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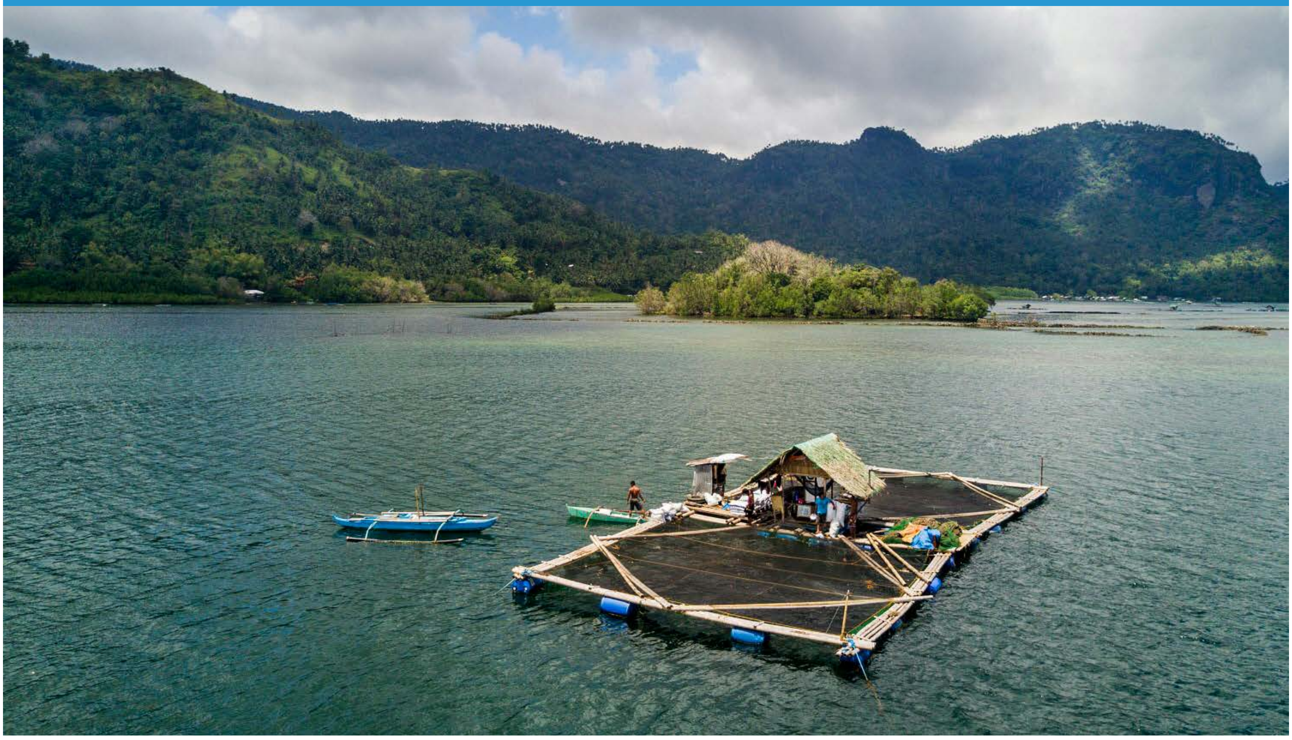
Report of the expert workshop on

SPATIAL MANAGEMENT FOR MARINE AQUACULTURE PLANNING: DEFINING NEEDS FOR ASSISTING COUNTRIES

Rome, 29–31 October 2024



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PREPARATION OF THIS DOCUMENT

This document provides a comprehensive summary of the presentations, discussions, conclusions, and recommendations from the expert workshop on spatial management for marine aquaculture planning: defining needs for assisting countries. The workshop was organized by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the Italian Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale - ISPRA). Taking place at FAO headquarters in Rome, Italy, from 29 to 31 October 2024, the workshop brought together 18 international experts from diverse regions to share knowledge and experiences on how marine spatial planning (MSP) can support aquaculture development.

The event was organized by the FAO Fisheries and Aquaculture Division, in collaboration with ISPRA, and focused on identifying priority actions to facilitate the implementation of MSP in aquaculture, particularly in countries where such approaches are new or underdeveloped. The document reflects the collaborative efforts of the workshop participants and organizers to address the challenges and opportunities for sustainable aquaculture development through spatial planning. What is more, the workshop outcomes will provide the foundation for a roadmap for future actions, aligning with FAO's strategic objectives, the Guidelines on Sustainable Aquaculture (GSA) and the Sustainable Development Goals (SDGs) adopted by the United Nations.

The report was prepared by Francesco Cardia, Giovanna Marino and Tommaso Petochi from ISPRA and Amber Himes-Cornell, Lucy Bowser and Chiara Buonfrate from FAO. The document is based on workshop notes and participant contributions; any views expressed herein are therefore those of the participants and do not necessarily reflect those of the participants' affiliated institutions.

ABSTRACT

FAO and ISPRA co-organized an expert workshop on spatial management for marine aquaculture planning that would help define the needs of countries requiring assistance. The workshop addressed challenges in integrating aquaculture into marine spatial planning. Discussions were organized around five priority areas: i) governance and institutional frameworks; ii) knowledge support for spatial planning in aquaculture; iii) criteria and guiding elements for spatial allocation; iv) capacity building and awareness; and v) marine conservation and restoration.

Invited experts provided insights covering regional and global aquaculture best practices for integrating aquaculture into marine spatial planning and implementing spatial tools like geographic information systems, predictive models and decision support systems. Case studies spanned six continents: North America (Mexico and the United States of America), South America (Brazil and Chile), Europe (Northern Europe, the Mediterranean and Macaronesia), Asia (China and the Philippines), Africa (Lake Victoria and South Africa) and Oceania (Australia and New Zealand). These diverse examples highlighted the different approaches and challenges that arise when integrating aquaculture into marine spatial planning frameworks.

Discussions were structured around the five priority areas, from which several key concepts emerged. In relation to governance and institutional frameworks, participants emphasized the importance of improving coordination among regulatory bodies to streamline spatial planning processes and reduce administrative burdens. With regard to knowledge support for spatial planning in aquaculture, the need to enhance data systems and promote the use of spatial tools and innovative technologies was widely recognized as essential for informed decision-making. Discussions on the criteria and guiding elements for spatial allocation pointed to the value of developing shared but flexible frameworks that take land–sea interactions, ecological constraints, and climate adaptation needs into account. In the area of capacity building and awareness, participants underscored the roles of extension services, training, stakeholder engagement, and inclusive processes to support the effective implementation of marine spatial planning. Finally, discussions on marine conservation and restoration highlighted the potential for aquaculture to contribute to social ecological objectives when it is spatially integrated with conservation and habitat restoration strategies.

The workshop’s outcomes included a draft roadmap towards a more effective integration of aquaculture into marine spatial planning, which outlined strategic objectives and practical actions to facilitate a broad and global implementation of marine spatial planning that supports sustainable aquaculture development. Workshop participants also provided valuable input into the structure and contents of complementary guidance that will be developed to facilitate the adoption of the roadmap and the implementation of relevant actions.

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ACKNOWLEDGEMENTS

The active participation, inputs and contributions of all those who took part in the workshop were critical to the effective outcomes of the event and are duly acknowledged. Amber Himes-Cornell, Giovanna Marino, Tommaso Petochi and Francesco Cardia facilitated the workshop's sessions.

Special thanks go to the five experts who led and facilitated the group work and sessions on the priority areas: Rebecca Gentry, Doris Soto, Andrej Abramic, Barry Costa-Pierce and Trevor Telfer. Their expertise and guidance were essential to identifying key actions for advancing maritime spatial planning in aquaculture during the workshop discussions.

The authors express their heartfelt thanks to the organizational team, including Lisa Falcone, Lucy Bowser and Chiara Buonfrate, whose efforts ensured the smooth coordination and execution of the workshop. The collaboration and support of ISPRA in the organization of the workshop is also gratefully acknowledged, within the framework of a Letter of Agreement (LoA) with FAO, as well as the backing of the FAO Fisheries and Aquaculture Division for its leadership in funding and organizing this important event.

ABBREVIATIONS

ADZ	aquaculture development zone
AI	artificial intelligence
AOA	aquaculture opportunity area
AZA	allocated zone for aquaculture
COFI	FAO Committee on Fisheries
DG MARE	Directorate General for Maritime Affairs and Fisheries of the European Commission
DSS	decision support system
EU	European Union
EAA	ecosystem approach to aquaculture
EBM	ecosystem-based management
EIA	environmental impact assessment
FAO	Food and Agriculture Organization of the United Nations
GES	good environmental status
GFCM	General Fisheries Commission for the Mediterranean
GIS	geographic information system
GSA	Guidelines for Sustainable Aquaculture
HABs	harmful algal blooms
IMTA	integrated multitrophic aquaculture
IOC-UNESCO	Intergovernmental Oceanographic Commission
IoT	internet of things
ISPRA	Istituto Superiore per la Protezione e Ricerca Ambientale
KPI	key performance indicator
LGU	local government unit
MPA	marine protected area
MSP	marine spatial planning
MSPdF	Maritime Spatial Planning Data Framework
NFI	Fisheries and Aquaculture Division
NOAA	National Oceanic and Atmospheric Administration
QA/QC	quality assurance and quality control
SAWA	Sustainable Activities in Water Areas (Initiative)
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SOFIA	State of World Fisheries and Aquaculture
TNC	The Nature Conservancy

BACKGROUND

Coastal and marine ecosystems, including transitional waters where land and sea converge, face significant challenges as a result of pollution, habitat destruction and resource depletion. Human activities, including aquaculture, can put further strain on these fragile systems, potentially impacting biodiversity and disrupting ecosystem services. Nevertheless, despite these challenges, marine aquaculture has emerged as a promising sector by virtue of its contributions to food security, economic development, and livelihood opportunities. However, its expansion necessitates addressing critical questions such as environmental sustainability, spatial conflicts, and regulatory challenges.

To tackle these issues and support the sustainable growth of marine aquaculture, integrated and forward-looking spatial planning strategies are increasingly recognized as essential. Such strategies are instrumental to balancing the development of human activities with the preservation of ecosystems and minimizing conflicts over how space is used.

In recent years, the Food and Agriculture Organization of the United Nations (FAO) and several regional bodies such as the General Fisheries Commission for the Mediterranean (GFCM), have undertaken initiatives to integrate aquaculture into spatial planning frameworks. These efforts align with the ecosystem approach to aquaculture (EAA) and emphasize the importance of minimizing negative interactions between aquaculture, the environment, and the social context. Notable progress has been made globally in this regard, through several national and regional initiatives including the Maritime Spatial Planning Directive 2014/89/EU (MSPD) in the European Union (EU); coastal spatial planning in Saudi Arabia and the United Arab Emirates; and the designation of aquaculture opportunity areas (AOA) in the United States of America. Nevertheless, there remains a pressing need for further dialogue and knowledge exchange on how to better integrate aquaculture into marine spatial planning (MSP).

In order to facilitate progress on the subject, FAO and ISPRA organized the “Expert workshop on spatial management for aquaculture planning: defining needs for assisting countries”. The workshop’s principal aim was to facilitate discussions on how to assist countries in integrating aquaculture with maritime and coastal spatial planning frameworks, particularly in regions where these approaches are either underdeveloped or only partially implemented.

International experts were invited to attend the workshop in order to explore and develop strategies collaboratively that would advance spatial planning in marine aquaculture, and to define needs for assisting countries with the spatial management aspects of aquaculture planning. Through the presentations of regional and national overviews of how spatial planning has been used to support aquaculture development, the workshop highlighted a range of challenges and opportunities: from integrating aquaculture into new or existing maritime or coastal spatial planning frameworks, to the spatial planning tools currently available; from the methods being used to site aquaculture farms, to the criteria that designate aquaculture zones in coastal areas; as well as the reasons, conditions and effective mechanisms adopted to introduce spatial planning methods to a given country.

The workshop aimed to guide FAO in its development of practical, technical advice for government, farmers and associations, while also seeking to gather inputs that will be used to produce a draft roadmap for MSP in marine aquaculture. A series of actionable outcomes will then guide countries to identify and address priority areas for improving how spatial planning is used to support aquaculture development.

The participants were presented with five priority areas to focus on, which were developed through a collaborative process between FAO and ISPRA, based on their alignment with broader marine spatial planning frameworks (IOC-UNESCO/European Commission, 2022) as well as specific considerations for the aquaculture sector. Each priority area was designed to address specific challenges and opportunities for the aquaculture sector, including governance and institutional frameworks, knowledge support through data and tools, spatial allocation criteria, capacity building and marine conservation and restoration. The priority areas for MSP in aquaculture included:

Priority area 1: Governance and institutional framework (e.g. streamlining interactions between authorities).

Priority area 2: Knowledge support for spatial planning in aquaculture (e.g. data, innovative tools, smart aquaculture).

Priority area 3: Criteria and guiding elements for the allocation of space (e.g. shared use of marine space, land and sea interactions, and adaptation to climate change).

Priority area 4: Capacity building, awareness and capacity extension (e.g. countries and stakeholder engagement, training, online platforms).

Priority area 5: Marine conservation and restoration (e.g. how spatial planning in aquaculture contributes to socioecological objectives/conservation targets).

Participants contributed to discussions on each of the priority areas by sharing successful case studies, highlighting innovative approaches and tools, and discussing challenges and opportunities for improving how spatial planning is used to support the development of aquaculture.

The workshop goals were achieved through collaborative discussions and expert-led explorations. The results are intended to align with FAO guidelines to contribute to the sustainable development of aquaculture globally and FAO's Strategic Framework 2022–2031.

Ultimately, the workshop served as a platform for fostering dialogue, building partnerships and catalysing action towards more effective and inclusive marine spatial planning in aquaculture. By coupling the collective expertise and commitment of experts from different regions, the workshop provided valuable tools to help Members towards a more sustainable development for coastal communities, and ensure the preservation of marine ecosystems.

Details on the agenda can be found in Appendix C.

INTRODUCTION

Opening remarks

Xinhua Yuan, Deputy Director of FAO's Fisheries and Aquaculture Division (NFI) welcomed the participants to the "Expert workshop on spatial management for aquaculture planning". He expressed his gratitude to the experts for their availability, as well as to the team behind the organization of the workshop, highlighting the efforts of NFI's National planning and development support team. Yuan provided an overview of FAO's recent milestones, including the publication of the State of World Fisheries and Aquaculture (SOFIA) 2024 and the adoption of the FAO Guidelines for Sustainable Aquaculture (GSA) during the Thirty-sixth Session of the Committee on Fisheries (COFI).

Yuan emphasized the global recognition of aquaculture's role in addressing food security challenges and the need for transformative actions to ensure the sustainable development of the sector. He highlighted recent international endorsements of FAO's Blue Transformation roadmap, including its inclusion in the Group of 20 or G20 Agriculture Ministers' Declaration and the Group of 7 or G7 Agriculture Ministers' Communiqué. Both documents underscored the critical role of aquaculture in fostering resilient and sustainable food systems, with spatial planning identified as a key component for the sector's sustainable growth.

Stressing the importance of spatial management, Yuan noted that spatial planning is a vital technical area requested by many Members, with significant gaps in capacity for implementing such frameworks. He highlighted examples of countries where spatial planning has been initiated – such as the designation of allowed zones for aquaculture in the Mediterranean area – and acknowledged that many nations still require technical support to undertake such exercises effectively.

Yuan concluded by underlining the workshop's objectives, which included fostering the exchange of knowledge, discussing the current state of spatial management in aquaculture and collaboratively developing strategies, tools, and approaches for integrating aquaculture into spatial planning frameworks. He encouraged active participation and expressed optimism for productive discussions and outcomes that would contribute to sustainable aquaculture development globally (see Appendix B for the full opening statement).

Introduction to marine spatial planning for aquaculture: overview of technical documents and guidelines

Linda Fourdain (General Fisheries Commission for the Mediterranean (GFCM)) and Tommaso Petochi (ISPRA) provided a comprehensive overview of the technical documents and guidelines essential to implementing spatial planning in aquaculture.

Aquaculture has emerged as a cornerstone for addressing global food security challenges, particularly within the context of an increasing global population and increasing demand for sustainable food sources. This presentation provided an overview of MSP in the context of aquaculture development, highlighting key frameworks, methodologies, and technical guidelines that support sustainable development in this sector. Critical drivers for integrating aquaculture into spatial planning were also outlined, emphasizing the need to increase production for food security, ensure socioeconomic well-being and adapt to climate change, while balancing natural resource use and environmental protection.

The growing importance of aquaculture

In 2022, global aquaculture production of animal species exceeded capture fisheries for the first time, reaching 94 million tonnes (FAO, 2024). This milestone reflects aquaculture's expanding role in global food systems. By 2050, the global population is projected to approach 10 billion people , intensifying the demand for sustainable aquatic production (FAO, 2022). Aquaculture is expected to nearly double its production, necessitating strategic planning to address the key challenges associated with balancing growth and sustainability (Table 1).

Table 1. Key challenges addressed through spatial planning that supports aquaculture development

Challenge	Objective of spatial planning
Food security	Expand aquaculture production to meet an increasing demand
Socioeconomic well-being	Enhance livelihoods, cultural and economic growth in aquaculture-dependent communities
Resource use and conflict resolution	Minimize competing demands for marine space and foster synergies with other blue economy sectors
Environmental sustainability	Balance aquaculture expansion with ecosystem conservation and resource protection
Climate adaptation	Ensure aquaculture systems are resilient in the face of climate change impacts

Source: Author's own elaboration.

Strategic guidelines and documentation

Over the years, a robust framework of technical guidelines and documentation has been developed to support spatial planning that encourages the development of aquaculture (Ehler and Douvere, 2009; Blue Prosperity Coalition, 2020; IOC-UNESCO/European Commission, 2021; and IOC-UNESCO, 2021). These resources provide the foundation for integrating aquaculture into MSP and ensuring its alignment with sustainable development principles.

The journey began with the 1992 integrated coastal zone management approach, which established a baseline for harmonizing aquaculture activities with broader coastal management (Clark, 1992). Building on this foundation, certain key publications have become essential references for practitioners; these include the FAO and World Bank's 2017 handbook on aquaculture zoning, site selection, and area management under the ecosystem approach (Aguilar-Manjarrez *et al.*, 2017), among others (see for example, Fourdain *et al.*, 2024, Aguilar-Manjarrez *et al.*, 2010; IUCN, 2009 and FAO, 2007). These resources provide detailed guidance on balancing ecological, social, and economic objectives when planning aquaculture.

FAO's 2016 report on marine spatial planning for enhanced fisheries and aquaculture sustainability expands on these principles, offering strategies to integrate aquaculture into broader marine planning efforts (Meaden *et al.*, 2016). In the Mediterranean and Black Sea context, the GFCM's 2019 guide provides tailored advice on establishing allocated zones for aquaculture (AZAs), addressing regionally specific challenges and opportunities (Macias *et al.*, 2019).

Additionally, recent publications on aquaculture opportunity areas (AOAs) by the US National Oceanic and Atmospheric Administration (NOAA) highlight advancements in pre-selecting marine regions with optimal conditions for aquaculture development (Riley *et al*., 2021; Morris *et al*., 2021). Studies from the European Union, including the 2022 technical report on access to space and water for marine aquaculture (European Commission, 2022) and the 2024 working document on implementing strategic guidelines for EU aquaculture, emphasize the importance of regulatory frameworks and streamlined processes to facilitate sustainable growth (European Commission, 2024).

These documents collectively provide a comprehensive foundation for the spatial planning that supports aquaculture development, and they have been essential in the implementation of aquaculture MSP at a national level (e.g. ISPRA Technical Guide on Allocated Zone for Aquaculture AZA, Marino *et al.*, 2020). These documents offer methodologies, case studies, and best practices that enable stakeholders to make informed decisions, aligning aquaculture development with environmental sustainability, socioeconomic benefits, and regulatory compliance.

Key frameworks and terms

Over the years, frameworks like MSP and EAA have introduced specific terminology to guide spatial planning.

Key terms include:

- zoning: a government-led process to designate areas suitable for aquaculture
- site selection: the identification of optimal locations for aquaculture, typically led by the private sector under regulatory frameworks.

Additional concepts integral to aquaculture planning include:

- aquaculture management areas (AMAs): aquaculture parks or clusters, or any aquaculture area in which farms share a common waterbody or source, and which may benefit from a common management system that facilitates the minimization of environmental, social and fish health risks. These management areas can be quite beneficial when clustering small farmers who may benefit from joint access to feed, seed, technical support and access to markets and post-harvest services. A whole aquaculture zone can be an AMA if the size and issues are manageable from a practical point of view.
- allocated zones for aquaculture (AZAs) or areas available for aquaculture (AAAs): regions designated for aquaculture through multicriteria spatial analysis, particularly in the Mediterranean and Black Sea or Chile
- aquaculture opportunity areas (AOAs): pre-evaluated marine areas with favourable conditions for aquaculture; used in the United States of America to identify spaces where aquaculture can grow sustainably.

Core steps in spatial planning

The systematic steps for undertaking spatial planning that supports the development of aquaculture were presented, from analysing regulatory frameworks to monitoring environmental impacts and adapting plans through feedback mechanisms.

1. **Scoping:** Analyse the regulatory framework, aquaculture sectors, stakeholders, key implementors and supporters of the plan, funding and budget.
2. **Setting objectives:** Define goals, consider economic, social, and environmental sustainability, stakeholders and planning needs.
3. **Strategies and zoning:** Designate areas suitable for aquaculture based on their compatibility with other uses, ecosystems and policy guidelines
4. **Siting and carrying capacity estimation:** Identify sites within zones, assessing the carrying capacity and species needs.
5. **Management and participatory process:** Implement management plans with stakeholder engagement, coordinating aquaculture activities.
6. **Monitoring and environmental monitoring programmes (EMPs):** Track environmental impacts regularly; AMA, AZA, AOA, and MSP often require EMPs to ensure sustainable practices.
7. **Adaptive management:** Update plans based on monitoring feedback to improve sustainability.

Tools, data and models

The presentation highlighted the importance of data and the various environmental, administrative and anthropic factors that influence planning, supported by GIS tools, suitability analysis and carrying capacity models. The effective implementation of spatial planning that supports aquaculture development relies on a combination of data platforms, GIS tools, and analytical models. Platforms like Copernicus Marine Services, the general bathymetric chart of the oceans (GEBCO, n.d.), and the European Marine

Observation and Data Network (European Commission, n.d. [a]) provide critical environmental and spatial data, including ocean conditions, bathymetry, and human activity mapping. GIS tools such as the open-source QGIS (QGIS, n.d.) and the commercial ArcGIS (ESRI, n.d.) therefore provide essential geospatial analysis, enabling visualization and decision support.

Specialized models like the FARM (Anonymous, n.d.) model and DEPOMOD (SAMS Enterprise, n.d.) assess carrying capacity and environmental impacts, while ecosystem-level tools like Ecopath (Ecopath International Initiative, n.d.) analyse broader interactions within marine environments. A model's accuracy can vary significantly with location and environmental conditions, and any model is only as good as the data inputted. Nevertheless, taken together these resources provide a robust framework for integrating environmental, socioeconomic, and operational factors into sustainable aquaculture planning. The private sector has also contributed to carrying capacity modelling, developing tools such as AQRATE (Ferreira, 2025), which addresses zone-scale indicators like eutrophication and pathogens, as well as ORGANIX (Cubillo *et al*., 2016) at the local scale to evaluate benthic effects. Additional innovations include the FINS (Farming in Natural Systems; Longline Environment Ltd, n.d.) platform, which integrates multiple indicators and incorporates a diagenesis model that accounts for nine sediment-state variables, including total organic carbon and sulphide.

Output and impact of the spatial planning process

The spatial planning process in an aquaculture context generates a variety of outputs that are essential for guiding sustainable development and fostering stakeholder collaboration, of which some of the most significant are web maps and decision support systems. Examples include the NOAA AquaMapper (NOAA, 2017), ISPRA AquaGIS (ISPRA, n.d.), The Nature Conservancy (TNC) Aquaculture Suitability tool (TNC, 2025), Aquaspace toolbox (Scottish Marine Institute, n.d.) and a range of atlases (e.g. the AOA Atlases published by NOAA; Morris *et al*., 2021; Riley *et al*., 2021). The latter provide detailed visual representations of areas identified as suitable, unsuitable or restricted for aquaculture activities, based on the different constraints and uses of the sea, together with specific criteria (e.g. environmental conditions, logistics, visibility). These spatial tools not only support decision-making but also serve as reference points for monitoring and managing aquaculture zones over time.

In addition to visual outputs, spatial planning can enable the establishment of legal frameworks. Although in many contexts such frameworks actually precede spatial planning, providing the mandate or requirement to conduct it, it is debatable whether MSP is predominantly a bottom-up or top-down process – indeed, incentives and mandates vary across jurisdictions. Nevertheless, spatial planning can also result in the establishment or refinement of legal frameworks that *formalize* the allocation of aquaculture zones, ensuring regulatory compliance and providing a clear basis for governance. By embedding these areas within legal structures, the process fosters consensus among stakeholders, creating a shared understanding of aquaculture's role within broader marine and coastal systems.

The impact of these various outputs extends beyond the operational level. They play a critical role in facilitating efficient decision-making by consolidating multilayered information into actionable insights. Furthermore, the integration of aquaculture zones into legal and regulatory frameworks enhances transparency and accountability, contributing to the sector's long-term sustainability. At the same time, the effectiveness of these tools depends on the availability of reliable site-specific data and decision-makers, who need to be aware of the models' possible limitations.

Ultimately, the outputs of spatial planning help balance environmental and biodiversity protection, socioeconomic benefits, and the efficient use of marine resources. By aligning aquaculture development with regulatory standards and fostering stakeholder consensus, these outputs ensure that the sector continues to grow responsibly while addressing global food security and sustainability goals.

Spatial planning for aquaculture is integral to balancing the growing demands for food security with environmental sustainability and socioeconomic development. By leveraging MSP frameworks, EAA principles and advanced tools, aquaculture can meet future challenges effectively, contributing to a more secure and sustainable global food system. One example of practical guidance in this area is provided by the Wildlife Conservation Society, which was developed in Myanmar and demonstrates how these principles can be translated into practice (Ya, 2016).

MARINE SPATIAL PLANNING AND AQUACULTURE: REGIONAL OVERVIEW AND CASE STUDIES

This session of the workshop was dedicated to the contributions of the invited experts, which explored regional overviews and practical case studies on the integration of MSP and aquaculture. The session provided a forum for the experts to present a range of diverse examples, tools and methodologies, while also highlighting existing gaps, challenges and innovative solutions in how spatial planning supports aquaculture development. The presentations aimed to offer valuable insights and provide background information that would guide and stimulate discussions during the workshop. Summaries of the presentations are given below.

Successful regional applications of MSP aiming to improve aquaculture were presented, as well as case studies where implementation is still in its early stages. Speakers detailed the tools used for spatial planning including GIS, decision support models and mapping technologies, alongside assessments of their effectiveness in balancing environmental, social and economic priorities. Many of the participants also submitted written summaries of their presentation and/or case study. These are provided in Appendix D.

Christopher Schillaci, National Oceanic and Atmospheric Administration (NOAA), and Jonathan MacKay, The Nature Conservancy (TNC), delivered a joint presentation providing an overview of aquaculture planning in North America.

Schillaci presented an overview of aquaculture in the United States of America, focusing on regulatory frameworks and spatial planning efforts. He highlighted key federal laws and tools developed by NOAA, such as the Aquaculture Opportunity Area Atlas (NOAA, 2025). Spatial suitability modelling was described as a tool applied in the United States of America, along with the different submodels employed to perform suitability analysis and marine area classification. Case studies demonstrated the application of spatial suitability modelling in Southern California to identify optimal locations for aquaculture while minimizing conflicts.

MacKay presented an overview of aquaculture planning in Mexico with a focus on the Gulf of California and Baja California Peninsula. He discussed the rapid growth of aquaculture production driven by mariculture of bivalves and finfish. He showcased an online mapping and decision support tool developed by TNC, emphasizing the spatial analysis capabilities available for users to plan for aquaculture (TNC, n.d.). This tool was designed internally at TNC and supports the identification of suitable sites by providing information on environmental and social constraints, thus supporting decision-making for aquaculture planning. MacKay highlighted collaborative initiatives with government and industry to foster sustainable aquaculture, supported by long-term capacity building and transparent management platforms.

Doris Soto, Interdisciplinary Center for Aquaculture Research, delivered a presentation entitled "Marine spatial planning of aquaculture in Latin America", highlighting Chile as a case study.

Soto gave an overview of designated aquaculture areas in Chile. These areas are deemed suitable for aquaculture and as aquaculture macrozones, in which conflicts with other users and environmental constraints are addressed. She shared innovative tools such as climate change risk maps and carrying capacity models. The Chilean Ministry of Environment promoted the development of climate change risk maps for mussel farming and salmon farming in the fjords of Chilean Patagonia. Such risk maps (Soto *et al*., 2020) provide an initial assessment of coastal marine aquaculture areas and systems that may be more affected and are more sensitive to climate change. They also provide recommendations on the spatial distribution of risks and needs for adaptation measures including the relocation of some farms. The carrying capacity of waterbodies to process nutrient inputs from aquaculture can also be a key sensitivity element under climate change, notably with respect to harmful algal blooms and hypoxic events (Soto *et al*., 2021). The presentation emphasized challenges in MSP processes related to regulatory gaps, indigenous community claims and ecosystem-scale impacts. By way of conclusion, Soto presented a traffic-light system used to regulate Chilean farmed salmon production, which is based on environmental and production risks for ecosystem-compatible aquaculture and collaborative approaches through the adoption of integrated spatial planning. The traffic-light system addresses the different environmental hazards from salmon farming as well as those that can affect farmed fish welfare and productivity; it focuses on the use of space and the timing of production, as well as technologically and socioeconomically innovative approaches.

Lucíola Magalhães, Brazilian Agricultural Research Corporation (EMBRAPA), delivered a presentation entitled "Strategic territorial intelligence for Brazilian aquaculture".

Magalhães presented Brazil's online GIS platform for aquaculture planning and an overview of EMBRAPA's aquaculture-related activities. She highlighted the rapid growth of aquaculture in the country, and the availability of a strategic territorial intelligence system for Brazilian aquaculture by way of a tool for spatial data management (GeoWeb, n.d.). This system uses remote sensing and automated or semi-automated mapping methodologies to map pond distribution in the country's different states. She provided examples of mapping done in the states of Rio Grande do Norte and the prevalence of coastal aquaculture in the states of Ceará, Sergipe, Rio Grande do Norte, Espírito Santo and Santa Catarina. The presentation illustrated how aquaculture intersects with conservation areas – mostly those that can be used sustainably – especially in coastal zones, stressing the importance of spatial planning. Examples of automated mapping of aquaculture ponds provided insights into challenges like incomplete spatial data and potential land-use conflicts.

Myriam Lacharité, University of Tasmania, and Rebecca Gentry, Hubbs-SeaWorld Research Institute, delivered a presentation entitled "Aquaculture planning in Australia and Aotearoa/New Zealand: challenges and opportunities".

Lacharité and Gentry outlined the governance systems of the sector in the respective countries. While New Zealand possesses a national policy and regulatory framework, with regional councils responsible for spatial planning and issuing permits, in Australia aquaculture only occurs in coastal waters as there is no legislative framework allowing aquaculture in the Commonwealth marine area beyond three nautical miles from the coast. States regulate aquaculture activities by issuing leases, and licenses to operate – which are periodically reviewed – but to date there is no systematic aquaculture zoning. Instead, most sites are proponent-led, with site selection followed by a regulatory process that may impose conditions. Key challenges included environmental impacts like excess nitrogen (primarily in Australia), and for fed species conflicts with other sectors. While in some cases Indigenous communities are impacted, particularly in the north of the country, most aquaculture is located in the south, in Tasmania and South Australia where opposition from local communities is stronger, underscoring the lack of social license of the industry with consumers.

In New Zealand, there has been a focus on honouring agreements with local communities and Indigenous Peoples, including giving agency to indigenous management of natural resources. Innovative tools like the Tasmania Marine Atlas (University of Tasmania n.d.) allow the visualization of key socioeconomic or environmental factors affecting site selection and zoning, supporting spatial optimization. The presentation stressed the need for social license to operate, informed consent and co-management approaches to mitigate conflicts and support sustainable aquaculture development.

Shenghui Li, Guangdong Ocean University, delivered a presentation entitled "Status of MSP implementation for aquaculture in China," showcasing China's progress in integrating MSP into aquaculture management.

The presentation outlined how China's MSP system integrates national strategies and evolving legal frameworks to promote sustainable and modern aquaculture. Central to this system are Marine Functional Zoning (1989–2020) and Territorial Spatial Planning (2021–2035), which provide a coordinated foundation for systematic marine resource management across national, provincial, and local levels. The Aquaculture Waters and Tidal Flats Plan stands out as one crucial operational tool, dividing aquaculture areas into allowed, restricted, and prohibited zones. Allowed aquaculture zones support eco-friendly, high-efficiency aquaculture practices with regular monitoring. Restricted aquaculture zones impose controls because of ecological sensitivity, requiring strict oversight and periodic resting. Prohibited aquaculture zones ban farming activities entirely in order to protect key ecological areas and mandate restoration efforts. This zoning framework is regularly updated to reflect changing ecological and industry conditions. Since 2019, national policies have increasingly focused on green growth, deep-sea and open-ocean aquaculture expansion, and intelligent infrastructure in aquaculture. Together, these instruments work in a coordinated manner to enhance sustainable aquaculture production, protect the health of marine ecosystems, and reinforce integrated ocean governance.

The presentation also showcased multi-use case studies, such as marine ranching integrated with offshore wind farms (Yangjiang and Shanwei, Guangdong Province), ecotourism initiatives (Zhuhai, Guangdong Province and Weihai, Shandong Province), and solar energy integration projects (Taishan, Guandong Province), illustrating China's efforts to create effective links between economic development and ecological sustainability. Nevertheless, persistent challenges remain, including competing policy priorities, ecological risks, gaps in intersectoral coordination, and the need for more robust data. The presentation emphasized the transformation of governance, technology innovation and a deeper integration of academia and industry as essential in order to balance aquaculture growth with ocean conservation. Tools like GIS-based suitability models and collaborative decision-making platforms were also highlighted as essential for advancing sustainable aquaculture development.

Alvin Baloloy, Oceana Philippines, delivered a presentation entitled "Integrated modelling and GIS-remote sensing for MSP: Optimizing fisheries and aquaculture planning in a data-limited site in the Philippines", focusing on an FAO-supported MSP project in Pagbilao Bay.

The primary objective of the project is to develop an MSP framework that facilitates marine spatial planning, even in areas with limited onsite data. The project employs innovative approaches, including the suitability, sensitivity, susceptibility – governance and socioecological integrated system and Bayesian network – GIS models, alongside active stakeholder engagement. Gaps in socioeconomic and governance information were addressed through focus group discussions. For ecosystem and water quality parameters, specific pre-processing techniques were introduced to enhance spatial completeness. First, Euclidean distance maps were created using the ArcGIS Euclidean distance tool. Spatially implicit features such as rivers and navigational routes were converted into raster format, covering the entire study area. Second, pixel interpolation was applied using kriging techniques to convert point shapefile data into raster format, ensuring compatibility with the Bayesian network models. This included field-acquired data from water sampling points (e.g. dissolved oxygen and salinity) as well as model-generated values for velocity and water retention time, which were initially available only as point data.

The project produced a viability map for marine protected areas (MPAs) and revealed that potential sites were influenced by a combination of biophysical, socioeconomic, and governance factors. Although existing MPAs demonstrated the potential for expansion, some areas that could have supported larger MPAs were constrained by conflicts with traditional fishing grounds. A second key output was a viability map for mariculture areas, which identified approximately 1 980 hectares (ha) of suitable zones for mariculture activities. Notable challenges included limited access to GIS tools and a continuing need for capacity building, and the absence of an explicit requirement for a comprehensive land- and water-use plan at the local level.

Pholphisin Suvanachai, Thailand Department of Fisheries, presented "Aquaculture planning and management with Agri-Map Online in Thailand".

Suvanachai introduced some online spatial planning tools used in Thailand, such as the Agri-Map Online and the Agri-map phase II, which integrates data from 22 agencies and serves diverse agricultural user groups, including freshwater and marine aquaculture. A case study was also presented on an early warning system that utilizes the internet of things and artificial intelligence to mitigate risks in finfish and mollusc cultures in selected coastal areas. An analytics platform for water quality data was also presented, which was capable of pre-processing and visualization, performing predictive analytics and statistical modelling. The presentation underlined the importance of political will, inter-agency collaboration and ongoing improvements in spatial tools and data integration.

Trevor Telfer, University of Stirling, and Barry Costa-Pierce, Nord University/Ecological Aquaculture International, delivered a presentation entitled "MSP implementation in aquaculture in Northern Europe," focusing on challenges and advancements in MSP across the region.

Telfer and Costa-Pierce first highlighted the EU Maritime Spatial Planning Directive and its role in reducing conflicts and fostering investment. They then presented case studies of Scotland's comprehensive National Marine Plan and regional initiatives, including the Shetland Islands Plan. Elsewhere, Denmark has developed a comprehensive MSP framework to designate areas for promoting farming of low trophic species and integrated multitrophic aquaculture (IMTA) systems, which includes strict environmental standards for aquaculture operations. Iceland has adopted MSP as part of its commitment to sustainable marine management and a focus on environmental protection. The aquaculture industry was supported by a new licensing system for aquaculture operators, which includes strict environmental monitoring and reporting requirements. Norway's aquaculture governance system was highlighted in this regard: it includes a traffic-light system for managing production risks and a stringent location licensing process that requires compliance with eight legislative frameworks and involves multiple regulatory authorities at national and local levels. The presentation addressed the socioeconomic concerns voiced by communities in terms of the benefits of aquaculture to the local and national economies, given that a significant proportion of salmon aquaculture is dominated by large multinational companies, which leads to unequal wealth distribution. However, the increase in scale of production, not possible in smaller-scale aquaculture, still brings considerable and probably more local and national economic benefits.

Environmental issues such as the increased presence and spread of salmon lice, pollution, disease outbreaks and climate change were examined alongside innovations like semi-closed cages, partial and full recirculating aquaculture systems, pump ashore, and offshore systems.

Amel Mzoughi Aldeek, National Institute of Marine Sciences and Technologies, delivered a presentation entitled "Regional Review of MSP in the Mediterranean Region," examining aquaculture trends, governance structures, regulatory framework, planning tools and stakeholder engagement across the Mediterranean coastal states.

Aquaculture production in the region has doubled since 2000, driven by technological advancements, increased market demand, expansion and offshore farming, with significant contributions from countries like Egypt, Tunisia, Türkiye and other Mediterranean countries. Türkiye, in particular, has witnessed a massive scale-up in marine cage farming, especially along its Aegean and eastern Mediterranean coasts and into the Black Sea. This rapid development has been supported by the delineation of aquaculture production areas (APAs), in which environmental suitability, carrying capacity, and regulatory oversight are integrated to manage sectoral expansion while mitigating ecological risks. The presentation detailed governance approaches, including decentralized versus centralized strategies in different Mediterranean countries.

Case studies on MSP applications were briefly mentioned for Spain, Italy, Tunisia, Türkiye as well as those already implemented in Greece, Italy and Spain, with centralized or hybrid approaches observed in some countries (i.e. Croatia, Malta, and Türkiye). In North Africa, Tunisia is advancing national aquaculture strategies with significant regional stakeholder involvement. The review also highlighted examples of MSP in practice, drawing on case studies from Algeria, Italy, Spain, Tunisia and Türkiye, where national authorities are applying spatial tools and environmental safeguards to balance aquaculture development with coastal ecosystem protection. The Regional Plan on Aquaculture Management under the Barcelona Convention was presented as a comprehensive framework for aquaculture sustainability. The plan provides technical guidance on the designation of allowable zones of effect (AZEs), the monitoring of environmental quality standards, and the implementation of ecosystem-based site management practices. It also includes specific provisions to address nutrient discharges, fish welfare, farm escapes, and marine litter, aligning with the convention's broader goal of pollution reduction and integrated coastal zone management.

Andrej Abramic, EcoAqua Institute, University of Las Palmas de Gran Canaria, delivered a presentation entitled "Aquaculture zoning following marine spatial planning principles within the Macaronesia use cases".

Abramic highlighted the PLASMAR and PLASMAR+ projects co-funded by the European Regional Development Fund, which developed scientific methodologies for MSP in the Macaronesia region (Abramic *et al*., 2024). Tools such as the Marine Spatial Data Infrastructure and Decision Support System (INDIMAR) were introduced for aquaculture development through marine spatial planning in the Macaronesian region (European Commission, n.d. [b]). A key focus was on suitability zoning for aquaculture, which integrates various thematic data clusters including environmental sensitivity, marine conservation, natural oceanographic potential, land–sea interactions, and operative maritime uses. This can be extended to include socio-economic socioeconomic and governance clusters, following the MSP Data Framework (MSPdF) (European Commission, n.d. (c)). These methodologies are applicable both for establishing new aquaculture operations and for expanding existing ones.

The innovative ReMAP framework was also presented (Abramic, 2023), which includes an input data module that can standardize the input data assessment for MSP. Conclusions emphasized how these methodologies can be adapted to different scales, and their reliance on high-quality spatial data.

Christopher Mulanda Aura, Kenya Marine and Fisheries Research Institute (KMFRI) delivered a presentation entitled "Lake Victoria marine spatial plan in relation to aquaculture suitability and carrying capacity".

Aura highlighted challenges such as population growth, socioeconomic issues, fishing pressure, prohibited areas and pollution affecting Lake Victoria. The Sustainable Activities in Water Areas (SAWA) Initiative played a key role, generating models that identified inshore, cage-suitable areas with an optimal depth range of about 6–10 m, alongside constraints like navigation routes, water hyacinth hot spots and breeding areas (SAWA Initiative, n.d.). The area recommended for inshore aquaculture in the lake is 291 km^2, which amounts to 8 percent of the lake. The "not suitable" and "less suitable" areas are recommended for accessing the lake for transport, navigation, capture fisheries, tourism, sports and other uses. The area available in the lake with high suitability potential for large-scale firms is only 11 percent of the lake surface area, representing about 408 km^2. This offshore aquaculture zone ranges at an optimum depth of about 10–40 m and has "suitable areas" that account for 21 percent (783 km^2) of the lake, depending on the existing production carrying capacity.

The spatial plan provides an opportunity for other lake uses and activities to be updated as new activities emerge. For example, the mapped fish landing sites and ports act as domains for several lake uses such as trade, tourism, lake accessibility and social activities, among others. Capture fisheries remains the lake communities' principal concern, and so the recommendation is for the plan to cover the entire lake, with aquaculture planned primarily in areas that are unsuitable or less suitable for capture fisheries. Following best management practices and EAA, the entire Kenyan part of Lake Victoria is estimated to have an annual cage culture production carrying capacity of 275 000 tonnes for riparian countries. Tools like SWAN (Simulating Waves Nearshore) for wave dynamics (TU Delft, n.d.) along with other submodels (e.g. socioeconomic suitability, land-based suitability, water quality suitability) were used to assess inshore and offshore aquaculture viability. A web-based marine spatial plan was developed to support policymaking, focusing on sustainability and governance frameworks. The project promoted multidimensional carrying capacity models and inter-agency coordination for effective implementation.

Michelle Pretorius, Department of Forestry, Fisheries and the Environment, gave a presentation entitled "Marine spatial planning: practical examples from the Republic of South Africa".

Pretorius outlined the regulatory framework in South Africa, including the Marine Living Resources Act and the development of the Aquaculture Development Bill and the Marine and Spatial Planning Act, as well as other policies that support the growth of the sector and streamline governance. South Africa has approached MSP by first developing a framework, then developing the MSP Act and the National Data and Information Report, which provides for the knowledge baseline in MSP. South Africa has also developed sector plans that outline the spatial ask from each sector and is currently developing marine area plans which provide guidance to resolve potential conflicts and competition between the marine users by specifying the priority areas for each sector required to support sustainable development and use. South Africa has identified land- and sea-based freshwater and marine aquaculture development zones (ADZ) by conducting strategic environmental assessments; while site-selection criteria were highlighted to ensure sustainability-integrated spatial analysis and iterative stakeholder consultation. An ADZ is an area that has been earmarked specifically for aquaculture activities with the aim of encouraging investor and consumer confidence, creating incentives for industry development and providing marine aquaculture services, while managing the risks associated with aquaculture and providing skills development and employment for coastal communities. One such example is the Saldanha Bay ADZ, which was presented as a case study: it covers 884 ha and targets species like oysters, mussels and seaweed. Several other tools have also been developed by the Department of Forestry, Fisheries and the Environment to support aquaculture project viability; these included feasibility studies, site-suitability assessments, species-specific economic models, market awareness tools, aquaculture support services and a communication resource repository.

Open discussion: best practices and lessons learned from implementing spatial planning in the marine aquaculture sector

The regional overviews and case study presentations were followed by prompt questions that aimed to collate valuable feedback on best practices, lessons learned and challenges in spatial planning which would support aquaculture development. The questions were presented using the online polling software "Mentimeter" to capture participants' responses.

The first question asked participants to identify "the best example of spatial planning they had experienced and explain why". Experts highlighted that the most effective examples engaged stakeholders from the outset, including integrated data flow and informed decision-making. Responses revealed diverse experiences, with some participants pointing to cases such as Türkiye, where zoning criteria included specific depths, current speeds and buffers between farms, or Lake Victoria, where spatial planning benefited from clear objectives and balanced information. In Italy, criteria and tools for spatial planning that support aquaculture development were developed to help competent authorities identify allocated zones for aquaculture and their integration in regional MSP plans. However, many noted the absence of universally recognized 'best' examples because of variations in context, objectives and limitations in monitoring and implementation.

The second question asked participants about "the worst examples of spatial planning and reasons for their failure and why". Responses highlighted various deficiencies that weakened the effectiveness of spatial planning in aquaculture. A recurring theme was the lack of adequate stakeholder involvement, as some plans were developed without participatory processes or with little consideration of the multiple uses of shared water spaces. Negative examples included projects where top-down approaches were used, neglecting the input and collaboration of key stakeholders. Similarly, cases where spatial planning was overly complex and failed to achieve implementation were cited as problematic, such as California's oyster aquaculture within protected areas. The criticism was primarily not for environmental reasons but because of political decisions that complicated the marine spatial planning process, making it hard to align conservation priorities with development objectives. Other negative examples included: the sole reliance on modelling results without considering real-world conditions; or the use of old technology – for example, the use of nearshore cages that employed outdated technologies despite the need to move sites further offshore in deeper locations.

Participants also pointed to insufficient coordination between governing bodies, particularly in regions like Asia, where municipal jurisdictions over waters often failed to align, which led to fragmented management. The absence of transparent and accessible plans, combined with contradictory or overlapping policies, further worsened these issues. Some participants noted that spatial planning efforts often lacked adaptability to local socioecological contexts and did not include performance evaluations or monitoring frameworks to ensure their ongoing relevance and effectiveness.

During the discussion, it was pointed out that even if spatial planning has been carried out based on robust methodology and data, this is often not sufficient to either simplify or reduce the time for issuing new licenses. This can be the result of various factors, including the complexity of the licensing regulatory framework, the lack of dedicated governmental/administrative offices with trained staff to support the process, and sociopolitical conditions at the local level.

Additional criticisms included the failure to address cumulative environmental impacts, the lack of data visualization to aid stakeholder understanding, and an insufficient consideration of long-term implications such as wastewater discharges affecting coastal ecosystems. These responses underscored the need for spatial planning to be a dynamic, inclusive and well-coordinated process that integrates scientific rigour, stakeholder collaboration and practical implementation frameworks to achieve sustainable outcomes.

The third question asked participants, "What do you think could have helped improve it?" Answers highlighted the need for more reliable and accessible data, as well as the development of shared and integrated databases that could feed into GIS systems and decision support models. Clear and achievable objectives were considered essential for ensuring alignment among stakeholders and for guiding effective implementation.

Respondents also emphasized that successful spatial planning should adhere to certain principles: it should be ecosystem-based, adaptive and participatory, allowing flexibility to incorporate changing environmental conditions and new information. Improved stakeholder awareness and engagement were seen as critical, with recommendations for communication strategies that effectively convey the benefits of spatial planning to local communities and stakeholders.

Enhanced inter-agency cooperation, and partnerships with relevant authorities, were also identified as critical to ensuring that planning outcomes align with broader policy goals and operational realities. Participants also underlined the importance of using simulation models to assess impacts, risk assessments to guide planning, and a better articulation of socioeconomic and environmental benefits.

The fourth question asked for the "biggest challenges faced when applying spatial planning". Common themes included data scarcity, particularly real-time data and cumulative impact analyses, as well as difficulties in achieving stakeholder agreement and addressing social acceptability issues. Other barriers were the resistance to data sharing by fish farmers and a lack of capacity within governmental agencies to use necessary tools. Participants emphasized the need for long-term monitoring, adaptive planning frameworks and inter-agency cooperation to address these challenges effectively and ensure sustainable aquaculture development.

These inputs from the Mentimeter survey (Table 2) highlighted critical areas for improvement and provided useful recommendations for the work to be done over the following days. The survey also stressed the importance of inclusive, adaptive and well-coordinated frameworks to advance sustainable and effective spatial planning that supports aquaculture development alongside robust data systems.

Table 2. Results of the Mentimeter poll on critical areas for the improvement of spatial planning in support of aquaculture development

Survey question	Main themes identified
Best example of spatial planning experienced	strong stakeholder engagement from the early phases clearly defined and measurable objectives robust data availability and flow adaptability of planning to context and needs successful implementation in real-world scenarios
Worst example of spatial planning experienced	minimal or absent stakeholder participation reliance on poor or outdated data lack of scientific or suitability criteria absence of coordination across institutions or jurisdictions top-down or politically driven planning
What could have improved it?	development of comprehensive, accessible data systems fostering inter-agency collaboration defining clear and achievable goals establishing monitoring and feedback mechanisms proactive development of local communication portals and extension involvement
The biggest challenges in spatial planning and management	insufficient or low-quality data stakeholder reluctance or distrust lack of monitoring and enforcement frameworks fragmented institutional responsibilities low social acceptance and resistance to change

Source: Author's own elaboration.

Marine spatial planning roadmap 2022–2027 – Agenda 2030

Following the open discussion on best practices, Amber Himes-Cornell delivered a presentation focused on the evolution of global MSP frameworks, including the updated roadmap for 2022–2027 and the process undertaken by ISPRA and FAO to adapt it to define the specific MSP needs for aquaculture.

Himes-Cornell began by presenting the "Joint roadmap to accelerate maritime/marine spatial planning processes worldwide" (2017–2022), developed by the Intergovernmental Oceanographic Commission of UNESCO in collaboration with the Directorate General for Maritime Affairs and Fisheries of the European Commission (DG MARE) in March 2017, as a foundational document outlining strategies to expand MSP coverage globally (IOC-UNESCO and European Commission, 2017).

Building on this foundation, the “Updated Joint Roadmap” (2022–2027) was introduced, carrying forward the lessons learned and providing updated priorities to address emerging challenges (IOC-UNESCO and European Commission, 2022). The overarching goal of this updated roadmap was explained as providing actionable guidance for implementing MSP globally, emphasizing its intersectoral benefits and capacity to align marine spatial planning with the objectives of the 2030 Agenda for Sustainable Development. The roadmap targeted the inclusion of at least one-third of maritime areas under national jurisdiction into marine spatial plans by 2030, aiming to foster sustainable ocean use through structured and collaborative planning approaches.

The “MSP Policy Brief on Blue Economy” (2021) was also presented (IOC-UNESCO and European Commission, 2021), underscoring the value of MSP as a tool for supporting sustainable ocean-based activities in increasingly crowded marine spaces. It was highlighted how MSP not only promotes a rational use of the oceans but also enhances investor confidence by introducing greater transparency and predictability to decision-making processes. This aspect of MSP was framed as particularly relevant for fostering innovation and attracting investment in emerging ocean-based industries, including aquaculture. Challenges outlined in the policy brief, such as threats to ecosystem services, climate change impacts, governance gaps and insufficient collaboration between sectors, were noted as significant barriers to progress towards a sustainable blue economy.

In the latter part of the presentation, explanations were provided on how the priorities established by the Updated Joint Roadmap were specifically adapted to address aquaculture needs. Here, the critical importance of governance and institutional frameworks in ensuring streamlined interactions between authorities and stakeholders was emphasized (IOC-UNESCO and European Commission, 2022).

PRIORITY AREAS FOR SPATIAL PLANNING IN AQUACULTURE

On the second day, Amber Himes-Cornell provided participants with information on the priority areas and collected feedback for the experts' discussions and group work.

The presentation aimed to: recall how the five priority areas for improving spatial planning for aquaculture (see Background) were selected; provide a detailed explanation of the rationale behind each area; collect feedback from participants using an interactive survey; and outline the organization of the breakout group sessions. Furthermore, the presentation served as a comprehensive introduction to the groups' activities, ensuring that participants understood the framework and their roles in contributing to the development of effective guidance for spatial planning that supports aquaculture development.

Prior to the workshop, an expert was selected to lead the preparation and discussions for each of the five priority areas, namely:

- Doris Soto (Governance and institutional framework: streamlining interactions between authorities)
- Trevor Telfer (Knowledge support for spatial planning in aquaculture)
- Andrej Abramic (Criteria and guiding elements for allocation of space)
- Barry Antonio Costa-Pierce (Capacity building, awareness and extension services)
- Rebecca Gentry (Marine conservation and restoration).

These experts were tasked with formulating the rationale for their assigned priority area and presenting it to the rest of the participants. After the rationale was presented, participants were invited to provide their input through a Mentimeter survey aimed at gathering feedback on the priority areas, refining the strategic focus, addressing specific guiding questions for each area and facilitating collaboration in drafting and editing content. For each priority area, participants were asked to respond, using the Mentimeter tool, to three key questions: "What does success look like?"; "What are the strategic objectives?"; and "What are the key actions to undertake?" The discussion on these questions aimed to clarify the desired outcomes, identify the main goals and outline the necessary steps to achieve them; they are summarized by priority area below.

Priority area 1: Governance and institutional framework: streamlining interactions between public sector institutions and public–private sector interactions

Doris Soto explained that governance plays a critical role in the success of spatial planning for aquaculture, emphasizing its importance for the effective implementation of spatial planning in support of aquaculture development. She highlighted that aquaculture governance involves managing complex regulatory, environmental and socioeconomic dimensions, which require the coordination of multiple authorities across various levels of government. A streamlined and coherent governance structure was described as critical for ensuring efficient management and minimizing conflicts between stakeholders. Soto pointed out that many countries lack specific laws or regulations dedicated to aquaculture and those with such frameworks tend to have more mature aquaculture sectors.

The context of mariculture development was identified as a key factor influencing governance needs. Soto noted that the governance challenges and frameworks vary significantly between regions with long-established aquaculture practices – such as China – and those where aquaculture is relatively new, notably countries in the Americas, the Caribbean, Europe and Africa. While overarching governance principles should remain consistent, specific approaches must be tailored to the governance frameworks, national systems, local authorities and relevant communities in different countries.

Rationale

Marine aquaculture governance is at the root of aquaculture planning and a strong and healthy governance is essential for MSP and its implementation in an aquaculture context.

Effective governance and a robust institutional framework are essential for the success of spatial planning that supports the development of aquaculture. Aquaculture involves various regulatory, environmental, and socioeconomic dimensions, making it necessary to coordinate multiple authorities across government levels. A streamlined governance structure ensures clear, coherent management and reduces conflicts between stakeholders.

However, this topic must be addressed in line with the specific aquaculture development context. For example, the MSP situation is very different in the various countries and regions where aquaculture is an ancient activity (e.g. China) than in regions where it is a more recent practice (e.g. countries in North and South America, Caribbean, Europe, Africa etc.). Although governance principles should be similar, the challenges differ based on the different countries' respective governance frameworks. Governance should also be revisited according to national and local situations/authorities.

Ecosystem-based approaches (linking to priority area 3) that promote improved interaction between aquaculture and other uses and users of coastal zones are essential, notably with marine conservation and with local fisheries.

In general, more often than not, there are countries which have a more established aquaculture sector despite a lack of specific aquaculture laws or acts.. Yet, conflicts on the use of marine space by aquaculture is a permanent challenge requiring appropriate intersectoral governance.

Participant discussion

What does success look like?

Success in the context of maritime spatial planning (MSP) for aquaculture was described as a situation where aquaculture is given priority within a clear and flexible governance framework, helped by well-defined rules and institutional support. Transparent and evidence-based decision-making processes would guide both aquaculture and other maritime activities, strengthened by a solid legal framework that integrates farm-permitting systems directly into MSP processes. The level of governance – national, regional, or municipal – should be tailored to the local context, ensuring decisions are appropriate, effective and coherent.

Participants also emphasized the importance of streamlined legislation, particularly with respect to licensing and MSP implementation: this ensures that planning outcomes translate into tangible actions rather than remaining on paper. Success also depends on eliminating overlaps and gaps in institutional mandates, with clear jurisdictional responsibilities assigned to relevant agencies.

A successful system would be one where MSP is adopted efficiently and equitably, involving communities in the decision-making process and ensuring robust governance through monitoring, enforcement, and collaboration. Participants stressed the need for institutional mechanisms that clearly recognize aquaculture within the MSP framework.

What are the strategic objectives?

The participants identified a series of strategic objectives to support the effective integration of aquaculture within MSP. One key objective is to enhance transboundary cooperation and coordination, particularly in shared marine areas. Planning approaches must remain adaptive, capable of responding to emerging technologies and the impacts of climate change. The sector's alignment with the Sustainable Development Goals (SDGs), especially through mariculture, should be emphasized to justify and secure its spatial needs.

Strategic allocation of aquaculture areas should aim to balance ecological integrity, economic viability, and social acceptability. Simplifying and harmonizing licensing procedures (such as through

Participant responses: What does success look like?

- priority is given to aquaculture with clear rules, support, and flexibility
- transparent and evidence-based decision-making in aquaculture and other activities
- appropriate governance level: national, regional, or municipal
- common/shared goals with good coordination
- a thriving, self-sustaining aquaculture industry
- streamlining legislation for MSP and aquaculture licensing
- implementation of MSP outputs in practice, not just in reports
- resilient aquaculture growth contributes to the SDGs
- clear agency jurisdiction, no overlaps or gaps
- efficient adoption of MSP and application of objectives
- community-consulted MSP decisions
- good governance framework with enforcement, monitoring, and cooperation
- equal decision-making access for aquaculture, as with other production sectors
- institutional mechanisms recognizing aquaculture in MSP
- food security, income generation, and environmental sustainability

one-stop-shop systems) was widely supported. Participants also noted the importance of distinguishing clearly between policy development and governance functions, while identifying mechanisms that enable sectoral growth without compromising sustainability.

The need for tailored strategies was also underlined, recognizing that countries are at different stages in aquaculture development. Improved cooperation between institutions that share marine space was seen as essential for coherent planning. Robust scientific evidence and key performance indicators (KPIs) should be provided to support policymaking. Strengthening stakeholder engagement through collaborative governance models was also emphasized.

Integrating One Health principles into aquaculture MSP was discussed as a cross-cutting priority, in addition to establishing environmental baselines and developing frameworks for cumulative impact assessments. These efforts are intended to ensure long-term sustainability and resilience in planning outcomes.

What are the key actions to undertake?

Several actions were proposed to achieve strategic objectives. First, it is essential to define and communicate MSP goals clearly to all stakeholders involved. Practical tools should be developed to simplify aquaculture-related administrative procedures, drawing lessons from sectors where MSP has already been successfully implemented. A comprehensive review of legislation governing aquaculture would help consolidate and streamline regulatory frameworks.

Participants recommended supporting comparative studies that will examine aquaculture's contributions to the SDGs, relative to other sectors. The development of intersectoral spatial plans was seen as necessary, along with mechanisms to resolve conflicts between competing interests. Training staff across competent government sectors would improve institutional awareness of aquaculture's spatial needs.

Securing political will and maintaining updated legal frameworks were identified as critical prerequisites. Strengthening regulations, promoting stakeholder engagement, and improving environmental monitoring practices, as well as establishing training programmes focused on governance enhancement were also proposed.

Participant responses: What are the strategic objectives?

- transboundary cooperation and coordination
- adaptive plans for technology and climate change
- highlight the positive contributions of mariculture to sustainable development as a reason to prioritize space allocation
- designate aquaculture areas balancing ecological, economic, and social priorities
- streamline licensing processes (e.g. one-stop-shop models)
- develop diverse aquaculture with minimal impacts and local benefits
- tailor strategies to countries at different aquaculture development stages
- improve cooperation between institutions sharing marine space
- provide KPIs and scientific evidence to policymakers
- inclusive planning with communities and underserved groups
- strengthen stakeholder engagement through collaborative governance
- apply One Health principles in aquaculture MSP
- set baselines and develop cumulative environmental assessment frameworks

Further action points included simplifying licensing documentation, centralizing access to relevant information, and establishing MSP teams within aquaculture agencies. Building capacity in key institutions and improving spatial coordination through the mapping of agency responsibilities and the formation of inter-agency working groups were also deemed important steps. In addition, participants highlighted the need for research on emerging spatial demands and the identification of potential conflicts.

Finally, linking aquaculture planning with adjacent sectors, such as offshore renewable energy and blue carbon initiatives, was presented as an opportunity to promote integrated ocean use and generate additional environmental and economic co-benefits.

Priority area 2: Knowledge support for spatial planning in aquaculture

Trevor Telfer emphasized that knowledge support is essential for effective spatial planning in aquaculture, integrating data, innovative tools and smart technologies. High-quality data on environmental, production and socioeconomic factors allow for informed decision-making, reducing risks and improving sustainability. Tools like GIS, remote sensing and predictive modelling all enhance site selection, assess ecological risks and simulate scenarios for better management. Smart aquaculture technologies, such as Internet of Things (IoT) sensors and artificial intelligence (AI), further optimize operations by enabling real-time monitoring and adaptive management.

However, several gaps limit the implementation of marine spatial planning in support of aquaculture development. The quality and availability of data is inconsistent, particularly for socioeconomic factors, and the lack of standardized formats complicates integration. Advanced tools are costly and often require expertise that is unavailable in many regions. Predictive models, while valuable, need reliable data for validation to ensure accurate planning. Smart technologies face barriers like insufficient digital infrastructure, lack of integration, unclear data-sharing protocols and administrative hurdles in adopting new technologies. Addressing these challenges is crucial to advancing spatial planning for aquaculture and achieving sustainable development.

Participant responses: What are the key actions to undertake?

- clearly identify and communicate MSP goals to stakeholders
- provide tools to simplify aquaculture administrative procedures
- learn from other sectors' MSP implementation successes
- review and consolidate aquaculture-related legislation
- promote studies comparing aquaculture and other sectors' SDG contributions
- create intersectoral area plans and negotiate conflicting interests
- improve aquaculture education among uncoordinated government sectors
- ensure political will and up-to-date legal frameworks
- strengthen regulations, stakeholder engagement, and environmental monitoring
- develop a training framework for governance improvement
- engage stakeholders and industry to meet broader community needs
- simplify licensing documents and centralize their location
- establish dedicated MSP teams within aquaculture agencies
- build capacity in key agencies
- intersectoral planning to manage spatial use
- map agency jurisdictions
- form inter-agency working groups
- conduct research on demand for new areas and potential conflicts
- link aquaculture with offshore renewables and blue carbon initiatives

Rationale

Knowledge support plays a fundamental role in improving spatial planning, by integrating data and employing innovative tools and smart aquaculture practices. These are therefore the key themes for this priority area.

High-quality, comprehensive and relevant data is essential for spatial planning in aquaculture. Data on water/environmental quality, production practice and social-economic trade-offs allow informed decisions about site selection and suitability, species compatibility, and carrying capacity, as well as insights into the local advantages and disadvantages of aquaculture initiatives. Data-driven planning can therefore mitigate environmental and social risks and increase sustainable production.

Innovative tools like GIS software, remote sensing technologies (including *in-situ* sensors, and earth observation technologies) and predictive modelling enhance the effectiveness of spatial planning in aquaculture. GIS tools allow visualization and analysis of spatial data for the assessment of ecological risks, identification of suitable sites, and prediction of environmental impacts. Predictive modelling tools simulate scenarios for various species under different environmental conditions, allowing modifications to farming practices.

Smart aquaculture encompasses the IoT, *in-situ* sensors, and (more commonly) AI to monitor and optimize farm operations. By integrating smart aquaculture technologies with spatial planning, stakeholders can continuously refine site management to reduce waste and wider environmental impacts, ultimately making spatial planning more effective.

Participant discussion

What does success look like?

A common vision emerged around the availability of robust, accurate, and accessible data systems that inform planning and decision-making processes at all levels. Monitoring systems that integrate production, environmental, and social variables were seen as critical to supporting both site selection and ongoing farm management. These systems should be capable of guiding spatial planning decisions with timely and reliable information.

Success was also associated with having clear and prioritized data needs identified from the outset, along with well-defined sourcing strategies. The availability of open-source carrying capacity modelling tools was highlighted as a key component, enabling planners and stakeholders to evaluate the sustainability of aquaculture development by adopting a science-based approach.

Data accessibility was another recurring theme. Participants emphasized the importance of user-friendly systems that make national and global spatial data readily available to a wide range of stakeholders, from government officials to local communities. These systems should present balanced environmental, social, and economic information, supported by strong metadata and sharing protocols. Decision support tools should not only be technically sound but also usable in practice, ensuring they are integrated into actual planning and management processes.

Ultimately, success would be marked by the presence of connected, interoperable data systems that inform farm- and regional-level decisions, supported by well-maintained online databases. These systems would help ensure that spatial planning processes are informed by accurate, representative, and regularly updated data.

Participant responses: What does success look like?

- monitoring systems for production, environmental, and social variables guide spatial planning decisions
- defined and prioritized data needs for MSP with clear sourcing strategies
- open-source carrying capacity modelling is available
- accessible data systems with balanced environmental, social, and economic information
- usable decision support systems for aquaculture area planning and management
- spatially and temporally representative data for model validation
- easy access to national and global spatial data for stakeholders
- connected data systems that feed into management decisions at farm and regional levels
- accurate, accessible data with strong metadata and sharing protocols
- established online databases

What are the strategic objectives?

Participants highlighted the establishment of open data platforms as a foundational step. These platforms must be based on high-quality data, presented in compatible formats and subject to accurate interpretation. Easy accessibility to these platforms, both globally and nationally, was seen as essential for inclusive participation and informed decision-making.

Capacity development emerged as a cross-cutting objective, with proposals for training materials and dedicated courses, including “training of trainers” schemes, aimed at strengthening institutional capabilities. Ensuring that data is validated and regularly updated was also mentioned, alongside efforts to strengthen national systems for spatial data collection and analysis.

Participant responses: What are the strategic objectives?

- establish/implement open data platforms
- ensure high-quality data, compatible formats, and accurate interpretation
- enable easy data accessibility at global and national levels
- provide training materials and courses, including 'training of trainers'
- ensure good data validation and quality systems
- strengthen national capacity for spatial data collection and analysis
- ensure data is representative, balanced, and regularly updated
- advance data management systems for storage, sharing, and analysis
- use robust prediction and adaptation tools, including bathymetric and current data
- design credible, cost-effective reporting systems for farmers
- ensure that MSP tools integrate data from all relevant sectors
- adopt global QA/QC protocols for simple data collection
- maintain collaborative national spatial data infrastructure (e.g. citizen/student data catalogues)
- engage farmers as data providers
- secure stakeholder buy-in early in the MSP process
- promote accessible data for non-experts
- enhance remote sensing for aquaculture monitoring and impact assessment

It was also noted that data should be balanced across key dimensions – environmental, economic, and social – and representative of spatial and temporal variability. Advanced data management systems were considered useful to support storage, sharing, and analysis, and to enable the use of predictive tools that incorporate bathymetric and current data for planning in uncertain times.

Participants also pointed out the need for credible, cost-effective reporting mechanisms for farmers, ensuring their data contributes to broader planning efforts. MSP tools must be designed to integrate data from multiple sectors, reflecting the complexity of marine and coastal systems. The adoption of global quality assurance and control (QA/QC) protocols was mentioned as a way of standardizing and simplifying data collection, particularly in resource-limited contexts.

Further objectives included the development of collaborative spatial data infrastructures, potentially engaging citizens and students in data cataloguing efforts. Engaging farmers as data providers, securing stakeholder commitment from the first steps of the MSP process, and promoting simplified access to data for non-experts were all seen as crucial. The strategic use of remote sensing tools was also emphasized to enhance aquaculture monitoring and environmental impact assessments, notably considering the climate change challenges aquaculture is facing.

What are the key actions to undertake?

Experts suggested developing online training courses focused on using, sharing, and managing spatial data. These should be complemented by policy frameworks that guide the use of knowledge support tools in aquaculture planning. Participants also highlighted the need for legislative structures, adaptable to different national contexts, that can enable and sustain these efforts.

The establishment of a global monitoring, evaluation, and learning framework was seen as an important step towards harmonizing performance tracking in aquaculture. Support for building the capacity to integrate diverse data types, including those related to production, environment, social dimensions, and fish health was also discussed. Establishing regional platforms for data exchange was proposed as a means to foster cooperation and collective learning among countries.

Participant responses: What are the key actions to undertake?

- promote data-sharing courses and cataloguing for spatial data infrastructures
- create policy to guide the effective use of knowledge support in spatial planning that supports aquaculture development
- establish achievable legislative frameworks for developed and developing countries
- implement a global MEL (monitoring, evaluation, and learning) framework for aquaculture
- promote capacity for integrating diverse data types (production, environment, social, fish health)
- establish regional platforms for data sharing between countries
- combine datasets from different agencies into unified databases
- define appropriate planning levels to match data resolution/modeling needs
- promote regional analysis and establish integrated databases
- use cost-effective, modeled data where real data is lacking
- ensure transparent monitoring of aquaculture zones (production and environment)
- plan for both data-rich and data-limited scenarios
- create open databases with long-term maintenance plans
- facilitate collaboration between environmental agencies and farmers on data/reporting
- harmonize sea uses through public consultation and participation

The unification of datasets from different institutions into shared databases was deemed a practical step towards interoperability. Planning levels should be matched with the appropriate data resolution to ensure that spatial models are meaningful and usable. Where real-time data is limited or unavailable, cost-effective modelling tools could be employed as an interim solution.

Ensuring transparency in the monitoring of aquaculture zones, both in terms of production and environmental conditions, was identified as an important step for public accountability. Planning processes should accommodate both data-rich and data-limited contexts, with adaptive measures built into system design. The harmonization of sea uses through participatory processes and public consultation was emphasized as a means of building trust and ensuring that spatial planning outcomes are broadly supported.

Priority area 3: Criteria and guiding elements for the allocation of space, shared use of marine space, land and sea interactions and adaptation to climate change

Andrej Abramic highlighted that developing the criteria for aquaculture zoning requires balancing marine environmental protection, societal needs and economic growth, guided by ecosystem-based management (EBM). Despite challenges in its practical application, EBM remains a critical framework for advancing spatial planning and policy development.

Integrated within the EBM framework, MSP has progressed through numerous European cross-border projects. These initiatives have provided practical tools and evidence-based results to inform policy decisions. Applying EBM principles to zoning involves multiparameter spatial analysis that identify optimal aquaculture sites while minimizing environmental trade-offs and societal conflicts.

Andrej Abramic referred to the Technical Expert Group on Data for MSP, which facilitated the MSP Data Framework (MSPdF) to support MSP zoning, offering guidance for data collection and monitoring. It organizes data into seven thematic clusters to inform planning decisions: marine and coastal environment, conservation, oceanography, coastal land and marine use, socioeconomic factors and governance.

For aquaculture, the priority is defining zoning criteria that incorporate environmental suitability, land–sea interactions, multi-use potential and climate adaptation. The MSPdF provides a structured approach to evaluate these elements, assess current practices and apply insights from existing criteria, creating a foundation for improved spatial planning that supports aquaculture development.

Rationale

To develop criteria and guiding elements for the allocation (zoning) of aquaculture that align with the ecosystem approach, there must be a balance between considerations related to the marine environment, societal needs, and continuous economic growth. While ecosystem-based management (EBM) has been discussed for many years, its real-world applications have faced numerous challenges. Yet these challenges do not undermine the approach itself so much as highlight the difficulty in achieving its goals. As such, EBM remains a critical guiding framework for advancing research and development.

Simultaneously, the concept of MSP within the EBM framework is being explored through European cross-border projects. Though often still discussed in theoretical terms, substantial progress has been made, despite obstacles to full-scale implementation. More than 20 cross-border projects have addressed EBM, equipping the MSP community with effective results that bridge theory and practice, supporting policy decisions informed by scientific evidence that is essential for the planning process.

Applying EBM and the corresponding zoning requires evaluating multiple, sometimes conflicting parameters. Technically, zoning is a multiparameter study that uses spatial analysis to identify the most suitable areas for various maritime activities, while aiming to minimize trade-offs with the marine environment, meet societal needs, and avoid conflicts with coastal communities.

To support MSP zoning data collection within the EBM framework, the Technical Expert Group on Data for MSP developed the MSP Data Framework (MSPdF). This document guides early-stage data collection and ongoing updates for monitoring and evaluation phases of MSP. The MSPdF is divided into seven clusters: marine and coastal environment; marine and coastal conservation and designated sites; oceanographic characteristics and climate; coastal land use and planning; operational maritime activities and planning; socioeconomic information; and governance information. Each cluster includes checklists of relevant data and topics for the multiparameter zoning analyses and MSP process.

For PA3, the objective is to identify criteria and guiding elements for space allocation, incorporating land–sea interactions (LSI), multi-use potential, and climate considerations. The workshop provided an opportunity to assess and apply the MSPdF specifically for aquaculture, evaluating which elements are most relevant for zoning, LSI, climate change adaptation, and multi-use. Additionally, it offered the chance to examine current applications of these elements and gather insights from existing criteria for site allocation, LSI, multi-use/co-use, and climate adaptation.

Participant discussion

What does success look like?

Among others, success was suggested as the establishment of transboundary MSP plans that coordinate the use of shared marine areas for aquaculture, particularly in instances where jurisdictions and ecosystems cross national boundaries. Such planning frameworks would enable the sustainable development of offshore aquaculture in underutilized marine areas, extending production beyond traditional coastal zones.

A successful approach would make use of measurable indicators to compare the spatial needs and impacts of different sectors, allowing for the fair allocation of space to aquaculture, and other industries, within a broader sustainable ocean economy. This would be supported by effective communication strategies that clearly convey the spatial requirements of aquaculture to planners, policymakers, and the public.

Participant responses: What does success look like?

- transboundary MSP plans in shared aquaculture spaces
- offshore aquaculture development in underutilized marine spaces
- use of indicators to compare sectors and allocate sustainable aquaculture space
- effective communication of the spatial needs of aquaculture
- validated national/regional criteria and parameters for site selection by species and technology
- planning scale is matched to activity scope
- climate change is effectively incorporated in MSP processes
- promotion of multi-use areas, e.g. clustering aquaculture with offshore wind farms
- 100 percent of coastal municipalities with basic sanitation coverage
- each sector defines priority areas, concentrates activities, and maps prohibited uses
- use of risk-based criteria considering environmental, social, and economic factors

Participants emphasized the need for validated national and regional criteria for site selection, tailored by species and production technologies. These criteria should be based on sound science and agreed-upon parameters, ensuring consistent and transparent decision-making. Planning scales would need to be aligned with the scope and intensity of aquaculture activities to ensure relevance and efficiency. The promotion of multi-use areas, such as co-locating aquaculture with offshore wind farms, was highlighted as an effective solution to optimize marine space and reduce competition between sectors.

A successful spatial planning process would also account for climate change, incorporating its anticipated effects into the identification and designation of suitable aquaculture zones.

Moreover, success would involve each sector clearly defining its priority areas, concentrating activities accordingly, and identifying areas where certain uses should be restricted. The application of risk-based criteria, taking into account environmental, social, and economic factors, was seen as integral to the informed and equitable allocation of space.

What are the strategic objectives?

The discussion then moved towards the strategic objectives necessary to achieving this vision such as the adoption of holistic, intersectoral planning that considers the needs, synergies, and trade-offs among all marine users. Exploring the potential for aquaculture to coexist with offshore renewables and contribute to blue carbon initiatives was identified as a relevant opportunity, especially in the context of climate action and spatial efficiency.

Participants mentioned the importance of strategies that can enable compatible sectors to share space through multi-use frameworks. Setting sector-specific goals and defining appropriate metrics were considered strategic to determine the best spatial fit and manage potential conflicts proactively. A better understanding of the real demand for marine and coastal space, particularly with respect to shared use, was seen as critical for anticipating needs and avoiding unnecessary competition.

It was suggested that FAO could play an expanded role as a global learning hub for aquaculture MSP, helping countries adopt and adapt spatial planning tools and approaches. Increasing social acceptability of aquaculture was also recognized as a strategic objective, requiring better communication, stakeholder involvement, and public engagement to address misconceptions and build trust.

Participants also highlighted the need to expand and regularly update FAO's spatial aquaculture maps to reflect new trends, technologies, and environmental data.

Participant responses: What are the strategic objectives?

- holistic, intersectoral planning
- explore aquaculture synergies with offshore renewables and blue carbon initiatives
- enable multi-use of space by compatible marine sectors
- set sector-specific goals and define metrics to assess best spatial fit
- understand real demand for co-use of marine/coastal zones
- position FAO as a global learning hub for aquaculture MSP
- increase social acceptability of aquaculture
- expand and update FAO aquaculture spatial maps
- harmonize criteria and define optimal thresholds for sustainable development
- ensure aquaculture has a voice in planning, including active industry participation

What are the key actions to undertake?

Participants proposed a range of targeted actions to meet these objectives. One of the first steps would be to create a global table of siting metrics across different marine industries, which could serve as a comparative reference for spatial allocation. Publishing clear, accessible data on coastal sanitation was also mentioned, as this information has direct implications for site suitability and environmental risk assessment.

Actions should include the integration of diverse datasets, such as aquaculture sites, bathymetry, and navigation routes, to improve spatial planning accuracy and minimize conflicts. Climate change indicators should also be used systematically in spatial planning to assess the suitability of zones across various scenarios and production systems.

To facilitate learning and alignment, one suggestion involved the drafting and publishing of regional or global overviews of the criteria and parameters used for the spatial allocation of aquaculture. Benchmarking international case studies, especially those adaptable to local contexts, would offer practical guidance for MSP implementation.

Increasing understanding of aquaculture's role and needs within the broader marine system is key to improving public perception, facilitating dialogue between sectors, and supporting the fair access to space in a rapidly evolving maritime landscape.

Participant responses: What are the key actions to undertake?

- create a global table of siting metrics across industries as a reference point
- publish metrics on coastal sanitation status
- integrate the mapping of aquaculture sites, bathymetry, and navigation routes
- use climate change indicators to plan aquaculture zones across scenarios and systems
- identify suitable aquaculture zones and reserve them, comparing use with other marine sectors
- harmonize site-selection methodologies and define development thresholds
- compile regional or global overviews of criteria and parameters for spatial allocation
- benchmark international case studies adaptable at local levels
- conduct systematic analysis to identify suitable areas
- promote ocean literacy to support the understanding and acceptance of aquaculture

Priority area 4: Capacity building, awareness and capacity extension

Barry Costa-Pierce highlighted that integrating aquaculture into marine spatial plans requires a focus on long-term socioecological processes and sustained financial support. Effective capacity building goes beyond technical training in GIS or marine science: it requires structural investments in extension services to lead neutral, participatory processes that address community concerns and foster collaboration across agencies and boundaries, including with Indigenous Peoples and communities.

Participatory scenario planning was highlighted as essential and required "setting the table correctly". This means neutral, professional and well-prepared facilitation; summary and rapid delivery of discussions to participants; evidence-based decision-making; and inclusive stakeholder engagement. Such efforts must ensure positive interactions, fair processes and actionable outcomes, fostering improvements in governance, rural development, business practices and financial mechanisms. Critical for capacity development and achieving sustainable development goals was the involvement of external experts with relevant experiences in similar contexts.

MSP is described as fundamental to national sustainability efforts, offering benefits such as reduced conflicts between sectors, legal security for investors, improved management and restoration efforts. However, the successful implementation of MSP involves making its frameworks more accessible and understandable for broader adoption. Aquaculture is not a familiar sector in many countries: its integration into spatial plans remains weak because of a lack of connections between existing sectoral plans and MSP.

Rationale

Establishing and maintaining aquaculture in marine spatial plans requires the thoughtful integration of long-term social-ecological processes that are well supported financially. National and regional institutions and their people are aligned with societal functions in primary production, conservation, business, etc. within and between their given sectors. As such, there are few opportunities to learn in a transdisciplinary way and to share local experiences globally. Successfully building the capacity of individuals and organizations requires the development of skills – and the confidence to practise them – beyond solid training and experiences in GIS and the latest aquaculture, fisheries and marine science findings. Significant, structural investments in extension services are needed so that they can lead neutral, non-advocacy participatory processes that address community concerns that scope transboundary, nationally, and with First Nations where relevant (e.g., Canada).

MSP can incorporate participatory scenario planning, but it requires the necessary elements to be set out thoughtfully for participants; for decisions to be based upon best available and complete information, ensuring and investing in active involvement; and for positive participant interactions and fair decision-making to be conducted. Directed actions can then make significant changes to build capacity for governance, rural development, businesses, and financing. Investment in the involvement of outside national, regional, and international experts and partners with similar planning efforts and experiences is crucial for the success of local capacity-development efforts and the collective goal of sustainable development.

MSP can be used to raise awareness, decentralize and break down the spatial planning process into its components to facilitate interpretation, adoption and implementation. MSP can also gather disciplines and lobbyist groups to win political will and to speak one language of importance related to management, sustainable economic development without additional environmental harm, restoration and stakeholder participation.

Ultimately, MSP should "leave no one behind" – there are many countries that want to embark on aquaculture and need assistance to build their capacity and knowledge in order to manage the sector well.

Participant discussion

What does success look like?

Experts mentioned that success in communication, training, and awareness requires a strategic, inclusive, and audience-specific approach, and agreed that effective dissemination of information must be tailored to the needs and capacities of different stakeholder groups, from policymakers and planners to farmers and local communities.

Success would involve the widespread availability of simplified, user-friendly guidelines that are understandable across a broad range of stakeholders; these materials would be adapted in tone and format depending on the audience, ensuring accessibility for technical experts, government officials, and the general public. Specific tools such as short online courses on MSP for public officials and public versions of aquaculture plans for communities were viewed as practical steps towards transparency and inclusion.

Broader training on best management practices would not only enhance sectoral performance but also support more informed governance. National aquaculture associations and industry groups would play a key role in this context, particularly if their capacities are strengthened and their collaboration with governments and regional organizations deepened.

Regional and international bodies, such as the Network of Aquaculture Centres in Asia-Pacific and WorldFish, were seen as possible players to support targeted training on MSP, especially in developing countries.

Raising awareness within ministries beyond fisheries and aquaculture was identified as another success factor, ensuring coordinated development and stronger institutional alignment across government sectors.

What are the strategic objectives?

The discussion focused on the strategic objectives needed to ensure widespread understanding and effective communication of MSP and aquaculture development. One primary objective identified was the broad dissemination of good practice guidelines for MSP, making them accessible and actionable in different national contexts. It was acknowledged that many developing countries lack sufficient technical staff, making dissemination and capacity-building efforts particularly urgent.

Another key objective is the provision of accurate and well-structured scientific, economic, and ecological information to decision-makers, enabling them to evaluate the trade-offs and benefits of aquaculture more clearly. Participants stressed the importance of identifying appropriate platforms and tools to facilitate knowledge sharing and promote capacity building in spatial planning, both nationally and regionally.

Participant responses: What does success look like?

- tailored dissemination of information based on the audience
- expanded training on best aquaculture management practices
- inclusion of aquaculture curricula for decision-makers and resource managers
- strengthened national aquaculture associations and industry groups
- short online courses for government officials on MSP tools
- public versions of aquaculture plans made available to local communities
- simplified, user-friendly guidelines understandable by various stakeholders
- regional organizations (e.g. Network of Aquaculture Centres in Asia-Pacific, WorldFish) focused on MSP training
- awareness programmes for other ministries with mandates over aquaculture development

Participant responses: What are the strategic objectives?

- disseminate MSP good practice guidelines
- build government capacity in developing countries that lack technical staff
- provide accurate scientific, economic, and ecological information for decision-makers
- identify platforms/tools for sharing and capacity building in spatial planning
- improve social license through better understanding of aquaculture
- use MSP scenario planning to demonstrate aquaculture growth pathways
- translate scientific information effectively for decision-making
- review MSP development regularly and promote good practices

Improving social license for aquaculture was considered a relevant priority, achievable through better public understanding and more transparent communication of aquaculture's role, impacts, and benefits.

MSP scenario planning was seen as a particularly effective tool for demonstrating future development pathways, helping stakeholders understand the spatial implications of different choices.

The ability to translate complex scientific findings into actionable knowledge for decision-making was identified as critical.

It was also proposed that MSP progress be regularly reviewed, with good practices continuously promoted through case studies, guidance materials, and peer learning initiatives.

What are the key actions to undertake?

The development of MSP scenario-planning tools tailored to different aquaculture growth objectives was identified as a high-impact measure, capable of fostering understanding among stakeholders and guiding strategic decision-making.

Media collaborations were put forward as another means of improving storytelling around aquaculture, with a focus on communicating its contributions to food security, livelihoods, and sustainability.

The creation of online training materials and structured training frameworks for different user groups was seen as essential in addressing the range of capacities and information needs across the sector. Participants suggested the development of a comprehensive information toolbox designed for various audiences, alongside continuing education programmes for aquaculture decision-makers. In addition, capacity-building efforts should be tailored to match technical levels and responsibilities, and online platforms should be established to facilitate the sharing of expert knowledge with a wide range of stakeholders. There was strong support for the integration of aquaculture training across educational levels, ranging from schools to tertiary institutions and professional development programmes.

Participants highlighted the value of open-source learning and skills development, especially in resource-constrained settings. Key actions included translating scientific outputs into accessible and multilingual materials to broaden reach, especially in diverse regional contexts.

Improving public knowledge and acceptance of aquaculture's impacts was considered a priority for building trust and legitimacy.

Specific tools to support the work of industry associations and facilitate intersectoral collaboration were also proposed.

Further actions included providing training on analysing spatial planning trade-offs and launching platforms for a scenario-based delivery of information. Strengthening connections between academia, research institutions, and decision-makers was emphasized as a means to ensure that planning processes are informed by up-to-date science and grounded in practical realities.

Priority area 5: Marine conservation and restoration

Rebecca Gentry explained that marine aquaculture interacts with surrounding ecosystems in diverse ways, highlighting that aquaculture can harm or help the environment depending on how it is done. Spatial planning must therefore set clear conservation goals, use measurable indicators, prevent harm, and also take advantage of aquaculture's potential to support ecosystem health. Moreover, it must ensure that development aligns with long-term ecological objectives and that trade-offs are managed transparently.

While avoiding sensitive habitats and preventing ecological harm remain central, aquaculture can also be planned strategically to deliver positive outcomes, such as improving water quality, supporting habitats, stabilizing shorelines, or enhancing nutrient removal and carbon sequestration through shellfish and seaweed farming.

Rationale

The interactions between marine aquaculture and the surrounding environment can vary significantly depending on the type and size of the farm, cultivated species, management practices, oceanic conditions and the location of the farming activity. Certain farms can cause considerable harm to local and surrounding ecosystems while some provide important conservation benefits, while many others are somewhere in between. Being explicit about conservation goals, developing indicators for these goals, and taking these

Participant responses: What are the key actions to undertake?

- develop scenario-planning tools for different aquaculture growth objectives
- collaborate with media to improve aquaculture storytelling
- create online training materials
- develop training frameworks for different stakeholder groups
- build an information toolbox tailored to various audiences
- expand continuing education for aquaculture decision-makers
- provide capacity building aligned to users' technical levels
- create online platforms to share expert knowledge with stakeholders
- translate scientific outputs into accessible language
- provide multilingual materials to broaden reach
- enhance public knowledge and acceptance of aquaculture impacts
- develop tools to support industry associations and collaborations
- offer aquaculture training across educational stages (e.g. schools, higher education, continuing professional development)
- implement skill development programmes in tertiary institutions and promote open-source learning
- provide training on analysing trade-offs in spatial planning
- launch platforms offering a scenario-based delivery of information
- connect academia/research with decision-makers
- integrate aquaculture education into all educational levels, including schools
- maintain continuous awareness-building throughout MSP processes
- initiate programmes for waste collection and sanitation in coastal cities

goals into account throughout the process of spatial planning allows for informed decisions about any potential trade-offs between farm development and conservation objectives, while also providing for aquaculture development that aligns with long-term conservation objectives in the region.

Avoiding ecological harm is an important part of spatial planning, such as choosing locations away from sensitive habitats, sensitive species and with adequate water flow. However, increasing attention is being devoted to aquaculture's strategic placement in specific areas and zones, and using it in ways that can provide conservation gains and/or contribute to ecosystem restoration. There are many ways that aquaculture can have restorative effects on ecosystems, including improving local water quality (e.g. unfed and shellfish/seaweed aquaculture), supporting habitat for wild species, and stabilizing shorelines. In addition, given that conservation/restoration efforts are often woefully underfunded, aquaculture could provide longer-term, more stable funding to such efforts.

Aquaculture can also be used specifically for conservation benefits in order to help restore threatened ecosystems and species or to provide carbon or other nutrient sequestration. Strategic spatial planning and a holistic view of aquaculture/environment interactions are essential for understanding, planning for, and managing the restorative potential of aquaculture.

Participant discussion

What does success look like?

Following the Mentimeter survey, the discussion on priority area 5 focused on how environmental safeguards and ecosystem services can be effectively integrated into aquaculture and MSP. Success in this area was described as the routine inclusion of aquaculture's ecosystem services in decision-making processes, including their incorporation into nutrient management plans and permitting frameworks. There was consensus that the aquaculture sector should be clearly defined as one that not only coexists with, but also supports, ecosystem services and conservation objectives.

Participants highlighted the importance of applying best practices for area-based management, with aquaculture farmers adopting management strategies that align with broader environmental goals. Strategic environmental and social impact assessments, specifically tailored to aquaculture zones, were

Participant responses: What does success look like?

- ecosystem service credits and integration into nutrient management plans
- best practices for area management adopted by aquaculture farmers
- strategic environmental and social impact assessments for aquaculture zones
- sector-specific strategic environmental assessments conducted before MSP implementation
- farmers recognize the benefits of conservation areas
- ecosystem services from aquaculture considered in permitting processes
- aquaculture contributes to conservation efforts
- clearly defined industry that supports ecosystem services
- conservation areas provide resilience to nearby aquaculture
- restoration areas offer economic incentives to farmers
- integrated fed and extractive species production
- methodologies and quantified standards used to assess impacts and services
- adoption of best aquaculture management practices
- eutrophication monitored using indicators such as TRIX
- environmental conditions continuously monitored with facility installation limits

seen as very important and ideally conducted prior to MSP implementation. In addition, it was proposed that sector-specific strategic environmental assessments should be integrated into planning processes to ensure that ecological considerations are addressed from the outset.

Farmers' recognition of the ecological and economic value of conservation areas was considered an indicator of success. In such scenarios, conservation and restoration areas would not only enhance resilience for nearby aquaculture operations but also provide direct economic incentives to producers.

Integrated production models – such as those combining fed and extractive species – were cited as examples of restorative approaches that support both environmental quality and farm productivity.

Participants also stressed the need for quantitative methodologies and standards to assess environmental impacts and ecosystem services. Environmental monitoring, including indicators such as TRIX (Trophic EX Index) for eutrophication, would need to be used continuously and linked to clear thresholds.

What are the strategic objectives?

Based on the priorities identified in the survey, several strategic objectives were discussed to enable a stronger alignment between aquaculture and environment. One proposal was the development of a global monitoring, evaluation, and learning framework, which would build on existing data systems to track progress in sustainability and ecosystem service delivery.

Education was also seen as a strategic lever, with calls for programmes focusing on material reuse, waste disposal, and overall environmental literacy. Encouraging the adoption of low-impact aquaculture through the promotion of best practices and universal sustainability standards, was identified as essential. Establishing a code of good environmental conduct and operational practice was proposed as a guiding document for producers, planners, and regulators.

Awareness-raising was considered a priority, particularly with regard to the role of conservation areas in supporting both ecosystem and aquaculture health. The potential of aquaculture to actively contribute to

Participant responses: What are the strategic objectives?

- develop a global MEL framework that leverages existing data
- implement educational programmes on material reuse and disposal
- encourage low-impact aquaculture
- establish a code of good environmental conduct and practice
- raise awareness of conservation areas' role in supporting ecosystem and aquaculture health
- promote aquaculture for the conservation of endangered species
- adopt universal sustainable aquaculture best practices
- use F1 native species in production
- promote restorative aquaculture for biodiversity recovery
- develop wildlife interaction guidelines
- improve methods to quantify ecosystem services with practical examples
- ensure proper accounting of MPAs
- include decommissioning plans in aquaculture projects
- highlight environmental quality and biodiversity enhancement benefits
- increase awareness of aquaculture–environment interactions to boost social acceptability
- explore opportunities linking ecological restoration with aquaculture for win-win outcomes

endangered species conservation and biodiversity recovery was highlighted, especially through the use of native (F1) species and restorative approaches such as integrated multitrophic aquaculture.

The development of practical tools to quantify ecosystem services was seen as necessary to communicate their value to planners and communities. Wildlife interaction guidelines and proper accounting for MPAs within planning frameworks were also discussed. Participants stressed the need to include decommissioning plans in aquaculture project design and to increase awareness of the links between aquaculture, environmental quality, and social acceptability.

What are the key actions to undertake?

Experts suggested the creation of practical tools, such as ecosystem services calculators, that could be integrated into MSP processes to support evidence-based decision-making. Quantifying the economic value of conservation services and estimating sustainable carrying capacity at farm and zone levels were also recommended.

The implementation of effective and strategic environmental impact assessments (EIA) tailored to aquaculture zones was also highlighted, coupled with environmental monitoring to monitor both water and sediment quality systematically, assess farm-level impacts, and apply spatial buffers.

Integrating restorative aquaculture and ecological sustainability objectives into spatial plans was seen as a key step in reorienting aquaculture towards a more regenerative role. Conservation objectives specific to aquaculture should be clearly included in spatial planning documents, and the use of indigenous species and IMTA should be encouraged through the appropriate legal and policy support. Additional actions included documenting the challenges and lessons from two decades of IMTA development, conducting large-scale restoration trials led by the aquaculture sector, and incorporating FAO's Guidelines for Sustainable Aquaculture into national planning efforts.

Proper consideration of MPAs and their potential synergies with aquaculture was discussed, alongside the need for zero-waste programmes, particularly in coastal and marine aquaculture systems. Good examples of nature-based solutions in aquaculture should be shared widely to inspire replication and innovation as well as promoting ecotourism linked to sustainable aquaculture. The latter was seen as a promising way to generate additional income and raise awareness about responsible practices.

Finally, environmental education programmes targeting various audiences, including schools, industry actors, and communities, were viewed as essential to building long-term support for sustainability and to enhance the role of aquaculture in protecting marine ecosystems.

The expert discussion, together with the identification of strategic objectives and priority actions that emerged from the Mentimeter survey, represented a key moment in the process.

These elements were further developed and refined during the plenary session, thanks to the direct contributions of participants and an open exchange of perspectives. This collective reflection provided a solid foundation for the drafting of the five final documents, each focused on one of the identified priority areas, with the aim of outlining a shared framework of actions to support the implementation of maritime spatial planning in aquaculture.

Participant responses: What are the key actions to undertake?

- develop frameworks for responsible aquaculture and environmental impact assessments
- create tools (e.g. ecosystem services calculators) for MSP integration
- scope and implement effective strategic environmental impact assessments
- integrate restorative aquaculture and ecological sustainability in MSP
- include aquaculture conservation objectives in spatial plans
- encourage use of indigenous species and IMTA, backed by strong legislation
- properly account for MPAs
- implement zero-waste programmes in aquaculture
- promote ecotourism linked to sustainable aquaculture
- monitor both water and sediment quality in aquaculture zones
- assess fish farm impacts and apply appropriate spatial buffers
- implement aquaculture environmental assessment systems
- evaluate the economic value of conservation services
- provide insight into challenges remaining in IMTA after 20 years
- conduct large-scale restoration trials led by aquaculture
- incorporate FAO's GSA guidelines into planning
- estimate the sustainable carrying capacity at farm and zone levels
- showcase good examples of nature-based solutions in aquaculture
- support countries to develop standards and monitoring methods
- quantify nutrient output from open aquaculture systems
- develop simple and fast permitting systems for restorative aquaculture
- implement environmental education programmes

DEVELOPING THE PRIORITY AREAS

Following the presentation of the five priority areas, the workshop participants were divided up into five small working groups that focused on one specific priority area at a time. The group discussions were designed to be participatory and collaborative, using rotating breakout groups to ensure that each priority area was explored and analysed in detail. The workshop facilitators drafted the order in which participants would rotate through the priority area groups so that the composition of each group would always be different. This rotation allowed every participant to contribute and bring their own experience and perspective to each priority area, while also building on the work done by previous groups. In this way, the development of each priority area document was an iterative and cumulative process, with multiple rounds of refinement leading to a final presentation from each priority area group.

The discussion in each group was facilitated by the assigned lead experts, as outlined, with rapporteurs documenting discussions and outcomes. The initial task for each group was to establish strategic objectives for improving spatial planning with a focus on the priority area topic. This involved analysing key challenges, opportunities, and gaps in the assigned priority area. Participants sought to align the strategic objectives with global frameworks, such as Agenda 2030, while addressing the specific needs of developing a sustainable aquaculture sector.

Following the development of strategic objectives, each group conducted a thorough needs assessment. They identified the institutional, technical and financial resources required to achieve the identified objectives, including changes to governance structures, improvements in legal frameworks, access to data and the application of innovative tools. Discussions also emphasized the importance of involving relevant stakeholders to ensure a collaborative approach to implementation. Finally, the working groups began drafting activities that could be done to help reach the objectives.

The Terms of Reference (ToRs) used to guide the working groups are included in Appendix E.

Summary of discussions by priority area

Each of the five breakout groups discussed and developed a dedicated working document focused on one priority area. These working documents, based on group discussions and analysis, were presented by the lead experts following the working group sessions, providing a comprehensive overview of findings and proposed strategic objectives. A summary of the breakout group discussions was presented in plenary to all workshop participants and is summarized below.

Priority area 1: Governance and institutional framework: streamlining interactions between public sector institutions and public–private sector interactions

Priority area 1 discussions outlined the essential role of governance and institutional frameworks in advancing MSP for aquaculture. Effective governance, defined by well-coordinated public institutions, clear legal systems, and strong public–private collaboration, is the foundation for sustainable aquaculture development. Given aquaculture's complex nature, which spans environmental, social, and economic dimensions, coordinated action across sectors and government levels is critical.

A key challenge for MSP in the Americas, Oceania, Europe, and Africa is the widespread negative perception of aquaculture – and particularly fed mariculture – which often influences public opinion and policy decisions, even extending to other forms of aquaculture. This perception, while sometimes grounded in science (by virtue of the sector's environmental footprint and the risks of intensive systems) leads to a reluctance to allocating marine space for its development.

In China and other Asian countries where mariculture is already well developed, the main governance issue lies in reorganizing existing spatial arrangements. The sector often occupies space inefficiently, making it difficult to introduce or adapt MSP to an aquaculture context.

Globally, the major hurdle remains the balancing of production goals with environmental and social objectives. While tools for undertaking marine spatial planning in an aquaculture context are increasingly available, these tend to focus on physical and oceanographic data, with less attention paid to ecosystem health, fish welfare, and social dimensions. Fragmentation among the institutions handling production, environment, and social aspects further limits integrated planning.

The discussions focused on governance and institutional frameworks, emphasizing the importance of clear coordination between authorities and robust legal structures to streamline aquaculture planning and permitting.

The participants identified five strategic objectives to improve MSP governance in support of aquaculture development and open more space for sustainable aquaculture:

- increase the United Nations' and individual nation's understanding of the comparative advantages of aquaculture as a food production system, and as a provider of livelihoods and other ecosystem services in the marine environment with lower environmental impacts. This involves improved marine spatial planning in support of aquaculture development to guarantee the minimization of environmental and social risks while increasing socioeconomic and even environmental benefits, following an EAA;
- improve the capacity of governments and the private sector to balance production and economic objectives with environmental and social objectives in MSP in support of aquaculture development;
- improve the coordination and integration of regulatory agencies, environmental authorities and local governments to develop and implement MSP in support of aquaculture development;
- promulgate specific national or sub-national aquaculture laws/acts to ensure aquaculture capacity to discuss and negotiate the use of marine space; and
- streamline an aquaculture licensing/permitting system to access and use space, one which provides the flexibility to respond to impacts and to risks.

Priority area 2: Knowledge support for spatial planning in aquaculture

Priority area 2 discussions identified three core components: i) high-quality data, ii) innovative tools; and iii) smart aquaculture technologies as key enablers for more effective and sustainable spatial planning. Together, these elements support better site selection, environmental assessment, and decision-making in aquaculture development.

Reliable and comprehensive data are essential for spatial planning. Environmental and socioeconomic data help determine site suitability, understand carrying capacity, and evaluate trade-offs between ecological protection and local economic benefits. Innovative tools such as GIS, remote sensing, and predictive modelling, enhance the ability to analyse spatial patterns, simulate future scenarios, and manage aquaculture impacts. By using technologies like IoT sensors and AI, smart aquaculture adds real-time monitoring and adaptive management capabilities, allowing producers and planners to reduce environmental impacts and improve efficiency.

The importance of data mapping was emphasized as a means to identify available resources and assess gaps. Additionally, the group highlighted the need for data networking and standardization, including the potential development of algorithms to integrate offline and online data for more effective management. Another possible strategy suggested was to investigate and gather lessons from other industries that have successfully standardized data collection.

Advanced tools like GIS, remote sensing and predictive models were recognized as fundamental for visualizing spatial data, assessing risks and simulating farming scenarios. Yet despite their potential, their adoption is constrained by high costs, insufficient technical expertise and inadequate validation processes. The integration of smart technologies, including IoT sensors and artificial intelligence, offers further opportunities to enhance farm operations and spatial planning. Still, challenges such as poor infrastructure and fragmented data sharing limit their full potential. International collaboration and initiatives such as open-source tools and technology transfer programmes were highlighted as opportunities to address these gaps and foster global progress in marine spatial planning in support of aquaculture development. Participants also recommended that countries receive tailored support to implement these actions, including legal and technical guidance, training in tool use, and development of data sharing and digital infrastructure. Monitoring and evaluation frameworks are suggested to track progress and improve accountability.

The participants identified six strategic objectives as potential contributions to this priority area:

- prioritize key minimal data requirements for marine spatial planning in support of aquaculture development at different geographic scales (global, national, local);
- standardize data collection for reliable and accurate data on ecological, economic, and sociocultural aspects of MSP in support of aquaculture development;
- increase stakeholder awareness of the availability of data, and decision support tools for MSP in support of aquaculture development;
- promote the use of decision support tools and AI analysis in developing aquaculture regions, particularly in under-resourced countries;
- integrate smart technologies: support the development, adoption and integration of cost-effective smart technologies that enhance sustainability and productivity in aquaculture; and
- leverage cutting-edge technology to enhance spatial planning for sustainable and optimized aquaculture operations.

Priority area 3: Criteria and guiding elements for the allocation of space, shared use of marine space, land and sea interactions and adaptation to climate change

The discussions for this priority area aimed to identify criteria and guiding elements for the allocation of space, including the use of multiparameter spatial analysis to balance environmental, social and economic priorities while addressing land–sea interactions and climate adaptation.

Applying EBM to MSP involves complex decisions, often requiring the reconciliation of environmental protection, economic objectives, and societal needs. Tools like the MSP Data Framework (MSPdF), which organizes spatial data into seven thematic clusters, provide a solid foundation that supports this process. These clusters include the marine environment, conservation areas, oceanographic and climate data, coastal land use, maritime activities, socioeconomic data, and governance structures.

Experts in this priority area aim to refine the criteria for zoning aquaculture space based on this framework while integrating new dimensions: identifying opportunities for co-location with other blue economy sectors, ensuring that spatial decisions reflect land–sea interactions, and incorporating climate change risk and adaptation. In this context, the creation of a global table of siting metrics across different marine industries was discussed as a prerequisite, serving as a comparative reference for spatial allocation.

Challenges include the need for consistent but flexible guidance across diverse regions, aligning scientific methods with community values, and addressing legal and logistical hurdles in multi-use planning. The experts also highlighted that while tools and knowledge exist, many of these approaches remain underused because of a lack of resources, technical expertise, or political will.

One suggested measure of success was increasing a country's ability to establish transboundary MSP plans, enabling neighbouring countries to coordinate the management of shared marine areas for aquaculture. Such cooperation is particularly important where jurisdictions overlap with interconnected ecosystems, as it helps ensure that environmental sustainability, economic development, and governance are addressed in a consistent and mutually supportive way across national boundaries.

The promotion of multi-use areas was then highlighted as an effective approach, with a particular emphasis on co-locating aquaculture activities alongside offshore wind farms. This form of spatial integration allows different sectors to operate within the same footprint, thereby making more efficient use of limited marine space, and reducing conflicts between users.

The participants identified three strategic objectives to identify a common approach. These provide key elements and parameters for the spatial allocation of aquaculture, incorporating land–sea interactions, multi-use potential, and climate change in spatial planning that supports of the development of aquaculture. The objectives are to:

- identify common guiding elements for the spatial allocation of aquaculture;
- streamline the potential co-use of marine space among blue sectors including aquaculture; and
- address climate change in aquaculture planning.

Priority area 4: Capacity building, awareness and capacity extension

The discussions for this priority area focused on the primary role of capacity building, stakeholder awareness, and professional extension services in supporting effective MSP for aquaculture. As aquaculture grows, and systems evolve and change rapidly within increasingly complex marine environments, building institutional and individual capacity across sectors is critical to the successful planning, implementation, and long-term sustainability of MSP initiatives.

The discussions suggested that well-informed, transdisciplinary professionals are essential, especially at the local and regional levels, in order to facilitate inclusive decision-making, ensure community participation, and link science to practice.

Countries often face limited technical capacity, have underfunded or non-existent extension systems, and fragmented stakeholder engagement. These gaps hinder MSP adoption, limit data-sharing, and reduce trust in the process.

The major challenge identified was the lack of funding to place experienced, educated, and informed MSP professionals with global/national knowledge at regional/municipal levels to ensure that aquaculture development does not "recreate the wheel" and duplicate past development mistakes but is developed using state-of-the-art technologies and governance.

Addressing these through collaboration and inclusivity can strengthen MSP capacity and support sustainable aquaculture.

The participants identified three strategic objectives to address this priority area:

- identify gaps, weaknesses and bottlenecks hindering the implementation and adoption of capacity building and extension forums in MSP;
- define the criteria and methodologies for capacity building and training in extension services to enhance public participation and the adoption of MSP; and
- undertake the transfer of the best available tools, knowledge, and practices in capacity building for marine spatial planning in support of aquaculture development.

Priority area 5: Marine conservation and restoration

The discussions for this priority area highlighted how spatial planning for aquaculture can contribute to marine conservation and ecosystem restoration. Participants agreed that collaboration between these two sectors is rare, but essential to achieving sustainable outcomes.

Participants highlighted that the aquaculture sector should not only be seen as an activity that needs to avoid harming the environment, but rather as one that can actively contribute to maintaining and enhancing ecosystem services (like water purification, carbon sequestration, or habitat provision) and can align with conservation goals.

Participants raised the role of the aquaculture industry in conservation efforts as an area requiring greater attention, including how industry actors can play an active role in habitat restoration and climate mitigation. These reflections underscored the need for holistic approaches that integrate data management, intersectoral collaboration and community involvement to advance spatial planning processes in aquaculture.

Suggestions were made to ensure that conservation and restoration aquaculture programmes support local community livelihoods, and integrate socioeconomic benefits with environmental goals. The recognition of the ecological and economic value of conservation areas would not only enhance resilience for nearby aquaculture operations but also provide direct economic incentives to producers.

Participants recognized the importance of the use of standardized tools and quantitative indicators for continuous monitoring so that environmental impacts and ecosystem services and can be measured and managed effectively.

Participants also highlighted the importance of promoting low-impact aquaculture through best practices and universal sustainability standards. They proposed the development of a code of good environmental conduct and operational practice to serve as a common reference for producers, planners, and regulators.

The participants identified four strategic objectives to address this priority area:

- improve the information and knowledge available to assess the environmental impact and benefits of aquaculture farms;
- develop better ways of consulting with stakeholders and knowledge holders and communicating the value of conservation and ecosystem services;
- incentivize conservation and restoration actions in aquaculture development, in line with MSP objectives; and
- create collaborative planning frameworks that allow for continuous improvement and adaptation as information develops and objectives change.

RECOMMENDATIONS AND WAY FORWARD

Participants agreed that a roadmap and practical guidance should be developed to help countries integrate spatial planning more effectively into sustainable aquaculture strategies. This would allow stakeholders to plan, manage, and expand aquaculture in a way that is environmentally responsible, socially inclusive, and economically viable. These documents would need to align with international frameworks such as the MSP Global Initiative, the Sustainable Development Goals, and the FAO Guidelines on Sustainable Aquaculture. They would also serve as both a strategic tool and a reference document to support policy development and implementation at national and regional levels.

The FAO-ISPRA workshop was convened to shape the content and structure of this roadmap and guidance. Experts worked collaboratively to define key priority areas, strategic objectives, and concrete actions. These discussions laid out the framework for the development of a coordinated and action-oriented roadmap and guidance, ensuring they are both evidence-based and grounded in the realities of aquaculture governance, development, and practice.

The final session, facilitated by Amber Himes-Cornell and Giovanna Marino, Aquaculture Research Manager at ISPRA, provided an overview of the recommendations and next steps for the development of the roadmap and guidance. The first part of the session was focused on recommendations for the further development of the roadmap. This presentation emphasized the need for consistency across the priority area documents, particularly in terms of the number of strategic objectives and actions outlined. The workshop organizers committed to reviewing the strategic objectives and actions developed during the workshop carefully, so as to eliminate duplications and to explicitly highlight cross-cutting initiatives that connect multiple areas. FAO and ISPRA will consolidate the draft documents developed for each priority area in order to put together a cohesive roadmap and guidance document. The involvement of workshop experts in developing the priority areas was essential to ensuring the products produced reflect a comprehensive and well-informed strategy.

Participants focused on the potential role of a spatial planning roadmap and guidance specific to aquaculture development within global policy frameworks such as the MSP Global initiative. To ensure the clarity and usability of the roadmap, participants highlighted the need to standardize the terms used throughout the document. The relevant definitions therefore need to be drafted to provide consistency and prevent misinterpretation.

The participants noted the need to identify key stakeholders who could contribute to the implementation of the actions outlined in the roadmap. These stakeholders should be identified at both global and national levels, as local stakeholders may vary significantly based on regional contexts and priorities. This led to a discussion on the best methods to involve stakeholders in the spatial planning processes, particularly farmers. Another aspect highlighted was the importance of defining the parties responsible for implementing specific activities within the roadmap.

Participants emphasized that monitoring system and evaluation mechanisms are needed to assess the implementation of a roadmap or any spatial planning actions. Such systems would help to monitor progress and identify where improvements can be made, allowing for adaptive management to ensure the roadmap and guidance remain relevant and effective.

Participants proposed multiple approaches to enhance the visibility and impact of the roadmap and decision support resources. These included developing peer-reviewed articles and publishing on platforms such as the IOC and MSPglobal websites.

Another relevant challenge discussed was the need to consider the resources required for implementing the actions and developing monitoring and evaluation programmes. It was noted that understanding the existing resources allocated within each country would be critical to planning and executing the roadmap effectively.

These comments and suggestions underlined the importance of refining the roadmap and decision support resources in a participatory manner, ensuring they are practical, actionable and aligned with both global frameworks and local needs.

The second part of the session was focused on the way the roadmap and decision support resources should be integrated into a broader plan of actions to further spatial planning in support of sustainable aquaculture development.

Amber Himes-Cornell facilitated a discussion on how FAO can support the implementation of the priority areas and the structure of the guidance required to catalyse actions, and the ideal format for the guidance was proposed and discussed. The participants were informed that a follow-up workshop on spatial planning for inland aquaculture would be organized to address the particular needs of inland systems. Workshop participants were encouraged to remain engaged in these processes, contributing their expertise to refining the outputs and ensuring their applicability to diverse aquaculture contexts.

The discussion focused on the key considerations for integrating a new aquaculture-focused spatial planning roadmap into broader action plans. One central point was whether to expand the roadmap to include inland aquaculture or maintain separate approaches and documents for marine and inland systems. Participants highlighted the different challenges and opportunities in freshwater and marine aquaculture contexts. They particularly noted the spatial limitation of freshwater resources, in contrast with the relatively abundant space available for marine aquaculture. Indeed, it was noted that inland aquaculture often shares physical space and resources (like land and water) with agricultural activities, while marine aquaculture typically occurs in the ocean or coastal waters, geographically far from land-based agriculture. Participants also highlighted that there are different governance needs, given that inland aquaculture is predominantly conducted on private properties and included in rural development plans, whereas marine aquaculture depends on the leasing of sea surfaces and needs to be planned within the broader context of MSP for blue economies.

With these differences in mind, the participants generally agreed that separate roadmap documents covering spatial planning for marine and inland aquaculture contexts should be developed. Participants suggested that both the guidance and the roadmaps should be disseminated through publications, workshops and training programmes to ensure widespread adoption and effective implementation.

Participants highlighted FAO's role in supporting the dissemination and implementation of the roadmaps and decision support resources, particularly through country programmes, though it was noted that direct funding of projects is not within FAO's mandate. They underlined the importance of FAO's facilitation role, including the potential to leverage funding opportunities.

The discussion concluded with agreement on the necessity of continued collaboration and engagement. Contributions from experts will remain essential in refining the roadmap and associated guidance to ensure alignment with the diverse and evolving needs of aquaculture development globally.

CLOSING REMARKS

KwangSuk Oh, Senior Fishery Officer at FAO, noted that the workshop provided a crucial step in defining aquaculture's role within spatial planning frameworks. He acknowledged the participants' dedication, emphasizing their work on five priority areas that were consolidated into draft documents, in addition to the recommendations for advancing roadmaps at global and national levels. A key suggestion was the development of FAO guidance to assist Members that undertake spatial planning exercises.

He confirmed FAO's commitment to producing guidance for marine and inland aquaculture, complementing ISPRA's leadership in creating a strategic roadmap. He stressed the distinct challenges of MSP, which balances diverse uses in open ecosystems and freshwater planning; this integrates aquaculture with land-based activities and therefore requires context-specific strategies.

KwangSuk Oh underlined the urgency of integrating aquaculture into spatial planning, given that it now surpasses traditional fisheries in terms of global seafood production. He concluded by thanking participants for their valuable contributions and emphasizing the strong foundation laid for future collaboration.

The full text of the statement is available in Appendix F.

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APPENDIX A – LIST OF PARTICIPANTS

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APPENDIX B – OPENING STATEMENT

Welcome remarks by Xinhua Yuan
Deputy Director, Fisheries and Aquaculture Division, FAO

Distinguished experts, Dear participants, Ladies and Gentlemen, Good morning!

First of all, on behalf of the Fisheries and Aquaculture Division, FAO, I'd like to welcome all of you to today's expert meeting on spatial management for aquaculture planning. My name is Xinhua Yuan, and I am the Deputy Director of the Fisheries and Aquaculture Division at FAO.

I would like to thank you for being available to gather here, and thank our colleagues who have been working very hard to make this expert workshop happen successfully today, both those present in the room or behind the scenes. In particular, I'd like to thank the team supporting national aquaculture development. You may know that the aquaculture area of the Fisheries and Aquaculture Division is composed of three teams: i.e. the global and regional process team; the national aquaculture support development team, and the aquaculture technology and production team. Each team has a mandate to support the development of sustainable aquaculture worldwide.

In July this year, FAO published its biennial flagship publication: the State of World Fisheries and Aquaculture, SOFIA 2024. As Director–General Qu Dongyu said: aquaculture has a major role to play, particularly in Africa where its great potential is not yet realized. We urgently need to explore all opportunities and take transformative action to make agrifood systems more efficient, more inclusive, more resilient and more sustainable. These transformative actions are needed to move forwards into a world with better production, better nutrition, a better environment and a better life, leaving no one behind.

At the same time, the Guidelines for Sustainable Aquaculture were adopted at the Thirty-sixth Session of the Committee on Fisheries, after a period of preparation, consultation, and finalization, in cooperation with Members, that lasted 7 years.

This year, on 12–13 September at the G20 summit in Brazil, the G20 Agriculture Ministers' Declaration endorsed FAO's Blue Transformation Roadmap for a more resilient, inclusive and efficient aquatic food system that supports the transformation of the global food system, and mitigates climate change.

The Declaration stated:

> We should foster a holistic approach to sustainable food production that acknowledges the synergies and trade-offs between land and aquaculture systems, in light of the recently adopted FAO Guidelines for Sustainable Aquaculture, in promoting the health and the sustainable use of fisheries resources and marine ecosystems, based on the best available scientific evidence.

This year, the Communiqué which came out of the meeting of G7 Agriculture Ministers that was held in Syracuse on 27–28 September 2024, also had a very clear message:

> We promote the sustainable and transparent management of fishery resources to contribute to the protection and conservation of marine biodiversity, based on the best available scientific evidence, as well as the development of aquaculture in line with the FAO Code of Conduct for Responsible Fisheries, taking into consideration the recently approved FAO Guidelines for Sustainable Aquaculture.

Under the Blue Transformation roadmap, the expansion and intensification of sustainable aquaculture was listed as the major direction. With regard to the GSA, policy and planning consisted of an important element in guiding the development of sustainable aquaculture. Spatial planning was also a frequently requested area of technical support from Members. Spatial planning often refers to where to allocate space to aquaculture farms. In some countries, the allowed zone for aquaculture was identified and implemented, though a lot of countries have not yet had the capacity to carry out spatial planning, in terms of aquaculture development in areas covering the inland waters, coastal and marine waterbodies.

To support this need, FAO is leading the workshop with your knowledge and experience to discuss the current state of spatial management for aquaculture development, and to explore strategies to improve spatial planning for offshore and coastal aquaculture collaboratively, identifying best practices and approaches, tools, opportunities, and challenges.

I truly appreciate your efforts to be here and share your valuable expertise. With such a diverse group, we are looking forward to a successful workshop and fruitful discussions.

Thank you.

APPENDIX C – AGENDA

Expert workshop

Spatial management for aquaculture planning: defining needs for assisting countries Food and Agriculture Organization, Rome

Queen Juliana Room (Building B, Floor 3, Room B323)
29–31 October 2024

Time	Session/Topic	Speaker	Facilitator	Venue
Day 1 – 29 October 2024				
08.30–09.30	**Participants' registration – DSA collection**			
	Introductions and workshop objectives			
09.30–10.30	Opening	Xinhua Yuan	Francesco Cardia	Plenary B-323
	Objectives and expected output of the workshop	Amber Himes-Cornell		
	Workshop agenda and programme	Francesco Cardia		
	Participants' introduction (name, institution, area of expertise)	All		
	MSP for aquaculture: overview on technical documents and guidelines	Linda Fourdain Tommaso Petochi		
	Session 1: Marine Spatial Planning and Aquaculture: regional overview and case studies *presentations + questions: 20 min for overview and 15 min for case study*			
10.30–11.30	Overview: **North America**	Christopher Schillaci Jonathan MacKay	Francesco Cardia	Plenary B-323
	Overview: **South America**	Doris Soto		
	Case study: Strategic Territorial Intelligence System for **Brazilian Aquaculture**	Lucíola Alves Magalhães		
11.30–11.50	**Coffee break**			
11.50–13.00	Overview: **Australia and Aotearoa/ New Zealand**	Myriam Lacharité Rebecca Gentry	Francesco Cardia	Plenary B-323
	Overview: **China**	Shenghui Li		
	Case study: Integrated modelling and GIS-remote sensing for marine spatial planning: Optimizing fisheries and aquaculture planning in a data-limited site in the **Philippines**	Alvin Baloloy		
	Case study: Aquaculture planning and management with Agri-Map Online in **Thailand**	Pholphisin Suvanachai		

Time	Session/Topic	Speaker	Facilitator	Venue
13.00–14.00	**Lunch**			
14.00–15.30	Overview: **Northern Europe**	Trevor Telfer, B. A. Costa-Pierce	Tommaso Petochi	Plenary B-323
	Overview: **Mediterranean**	Amel Mzoughi Aldeek		
	Case study: Aquaculture zoning following marine spatial planning principles within the **Macaronesia** use-cases	Andrej Abramic		
	Case study: **Lake Victoria** Spatial Plan in relation to aquaculture suitability and carrying capacity	Christopher Aura		
	Case study: Marine and spatial planning practical examples from the **Republic of South Africa**	Michelle Pretorius		
15.30–15.45	**Coffee break**			
15.45–16.45	**Open Discussion:** Best practices, lessons learnt, etc.	All	Amber Himes-Cornell	Plenary B-323
16.45–17.00	Presentation on **MSP roadmap 2022–2027 – Agenda 2030**	Amber Himes-Cornell		
17.00–17.15	Wrap up of the day			
Day 2 – 30 October 2024				
	Session 2: Priority areas for spatial planning in Aquaculture			
08.30–10.30	Presentation of **priority areas** for aquaculture roadmap	Amber Himes-Cornell		Plenary B-323
	Governance and institutional framework: streamlining interactions between authorities	Amber Himes-Cornell with experts		
	Knowledge support for spatial planning in aquaculture (data, innovative tools, smart aquaculture)			
	Criteria and guiding elements for allocation of space, co-use of marine space, land and sea interactions and adaptation to climate change			
	Capacity building, awareness and capacity extension (countries and Stakeholder engagement, training course, online platforms….)			
	Marine conservation and restoration (how spatial planning in aquaculture contributes to ecological objectives/conservation targets)			

Time	Session/Topic	Speaker	Facilitator	Venue
10.30–10.50	**Coffee break**			
10.50–13.00	**Session 3: Breakout groups to develop the priority areas**			
	Breakout group round 1: Drafting first version of priority area documents For each priority area identify strategic objectives and actions			Groups
	PA1: first drafting	Doris Soto		B-323
	PA2 first drafting	Trevor Telfer		B-323
	PA3 first drafting	Barry A. Costa Pierce		A-327
	PA4 first drafting	Andrej Abramic		C-283
	PA5 first drafting	Rebecca Gentry		C-283
13.00–14.00	**Lunch**			
	Revision of priority area documents			Groups
14.00–15.00	Breakout group round 2: Comments/edits on the priority area documents 1–5			Rooms as above
15.00–16.00	Breakout group round 3: Comments/edits on the priority area documents 1–5			
16.00–16.20	**Coffee break**			
16.20–17.00	**Open discussion** Wrap up of the day and participants' comments	All	Amber Himes-Cornell	Plenary B-323
DAY 3 – 31 October 2024				
	Session 3: Continued			
09.00–10.00	Breakout group round 4: Comments/edits on the priority area documents 1–5			Rooms as above
10.00–11.00	Breakout group round 5: Comments/edits on the priority area documents 1–5			
11.00–11.20	**Coffee break**			
11.20–13.00	**Consolidation of the draft documents** Breakout group round 6 edits: Finalization of each priority area document Preparation of presentation for session 4			Rooms as above
13.00–14.00	**Lunch**			

<table>
<tr><th>Time</th><th>Session/Topic</th><th>Speaker</th><th>Facilitator</th><th>Venue</th></tr>
<tr><td rowspan="7">14.00–
15.30</td><td colspan="4">Session 4: Findings</td></tr>
<tr><td colspan="2">Presentations of priority area documents</td><td rowspan="6">ISPRA</td><td rowspan="10">Plenary
B-323</td></tr>
<tr><td>Priority area 1</td><td>Expert from PA1</td></tr>
<tr><td>Priority area 2</td><td>Expert from PA2</td></tr>
<tr><td>Priority area 3</td><td>Expert from PA3</td></tr>
<tr><td>Priority area 4</td><td>Expert from PA4</td></tr>
<tr><td>Priority area 5</td><td>Expert from PA5</td></tr>
<tr><td>15.30–
15.45</td><td colspan="3">Coffee break</td></tr>
<tr><td rowspan="3">15.45–
17.15</td><td>Recommendations for development of roadmap with actions to take to address each priority area</td><td rowspan="2">All</td><td rowspan="2">ISPRA
Amber Himes-Cornell</td></tr>
<tr><td>Recommendations for development of a future FAO guidebook to support Member countries in taking action</td></tr>
<tr><td>Closing remarks</td><td colspan="2">KwangSuk Oh</td></tr>
</table>

APPENDIX D – SUMMARIES OF PRESENTATIONS AND EXPERT CONTRIBUTIONS

This appendix provides a summary of the presentations delivered by invited experts during the workshop. These contributions reflect a diverse range of national and regional experiences in the integration of aquaculture and marine spatial planning (MSP).

Experts were invited to share both presentations (described in the main body of this report) as well as written contributions with their insights on the current state of MSP in their respective countries or regions. They focus on governance structures, planning tools, practical case studies, and challenges related to the spatial management of aquaculture.

The presentations aimed to provide a background of experiences and methodologies to inform discussions throughout the workshop and support the development of the final roadmap. The written contributions include here provide additional detail shared by the participants.

United States of America aquaculture overview

Christopher Schillaci

NOAA National Ocean Service, United States of America

This presentation provides an overview of the US aquaculture industry and efforts led by the US National Oceanic and Atmospheric Administration (NOAA) and its partners to support an increase US domestic aquaculture production. In 2022, the United States of America ranked 19th in global aquaculture production, with an estimated freshwater and marine aquaculture production of 663 million pounds with a value of USD 1.7 billion. The majority of marine aquaculture production was associated with oyster, clam, salmon, and mussel harvest in state waters. While aquaculture only accounts for 7 percent of total domestic seafood production, the focus on high-value products means that 23 percent of the value of US seafood products comes from aquaculture. The presentation details MSP efforts and methodology led by the NOAA National Centers for Coastal Ocean Science and partners to develop regional geodatabases, operational spatial models, and relationships across government and with regional stakeholders for the purpose of supporting the identification of aquaculture opportunity areas in US state and federal waters.

Overview: North America - Mexico aquaculture planning

Jonathan MacKay

The Nature Conservancy, United States

Mexico's aquaculture industry ranks 23rd globally, producing 289 000 tonnes in 2022. The industry is relatively small but very diverse, with a total of 88 species cultivated. There is high demand for seafood within the country and the government has an ambitious goal of increasing fisheries and aquaculture production to meet this demand. The plan includes increasing total production of both fisheries and aquaculture from 1.7 million tonnes annually to over 2.7 million tonnes by 2030. Currently 72 percent of aquaculture production occurs in five states: Sinaloa, Sonora, Baja California, Baja California Sur, and Nayarit. These states represent 83 percent of the value and 67 percent of the total aquaculture leased areas. There has been growth in the sector, with notable growth in the Baja peninsula, with 68 percent growth in production and 98 percent in value from 2010 to 2020.

There are several key aquaculture regulations within Mexico that help guide the growth of the industry, with several key decrees, internal regulations, and laws. Additionally, there are several key actions the government has taken to promote spatial planning within the country. TNC is supporting this growth through a collaborative approach with government managers, industry, and stakeholders to promote aquaculture planning through spatial scientific methods, the use of advanced data and mapping tools, and capacity-building programmes. This approach focuses on the importance of fostering strong relationships on the ground to build spatial planning initiatives and encourage the development of sustainable aquaculture in Mexico.

TNC's project focuses on the Baja Peninsula, which is surrounded by the Gulf of California and the Pacific Coast and presents a marine ecosystem with outstanding potential for sustainable aquaculture expansion. In Baja California Sur alone, over 90 fisher cooperatives exist. Each hold permits to foster aquaculture, which allows for the development of almost 1 500 hectares (ha), coexisting with more than 264 fishing camps. There is also growing interest in developing the area with additional large-scale farms, including finfish farms. But if these developments occur improperly there could be significant impacts to the seas surrounding the Baja California peninsula. In addition, if appropriate business models and species are not supported, aquaculture may not serve to benefit coastal fishing communities along the peninsula, many of whom are facing diminished economic opportunities as a result of overfishing.

The project utilizes best practices from around the world to apply TNC's smart growth strategy, working directly with state and federal government officials from Instituto Mexicano de Investigación en Pesca y Acuacultura Sustentables (IMIPAS) to co-develop sustainable aquaculture guidelines and siting advice as well as deliver a training curriculum on aquaculture management techniques and practices. This project focused on building governance capacity to manage aquaculture effectively in the Gulf of California. Decision support tools and guidelines were also developed, including spatial planning, site screening, and siting tools and guidelines, in order to identify suitable coastal and marine areas for the future development of aquaculture operations.

The Nature Conservancy's role

- facilitation of participatory workshops to engage stakeholders, strengthen collaboration and develop partnerships;
- science and technical expertise;
- completion of aquaculture suitability analysis for Baja Peninsula;
- co-development of guidelines for sustainable aquaculture practices;
- co-development of decision support tool;

- capacity building through training curriculum; and
- analysis and recommendations of current legal framework with input from key aquaculture stakeholders (producers, state governments, non-profits and academia).

The project launched with a partner workshop held in La Paz, Mexico, in February 2023. Participants representing a range of groups attended, including regulators, national government scientists, aquaculture farmers, aquaculture researchers, and non-governmental organizations. The workshop served as an important forum to discuss the status of aquaculture around the Baja California Peninsula, the interests of stakeholders in having a suitability analysis completed, and critical data for the assessment.

In October 2023, TNC presented the final version of the suitability analysis and decision support tool to stakeholders. It also released a legislative assessment and recommendations for sustainable aquaculture development in the region, and ran several meetings and training workshops to build capacity for siting and spatial planning. The decision support tool released in June 2024 is available at: www.maps.tnc.org/acuaculturabaja.

Project partners

- IMIPAS
- The Nature Conservancy

Marine spatial planning of aquaculture in Latin America focusing on Chile as a case study

Doris Soto

Interdisciplinary center for aquaculture research (INCAR)

Chile

Marine aquaculture in Latin America and the Caribbean (LAC) reached about 1.6 million tonnes in 2022. Of this total, Chile accounts for 94 percent; Peru contributes 3.6 percent, while Mexico and Brazil contribute about 0.8 percent each.

Although there is plenty of space and areas suitable for mariculture in this region in countries such as Argentina, Brazil and Mexico, its development is largely restricted to Chile. Since the mariculture of fish – and to a lesser extent of bivalves – requires the relevant investment in infrastructure, feeds and other supplies, in LAC it has mostly been developed in mid-to-large scale intensive farming. This is the case in Chile, largely due to the success of salmon and mussel farming. Both commodities have relevant global markets and demand, and these are the primary reasons for their successful development. The most relevant experience with regard to the marine spatial planning of aquaculture therefore resides in this country. Since 1991 Chile has designated aquaculture areas (areas available for aquaculture; AAA) and aquaculture macrozones, where conflicts with other users and environmental constraints must be addressed; they are also the only zones in the coastal marine environment in which aquaculture concessions can be granted. Mussel farming takes place in aquaculture areas concentrated in northern Patagonia around processing plants and landing coves, while salmon farming and the marine fattening stage takes place along the whole Pacific Ocean coastal area between 42° south and 54° south.

Chile is the second-largest producer and exporter of farmed salmon, with a production of nearly 1 million tonnes in 2023, worth about USD 6 billion. Farmed species include Atlantic salmon (about 70 percent of production), Coho salmon (18 percent), and rainbow trout (12 percent). The salmon fattening phase takes place in intensive farming in marine cages, with an average production per farm of around 3000 tonnes per cycle (16 to 18 months). There are about 400 active farming sites distributed along the fjords, channels and inlets of Patagonia; these are organized in about 78 salmon farming areas or neighbourhoods (SFAs) distributed among the three salmon farming districts, namely Los Lagos, Aysén and Magallanes.

However, the current marine spatial planning of aquaculture in Chile is not sufficient to allow further growth of salmon farming much beyond 1 million tonnes and the sector complains of a lack of governance and effectiveness in implementation. The main issues and obstacles to the further use of space relate to environmental concerns from intensive salmon farming and more recently the designation of marine conservation areas and laws concerning the use of space by Indigenous People, all of which overlap with areas suitable for salmon farming.

In Chile, most studies, norms and regulations focus on the local impacts of individual farms. Environmental regulation requires monitoring under cages (bottom ecosystem) and the water column below the farm. However, there are growing concerns about intensive salmon farming's cumulative and potentially synergistic impacts at the ecosystem scale. Understanding the side effects of fish farming and a better knowledge of the capacity of waterbodies to support production is essential to avoid significant environmental impacts and poor farmed fish welfare, as well as the social and economic consequences of both. Carrying capacity is at the core of the ecosystem approach to aquaculture and one health approach. Therefore, current initiatives focus on spatial planning with an attention to the ecosystem-scale impacts and management, while also considering climate change as an additional forcing factor.

As a result, innovative tools such as climate change risk maps and carrying capacity models are being developed. In 2020, Chile Ministry of environment promoted the development of climate change risk maps for mussel and salmon farming in the fjord systems of fjords of Chilean Patagonia. Such risk maps (Soto *et al*., 2020) provide an initial assessment of coastal marine aquaculture areas and systems that can be more sensitive to climate-change impacts. These risk maps may also provide recommendations on the spatial distribution of risks, and the need for adaptive measures such as the spatial relocation of some farms and production. The carrying capacity of waterbodies to process nutrient inputs from aquaculture can also be a key sensitivity element under climate change, notably with respect to triggering or enhancing harmful algal blooms and hypoxic events (Soto *et al*., 2021). To this end, a traffic-light system (TLS) has been proposed to regulate Chilean farmed salmon production at the ecosystem scale (currently based on salmon farming areas). The model is based on environmental and production risk assessments for ecosystem-compatible aquaculture, along with collaborative approaches, through integrated spatial planning. The TLS addresses the different environmental hazards from salmon farming as well as those that can affect farmed fish welfare and productivity. It focuses on the use of space and the timing of the production as well as technologically and socioeconomically innovative approaches. The risk model feeding the TLS also includes a sensitivity component to cover those oceanographic aspects that yield an area more sensitive to impacts from salmon farming based on recent information and research on oceanographic processes and their interactions with climate. Such information was not available at the time of the designation of the AAA more than 30 years ago, and it is one of the reasons that prompts the need for the permanent assessment and improvement of MSP in an aquaculture context, notably considering the need to adapt to climate change.

This is one of the main challenges in spatial planning processes: namely, how to integrate flexibility into the designation of marine space for aquaculture in a changing environment.

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Strategic territorial intelligence system for Brazilian aquaculture

Lucíola Alves Magalhães, André Rodrigo Farias, Marcelo Fernando Fonseca e Marta Eichemberger Ummus

Brazilian Agricultural Research Corporation - EMBRAPA

Brazil

Marine spatial planning in Brazil

The Interministerial Commission for Sea Resources is responsible for MSP in Brazil. This commission is made up of 17 Ministries under the coordination of the Brazilian Navy. The marine spatial planning itself is coordinated by the Brazilian Navy and the Ministry of Environment, with financial support from the Brazilian Development Bank and the Brazilian Biodiversity Fund. By virtue of the territorial dimensions of the Brazilian coastline (8 000 km), for the purposes of implementing MSP, the Brazilian maritime area (5.7 million km^2) was divided into four regions: south, southeast, northeast, and north. These projects are currently at different stages. The activities in the south region began in January 2024 and will be carried out within three years. As a pilot project, its knowledge and results will be shared with other regions. Each region's MSP will focus on 10 different sectors as well as general guidance on investment deficit. The Brazilian National Spatial Data Infrastructure, established under national legislation (Decree n° 6.666/2008), will provide the spatial data and information collected in the first stage of the MSP (Infraestructura Nacional de Dados Espaciais, n.d.). This data and information will be shared and submitted for validation by the local population during several local workshops.

Project overview

The Strategic Territorial Intelligence System for Brazilian Aquaculture was a collaborative initiative between the Brazilian Ministry of Fishing and Aquaculture (MPA) and the Brazilian Agricultural Research Corporation (Embrapa). The project was funded by multiple sponsors, including the Brazilian National Development Bank (BNDES), the Amazon Fund, and internal resources of the Ministry. Its primary goal was to deliver a comprehensive spatial analysis of aquaculture activities across Brazil, serving as a foundation for sustainable development, evidence-based policymaking, and optimization of production chains. The project's main objectives were to generate accurate aquaculture statistics, support territorial planning for sustainable aquaculture development, conduct strategic analyses to guide public policy development and provide critical information to enhance the efficiency of the aquaculture production chain.

Methodology and tools

The initiative employed the Strategic Territorial Intelligence System method, which involves analysing data from five contexts: natural, agrarian, agricultural, infrastructural, and socioeconomic. This information was integrated into a geographic information system (GIS) allowing the date to be analysed at various scales and within different timeframes. A publicly accessible WebGIS platform was developed to disseminate the spatial information sourced from different public institutions (GeoWeb, n.d.). Given the usefulness of the platform for the aquaculture sector, the team decided to include primary spatial data collected during the project. This included information on key stakeholders in the fish production chain such as government agencies and educational institutions that offer aquaculture programmes; aquaculturist associations and cooperatives; fishermen's colonies; hatcheries for fish juveniles; larvae and post-larvae; feed and ice factories; processing units; aquaculture consulting companies; animal health product suppliers; aquaculture equipment manufacturers; fish marketing companies and the mapping of aquaculture ponds. The pond mapping made use of an innovative remote sensing methodology based on the interpretation of medium- to high-resolution satellite imagery, which was validated using data from numerous national aquaculture institutions.

Challenges and innovations

The primary challenge was mapping aquaculture ponds using remote sensing data. One of the significant issues encountered when mapping aquaculture ponds in inland waters/continental zones was to distinguish them from natural waterbodies or those used for other purposes, such as rice cultivation or livestock watering. Aquaculture ponds differ significantly in size and shape in Brazil, because of the varying characteristics in species management. This makes it difficult to develop a method for automatic extraction based on satellite imagery that can be applied across the entire territory. To address this challenge, Embrapa employed both semi-automated and automated methods. The semi-automated method integrated remote sensing feature extraction with visual analysis; the automated method is still under development.

Results and achievements

The project team identified 513 municipalities as the most significant for aquaculture production: these collectively accounted for 75 percent of the total production within each federative unit/state. Utilizing a semi-automated method, we mapped an area of 930 000 km², which represents approximately 10–11 percent of Brazil's total land area. To put that in perspective, this area is larger than the combined size of Germany and France, or nearly twice the size of Spain. In this mapped area, 48 471 sets of aquaculture ponds were identified, covering a total of 7 874.38 km². We were then able to validate the results by leveraging data from various government institutions or aquaculture producer associations such as the Brazilian National Portal for Environmental Licensing (Portal Nacional de Licenciamento Ambiental), state secretariats for the environment and technical assistance institutions, among others. Approximately 20 000 sets of aquaculture ponds (19.2 percent of the total) and 2 007 km² (25.5 percent of the total area) were validated.

The Brazilian coastal zone includes 443 municipalities (426.816 km²). Only 2.3 percent (183 km²) of the total area of mapped ponds is located within the municipalities of the Brazilian coastal zone, where we counted 4 333 aquaculture ponds (9 percent of the total 48 471 mapped). We counted only 2.9 percent (227 km²) of the total area of mapped ponds within 50 km of the Brazilian coastline, across which we counted 6 111 aquaculture ponds. Approximately 38 percent of the aquaculture ponds mapped in the Brazilian coastal zone overlap with conservation units, primarily sustainable use areas, which highlights the crucial role of spatial planning in ensuring sustainable aquaculture practices within the region.

Conclusion

The Strategic Territorial Intelligence System for Brazilian Aquaculture has made substantial contributions to enhancing the understanding and supporting the sustainable development of aquaculture in Brazil. By providing reliable data and analytical tools, the project has empowered policymakers, researchers, and industry stakeholders to make informed decisions and promote the growth of this vital sector. A wide variety of aquaculture pond designs were identified, reflecting diverse production systems, topography, soil conditions, and property sizes. Developing an automated method for this production system remains a major challenge. While inland aquaculture is more prevalent, coastal aquaculture remains significant, particularly in the northeast and south. The large number of Brazilian conservation units – around 2 040 areas located in maritime and terrestrial zones – underlines the importance of spatial planning for aquaculture activities within the Brazilian coastal zone. The organization and publication of these data can support the development of MSP in Brazil.

Future directions

Continuous data collection is crucial for the regular updating of the SITE Aquiculture WebGIS, ensuring that the information remains accurate and up-to-date. Furthermore, advancing automated mapping methods is essential to improving efficiency and reducing costs. For effective MSP, it is mandatory to map the 443 municipalities of the Brazilian Coastal Zone. This information will provide valuable insights into the significance of aquaculture activities across different regions.

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Overview of aquaculture planning in Australia and Aotearoa/New Zealand – Challenges and opportunities

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Australia and New Zealand are island states with rich endemic marine biodiversity and ecosystems. Aquaculture has expanded in recent years in both countries, and there are aspirations to develop the industry further in the future. Australia's aquaculture industry is valued at AUD 1.94 billion (gross value production; 2021–22) and is dominated by salmonids (>AUD 1 billion) in the state of Tasmania (Tuynman *et al*, 2023). Other key species include Southern Bluefin Tuna in South Australia, land-based prawn aquaculture in Queensland, and oysters (New South Wales, South Australia, Tasmania). Aquaculture in New Zealand is valued at NZD 763 million (2023) with exports to 81 countries (New Zealand Government, 2024). There are only three commercial species: Greenshell mussels, Pacific oysters and King salmon. In both countries, other species are either in development or cultivated at smaller scales, including seaweeds. Challenges persist in terms of aquaculture siting that meets sustainable development objectives; that is culturally responsible and aware of recent colonial history in the region; that accounts for anticipated cumulative environmental impacts, and ensures local communities provide informed consent for and benefit from development.

The geography of Australia and New Zealand

Australia and New Zealand together host significant marine ecosystem diversity. The large Australian continent spans nearly 33 ° of latitude, with rich and unique tropical-to-temperate marine ecosystems. At subtropical-to-temperate latitudes, much of the Australian coastline is exposed to significant wave energy because of a relatively narrow continental shelf and the influence of the dynamic Southern, Pacific and Indian oceans. Sheltered bays and inlets occur sporadically. New Zealand's marine ecosystems are primarily temperate, but range from subtropical to sub-Antarctic, resulting in significant ecosystem variation. New Zealand is comprised of three main islands, and many smaller islands. In contrast to Australia, New Zealand boasts significant sheltered areas that occur between these islands, along with a high proportion of highly exposed coastlines.

Both Australia and New Zealand have large exclusive economic zones (EEZs) but relatively small populations. Australia's population is close to 27 million (2024) and is largely concentrated in population centres along the east coast (Melbourne, Sydney, Brisbane) and southwest coast (Perth) (Australian Bureau of Statistics, 2025). Most of regional Australia is not densely populated. New Zealand hosts just over 5 million people (2024) and is similarly concentrated in urban centres, particularly on the North Island, where Wellington (the national capital) and Auckland (the most populous city) are both located. This geography means that while there is a lot of ocean and coastal space in both countries, much of it is unsuitable for aquaculture, either because of environmental or economic factors.

Aquaculture siting in Australia and New Zealand

Both Australia and New Zealand have long coastlines, but most of the current marine-based aquaculture activities occur in sporadic sheltered coastal waters, such as bays, sounds and inlets; in most cases, these are adjacent to populated areas (of varying density). These areas are connected to transport hubs that are necessary for supply chains. They are also home to a skilled workforce, and they generally benefit from existing land infrastructure and services. Because these places are attractive and occur relatively sporadically, conflicts can emerge with other ocean users, in addition to interactions with the environment, which can at times be intense and persistent. In Australia, aquaculture mostly occurs in South Australia (i.e. the large Spencer Gulf) close to Adelaide, the sheltered southeast of Tasmania close to Hobart, and estuaries along the coast of New South Wales. Negative interactions with local communities and stakeholders, and documented impacts on the recipient environment are present in Tasmania. In New Zealand, the largest aquaculture areas are in places that are valued for many other uses, including fishing, recreation, and tourism. This has created conflict with local communities, particularly around the potential expansion of salmon farming.

Aquaculture planning in Australia and New Zealand

Aquaculture planning in the region is either largely decentralized (Australia) or under a mixed system of federal and local/regional governance (New Zealand). In both cases, this has led to inefficiencies and potential conflicts between jurisdictions and levels of government; this has been recognized as an impediment to efficient and sustainable industry growth.

Australia operates under a federated system, whereby individual states and the Northern Territory have jurisdiction over their coastal waters – these generally extend three nautical miles from shore. Aquaculture in Australia is therefore governed largely independently, planned by states and the Northern Territory, but this often leads to a lack of coordination. There is currently no legal mechanism allowing commercial aquaculture in Commonwealth waters (waters managed by the federal government, beyond coastal waters), but the federal government can develop umbrella policy for the growth of aquaculture. Spatial planning has emerged in some states, e.g. through the establishment of 'aquaculture zones'. New Zealand operates a 'mixed' system of governance, where most coastal planning is done by regional councils within a framework set out in national legislation, and a context of ambitious, government-supported growth targets. In some cases, the differing incentives at the local and national level have led to uncertainty and contention around the expansion of aquaculture. In recent decades, New Zealand has tried multiple approaches to the spatial management of aquaculture; over time a 'push–pull' dynamic has emerged over how much spatial planning and specific legislation needs to be in place in order to support and manage aquaculture. This remains in flux today as major changes to natural resource management are currently being put forward by the government. One notable part of aquaculture planning in New Zealand is the requirement that any new farm is assessed for its potential impact on fishing. This fisheries test arose out of New Zealand's strong emphasis on rights-based fisheries management. If the rights to fish – whether commercially or for customary or recreation purposes – are already owned, then a new farm is not allowed to infringe on this right.

Recent colonial history and aquaculture in Australia and New Zealand

Both Australia and New Zealand have a recent colonial history, with British rule dominating the region from the late eighteenth century onwards. Colonization has had sustained and broad impacts on Indigenous communities. In the context of marine resources and environment, this includes a questioning of the legitimacy of the nature and magnitude of fishing activities, fair access to resources, as well as a degraded cultural connection to marine places, ecosystems and species.

Australia and New Zealand differ in how Indigenous communities participate in marine planning as rights holders. In New Zealand, Māori own a substantial proportion of aquaculture space. This is the result of an 1840 treaty with the British Government, and a subsequent settlement of Treaty claims related to Aquaculture in 2004. As Treaty partners, Māori also have a very strong voice in natural resource management more generally, including marine planning and management. While achieving true "co-management" presents many challenges and is not without controversy, there are strong ongoing efforts to create a partnership between Indigenous and western management. In contrast, there is no treaty governing the relationship with and rights of Indigenous Peoples with respect to marine resources in Australia. Instead, Aboriginal and Torres Strait Islander people can lodge claims to land rights and native titles to have their rights legally recognized and engage in the (co-)management of natural resources. In 2022, the first successful native title claim over Sea Country was granted in northern Australia (Northern Territory Government, 2024). This could have significant implications on how rights holders engage in marine activities in the future.

Way forward: social license and benefits to communities

Australia and New Zealand host mature aquaculture industries with an appetite for growth. However, despite their natural expanses, activities are largely concentrated in areas with access to land infrastructure and services, which often places aquaculture in direct competition with other ocean users and communities, magnifying the potential for cumulative environmental impacts. Spatial planning has been used and continues to be developed as a potential mechanism to enhance local and regional coordination, alleviate conflict, and mitigate negative environmental impacts by adopting evidence-based decision-making. This has resulted in increased interest to share accurate and reliable information in accessible formats.

A key aspect of the rationale behind adopting spatial planning in both countries is to foster a 'social license to operate' for local communities, both indigenous and non-indigenous. This has resulted in an increased acknowledgement of informed consent for development, co-benefit and cost recovery schemes, spatial optimization to minimize conflict, consideration for co-location to mitigate impacts and/or optimize space use, and 'regenerative aquaculture'.

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Status of marine spatial planning implementation for aquaculture in China

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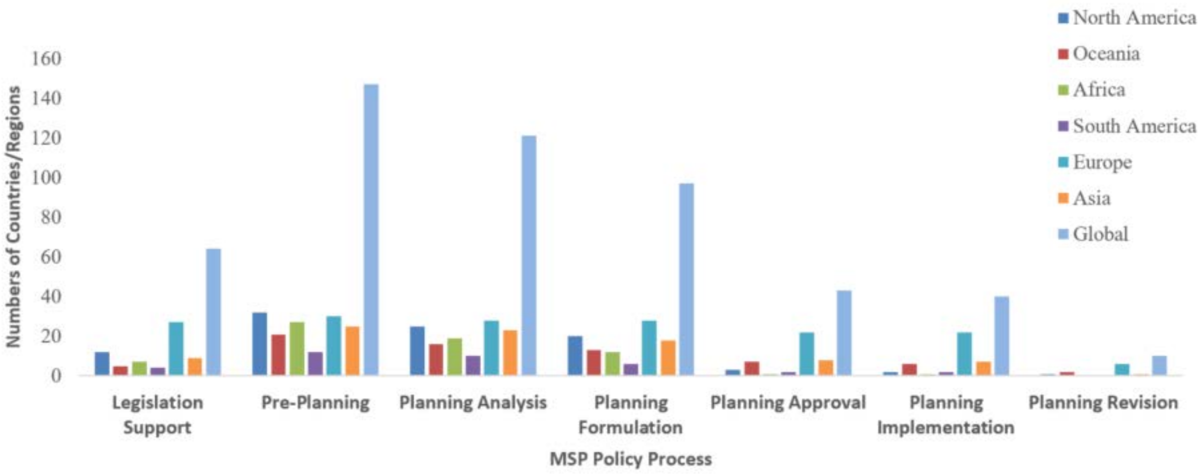
Background

MSP is a globally recognized process aimed at promoting sustainable ocean governance, but most coastal countries remain in the early pre-planning phase, with significantly fewer having reached full implementation or revision stages (Li, 2022). With process tracking of MSP progress at the global scale, it is evident that more than 140 coastal countries or territories are currently in the MSP pre-planning stage, underscoring both global interest and the early nature of most national efforts (Figure D1). As countries move through the stages – from legislation support and planning analysis, to formulation, approval, and eventually implementation and revision – the number of participants drops sharply at each successive phase. This decline highlights the increasing challenges countries face as they move towards practical implementation and the adaptive management of marine areas.

Figure D1. MSP progress at the global scale, updated to March 2024



Source: Author's own elaboration using unpublished data

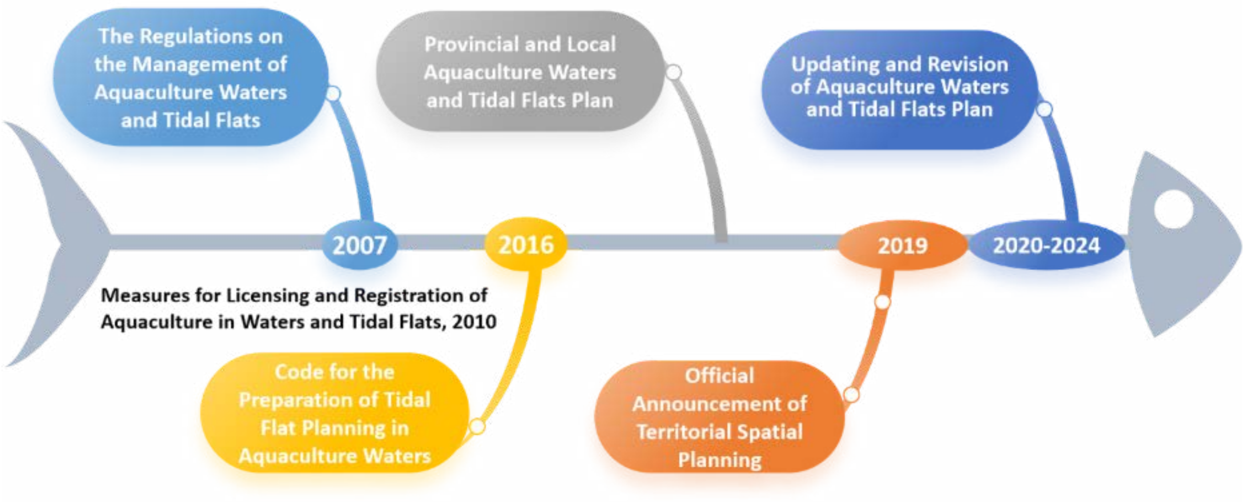
While most countries are still in the early phases, a few have emerged as global leaders in MSP practice. China stands out as an example, having conducted four rounds of MSP. This demonstrates China's long-term commitment to adaptive ocean governance and continuous policy refinement. China's MSP cycles provide valuable lessons in terms of how scale up implementation, mitigating spatial conflicts, and continually refining national frameworks to meet both domestic needs and evolving international priorities for sustainable oceans.

The key policies and regulations that guide MSP and aquaculture

Since the late 1980s, China has achieved significant progress in developing and implementing MSP, especially within the aquaculture sector. National policies that focus on building an "ecological civilization" reflect China's alignment with global environmental governance trends, emphasizing sustainable ocean use and strengthened environmental protection. China's progress in MSP is underpinned by an integrated regulatory framework supported by key foundational policies: several periods of marine functional zoning (1989–1998; 1999–2010; 2011–2020) established designated zones for various uses, enabling rational allocation and the resolution of conflicts between different marine activities such as aquaculture, shipping, tourism, and conservation. Thereafter, territorial spatial planning (2021–2035) expanded these efforts, integrating aquaculture waters and tidal flats into broader planning to balance land–sea interests across governance levels. The Marine Environmental Protection Law (1982; revised in 2023) is central to protecting marine ecosystems through requirements for environmental impact assessment, pollution control and ecosystem conservation in marine activities, while the multilayered sea use rights (initiated in 2019) system provides an innovative framework for managing marine space in three dimensions. This system spans the water surface, water column, seabed, and subsoil, to coordinate stakeholder interests and optimize the use of ocean resources more effectively.

The Aquaculture Waters and Tidal Flats Plan stands out as a fundamental system for fisheries management and industry transformation in China (Figure D2; Table D1). This plan divides aquaculture areas into allowed, restricted, and prohibited zones. Each is governed by tailored management measures (Figure D2). Allowed aquaculture zones encourage high-efficiency, eco-friendly practices and regular water quality monitoring; restricted aquaculture zones impose controls because of ecological sensitivity, requiring strict oversight and periodic resting; prohibited aquaculture zones entirely ban aquaculture to protect ecologically valuable regions and mandate restoration. These zones are regularly updated in response to changing ecological and industry conditions, ensuring the plan remains a dynamic tool for promoting sustainable aquaculture and environmental health.

Figure D2. Key milestones in the Aquaculture Waters and Tidal Flats Plan in China



Source: Author.

Table D1. Zoning framework and management measures for aquaculture waters and tidal flats in China

Three Zones	Definition	Key Characteristics	Management Measures
Allowed Aquaculture Zone 养殖区	Areas where aquaculture is permitted without strict limitations	- Suitable for high-density aquaculture - Promotes eco-friendly practices	- Regular water quality monitoring - Encourage sustainable practices
Restricted Aquaculture Zone 限制养殖区	Areas where aquaculture is permitted with limitations	- Limited, low-density aquaculture - Sensitive ecological conditions	- Strict approval and oversight - Periodic resting and reduced stocking
Prohibited Aquaculture Zone 禁止养殖区	Areas where all aquaculture activities are banned	- High ecological value (e.g., water sources, nature reserves) - Complete ban on aquaculture	- Mandatory removal of existing operations - Implementation of ecological restoration measures

Source: Compiled and organized by the author from "Code for the Preparation of Tidal Flats Planning in Aquaculture Waters" (2016).

China is now prioritizing high-quality fisheries development by accelerating deep-sea and open-ocean aquaculture, promoting the adoption of large-scale intelligent aquaculture equipment, and undertaking proactive, advanced planning to modernize the sector and strengthen sustainability. Together, these frameworks provide mechanisms for stakeholder coordination and conflict mitigation; they ensure the sustainable use of marine resources and support China's blue transition to environmentally responsible and economically dynamic coastal development.

Integration of spatial planning in aquaculture with other coastal economic sectors

China is actively furthering the integration of MSP with other coastal economic sectors through a series of innovative, multi-use ocean models. These approaches, including merging aquaculture with offshore renewable energy and ecotourism, not only create new synergies for economic and ecological benefits, but also help diversify income sources for coastal communities and promote a more sustainable, efficient use of ocean space.

Marine ranching and offshore wind farms

This model strategically integrates marine ranching with large-scale offshore wind energy projects, achieving both spatial efficiency and the shared use of ocean resources. A prime example is the "Fuxi No. 1" wind power-fishery integrated platform (Figure D3), located in the Wind Power Integrated National-Level Marine Ranch Demonstration Zone at Qingzhou Island, within the CGN Houhu 500 MW Offshore Wind Farm in Shanwei, Guangdong Province. In these demonstration zones, offshore wind turbines and advanced ranching facilities coexist, producing renewable energy and high-quality fish, and providing a blueprint for efficient, multi-use ocean management.

Figure D3. Fuxi No.1 An aerial drone photo taken on Sept. 2, 2024, full news link here: https://english.www.gov.cn/news/202409/05/content_WS66d907dec6d0868f4e8ea9e5.html

Aquaculture and ecotourism

China is also pioneering the integration of aquaculture with ecotourism, pairing sustainable farming practices with recreational and educational experiences. On 14 June 2023, Zhuhai City's Jiuzhou Floating Island Marine Tourism Project received approval for sea use, marking a milestone for this model. The project features a semi-submersible wave energy aquaculture tourism platform offering ecological farming, recreational fishing, amusement parks, ocean science education, and underwater parks, providing visitors with immersive marine experiences. Similarly, in Ailun Bay, Rongcheng, Weihai City, Shandong Province, a National Marine Ranch brings together aquaculture and tourism, attracting visitors and raising awareness about sustainable seafood and marine conservation.

Aquaculture and solar energy

Another innovative practice is the integration of aquaculture with solar energy projects, such as the 500 MW Fisheries Photovoltaic Power Generation Project in Haiyan, Taishan, Guangdong Province (Figure D4). This model deploys large-scale solar panels above or adjacent to aquaculture areas and ponds. The simultaneous production of clean solar power and aquatic products demonstrates a dual-use of coastal resources; helps reduce the carbon footprint of fisheries; and supports the transition to green energy for local industry (Zhu *et al*., 2024).

Figure D4. 500 MW Fisheries Photovoltaic Power Generation Project in Haiyan, Taishan

Bottlenecks in the implementation processes

The implementation of MSP for aquaculture in China faces several significant bottlenecks. First, intense competition for marine and coastal space arises from overlapping policy priorities, including carbon neutrality initiatives, biodiversity conservation targets, and large-scale ecological restoration projects. These overlapping agendas create pressure and potential conflicts for the allocation of space, making it difficult to balance economic, environmental, and conservation needs.

Second, the processes are hindered by insufficient, fragmented, and uncertain data. Key limitations include incomplete regional environmental risk assessments, a limited understanding of cumulative ecological impacts, and unpredictable variables such as seasonal typhoons and climate change. Moreover, long-term, integrated monitoring systems remain underdeveloped, hindering the ability to anticipate and respond to environmental risks and dynamic ocean conditions.

Third, intersectoral integration remains weak, particularly regarding the lifecycle management and integration of aquaculture with other coastal economic sectors, such as offshore wind farms. Common challenges include the absence of unified technical standards, the inadequate consideration of multi-use synergies across project phases, and limited stakeholder participation. Addressing these constraints requires the strengthening of governance frameworks, enhancing multistakeholder engagement, leveraging innovative digital tools, and promoting sustained intersectoral dialogue to enable more effective, adaptive, and sustainable implementation of MSP for aquaculture development.

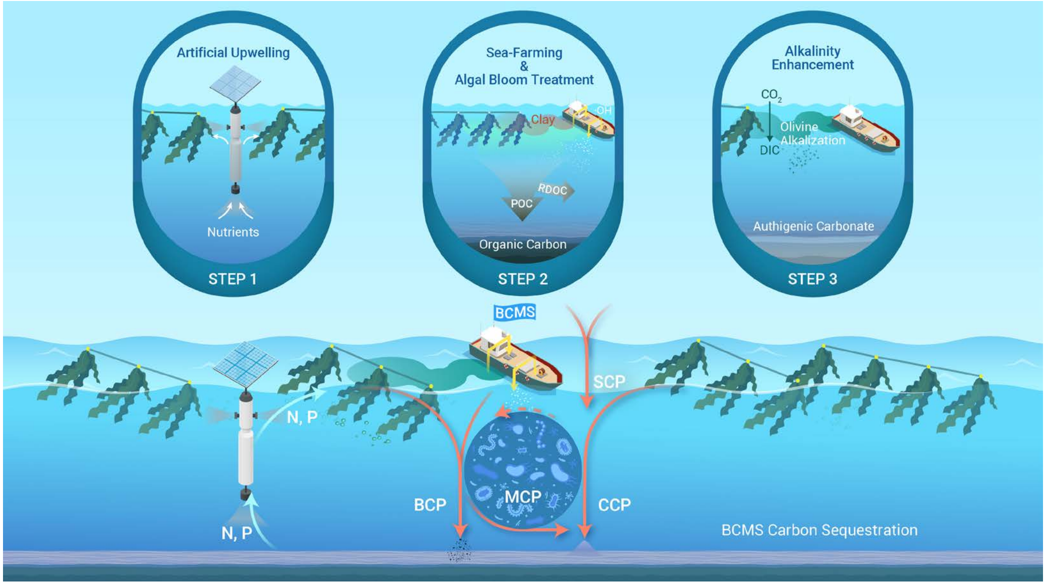
Innovative approaches and tools for spatial planning in aquaculture at the regional and national levels

China is pursuing a range of innovative approaches and tools for spatial planning in aquaculture at both regional and national levels, driven by complex coastal development pressures and urgent climate adaptation needs. A major focus has been on "ocean multi-use" models, which enable multiple economic activities (such as aquaculture, renewable energy, and ecotourism) to coexist spatially and functionally. To support this, new technical guidelines for MSP now call for spatial-use-access evaluation systems that clarify access requirements, assess risks, and encourage compatible, multi-use sea area licensing. Many provinces of China are now actively piloting these integrated approaches, and cities like Yantai have piloted compatibility assessment frameworks to balance aquaculture with emerging marine sectors (Li *et al*.,2024). This marks a shift from traditional single-industry zoning towards spatially complex, risk-managed planning, enhancing both efficiency and economic resilience.

In addition to regulatory and technological innovations, China is also advancing cutting-edge approaches for marine carbon management within spatial planning that supports aquaculture development. One notable example is the Global Ocean Negative Carbon Emissions (Global-ONCE) programme, which promotes ocean-based carbon sequestration solutions. Global-ONCE supports research and demonstration projects such as artificial upwelling, integrated sea-farming, and ecoengineering techniques that enhance the ocean's ability to absorb and store carbon (Figure D5). This multifaceted approach highlights China's commitment to embedding climate-focused technological innovation and ecological restoration into multilevel MSP, fostering a more sustainable and climate-resilient ocean economy.

Figure D5. An illustration of the BCMS ecoengineering approaches

POC: Particulate Organic Carbon, RDOC: Refractory Dissolved Organic Carbon, N,P: Nitrogen and phosphorus



Source: **Jiao, N., Zhu, C., Liu, J., Luo, T., Bai, M., Yu, Z., Chen, Q., Rinkevich, B., Weinbauer, M., Thomas, H., & Nagappa, R.** 2023. A roadmap for Ocean Negative Carbon Emission eco-engineering in sea-farming fields. *The Innovation Geoscience*, *1*(2), p.100029

In summary, climate adaptation has become increasingly important within China's MSP for aquaculture. Policy and management initiatives increasingly focus on regional differences in climate vulnerability and resilience, using tools such as cluster analyses of aquaculture production, climate exposure, and site-specific management practices to design targeted adaptation strategies (Froehlich *et al.*,2022; Wang *et al.*, 2024). Practical measures include establishing buffer zones, relocating sensitive facilities from high-risk areas, breeding climate-resilient species, and developing ecosystem-based management frameworks. By integrating these innovations with broader MSP reforms and aligning with local economic realities, China provides a practical blueprint for balancing sustainability, industry stability, and climate resilience, offering important lessons for other coastal countries seeking to modernize their aquaculture planning.

Acknowledgement

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Integrated modelling and GIS-remote sensing for MSP: Optimizing fisheries and aquaculture planning in a data-limited site in the Philippines

Alvin Baloloy

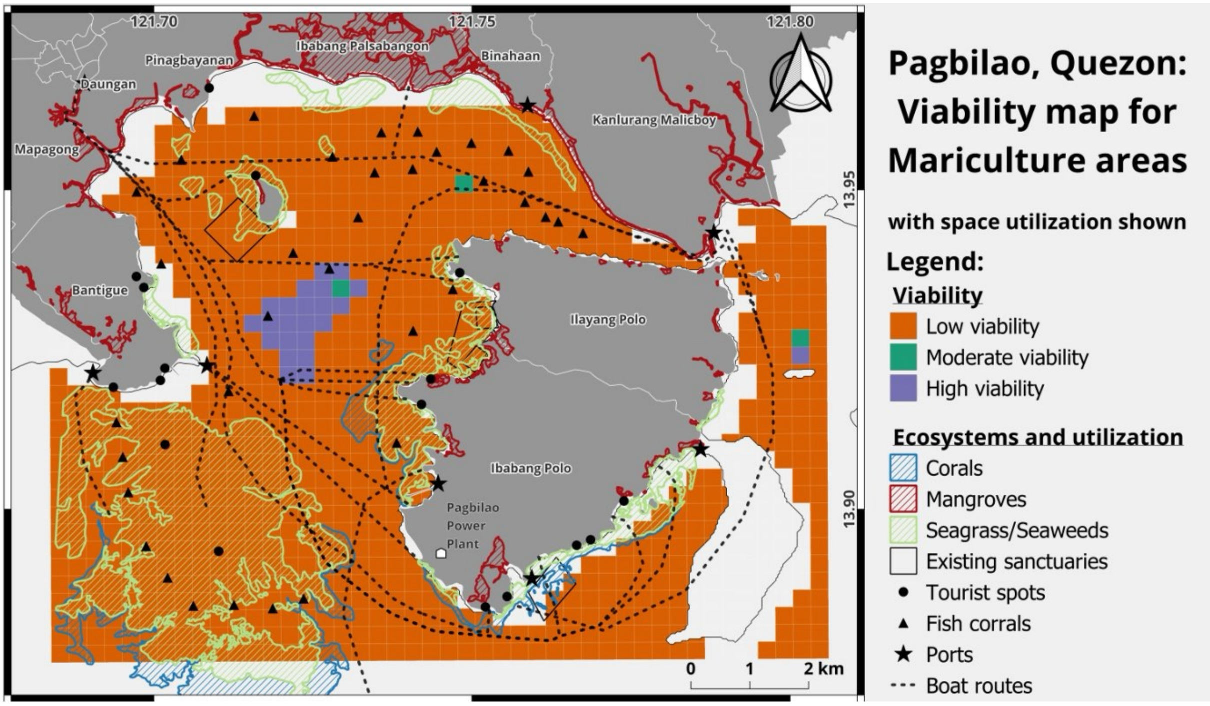
Oceana Philippines

As an archipelagic nation, the Philippines is endowed with some of the most diverse and productive marine ecosystems in the world. These marine resources are vital not only to the country's economy but also to the livelihoods of millions of Filipinos who depend on fishing and aquaculture for their sustenance. Despite their importance, the Philippines faces increasing conflicts over the use of its marine resources, often leading to unsustainable practices such as overfishing, pollution, and habitat destruction. To address these issues, national and local governments have implemented integrated coastal resource management (ICRM) together with MSP to allocate marine spaces for various uses in a sustainable manner.

The Philippines is among the countries with the earliest experience of ICRM, having begun in the 1970s, and it has been engaged in specific MSP activities since 2000. Some examples of ICRM include *The Fisheries Sector Program* (1991–1997), funded by the Asian Development Bank, and the *Coastal Resource Management Project* (1992–2002), funded by USAID. More recent projects have specifically included an MSP phase, such as the *Coastal Land- and Sea-Use Zoning Plan* of the province of Bataan (2007) and the USAID-funded *Ecosystems Improved for Sustainable Fisheries (ECOFISH)* project, implemented from 2012 to 2017. Both projects identified a similar limitation during the initial stages of MSP: the lack of comprehensive and spatially explicit data on ecosystem characteristics, human uses, and municipal water jurisdictions in most target municipalities (ECOFISH Completion Report, 2017; Reimer *et al*., 2023).

The latest MSP project in the Philippines, FAO's Technical Cooperation Program (TCP) – *Support to ICT-based Marine Spatial Planning (MSP) for Fisheries and Aquaculture Management* – was implemented by building on best practices and addressing the limitations encountered in previous initiatives. The MSP process was also designed to adhere to the key fundamental characteristics outlined by UNESCO, ensuring it is ecosystem-based, integrated, area-based, adaptive, participatory, and strategic (Meaden *et al*., 2016).

Figure D6. Mariculture Viability Map generated for Pagbilao Bay, Philippines



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

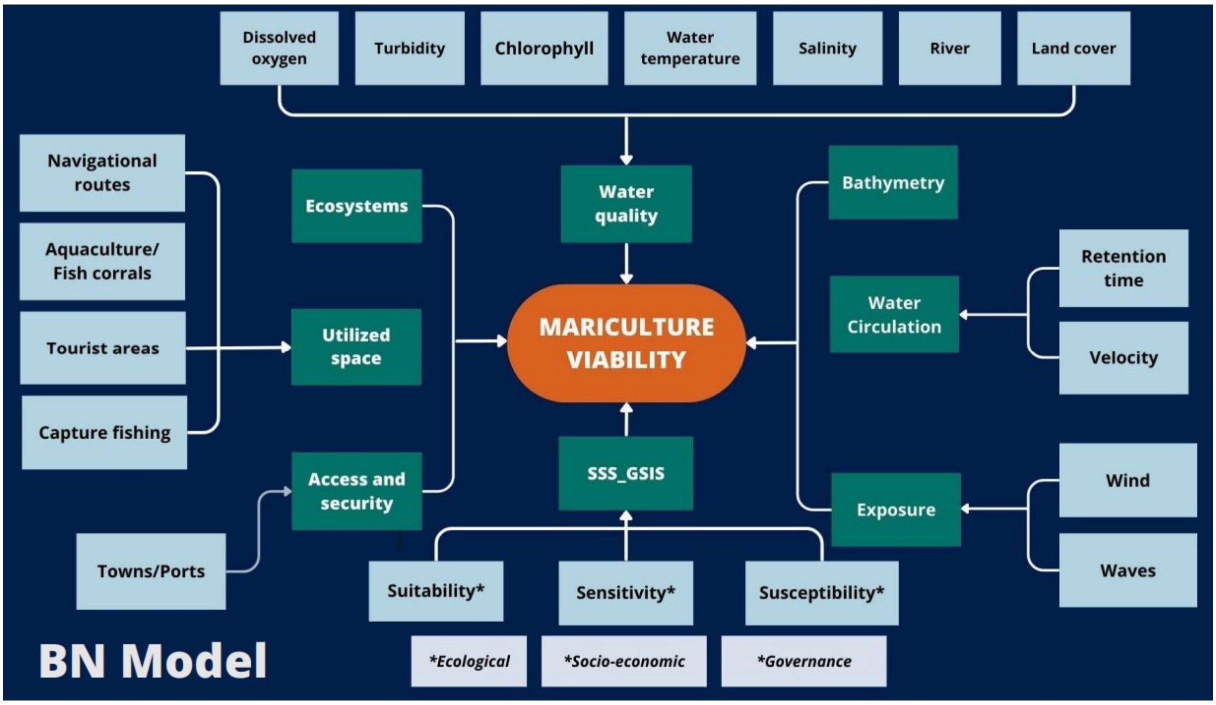
Source: **FAO Philippines.** 2023. Support to ICT-based Marine Spatial Planning for Fisheries and Aquaculture Management - Terminal Report (2023).

The primary objective of the project is to develop an MSP framework that facilitates marine spatial planning, even in areas with limited onsite data. The project employs innovative approaches, including the Suitability, Sensitivity, Susceptibility – Governance and Socio-Ecological Integrated System (SSS–GSIS) and Bayesian network (BN) – GIS models, alongside active stakeholder engagement. The framework was first applied to Pagbilao Bay (Figure D6), a region rich in capture fisheries, mangroves, and coral reef ecosystems, and which is exploring the potential for establishing a mariculture zone.

The project successfully established an MSP structure that integrates remote sensing and GIS techniques to address data gaps. As a result, two key outputs were generated using the BN–GIS model. The Viability Map for Marine Protected Areas (MPAs) was found to be influenced by a combination of significant SSS-GSIS data, including biophysical, socioeconomic, and governance factors. While existing MPAs show potential for expansion, certain areas that could have been designated as larger MPAs were constrained by conflicts with traditional fishing grounds. The second output, the *Viability Map for Mariculture Areas* (Figure D6), highlighted that the central portions of Pagbilao Bay are particularly suitable for mariculture, as they do not conflict with other uses. These MSP outputs now serve as a crucial references for future government planning and stakeholder discussions.

A combination of remote sensing, GIS, and modelling tools was used to create the supplementary water quality parameters needed for MSP generation (Figure D7). Google Earth Engine processed and downloaded the necessary remote sensing datasets, supplementing missing field data such as GEBCO bathymetry, European Space Agency (ESA) Land Cover, and Sentinel-3 data. The Sentinel Application Platform (SNAP) software, using the Case 2 Regional Coast Colour (C2RCC) processor, generated Chlorophyll-a and Total Suspended Matter from the Sentinel-3 layers. ArcGIS converted 'utilize space' datasets into distance maps and interpolated hydrodynamic modelling outputs like water velocity and retention time. Once pre-processed, the pixelated data were introduced to Netica for BN generation and gBay for the spatial BN model.

Figure D7. Conceptual framework for the Bayesian Network on viability of space for aquaculture / mariculture



Source: **FAO Philippines.** 2023. Support to ICT-based Marine Spatial Planning for Fisheries and Aquaculture Management - Terminal Report (2023).

The lack of socioeconomic and governance information was easily addressed through the conducting of focus group discussions under the SSS-GSIS component (Figure D8). However, for ecosystem and water quality parameters, specific pre-processing techniques were introduced to make the available data more spatially complete. First, Euclidean Distance Maps were created, in which spatially implicit features like rivers and navigational routes (line shapefiles) were processed using ArcGIS' Euclidean Distance tool to generate input raster covering the whole study area. Secondly, pixel interpolation using Kriging techniques were applied to transform point shapefile data into raster format for compatibility with BN models. This included the field-acquired parameters from water sampling points such as dissolved oxygen and salinity, as well as model-generated velocity and water retention time data, which were originally available only as point data.

The spatial planning process in Pagbilao Bay has made notable progress but has revealed some needs and gaps requiring attention for future projects. Access to GIS tools, particularly for LGUs, is constrained by reliance on proprietary software like ArcGIS; exploring open-source alternatives such as Google Earth Engine could therefore improve accessibility and reduce costs. Additionally, housing MSP-related remote sensing data, such as chlorophyll and turbidity on platforms like FAO's Hand-in-Hand Geospatial Platform or Oceana's Global Fishing Watch could facilitate easier access to data visualization. Capacity building remains a critical issue, as many LGUs lack the technical expertise, and sometimes the equipment, to independently conduct complex spatial analyses. There is also a need for robust monitoring and evaluation tools to ensure effective MSP implementation.

In the Philippines, the current legal framework mandates the Comprehensive Land Use Plan for all local government units but lacks an explicit requirement for a Comprehensive Land and Water Use Plan (CLWUP), which is crucial in areas with significant land and water interactions. Establishing clear criteria for CLWUP implementation would strengthen resource management. Finally, updated onsite ecological data is still needed to ensure proper validation for satellite-derived parameters.

TCP/PHI/3802/C2 was designed to address data gaps encountered in the previous MSP programmes in the country. This challenge was effectively mitigated through the use of the BN model and the integration of remote sensing and GIS technologies, which supplemented the spatial limitations in the available input data. The following best practices and lessons learned were identified:

- Collaboration among stakeholders in all phases of MSP. Close coordination between the funding agency, partner government agencies, local government units, and other stakeholders proved to be essential at every stage of MSP development.
- Timely conduct of validation workshops. During the development of the MSP model, draft results were consistently shared with LGUs and stakeholders (Figure D8). This approach allowed for early feedback, validation, resolution of issues, and refinement of the model and workflows.
- Use of adaptive and modelling approaches. The integration of remote sensing and GIS allowed for adaptive solutions when faced with data limitations. The flexibility of the BN model ensured that different types of spatial and non-spatial data could be incorporated, making the MSP process more resilient to gaps in onsite data.
- Capacity building and training. Technical training for local stakeholders on the application of remote sensing, GIS, and MSP tools was crucial and must be tailored to the technical level and needs of the community.
- Alignment with local governance structure and reporting. The effective implementation of the MSP process in Pagbilao Bay was facilitated by strong local government support. Since the integration of MSP contributes to the completion of their Comprehensive Land and Water Use Plan, local officials demonstrated continuous commitment and engagement.

Figure D8. Data validation workshop with stakeholders on the MPA and Mariculture model results

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Aquaculture planning and management with Agri-Map Online in Thailand

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In Thailand, aquaculture has long played a vital socioeconomic role, contributing not only to food security for the Thai people but also to fishery product exports. In 2023, the aquaculture production amounted to about one million tonnes, with a value of approximately USD 2.9 billion.

The Department of Fisheries, established in 1926, is responsible for aquaculture planning and management in Thailand. In 2023, the Ministry of Agriculture and Cooperatives (MOAC) introduced site suitability maps for agricultural purposes. These maps indicate the optimal locations for economic plants, livestock, and aquatic animals, and are used by government offices at the provincial level. The 77 provincial fisheries offices utilize these maps, notably, to assess site suitability for fish pond development. Farmers can also leverage this spatial information – combined with economic information on local market situations – to make informed decisions about operating pond cultures for their businesses.

In 2013, an aquaculture site suitability assessment was conducted over about one year, using the best available digitized spatial data from various relevant government agencies. The data, scaled at 1:50 000, covered the entire country and included factors such as soil texture, soil pH, soil permeability, slope, rainfall, proximity to rivers, electricity, and road accessibility. These spatial datasets were mainly used as criteria in allocating sites for pond aquaculture, excluding marine finfish and offshore aquaculture. Additional spatial data, including land use, conservation area, military zone, etc., were also incorporated into the analysis.

GIS using a map modeler with the weighted linear combination, and spatial multicriteria evaluation techniques designed by expert groups, were applied to classify site suitability for pond aquaculture into five classes: most suitable, suitable, moderately suitable, less suitable, not suitable. The analysis revealed that the suitable area for shrimp farming covered 4 160 km^2 across 24 provinces, while freshwater species such as tilapia and prawn had suitable areas extending over 72 000 km^2 across 75 provinces. It should be noted that the site suitability maps were also revised and updated in 2014 and remain applicable today.

In 2022, the MOAC initiated a data integration effort among 12 government agencies under its authority, particularly with regard to site suitability for all agriculture production sectors, including plant, livestock, and fisheries. A spatial data integration tool, Agri-Map Online, was developed with the support of the National Electronics and Computer Technology Center, under the Ministry of Science and Technology. General users can access Agri-Map Online at https://agri-map-online.moac.go.th/login. The resource is also available on the Play Store and App Store, allowing users to search and save spatial data (e.g. base map, site suitability, factory, logistics, market, airport), and other economic data or regulations for their personal uses anytime, anywhere, online. Local officers from government agencies can use this platform to advise stakeholders, such as farmers, within their areas of responsibility. The tool has been used approximately 950 000 times over the past 2 years.

The MOAC is currently advancing the Agri-Map to its next iteration, Agri-Map Phase 2, which will enhance its capabilities and integrate data from 22 agencies. This update aims to serve a broader range of user groups, including Agriculture and Aquaculture GIS Analysts (Agri-Map Pro), Executives at Ministry and Departmental Levels (Agri-Map Ex), and the General Users/Public (Agri-Map II). The improvements address the weaknesses of the current Agri-Map, which will be replaced by the new Agri-Map II in 2026. A budget of approximately USD 2.76 million has already been allocated for this project.

In addition, the Department of Fisheries will contribute more available spatial data on marine aquaculture activities in the upcoming Agri-Map II, including fish cages, mollusc culture areas, and artificial reef locations. In the case of annual artificial reef deployment, which has been conducted for over 46 years in Thailand, the Department of Fisheries will collaborate with other government agencies, including the Marine Department, Navy, and Department of Marine Coastal Resources to secure the necessary permits.

It is important to note that coastal fisheries and aquaculture activities must adhere to the regulations of other relevant government agencies mentioned above. Moreover, the Department of Marine Coastal Resources (Ministry of Natural Resources and Environment) has been implementing the National Policy and Planning for Coastal Resource Management since 2015.

Additionally, the Thai Maritime Enforcement Command Center (Thai-MECC), which includes seven government agencies (the Navy, Marine Department, Department of Fisheries, Customs Department, Department of Marine Coastal Resources, Thai Marine Police Division, and Department of Labour Protection and Welfare), is responsible for protecting national maritime interests. The Thai-MECC has the authority and duties to formulate policies, strategies, and plans for national maritime security, as well as measures to safeguard the interests of maritime nations in accordance with government policies and relevant national plans.

One of the Royal Development Projects demonstrating effective coastal resources management is the Kung Krabaen Bay Royal Development Study Centre, which was established on 28 December 1981, in Tha Mai District, Chanthaburi Province, on the eastern coast of Thailand. This coastal area, characterized by saline soil, faced significant challenges, including the deterioration of the mangrove forest, which hindered local fishing activities. To address these issues, the Centre focuses on conducting studies and research aimed at developing and improving fisheries and propagating marine life in coastal areas, together with integrated farming practices. Its activities also include the sustainable utilization and conservation of coastal natural resources to achieve ecological balance. The overarching goal is to enable farmers to increase their production and attain long-term self-sufficiency.

The Department of Fisheries oversees coordination efforts, and currently, 23 surrounding villages serve as models for other farmers in neighbouring areas, helping them enhance their careers and improve land productivity.

The MOAC and the Department of Fisheries believe that agriculture spatial planning is essential for sustaining food security and enhancing farmers' socioeconomic well-being. In particular, inland and coastal aquaculture activities must be strategically planned and managed using effective spatial planning tools, coupled with strong political will. This approach is crucial for achieving a more efficient supply chain for aquaculture products and ensuring the sector's resilience in the face of challenges such as climate change, disease outbreaks, and rising operational costs.

Currently, the Department of Fisheries has initiated the research and development project on an early warning system that utilizes the internet of things and artificial intelligence to mitigate risks in finfish and mollusc cultures in selected coastal areas in Suratthani and Nakhonsithammrat provinces. Water quality parameters, such as dissolved oxygen, temperature, salinity, and pH, are collected hourly and transmitted to computer servers with a data analytics platform (RapidMiner®). This platform handles data loading and transformation, data pre-processing and visualization, predictive analytics and statistical modelling, evaluation and deployment at https://iotews.fisheries.go.th.

This e-service, based on advanced digital technology, will support farmers to prepare for and adapt to climate variation in a timely manner. Additionally, the Department of Fisheries launched the Telemedicine Project in March 2024, which aims to provide shrimp farmers in Songkhla Province with helpful and timely advice from Department of Fisheries veterinarians through mobile devices. Machine learning is being applied to assess disease probability and provide guidance on farm management. Therefore, the application of digital technology is being applied spatially in the planning and management of aquaculture.

In summary, Thailand has effectively applied spatial planning in aquaculture development and management. Key factors contributing to this success include political will, inter-agency collaboration, data integration, site suitability assessment, the use of selected spatial tools, and ongoing improvements.

Implementation of marine spatial planning in northern Europe for aquaculture

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Introduction

In northern Europe, where there is a high demand for marine resources and space, MSP and the tools developed for its implementation have become crucial to sustainable development, particularly in the case of aquaculture, as northern Europe is one of the key regions for its expansion. However, aquaculture competes for space with other marine industries such as shipping, fishing, and tourism, as well as with environmental conservation efforts.

Here we look at the implementation of MSP in northern Europe with a focus on aquaculture, examining its benefits, challenges, and outlook. northern European countries, particularly Norway, Denmark, Scotland, and Iceland, have emerged as leaders in integrating MSP into national and local policies to promote the development of sustainable aquaculture. These countries have worked with the intricacies of MSP within a multi-user environment to ensure that aquaculture can coexist with other marine activities while protecting marine ecosystems.

The importance of marine spatial planning for aquaculture

Marine spatial planning is essential for aquaculture development in coastal regions of northern Europe in several ways. Firstly, it helps to prevent conflicts between different users of coastal space. In Northern Europe coastal aquaculture competes with industries such as shipping, energy (especially offshore wind farms), fisheries, and tourism. MSP allows these competing uses to be mapped and managed in a way that minimizes conflicts and ensures that aquaculture operations are placed in suitable locations, ideal for the cultured organisms and environmental mitigation measures.

Secondly, MSP helps to protect the marine environment by identifying ecologically sensitive areas that need protection from the potentially harmful impacts of aquaculture and other marine industries. Using MSP procedures and policies, governments have designated marine protected areas in several northern European countries and restrict activities in these zones, including aquaculture, to prevent habitat destruction, and other environmental impacts.

Thirdly, MSP supports the sustainable growth of aquaculture by providing a clear framework for decision-making. This helps policymakers, regulators and other stakeholders understand where aquaculture development is most suitable in relation to other coastal activities and environmental suitability, and for the growth and welfare of the cultured organisms. MSP therefore allocates space to aquaculture zones or areas that balance economic growth with environmental sustainability.

Key drivers for implementing marine spatial planning in northern Europe

Several key drivers have encouraged the implementation of MSP for aquaculture in northern Europe.

Growing demand

The demand for seafood from aquaculture in Europe has increased significantly because of growing populations, changing diets, and concerns over the sustainability of wild fisheries. Europe is one of the largest markets for seafood, and aquaculture is seen as a way to meet this demand while reducing pressure on wild fish stocks. Northern Europe, in particular, has the potential to meet a substantial portion of this demand through its extensive coastline and cold-water resources ideal for species like salmon, trout, and mussels, and with future potential for a range of seaweeds.

Environmental concerns

Northern European governments have implemented MSP in part to address the environmental concerns associated with aquaculture. In the past, unregulated aquaculture has led to problems such as nutrient pollution, habitat degradation, and the spread of diseases to wild fish populations. By using MSP, countries can mitigate these impacts through strategic siting and the enforcement of environmental standards.

Economic opportunities

The aquaculture industry represents a significant economic opportunity for Northern European countries. Aquaculture has become an important source of jobs and economic development, especially in rural and coastal areas. The development of new technologies for offshore aquaculture, such as deepwater cages and IMTA, has the potential to further expand the industry once proven under commercial conditions. MSP provides a framework for capitalizing on these opportunities by promoting sustainable aquaculture growth.

European Union policies

For European Union (EU) Member States, the EU has played a major role in driving MSP implementation through its Integrated Maritime Policy and the EU MSP Directive (2014/89/EU). This directive requires all EU Member States to develop marine spatial plans to coordinate the sustainable use of their marine waters by 2021. While countries like Norway, the United Kingdom and Iceland are not EU members, they tend to adopt EU policies and are part of regional cooperation efforts through frameworks such as the OSPAR Convention (the Convention for the Protection of the Marine Environment of the North-East Atlantic).

Examples of MSP implementation in northern Europe

Norway

Norway is a global leader in aquaculture, as the world’s largest producer of farmed Atlantic salmon. The Norwegian government has implemented marine spatial plans at both national and regional levels to balance the needs of different users of the marine environment.

One of the key features of Norway’s MSP is its zoning system, which designates areas for different types of marine activities, including aquaculture. The zoning system helps to avoid conflicts between aquaculture and other industries such as oil and gas, shipping, and fishing. It also helps to protect sensitive marine habitats by restricting aquaculture in ecologically important areas. For example, Norway has designated several MPAs where aquaculture activities are prohibited or strictly regulated to protect vulnerable ecosystems.

In addition to zoning, Norway has implemented a rigorous licensing system for aquaculture that specifies where and how producers can operate They are also subject to strict environmental monitoring and reporting requirements. The licensing system is closely tied to Norway’s MSP framework, ensuring that aquaculture development aligns with broader marine management goals.

Norway has also been at the forefront of developing new technologies for nearshore and offshore aquaculture, such as deepwater farming, the use of semi-submersible cages, full and partial RAS and pump-ashore facilities. These innovations have been incorporated into the national MSP, which has identified suitable offshore areas for aquaculture expansion while reducing environmental impacts.

Scotland

Scotland is another important aquaculture producer, particularly in the production of Atlantic salmon and shellfish. The Scottish government has taken an active role in implementing MSP to support the sustainable development of aquaculture while protecting the marine environment. Scotland’s approach to MSP is guided by its National Marine Plan, which sets out a vision for the sustainable use of Scottish waters. The plan includes specific policies for aquaculture, emphasizing the need for sustainable growth, environmental protection, and the minimization of conflicts with other marine industries.

Like Norway, Scotland uses a zoning system to manage aquaculture activities. Aquaculture operators are required to obtain licenses from the Scottish Environment Protection Agency (SEPA), which evaluates the potential environmental impacts of proposed developments. SEPA works closely with the Scottish government's Marine Directorate to ensure that aquaculture activities are compatible with the country's MSP framework.

Scotland has also pioneered the use of IMTA, a system that combines the farming of fish with other species such as shellfish and seaweed to recycle waste products, which may contain nutrients, and give potential growth benefits to the low trophic species. Scotland's MSP framework has supported the development of IMTA by identifying suitable areas for this type of aquaculture.

Denmark

The Danish government has developed a comprehensive MSP framework that includes detailed marine spatial plans for its waters. These plans designate areas for different types of marine activities, including aquaculture, offshore wind farms, and shipping lanes.

Denmark has focused on promoting sustainable aquaculture practices, particularly in the farming of mussels and seaweed, which generally have lower environmental impacts than finfish farming. The Danish government has also encouraged the use of IMTA systems, which combine mussel and seaweed farming with fish farming.

Denmark's MSP framework also includes strict environmental standards for aquaculture operations. Aquaculture operators are required to monitor and report on the environmental impacts of their activities, and they are subject to regular inspections by government authorities.

Iceland

Iceland has adopted MSP as part of its commitment to sustainable marine management. The country has a relatively small aquaculture industry compared to other northern European nations, but it has been growing steadily in recent years, particularly in the farming of Arctic char and Atlantic salmon.

Iceland's approach to MSP is closely tied to its focus on environmental protection. The country's marine spatial plan prioritizes the protection of its unique marine ecosystems, including cold-water coral reefs and important fish spawning areas. Aquaculture development is highly restricted in these areas to minimize environmental impacts.

At the same time, Iceland's MSP framework aims to support the growth of its aquaculture industry by identifying suitable areas for aquaculture expansion. The government has also introduced a licensing system for aquaculture operators, which includes strict environmental monitoring and reporting requirements. However, a recent poll indicated that over 65 percent of the Icelandic population are against open-net salmon farming and support a ban. This makes an MSP within the coastal regions of Iceland important for the provision of information for wider communication and social license of aquaculture.

Challenges of implementing marine spatial planning for aquaculture in northern Europe

Despite the progress made in implementing MSP for aquaculture, several challenges remain, notably the conflicts between users, environmental sustainability, gaps in the provision of relevant data and climate change.

While MSP aims to reduce conflicts through communication, the implementation of policy and adaptive combined management, there are still instances in northern Europe where industries such as aquaculture, shipping, and energy compete for the same space, leading to tensions relying on regulation rather than consensus for implementation. Though an MSP can mitigate impacts of the intensive coastal aquaculture found in northern Europe through strategic siting and regulation, there is still a need for improved technologies and production practices to make aquaculture more sustainable within the wider ecosystem. In addition, there are still significant gaps in data collection, storage/availability and analysis for farm management, regulation and legislation purposes. To this end modern technology can be used for automated and real time data collection, though there are still issues in terms of data quality and robustness for effective support of the decision-making process.

Climate change also poses a significant challenge to aquaculture in northern Europe. Rising sea temperatures, general increases in precipitation, ocean acidification, and changes in ocean currents could affect the viability of aquaculture in some areas, requiring adjustments to MSP frameworks and consequent implementation.

Regional review of marine spatial planning in the Mediterranean region

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Mediterranean aquaculture has expanded significantly over the past two decades, in response to rising demand for seafood, stagnating wild fisheries, and advancements in farming technologies. The Mediterranean's semi-enclosed geography and ecological variability pose distinct challenges for the expansion of aquaculture, necessitating ecosystem-based planning and robust governance mechanisms. The region now hosts a mix of intensive marine finfish and shellfish production systems, predominantly in nearshore and offshore environments. This growth has prompted national and regional authorities to refine governance structures, adopt ecosystem-based approaches, and integrate aquaculture more effectively into broader marine spatial planning (MSP) frameworks. The integration of aquaculture into MSP frameworks has become central to achieving sustainable development objectives, ensuring that growth is balanced with environmental protection, stakeholder inclusion, and policy coherence.

Aquaculture trends in the Mediterranean

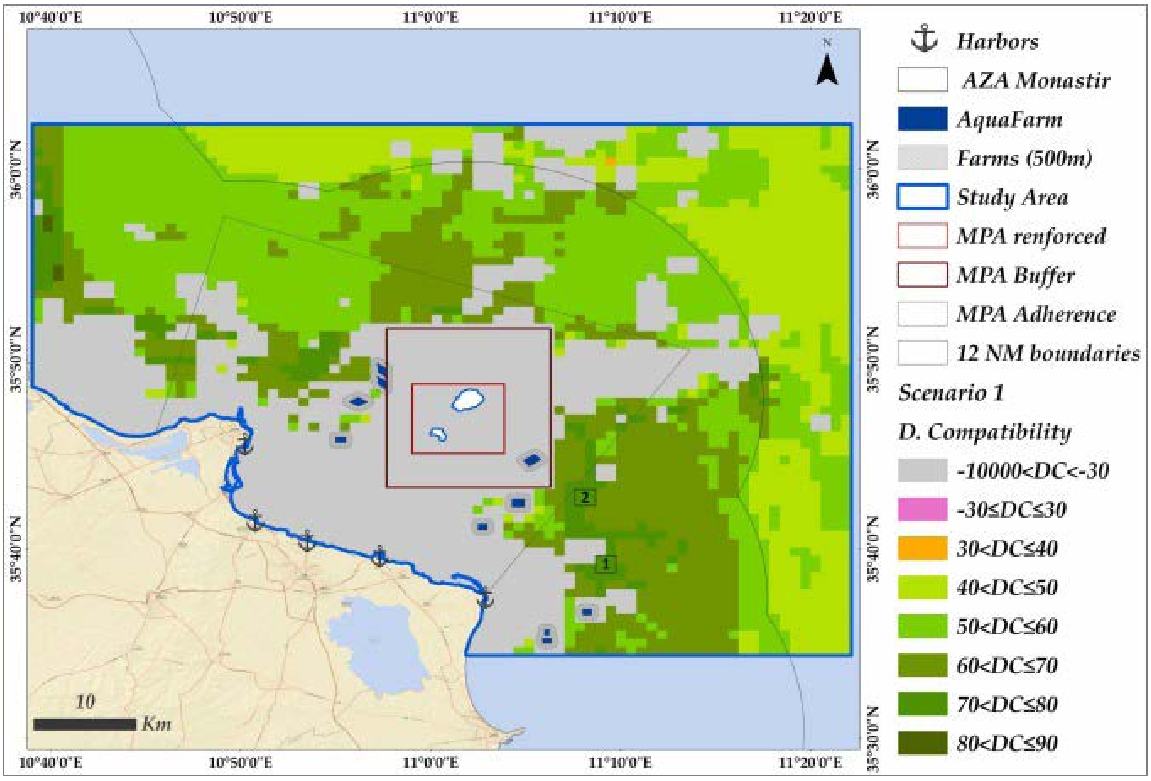
Aquaculture has emerged as a cornerstone of the Mediterranean's blue economy, contributing significantly to regional food security, livelihoods, and economic resilience. In 2023, aquaculture production in the Mediterranean and Black Sea region reached approximately 2.9 million tonnes, generating around USD 9.18 billion in revenue (FAO, 2025). In 2021, the sector directly employed nearly 350 000 people across more than 35 000 farms (FAO, 2021). This sector not only helps relieve pressure on overexploited fish stocks but also drives innovation in coastal communities, particularly through initiatives under the General Fisheries Commission for the Mediterranean and the Black Sea (GFCM) 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea (FAO, 2021). Growth has been especially rapid in marine finfish and shellfish farming, with gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*), and Mediterranean mussel (*Mytilus galloprovincialis*) accounting for 77 percent of total production volume (FAO, 2025).

Production remains geographically concentrated, with Croatia, Egypt, France, Greece, Italy, Spain, Tunisia and Türkiye contributing around 87 percent of total regional output in 2023 (FAO, 2025). Egypt leads with approximately 46.7 percent of total production volume (~1.6 million tonnes), mainly due to high tilapia output, followed by Türkiye (about 556 000 tonnes in 2023), Spain (~7.4 percent), France (~6 percent), Italy (~4 percent), Greece (~4.4 percent), Croatia (~0.8 percent), and Tunisia (~0.6 percent) (FAO, 2025). Tunisia's aquaculture sector has demonstrated the fastest growth in the Mediterranean over the past two decades, increasing production from 1 554 tonnes in 2000 to nearly 21 300 tonnes in 2023. This accounts for approximately 16 percent of its total fisheries production (FAO, 2025), with the sector aiming to contribute 30 percent of national production by 2030.

For several years, Tunisia has pursued efforts to integrate MSP into the development of its aquaculture sector, employing GIS-based site selection tools and environmental criteria to identify suitable offshore zones (Figure D9). This integration seeks to guide spatial expansion through environmentally sound, data-driven, and participatory approaches (Mzoughi *et al.*, 2025).

Türkiye's aquaculture sector has experienced remarkable growth, with total fisheries production reaching 1 million tonnes in 2023, 55 percent of which was attributed to aquaculture. Finfish production increased substantially, rising from approximately 79 000 tonnes in 2000 to 547 000 tonnes in 2023, and generating an estimated USD 2.8 billion (FAO, 2025). This expansion has been largely driven by the development of marine cage farming along the Aegean, Eastern Mediterranean, and Black Sea coasts. In the Black Sea, trout accounted for roughly 40 percent of cage-based production in 2023, while the remaining output was primarily composed of seabass and seabream.

Figure D9. GIS-based suitability map for offshore finfish farming on Tunisia's central–east coast, produced through multicriteria spatial analysis incorporating environmental, regulatory, and technical factors



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **Mzoughi, A., Romdhane, N., & Azaza, M.S.** 2025. Spatial suitability analysis for finfish aquaculture: A case study from center-east coast of Tunisia. Regional Studies in Marine Science 87, 104225. https://doi.org/10.1016/j.rsma.2025.104225

To manage such rapid growth, Türkiye implemented a zoning system through the designation of aquaculture production areas (APAs), supported by environmental impact assessments, public consultations, and stakeholder involvement in the licensing process (Corner *et al.*, 2020).

Governance and regulatory frameworks

Aquaculture governance in the Mediterranean is diverse and reflects varying administrative structures and regulatory priorities. EU Member States generally operate under the 2014/89/EU Maritime Spatial Planning Directive, complemented by national frameworks. These often promote decentralized governance, where both national and regional authorities are engaged in siting and permitting aquaculture activities – as seen in Italy, Spain, and Greece. In contrast, several non-EU countries adopt centralized or hybrid systems. For instance, Türkiye and Malta apply top-down licensing frameworks, while Croatia employs a unified regulatory regime for both marine and freshwater aquaculture. Tunisia and Morocco, on the other hand, have emphasized stakeholder consultation and participatory approaches in shaping their MSP and aquaculture strategies.

National aquaculture strategies frequently guide spatial planning. For example, Italy and Spain have developed EU-aligned strategies that support regional MSP implementation, while Croatia applies standardized national rules.

Within this regional context, allocated zones for aquaculture (AZAs) have emerged as a core MSP instrument in the Mediterranean and Black Sea. Regionally endorsed by the GFCM (e.g. Resolution GFCM/36/2012/1) and operationalized through GFCM technical guidance, AZAs provide a transparent, participatory, ecosystem-based process (Macias *et al.*, 2019). This process combines GIS-based (Fourdain, Macias & Porporato, 2024) screening and exclusion criteria with an assessment of carrying capacity, environmental impact assessments (EIA) linkages, as well as monitoring/management plans to designate suitable areas for aquaculture while minimizing conflicts with other maritime uses. Embedding AZAs within MSP helps align national strategies with site-level decisions, giving regulators and operators greater certainty and facilitating sustainable expansion.

Emerging zoning systems further illustrate the regional diversity. Türkiye has designated APAs in deeper offshore waters based on environmental suitability criteria. Malta and others focus on reducing environmental impacts through mandatory EIAs and carrying-capacity analyses during farm approvals.

Overall, regulatory frameworks across the Mediterranean attempt to balance environmental protection with aquaculture growth. However, implementation remains uneven, often constrained by administrative capacity and delayed institutional coordination (Corner *et al.*, 2020; FAO, 2023).

Stakeholder engagement and marine spatial planning tools

Effective MSP requires inclusive, participatory processes that incorporate diverse stakeholder interests and local knowledge. Across the Mediterranean, approaches to stakeholder engagement vary significantly. In many EU Member States such as Italy, Spain, and Croatia, MSP has been implemented through multistakeholder dialogue that integrates site-specific data on water quality, ecosystem services, and socioeconomic considerations. These inclusive processes help build community trust and improve the social license to operate for aquaculture activities (Corner *et al.*, 2020; FAO, 2023).

Italy and Spain have indeed implemented participatory MSP approaches, especially at the regional level. While more centralized than Italy and Spain, Croatia has engaged stakeholders in the development of national aquaculture strategies and spatial plans, particularly in areas with high tourism or ecological sensitivity. Türkiye uses a top-down APA zoning system with limited stakeholder engagement at early planning stages. The process is highly centralized. Malta, although an EU member, applies a centralized licensing and planning model through its Fisheries and Aquaculture Department. Stakeholder involvement tends to occur during EIA procedures, rather than at the initial planning stage.

A variety of GIS-based and decision support tools have been developed to facilitate aquaculture planning and improve transparency. These include the NOAA AquaMapper, ISPRA's AquaGIS (Italy), and the Nature Conservancy's Aquaculture Planning Tool. Such systems enable planners to overlay biophysical, legal, and social constraints, identify potential conflicts, and optimize site selection for aquaculture (Aguilar-Manjarrez *et al*., 2017; Marino *et al*., 2020; FAO, 2021). While these tools enhance technical capacity, stakeholder surveys across the region continue to report barriers to effective implementation, including limited technical knowledge, unclear jurisdictional authority, and time-consuming approval procedures.

Notably, successful MSP experiences (such as those in Italy) combine early and structured stakeholder involvement with spatial tools. For instance, several Italian regional plans have designated AZAs based on criteria co-developed by regulatory authorities and aquaculture producers (Corner *et al.*, 2020). Italy has been a leader in promoting AZAs, particularly through regional initiatives (e.g. Puglia, Emilia-Romagna). These cases underscore the importance of both procedural legitimacy and data-driven decision-making for sustainable marine aquaculture development.

Environmental considerations

Environmental protection is a core objective of MSP, particularly in ecologically sensitive marine ecosystems like the Mediterranean. Mitigating environmental impacts is a central pillar of MSP for aquaculture in the Mediterranean Sea. Most countries in the region require comprehensive EIAs. EIAs are a legal requirement in most Mediterranean countries (especially EU Member States) for new aquaculture operations. Nutrient budgeting and carrying capacity models (e.g. FARM, DEPOMOD) are also commonly used to assess ecological impacts.

Siting is particularly sensitive in areas hosting *Posidonia oceanica* meadows, Natura 2000 sites, and marine turtle foraging zones, which are commonly excluded from farming zones to preserve critical habitats. These habitats are protected under EU directives (e.g. Habitats Directive) and international conservation frameworks. Farming is generally restricted or prohibited in such areas.

Climate change introduces further risks, including rising sea-surface temperatures and more frequent extreme weather events, both of which increase the likelihood of disease outbreaks, particularly in finfish farming. These environmental stressors demand more resilient and adaptive planning frameworks.

Regional case studies

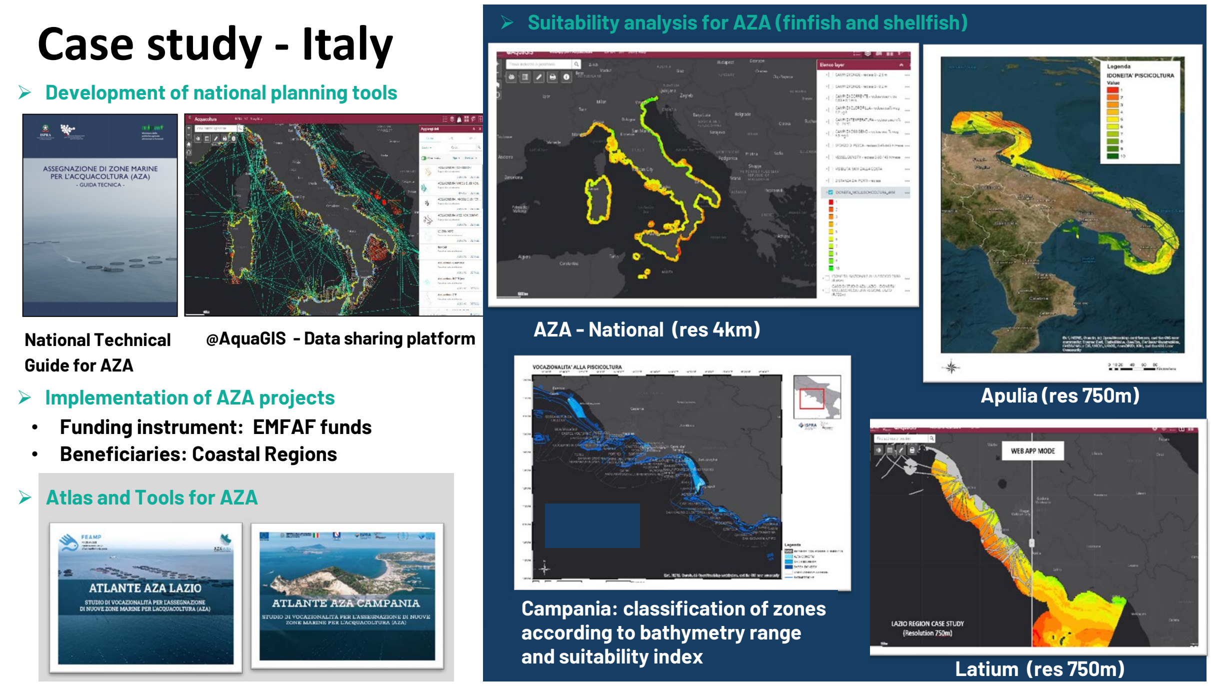
National experiences across the Mediterranean Sea illustrate the diversity of approaches to MSP for aquaculture, which can be shaped by governance systems, stakeholder engagement, and ecological priorities.

In Türkiye, MSP has prioritized the designation of APAs in deeper offshore waters. These zones are defined based on environmental suitability (e.g. current velocities, buffer zones, nutrient dynamics) and stakeholder inputs. Tools such as the Trophic State Index (TRIX) are used to assess ecosystem carrying capacity, and public consultations are mandatory during EIAs. This structured, criteria-based zoning has enabled Türkiye to manage its rapid aquaculture growth while minimizing spatial conflicts (FAO, 2023).

Italy has integrated aquaculture into broader MSP frameworks by delineating AZAs (Figure D10). These zones are established under regional marine spatial plans and are assessed through ecological, social, and economic indicators. The approach supports decentralized planning, allowing regional authorities to guide both MSP and site licensing while maintaining alignment with national sustainability goals (Corner *et al.*, 2020; Marino *et al.*, 2020). Currently, only 5 out of 15 Italian coastal regions have established AZAs, amounting to a total of 40 areas, for 28 133 ha allocated to aquaculture. Several regions, including Lazio, Campania and Sardinia, are moving forward with AZA planning and are about to finalize the process; others, such as Abruzzo, Calabria, Liguria, and Apulia, have begun preliminary work under European Maritime and Fisheries Fund and the European Maritime, Fisheries and Aquaculture Fund funding programmes (ISPRA 2025).

In Tunisia, MSP implementation is emerging through GIS-based decision support tools. The use of spatial multicriteria evaluation methods for finfish cage site selection reflects the country’s strategy to expand aquaculture production offshore, while avoiding sensitive coastal habitats. Tunisia’s approach emphasizes compatibility assessments to reduce conflict and support sustainable marine farming (Mzoughi *et al.*, 2025).

Figure D10. Examples of Technical Guidelines and WebGIS Tools Developed by ISPRA to Support Marine Aquaculture Planning in Italy.



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

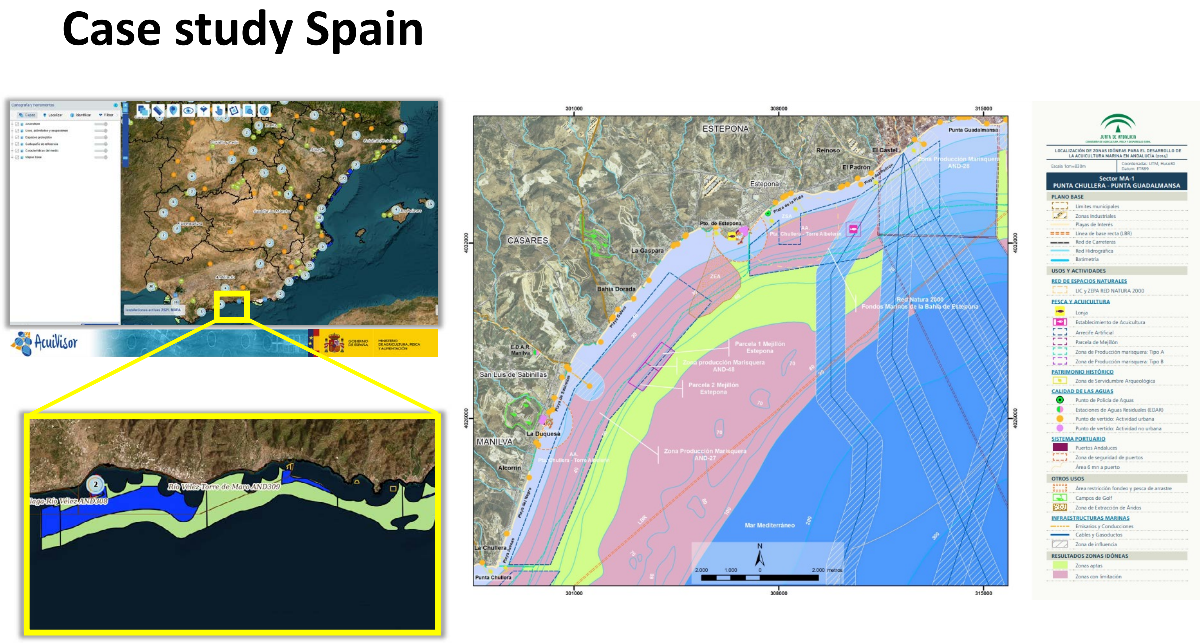
Source: Author's own elaboration (Francesco Cardia, ISPRA)

Algeria has initiated preliminary zoning studies using multicriteria suitability models (Laama *et al.*, 2020) to guide aquaculture development in ecologically and economically feasible zones. Although MSP in Algeria is still in a nascent phase, these tools aim to support national efforts towards integrated coastal management. Algeria lacks a fully implemented MSP framework but is gradually moving towards ecosystem-based marine planning. The use of spatial models represents the preliminary steps towards MSP.

In Spain, some autonomous communities have incorporated aquaculture into coastal zone plans through innovative spatial strategies. Pilot models exploring the integration of tuna aquaculture with ecotourism have been reported in selected coastal areas. Regions like Andalusia, Galicia, and Catalonia have integrated aquaculture into coastal planning, often including shellfish zones and sustainability measures (Figure D11). However, outcomes vary widely by region, depending on the level of stakeholder collaboration and institutional capacity (Sicuro, 2024).

In summary, Mediterranean case studies underscore the emergence of tailored MSP solutions: from nationally designated offshore zones to locally co-managed shellfish areas. While many countries demonstrate innovation and progress, the implementation of MSP for aquaculture remains uneven, and best practices continue to evolve in response to national priorities and ecological constraints.

Figure D11. Example of the Acuivisor tool showing allocated zones for aquaculture to support marine aquaculture planning in Spain



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **Ministero de Agricultura, Pesca y Alimentación. n.d. AcuiVisor.** [Cited 1 October 2025] https://servicio.pesca.mapama.es/acuivisor/

Barcelona Convention Regional Plan on Aquaculture

The Regional Plan on Aquaculture Management under the 2005 Mediterranean Action Plan of the Barcelona Convention is intrinsically linked to MSP as a tool to guide the sustainable development of aquaculture activities in Mediterranean coastal regions and their associated hydrologic basins. Given the Mediterranean Sea's ecological vulnerability and the cumulative pressures from multiple marine uses, the plan advocates the integration of aquaculture management within MSP frameworks to optimize spatial allocation and mitigate environmental impacts.

To address environmental aquaculture pressures, the Regional Plan on Aquaculture Management advocates for the adoption of best environmental practices, such as:

- designation of mixing zones and allowable zones of effect;
- definition of environmental quality standards for water and sediment; and
- site-specific monitoring programmes using biological and physical indicators.

This approach is particularly critical in coastal and watershed areas where aquaculture effluents and pollutant discharges can adversely affect water quality and marine ecosystems. By applying MSP principles, the Plan promotes the delineation of suitable zones for aquaculture that consider ecological sensitivity, pollutant dispersion patterns, and socioeconomic factors, thereby reducing conflicts with other coastal activities and enhancing environmental protection. The coordinated management of aquaculture within MSP ensures that nutrient loading, chemical inputs, and organic waste are controlled, contributing to the reduction of pollution inputs from river basins into the Mediterranean Sea. Ultimately, this spatially informed governance framework supports the sustainable growth of aquaculture while preserving the health and resilience of the Mediterranean's coastal and marine environments.

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Aquaculture zoning following marine spatial planning principles within the Macaronesia use-cases

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The Interreg MAC PLASMAR project (2017–2020) and its follow-up, PLASMAR+ (2020-2023), were both focused on marine spatial planning (MSP) in the Macaronesian region, which includes the Canary Islands, Madeira, and the Azores. The main goals of these projects were to develop and propose scientific methodologies to support sustainable maritime activities and blue growth, while balancing development with environmental conservation. They created tools based on scientific and technical knowledge to help plan and manage marine spaces, working across several key sectors to promote sustainable maritime activities and blue growth.

Within 2018, a study was undertaken in which the main maritime sectors related to the blue economy in the archipelagos were identified and analysed. Based on this study, five maritime sectors were selected as relevant and considered for the MSP zoning process in Macaronesia: Offshore wind energy, aquaculture, fisheries, maritime transport and mineral extraction. Aquaculture production is an established maritime sector contributing to the island economy both in Madeira and in the Canary Islands. In the Azores it is in an early stage of research, development and innovation (Figure D12).

Figure D12. State in 2018 and future trends for the sectors of the blue economy in the Macaronesian archipelagos and in the international context.

Maritime Sectors		International		Archipelagos of the European Macaronesia					
		EU	World	Madeira		Azores		Canaries	
		State	Prospects	State	Prospects	State	Prospects	State	Prospects
1	Fisheries	✔	↗	✔	→	✔	→	✔	→
2	Marine aquaculture	✔	↑	✔	↑	✓	⚙	✔	↑
3	Marine biotechnology	✓	⚙	✓	⚙	✓	⚙	✓	⚙
4	Coastal & maritime tourism	✔	↑	✔	↑	✔	↑	✔	↑
5	Maritime transport	✔	↑	✔	↑	✔	↑	✔	↑
6	Ship repair and maintenance	✔	↑	✖	✗	✖	✗	✔	↑
7	Extraction of aggregates	NA	NA	✔	→	✔	→	✖	?
8	Deep-sea mining	✓	⚙	✖	✗	✖	?	✖	?
9	Offshore oil & gas	✔	↗	✖	✗	✖	✗	✖	✗
10	Renewable ocean energies	✓	⚙	✓	?	✖	✗	✓	⚙
11	Desalination	✓	↑	✔	→	✖	✗	✔	↗

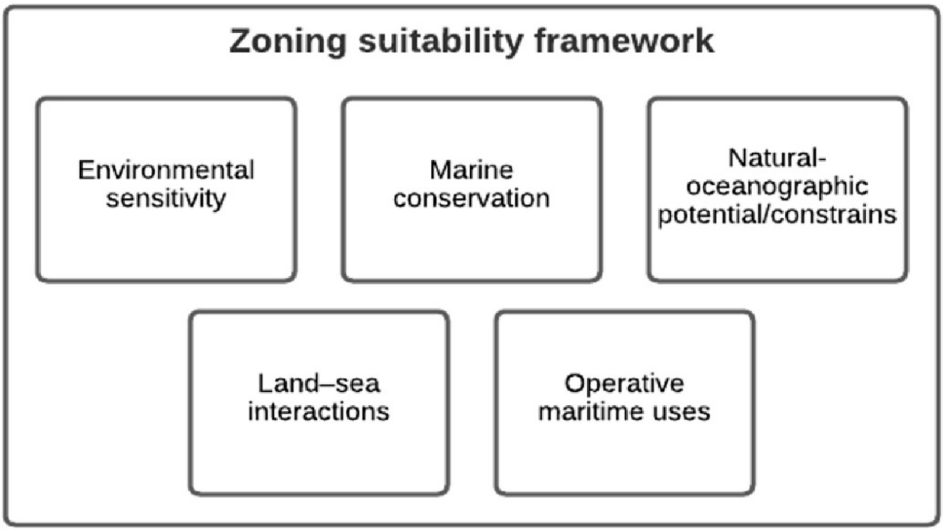
Note: The nomenclature used in the reports cited as information sources for the international context has been used and translated to symbols. Thus, the state was defined as: ✖ non-existent; ✓ emerging; and ✔ established. The development prospect was defined as: ✗ no development; ? unknown; ⚙ significant long-term potential but not yet at commercial scale; → stable; ↗ modest business and employment growth; ↑ high long-term growth of business and employment.

Source: Table 5 in **Fernández-Palacios, Y., Kaushik, S., Abramic, A., Cordero-Penín, V., García Mendoza, A., Bilbao-Sieyro, A., Pérez-González, Y., Sepulveda, P., Lpes, I., Andrade, C., Nogueira, N., Carrera, G.P., Magalhaes, M., & Haroun, R.** 2023. Status and perspectives of blue economy sectors across the Macaronesian archipelagos. *J Coast Conserv* 27, 39. https://doi.org/10.1007/s11852-023-00961-z

The first study in the development of zoning methodologies was conducted with an extensive literature review of the environmental effects and changes that the five maritime sectors considered, including aquaculture, can have on Good Environmental Status (GES), as described by the European Marine Strategy Framework Directive (2008/56/EC). In this context, an environmental impact assessment checklist has been developed to encompass the construction, operation, and decommissioning phases of aquaculture production sites aiming to enable the evaluation of the aquaculture developments stages are compatible with the GES of the marine environment (Png-Gonzalez *et al*. 2019).

In parallel with these studies, the Suitability Zoning Framework was developed as a structured way to study relevant topics for the MSP process and collect data for zoning exercise. This included five components aimed at achieving environmental sustainability, identifying natural potential and avoiding conflicts with nature conservation, coastal land use and operative maritime sectors (Figure D13).

Figure D13. Suitability zoning framework including its five fundamental components



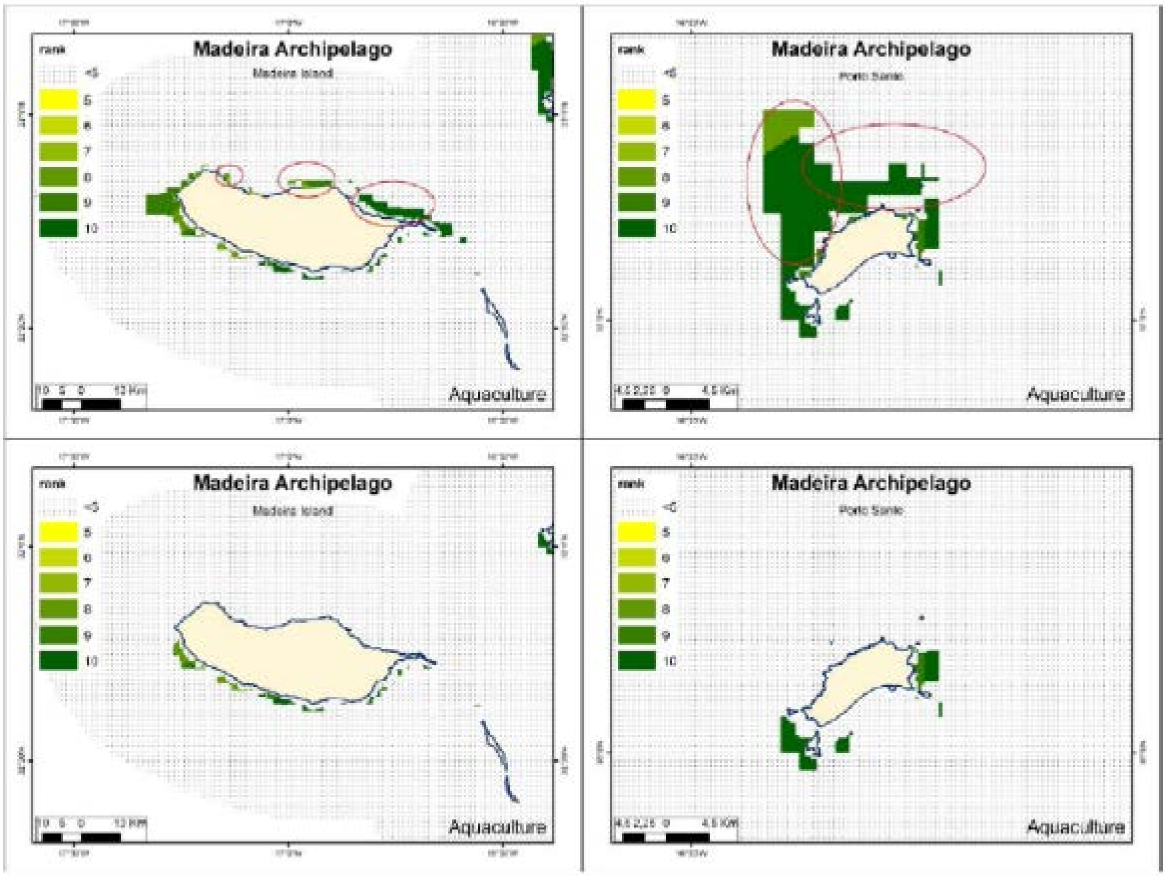
Source: **Abramic, A., García Mendoza, A, Cordero-Penin, V., Magalhães, M., Fernández-Palacios, Y., Andrade, C., Calado, H., i Kaushik, S., Carreira, G., Nogueira, N., Shinoda, D., & Haroun, R.** 2024. Site selection within the maritime spatial planning: Insights from use-cases on aquaculture, offshore wind energy and aggregates extraction. *Ocean & Coastal Management,* 251, 107051. https://doi.org/10.1016/j.ocecoaman.2024.107051

Following the GES studies and the Suitability Zoning Framework, which introduced concepts for achieving environmental suitability, the potential conflicts and compatibilities of each considered sector with marine conservation were analysed. Additional studies examined oceanographic potential, considering physical parameters such as currents, winds, waves, temperature, and depth. Finally, land–sea interactions were assessed, focusing on potential conflicts and compatibility with coastal and maritime operational sectors.

Data for all three EU archipelagos were collected in a structured and harmonized manner, adhering to the Suitability Zoning Framework. This data was then hosted in a dedicated Marine Spatial Data Infrastructure, ensuring public accessibility to data and services following INSPIRE Directive (2007/2/EC) principles. To support the application of the suitability zoning, the INDIMAR Decision Supporting System was developed specifically for the case study on archipelagos (Abramic *et al*., 2021). Using geographic information system technology, INDIMAR DSS integrates spatial data layers representing the key framework components. The suitability index was calculated via a weighted overlay technique, where each spatial data layer (or parameter) was weighted according to its importance for the targeted maritime activity (e.g. aquaculture). This approach enabled the integration of all the suitability components and parameters, with varying significance assigned to each.

Utilizing data hosted in the MSDI, the INDIMAR DSS developed a methodology under the Zoning Suitability Framework, and began producing results for all sectors, including aquaculture. The first aquaculture zoning exercise covered the entire Madeira archipelago (Figure D14). The weights used in this exercise were established through the analytical hierarchy process by a panel of regional aquaculture experts. The model identified areas with existing aquaculture facilities and zones designated for future expansion. It also reflected the panel's policy to prioritize areas with high oceanographic potential, focusing on avoiding conflicts with coastal and maritime sectors while still considering environmental conservation. However, the model did not exclude northern areas of the island, which have challenging oceanographic conditions for aquaculture infrastructure development and maintenance.

Figure D14. Madeira aquaculture suitability analysis applying the panel policy



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **Abramic, A., García Mendoza, A, Cordero-Penin, V., Magalhães, M., Fernández-Palacios, Y., Andrade, C., Calado, H., i Kaushik, S., Carreira, G., Nogueira, N., Shinoda, D., & Haroun, R.** 2024. Site selection within the maritime spatial planning: Insights from use-cases on aquaculture, offshore wind energy and aggregates extraction. *Ocean & Coastal Management,* 251, 107051. https://doi.org/10.1016/j.ocecoaman.2024.107051

A second aquaculture suitability model was developed and applied to the Canary Islands. Before implementing this model, the dataset was updated with extended oceanographic time-series data (Copernicus data including waves, currents, and winds) to improve the model's capacity to identify and exclude areas that are unsuitable by virtue of challenging oceanographic conditions.

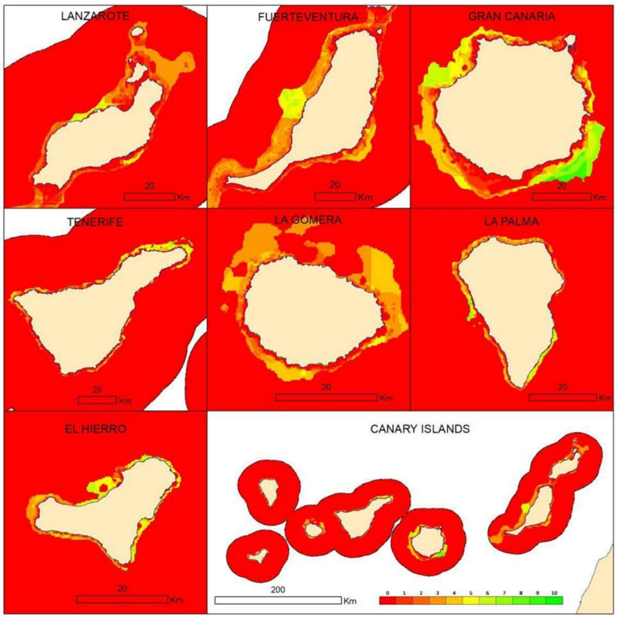
Additionally, the INDIMAR DSS incorporated flexibility to adjust weights according to different policy scenarios. Three policy-driven scenarios were tested, each reflecting distinct objectives:

1. Expert consensus from a regional panel, prioritizing balanced aquaculture development.
2. Environmentalist approach aimed at minimizing environmental impacts, although potentially increasing conflicts with other maritime and coastal sectors, thereby reducing the emphasis on natural potential.
3. Conservation-focused approach with marine protected area restrictions, emphasizing conservation above other considerations.

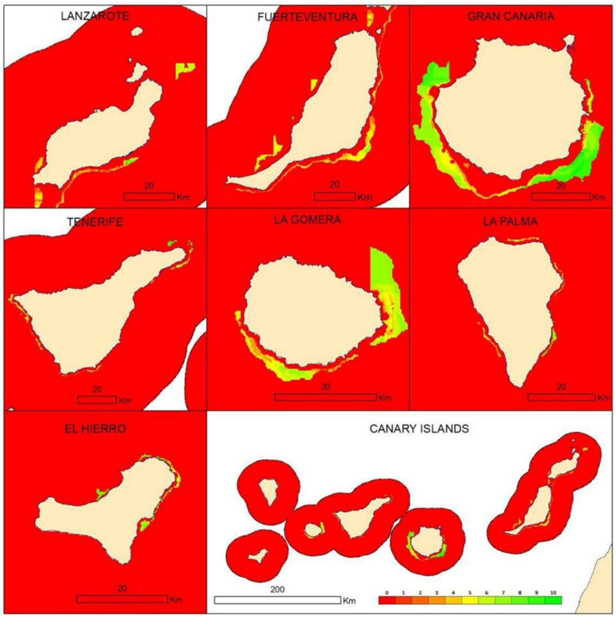
Each scenario produced a unique suitability map, pinpointing areas best aligned with each specific policy goal (see Figure D15).

Figure D15. Suitability zoning for aquaculture, two use cases for Canary Islands

X scenario



Y scenario



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Note: The first use case applies multiparameter weights defined with expert panel consensus; the second is an environmental scenario, that applies weights to minimize environmental trade-offs.

Source: **Abramic, A., García Mendoza, A, Cordero-Penin, V., Magalhães, M., Fernández-Palacios, Y., Andrade, C., Calado, H., i Kaushik, S., Carreira, G., Nogueira, N., Shinoda, D., & Haroun, R.** 2024. Site selection within the maritime spatial planning: Insights from use-cases on aquaculture, offshore wind energy and aggregates extraction. *Ocean & Coastal Management,* 251, 107051. https://doi.org/10.1016/j.ocecoaman.2024.107051

The study's suitability zoning methodology effectively identified areas suitable for aquaculture development while considering regional policy goals. This was demonstrated in the Canary Islands use case, where different policy scenarios, prioritizing environmental protection or balanced development, were successfully modelled (Figure D15). The accuracy of these models relies heavily on data availability;

detailed data in the Canary Islands allowed for a precise suitability assessment, while identified data gaps highlight the need for structured data collection to avoid overlooking potential environmental impacts. Although tested in the Canary Islands, this methodological approach can be adapted to other regional settings.

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Lake Victoria marine spatial plan in relation to aquaculture suitability and carrying capacity

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Lake Victoria has enormous environmental and economic significance, yet this waterbody faces significant challenges that require practical solutions to ensure its resilience and long-term sustainability. The main reasons for determining a spatial plan and the carrying capacity are to organize lake uses, in order to: minimize lake-use conflicts; minimize risks of environmental load; solve lake scape space demand; determine the potential of lake scape firms; and determine indicators of changes in the socioecological well-being of the resource base. The Lake Victoria Marine Spatial Plan in relation to Aquaculture Suitability under the Sustainable Activities of Water Areas (SAWA) project is a state-of-the-art and world-class decision-making, tool-oriented research and management project focused on the Kenyan portion of Lake Victoria. The SAWA project intends to build, in partnership with Kenyan governance stakeholders, an evolving aquaculture governance framework that improves decision-making and addresses the challenges of multiple lakes uses, notably areas with resource competition.

Using geographical information system tools such as Geostore and AquaFish Model for data processing, and QGIS for analytical hierarchical process, the plan delineates the lake into inshore and offshore aquaculture through an innovative set of web-based tools and products (https://www.sawa.blue/explore). The inshore, cage-suitable areas optimally range at a depth of about 6–10 m for cage culture, alongside constraints like navigation routes, water hyacinth hot spots and breeding areas. The area recommended for inshore aquaculture in the lake is 291 km^2, which represents 8 percent of the lake. The “not suitable” and “less suitable” areas are recommended for accessing the lake for transport, navigation, capture fisheries, tourism, sports and other lake uses. The recommended inshore aquaculture zones are potential areas for small-scale farmers with low capital requirements. The suitable offshore areas have an optimum depth range of about 10–50 m for cage culture and sit alongside constraints like navigation routes, water hyacinth hot spots, and breeding areas. Such installations require firm anchorage to withstand strong currents and could be mainly for capital-intensive farms. These sites will be suitable for commercial aquaculture and large-scale farms/firms. It is suggested that the “highly suitable” potential portion of the lake is utilized for cage culture depending on requests from investors, after which more room can be sought for the “suitable” areas, depending on the existing production carrying capacity. Just like inshore cage-farming suitability, the other “not suitable” and “less suitable” areas are recommended for accessing the lake for transport, navigation, capture fisheries, tourism and sports.

The carrying capacity of the entire Lake Victoria – applying best cage culture management practices – is estimated at more than 500 percent of the current cage culture production (currently estimated at 21 000 tonnes, using the FINS, ORGANIX and FARM models). The number of cages per site or per investor (carrying capacity) for each of the inshore and offshore categories will be calculated based on the investor’s chosen sizes of cages, stocking density and the location characteristics. The production carrying capacity for cage culture for riparian counties is estimated at 275 000 tonnes per year.

To support the implementation of the spatial plan and related carrying capacity thresholds, an Executive Committee will be formed. This will include the Principal Secretary responsible for Blue Economy and Fisheries (Chairperson) and the Principal Secretary responsible to Maritime Affairs (Co-Chair) with a representative from the Council of Governors. Other members will be drawn from the relevant government ministries to support the licensing and issuance of permits. Kenya Marine and Fisheries Research Institute (KMFRI) will chair the technical committee comprised of representatives from all state agencies that have a role in the use and/or management of Lake Victoria. KMFRI will play the role of technical lead responsible for updating the spatial plan, aquaculture suitability maps and the carrying capacity assessment.

Marine spatial planning: practical examples from the Republic of South Africa

Michelle Pretorius

Department of Forestry, Fisheries and the Environment, Republic of South Africa

The Department of Forestry, Fisheries and the Environment is a national department mandated to manage, protect and conserve South Africa's environment and natural resources. With its vision of a prosperous and equitable society living in harmony with our natural resources. For some years, the management and planning of human uses in the ocean space have been pursued on an individual sectoral basis with little or no consideration of policies and plans of other sectors or requirements that may be conflicting or incompatible. The need for a more holistic and integrated approach to ocean management is underscored by South Africa's development requirements to grow our ocean economy, including the growth of existing and emerging sectors, many with overlapping areas of interest and some with incompatible development objectives.

In 2012, Cabinet adopted the National Development Plan, which outlined South Africa's plan to accelerate infrastructure development and address service delivery backlogs. In 2014, Operation Phakisa was launched with the sole aim of implementing priority economic and social programmes and projects faster and more effectively. One of the key sectors within Operation Phakisa is the promotion of the Oceans Economy, with aquaculture being a focus area earmarked for enhancement.

To remedy the potential conflict or incompatible objectives of different sectors, the MSP Framework was gazetted in May 2017 for implementation to provide the high-level direction for the undertaking of MSP in the South African ocean environment. This was followed by the Marine Spatial Planning Act, 2018 (Act No. 16 of 2018), which aims to provide the legislative framework for MSP in South Africa. The act offers a practical way to address both specific challenges and select appropriate management strategies to maintain sound ecosystem health which will, in turn, facilitate the advancement of national and regional economic and sociocultural development.

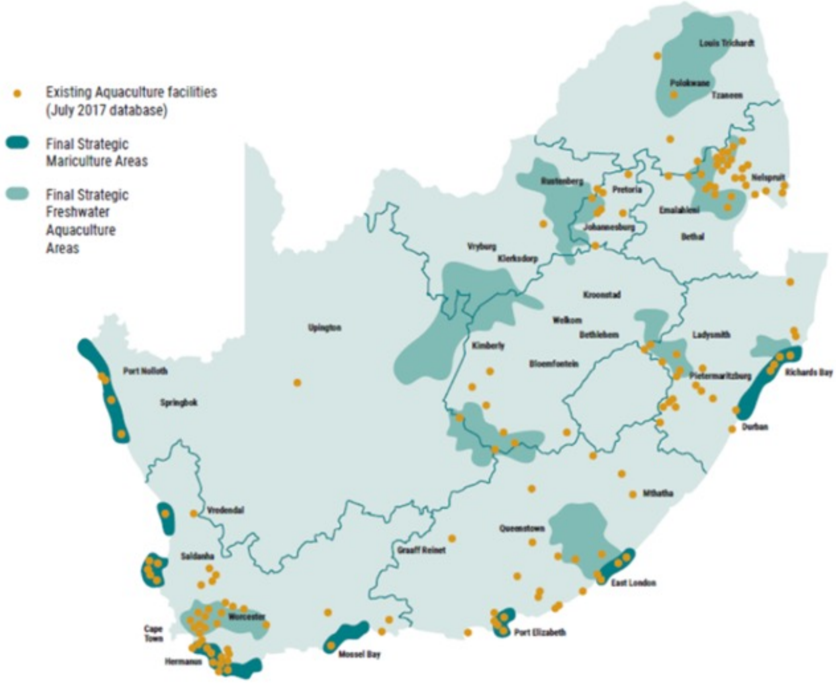
Marine sector plans specify the overall development objectives and priorities of each marine sector for the coming two decades from a national point of view. Ten sector plans were gazetted for comment on 10 March 2023, with a spatial ask per sector coastal and marine tourism, aquaculture, biodiversity, marine defence, offshore oil and gas, marine scientific and innovation sector, transport and ports, underwater infrastructure, maritime and underwater heritage and wild fisheries sector plans.

The Western Marine Area Plan is one of four marine spatial plans that will be developed for South Africa's marine area. Western, Southern, and Eastern MSP areas have been defined for the South African mainland exclusive economic zone. A Prince Edward Islands MSP area covers South Africa's Southern Ocean extent. These separate areas enable specific plans to be drawn up that take account of the specific conditions and needs of each marine area plan.

The first of four marine area plans in draft format is the "Draft Western Marine Area Plan". It involves overlapping the spatial asks per sector and seeing where different needs would have to be accommodated in overlapping areas, in addition to a consultative process between sectors to determine priority per area plan. Stakeholder engagement workshops are currently underway to seek stakeholder buy-in and to allow for further inputs into the draft plan.

South African environmental legislation allows for other spatial planning tools such as SEA and EIA; both these tools have been undertaken for the aquaculture sector in South Africa to further support the development of the industry. An SEA for the marine and freshwater industry was undertaken in 2009 and identified proposed aquaculture development zones (ADZs) through integrated spatial analysis and iterative stakeholder consultations (see Figure D16). ADZs have also been undertaken through the EIA process to earmark land and seawater space in South Africa as another support initiative through National government.

Figure D16. Marine and freshwater strategic environmental assessment identifying zones where aquaculture is environmentally suitable in South Africa



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **Department of Environment, Forestry and Fisheries (DFFE).** 2019. *Strategic Environmental Assessment for Marine and Freshwater Aquaculture Development in South Africa.* ISBN: 978-0-7988-5646-1. CSIR Report Number: CSIR/IU/021MH/ER/2019/0050/A. Stellenbosch, Western Cape.

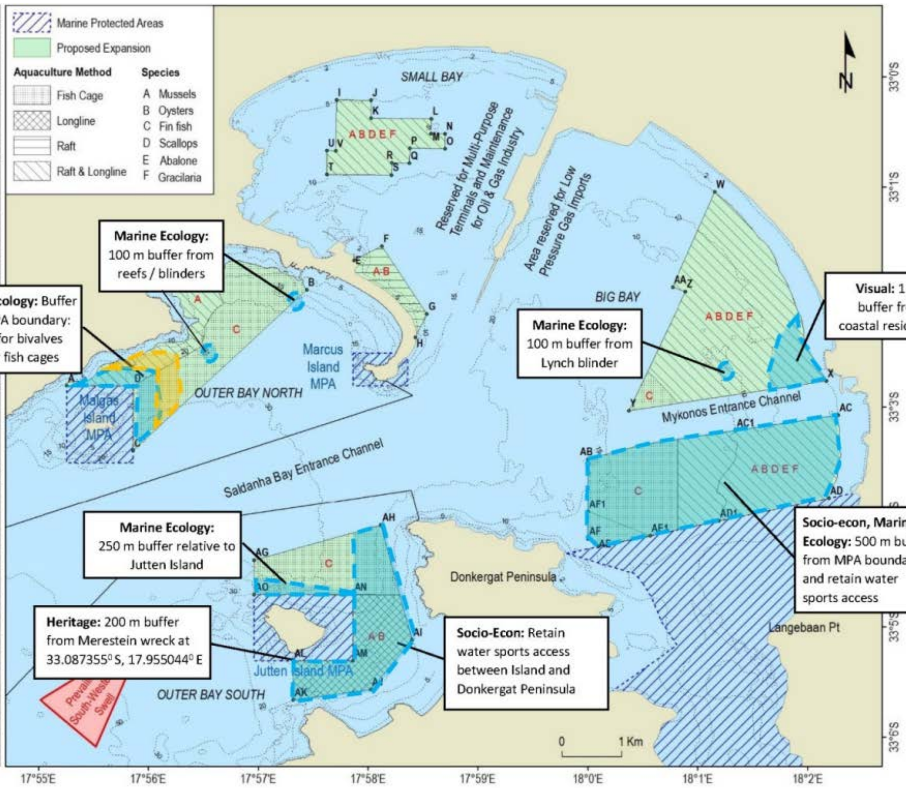
An ADZ is an area that has been earmarked specifically for aquaculture activities with the aim of encouraging investor and consumer confidence. It creates incentives for industry development and provides marine aquaculture services; it manages the risks associated with aquaculture; and it provides skills development and employment for coastal communities.

The case study presented here is in the Saldanha Bay ADZ on the west coast of South Africa, which is the primary area for bivalve production, where the majority of South Africa's oyster and mussel production to date originates from. As a result of improved opportunities for local mussel import substitution, the opening of export markets for oysters, and improved access to water and land space through the Oceans Economy Operation Phakisa initiative, there has been a renewed interest in expanding the bay for further oyster and mussel production. There is also a desire to explore the potential for finfish production in the outer, more exposed parts of the bay.

To manage the bay holistically and create an enabling environment, the Department undertook an EIA for the establishment of an ADZ in Saldanha Bay in 2016/2017 and the Environmental Authorization was granted on 8 January 2018. The Saldanha Bay ADZ has been implemented for the last 6 years, and the Department supports the industry by appointing the Environmental Control Officer as well as undertaking environmental monitoring to ensure that these costs are not carried by the industry, which has very little profit margins to keep up with the rising costs of farming. The challenges and lessons learnt from implementing the ADZ in Saldanha Bay (see Figure D17 for user conflicts) has been the template for the implementation of ADZs in other areas of the coast in South Africa such as Algoa Bay ADZ: these will be unpacked and shared with the hope of finding possible solutions from this workshop.

Figure D17. Overlay of the user conflicts within Saldanha Bay ADZ identified during the EIA process

Point	Lat S		Long E	
A	33°	2.806′	17°	55.261′
B	33°	1.934′	17°	57.442′
C	33°	3.393′	17°	55.862′
D	33°	2.806′	17°	55.862′
E	33°	1.665′	17°	57.870′
F	33°	1.537′	17°	58.127′
G	33°	2.153′	17°	58.537′
H	33°	2.365′	17°	58.432′
I	33°	0.21′	17°	57.71′
J	33°	0.213′	17°	58.03′
K	33°	0.375′	17°	58.028′
L	33°	0.38′	17°	58.575′
M	33°	0.515′	17°	58.573′
N	33°	0.517′	17°	58.702′
O	33°	0.652′	17°	58.7′
P	33°	0.648′	17°	58.379′
Q	33°	0.783	[illegible]	[illegible]
R	33°	0.782	[illegible]	[illegible]
S	33°	0.89	[illegible]	[illegible]
T	33°	0.889	[illegible]	[illegible]
U	33°	0.67	[illegible]	[illegible]
V	33°	0.671′	17°	57.704′
W	33°	1.045′	18°	1.156′
X	33°	2.763′	18°	2.171′
Y	33°	3.031′	18°	0.371′
Z	33°	1.948′	18°	0.89′
AA	33°	1.91′	18°	0.77′
AB	33°	3.47′	18°	0
AC	33°	3.072′	18°	2.278′
AC1	33°	3.212′	18°	1.345′
AD	33°	3.82′	18°	2.193′
AD1	33°	4.036′	18°	1.195′
AE	33°	4.27′	18°	0.089′
AE1	33°	4.17′	18°	0.563′
AF	33°	4.2′	18°	0
AF1	33°	3.95′	18°	0
AG	33°	4.393′	17°	56.961′
AH	33°	4.074′	17°	58.118′
AI	33°	5.117′	17°	58.401′
AJ	33°	5.566′	17°	58.024′
AK	33°	5.662′	17°	57.316′
AL	33°	5.306′	17°	57.316′
AM	33°	5.307′	17°	57.861′
AN	33°	4.706′	17°	57.861′
AO	33°	4.706′	17°	56.961′



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **Heinecken, C., Japp, D., & Olivier, D.** 2016. *Concept for a Proposed Sea-Based Aquaculture Development Zone in Saldanha Bay, South Africa. Analysis of information and mapping to determine suitable aquaculture areas, species and methods in Saldanha Bay and land-based support activities.* Capricorn Marine Environmental (Pty) Ltd.

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Case study focusing on the implementation of MSP applied to aquaculture in the Republic of Korea

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Introduction

Aquaculture in the Republic of Korea has been steadily expanding, and now accounts for 63 percent of the country's total seafood supply, with the active exports of products like *gim* ("seaweed", in Korean). In terms of production volume, major aquaculture species include seaweed (laver, kelp, sea mustard) and shellfish (oysters, abalone, scallops). Seaweed and shellfish farms are predominantly concentrated in the shallow, coastal waters south of the Korean Peninsula, which are managed by local fishermen's associations. These areas are exposed to cumulative environmental loads and climate variability and face potential conflicts and impacts from coastal development or other marine use. To address these challenges, recent policy initiatives have aimed to develop smart aquaculture farms, with technologically advanced management systems operating in offshore and midwater regions. New management tools are also being considered to grade and sort areas suitable for aquaculture based on health and environmental conditions, or to relocate farms from degraded areas to more suitable sites based on ongoing environmental monitoring. In marine spatial management, when designating fishery activity protection zones within the marine-use zoning process, the conditions of local aquaculture sites and surrounding areas are measured. A suitability analysis of marine space includes a prohibition of the designation of new aquaculture sites in areas with high spatial overlap with other uses. It adjusts farm placements after reviewing the compatibility of proposals concerning other marine uses, development activities, and overall marine spatial planning objectives. In addition, research is underway to develop a monitoring system that utilizes satellite imagery to detect unpermitted aquaculture facilities or discrepancies with licensing requirements.

Zoning-based management systems for aquaculture sites

Marine-use zoning is done using spatial information of farms to conduct a marine spatial characteristics assessment. Marine spatial characteristics assessment involves a quantitative assessment that supports the sustainable use, development, and conservation of marine space. Grading of the marine spatial characteristics and identification of the marine space can be achieved through an overlay analysis of marine spatial data on resources and usage over the grid map (assessment unit) of the targeted assessment area, using a geographic information system software.

Evaluation of fishery activity characteristics using aquaculture spatial data

In South Korea, marine spatial characteristic assessments have been conducted for the nine key marine activities designated within the marine-use zoning process. For each designated assessment area, specific criteria are provided to evaluate the characteristics of core activities. Table D2 below outlines the evaluation criteria for fishery activities in the waters of the Republic of Korea near Jeollanam-do. Figure D18 shows an example of the assessment results visualized on a grid system, highlighting the spatial scoring outcome for fishery activities in the same region. As shown in Table D2, aquaculture sites are included as an evaluation criterion for assessing fishery activity characteristics. In all designated assessment areas around the Korean Peninsula, spatial data on aquaculture farms is utilized as a major evaluation criterion for "fishery activities". The results of the marine spatial characteristic assessments are published on the Ministry of Oceans and Fisheries' Integrated Marine Spatial Management Information System, allowing public access to the information.

Table D2. Evaluation criteria for fishery activity characteristics in Jeollanam-do

Category	Assessment items	Grid-based input criteria
High-density fishing vessel areas	High-density fishing activity areas	5-year arithmetic mean average, normalized value (0–1)
	High-density fishing vessel (v-pass) areas	5-year arithmetic mean average, normalized value (0–1)
Catch volume	High-density catch volume areas	Normalized value (0–1)
	High-density specialty species areas	Normalized value (0–1)
Fishing licenses	Aquaculture sites (including 1km-buffer zone)	Presence or absence (1, 0)
	Fishing port areas	Presence or absence (1, 0)
Legally designated fishing-related areas	Protected waters	Presence or absence (1, 0)
	Marine resources protection zone	Presence or absence (1, 0)
	Marine resources management waters	Presence or absence (1, 0)
Fishing port	National fishing port	Presence or absence (1, 0)
	Fishing port area	Presence or absence (1, 0)
Ocean ranching site	Ocean forest	Presence or absence (1, 0)
	Ocean ranching site	Presence or absence (1, 0)

Source: **Ministry of Oceans and Fisheries.** Republic of Korea. 2024. Marine Spatial Management Information System. In: *Ministry of Oceans and Fisheries*. [Cited 23 October 2024]. www.msp.go.kr

Figure D18. Example of marine spatial characteristics assessment result in Jeollanam-do

Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **Ministry of Oceans and Fisheries.** Republic of Korea. 2024. Marine Spatial Management Information System. In: *Ministry of Oceans and Fisheries*. [Cited 23 October 2024]. www.msp.go.kr

The designation of use zones based on marine spatial characteristic assessments: the results of the marine spatial characteristic assessments are considered when designating relevant marine use zones. Aquaculture spatial data plays a significant role in the designation of fishery activity protection zones. For instance, in Jeollanam-do's Marine Spatial Plan, fishery activity protection zones were designated in most of its coastal areas based on spatial data incorporating a 1 km buffer around aquaculture sites. Figure D19 presents the results of an overlay analysis conducted in the case study area, showing the spatial relationship between aquaculture sites (including the 1 km buffer) and designated fishery activity protection zones.

Figure D19. Overlay analysis of aquaculture spatial data (with 1km buffer) and fishery activity protection zones in the case study area

Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: Author's own elaboration based on spatial data from: **Ministry of Oceans and Fisheries.** Republic of Korea. 2024. Marine Spatial Management Information System. In: *Ministry of Oceans and Fisheries*. [Cited 23 October 2024]. www.msp.go.kr

Aquaculture site detection using marine spatial monitoring technology

With regard to limitations of marine spatial management information and onsite management, local governments in the Republic of Korea manage information on occupancy permits, aquaculture licenses, and reclamation permits. However, there are limitations in determining the alignment and legality of actual marine space use and development activities with these permissions. It is impossible for local governments to detect all illegal or inappropriate activities related to marine space use given the nature of coastal environments, which make regular onsite inspection a challenging task.

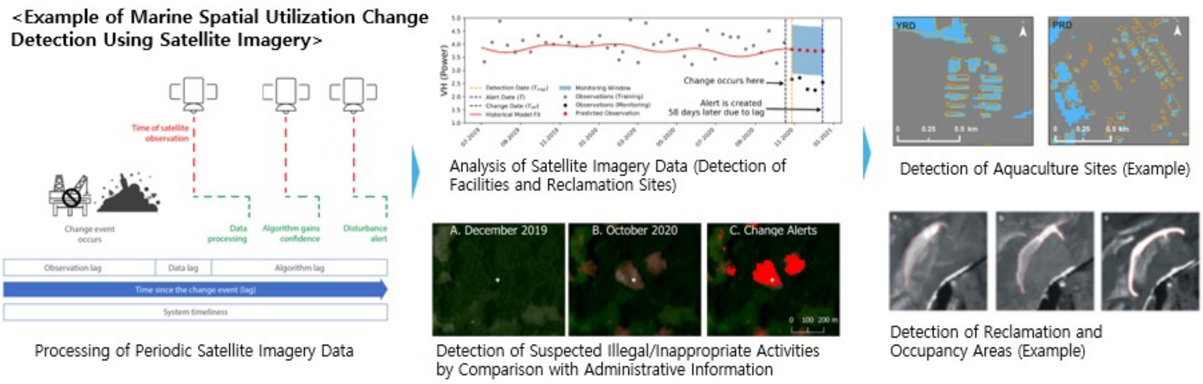
Marine space monitoring and management simulator: the marine space monitoring and management simulator, currently being developed by the Korea Institute of Ocean Science & Technology, aims to provide appropriate management directions in line with the established guidelines, monitoring and assessing marine space uses using near-real-time remote sensing techniques (satellite and aerial imagery). The simulator serves as a useful tool when determining suitable management directions, providing information on scientifically identified marine space usage (occupancy and use permits for shared waters and aquaculture farms), which are difficult to monitor directly. Aquaculture site detection using marine space monitoring technology follows a series of steps, including data collection and pre-processing, image segmentation and feature extraction, and change detection, as outlined in Table D3. Aquaculture site detection process using marine space monitoring technology. Figure D20 illustrates this overall approach by showing how satellite imagery can be used to detect changes in marine spatial utilization, such as aquaculture development, reclamation activities, and unauthorized marine space use.

Table D3. Aquaculture site detection process using marine space monitoring technology

Step	Description
Data collection and pre-processing	Collect satellite optical imagery, synthetic aperture radar imagery, aerial imagery, topographic maps, marine spatial databases (e.g. aquaculture farms, reclamation sites, occupancy permits)and perform pre-processing.
Image segmentation and feature extraction	Classify consulted and permitted zones, such as aquaculture farms, reclamation sites, and occupancy areas, according to the characteristics of information on specific objects within the imagery and extract their size, target, and shape information.
Change detection	Detect unused, illegally utilized aquaculture sites, reclamation areas, or occupancy zones by applying change detection techniques to periodic imagery and comparing it with the spatial database of currently authorized activities.

Source: **KIOST.** 2024. *Development of simulation technology for maritime spatial policy* (2022–2026 R&D project funded by the Ministry of Oceans and Fisheries, Republic of Korea)

Figure D20. Method for detecting changes in marine space utilization using satellite imagery

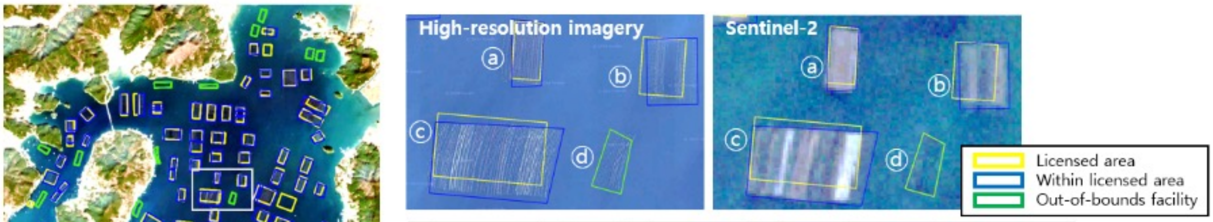


Source: **KIOST.** 2024. *Development of simulation technology for maritime spatial policy* (2022–2026 R&D project funded by the Ministry of Oceans and Fisheries, Republic of Korea).

Aquaculture detection information for decision-making support

By comparing aquaculture detection results with fishery data provided by government agencies, information can be generated such as the proportion of aquaculture facilities located outside of licensed areas, or those that have deviated from their permitted locations, which may facilitate aquaculture management decision-making. Figure D21 illustrates an example of such spatial comparison, where satellite imagery is used to assess the degree to which aquaculture facilities deviate from their officially licensed boundaries.

Figure D21. Comparison of licensed aquaculture areas and actual facility locations using satellite imagery



	Fishing method	Type of cultured species	License start date	License expiration date	Area (ha)	Satellite-detected area (ha)
ⓐ	Longline	Oyster	2018.05.17	2028.05.16	2	2.46
ⓑ	Longline	Oyster	2015.10.06	2025.10.05	3	4.09
ⓒ	Longline	Oyster	2004.06.29	2024.06.27	8.36	11.0
ⓓ	Out-of-bounds facility					1.87

Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

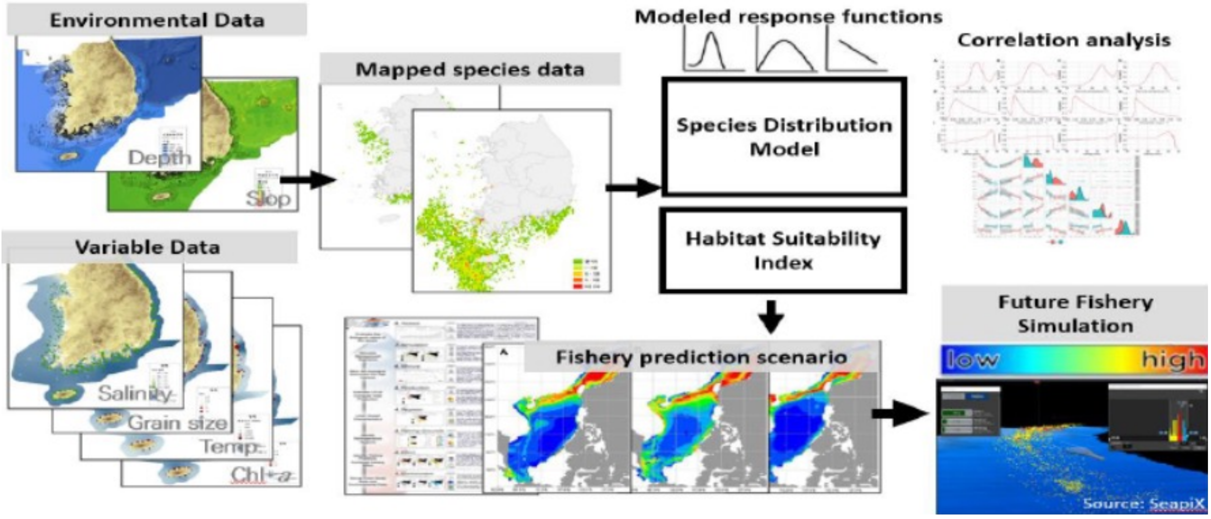
Source: **KIOST.** 2024. *Development of simulation technology for maritime spatial policy* (2022–2026 R&D project funded by the Ministry of Oceans and Fisheries, Republic of Korea)

Policy support for spatial management using fishery environment change prediction technology

Fishery activity protection zones in the Republic of Korea are currently designated under the Marine Spatial Management Plan based on factors such as licensed fishing areas, catch volume, and fishing vessel density. However, such an approach is limited because of its reliance on historical data, which does not account for future demands or predicted changes in the marine environment. To address this problem, KIOST is developing a simulator that will support fishery spatial management policy tasks such as evaluating and designating the suitability of fishery activity protection zones, predicting the suitability of fishing grounds, and assessing changes in fishing ground environments by predicting the distribution of current fishing grounds and future shifts in fishing grounds as a result of climate change across all waters.

The simulator generates fishery environment change scenarios based on the MaxEnt model that uses input variables, catch data, and climate change data. Species distribution maps and species abundance projections can be obtained based on various current and future scenarios (IPCC SSP1-2.6, SSP5-8.5). The contribution levels of various environmental factors (chlorophyll-a, dissolved oxygen, salinity, sea surface temperature) to catch volume can also be calculated for each species. Policymakers can use the range of scenario data produced by the simulator to inform marine spatial management tasks involving the fishery sector, including the designation of fishery activity protection zones or the assessment of fishing ground suitability. Figure D22 illustrates how the fishery environment change prediction simulator operates, showing the process of generating habitat suitability indices and future fishery scenarios based on environmental variables and species distribution data.

Figure D22. Workflow of the fishery environment change prediction simulator using environmental and species distribution data



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **KIOST.** 2024. *Development of simulation technology for maritime spatial policy* (2022–2026 R&D project funded by the Ministry of Oceans and Fisheries, Republic of Korea).

Aquaculture environmental assessment

License renewal or continuation decision after evaluating the environmental suitability of aquaculture zones. Eutrophication and self-pollution increase as a result of the long-term use of aquaculture sites concentrated along coastal areas; this in turn leads to the degradation of fishing grounds and reduced productivity. Assessing the environmental health of these aquaculture sites is essential for deciding whether to renew or maintain site licenses. To prevent environmental degradation, all aquaculture sites are assessed on their environmental conditions one year before license expiration and classified into four grades. Those sites that receive the two lowest grades for their poor environmental performance may have license extensions restricted and administrative actions taken to improve the aquaculture environment and relocate facilities. The environmental assessment of aquaculture sites is based on the benthic health index and total organic carbon measured from the samples collected from the area.

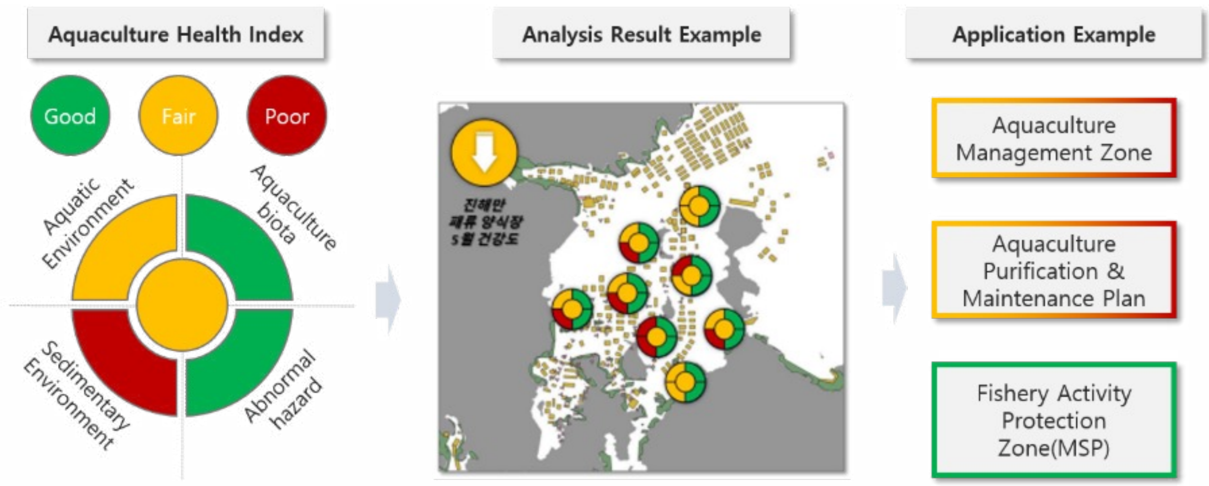
Aquaculture health index

Regular environmental monitoring is conducted at 273 points across 60 marine areas with high aquaculture density across the Republic of Korea, with assessment conducted on categories related to seawater, sediment, and marine organisms. The Aquaculture Health Index is used to assess ecosystem health based on this coastal environmental monitoring data to inform future site selection and fishery activity protection zone designation. It considers a range of factors, including water and sediment quality data, natural disaster occurrences that directly or indirectly impact aquaculture sites, and the presence of heavy metals and harmful substances within farmed marine organisms produced in each area. The results are classified into three grades of good, normal, and poor.

The Aquaculture Health Index evaluation can provide decision-making criteria particularly in placement of new aquaculture sites, or the designation/release of aquaculture management areas under an aquaculture development plan; and as foundational data for establishing clean-up and maintenance plans across all aquaculture regions. In addition, areas with sustained healthy aquaculture environments may be designated as fishery activity protection zones in the marine spatial plan. Figure D23 summarizes the structure and evaluation categories of the Aquaculture Health Index and illustrates how the results can be applied to spatial management decisions, such as designation of aquaculture management zones, purification plans, or fishery activity protection zones.

The Aquaculture Health Index system has currently been applied on a trial basis in selected waters with plans to revise aquaculture-related legislation and develop relevant assessment and management guidelines that would enhance the health assessment process and implement management actions based on the results.

Figure D23. Structure and application of the Aquaculture Health Index for spatial management decision-making



Note: Refer to the disclaimer on the copyright page for the names and boundaries used in this map.

Source: **KIOST.** 2024. *Final report on the study on institutionalization of aquaculture assessment system*. National Institute of Fisheries Science.

APPENDIX E – TERMS OF REFERENCE FOR EXPERT GROUPS WORKING ON PRIORITY AREAS

The expert workshop aims to create a detailed and well-structured roadmap that will provide technical guidance to help countries develop and apply spatial planning processes specifically for aquaculture planning. This will facilitate the allocation of space to aquaculture in a sustainable way, balancing environmental, economic, and social factors. This roadmap will be structured around priority areas, which will be identified during the workshop.

Each of these priority areas will be assigned to a group of experts, who will develop a detailed document (outlined in the "Deliverables" section below).

Objective:

Each expert group is tasked with developing strategic objectives (targets) for each assigned priority area. The groups will also identify the specific needs and potential actions/activities that should be undertaken at national and regional levels. Additionally, they will propose areas where technical assistance from FAO may be necessary.

The analyses and documents produced by each group will form the core content of the roadmap for marine spatial planning (MSP) in aquaculture.

Scope of work:

1. Define strategic objectives:

- Identify key challenges, opportunities, and existing gaps in relation to the given priority area – and considering, as far as possible, the global and regional contexts.
- Establish clear, measurable, and achievable strategic objectives for the given priority area. These strategic objectives should align with broader global frameworks (e.g. Agenda 2030) and regional goals, if any.
- Discuss and outline the specific needs required to achieve the strategic objectives. The following may be considered:
  - **Institutional needs:** what changes or improvements in governance, legal frameworks, or policies are needed?
  - **Technical needs:** what technical expertise, data, and innovative tools are necessary?
  - **Financial needs:** what financial resources or funding mechanisms are needed to support these objectives?
  - **Other relevant needs**

2. Propose actions/activities:

- List key and recommended actions and activities to adequately address the identified needs. These should be practical, feasible, and ranked according to priority.
- Actions should include both short- and long-term initiatives and may consider possible synergies with ongoing programmes and projects.
- Determine areas where FAO could provide technical assistance to support the achievement of the strategic objectives. This may include:
  - the development and dissemination of technical guidelines and best practices;
  - facilitation of regional or cross-border collaborations;
  - provision of expertise and advisory services; and
  - support with data collection, analysis, and the application of innovative tools.

Deliverables:

Priority area document:

- A detailed document outlining the strategic objectives (targets) for the given priority area, including a rationale and needs at national and regional levels.
- A clear and actionable plan of recommended activities, possibly including timelines, responsible parties, and, if possible or applicable, an assessment of required resources.
- Specific areas where FAO could provide support, indicating the type and scope of the assistance.

Presentation for plenary session:

- A summary presentation of the group's findings and proposals, to be delivered during the final plenary session.

Working methodology:

- Each group will have an appointed facilitator to lead the discussions
- Rapporteur(s) should be designated to report the group's discussions, decisions, and outcomes.
- The draft report of each priority area will be shared with the other groups for review and comments. This process will help to ensure consistency and alignment across all identified priority areas.
- Workshop experts will rotate between different groups to engage in discussions on the documents, provide feedback, and integrate perspectives from other priority areas.

APPENDIX F – CLOSING STATEMENT

Closing remarks by KwangSuk Oh, Senior Fishery Officer, FAO

Distinguished experts and colleagues,

First and foremost, I would like to express my sincere gratitude to everyone who made a strong commitment to achieving the objectives of this workshop. This workshop marked an important initial step towards defining aquaculture's role within broader spatial planning frameworks.

I would like to take a moment to reflect on what we've accomplished together over the past three days and consider the steps that lie ahead.

During our sessions, we focused on five key priority areas essential for effective spatial planning in aquaculture, and all participants consolidated them into draft documents for further development. Together, just now, we explored who, what, when, and how to take action to develop the roadmaps for these areas at both global and national levels, acknowledging the unique challenges and opportunities each region may face. Also, we recommended the development of a future FAO guidebook to support Members in taking action.

At this moment, we have made significant progress towards a shared understanding and outlined a collaborative path forward. FAO is committed to developing a comprehensive, practical guide to support Members implement spatial planning strategies for marine and inland aquaculture as well. In parallel, ISPRA will be leading the creation of a strategic roadmap. These efforts – the FAO guide and ISPRA's roadmap – are complementary, reinforcing each other to establish a strong foundation for spatial planning in aquaculture.

As we look to the future, it is essential to recognize the unique needs of marine and freshwater spatial planning. Marine spatial planning often manages open ecosystems, balancing multiple uses, such as fishing, tourism, and conservation, across broad areas. Freshwater spatial planning, in contrast, typically operates within more defined boundaries, where aquaculture must integrate with land-based activities, such as agriculture and urban development. These different contexts emphasize the need for tailored, context-specific approaches.

With aquaculture now surpassing traditional fisheries in global seafood production, as highlighted in recent SOFIA reports, the urgency to integrate aquaculture into broader spatial planning is clear. This is not only about supporting industry growth but ensuring aquaculture's contributions to food security, conservation, and the blue economy.

Finally, I would like to extend my sincere gratitude to each of you for your time, insights, and expertise. Your contributions have made this workshop a success and established a strong foundation for the critical work ahead. I hope we see you again in the near future. Have a safe trip home.

Thank you very much.

This report summarizes the presentations, discussions, conclusions, and recommendations from the Expert workshop on spatial management for marine aquaculture planning: defining needs for assisting countries, held in Rome from 29 to 31 October 2024. This workshop addressed challenges in integrating aquaculture into marine spatial planning through discussions organized around five priority areas: i) governance and institutional frameworks; ii) knowledge support for spatial planning in aquaculture; iii) criteria and guiding elements for spatial allocation; iv) capacity building and awareness; and v) marine conservation and restoration. Invited experts shared global best practices and case studies from six continents, highlighting diverse approaches and tools. Key outcomes included identified strategic objectives and practical actions for effectively integrating aquaculture into spatial planning.

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