stress. The region's rich marine biodiversity and the reliance on fisheries and aquaculture for local economies present both opportunities and challenges for balancing ecological sustainability with social economic development (Fudge et al. 2023; Chaturvedi et al. 2024).

Developing the governance framework

The governance framework proposed in this study emphasizes core principles of interactive governance, which include stakeholder engagement, adaptive management, and integration of scientific knowledge with local practices. The framework's key components are:

1. *Stakeholder Engagement:* Involving all relevant stakeholders in decision-making to ensure diverse perspectives are considered and potential conflicts are addressed early.
2. *Adaptive Management:* Implementing flexible strategies that adjust to environmental feedback and evolving socio-economic conditions.
3. *Integrated Approach:* Balancing ecological and social considerations to create holistic management practices that promote both sustainability and social economic viability.

Applying the framework in Northern Norway

To apply this framework in Northern Norway, the following steps were outlined:

1. *Stakeholder Mapping:* Identifying and engaging key stakeholders, including fishers, aquaculture operators, community leaders, policymakers, and scientists.
2. *Baseline Assessment:* Conducting a comprehensive evaluation of current ecological and social conditions in the region's coastal zones.
3. *Scenario Planning:* Developing and accessing different management scenarios to understand potential outcomes and trade-offs between ecological sustainability and social dimensions.
4. *Implementation and Monitoring:* Establishing a monitoring system to track the performance of selected management strategies and adjust them as necessary to adapt to environmental changes.

This multi-step approach ensures that governance remains adaptive and responsive to both ecological feedback and stakeholder needs, contributing to sustainable management of fisheries and aquaculture in the region.

Results

Insights of Case Study

Survey Insights: Respondent perspectives on coastal zone planning in Norway

A comprehensive survey conducted in 2020 highlighted significant dissatisfaction with the effectiveness of Norway's coastal zone plans in reducing conflicts among stakeholders. The survey, which included 38 detailed responses, revealed several recurring themes regarding the challenges and concerns associated with coastal zone management.

Concerns about aquaculture
A major theme that emerged from the survey was the dissatisfaction with aquaculture practices. Several respondents expressed concerns that the industry prioritizes short-term profits at the expense of long-term environmental sustainability and ethical standards. Many felt that aquaculture facilities were being established without adequate consultation or input from stakeholders, particularly when these facilities encroached upon vital fishing grounds. Tromsø's coastal zone plan, in particular, was heavily criticized for disproportionately favouring aquaculture interests over the concerns of other stakeholders, highlighting a potential imbalance in representation.

Environmental and ethical issues
Broader environmental and ethical concerns also featured prominently in the feedback. Some respondents pointed to the use of fjords as dumping grounds for mining waste, raising issues of irreversible environmental harm. There was also frustration over the difficulties in documenting essential natural features, such as spawning grounds for important fish species, which are critical for maintaining biodiversity and ecosystem health.

Stakeholder inclusion and engagement
Another key concern revolved around the inclusion of stakeholders in the planning process. Respondents advocated for more inclusive and transparent mechanisms that would allow all stakeholders to be heard and for decision-making to be based on evidence and sound science. Many proposed improving early consultations, particularly with local associations, and enhancing transparency by disseminating information on platforms such as "Altinn", a technical platform of government bodies for developing digital services, which could serve as a central repository for significant issues.

Link to Theoretical Framework
The findings reinforce the interactive governance theory by illustrating how stakeholder inclusion and adaptive governance can address governance gaps in coastal zones. However, the model contributes to overcoming a key shortcoming of the theory—its limited practical guidance on conflict resolution between stakeholders. By integrating robust enforcement mechanisms and cultural knowledge, the model advances the theoretical framework toward real-world applicability. To address these needs, the governance model requires further elaboration on concrete implementation steps and potential challenges. This includes stakeholder mapping, scenario planning, and establishing adaptive monitoring systems. Involving local councils to ensure inclusive decision-making and leveraging tools like "Altinn" for transparent communication are essential first steps. Additionally, using technological tools like satellite monitoring and automated environmental sensors can enhance the tracking of aquaculture impacts and compliance with regulations.

Knowledge and planning integrity
The role of knowledge and planning integrity was also emphasized. Several respondents highlighted the need for high-quality, relevant data to inform decision-making processes, particularly in the context of environmental impact assessments. However, some expressed scepticism about the feasibility of creating a centralized database for coastal zone planning, given the dynamic nature of the field and the broad range of pre-existing integrated databases.

Cultural and local considerations
The feedback also touched on the importance of incorporating cultural and local knowledge into planning processes. One example cited involved a costly and culturally insensitive road

project that could have been avoided had local insights been taken into account. This underscores the importance of considering local perspectives and cultural heritage when planning development projects that affect coastal zones.

General discontent with power dynamics

Finally, a sense of general discontent permeated the responses, particularly regarding the influence of powerful interests in the decision-making process. One respondent referred to these influential groups as "aquaculture oligarchs," reflecting a perception that certain industry players wield disproportionate power in coastal planning processes. This perception of unequal power dynamics has led to calls for a more equitable and accountable governance framework that can ensure the fair distribution of decision-making power among all stakeholders.

Challenges

Potential challenges include resistance from dominant stakeholders such as large-scale aquaculture operators, funding limitations for implementing advanced technologies, and aligning local and national interests in policy execution. Further, achieving an equitable power dynamic among stakeholders may be complex, especially in regions where aquaculture interests are politically influential. In summary, Table 1 and Figure 1 portrays the key themes and/or message from the 2020 Coastal Zone Planning Survey.

Table 1. Key Themes from the 2020 Coastal Zone Planning Survey

Theme	Description	Example / Insight
Aquaculture Practices	Concerns about short-term profitability vs long-term environmental sustainability	Aquaculture facilities set up on vital fishing grounds with minimal stakeholder input
Environmental and Ethical Issues	Irreversible environmental harm, e.g., fjords as mining waste dumping grounds	Challenges in documenting spawning grounds
Stakeholder Engagement	Calls for more inclusive and transparent stakeholder engagement	Use of Altinn platform for early and transparent communication
Knowledge and Planning Integrity	Demand for high-quality, relevant data for decision-making	Scepticism about centralized databases
Cultural and Local Knowledge	Need for integrating cultural and local knowledge into planning	Road project that could have been avoided with local insights
General Discontent	Concerns about the undue influence of powerful aquaculture interests	Perception of "aquaculture oligarchs" influencing decisions

Table 1 provides an overview of the main themes identified in the 2020 Coastal Zone Planning Survey, outlining the primary concerns raised by respondents regarding aquaculture practices, environmental and ethical issues, stakeholder engagement, planning integrity, and the integration of cultural and local knowledge. Each theme includes a brief description and a real-world example or insight to illustrate the type of feedback provided. Key issues include conflicts between short-term aquaculture profitability and long-term sustainability, insufficient stakeholder engagement, and the lack of integration of local knowledge in planning decisions. There is also a general discontent with the influence of powerful aquaculture interests on policy.

Figure 1 below summarizes the percentage of survey respondents dissatisfied with aquaculture practices, environmental concerns, stakeholder engagement, and other issues identified in Table 1.

Figure 1 visually represents the levels of dissatisfaction among survey respondents regarding these themes. It shows the percentage of respondents who expressed dissatisfaction with aquaculture practices, environmental impacts, stakeholder engagement, and other areas highlighted in Table 1, underscoring widespread concerns across multiple aspects of coastal zone planning.

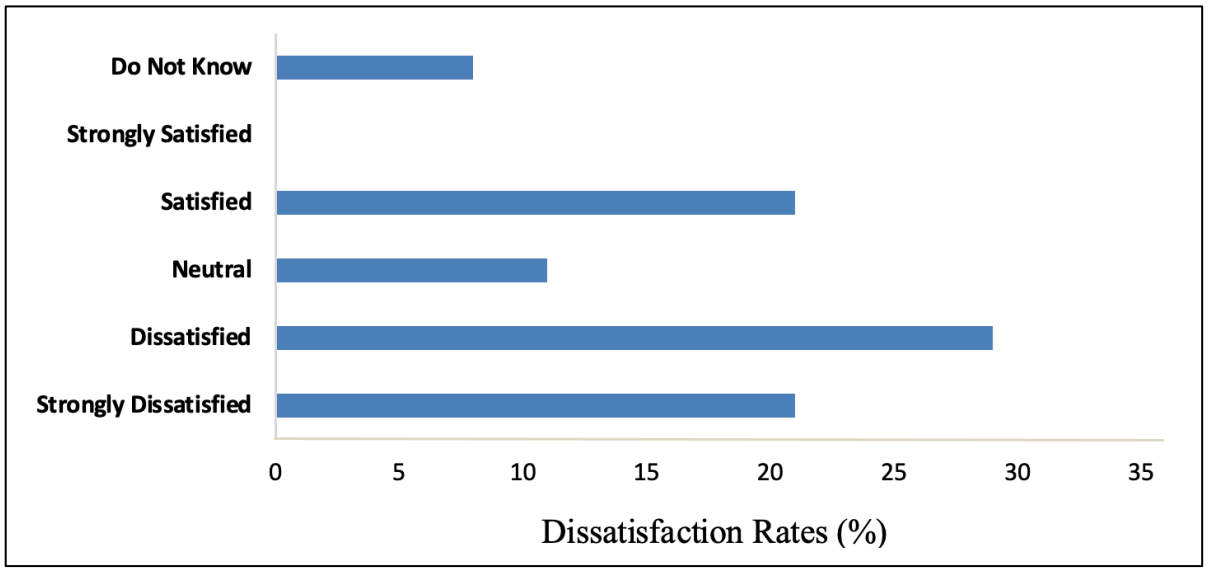

Figure 1. Coastal Zone Planning Survey Results – Dissatisfaction Rates (%)

Fisheries ecosystems and complex regulatory environments: Focus on ecosystem effects of aquaculture

The coexistence of fisheries and aquaculture within Norway's coastal zones continues to present unique challenges. While aquaculture can reduce pressure on wild fish stocks by providing an alternative source of seafood, the expansion of aquaculture operations in Northern Norway is increasingly occurring near critical habitats for coastal fisheries. One significant area of concern is the overlap between aquaculture facilities and coastal cod spawning grounds. This overlap has raised alarms regarding the sustainability of such activities, particularly in terms of habitat degradation and the long-term effects on marine ecosystems (Tiller et al., 2012; Naylor et al., 2000), and more so, contributing to conflicts with local fisheries. In addition to spatial conflicts, interactions between aquaculture and fisheries can manifest through market dynamics. For example, aquaculture depends heavily on wild fish stocks for fishmeal production, while fluctuations in seafood demand and market prices for farmed species can influence the economic viability of wild fisheries (Natale et al., 2013). As aquaculture sites expand or increase in number, the likelihood of disputes between these two sectors is expected to grow.

Aquaculture and fisheries interactions in coastal zones

Figure 2 visually depicts the relationship between aquaculture activities and key fishery habitats in Northern Norway. The map highlights the three counties in North Norway-Troms, Finnmark,

and Nordland-and shows critical zones such as cod feeding areas and spawning grounds, in relation to aquaculture sites for salmon and trout farming. These vital ecological areas overlap with regions where aquaculture licenses for salmon and trout have been steadily increasing. The spatial overlap between aquaculture facilities and fisheries (Figure 2) presents potential environmental stress points. For instance, aquaculture facilities situated near spawning grounds for coastal cod risk contributing to habitat degradation through pollution, nutrient runoff, and displacement of wild species. The autumn of 2024 witnessed a surge in environmental concerns due to unusually high sea temperatures leading to an explosion in salmon lice (lakselus) in Northern Norway. This situation has sparked significant attention, highlighting the interplay between climatic factors and aquaculture sustainability. Such developments underline the pressing need for adaptive governance strategies to address these emerging ecological challenges effectively. Environmental impacts can disrupt the spawning process, reduce biodiversity, and affect the long-term sustainability of fish stocks. Aquaculture facilities also pose risks of salmon lice infestations, which spread to wild populations, particularly wild salmonids. Additionally, the escape of farmed fish can lead to genetic interbreeding with wild populations, further impacting marine ecosystems.

Local stakeholders have expressed concerns that aquaculture's proximity to these critical habitats can cause degradation of spawning grounds, leading to negative impacts on both biodiversity and the overall health of marine ecosystems. These issues were emphasised in the survey results, where multiple respondents highlighted the need for better regulatory frameworks and stricter environmental oversight. This includes ensuring that aquaculture does not harm sensitive coastal ecosystems like those supporting fisheries, particularly cod spawning grounds.

As seen in Figure 2, the counties in Northern Norway have witnessed a growing number of aquaculture licenses issued annually for salmon and trout production. This expansion, while economically beneficial, brings environmental challenges that need to be carefully managed. Local stakeholders, including traditional fishers, have voiced concerns about these issues, urging stronger enforcement of environmental regulations and stricter controls on the siting of aquaculture facilities near vulnerable fishery habitats. Moreover, Table 2 below outlines the regulatory measures currently in place to address the environmental impacts of aquaculture, but as highlighted in the survey results, enforcement remains a challenge, and stakeholders continue to report instances of habitat degradation and non-compliance with environmental standards.

With the political will in Norway focused on fostering sustainable aquaculture growth, future expansion will require addressing major challenges such as salmon lice control, fish welfare, and escaped fish management. Ensuring the long-term sustainability of aquaculture and minimizing its conflicts with fisheries will also necessitate the development of marine fish species and the promotion of low-trophic organisms as alternative aquaculture species.

The potential for conflict between aquaculture and fisheries is likely to increase as the spatial footprint of aquaculture sites grows within municipalities. Effective management will depend on integrated governance, robust enforcement mechanisms, and transparent collaboration among stakeholders to balance economic growth with environmental stewardship.

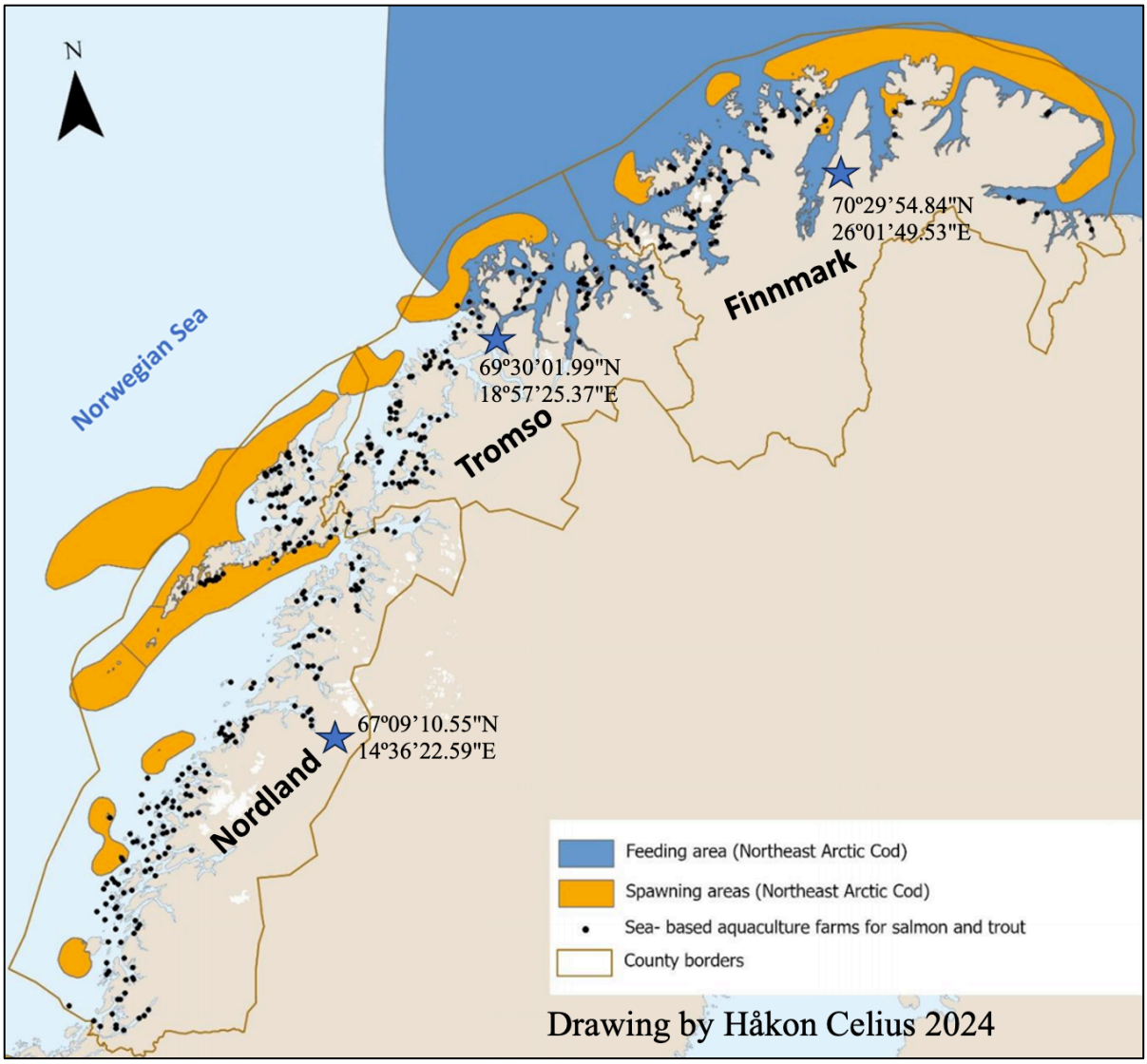

Figure 2. Spatial Relationship Between Aquaculture Sites and Fishery Habitats in Northern Norway.

Table 2. Regulatory Measures in Aquaculture and Fisheries

Regulation	Purpose	Stakeholder Feedback
Stricter controls on aquaculture expansion	To limit environmental impacts and habitat degradation	Requires better enforcement and local consultation
Improved environmental monitoring systems	To ensure sustainability through advanced technology	Effectiveness depends on transparent sharing of data
Eco-friendly incentives for aquaculture	Promote eco-friendly technologies in the aquaculture sector	Incentives should consider local ecosystem conditions and needs
Sustainable use of fjords	Prevent the use of fjords for waste disposal	Stakeholders report minimal enforcement and continued environmental harm

Developing the governance framework for coastal zones

Effective governance of coastal zones requires an integrated approach that considers both ecological and social dimensions. In Norway, this involves multiple layers of governance, from local councils to national authorities, each with their own roles and responsibilities. However, as the 2020 survey revealed, there are significant challenges in ensuring that these governance structures are both inclusive and effective.

One of the key themes from the survey was the need for better stakeholder engagement. Respondents advocated for more transparent decision-making processes that include early consultations with local communities and more extensive dissemination of information. This aligns with the interactive governance framework, which emphasises the importance of stakeholder interactions in addressing everyday governance challenges.

Moreover, the governance framework needs to incorporate high-quality, relevant knowledge to inform decision-making processes. This includes both scientific data and local knowledge, as the latter can provide critical insights into cultural and ecological considerations that may otherwise be overlooked.

The diagram below (Figure 3), with focus on aquaculture and fisheries industries, represents the hierarchical structure of governance in Northern Norway, detailing each level's responsibilities and challenges. It also emphasizes the critical role of stakeholder engagement and knowledge integration across all levels to ensure effective and sustainable coastal zone management. The diagram (Figure 3) illustrates the multi-layered governance structure in Norway's coastal zones, with special focus on Aquaculture and fisheries industries. It shows how governance is distributed across three levels-national, regional, and local-with each level playing specific roles. It also highlights the role of stakeholder engagement and the integration of scientific knowledge, particularly from the Institute of Marine Research (IMR)

At the National Level (Figure 3), institutions like the Ministry of Fisheries and the Directorate of Fisheries on top, are responsible for setting policies, regulations, and overarching strategies for the sustainable use of marine resources, including aquaculture. These bodies, for instance, oversee: 1) Policy Formulation: Creating laws and regulations for coastal management and aquaculture; 2) Sustainability Oversight: Ensuring that practices like fish farming and fishing do not harm marine ecosystems; 3) Coordination: Aligning national policies with regional and local actions. The Institute of Marine Research (IMR) plays a key advisory role here. As Norway's largest marine science centre, the IMR provides scientific research and monitoring data, which inform the Ministry and Directorate's decisions on how to sustainably manage resources. The IMR's research covers areas like fish stock health, environmental impacts of aquaculture, and sea-lice control, which are crucial for regulating aquaculture. At Regional Level, the focus is on implementing national policies and adapting them to local conditions while coordinating inter-county challenges. Regional Environmental Councils in counties like Troms, Finnmark, and Nordland in Northern Norway are, among others, responsible for: 1) Permit Issuance: Approving aquaculture licenses in line with both national policies and local needs; 2) Policy Implementation: Applying national directives to manage coastal and marine resources in a way that suits regional ecological and socio-economic conditions; 3) Ecosystem Management: Overseeing the balance between aquaculture expansion and the protection of critical areas, such as cod spawning grounds; and 4) Inter-County Coordination: Addressing cross-county challenges, like shared fjords or regional aquaculture issues. A key challenge is managing the balance between expanding aquaculture operations and protecting critical ecosystems, including cod spawning areas. This level faces the challenge of managing site

availability for aquaculture, as many regions are at their capacity due to ecological constraints. The IMR also advises regional councils by providing region-specific research, particularly in areas like sea-lice management, which has resulted in the implementation of the traffic light system (green, yellow, red) to regulate aquaculture activity based on environmental health.

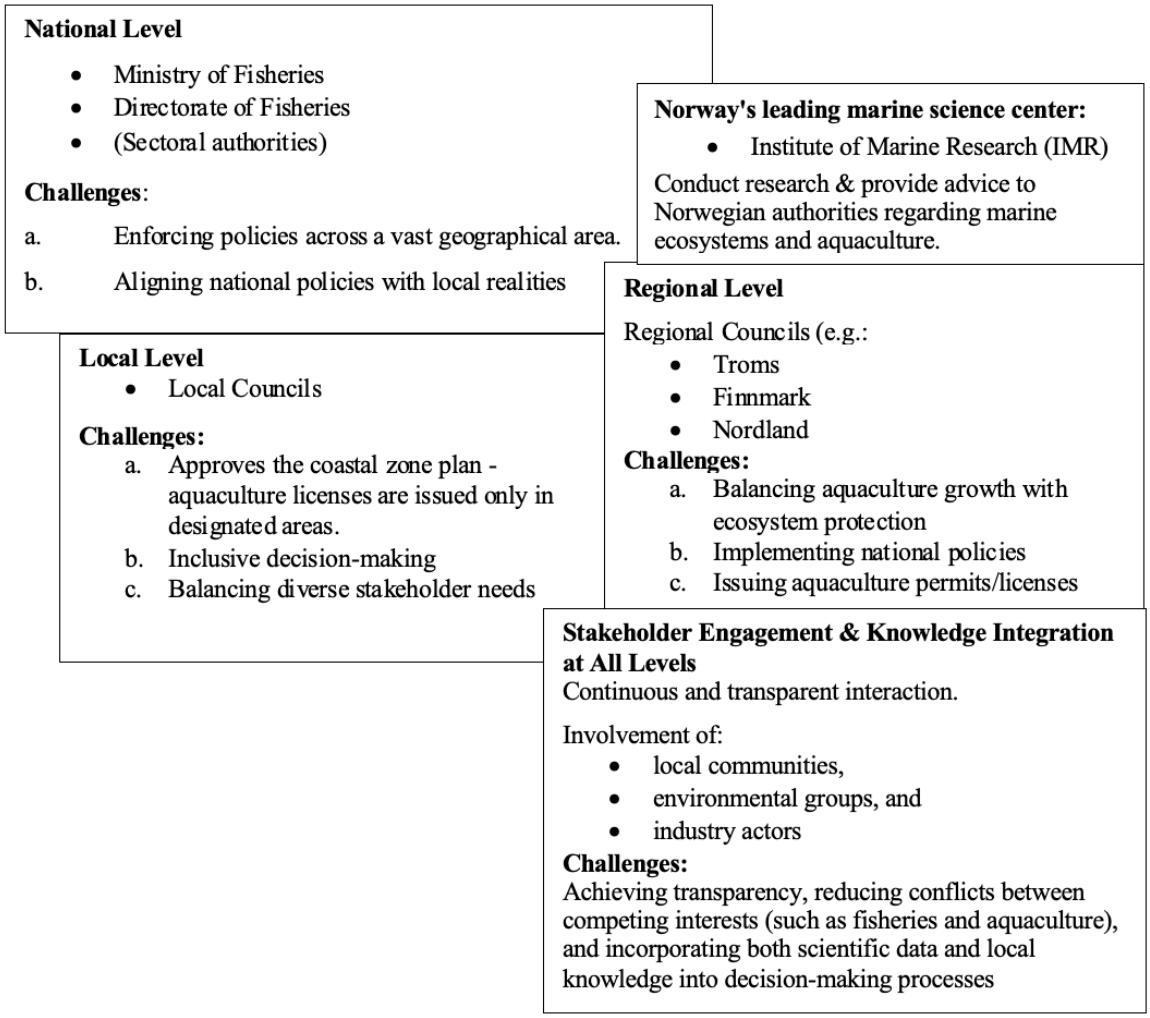

Figure 3. Multi-Layered Governance Structure and Challenges in Northern

At Local Level, the Local councils are responsible for daily decision-making, including stakeholder Engagement, and addressing stakeholder concerns. At this level, Local Coastal Management Boards or local councils are responsible for the daily management of coastal resources, including:

1) *Controlling new projects* in line with both national policies and regional needs, including being in line with the local requirements;
2) *Stakeholder Engagement:* Involving local fishers, community members, and environmental groups in the decision-making process, among others; and
3) *Direct Resource Management:* Ensuring sustainable use of local marine resources, balancing aquaculture with traditional fisheries and ecosystem protection.

Their challenge is ensuring that the decisions made are inclusive, balancing the needs of fisheries, aquaculture operators, and local communities. More so, the Local councils play a crucial role in managing conflicts between different stakeholders, such as between aquaculture

operators and local fishers. IMR's local research on fish populations, environmental conditions, and the impact of aquaculture is critical in helping local councils make informed decisions about resource use and protection. Stakeholder Engagement and Knowledge dissemination is a critical element cutting across all governance level. The diagram emphasizes the need for continuous and transparent stakeholder interactions across all governance levels. Stakeholder engagement, involving, among others, fishers, local communities, environmental groups, aquaculture operators, and scientific institutions, being part of the dialog. Transparent decision-making processes ensure that all stakeholders are heard and their concerns considered, and thereby ensuring sustainable management of coastal zones. The role of the IMR in this is to provide high-quality, scientific data that helps stakeholders understand the ecological impacts of aquaculture and fisheries activities. This information ensures that discussions are based on sound evidence, leading to better decision-making.

The role of the Institute of Marine Research (IMR) is woven into every governance level. IMR's role includes:

1) *Scientific Research:* Providing data on marine ecosystems, aquaculture impacts, and fish populations;
2) *Monitoring:* Tracking environmental health (e.g., sea-lice levels, water quality) to inform regulatory actions;
3) *Advisory:* Offering insights to both national authorities and local managers to ensure that decisions promote sustainability; and
4) *Through IMR's ongoing research and monitoring*, all governance levels can make evidence-based decisions that are crucial for the long-term health of Norway's coastal zones.

Figure 3 complements the survey findings by visually demonstrating the governance complexities and the critical role of stakeholder involvement in coastal zone management. Despite the complexity, the figure also visually depicts a coordinated structure where each level of governance has a distinct role, supported by scientific advice from the Institute of Marine Research (IMR). This integrated framework ensures that Norway's coastal zones are managed in a sustainable and inclusive manner, balancing economic interests, like aquaculture, with ecological protection and local community needs.

Discussion

Drawing insights from the survey results and governance challenges in Northern Norway, this discussion proposes a global governance framework for integrated coastal zone management. The multi-layered governance structure, as illustrated in Figure 3, provides a foundational framework that can be adapted and implemented worldwide to ensure sustainability and inclusivity in coastal zone management.

Enhanced stakeholder engagement

A significant insight from the Norway case is the need for a more robust and inclusive stakeholder engagement process. The current model tends to favour powerful interests, such as large-scale aquaculture operators, often at the expense of smaller local fisheries and communities (Tiller et al., 2012). This imbalance has been exacerbated by the rapid expansion of fish farming, which has become an important export industry, contributing over NOK 122.5 billion in exports in 2023 (Larsen & Håland, 2024). While this growth is economically beneficial, it risks marginalizing the voices of those most directly affected by coastal zone management decisions. The results highlight challenges such as balancing local economic

interests with environmental sustainability. For example, aquaculture expansions may generate economic benefits but risk damaging vital fishery habitats like cod spawning grounds. Addressing this conflict requires collaborative decision-making mechanisms that prioritize ecological thresholds while offering economic incentives for sustainable practices (Msomphora & Aanesen. 2015).

Global strategic improvement
A revised governance framework should introduce mechanisms to balance these interests, such as more inclusive consultation processes that give smaller stakeholders, including local fishers, environmental groups, and indigenous communities, a stronger voice. These mechanisms could be visualized in an ideal model based on interactive governance theory (Jentoft & Chuenpagdee, 2015; Kooiman, 2003, 2008, 2013), with feedback loops that ensure responsiveness and adaptability in decision-making, as would be outlined in a hypothetical Figure 4.

Strengthening regulatory frameworks
Norway's experience highlights the challenges of enforcing regulatory frameworks, particularly in regions like fjords and inner coastal areas where aquaculture production is concentrated. Effective management of sea-lice problems, for instance, requires not only stringent regulations but also the technological means to monitor compliance. The government's efforts to address the sea-lice problem through a traffic light system, where regions are classified into green, yellow, or red categories based on lice levels (Larsen & Håland, 2024), demonstrate the challenges of balancing production with ecological sustainability. The purpose of the traffic light system is to control and reduce the environmental impact of aquaculture by linking production capacity to the health of the ecosystem. Green zones indicate areas where production can continue or expand safely, yellow zones suggest caution and may require limited production, and red zones require significant reductions in activity to protect the ecosystem.

Global strategic improvement
Globally, enhanced enforcement mechanisms are needed. This can be achieved by implementing dynamic regulations that adjust based on real-time environmental data and by utilising advanced monitoring technologies such as satellite tracking and automated sensors to ensure compliance. Penalties for non-compliance should be robust, ensuring that operators adhere to environmental standards even as production scales up.

Integrating local and cultural knowledge
A critical insight from Norway is the importance of local and cultural knowledge in coastal governance. This is particularly relevant in Northern Norway, where coastal communities have a long tradition of fishing and local resource management. Ignoring these aspects can lead to culturally insensitive decisions that undermine both the ecological sustainability and the socio-economic well-being of these communities.

Broader Contextual Adaptations
The model's adaptability can be enhanced by integrating participatory decision-making processes that consider regional cultural nuances. For example, in regions with strong indigenous populations, decision-making structures must incorporate traditional ecological knowledge. Building capacity through education and training for local stakeholders ensures more consistent adoption across diverse global contexts.

Global strategic improvement

Formal mechanisms should be established to systematically integrate local and cultural knowledge into the governance framework. This could include setting up advisory councils comprising local community leaders and cultural experts who can provide insights into the planning and ongoing management processes.

Implementing the framework globally

Implementing this governance framework globally involves adapting the Norwegian model to different geographical and cultural contexts. While regions like Northern Norway face unique challenges such as limited site availability for aquaculture and environmental pressures from intensive production, other coastal areas may struggle with different ecological and socio-economic constraints. However, the core principles of stakeholder inclusivity, dynamic regulation, and local knowledge integration can be adapted universally as indicated in Figure 4.

Generalizability to other contexts

While the Norwegian model emphasizes adaptive management and technological innovation, applying it in other coastal areas might require adjustments based on socio-economic and ecological conditions. For instance, regions with lower technological capacities or less robust governance frameworks may struggle to adopt dynamic monitoring systems or enforce regulations effectively. The proposed governance framework, as visualized through the diagram (Figure 4), serves as a blueprint for coastal zone management worldwide, promoting sustainability, inclusivity, and adaptability across diverse contexts. Figure 4 illustrates a detailed governance framework designed for effective integrated coastal zone management on a global scale.

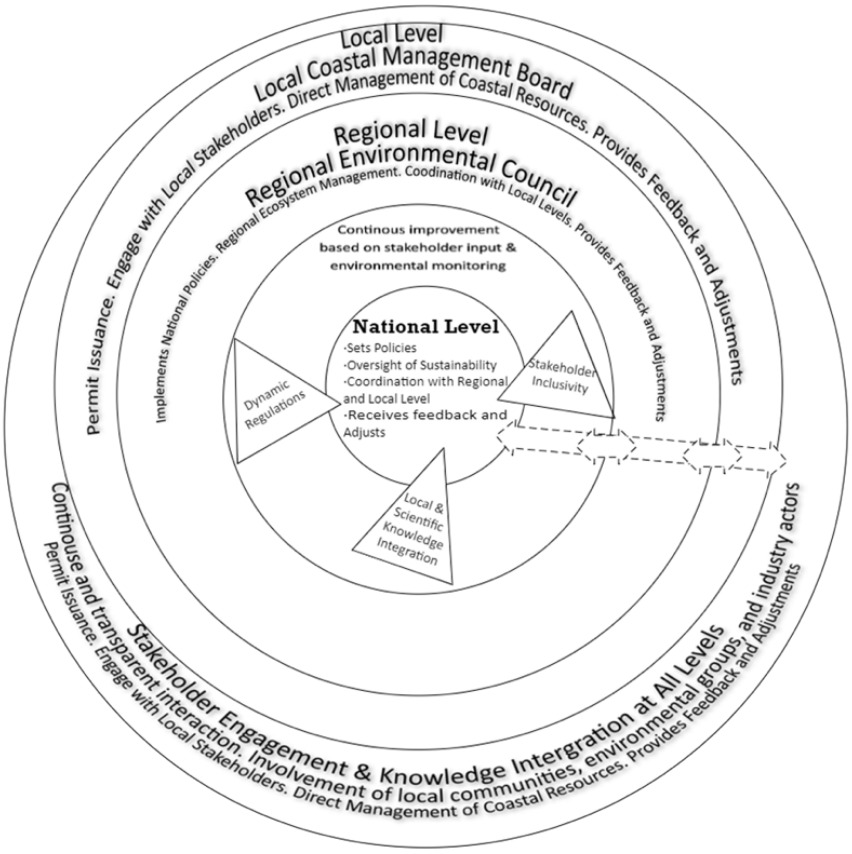

Figure 4. Governance Framework for Integrated Coastal Zone Management

The diagram (Figure 4) is structured to show the hierarchical relationships and feedback mechanisms between different levels of governance and stakeholders. It is comprised of the following component:

National level:

- *Responsibilities*: This level involves the highest regulatory bodies such as the Ministry of Fisheries and the Directorate of Fisheries, which are responsible for policy formulation, oversight of sustainability practices, and coordination with lower levels of governance.
- *Interactions*: National authorities set the overarching policies and guidelines that are to be implemented at regional and local levels. They also receive feedback to adjust national policies based on regional and local experiences and challenges.

Regional level:

- *Responsibilities*: Regional Environmental Councils implement the policies set at the national level. They manage regional ecosystems and coordinate with local management boards to ensure policies fit the specific environmental and socio-economic contexts of their regions.
- *Interactions*: This level acts as a bridge between national directives and local implementation, ensuring that policies are effectively adapted to regional conditions. They also provide feedback to the national level about the effectiveness and challenges of policy implementation.

Local level:

- *Responsibilities*: Local Coastal Management Boards are directly involved in the day-to-day management of coastal resources. They issue permits, engage with local stakeholders, and manage resources based on both higher-level policies and local needs.
- *Interactions*: This level is crucial for integrating local stakeholder inputs into the governance model. They provide ground-level feedback to regional and national levels, ensuring that policies are practical and beneficial for local communities.

Stakeholder engagement and knowledge integration:

- *Responsibilities*: Continuous and transparent interaction with local communities, environmental groups, and industry actors is maintained across all levels. This ensures that all stakeholder views are considered in decision-making processes.
- *Interactions*: Stakeholder engagement is critical for gathering diverse inputs and integrating practical knowledge into governance. This feedback is essential for adapting management practices to be more inclusive and effective (Gupta and Bavinck, 2017) .

Feedback loop:

- *Responsibilities*: A continuous improvement mechanism based on stakeholder input and environmental monitoring. This loop ensures that the governance framework remains dynamic and responsive to changes in environmental conditions and stakeholder needs.
- *Interactions*: The feedback loop connects all levels of governance and stakeholders, facilitating ongoing adjustments and improvements to policies and practices based on real-time data and experiences.

This governance framework emphasizes the importance of multi-level coordination and inclusive stakeholder participation, ensuring that coastal zone management is both sustainable

and responsive to the needs of all parties involved. By addressing these key areas, a global framework for integrated and sustainable coastal zone management can be developed, promoting equitable and effective management practices that respect both ecological balance and the socio-economic and cultural dimensions of coastal communities worldwide.

Conclusion

The findings of this study reveal a complex and often contentious landscape in the management of coastal zones in Northern Norway. The survey results show widespread dissatisfaction with the current planning processes, particularly concerning the influence of powerful aquaculture interests and the lack of inclusive stakeholder engagement. These insights highlight critical areas where improvements are necessary to foster a more balanced and equitable approach to coastal zone management. Addressing these issues will require a multi-faceted approach that combines stronger enforcement of environmental regulations, more transparent and inclusive governance processes, and a greater emphasis on local and cultural knowledge. The current governance model, while robust in some areas, falls short in effectively integrating the diverse needs and voices of all stakeholders involved, particularly those at the local level who are directly impacted by these policies. To rectify these shortcomings, it is imperative to develop a governance framework that not only addresses the immediate regulatory and enforcement gaps but also prioritizes the inclusion of local communities and cultural insights into the planning process. This approach will help ensure that decisions are not only made with a comprehensive understanding of the ecological and economic aspects but are also culturally sensitive and locally relevant. Moreover, by enhancing stakeholder engagement, Norway can pave the way for more democratic and participatory governance in coastal zone management. This involves not only opening up channels for dialogue and feedback but also actively incorporating this input into policymaking and implementation processes. Such a strategy will not only improve the legitimacy of the governance framework but also its effectiveness in achieving sustainable outcomes.

This study's interactive governance model advances the theoretical framework by providing actionable guidance on stakeholder engagement and conflict resolution. It underscores the importance of combining technological advancements, adaptive policies, and inclusive stakeholder practices in coastal zone management. Concrete implementation steps include developing advisory committees at all governance levels, comprising local leaders, fishers, and environmental experts; implementing dynamic monitoring using tools such as real-time satellite imaging and machine learning models to predict ecological impacts; and institutionalizing mediation platforms for balancing aquaculture and fisheries interests, ensuring equitable representation. By developing a governance framework that incorporates stronger enforcement, transparency, inclusivity, scientific and local knowledge, Norway can ensure that its coastal zones are managed sustainably and equitably. This will enable a balance between economic growth and environmental stewardship, fostering social inclusion and protecting the rights and livelihoods of all stakeholders involved.

Through addressing gaps in interactive governance theory—particularly its underdeveloped mechanisms for resolving socio-economic and ecological conflicts—the study provides a comprehensive framework adaptable to global contexts. This expands the literature's scope by merging practical and theoretical insights. The proposed global framework serves as a blueprint that can be adapted not only in Norway but also in other regions facing similar challenges, promoting a more integrated and holistic approach to coastal zone management worldwide.

Ethical approval
Ethical approval was obtained from the relevant institutional review board (NSD, Norwegian Centre for Research Data.

Informed consent
The study adhered to ethical guidelines for research involving human subjects, including informed consent, confidentiality, and the right to withdraw from the study at any time.

Data availability statement
The authors declare that data can be provided by corresponding author upon reasonable request.

Conflicts of interest
There is no conflict of interests for publishing this study.

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Contribution of authors
Mbachi Ruth MSOMPHORA: Resources, Methodology, Conceptualization, Data curation, Writing original draft, Validation, Visualization, Review, Editing.

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