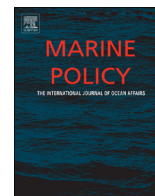




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Maritime ecosystem-based management in practice: Lessons learned from the application of a generic spatial planning framework in Europe

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ABSTRACT

A generic framework (FW) for the monitoring and evaluation of spatially managed areas (here defined as marine areas subject to a planning and management regime) was developed and tested in nine marine areas of 13 European countries under the EU funded project MESMA (Monitoring and Evaluation of Spatially Managed Areas). This paper describes the lessons learned in the use of the FW and draws conclusions for its future use and development. The selected case studies represented diverse spatial scales, management status and complexity, ranging from sub-national areas to entire national coastlines, and large offshore regions. The application of the FW consisted of seven steps: starting with (i) context setting and (ii) gathering of relevant ecosystem information, human activities and management goals; it continues with (iii) indicator selection and (iv) risk assessment; and the final steps considers the (v) analysis of findings and (vi) the evaluation of management effectiveness, to end up with (vii) the revision and proposal of adaptation to current management. The lessons learnt through the application of the FW in the case studies have proved the value of the FW. However, difficulties rose due to the diversity of the nature and the different stages of development in planning and management in the case study areas; as well as, limited knowledge on ecosystem functioning needed for its implementation. As a conclusion the FW allowed for a flexible and creative application and provided important gap analyses.

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1. Introduction

Environmental policies are increasingly emphasizing the need for a holistic approach to marine resource management. Such a management approach needs to address the increasing amount of

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anthropogenic pressures on marine environments as well as conflicts between multiple users competing for space and resources. Thus, the need for an 'ecosystem-approach' has been advocated widely since its adoption as an integral concept of the Convention on Biological Diversity at the Earth Summit in Rio de Janeiro in 1992 [1,2].

Ecosystem-based management has been defined as: The comprehensive integrated management of human activities, based upon the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems and thereby achieving sustainable use of goods and services and maintenance of ecosystem integrity [3]. Consequently a number of recent European legislations have been issued with the aim of achieving the maintenance of good environmental status (GES) through the sustainable use and conservation of marine biodiversity (e.g. the Habitats Directive [4], Integrated Maritime Policy [5], the Mediterranean Regulation [6,7], the Water Framework Directive [8] and more recently, the Marine Strategy Framework Directive [9]. A much-advocated tool to progress from the traditional fragmented single sector management approach to an ecosystem-based approach is the concept of place based management such as Marine Spatial Planning (MSP) [10,11]. MSP has the potential to improve decision making by providing a framework to analyse competing human activities and managing their impact on the marine environment, and as such is one of the core concepts of the EU Sustainable Development Strategy [12,13].

The EU funded project MESMA (Monitoring and Evaluation of Spatially Managed Areas) addressed the challenge of an interdisciplinary approach to monitor and evaluate spatially managed areas (SMAs). It suggests a coherent set of tools (concepts, models and guidelines) to support the practical implementation of an ecosystem based management. The MESMA integrated framework (FW) is a key tool that was developed for monitoring and evaluation of SMAs [14] that was tested and evaluated in case studies (CSs). The FW was built on the basis of good practice of ecosystem-based management and lessons learned from existing practical applications for evaluating the success of maritime spatial management [11]. It can be used as guidance in which, step by step, the user applies an indicator based assessment of spatial management plan effectiveness regarding to predefined operational objectives. A detailed and flexible manual has been developed [15] to provide guidance on the application of the FW.

The FW was applied and tested within nine SMAs in Europe, representing different stages of management implementation, and spatial scales. Existing management objectives were identified where they were available. In the absence of objectives, the FW provided guidance on how to define operational objectives. The defined CSs were diverse in nature. Among other, they were differing in population density, socioeconomic settings, human activities and governance settings, and included a variety of marine landscapes from small and highly populated bays and islands, to whole national coastlines and large offshore regions.

One aim of the MESMA Project has been to identify a generic approach to support MSP which cuts across the area differences. The MESMA FW is the result. It was designed as an easy to use tool taking the user step by step through monitoring and assessment to set and subsequently to adapt measures. Synthesis of the experiences gained from the tests is presented here in the different settings of the CSs and the information and actions required at each step of the FW.

The goal of the project has been to gather evidence from all nine CSs however one CS could not be included.

The present research was designed to give response to the following questions:

- a) How was the FW a useful starting point for the monitoring and evaluation of an SMA?
- b) Did it help to assess or formulate clear management goals and their implementation?
- c) Were any FW steps particularly useful or hard to complete?
- d) Is the FW suited to specific circumstances of each case study? For example, availability of information, unrealistic input requirements at specific steps of the FW, or an excessive complexity of the assessment?

2. Material and methods

2.1. Case study (CS) area descriptions

The eight case studies (CSs) analysed here are widely distributed across European waters (Fig. 1) and with heterogeneous characteristics. They vary in size from 3500 km² (Belgian part of the North Sea) to 1,400,000 km² (Barents Sea). They host a variety of different uses by sector and intensity. Their natural environments are diverse as well as the degree of degradation, and pressures they face could be considered as being intense. However, the countries of the CS areas share a common interest in marine planning and management. In some areas management barely exists and regulations to build on are lacking. Others, show advanced integrated management approaches in place, although these tend towards ecosystem protection or recovery objectives. One area (Pentland Firth and Orkney waters) is under immediate pressure of renewable energy development which is driving the marine spatial planning approach there. Table 1 provides a summary of the general case study information and maps are presented as Supplementary material (S1). In the following additional key information characterizing each case study areas, also with respect to the current state of spatial management, are given:

- i) Southern North Sea – the Belgian part of the North Sea (BPNS) – BPNS is characterized by a unique complex of sandbanks with several ecologically valuable habitats including gravel beds and biogenic reefs [16]. Despite its small size the area is intensively used for maritime industrial activities including aggregate extraction, fisheries, wind energy, shipping and dredging. Belgium was one of the first countries to introduce MSP, helped by the appointment of a federal Minister for the North Sea in 2002. In March 2014, Belgium approved a legally binding MSP for the BPNS (Royal Decree of 20th March 2014 adopting the MSP).
- ii) Pentland Firth and Orkney Waters (PFOW), Scotland – PFOW area is relatively pristine and subjected to several protective designations including: marine Special Areas for Conservation, Special Protected Areas, adjacent coastal Sites of Special Scientific Interest (SSSIs), and National Scenic Areas. Four possible Marine Protected Areas (MPAs) are under study by the Scottish government. Traditional marine activities include fisheries, shipping and tourism/recreation. More recent developments include the reception/processing of North Sea offshore oil production and the research and testing of marine renewable energy (MRE) devices (wave and tide). It is a designated 'Marine Energy Park' (one of the only two in the UK) where intensive MRE development (1.6 GW by 2020) is planned in near-shore waters. The PFOW pilot marine plan is a test bed for the development of regional marine planning in all Scottish waters [17]. The draft for MSP was published in March 2015.
- iii) The Barents Sea (BS), Norway – BS is characterized by relatively clean water and an intact marine ecosystem comprising diverse marine habitats and it is home of highly valued species

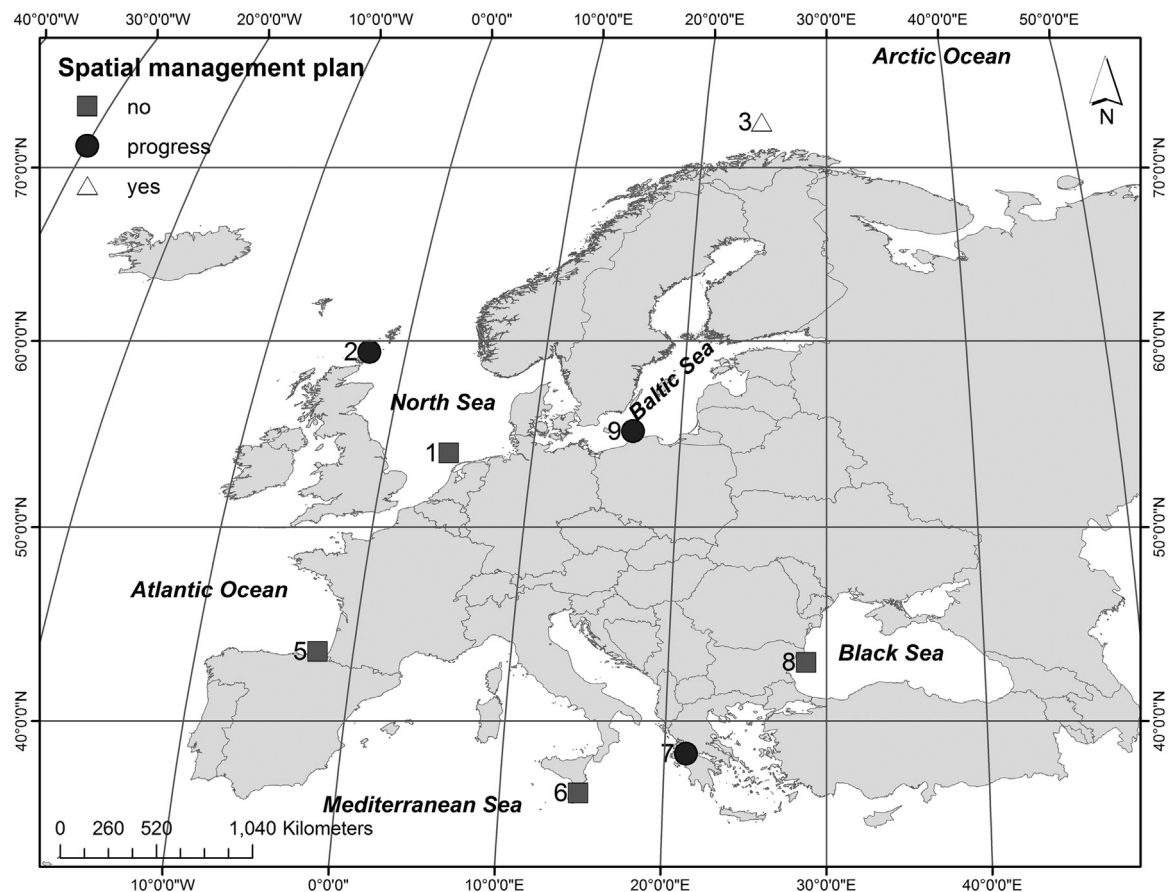


Fig. 1. Localization of the eight cases that was part of the MESMA EU-project and are included in this study, figure modified from [14].

Table 1

Description of the eight cases used in the MESMA-Framework test. Additional case study information and maps are presented in Supplementary material (S1).

	Southern North Sea (Belgian coast)	The Basque Country (Bay of Biscay)	Pentland Firth and Orkney Waters (PFOW), Scotland	Inner Ionian Archipelago, Patraikos and Korinthiakos Gulf	The Bugarian part of the Black Sea	Strait of Sicily, Italy	The Baltic Sea	The Barents Sea, Norway
Context								
Management plan	No	No	PFOW MSP	No	BSRBMP	No	BSAP	BSMP
Size of SMA (km ²)	3454	10,815	12,000	14,285	27 294	60,000	415,266	1,400,000
Position (coast, offshore)	C	O	C	C-O	C	O	C-O	O
Population size (millions)	10	2.2	5.6	1	7.4	5	> 85	5
Number of nations involved	1	1	2	1	2	2	9	2
Number of stakeholders	M	H	H	L	H	M	H	L
Complexity and information availability								
Activity complexity	M	H	H	M	H	H	H	L
Information on activities	M	H	H	M	H	L	H	H
Biological complexity	H	H	H	H	L	H	H	H
Information on ecosystem components	M	M	M	M	L	L	H	M
Information on management initiatives	M	H	H	M	M	M	H	H

Context includes: presence of management plan, size of spatially managed area (SMA), position (C: coast and O: Offshore), size of population, number of nations, and stakeholders. Complexity and availability of information related to human activities and biological setting (H=High; M=Moderate, and L=Low).

of whales and seabirds. It is experiencing an increase of pressured derived from human activities such as commercial fisheries, oil and gas exploration/production, shipping and

aquaculture; moreover it is experiencing additional pressure from the effects of climate change and pollution. It is of significance to the economies of Norway and Russia with

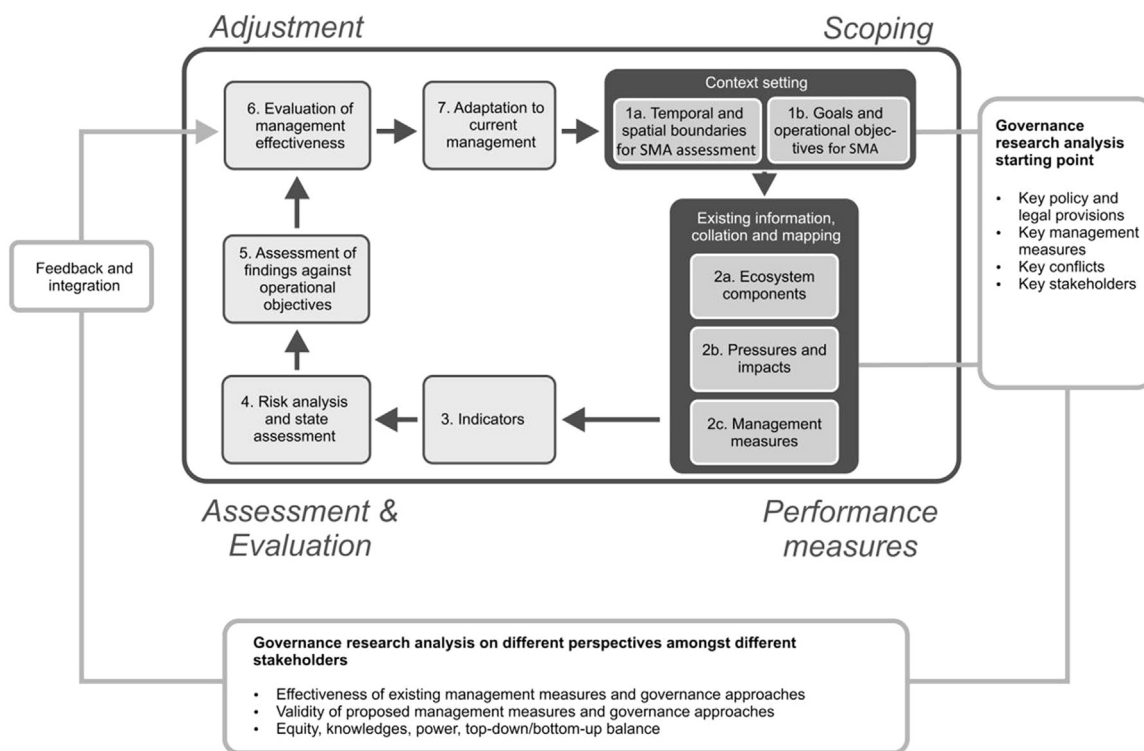


Fig. 2. The cycle of steps of the framework (FW) developed within the MESMA EU-project to monitor and evaluate spatially managed areas that was tested by the MESMA-cases, from [14].

transboundary issues to be considered. The area is subjected to intensive commercial fishing pressure. Small scale coastal fisheries, and the marine industries as a whole, are very important to remote coastal communities. The Norwegian Barents Sea Management Plan (BSMP) was completed in 2006 [18] and revised in 2010 [19] leading to greater integration of decision making about development and protection. The MAREANO (MARine aREAL database for NORwegian Coasts and Sea Areas) conducts sea mapping to fill knowledge gaps identified under the BPMS.

- iv) The Basque Continental Shelf (BCS), Spain – The Basque coast presents unique biogeographical characteristics (Borja et al. [20]). Seafloor morphological diversity and its oceanographic characteristics are reflected in ecological richness. The area supports intense and varied human activities including commercial and artisanal fishing. A significant feature is recreational fishing with over 5000 boats [21]. Marine industries include tourism and sand mining for beach nourishment. New industrial activities include marine renewable energy (wave) and offshore aquaculture. No marine spatial plan is in place but littoral ordination are sectorial plans implemented for inner waters.
- v) Strait of Sicily (SoS), Italy and Malta – SoS is characterised by high levels of energy, diversity and productivity [22,23]. Human activities include fishing, aquaculture, shipping, tourism, offshore oil, pipelines, cables and wind farms. Aquaculture is a particular feature in Malta [24]. The intensity of maritime traffic and tourism are key pressures related to habitat degradation. MSP is still at a very early stage with no integrated management. However, two MPAs in Sicily and five in Malta are already designated and trawl fishery management plans are well developed and in place.
- vi) Inner Ionian Archipelago (IIA), Greece – The IIA together with the Patraikos and Korinthiakos Gulfs include ten Natura 2000 sites and two National Parks (Zakynthos and Messolonghi).

Exceptional habitats and species diversity reflect a variety of oceanographic features – loggerhead turtle, monk seal and sperm whale feature in the list of rare and priority species. Adjacent coasts are heavily populated giving rise to resultant pollution concerns – extensive human activities including tourism, shipping, fisheries and aquaculture. Korianthiakos Gulf has limited connection to the open sea and poor water exchange making it vulnerable to eutrophication. Some sectoral and small area management plans are in place such as the zoning regulations in the Zakynthos marine park. Nevertheless no integrated marine spatial plan is in place.

- vii) Baltic Sea Action Plan (BSAP), several Baltic countries – It is the largest area of brackish water in the world and is characterized by very busy shipping traffic. The area contains relatively few species and most are close to their salinity tolerance level. It has poor water exchange with a large terrestrial catchment area. All nine coastal Baltic states and the EU are contracting parties to the Baltic Marine Environment Protection Commission, the Helsinki Commission (HELCOM), which is the governing body for the Helsinki Convention. The BSAP was adopted by all nine states in 2007. It is designed to restore good ecological status in the Baltic sea by 2021 [25,26]. It is divided into the four segments of eutrophication; hazardous substances; biodiversity and safety. It applies to the whole catchment area including terrestrial and marine areas – individual National Action Plans are established by contributing states. It is regarded as a pilot for ecosystem-based management in the context of the MSFD. MSP is not in place but ecological objectives are defined and seek now the integration of the management of human activities.
- viii) Black Sea, Bulgaria (BSB) – The Black Sea as a whole drains a massive catchment of 16 countries and 100 million people. The main pollutant load is delivered by the River Danube [27]. It is politically diverse with environmental cooperation established under the Bucharest Convention administered by the Black Sea

Tasks related to each step of the framework
<p>STEP 1: Context setting: Tasks at this initial stage are to set the spatial and temporal boundaries and define the goals and operational objectives. In cases where a spatial management plan is implemented the boundaries are defined by the management plan. In other cases potential administrative, ecological, economic or social boundaries should be considered. With an existing or already proposed spatial management plan high level goals and related operational objectives may be defined. In other cases where there is no predefined set of goals and operational objectives numerous marine policies may apply at an international, regional and local level where high level goals are clearly defined and operational objectives can be derived.</p>
<p>STEP 2: Existing information: At this step the ecosystem components that are relevant to the objectives are identified and a list of relevant ecosystem components along with GIS maps of their coverage should be generated. Then relevant sectors are identified and the pressures these exert on the ecosystem components. The final output should be a list of pressures and GIS maps showing their cumulative impacts on ecosystem components or a table of ecosystem component sensitivity.</p>
<p>STEP 3: Selection of indicators and thresholds: Based on information from step 1 and 2 indicators for each operational objective should be selected that can track whether the operational objectives are met or not. The manual provides examples of relevant indicators (e.g. Good Environmental Status, as described in the Marine Strategy FD [9]). For each of the case relevant indicators a viability analysis should be conducted using a set of criteria modified after ICES criteria for good indicators and criteria are scored good (3), medium (2) or poor (1).</p>
<p>STEP 4: Risk analysis and state assessment: In the former step performance indicators were selected and their thresholds were determined based on this the technical characterisation of risk and/or state is assessed. If a spatial management plan is not in place a risk assessment is conducted by calculating the likelihood of meeting the operational objectives (i.e. risk analysis, step 4.a). If a spatial management plan is in place, whether or not the operational objectives were met should be assessed (i.e. state assessment, step 4.b).</p>
<p>STEP 5: Assessment of findings against operational objectives: The results of the risk analysis and/or state assessment are now interpreted to evaluate whether the operational objectives have been achieved or failed, by how much and their relative importance in terms of future management adaptations. A summary of the state of the indicators and how these are linked to the operational objectives is made. An evaluation is conducted on how successful or unsuccessful operational objectives and indicators were, if these have been achieved or failed. A revisit of the evaluation of indicators (step 3) to assess if the indicators were appropriate is suggested.</p>
<p>STEP 6: Evaluate management effectiveness: The success of the chosen management measures in terms of achieving the operational objectives is evaluated (implemented or recommended). This involves an assessment of which management measures were/ were not/were partly successful for which objectives. To complement this "scientific evaluation" it is important to understand the views of different stakeholders (governance, management, operational and others) on the effectiveness of the existing management measures in achieving the environmental goals/objectives, including their views on the validity of these objectives.</p>
<p>STEP 7: Recommendations for future management: Depending on the suitability of the current management, adaptations might be needed based on results from step 5 and 6. A report on adaptive management needs should be written and results prioritized. The output of the report should link to a governance analysis that could support the implementation of the management recommendations.</p>

Fig. 3. A short description of the main tasks related to each step of the framework (FW) cycle presented in Fig. 2 (modified from [15]).

Commission (BSC) and their Black Sea Integrated Monitoring and Assessment Programme. The BSC promotes processes that will stimulate the sustainable development of maritime activities with a focus on transboundary issues. MSP and implementation of the MSFD lay critical foundations to the process [28]. This case study reviews the Bulgarian Black Sea River Basin Monitoring Programme (BSRBMP). The aim of the BSRMP is to achieve 'Good Environmental Status' in all Bulgarian waters including coastal waters.

2.2. Application of the framework

2.2.1. Case study findings

The framework (FW) steps and their practical implementation have been described in detail [14]. The assessment was carried out through structured tasks, guided by a user manual [15], in seven successive steps (Figs. 2–4) comprising the key elements of scoping, performance measures, assessment evaluation and adjustment.

Each case study followed as closely as possible and modified if necessary the iterative process described by the FW and used the related manual. The experience from the case studies running through the FW steps is summarized below. The lessons learned relate to both the setting of the case studies (Table 1; Supplementary Figs. S1–S8) and to the general requirements for a successful application of the FW (Table 2; Figs. 5 and 6).

The main findings conducting in each of the steps of the FW are presented below:

STEP 1: Context setting: Some study areas already had integrated management plans in place (i.e. BSMP, BSAP, BSIMAP) or in advanced state of development (PFOW), while management relied on an array of sectoral plans, independent legal or administrative initiatives in most cases (BSNS, BC, SoS, IIA, BSRBMP). Areas with integrated management plans in place had clear spatial and temporal boundaries as well as operational objectives. However, when this was lacking relevant operational objectives were based on available management documents (BSNS, PFOW) or mainly based on expert judgment and distilled from different documents (BC, SoS, IIA) (Fig. 6). The gathering of relevant information was particularly hard for transnational areas to lack of harmonization among management strategies (SoS) or hindered information exchange (BSIMAP/BSRBMP).

STEP 2: Existing information: Geographic Information

Systems (GIS) were widely applied to collate and visualize the information for each area except one (BSIMAP/BSRBMP). Although the spatial extent of human activities was mapped, the definition of proper indicators and their harmonization at regional level was identified as the main obstacle towards implementation of the respective management plans. Other knowledge gaps were identified using the information gathered in the areas through long-term monitoring programs (BSNS, SoS, BSAP). Specific research projects were also carried out during multiple years by the involved research institutions (BSNS, BSMP), as well as other national (PFOW) or regional bodies (BSAP) which were identified as being relevant source of information for the implementation of the FW. In some cases (SoS, IIA), data were asymmetrically distributed across different activities, being concentrated on the most economically relevant ones (e.g. trawl fishing) while others, remained largely uncovered (e.g. tourism). When collating and mapping ecosystem information, this was highly based on expert judgment, mainly because data were too few, or the associated uncertainty was substantial (Fig. 6). Step 2b, mapping pressure and impact, was the most difficult one in all the process due to the lack of scientific knowledge and data regarding to the impact produced by the different human activities, and its associated uncertainty (Fig. 5).

STEP 3: Selection of indicators and thresholds: Case studies applied the FW criteria for the selection of indicators. Thresholds for indicators were possible to establish for all case studies except for two areas (BSIMAP/BSRBMP). However, both, the selection of indicators and definition of thresholds were also supported by external documents (BSNS, BSMP, PFOW, BC, BSAP, IIA); expert judgement (SoS); or meetings with stakeholders (BSNS).

STEP 4: Risk analysis and state assessment: The analysis of the risk of failing to reach the stated management operational objectives was made in five out of the eight areas following different approaches encompassing workshop with experts (BSNS); stakeholders (PFOW); and the development of specific tools feed with monitoring data (BSAP). Expert judgment was the most used method because data from state assessment were lacking or incomplete (Fig. 6). This required management of the necessary assumptions and possible bias. Assessment of 'state' was carried out in two cases, either based on regular monitoring data (BSMP) or partially relying on expert judgement to overcome shortfall of available data (BC). However, in some instances (BSIMAP/BSRBMP) data scarcity and fragmentation were severe enough to prevent

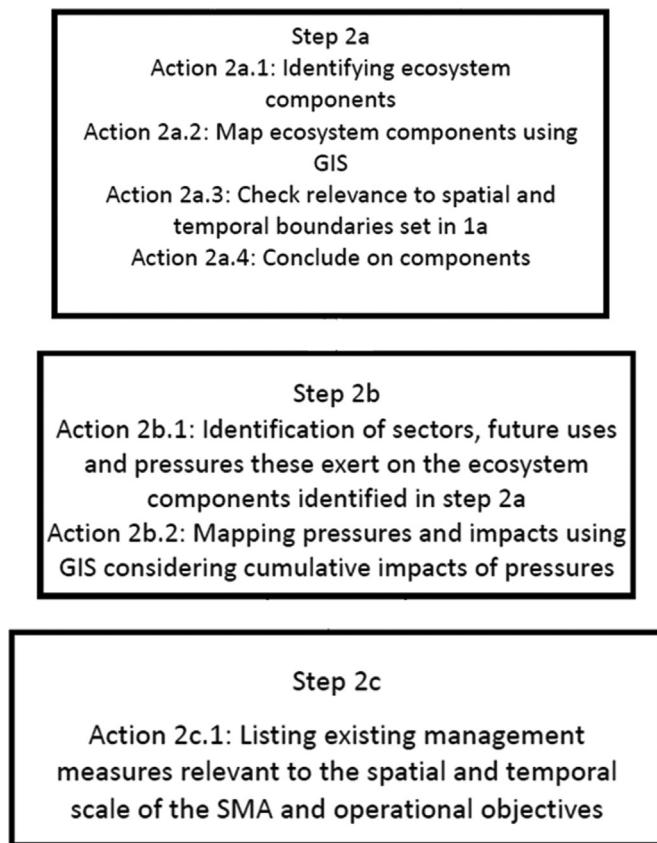


Fig. 4. An example of successive actions presented in the framework manual [15] that are connected to the the step 2 task “Existing information collation and mapping” of the framework cycle (see Figs. 2 and 3), figure modified from [15].

the completion of this step.

STEP 5: Assessment of findings against operational objectives: In two out of the eight cases (BS, BSAP) the assessment was routinely conducted as a part of the integrated management plan already in place. Where the assessment was performed on available data, either under an integrated management plan (BSAP) or sectoral ones (IIA), the availability of sound data limited the robustness of the conclusions or even precluded the ability to make them. It also happened to be too early in the management process to perform this step where an integrated management plan was under development (BSNS, PFOW). Some cases focused on a limited array of either current activities (SoS) or the administrative process and public participation of planned ones (BC), and the assessments were worked out through the analysis of trends, available documents and expert opinion. Expert judgement was the most used method to assess if operational objectives were being fulfilled because assessment data was lacking (Fig. 6).

STEP 6: Evaluate management effectiveness: Where integrated management plans were in place, effectiveness evaluation was already estimated as a part of the management process (BSMP, BSAP). By contrast, the task was partly or completely not possible in those areas where the integrated management plan was in an early phase of implementation (BSNS, BSIMAP/BSRBMP). Yet, sometimes was possible to identify the emerging process of planning and development consent management and draw early conclusions about the likely effectiveness in some areas (PFOW). In other cases, the evaluation was performed for the first time and revealed a lack of alignment between inspiring policies and operational objectives. The absence of coordination among sectoral policies, which was ultimately reflected in the incapacity to enforce the stated zoning scheme (SoS). Consultation and negotiation

led to the proposal of economic and non-economic compensatory measures in some cases (BC). In contrast, the sustainability of economic activities was in practice overlooked in other areas (SoS).

STEP 7: Recommendations for future management: This step was fulfilled by the half of the case studies mainly because it requires the fulfillment of all the previous steps (Figs. 5 and 6). This step allowed recommendations and adaptations to current management at whatever stage the plan had reached, also including new information generated during the process (PFOW, BSMP). Adaptations needed were identified by combining the results from previous steps and the projection of scenarios (BC, SoS). Recommendations were made to enhance integration; reduce conflicts among stakeholders; benefit as many stakeholders as possible; and promote equity in the distribution of the costs (BC, SoS, IIA). The availability of stakeholder's views from the parallel governance analysis and the use of systematic conservation planning techniques (i.e. MARXAN software in IIA and BSAP) greatly helped to work out this step.

2.2.2. Reflection on applicability of framework

The availability and access to the information required constrained some of the targeted actions required under each of the seven FW steps. This introduced varying degrees of uncertainty in the outcomes of the case studies. Because of the FW flexibility and case study diversity, different approaches were used to fulfill the needed information and analysis. Moreover, depending on the case, certain actions were either irrelevant or unrealistic to undertake. Where integrated management plans were not in place, the FW and manual helped to formulate management goals in a clear way through the systematic identification of potential issues and flaws, as well as the prioritization of management needs within the specific context of each case. Conversely, in those cases where integrated or large management plans already existed, the FW helped the practical implementation of the management goals by means of the critical identification, assessment and evaluation of gaps and flaws in operational objectives and their related indicators.

In what follows, the reflections on using the FW are reported. We have listed the experiences from the cases in using the manual for each step in succession (Table 2, Figs. 5 and 6). The variety in experience from the cases relates both to the setting of each case (Table 1) and the required actions by each FW step (Table 2).

In *Step 1* the main action is to define management area, goals and operational objectives, and in *Step 2* to gather relevant data. The challenges experienced are related to: definition of area (1a), selecting relevant goals and objectives for the defined area (1b), and data availability from relevant ecosystem components and human activities and actors (2a and 2b) within the selected area. The initial steps (step 1a1–1b2) were completed by almost all cases and viewed as useful and uncomplicated to undertake. Literature was the main source of information while for the assessment of objectives and policy approach (1b3–1b8) expert judgement was used in 50% of the cases (Table 2, Figs. 5 and 6).

For cases where an integrated management plan existed (i.e. The Barents Sea, the Baltic Sea, PFOW and The Black Sea cases) these steps were less demanding. However, the level of goals, objectives and targets, and the structure of indicators and actions did not match the FW and these differences were necessary to sort out when running existing plans through the FW procedure. For cases where no management plan was in place, the study area was defined using existing management initiatives (e.g. legal frameworks, sectoral plans, policy documents...) and objectives were in principle based on MSFD requirements. The objectives guided what data was relevant for *Step 2* – the more complex the context of the case (e.g. rich and varied marine ecosystem and presence of many sectors), the more demanding the data requirement.

Table 2

Data source used in the eight cases to complete the seven steps of the framework (FW) and evaluation by the case-groups of the process and tasks involved to complete the steps.

Cases	Southern North Sea (Belgian coast)	Bay of Biscay, The Basque Country	Pentland Firth and Orkney Waters (PFW), Scotland	Inner Ionian Archipelago, Patraikos and Korinthiakos Gulf	The Bugarian part of the Black Sea	Strait of Sicily, Italy	The Baltic Sea	The Barents Sea, Norway	Order of cases as to the left	Evaluation							
Steps in the framework (FW)	Type of data																
1 Context setting																	
1a Set temporal and spatial boundaries																	
1a1 Existing management and sector plans	L	L	LO	L	L	L	L	L	U	U	U	U	U	U	U	U	
1a2 Planned spatial management initiatives	L	L	LO	L	L	E	L	L	U	U	U	U	U	U	U	U	
1a3 Patterns of activities	L	O	LO	LOE	L	O	L	L	U	U	U	U	U	U	U	U	
1a4 Institutional landscapes	L	L	LO		L	O		L	U	U	U	U	U	U	U	U	
1a5 Temporal and spatial boundaries		LE	LO	L	L	L	L	L	U	U	U	U	U	U	U	U	
1b Goals and operational objectives																	
1b1 Existing management plans and goals	L	L	LOE	L	L	L	L	L	U	U	U	U	U	U	U	U	
1b2 Existing legal obligation and policy objectives	L	L	LO	L	L	L		L	U	U	U	U	U	U	U	U	
1b3 Defining objectives and assessment of balance	E	E	LOE	E	L	L	L	E	U	C	U	U	U	U	U	U	
1b4 Assessment of operational objectives	E	E	E	E	L	E	L	E	U	C	U	U	U	U	U	U	
1b5 Assessment of policy approaches	LOE	L	E	E	L	E		E	U	U	U	U	U	U	U	U	
1b6 Concluding on goals and operational objectives	E	E	E	E	L	E		E	U	U	U	U	U	U	U	U	
1b7 Identifying stakeholders		O	LOE		L	O		L	U	U	U	U	U	U	U	U	
1b8 Collate and summarize operational objective information		E	E			E		E	U	U	U	U	U	U	U	U	
2 Existing information collation and mapping																	
2a Ecosystem components																	
2a1 Identifying ecosystem components	LE	L	LO	LOE	E	M		OL	U	U	C	U	U	NR	U	C	
2a2 Map ecosystem components using GIS		LOM	L	LOE	L	M		OL	U	U	U	U	U	NR	U	U	
2a3 Check relevance to spatial and temporal boundaries set in 1a		E			E	E		L	U	U	U	U	U	NR	U	NR	
2a4 Conclude on components		E		O	E	E		L	U	U	U	U	U	NR	U	NR	
2b Identify pressures and impacts																	
2b1 Sectors and pressures these exert on the ecosystem	L	LE	LOE	LOE	E	M		OE	C	C	C	C	U	NR	U	C	
2b2 Mapping cumulative impacts of pressures using GIS		M	L	LOE	E			OE	C	C	C	U	C		U	C	
2c1 Listing existing management measures relevant to operational objectives		L	LOE		E			LE	U	U		C			U		
3 Selecting indicators and thresholds																	
3.1 For each objective identify the relevant ecological, social, economic and other components (data from 1b and 2b)		LE	LE	LE	L	O		LE	U	U	U	U	U	U	U	U	
3.2.1 Validating indicators using viability analyses		LE	LE	LE	O	O		LE	U	U	U	U	U	U	U	U	
3.2.2 Identify gaps in available data for the best indicator for each goal/operational objective		E	LE	LE	O	E		LE	U	U	U	U	U	U		U	
3.2.3 List the indicators and the		LE	LE	LE	O	L		LE	C	U	U	U	U	U		U	

Table 2 (continued)

Cases	Southern North Sea (Belgian coast)	Bay of Biscay, The Basque Country	Pentland Firth and Orkney Waters (PFOW), Scotland	Inner Ionian Achipelago, Patraikos and Korinthiakos Gulf	The Bugarian part of the Black Sea	Strait of Sicily, Italy	The Baltic Sea	The Barents Sea, Norway	Order of cases as to the left															
Steps in the framework (FW)	Type of data								Evaluation															
availability of thresholds																								
4 Risk analysis and state assessment																								
4a Risk analysis																								
4a1 Pressure identification	E	L E	E	LE	E	M			U	U	C	U	U	U	U	U	NR							
4a2 Impact magnitude assessment	E		E	E	E	E			U		C	U	U	U	U	U	NR							
4a3 Impact probability assessment	E		E	E	E	E			U		C	U	U	U	U	U	NR							
4a4 Risk characterization	E		E	E	E	E			U		C	U	U	U	U	U	NR							
4b State assessment (Management plan exists)																								
4b1 Data availability					O	D		O	NR		NR	U	U	U	U	U								
4b2 Indicator state assessment					E	D		O	NR		NR	U	U	U	U	U								
5 Assessing findings against operational objectives																								
5.1 Identifying success or failure of operational objectives	E	E	E	LE	L	O		E	U	U	U	U	U	U	C	U								
5.2 Assessing the overall success and importance		E	E	E	NR	E		E	U	U	U	U	U	U	C	U								
5.3 Reassess indicators and benchmarks			E	E	E	E		E			U	U	U	U	C	U								
6 Evaluate management effectiveness																								
6.1 Evaluate effectiveness of management measures	E	E	E		E	E		E	U	U	U	U	U	U	U	U								
6.2 Write a report on the management effectiveness		E	E			E		E			U	U	U	NR	U	U	U							
7 Recommend adaptation to current management																								
7.1 Identify if adaptations to current management are needed	E	E	E			O		E	U	U	U	U	C	U		U								
7.2 Develop alternative policy scenarios			E			E		E			U	U	C	U		U								
7.3 Recommend improvements in management strategies		E	E			E		E			U	U	U	C	U	U								
7.4 Check for improvement in management measures			E			O		E			U		C	U		U								
7.5 External orientation: Relation with the EU policy framework			E			O		E			U		C	U		U								
7.6 Write a report on adaptive management needs for the SMA			E			E		E			U	U	C	U	U	U								

Type of data sources are: L=Literature; O=Observed; M=Model; and E=Expert judgement and evaluations are: U=Useful; C=Complicated; NR=Not relevant. Empty cells are steps that were not completed by the cases. Gray cells for type of data indicate use of expert judgment and for evaluated that a step was complicated to complete.

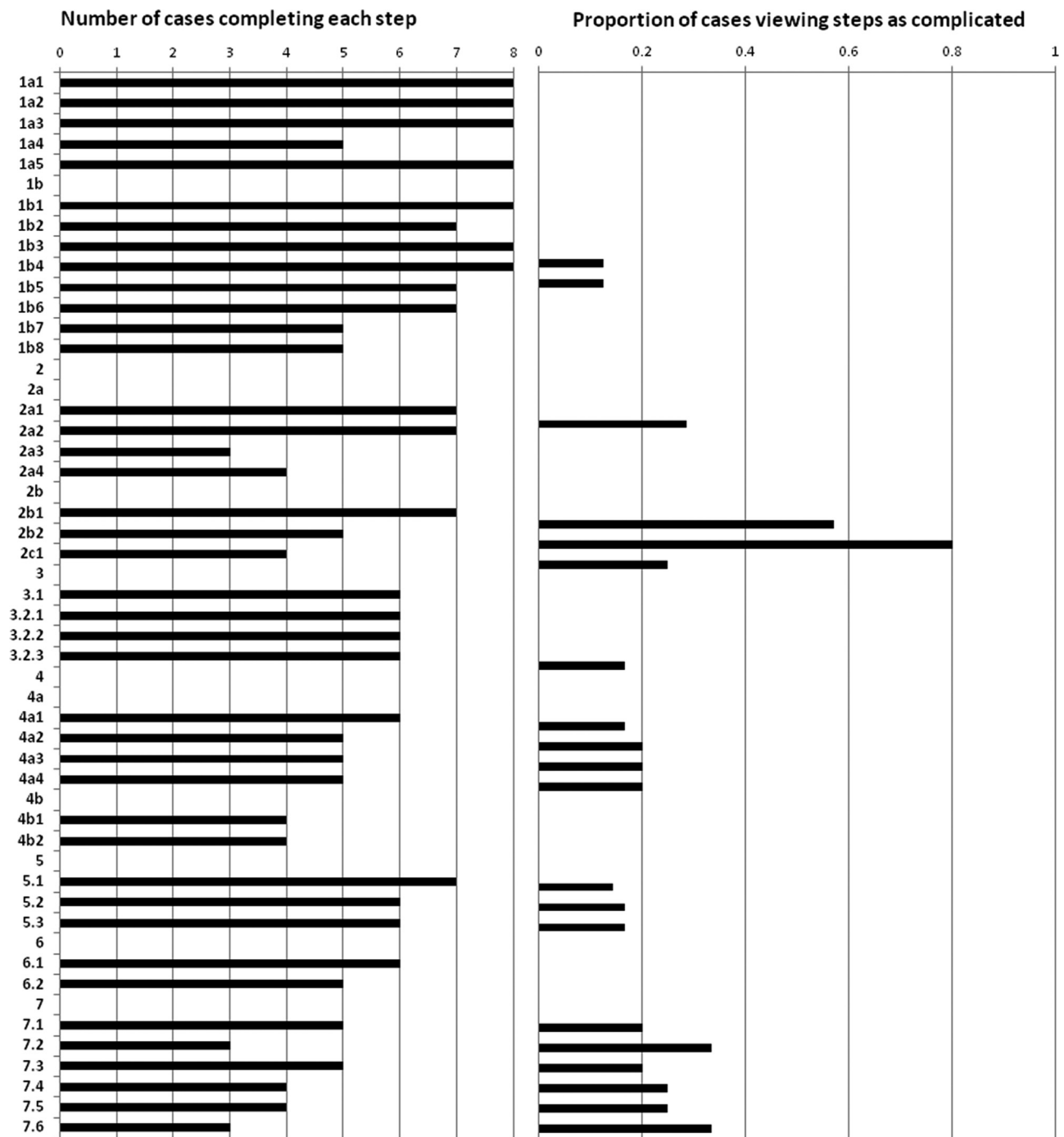


Fig. 5. Experience from testing of the MESMA framework (FW) [14] in the eight cases. Left diagram shows the number of cases that completed each of the steps and to the right the proportion of the cases that completed each step that experienced it as complicated.

Additionally, some obstacles were connected to military security. In all cases the best available data were used. The lack of high quality data was an issue for most cases and often surrogates of low spatial and temporal resolution were used. This highlighted the need for higher quality data, both for environmental and socio-economic components. This is crucial for conducting an integrated monitoring and evaluation of a spatially managed area, as well as for proposing effective management plans. Also Steps 2a, 3, and 4a, which deal with assessing the relevance of selected boundaries and ecosystem components, lacked objective data and were mainly based on expert judgment (Fig. 6). Information requested in Step 2b, which concerned the impacts and pressure from human activities on ecosystem components, revealed another aspect in

which our present knowledge is incomplete. In particular mapping cumulative impact and pressure were viewed as complicated and demanding (Table 2 and Fig. 5). Therefore the time allocated to Step 2 was disproportionately long with respect to the remaining FW steps. The reasons were: fragmentation of the information; dispersion of the sources and lack of coherence among them which resulted in frequent overlap, redundancy and even contradiction amongst documents. It was also challenging to combine the information from national jurisdictions in transnational case studies. In Step 3 indicators were selected and tested in terms of their usefulness for the achievement of the management objectives. In Step 4 a risk analysis and state assessment is conducted based on these indicators. When conducting Step 3, the need for a

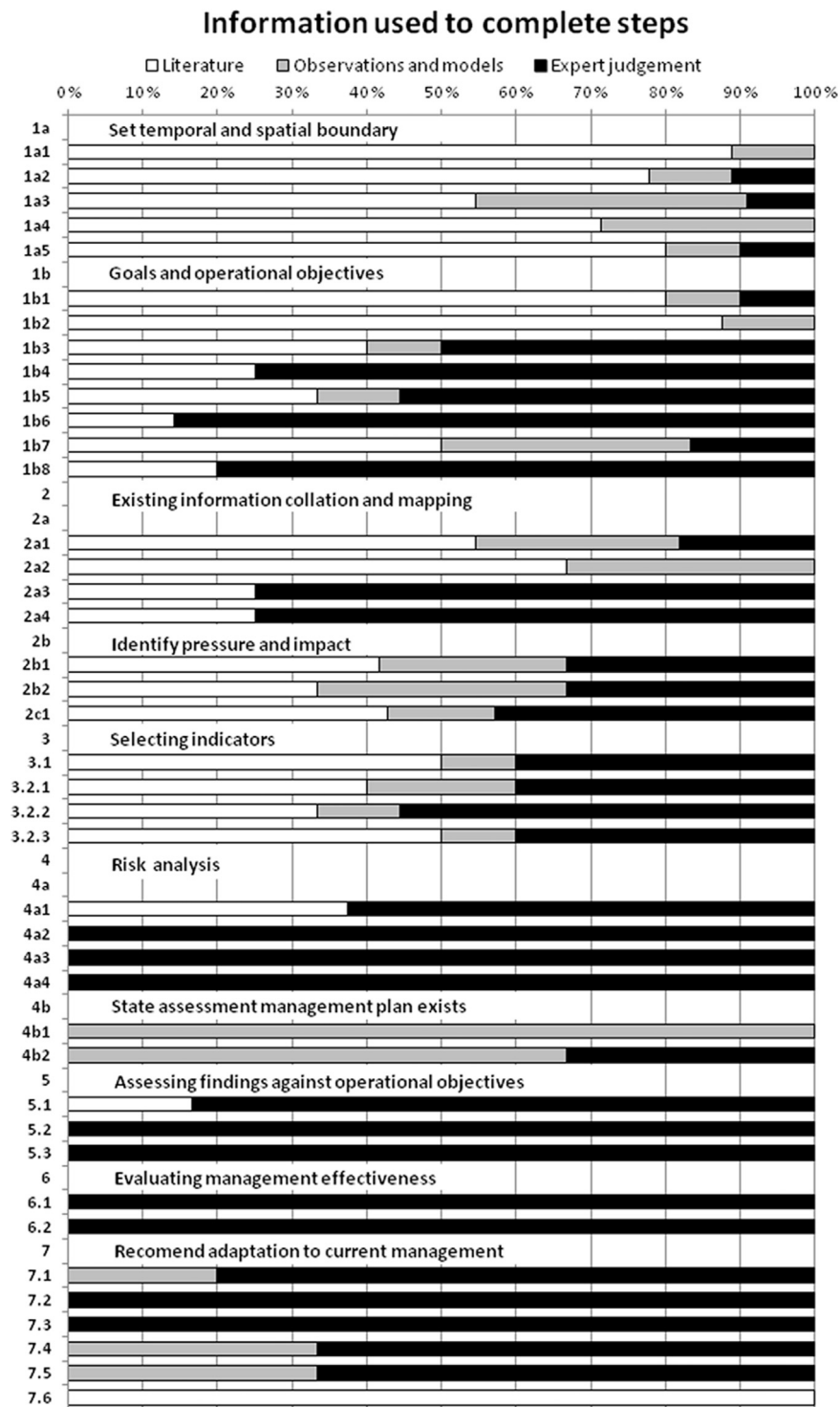


Fig. 6. Source of information, provided in percentage, used when completing each Framework step in the case studies. Black: expert judgement, gray: observations or model, and white: literature (See also Table 2).

comprehensive development of objectives and related indicators became clear for most cases, not just for ecosystem state but also for pressures. When existing management plans were tested, possibilities for improvement were indicated and it became clear that the link between objectives and indicators was often lacking (i.e. BSMP, SoS). The quality of the assessment on ecosystem health and pressures in Step 4 also relies on available surveys. The detailed Step 4 assessment possible for a newly mapped area by MAREANO (part of the BSMP) showed the importance of high-

resolution data on the distribution of vulnerable habitats and human impacts (Step 4a3 and 4b2).

However, most of the tools needed to assess impact probability and magnitude, as e.g. relevant indicators connected to GES, or quantification of pressure and impact from human activities on specific ecosystem components, are lacking yet. This is mainly because at present there is no agreement upon the way to quantify and accumulate pressures and to produce an ecosystem component impact maps based on specific sensitivity to different

pressures. Thus the FW allows room to select how to quantify accumulated pressures in order to complete the impact probability assessment (4a3). This was often based on expert judgment and tools that had to be developed, being case specific and not scientifically proven [29].

The gap between the status defined by the indicators with respect to the goals and objectives of the management plan was assessed in *Step 5*, effectiveness of management in *Step 6* followed by recommended adaptations in *Step 7*. This part of the FW was developed to evaluate the success of the management initiatives in a marine area by assessing to which degree the objectives were matched. However, *Steps 6 and 7* could not be conducted in many cases because either management plans with clear objectives were not in place or information before and after the management action was not available (Fig. 5). For many cases there were so many management goals that it was impossible to test them within a single FW run. As a result the Basque Country (SE Bay of Biscay) case tested only one out of six relevant objectives. The Strait of Sicily case derived five objectives from an initial number of 54 overlapping ones. For the Baltic case the HELCOM management approach was applied instead. This approach was more integrated than the FW: the gaps were calculated directly and this information was used in the FW to evaluate the management status. It was rewarding to reflect on the differences between both approaches. In the HELCOM approach, specific management measures are developed and decided at national level and the FW *Step 6* was only applied briefly. Where a management plan was in place (BS) or under development (PFOW) it was clear that the groups involved in the revision of the management process (FW *Steps 5 and 6*) also should have a mandate to suggest management actions to remedy failures of objectives (FW *Step 7*). Indeed, governmental institutions (e.g. ministries and directorates) should be charged to follow up on failures of objectives in a clear way. Instead, the FW did not influence management plans directly. Nevertheless, local governments were informed and benefited from the comparison between the current status of the areas and the desired ones as stated in the management plans. Another lesson learned from the case studies was the need for better integration between marine and terrestrial plans that influence coastal activities. The importance of this link between plans and activities should be also emphasized in the application of the FW to other coastal areas.

3. Discussion

The application of a stepwise framework to monitor and evaluate spatially managed areas has been tested here. Conducting all steps of the FW for area-based marine management informed about the effectiveness of management plans in fulfilling the predefined objectives in a transparent and reproducible way. Moreover it allowed identification of knowledge gaps and it could be used to suggest initiatives to increase knowledge and inform management decisions. The case studies showed that, even without an integrated management plan in place, the findings provide a base for recommendations of future management in such areas.

3.1. Objective related indicators

Close connection between management goals, operational objectives and choice of indicators is important to successful management. This is highlighted in the first part of the FW (*Steps 1–3*) where pressure and state indicators are defined. The FW presents a logical and rational process of assessment, progressing from management objectives (*Step 1*) to the selection of indicators for both ecosystem states and related pressures (*Step 3*). However, the importance of using indicators tailored to management goals is

often overlooked when monitoring the environmental state. This results in a lack of information about the effectiveness of the management measures that have been undertaken. In addition, testing the FW highlighted the need for a comprehensive development of objectives for ecosystem state, as well as indicators for pressures and states. In a European context such development should be linked to the implementation of the MSFD to support the achievement of a Good Environmental Status (GES) of the territorial seas by 2020. It is noted that indicators of GES appear often to be chosen from existing data, even though these may not be informative in relation to the management objectives. Social and economic indicators are equally crucial with biological indicators for the decision making process. Early recognition of the strategic plans of different stakeholders and management bodies is essential to the adaptive capacity of the management action.

3.2. Data requirements

A complete management plan needs specific information of ecosystem components and characterisation of marine activities in order to calculate the pressures and impacts of activities. It is evident that an improved data quality for both environmental and socio-economic components is required for conducting an integrated monitoring and evaluation of spatially managed areas. In some case studies some FW steps could not be conducted due to lack of information; and thus, a sound proposal to improve the management plan in such cases was therefore not possible. However, the results from the detailed assessment have shown that present knowledge frequently does not allow for the detailed analysis required by the FW. However, knowledge gaps indicating research needs are highlighted; which in turn, could be communicated to the decision makers. In addition, new and subsequent knowledge can be incorporated into particular steps for future assessments. The need for comprehensive data in *Step 2* was an issue in cases where such information was fragmented, difficult to access or simply not available. The FW was particularly hard to apply in a cross-border setting, involving several nations or the high seas, as for instance in the southern North Sea, the Baltic Sea and the Strait of Sicily, due to the increased volume of information required and the lack of harmonization among distinct jurisdictions. The amount of work needed to properly use the FW is considerable and requires a multidisciplinary team including marine and socio-economic scientists. This may not be possible for many locally based initiatives.

3.3. State assessment and management adjustment

In *Steps 4–7* the structured analysis represented by the FW was valuable in identifying management weaknesses. This is a valuable outcome that could be used for indicating improvements and forecasting present human activities in the face of external drivers like climate change, energy demand and the spread of invasive species. In several cases the tools suggested by the manual, to conduct the pressure and impact analysis in *Step 4* and to identify areas with conflict potential were not available. What was particularly demanding was the quantification of pressure related impact from human activities on different ecosystem components and ad hoc tools were developed to fill some information gaps derived from poor scientific knowledge. Even though several obstacles were identified when testing the FW in the cases, it was clear that the complex reality of spatially managed areas in Europe can benefit from the strict step by step approach. The built-in flexibility and creativity needed to work through FW is of vital importance. The step-by-step approach of the FW, backed up with a comprehensive manual, provides a valuable tool to evaluate spatially managed areas in different settings.

This extensive assessment process highlighted the trade-off between the need to implement integrated spatial management and the lack of key data to underpin a decision making process. In the absence of crucial knowledge such as on the sensitivity of ecosystem components to single or combined human pressures the FW manual enables also a transparent assessment of related uncertainty [30]. Moreover, the here tested systematic approach is a promising means to tackle the trade-offs between ecological conservation and social development by means of the mapping of the impacts of human activities on ecological components.

The FW requires such amount of different data covering from, the spatial and temporal setting an area and ecosystem and human activities information collation for that area, to the calculation of indicators and assessment of management effectiveness, a process that is very complex. Thus, the manual designed to guide such process must be inherently complex. In spite of the information on the relationships between the steps (e.g. Figs. 3 and 4), it was challenging to judge which actions are relevant and at what level of detail for the aim in question. A recurring problem was to collate and enter information at an early stage, while the FW rather asks for it in small separate steps. However, the main discoveries made after completing the FW represents the relevant information for improvement of the management in the case area. This would have been difficult to obtain without the structured way of assessing the information but to be fully effective, the FW should be used on a long-term basis.

Applying the FW in the case studies demonstrated a realistic and practical process when existing plans were evaluated. In cases when no plans exist, or there is a lack of data, it provides useful indicative results. It can be used to evaluate objectives linked to high level policy goals, identify data and knowledge gaps. However, integration of management decisions relies much on the future views of different stakeholders and government bodies, which behave according to their strategic plans. Thus in addition to the informative assessment suggested by the FW, it is important to identify drivers behind the different objectives. If vocal and influential stakeholders are involved, a well-designed management plan following the FW with clear environmental management goals and relevant indicators, may still have very limited effects on political decisions. Interaction with key stakeholders at all stages of the FW process is crucial. It ensures transparency when expert judgment is adopted in several steps. Thorough stakeholder participation supports a more effective approach towards adaptive management.

4. Conclusions

An application of a generic framework (FW) for assessing and evaluation of spatially managed marine areas has been tested in eight case studies in Europe. The test analysis has been carried out through structured tasks, guided by a manual, in seven successive steps comprising the key elements of scoping, performance measures, assessment evaluation and adjustment of existing management plans in each of the case studies. The resulting outputs and lessons learned from its application demonstrates that the FW is a logical and well-worn path of analysis of the effectiveness of the management plans and the proposal of new measurements based on the outputs of each of the steps. Applied to the specific questions of MSP, the FW permits the identification of the questions to be asked at each stage of the analysis process as well as the data to be collected. Moreover, at each stage the available tools are listed and described. Links are provided to tools and the associated issues of governance and stakeholder participation.

The FW has, therefore, has demonstrated to be a valuable tool for the monitoring and evaluation of spatially managed areas in

the marine environment. It has to be noted that the case studies differed fundamentally in their make-up and needs, but experience showed that there was always commonalities which can be used as a starting position to build upon which could be identified through the FW. Some areas already had comprehensive plans in progress; others had little in the way of overarching plans but included sectoral initiatives such as fisheries management measures, local marine protected areas and agreements for existing human activities such as sand mining. Using the FW relies on existing background information regarding relevant ecosystem components, human activities and indicators. In most of the case studies much of this information was lacking resulting in a high level of unknowns and uncertainty, and the need of application of expert judgment to be able to apply the FW. In some cases, the lack of information made it even hard to complete. However, the FW proved resilient in spanning these uncertainties and differences among case studies. It has set a logical and guided process towards a management baseline for adaptation over time into a plan which is appropriate to the needs of the day.

Marine Spatial Planning is by its nature a future oriented process which requires a dynamic analysis process to assess its success in fulfilling the pre-established operational objectives. Moreover, the implementation of the Marine Spatial Planning relies on key knowledge and experience which are often lacking and that was identified when applying the FW:

- Data – Little is known about the working of the marine ecosystem. Projected marine industries including renewable energy and seabed mining are at a very early stage of technological development and their effects uncertain. Ecosystem based management is internationally agreed as the aim.
- Governance – Bringing jurisdiction and management to areas which were formally held in common with open access requires negotiation and a deep understanding of the socio-economic tensions.
- Stakeholders – It is recognized that a sustainable plan requires a high level of stakeholder understanding and support as user rights are awarded or re-allocated.

Based on the vast case study experience we can conclude that the application of the systematic FW allows for (i) a gap analysis with respect to the knowledge base, (ii) an assessment of strength of the relationships between goals, objectives and indicators, and (iii) a quick starting point to develop an ecosystem-based management plan.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.marpol.2016.01.024>.

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