DELIVERABLE 6.10

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SEAWISE

Executive summary

This deliverable report provides guidance on design an internally consistent ecosystem-based fisheries management (EBFM) plan and applies this guidance in the various regional case studies to monitor the advancement towards their objectives. The guidance is based on a typology for management interventions and an evaluation of their performance based on fine-tuned management models. The typology firstly distinguishes between management interventions occurring in the social system and those occurring in the ecological system, as these require different approaches to evaluate their performance. As fisheries governance must be considered as part of marine governance (also targeting other sectors), so should EBFM fit into Ecosystem-based management (EBM) required to achieve the MSFD objectives as well as the Maritime Spatial Planning Directive (MSPD). To that end, a wide variety of simulation models (from bio-economic to full ecosystem models) was applied to case studies across the Northeast Atlantic and Mediterranean to assess the performance of different management under alternative climate scenarios. The performance was evaluated through ecological and socio-economic indicators related to CFP and MSFD objectives, thus translating the scenarios to testable EBM measure categories. The future indicator values compared to the present-day baseline can be considered a measure of effectiveness (the blue arrow in the figure below).

Spatio-temporal distribution control								MSFD
Input control			Output control		X	X	X	D1
					X	X	X	D4
				X				D6
				X			X	CFP
Benthic trawls an… dred…	…gic trawls	St… …ars	Pressures	Benthic habi…	…gic …ts	Birds	Fish & Cephalopo…	…als …tiles
			Abrasion/Damage					
			Barrier to species movement					
			Changes in input of organic matter					
			Changes in Siltation					
			Continuous noise					
			Death or Injury by Collision					
			Disturbance (visual) of species					
			Extraction of flora and/or fauna					
			Ghost… …d other litter causing entanglement					
			Introduction of Microbial pathogens					
			Introduction of non-indigenous species					
			Introduction of Non-synthetic compounds					
			Introduction of Synthetic compounds					
			Microplastics and other litter that may be ingested					
			N&P Enrichment					
			Smothering					
			Translocations of species (native or non-native)					

The guidance in this report aims to design a more effective EBFM plan than the management currently in place. This process is represented by the red arrow and includes information on the severity of the threats experienced by different ecosystem components or species groups (green cells) from specific pressures (white cells) caused by different types of fisheries (red cells). Effective management should target the fishery types and their pressures that are causing the main threats to achieving policy objectives as indicated by red and to a lesser extent orange traffic lights. The choice of management to implement should be determined by the selection of the most effective type(s) of management measure where effectiveness comes from the blue arrow model-based evaluation. Together this determines the design of an EBFM plan which can be easily aligned to cross-sectoral EBM or MSP initiatives.

The effectiveness of management measures is (partly) addressed with these first estimates of management effectiveness. Effectiveness is expressed as the degree to which a particular type of measure can change a selection of indicators of policy objectives in a desirable direction, i.e. advancing toward the achievement of that policy objective.

The report identifies different perspectives to improve the EBFM plan to illustrate how the information on effectiveness of management measures in relation to the aim to advance towards specific objectives (i.e. Commercial Stocks, Social, Economic, Fishing Opportunities and Biodiversity). Generally, the current output controls (e.g. TAC management), perform well in advancing stock status while also advancing several of the other objectives. Depending on the specific Harvest Control Rules applied (e.g. Maximum Sustainable Yield, Pretty good Yield), different trade-offs occur between MSY and PGY, which advance most of the commercial stocks and the wider ecosystem objectives but not the socio-economic objectives, and case-study specific management, which performs well on the socio-economic objectives but less on the ecological objectives. The more restrictive MSY is more effective than PGY in attaining ecological objectives.

In addition to existing output controls, specific types of additional management measures can be implemented to (further) advance towards specific objectives. The effectiveness of these depends on the main objective. If this is to improve the status of the commercial stocks, then effort management and seasonal closures appear to be an effective management measures in the Mediterranean. However, effort management carries disadvantages for the social objectives, whereas seasonal closures have disadvantages for economic objectives. Effort management advanced the achievement of the economic objectives whereas the seasonal closure can potentially reduce the bycatch of marine mammals. If the aim is to protect biodiversity, a reduction of the bycatch of other ecosystem components like mammals, turtles or birds or a decrease of the physical disturbance of the seafloor is required. Bycatch is often most effectively reduced through gear change or effort reductions. Gear changes also benefitted social and economic objectives.

Spatial closures were specifically suited to protect the seafloor and potentially enhance fishing opportunities. Spatial closures can potentially be applied together with (or to reinforce) any of the other management measures if the aim is to protect a specific seabed habitat like Vulnerable Marine Ecosystems (VMEs) from fishing. The management measure can also be applied to reduce the bycatch of seabirds or elasmobranchs if these are prevalent in a specific area. However, if this is the main goal of the management intervention then seasonal closures in periods when that particular species are most vulnerable can be more effective. If the main objective is to achieve economic objectives and improve fishing opportunities, then technical conservation measures (TCMs) are the preferred management measure. These, however, do not advance social objectives.

The guidance was based on the combined results of various simulations of regional applications using specific models. This should provide a qualitative indication of the effectiveness of these broad types of management measures. With this information, every marine region should be able to develop an EBFM plan that can perform better than the current management. To ensure the long-term sustainability of fisheries in a changing environment (e.g climate change), an adaptive EBFM approach must be implemented. By continuously assessing management measures and refining strategies based on regional monitoring, marine ecosystems can achieve better ecological, economic, and social outcomes. This flexible, evidence-based framework will help mitigate climate change impacts and enhance the effectiveness of fisheries management in dynamic environmental conditions.

New regional EBFM plans potentially developed with guidance from the SEAwise project will go beyond traditional fishery controls like TAC (Total Allowable Catch) and effort limits and include broader ecosystem health (e.g. seafloor disturbance, bycatch of protected species), climate change effects, and socio-economic goals. While TAC/effort controls remain central, tools like spatial closures (e.g. marine protected areas), gear innovations, and alternative targets like PGY (Pretty Good Yield) are used to address trade-offs and enhance resilience.

Contents

1. SEAwise background

The SEAwise project works to deliver a fully operational tool that will allow fishers, managers, and policymakers to easily apply Ecosystem-Based Fisheries Management (EBFM) in their fisheries. With the input from advice users, SEAwise identifies and addresses core challenges facing EBFM, creating tools and advice for collaborative management aimed at achieving long-term goals under environmental change and increasing competition for space. SEAwise operates through four key stages, drawing upon existing management structures and centred on stakeholder input, to create a comprehensive overview of all fisheries interactions in the European Atlantic and Mediterranean. Working with stakeholders, SEAwise acts to:

- Build a network of experts - from fishers to advisory bodies, decision-makers and scientists - to identify widely-accepted key priorities and co-design innovative approaches to EBFM.
- Assemble a new knowledge base, drawing upon existing knowledge and latest insights from stakeholders and science, to create a comprehensive overview of the social, economic, and ecological interactions of fisheries in the European Atlantic and Mediterranean.
- Develop predictive models, underpinned by the new knowledge base, that allows users to evaluate the potential trade-offs of management decisions, and forecast their long term impacts on the ecosystem.
- Provide practical, ready-for-uptake advice that is resilient to the changing landscapes of environmental change and competition for marine space.

The project links the first ecosystem-scale impact assessment of maritime activities with the welfare of the fish stocks these ecosystems support, enabling a full-circle view of ecosystem effects on fishing productivity in the European Atlantic and Mediterranean. Drawing these links will pave the way for a whole-ecosystem management approach that places fisheries at the heart of ecosystem welfare. In four cross-cutting case studies, each centred on the link between social and economic objectives, target stocks and management at a regional scale SEAwise provides:

- Estimates of impacts of management measures and climate change on fisheries, fish and shellfish stocks living close to the bottom, wildlife bycatch, fisheries-related litter and conflicts in the use of marine space in the Mediterranean Sea,
- Integrated EBFM advice on fisheries in the North Sea, and their influence on sensitive species and habitats in the context of ocean warming and offshore renewable energy,
- Estimates of effects of environmental change on recruitment, fish growth, maturity and production in the Western Waters,
- Critical priorities for integrating changes in productivity, spatial distribution, and fishers' decision-making in the Baltic Sea to create effective EBFM, prediction models.

Each of the four case studies will be directly informed by expert local knowledge and open discussion, allowing the work to remain adaptive to change and responsive to the needs of advice users.

1.1 The role of this deliverable

This deliverable aims to design internally consistent ecosystem-based fisheries management (EBFM) plans that can contribute to achieving objectives of the European fisheries legislation to manage human activities under an ecosystem approach (Common Fisheries Policy (CFP; European Commission 2013); Marine Strategy Framework Directive (MSFD; European Commission 2008, 2017, 2022a)). The EBFM plan should conform to the interconnected dynamics of a social-ecological system (SES) and is therefore constructed as the combination of policy instruments operating in the social system which drive the implementation of management measures operating in the ecological system, where they mitigate or enhance specific fishing impacts. The policy instruments include legislative instruments (e.g. conservation laws); regulatory instruments (e.g. setting targets or standards to maintain a certain level of environmental quality, bans or permits); and economic instruments (e.g., tariffs, taxes and charges). Management measures consist of e.g. catch or habitat quota, effort control, technical measures, Marine Protected Areas (MPAs) and other spatial distribution controls. A comprehensive list of management interventions by region is compiled by combining outcomes of previous projects with input from the stakeholder consultations described in deliverable 1.9. The present deliverable complements the previous D6.9 which established the performance of the baseline management in terms of achieving selected policy objectives (e.g. CFP and MSFD). The deliverable provides guidance for the design of a future EBFM plan based on the evaluation of simulated management interventions compared to the baseline situation. The evaluation focuses on the effectiveness of those management interventions in terms of their contribution to advance towards desired targets.

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1.3 Glossary of terms, acronyms and abbreviations

Table 1.1. Glossary of terms

Term	Description
Ecosystem	An ecological system composed of biological communities of interacting organisms and their physical environment. Humans are an integral part of an ecosystem.
Ecosystem-based Approach to Fisheries Management	Here we distinguish between the concept of Ecosystem-based Approach to Fisheries Management (EAFM) and the actual implementation of an Ecosystem-based Approach to Fisheries Management, as there can be many different configurations depending on the context. We have not adopted any specific definition but work from a suite of common principles that drive the implementation of an EAFM.
Fishery	"A group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area" (ICES, 2003). The commercial fisheries correspond to a unity of gear type, target species (group), area and time of the year, and can therefore be expected to have the same (or sufficiently similar) impacts on the ecosystem and its different components. A fishery is the basic unit to which management measures apply. A fishery may consist of several métiers.
Policy Instrument	An intervention in the governance arrangements covering the advisory and decision-making process, typically through policies, which is intended to facilitate the implementation and/or enforcement of management measures.
Management measure	"Management measures are the specific elements of fisheries control which are embodied in regulations and which become a focus for surveillance activities."[1] In the context of the social-ecological system that is at the basis of EAFM, we define measures as operating solely in the ecological system where they mitigate the impact of fishing on the ecosystem including all its relevant components and aspects.
Management Strategy	The combination of a policy instrument and a management measure (This study). The policy instrument is the means to implement the measure.
Management Plan	An internally consistent combination of different management measures and policy instruments aimed at achieving a selection of policy objectives for a specific ecosystem and its socio-economic/institutional context.
Métier	"Part of the activity of a fishing fleet taking place in a given area, with a specific gear and targeting a specific (assemblage of) species" (ICES, 2003). For practical reasons, the métier definition chosen for this work was the Data Collection Framework (DCF) métiers used by Member States for reporting landings data.

[1] https://www.fao.org/3/v4250e/V4250E05.htm

Table 1.2. List of abbreviations

Term	Description
CBD	Convention on Biological Diversity
CINEA	European Climate, Infrastructure and Environment Executive Agency
CFP	Common Fisheries Policy
CS	Case Study
DCF	Data Collection Framework
EAF	Ecosystem Approach to Fisheries
EAFM	Ecosystem-based Approach to Fisheries Management
EASME	Executive Agency for Small and Medium-sized Enterprises
EBFM	Ecosystem-Based Fisheries Management
EBM	Ecosystem-Based Management
EMFF	European Maritime and Fisheries Fund
eNGO	Environmental Non-Governmental Organization
EU	European Union
FRA	Fisheries Restricted Area
GES	Good Environmental Status
GFCM	General Fisheries Commission for the Mediterranean
GSA	Geographical Sub Area
ICES	International Council for the Exploration of the Sea
ITQ	Individual Transferrable Quota
LO	Landing Obligation
MAP	Multi-Annual Plan
MCRS	Minimum Conservation Reference Size
MLS	Minimum Landing Size
MPA	Marine Protected Area
MS	Member State (of the European Union)
MSC	Marine Stewardship Council
MSFD	Marine Strategy Framework Directive
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PETS	Protected, Endangered and Threatened Species
RAC	Regional Advisory Council
RFMO	Regional Fisheries Management Organization
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch
TCM	Technical Conservation Measures
TMR	Technical Measures Regulation
UNEP-MAP	United Nations Environment Programme Mediterranean Action Plan

2. Approach

To develop guidance for internally consistent regional EBFM plans, this report provides a typology for management interventions and an evaluation of their performance based on fine-tuned management models. As EBFM operates in a Social-Ecological System (SES) the typology distinguishes between management interventions occurring in the social system and those occurring in the ecological system. These require different approaches to evaluate their performance. The report focusses on the effectiveness of the management measures that mitigate negative effects of the fishing activity to contribute to the achievement of various policy objectives. Where fisheries governance must be considered as part of the marine governance targeting several sectors, so should EBFM fit into Ecosystem-based management (EBM) required to achieve the MSFD objectives as well as the Maritime Spatial Planning Directive (MSPD). To that end, a wide variety of simulation models (from bio-economic to full ecosystem models) was applied to case studies across the Northeast Atlantic and Mediterranean. The models were used to simulate various indicators under different management and climate scenarios. By linking the indicators to specific policy objectives and translating the scenarios to ecosystem-based management measure categories, the future indicator values compared to the present-day baseline is used as a measure of effectiveness. From the latest status assessments per case-study reported in Deliverable 6.9, policy objectives that still require additional management can be identified. The effectiveness per type of management measure then determines the design of the EBFM plan which can subsequently be aligned to any cross-sectoral EBM or MSP initiatives.

In Deliverable 6.9, a five-step EBFM cycle was introduced (Figure 2.1). For the purpose of understanding the relationship between the Deliverables 6.9 and 6.10, we assume a first EBFM cycle commenced more or less at the time the MSFD was initiated (EC, 2008) – and we have now completed this first cycle. Deliverable 6.9 covers the follow-up of this first cycle, evaluating the performance in achieving the specific policy objectives. This then provides the basis for the next cycle for which SEAwise has developed the knowledge base and assessed various scenarios using the management strategy simulation models. In this report, we apply the knowledge gained to provide guidance aimed at improving the performance of this next (and subsequent) EBFM cycles.

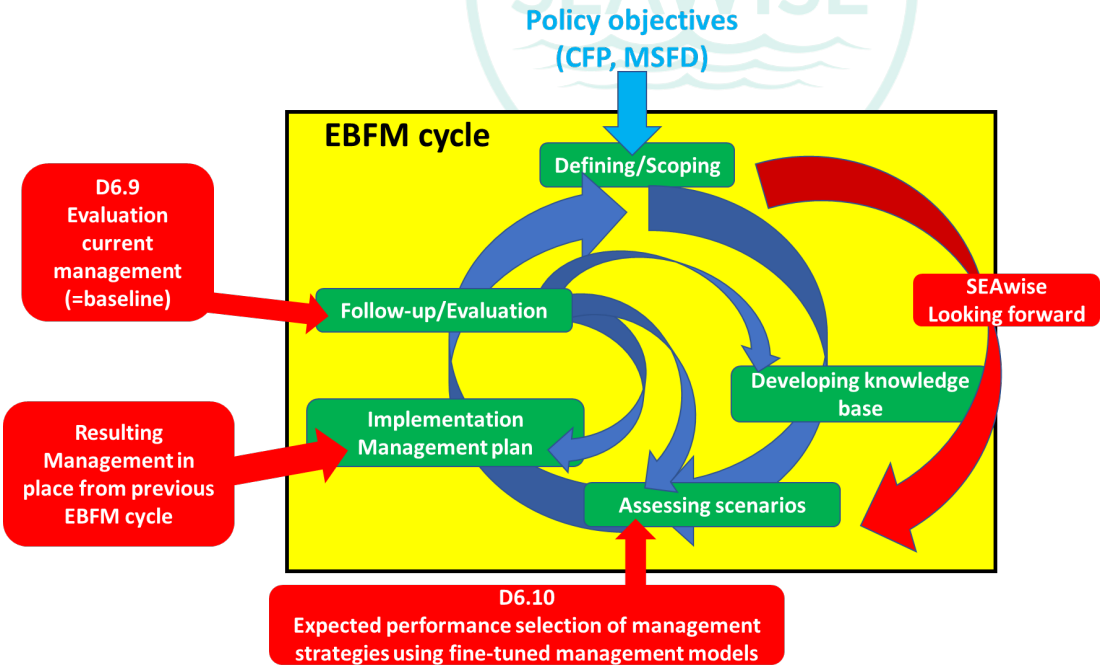

Figure 2.1. The five-step EBFM cycle and how the two Task 6.5 deliverables fit into the process to develop an internally consistent and high-performance regional EBFM plan.

2.1 Introduction

Adequately managing the complex marine system requires a shift from 'conventional' management approaches focussing on single goals (e.g. MSY) or operating within specific, often sectoral, silos (e.g. EBFM) to more integrated and holistic Ecosystem-Based Management (EBM) or Ecosystem-Based Approach (EBA) (Long et al., 2015). A plethora of definitions for EBM or EBA is available illustrating that the terms may be used interchangeably, but there appear to be subtle differences in emphasis, particularly in the context in which each is applied. EBM is often seen as a broad, overarching strategy focused on managing ecosystems and their components directly whereas EBA typically refers to the methodology or framework of applying ecosystem-based thinking to certain management activities, e.g. fisheries, or policies, e.g. Marine Spatial Planning (MSP) resulting in terms like EBA-MSP (Piet, 2021). In this study we will use EBM to represent both terms of an integrated approach to environmental management and seeking to provide comprehensive and integrative principles. EBM should also explicitly consider the interlinkages between the ecological system and the social (or socio-economic and including institutional) system (Delacámara et al., 2020). Taking into account this entire Social-Ecological System (SES) is crucial for effective environmental management (Berkes, 2011; Virapongse et al., 2016).

EBFM is essentially an adaptive cyclical process that builds on approaches like PACE (plan, action, check, evaluate (BSPC, 2006; Elliott et al., 2017)) and cause-consequence-response frameworks such as the modified DPSIR-related (Drivers, Pressures, State, Impacts, Response) frameworks like DAPSES-MMM (Drivers-Activity-Pressures-State-Ecosystem Services-Management (Policies and Governance)- Measures-Monitoring (EC, 2020) or DAPSI(W)R(M) (Drivers-Activities-Pressures-State change-Impacts (on human Welfare)-Responses (using management Measures) (Elliott et al., 2017). The acknowledgement of EBFM as the current guiding principle for marine management is evidenced by its inclusion in both international guidelines, frameworks and legislation, including the Kunming-Montreal Global Biodiversity Framework (GBF), the EU Marine Strategy Framework Directive (MSFD) and the EU Green Deal, as well as national frameworks (Borgström et al., 2015).

Management measures (also often referred to as management interventions or management actions) aim to control 'source and effect of environmental change that is needed to achieve ecosystem sustainability' (Cormier et al., 2016; Langeweg, 1998). The effect of management measures is thus seen as the answer to whether EBFM has been successful or not (Cormier et al., 2016). However, the development, operationalization and evaluation of EBFM is not confined to the selection and implementation process of certain management measures. The process of EBFM is deeply connected to policy cycles practiced in the institutional area (Cormier et al., 2016; Jann and Wegrich, 2007). The institutional context is characterized by specific modes of governance which is linked to the manner in which EBFM management measures can be implemented, to their likelihood of being leveraged and, consequently, to effectively achieving the defined policy objectives (Bouwma et al., 2015; Cormier et al., 2017; Salamon, 2002). The institutional arena produces policy outcomes, including goals and objectives, which directly or indirectly drive the development of management actions (Cormier et al., 2017). EBFM should therefore consider the specific institutional context in which it takes place (Borgström et al., 2015; Jann and Wegrich, 2007). As the institutional context ultimately guides, directs and enables the implementation of management measures, it must be considered in planning, development, implementation and evaluation of EBFM (Cormier et al., 2017; Salamon, 2002). Public policymaking processes, goalsetting, cross-sectoral planning, socioeconomic objectives, management measures and outcomes are all subsequent interventions in the, as named by Cormier et al. (2017) "EBM meta-logic policy cycle". Effective implementation and operationalisation of EBFM explicitly requires consideration of this institutional part of the SES (Borgström et al., 2015).

Although the connection between policy and practice is widely recognized across scholars, we argue that EBFM interventions have so far mostly been implemented independent of the *institutional enabling context*, or at least with insufficient consideration of the SES. This lack of awareness and understanding of the full EBFM approach—

spanning policy-making processes to operational management—impedes the effectiveness of EBFM in marine environments and complicates its evaluation. To build operational EBFM, that is successful in supporting sustainable exploitation, biodiversity conservation and protection based on the concept of SES (Berkes, 2011), further awareness of the interlinkages between the enabling institutional arena and the actual intervention in the marine environment is needed. This work and the typologies presented here addresses this need by first disentangling the full range of interventions (policy instruments to management measures) that build EBFM and proposing a unified typology. Second, the approach establishes an integrative framework that can be linked to existing cause-consequence-response frameworks as part of an adaptive EBFM process to guide the selection and evaluation of policy instruments and management measures based on their expected effectiveness in advancing the performance of that EBFM process.

2.2 Management interventions identified by stakeholder scoping

SEAwise conducted scoping meetings from October 2021 to April 2022 with stakeholders in the Mediterranean Sea and the North-East Atlantic. These meetings aimed to identify the elements of the SES and the management measures that stakeholders were most interested in or concerned about. The by far most frequently mentioned management intervention by stakeholders in all regions except the Baltic Sea was spatial management. Limits to total allowable catches (TAC) was the second most frequently mentioned, followed by control and enforcement, landing obligation, co-management, technical measures, Brexit, OECM (other effective conservation measures) and culling (Figure 2.2). Culling was only mentioned in the Baltic Sea and Brexit only in the North Sea and Northwestern Waters. The stakeholder scoping methods and results are described in detail in Deliverable 1.9.

The management interventions identified by stakeholder scoping showed no distinction between exogenous drivers. For example, Brexit was mentioned, though this is not part of fisheries management but rather determines the context in which it occurs, alongside management interventions occurring in the social system, i.e. co-management or control and enforcement, and management interventions interfering with the fishing activity and its impact on the resource as well as the wider environment. When designing effective EBFM the proposal is therefore to acknowledge that this plan is implemented in a specific environmental and institutional context and distinguish between management interventions operating in the social system, i.e. policy instruments, with the purpose to have the actual management measures implemented that mitigate the fishing activity and achieve the policy objectives.

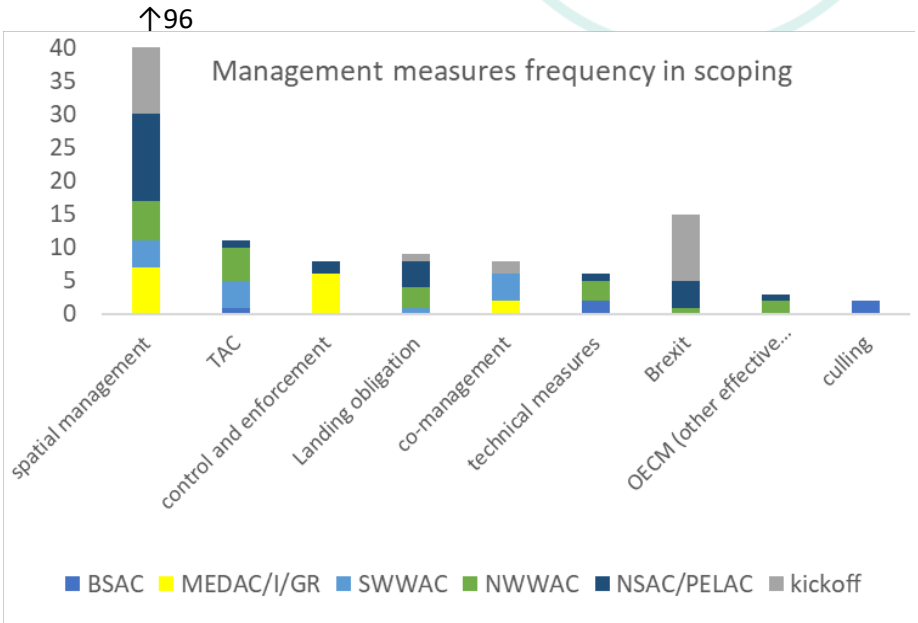

Figure 2.2. Frequency of different management interventions (then still referred to as management measures) in the stakeholder scoping.

3. Development of an internally consistent regional EBFM plan

3.1 EBFM as part of a social-ecological system

This guiding framework for EBFM works from the five-step process often applied for ecosystem-based approaches (Altvater, 2019), which is aligned with the ten-step cycle for MSP (Ehler, 2009). For this study, it is matched to a five-step policy cycle to represent the simultaneous and intertwined processes required for the development and implementation of an EBFM plan, consisting of both management measures and policy instruments (Figure 3.1). This enables us to consider the two SES components, i.e. the enabling governance arena situated in the social system and management measures that do the actual intervention in the ecological system, as they apply to each step in the EBFM process until they merge in the third step when the science advice (i.e. EBFM plan) is presented and adopted.

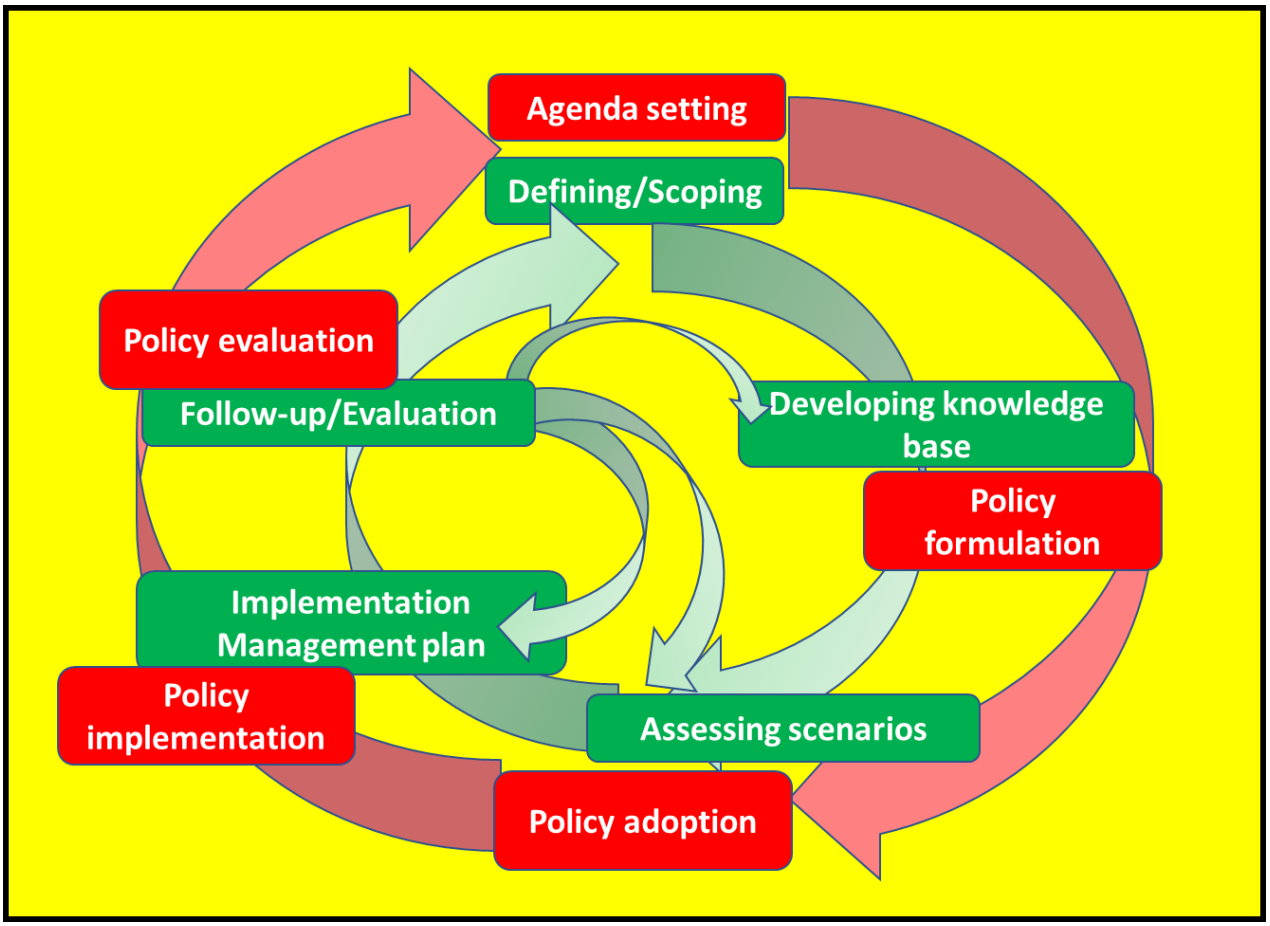

Figure 3.1. Five-step EBFM process in a SES context. The steps in red show the policy cycle, the steps in green apply to marine management measures. The box is to stress that the whole process occurs in a specific environmental and institutional context. Stakeholder involvement can be part of any step and should take place throughout the EBFM process.

3.2 Typology of management interventions

This section explores the foundations of environmental governance, policy and management and presents a typology for EBFM interventions in the marine system. We distinguish between the *management measures* that directly affect the ecological system, and the *policy instruments* required for their implementation, based on governance arrangements within the social system. Together they constitute the EBFM plan. This guidance is mostly

based on normative definitions based on (Barnard and Elliott, 2015) but modified with a proposed typology.

Governance is a widely used concept, that remains underpinned by many meanings and lacks one universally adopted definition. In deliverable 2.7, governance is defined as "*the whole of public as well as private interactions taken to solve societal problems and create societal opportunities. It includes the formulation and application of principles guiding those interactions and care for institutions that enable them*" (Kooiman, J. & Bavinck, M., 2005). Another definition of ocean governance is given by (Blythe et al., 2021): "*a broad-stroke term that combines governing structures, processes, rules, and norms that shape how relevant actors make decisions, share power, assign responsibility, and pursue accountability in the use and management of the marine environment*". What these have in common is that governance involves the interplay between actors, networks, power dynamics and organisational systems in political, ecological and social contexts. When the content and structure of a policy domain are somewhat stabilised, one can speak of governance arrangements. Figure 3.2 characterizes the governance of the marine SES involving the main actors relevant for the design of the EBFM plan consisting of policy instruments as well as how specific types of management measures may target the (combinations of) Activities, Pressures or State as occurring in the cause-consequence-response frameworks often at the basis of EBFM.

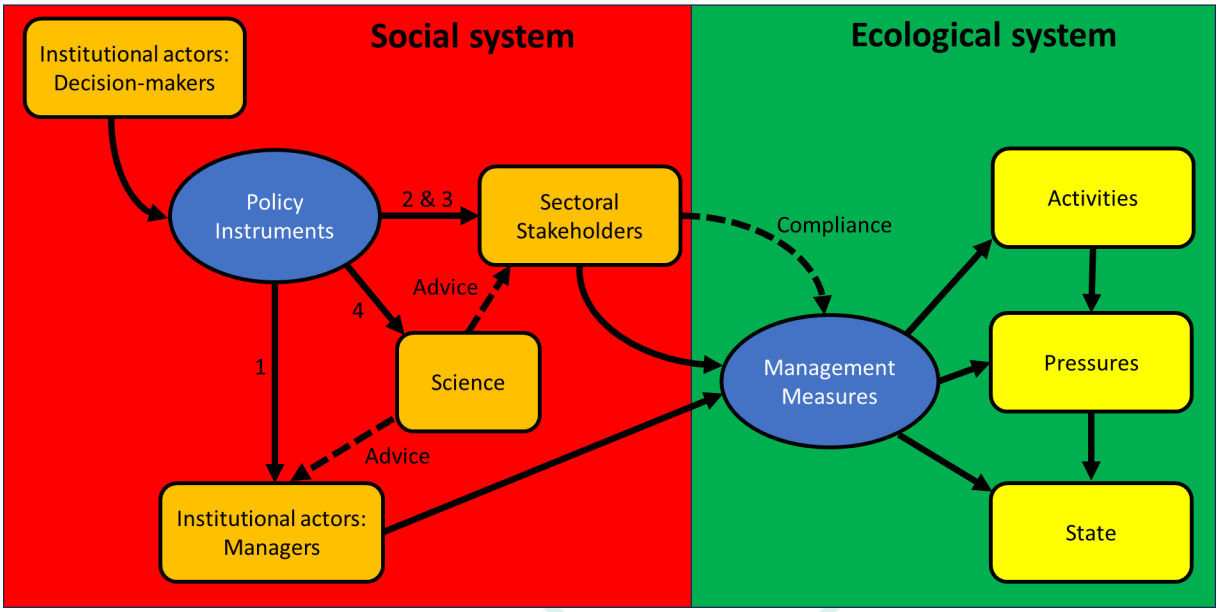

Figure 3.2. The governance of the marine SES and some of its main actors and relevant processes in relation to the proposed EBFM plan consisting of policy instruments and management measures. The numbers refer to the policy instrument categories (1) Legal and regulatory instruments; (2) Voluntary agreements and information instruments; (3) Economic incentive-based instruments (including market-based instruments); (4) Research and development (knowledge base) (see table 3.1). The arrows indicate clear cause-effect linkages, in case of dashed lines this is uncertain.

3.2.1 Policy instruments

Though a clear definition of *policy* is lacking and its outlines appear blurred, it can generally be described as an instrument, a set of decisions, principles, or guidelines designed to influence (guide, steer…) (collective) decisions in a particular area of concern and achieve specific outcomes (Jiao and Boons, 2014). Policies underpin environmental management and are not confined to public administration, but also emerge among non-state institutions, actors and processes (Bryant and Wilson, 1998). Although policy can expand broader than the political system (e.g. policy established within business), it usually refers to the political institutional system in which policies are reflected in legislative and regulatory frameworks (Cormier et al., 2017). Along the lines of the policy cycle described in Jann & Wegrich (2007), policy development is initiated by preceding political, economic, or cultural forces such as looming societal beliefs, technological developments and emerging knowledge initiate agenda setting (Cormier et al., 2017).

Consequent agenda-setting drives defining or redirecting of policy objectives and targets (Jann and Wegrich, 2007). This policy formulation phase involves both prioritizing values as well as providing directions for management (Borgström et al., 2015). In case policy objectives cannot be attained under the existing status quo of policy, new policy must be induced to steer society, industries or any other process in the desired direction.

Once policies are formulated, their adoption can be arranged through various *instruments*[2]. (EC-CINEA, 2021) defines a policy instrument as "*an intervention in the governance arrangements often covering the advisory and decision-making processes intended to facilitate the implementation and/or enforcement of management measures*". Policy instruments are therefore deliberate modes by governments, organizations, or institutions to address specific issues. The four most commonly applied[3] categories of policy instruments are: Legal and Regulatory Instruments (also referred to as command-and-control), Voluntary agreements and information instruments, Economic incentive-based instruments (including, but not limited to, market-based instruments), and Research and development (knowledge base). These may consist of individual actions or comprehensive strategies and programs (Salamon, 2002). Table 3.1 provides an overview of these four categories, a selection of types of instruments that can be applied in these modes and some examples relating to EBFM in the marine domain.

Policy (indirectly) steers or guides the implementation of concrete management actions (e.g. programs, measures, procedures and controls) needed to reach the defined policy objectives (Borgström et al., 2015; Cormier et al., 2017). In other words, policy instruments operate in the social system in which they target specific actors to induce behavioural change or stimulate actions that contribute to achieving policy goals (EC-CINEA, 2021) (Howlett, 1991; Bemelmans-Videc & Rist, 1998). Hence, policy instruments enable, steer or trigger certain actions that directly affect the natural environment management measures. These can include programs, measures and controls (see next section). An example of management measures that translate top-down policy into specific actions are the Program of Measures under the MSFD.

Table 3.1. Policy instrument categories and types

Policy instrument categories	Policy instrument types	Examples
1. Legal and regulatory instruments	1.1. Standards / limits / requirements	EU Marine Strategy Framework Directive, EU Birds and Habitats Directive
	1.2. Supervision / enforcement	IMO Marine Environment Protection Committee (MEPC)
	1.3. Treaties	High Seas Treaty
	1.4. Targets / policy development	EU Biodiversity Strategy for 2030 The EU Nature Restoration Law The EU Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries
	1.5. Bans	EU Commission Action Plan to phase out all bottom trawling within MPAs and Natura 2000 sites by 2030

[2] Term often interchangeably used with *interventions*, though sometimes seen as differing concepts. We use the term instruments here, as we see the entire EBFM plan (implementation of a management measure in its institutional context, i.e. governance) as the *intervention*.

[3] Numerous variations on this categorization exist, but drawing on many sources, this formulation has been adopted here.

Policy instrument categories	Policy instrument types	Examples
2. Voluntary agreements and information instruments	2.1. Codes of Conduct	FAO Code of Conduct for Responsible Fisheries. Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication ("the SSF Guidelines"). Minimum Conservation Reference Size (MCRS)
	2.2. Certification schemes	Marine Stewardship Council (MSC)
	2.3. Awareness campaigns / education	EU-funded multi-media public awareness campaign ''Exploring Together the Treasures of the Sea!''
	2.4. Labelling	https://op.europa.eu/en/publication-detail/-/publication/c11b6cb8-0524-4aff-9ea1-901189690dc9/language-en
	2.5. Nudging (shaping public opinion)	https://www.frontiersin.org/journals/communication/articles/10.3389/fcomm.2020.610186/full, examples: https://norden.diva-portal.org/smash/get/diva2:1065958/FULLTEXT01.pdf
3. Economic incentive-based instruments (including market-based instruments)	3.1. Subsidies and grants	#nudgeforclimate – European Climate Act
	3.2. Tariffs	EU Carbon Border Adjustment Mechanism
	3.3. Deposit-refund schemes	Small plastic bottles deposit scheme
	3.4. Taxes (relief) and charges	Shipping & tax relief schemes (e.g. Tonnage tax scheme)
	3.6. Liability schemes	International Convention on Civil Liability for Oil Pollution Damage
	3.7. Individual Tradeable Quota / cap-and-trade	EU Emissions Trading System (ETS)
4. Research and development (knowledge base	4.1. Research (monitoring / investments / programmes)	EU Data Collection Framework. Work Programme of Horizon Europe under the EU Mission Restore our Ocean and waters
	4.2. Impact assessments	EU Environmental Impact Assessment Directive, EU Strategic Environmental Assessment Directive, SEA protocol
	4.3. Evaluation	ICES, OSPAR and HELCOM assessments

3.2.2 Management measures

Whereas *policy* refers to the overall 'set of rules, principles, and guidelines', *management* refers to the biophysical interference with the human activities, their pressures and/or specific ecosystem components or processes which compromise the achievement of policy objectives or societal goals. Management measures are thus specific interventions in the ecological system that may target the stressors and/or receptors with the aim to achieve policy

objectives or societal goals. In a fisheries context, management measures are "*specific elements of fisheries control which are embodied in regulations and which become a focus for surveillance activities*" (EC-CINEA, 2021). As argued by Cormier et al., (2017), "*the competent authorities of specific sectors that are accountable to implement the measures that are designed to manage their specific operations*".

For the purpose of assessing the effectiveness of management measures and providing guidance for the implementation of EBFM, we distinguish six major categories: Spatio-temporal distribution control, Input control, Output control, Remediation, Restoration and Nature-based solutions (NBS). While NBS may partly overlap with the other categories (depending on the applied definitions), it also includes some novel interventions that for the sake of comprehensiveness could not be excluded. Table 3.2 presents our proposed definition for each of these categories and presents an additional level of detail with the different types of management measures, including examples related to marine EBFM. For EBFM, only the first three categories are relevant and will be considered for the evaluation of effectiveness.

These different management measure categories may help to differentiate how the management response (R) targets the human Activities (A) and their pressures (P) or the ecosystem state (S) and how this is impacted (I) according to the cause-consequence-response frameworks like DPSIR, DAPSES-MMM or DAPSIWRM (Piet et al., 2015; 2023). Input controls are primarily aimed at the (often sectoral) human activities (A) such as specific fisheries metiers, whereas output controls target the pressure (P), e.g. catch or littering from loss or damage of gear. Remediation is aimed at the pressures (P) from past activities while (active) restoration targets the ecosystem state (S) to alleviate the impacts (I) from past and ongoing activities and their pressures. Finally, the spatio-temporal distribution controls may target any part of the A-P-S impact chain but with a focus on their spatial occurrence or seasonal patterns.

Table 3.2. Management measure categories and types.

Management measure categories	Proposed definition	Management measure types	Examples
Spatio-temporal distribution control	Mitigation of the extent in space and time of the activity and/or pressure(s)	Spatial closure/restriction	Marine Protected Area (MPA), no-take zones. See MPA guide (Grorud-Colvert et al., 2021). Fisheries Restricted Areas (FRAs) in the Mediterranean (https://www.fao.org/gfcm/data/maps/fras/en/) Restrictions can also be considered spatial input or output measures, e.g. area to discharge ballast water. Other Effective area-based Conservation Measures (OECMs) (Jonas HD, MacKinnon, K., Marnewick, D. and Wood, P., 2023)
		Seasonal closure/restriction	Closure of season (March-June) for sole fisheries; closed season for trawlers in certain Mediterranean sub-regions
		Real-Time Closure	Fisheries closures in specific areas in case of too much undersized catch

Management measure categories	Proposed definition	Management measure types	Examples
Input control	Mitigation of the activity (e.g. fishing metier) and hence all associated pressures	Capacity	Capacity reduction by decreasing size of fleet (decommissioning)
		Effort	Effort reduction of a fishing fleet in days-at-sea
		Gear change	(Part of a) fleet segment changing from one fishing technique to another
		Technical Conservation Measures	Modification to a specific fishing technique, e.g. mesh size, sorting grids, escape panels.
Output control	Mitigation of any specific pressure(s) (e.g. catches, contaminants) while allowing the activity to continue	Pressure-specific output controls	Reduction of catch through TAC/Quota, bycatch through landing obligation, ban on littering, Minimum Conservation Reference Size (MCRS)
Remediation	Intervention to reduce the pressure(s) from past activities	Remediation measure	Collection of litter (Fishing for Litter), beach cleaning, retrieval of lost fishing gear, cleaning pollution from offshore drilling operations, ship/boat hull cleaning
Restoration	Intervention to enhance the state of the ecosystem component(s), biotic or abiotic	Biotic community, species or stock restoration	Breeding program of seabirds and marine mammals, Rebuilding of exploited fish stocks
		Abiotic (physical) habitat restoration	Greening of grey hard infrastructure, e.g. Nature-inspired surfaces, Shoreline protection
Nature-based solutions	Introduction of novel (configurations of) activities expected to enhance the ecosystem state	Enhance ecosystem state	Artificial reefs, nature-inclusive design of scour protection offshore windfarms
		Multi-use	Co-existence, Co-location, Symbiotic use, Multi-purpose, Multi-functional instead of single-use, Offshore aquaculture
		Replace existing activities	Lower-trophic and multitrophic aquaculture, Wind powered shipping

3.3 Toward a SEAwise EBFM plan

For the design of a high-performance EBFM plan the challenge is to implement the management measures deemed most effective to achieve the selected policy objectives or at least advance the status of the ecosystem and its components toward those goals. To guide this design process, information is required on the effectiveness of the potential management measures. This information should come from the evaluation of management measures,

either from monitoring of the consequences of those already implemented or from modelling studies. Figure 3.3 attempts to capture how different entities within the EBFM evaluation and design processes are connected. In order to bridge the gap between EBFM and EBM but also between CFP and MSFD, the typology is aligned as much as possible to those processes/policies. For example, the pressure and ecosystem component categories come from the MSFD but can be matched to equivalent terms in the CFP. For example, fish and cephalopods can be assumed cover the commercially exploited stocks (including crustacea). Spawning Stock Biomass (SSB) is used as an indicator for both policies. The main (only?) pressure relevant for the CFP is the "Extraction of flora and/or fauna" representing catches and the indicator of choice in both policies is fishing mortality (F).

Two pathways can be distinguished: (1) Evaluation of existing management measures goes counter-clockwise starting from the management options via the fisheries types and/or objectives into the ecosystem components and policy objectives; and (2) Design of an EBFM plan which goes clock-wise starting from the policy objectives that are not achieved and ecosystem components not in Good Environmental Status via the pressures impacting them and the fisheries causing those pressures to the selection of the most effective management measures to mitigate those fisheries and their pressures.

These pathways are further elaborated in the subsequent chapters 4 and 5.

Figure 3.3. Main entities in the EBFM process and their linkages. The distinguish between the management measures categories (Blue), the fisheries types (red) and their pressures according to the MSFD (white), the ecosystem components according to the MSFD (green) and the policy objectives (orange). The traffic light symbols indicate if there is a potential linkage while the colour indicates the threat to the status of the ecosystem components and hence the achievement of policy objectives, based on an assessment of so-called Impact Risk according to Piet et al. (2023), varying from high (red) to low (green). Effective management should aim for the highest mitigation of risk.

Spatio-temporal distribution control									**MSFD**
Input control			**Output control**		X	X	X	X	**D1**
					X	X	X	X	**D4**
				X					**D6**
				X			X		**CFP**
Benthic trawls and dredges	**Pelagic trawls**	**Static gears**	**Pressures**	**Benthic habitats**	**Pelagic habitats**	**Birds**	**Fish & Cephalopods**	**Mammals & Reptiles**	
			Abrasion/Damage						
			Barrier to species movement						
			Changes in input of organic matter						
			Changes in Siltation						
			Continuous noise						
			Death or Injury by Collision						
			Disturbance (visual) of species						
			Extraction of flora and/or fauna						
			Ghost nets and other litter causing entanglement						
			Introduction of Microbial pathogens						
			Introduction of non-indigenous species						
			Introduction of Non-synthetic compounds						
			Introduction of Synthetic compounds						
			Microplastics and other litter that may be ingested						
			N&P Enrichment						
			Smothering						
			Translocations of species (native or non-native)						
X	X	X							
Socio-economic objectives			**Output control**	**Restoration/Stocking**					

4. Evaluation of effectiveness management measures

In Deliverable 6.12, the performance of various management strategies was assessed based on indicators ranging from those focussing specifically on fisheries and commercial (shell)fish stocks relevant for the CFP and those covering the wider ecosystem for the MSFD. This work built on material already reported in D6.8 and involved scenarios of those management interventions under current and climate change conditions also considering the performance over longer time periods (see the description of those scenarios in D6.8 and D6.12).

To align the term management strategy used in D6.12 with the typology for EBFM proposed in this deliverable, the assumption was that in the context of fisheries management, a management strategy evaluation mostly meant assessing the performance (or effectiveness) of a management measure as defined in this study (and hence with the implicit assumption that they are implemented through 100% effective top-down regulatory policy instruments). This chapter therefore only addresses the effectiveness of the term management measures.

While tables 3.1 and 3.2 are intended to be comprehensive and applicable for EBM, typical fisheries management only consists of mitigation and therefore only the management measures categories and types from table 3.2 that are applicable to fisheries management were included in the Table 4.1. The scenarios were then matched to the management measure typology in Table 4.1.

Table 4.1. *Mitigation management measure categories and types with matching scenarios.*

Management measure categories	Management measure types	Case study	Scenarios
Baseline	Baseline scenarios represent current management (Period = 2025-2030) and climate conditions (noCC)		
Spatio-temporal distribution control	Spatial	NS-FLBEIA	Natura 2000 closures where effort is redistributed either uniformly or weighted: • Status-quo_noCC_uniformCls • Status-quo_noCC_weightedCls • FMSY-Min_noCC_uniformCls • FMSY-Min_noCC_weightedCls • PGY-Min_noCC_uniformCls • PGY-Min_noCC_weightedCls

	Spatial	BoB-ISISFish	A gradient of MPA closures based on the proportion of each habitat closed to fishing (0%, 10%, 20%, 30% and 50%) was simulated; • min-fbit_mpa10pc • min-fbit_mpa20pc • min-fbit_mpa30pc • min-fbit_mpa50pc
	Spatial	NS-OSMOSE	Natura 2000 and windpark closures (D6.8): • FMSY-RCP8.5 + Spatial Closures
	Spatial	Med-BEMTOOL	Natura 2000, FRA and MPA closures (D6.8): • Fmsy_current_closures • PGY_current_closures
	Seasonal	BoB-FLBEIA	A one-month closure aimed at reducing the bycatch of common dolphins: • CaseSpecific_Current_dolphinClosure • FMSY-LandingObligation_Current_dolphinClosure • PrettyGoodYield_Current_dolphinClosure • StatusQuo_Current_dolphinClosure
Input control	Capacity	None	
	Effort	Mediterranean case studies	CS, PGY and MSY simulating different effort reduction scenarios.
	Gear change	CS-FLBEIA	Gear shifts based on the effort reduction of bottom trawlers: • Cst_Ef_bottom_trw_50p_reduction_ static_1000p_increase_no_CC • Cst_Ef_bottom_trw_50p_reduction_ static_100p_increase_no_CC • Cst_Ef_bottom_trw_50p_reduction_ static_500p_increase_no_CC
	Gear change	BoB-FLBEIA	Gear shifts based on the activity reduction of trawlers (100%, 50% and 25%): • CaseSpecific_Current_trawlerban.100 • CaseSpecific_Current_trawlerban.25 • CaseSpecific_Current_trawlerban.50 • FMSY-LandingObligation_Current_ trawlerban.100 • FMSY-LandingObligation_Current_ trawlerban.25 • FMSY-LandingObligation_Current_ trawlerban.50 • PrettyGoodYield_Current_trawlerban.100 • PrettyGoodYield_Current_trawlerban.25 • PrettyGoodYield_Current_trawlerban.50 • StatusQuo_Current_trawlerban.100 • StatusQuo_Current_trawlerban.25 • StatusQuo_Current_trawlerban.50

	Technical conservation measures	NS-FLBEIA	Gear modifications (increased mesh sizes) affecting beam and otter trawls: • Case-study_rcp45_gearMod • FMSY-Min_rcp45_gearMod
	Technical conservation measures	Med-BEMTOOL	Gear modifications for trawlers (mesh size & sorting grid) and non-trawlers (longlines and polyvalent using gill nets and trammelnets): • ChangeSel_current • ChangeSel_Red25_current
Output control	Pressure-specific output controls	Northeast Atlantic case studies	SQ, PGY, MSY and CS scenarios simulating harvest control rules with different levels of implementation of the landing obligation.

4.1 Approach

To assess the effectiveness of the management measures from the scenarios, comparisons were made between baseline scenarios (i.e. without any management measure not currently in use) and a scenario with a specific management measure. The effects were distinguished between short-term (ST, Period = 2035-2040) and long-term (LT, Period = 2055-2060[4]) and the baseline scenarios represent current management (Period = 2025-2030) and climate conditions (noCC).

The effectiveness of the management measures (*MM*) to advance the status of specific indicators was thus calculated as:

$$\text{Effectiveness} = (\text{Indicator}_{MM,Period} - \text{Indicator}_{Baseline,Present}) * 100\% / \text{Indicator}_{Baseline,Present}$$

Management scenarios applied in the Northeast Atlantic case studies differ from those applied in the Mediterranean case studies. In the Northeast Atlantic, management is mainly based on Total Allowable Catches (TACs) (output control), and scenarios were defined for several harvest control rules with different levels of implementation of the landing obligation (SQ = "status quo"; MSY = "minimum" scenario; PGY = "pretty good yield"; and CS = case-specific scenario, see D6.8). For comparing these different scenarios, the SQ scenario was used as the baseline. For some of these scenarios, output control management was complemented by additional management measures (e.g., spatial closure restrictions, technical conservation measures; see Table 3.2). To isolate the effect of specific management measure types, the baseline was selected with the same type of output control scenario (CS, MSY, PGY and SQ).

In the Mediterranean, management is mainly based on fishing effort regulation. For these case studies, scenarios were defined for several effort reductions (SQ = Status quo; MSY = FMSY or F0.1; PGY = Fcomb, see D6.8). Some of the effort scenarios were complemented by additional management measures, including spatial closure restrictions and technical conservation measures. The SQ scenario was always used as the baseline to compare the different effort scenarios.

As the management measure should advance toward achieving the policy objectives it is necessary to know the desirable direction of change. This is given for each MSFD objective in the table 4.2. This was then used to interpret the effectiveness estimate as desirable or not (see Table 4.3).

[4] For the NS-OSMOSE case study only LT effects were evaluated for which the scenarios were projected only for the year 2060.

4.2 Results

The effectiveness assessment shows marked differences in effectiveness between the management measure-policy objective combinations. Because of this, it makes sense to implement specific types of management measures to advance toward specific policy objectives. Note, however, that while the obvious choice to advance toward the achievement of a specific policy objective is by selecting the most effective management measure for that objective, there can be good reasons to select a measure which may be less effective in achieving that particular objective but may also advance toward other important objectives or because of issues not included in the effectiveness, e.g. compliance or likelihood in getting the measure implemented. These are the typical regional issues that need to be considered when designing a regional EBFM plan.

To safeguard biodiversity effort restrictions or a shift to another gear type may markedly decrease the bycatch of marine mammals and seabirds (D1C1 indicator, see Table 4.2) and appear to be the preferable measures for these ecosystem components. The reason output management also appeared to be effective is that it translated into a *de facto* effort control. Spatial restrictions were not very effective but this may be because these spatial restrictions were not aimed specifically at reducing the bycatch of these species groups. Figure 4.4 shows that for all measures, there was little difference between the short term and the long(er) term.

For the food web D4 indicators, it is often unclear what the desired direction of change should be. Overall the objective was to have more older (increase D3C3) and larger (increase LFI) fish but this usually clashes with the objective to increase recruitment success and have abundant forage fish for e.g. seabirds. As there may be regional preferences to increase certain feeding guilds implementation should be specific to the regional context.

Table 4.2. The different policy objectives and their assessed indicators. The sign under effectiveness indicates an increase (+) or decrease (-) compared to the baseline was interpreted as more effective to achieve the policy objective.

Objectives		Indicators	Effectiveness
CFP commercial stocks		Proportion of stocks fished at or below F_{MSY}	+
		Proportion of stocks with median SSB below MSY $B_{trigger}$	-
		Proportion of stocks with >5% probability to fall below B_{lim}	-
MSFD	D1C1	Total bycatch in number of individuals, summed over all the bycatch species. The indicators distinguish between Marine mammals (i.e. dolphins and Harbour porpoise), Seabirds (i.e. Shearwater), Turtles and Elasmobranchs (i.e. sharks, Spurdog and Undulate ray)	-
	D1C3	Total biomass of forage fish species, summed over all forage fish species	+
	D3C3	Mean average age over all commercial species	+
	D4C1	Shannon indices can be used to measure biodiversity of specific trophic guilds. Several trophic guilds, both invertebrate and fish are distinguished	+

	D4C2	Balance between trophic guilds based on biomass, e.g. demersal/pelagic	0*
	D4C3	Large Fish Indicator (LFI) for all fish, or only the benthivores or piscivores. Mean maximum Length (MML)	-
	D4C4	The R/SSB may be used as proxy for recruitment success. The indicators distinguish between apex fish predators, planktivorous fish and invertebrates, sub-apex demersal predators and sub-apex pelagic predators	+
	D6	The indicator gives the effort per demersal gear type and distinguishes between bottom otter trawl, bottom pair trawl, gillnets, handlines, handlines mechanized, longlines, seines and trolling lines	-**
Socio-economic context and Fisheries Opportunities	Social	Employment (average of yearly sums across fleets/metiers)	+
		Wages (average of yearly sums across fleets/metiers)	+
	Economic	Average yearly ratio of current revenue/break even revenue (sum across fleets/metiers)	+
		Revenue (average of yearly sums across fleets/metiers)	+
		Gross profit (average of yearly sums across fleets/metiers)	+
		Gross value added (average of yearly sums across fleets/metiers)	+
	Fisheries Opportunities	Landings (average of yearly sums across fleets/metiers)	+
		Unwanted catch/discards (average of yearly sums across fleets/metiers)	-

* The preferred direction should depend on the regional situation. Any change is taken as at least the potential to intervene through management

** For D6 the issue is the fishing pressure as a proxy for D6C1 (physical loss of seabed) and D6C2 (physical disturbance to the seabed). As the management measure should aim to advance the status of this descriptor through a shift from fishing gears causing high physical disturbance (i.e. bottom trawls and dredge) to gears causing less physical disturbance (e.g. gillnets or handlines). A decrease of the high-impacting gears is thus concomitant with a decrease in fishing pressure and advances toward achieving D6, even if this coincides with an increase in the low-impacting gears.

Table 4.3. Effectiveness of management measures to advance policy objectives and their specific indicators. The effectiveness was estimated for the longer term and without effects of climate change

Policy objectives	Indicators	Input Control		Spatio-temporal closures		Output Control	
		Effort	TCM	Gear change	Effort	TCM	Gear change
Commercial stocks	At or below F_{MSY}	60		8	5	-1	83
	>5% probability to fall below B_{lim}	0		12	14	-30	93
	Median SSB below MSY $B_{trigger}$	14		13	38	-36	100
Economic	Ratio Current / Break even revenue	208	37	10	2	6	9
	Gross profit	-15	33	123	-6	13	29
	Gross value added	2	27	482	-57	13	7
	Revenue landings	-10	21	4	6	11	8
Social	Employment	-27	0	47	0	2	-7
	Wages	-7	20	6	7	7	-11
Fishing Opportunities	Landings	-14	28	-12	-1	8	-1
	Unwanted catch discards	13	53	29	2	-9	17
D1C1	Dolphins	39		56	37	7	40
	Harbour porpoise					-3	57
	Seals					-3	45
	Sharks	21					
	Spurdog			0	0	6	25
	Thornback ray						83
	Undulate ray			18	-6	6	40
	Shearwater			27	-1	7	27
D1C3	Biomass	0		36	36		18
	Ratio	1		36	36		18
D3C3	Age			2	2	-6	20
D4C3	LFI					0	64
	MML	0					

D4C4	Apex fish predators	2		2	2	-7	-26
	Benthic feeding invertebrates	5				1	-61
	Planktivores fish invertebrates			16	16		13
	Subapex demersal predators	14		-7	-3	17	-21
	Subapex pelagic predators			5	5	39	-27
	Mean recruitment succes					-30	-38
D6	Beam trawl	0				25	56
	Bottom otter trawl	12		56	-2	11	48
	Bottom pair trawl			59	5		5
	Dredges	0					
	Demersal trawl	12					

Table 4.4. Effectiveness of the different types of management measures to achieve specific policy objectives in the short term (ST=10 years) and the longer term (LT=30 years) assuming no climate change. Indicated is the effectiveness based on the % improvement of indicators relative to baseline (see Table 4.2 for explanation and Table 4.3 for results per indicator). The colours indicate a marked improvement (green), decline (red) or negligible change (orange) toward achieving the policy objective.

Policy objectives		Effort reduction		Gear mod		Gear shift		Seasonal closure		Spatial closure		TAC management	
		LT	ST	LT	ST	LT	ST	LT	ST	LT	ST	LT	ST
CFP	Commercial Stocks	28	28			17	16	29	26	-22	-22	94	90
Socio-economic	Social	-27	-27	0	0	47	47	0	0	6	7	-1	0
	Economic	49	52	40	38	146	151	-24	-20	22	21	23	24
	Fishing Opportunities	-12	-12	35	34	-14	-12	-3	-1	17	15	7	6
MSFD	D1C1 Mammals		37			56	56	37	37	-2	-2	46	45
	D1C1 Elasmobranchs	22	22			8	8	-4	-3	8	8	39	38
	D1C1 Birds					25	26	-2	-2	9	9	27	27
	D1C1 Turtles		17										
	D4C1												
	D4C3	0	0							2	6	71	76
	D4C4	11	8			5	8	6	9	0	4	-28	-25
	D6 Seafloor	4	7			57	57	1	1	16	16	41	41

The current output controls, e.g. through TAC management, perform well in advancing stock status while also advancing several of the other objectives. Further analysis of the various forms of TAC management (Table 4.5) shows a striking difference between the MSY, PGY which advance both the commercial stocks and also most of the wider ecosystem objectives but not the socio-economic, and CS management which performs well on the socio-economic objectives but slightly less on the biodiversity objectives. The more stringent MSY is more effective than PGY in attaining ecological objectives. The reduced recruitment success (D4C4) that accompanies output controls is also striking.

Table 4.5. The effectiveness of different TAC management Harvest Control Rules (HCRs) to improve compared to the current situation, over the long term (30 years) without climate change.

	CS	MSY	PGY
Commercial Stocks	92	97	92
Social	21	-13	-14

Economic	29	3	9
Fishing Opportunities	10	-3	-9
D1 Birds	0	36	33
D1 Elasmobranchs	-2	36	42
D1 Mammals	16	50	48
D4C3	15	29	15
D4C4	-26	-33	-26
D6 Seafloor	19	44	43

In addition to the ongoing TAC management specific types of management can be implemented to (further) advance against specific objectives.

- If the main objective is to improve the status of the commercial stocks, then effort management and seasonal closures appear to be the most effective management measures. For effort management, the main drawback involves the social objectives whereas for the seasonal closures these are the economic objectives. Effort management was also found to advance the achievement of economic objectives whereas the seasonal closure may also reduce bycatch of marine mammals.
- If the aim is to protect biodiversity, this can be achieved through a reduction of the bycatch of mammals, turtles or birds or a decrease of the physical disturbance of the seafloor.
    - To reduce the bycatch, a gear change is the preferred option followed by effort reductions. The gear change also benefitted social and economic objectives but not the fishing opportunities. The social objectives suffered most from the effort reductions.
    - Spatial closures were found to be specifically suited to protect the seafloor and fishing opportunities. Spatial closures can also be applied together with (or to reinforce) any of the other management measures if the aim is to protect a specific seabed habitat like Vulnerable Marine Ecosystems (VMEs) from fishing. The management measure can also be applied to reduce the bycatch of seabirds or elasmobranchs but if this is the main goal of the management intervention then closures in periods when that particular species is most vulnerable can be the preferred management measure in terms of effectiveness for seabirds.
- If the main objective is to achieve the economic objectives and improve fishing opportunities, then technical conservation measures (TCMs) are the preferred management measure. These, however, do not advance social objectives.

This guidance was based on various simulations of regional applications using specific models. In order to provide generic guidance for the design of an EBFM plan, the analysis was based on a combination of all simulations with the aim that this should provide a qualitative indication of the effectiveness of such broad types of management measures, i.e. A is likely to perform better than B, acknowledging that the effectiveness actually achieved differs depending on the regional context. This is to be taken on board when designing the regional EBFM plans.

5. Design of an EBFM plan

This chapter provides an outline and guidance for the design of an EBFM plan using the knowledge generated as part of SEAwise. The aim is for this EBFM plan to be aligned as much as possible to any other EBM approaches (i.e. beyond fisheries management) such as Ecosystem-Based Approach to Maritime Spatial Planning (EBA-MSP) as part of MSPD or any other management interventions aimed at achieving MSFD or Birds & Habitat Directives (e.g. N2000).

This outline and guidance for the design of an EBFM plan starts with an outline of the EBFM process this plan is part of. This is based on the EBFM cycle that fits in the context of a SES (figure 3.1) distinguishing both policy instruments operating in the social system and management measures in the ecological system (see chapter 5.1). The performance of the EBFM plan across a wide range of policy objectives covering both the commercial (shell)fish stocks as well as other ecosystem components is explicitly considered in the design process through (1) incorporating all potential fisheries impacts and the degree to which these compromise the achievement of policy objectives (chapter 5.2) and (2) considering the effectiveness of management measures (chapter 5.3).

5.1 The EBFM cycle incorporating typologies of management interventions

The five-step EBFM process in a SES context can now be elaborated applying the policy instruments and management measures (Table 5.1).

5.2 Performance of the EBFM plan

Ultimately, it is the 'EBFM plan' (e.g. MSFD Programme of Measures) that should achieve the relevant societal goals for that specific regional ecosystem. The performance of the EBFM plan determines the degree to which objectives and goals are met, but different perspectives apply depending on where in the EBFM adaptive cyclical process the assessment occurs (Figure 2.1). The current management in place can be considered the existing 'EBFM plan' (see Deliverable 6.9) even though these were never intended as such. The existing EBFM plans are thus a rather haphazard collection of mostly sectoral management measures which are enabled by policy instruments primarily intended to operate in a more conventional fisheries management setting as opposed to EBFM. Overall performance was rarely an explicit selection criterion and, if considered at all, often only included the expected effectiveness of management measures to achieve a single environmental objective. More valuable would be to evaluate the performance of an EBFM plan in its entirety in terms of progress towards a wide range of policy objectives. This should ideally be based on the data from existing monitoring programs and calculated indicators and would then essentially be considered the follow-up step of the previous EBFM cycle. If (some of) the assessed policy objectives are not achieved, then this sets the baseline against which the next EBFM cycle must be adapted to improve the performance of the plan.

For the next EBFM plan emerging from a new EBFM cycle, the proposed framework becomes essential to advance from the previous EBFM plan: the previous cycle was used to disentangle the EBFM plan into the policy instruments and management measures categories and types, while in the current cycle, it supports the design of the new EBFM plan that will perform better than the previous. This may include adding, but also removing or strengthening certain interventions (policy instruments or management measures) guided by the experiences gained in the previous EBFM cycle and improved knowledge base of the current cycle. As a guiding framework, it allows for a deliberate consideration and selection process of which management measures or policy instruments to apply within an EBFM plan, based on their expected ease of implementation and performance. As such it provides the basis for the

piecemeal adaptive process of increasingly more effective EBFM plans that continuously advances towards the achievement of the selected policy objectives.

Table 5.1. Elaboration of the five-step EBFM process in a SES context.

Step	Policy Instruments	Management measures
1	Scoping exercise of the relevant policy objectives and societal goals to define the required EBFM components, starting with its aim to achieve specific policy objectives or societal goals within the social and environmental context, including the legal setting. Note that these objectives and societal goals are often understood to refer to the state of the ecosystem but may also involve social or economic objectives/goals. Sustainable exploitation across its different dimensions (environmental, social, economic) is often the overriding goal but whether this implies weak or strong sustainability often remains implicit. EBFM is assumed to be embedded in the model for strong sustainability where economic sustainability can only be achieved if social and environmental sustainability are achieved. This step is described in SEAwise deliverable 1.9.	
	Agenda setting: Defining policy objectives is driven by (inter)national societal (e.g. media), political or economic agendas. Identification of the relevant governance actors in the regional context.	Scoping of the relevant fishing métiers, their pressures and fish stocks or other ecosystem components of concern. Identification of the existing management measures
2	Policy formulation: Deciding upon appropriate policy instruments based on a thoughtful integration of EBFM principles into decision-making processes, such as stakeholder engagement (e.g. local and indigenous people. Includes considering current institutional setup, its governance and relevant actors and the expected effectiveness of the policy instruments.	Developing the knowledge base (which may include scientific as well as local indigenous knowledge) driven by the policy objectives or societal goals to be achieved, the different types of fisheries operating in the regions as well as other relevant human activities and their pressures operating in that ecosystem with the species or species groups of concern and potential EBFM measures. This is described across all SEAwise deliverables.
3	Policy adoption: Communicating of formulated policies across stakeholders, establishing institutions or governance structures to oversee implementation and enforcement developing evaluation schemes. Compliance is another issue of concern determining effectiveness.	Assessing and weighing the EBFM measures in terms of their expected performance (i.e. effectiveness) using the knowledge base and appropriate tools. This is described in SEAwise deliverable 6.10.
	A synergy test to assess how the various management interventions (policy instruments and management measures) can reinforce one another, e.g. a measure intended to achieve one policy objective may also contribute to the achievement of other objectives or the same policy instrument may initiate several management measures. This results in scientific advice for a single internally consistent EBFM plan which may include many management strategies (=policy instrument and a management measure).	
4	Implementing the EBFM plan based on informed decision-making guided by best practices. Implementation of an adequate monitoring program (with a focus on the pressures and ecosystem components) and enforcement (often focused on the activities causing the pressures of concern) should be part of this step.	
5	Follow-up in which both the EBFM process (i.e. the preceding steps), as well as its performance in achieving the specific policy objectives or societal goals, are evaluated using the scientific tools developed in step 2 and the monitoring data from step 4, ensuring adaptive governance capacity (Borgström et al., 2015; Cormier et al., 2017).	

These EBFM plans thus consist of many different policy instruments and management measures, in a variety of combinations. This to make it explicit that the performance of a management intervention needs to be considered from the perspective of the full social-ecological system. This also implies that we broaden the term management strategy which in the context of fisheries management strategy evaluation with the implicit assumption that they are implemented through 100% effective top-down regulatory policy instruments. The overall performance of a specific management strategy as a combination of a policy instrument and a management measure may be difficult to assess since a single policy instrument may be applied to set in motion the implementation of several management measures and several policy instruments may contribute to the implementation of a single management measure. To guide the design of a more effective EBFM plan, this study works from the assumption that this can be achieved through a piecemeal substitution of the specific less-effective components of the EBFM plan, i.e. the policy instruments and management measures, with more effective equivalents. In addition to this reductionist approach, a more holistic synergy test would be required to identify where specific combinations may reinforce one another. Thus, the performance of an internally consistent EBFM plan may be determined by the expected performance of each of its different components and the synergy between them. Both the performance of each of the components as well as the synergy between them are likely to be context-specific as that of the policy instruments depends on the institutional set-up and that of the management measures on the biophysical ecosystem.

5.3 Guidance for the design of the EBFM plan

The design process of an EBFM plan is illustrated in figure 3.3 (chapter 3) and goes clock-wise starting in the upper right corner from the policy objectives that are not achieved and ecosystem components not in Good Environmental Status via the pressures impacting them and the fisheries causing those pressures to the selection of the most effective management measures (upper left corner) to mitigate those fisheries and their pressures.

An evaluation per EU marine region of the policy objectives that have yet to be achieved is given in Deliverable 6.9 (CFP Chapter 4, MSFD Chapter 5) together with a first inventory of the types of management measures already implemented (Chapter 3.2). This is the starting point for the design process of the regional EBFM plans. All EU regions have in common that (most of) the CFP objectives are not achieved which translates to two ecosystem components, obviously fish and cephalopods covering the commercial fish stocks but also the benthic habitats which include the shellfish stocks. For this the main pressure to be mitigated is the “Extraction of flora and/or fauna” equivalent to the catches and for which fishing mortality (F) can be used as proxy.

Clearly any input control (and/or spatio-temporal distribution control) that mitigates a (specific type of) fishery in terms of its capacity or effort reduces all the pressures of that fishery, not just lower catches as intended but also, notably in case of a benthic trawl fishery, less abrasion of the seafloor. The traffic light colours suggest this also applies for Static gears and Pelagic trawls but to a lesser extent as they are known to cause very little abrasion but cannot be excluded. While it is relevant to be aware of all those potential impacts, effective fisheries management should focus primarily on the impacts that matter most (i.e. the red and orange traffic lights in 3.3). Of note is that in case of Input controls and/or spatio-temporal distribution controls that target a specific type of fishery to mitigate fishing mortality of specific stocks, other species (fish but also seabirds or marine mammals) are likely to benefit, not just from reduced bycatches but also any of the other pressures caused by that type of fishery.

Incorporating the achievement of the MSFD objectives into the design of the EBFM plan may require additional management measures as there often is very little fisheries management in place to mitigate the impacts of fishing activities and notably specific fishing-induced pressures on ecosystem components other than the commercial fish and shellfish stocks. Examples are the bycatch of seabirds, marine mammals and reptiles, mostly through static gears but also the physical disturbance of the seafloor through pressures such as abrasion/damage and smothering from benthic trawls and dredges.

In order to advance the performance of the new EBFM plan as compared to the existing fisheries management plan,

the new suite of management measures should (1) cover all relevant threats to the status of the ecosystem components and hence the achievement of policy objectives as identified in figure 3.3 (i.e. red and orange traffic lights) through (2) effective management measures that can be expected to advance the status of the selected ecosystem components but without compromising the achievement of other ecosystem components/objectives. Effectiveness of management measures is (partly) addressed with the information in chapter 4. Even though these are still limited examples they do show that relevant information on effectiveness can be obtained from modelling exercises and that, depending on the objective(s) the management aims to advance, it does make a difference what type of management measure is implemented.

A Standard Operating Procedure (SOP) was developed to guide the design of the regional SEAwise EBFM plans (Table 5.2). With this information every marine region should be able to come up with an EBFM plan that can be expected to perform better than the previous plan. Clearly its actual performance can only be assessed from monitoring data after implementation.

Table 5.2 Standard Operating Procedure for the SEAwise EBFM plans

Step	Guidance
Identify the relevant policy objectives and/or societal goals and prioritise those that need to be advanced through the regional EBFM plan.	For this you can refer back to D1.9 and D6.9 where you indicated the policy objectives that were not achieved. You can then select one or more of those objectives for the design of your improved regional EBFM plan.
Identify the main types of fisheries (i.e. metiers) and their pressures that need to be managed	Which fisheries metiers and/or which pressures are known to compromise the achievement of the selected objective(s). See figure 3.3 (i.e. red and orange traffic lights) for guidance. Examples of this is given in D4.9.
Identify the most effective management measure types to achieve policy objectives and/or societal goals.	See the typology of management measure (Table 3.2, chapter 3) and chapter 4 guidance on effectiveness of those management measure types. This addresses the question of which management types should be applied.
Decide on most effective operational management measures in the CS-specific regional context.	This should be the main part of the CS contribution based on all the available information. The intention for this deliverable is that it can be informed by the previous step but this decision-support should be used in that capacity. To distinguish from the previous: this addresses the question of how the management should be made operational through e.g. Harvest Control Rules (HCRs). See for example when it comes to effort controls the difference between the following scenarios presented in D6.12: • Landing obligation – *MSY* • Landing obligation – *PGY* • Flexibility in landing obligation – MSY
Identify the most effective policy instruments to implement those management measures.	While the focus is on the operational management measures, the effectiveness of the EBFM plan can be improved through the implementation of appropriate alternative policy instruments than the ones already in place. D2.7 may provide some information. The default answer can be along the lines of "The policy Instruments and governance arrangements currently in place are considered sufficient to effectively implement the newly proposed management measures". Clearly any additional recommendations deemed to improve the effectiveness can be added to this.

Combine the final management measures and policy instruments to create an internally consistent EBFM plan.	This considers the synergy between various measures (see figure 3.3), e.g. how a reduction in effort of a bottom trawl fishery in order to reduce catches of a certain stock also results in reduced seafloor disturbance and a closed area also reduces bycatch of dolphins. The basic rule is that output control only reduces a specific pressure, input control reduces all pressures caused by that fishery. A spatio-temporal control without an input control does reduce the impact on a specific area or seasonal migrant but overall mostly implies a redistribution of fishing effort in space and/or time with unclear benefits to the environment. Explaining how certain governance arrangements may also benefit alternative management measures is important. Pertaining to the Policy Instruments, it is obvious that "Voluntary agreements and information instruments" may have a broader use than what they were initially intended for. The more generic Policy Instruments like "Research and development" are also likely to generate spin-offs other than intended.
Discussion/Conclusion on the process and available information to design the regional EBFM plan. Can you identify obstacles or best practices?	Any lessons learned should be synthesised.

6. SEAwise regional EBFM plans

6.1 Mediterranean EBFM Plan

The Mediterranean case consists of two subcases: the Adriatic and western Ionian Sea (GSAs 17-18-19; A-WIS) and the Eastern Ionian Sea (GSA 20; EIS). There are significant differences between the two fisheries social-ecological systems (SES) in central Mediterranean, stemming mainly from the environmental characteristics and from the structure of the fisheries sector in the two areas.

EBFM is to a large extent determined by the adaptive capacity of the fisheries SES to existing challenges, with barriers to adaptation including prevailing fishing cultures and governance structures (Stelzenmüller et al., 2024). Thus, the SES components of EIS and A-WIS fisheries have different dynamics, upon which tailored strategies should be developed to implement EBFM plans. The independence applies both socially, by SEAwise interactions with local (national) groups of stakeholders in addition to the MEDAC, as well as ecologically, through the applied models focusing on the A-WIS (e.g. BEMTOOL, EwE and Ecospace) or on the EIS (FLBEIA, DISPLACE, EwE and Ecospace) (SEAwise Deliverables in WP2, WP3, WP5 and WP6).

A variety of management measures are currently implemented based on EU regulations (e.g., Council Regulations (EC) No. 1967/2006¸ known as “Mediterranean Regulation”; Regulation (EU) 2019/1241, which includes regionalization) that set out common technical measures including on gears and methods; protection of sensitive species and their habitats; catches of marine mammals, seabirds and marine reptiles; protection of vulnerable marine ecosystems; minimum conservation reference sizes; measures to reduce discarding. In the Adriatic Sea GSA17-18 a fishing effort regime for the management key demersal stocks is also implemented according to the GFCM Recommendation GFCM/47/2024/5 (stemming from Recommendation GFCM/43/2019/5). In addition to the management plans for the demersal stocks, the Recommendation GFCM/47/2024/4 enforces a long-term fishing regime and the establishment of catch limits in 2025 for small pelagic stocks (stemming from Recommendation GFCM/44/2021/20). On the Western Ionian (GSA19) and EIS, a multiannual management plan for the sustainable exploitation of giant red shrimp and blue and red shrimp stocks is implemented (Recommendations GFCM/45/2022/6 on GSAs19-21 repealing Recommendations GFCM/44/2021/8 and GFCM/42/2018/4). This is complemented by the Recommendation GFCM/46/2023/3 on the definition of a minimum conservation reference size for the same species in the whole Ionian Sea (geographical subareas 19 to 21), that was not considered in the (EC) Regulation 1967/2006. The implementation of the measures is supported by an international joint inspection and surveillance scheme.

6.1.1 Evaluation of today’s fisheries management

The first step is an evaluation of the baseline or today’s situation, using prior SEAwise Deliverables on scoping key items for EBFM with the MEDAC, national stakeholders and scientists (Rindorf et al. 2022-D1.9) as well as assessing the performance of current management on CFP indicators, like stock status and economic performance as well as MSFD indicators related to GES of the marine environment (Piet et al. 2022, D6.9; Bitetto et al. 2023, D2.10).

The scoping exercises with stakeholders and scientists revealed that, for ecological well-being, fish/shellfish and PETS together made up around 80% of all the words allocated by stakeholders. Food web structure, function and biodiversity were also raised as priority objectives, while economy was listed in the top three most frequent occurring topics under human well-being. The most frequently mentioned topic under external ecological drivers was climate, but also pollution and marine litter, while management and spatial management were the most frequently mentioned human drivers.

Assessment of stock status under current management showed a steeper declining trend in recent years (2019-2022), with overall F/F_{MSY} decreasing from 1.52 to 0.94 showing a positive change in fisheries sustainability, as highlighted also by the last SoMFi Report (FAO, 2023). Regional indicators also show a reduction in exploitation rates from 2018 to 2022 across all ecoregions. While biomass is still low, there is an increasing B/B2003 trend from 0.70 to 0.87 in the period 2008 to 2022 (STECF, 2025). Among 14 stocks assessed in 2022-2023 in the Adriatic and Western Ionian Sea (A-WIS) subregion, 50% had F/F_{MSY} ratio ≤1 (STECF, 2025). In the Eastern Ionian Sea (EIS) demersal fishery, 50% of the assessed stock were fished above F_{MSY}. The other two stocks are sustainably exploited with fishing pressure well below that corresponding to MSY. The rest of the stocks in the fishery remain unassessed. In addition, the coverage of the objectives for the management measures implemented is poor: for example, 19% for catches in the Eastern Ionian Sea and 20% (computed on fishing days of all the fleets) in the Adriatic Sea (Rindorf et al., 2024).

Economic assessment of today's fisheries showed a mixed picture in the two sides of the Adriatic-Ionian Region. In the EIS the large-scale fleet (LSF) targeting demersal resources consists of 26 trawlers, and small-scale fisheries (SSF) include ~ 3000 vessels, with both sectors exploiting a large number of stocks (~80). From the two demersal fleets modelled in the EIS case, the SSF contributes 74% of total catches and 80% of landings' value, while it is responsible for ~70% of the catch weight of European hake and red mullet. The SSF, operated by local fishers and their families as a means of living, is only marginally viable but provide sufficient income to support the fishing families (Liontakis et al., 2020), although is less resilient to fluctuations of the ecological or the economic system. By contrast, the OTB fleet is profitable adding annually around 50 million euros to the country's GDP. The fishing fleet has been in decline since mid-1990, with withdrawal of 3,333 vessels (17.57%) in the period 2003-2020, corresponding to a capacity reduction (GT) of 31,27% (Anonymous, 2021). On the other hand, the Adriatic Sea is one of the more productive and exploited areas in the Mediterranean due to the inflow of nutrients from the Po River. Further, the circulation of water masses in the south Adriatic contribute to the Mediterranean water circulation. In the Adriatic Sea, the fleet of trawlers accounts for approximately 1661 vessels (14% of the total fleet), while the small scale fleet accounts for approximately 9300 vessels (76%), mostly located on the east side; in terms of share of the total production, the demersal LSF accounts for 33%, whereas the SSF of 8%, being the larger share of the small pelagic fishery (approximately 57% considering the two main species: anchovy and sardine). In the western Ionian Sea, trawlers account for 16% of the fleet (1323 vessels) with a share on the total production of 36%, while SSF accounts for 80%. of the capacity with a share on the production of 36% (data from GFCM fleet Register and from AER, STECF 2024).

SEAwise (Rindorf et al. 2024; D1.16) identified priority objectives on economy, employment, food supply, health and CO_2 emissions that were assessed through indicators of full-time equivalent employment (FTE), gross value added (GVA), number of adults served annually with the recommended intake of fish and CO_2 emission from fuel. The indicators were assessed separately for small- and large-scale fisheries (SSF, LSF) to demonstrate differences between these. Small scale fisheries are responsible for 98% and 44% of the employment in EIS and A-WIS respectively, while its contribution to total GVA is less than the total employment with percentage of 30% and 73% in the A-WIS and EIS respectively. Larger differences between the two subregions were estimated for the number of adults served in a year. The percentage of total landing value that is necessary to cover energy costs is similar for the LSF in the two subregions, while in the A-WIS subregion it was half the value than in the EIS.

Today's attainment of MSFD objectives, in accordance with CFP, is to maintain stocks of retained species at levels capable of producing MSY ($F<=F_{MSY}$ and SSB≥ MSY $B_{trigger}$). In EIS, the desired biomass levels ($MSYB_{trigger}$) and fishing mortality rates (F_{MSY}) are achieved for about 50% of assessed stocks, and hence a significant portion of stocks (50%) still does not meet the objectives for MSFD Descriptor 3 on fish stocks. The Ryther index (Link & Watson, 2019), a global index of ecosystem overfishing measuring the total catches per km^2 per year, is just above the suggested overfishing threshold of 1 ton/km^2/year, in the EIS (Kempf et al. 2024– D6.8). The EIS is an oligotrophic ecosystem with moderately complex structure, and although fishing practices have been categorized as sustainable by exploitation indices, some stocks remain overexploited (e.g., hake, cuttlefish). The EwE model, that integrated trophic interactions, climate warming, fishing activity, and primary production, indicated that both anthropogenic exploitation and environmental factors have historically shaped ecosystem dynamics in the study area. The

assessment of the food web dynamics (Descriptor 4) showed that the ecosystem already exhibited a high depletion risk at the baseline rates of fishing (>60%) for the entire community, exceeding the community risk score for sustainability (48%) (Lynam et al., 2023). Aggregation across communities and guilds showed that the highest community risks were scored for the demersal community and especially for benthivores and piscivores, also exceeding risk scores for sustainability (49%, 52% and 50%, respectively). On the other hand, depletion risk for the pelagic community, fluctuated at lower levels than scores for sustainability (50%) with planktivores being sustainably fished even under high fishing pressure (<0.51%).

The MSFD Descriptor 1 on by-catch caused by trawlers and SSF vessels at the northern part of **EIS** seemed to be high for the critically endangered bull ray (Astarloa et al., 2024). However, the analysis underlined the need of well-designed spatial monitoring programs, including SSF vessels, enabling multi-objective optimization setting, tackled via an integrated planning framework based on the characteristics of the specific social-ecological system (SES) (Maina et al., 2025). For Descriptor 2, ocean warming has increased the expansion of thermophilic lessepsian migrants towards central Mediterranean waters, and specific alien species such as the invasive rabbitfishes have significant effects on certain métiers, particularly of SSF at the southern part of the EIS. The results suggest that fine-scale analysis at the métier level facilitates accounting for such impacts, while also addressing issues of social heterogeneity and fishers' motivations, ensuring more efficient scientific advice in decision making (Liontakis & Vassilopoulou, 2023). For Descriptor 6, the lowest RBS score (highest impact), which was higher than 0.8, was recorded in the outer part of Patraikos Gulf area. There were no values lower than 0.8, and in fact average values in each of the habitat types assessed, higher than 0.97, highlighted a very low average impact on this area's habitats (Van Hoey et al., 2023). The results, based on the EMODnet broad habitat types distribution, which in certain locations may be of rather low resolution (Katikas et al., 2025), question the necessity of trawl banning implementation across all MPAs/Natura sites by 2030 to improve the status of seabed habitats in Greek waters, as declared recently by the Greek government (Our Ocean, 2024). On Descriptor 10, marine litter assessments on the seafloor suggested that plastic was the most dominant category in mass and number of items, particularly in NE Ionian Sea (Spedicato et al., 2023), while according to the recent assessment conducted under the MSFD Article 8 for the period 2018-2023 in Greek waters, the median value of litter items in MEDITS stations in EIS was 132,8 items /km², which is well above the threshold of 38 items/km² indicating good status (UNEP, 2024), underlining the fact that litter remains a major pressure threatening marine ecosystems of the Mediterranean Sea.

For the **Adriatic Sea**, the current achievement of stock objectives highlighted that 14% of the demersal stocks under management plans was in a sustainable state, while in the western Ionian Sea, the landings of the assessed stocks from mixed demersal fisheries included in the bioeconomic modelling were all from unsustainably fished stocks. For Descriptor 1, a risk analysis approach was implemented for fish (elasmobranchs species as longnose spurdog and blue sharks) in the Adriatic Sea (Astarloa et al., 2024) given the limited availability of PET bycatch data. A reduction of bycatch risk was observed for otter trawls and longlines when applying the most restrictive management scenario that combined multiple spatial closures. Furthermore, Carbonara et al. (2025) reported seasonal variations of loggerhead sea turtle bycatch with an increased rate in summer and autumn, coinciding with the turtles' southward migration to warmer waters and identified two bycatch hotspots, as possible areas for the implementation of spatio-temporal measures. However, increased sampling and surveys are needed to improvs the data for bycatch species. Descriptor 6 seafloor integrity was assessed by the RBS model. The extent of habitats negatively impacted by fisheries (RBS<0.8) was about 59% on the continental shelf of the Adriatic Sea (16% on the slope), and 18% in the western Ionian Sea (8% on the slope). The RBS method is a steady state model, which cannot be used to evaluate whether or how quickly recovery takes place, but only whether the pressure is excessive. Thus, other methods as state-based indicators are needed to determine whether the status objectives are achieved within a specific timeframe (Rindorf et al., 2024). The benthic impact of trawlers was estimated across the Status quo, F_{MSY} and PGY scenarios. The F_{MSY} scenario associated with closure areas results in the lowest percentage of area with RBS <0.8 (improved status), especially in the Adriatic Sea. Both fishing effort levels and closed areas influence RBS, with PGY associated with closures having a higher RBS (<0.8 percentage) than F_{MSY} without closures, thus with an improved status with more moderate consequences for fishers. Regarding ecological wellbeing and food web structure,

function and biodiversity, guild total biomass and Guild diversity (Shannon Wiener indices), Mean Trophic Level (MTL) and Large Species Index (LSI) were considered (all species combined). Biomass of top predators and diversity of demersal fish decrease and depletion risks increase as average fishing mortality across all species increases, likewise MML for all fish and LSI (Lynam et al., 2023). Macrolitter assessments on the seafloor indicated that plastic was the dominant category in mass and number of items (Spedicato et al., 2023) and highlighted that significant reductions of macrolitter are needed (UNEP, 2024).

6.1.2 Towards EBFM in the Mediterranean

Regional EBFM plans require a good understanding of fish productivity changes, especially in areas with highly multi-specific mixed fisheries (e.g., Sun et al., 2023), where many stocks are overexploited. Piet et al. (2022; D6.9) considered the EBFM from the perspective of a social-ecological system and work from the assumption that EBFM advances through an adaptive management process consisting of subsequent assessment and management cycles resulting in EBFM plans. However, the scientific understanding of the effect of external human drivers on fish productivity in scientific literature was limited at the onset of the SEAwise project (Savina-Rolland et al. 2022).

In **EIS**, our findings highlighted the existing dynamics within the trawling sector operating in GSA 20, and emphasized the critical role of investigating key points related to fishing communities under an activity-based perspective, in defining the operational landscape. The distinct operational patterns and strategic decision-making of those communities, shaped by their unique geographical locations and fishing techniques, required shedding light on socio-economic and ecological complexities at a finer-than-GSA 20 scale (Kraan et al., 2024). The latter is also true for SSF communities in EIS, for which the important lack of data has limited robust assessments. Structural deficiencies, like the persistent lack of cooperative culture among small scale fishers, and the need for focused capacity building, that would mitigate competition among them while enabling effective consideration of environmental challenges impede the implantation of EBFM (Asif et al., 2025). Small scale fishers' lack trust in the governance system and their minimal involvement in the top-down decision-making process are key challenges for operationalising EBFM. Current management in the EIS is based on ineffective monitoring and surveillance (in part due to the large number of SSF vessels). This causes the coastal fishery to be largely unregulated, and a key issue is the Illegal, Unreported and Unregulated (IUU) fishing. Cooperation with neighbouring countries regarding shared stocks (e.g. hakes, red shrimps) in the Ionian Sea is also a prerequisite towards EBFM.

Efforts within SEAwise, integrating bioeconomic and ecosystem modelling frameworks, constitute key steps for making EBFM operational. A suite of biological, economic, and ecosystem-level indicators was estimated to assess the trade-offs and potential conflicts among competing management objectives, including fleet profitability, stock conservation, and ecosystem integrity. These tools can be used to explore a large set of fishing, spatial and environmental scenarios, and their combinations, to evaluate potential changes and optimize management strategies.

It should be noted that institutional settings, standards, cultural values, and mistrust can significantly inhibit scientific knowledge sharing, especially in complex, multi-stakeholder contexts like fisheries governance, and the latter is particularly true in Greek waters, where key actors of the triple helix expressed dissatisfaction with current governance practices affecting the viability of resources and the sector (Syrou et al. 2025). Indeed, stakeholder transformation and political will are essential counterparts to good science, as usually high-quality scientific tools and knowledge are not applied. Regional EBFM plans thus require high quality science and an integrated and participatory governance system that provides institutional support to foster trust and accountability encouraging collaboration between key stakeholders from central and regional institutions, academia/research and the fishery sector.

In **A-WIS**, strong reductions in effort are needed to achieve the target fishing mortalities for the most limiting stocks under a strict MSY approach. This reduction had large negative consequences for social benefits like employment,

especially in the short terms, and a PGY approach led to similar results. The PGY scenario returned the highest GVA for LSF, whereas the F_{MSY} scenario performed better for SSF due to the greater effort reduction impacting trawlers (part of LSF). In both F_{MSY} (returning the lowest values) and PGY scenarios, CO_2 emissions per kilogram of fish landed decreased over time, in contrast to the status quo scenario, which remained stable. The ratio between SSF and LSF landing value remained relatively stable for Adriatic fleets across all scenarios. The F_{MSY} scenario performed best for all ecological indicators closely followed by the PGY scenario that would lead to less severe effort and, subsequently, overall GVA reduction. The simulations showed that continued fishing in status-quo scenarios is suboptimal in socio-economic terms compared to the alternative scenarios explored. Depending on the specific fleet, management measures positioned between the extremes of status quo and F_{MSY} can potentially mitigate some of the negative socioeconomic impacts on the fishery and decrease CO_2 emissions per kg of fish landed (Bitetto et al., 2024; Deliverable 6.5). The F_{MSY} and PGY scenarios, especially when combined with spatial closures aimed at protecting sensitive stages of target stocks and/or at reducing by-catch, are expected to have different impacts on the local fishing communities operating in the areas, depending on their main fishing strategy (e.g., fishing grounds more visited, target species, seasonality). The prompt communication with stakeholders through MEDAC represented a strength point in the application of the participatory approach, contributing to improve the governance process (Asif et al. 2025, D2.8).

Marine protection while ensuring sustainable use is a prerequisite for a regional plan. Among the scenario tested in the A-WIS, only the strict MSY scenario combined with areas closed to fishing came near the potential GES threshold for benthic habitats. The spatial management scenarios only had minor effects on indicators and associated trade-offs. The ecosystem model applied for this region predicted climate change effects that could be mitigated to some extent by the strict MSY and PGY scenarios. Reductions in biomass of most functional groups were seen in the model predictions (Kempf et al., 2024; Deliverable 6.8)

Scenarios evaluating prohibition of certain fishing techniques in all currently designated MPAs had minimal impact on the fisheries selectivity of most fleet-segments examined and fish populations in the short term (Bastardie et al 2023 – D5.5). This was primarily because these areas were selected for their significance for biodiversity and habitats, rather than for a high abundance of commercial fish. Some fleets were severely impacted by the closures whereas others were affected minimally. ECOSPACE showed a moderate increase in the biomass of juveniles when protecting Essential Fish Habitats (especially red shrimps) with a closed area. Combining closed areas with effort reduction to F_{MSY} resulted in increased biomass for many species and decreased bycatch of juveniles. Combining the closed area with the PGY scenario, a catch reduction of juveniles also occurred. The spatial BEMTOOL component and ECOSPACE agreed that fisheries closures will lead to changes in fleet distribution and hence fuel consumption. The ECOSPACE model demonstrated that the closure areas led to decreased pressure on juveniles and that reductions of fishing pressure are needed to attain full stock recovery (Bastardie et al 2024 – D5.6).

6.1.3 Climate-resilient management strategies

In the **EIS** sub-region, overall, climate change had only moderate effects on the mean future ecological and economic variables, while the uncertainty around the predictions was very high. Nevertheless, the simulations incorporating climatic variability showed that fluctuations in recruitment can cause considerable fluctuations in the landings of hake and as a result an increasing risk of suffering a 20% income loss in a year for the SSF (Bitetto et al. 2024 – D6.5). In the EwE model, climate change was simulated by including temperature responses to the dynamics of the functional groups and projecting RCP4.5 and RCP8.5 climatic scenarios. Indicators showed that multiple stressors led to less abundant, less diverse, and lower trophic level benthivore communities, while piscivores were particularly vulnerable to rising temperatures, supporting projections of top-predator declines. Long term results showed that the adaptive capacity of fisheries strategies was able to mitigate climate-driven changes only up to a certain point, revealing high impacts after 2050 in the high emissions scenario.

In the A-WIS sub-region, scenarios explored under climate change with the BEMTOOL bio-economic model

demonstrated potential socio-economic consequences (e.g. changes in catches, catch value, etc..) with a decline of catches of European hake and red mullet, and an increase for shrimps under moderate climate change (RCP4.5). SSF fleets relying more on fish catches would be negatively impacted by rising temperatures with a negative impact on the overall number of meals provided (Bitetto et al. 2024 – D6.5). Looking at the indicators calculated from EwE, it seems that climate has a negative effect on biomass for most if not all groups, with the scenario RCP 4.5 having generally larger or similar impact as RCP8.5. Biodiversity patterns also seem to be negatively impacted by climate change (with the exception of pelagic guilds), and similarly for the Mean Maximum Length indicator. Conversely, the fishing effort reduction scenarios seem to benefit the ecological system, with increase in the biomass of some guilds, overall marginal improvement in bycatch of PET species and biodiversity of some guilds (chiefly those directly targeted by demersal fisheries) and resulting in increased Mean Maximum Length. Overall, the adoption of either management strategy (FMSY or PGY) helps to buffer the negative effects of climate change. The conclusions from the ecosystem model results confirm the expected positive effects of restrictive fisheries management strategies, while at the same time, the difference between the two management scenarios FMSY and PGY seem to be marginal for most indicators and as such, the more restrictive FMSY might not produce additional benefits (Kempf et al., 2024; D6.8).

6.1.4 Designing the EBFM plan for the Mediterranean

The FLBEIA model used in the EIS indicates that a general reduction in fishing effort typically result in improved ecological health and enhanced stock sustainability. However, the model also highlights conflicts between the sustainability objectives of individual stocks.

As the main stocks of the fishery, European hake and red mullet, are predominantly harvested by the small-scale fleet (SSF), a reduction in fishing effort of the SSF, necessary for achieving the sustainable exploitation of hake, could negatively impact the yield of red mullet, which is currently being exploited at nearly optimal levels. Conversely, controlling effort in the large-scale fleet (LSF), which uses otter trawl (OTB) gear, would have minimal effects on hake but could further reduce the yield of deep-water rose shrimp, a species that is currently underutilized. Thus, a uniform effort control across the entire fleet is only partially effective in resolving the conflicts arising from the technical interactions between the various stocks. To achieve optimal results, it is important to explore more targeted management strategies. These could include spatial measures aimed at protecting specific parts of the populations (such as hake nurseries) or management interventions tailored to the different métiers within the fleets. This is especially relevant for the SSF, which, despite being considered a uniform fleet for management purposes, consists of a variety of gears and métiers targeting different components of the stocks.

EwE-simulated reductions in fishing effort increased biomass of FGs targeted by commercial fisheries. However, due to trophic interactions within the food web, the reduced levels of fishing pressure did not lead to stock recovery for all heavily fished groups, and had a negative impact on the biomass of less fished FGs, mainly demersal fishes. Furthermore, biomass increases were insufficient to sustain an increase in landings. Directing effort reductions to gears/métiers that primarily target overexploited species, seems a more effective approach that should be further considered. Furthermore, the ecosystem model results emphasize the urgency of utilizing the window of opportunity until 2050 to increase adaptation of the sector and prevent future declines of marine resources (Papantoniou et al. 2025).

In the A-WIS subregion, case-specific management measures were also evaluated. These measures include an improvement of the trawl selectivity (square mesh size of 45 mm opening when targeting fish and shrimps and sorting grid when targeting Norway lobster), a 25% effort reduction on the other gears and effort quotas to achieve a compromise among the F_{MSY} of Norway lobster, giant red shrimp and blue and red shrimp stocks (F_{MSY}_crust scenario; Garcia et al. 2025/in prep – D6.12).

The results show that the improvement of trawl selectivity impacts SSB of the shrimp stocks more positively than

European hake, due to the presence of SSF benefiting of the selectivity measures applied to trawlers. This scenario is also the one improving total landings, as well as being more efficient in terms of carbon emissions per kg of fish landed, both for SSF and LSF in the current climate conditions. The combination of the trawl gear selectivity improvement and a 25% effort reduction of the other gears has an even greater positive effect on European hake SSB, while maintaining similar catch levels. The F_{MSY}_crust scenario represents the best alternative followed by the F_{MSY} scenario in terms of SSB for all the key stocks, but with higher positive impact on crustacean stocks. This alternative was identified as the one maximising the giant red shrimp and blue and red shrimp catches among the scenarios explored. Under current climate conditions, the benefit observed on socio-economic indicators for the LSF operating in the A-WIS is highest in the short term for the change in selectivity scenario, while in the medium and long term the Fmsy_crust scenario provides better values. For SSF the change of selectivity scenario returns the higher economic indicators across all time periods, followed by F_{MSY}. This scenario also reduces the catch of blue shark of 18% and the catch of demersal selachians of about 30%, thus slightly more than F_{MSY} scenario.

Overall, our results indicate that the effectiveness of management measures varies depending on the specific objectives being pursued, objectives that are often in conflict. Multi-criteria decision tools can support decision-making by highlighting these trade-offs and helping to identify balanced solutions (Garcia et al., 2025), while the weighing of different attributes, which can reflect stakeholder priorities (e.g. more focused on ecological or economic results). In the A-WIS framework, the F_{MSY}_crust scenario delivered the highest performance when ecological goals were prioritized. Conversely, under the “economy-first” approach, the F_{MSY} scenario achieved the greatest overall utility.

6.1.5 Discussion and conclusion

The management measures tested through modelling in A-WIS and EIS in SEAwise are based on effort control and catch limit control (only for deep-sea fisheries in A-WIS) to attain F_{MSY} objectives. Such measures are complemented with spatial closures of areas for the protection of juveniles of key commercial species, avoidance of bycatch of EPT species and improvement of benthic state (RBS). The improvement of gear selectivity, through specific devices was also included in scenario modelling, to improve the exploitation pattern of key commercial species, by reducing the mortality of the juvenile component of the population.

Simulation of management scenarios highlighted that a strict implementation of the MSY concept led to underutilization of commercial stocks that are currently in sustainable conditions and for which new fishing opportunities could be explored. This is particularly true in recent years where the situation of different stocks is improving. Further, a strict implementation of MSY would severely affect the economic situations of the fleets especially the ones more impacted by the measures, while reducing the number of meals per kg of landings, as these will decrease at least in the short-medium terms.

A more flexible interpretation of the MSY concept (Pretty Good Yield) offers some flexibility and can improve socio-economic indicators, to some extent. Depending on the specific fleet, the results indicated that management measures positioned between the extremes of status quo and F_{MSY} (e.g., PGY) can potentially mitigate some of the negative socioeconomic impacts on the fishery and decrease CO_2 emissions per kg of fish landed. For example, combining area closures with PGY could achieve comparable results as F_{MSY}. Technical measures like gear modifications for improving selectivity can reduce the impact of fishing activity.

The associated lower fishing effort compared to status quo improved MSFD related indicators. The scenarios of fishing effort reduction benefitted the ecological system, with increase in the biomass of some guilds, overall marginal improvement in bycatch of PET species, biodiversity of some guilds (chiefly those directly targeted by demersal fisheries), resulting in increased MML. Only a moderate impact of climate change was estimated, especially in A-WIS for SSF fleets that are relying more on the catches of fish species likely to be negatively affected by CC with, in turn, a negative impact on the overall number of meals provided. This negative effect of climate change could be

reduced through the adoption of either management strategy (F_{MSY} or PGY) .

Finally, as pointed out by Rindorf et al., 2024 (D1.16), even with the additions made in the SEAwise project, there will still be substantial areas in need of further knowledge, including a better understanding of fisher behaviour, particularly in relation to closed areas, between fleet effort and employment and between fleet effort and CO_2 impact. Other areas include the links between climate and the distribution of fish and fisheries, particularly in relation to closed areas. Further, closure of areas for fishery with bottom contacting gear are not widely implemented or when implemented are too recent to have enough data to make conclusions on potential status improvements. For this reason, it is essential to monitor changes in status of any new closures implemented.

6.2 Western Waters EBFM Plan

The SEAwise Western Waters case consists of two subcases: the Northwestern Waters (NWW) and the Southwestern Waters (SWW). These subcases have independent but closely connected Socio-Ecological Systems. The independence of both socio-ecological systems is reflected socially, by SEAwise interactions with three advisory councils: NWWAC, SWWAC (CCSUD) and PELAC, as well as ecologically, by the applied WP6 models focusing on either the Celtic Seas (e.g. FLBEIA-CS, StrathE2E-CS) or the Bay of Biscay (FLBEIA-BOB, ISIS-FISH-BOB) (ref D6.11/D6.12).

6.2.1 Evaluation of today's fisheries management

The scoping exercises with the NWWAC and SWWAC (Rindorf et al. 2022-D1.9) revealed that stakeholders were broadly concerned with the ecological topics retained species and potentially endangered or threatened species (PETS), while for human well-being, the primary concerns were economy, employment and coastal communities. There was limited scientific literature addressing human well-being, revealing a key gap in EBFM research for this region. Key drivers that were mentioned included external ecological drivers such as climate and plankton and external human drivers, such spatial management and pollution. While ecological well-being and retained species were well covered by current management targets, human well-being and external drivers were underrepresented in scientific literature. These priorities aligned relatively well with the ICES ecosystem overviews (ICES, 2024a, b). ICES (2024a) showed that the Bay of Biscay and Iberian Coast ecoregion is impacted by climate change, with warming waters and shifting species distributions, such as the northward movement of warm-water copepods. Overfishing, changes in fishing practices, and increased recreational fishing contributed to declines in species condition and spawning-stock biomass. Fishing remained the primary threat in the Celtic Seas ecoregion despite a decrease in intensity since the late 1990s. Bottom fishing on continental shelves and changes in plankton composition signal broader ecosystem disturbances, possibly linked to harmful algal blooms and contaminants. While economic factors like rising fuel prices may reduce fishing pressure, they could also increase bycatch risks for seabirds and marine mammals. Small-scale coastal fisheries, although accounting for less than 10% of total fish landings, are crucial to local economies, providing significant employment and revenue for coastal communities.

Assessment of stock status of current management showed that five out of eleven SWW stocks are within safe biological limits, while one stock (sole in area 8ab) is not, and five others have limited data available. Six out of fifteen NWW stocks are within safe biological limits, while five stocks remain overfished and four lack sufficient data. While there has been a general reduction in the exploitation rate and progress has been made in improving stock health, the CFP's goal of ensuring sustainable fishing at or below F_{MSY} by 2020 has not been fully achieved.

Economic assessment of today's fisheries showed a mixed picture (STECF, 2021). NWW fleets were profitable due to higher TACs for species like haddock and anglerfish, and stable fish prices for sole and lobster. However, overall performance was affected by reduced landed weight, rising energy costs, and the Brexit trade agreement, impacting

countries like Ireland, France, and Spain. In the SWW, fleets remained profitable despite lower TACs for mackerel and hake, reduced prices for anchovy and chub mackerel, and rising fuel costs. Small-scale fishing dominated the number of vessels, while large-scale fishing accounted for most landings by weight and value. Large-scale fishing fleets dominated in terms of landings, revenue, and employment in both the Bay of Biscay and the Celtic Sea (Bitetto et al. 2023). In the Bay of Biscay, the French demersal fleet is primarily small-scale, with seabass and *Nephrops* as key products, and over 80% of its revenue coming from vessels under 24 meters. Spanish fleets are more balanced, with large vessels accounting for most landings and revenue. Employment patterns also differ, with more workers in the French small-scale fleet, while Spain's large-scale fleet employs the majority. The Basque pelagic fleet, which targets species like mackerel and albacore, is dominated by large vessels, which also have a higher carbon footprint than small-scale fleets. In the Celtic Sea, small-scale fleets from France, Ireland, and the UK generate higher Gross Value Added (GVA) than large-scale fleets, which are more prevalent in Belgium, Germany and Spain.

Today's attainment of MSFD objectives (Piet et al. 2022-D6.9) showed varying levels of success. While fishing mortality has been reduced for certain stocks, the desired biomass levels (MSYBtrigger) and fishing mortality rates (F_{MSY}) are only achieved for about 57% of stocks. Hence, there is a significant portion of stocks (43%) that still do not meet the objectives for MSFD Descriptor 3 on fish stocks. Various aspects have been evaluated for MSFD Descriptor 1 on biodiversity. Marine mammals that were unsustainably impacted were common dolphins and harbour porpoise in all WW areas, and Balearic shearwaters in the Bay of Biscay (Astarloa et al. 2024, 2025; Rindorf et al. 2025 D4.9). Bird populations in the Celtic Seas have not been healthy since the mid-2000s, with breeding failures common and many species experiencing reduced abundances. Fish communities in the Celtic Sea have halted the decline of sensitive species but recovery is only apparent for a limited number of species. The abundance of large fish shows regional variation in the demersal fish community, with improvements in northern areas but not in the south or west. MSFD Descriptor 6 on seafloor integrity was performing well for all macrofauna habitats in NWW except offshore circalittoral mud, while 8 out of 19 MSFD habitats did not meet an RBS-threshold of 0.8 in the Bay of Biscay epifaunal habitats (Van Hoey et al. 2023, 2024, Rindorf et al., 2025 D4.9). MSFD-Descriptor 10 on marine litter, particularly beach litter, has been monitored with an average of 434 items per square kilometer in the Celtic Seas and 365 items in the Bay of Biscay and Iberian coast. While some MSFD objectives are being met in the Western Waters, mainly those related to improvements in fish stock status, many challenges remain, and the assessment suggests that further efforts are needed to fully achieve the MSFD objectives in this region.

6.2.2 Towards EBFM in Western waters

The assessment of today's situation highlighted the future needs in NWW and SWW. While there's a positive trend towards better achievement of fisheries policy objectives, they are not fully met, neither in terms of ecological status nor economic performance. Substantial efforts have been undertaken to improve stock status, particularly with the regionalization reforms under CFP 2002 and 2013. Regionalization facilitated greater stakeholder involvement, enshrined through the establishment of NWWAC and SWWAC, but also through region-tailored management measures, which became operational in the WW through the WW multi-annual plan (MAP, EU 2019/472) established since 2019 for both NWW and SWW. The WW MAP helped locking in MSY principles, preventing political backsliding on TACs and facilitated mixed-fisheries management (e.g. addressing potential choking issues by pollack in the Bay of Biscay) (EC, 2024). ICES (2024a, b) noted that fishing mortality declined since the mid-1990s for demersal stocks with known stock status and to a lesser extent also for benthic stocks, and is now, on average, at or below Fmsy. Several stocks nevertheless have not fully recovered, including cod and whiting in the Celtic Seas. Stakeholders expressed their concerns on the lack of recovery, and pointed at external, non-fisheries related drivers, including both human (e.g. pollution and offshore renewable energy) and natural drivers (predation and climate effects). These concerns were not only expressed during the SEAwise scoping workshops (Rindorf et al. 2022-D1.9), but some of those also became apparent in the implementation of the WW MAP (EC, 2024).

Regional EBFM plans thus require an improved understanding of fish productivity changes. An understanding of the

effect of external human drivers on fish productivity in scientific literature was limited at the onset of the SEAwise project (Savina-Rolland et al. 2022), and although SEAwise contributed to improved understanding, e.g. through examining contamination effects on e.g. seabass growth (Ibaibarriaga et al. 2025), most of those effects remain insufficiently conclusive for uptake into advice on fishing opportunities, including effects of ORE on fish productivity (e.g. Gill et al. 2025). In contrast, climate effects on fish productivity have been studied much more extensively (Savina-Rolland et al. 2022). The vulnerability of WW fish stocks to climate-induced productivity shifts were studied in great amount of detail in several SEAwise Deliverables, such as decreased growth and size-at-age of sardine in the Bay of Biscay, impaired cod recruitment in the Irish Sea (Travers-Trolet et al. 2023; Bitetto et al. 2024; Meliá et al. 2024; Ibaibarriaga et al. 2025). Therefore, future EBFM plans should incorporate climate-proof concepts. WW simulation studies were conducted to evaluate the effect of climate-mediated productivity changes.

Marine protection while ensuring sustainable use is another prerequisite for a regional WW EBFM plan. Several European initiatives are under way, and are expected to result in new management measures. SEAwise has evaluated the extent to which MSFD-targets can be achieved using fisheries management strategies (see below, Kempf et al., 2024 – D6.8), or the ongoing developments under environmental legislation (e.g. the EU Marine Action plan to phase out bottom trawling in MPAs, EC (2023)). Using WW and North Sea examples, Asif et al. (2025 – D2.8) highlighted that the challenge of coordinating fisheries and environmental policies during establishment of Natura2000 restrictions, because those are largely nationally controlled while fisheries regulations fall under EU competence (Regulation 1380/2013, Article 11). Asif et al. (2025) concluded that stakeholders generally felt well-consulted, though they also suggested the need for broader, regional coordination to balance fisheries, biodiversity, and other marine activities more effectively. As SEAwise is focused on EBFM, we assessed the achievement of MSFD-targets at regional ecosystem scale rather than nationally. Evaluated spatial measures included either existing closures of Natura 2000 sites or newly (SEAwise-) proposed measures. Simulations mostly followed a static approach in the NWW and SWW (Bastardie et al 2023 – D5.5), though also a dynamic approach was tested in the Bay of Biscay (Bastardie et al 2025 – D5.6).

6.2.3 Climate-resilient management strategies

The modelling of the Celtic Sea ecosystem under different climate and management scenarios using three models — FLBEIA, StrathE2E, and Ecopath with Ecosim (EwE) — revealed insights into the impact of fishing management strategies under climate change (Kempf et al., 2024 – D6.8). All three models agreed that reducing fishing effort improves the sustainability of fish stocks, but they differed in their predictions about how fishing effort affected the ecological system and socio-economic outcomes. Under the F_{MSY}-min and F_{MSY}-range (PGY) management scenarios in FLBEIA, sustainability indicators, such as a reduction in stocks falling below critical thresholds (B_{lim}), are improved. However, these benefits come at a cost of lower landings and employment. F_{MSY}-min performs better than F_{MSY}-range, particularly in the long term. StrathE2E and EwE also show that reducing fishing effort improves ecosystem health indicators, with StrathE2E predicting improvements in benthic state and a reduction in bycatch. EwE predicts that this reduced effort leads to declines in apex predators and forage species over time, which could eventually affect fisheries. The predicted effects of climate change on the ecosystem are where the models diverge the most. FLBEIA suggests that climate change has a modulating effect, with some species (such as hake and megrim) benefiting from warmer temperatures, while others (like cod and whiting) experience negative impacts. This could lead to higher landings and a lower CO_2 footprint, as climate change potentially favours certain species. However, StrathE2E and EwE predict stronger negative impacts. StrathE2E shows declining primary production due to climate change with resulting large-scale biomass declines, particularly among top predators. In EwE, the bottom-up effects of climate change (due to zooplankton and plankton declines) lead to reduced food availability for pelagic fish and predators, particularly in the later decades of the century. In both models, top predators (like cetaceans) suffer significant declines under climate change, reflecting the cascading effects on the food web. Interestingly, FLBEIA predicts an increase in catches under the RCP8.5 climate change scenario, whereas StrathE2E predicts decreased catches due to primary production declines and trophic disruptions. EwE, on the other hand, suggests minor impacts

on catches until 2060 but warns that future declines in pelagic fish populations may negatively affect fisheries, particularly for species reliant on zooplankton. FLBEIA shows more optimistic predictions for catch potential due to species shifts, while StrathE2E highlights the vulnerability of the foodweb.

Bay of Biscay simulations using both FLBEIA and ISIS-Fish models were more conclusive. The FLBEIA model explored four management scenarios. The "Status Quo" scenario (input control), where total fishing effort and distribution remained constant, resulted in the highest landings and wages but performed poorly on ecological and many socio-economic indicators. This scenario also had most stocks with a greater than 5% probability of falling below the biomass limit B_{lim}. In contrast, the more restrictive management scenarios—such as the F_{MSY}-landing obligation, Pretty Good Yield (PGY), and Case-specific scenario—improved most ecological indicators, like bycatch of dolphins and the impact of bottom-contacting gears, and helped reduce the carbon footprint per kg of landed fish. Among these, the F_{MSY}-landing obligation scenario performed best in terms of achieving MSFD objectives, while the Case-specific scenario led to larger landings and improved socio-economic outcomes. The Case-specific scenario was implemented by adjusting fleet dynamics based on the previous year's catch quota and effort, maintaining a level of continuity in fleet behavior while still being constrained by the quotas. This approach allowed for a gradual adaptation to changing quotas and contributed to higher socio-economic benefits compared to stricter management scenarios. PGY performed worse than expected, as it led to higher catches of demersal species outside the Bay of Biscay, which negatively impacted stocks. Overall, the results highlight a clear trade-off between sustainability and socio-economic benefits, with stricter management offering ecological improvements at the cost of food security and wages.

In the ISIS-Fish model focused on the demersal mixed fisheries, changes in body condition of key species were incorporated, such as megrim, hake, and sole, and they were projected to decline due to climate change. The results showed that climate change had only minor negative effects on the indicators, similar to the FLBEIA findings. The "Status Quo" scenario again led to the highest landings in the medium term (2025-2030), but F_{MSY}-min scenario outperformed the others in the long-term in terms of landings. This scenario, which applied the F_{MSY} harvest control rule to all stocks, was also the most favorable for MSFD-related indicators and CO_2 emissions per landed kg. However, the PGY scenario, which allowed for more flexibility in fishing strategies, led to the highest number of stocks falling below MSY Btrigger. The results indicated that climate change and the associated decline in fish body condition would complicate efforts to maintain sustainable fisheries in the Bay of Biscay.

The models highlight that reducing fishing effort (either directly or through output/TAC control) generally improved ecological health and sustainability in both the Celtic Sea and Bay of Biscay. However, climate change poses significant challenges, with StrathE2E and EwE predicting negative impacts, especially on primary production and top predators in the Celtic Sea, while FLBEIA showed some positive effects for certain species. This reflects structural uncertainties in assessing climate impacts and underscores the variability across models. The models' different approaches—focusing on food webs, economic factors, and stock dynamics—demonstrate the need for integrating multiple models to capture the full range of potential outcomes. Despite climate change having a minor overall effect in the Bay of Biscay, pressures from fishing and environmental changes persist. In both regions, balancing ecological sustainability with socio-economic goals remains a key challenge.

6.2.4 Designing the EBFM plan for the Western waters

SEAwise also evaluated the performance of case-specific management measures to achieve biodiversity goals in EBFM (Garcia et al. 2025 – D6.12). In the WW case study, the case specific measures include spatio-temporal closures to avoid by-catch of dolphins, effort reduction of trawlers to protect seabed and spatial closures to safeguard benthic habitats.

In the by-catch risk assessment (Astarloa et al. 2024 – D4.3), effort displacement due to the closure of designated areas in the WW (Natura 2000 and Common Database on Designated Areas) led to an increase in the by-catch risk of

common dolphin in the Bay of Biscay, while the bycatch risk of spotted ray decreased from medium to low under the RCP 4.5 climate scenario. Bycatch risk of Balearic shearwater, bottlenose dolphin, some elasmobranchs and some teleost fishes remained at similar levels. Based on the gears that implied the largest by-catch risks for each group of species, Astarloa et al (2024) proposed new management measures for the WW, that consisted of banning pelagic trawlers and gillnets from areas with high cetaceans' abundance and/or diversity, banning longlines from areas with high seabirds' abundance and bottom trawlers from areas with high abundance and/or diversity of demersal fishes. Spatiotemporal closures proposed to reduce bycatch of common dolphin and Balearic shearwater in the Bay of Biscay were tested using ISIS-Fish for the demersal French fisheries (Bastardie et al 2024 - D5.6). The results indicated that the restrictions to reduce bycatch of Balearic shearwater did not have a great economic impact on the French demersal fisheries. In contrast, restricting fishing in the continental slope to avoid bycatch of dolphins led to negative economic impacts for fleets with larger vessels that operate offshore, whereas coastal fleets operating both with active and passive gears generally improved their economic return.

The incidental bycatch rates of common dolphin are a major concern in the WW in the later years. Upon request of the EC, ICES has been providing scientific advice proposing measures to reduce these rates. STECF has also evaluated several joint recommendations put forward by the SWW member states with the same aim. Finally, in 2024 France adopted a spatiotemporal closure for 30 days (22/01/2024 to 20/02/2024) that was later extended to the other member states. The same closure, together with some additional mitigation and monitoring measures, was in place in 2025 (Commission Delegated Regulation (EU) 2024/3089). This spatiotemporal measure was tested in the simulation studies in SEAwise (Garcia et al. 2025). The ban achieved a reduction of 30% of the dolphin bycatch. However, it had no major impact on the other MSFD indicators, but negatively impacted the socio-economic indicators with a reduction of 12% in the landings and 7% in the GVA.

Bottom trawling has received much attention in later years due to its high impact on seafloor habitats and benthic communities (Hilborn et al. 2023). Accordingly, these gears have been restricted or forbidden in many areas worldwide. The WW case study simulations included several scenarios that mimicked reductions or even total elimination of bottom trawl fishing (Garcia et al 2025) with the corresponding effort either removed or translated to static gears. In the Celtic Sea, a reduction of 50% of the effort resulted in large declines in catches for most of the stocks which could only be compensated when the effort of the static gears was increased by a factor two or more. This had a positive effect on the biomass of the stocks except for hake, which is a target species for static gears. The socio-economic implications for the small-scale and for the large-scale fisheries varied depending on the effort level for the static gears. Regarding other indicators, the trawl ban led to an increase in the bycatch rates but decreased CO_2 emissions per landed kg of fish that only increased when the effort of the static gears was multiplied by more than 2. In the Bay of Biscay, the surplus quotas after the trawler effort reduction were reassigned to the static gears, having a lower impact in the stocks and the catches than in the Celtic Sea. While the trawl ban had a negative impact on all the CFP socio-economic indicators except on employment and GVA of the small-scale fishery, it reduced bycatch rates and to a lesser extent, CO_2 emissions per kg landed.

Management measures to protect benthic habitats were identified and evaluated by (Van Hoey et al. 2024 – D4.5). In the WW, changes in the level and distribution of relative benthic state (RBS) were negligible between scenarios. Even in the regions where a high extent of the area was classified as MPA sites and effort was displaced, changes in the average level of RBS were minor. The effectiveness of MPAs to protect from 10% to 50% of the benthic habitats in the Bay of Biscay was also tested by simulation (Garcia et al. 2025). The protection of the benthic areas had a small positive effect on stock biomass, revenue and employment and a negative impact on wages, CO_2 emissions per landed fish and GVA.

Overall, the management measures have different degrees of effectiveness achieving different management objectives and these are often conflicting. Multi-criteria decision tools can help to account for the different trade-offs and make a final decision (Garcia et al. 2025). Different attribute weighting reflecting alternative stakeholder priorities (environment-first or economic-first) significantly influenced the final choice of management measures. In

the Bay of Biscay, status quo scenarios were favoured by balanced or economy-first preferences, while MSY and PGY rules aligned better with environmental priorities.

6.2.5 Conclusion

The SEAwise Western Waters case study, encompassing the Northwestern (NWW) and Southwestern Waters (SWW), assessed current fisheries management and future pathways toward Ecosystem-Based Fisheries Management (EBFM) using a combination of ecological, socio-economic, and spatial analyses. While some progress has been made in achieving sustainable fisheries, many challenges remain. The assessment revealed that ecological indicators such as retained species and biodiversity were better represented than human well-being and external pressures like climate change and pollution. Scientific models, including FLBEIA, StrathE2E, Ecopath with Ecosim (EwE), and ISIS-Fish, were employed to simulate the impacts of different management strategies and climate change scenarios. These models consistently showed that stricter management approaches—such as FMSY-min and FMSY-range—led to improvements in ecological sustainability, including healthier fish stocks, reduced bycatch, and improved benthic conditions. However, these ecological gains often came at socio-economic costs, such as reduced landings, employment, and income, highlighting a critical trade-off between ecological sustainability and economic viability. Climate change was shown to have complex effects, with FLBEIA projecting some benefits for warmer-water species like hake, while StrathE2E and EwE highlighted more pessimistic outcomes, including declines in primary production, top predator populations, and long-term fishery productivity. In the Bay of Biscay, ISIS-Fish and FLBEIA simulations indicated that while the “Status Quo” scenario yielded the highest short-term landings and wages, it underperformed in ecological terms, with a higher risk of stock collapse. More restrictive, adaptive scenarios—particularly the Case-specific scenario—balanced ecological improvement with socio-economic continuity. Spatial management strategies, such as area closures to reduce bycatch or protect benthic habitats, were also assessed. Results indicated that targeted spatiotemporal closures could effectively reduce bycatch risks for species like the Balearic shearwater and common dolphin, though sometimes at the expense of offshore fleet profitability. Spatial displacement scenarios of bottom trawling to static gears improved specific ecological indicators but often required significant increasesshowed that the regional gain of benthic state was modest by simulating closures of the currently designated Natura2000-sites, while newly developed scenarios increased contrasts between closed areas in (very) good environmental states as opposed to degraded quality of the remaining open areas. The reallocation of fishing effort from bottom trawling to static gears improved ecological indicators but often required significant increases in effort to attempt maintaining landings of trawled species. Ultimately, SEAwise’s multi-model, multi-scenario approach underscores the importance of integrating climate-resilient and spatially targeted strategies into EBFM, while also considering socio-economic impacts.

6.3 North Sea EBFM Plan

The North Sea is a highly complex ecosystem and policy objectives abound. Therefore, only policy objectives and societal goals that appeared as high priority in deliverable 6.9 and in general during the SEAwise project were considered.

In the past two decades, overall fishing pressure has been reduced towards levels compatible with maximum sustainable yield. However, around one third of the stocks are still fished at levels above F_{MSY} (e.g., cod, witch, some Nephrops functional units). North Sea stocks are increasingly negatively impacted by climate change, particularly the productivity of cod and saithe (Deliverables 6.2, 6.8). These two species are also top-predators in the North Sea ecosystem. Cod occurs frequently in unwanted catch and as a result, discard rates are high. The landing obligation designed to reduce catch of undersized fish and over-quota catches is still not implemented successfully (Deliverable 6.9). Therefore, one of the main aims for an EBFM plan for the North Sea is to introduce management measures that are effective under climate change and preferably mitigates its negative effects. This requires an improvement of the

selectivity in mixed fisheries to ensure the sustainable exploitation of all commercially important stocks.

Although there is considerable uncertainty around bycatch rates, harbour porpoise is one of the PET species where assessments of ICES and OSPAR indicate a potential conflict between conservation and current bycatch, particularly in static nets (Deliverable 4.8). Other ETP fish species (e.g., wolffish, skates) are bycatch in the North Sea trawl fisheries. For the species investigated during SEAwise, the North Sea demersal fisheries (passive and active; Deliverable 4.8) create the highest bycatch risks whereas pelagic fisheries are expected to have lower bycatch.

Effort from demersal fisheries impacts some benthic habitats excessively (Deliverable 4.9). Management measures are therefore needed to restrict effort from demersal fleets and metiers in space and time to levels in line with achieving GES for all major habitat types. It is at present unclear whether GES needs to be achieved overall for the whole North Sea or by jurisdiction. The status-quo situation suggests that one habitat type (Offshore circalittoral mud; OC-mud) does not meet GES criteria if looking at the North Sea wide level when GES is met if 75% of the area of the respective habitat type has a relative benthic state (RBS) above 0.8. More conservative definitions of GES like RBS > 0.9 would increase the number of habitats that do not meet GES to four (OC-mud, circalittoral mud and offshore circalittoral mixed sediment, Circalittoral sand).

Blue growth initiatives aim for increased economic and social benefits from the fishing sector. After some years with improvements in the economic situation of fleets fishing in the North Sea, the years after 2018 showed lower economic performance (Deliverable 6.9). This was caused by a mixture of low productivity and decreasing stock biomasses (e.g., cod, herring, saithe) and external factors as COVID, Brexit and increased fuel prices. In addition, space is becoming limiting in the North Sea due to offshore windfarms and an increasing number of MPAs (e.g., Natura 2000 network) with implemented fisheries restrictions. An EBFM plan also needs to consider its impact on social (e.g, food security, employment) and economic (e.g., Gross Value Added, Profit) indicators.

6.3.1 Main types of fisheries that need to be managed

The issues identified in the North Sea case study during SEAwise are mainly related to the mixed demersal fisheries (see above). Both active and passive fishing gears need to be managed to achieve CFP and MSFD objectives as outlined above. Trade-offs are expected between active and passive gear options. For example, while restrictions for bottom trawls will improve indicator D6 (bottom impact) and improve selectivity, a shift to passive gear options (e.g., gill and trammel nets) will increase bycatch rates for e.g., harbour porpoise or sea birds. The main pressures to be managed are extraction of fauna as well as abrasion/damage. However, ghost nets and other litter from fishing operations are also a cause of concern.

6.3.2 Effective management measure types to achieve policy objectives and societal goals.

TAC management in combination with a landing obligation (output control) is effective in reaching policy objectives for commercial stocks (i.e. all stock fished at or below F_{MSY}, stocks within safe biological limits; table 4.4). TAC management can also have positive effects on ETP species and bottom impact if TACs under MSY management lead to lower fishing effort compared to the status quo situation. The effect on the social and economic situation in comparison to status quo is case specific because it depends on current stock status, the recovery potential of stocks and the exact type of harvest control rule applied whether TACs will have a positive or negative effect on economic and social indicators (deliverables 6.8 and 6.12). Technical gear measures can support TAC management by improving selectivity. This is important to avoid choke effects in mixed fisheries, but also to safeguard stocks with high unwanted catch rates like North Sea cod. A reduction of choke effects has the potential to also improve economic and social indicators. However, it can also lead to higher fishing effort, ultimately leading to more pressure on ETP species and bottom impact. Therefore, the exact direction of effects is highly case and indicator specific. In

addition to TAC management, spatial closures are relevant to protect benthic habitats (Deliverable 5.6, table 4.4) and are an option to restrict negative effects on ETP species, although this is highly species specific.

6.3.3 Effective operational management measures in the CS-specific regional context

The following conclusions are based on model runs and analyses carried out during SEAwise. It needs to be highlighted that structural uncertainties exist between models and only a subset of potential models was available to SEAwise. Conclusions can change if other models and /or settings are used in future evaluations. However, models utilized in SEAwise for the North Sea include the main models used at ICES as the basis for advice and in other large projects (e.g., Mission Atlantic). The work in SEAwise has provided a consolidated framework to evaluate management strategies under EBFM and the results of an application of this framework with the best available models can be found below.

6.3.4 TAC management

Several models (FLBEIA, StrathE2E, SMS) were applied for the North Sea region to simulate different options for MSY based management and different implementation levels of the landing obligation (see deliverables 6.5, 6.8, 6.12 for more details). Strict TAC management aimed at F_{MSY} in combination with a strict implementation of the landing obligation led to a clear improvement in GES of e.g. harbour porpoise bycatch) and social indicators (e.g., CO_2 footprint) with a more sustainable exploitation of fish stocks. Potential GES thresholds for benthic habitats were met under all tested scenarios with an RBS threshold of 0.8. However, an RBS threshold of 0.9 would mean that even under the strictest MSY and landing obligation scenario alone, GES cannot be achieved for three habitat types (OC-mud, circalittoral mud and offshore circalittoral mixed sediment).

Even though the models demonstrate that the consequences of climate change can be partly compensated so that sustainable management of stocks is still possible under TAC management aiming for MSY and the landing obligation, productivity declines for e.g., cod and saithe were predicted to lead to major losses in long-term yield. The ecosystem models confirmed the overall negative impact of climate change causing a combination of declining primary production and rising temperatures, resulting in a decreased efficiency of energy transfer up the food web.

A strict implementation of MSY management and the landing obligation via restrictive TAC setting in combination with choke effects led to fishing below F_{MSY} for most stocks and losses in landings and therefore food security compared to fishing with status quo effort. Climate change increased the predicted losses in landings. Economic indicators as well as employment improved in general in the long-term compared to the status quo situation under current climate due to the predicted recovery of stocks under lower fishing mortalities and associated higher catches per unit of effort. However, climate change will also impact the economic and social performance negatively and the tested management strategies can only partly mitigate this.

Among the different MSY approaches tested, there was no single management rule that attained all objectives. TAC management based on Pretty Good Yield and associated F_{MSY} ranges allowing fishing at sustainable levels above F_{MSY} if stock biomass is above safe biological limits, represented a potential improvement of economic and social performance over strict management based on F_{MSY}. PGY led to higher landings and socio-economic benefits from fisheries compared to using F_{MSY} as strict limit in the simulations for the North Sea, but led to higher CO_2 emissions per landed kg, higher bycatch of harbour porpoise (but still below the threshold of 1622 individuals; though this is overall an uncertain prediction), lower biomass of large fish (where thresholds will need to be lowered in any case under climate change due to lower predicted biomasses for larger fish like cod and saithe) as well as higher benthic impact (but still within potential GES thresholds when analysing RBS for the whole North Sea area; i.e. 75% of the area with RBS > 0.8 for all habitat types). Therefore, PGY potentially constitutes a viable alternative to strict MSY

management for the demersal fleets in the North Sea leading to higher landings and food security as well as improved economic performance.

A multispecies model with predation was applied for the North Sea analysing the impact on forage fish specifically. It shows that due to predation, the choice of management applied for the demersal stocks will affect the stock sizes, yield and eaten biomass of the small pelagic and forage fish stocks. However, the harvest strategies for forage fish applied in the North Sea under TAC management were robust to changes in climate and management options for the demersal predators. There was no scenario where forage fish biomass on average fell below one third of the maximum biomass threshold but the lower the harvest of demersal predators, the lower the yield that can be taken from pelagic forage fish without risking a collapse of stocks below B_{lim}. The predictions may change if more uncertainties are taken into account in the simulations.

6.3.5 Additional technical measures

In support of TAC management, additional technical measures can be applied to lower the catch of undersized individuals or protect benthic habitats. In SEAwise, a set of gear modifications was evaluated in the model to improve size selectivity (i.e. for roundfish like cod) for the most important types of demersal fisheries in the North Sea (deliverable 6.12). For the fisheries targeting gadoids (cod, saithe, haddock), an increase in mesh size from 120mm to 140mm was proposed, for Nephrops and flatfish fisheries with smaller meshed otter trawls, the use of a separator panel with different mesh sizes in the upper (140mm) and lower panel (80mm) and for the beam trawl fisheries targeting sole, the use of a T90 mesh configuration and increased mesh size from 80mm to 100mm. The simulations indicate that the proposed gear modifications indeed help to decrease fishing mortalities of juveniles and shift exploitation patterns towards older ages. Due to higher prices for larger individuals, revenues increased compared to baseline scenarios. This may have also a slight positive effect on employment. However, the gear modifications also lead to higher effort needed to fish up quotas set under the different management strategies. This led to a reduced performance of economic indicators. Further, positive effects on spawning stock biomass were limited and species specific with some improvement for saithe, haddock and whiting, but hardly any changes for cod. The increased effort may lead to higher CO_2 footprints per kg landed indicating less efficient fisheries. Slightly more bycatch of harbour porpoise and slightly lower RBS values can be expected as the consequence of the increased fishing effort. However, all are predicted to be still within GES levels when accompanied by TAC management. The gear modifications should improve the large fish indicator. Overall, this highlights that gear modifications lead to trade-offs and should be applied carefully to avoid too high losses in the efficiency of fisheries finally leading to higher fishing effort necessary to fish out quotas and slightly deteriorated MSFD as well as economic indicators, though this will be fleet and metier specific.

Trade-offs were also encountered for spatial management (Deliverable 5.6). In the North Sea, the DISPLACE model showed that relative benthic status improved in areas where bottom fishing was excluded from previously fished areas and decreased in newly fished areas. When testing the closure of 30% of the highest RBS area, the main outcome was a gain for long-lived benthic groups. Protecting current high RBS areas may lead to a net gain in RBS with a large potential for recovery at a low cost of fisheries catch. ECOSPACE estimated an increase in biomass in the southern part of the North Sea inside closed areas but the losses of catches inside the MPAs were not outweighed by increased catches outside the closed areas. Larger coherent protection zones were more efficient than small er scattered protection zones for reducing the bycatch risk and the effect on sensitive benthic habitats. The FISHCODE model of the southern North Sea and the German fisheries found that closing existing MPAs leads to ecological benefits, but also short-term profit losses for both bottom and beam trawl fleets. The spatial fishing effort increased in remaining fishable areas across all scenarios, with possible devastating ecological consequences. The OSMOSE model showed that climate change results in a decrease in future ecosystem productivity that will have a more pronounced effect on ecological and catch indicators than area closure in 2060. Approximately a 10% reduction in the overall catch was anticipated under the RCP8.5 2060 climate scenario. Implementing spatial restrictions (MPAs

and OWFs) did not strongly affect fish biomass when combined with the climate scenario. Taking all model results together, the models point to closed areas potentially being an efficient tool to protect sensitive benthic habitats, preferably in the shape of larger areas. However, depending on the location of these areas, they may lead to substantial losses in profit and via effort displacement to unintended negative consequences for areas which are not currently fished. Therefore, successful spatial management first require an in-depth evaluation of consequences to optimize size and location. Further, the negative impacts of climate change on the ecosystem may override any potential benefits of area closure, leading to future losses of catch and profit.

6.3.6 Effective policy instruments to implement EBFM management measures.

In general, the policy instruments and governance arrangements currently in place are considered sufficient to effectively implement EBFM. However, climate change as well as marine spatial planning (windfarms, MPAs) are rapidly changing the North Sea ecosystem. As a result, legal and regulatory instruments must be applied in a suitable time-frame to adapt e.g., targets and limits for commercially important stocks, including emerging species and fisheries like for squids and cuttlefish, brown crab and lobsters, and other ecosystem components such as bycatch of ETP species and the Large fish indicator. The introduction of new technical measures like innovative gears or spatial closures must be ensured within a suitable time-frame. This confirms the need for adaptive management. Currently many argue that the implementation of technical measures via joint recommendations from regional EU groups like Scheveningen, STECF evaluations and delegated acts is too time consuming and prevents fishermen from applying innovative solutions. At the same time, new measures should not lead to unintended impacts on the ecosystem making it necessary to allow for enough time for scrutiny by science and stakeholders. Having three major jurisdictions covering the North Sea (EU, UK, Norway) further complicates the agreement and implementation of management measures.

Policy instruments may also incentivise (economically) a broadening of the business concepts especially of fishermen operating in small scale fisheries. Results of SEAwise modelling studies clearly highlight that EBFM under climate change is likely to lead to losses in landings as well as poorer social and economic performance unless new emerging species like squids and cuttlefish can compensate for the losses from boreal species and loss of fishing grounds to windfarms and MPAs. This means that to avoid declines in fishers income, policy instruments (e.g., science, training programmes, public money for fishing for litter) are needed to provide fishermen with alternative incomes like data collection for science, collection of litter, educational trips with tourists or as part of multi-use exploitation of windfarms through aquaculture or passive fisheries for crustaceans like brown crab and lobster. However, any multi-use within windfarms needs policy instruments to allow for this and to ensure sufficient insurance in case of damage of infrastructure due to fishing operations or aquaculture.

6.3.7 Combining management measures and policy instruments to create an internally consistent EBFM plan

TAC management under the MSY concept and in combination with a fully implemented landing obligation ensure the sustainable exploitation of many ecosystem components also under climate change. However, in order to optimise for economic and social benefits within the frame of achieving GES for all ecosystem components, the MSY concept may need to be interpreted through the Pretty Good Yield concept to allow for some flexibility when stocks are in good condition, but choke effects limit the yield. In addition to TAC management and the landing obligation, specific technical measures are needed to reach all objectives and lower the amount of foregone economic and social benefits caused by choke species problems and the need to reach GES. Gear modifications can increase species and size selectivity leading to an overall slightly better performance for some indicators (revenues, large fish indicator).

However, care is needed to avoid that fisheries become too inefficient by lowering catch rates also for target species as this leads to higher fishing effort levels needed to fish out quotas. This impacts both biodiversity, CO_2 emissions and economic objectives negatively. The tested gear modifications (larger mesh sizes in gadoid fisheries, separator panel in Nephrops fisheries, T90 and increased mesh size in sole fisheries) clearly showed these trade-offs. Further work is needed to test a full set of options available from innovative gears. In general, gear modifications are an important tool to improve size and species selectivity and potentially lower choke effects under the landing obligation. SEAwise provides a base model and framework for future evaluations.

Spatial closures are especially suitable to protect benthic habitats (Deliverable 5.6). However, also for this type of management measure, the location and size needs to be carefully chosen to avoid unintended impacts from effort displacement. To fully close areas that are currently lightly fished (leading to finally to high RBS) may be an option to improve RBS with relatively small losses in fisheries yield and relatively small potential problems from effort displacements (deliverable 5.6).

Climate change will lead to major changes in the North Sea ecosystem. Adaptive management must aim to ensure that necessary changes in TAC management (e.g., emerging species) and technical measures are possible within a rapidly changing environment. Regionalisation is important to allow fit for purpose regional management measures, but in the North Sea the presence of three major jurisdictions (EU, UK, Norway) complicates governance processes that seek agreement on necessary changes without violating „level playing fields“. Although bi- and tri-lateral negotiations and working groups (e.g., Specialised Committee for Fisheries between EU and UK) have been established, each jurisdiction has its own regional management bodies (e.g., Scheveningen group in the EU). A standing committee representing all countries surrounding the North Sea could be a useful addition to allow for a more efficient agreement and implementation of management measures for the whole North Sea.

Although the Natura 2000 network aims to protect certain habitats, it is likely that additional or alternative area closures are needed to reach certain objectives (Deliverable 5.6). Policy instruments are needed that allow for such fit for purpose closures in an international context across national jurisdictions. The predicted losses of yield because of climate change and loss of fishing grounds due to marine spatial planning may require alternative incomes for fishermen in order to achieve social and/or economic objectives.

6.3.8 Conclusions

It needs to be highlighted again upfront that structural uncertainties exist between models and only a subset of potential models was available to SEAwise. Conclusions can change if other models and /or settings are used in future evaluations. However, the work in SEAwise has provided a consolidated framework to evaluate management strategies under EBFM. Organisations like ICES can make use of the work conducted in SEAwise and parameterise models within “benchmarks” to follow the general guidance from SEAwise (see chapter 4 and 5 of this deliverable) on how to design or evaluate EBFM management plans.

Based on SEAwise results, the central element for a North Sea EBFM plan can remain TAC management in combination with a landing obligation. Model predictions indicate that a sustainable exploitation of commercially important stocks is possible also under climate change under this management approach. However, choke effects from the landing obligation led to fishing well below F_{MSY} for many stocks. The associated lower fishing effort compared to status quo improved MSFD related indicators towards agreed and potential GES levels.

Strict implementation of the MSY concept and the landing obligation in the context of climate change will lead to decreasing economic and social performance compared to the status quo, particularly if warming is as great as under RCP 8.5. A more flexible interpretation of the MSY concept (i.e. Pretty Good Yield) offers some flexibility and can improve socio-economic indicators to some extent. Technical measures like gear modifications are additionally needed to improve selectivity leading to less choke effects and further improvements in socio-economic indicators. However, reduced choke effects likely lead to more fishing effort and a balance is needed to avoid that wider

ecosystem objectives are violated. Gear modifications should also not lead to too great decreases in catch rates of target species. Otherwise, the resulting increase in fishing effort leads toy deteriorated economic and MSFD related indicators. This proves to be the biggest challenge when developing innovative gears. Spatial management options can help to reach certain objectives like improvements in the status of benthic habitats and steer fishing effort towards less vulnerable areas. However, effort displacement effects must be considered carefully as not all tested closure scenarios lead to improvements in wider ecosystem status. Overall, implementation of EBFM and marine spatial planning in the context of climate change will likely lead to substantial income loss for fishermen. Policy instruments may promote alternative incomes of fishermen. In addition, governance processes and adaptive management should ensure that the rapid changes happening in the North Sea ecosystem due to climate change can be mitigated by new and/or modified management measures. The complex situation of three major jurisdictions surrounding the North Sea has to be considered when optimising policy instruments.

6.4 Conclusion

A high-performance EBFM plan should implement the management measures deemed most effective to achieve the selected policy objectives or at least advance the status of the ecosystem and its components toward those goals. To guide the design process, information is required on the effectiveness of the potential management measures. SEAwise conducted a variety of different modelling studies showing how indicators representative of policy objectives are effected by specific (scenarios of) management measures thus linking the key entities that drive the EBFM evaluation and design processes. For consistency a typology of management interventions was created. In order to bridge the gap between EBFM and EBM and the CFP and MSFD, the typology is aligned as much as possible to those processes/policies. To assess the effectiveness of the management measures from the scenarios, comparisons were made between baseline scenarios (i.e. with management measure currently in use) and a scenario with a specific management measure. The effects were distinguished between short-term (ST, Period = 2035-2040) and long-term (LT, Period = 2055-2060) and the baseline scenarios represent current management (Period = 2025-2030) and climate conditions (noCC). This exercise provided a first standardized overview of the performance of management measures in relation to the achievement of specific policy objectives. This was the basis for the design of regional EBFM plans.

These first attempts to design regional EBFM plans based on knowledge generated in SEAwise shows how these go beyond the traditional TAC- (North Sea and Western waters) or effort-based (Mediterranean) fisheries management, recognizing that other types of management measures may complement such management and even be more effective to achieve a wider suite of policy objectives. Instead of only considering the status of the commercial (shell)fish stocks the EBFM plans now also consider the health of the wider ecosystem including the disturbance of the seafloor and bycatch of PET species as well as social and economic objectives. Trade-offs between the various goals are acknowledged and could sometimes even be reconciled. The potential effects of climate change on management effectiveness were also considered.

TAC- or effort-based management, however, remains at the core of the EBFM plans but now including the landing obligation and the application of other targets than MSY, e.g. PGY, in some cases proven more effective than MSY, e.g. to achieve socio-economic objectives (North Sea) and decrease CO_2 emissions per kg of fish landed (Mediterranean). The strict(er) application of MSY or PGY was found to at least partly buffer the effects of climate change.

Other types of management measures that were applied are spatial controls, i.e. closed areas or MPAs, specifically to protect the seafloor. However, effort displacement effects must be considered carefully as not all closures necessarily lead to improvements in wider ecosystem status. As long as displacement ends up in less vulnerable or already fished areas it is likely that a net improvement can be achieved.

Similarly gear innovations can reduce the bycatch of unwanted species (PET or otherwise). However, such gear

modifications should not lead to too great decreases in catch rates of target species as the resulting increase in fishing effort is likely to lead to a deterioration of the wider ecosystem and negative socio-economic effects.

In general any reduction in effort, be it from TAC-, effort-management or closed areas was found to benefit the wider ecosystem but often came with socio-economic consequences, albeit sometimes only in the short term.

Thus, with the extended knowledge base provided by SEAwise it was shown how this may contribute to an improved design of the regional EBFM plans so that they can be expected to better perform in achieving the wide range of environmental and socio-economic objectives that were selected to drive the development of these plans.

7. References

Altvater, S., S. Lukic, I., Eilers, 2019. EBA in MSP – a SEA inclusive handbook, Pan Baltic Scope, 2019. Available at: http://www.panbalticscope.eu/results/reports/ (Report).

Anonymous, 2021. Fishing Fleet 2020 Annual Report. Pursuant to Article 22(4) of Regulation (EU) No 1380/2013 of the European Parliament and of the Council. Ministry of Rural Development and Food, 69 p. https://tinyurl.com/cjf4stru

Asif, F., Hegland, T.J., Frangoudes, K., Kraan, M., Depestele, J., Bellanger, M., Melià, P., Gil, N.M., Ojaveer, H., Spedicato, M.T., Chiarini, M., Lembo, G., Syrou, D., Vassilopoulou, V., Liontakis, A., Voss, R., Bitetto, I., and Rindorf, A. (2025): Report on evaluation of alternative management measures from a governance perspective. Technical University of Denmark

Astarloa, A., Bastardie, F., Batts, L., Binch, L., Bitetto, I., Bluemel, J. K., Carbonara, P., Chatzispyrou, A., Couce, E., Fotiadis, N., García-Barón, I., Kavadas, S., Lefkaditou, E., Louzao, M., Maina, I., Neglia, C., Poos, J. J., Reid, D., Romagnoni, G., Spedicato, M.-T., van de Wolfshaar, K., Vassilopoulo, C., Zupa, W., and Rindorf, A. (2024): SEAwise Report on changes in bycatch of fish, seabirds, reptiles and mammals in response to spatial management. Technical University of Denmark. https://doi.org/10.11583/DTU.25041257.v1

Barnard, S., Elliott, M., 2015. The 10-tenets of adaptive management and sustainability: An holistic framework for understanding and managing the socio-ecological system. Environ. Sci. Policy. https://doi.org/10.1016/j.envsci.2015.04.008

Bastardie, F., Batts, L., Binch, L., Bitetto, I., Bluemel, J., Damalas, D., Depestele, J., Astarloa Diaz, A., Hernvann, P.-Y., Lehuta, S., Letschert, J., Kavadas, S., Maina, I., Papadopoulou, N. K., Papantoniou, G., Poos, J.-J., Püts, M., Romagnoni, G., Smith, C. J., Spedicato, M.-T., Tsagarakis, K., Tsikopoulou, I., Vassilopoulou, V., van de Wolfshaar, K., Youen Vermard, Zupa, W. and Rindorf, A. (2024): SEAwise report on effects of spatial management measures suggested in SEAwise to safeguard species, habitats and choke species on fisheries selectivity and fuel cost. Technical University of Denmark.

Bastardie, F., Spedicato, M.-T., Bitetto, I., Romagnoni, G., Zupa, W., Letschert, J., Püts, M., Damalas, D., Kavadas, S., Maina, I., Tsagarakis, K., Poos, J. J., Papantoniou, G., Depestele, J., Batts, L., Bluemel, J., Astarloa Diaz, A., van de Wolfshaar, K., Binch, L., and Rindorf, A. (2023): SEAwise report on predicting effect of changes in 'fishable' areas on fish and fisheries, September 2023. Technical University of Denmark. https://doi.org/10.11583/DTU.24331198

Berkes, F., 2011. Restoring Unity, in: World Fisheries. John Wiley & Sons, Ltd, pp. 9–28. https://doi.org/10.1002/9781444392241.ch2

Bitetto, I., Andrés, M., Sánchez-Maroño, S., Altuna-Etxabe M., García, D., Ibaibarriaga, L., Spedicato, M. T., Lembo G., Carbonara P., Zupa W., Giannoulaki, M., Sgardeli, V., Tsoukali, S., Liontakis, A., Vassilopoulou, V., Sys, K., Depestele, J., Kühn, B., Taylor, M., Kempf, A., and Rindorf, A. (2024): SEAwise report on the impact of socio-economic effects of fisheries management. Technical University of Denmark. https://doi.org/10.11583/DTU.28081571

Bitetto, I., Spedicato, M.T., Lembo, G., Plataniotis, A., Halkos, G., Koundouri, P., Andrés, M., Caro, M., García, D., Voss, R., Vasilopoulou, V., Liontakis, A., Sgardeli, V., Kempf, A., Taylor, M., Kühn, B., Kraan, M., Hamon, K., Pedreschi, D., Batts, L., Muench, A., Hegland, T. J., Asif, F., Frangoudes, K., Le Grand, C., Sys, K., Depestele, J. and Rindorf, A. (2023): SEAwise first synthetic summary report on social and economic aspects of fishing for online tool. Technical University of Denmark. https://doi.org/10.11583/DTU.25634508

Blythe, J.L., Armitage, D., Bennett, N.J., Silver, J.J., Song, A.M., 2021. The Politics of Ocean Governance

Transformations. Front. Mar. Sci. 8. https://doi.org/10.3389/fmars.2021.634718

Borgström, S., Bodin, Ö., Sandström, A., Crona, B., 2015. Developing an analytical framework for assessing progress toward ecosystem-based management. AMBIO 44, 357–369. https://doi.org/10.1007/s13280-015-0655-7

Bouwma, I.M., Gerritsen, A.L., Kamphorst, D.A., Kistenkas, F.H., 2015. Policy instruments and modes of governance in environmental policies of the European Union : past, present and future (No. 60). WOT Natuur & Milieu.

Bryant, R.L., Wilson, G.A., 1998. Rethinking environmental management. Prog. Hum. Geogr. 22, 321–343. https://doi.org/10.1191/030913298672031592

BSPC, 2006. Nutrient and Eutrophication in the Baltic Sea: Effects / Causes / Solutions., In: Baltic Sea Parliamentary Conference NC, Copenhagen 2006., editor, 2006.

Carbonara P. et al. 2025.Turtle bycatch from trawlers: What modelling is telling us in the southern Adriatic sea. https://doi.org/10.1016/j.ecss.2025.109293

Cormier, R., Kelble, C.R., Anderson, M.R., Allen, J.I., Grehan, A., Gregersen, Ó., 2017. Moving from ecosystem-based policy objectives to operational implementation of ecosystem-based management measures. ICES J. Mar. Sci. 74, 406–413. https://doi.org/10.1093/icesjms/fsw181

Delacámara, G., O'Higgins, T.G., Lago, M., Langhans, S., 2020. Ecosystem-Based Management: Moving from Concept to Practice, in: O'Higgins, T.G., Lago, M., DeWitt, T.H. (Eds.), Ecosystem-Based Management, Ecosystem Services and Aquatic Biodiversity : Theory, Tools and Applications. Springer International Publishing, Cham, pp. 39–60. https://doi.org/10.1007/978-3-030-45843-0_3

EC (European Commission). 2023. *EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries* (COM(2023) 102 final). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0102

EC (European Commission). 2024. First report on the implementation of the multiannual plans for the North Sea and Western Waters and the fisheries exploiting those stocks and on the delegation of powers conferred to the Commission by these multiannual plans and by the Deep-Sea Access Regulation. Report from the Commission to the European Parliament and the Council, COM(2024) 406 final. Brussels, Belgium.

EC, 2008. The role of the CFP in implementing an ecosystem approach to marine management. SEC(2008) 449 (Report).

EC, 2020. Commission Staff Working Document: Background document for the Marine Strategy Framework Directive on the determination of good environmental status and its links to assessments and the setting of environmental targets. Accompanying the Report from the Commission to the European Parliament and the Council on the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC)., In: final. ECS, editor, 2020.

EC-CINEA, 2021. Guidelines for implementing an ecosystem-based approach in maritime spatial planning : including a method for the evaluation, monitoring and review of EBA in MSP (Report). Publications Office. https://doi.org/doi/10.2926/84261

Ehler, F., C.N., Douvere, 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Man-ual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO. 2009 (English), p. 18. (Report).

Elliott, M., Burdon, D., Atkins, J.P., Borja, A., Cormier, R., de Jonge, V.N., Turner, R.K., 2017. "And DPSIR begat DAPSI(W)R(M) !" - A unifying framework for marine environmental management. Mar. Pollut. Bull.

https://doi.org/10.1016/j.marpolbul.2017.03.049

European Commission, Joint Research Centre, Scientific Technical and Economic Committee for Fisheries (STECF) – The 2024 Annual Economic Report on the EU Fishing Fleet (STECF-24-03 & STECF-24-07), Prellezo, R., Sabatella, E.C., Virtanen, J., Tardy Martorell, M., and Guillen, J. editor(s), Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/5037826, JRC139642.

FAO. 2023. The State of Mediterranean and Black Sea Fisheries 2023 – Special edition. General Fisheries Commission for the Mediterranean. Rome. https://doi.org/10.4060/cc8888en

Garcia, D., Sánchez-Maroño, S., Altuna-Etxabe, M., Andres, M., Kempf, A., Taylor, M., Kühn, B., Letschert, J.,Lehuta, S.,Bitetto, I., Spedicato, M.-T., Zupa W., Carbonara P., Romagnoni, G., Giannoulaki, M., Sgardeli, V., Giannoulaki, M., Tsoukali, S., Papantoniou, G., Liontakis, A., Vassilopoulou, V., Depestele, J., Sys, K., Voss, R., Melià, P., Schiavo, A., Heath, M., Binch, L. and Rindorf, A. (2025): SEAwise Report on the impacts of fisheries on stocks and landings under existing management plans. Technical University of Denmark.

Gill, A.B., Bremner, J., Vanstaen, K., Blake, S., Mynott, F. and Lincoln, S. (2025), Limited Evidence Base for Determining Impacts (Or Not) of Offshore Wind Energy Developments on Commercial Fisheries Species. Fish Fish, 26: 155-170. https://doi.org/10.1111/faf.12871

Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta E Costa, B., Pike, E.P., Kingston, N., Laffoley, D., Sala, E., Claudet, J., Friedlander, A.M., Gill, D.A., Lester, S.E., Day, J.C., Gonçalves, E.J., Ahmadia, G.N., Rand, M., Villagomez, A., Ban, N.C., Gurney, G.G., Spalding, A.K., Bennett, N.J., Briggs, J., Morgan, L.E., Moffitt, R., Deguignet, M., Pikitch, E.K., Darling, E.S., Jessen, S., Hameed, S.O., Di Carlo, G., Guidetti, P., Harris, J.M., Torre, J., Kizilkaya, Z., Agardy, T., Cury, P., Shah, N.J., Sack, K., Cao, L., Fernandez, M., Lubchenco, J., 2021. The MPA Guide: A framework to achieve global goals for the ocean. Science. https://doi.org/10.1126/science.abf0861

Hilborn, R., et al. (2023). "Evaluating the sustainability and environmental impacts of trawling compared to other food production systems." ICES Journal of Marine Science.

Ibaibarriaga, Leire; Aldanondo, Naroa; Álvarez, Paula; Aminot, Yann; Batts, Luke; Bely, Nadège; et al. (2025). SEAwise Report on improved predictive models of growth, production and stock quality under different habitat scenarios and incorporating experimental results. Technical University of Denmark. Online resource. https://doi.org/10.11583/dtu.28049597.v1

ICES (2024a). Bay of Biscay and the Iberian Coast Ecoregion - Fisheries Overview. ICES Advice: Fisheries Overviews. Report. https://doi.org/10.17895/ices.advice.27879951.v4

ICES (2024b). Celtic Seas Ecoregion - Fisheries Overview. ICES Advice: Fisheries Overviews. Report. https://doi.org/10.17895/ices.advice.27879936.v2

Jann, W., Wegrich, K., 2007. Theories of the Policy Cycle, in: Handbook of Public Policy Analysis. Routledge.

Jiao, W., Boons, F., 2014. Toward a research agenda for policy intervention and facilitation to enhance industrial symbiosis based on a comprehensive literature review. J. Clean. Prod. 67, 14–25. https://doi.org/10.1016/j.jclepro.2013.12.050

Jonas HD, MacKinnon, K., Marnewick, D. and Wood, P., 2023. Site-level tool for identifying other effective area-based conservation measures (OECMs). (Report). https://doi.org/10.2305/WZJH1425

Katikas L., Reizopoulou, S., Drakopoulou, V., Vassilopoulou, V. 2025. https://www.sciencedirect.com/science/article/pii/S1574954125001633?utm_campaign=STMJ_219742_AUTH_SERV_PA&utm_medium=email&utm_acid=79743905&SIS_ID=&dgcid=STMJ_219742_AUTH_SERV_PA&CMX_ID=&utm_in=DM561503&utm_source=AC_

Kempf, A., Taylor, M., Kühn, B., Letschert, J., Brown, E., Trijoulet, V., Vinther, M., Hernvann, P.Y., Girardin, R., Savina-Rolland, M., Lehuta, S., Halouani, G., Robert, M., Woillez, M., Mahevas, S., Travers, M., Andres, M., Garcia, D., Ibaibarriaga, L., Sánchez-Maroño, S., Astarloa Diaz, Altuna, M., Mencia, A., A., Batts, L., Reid, D., Bitetto, I., Spedicato, M.-T., Romagnoni, G., Zupa, W., Giannoulaki, M., Sgardeli, V., Papantoniou, G., Tsoukali, S., Liontakis, A., Vassilopoulou, C., Millar, S., Depestele, J., van Hoey, G., Sys, K., van de Wolfshaar, K., Piet, G., Hamon, K., Kraan, M., Smout. S., Ransijn, J., Thorpe, R., Lynam, C., Bluemel, J., Voss, R., Ojaveer, H., Hommik, K., Melia, P., Gascuel, D., Potier, M., Ustups, D., Plikss, M., Heath, M., Poos, J.-J., Binch, L., and Rindorf, A. (2024): SEAwise Report on consistency of existing targets and limits for indicators in an ecosystem context. Technical University of Denmark. https://doi.org/10.11583/DTU.28081649.v1

Kooiman, J. & Bavinck, M., 2005. The Governance Perspective.

Kraan et al., 2024. https://doi.org/10.11583/DTU.26236598

Langeweg, F., 1998. The implementation of Agenda 21 `our common failure'? Sci. Total Environ. 218, 227–238. https://doi.org/10.1016/S0048-9697(98)00210-1

Link, J.S. and Watson, R.A. 2019. Global ecosystem overfishing: Clear delineation within real limits to production. Sci. Adv. 5. eaav0474.

Liontakis, A. & Vassilopoulou, V., 2023. https://www.mdpi.com/2410-3888/8/9/447

Liontakis, A., Tzouramani, I., Mantziaris, S., Sintori, A., 2020. Unravelling the Role of Gender in Fisheries' Socio-Economic Performance: The Case of Greek Small-Scale Fisheries. Sustainability, 12, 5304.

Long, R.D., Charles, A., Stephenson, R.L., 2015. Key principles of marine ecosystem-based management. Mar. Policy 57, 53–60. https://doi.org/10.1016/j.marpol.2015.01.013

Lynam, C., Thorpe, R., Thompson, M., van de Wolfshaar, K., Püts, M., Corrales, X., Romagnoni, G., Tsagarakis, K., Potier, M., Papantoniou, G., Halouani, G., Heath, M., Kempf, A., Taylor, M., and Jacobsen, N. S. (2023): SEAwise Report on the effects of fishing on food webs and community diversity aimed at populating the MSFD Descriptor 4 and based on food web and end-to-end modelling. Technical University of Denmark. https://doi.org/10.11583/DTU.25158746

Maina, I., Chatzispyrou, A., Fotiadis, N., Kavadas, S., Astarloa, A., Bastardie, F., Lefkaditou, E., Vassilopoulou, V., 2025. Bycatch risk assessment and spatial restrictions of fishing: a study focusing on a critically endangered elasmobranch (Bull Ray, Aetomylaeus bovinus) in Central Mediterranean Waters (submitted to Fisheries Research)

Melià, P., Schiavo, A., Ojaveer, H., Einberg, H., Rubene, G., Putnis, I., Neuenfeldt, S., Voss, R., Kühn, B., Taylor, M., Kempf, A., Henriksen, O., Thorpe, R., Spence, M., Heath, M., Dolder, P., Tirronen, M., Depestele, J., Kuparinen, A., Allison, C., Blanco, C., Burt, G., Clare, D., Couce, E., Thompson, M., Van Moorleghem, C., Sys, K., Ibaibarriaga, L., Uriarte, A., Citores, L., Sarasua, I., Fontán, A., Sánchez-Maroño, S., López de Gamiz, A., Garcia, D., Gatti, P., Woillez, M., Lebigre, C., Servili, A., Mazurais, D., Savina-Rolland, M., Garcia-Fernandez, C., Mouchel, O., Collet, S., Simon, V., Martiradonna, A., Bitetto, I., Zupa, W., Spedicato, M.T., Tsagarakis, K., Sgardeli, V., Damalas, D., Vassilopoulou, V., Maina, I. and Rindorf, A. (2024): SEAwise Report on improved predictive models of recruitment under different environmental scenarios. Technical University of Denmark.

Our Ocean, 2024. Greece's Commitments. 28pp https://www.ourocean2024.gov.gr/wp-content/uploads/2024/04/A5_OOC-9_PROPOSED-COMMITMENTS_12.4.pdf

Papantoniou, G., Sgardeli, V., Vassilopoulou, V., Tsagarakis, K., 2025. Investigating the potential impacts and interactive effects of climate warming and multi-gear fishing on the Eastern Ionian Sea ecosystem using EwEand ecological indicators (submitted to Frontiers in Marine Science).

Piet, Gerjan; Rindorf, Anna; Teresa Spedicato, Maria; Depestele, J. (Jochen); Kempf, Alexander; Ibaibarriaga, Leire; et

al. (2022). SEAwise Report on performance of existing management plans. Technical University of Denmark. Online resource. https://doi.org/10.11583/dtu.21687653.v1

Regulation (EU) 2019/472 of the European Parliament and of the Council of 19 March 2019 establishing a multiannual plan for stocks fished in the Western Waters and adjacent waters, and for fisheries exploiting those stocks, amending Regulations (EU) 2016/1139 and (EU) 2018/973, and repealing Council Regulations (EC) No 811/2004, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007 and (EC) No 1300/2008. Official Journal of the European Union. L 83/1. 17p

Reid, Dave; Anastasopoulou, Katerina; Astarloa, Amaia; Batts, Luke; Berg, Casper Willestofte; K. Bluemel, Joanna; et al. (2024). SEAwise synthetic summary report of the findings of WP4 on the ecosystem impacts of fishing for online tool. Technical University of Denmark. Online resource. https://doi.org/10.11583/DTU.26075323.v1

Rindorf, A., Astarloa Diaz, A., Batts, L., Bitetto, I., Brown, E., Damalas, D., Depestele, J., Garcia, D., Kempf, A., Kühn, B., Reid, D., Savina-Rolland, M., Spedicato, M. T., Taylor, M., van Hoey, G., and Jacobsen, N. S. (2024): SEAwise 2nd synthesis report on implementation of the EBFM and remaining knowledge gaps. Technical University of Denmark.

Rindorf, Anna; Brown, Elliot John; Depestele, Jochen; Damalas, Dimitris; Eliasen, Søren Qvist; Garcia, Dorleta; et al. (2022). SEAwise Report on scoping workshops. Technical University of Denmark. Online resource. https://doi.org/10.11583/dtu.21268563.v2

Salamon, L.M., 2002. The Tools of Government: A Guide to the New Governance. Oxford University Press.

Savina-Rolland, Marie; Rindorf, Anna; Brown, Elliot John; Neuenfeldt, Stefan; van Deurs, Mikael; Carbonara, Perluigi; et al. (2022). SEAwise Report on the key drivers of stock productivity and future environmental scenarios. Technical University of Denmark. Online resource. https://doi.org/10.11583/dtu.21269295.v1

Scientific, Technical and Economic Committee for Fisheries (STECF) – Monitoring the Performance of the Common Fisheries Policy (STECF-Ad hoc-25-01), Publication Office of the European Union, Luxembourg, 2025

Scientific, Technical and Economic Committee for Fisheries (STECF) - The 2021 Annual Economic Report on the EU Fishing Fleet (STECF 21-08), EUR 28359 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-40959-5, doi:10.2760/60996, JRC126139

Spedicato et al., 2023. https://doi.org/10.11583/DTU.23284649

Stelzenmüller et al., 2024. https://www.sciencedirect.com/science/article/pii/S0964569124003764

Sun et al., 2023 Status and Management of Mixed Fisheries: A Global Synthesis. https://doi.org/10.1080/23308249.2023.2213769

Syrou, D. Liontakis, A., Vassilopoulou V. 2025 Assessing fisheries governance quality in Greek waters through triple helix stakeholder perceptions (submitted to the SEAwise Symposium).

Travers-Trolet M., Hernvann P.-Y., Lehuta S., Gernez M., Sánchez-Maroño S., Ibaibarriaga L., García D., Citores L., Andrés M., Bitetto I., Romagnoni G., Sgardeli V., Tsoukali S., Giannoulaki M., Papantoniou G., Tsagarakis K., Vassilopoulou V., Kempf A., Kühn B., Taylor M., van de Wolfshaar K., Potier M., Heath M., Melià P., Binch L. and Rindorf, A. (2023): SEAwise Report on how integration of ecological indicators in multispecies-multifleet management evaluation models changes impacts of management strategies on fished stocks. Technical University of Denmark.

Van Hoey, G., Batts, L., Bolam, S., Carbonara, P., Clare, D., Depestele, J., Desmidt, J., Dinesen, G. E., Egekvist, J., Eigaard, O. R., Garcia, C., Kavadas, S., Lafarque, P., Maina, I., Mavraki, N., Olsen, J., Papadopoulou, N., Parker, R., Piet, G., Reid, D., Smith, C., Spedicato, M. T., Stounberg, J., Tsikopoulou, I., Zupa, W., and Rindorf A. (2023): SEAwise Report on the spatiotemporal benthic effects of fishing on benthic habitats relative to suggested threshold levels,

both with respect to area impacted and impact intensity. Technical University of Denmark.

Van Hoey, Gert; Batts, Luke; Beukhof, Esther; Carbonara, Pierluigi; Christensen, Asbjørn; Depestele, J. (Jochen); et al. (2024). SEAwise Report on changes in the spatiotemporal benthic effects of fishing on benthic habitats relative to suggested reference levels, both with respect to area impacted and impact intensity in response to spatial management. Technical University of Denmark. Online resource. https://doi.org/10.11583/DTU.28078970.v1

Virapongse, A., Brooks, S., Metcalf, E.C., Zedalis, M., Gosz, J., Kliskey, A., Alessa, L., 2016. A social-ecological systems approach for environmental management. J. Environ. Manage. 178, 83–91. https://doi.org/10.1016/j.jenvman.2016.02.028

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