

Making ecosystem-based management operational

Deliverable 8.1

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List of Abbreviations

AF	AQUACROSS Assessment Framework
BAU	Business as usual
CAS	Complex adaptive system
CBA	Cost benefit analysis
CS	Case study
DEL	Deliverable
EBM	Ecosystem-based management
PI	Policy instrument
PoM	Programme of Measures
SES	Socio-ecological system
WP	Work Package

About AQUACROSS

Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies (AQUACROSS) aims to support EU efforts to protect aquatic biodiversity and ensure the provision of aquatic ecosystem services. Funded by Europe's Horizon 2020 research programme, AQUACROSS seeks to advance knowledge and application of ecosystem-based management (EBM) for aquatic ecosystems to support the timely achievement of the EU 2020 Biodiversity Strategy targets.

Aquatic ecosystems are rich in biodiversity and home to a diverse array of species and habitats, providing numerous economic and societal benefits to Europe. Many of these valuable ecosystems are at risk of being irreversibly damaged by human activities and pressures, including pollution, contamination, invasive species, overfishing and climate change. These pressures threaten the sustainability of these ecosystems, their provision of ecosystem services and ultimately human wellbeing.

AQUACROSS responds to pressing societal and economic needs, tackling policy challenges from an integrated perspective and adding value to the use of available knowledge. Through advancing science and knowledge; connecting science, policy and business; and supporting the achievement of EU and international biodiversity targets, AQUACROSS aims to improve ecosystem-based management of aquatic ecosystems across Europe.

The project consortium is made up of sixteen partners from across Europe and led by Ecologic Institute in Berlin, Germany.

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1 Introduction

This report frames the ecosystem-based management (EBM) planning process and sets the basis for the evaluation of the performance of EBM towards achieving societal goals, the ultimate aim of EBM. AQUACROSS focuses on those societal goals related to biodiversity (i.e., EU Biodiversity Strategy 2020 and other international biodiversity targets) for EU aquatic ecosystems.

The AQUACROSS Innovative Concept and Assessment Framework (Work Package/WP3) make up the theoretical background to assess the performance of EBM to advance the state of the socio-ecological system (SES) in order to achieve policy objectives. Thus, making EBM operational in each of the AQUACROSS case studies (CS) requires all input assembled until now in the AQUACROSS project, i.e. information on the policy objectives (WP2) and their relative importance according to stakeholders (WP1), understanding of the SES (WP4, WP5), and the conceptual basis (i.e., AQUACROSS Concept and Assessment Framework, WP3).

This AQUACROSS EBM approach is based on a wealth of published AQUACROSS research. In the following sections of this introduction, we provide brief syntheses of the main results and conclusions of these key AQUACROSS reports/outputs.

- Section 1.1 introduces the stakeholder participation process, which is key to EBM and occurs throughout the process. This section is based on the Assessment Framework (Deliverable/DEL 3.2) and on-going work in WP1.
- Section 1.2 synthesises the main conclusions regarding policy objectives with stakeholder preferences for a collective agreement on the set of operational policy objectives at the local level. This is based on DEL2.1 that deals with "Synergies and Differences between Biodiversity, Nature, Water and Marine Environment EU Policies" (main report and Executive summary) and DEL2.2: Report on the review and analysis of policy data and information requirements and lessons learnt in the context of aquatic ecosystems (main report).
- Section 1.3 explains how AQUACROSS understands the SES, based on the AQUACROSS Innovative Concept (DEL3.1, main report and executive summary) and Assessment Framework (DEL3.2, main report and executive summary). It requires understanding of how human activities and pressures affect the aquatic ecosystems on one side (DEL4.1, main report and executive summary) and the causal flows between the aquatic ecosystem with its structure and functions providing ecosystem services on the other side (DEL5.1, main report, excel annex and executive summary). Both sets of causal linkages and the complex processes taking place at both the social and the ecological systems determines the knowledge base for the assessment of EBM measures, programmes, and plans.
- Section 1.4 summarises the key assessment criteria presented in the AQUACROSS Integrative Assessment Framework (AF), as depicted in DEL3.2 (main report and executive summary), and their connection with the identification, design, and implementation of EBM as alternative to current practice.

- Section 1.5 provides the AQUACROSS definition of EBM and elaborates on principles of EBM which is considered the backbone of AQUACROSS.

In chapter 2, the EBM planning process is framed consisting of the following elements: (1) identification and characterisation of measures and the actions required to put them into practice; (2) screening and evaluation of measures (and the actions for their implementation) and design of a comprehensive programme of measures (PoM) to reach the environmental objectives; (3) identification, characterisation screening, and design of social and institutional changes to enhance the governance of the SES so as to develop the means required for the implementation of the PoM; (4) design of the implementation plan; and (5) design and implementation of the EBM management plan formed by the PoM and the Information Platform (IP).

Finally, some of the above steps are further illustrated with examples from the AQUACROSS CS in chapter 3 and conclusions for further improvements in the operationalisation of the AQUACROSS EBM approach are included in section 3.4.

1.1 Stakeholder engagement

Stakeholder engagement is an essential component of EBM. The AF stresses upon the critical importance of stakeholder engagement for EBM. The co-production of EBM plans with stakeholders will optimise the uptake by end-users through the enhancement of science-based perceptions (learning), the alignment of stakeholder expectations, and the promotion of cooperation.

Stakeholder engagement is necessary to support the deployment of the AQUACROSS AF and its practical application in the different case studies. This requires an operational stakeholder engagement process. The AQUACROSS stakeholder engagement approach distinguishes between several steps in which stakeholder participation is considered fundamental.

- *Co-defining* policy objectives

Developing *integrated* (across aquatic realms, inter-sectoral and across spatial scales) EBM plans for aquatic ecosystems is challenging among other things, due to complexity of the policy context. The management of aquatic ecosystems is guided by several interrelated European directives that are translated into national and local policy goals and objectives that involve several sectors and local agencies. Ideally, the setting of goals and objectives must be founded on those established at the international and/or EU level but tailored to the local level and the stakeholders involved therein.

However, policy goals and objectives are often incompatible. Thus, forming a source of potential conflicts and eventually threaten cooperation and collective action. Effective stakeholder engagement is crucial to set policy objectives. Some level of common understanding and consensus of the status and trends of aquatic ecosystems and priorities to improve the status, between scientists, policy-makers and stakeholders, is needed to support EBM.

So, a commonly agreed upon and shared representation of current and future problems and objectives (assessed using indicators and targets) is best co-built with stakeholders. Scientific input is important in this step as it provides accurate knowledge on the status of aquatic ecosystems. Therefore, AQUACROSS should provide stakeholders with the very best science to understand management challenges and opportunities at hand; help them build a shared perception of problems; and to set objectives.

- *Co-defining* EBM management alternatives

Once policy objectives have been jointly agreed upon different courses of action to reach the objectives need to be identified and prioritised. One of the main challenges is to identify cooperative responses rather than competitive ones. This requires effective stakeholder engagement in which a common understanding of potential management alternatives and their effectiveness is created, as well as some transparency concerning the division of responsibilities (roles) and resources. The role of AQUACROSS in this step is to convey knowledge in such a way that it can be understood and used by stakeholders to screen out alternatives and understand the foreseeable consequences of the different courses of action.

- *Co-evaluation* of management alternatives

This step makes society accountable to increase the effectiveness, efficiency, and equity of EBM to achieve the stated policy objectives and to identify optimal (environmental and socio-economic) management options, both when evaluating against the baseline scenarios as well as any alternative scenarios. This does not preclude anything as per the consideration of socio-cultural criteria to fully understand the impact of EBM plans. They could inform about the negative consequences of nature degradation over people (in terms of wellbeing), rather than only over nature itself. As it happened since the CBD Ecosystem Approach came into play, economic progress and human wellbeing are added to the criteria to favour nature preservation that was previously dominated by strict conservationist approaches. EBM decisions should be based on social priorities, and the definition of societal preferences is a major challenge.

Choices (in the context of uncertainty) should be made and trade-offs stem from different sources such as the conflicting interests amongst stakeholders concerning the division of costs and benefits, the balance between short and longer term benefits, the need to forgo current rents in exchange of future security, or between the local opportunity costs and regional and global benefits. Ecosystem services trade-offs often reflect rivalry between wellbeing components (Iniesta-Arandia et al., 2014) or value dimensions (Martín-López et al., 2014).

It is challenging to integrate all stakeholders' societal preferences, since society consists of a large number of stakeholder groups with diverging interests, perspectives and knowledge bases. The role of AQUACROSS is to build up a comprehensive management plan based upon the systematic assessment of alternative measures and instruments, using different methods that rely on different levels of stakeholder engagement, e.g. Multi-Criteria Analysis (MCA), and to be transparent about the underlying assumptions. This should provide decision-makers with the necessary information to make choices.

1.2 Policy objectives

The definition of policy objectives is the basic starting point of the development of elements of the EBM management alternatives to current practice. The setting of precisely defined policy objectives is one important outcome of the baseline assessment: it requires examining existing policy targets, identifying existing and prospective ecological deficits and balancing the advantages and disadvantages of current management practices. A closer look of the baseline allows highlighting opportunities for EBM responses and anticipating the challenges of their implementation. Examining policy drivers can also inform on the underlying causes of the processes affecting the SES (e.g., from incentives and regulation) and support the design of corrective action. The definition of policy objectives should inform on the level of policy "integration" that may potentially be achieved at different scales, for example the degree to which policy and management work across aquatic realms, foster sectoral coordination, or address SES as a whole. Integration across realms, objectives and the SES as a whole is an essential ingredient of successful EBM.

It is expected that the definition of policy objectives results in the following type of outcomes:

1. An overview of the policy context of the case study and how they influence the pressures of interest in the CS;
2. A detailed presentation of the existing (and relevant) policy targets and deficits towards which EBM responses will contribute to;
3. A listing of current management practices in the case study, some of which will be modified/enhanced by EBM responses;
4. An overview of the key policy challenges and gaps, which will inform the development of EBM responses or identified solutions.

In AQUACROSS, such information proceeds from the evaluation of the baseline scenario. AQUACROSS baseline scenarios are built to provide a comprehensive representation of the overall SES focusing on the relevant interactions and identifying environmental and policy challenges. Furthermore, a good understanding of relevant policy actions at the local level for the management of biodiversity, ecosystem services and abiotic components of aquatic ecosystems should also provide a standpoint for screening, assessing, designing, and implementing the management alternatives to reach these objectives.

According to the AQUACROSS AF, policy objectives in the CS refer to conservation and biodiversity but must take into account the structure and functioning of an ecosystem and its biological components to address a variety of human needs (Tear et al, 2005). The characterisation of policies should start from the analysis of drivers of ecosystems change, the resulting pressures and the assessment of the current and baseline status of the relevant ecosystems, as well as from the analysis of how all this links to biodiversity, and ecosystem services.

The AQUACROSS Policy Review and the AQUACROSS AF highlight the need to take into account two complementary levels of analysis in the policy characterisation at different scales:

- At a global and EU level, objectives need to be defined in terms of contributions to meet the targets of the EU 2020 Biodiversity Strategy and other international targets within aquatic ecosystems, while contributing to the objectives set in the EU directives and strategies related to habitats, biodiversity, and aquatic ecosystems.
- At a local level, objectives need to be defined to respond to a well-defined environmental challenge or threat to biodiversity and conservation (such as dealing with invasive species, reducing nutrient pollution, improving hydrological flows and water retention, etc.).

These levels do not refer to different objectives but rather to how abstract EU-level goals are defined and specified at local and ecosystem scales so that, besides compliance with EU regulations, the local-level policy priorities, available information and environmental circumstances should be taken into account. Accordingly, an assessment of policy objectives should acknowledge abstract, general goals (from global and EU policy) as well as specific and measurable targets tailored at the regional and local level.

Environmental policy objectives and targets are usually expressed through the use of descriptors and indicators describing the status of ecosystems. The distance between existing and target values of these descriptors and indicators are the "deficits" that must be bridged in order to fulfil the desired objectives. Policy instruments encourage the application of a number of management strategies to restore and protect aquatic ecosystems and fill in the existing deficits. Compiling information on existing targets, deficits and management strategies would provide useful information for the definition and assessment of baseline scenarios in the AQUACROSS CS.

Descriptors and indicators currently used in policies can provide a starting point to help case studies focus on key aspects of ecosystems and develop targeted and measurable objectives to reach a desired state or status. This can then be used to assess effectiveness and facilitate the choice of alternative management responses. Using existing descriptors and indicators not only connects the local level to the national level, but also provides an opportunity to integrate higher-level (inter-)national objectives into local-level environmental decision-making processes.

As noted by the AQUACROSS AF, alternative management responses should be designed to restore the resilience and sustainability of the whole SES and not only the ecological system (via the identified policy objectives). In this sense, the design of alternative management strategies should consider a wider range of criteria (including e.g. socio-cultural dimensions) than the need to contribute to environmental policy objectives. According to the AQUACROSS Concept, responses should follow EBM principles and perform adequately against a set of assessment criteria. The following sections present in more detail key elements for the development of an operational EBM approach including the design and implementation of alternative management responses.

1.3 The Socio-Ecological System (SES)

According to the AQUACROSS Innovative Concept (DEL3.1), AQUACROSS' holistic approach to sustainability considers social and ecological systems as being complex, adaptive, and mutually interdependent. Hence, AQUACROSS builds upon the understanding of both systems and their interlinkages to develop innovative management approaches and tools. These are focused on the restoration and protection of critical aquatic ecosystem components as a means to sustain biodiversity and the delivery of ecosystem services in the long term.

The analysis of the relationship between social and ecological systems can actually be based on the analysis of the complex and adaptive processes taking place in the ecosystem and society, on one side, and on how these two are connected to each other. As shown in Figure 1, the social and ecological processes are intertwined by two sets of linkages: the demand-side connections, from society to ecosystems, and the supply-side connections, from ecosystems to society.

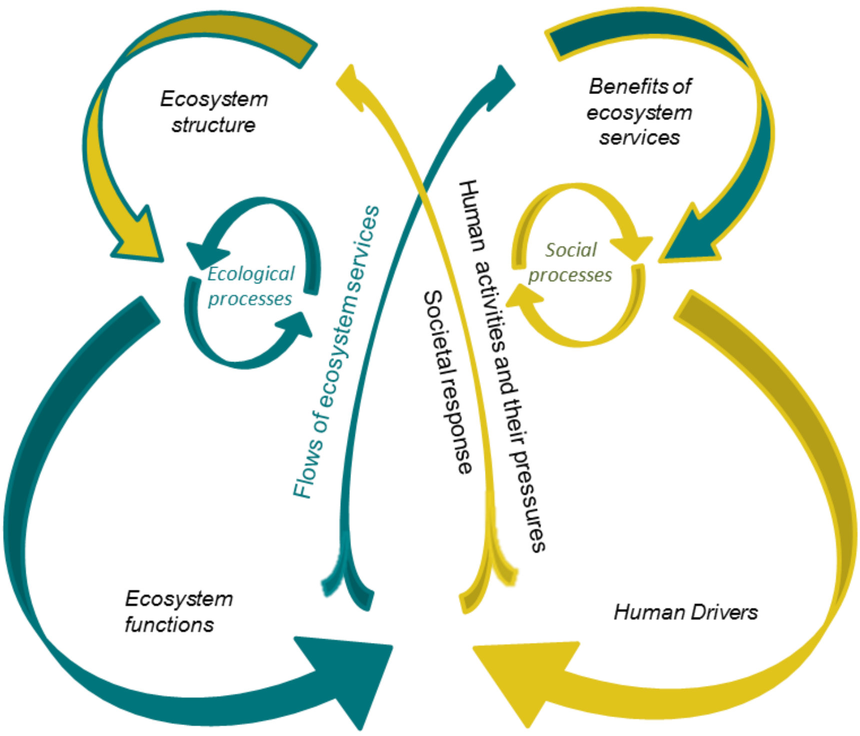

Figure 1: The Socio-Ecological System, adopted from AQUACROSS DEL3.1

Figure 1 shows how supply side linkages allow understanding the adaptive processes taking place in the social system (technological progress, adaptation to climate change, scarcity, water-borne risks, institutional change, population change, etc.). These supply side linkages are shaped by changes in ecosystems that affect their potential to continue delivering the ecosystems services that people should and/or actually care about (resource scarcity, increased risk, degraded water quality, climate change, changes in biodiversity, etc.). Within this framework the identification, design and implementation of policy responses in general and of EBM strategies in particular should be understood as a deliberate collective effort to provide a consistent adaptive response. This response should be better than current practice and make a real contribution to the improvement of the ecosystem (in an effective, efficient and fair way) and enhance the resilience and the sustainability of the whole SES.

The supply-side connections help understand the consequences of all ecological processes on human wellbeing, including those driven by human activities and social responses to ecosystem changes. This perspective contributes to represent and assess the changes in the status of the structural components of ecosystem (including biodiversity, as a macroscopic property) and how their functioning ultimately determines the current and future delivery of ecosystem services enjoyed by society. Nature contributions to people (NCP, the new IPBES approach as in Díaz et al., 2018) are all the outcomes, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) contributing to people's quality of life. The novelties of this approach are to recognise the central and pervasive role that culture plays in defining all links between people and nature and to operationalize the role of indigenous and local knowledge in understanding nature's contribution to people.

Likewise, the demand-side set of connections is key to understand the consequences of all social adaptive processes on the status of ecosystems, including those driven by changes in the ecological system. As a result of that, it is possible to understand and assess ecosystem impacts caused by human activities and their corresponding pressures as well as the consequences of the societal response to those changes in the ecosystem.

Policymaking is one of the relevant social adaptive processes that - along with research and innovation, technological development, institutional adjustments, changes in behaviour, investment in infrastructures, etc. - shape the social response to the challenges raised by ecosystem change. Policy making provides a deliberate and agreed collective response to the changes of ecosystems and the consequences of these changes for human wellbeing. EBM is an innovative approach guiding the decision-making process that intends to change current practices and provide better responses to current and emerging environmental challenges.

Figure 1 shows how ecosystem change triggers social processes, through supply-side linkages, and the outcomes of social processes result in changes in ecosystems, through demand-side linkages. The AQUACROSS AF allows the understanding of adaptive processes taking place in the social system (technological progress, adaptation to climate change, scarcity, water-borne risks, institutional change, population change, etc.) that are shaped by changes in the ecological system that affect (through e.g. resource scarcity, increased risk, degraded water quality, climate change, changes in biodiversity, etc.) the potential to continue delivering ecosystem services that individuals and society care about.

1.3.1 The AQUACROSS architecture to support EBM

The AQUACROSS architecture provides the analytical foundations to support the decision-making process when both establishing the problem (by assessing the baseline) and providing a solution through EBM, i.e. the design and assessment of alternative policy/management scenarios.

A resilient SES is one in which the effective co-production of ecosystem services (the demand side in the AQUACROSS architecture) does not exceed the capacity of ecosystems to provide them in a sustainable way (which is determined by the supply side in the AQUACROSS architecture). To understand this, we need to acknowledge that the benefits for society emerge from the co-production of ecosystem services provided by the ecological system, but which require the intervention of the social system in terms of its physical capital (infrastructures, fishing boats, etc.), human capital (skilled and unskilled labour), and social capital (institutions and norms).

Problems such as overinvestment in physical capital (irrigation, water storage and delivery, fishing vessels, turbines, mills and other infrastructures), together with excessive effort applied to the co-production of ecosystem services (e.g., water abstraction, fishing, hydropower production) lead to demands that exceed the ecosystems' natural capacity (over-abstraction, over-fishing, excessive regulation), resulting in environmental degradation (ecosystem processes impacted by excess demand) and an impaired capacity to provide benefits to human wellbeing (hence reducing ecosystems' supply in the short and the long term).

Identifying the demand-supply mismatch of ecosystem services is as important as understanding it as the outcome of social processes which need to be addressed to restore the resilience of the whole system. The lack of resilience not only involves a reduction of natural capital with immediate consequences for the allocation of physical and human capital. Besides inappropriate levels of natural physical and human capital, environmental challenges are the result of institutional or governance failures, hence of inadequate social capital. These failures are the result of rules governing the co-production of ecosystems services that are either inappropriate (e.g., excess fishing quotas or water use rights) or inadequately enforced (e.g., open access, abided overexploitation of groundwater, poorly protected natural reserves), or not responding to a legitimate collective interest but instead to the vested interest of specific stakeholder groups through, e.g. regulatory capture, lack of transparency and accountability, and other failures of the institutional processes.

Within this framework the identification, design, and implementation of policy responses in general, and of EBM strategies in particular, should be understood as a deliberate collective effort to provide a consistent adaptive response, that is better than current practice (by definition), which makes a real contribution to the improvement of the ecosystem (in an effective, efficient and fair way) and enhances the resilience and the sustainability of the whole SES.

The AQUACROSS architecture supports the institutional processes (including decision-making) by conveying scientific knowledge and integrating stakeholders' perceptions and information to help establish the problem (through an assessment of the baseline scenario) and the design of comprehensive societal responses involving EBM (management/policy scenarios). To that end, we distinguish three levels for the analysis:

1. The analysis of social processes (policy making, resource allocation decisions, investments in physical and human capital, etc.) that explain the mismatch between demand and supply of ecosystem services (problem setting) and that must be addressed to enhance the resilience and sustainability of the SES through EBM. From a policy perspective, the analysis of social processes should therefore focus on governance institutions involved in regulating

the economic activities that exploit ecosystem services and impact the ecological system. All these processes are dynamic and must be understood in relation to broader processes including technological improvement, institutional development, population dynamics, and climate change adaptation. Yet, their relevance (often as exogenous variables) can only be determined at the case study level.

2. The supply-side connection (from ecosystem to society), which depends on the capacity of natural capital to provide ecosystem services and which may be impacted by excess demand. The supply-side analysis focuses on understanding the mechanisms through which the ecosystem structure and functioning (which may be impacted by human pressures) affect the delivery of ecosystem services. This can be assessed both under the baseline scenario as well as potential alternative management scenarios. The supply-side analysis requires an understanding of how the ecosystem structure (including biodiversity) and its functioning support the co-production of three distinct sets of ecosystem services (i.e., provisioning, regulation and maintenance, cultural).

3. The demand-side connections (from society to ecosystem), which are about the effective capacity to co-produce these services combining natural capital with physical, human and social (including institutional) capital. The demand-side analysis, in turn, focuses on understanding the physical, human and social capital and their application to the effective exploitation of these ecosystem services. The economic activities that combine natural capital with other sorts of capital to produce ecosystem services cause pressures that may impact the ecosystem.

These three levels of the analysis support the establishment of the policy problems at hand in each CS, through an identification of the ecosystem services concerned, the economic activities that may be affected either positively or negatively, and who the actual winners and losers are or would be. This applies both to the baseline scenario, as well as in any alternative scenario. In addition, this analysis supports the identification of institutional failures that need to be addressed to provide better adaptive responses of the social system.

A holistic analysis does not necessarily cover all the dimensions of the SES or all the components that make up the SES. That is a misconception of holistic assessments, and one of the reasons EBM fails (DeFries and Nagendra, 2017). Detailed information, even if based upon strict classifications, might be useless if not linked to the problem at hand. Holistic analyses are based upon a meaningful and relevant knowledge base. This does not mean covering everything, but rather avoiding downplaying or even overlooking relevant linkages and processes.

Similarly, information and data are not valuable in themselves but rather as a result of their relevance to support the making of better decisions. This, therefore, requires a problem-oriented assessment of the knowledge base and the institutional set-up that is intended to support EBM decision-making. The inter-linked social and ecological processes are complex and adaptive and "the connections between ecosystem processes and benefits to humans are complex, non-linear and dynamic" (Costanza et al., 2017). The identification and definition of all the variables and connections implied in the three perspectives, at every possible temporal, spatial and institutional scale if feasible, are well beyond the scope of current knowledge. Moreover, efforts in this direction might distract time and resources away from the analysis of those linkages and processes that are relevant in the particular context and scale at hand. Therefore, instead of screening and listing all the potential variables and indicators implied in these analyses, the assessment should rather focus from the onset on the relevant social processes and ecosystem components that are key to understand the social processes and how they are connected to the ecological system for both the supply and the demand sides.

1.3.2 EBM components: enhancing ecosystems and their governance

A comprehensive analysis of EBM should, therefore, not only cover the individual actions or strategies with the best potential to contribute to the societal goals of enhancing and restoring ecosystems and their potential to deliver ecosystem services, but also to build the capacity of the social system to go forward and adapt itself to make EBM happen. EBM's social capacity includes changing and adapting rules and institutions, harnessing scientific knowledge to better support social decisions, seizing the opportunities of new technologies, and all other social changes that might enhance the capacity to improve societal responses to actual and future ecological challenges.

This is why when designing EBM responses, we need to distinguish between institutional and other changes in the social system. That means distinguishing the EBM policy instruments from the measures directly intended to act over the ecological system (i.e., the individual measures and the programmes of measures intended to enhance the ecosystem). Policy instruments refer to all complementary, encompassing actions designed to overcome the political, economic, institutional, and technical information and other drawbacks that prevent or limit the effectiveness of strategies as well as all the support actions intended to enhance the capacity of the social system to better adapt and respond to current and future changes in ecosystems. PoMs refer to actions that if properly designed and implemented, would result in an improvement of the ecosystems and their constituent parts, and then contribute to the primary environmental objectives of public policy.

An EBM management plan is a structured combination of a PoM, intended to reach precisely defined environmental objectives, and an implementation plan with all the means for their implementation, chosen and designed to make them happen (thus to make them technically feasible, affordable, acceptable, legitimate, etc.) and to maximise their effectiveness, efficiency, and fairness, as well as their socio-cultural impact (for instance through social cohesion), and thus to contribute to the sustainability and the resilience of the whole SES.

The building of an EBM management plan must start with the pre-screening of both the measures and the means for their implementation. On this basis, once environmental challenges and policy objectives have already been defined, the first two steps are:

1. *Identify which EBM actions or measures, if adequately designed and implemented, offer the largest potential to meet environmental goals at the case study level.* The outcome of this process is a catalogue of potential measures, addressed to change activities, reduce their pressures, mitigate their impacts, restore components of the environment, etc. that might be combined to design a PoM. Individual measures are to be compared to each other based on different criteria. This analysis should be refined and updated after the consideration of policy instruments.

2. *Identify policy instruments* required to improve the social capabilities to take advantage of the opportunities of EBM resulting in the successful implementation of the PoM. The assessment of the baseline scenario is the basis for the identification of political, institutional, financial, technical, and other barriers that should be overcome to implementing the above-mentioned package of measures, as well as of the complementary and support measures with the best potential to maximise their effectiveness and reduce their implementation costs, among all above-mentioned criteria, and as explained in the next section.

1.4 The AQUACROSS assessment criteria

The AQUACROSS Innovative Concept and Assessment Framework stand for the comprehensive assessment of baseline and alternative courses of action, through the systematic application of three sets of assessment criteria designed to be applied also at three different but closely intertwined levels of analysis:

1. Process-oriented criteria to assess decision-making processes and institutions in the baseline scenario and the changes to these pathways and institutions required to build, design, and implement EBM management plans. Process-oriented criteria (e.g., stakeholder involvement or the implementation of integrated and/or adaptive management) are key to evaluate the governance failures that lead to baseline environmental challenges and that should be addressed to enable the social system to grow to the challenge of implementing EBM.

2. System-oriented criteria to assess the knowledge base of the SES in terms of its capacity to guide EBM thereby contributing to the resilience, adaptability, and transformability of the SES.

3. Outcome-oriented criteria to assess the actual and potential consequences of current and prospective management actions in terms of their (see Section 2.3.2 of DEL3.2):

    - effectiveness (to reach predefined environmental goals),
    - efficiency (in terms of subsequent gains and losses of wellbeing at individual and collective levels, and the distribution of these impacts and costs throughout society),
    - equity (in terms of the distribution of benefits and costs across society and for the alternative courses of action).

Outcome-oriented criteria are instrumental to judging the baseline by focusing on the cost of inaction and on opportunities to achieve societal goals, enhance wellbeing and equity that can be seized by implementing EBM strategies. Socio-cultural dimensions are within this third set. These outcome-oriented criteria are the cornerstone in the analysis of measures and instruments both on a one-by-one basis and in the building of management plans to achieve societal goals.

These criteria will be further developed in chapter 2.

1.5 Principles of Ecosystem-based Management

EBM is the cornerstone of all AQUACROSS work, and is probably best understood by considering its foundational concepts or principles as many definitions of EBM exist. The following definition, proposed by Long et al. (2015), is based on a thorough review of the extensive literature around EBM, comfortably fits within the AQUACROSS concept (DEL3.1):

"Ecosystem-based management is an interdisciplinary approach that balances ecological, social and governance principles at appropriate temporal and spatial scales in a distinct geographical area to achieve sustainable resource use. Scientific knowledge and effective monitoring are used to acknowledge the connections, integrity and biodiversity within an ecosystem along with its dynamic nature and associated uncertainties. EBM recognises coupled SES with stakeholders involved in an integrated and adaptive management process where decisions reflect societal choice".

EBM thus aims at achieving the long-term sustainability of resource use by focusing on protecting the capacity of ecosystems to provide key services to society, ultimately contributing to human wellbeing. Long et al. (2015) analysed the relative importance of 15 different EBM principles in peer-reviewed literature. In order of decreasing importance, these 15 principles are:

1. Consider Ecosystem Connections
2. Appropriate Spatial and Temporal Scales
3. Adaptive Management
4. Use of Scientific Knowledge
5. Integrated Management
6. Stakeholder Involvement
7. Account for Dynamic Nature of Ecosystems
8. Ecological Integrity and Biodiversity
9. Sustainability
10. Recognise Coupled Social-Ecological Systems
11. Decisions reflect Societal Choice
12. Distinct Boundaries
13. Inter-disciplinarity
14. Appropriate Monitoring
15. Acknowledge Uncertainty.

These 15 EBM principles are compared to requirements that come from the concept of resilience thinking and will be the basis to assess the SES knowledge base in terms of its capacity to guide the development and implementation of EBM.

1.6 Scenarios and management plans

If societal goals are not achieved under current or future scenarios, a societal response involving EBM should contribute to the achievement of those societal goals. Here the main phrases are introduced and described based on information in previous AQUACROSS deliverables.

Scenarios are coherent, internally consistent, and plausible descriptions of a potential future trajectory of a system to assess current practice, screen new opportunities, and improve the design and implementation of policy responses (see AQUACROSS DEL3.2). The AQUACROSS DEL7.2 provides a clarification of terms that are often used in relation to describing the state and future trajectories of a SES. From the holistic perspective of a SES, it is of particular relevance how a societal response emerges, i.e. from social feedbacks, but also directly interacts with the ecological system, through i.e. management strategies.

Within AQUACROSS, a distinction is made between:

- **A baseline scenario** represents a shared view of past, current and prospective trends and vulnerabilities in ecosystem services and biodiversity. It is associated with challenges and opportunities in a case study and based on management practice as usual (sometimes called "business as usual" or BAU scenario). It describes a trend under the assumption that there is no alternative, new action: what would happen if the different drivers exert pressures over European aquatic ecosystems on a pathway from today towards 2020 and 2030 (Gómez et al., 2017). In other words, AQUACROSS baseline scenarios integrate future, dynamic social-ecological interactions. This is beyond conventional baseline scenarios, where only the consequences from currently implemented policies of what is happening today are projected together with biophysical trends. Therefore, for example, current adaptive strategies that foresee the dynamic adjustment of management indicators (i.e., fishing quotas) are included in the AQUACROSS baseline scenario.
- **An alternative policy scenario (or Management scenario)** represents objectives, deficits and alternative pathways (potential management interventions) for reaching a target (normative) or to represent, assess and compare the outcomes of several alternative policy instruments or measures (descriptive), both ex-ante or ex-post, by comparison against baseline scenarios.

To develop and operationalise EBM, alternative scenarios can be used to estimate and test the consequences over time from putting different management strategies into practice. Those scenarios can be evaluated with various tools, i.e. analytical tools or simulation models, and in collaboration with stakeholders in two ways: a) in a more descriptive way, where the consequences from applying the management strategy are projected and later assessed to which degree they meet selected management targets (derived from societal goals), or b), in a more normative way, where from the perspective of a management target, only management responses that are expected to meet the target are assessed regarding their implied costs. Ideally, new policy or management scenarios take into account multiple measures and policy instruments. The degree to which the scientific knowledge base and the institutional set-up that inform the design and implementation of the management plans fulfils EBM principles, e.g. the robustness against climate change or the ability to adapt institutions over time, can then be assessed via the system-oriented and process-oriented criteria based on the AQUACROSS AF.

1.7 Indicators

In a management context, indicators are chosen to facilitate tracking of ecosystem status and trends relative to policy objectives (Levin et al., 2009). Indicators can relate to the condition of natural or human systems, and should encompass both (Tallis et al., 2010)[1].

An indicator refers to a variable that provides aggregated information on certain phenomena, acting as a communication tool that facilitates a simplification of a complex process. It relates to the component or process responsive to changes in the SES, but does not possess a measurable dimension. Therefore, it is not an operational tool in itself.

A summary of potential indicators is provided for human activities, pressures and ecosystem state in DEL4.1. In addition, DEL5.1 brings together classifications used by different approaches in an attempt to facilitate the identification of indicators for biodiversity and the state of the ecosystem (Table 1) as well as the functions, services, and benefits (Table 2) based on this.

[1] The term indicator is interchangeably used in the literature with related concepts like measure, metric and index. Please see DEL4.1 and DEL5.1 for the consolidated definitions used in AQUACROSS.

Table 1: Classification for biodiversity and the state of the ecosystem, applicable to aquatic ecosystems

AF stage	Biodiversity (BD) *hierarchical (non-hierarchical)*				
Levels	**Category (C)**	**Section (S)**	**Division (D)**	**Group (G)**	**Class (Cl)**
Instructions	two approaches are possible:	for each of the previous approaches, there are several alternatives:	for each of the three previous alternatives in Category 1 Diversity, any of the following three approaches is possible:	Diversity or Ecosystem State can be assessed at different levels (as suitable):	for the different levels grouped under Biodiversity components there are several detailed classifications available, linked to different environmental policies, as indicated below:
	1. Diversity	1. genetic diversity 2. structural diversity 3. functional diversity	**(Diversity assessment scale)** 1. alpha diversity ("local") 2. gamma diversity ("regional") 3. beta diversity (turnover or dissimilarity)	**(Biodiversity components)** 1. species 2. population 3. community 4. habitat (includes abiotic features) 5. ecosystem	1.1. WFD & MSFD taxonomic classific.* 1.2. MSFD functional groups classific.* 1.3. Functional traits classifications* 2.1. n.a. - *go to next level:* ***Indicators and /or indices (I;i)***
	2. Ecosystem State	*(taken from Teixeira et al. 2016; definitions therein)* 1. Indicator Species 2. Target Groups 3. Physiological Condition 4. Population Ecology 5. Community Structure 6. Life Traits 7. Foodweb 8. Thermodinamically Oriented 9. Biotope Features	n.a. - *go to next level:* ***Group (G)***		3.1. EUNIS classification level 4* 4.1. HD classifications 'level 3' (habitat type)* 4.2. EUNIS classification level 3 *(habitat)** 4.3. MSFD predominant habitats classification* 4.4. WFD supporting elements & Hydromorphological features* 5.1. n.a. - *go to next level:* ***Indicators and /or indices (I;i)***

Table 2: Classification proposed for ecosystem functions and ecological processes

AF stage	Ecosystem Functions (EF) *hierarchical (non-hierarchical)*				
Levels	**Category (C)** **Function category**	**Section (S)**	**Division (D)** **Ecosystem Function**	**Group (G)** **Ecological Processes**	**Class (Cl)**
Instructions	n.a.			(a Process can be associated to several EF)	n.a.
	1. Production		1.1. Primary production 1.2. Secondary production	1.Bioturbation 2.Denitrification	*n.a. - go to next level:* ***Indicators and /or indices***
	2. Biogeochemical cycles		2.1. Hidrological cycling (O and H) 2.2. Carbon cycling (C) 2.3. Nitrogen cycling (N) 2.4. Phosphorus cycling (P) 2.5. Sulfur cycling (S) 2.6. other element cycling 2.7. Nutrient retention 2.8. Carbon sequestration	3.Evapotranspiration 4.Grazing 5.Growth 6.Mineral weathering 7.Mobility 8.Mutualistic interactions 9.Nitrification 10.Nitrogen fixation	*n.a. - go to next level:* ***Indicators and /or indices (I;i)***
	3. Structural (Directly mediated by ecosystem structural components - Mechanically & Physically structuring)		3.1. Habitat provision 3.2. Nursery function 3.3. Breeding grounds 3.4. Feeding grounds 3.5. Refugia 3.6. Dispersal 3.7. Biological control 3.8. Decomposition (mechanical&chemical) 3.9. Filtration 3.10. Sediment stability & formation	11.Nutrient uptake 12.Pellitization 13.Photosynthesis 14.Predator-prey interactions 15.Productivity 16.Respiration 17.Sediment food web dynamics 18.Shell formation 19.Structure building 20.Vegetation succession	*n.a. - go to next level:* ***Indicators and /or indices (I;i)***

While these indicators were primarily intended to enable the structuring and organisation of the knowledge base including the forecasting tools in relation to the SES, CS-specific indicators (or metrics or indices) will need to be selected for the actual evaluation of the performance of management strategies. These CS-specific indicators are not necessarily identical to the potential indicators proposed in AQUACROSS DEL4.1 and DEL5.1.

2 An operational EBM approach

Because of the inherent complexity of ecosystems and the inability to foresee all consequences of management interventions across different spatial, temporal, and administrative scales, EBM is considered a "wicked problem" that has no clear-cut solution (DeFries and Nagendra, 2017). DeFries and Nagendra distinguish two types of traps that can curtail the desired incremental, partial improvements to such a wicked problem as EBM is: (1) oversimplifying a problem and assuming that a technical solution will fix the problem and (2) inaction from overwhelming complexity. In developing an operational EBM approach, we follow the AQUACROSS AF way of thinking (which is in line with that of DeFries and Nagendra, 2017 and Borgstrom et al., 2015) that EBM should be considered an incremental piecemeal process as opposed to a single (giant) leap from traditional management to EBM. Together with this requirement to develop an EBM approach that can be applied as part of "adaptive management" and "complex adaptive systems thinking", this resulted in the development of the cyclical AQUACROSS EBM approach that may be advanced with every iteration of the management cycle. The further development of this EBM approach builds on the AQUACROSS AF, which introduces the key principles of EBM (Long et al., 2015) (see chapter 1.5), but these are merged with examples from recent literature including:

- the systemic approaches to wicked problems proposed by (DeFries and Nagendra, 2017) and aligned to
- the management phases in (Borgstrom et al., 2015) as well as
- the core elements in the planning process for ecosystem-based marine spatial planning (Ansong et al., 2017).

Each of these approaches and their relevance to the AQUACROSS EBM approach are described in the Annex.

This, then, leaves us with 4 distinct phases in the AQUACROSS EBM approach (see Figure 2):

- **Societal goals**: Identification of societal goals based on policy objectives and stakeholder preferences. This is further elaborated in chapter 2.1.
- **Description of the socio-ecological system**: Assessment of the baseline scenario, which is the equivalent of the "defining and analysing existing conditions" in (Ansong et al., 2017). Following the AQUACROSS architecture we explicitly distinguish between the ecological system and the social system. This is further elaborated in chapter 2.2.
- **Planning a comprehensive EBM response**: For the AQUACROSS EBM approach this planning phase starts with the pre-screening of alternatives and finalises with the agreement on an EBM plan. In this planning phase, we distinguish between the sub-phases "identification and pre-screening" of measures and policy instruments (chapter 2.3) and "evaluation of expected performance" of measures (chapter 2.4).

- **Implementation, monitoring and evaluation:** This is where the implementation of the management coincides with the initiation or continuation of a monitoring and evaluation program.

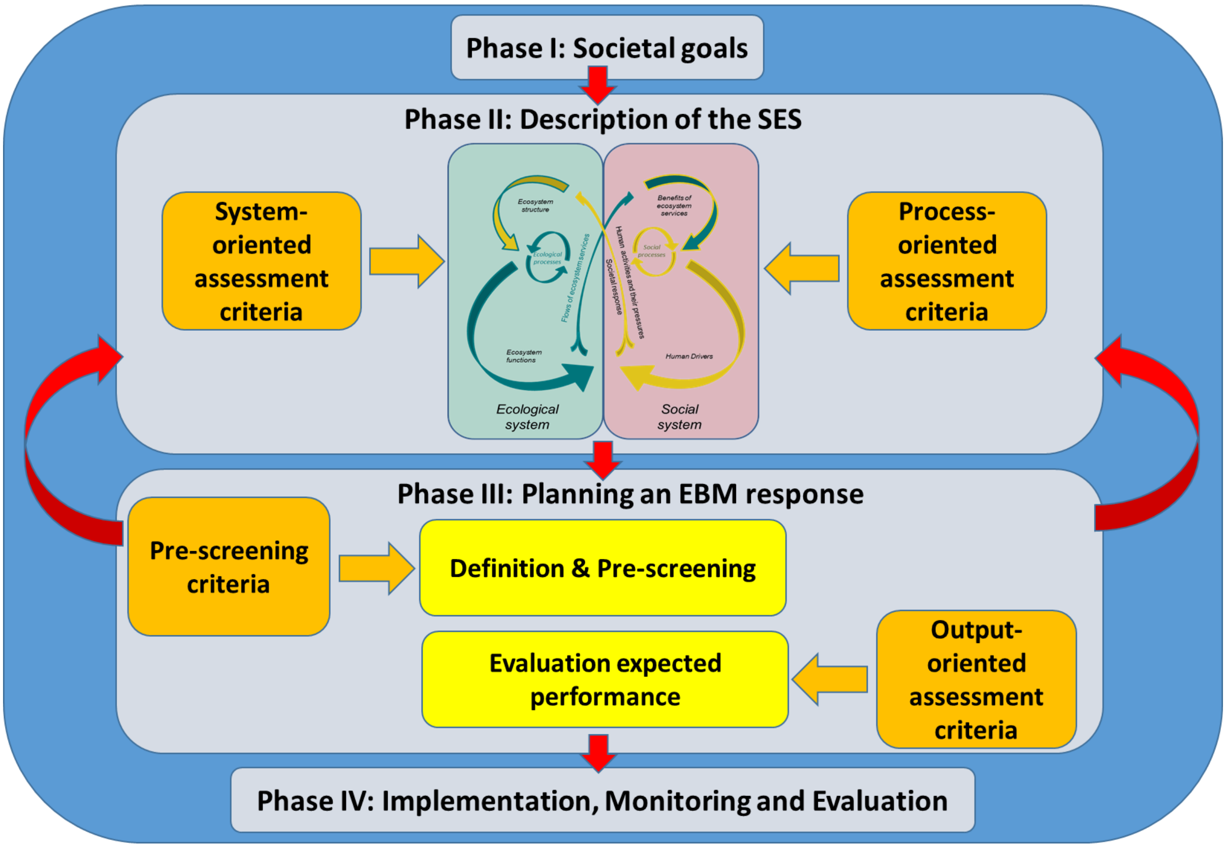

Figure 2: The AQUACROSS EBM approach consisting of 4 phases for which different assessment criteria apply[2]

This distinction helps in understanding the relevance of the AQUACROSS assessment criteria and the role of the different governance actors in the EBM approach and guides the assessment of this EBM approach aimed and its performance to achieve the societal goals. Each phase of the AQUACROSS EBM approach thus consists of an assessment part that feeds back into the same phase or one of the previous phases. This will be further elaborated in the remainder of this chapter.

Stakeholder participation occurs throughout the EBM approach in each of the phases. The AQUACROSS EBM approach allows feedback from the “Management plan” phase back into the

[2] Note: The different EBM phases consist of Phase I “ Societal goals” (see chapter 2.1), “Description of the socio-ecological system” (see chapter 2.2), “Management strategies” phase (with sub-phases described in chapters 2.3 and 2.4) and Phase IV “ Implementation, monitoring and evaluation”. This approach is further elaborated in figure 5.

“Description of the socio-ecological system”. This feedback may be based on the pre-screening or the evaluation of the performance of the management alternatives through management strategy evaluation (see chapter 2.3).

These elaborate feedback loops in the AQUACROSS EBM approach are shown in figure 3. This commences with an assessment of the current situation against societal goals. This current situation emerged after the completion of a past management cycle resulting in the implementation of what we now consider the baseline or BAU management strategies. This baseline assessment is thus based on the outcome of the “Monitoring and evaluation” phase from what can be considered a previous management cycle. This, then, is the starting point of the first cycle in the AQUACROSS EBM approach as reflected in the flowchart below and resulting in alternative management strategies that can be assumed to perform better in achieving the societal goals (Figure 3).

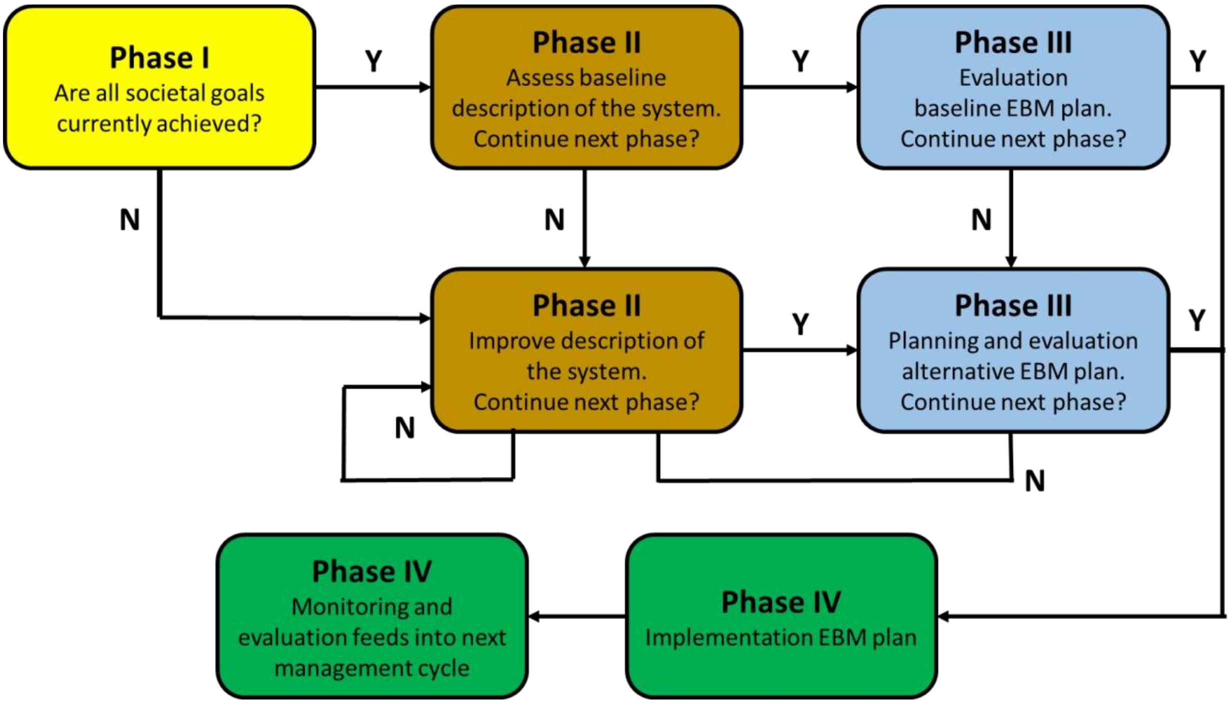

Figure 3: Flowchart of a typical EBM cycle in the AQUACROSS EBM approach distinguishing different management phases and sub-phases

2.1 Societal goals

Based on the framing outlined in Section 1.2, this section presents the concrete steps to carry out a policy characterisation of the CS and the definition of policy objectives and societal goals:

1. Key threats: Identify and describe the main human activities and their pressures leading to the loss of aquatic biodiversity, and report relevant information on ecosystem status

2. Key policies: Assess how existing policies restore or protect aquatic biodiversity, or lead to the contrary, and describe their objectives, targets and instruments
3. Key synergies and conflicts: Assess key synergies and conflicts between identified policies, and evaluate policy gaps (integrative assessment)

2.1.1 Key threats

This step aims to provide a brief overview of the key threats impacting aquatic biodiversity. This step involves selecting specific human activities and their pressures (i.e., threats) to focus on for the policy analysis. This selection should not only reflect the most significant pressure with regards to the loss of biodiversity, but also their social significance and salience to local actors. This first step involves using information from the characterisation of the SES (i.e., from WP4 and 5) to construct a knowledge base on the key CS-specific threats. Member State assessments and reports for the different policy directives can also help guide the identification of relevant descriptors and the best sources of information within a specific region or area.

2.1.2 Key policies

This step aims to provide an overview of the relevant policy instruments with a more detailed description of those selected. This description should include their objectives, targets, current deficits or gaps (difference between current state/status and policy targets), management strategies, administrative body in charge, scale of implementation, stakeholder groups, and funding. As discussed in Chapter 1, it is likely that multiple policy instruments at European, national, regional and local levels are relevant in any given case study, especially when multiple significant threats affect the aquatic environment. It is thus important not to try to describe in detail all relevant policy instruments but only select the most relevant ones. Criteria that can be used to select the most relevant policy instruments include in particular:

- The policy instrument increases the main threats, i.e. human activities and their pressures leading to the loss of biodiversity in the CS (i.e., key sectoral policy).
- The policy instrument mitigates the main threat leading to the loss of biodiversity in the CS (i.e., key environmental policy).
- The policy instrument, or parts of it, is a good example for the rest of the EU of how to promote effective restoration and protection of the type of aquatic ecosystems occurring in the CS.
- The policy instrument prevents or creates challenges to effective restoration and protection of aquatic ecosystems of the CS.

It is important to consider the national/regional/local instruments of one of the four key EU environmental policies (i.e., WFD, MSFD and Nature Directives). This will provide a link between the top-down/ European perspective with what is done at the local level. There will also be local policies of interest to the project, in particular strategies, instruments, and (funding) mechanisms used in the CS countries, regions, cities, etc. which offer innovative ways of dealing with the threat(s) of interest.

An area of interest for the policy characterisation at the CS level is to examine how to overcome conflicts between environmental and sectoral policies. It is thus important to consider both “positive” environmental policies (e.g., contributing to the protection of aquatic biodiversity) and “negative” sectoral policies (e.g., intensifying activities and pressures). Evaluation of synergies and conflicts between environmental policies is a key area of interest for the establishment of integrative policy objectives, as the next step presents.

Policy instruments do not work in isolation. Thus, one, two or more policy instruments may be used purposefully collectively to tackle a particular pressure or driver, as part of a well-designed policy mix. In this situation, it is recommended to consider combination of policies in the more detailed analysis.

2.1.3 Key synergies and conflicts

This step aims to provide (i) an overview of the ways in which the key policies tackle the threat(s) or reinforce the threat(s), (ii) an assessment of key synergies and conflicts between these key policies, and (iii) an evaluation of important gaps in this policy framework. In doing this we distinguish between

- A screening phase, which is a more systematic assessment to highlight the range of synergies, conflicts and gaps that can be observed between the selected policies.
- A more in-depth analysis, which will provide more information / detail on the nature, implications and underlying reasons of key synergies, conflicts and gaps.

It is possible that ad-hoc interviews with relevant stakeholders (e.g., policy makers in the biodiversity, inland water or marine areas of the case study; local experts and interest group representatives; local managers; etc.) are useful or needed to better characterise these synergies, conflicts and gaps. Other considerations are:

- The key question for all case studies remains the examination of policy integration related to the implementation of the EU Biodiversity Strategy 2020: i.e. what are best practices, what are the challenges, how can we respond to it (using EBM).
- It is relevant to look at the interaction of biodiversity policy (for example linked to the Habitats and Birds Directive) with other environmental policies (in particular water and marine policies with the WFD and MSFD, but others should also be considered) and sectoral policies (for example fisheries, agriculture, hydropower, transport to name a few significant ones).
- Case studies should focus on providing local expressions of the strategic questions for greater policy integration at EU level: integration of MSFD/WFD and Nature Directives (e.g., on coordination of responsibilities, management systems and data & monitoring), WFD and CAP (e.g., conflicts with direct payments, insufficient cross-compliance, rural development targets coordinated with HBD/WFD), MPAs and fisheries policies, green infrastructure, etc.

The analysis of policy synergies, conflicts and gaps should provide a good understanding of the key opportunities and challenges for developing and implementing alternative EBM options. The contents of the knowledge base describing the SES with the aim to guide this EBM process are shaped by the outcome of this phase. The requirements of this knowledge base to inform the decision-making process in order to achieve the societal objectives are presented in the next section.

2.2 Understanding the socio-ecological system

The description of the SES constitutes the knowledge base of the AQUACROSS EBM approach (see chapter 2): the baseline scenario (to set the problem up) and the decision-making processes (to improve them). In order to inform the decision-making process this knowledge base should:

- cover all the relevant components and aspects of the ecological system that are necessary to assess the current or future status of the ecological system in relation to the societal goals;
- include all the major institutional actors that drive the processes of the social system responsible for
    - the societal response, i.e. management strategies, to mitigate the impact of the human activities or restore the ecological system in order to achieve the societal goals,
    - and the co-production of the ecosystem services and abiotic outputs to improve human wellbeing.

Therefore, this phase consists of an assessment to determine if this knowledge base is fit for purpose. To that end we have developed process-oriented and system-oriented criteria.

The AQUACROSS SES consists of the ecological system and the social system each with their own internal processes. These two systems are connected through supply-side connections, i.e. ecosystem services (from the ecological system into social system) and demand-side connections, i.e. the allocation of human activities mitigated through a societal response (social system into ecological system) (see chapter 1.3 and figure 4).

As previously mentioned (chapter 2) each phase of the AQUACROSS EBM approach consists of an assessment part of which the outcome feeds back into the same phase or into one of the previous phases (see figures 3 and 4). The assessment of this phase therefore consists of a focus on:

- The SES in terms of its capacity to co-produce the ecosystem services and abiotic outputs demanded by society. This involves an understanding of the ecological system including its ecological integrity and biodiversity and the human activities and their pressures which co-produce the services demanded by society while simultaneously causing an impact that may compromise achieving societal (environmental) goals. The system-oriented criteria for assessment are introduced in chapter 2.2.1 and Table 3.
- The social processes and their institutional actors on which the development and implementation of EBM depends. Here we distinguish the main governance actors based on Rockmann et al. (2015) but slightly modified so that instead of a category called 'decision-

makers' they distinguish between policy-makers (responsible for setting the goals) and managers (responsible for implementation of the management strategies). The process-oriented criteria for assessment are introduced in chapter 2.2.2 and Table 4.

The feedback loops in the EBM approach should then result in a continued incremental improvement of the description of the SES, i.e. the knowledge base, and an improved understanding of the relevant processes and the institutional actors involved.

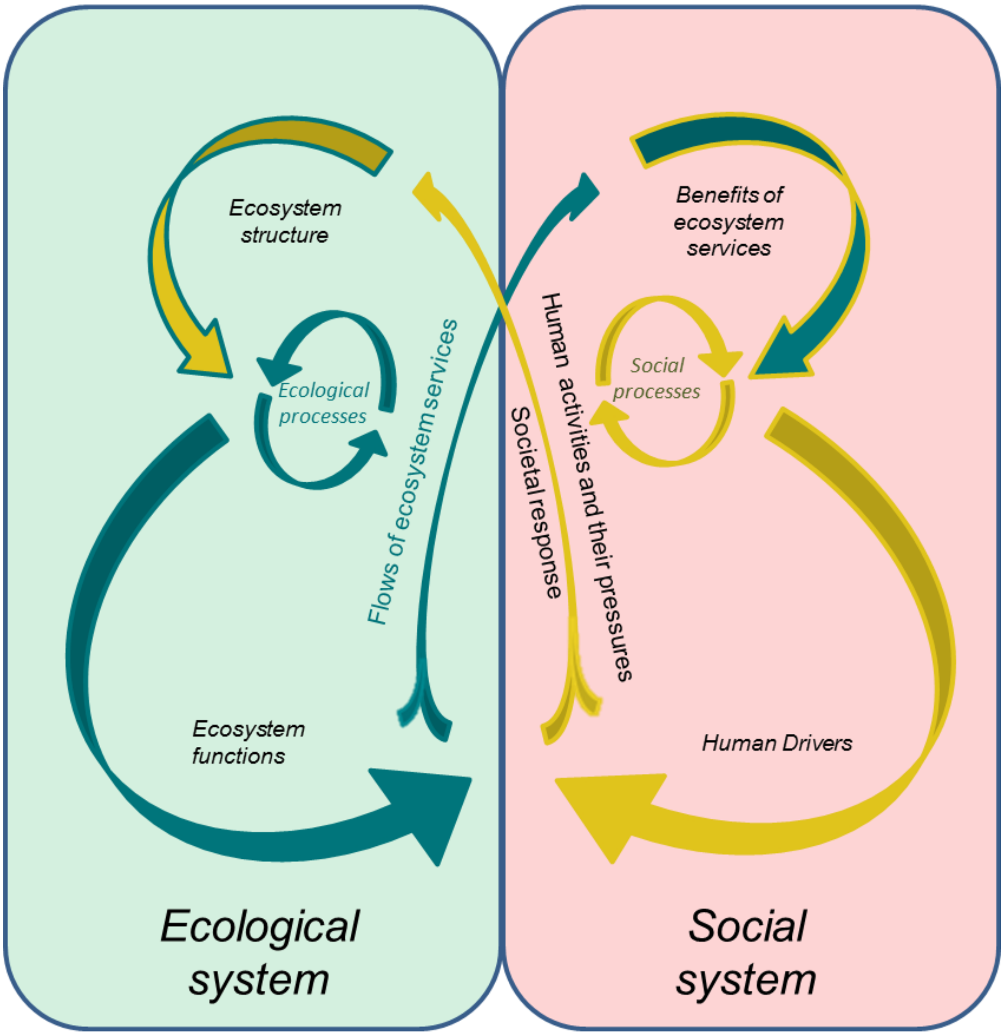

Figure 4: The AQUACROSS architecture of SES and its processes (AQUACROSS DEL3.1)

2.2.1 Assessing the SES: a focus on relevant linkages and knowledge

To avoid one of the two traps for a wicked problem such as EBM, i.e. inaction from overwhelming complexity, each CS should determine the different components of the SES that are more relevant for assessment, including all relevant components and their potential linkages (see chapter 1.3). These "relevant" components for assessment need to be covered by the knowledge base in order to allow the assessment of the current state as well as the performance of the management strategies to achieve the societal goals.

Table 3 introduces the relevant questions to advance towards a better understanding of the system and of the knowledge base that allows understanding it. The table links ecosystem aspects according to (Borgstrom et al., 2015) their match with the EBM principles (Long et al., 2015), the resilience thinking (including complex adaptive systems, CAS) and the systemic approaches to solve wicked problems (DeFries and Nagendra, 2017).

Table 3: System-oriented criteria to assess the knowledge base of the SES

Ecosystem aspect	EBM principles	Resilience principles	Systemic approaches	Generic assessment questions
Ecological integrity and biodiversity	Ecological integrity and biodiversity	Maintain diversity and redundancy	Incorporating natural capital and ecosystem services in markets	This can be achieved by defining and conserving a diversity of species traits or functional groups that support the integrity of the ecosystem, or check the three aspects: variety, balance and disparity. Are these explicitly considered in the knowledge base? The ecological structural components determine the functioning of the ecological system. Hence the link to the "Relations and ecological processes" criterion: a knowledge base that covers more relevant components or detail is better.
Relations and Ecological processes	Consider ecosystem connections	Manage connectivity	Incorporating natural capital and ecosystem services in markets	Is determined by the ecological part of the SES (e.g., by mapping critical connections) and is linked to the "Biodiversity" aspect as more components and/or detail increase this aspect (e.g., in terms of taxa considered in the food web). This can be improved with an indication of the importance of a connection (e.g., strength of predator-prey relationships). Ecological functioning determines the provisioning of ecosystem services which contribute to human wellbeing and as such can be incorporated into (economic) markets.
Changes and Uncertainty	Account for dynamic nature of ecosystems	Manage slow variables and feedbacks, CAS		Variation in the ecological part of the SES, e.g. due to perturbations, should be considered. Longer time-series are better. Do exogenous scenarios of environmental change, e.g. climate scenarios, exist? Strengthen feedbacks that maintain desired regimes, break or disturb feedbacks that maintain undesired regimes; look for non-linearity's in the system as these are often the cause for the dynamic nature.
	Acknowledge uncertainty	Part of CAS		This requires transparency on the quality of the knowledge base which could be reflected, e.g. through the assessment of uncertainties, reporting of crucial (model) assumptions and confidence intervals in the output, and communication about these. The EBM process aspect "Adaptive management" and "stakeholder participation" is required if uncertainty is high.
Scales and boundaries	Appropriate Spatial and	Part of CAS		Which scales to consider (in different domains also; e.g., ecological, jurisdictional, administrative or

	Temporal Scales			political)? Use a systems framework to address relevant scales and how they interact. Assessment should occur at the ecosystem scale. If other scales are relevant and do not match with the ecosystem scale this needs to be identified. What are the appropriate spatial and temporal scales (or resolution) of the (eco)system? For example, size of spatial grid and temporal units, e.g. years, months.
	Distinct boundaries	Part of CAS		Acknowledge boundaries and thus the fluxes and influences from outside of the boundaries of the ecosystem. Consider both jurisdictional boundaries as well as ecosystem boundaries. Are transboundary issues considered? E.g., terrestrial run-off into rivers and lakes or inflow of rivers into the coastal/marine ecosystem. The definition of boundaries should allow the adaptation of institutions in a good social-ecological fit
Human activities and their pressures	Recognise coupled SES	Foster CAS thinking	Incorporating natural capital and ecosystem services in markets	Are all relevant flows between the social and the ecological system that make up the SES considered? How many linkages, or how much of the activities, pressures and ecosystem components (and ecosystem services?) does the relevant SES (used in the MSE) cover compared to the comprehensive SES.
	Consider cumulative impacts	Part of CAS, feedbacks		Apply an integrated perspective, including all activities and their pressures acting on the ecosystem is better. See row above. Consider synergistic or antagonistic cumulative effects.

2.2.2 Understanding the policy making process: focusing on the relevant actors, objectives and institutions

Policy making is a central social process that must be understood in order to ascertain current policy decisions and the changes that would need to be made to improve governance and identify the changes required to help the social system grow to the challenge of providing EBM responses to current and prospective sustainability challenges.

Understanding current policy making processes is as important as understanding the full SESs. Current drivers and pressures are the outcome of multiple individual decisions regulated by institutions and thus they can be understood as the outcome of a social process on which the ecosystems users, scientists, managers, authorities, third parties and other stakeholders play a differential role in defining the collective or societal goals. From a governance perspective, it is critical to consider the asymmetry between individual interests and public or collectively agreed objectives. The planning of the management responses up to their implementation is based on the collaboration of science, policy and all other stakeholders whereas the implementation of the management plans is primarily done by the managers and the user with some input from science (e.g., in applying the precautionary approach, see Table 4). Finally, the “monitoring and ex-post evaluation”, provided there is such a thing, should be, primarily a scientific exercise. These roles translate into the matching of the specific EBM principles (see section 1.5) to the actors and their interpretation reflected in the specification of the process-oriented criteria (see table 4).

The following table presents a detailed list of the relevant questions to be answered in order to represent and understand the policy making processes. These questions are organised around the EBM principles and their answers will support the identification of the drawbacks of current decision processes as well as the opportunities to advance towards EBM by enhancing the application of the EBM principles

Table 4: Process-oriented criteria to assess the SES governance in terms of its capacity to implement EBM.

Policy Dimensions	EBM principles	Systemic approaches	Generic assessment questions
Scientific knowledge	Use of Scientific Knowledge		Has the knowledge been produced according to the scientific standards? Is the methodology appropriate? Are procedures transparent? Is there consensus on the quality of the available (scientific) knowledge? See "Interaction between scientists and decision-makers to foster salience in scientific input" and "Interaction between scientists and other actors to foster credibility in knowledge production" (Rockmann et al., 2015).
	Inter-disciplinarity	Incorporating natural capital and ecosystem services in markets	Was the appropriate expertise in terms of relevant disciplines applied when producing the knowledge? Can stakeholder knowledge be integrated? The aim is to progress from multi- to inter- to transdisciplinary science. Where would you position the CS science on this continuum?
	Stakeholder involvement		Science could benefit from knowledge available with other stakeholders, notably the business sector. Stakeholders can play a role in collecting data (monitoring; cooperative research). Also the feedback of stakeholders on making choices under uncertainty is important.
Management	Integrated Management	Multisector decision-making, Decision-making across administrative boundaries	In this context integrated can be interpreted as cross-sectoral, inter-disciplinary and/or holistic, i.e. encompassing the whole SES. Are all these perspectives incorporated into the management process? Compliance of the SES aspect "Human activities and their pressures" is a requirement. The Decision-making across administrative boundaries is tightly linked to the "Distinct boundaries" principle where jurisdictional boundaries may be different from ecosystem boundaries (see the ecosystem aspect of "scales").
	Adaptive Management	Adaptive Management	The management should be adaptive as it needs to deal with the inherent uncertainty of EBM. Learning-by-doing is needed when outcomes of decisions are uncertain because of complex system dynamics. This is linked to "Acknowledge uncertainty" "account for dynamic nature of ecosystems" and "Appropriate monitoring" is a requirement. Does the institutional set-up allow its implementation?
	Apply the Precautionary Approach		Does the institutional set-up allow the application of the precautionary approach? This requires compliance to the SES aspect "Changes and Uncertainty".
	Stakeholder involvement	Balancing ideologies and political realities of diverse stakeholders	Managers depend on the input from science but could benefit from knowledge available with other stakeholders, notably the business sector. Also, the feedback of stakeholders on making choices (or co-decision making) under uncertainty is important. As compliance of the SES aspect is a requirement; stakeholder involvement in policy implementation can be instrumental.
	Appropriate Monitoring		A requirement of adaptive management is adequate monitoring. The quality of the monitoring is reflected in the proportion of the relevant components of the SES for which sufficient data is collected at appropriate spatio-temporal scale and level of uncertainty to allow scientific knowledge to be used to guide informed decision-making. Monitoring programs can be developed in collaboration with the „Other stakeholders", i.e. multi-sector actor (i.e., cooperative research).

			The monitoring data should be transformed into salient and legitimate scientific knowledge to guide informed decision-making. The degree to which that actually occurs needs to increase in order to advance EBM.
Policy making	Decisions reflect Societal Choice	Multisector Decision-making	Specifying clear goals for MSP increases efficiency and efficacy of the process and allow the identification of potential trade-offs of proposed management strategies. "Stakeholder involvement" is required specifically in order to make Decision-making inclusive and reflect societal choice (i.e. legitimacy).
	Stakeholder involvement	Multisector decision-making, Balancing ideologies and political realities of diverse stakeholders	For rationale see Rockmann et al. (2015). Apply "typology of eight levels of participation". The degree of stakeholder interaction should be specific to the case study context. Also, the feedback of stakeholders on making choices (or co-decision making) under uncertainty is important. As compliance of the SES aspect is a requirement; stakeholder involvement in decision making can be instrumental.
	Sustainability		All three pillars of sustainability, i.e. ecological, economic and social, should be considered in the trade-offs informing the decision-making process. To what extent is this achieved in the CS?
Social participation	Stakeholder involvement	Multisector decision-making, Balancing ideologies and political realities of diverse stakeholders	The participation and involvement of stakeholders is the backbone of a successful EBM process. In addition to the stakeholders specifically mentioned, i.e. science, policy makers and managers; stakeholder participation should reflect and be based on all sectors which are affected by the plan, local community actors and environmental NGO's. This to ascertain all relevant societal claims, values and relevant aspects and impacts can be considered in the process and involved at each stage and that implementation and monitoring of strategies are effectively done.

2.3 The design of EBM management plans.

The main purpose of AQUACROSS' WP8 is to provide guidance to build a comprehensive EBM plan, ready to cope with ecological and societal challenges. According to the AQUACROSS Concept and AF, the key governance challenge consists in providing a comprehensive response to achieve the societal goals of the SES. This is done both through leading ecosystems to a status that is compatible with the sustainable delivery of the set of ecosystem services required by the social system and through improving and enhancing the social system so as to manage and use these ecosystem services in a sustainable way.

Hence, EBM Plans are wide-ranging responses addressed to restore and preserve the resilience and the sustainability of the whole SES. They are actually intended to recover the ecological system but also to reform governing institutions and markets. This is why EBM strategies envisioned by AQUACROSS are shaped by two interconnected and structured (yet well differentiated) set of decisions:

- Measures which are integrated into a PoM
- Policy instruments which are integrated into an Implementation Plan

The first set of actions, the PoM (see Box 3 and Figure 5), is formed by an integrated set of actions that if properly designed and implemented are intended to contribute to the environmental objectives and thus to enhance and protect the ecological system.

According to the AF, each individual measure is to be judged by its effectiveness to reach the desired ecological status as well as by their efficiency and fairness in doing so (see outcome-oriented criteria, including socio-cultural dimensions, in section 2.4.).

Measures may include the restoration or protection of specific aspects or components of the ecosystem, or the mitigation of specific human activities and their pressures, or changing the driving factors that emerge from the need to co-produce the ecosystem services.

These measures must be identified, subsequently classified by their contribution to improve specific aspects of the status of ecosystems, analysed in terms of their individual opportunity costs, compared with other measures to identify potential synergies, and packed into a PoM with the potential to effectively deliver the desired environmental outcomes for each CS. An important milestone towards completion of the management strategy phase is the design of a consistent programme of measures to meet environmental targets.

Box 1: Definitions of the elements in the AQUACROSS EBM approach

Measure (M): A measure (or environmental measure) is any action with the potential to contribute to a predetermined environmental objective, i.e. to bridge the gap between the baseline and the desired status of the ecosystem. Each measure is defined by a specific configuration, i.e. human activity(s), pressure(s) and ecosystem component(s) that determine its interaction with the ecological system. The impacts of these measures over ecosystems can either be direct, such as in the restoration or protection of ecosystems, or indirect, as a result of targeting pressures, the regulation of the activities of co-producing ecosystem services or affecting their driving factors. A measure is formed by a specific action that results in beneficial impacts over the ecosystem along with the specific means to make this action effective if required. For example, a prohibition to take water from the river along with a catchment officer to enforce the prohibition and the means to fine the polluter in case of infringement.

Programme of Measures (PoMs): Rather than single measures, changes required to take the status of ecosystems to the level required to achieve the societal goals can only be the joint outcome of the successful implementation of a comprehensive PoM. This programme of measures is a suite of measures intended to attain a desired ecosystem status. The measures included in the programme must be selected on the basis of their cost-effectiveness and the full package may take advantage of the distinctive co-benefits of management that is ecosystem-based, e.g. a reduction of implementation costs and maximised wellbeing gains, for the full PoM (see section 1.4).

A **Policy Instrument (PI)** is any action with the potential to contribute to the implementation of the PoM directly or indirectly through an improvement of the institutional set-up.

These policy instruments encompass any action designed to improve decision support systems in place (such as focused research, integration of scientific knowledge, development of information systems, improved monitoring, ex-post policy evaluation), to overcome institutional lock-ins (by breaking institutional silos, improving policy coordination), adapt the legal framework (allowing new fiscal, financial or economic instruments, enacting regulations, redefining permits, licences and use rights, etc.), change water users' behaviour (incentivising resource saving decisions, reducing water demand, etc.), foster cooperation among stakeholders (to agree on conservation targets and share benefits), develop alternatives to improve the financial feasibility of the PoM (through direct subsidies, compensation to potential losers, cross subsidies between ecosystem services' users to restore fairness and increase the social acceptability of the PoM), promote the adoption and swift diffusion of alternative technologies, enforcing regulations, etc. Policy instruments are thus not defined on a measure-by-measure basis but rather for a programme of measures.

Policy instruments must be selected for their potential and actual contribution to make the PoMs possible, that is to say to: break the institutional, technological and methodological barriers hindering the adoption of EBM alternatives. To improve the knowledge base that supports the design of more effective, cheaper and more beneficial PoMs, to enhance stakeholders' cooperation and institutional coordination, to improve the financial sustainability and the acceptability of the PoM, to enforce regulations, etc.

These policy instruments must be integrated into an **implementation plan** (IP).

Therefore, the **Ecosystem Based Management Plan**, the *EBM plan*, the final outcome of the policy making process, is formed by the **Programme of Measures** *PoMs* and the **Implementation Plan** *IP*.

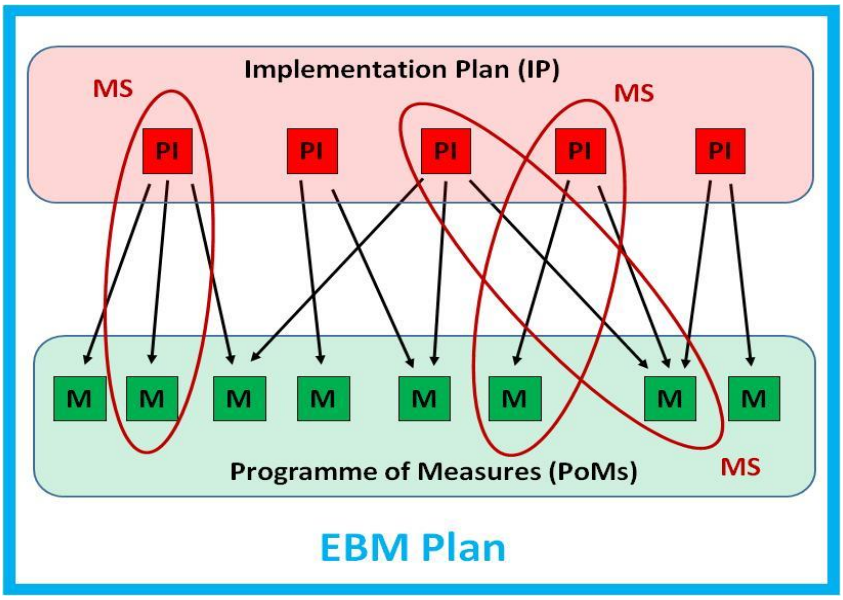

Figure 5: Diagram explaining the elements that make up an EBM plan

In the second set of actions (see Box 3 and Figure 5), the policy instruments consist of all the arrangements or reforms that are required in the social system so as to make the implementation of the PoM feasible and grow to the challenge of building up and implementing the full EBM plan. Therefore, the policy instruments encompass any action designed to improve decision support systems in place. The policy instruments are thus not defined on a measure-by-measure basis but rather for a PoM and must be selected for their potential and actual contribution to make the implementation of the measure possible. This implementation may require (1) to break the institutional, technological and methodological barriers hindering the adoption of EBM alternatives, (2) to improve the knowledge base that supports the design of more effective, cheaper and more beneficial measures, (3) to enhance stakeholders' cooperation and institutional coordination, (4) to improve the financial sustainability and the acceptability of the measure, (5) to enforce regulations, and more.

An important milestone towards completion of the planning phase is the integration of all the management measures (as part of a PoM) and all the policy instruments (as part of the implementation plan). Completion of the management plan requires a final assessment if the implementation plan is adequate as the means to implement the full PoM and which should have the potential to achieve the environmental and societal goals. The management plan concludes the planning phase and is what is transferred to the implementation phase.

The AQUACROSS EBM approach would allow comparing and standardising the concepts that have been in use in management if different water policy realms that are not exactly in line with the above presented definitions. Deliverable 8.2 will offer a revision of the different alternatives developed along the implementation process of the MSFD, the WFD, the Biodiversity Strategy, etc. and will offer a detailed classification of measures and policy instruments to support the development of EBM plans across water policy realms based upon enhancing ecosystems and biodiversity.

2.3.1 Management measures: typology

Measures are interventions in the system intended to contribute directly to the status of the ecological system. In this sense, there are multiple alternatives to classify all potential measures.

For instance, measures can be classified according to where in the linkage framework the measure intervenes (at the activity level (e.g., reducing agricultural surface), at the pressure level, (e.g., reducing water abstractions allowances), or at the level of an ecosystem component (e.g., restoring river connectivity)).

In the case of measures to protect the ecosystem, they can be classified by the type of intervention (such as remediation, mitigation, restoration or prevention); or by the time horizon when results are expected (emergency and reactive measures versus preventive planned measures; immediate response to reduce risk of existing activities; preventive response to avoid risk of potential activities). Measures can also be classified by the environmental objective they are aimed to contribute to (see the table on the WFD measures), or by the type of intervention (species spatial versus temporal distribution control; input versus output control and remediation versus mitigation as in the MSFD).

Box 2: Classification of measures for WFD

Measures for the Water Framework Directive (WFD) can be classified according to the environmental objective the intend to contribute to:

Measures:

a) Measures to protect drinking water quality and to reduce the level of treatment required.

b) Measures to control abstraction from surface and groundwater supply sources.

c) Measures to control recharging of groundwater.

d) Measures to control point source discharges.

e) Measures to prevent or control inputs of diffuse pollutants.

f) Measures to address any other significant impacts on status, in particular the hydro-morphological condition.

g) Measures to ban direct discharges to groundwater.

h) Measures to eliminate or reduce pollution from Priority Substances.

i) Measures to prevent pollution incidents.

Policy instruments are defined by its contribution to improve the institutional objectives and the outcomes of the overall river basin management plan:

j) Measures required to implement prevailing Community water legislation and other environmental legislation (set out in Article 10).

k) Measures to implement Article 9 (cost recovery).

l) Measures to promote efficient and sustainable water use.

Box 3: Management measures for the MSFD

Management measures for the Marine Strategy Framework Directive (Annex VI MSFD)
Measures:
a) Input controls: management measures that influence the amount of a human activity that is permitted.
b) Output controls: management measures that influence the degree of perturbation of an ecosystem component that is permitted.
c) Spatial and temporal distribution controls: management measures that influence where and when an activity is allowed to occur.
d) Mitigation and remediation tools: management tools which guide human activities to restore dam-aged components of marine ecosystems.
Policy instruments:
a) Management coordination measures: tools to ensure that management is coordinated.
b) Measures to improve the traceability, where feasible, of marine pollution.
c) Economic incentives: management measures which make it in the economic interest of those using the marine ecosystems to act in ways which help to achieve the good environmental status objective.
d) Communication, stakeholder involvement and raising public awareness.

In the AQUACROSS EBM approach we attempt to formalise the design of management plans so that it is clear right from the start how they match to the knowledge base available for their evaluation. To that end, we provide typologies for both the management measures and the policy instruments as an aid to define them in relation to the relevant elements of our AF.

To ascertain adequate integration across the AQUACROSS CS, a minimum requirement of the characterisation of measures is to define them in terms of their specific activity types/primary activity, pressures and/or ecosystem components and some spatio-temporal specification, i.e. area and time period (see Table 5). More detail should only be provided if the specificity requires this and this can be matched with specific information in the knowledge base. The specificity requirements need to be acquired from interaction with the CS-specific managers. For a more detailed example, see Table 5 in chapter 3.

2.3.2 Policy instruments: typology

A range of policy instruments are available to policy makers in order to help in the achievement of pre-defined targets. As introduced above, it is likely that any given measure or PoM will be accompanied by the use of one or multiple policy instruments. The table below illustrates the range of potential policy instruments at European, national, regional and local levels. The example is modified from Lago et al., 2015 and Frelih-Larsen, 2016. The table has been modified to tailor aquatic environments.

A. Overarching / formal EU legislation:

- Directives and their regulations: e.g. Water Framework Directive, Landfill Directive
- Strategies, programmes, action plans: e.g. EU Biodiversity Strategy 2020, Adaptation Strategy
- Funding mechanisms: e.g. Common Agricultural Policy, LIFE, Structural and Cohesion Fund

B. Examples of specific policy instruments mandated by the formal EU legislation or national policy instruments independent of EU legislation

Table 5. Typology of potential policy instruments with examples

Type of instrument	Examples
Legislative Instruments	
National water, marine, biodiversity protection law or regulations	• For example, UK Clean Water Act
National and local strategies and action plans for water, marine, biodiversity protection....	• Example: WFD River Basin Management Plans (RBMPs)
Command and control instruments	
Standards	• Legal or regulatory requirement for all persons or businesses to whom it applies to maintain a certain level of environmental quality (e.g., water quality emissions), confine actions to a certain type of practice or limit, or to rehabilitate resources. ○ Levels of Nitrogen
Bans	• A legal or regulatory prohibition of a certain type of activity or use of a material / product. ○ Pesticides, types of fishing practices and nets, etc.
Permits / quotas	• A license or authorisation issued by a public official or administrative agency allowing an individual or business to perform certain acts or to have a certain portion / amount of a product. ○ Permit to construct manure storage facility or discharge certain level of pollutants into water body; mandatory offsetting scheme for destruction of wetlands; etc.
Planning / zoning Timing	• Comprehensive planning of the different uses to be conducted in areas of an urban settlement designated by certain categories (e.g., residential, commercial, industrial). ○ Comprehensive land use plans, zoning applications, non-conforming use applications, eminent domain ○ Seasonal controls for fisheries management
Economic instruments	
Pricing	• *Tariffs*: A price paid by users to a service provider for a given quantity of service or a schedule of rates or charges of a business or a public utility that provides a product or service which may affect environmental quality and quantity: e.g. price to be paid for fertilisers, fuel, advisory services, water utility (irrigation), sanitation services • *Taxes and charges*: Compulsory payment to the fiscal authority for performing an action or using a product which leads to degradation of the soil, or a service from a regulatory authority: e.g., tax on nitrate surplus or fertiliser and pesticide taxes • *Trading of permits* for using a resource or trading (building or development permits, excavation or mining rights, etc.) of permits for pollution / emission

	levels (dumping permit for industrial waste discharge): e.g. landfill dumping permits
Payments	• ***Payments*** to landowners or private actors for practices or products • Payments of ***insurance premiums*** in order to be protected in the event of a loss.
Voluntary agreements	• ***Individual voluntary agreements***: negotiated voluntary arrangement between parties to adopt agreed practices by governmental bodies to producers in order to influence the development of products or the adoption of production processes that benefit the environment / reduce degradation. These are not linked to payments. Voluntary agreements linked to payments (such as agri-environment-climate measure) are included under payments category. • ***Public-Private Partnerships***: Contractual instruments between public and private actors that enhance the ability of the public sector to provide public services thanks to the involvement of the private sector. These are a sub-form of voluntary agreements, and can include multiple public and private actors. E.g. flood protection projects, coastal defences These can be structured in many different ways: • private sector has control over all assets, including investment, maintenance, and operations decisions, although some specific, strategic decisions remain subject to regulatory oversight; • concessions in the form of long-term contracts…[where] the private sector has full responsibility for the operation of the asset, usually recouping investment costs with service provision revenues (i.e. tariff collections); • management and lease agreements, the private sector takes control on operations for shorter time, but also bears less financial risks, and initial capital investment is assured by the public.
Liability schemes	• Offsetting schemes where liability for environmental degradation leads to payments of compensation for environmental damage, e.g. eco-accounts, wetland destruction, brownfields funds
Information, awareness-raising and public engagement instruments	
Trainings and qualifications	• Training and qualifications (obtaining certificates or proof of qualification) related to environmental protection ○ Farm advisory services, extension/outreach programmes from university centres
Public information programmes	• A series of activities geared toward raising the amount of information available and people's awareness about water, marine and biodiversity issues. ○ Events around the value of water
Stakeholder and public participation	• Decision-making processes or knowledge-building consultations by policy makers which involve stakeholders with a direct interest in or practical knowledge of the issue being discussed. ○ Town hall meetings, citizen councils, workshops for stakeholders, stakeholder advisory groups
Innovation groups	• Ongoing stakeholder interactive groups or events which aim to build capacity and knowledge of the other members of the group or the broader community (e.g., about a particular environmental, economic, or practical issue) through demonstration examples, talks between farmers, etc. ○ European Innovation Partnerships (EIPs) operational groups, demonstration farms, farmer-to-farmer exchanges
Farm advisory services	Publicly funded advice on soil protection related to actions and measures to landowners, farmers, stakeholders.
Monitoring and research instruments	
National monitoring systems	• Manual or automatic system (technological or by hand) which collects data about activities, products used, timing, etc. ○ Monitoring and reporting of status ○ Monitoring of activities relevant to the environment

	• Also, e.g. national overviews on the status of water resources.
Private monitoring systems	• For example, book-keeping and monitoring at farm level. Monitoring by non-profit organisations etc
Innovation and research projects	• Research related to aquatic ecosystems, including on ecosystem conditions, new methods for environmental protection (agriculture or other) • Oral or handwritten inquiries of either a random sample or a targeted group of stakeholders about their opinions, past actions, expectations, impressions, etc. regarding soils
Assessments of aquatic ecosystems status and ecosystem services	• E.g. national overviews on the status of aquatic ecosystem services

2.3.3 Pre-screening criteria for Measures and Policy instruments

As part of the planning phase and before measures can be considered for a full evaluation of their performance against the output-oriented criteria (chapter 2.4 and chapter 3), we recommend a pre-screening to ascertain *a priori* that various issues that may prevent the management measure or policy instrument from being implemented, are considered. For example, a management strategy that performs well in terms of effectiveness, efficiency and equity may not be implemented if, e.g. the required technology is not available or the legal basis is lacking.

Based on the AQUACROSS AF and other sources (Barnard and Elliott, 2015), Table 6 introduces some relevant criteria that should be considered as part of the pre-screening exercise.

Table 5: Proposed pre-screening criteria for alternative EBM measures

Pre-screening criteria	Compliance	
	Minimal	**Full**
Ecologically sustainable	The required measures are absent or will not ensure safeguarding ecosystem features and functioning, or fundamental and final ecosystem services	There is confidence that the measures will ensure ecosystem features and functioning, and fundamental and final ecosystem services, will be completely safeguarded (i.e., the natural ecology is maintained where possible) at a local (site) scale; the measures associated with the activity/project will protect the site potentially impacted by the proposed development or activity
Technologically feasible	There is no technology or practice currently available to support the proposed measures	Methods, techniques and equipment for ecosystem and society/ infrastructure protection are available and have been demonstrated on similar projects, at a similar scale and under similar environmental circumstances
Financially feasible	The measure is not financially viable, according to available budgets (public and/or private) even in the short-term. Capital and operating costs cannot be recovered.	A costs effectiveness analysis is performed to ensure the selected measure is the one from a selection of options that delivers highest environmental benefits at least financial costs (public or private) according to an available budget.
Economically efficient	The measure does not deliver benefits to society (financial costs higher than expected economic benefits). The measure has a negative net present value.	The selected measure is the most efficient – it delivers the highest benefits to society at least costs. In a cost benefit analysis the measure has the highest net present value from a selection of options.

Socially desirable/tolerable	Society at large actively rejects any suggestion that the management measures are needed; if implemented, measures would not be tolerated	Society at large views the management measures as an imperative; they are regarded as necessary
Ethically defensible	Although there may be an understanding, or even acceptance, of the underlying need for the measures, there is nevertheless the general view that the specifics of the proposal render it ethically or morally indefensible	The wishes and practices of individuals who are potentially affected by the project/activity have been fully respected in decision-making with no single sector or group being unduly favoured; there is general view that the measures including the future costs are acceptable on moral or ethical grounds
Culturally inclusive	The measures take no consideration whatsoever of local customs and practices	Local customs and practices are fully considered with local needs embedded within the proposals-the proposed measures ensure the customs and practices of local communities are not adversely affected; where applicable, aboriginal/first-nation rights are defended
Legally permissible	Regional, national or international agreements and/or statutes relating to the implementation of the likely required measures are absent	There are regional, national and/ or international agreements and/or statutes currently in place which will enable and force the likely required measures to be implemented to a full and adequate degree
Administratively achievable	Statutory (administrative) bodies (e.g., governmental departments, environmental protection and conservation bodies) required to implement (and subsequently operate) the measures are not in place	The requisite statutory (administrative) bodies (e.g., governmental departments, environmental protection and conservation bodies) are in place and are capable of fully enabling successful and sustainable management (critically, they have a demonstrable 'track record' in enabling such management)
Effectively communicable	Irrespective of the degree of public understanding of the issues surrounding the proposed measures, full and open communication is absent or problematic (e.g., full disclosure of the underlying evidence base may not be possible due to military or commercial sensitivity)	Irrespective of their views, the consequences of adoption or rejection of the proposed measures are readily appreciated by the public; relevant stakeholder sectors are aware of the proposed measures (for example through newsletters, press articles or roadshows) and communication has been opened across horizontal links and vertical hierarchies of governance and decision-making
Politically expedient	Underlying management approaches and philosophies are non-consistent with the prevailing political climate; the measures are at odds with prevailing policy or strategy statements	Underlying management approaches and philosophies are fully consistent with the prevailing (national) political climate and have the explicit support of political leaders; supporting drivers for the measures are documented (for example within policy statements at the national or international level)

The table highlights the two extremes that may characterise the situation in relation to each of the pre-screening criteria. Failing to meet these criteria, i.e. minimal compliance should be reason for reconsidering a specific management strategy, certainly if there are other management strategies possible that may (contribute to) achieve the same societal goals.

2.4 Evaluation of the performance of the management strategies

For the evaluation of individual EBM plans (PoM + IP), the AQUACROSS evaluation process typically involves three steps:

- Identification of indicators and their targets;
- Forecasting and scenarios;
- Evaluation of specific options versus alternatives;

for which further detail will be provided in the following sections.

2.4.1 Identification of indicators and their targets

Based on the guidance in chapter 1.7 each CS will need to select their CS-specific suite of indicators with a target that covers the societal goals they aim to achieve. This target usually represents a healthy state, pristine condition or sustainable level which may be characterised by reference points (or reference levels). In Samhouri et al. (2012), a protocol to estimate reference points for a very wide range of ecological indicators is presented (figure 6). The framework is compatible with different levels of scientific understanding and data availability and emphasises practical approaches that can be used to evaluate ecosystem status at local, regional, or even global scales. A set of decision trees is developed, which provide guidance for choosing among three types of reference points (or levels) to use in the assessment of the current ecosystem state:

(1) Functional relationships: a reference level based on an understanding of its functional relationship with environmental conditions (equivalent to modelling option from (Rossberg et al., 2017)). This therefore requires at least an understanding of the functional relationship.

(2) Time-series approaches: a reference level of the same ecosystem or ecosystem component based on some historical status representing a desirable status, e.g. pristine or sustainably exploited. This therefore requires at least a long enough time-series.

(3) Spatial comparisons: a reference level of a comparable ecosystem or ecosystem component elsewhere in the region or across the globe. This requires a comparable situation elsewhere.

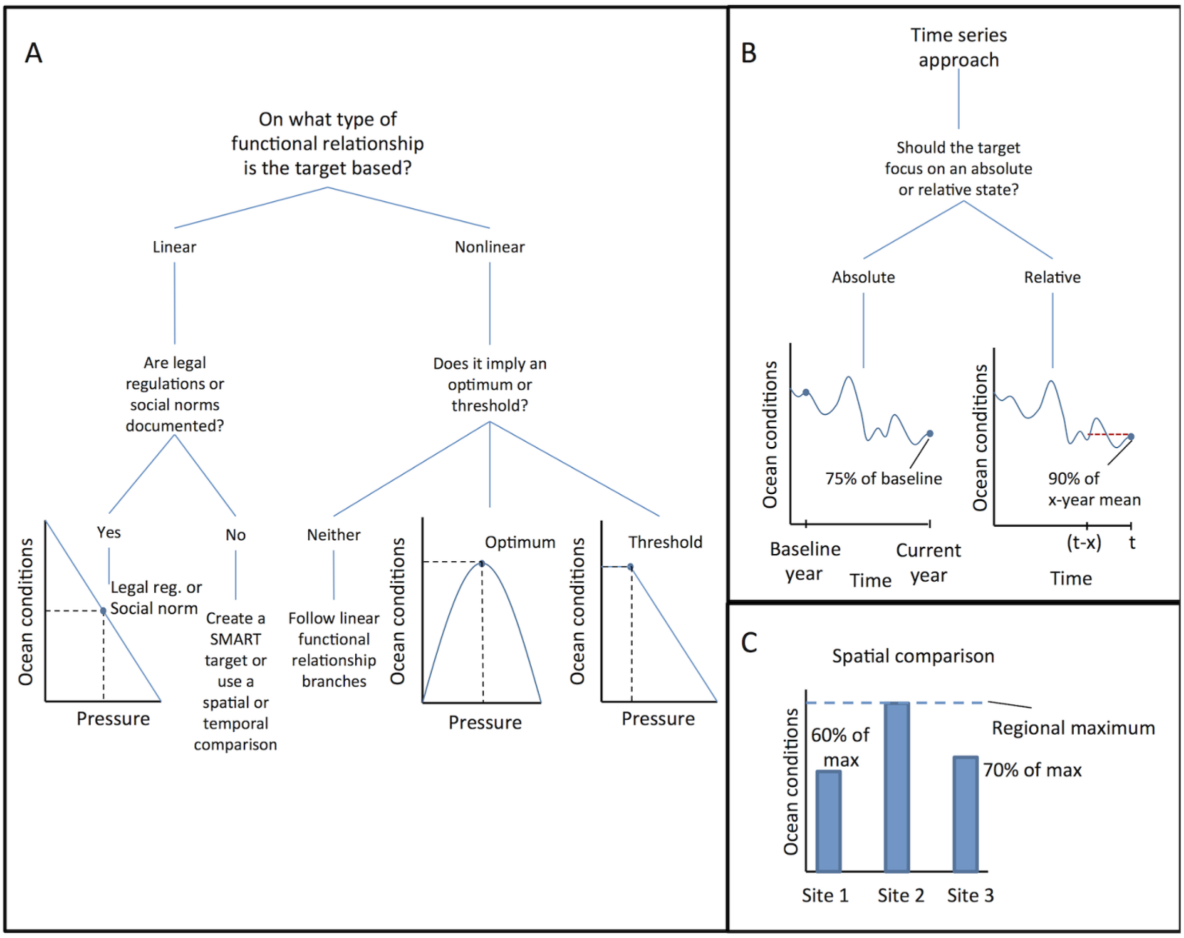

Figure 6: Decision trees for choosing between targets based on (A) functional relationships, (B) time series approaches, and (C) spatial comparisons (Samhouri et al., 2012)

These indicators and their targets can then be applied to assess the effectiveness of an individual measure, PoM or entire management strategies in terms of their contribution to bridge the gap between baseline conditions and target conditions that would meet the environmental policy objectives (see chapter 2.4.3).

2.4.2 Selection of forecasting tools or approaches

Environmental management decisions are based on the prediction of consequences that different management options will have on the likelihood to achieve management objectives. Such predictions can be derived from expert knowledge, transfer of experience from similar cases, or from models (mathematical, conceptual or otherwise). Formulating the knowledge about the system to be managed in a model has the advantage of facilitating a learning process where knowledge can be updated with data, e.g. from (additional) monitoring programs initiated or expanded after the implementation of (alternative) management strategies. However, environmental systems are complex and the development of models that are useful for environmental management is challenging. Various modelling approaches exist, from simple statistical regression models to complex dynamic and mechanistic models.

Such modelling approaches are described in DEL7.1, and the development and application of external scenarios are described in DEL7.2. External input scenarios are those that come from outside the CS-specific SES, e.g. IPCC scenarios or the EU Reference Scenario 2016. Spatially, and where data allows dynamically, modelled species distributions for biodiversity information and ES supply and demand information should be considered together to allow the spatially-explicit allocation of areas important for biodiversity conservation or ecosystem services. Models need to account for temporal environmental changes and uncertainties, and outputs can be evaluated against targeted measurable societal goals using the output-criteria described in chapter 2.4.

Independent from the chosen approach and especially when management decisions have to be justified to the public, the following criteria can help decide if a model is suitable for decision support:

a) The model is based on a basic mechanistic understanding of the system regarding causality.

b) Confounding factors can be disentangled.

c) The model has an appropriate resolution (spatial, temporal, specifically in relation to output variables) to address the management problem.

d) The model includes predictor variables that can be linked to management strategies.

e) Model uncertainty can be quantified.

f) The model has a sufficient predictive capability and sufficient universality to be applied to (parts of) the "relevant SES".

g) The modelling procedure and the model assumptions can be transparently communicated.

Regarding criteria a) and b), it is important to ensure that the model structure is meaningful. The criteria c) and d) are important to make the model applicable to the management question. Criteria e) and f) are important to assess if differences in predicted outcomes of different management strategies are significant or to assess the risk of not achieving the management objectives. Criteria e) and g) are needed to facilitate the learning process by inference with data, for credibility of the scientific process and to make the management decisions justifiable to the public.

2.4.3 Evaluation of management plans

The evaluation of the EBM plans involves the AQUACROSS forecasting tools in order to compare the future performance of the alternative management scenario (consisting of several alternative management strategies) to that of the baseline scenario (consisting of several BAU management strategies) in terms of their outcome (indicators representative of some policy objective). These baseline scenario(s) include EBM measures, programs and plans both already implemented and agreed on to be implemented in the coming years but which may result in different outcomes of the status assessment depending on autonomous development, i.e. future developments.

According to the AQUACROSS AF (see chapter 1.4) the evaluation of the EBM measures is based on the outcome-oriented criteria:

- effectiveness
- efficiency
- equity and fairness

This assessment is meant to identify the drawbacks of 'business-as-usual' decisions in terms of environmental impacts, subsequent costs and benefits of human wellbeing at individual and collective levels, and the distribution of these impacts and costs throughout society. This evaluation level is an important starting point to identify the potential gains of alternative courses of action in general and from the successful planning of EBM measures (see chapter 2.2), should they be effectively implemented. Each of the outcome-oriented criteria are described in more detail below.

Effectiveness – hitting the environmental target

The concept of effectiveness is restricted to a previously agreed and well-defined set of environmental targets that can be represented by a suite of indicators and their target or limit threshold values reflecting the status of the ecosystems at stake. The effectiveness of an individual measure (with its corresponding actions to implement it) or of a package of measures, along with the implementation plan, is defined by the contribution they make to bridge the gap between baseline conditions and target conditions that would meet the environmental policy objectives.

Above all, management measures, programmes and plans must fulfil environmental policy objectives indeed. Therefore, the first step in preparing an EBM plan consists in identifying the full catalogue of management measures that may contribute to achieving those environmental objectives. Measures can differ in scale (e.g., numbers of hectares transformed, restored, or protected; the design size of a wastewater treatment plant; the height of flood defences; etc.) and/or the activity(s), pressure(s) or ecosystem component(s) they cover. Some measures are mutually exclusive (such as dams and floodplain restoration to manage flood risks), others may be mutually reinforcing (such as shifting from channels to pipelines for water delivery and, at the same time, from gravity to drip irrigation). All these alternatives must be identified, characterised, and compared with respect to their effectiveness. They all might be candidates for the PoM, but the selection of the management strategies for this management scenario requires that wellbeing-related objectives be factored into the analysis.

Efficiency – making the most for human wellbeing.

Efficiency refers to the capacity of citizens and social institutions to take advantage of existing opportunities (determined by technology, resource endowments and actual availability, physical and human capital, etc.) to improve human wellbeing in a sustainable way. This is a concept that applies to the users of a particular service (that may have the opportunity to get most out of it without making anyone else worse off), the stakeholders in a particular decision context (that may have the option to cooperate in the preservation of a resource and share the benefits amongst them), governments (that may have the possibility of improving the environment without worsening opportunities in terms of economic activities), which is ultimately the case of sustainable development (where each generation should aim to improve its wellbeing within available opportunities as far as this does not compromise the options of future generations).

Efficiency is an overarching assessment criterion that can be applied to:

- Assessing wellbeing outcomes of a baseline scenario through identifying the opportunity costs (welfare losses) of current environmental degradation patterns, the benefits (gains in wellbeing) of those interested in preserving the status quo, and the evolution of these losses and gains in the baseline scenario (the cost of inaction).
- Assessing the potential gains associated to the improvement of the ecological system through the effective implementation of EBM.
- Identifying the potential benefits (gains in wellbeing) of individual measures so that they can be compared versus the opportunity costs (welfare losses) of their implementation to ponder the convenience of integrating it into programs of measures and management plans.
- Assessing joint wellbeing gains and losses of (integrated) management responses in general and of EBM measures in particular.

Benefits and costs are defined as respectively any positive and negative impact on human wellbeing, irrespective of whether the affected individuals are aware of them or whether they can be valued through market prices or elicited via any ad-hoc valuation exercise. When assessing EBM measures, programmes and plans under efficiency criteria one should be aware of the difficulties in comparing costs (that are often monetised and are relatively certain) and benefits (that may sometimes be difficult to monetise and are definitely more uncertain, though mostly not less real).

Nevertheless, given the uncertainties about future conditions, bounded information and acceptability issues surrounding the economic valuation of non-market benefits, developing a full-fledged cost-benefit analysis to compare baseline and policy scenarios is barely feasible. To a certain extent, it might not even be genuinely desirable. Therefore, while the cost analysis can actually be performed with a sufficient level of detail so as to inform a cost-effectiveness based selection of management alternatives, the assessment of benefits should be designed to solve practical questions and to support decision-making to sort out at least two issues: first, to show that the benefits of the management scenario are at least equal to its opportunity cost (such as, for instance, in the disproportionate cost analysis considered in the WFD), and second, in maximising the benefits of the management scenario by increasing the weight of ecosystem-based alternatives within the management scenario. In what follows, we first present the cost-effectiveness analysis, and then proceed by developing the alternatives to advance towards a wider cost-benefit analysis.

A first practical step towards the operationalisation of efficiency criteria consists in applying a cost-effectiveness analysis when considering an individual measure to attain the environmental objectives. This analysis considers the effectiveness and the cost of the measures and provides a first step to be refined in subsequent steps of the analysis, once the benefits and the distributional outcomes are considered, and further on, when the means to implement the management scenario are factored into the analysis. Cost-effectiveness analysis is based on the idea that whatever the environmental objective (assessed under the effectiveness criterion), this should be reached at the lowest possible opportunity costs, thus leaving room to a higher level of wellbeing. This requires characterising each measure by its costs, including capital, operational and maintenance costs, along the investment and operation timespan and together with other opportunity costs (such as, for instance, the foregone benefits of reducing fishing, agriculture or other activities, the increased costs of soil conservation practices or changing land uses, the external costs of reducing water flows downstream) and the avoided costs (for instance, of treating water due to its better quality). The two main objectives of any cost analysis consist of (1) reducing all cost categories so that they can be aggregated to represent the overall cost of an individual measure which requires a precise typology of all cost items and (2) homogenising these costs to a common yardstick to compare different alternatives (this is, for instance, the notion of the equivalent annual cost of each measure that is obtained discounting the flow of costs over a common time horizon (e.g., 30 years) and using a common discount rate (such as 1% or 2%), see (van Engelen, 2008)). Each alternative can then be associated to a cost-effectiveness ratio that measures the levelled costs of the measure (its annual equivalent cost) per unit of effectiveness (for instance, euros per unit of nitrate concentration reduced, or per saved cubic meter, or per restored hectare, etc.). This indicator allows sorting the alternative measures, from the cheapest to the most expensive ones, and combining them to obtain the least cost management combination of measures to attain environmental objectives.

The previous analysis does not account for the benefits of reaching environmental objectives. Valuing benefits of alternative courses of action is in general harder than valuing opportunity costs, as above. This may suggest that we could replace a cost-benefit rationale completely. Yet, this is not the case at all. If one wants to compare baseline and policy scenarios there is a need to make some kind of cost-benefit comparison – even if it is not a full-fledged CBA. A basic question to be solved is whether the cost of reaching the environmental target is higher than the benefits such improvement could yield. This is for instance the purpose of disproportionate cost analysis considered in the building of the WFD management plans (see Hanley, 2006). To progress from cost-effectiveness towards a cost-benefit analysis, a first step consists in identifying the set of environmental services that would improve in supply if the cost-effective management strategies are properly designed and successfully implemented (such as recreation, flood control, provision of better quality water, reduced drought risk, etc.). These benefits are not necessarily associated with the improvement of the status of the ecosystems nor to individual measures (so different from costs, the benefit analysis should not necessarily be performed on a per-measure basis). Nevertheless, some particular measures can bring about distinctive benefits that should be taken into account to refine the management scenario and then to increase the benefits associated to meeting the environmental objectives the management scenario was aiming to achieve.

This is the specific case of management alternatives to restore the environment (floodplain restoration, soil conservation practices, distant marine reserves, etc.) or to emulate and mimic functions traditionally performed by natural systems (sustainable drainage systems in urban and rural areas, buffer strips, land-based water treatment, etc.). Besides contributing to the pre-determined environmental targets (flood risk reduction, reduction in nitrate concentrations, increase in water flows, etc.) which come about with a relevant set of ancillary benefits (improved landscape, pest control, temperature reductions, recreation opportunities, biodiversity, etc.) that will never be attained if traditional alternatives (such as dams, wastewater treatment plants, reclaimed wastewater reuse, etc.) were used.

Within this context, the benefit analysis plays a key role in bringing the distinctive benefits of ecosystem-based measures to the centre stage and thus in providing the information required to refine the package of measures so as to increase the relative weight of these strategies and make the most out of them for human wellbeing.

Deliverable 8.2 will provide further information on which methods are most suitable to evaluate the efficiency criterion: cost-benefit-analysis, multi-criteria decision methods, and cost-effectiveness analysis.

Equity and fairness - sharing the benefits

The distribution of benefits and costs across stakeholders must be perceived as fair. Besides the contribution of the management scenario, if any, to social equity, the legitimacy, or the acceptability of the management scenario, requires the perception that their consequences are fairly distributed among the affected parties. Unlike efficiency, what is meant by an equitable distribution of the costs and benefits of something is a matter of opinion: for some the idea that the cost of pollution must be borne by the polluter is fair enough as a justice criterion, whilst for others it may only be so provided if no one is crowded out of business or left below a minimum income threshold.

The first step in this analysis requires the identification of benefits and the beneficiaries of current and prospective status is required. This can rely on the analysis of ecosystem services and the drivers and responses in the baseline. A second practical step consists of checking whether there are vested interest groups whose wellbeing might be damaged and how likely it is that these groups may block the implementation of the management plan. Thus, fairness criteria are necessarily linked to coping with potential acceptability and legitimacy barriers that may impede the implementation of EBM.

Links with other criteria imply trade-offs with efficiency and synergies: sharing the benefits increases feasibility and strengthens conditions for cooperation. The analysis of this criterion must be linked with who pays for the strategies (and how). This is an opportunity to connect the three outcome-oriented criteria. For instance, if an effective management alternative increases efficiency it can be implemented in a fair way, provided their effects on the distribution of wellbeing are somehow compensated. This can be done for instance via reduced tariffs, cross subsidies, and other financial mechanisms that should be discussed along the design of the EBM, i.e. as part of the planning phase. Thus, fairness is an objective output-oriented criterion closely connected with the process-oriented criteria. For instance, acceptability and the financial sustainability of an alternative course of action depend on how these equity issues are handled throughout the EBM process.

3 Guidance for case studies to make EBM operational

This chapter aims to provide the guidance that allows the AQUACROSS case studies (CS) to design suitable EBM plans. As operational EBM is explicitly context dependent, each CS should provide that context for each of the EBM phases that make up the AQUACROSS EBM approach (see figures 2 and 3):

I. Societal goals: see chapter 2.1.
II. Description of the socio-ecological system: see chapter 2.2.
III. Planning management strategies
    a. Definition and pre-screening: see chapter 2.3
    b. Evaluation expected performance: see chapter 2.4
IV. Implementation, monitoring and evaluation

Below we provide guidance by providing templates and examples to support the CS in describing that context necessary to make EBM operational. This description of the context is the basis for the "assessment of the impact of management responses in case studies" reported in AQUACROSS DEL8.2 and will be reported in each of the CS reports. To that end, we provide a "cross-walk", showing how the CS-specific products required for each of the EBM phases match the relevant sections in the CS reports.

3.1 Societal goals

Based on the policy instruments considered most relevant by the CSs and the opinions solicited from CS stakeholders, the key CS-specific societal goals should be identified. These societal goals then determine the following:

- the identification of those elements of the SES that are relevant for assessment, i.e. "Description of the socio-ecological system". The CS-specific details are provided in chapter 3.2;
- the indicators and their targets for the phase "Management strategies, Implementation and evaluation" (see table 6);
- the indicators and their targets for the phase "Monitoring and evaluation" (see table 6).

These societal goals should emerge from the co-design process based on the policy objectives identified in chapter 2 of the CS report. Table 6 shows an example from CS1 North Sea indicating the societal goals that emerged from the relevant EU Biodiversity Strategy 2020 targets and the matching guidance for assessment. The table details concepts, indicators and targets. This is for guidance purposes and hence not (yet) intended to be comprehensive.

Table 6: Societal goals in the North Sea CS under relevant EU Biodiversity Strategy 2020 targets and the matching guidance for assessment

Biodiversity Strategy	Policy Details	Assessment
Target 1: Fully implement the Birds and Habitats Directives	Conserve at least 10% of coastal and marine areas through effectively and equitably managed, ecologically representative, and well-connected systems of protected areas, and other effective area-based conservation measures (CBD, 2010). A central component of these directives is the use of special conservation areas to help achieve their objectives, through a 'coherent European ecological network' (Natura 2000) covering both land and sea. The Natura 2000 network thus contains Special Areas of Conservation (SACs) designated to implement the Habitats Directive.	• Indicator: Extent of North sea area covered by N2000 SACs • Target: a 'coherent European ecological network' (indicator yet unknown)
Target 2: Maintain and restore ecosystems and their services	By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems.	• Adopt or develop appropriate indicators for ecosystem services • The green infrastructure target is achieved through a 'coherent European ecological network' (indicator yet unknown) • Assess if 15% restoration of degraded ecosystems is achieved
Target 4: Ensure the sustainable use of fisheries resources	MSFD D3: Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock. GES is based on three criteria: • Exploited sustainably consistent with high long-term yields, • have full reproductive capacity	• Fishing mortality (F) should be below the value of F expected to produce the high long-term sustainable yield (F_{MSY}): $F<F_{MSY}$ • Spawning-stock biomass (SSB) should be at or above a biomass safeguard (MSY $B_{trigger}$) capable of producing maximum sustainable yield: SSB>MSY $B_{trigger}$ for all stocks
Target 6: Help avert global biodiversity loss.	MSFD D1D6: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	• Spatial extent and distribution of physical disturbance pressures on the seabed. Unit of measurement is the extent of the assessment area physically disturbed in square kilometres (km2) • Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance. Unit of measurement is the extent of each habitat type adversely affected in square kilometres (km2) or as a proportion (percentage) of the total natural extent of the habitat in the assessment area.

3.2 Description of the socio-ecological system

Each CS should identify and describe the different elements of the ecological system and the social system that are relevant for the assessment of the SES.

The ecological system emerges from the identification of the relevant human activities, their pressures, and the ecosystem components (representing biodiversity) affected by them which provide the ecosystem services that contribute to societal wellbeing. This represents the supply-side. As an example, an illustration of the elements of the SES that are relevant for the assessment is the linkage framework shown in Figure 7. The components represented in the relevant SES need to be covered by the CS-specific knowledge base. Each CS should perform an assessment of the quality of their knowledge base to inform EBM. System-oriented criteria are provided to guide the narrative each CS should provide to characterise this aspect of their knowledge base (Table 7). These criteria are intended to guide the CS in describing the suitability of their knowledge base to inform EBM (for more information see table 3, chapter 2.2). This CS-specific product would fit best in chapter 3/5 of the CS report.

Table 7: Template of system-oriented criteria that apply to the ecological system

System-oriented criteria	CS-specific narrative describing the knowledge base
Ecological integrity and biodiversity	
Consider ecosystem connections	
Account for dynamic nature of ecosystems	
Acknowledge uncertainty	
Appropriate spatial and temporal scales	
Distinct boundaries	
Recognise coupled SES	
Consider cumulative impacts	

Assessing the social system involves the identification of main societal actors and how they contribute to the social adaptive processes that respond to the status of ecosystems through the input and allocation of physical, human and social capital. These inputs, in turn, may impact the ecosystem requiring EBM to mitigate the impacts in order to meet environmental policy goals. This represents the demand side. Each CS should assess the capacity of their social system to sustainably co-produce the ecosystem services and implement EBM in order to ultimately achieve the societal goals. This should be assessed using the template provided as Table 8. The identified criteria are intended to guide CS in describing the capacity of their social system including its governance actors to plan and implement EBM (for more information see table 4, chapter 2.2). This CS-specific product would fit best in chapter 3/5 of the CS report.

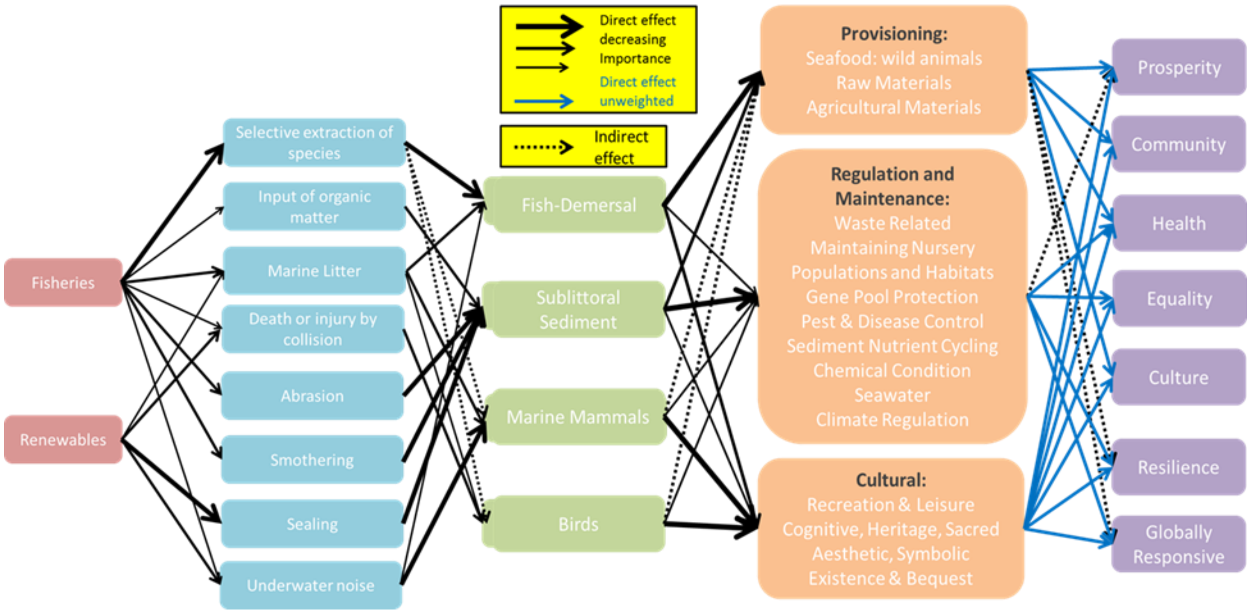

Figure 7: Linkage framework (human activities-pressures-ecosystem components-ecosystem services-human wellbeing) illustrating relevant elements for assessment of SES in the North Sea CS.

Table 8: Template of process-oriented criteria linked to the main actors in the social system

Policy Dimensions	Process-oriented criteria	CS-specific narrative describing the capacity of their social system and its actors
Scientific knowledge	Use of Scientific Knowledge	
	Inter-disciplinarity	
	Stakeholder involvement	
Management	Integrated Management	
	Adaptive Management	
	Apply the Precautionary Approach	
	Stakeholder involvement	
	Appropriate Monitoring	
Policy making	Decisions reflect Societal Choice	
	Stakeholder involvement	
	Sustainability	
Social participation	Stakeholder involvement	

3.3 Planning management strategies

In the AQUACROSS EBM approach, the planning phase of an EBM cycle should result in a suite of management strategies consisting of measures (as part of a PoM) linked to policy instruments (as part of an implementation plan). To that end, the planning phase commences with (1) an identification of the potential management strategies each consisting of management measure/s and policy instrument/s, followed by (2) a pre-screening of these potential management strategies to arrive at a suite of appropriate management strategies leading to (3) and evaluation of their expected performance. This then concludes the planning phase with a recommendation of an EBM plan as part of a PoM with an implementation plan to be applied in the next and final phase of the AQUACROSS EBM approach: the implementation phase (see chapter 3.4).

For the identification of the potential management strategies (see chapter 2.3) we work from the premise that

- each management measure is defined by a specific configuration, i.e. human activity(s), pressure(s) and ecosystem component(s), that determines its interaction with the ecological system (see chapter 2.3.1) and;
- it requires at least one policy instrument to initiate its implementation (but in practice there may be several) (see chapter 2.3.2).

This is captured in a table showing different management strategies that are identified for the CS (see for example Table 9). Table 9 provides an example of the early characterisation of potential measures that are under consideration in the North Sea case study. Each measure is determined by a policy instrument that initiates a management measure. The policy instrument is determined by the policy target and should follow the typology provided in chapter 2.3.2. The measure is defined by the specific activity types/primary activity, pressures and/or ecosystem components and some spatio-temporal specification, i.e. area (MPA1 is one specific configuration of the MPAs) and time period (i.e., years or season).

For the pre-screening of the potential management strategies (see chapter 2.3.3), we provide a set of questions for the assessor to consider and discuss with the relevant stakeholders (Table 10). Their answers should be the basis to characterise the potential management strategies in relation to each of the pre-screening criteria from Table 7. Failing to meet these pre-screening criteria, i.e. minimal compliance should be reason for reconsidering a specific measure, certainly if there are other potential management strategies possible that may (contribute to) achieve the same societal goals.

The background information for evaluation of the management strategies is provided in chapter 2.4 but will be further elaborated in DEL8.2.

Table 9: Measures under consideration in CS1 – North Sea

MS #	Measure	Type of measure, detail	Policy target	Policy instrument typology	Activity	Primary activity	Pressure	Component	Area	Time period
1.1	Change from beam trawl to pulse trawl	Technical measures to reduce fishing impact	Reduce physical disturbance to seabed (MSFD)	Subsidies	Fishing	Benthic trawl	Selective extraction, Abrasion/Damage	Fish, Sublittoral sediment	CS area	
1.2				Voluntary agreements						
1.3				Quotas. Fisheries Credit system						
2	Fishing fleet scrapping,	Economic incentive to reduce fishing fleet	Reduce fishing pressure (MSFD/CFP)	Subsidies (EMFF) CFP	Fishing	Benthic trawl	All	All	CS area	
3.1	N2000 SCA	N2000 SCA for protection of seafloor habitat	Natura2000	Bans, Permits	All, i.e. Fishing and Renewable Energy	All	All	Fish, Sublittoral sediment	MPA1	
3.2	N2000 SCA Member State			Bans, Permits, Zoning, Timing					MPA1	
3.3	N2000 SCA Regional			Bans, Permits, Quotas, Planning, Zoning, Timing					MPA2	
3.3.1	N2000 SCA Member States/Regional Exception	Allow (specific types of) fishing in wind parks in MPAs	MSP, IMP, MSFD	Permits	Fishing and Renewable Energy	Renewable Energy – Wind, Fisheries – Fixed nets	Selective extraction, Abrasion/Damage	Sublittoral sediment	MPA1.1 MPA2.1	
3.3.2		Allow Wind parks with shellfish farming, i.e. oyster or mussels in MPAs			Renewable Energy and Aquaculture	Renewable Energy – Wind Aquaculture – shellfisheries	Abrasion/Damage	Water column, Sublittoral sediment	MPA1.2 MPA 2.2	
3.3.3		Multi-Use. Wind parks with seaweed culture in MPAs			Renewable energy and Aquaculture	Renewable Energy – Wind Aquaculture – Macroalgae		Sublittoral sediment	MPA51.3 MPA2.3	

Table 10: Example questions for each pre-screening criteria for the assessor to insert relevant stakeholders

Pre-screening criteria	Question
Ecologically sustainable	Are we confident that the management measure contributes towards achieving environmental targets?
Technologically feasible	Do we have the technology to apply the solution? Has it been widely applied? Have provisions been made to ensure the operation and maintenance of such technology, further to any ulterior financial consideration?
Financially feasible	Who would pay? Is the amount enough to sustain the measures in the long term, and can the potential beneficiaries afford to contribute? By how much? Is there a public interest in making the measure possible? Does it concern public interest? Is it feasible to ask for financial support from governments at regional, national and EU levels?
Economically efficient	Is it good value for money compared to other alternatives? Is it a best value alternative, further to being least cost one?
Socially desirable/tolerable	Would stakeholders back it up or reject it?
Ethically defensible	Is the implementation morally correct?
Culturally inclusive	Are local customs and practices adequately addressed?
Legally permissible	Does it comply with existing law and regulations?
Administratively achievable	Is it implementable? Are transaction costs relevant in size and type?
Effectively communicable	Is it possible to have open communication on the relevant issues?
Politically expedient	Are the management strategies consistent with the prevailing political climate?

3.4 Implementation, monitoring and evaluation

This EBM phase commences after the implementation of the EBM management plan. For this EBM phase, each CS should identify the relevant monitoring programmes and describe their suitability to (1) contribute to the knowledge base taking account of the system-oriented criteria and (2) allowing the evaluation of baseline and alternative management scenarios against the societal objectives represented by indicators and their targets. This should be adequately covered by tables 3 and 4. The “ex ante” evaluation of the current situation, i.e. under a baseline management scenario, against the societal goals as reported in chapter 4.1 of the CS report should match what is in Table 4. The “ex post” evaluation of the alternative management scenario(s) is only possible if these are actually implemented and the results of the monitoring programs become available. This obviously is not within the remit of AQUACROSS.

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Annex

Box I: Systemic approaches (adapted from DeFreis and Nagendra, 2017)

- **Multisector decision-making.** Management decisions can lead to trade-offs or synergies among ecosystem services (31). The knowledge base should therefore allow evaluation of such trade-offs and synergies from different management scenarios to inform decision-making (32, 33). In the AQUACROSS EBM approach this goes beyond multi-sector trade-offs and can also involve trade-offs between multiple policy objectives, ecosystem services or stakeholder interests.
- **Decision-making across administrative boundaries.** Ecological processes encompass spatial scales that often transcend administrative boundaries. In the AQUACROSS EBM approach this requires governance arrangements that span administrative boundaries, managers that are incentivised and have the authority to apply the mechanisms for considering the consequences of their decisions beyond their own jurisdictions.
- **Adaptive management.** The essence of adaptive management is learning by doing and recognition of uncertain outcomes. Adaptive management requires an explicit consideration that the future may be unknowable and predictions have limited reliability. Key features of adaptive management are monitoring, reassessing initial plans, redefining goals on the basis of new evidence, social learning, and collaborations (44-46). Planning needs to be geared toward flexible decision-making, with nimble management structures that are capable of swift changes (47). This requirement of adaptive management resulted in the development of a cyclical AQUACROSS EBM approach that may be advanced with every iteration of the management cycle.
- **Incorporating natural capital and ecosystem services in markets.** Impacts on non-marketed ecosystem services (e.g., watershed protection) or natural capital (e.g., stocks of minerals, energy sources) are externalities that are not factored into traditional economic accounting systems and hence do not provide incentives to conserve these aspects of the ecological system. Approaches to correct these market failures target different decision-makers. At a national level, tax policies and environmental regulations provide incentives or penalties to corporations and other natural resource users. At a regional level, payment for ecosystem services by the beneficiaries incentivises the providers' use of natural resources. At an individual consumer level, product certifications and labels allow consumers to identify products that are produced in ways that conform to guidelines aimed at protecting the ecological system (53). To that end ecosystem services are explicitly considered both in the knowledge base as well as the decision-making context of the AQUACROSS EBM approach.
- **Balancing ideological differences among stakeholders.** EBM decisions that may seem to be a simple matter of setting scientific limits on resource use frequently fail because of the political process of decision-making, differing values and norms, and power imbalances. Collaborative processes that engage diverse stakeholders and address inequalities can contribute to an improved understanding and incorporation of the different perspectives into the development of EBM and increased compliance once implemented. In the AQUACROSS EBM approach this is ascertained through the design of the stakeholder process involving a balanced selection of all relevant stakeholders.

Table I: System approaches to address EBM as wicked problem (DeFries and Nagendra, 2017)

Approach	Problem to address	Examples of implementation	Obstacles
Multisector decision-making	Services from multifunctional landscapes and seascapes are not factored into decisions about single sectors	National-level spatial planning (*34*); multilevel governance (*35*)	"Stovepiped"administrative structures
Decision-making across administrative boundaries	Ecological processes transcend administrative boundaries	River basin commissions (*40*); large-scale corridor planning (*42, 43*)	Managers lack incentives and authority to consider other jurisdictions
Adaptive management	Learn-by-doing when outcomes of decisions are uncertain because of complex system dynamics	Ecosystem restoration; fisheries management (*48*)	Inflexible bureaucracies; lack of monitoring
Incorporating natural capital and ecosystem services in markets	Externalities are not included in economic accounting systems	Payments for ecosystem services; certification; inclusive wealth accounting (*50*)	Difficulty in determining value of nonmarketed ecosystem services
Balancing ideologies and political realities of diverse stakeholders	Politics and different expectations of ecosystem management lead to logjams in decision-making	Collaborative planning (*67*)	Differences in ideology and values; political realities

For the (further) development and assessment of the AQUACROSS EBM approach, we consider different EBM phases and how they link to specific aspects of the ecological system or the social system. These phases are based on (Borgstrom et al., 2015) (see figure I) and (Ansong et al., 2017) (see Figure II) where the management phases were aligned to the core elements by shifting the "Goals" management phase to occur before the other management phases.

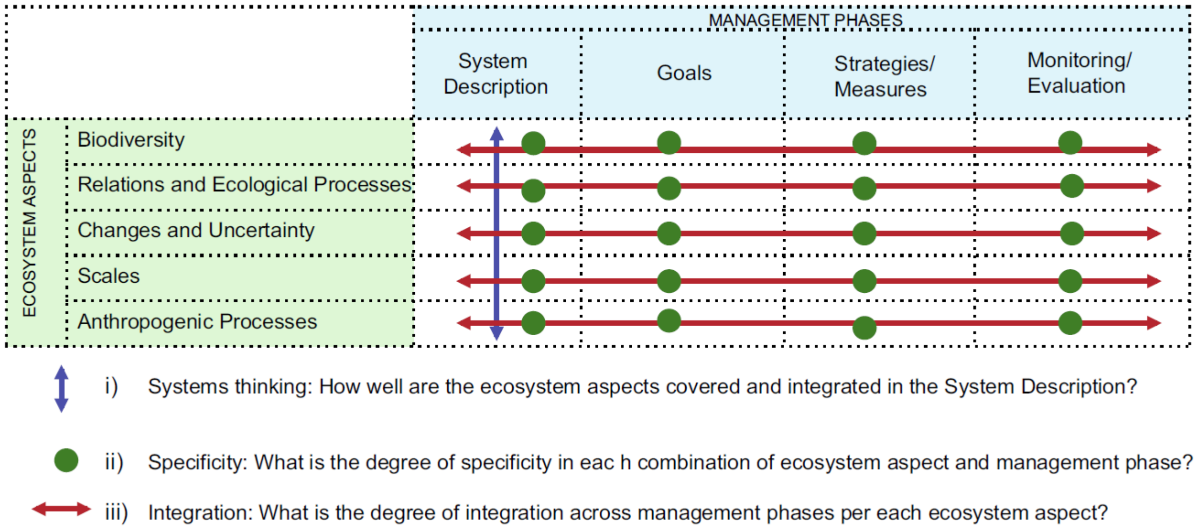

Figure I: The EBM assessment matrix combines a set of ecosystem aspects with management phases (Borgstrom et al., 2015)

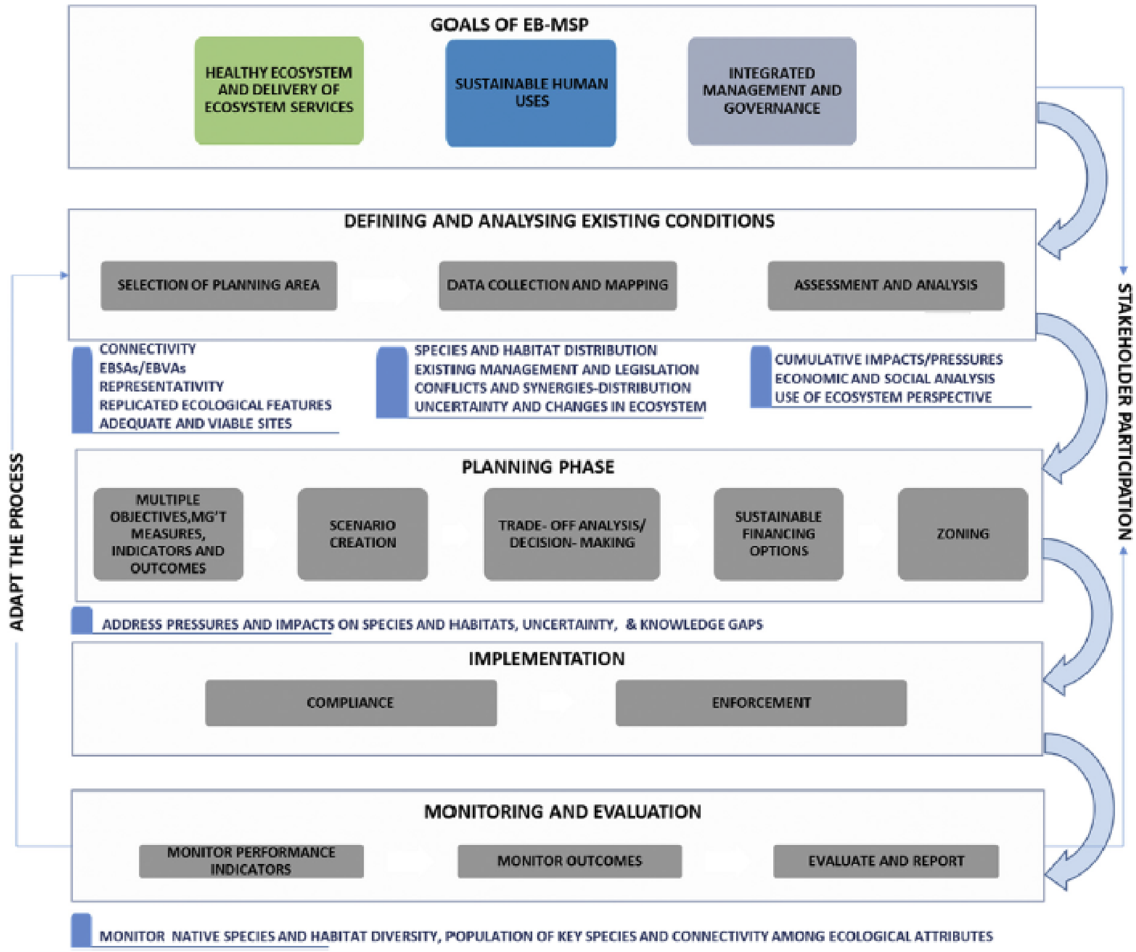

Figure II: Framework for ecosystem-based marine spatial planning distinguishing five core elements (Ansong et al., 2017)

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