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MARBEFES Project

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Executive Summary

This Deliverable presents the outcomes of the MARBEFES out-scaling exercise, which 1) applied the WP1 model of stakeholder engagement approaches to gain insights into stakeholder perspectives and 2) tested the transferability of the tools and from European case studies to two contrasting marine regions: Martinique (Caribbean) and the Romanian Black Sea coast. The objective was to evaluate whether the WP1 model can provide relevant insights into the local context, and whether the biodiversity Toolbox methods remain relevant and effective when applied in ecological, governance, and socio-economic contexts that differ from the original European case study sites.

In the first part, the study applied the WP1 model, which combined stakeholder consultations, Fuzzy Cognitive Mapping, governance and Marine Protected Area (MPA) assessments, and second, the testing of selected MARBEFES tools, including Bow-Tie Analysis, Scenario Downscaling, Ecological Value Assessment (EVA), Habitat Function Metric (HFM), and other biodiversity assessment approaches.

Results showed that the WP1 model could provide a relevant local lense and insights into the local governance and MPA perceptions of stakeholders. Stakeholders in Martinique placed particular emphasis on local governance, awareness and knowledge, habitat conservation, and land-sea interactions, while Romanian stakeholders highlighted national governance, institutional complexity, bureaucracy, monitoring gaps, and regulatory implementation. In both regions, stronger stakeholder engagement, improved communication, better access to knowledge, and more effective governance emerged as key prerequisites for successful biodiversity management and marine spatial planning.

The out-scaling exercise of the MARBEFES toolbox and methods confirmed that the MARBEFES methodologies and tools are broadly transferable and capable of generating relevant insights beyond their original development context. However, the testing also revealed the importance of adapting tools to local context, improving guidance materials and simplifying implementation procedures.

Overall, the deliverable demonstrates that successful out-scaling relies on balancing methodological consistency with local adaptability. The experience gained in Martinique and Romania validates the robustness of the MARBEFES Biodiversity Toolbox while providing valuable recommendations for its future application in diverse marine ecosystems and governance systems.

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List of Abbreviations

BBT – Broad Belt Transect, i.e. the name of the case study sites in MARBEFES

DAPSI(W)R(M) – Drivers-Activities-Pressures-State-Impacts (on human Welfare)-Responses (Measures)

EEZ – Exclusive Economic Zone

EU – European Union

EVA – Ecological Value Assessment

FCM – Fuzzy Cognitive Mapping

HFM – Habitat Function Metric

MARBEFES – MARine Biodiversity and Ecosystem Functioning leading to Ecosystem Services

MPA – Marine Protected Area

PESTEL framework – Political, Economic, Social, Technological, Environmental, Legal

Deliverable 6.3 Position-document on lessons learned from overseas

Introduction

Methods and analytical tools for assessing marine biodiversity and its governance are often developed within specific regional and institutional settings, raising questions about their broader applicability in diverse global contexts. In this work, we examine the out-scaling of the biodiversity toolbox by testing its tools developed by and for European case studies (BBTs) in different European (Romania) and non-European (Martinique) marine systems in the Caribbean and the Black Sea. These regions differ from the European BBTs in their ecological, socio-political, and governance characteristics, offering a robust testing ground for evaluating tool relevance and adaptability.
Hence, the objective of this deliverable is to transfer engagement approaches to provide a status overview of existing policy and governance needs and challenges from the case study areas in the Black Sea (Romania) and Martinique (Caribbean France) to better understand the governance context through a local lense. It also outlines the applicability and adaptability of parts of the Biodiversity Toolbox and Handbooks in the context of these study areas. Finally, the Lessons learned from the out-scaling experience in the case study areas are discussed.

Background and Rationale

Generally, out-scaling can be understood as the process of "*impacting greater numbers through replication*" (Moore et al., 2015), sometimes also referred to as "*amplification*" (Lam et al., 2020). In this report, we use the term out-scaling to refer to the process of transferring a method or tool from its original context to a new setting and adapting it as needed to ensure relevance and functionality. Prior research on cross-context methodological transfer highlights that tools developed in one region often embed implicit assumptions about governance structures, data availability, stakeholder engagement practices, and environmental conditions. When such tools are applied in different settings, particularly those characterized by distinct institutional capacities, cultural norms, or ecological dynamics, these assumptions may not hold, potentially affecting both their applicability and interpretability (Hermans et al., 2016). Scholarship in governance research, sustainability science, and innovation transfer emphasizes the importance of examining context sensitivity and adaptability to ensure methods remain robust beyond their region of origin (Moore et al., 2015). Out-scaling thus assumes that some elements of an intervention or practice are sufficiently generalizable to transfer across contexts, an assumption that must be tested against context-dependent emergence (Lam et al., 2020). This understanding provides the rationale for out-scaling the European-developed engagement methods and biodiversity tools to the Caribbean and Black Sea contexts and to draw some lesson-learned from the experiences.

BBTs as a baseline

The European case study sites (BBTs) span a wide range of marine environments—from Arctic fjords to temperate coastal seas and semi-enclosed basins—providing a diverse baseline for evaluating biodiversity tools. The **Arctic sites** (Porsanger Fjord–Barents Sea, South and North Spitsbergen) are characterized by oceanic salinity, deep fjord geomorphology, and moderate biodiversity, with dominant activities including fishing, tourism, research, and in some areas oil and gas operations. In contrast, the **Baltic Sea sites** (Finnish Archipelago, Curonian Lagoon–Lithuanian Coast, Gulf of Gdańsk) represent shallow, brackish, and highly enclosed systems with generally low biodiversity. These areas support mixed-use coastal economies centred on tourism, fishery, and shipping, shaped by the Baltic's unique salinity gradient and restricted water exchange. The **Atlantic sites** (Belgium–Dogger Bank, Liverpool–Dublin Bay, Southern Gulf of Biscay) comprise mainly open coastal and channel environments with moderate biodiversity, influenced by intensive maritime traffic, fisheries, wind-energy development, and urban pressures. Finally, the **Mediterranean sites** (Balearic Islands, Sardinia, Gulf of Heraklion) feature high biodiversity and oceanic conditions in coastal-sea settings, where tourism, fisheries, aquaculture, and shipping are the predominant activities. Together, these regions capture a broad spectrum of bio-ecological settings and provide a rich reference baseline for assessing the out-scaling of the MARBEFES tools to different contexts and ecosystems.

Out-scaling case study areas: Romania and Martinique

The Caribbean and Black Sea contexts present a broader range of socio-ecological conditions. Ecologically, the Caribbean's tropical marine systems and the Black Sea's semi-enclosed basin dynamics differ markedly from European temperate waters, shaping both biodiversity pressures and management priorities.

The limited extent of the oxic layer in the **Black Sea** supports lower species richness and biological production compared to other European seas, resulting in higher functional vulnerability than in other European temperate marine systems. The socio-economic context of the Black Sea is largely structured around resource-dependent activities such as fisheries, maritime transport, coastal tourism, and energy transit, in parallel with major offshore energy projects, with the potential to strengthen economic diversification and energy security in the future. However, these socio-economic strides occur within an ecological context of environmental sensitivity, shaping policy priorities that often lead to social and economic conflicts and ecological strain.

Martinique is a small volcanic island in the Lesser Antilles and one of the EU's outermost regions, located between the Atlantic Ocean and the Caribbean Sea. Despite its limited land area (1,128 km²), it concentrates relatively high population density, urbanisation, agriculture, quarrying activities, and tourism, with strong pressure on the coastal zone. Over the past decades, demographic growth, coastal development, banana and sugarcane agriculture, high fertiliser and pesticide use, and historically insufficient wastewater treatment have increased sediment, nutrient, and pollutant inputs to nearshore waters.

These land-based pressures have contributed to the long-term degradation of coastal marine ecosystems, particularly coral reefs, which have shifted in many places from coral-dominated to macroalgae-dominated states. This decline has been driven by eutrophication, overfishing, and habitat disturbance, and has been further amplified in recent years by climate-related and regional stressors such as marine heatwaves and bleaching, hurricanes, coral diseases, and mass sea-urchin mortality. Together, these cumulative pressures have reduced coral cover, ecosystem resilience, and the functional integrity of marine habitats.

Martinique nevertheless hosts a highly valuable mosaic of coastal ecosystems, including coral reefs, seagrass beds, mangroves, algal communities, sponge and gorgonian assemblages, and extensive unconsolidated sea beds. These ecosystems support biodiversity, fisheries, recreation and tourism, while also providing essential regulating services such as coastal protection, carbon sequestration, fish biomass production, and water purification. Their total annual economic value has been estimated at around €250 million/year, with a substantial share linked to indirect ecosystem services.
Knowledge of these ecosystems has improved through mapping campaigns and monitoring programs since the 2000s, and this contributed to the establishment of the Martinique Marine Natural Park in 2017, covering the island's entire EEZ. However, existing ecological monitoring remains spatially limited and does not fully capture the condition and functional capacity of reefs and associated habitats across the island. In this context, Martinique is a highly relevant case study for MARBEFES, as it illustrates the challenges faced by outermost island territories where intense land–sea interactions, multiple cumulative pressures, and climate vulnerability require spatially explicit, functional, and ecosystem-based assessment tools to support conservation and management.

Methodology

This section provides an overview with brief descriptions of the methods of the WP1 model that were used to gain insights into the policy and governance landscape; and the tools of the biodiversity toolbox that were pilot tested to evaluate the adaptability and applicability in the two out-scaling case study sites.

Mapping Socio-ecological system perspectives

To map the perceptions of stakeholders on their Socio-Ecological environment, in both Romania and Martinique, the technique of Fuzzy Cognitive Mapping (FCM) was used (Kosko, 1986, Hummel *et al.*, 2022). The details of the method used in the MARBEFES project has been described extensively in Hummel *et al.* (2023). In short, all elements, i.e., factors, actors, or processes, being perceived important by the stakeholder are depicted in diagrams as nodes that are connected with arrows showing the direction and strength of influence between the elements as perceived by the interviewed stakeholder (see example in Fig. 1, adopted from Hummel et al 2022)

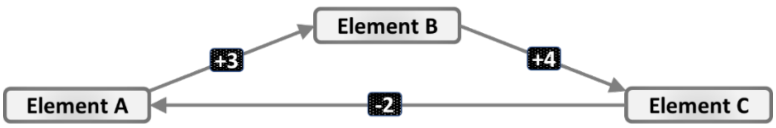

Figure 1: An example of the Fuzzy Cognitive Model whereby Elements such as factors (e.g. fish), actors (e.g. policies) or processes (e.g. eutrophication) form nodes in the diagram. Related Elements are connected with arrows (vectors) showing the direction and strength of influence between these Elements. The values of the vectors (ranging from -5 to +5) indicate the strength of the influence. An arrow with a positive value pointing from element A to element B indicates that element A increases or stimulates element B, and a negative arrow from element C to element A indicates that element C decreases element A. In this example a feed-back mechanism can be seen as element A increases element B which increases element C, which in turn decreases element A.

All interviews were performed in English by HuFoSS colleagues, with one stakeholder at a time, though more representatives per stakeholder were possible, together with one representative of GeoEcoMar (Romania) or Nova Blue Environment (Martinique) in case translation of/in the local language was needed. The duration of the interview was each time about 1 hour.

In the first phase of the interview the stakeholder was allowed to speak freely for about 10 to 15 minutes on the balance between the ecology (nature), economy, and society in their coastal area, and what the pressures are on this balance, without any interference by the interviewer. The interviewer in the meantime made notes on the factors, variables, actors, or processes, further to be called the elements, that were perceived by the stakeholders to be important.

In the second phase of the interview the stakeholders were asked to link the elements that influence each other and rate the strength of these relationships. The strength of the relationships could be more or less positive or negative (-5 to +5). The strength and direction of the dependencies and influences between the elements (that were written on magnetic cards) were mapped on a large (magnetic) poster. Thereby the interview resulted in a mind map that depicts what the stakeholder perceives as the key issues at play in their coastal area (Figure 2).

Since different stakeholders used various synonyms for factually similar elements in their FCM diagrams, these elements were harmonised. For example, biodiversity, species diversity, and species, were all called biodiversity.

On basis of the harmonised elements the following indices were calculated to characterise the stakeholder's FCM networks, and to indicate the most important elements and vectors, at a location:

- The frequency of an element mentioned by stakeholders in an area
- The total number of vectors per element
- The total (absolute, negative, positive) strength of the vectors per element
- The frequency of a specific combination (pair) of elements
- The sum of the strength of the connections between a specific combination of elements.

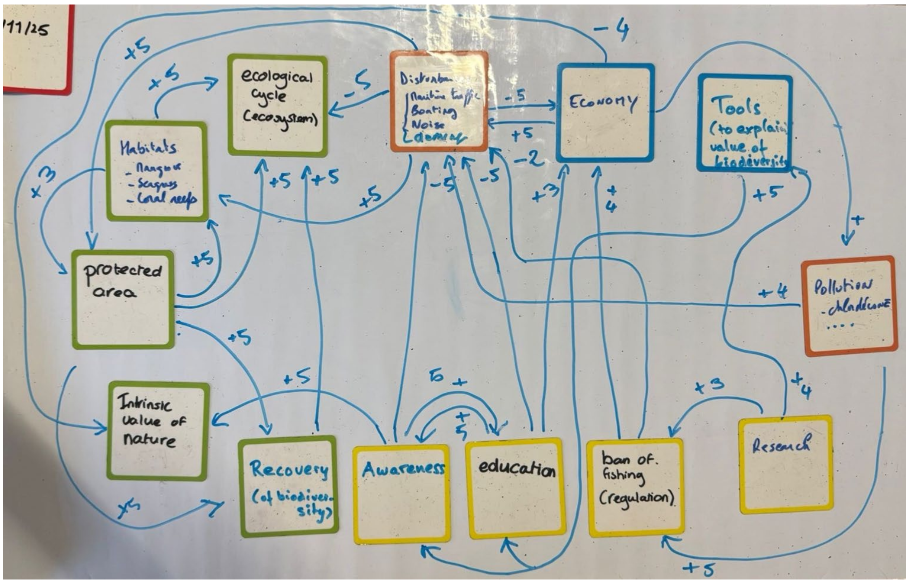

Figure 2. Example of a FCM network composed by a stakeholder of Martinique, in this specific case resulting in a mind-map with 13 elements and many more interactions (vectors) between the elements.

Identifying biodiversity governance and marine spatial planning needs and challenges

To collect stakeholders' perspectives on marine biodiversity governance and Marine Protected Areas (MPAs) stakeholders were consulted through workshops. Both for Martinique and Romania, stakeholders involved in the marine and coastal environment were identified by the research partner Nova Blue Environment and GeoEcoMar respectively. Stakeholders were categorized into four main groups:

- **Governance representatives** (e.g., municipal, regional, or national authorities)
- **Industry and commerce actors** (e.g., fisheries, tourism, shipping, or marine energy sectors)
- **Education and research institutions** (e.g., universities, marine research centres, or local knowledge experts)
- **Civil society organizations** (e.g., NGOs, community groups, or citizen initiatives).

Data collection

For data collection, digital workshops of one-hour were conducted. For Martinique, all workshops were held in French by Akvaplan-niva while one representative of Nova Blue Environment was also present as a neutral observer. For Romania, all workshops were held in English by Akvaplan-niva while two representatives of GeoEcoMar were present as neutral observers. The workshops had three main objectives:

- Objective 1: To collect the stakeholders' **challenges and obstacles** regarding the governance of marine biodiversity and of marine protected areas.
- Objective 2: To collect the **objectives and long-term visions** regarding those identified challenges.
- Objective 3: To collect the concrete **needs and interventions** to achieve the named objectives.

The online workshops followed a structured procedure. First, the moderator and stakeholders briefly introduced themselves, followed by an overview of the EU MARBEFES project and the objectives of the workshop. Then the workshop was split into two sessions: first, a session to collect stakeholders' perspectives on marine biodiversity governance, followed by a short session to collect perspectives on marine protected areas. The session on marine biodiversity governance addressed predefined questions aligned with the study objectives. Stakeholders first identified key governance challenges in their respective areas. Based on these challenges, they then formulated long-term visions and proposed interventions to achieve them. Stakeholders’ inputs were collected using the online platform Canva and displayed on a shared screen throughout the workshop.

The session on marine protected areas (MPAs) followed the same format, using the three guiding questions on challenges, visions, and interventions. All contributions and discussions were documented in Canva.

Ethical considerations: All workshop participants were informed about data use and confidentiality. Consent forms were distributed during the workshop, and signed copies were subsequently collected.

Data analysis:

To categorize the types of interventions proposed by stakeholders, we applied the PESTEL analytical framework, which encompasses six macro-level domains: Political, Economic, Social, Technological, Environmental, and Legal. Originally introduced by Aguilar in 1967 as the PEST model (Aguilar, 1967), the framework was later expanded to include Environmental and Legal dimensions to better capture the complexity of strategic decision-making contexts (Bitoun et al., 2023; Mahadiansar et al., 2023). PESTEL analysis is widely used in strategic and systems analysis to assess external influences on institutions, sectors, or regions. In this study, it served as a structured lens through which to classify and compare the stakeholder-identified interventions. Each proposed intervention was reviewed and coded into one or more of the PESTEL categories, depending on its primary focus. For instance, a call for stronger regulatory enforcement was categorized under “Legal,” while suggestions for improved marine monitoring technologies were assigned to “Technological.” An overview of the analytical framework applied and the coding structure used is provided in Table 1.

Table 1: Analytical PESTEL framework that was applied to categorize the intervention types of the pathways suggested by stakeholders (adapted from Aguilar, 1967).

Component	**Definition and intervention type**
Political	Governmental decisions and public policies Changing policy or coordination mechanism
Economical	Impacts of economic structures and trends Using financial mechanisms or market-based tools
Sociocultural	Social, demographic, cultural norms and education level Changing behaviour, awareness, social norms or social structures
Technological	Technological innovations Using new technologies, artificial intelligence, technology infrastructure
Environmental	Climate policies and sustainability initiatives Aiming to restore or protect natural systems
Legal	Legislative, legal and regulatory regulations Changing laws

Further data analysis was conducted using RStudio Version 2025.9.2.418 (Posit Team, 2025), complemented with manual qualitative analysis of the data.

Regarding the MPAs session, the challenges provided by stakeholders were later classified into eight categories. Each challenge has been categorised into overarching challenge domains related to MPA identification, design and implementation:

- Data Availability and Quality
- Stakeholder Conflicts
- Ecological connectivity
- Ecosystem Representation
- Enforcement, Conformity and Regulation
- Community Engagement

- Funding and Resources
- Management

Tool out-scaling

This section describes the various tools that have been out-scaled. These tools have been first developed and tested in the various BBTs before being tested in the Black Sea in Romania and in Martinique.
A list of the tools tested in Romania and Martinique is presented in Table 2.

Table 2: Overview of tools out-scaled and tested in Martinique and Romania.

Tool name	Martinique	Romania
Bow-tie analysis	Tested	Tested
EVA (Ecological Value Assessment)	Tested	Tested
DAPSI(W)R(M)	Tested	n/a
Ecological Interaction Networks	In progress	n/a
Metric of habitat function	Tested	n/a
Structured surveys	Tested	n/a
Scenario downscaling	Tested	n/a
Broad-scale trait-based approaches	In progress	n/a

Tool descriptions:
A brief description, purpose and expected outcomes of each tool that has been out-scaled is described below.

The Bow-tie analysis
Expectation of the tool by the tool developers:

- *Purpose of the tool*: For all marine areas in which there is a defined central concern (such as the loss of biodiversity), the causes of that loss and the resulting consequences, and the prevention and mitigation measures that can be put in place to minimise or prevent the consequences.
- *Expected outcome*: A rigorous risk assessment and risk management framework, built to ISO standards, which can also be used as opportunity assessment and management; a framework which can then be developed further such as with Bayesian Belief Network Modelling; it can be used in scenario testing (to show the results of various options).

EVA (Ecological Value Assessment)
Expectation of the tool by the tool developers:

- *Purpose of the tool: Ecology:* Providing a spatial assessment of the ecosystem within an area based on the inherent ecological value of its biodiversity components.
- *Expected outcome:* Ability to identify subareas with higher ecological value thus informing greater-than-usual degree of risk aversion in spatial planning in those areas.

DAPSI(W)R(M)

Expectation of the tool by the tool developers:

- *Purpose of the tool:* It gives the cause-consequence-response pathway for addressing a problem resulting in the degradation of biodiversity in an area.
- *Expected outcome:* A conceptual model of the cause-consequence-response sequence which can then be quantified as necessary; it gives the ability to tackle the effects of activities and pressures on natural and human attributes of the system; it is also the starting point of Bow-Tie diagrams in which the D, A, P are the causes, the S and I(W) are the main problem and the consequences, and the R(M) are the prevention and mitigation measures stopping the causes creating consequences.

Ecological Interaction Networks

Expectation of the tool by the tool developers:

- *Purpose of the tool:* To describe diversity (food web structure) and ecosystem function (trophic transfer). Application of general food web knowledge varies strongly, from formalized integration in management decisions, to support in selecting indicators and setting threshold values, to informal knowledge explaining ecosystem dynamics and management performance.
- *Expected outcome:* Spatial/temporal descriptions of communities

Metric of habitat function

Expectation of the tool by the tool developers:

- *Purpose of the tool*: Identify the spatial extent of ecological functions in the BBT and areas with high/low potential
- *Expected outcome*: Map of potential for ecological functions in the BBT

Structured surveys

Expectation of the tool by the tool developers:

- *Purpose of the tool:* 1) To obtain the perception of stakeholders on most important socio-economic and ecological variables in their area, 2) To direct other WPs and tasks within those WPs with their building of tools towards the most important socio-economic and ecological variables in an area, 3) to be informed on major shared issues in their area and to give feedback once informed on the tools produced with their help.
- *Expected outcome:* Indirectly, thus, the other WPs should integrate WP1s outputs into all other tools.

Scenario downscaling

Expectation of the tool by the tool developer:

- *Purpose of the tool*: To imagine the changes in biodiversity and ecosystem variables under a range of possible future societal conditions
- *Expected outcome:* Matrix of scores for direction and strength of changes in biodiversity and society variables under different possible futures

Broad-scale trait-based approaches

Expectation of the tool by the tool developers:

- *Purpose of the tool:* 1) To evaluate structural biodiversity (traits) change e.g. between impacted and non-impacted areas, along biodiversity or geographic gradients. 2) To mechanistically assess changes in functions within habitats, BBTs or across regions.
- *Expected outcome:* Various outcomes, such as trait matrices, trait distributions, trait maps, multivariate analysis data.

Tool evaluation:
To assess the adaptability and applicability of the tools, feedback has been collected through an evaluation scheme, which was circulated among the research partners GeoEcoMar and Nova Blue Environment, in Romania and Martinique respectively. The evaluation scheme is presented in Table 3.

Table 3: Tool evaluation scheme for tool testers in Martinique and Romania.

How easy was the guidance to understand and follow?	Scale from 1-5, from very easy (1) to very hard (5)
How much time does the implementation take?	Few days / Weeks / Months
Can the tool be used by non-scientists?	Yes / No / With guidance
Do you see the application of the tool relevant regarding the issues in your BBT?	Yes / Potentially Yes / No
What is the main obstacle for the implementation of this tool?	Short answer in free text

Results Martinique

Socio-ecological system perspectives

The stakeholders in Martinique indicated "Awareness & Knowledge, "Local governance" and "Habitats" as most important elements influencing the balance between the nature, economic and socio-cultural issues in their coastal environment (Table 4). These elements belonged also among the highest scoring for all Europe.
These important elements do appear also most frequently and with the highest strength in the connections between elements (Table 5)

Table 4. The most important elements out of 67 in the coastal environment of Martinique, according the 13 interviewed stakeholders (after Van der Vliet et al. 2026)

Elements (67 in 13 interviews)	Times mentioned (%)	Total connections	Power of connections
Awareness & Knowledge	92	38	183
Local governance	85	24	97
Habitats	85	40	171

Economy	77	18	84
Local rules and regulations	77	30	119
Pollution	77	24	124
Research	69	17	61
Sanitation	69	18	82
Ecological dynamics	62	19	75
Small scale tourism	54	24	82
Biodiversity	54	27	131
Local fisheries	46	19	75
Education	46	13	71
Protected areas	46	20	80
Natural hazards (sedimentation)	46	19	68
Strategic plans	46	19	74
Collaboration	46	15	58
Orange cells: Elements for which Martinique is among highest scoring in all Europe. Other colors indicate the most important elements according the criteria given in the Material and Methods (see also Hummel et al. 2023)			

Table 5. The most important connections between elements in the coastal environment of Martinique, according to the interviewed stakeholders (after Van der Vliet et al. 2026)

Sending elements	Receiving elements	Frequency	Strength
Education	Awareness & Knowledge	3	15
Local governance	Strategic plans	3	15
Awareness & Knowledge	Intrinsic value of Nature	3	10
Local fisheries	Economy	3	10
Agriculture	Pollution	2	10
Awareness & Knowledge	Political trust & Good governance	2	10
Communication	Awareness & Knowledge	2	10
Staff & Equipment	Habitats	2	10
Protected areas	Small scale tourism	2	9
Sanitation	Biodiversity	2	9
Climate change	Natural hazards	2	8
Large scale tourism	Economy	2	8
Protected areas	Habitats	2	8
Respect	Urbanisation & Coastal development	2	8
Disturbance	Habitats	3	-4
Small scale tourism	Biodiversity	3	-6
Local governance	Sanitation	2	-8
Sanitation	Pollution	2	-8
Cultural heritage & Traditions	Local rules and regulations	2	-10
Disturbance	Ecological dynamics	2	-10
Habitats	Erosion	2	-10
Pollution	Local fisheries	3	-12
Pollution	Habitats	3	-14

Fisheries and Tourism, promoted by the protected areas, are seen as factors promoting the economy of the island. Yet, the stakeholders are aware that tourism may also have a negative impact on the biodiversity of the area.

Negative impacts are seen also from pollution and disturbances on the nature, i.e. habitats and ecological dynamics, and on the local fisheries. The stakeholders feel that the governance has to act more through sanitation, and put more staff on this topic, which would help to improve the biodiversity at the island.

Regarding governance their focus is on the Local governance that has a positive impact on strategic plans for the island. However, the implementation of local rules and regulations are hampered by local traditions. The focus on local governance is a trend also found in general for other European oceanic islands, whereas at the European mainland national governance is judged more important.

In addition, the stakeholders emphasised the important roles of Education and Communication that may have a positive impact on the Awareness and Knowledge in their society, which in its turn has a positive impact on their opinion about the value of nature.

Marine biodiversity governance challenges and needs

Most common challenge domains in Martinique:

Main challenges related to marine biodiversity governance in Martinique according to stakeholders are presented in Figure 3.

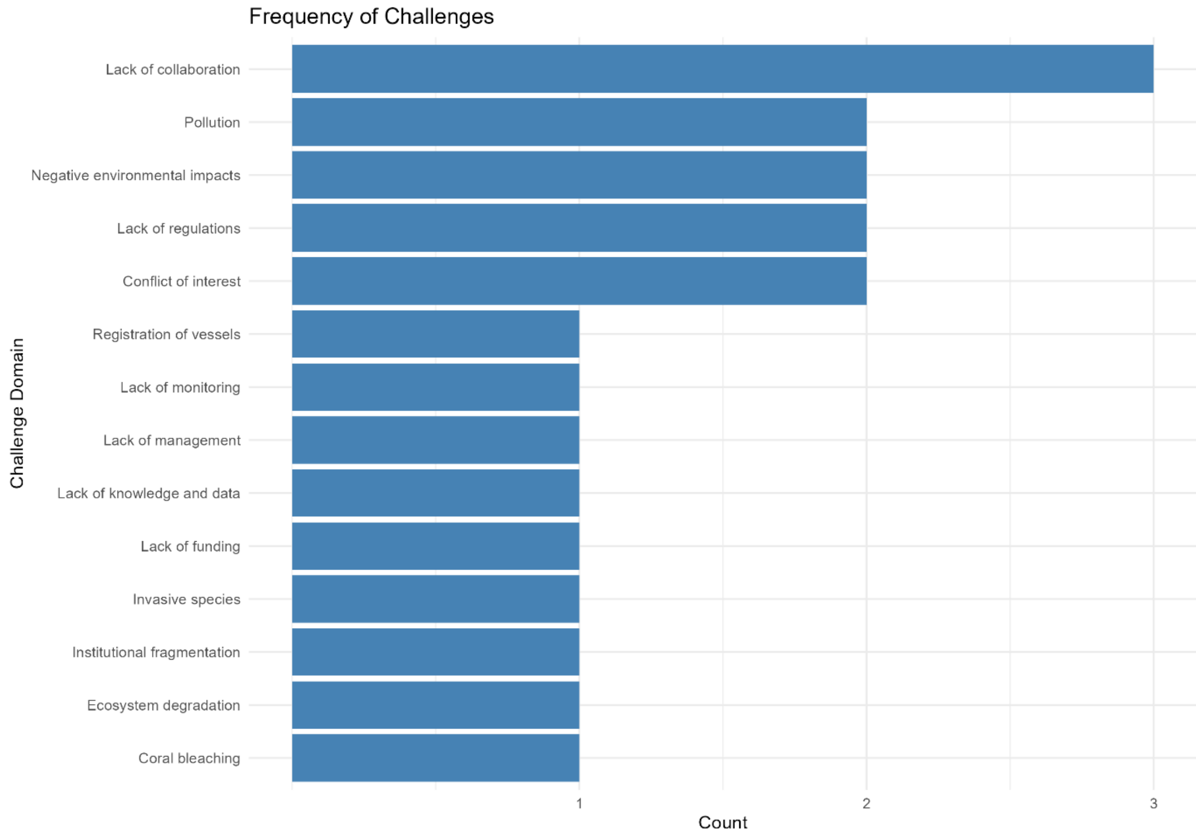

Figure 3: Frequency of the most common challenge domains

The most prominent challenge is the lack of collaboration. Stakeholders pinpointed the governance complexity composed by a multiplicity of actors that hardly coordinate efficiently. This institutional fragmentation can lead to political and administrative inertia while the marine ecosystems face increasing degradation. In addition, stakeholders underlined the issue regarding the lack of knowledge transfer between the various scientific and administrative organisations.

Another challenge highlighted by most of the stakeholders is pollution, which includes several sub-themes. First, Martinique faces water treatment problems with too little common treatment of waste and grey water, which ends up to sea pollution. The land-sea continuum also implies sea pollution by agricultural pollutants, and plastic pollution remain an important problem for marine life in Martinique.

Equally pinpointed were negative environmental impacts and conflict of interest. Indeed, despite all Martinique's seas being included in the "Parc naturel marin de la Martinique" since 2017, a lot of actors and activities are at stake. Stakeholders thus underlined the hard conciliation between fisheries, port activities, tourism, local recreational water users, mooring areas and marine conservation activities.

Lack of regulations is another challenge, which has been linked by stakeholders to the challenge of registration and declaration of all vessels.

Last but not least, stakeholders emphasized other challenges such as the lack of funding, monitoring, management, knowledge and data, as well as global pressures on marine ecosystems, including climate change, sea level rise, new diseases, invasive species and the phenomenon of coral bleaching.

Most common intervention domains in Martinique:

The most common intervention types suggested by stakeholders included political and sociocultural interventions. The most common scale on where the intervention should be applied was the local scale (Figure 4). Examples of the interventions named under each type of intervention are provided below.

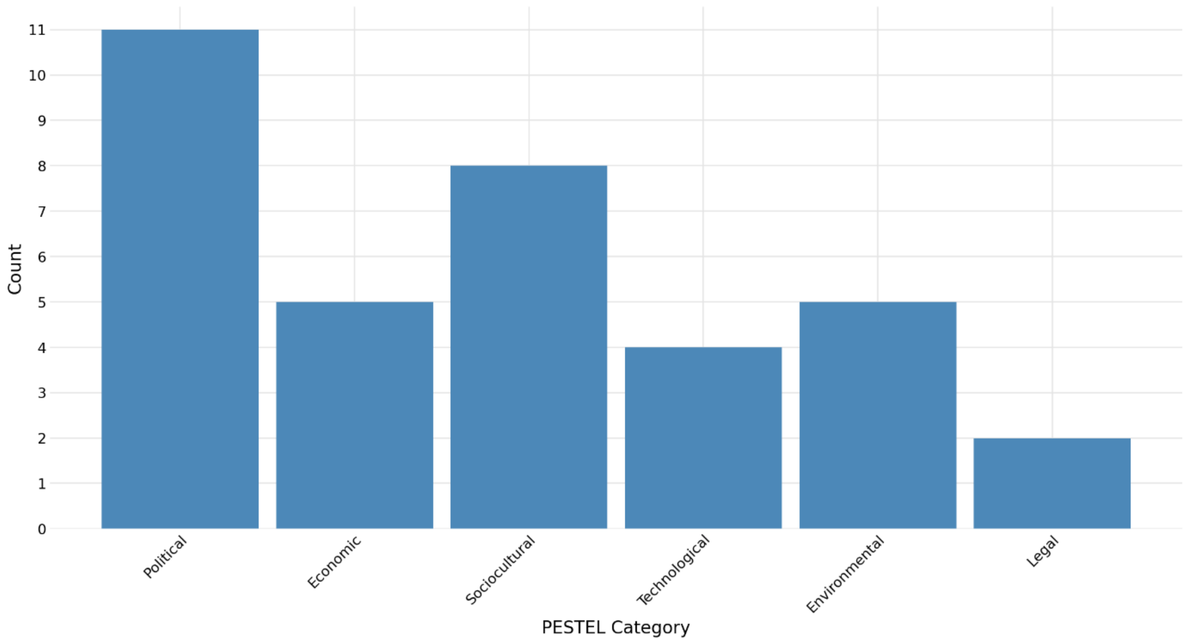

Figure 4: Frequency of intervention counts and scale per intervention type according to PESTEL.

Political interventions: A re-occurring theme was the need for inclusive decision-making through extensive consultation of the various sectors and actors, both residents and users of the sea. The need of direct communication with local representatives and better communication systems from the Directorate of the Sea were also underlined. In addition, strategy and plans for monitoring anchorage and mooring areas are required.

Sociocultural interventions: Stakeholders highlighted the need for increasing awareness on the marine biodiversity issues. Concretely, they proposed training for elected representatives on the issues at stake but also training for experts to be able to disseminate knowledge. L'IFRECOR newsletter was given as a great example of communication. Regarding the grey water pollution, some stakeholders asked for some campaign to raise awareness on septic tanks. Finally, the diving club could also play a positive role, by raising awareness and communicate about marine biodiversity importance.

Environmental interventions: Marine ecosystem restoration was a re-occurring theme, including the need to attempt coral transplantation, even if these operations are complex. Launching more specific micro-projects could potentially have more positive impacts than long-term projects with too vast and vague ambition.

Economical interventions: Financial support and human resources mainly in public institutes are necessary according to some of the stakeholders.

Technological interventions: This mainly applied for the need of renovation and installation of cost-efficient water-treatment plans, which goes hand-in-hand with political willingness. In addition, usable and shared databases were propositions that emerged from a few stakeholders.

Legal interventions: Closely linked to the governance complexity and lack of collaboration between actors, the need of combining efforts and resources through legal plans was highlighted.

Most common vision domains in Martinique:

Main visions proposed by stakeholders in Martinique are presented in Figure 5.

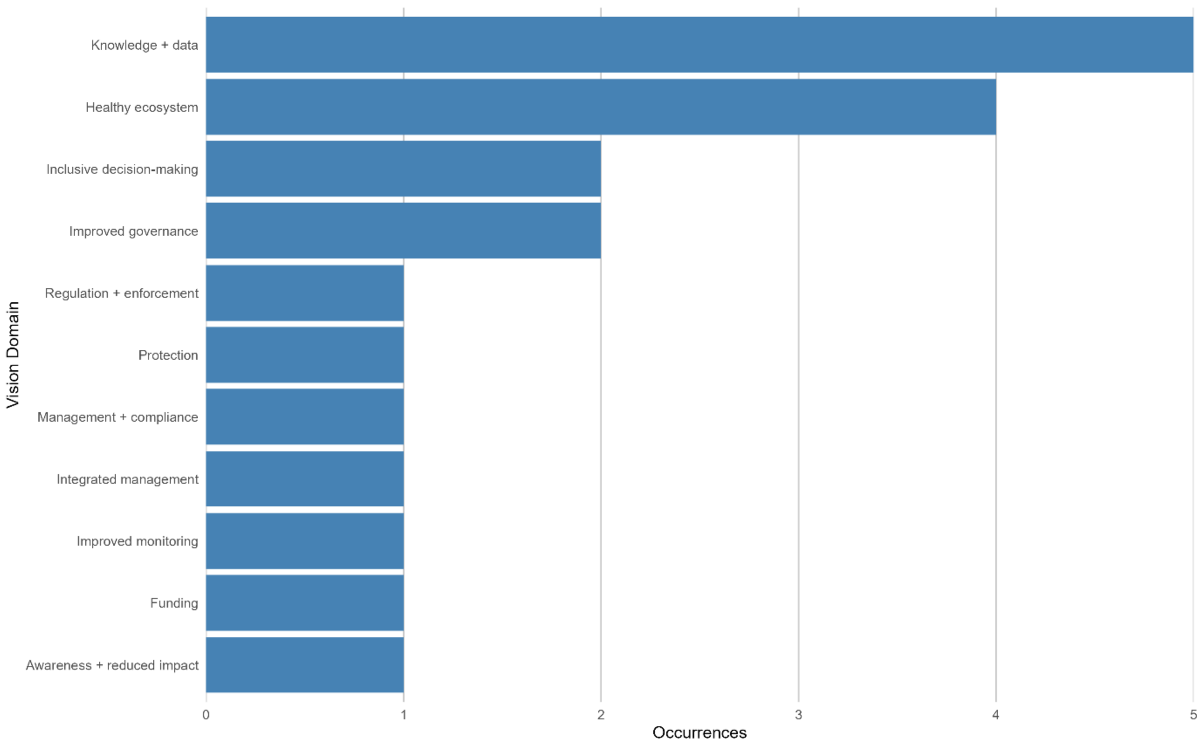

Figure 5. Frequency of vision domains regarding marine biodiversity governance in Martinique.

Stakeholders most frequently envisioned more knowledge and data, namely through a governance system that facilitates information to flow efficiently for knowledge-based decision-making and more long-term information monitoring. They emphasize the importance of making the scientific knowledge a political priority and the use of measurable indicators. Another vision frequently provided was healthy marine ecosystems. Preservation and increase of fish stocks, reduction of invasive toxic species, and healthy coral reefs were all desirable objectives proposed by stakeholders. In addition, they equally quoted inclusive decision-making and improved governance with consultation of all interested parties at each step of various projects and shared monitoring systems for the various marine scientific stations. Finally, other visions were formulated such as regulation and enforcement, protection, integrated management, improved monitoring, fundings and awareness.

Marine spatial planning challenges and MPA needs

Most common challenge domains in Martinique:

The challenge domains highlighted by stakeholders regarding MPAs in Martinique are presented in Figure 6.

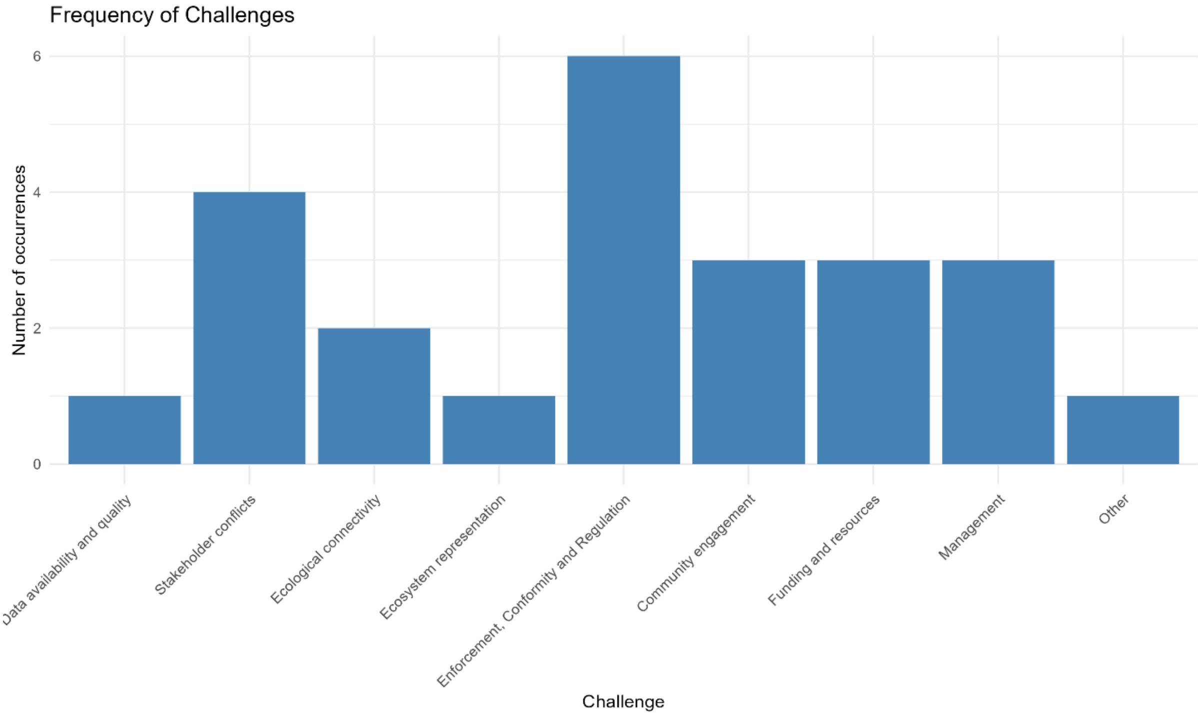

Figure 6: Frequency of the most common challenges in regard to MPAs in Martinique.

Most frequently mentioned was the challenge of enforcement, conformity, and regulation related to MPAs. Several factors come into play, namely the complexity of protection types, status and tools which are perceived as confusing even for informed professionals. In addition, several stakeholders pinpointed the gap between protection "on paper" and their concrete application. They gave the example of some fishing reserves which are clearly regulated, while in practice all activities are tolerated. The perceived lack of resources for surveillance and control reinforced this lack of MPA's compliance.

The second most prominent challenge named by stakeholders was stakeholder conflict, due to the numerous activities and interested parties at stake on Martinique sea. A person gave the example of a coral reintroduction project, located in a municipality that had a concerted marine area project to reconcile the different marine uses. The project nevertheless remained an empty shell because of political conflicts. Conflicts of interest and political blockage thus remain an obstacle to the efficient management of MPAs.

Community engagement, funding and resources, as well as management remain equally challenging regarding the MPAs in Martinique, according to stakeholders. First, all of Martinique's waters are part of MPAs, with protection and restriction levels to different degrees. A person explained for instance that a large part of the coastline is strictly prohibited for fishing activities due to historical and health reasons linked to chlordecone pollution. As a result, approximately one-third of the waters are cut off for fishing grounds, which does not encourage the strengthening of MPAs and breaks down the potential support of fishers for MPAs according to the stakeholder. In addition, the lack of funding and resources does not allow investment in permanent teams in public organizations managing the MPAs, according to some of the stakeholders. Finally, management issues can be explained by the stakeholders' perceptions of weakness in the scope of management plans, the lack of prioritization, and administrative delays. A person highlighted for instance the case of la "Réserve naturelle régionale du Prêcheur", which took 15 years to obtain national and regional approvals.

Last but not least, few stakeholders highlighted issues linked to ecological connectivity, data availability and quality, and ecosystem representation regarding MPAs. The challenge classified as "other" pinpointed the issue of water quality. A person was advocating that even if sea activities were banned, MPAs would for now still remain a fail due to the lack of efficient grey water system treatment in Martinique.

Most common intervention domains in Martinique:
Intervention types in regard to MPAs are presented in Figure 7. The most common intervention types required by stakeholders are by far political and sociocultural interventions. Followed by economical and legal interventions, and finally environmental and technological interventions. This suggests that decision-making, political willingness and society awareness are more needed than new regulations or more funding. Further details on the different types of interventions are given below.

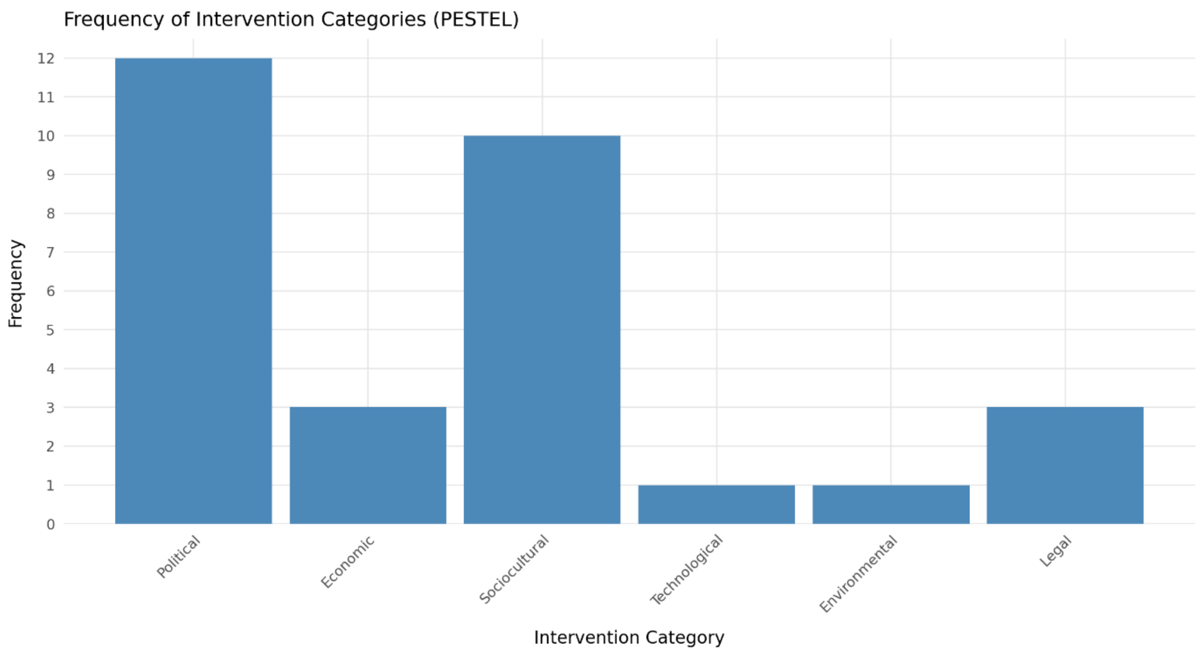

Figure 7: Frequency of intervention types in regard to MPAs in Martinique.

Political interventions: Stakeholders suggested a better prioritisation through the reduction of vague policy plans' objectives and the increase of efforts on a reduced number of objectives. They also recommend the efficient use of monitoring indicators and a better visibility and understanding of rules and better control of usage. Some people pinpointed the necessity of upgrading some areas of MPAs with higher protection status and consolidate the existing ones, while the creation time of an MPA must be optimised.

Sociocultural interventions: Two main thematics came out, namely the need for inclusiveness in decision-making and the need for awareness raising concerning the benefits of MPAs. Stakeholders underlined the importance of including coastal municipalities and communities of fishers in the MPAs management process. They should be given political support, while politics need to dare to be transparent on the various projects, through open communication and acceptance of failure on some of the projects. In addition, awareness raising is still necessary, by demonstrating the benefits of MPAs, even for fisher communities, and by, for instance, increasing the number of flat-bottomed glass boats in tourism to increase access to and awareness of the beaty of nature.

Economical interventions: They referred to the allocation of more budgets and resources, while legal interventions referred to the proposition of setting up stronger protection zones and tighten regulations around coral.

Environmental interventions: Few of the propositions about environmental interventions were seeking for habitat restoration initiatives and coral transplantation.

Technological interventions: referred to better data centralisation.

Most common vision domains in Martinique:
Stakeholders in Martinique most frequently envisioned increased stakeholder engagement, closely followed by visions of improved data availability and quality as well as strong protection zones within MPAs (Figure 8). Also named more than once were visions of ecosystem restoration, more funding and more integrated management of MPAs.

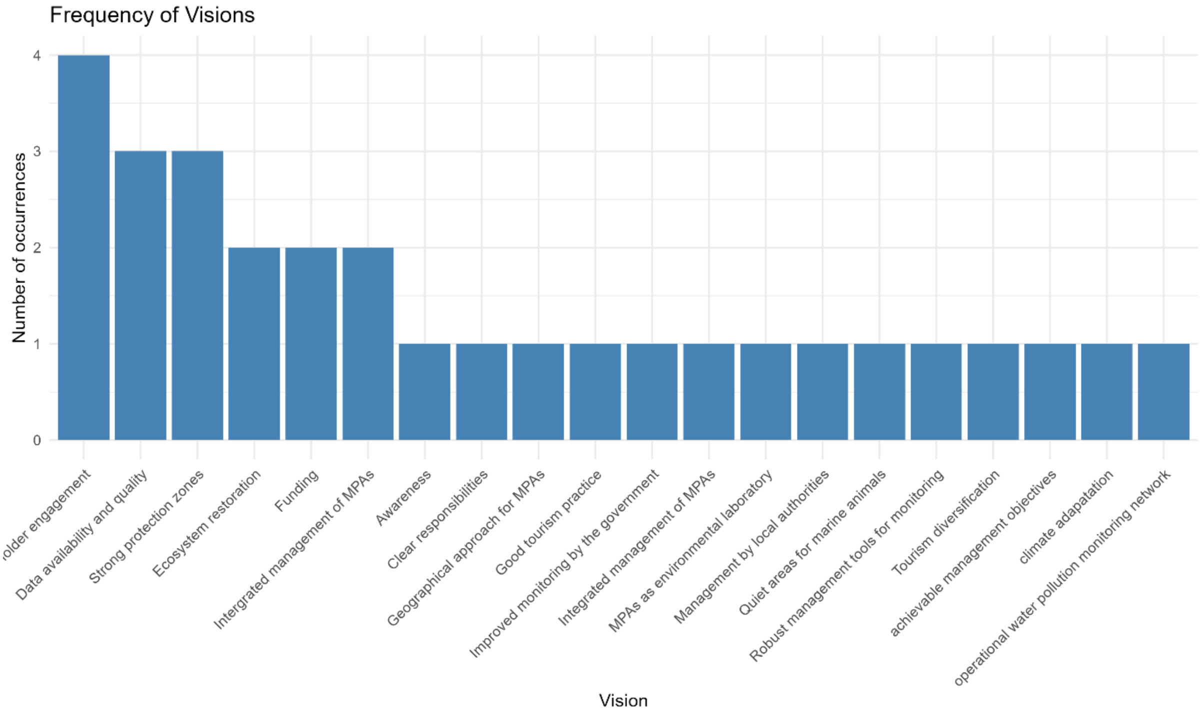

Figure 8: Frequency of vision domains regarding MPAs in Martinique.

Tool evaluations

The tools tested in Martinique were evaluated by the tool testers in the respective case study. The evaluations are presented in Table 6 below.

Table 6: Tool evaluation from Martinique.

	Bow-tie	DAPSI(w)R(M)	Ecological interaction networks	Metric of habitat function	Structured surveys	Scenario downscaling	Broad-scale Trait-based approach
Understandability of the guidance	2	5	4	1	3	4	2
Implementation time	Weeks	Weeks	Months	Months	Weeks	Weeks	Weeks
Can the tool be used by non-scientists?	With guidance	Yes	No	No	Yes	With guidance	No
Tool relevant to BBT?	Yes	Yes	Potentially yes	Yes	Yes	Yes	Yes
Main obstacle to tool implementation	Co-construction is a long process. Global approach is limited in terms of interpretation and local uses → needs tailorisation at the local scale Lack of guidance for analysis and interpretation of Bow-Tie simulation results. The online tool needs to be tested as a specific Bow-Tie and scenario tool was developed internally independently of the tool under development in WP1.	There is no relevant guidance. The document is very similar to the Bow-Tie guidance if the latter follows a DAPSI(W)R(M) framework structure.	The guidance refers to scientific papers and repository. Implementation requires a step-by-step guidance. It also requires detailed biodiversity and trophic interaction data. The principal limitation of implementing EIN is the Martinique data-deficient context	Time of implementation depends on the number of functions, habitats, and level of details. Requires large dataset of preliminary knowledge: habitat distribution, ecological status. Requires function evaluation methodology and specific process to compare function across various habitat types.	Test conducted by HuFoss, in collaboration with Nova Blue Environment. No major obstacle to report, having stakeholders willing to participate is the main challenge because they tend to be over-solicited.	The guidance is too brief. The Dublin example does not follow rigorously the guidance template leading to confusion. No guidance for climate change projections / RCP yet.	Except the need of having extensive datasets covering multiple habitats, it is too soon to define obstacles based on our current progress.

Additional comments on the different tools:

DAPSI(W)R(M) & Bow-Tie: the DAPSI(W)R(M) approach has been part of the Bow-Tie development, and was therefore, not tested as a stand-alone tool. If it were to be used as such, a clearer guidance document should be provided.

Scenario-Downscaling: this tool has been applied to Bow-Ties developed for coral reefs, seagrass and mangrove forests, but only validated in a workshop for coral reefs. By the end of the project, we aim to validate Bow-Ties / scenario downscaling for all ecosystems. Regarding the main obstacles to tool implementation, it would help the potential users to have a step-by-step guidance document, to complement the Excel Sheet Template. Understand better that this tool should be implemented once the Bow-Tie is finalised. Furthermore, additional guidance should be provided for climate change projections per SSP / RCP, whether the increase in climate change under various SSP is assessed by expert knowledge, or by actual projections from IPCC.

Bow-Tie: as there was no clear guidance yet at the time of the testing for the analysis of the Bow-Tie, we developed on our side a ShinyApp interface to analyse the Bow-Tie with Bayesian networks. We have also developed a methodology framework based on the Bow-Tie for ecosystem services valuation, by adjusting the production function based on the vulnerability of ecosystems in the face of current and future pressures. Therefore, the relevance of the tool is really high and can be a good starting point for many applications and studies.

Habitat Function Metric (HFM) and Ecological Value Assessment (EVA): we started with the HFM tool. The step-by-step guidance is welcome and relatively clear to follow, but additional elements of understanding would help potential users (not experts in QGIS) to grasp the meaning of each step (spatial analysis). By fully understanding each step of the process (rather than repeating the steps machinally), the users will certainly feel more at ease and confident with the tool. With just habitat distribution, and expert-based functional scores, the tool can be implemented rather quickly.
On our side, we tested the tools on two different maps of coastal biocenoses in Martinique, from 2009 and 2023 for HFM comparison. Those maps also included health status assessment (>1000 points each). The Coordinate Reference System between 2009 and 2023 was also different (2009 : Fort-Desaix; 2023: WGS84). In order to make the HFM comparison between 2009 and 2023, several steps were particularly difficult to do in QGIS (if not impossible). For instance, the transformation from Fort-Desaix to WGS84 was not supported by QGIS as Fort-Desaix is a very old CRS (Coordinate Reference System). The interpolation of habitat health by the nearest point, could only be done one habitat at a time (we have 7 habitats in Martinique). If potential users have the same ambition, the step-by-step guidance could be limiting. GIS experts might use Python, in our case, all operations were implemented in R.
Finally, moving from an expert-based functional matrix to a literature-supported functional matrix can significantly increase the time required, depending on the number of ecological functions being assessed. In our case, 9 functions were assessed (expert-knowledge), and a couple of functions are now supported by literature.

After HFM application, and given data availability in Martinique to implement the EVA tool, we felt the EVA tool was not relevant yet to Martinique.

Indeed, both tools rely on habitat distribution, hexagonal grid of 250 m of resolution (for benthic component), score per habitat (or per Ecological Component), aggregated into a final index (HFM or EVA). At the level of habitat only, HFM is much more complete and informative (up to 13 functions, adjusted by ecological condition), while EVA rely only on the proportion of habitat of significant importance in each subzone (hexagonal mesh), something that is considered already in HFM, but with ecological function on top.
For EVA to be a great added value compared to HFM, a lot more biodiversity data are required, at large scale, which is unfortunately not the case in Martinique yet. However, additional taxon could be included in the tool, but at a smaller scale, not the entire island.

Broad-scale Trait-based Approaches:
This tool has not been implemented yet but we are preparing the datasets for implementation. We are currently collaborating with a PhD student at the National Marine Park of Martinique to analyse fish data in the Fort-de-France Bay, which can be connected to habitats, at a higher spatial resolution than data collected from the long-term monitoring. In that case, the "BBT delimitation" will be smaller, compared to the one used for HFM.

Ecological Interaction Network:
A literature review identified a metaweb in the Caribbean, which is a great starting point for an application in Martinique.
The R script and methodology from the developer of the tool was fully tested with data from the gulf of Riga. The remaining steps consist in translating the metaweb and potentially complete it to the fish community found in Martinique, with data on the benthic community as well (if possible). This will be a rather time-consuming task, but which can be interesting for Martinique, given the context of reef degradation, overfishing and other chronic stressors.

Results Romania

Socio-ecological system perspectives

The 14 stakeholders at Constanta, Romania, mentioned "Economy", "Nature", "Research", and ": National governance" as the most important elements influencing the balance between the nature, economic and socio-cultural issues in their coastal environment (Table 7). Of these elements "National governance" belonged, together with "National rules and regulations" and "Bureaucracy, mismanagement, bad governance", to the highest scoring over all Europe.

These important elements do appear also most frequently and with the highest strength in the connections between elements (Table 8).
Stakeholders emphasized the need to preserve Constanta's nature, its habitats, and protected areas, but recognized the often conflicting importance of economic development, and the strong negative impacts of the coinciding urbanisation and coastal development.
Though governance does promote protected areas, which may increase the biodiversity in the region, an often mentioned issue was the high number of rules and regulations, and the mismanagement and bureaucracy associated with these, at the level of the national governance. More communication and fairness are indicated for promoting a better society, whereby education and research are suggested as a way forward to support further the public awareness, knowledge and the economy.

Table 7. The most important elements out of 82 in the coastal environment of Constanta, Romania, according the 14 interviewed stakeholders

Elements (82 in 14 interviews)	Times mentioned (%)	Total connections	Power of connections
Economy	86	49	197
Nature	86	36	144
Research	64	43	160
National governance and policy	57	36	125
SME	57	31	97
National rules and regulations	57	25	85
Urbanisation & Coastal development	57	22	74
Biodiversity	57	19	71
Communication	50	29	101
Industry	50	23	76
Habitats	50	17	58
Geophysical characteristics	50	14	45
Protected areas	43	27	90
Society	43	25	98
Local fisheries	43	25	92
Infrastructure & Transport	43	17	69
Bureaucracy, mismanagement & bad governance	43	13	55

Orange cells: Elements for which Romania has highest European scores. Other colors indicate the most important elements according the criteria given in the Material and Methods (see also Hummel et al. 2023)

Table 8. The most important connections between elements in the coastal environment of Constanta, Romania, according to the interviewed stakeholders.

Sending elements	Receiving elements	Frequency	Strength
Protected.Areas	Biodiversity	3	15
Local.fisheries	SME	3	14
National.governance.and.policy	National.rules.and.regulations	3	13
Industry	Pollution	3	12
Research	Economy	3	11
Economy	SME	2	10
Education	Awareness...Knowledge	2	10
Education	Demographics	2	10
International.governance	Bureaucracy..Mismanagement...Bad.Governance	2	10
National.governance.and.policy	Bureaucracy..Mismanagement...Bad.Governance	2	10
SME	Local.fisheries	2	10
Fairness	Society	2	9
International.governance	National.governance.and.policy	2	9
National.governance.and.policy	Local.governance	2	9
National.rules.and.regulations	Bureaucracy..Mismanagement...Bad.Governance	2	9
National.rules.and.regulations	Protected.Areas	2	9
Research	Decision.support...Management.tools	2	9
Urbanisation...Coastal.development	Economy	2	9
Awareness...Knowledge	Cultural.heritage...Traditions	2	8
Communication	Society	2	8
Education	Public.opinion	2	8
Funding	Research	2	8
Urbanisation...Coastal.development	Infrastructure...Transport	2	-8
Local.governance	Infrastructure...Transport	2	-9
Urbanisation...Coastal.development	Habitats	3	-11

Marine Biodiversity governance challenges and needs

Most common governance challenge domains in Romania:

The perceived governance challenge domains in Romania are presented in Figure 9.

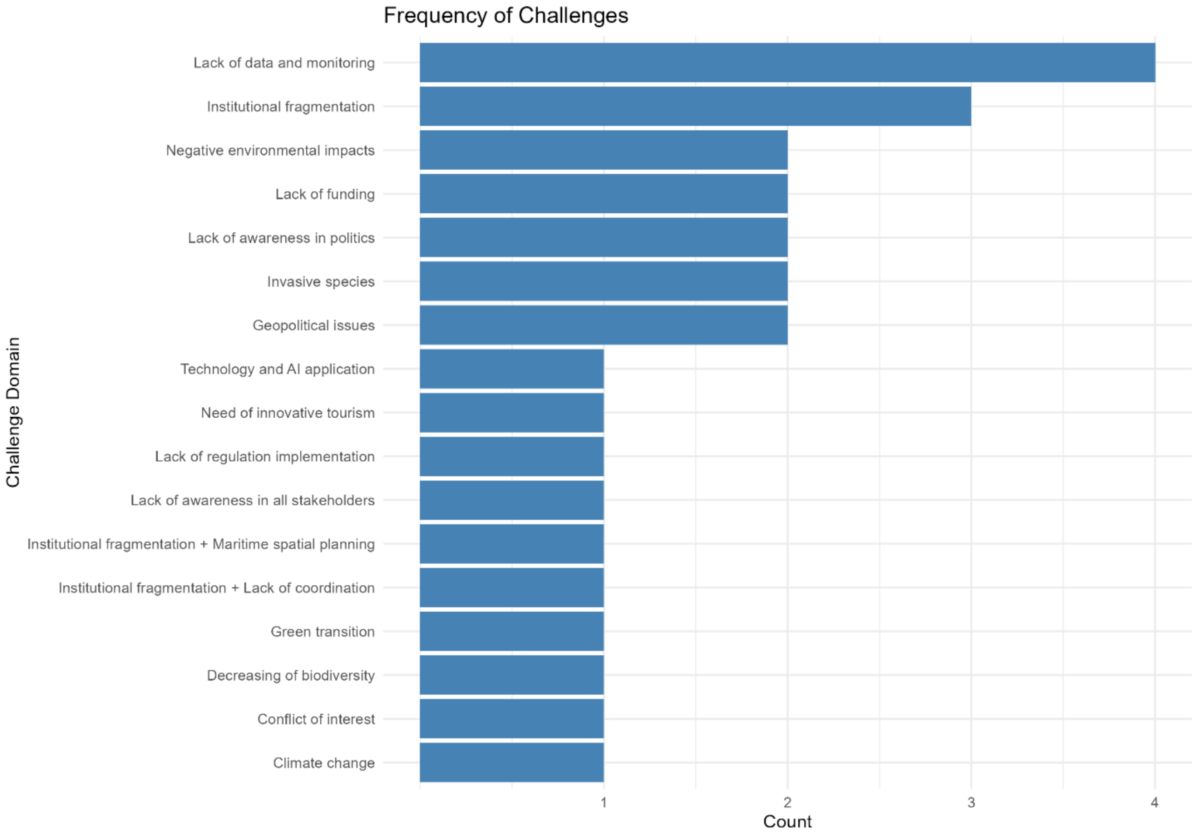

Figure 9: Frequency of the most common governance challenge domains

The most common governance challenge domain according to stakeholders is the lack of data and monitoring, as well as institutional fragmentation within marine biodiversity governance. Indeed, they highlighted the lack of centralisation for public scientific data and global and usable indicators. Precisely about MPAs, it appears to be very formally designated without many studies on their habitats or species, thus leading to non-efficient monitoring.

The institutional fragmentation within marine biodiversity is the second most important goverancne challenge for stakeholders. For them, existing legislations lack visibility and clarity, and the various ministries (environment and fisheries given as examples) appear to act in contradiction to existing amendments and laws. Communication and sharing of responsibilities among the institutions is seen as challenging.

In addition, also named more than once were the challenges of negative environmental impacts, lack of funding and lack of biodiversity awareness in politics. These various challenges respectively refer to pressure put on marine ecosystems through urban and tourism development, lack of funding dedicated to marine conservation measures and lack of interest from local government for marine issues. Equally, invasive species and geopolitical issues were perceived as important challenges by

Romanian stakeholders. Invasive species have impacted fishery sector according to stakeholders. Finally, the geopolitical issues refer to the war between Russia and Ukraine, geographically close to Constanta.

Most common governance intervention domains in Romania:
The most common intervention types to address challenges of marine biodiversity governance were mainly socio-cultural and political. Technological and legal interventions were also named more often, while environmental interventions were named the least (Figure 10). Examples of the different intervention types are provided below.

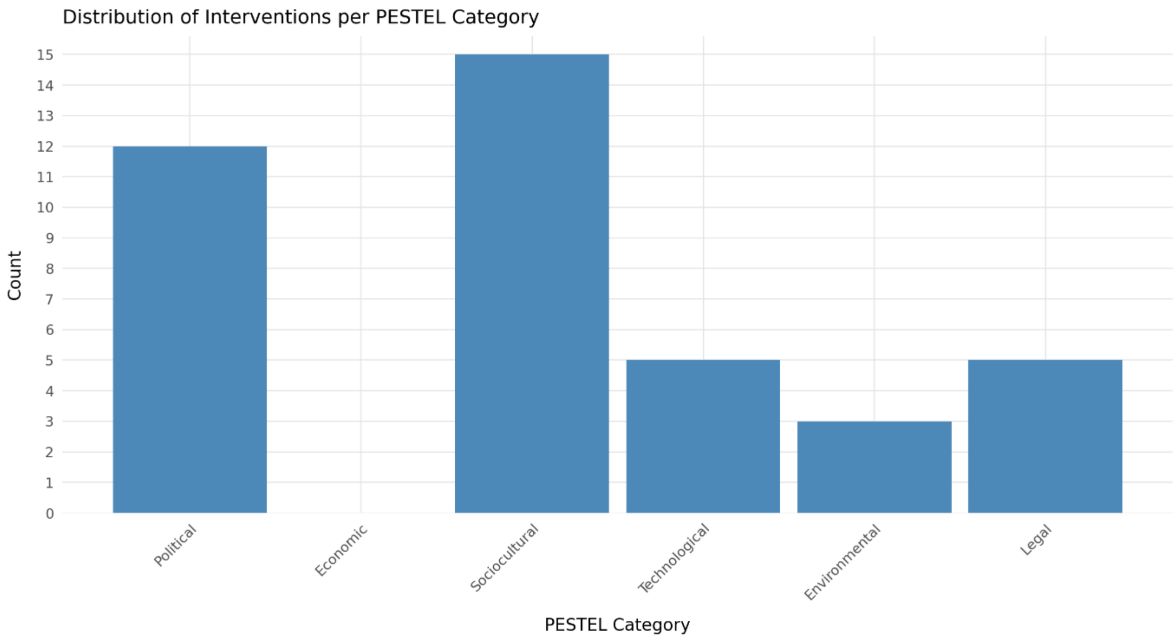

Figure 10: Most common intervention domains regarding marine biodiversity governance in Romania.

Sociocultural interventions: This includes several subthemes, namely awareness raising of the political class on marine biodiversity issues, better communication and collaboration between the institutions, transparency, as well as capacity building for the responsible institutes on marine questions. In addition, the idea of inclusion of all the stakeholders during the decision-making process came up several times, with a focus on researchers, fishermen and local communities' inclusion. Finally, some stakeholders pinpointed that research made in marine protected areas in Romania should be publicly accessible, and that communication regarding projects carried on should increase from research institutes to national agencies.

Political interventions: Stakeholders proposed various ideas, such as better pelagic species monitoring while taking into consideration the invasive species, political plans to limit ecosystems damages, adapted balance between urban development and nature protection, as well as finding recycling opportunities for fishers regarding the fishing gears. Finally, stakeholders are aware of the complexity of conflict resolution and the use of diplomacy to stop address conflict.

Legal interventions: The propositions were to identify and create procedures amended to the existing laws, and to add some audit to the existing legislation in order to exclude the duplication, ambiguities and artefact. In addition, this existing legislation should be updated according to some stakeholders, with a stronger focus on environmental conservation, currently out of the political priorities.

Technological interventions: Some of these applied specifically to the port of Constanta: some of the stakeholders proposed the development of railway infrastructure to decrease the track traffic, the installation of charging station for electric cars, the supply of the port in electricity to connect ships to renewable energy, and the acquisition of multifunctional tanker vessels. More generally, the need for marine technologies to obtain broad picture of MPAs and what they contain was also underlined. This would be deployed through more sampling stations and under-water videos for instance.

Environmental interventions: Needs highlighted designated ecosystems restoration, and actions related to the management of invasive species to overcome their impacts.

Interestingly, no economic interventions were mentioned by stakeholders.

Most common governance vision domains in Romania:
Main governance vision suggested by stakeholders in Romania are presented in Figure 11.

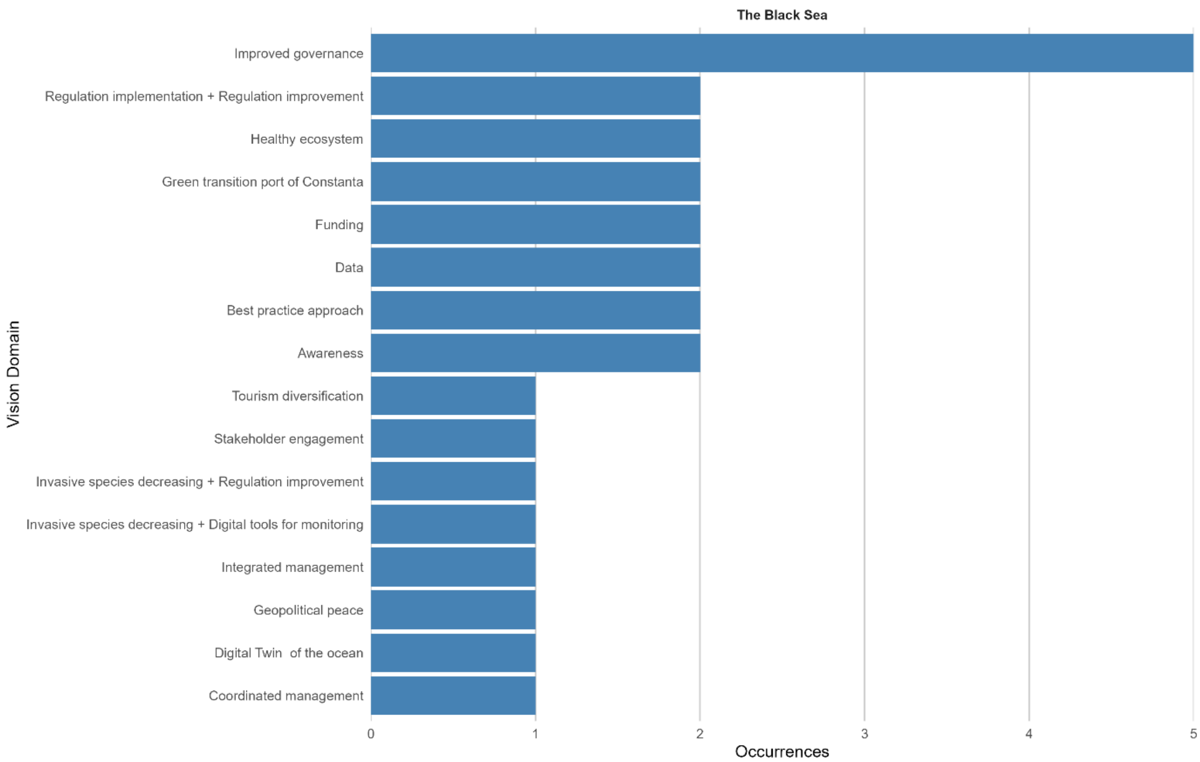

Figure 11: Frequency of vision domains regarding marine biodiversity governance in Romania.

Stakeholders in Romania most commonly envisioned improved governance of marine biodiversity, including improved coordination, stronger role of local government and simplified contact points for stakeholders. Visions named more than once also included improved regulation and better implementation thereof. Stakeholders also envision healthy ecosystems, the Green transition of the port of Constanta, more available funding and data, development and sharing of best practice approaches for marine biodiversity governance and improved awareness for biodiversity. Less frequently named were visions of e.g. better handling of invasive species through improved regulations and monitoring, better stakeholder engagement and more integrated and coordinated management approaches.

Marine spatial planning challenges and needs with MPAs

Most common MPA challenge domains in Romania:

The most common challenge domains for MPAs in Romania are presented in (Figure 12).

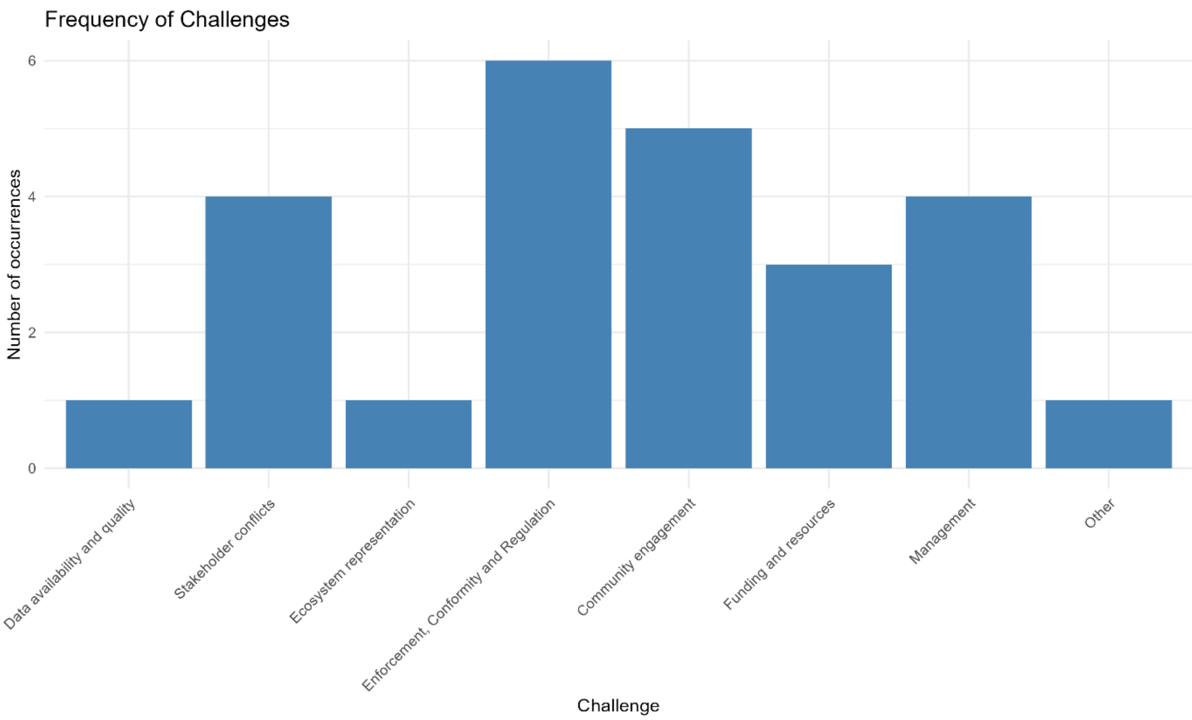

Figure 12: Frequency of challenge domains regarding MPAs in Romania.

The most prominent perceived MPA challenge is related to enforcement, conformity and regulation. Stakeholders highlighted the "paper parks" problem, with MPAs that don't have real monitoring and control on the ground, the issue of some black market of gobies happening within recreational fisheries, and the absence of control from the authorities.

The enforcement, conformity and regulation challenge domain was closely followed by community engagement. This was due to stakeholders perceiving a lack of awareness of the benefits of MPAs, which is linked to the collective mentality being against it. Education on those topics is thus seen as both lacking and needed according to some of the stakeholders.

Following closely were the challenges of stakeholder conflicts, and management. Technically, Romania's MPAs cover most of the Romanian coasts with different degrees of protection, but stakeholders see a lack of efficient management in practice. As a result, different dynamics are at stake, namely fishery sector, conservation imperatives, tourism operators and urban development on the coast. Regarding the management, stakeholders pointed out heavy bureaucracy and administrative inertia because of recent restructuration and lack of clear coordination between the different institutes.

Challenges related to funding and resources were also named several times, thus concerning the funding allocated to the public institutes in charge of the management of MPA.

Most common intervention domains in Romania:
The most common intervention types in Romania were by far socio-cultural, followed by political and legal intervention types (Figure 13). Technological and environmental intervention types were named less frequently. Examples of the different intervention types are given below.

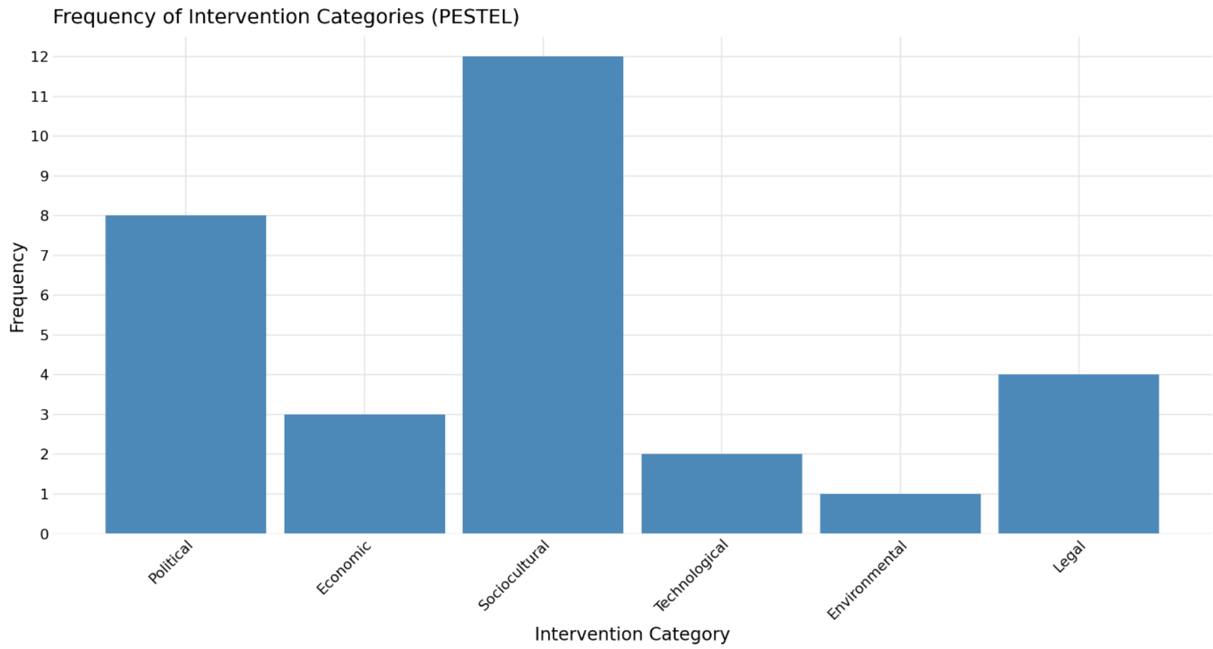

Figure 13: Frequency of intervention types regarding MPAs in Romania.

Sociocultural interventions: Regarding MPAs, they were referring to the need for better communication from scientific institutions using social media, and the increase of their representation in the traditional medias. In addition, sharing best practices by taking examples of well management MPAs in Mediterranean, highlighting the positive effects for fisheries, were presented as beneficial activities. Awareness campaigns from the government regarding MPAs, as well as communication and visibility of their rules, and finally capacity building for the management authorities were also emphasised.

Political interventions: Stakeholders highlighted the need for implementing marine spatial plans, and the importance of authorities' involvement into fisheries, to better control this sector. As a result, existing MPAs would be better protected.

Legal interventions: They referred to the importance of regulate fisheries and the use of pelagic fishes, and to reinforce regulations and control regarding recreational fisheries.

Economical interventions: They referred to the need for more funding for NGOs, and to the idea that national projects for MPAs should be sponsored by big polluters, gas and oil companies.

Technological interventions: The objective would be to depollute the MPAs, and to do so, some stakeholders proposed to have more models and technologies to predict pollution spots, as well as cooperation between scientific institutes to take actions based on latest knowledge.

Environmental interventions: According to few stakeholders, MPAs should be designed based on tourism areas to avoid user conflicts, and thus not include the coasts where pressure from tourism is high. Instead, some areas should be designated as high degree of protection, where no one should have access to.

Most common vision domains in Romania:

Stakeholders most commonly envisioned more awareness for MPAs in Romania (Figure 14). They also frequently named visions of better balance between protection and economy, improved coordination, data accessibility and quality, more integrated MPA management, better maritime planning and control, as well as improved stakeholder engagement.

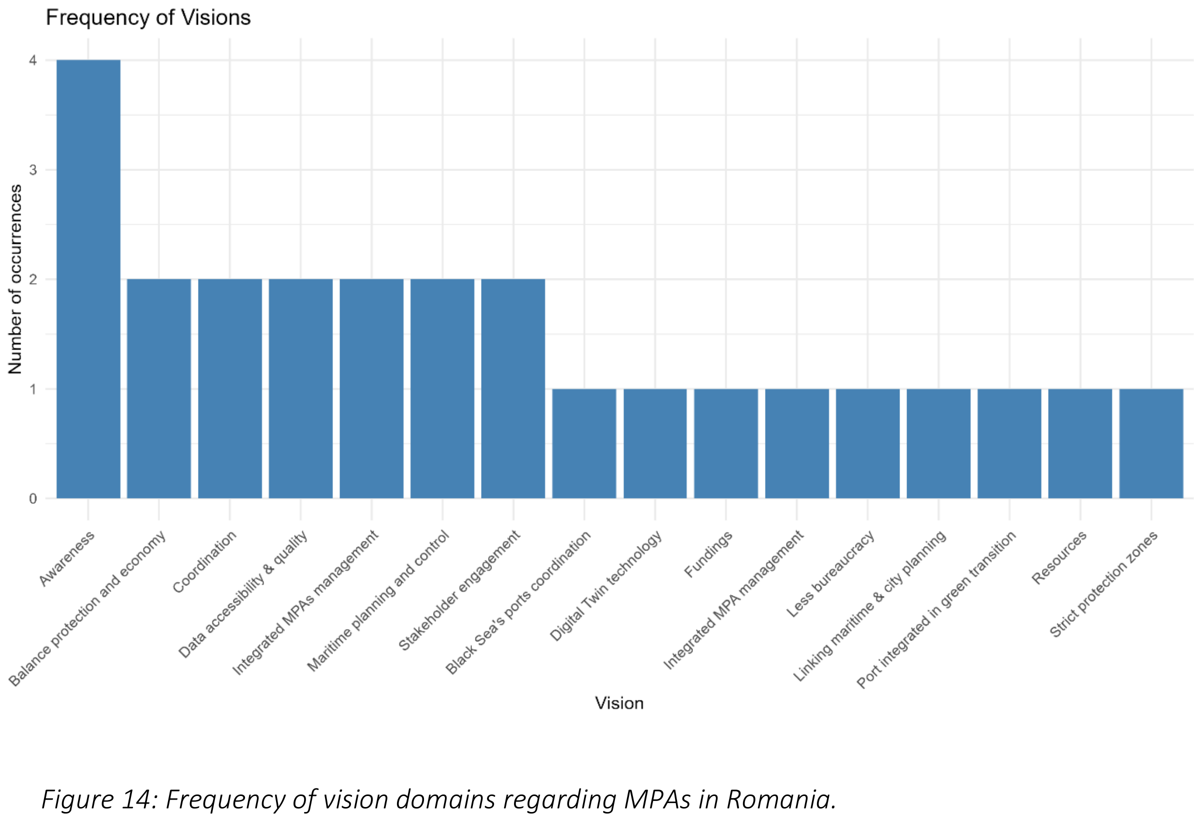

Figure 14: Frequency of vision domains regarding MPAs in Romania.

Tool evaluations

The tools tested in Romania were evaluated by the tool testers in the respective case study. The evaluations are presented in Table 9 below.

Table 9: Tool evaluation from Romania.

	Bow-tie	Ecological value assessment
Understandability of the guidance	3.5	2.5
Implementation time	Week and/or months	Week and/or months
Can the tool be used by non-scientists?	With guidance	With guidance
Tool relevant to BBT?	Yes or potentially yes	Yes or potentially yes
Main obstacle to tool implementation	The tool is currently not interactive. Developing it as an application and incorporating risk evaluation would enhance usability and uptake.	A lot of data is needed for implementing the tool, which might hinder its application by non-scientists. + in general, the low level of stakeholder expertise, the fact that the tool is not directly linked to reporting obligations (in the case of environmental agencies), and the lack of knowledge on ecological/biodiversity valuation among most stakeholders;

Lessons learned

Lessons learned on socio-ecological perspectives

The elements viewed by the stakeholders at both out-scaling locations, Martinique and Constanza, as being most important in determining the balance in their ecological, economical and socio-cultural environment, do fall in general also within the range of values for the top elements at other European locations (Table 10).

The Economy is mentioned highly important at all locations, with Tourism and Fisheries as important factors.

Nature is, together with Protected areas, are also highly important factors, whereby Habitats and Biodiversity are judged important factors too. For these last two elements Martinique stands out as being highly important according to the stakeholders.
Threats by Pollution or Invading Species are, as all over Europe, judged more or less important, though again in Martinique the stakeholders emphasise more than elsewhere that sanitation should be strengthened.
It indicates an above average interest of the population at Martinique in their natural environment.

This may connect also to the above average high importance of Awareness and Knowledge in Martinique, whereas at other locations such is, as Education, Communication or Research, at a moderate important level.

Regarding the governance issues, it became clear that in Constanta, the governance at National level is much more important than elsewhere, however connected also with Bureaucracy & Mismanagement. Whereas at Martinique the reverse holds true and governance at the Local level is judged very important.
The focus on local governance was found also for the other oceanic European islands (Macaronesia in table EE), which can be interpreted as a trend for those locations far from the mainland and thereby the closer connections to and with the governmental individuals on the spot.

In summary we can conclude that in Martinique, France, the viewpoints of the stakeholders are, more than at other European locations, strongly directed towards Local Governance issues, next to a high Awareness & Knowledge on their unique habitats. The location of the island, far from the European mainland, may have contributed to this situation.
For Constanta, Romania, it became clear that the viewpoints of the stakeholders largely correspond with the average viewpoints elsewhere in Europe, though the balance of nature economy, and society, is to a higher extend influenced by the National Governance, together with National Rules & Regulations, and Bureaucracy & Mismanagement, whereby stakeholders called for a higher fairness and more communication.

Altogether, this study showed that the approaches and tools developed in the European BBTs to interview stakeholders, i.e. Fuzzy Cognitive Mapping (FCM), were relevant and applicable to the socio-ecological situation at both out-scaling stations and can point to the unique issues to be taken into account for policy-making and planning in the specific areas.

Table 10: Overview of important elements mentioned by stakeholders at the out-scaling stations Martinique, France, and Constanta, Romania, compared to those mentioned at the study areas in the MARBEFES and Marine SABRES projects (indicated are averages of the frequency mentioned per area: +/-: 0 – 12.5 %, +: 12.5 – 25 %, ++: > 25 %, +++: > 50 %, and for +++ the total and strength of the connections has to be higher than 50 % of the maximum at a location)

	BBTs					Out-scaling	
	Macaro-nesia	Mediter-ranean	Atlantic Coast	Baltic	Arctic	Romania	Martinique
Economy	+++	++	++	++	+++	+++	+++
Tourism	+++	+++	++	+++	+++	++	++
Fisheries	++	++	++	++	++	++	++
Industry	+	+	++	+	++	++	+
SME	+	++	+	+	++	++	+
Nature & Ecological dynamics	+++	++	+++	++	+++	+++	++
MPAs/protected areas	+++	+++	++	++	+	++	++
Habitats	+	+	++	++	+	++	+++
Biodiversity	++	++	++	++	++	++	+++
Invading species	+/-	+	+/-	+	+	+	+
Pollution	++	++	++	+++	++	++	+++
Sanitation	+/-	+	+	+	+/-	+/-	++
Research	+	++	+++	+	++	+++	++
Knowledge & Awareness	++	++	++	++	++	++	+++
Training & Education	+	++	+	+	+	++	++
Communication	+	++	+	+	+	++	++
National governance and policy	+	+	++	+	+	+++	+
National rules and regulations	+/-	+	+	+	+	++	+/-
Bureaucracy, mismanagement	+/-	+/-	+/-	+/-	+/-	++	+/-
Local governance	+++	++	++	++	++	++	+++
Local rules and regulations	++	++	+/-	+	++	+/-	+++
Society	+++	+	++	++	+++	++	++
Urbanisation	+	+	++	++	+	++	+

Lessons learned for policy and governance

Methodology: key findings and lessons learned

The two case study sites in Martinique and the Black Sea presented different political, social and ecological contexts compared to the twelve case study sites in the European waters. The initial idea of this study was to replicate the approach followed by WP1 within the two case study sites by carrying out physical workshops led collectively. In Martinique, political unrest, followed by financial constraints coupled with too few stakeholders willing to participate to a full day workshop obliged to review the approach. The choice was made to carry out stakeholder engagement online. For methodology replicability and data comparison, the same had to be done with the Romania case study site. Within the 12 BBTs' study in Europe, workshops took place physically and collectively.
Hence, the differing socio-cultural context, in particular the political unrest, led to an adjustment of the approach from a physical to a digital implementation. However, even though the set up was different, the overall content and data collection approach remained the same as in the original approach applied to BBTs. The method produced meaningful results comparable in depth to the European case study sites. As a result, the method showed flexibility and adaptability, while the data collected in Martinique and Romania can fully be comparable to data collected in the 12 other case study sites, highlighting a methodology conformity with the expectations. Therefore, **the key lesson-learned regarding the collection of governance and MPA challenges is that the methodology transferred well in the out-scaling process, and it was mainly the implementation that had to be adjusted (from physical to digital).**

Governance: key findings and lessons learned

The out-scaled case study of **Martinique** provides useful insights into how governance challenges, interventions, and visions may be articulated in contexts beyond the BBTs. Challenges were primarily framed around limited collaboration, pollution, environmental impacts, and conflicts of interest, suggesting that coordination and governance-related constraints often shape how environmental problems are perceived and prioritised. Interventions were predominantly formulated at the local level, with political and socio-cultural actions featuring most prominently, which may reflect the relevance of locally embedded governance processes in geographically bounded contexts, highlighting an island perspective. Stakeholder visions frequently emphasised the importance of knowledge and data, inclusive decision-making, and the translation of scientific knowledge into political priorities through measurable indicators, alongside ecological aspirations including healthy marine ecosystems. **Taken together, this case suggests that effective environmental outcomes are commonly envisioned as contingent upon governance capacity and knowledge integration, rather than as standalone ecological objectives.**
In the case of **Romania,** the analysis highlights governance dynamics that appear characteristic of institutionally dense and multi-level policy contexts. Challenges were articulated around limited data availability and monitoring, institutional fragmentation, funding constraints, environmental degradation, invasive species, and geopolitical considerations, pointing to the complexity of managing marine biodiversity within overlapping governance structures. Socio-cultural interventions were particularly prominent, notably through awareness-raising among political decision-makers, improved

communication and collaboration across institutions, enhanced transparency, and capacity-building for institutions responsible for marine governance, complemented by political interventions. Stakeholder visions were largely centred on the improvement of governance systems, including stronger coordination mechanisms, an enhanced role for local authorities, and simplified institutional interfaces for stakeholder engagement. **Overall, this case suggests that in multi-level governance settings, environmental challenges are often approached through efforts to rationalise and strengthen governance structures, rather than through the direct articulation of sector-specific ecological objectives**.

Marine Spatial planning (MPAs): key findings and lessons learned

The out-scaled application of the analytical framework to the case of **Martinique** focusing on marine protected areas (MPAs) within the context of marine spatial planning offers additional insights into governance dynamics at the interface between spatial planning and conservation. Challenges were predominantly framed around enforcement, compliance, and the regulation of MPAs, alongside stakeholder conflicts, indicating persistent difficulties in translating spatial designations into effective management outcomes. Interventions were largely articulated in political terms, with stakeholders emphasising the need for clearer prioritisation through the reduction of vague policy objectives and a stronger focus on a more limited set of actionable goals. Visions expressed by stakeholders centred primarily on increased stakeholder engagement, followed by improved availability and quality of data, as well as the establishment of strongly protected zones within MPAs. **Taken together, this case suggests that within marine spatial planning contexts, the effectiveness of MPAs is commonly perceived as contingent on governance clarity, political prioritisation, and participatory processes, rather than on spatial designation alone.**

The out-scaled analysis of the case of **Romania** concerning marine protected areas within marine spatial planning further illuminates the social and governance dimensions shaping MPA effectiveness. Challenges were primarily articulated around enforcement, compliance, and regulatory implementation, alongside limited community engagement, which stakeholders often linked to low awareness of the benefits associated with MPAs and, in some instances, to collective attitudes resistant to their establishment. These challenges were further associated with perceived shortcomings in the effective management of MPAs. In response, interventions were predominantly framed in socio-cultural terms, with stakeholders emphasising improved communication by scientific institutions through both social and traditional media, the dissemination of best practices from well-managed MPAs, and targeted awareness campaigns led by public authorities. Capacity-building for MPA management bodies and clearer communication of rules and objectives were also highlighted as important enabling measures. Stakeholder visions most frequently centred on increased awareness of MPAs and a better balance between economic priorities and conservation objectives, alongside improved coordination, enhanced data accessibility, and more integrated MPA management approaches. **Overall, this case suggests that where social acceptance of MPAs is limited, stakeholders tend to frame effectiveness less in terms of spatial or regulatory design and more in terms of communication, awareness, and social legitimacy.**

Lessons learned for tool out-scaling

Lessons learned from Martinique

<u>Bow-Tie & Scenario Downscaling</u>

The Martinique workshop provided valuable insight into the practical use of the bow-tie and scenario down-scaling tools in a participatory setting. While both tools proved relevant and promising for structuring discussion around ecosystem vulnerability and future change, the testing also revealed several methodological and operational questions that should be addressed more explicitly in the guidelines if these tools are to be used consistently across BBTs and by users without direct MARBEFES support.

<u>Bow-tie co-construction</u>

A first key lesson concerns the co-construction process. In principle, the bow-tie framework is intuitive. It links activities and pressures on the one hand, and consequences and control measures on the other, offering a structured way to explore ecosystem response to environmental constraints. In practice, however, using the tool with stakeholders raises a few questions that are not yet fully resolved in the current guidance.

One of the first difficulties encountered in Martinique was simply where and how should the exercise start? Should the discussion begin with activities, with pressures, with consequences, or with a central event issue (i.e. biodiversity loss)? Different entry points may lead to different dynamics and outputs. In Martinique, stakeholders were first presented with lists of activities and pressures, followed by consequences, and were then invited to build their own bow-ties in small groups. This approach was workable, but it required considerable facilitation and time. It was not always obvious to participants how to move from a list of elements to a logically structured bow-tie, especially when multiple pressures and consequences could be connected in different ways.

This suggests that the guidelines should provide much clearer step-by-step instructions on how to initiate and sequence the co-construction process. For example, they could clarify whether bow-tie development should begin from:

- a predefined central issue or consequence endpoint,
- a set of priority activities,
- a list of dominant pressures,
- or a management question to be addressed.

Without such clarification, implementation may remain highly dependent on the facilitator's own interpretation of the method.

Standard nomenclature vs. local language

Another major issue concerns the use of the EU-level nomenclature for activities, pressures, consequences, and control measures. A common nomenclature is clearly necessary if bow-ties are to be compared across BBTs. However, the Martinique workshop showed that these terms are not always intuitive for stakeholders, especially when they are perceived as overly technical, generic, or disconnected from local realities. Stakeholders often found it easier to work with their own wording, reflecting local uses, locally recognised pressures, or context-specific management practices.

This raises an important critical point for implementation: should standardisation occur before, during, or after stakeholder engagement? The Martinique experience suggests that imposing standardised terminology too early may slow down discussion and make the process less accessible. A more effective approach may be to allow participants to work first with their own vocabulary and then align these terms afterwards with the common nomenclature once the bow-tie has been finalised. The guidelines would benefit from explicitly recognising this two-step process and providing practical advice on how to translate locally expressed terms into the shared framework.

What participatory method should be used?

The workshop also highlighted the need for more guidance on the active participation method itself. In Martinique, the small-group format worked very well in terms of engagement. Stakeholders appreciated the interactive setting, felt comfortable contributing, and valued the opportunity to exchange perspectives. This participatory dimension was clearly one of the strengths of the process.

However, the test also showed that the success of co-construction depends strongly on the facilitation method used. Questions remain open, such as:

- Should participants work in homogeneous groups or mixed groups?
- Should they complete a fully blank bow-tie, or work from a partially pre-filled structure?
- Should the exercise be done on paper, with cards, on spreadsheets, or with digital interfaces (Bow-Tie app)?
- How much information should be provided in advance to avoid spending too much workshop time explaining the logic of the tool?

In Martinique, the exercise appeared simple on paper but was in fact relatively time-consuming. Participants needed time to understand the framework, discuss the relevance of terms, and organise the elements into a meaningful structure. This points to the need for more operational guidance on facilitation formats, time allocation, and levels of pre-structuring. The guidelines should help future users decide what should be prepared beforehand by the scientific team and what should genuinely emerge from stakeholder discussion.

Adaptability of bow-ties to local context and smaller-scale questions

Another important lesson is that the bow-tie tool must remain adaptable to local context and scale. In Martinique, it became clear that the value of the method depends on its capacity to be tailored to more specific local questions, besides its use as a general comparative framework across territories. For example, stakeholders may wish to use the bow-tie to explore broad ecosystem changes, or focus on a particular site, habitat, pressure, activity sector, or management issue.

This raises a critical point for future use: to what extent should bow-ties be standardised, and to what extent should they remain flexible and down-scalable? If the framework is too rigid, it may fail to capture the local specificity that makes the exercise meaningful. If it is too flexible, comparability across BBTs or territories becomes difficult (however, this comparability level was not relevant for the Martinique case study and might better occur at local scale for site comparison). The guidelines should therefore better explain how the tool can be adapted to smaller spatial scales or to targeted management questions while still preserving a common conceptual backbone. This would make the bow-tie approach more useful as a practical decision-support framework for local stakeholders.

Scenario down-scaling

Scenario down-scaling was implemented during the same workshop, alongside the bow-tie exercise. After a short presentation of the selected scenarios (SSP1, SSP3, and SSP5), stakeholders were asked to complete a spreadsheet individually by assigning scores of expected changes, from -3 to +3. In Martinique, this approach proved to be effective and relatively easy for participants to apply. The scoring system was simple enough to generate individual judgments while producing results that could later be aggregated.

However, the testing also revealed several unresolved questions. A first issue concerns scenario choice itself. How should users decide which scenarios are most relevant for simulation? Should all sites test the same scenarios for comparability, or should they be allowed to select those most meaningful in their local context? How much explanation is needed to ensure that stakeholders interpret the scenarios consistently? In Martinique, a short presentation was sufficient to launch the exercise, but for users working independently, the current guidance may not be detailed enough to ensure a shared understanding of scenario content and assumptions.

The guidelines would therefore benefit from more explicit instructions on:

- how to select scenarios for testing,
- how to present them to stakeholders,
- how to justify scenario choice in relation to local objectives,
- and how to ensure consistency in scoring across participants and workshops.

How should bow-ties be analysed under different scenarios?

Another major issue concerns the analytical framework for linking scenarios to bow-tie outputs. This remains one of the least specified parts of the process. In Martinique, scenario scoring generated useful information on perceived future changes, but the methodological pathway from these scores to bow-tie analysis was not fully clear. For example:

- How should scenario scores modify the relative importance of activities or pressures?
- Should they affect the probability of occurrence, the intensity of consequences, or the effectiveness of control measures?
- What is the expected output of a scenario-based bow-tie analysis: qualitative comparison, semi-quantitative ranking, or formal simulation?

These questions are critical because they determine whether the down-scaled scenarios remain a parallel exercise or become fully integrated into the simulation assessment. At present, further methodological guidance is clearly needed to define a relevant framework for simulation result analysis. Without this, different users may interpret and analyse scenario effects in inconsistent ways, reducing comparability and limiting the operational value of the tool.

The guidelines should therefore propose a clearer framework for analysis, including:

- what elements of the bow-tie can be modified under scenarios,
- what assumptions are acceptable,
- how results should be summarised and compared,
- and how uncertainty or stakeholder disagreement should be handled.

How can users apply the tools without in-person guidance?

One of the most important lessons from the Martinique testing is that both tools currently still depend heavily on in-person facilitation. Their implementation was successful because workshop participants were guided through the process, both conceptually and practically. Without such support, it is not yet certain that external users would be able to implement the tools in a consistent and efficient way.

This raises a key operational question: how can people use the bow-tie and scenario down-scaling tools autonomously? The answer likely depends on strengthening the guidance material beyond conceptual description. Future guidelines should include:

- a step-by-step implementation protocol,
- examples of workshop agendas,
- facilitation tips,
- worked examples of completed bow-ties,
- examples of scenario scoring and interpretation,
- decision trees for choosing starting points and levels of complexity,
- and practical advice on how to standardise outputs afterwards.

The development of simple templates, annotated examples, and perhaps short training modules would greatly improve transferability. This is especially important if the tools are intended for use by practitioners, local managers, or researchers who did not participate directly in MARBEFES discussions.

Overall assessment and suggested improvements

The Martinique workshop confirmed that both the bow-tie and scenario down-scaling tools have strong potential as participatory approaches for ecosystem change context assessment. The bow-tie framework is particularly useful for structuring complex discussions, while scenario down-scaling provides an accessible way to explore how these relationships may change under alternative futures. Stakeholders responded positively to the active and small-group-based format, and the tools supported meaningful dialogue.

At the same time, the testing clearly showed that the current guidance should be improved to address several critical implementation issues:

- how to start the bow-tie construction process;

- how to sequence the steps of co-construction;
- how to handle the differences between standard nomenclature and local terminology;
- what participatory method is most appropriate;
- how to adapt the bow-tie to smaller-scale or more specific local questions;
- how to choose scenarios for simulation;
- how to integrate scenario scores into bow-tie analysis;
- how to interpret simulation results;
- and how to enable users to apply the tools without direct facilitation.

The Martinique experience was a test of the guidelines for their implementation, along with a test of the tools. It showed that the tools are conceptually strong and well received, but that their broader uptake will depend on the development of more operational, explicit, and user-oriented guidance. Strengthening this guidance would help ensure that future applications are locally meaningful and comparable across sites, case studies, BBTs.

<u>Habitat Function Metric</u>

The Habitat Function Metric (HFM) provides a structured framework to assess ecosystem functioning across marine seascapes by linking habitat distribution, functional scores, and environmental status. Its stepwise workflow, from habitat spatialization to function aggregation and normalisation, ensures methodological consistency and reproducibility. However, its practical implementation revealed several key lessons.

Accessibility and technical implementation

The HFM guidelines are well structured and provide clear step-by-step instructions for implementation in GIS software such as QGIS. However, in practice, several operations, in particular for data preparation, appeared technically demanding, such as harmonising coordinate reference systems, or performing iterative spatial operations (e.g., nearest-neighbour interpolation by habitat), which can become cumbersome within standard GIS interfaces. As a result, the level of expertise required to fully implement the tool may be higher than initially anticipated. In complex case studies, implementation may benefit from scripting approaches (e.g., R or Python), which enables automation, reproducibility, and more flexibility in handling large or heterogeneous datasets. Providing optional guidance for coding-based workflows could significantly enhance usability for advanced applications.

Need for better conceptual guidance alongside technical steps

While the step-by-step workflow is clearly described, additional explanations of the rationale behind each step would greatly benefit non-expert users. A deeper understanding of the spatial and ecological logic (e.g., intersection, merging, aggregation, join by location, normalisation) would improve user confidence and reduce the risk of misapplication. Strengthening the guidelines with conceptual explanations and illustrative examples would help users move from a procedural to an interpretative use of the tool.

Data preparation

Applying HFM to temporal datasets highlighted important technical challenges related to data harmonisation. In our case study, differences in coordinate reference systems (e.g., Fort-Desaix in 2009 vs. WGS84 in 2023) created significant difficulties for spatial comparison. Some transformations were not readily supported in QGIS and required external processing. Similarly, certain operations, such as interpolating ecological conditions within habitats, were not easily scalable within GIS and had to be performed iteratively (one habitat at a time) or through coding (e.g., Python or R). These challenges indicate that data interoperability and preprocessing could be critical bottlenecks in HFM applications and should be explicitly acknowledged in the guidelines.

Functional matrix: expert knowledge vs. empirical data

The construction of the habitat–function matrix based on expert knowledge (Level 1) is one of the strengths of the HFM approach, as it allows flexibility depending on data availability. Expert-based scoring can be implemented relatively quickly and provides a practical entry point for applications. However, transitioning from expert-based scores to literature-supported or quantitative values is considerably more challenging. For many ecosystem functions, quantitative data are scarce or fragmented, derived from different methodologies, measured under varying environmental conditions, and/or expressed in incompatible units. This makes it difficult to compare habitats and normalise values on a common scale (e.g., 0-1). This limitation does not reflect a weakness of the HFM tool itself, but rather a fundamental knowledge gap in ecosystem functioning. Explicitly acknowledging this limitation in the guidelines would help users set realistic expectations, justify the continued use of expert knowledge where necessary, or collect functional data if possible.

Integration of environmental status

Incorporating environmental or health status (Level 2) is a significant added value to the HFM framework, as it allows functional scores to be adjusted to ecosystem conditions, thereby improving the ecological relevance of the metric. However, this step also introduces an additional layer of uncertainty, particularly when health data are sparse or unevenly distributed, interpolation is required, different assessment methods are used across datasets. While this uncertainty should not prevent the use of the tool, results must be interpreted with caution. Clear documentation of data sources, assumptions, and interpolation methods is essential.

Temporal analysis: high potential but strong data requirements

Temporal comparisons using HFM (e.g., identifying functional gains or losses) represent a powerful application for marine spatial planning and conservation. In our case study, comparing 2009 and 2023 datasets provided valuable insights into spatial changes in ecosystem functioning. However, such analyses require consistent habitat classification across time, harmonised spatial datasets, and comparable environmental status assessments. Otherwise, temporal comparisons may introduce artefacts (e.g., apparent gains due to missing baseline data, apparent loss due to misclassified habitats, for instance between degraded coral communities vs. healthy algal communities). Therefore, temporal analysis of HFM should be conducted with particular attention to data quality and comparability.

Time investment

The time required to implement HFM strongly depends on the level of detail and data sources used. While a basic implementation (habitat maps + expert scores) can be performed relatively quickly, incorporating multiple ecosystem functions, environmental status layers, or literature-based functional scores can significantly increase the workload. For example, in our case study, nine ecosystem functions were initially assessed using expert knowledge, with only a subset later supported by literature (2 functions). This highlights the trade-off between scientific robustness and operational feasibility.

Overall assessment and suggested improvements

The HFM tool is an interesting framework for assessing ecosystem functioning across marine landscapes. Its adaptability to different data availability scenarios is a major strength. However, its effective implementation requires solid GIS expertise (with preferably coding skills), careful data preparation and harmonisation, transparent handling of uncertainty, and realistic expectations regarding data availability. Future developments of the guidelines could further enhance usability by integrating conceptual explanations alongside technical steps, providing optional coding workflows, and explicitly addressing data limitations and uncertainty.

<u>**Ecological Interaction Network**</u>

The initial exploration of the Ecological Interaction Network (EIN) tool for Martinique showed that the approach is conceptually highly relevant, but that its implementation is primarily constrained by data preparation rather than by the code itself. The MARBEFES guidance makes clear that the workflow depends on three main steps: defining the study system, assembling a metaweb and extracting local networks, and then assessing structure and function. In that sense, our experience confirmed that the main bottleneck for Martinique lies in compiling and harmonising the biological inputs required for the second step, especially the trophic links and biomass data across food-web compartments.

Caribbean reef fishes metaweb

A major strength for Martinique is that a Caribbean reef-fish metaweb already exists. The Caribbean food web used by Rezende et al. (2009) includes a large set of trophic interactions and habitat information and, therefore, provides a strong starting point for implementing the EIN tool locally. This means that Martinique does not need to start from scratch, and that the existing Caribbean metaweb can serve as a useful backbone for extracting local food webs based on species occurrence data from Martinique. The MARBEFES guidance explicitly envisages this type of approach, where published metawebs are used and then complemented or tailored to the local case study.

At the same time, our review of the available Caribbean metaweb highlighted an important limitation: the underlying trophic information is not entirely straightforward to trace and validate. In comparing the Rezende et al. dataset with earlier trophic interactions from Randall (1967), we noticed that some predator-prey interactions appeared to be missing in one source and present in another. Because Randall’s original food-habits information is not readily available in a format that can be checked quickly, a full validation of the metaweb would require a substantial manual effort. This experience underlines that, although published metawebs are valuable, their provenance, level of aggregation, and reproducibility should be carefully documented before local application.

Data gaps and assumptions

A second lesson concerns data completeness across trophic compartments. Fish biomass can be estimated relatively well from underwater visual census and existing reef-fish monitoring, which makes the fish component the most operational entry point for Martinique. However, local biomass data remain sparse for benthic invertebrates, macroalgae, plankton, and other lower trophic levels. Reliable information on artisanal fisheries removals is also limited. This is important because the MARBEFES guidance stresses that the food-web approach ideally includes basal producers, zooplankton, benthos, fishes, and other top consumers, and that moving from structural networks to functional analyses requires biomass information across the network. Without these data, the analyses remain largely structural and rely on strong assumptions when estimating energy fluxes.

This leads to a third lesson: applying EIN in Martinique will inevitably require assumptions and external data. The MARBEFES guidance itself acknowledges that metaweb approaches are based on potential rather than realised interactions, that link strengths are often poorly known, and that high-resolution, harmonised data are rarely available across the whole food web. Our assessment in Martinique fully supports this point. In practice, many parameters would need to be filled using literature values or information from other Caribbean locations, especially for non-fish compartments and interaction strengths.

Overall assessment and suggested improvements

Despite these limitations, the tool remains promising and worth pursuing. EIN offers a different perspective from more commonly used reef indicators because it explicitly links biodiversity, trophic structure, and ecosystem functioning. Even with partial local data, the tool could be highly informative for comparing coral reef communities along gradients of environmental pressure or management, such as protected versus non-protected areas, or across sites exposed to different levels of pressure. This is particularly relevant in Martinique.

Overall, the main lesson from this first exploration is that the EIN tool is feasible for Martinique, but the priority is to prepare harmonised datasets, document assumptions transparently, and clearly distinguish observed local information from inferred or literature-based inputs.

Broad-scale trait-based Approach

The initial phase of implementing the Broad-scale Biological Trait approach in Martinique has highlighted several challenges that are important to consider for future applications.

The Broad-scale Biological Trait approach is intrinsically data demanding, requiring both spatially explicit habitat maps (e.g. EUNIS level 3), and detailed biological community data, including presence/absence, but preferably abundance or biomass. While Martinique benefits from a relatively good map of coastal biocenoses (from 2009, and updated in 2023), biological monitoring is strongly biased toward coral reef ecosystems, with limited data available for other biocenoses, such as algal communities, soft-bottom communities, sponge and gorgonian assemblages or even seagrass beds, although the latter benefits from punctual surveys. This creates a strong sampling bias, making it difficult to compare functional diversity across habitats, or interpolate trait distributions at broad spatial scales. As a result, the available datasets are not representative of the full seascape, which prevents application of the method at the island scale.

Trait-based analyses (e.g. Community Weighted Means, functional diversity indices) rely heavily on abundance or biomass-weighted metrics. In the ongoing TRACE project, innovative video-based sampling provides a good spatial coverage (~140 videos across habitats and seasons in the Bay of Fort de France and Bay du Marin). However, true abundance data is lacking, and only proxies (e.g. time of first detection) are available. Although such proxies can be adjusted using detectability assumptions (species traits, habitat complexity, turbidity), this introduces additional uncertainty and limits the robustness of spatial interpolation of trait distributions. This confirms that abundance (or biomass) remains a key limiting variable for applying the BBT framework. Despite limitations at the island scale, the TRACE project demonstrates that smaller, well-sampled areas (e.g. bays with multiple habitats) can provide sufficient data to apply trait-based approaches meaningfully. This suggests that BBT approaches may be more feasible and informative at local or sub-regional scales, particularly when sampling is designed to capture habitat diversity, and effort is standardised across sites.

Finally, the implementation relies on R-based workflows (e.g. FD package), external scripts and repositories (e.g. Trait Environment tutorial), and GIS processing steps. This makes the approach highly accessible to scientific users but less suitable for managers, practitioners, or stakeholders without programming skills. If the intention is to make this tool accessible to the wider audience, the current guidelines could benefit from more user-friendly tools (e.g. templates, Graphical User Interface), clearer step-by-step workflows for non-specialists, and worked examples adapted to different data availability contexts.

While the Broad-scale trait-based approach offers strong potential to link biodiversity and ecosystem functioning across seascapes, its implementation in Martinique is currently constrained by data availability, spatial representativeness, and technical complexity. For future applications, the focus should be on improving multi-habitat monitoring, developing approaches to ensure reliable abundance data across habitats, and enhancing accessibility of the methodology for non-specialist users.

Lessons learned in Romania

An online demonstration using a GIS-based application was conducted to showcase and evaluate the suitability of several tools developed within the Marbefes project for different stakeholder categories. The demonstrated tools included EVA and the Bow-Tie approach. In addition, two newly developed applications, the Eco Tool and the Mussel App (not shown in the current document), were presented, targeting stakeholders from the aquaculture industry and the cultural sector.

The Ecosystem Valuation Assessment (EVA)

The Ecosystem Valuation Assessment (EVA) tool was performed in the southern sector of Romanian territorial waters, integrating spatially explicit information on multiple ecosystem components, including birds, macrozoobenthos and habitats, zooplankton, phytoplankton, marine mammals (dolphins), and fish communities. The assessment covered an area of approximately 2,540 km², extending from the shoreline to depths of up to ~50 m, between Constanta and Mangalia. Following the established methodology, a selected set of assessment questions (AQs), together with their associated metrics and algorithms, was applied to evaluate ecosystem components (ECs). These ECs were defined as both taxonomic groups and habitat types, collectively referred to as “features”.

Lessons Learned from Stakeholder Testing of the EVA Tool

- Stakeholder testing of the Ecosystem Valuation Assessment (EVA) tool confirmed its strong potential to support marine spatial planning and ecosystem-based management by integrating ecological information with decision-relevant outputs. Participants recognised the value of EVA in improving understanding of ecosystem components and the intrinsic value of biodiversity, particularly within marine protected areas (MPAs), and in supporting a balanced consideration of conservation and economic activities.

- A key lesson learned concerns the critical role of data availability and quality. Stakeholders noted that limited and uneven datasets may constrain the robustness of assessments, highlighting the need for EVA to better accommodate data-poor contexts through flexible assessment pathways, transparent data requirements, and the use of proxy indicators and uncertainty estimates.

- The testing also revealed that technical complexity and limited user capacity may hinder broader uptake. This underlines the importance of further simplifying the user interface, introducing guided workflows, and providing training materials and case studies to support non-technical users and institutional adoption.

- Transparency and interpretability of results emerged as another important lesson. Stakeholders expressed the need for clearer explanations of assessment questions, metrics, and algorithms, suggesting that improved communication of methodological assumptions and uncertainty would increase confidence in the tool's outputs.

Bow-tie

The Bow-Tie tool was generally perceived by Romanian stakeholders as conceptually clear and easy to understand; however, it was considered less mature as a ready-to-use decision-support instrument. Stakeholders indicated that wider acceptance would likely depend on the future implementation of a fully operational online version, such as the web-based application currently under development.

The version presented to Romanian stakeholders was based on expert judgement and explored two alternative scenarios.

Scenario A: Baseline / Business-as-Usual (BAU)

This scenario approximated current conditions and included a range of human activities -such as transport (A6), extraction of living resources (A4), physical restructuring (A1), and energy production (A3) -leading to multiple pressures, including marine litter (P3.4), underwater noise (P3.5), habitat loss (P2.2), extraction of wild species (P1.6), introduction of non-indigenous species (P1.1), hydrological changes (P2.3), and chemical pollution (P3.9).

These pressures collectively drove a central biodiversity-change event, characterised by degraded pelagic and benthic habitat quality, loss of macrophyte and seagrass canopies, and altered feeding and reproduction grounds. The resulting consequences included reduced carbon storage and fish and shellfish provisioning, deterioration of conservation status, increased management and socio-economic costs, impacts on Blue Economy sectors, and potential effects on human health and governance.

Scenario B: Blue Economy / Green Infrastructure

This scenario assumed a transition towards a more sustainable Blue Economy, where green infrastructure and improved management practices prevail over BAU. While involving the same core activities, this scenario incorporated enhanced protection measures (PMs) and mitigation measures (MMs).

The implementation of green solutions, technological innovations, and increased public participation in decision-making was assumed to substantially reduce negative impacts. Measures with the greatest expected effectiveness were assigned higher positive scores (3–5), reflecting their potential to improve the state of the central biodiversity event and to significantly reduce negative consequences, thereby maximising positive outcomes.

Lessons Learned from the Bow-tie Tool

The application of the Bow-Tie tool led to several key lessons:

- The availability of a fully operational, ready-to-use online application would greatly facilitate adoption in marine spatial planning (MSP), MPA management, and educational contexts.
- Increased flexibility, allowing the integration of additional activities, pressures, drivers, and management measures, would enhance the tool's applicability across diverse management settings.
- Incorporating a more explicit quantitative component, including causal relationships and probabilities (e.g. through a Bayesian framework), would improve the robustness of impact and consequence assessments.
- Combining the Bow-Tie tool with complementary ecological assessment tools would substantially increase its analytical and decision-support value.

Conclusion

This deliverable demonstrates that the MARBEFES tools and WP1 model with its associated stakeholder engagement approaches can be successfully out-scaled beyond their original European case-study settings while remaining scientifically robust, policy-relevant, and operationally useful. The application of the MARBEFES tools and WP1 model in Martinique and Romania showed that, despite substantial differences in ecological conditions, governance systems, cultural contexts, and data availability, the overall conceptual frameworks remained valid and capable of generating meaningful insights for biodiversity governance, marine spatial planning, and the application of the MARBEFES toolbox.

A central finding of the out-scaling exercise is that context matters as much as methodology. Martinique was characterised by a strong emphasis on local governance, awareness, knowledge, habitat protection, and land-sea interactions, whereas Romanian stakeholders focused more strongly on national governance structures, institutional fragmentation, bureaucracy, regulatory effectiveness, and marine biodiversity monitoring. These results confirm that while biodiversity governance challenges may be broadly shared, their manifestation and potential solutions remain highly context dependent and require a local lense.

The out-scaling activities further demonstrated the value of stakeholder engagement approaches. Fuzzy Cognitive Mapping, governance workshops, and MPA consultations successfully captured local perceptions, priorities, and knowledge systems while remaining comparable with the outputs obtained from the European case study sites. Importantly, the adaptation from physical to online implementation showed that methodological flexibility can maintain data quality and stakeholder engagement even when local circumstances require modifications to the original process. This finding is particularly relevant for future international applications of the MARBEFES tools, where logistical, cultural, or political constraints may necessitate alternative implementation pathways.

A second major lesson concerns the transferability of the MARBEFES tools themselves. Overall, the tested tools proved to be highly relevant in both case-study areas, but their successful application depended on several enabling factors, most notably data availability, technical expertise, and the quality of guidance materials. Tools such as the Bow-Tie framework, Scenario Downscaling, Habitat Function Metric (HFM), Ecological Value Assessment (EVA), Ecological Interaction Networks, and trait-based approaches all offered valuable perspectives for supporting ecosystem-based management. At the same time, the testing highlighted that broader uptake beyond the scientific community will require more operational guidance, simplified workflows, user-friendly interfaces, and clearer explanations of assumptions, uncertainties, and expected outputs. Across almost all tools, stakeholders and practitioners consistently identified the need for step-by-step implementation support as a prerequisite for wider adoption.

In addition, another lesson from the out-scaling exercise is that successful transfer does not mean replication without adaptation. The tools performed best when their core scientific principles were maintained while allowing sufficient flexibility to accommodate local ecological characteristics, governance structures, stakeholder priorities, and available datasets. This balance between standardisation and adaptability emerged as a recurring theme throughout the project. Future applications should therefore preserve common methodological foundations to ensure comparability, while explicitly allowing contextual tailoring to maximize relevance and usefulness for local decision-makers.

Finally, the overall out-scaling experience confirms that MARBEFES has produced a suite of understanding, methods and tools with significant potential for broader international application. The work conducted in Martinique and Romania demonstrated that biodiversity assessment and governance-support frameworks developed in European contexts can provide valuable insights in diverse marine regions when accompanied by appropriate adaptation and stakeholder engagement processes. The lessons learned provide a strong foundation for future deployment of these approaches across a wider range of marine ecosystems and governance contexts, contributing to more evidence-based, inclusive, and adaptive marine biodiversity management globally.

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