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Evaluation of ecosystem-based management responses in case studies

Deliverable 8.2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642317.

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Suggested citation: Mattheiß, Verena, Pierre Strosser, Anneliese Krautkraemer, Clément Charbonnier, Hugh McDonald, Lina Röschel, Helene Hoffmann, Manuel Lago, Gonzalo Delacámara, Carlos M. Gómez, Gerjan Piet, Nele Schuwirth, Mathias Kuemmerlen and Peter Reichert. 2018. Evaluation of ecosystem-based management responses in case studies: AQUACROSS Deliverable 8.2. European Union's Horizon 2020 Framework Programme for Research and Innovation Grant Agreement No. 642317

Project coordination and editing provided by Ecologic Institute.

This document is available on the Internet at: www.aquacross.eu

Document title	Deliverable 8.2 – Evaluation of management responses in case studies
Work Package	WP8
Document Type	Deliverable
Date	20 November 2018
Document Status	Final report

Acknowledgments & Disclaimer

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 642317.

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List of abbreviations

AF	Assessment framework
CEA	Cost-effectiveness analysis
CFP	Common Fisheries Policy
CS	Case study
Del.	AQUACROSS Deliverable
DRBMP	Danube River Basin Management Plan
EBM	Ecosystem-based management
GBI	Green and blue infrastructure
HFI	Human Footprint Index
IAS	Invasive alien species
IBRM	Intercontinental Biosphere Reserve of the Mediterranean
ICPDR	International Commission for the Protection of the Danube River
MPA	Marine protected area
MSFD	Marine Strategy Framework Directive
NPA	Natural protected area
OWF	Offshore wind farm
PoM	Programme of measures
SES	Socio-Ecological System
WFD	Water Framework Directive
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 well-being.

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

1.1 Background

Aquatic ecosystems are rich in biodiversity and linked to a multitude of valuable ecosystem services. These include, for example, the provision of water and fish, water purification, flood regulation, or recreational opportunities (Millennium Ecosystem Assessment 2005; Grizzetti et al. 2016). At the same time, rivers, lakes, wetlands, coastal zones and marine areas are threatened by a variety of human activities and pressures, including pollution, morphological alterations, invasive species or conversion of habitats. The existing European policy framework (e.g. the Water Framework Directive, the Marine Strategy Framework Directive, and the Birds and Habitats Directive) recognises the need for stronger protection of aquatic ecosystems and their sustainable use, and deploys extensive policy measures and instruments in response to the complex matter of aquatic biodiversity protection (Rouillard et al. 2017). Despite some progress due to the continuing efforts of the different EU member states to comply with existing environmental legislation (EEA 2018), initiatives have so far not been able to halt and reverse trends of declining biodiversity of aquatic ecosystems in order to reach the objectives set by the EU 2020 Biodiversity Strategy (EC 2015a).

The AQUACROSS project aims to support EU efforts to protect aquatic biodiversity and to ensure the provision of aquatic ecosystem services. In particular, 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.

The present report has been developed within work package (WP) 8 of the AQUACROSS project. This WP forms the "improving management" pillar of the project, which builds on work undertaken in the previous pillars to develop concepts, practices and tools **for better understanding and implementation of EBM for the protection of aquatic biodiversity**. The relevant basis includes, in particular, the information on related policy objectives (WP2), the understanding of the socio-ecological system (SES) (WP4, WP5), the development of scenarios and the forecasting exercise (WP7) and finally, constructive exchanges with stakeholders (WP1).

WP8 seeks to identify and provide best practice on how to develop and implement EBM across all aquatic ecosystems. It furthermore evaluates the proposed approaches to assess their performance in reaching biodiversity targets compared to existing, currently applied management approaches.

The work which forms the basis for this report is built on the conceptual (AQUACROSS Innovative Concept, Gomez et al. 2016 (D3.1)) and methodological foundations (AQUACROSS Assessment Framework, Gomez et al. 2017 (D3.2)) laid in the initial parts of the AQUACROSS project, which have already been taken up by Piet et al. 2017 (D8.1) "Making ecosystem-based management operational". WP8 concentrates on the practical proposals for EBM-based management in the AQUACROSS case studies as well as the evaluation of these propositions. The AQUACROSS approach for these tasks is shortly introduced in the following.

1.1.1 AQUACROSS's definition of ecosystem-based management

Based upon a thorough revision of the extensive available literature around EBM, the AQUACROSS concept (Gomez et al. 2016 (D3.1)) and Assessment Framework (Gomez et al. 2017 (D3.2)) define EBM "as any management or policy options intended to restore, enhance and/or protect the resilience of the ecosystem" (Gomez et al. 2017 and 2016). Put simply, the AQUACROSS definition of EBM focuses on the concept of ecosystem health. This definition also includes any course of action intended to improve the ability of ecosystems to remain within critical thresholds, to respond to change and/or to transform to find a new equilibrium or development path. In this context, EBM sets the foundations for the development of effective and widely applicable management concepts and practices for aquatic ecosystems. This EBM concept further clarifies the aims to achieve sustainable resource use (see Long et al. 2015 EBM definition) by ensuring that appropriate management decisions according to EBM objectives are those that do not adversely affect ecosystem functions and productivity, so that the provisioning of aquatic ecosystem services (and subsequent socio-economic benefits) can be sustained in the long-term. EBM is also relevant for maintaining and restoring the connection between social and ecological systems. AQUACROSS also recognises EBM as a way to address uncertainty and variability in dynamic ecosystems in an effort to embrace change, to learn from experience and to adapt policies throughout the management process. EBM measures will need to be supported by an effective policy and governance framework that enables their adoption amongst a wide range of actors from public authorities to businesses, civil society organisations and citizens.

EBM thus aims at achieving the long term sustainability of resource use by focusing on restoring, enhancing and/or protecting the resilience of the ecosystem and thus, their capacity to provide key services – which ultimately determine human well-being – to society. Previous AQUACROSS reports have clarified important terms for the understanding of different elements of EBM, such as the definition of ecosystems, ecosystem services, resilience and appropriate management and policy options.

Box 1 Important definitions used in AQUACROSS

Biodiversity = **Biological Diversity** means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity, article 2). Biological diversity is often understood at four levels: genetic diversity, species diversity, functional diversity, and ecosystem diversity.

Ecosystem Process is a physical, chemical or biological action or event that links organisms and their environment. Ecosystem processes include, among others, bioturbation, photosynthesis, nitrification, nitrogen fixation, respiration, productivity, vegetation succession.

Ecosystem Function is a precise effect of a given constraint on the ecosystem flow of matter and energy performed by a given item of biodiversity, within a closure of constraints. Ecosystem functions include decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem Services are the final outputs from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people. In the context of the Common International Classification of Ecosystem Services (CICES), they are biologically mediated (human-environmental interactions are not always considered ecosystem services).

Resilience refers to the capacity of a system to deal with disturbance and continue to develop (Folke et al. 2010). The term is related with the amount of perturbation a linked social-ecological system (SES) can withstand and still maintain the same structure and functions (Holling et al. 2002; Walker et al. 2004).In AQUACROSS, this refers to the capacity of the social-ecological systems to co-produce the ecosystems services and abiotic outputs that would be demanded by society in the long term.

Adaptability is the capacity of actors in the system to manage change so as to maintain the system within sustainability boundaries. One critical objective of policy actions within AQUACROSS consists ofenhancing the robustness of the system, that is to say its capacity to absorb shocks and adapt to circumstances that are not completely predictable in advance.

Transformability refers to the capacity to create a new system when ecological, economic, or social structures make the current system untenable (Folke et al. 2010). Transformability addresses active steps that might be adopted to change the system to a different, potentially more desirable, state. It includes actions to identify potential future options and pathways to get there, the capacity to learn from crises and to navigate thresholds for transformations (Chapin et al. 2009).

Further, Long et al. (2015) analysed the presence of different EBM principles in peer-reviewed literature and identified 15 main principles with the objective to make the EBM concept operational and more easily understood. See table 1.

Table 1 EBM principles and AQUACROSS process- and system-oriented criteria

EBM principles according to Long et al. (2015)	AQUACROSS process-oriented criteria	AQUACROSS system-oriented criteria
1. Consider Ecosystem Connections		X
2. Appropriate Spatial and Temporal Scales		X
3. Adaptive Management	X	
4. Use of Scientific Knowledge	X	
5. Integrated Management	X	
6. Stakeholder Involvement	X	
7. Account for Dynamic Nature of Ecosystems		X
8. Ecological Integrity and Biodiversity		X
9. Sustainability	X	
10. Recognise Coupled Social-Ecological Systems		X
11. Decisions reflect Societal Choice	X	
12. Distinct Boundaries		X
13. Inter-disciplinarity	X	
14. Appropriate Monitoring	X	
15. Acknowledge Uncertainty		X

In the context of AQUACROSS, these principles have been translated into so-called process- and system-oriented criteria, which are used to assess the knowledge base of the socio-ecological system in terms of its capacity to guide the development and implementation of EBM.

As indicated in Piet et al. 2017 (D8.1), process-oriented criteria assess the decision-making processes and institutions in the baseline scenario and the changes to these pathways and institutions that are required to build, design, and implement EBM management plans. Process-oriented criteria are key to evaluate the governance failures that lead to environmental challenges and that should be addressed to enable the social system to grow to the challenge of implementing EBM. In addition to the principles highlighted in the table above, process-oriented criteria also include the application of the precautionary approach (for more information, please have a look at Piet et al. 2017 (D8.1)).

System-oriented criteria, on the other hand, assess the knowledge base of the SES in terms of its capacity to provide an adequate basis for developing EBM approaches from an ecological point of view. In addition to the principles highlighted in the table above, system-oriented criteria include also the consideration of cumulative impacts (for more information, please have a look at Piet et al. 2017 (D8.1)).

In this respect, EBM principles can be seen as means to further break down the definition of EBM into sub-components for the purposes of analysis and broader applications, for example the understanding of the complex SES. Arguably, the principles have not been designed to conclude what is or is not EBM for the purposes of labelling management options, but instead in order to understand how they match or by how far current or future management approaches are in line with the ecosystem-based management approach.

To this end, the AQUACROSS assessment framework specifies the distinctive features of EBM, which are defined in the box below as the components of EBM (see for further information Gomez et al. 2016 (D3.1), Gomez et al. 2017 (D3.2) and Piet et al. 2017 (D8.1)).

Box 2 What makes EBM different to other approaches for the protection of aquatic biodiversity?

1. EBM considers ecological integrity, biodiversity, resilience and ecosystem services

EBM aims to maximise the joint value of all ecosystem services rather than focusing on maximising the provision of some ecosystem services (drinking water, water for irrigation, urban soil, dilution of pollutants, etc.) over others. EBM considers the dynamic relationship among and between species, as well as their abiotic environment, and protects the integrity of the ecosystem as a means to preserve a complementary array of ecosystem services as well as to preserve biodiversity in its own rights. EBM is thus characterised by a focus on multiple benefits or environmental services and its simultaneous contribution to a range of targets across different policy domains.

2. EBM is carried out at appropriate spatial scales

Managing ecosystems is far more ambitious than managing water bodies, single assets or even river basins or regional seas. Hence, EBM management decisions and actions must take place at the appropriate level, taking into account ecosystem boundaries and complex connections and adaptive processes. This might imply decentralisation to the level of local communities, but may also require action at higher levels through, for example, transboundary cooperation or even cooperation at the global level. Ecosystem connections within and across realms should be considered, as management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems.

3. EBM develops and uses multi-disciplinary knowledge

Effective design and implementation of EBM requires an understanding of the complex ecological and social systems to be managed, which in turn requires the development of multi-disciplinary knowledge. A more detailed understanding of ecosystem functions and structure, and the roles of the components of biological diversity in ecosystems, as well as a better understanding of social institutions and decision-making processes are needed to understand ecosystem resilience and the effects of biodiversity loss and habitat fragmentation; underlying causes of biodiversity loss; and determinants of local biological diversity in management decisions. EBM draws on scientific knowledge to ascertain the connections, integrity and biodiversity within an ecosystem as well as its dynamic nature and associated uncertainties, while also drawing on local and traditional knowledge of stakeholders.

4. EBM builds on social-ecological interactions, stakeholder participation and transparency

Rather than treating society and the environment as separate entities, EBM acknowledges social-ecological interactions and seeks to balance ecological and social concerns. It requires an identification of what set of ecosystem services could and should be sustainably provided while taking into account potential impacts on biodiversity. As ecosystem services are asymmetrically valued by different users, deciding on EBM alternatives implies synergies and trade-offs between benefits and beneficiaries. EBM gives prominence to transparent and inclusive decision-making between authorities and stakeholders. It seeks to results in agreements amongst stakeholders with potentially conflicting interests and advance collective action by building consensus on a shared vision for the future (e.g. the array of ecosystem services to be preserved).

5. EBM supports policy coordination

Effective EBM requires cooperation and collective action to share the array of ecosystem services obtained across different stakeholders and policy domains, and to break institutional silos along with disciplinary borders. By seeking to balance ecological and social concerns, EBM opens new opportunities of pursuing different policy objectives simultaneously (in water provision, energy, land use, food, climate change adaptation, etc.). EBM also contributes to designing cooperative instruments and policy synergies to take advantage of these opportunities and minimises associated transaction costs.

6. EBM incorporates adaptive management

Ecosystem processes and functions are complex and variable. Accepting that there are no optimal solutions and that the future is uncertain, EBM seeks to build adaptation capacities by restoring critical ecosystems and strengthening social abilities to respond to a range of possible future scenarios. Short-term opportunities of management interventions should be weighed against long-term benefits of alternative interventions. While long-term goals must be spelled out, inevitably, unforeseen issues will modify those goals or show new ways to reach them. As a consequence, long-term goals and the management tools used to achieve them must be regularly revisited. Monitoring should be implemented so that indications of potential problems or changes are spotted early.

1.1.2 Which planning process for ecosystem-based management?

As mentioned in Piet et al. 2017 (D8.1) and Piet et al. (*forthcoming*), EBM should be considered foremost a decision process. Within AQUACROSS, EBM is seen as an incremental piecemeal process, with case studies aiming to advance on the different principles as much as they can, acknowledging that advancing on all criteria at the same time and to a full extent is hardly achievable. Based on this understanding, Piet et al. 2017 (D8.1) proposes a cyclical approach, which is divided into four distinct phases:

1. Societal goals: Identification of societal goals based on policy objectives and stakeholder preferences.

2. Description of the socio-ecological system: assessment of the baseline scenario, explicitly distinguishing between the ecological system and the social system.

3. Planning an EBM response: For the AQUACROSS EBM approach, this planning phase starts with the pre-screening of alternatives and ends up in 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 and "evaluation of expected performance" of measures.

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.

As part of phase 3, an EBM plan is elaborated, consisting of measures, which are directly intended to act over the ecological system, and policy instruments, which act on the social system (see Piet et al. 2017 (D8.1) and chapter 2 for more details). The EBM plans proposed by the AQUACROSS case studies are presented in chapter 2.

1.1.3 How are EBM approaches evaluated within AQUACROSS?

Following the approach indicated in Deliverable 8.1, the evaluation process of individual EBM plans, which consists of both measures and policy instruments, typically involves three steps:

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

Whereas the first two steps are covered by other WPs and other Deliverables (Roeschel et al. 2018 (D2.3), Costea et al. 2018 (D4.2) and Kakouei et al. 2018 (D7.3)), the present report focuses on the last step, the evaluation of the proposed options against existing alternatives.

As foreseen already by the Assessment Framework (Gomez et al. 2017 (D3.2)) and confirmed by Piet et al. 2017 (D8.1), the EBM plans are evaluated against three so-called outcome-oriented criteria:

- effectiveness
- efficiency
- equity and fairness

The evaluation of effectiveness investigates to what extent the proposed management approaches will achieve previously defined environmental targets. These targets may consist of a suite of indicators and their target or limit threshold values which reflect the status of the ecosystem at stake or may simply be the reduction of risk that a certain threat compromises the achievement of specific objectives. The effectiveness of an individual measure, or of a program of measures, is defined by the contribution they make to bridge the gap between the current situation and the target conditions that would meet the environmental policy objectives.

The evaluation of efficiency, in terms of evaluating the expected performance of proposed approaches, looks at the costs and benefits generated by the proposed EBM plan. These include both financial costs and benefits (e.g. the direct costs of implementing measures), as well as economic costs and benefits, e.g., changes in the provision of ecosystem services, which have an impact on human wellbeing. The figure below illustrates the different costs and benefits that ideally should be considered for an evaluation of efficiency in the context of a proposed EBM plan. All costs and benefits should at least be qualitatively described, and quantified and monetised as far as possible.

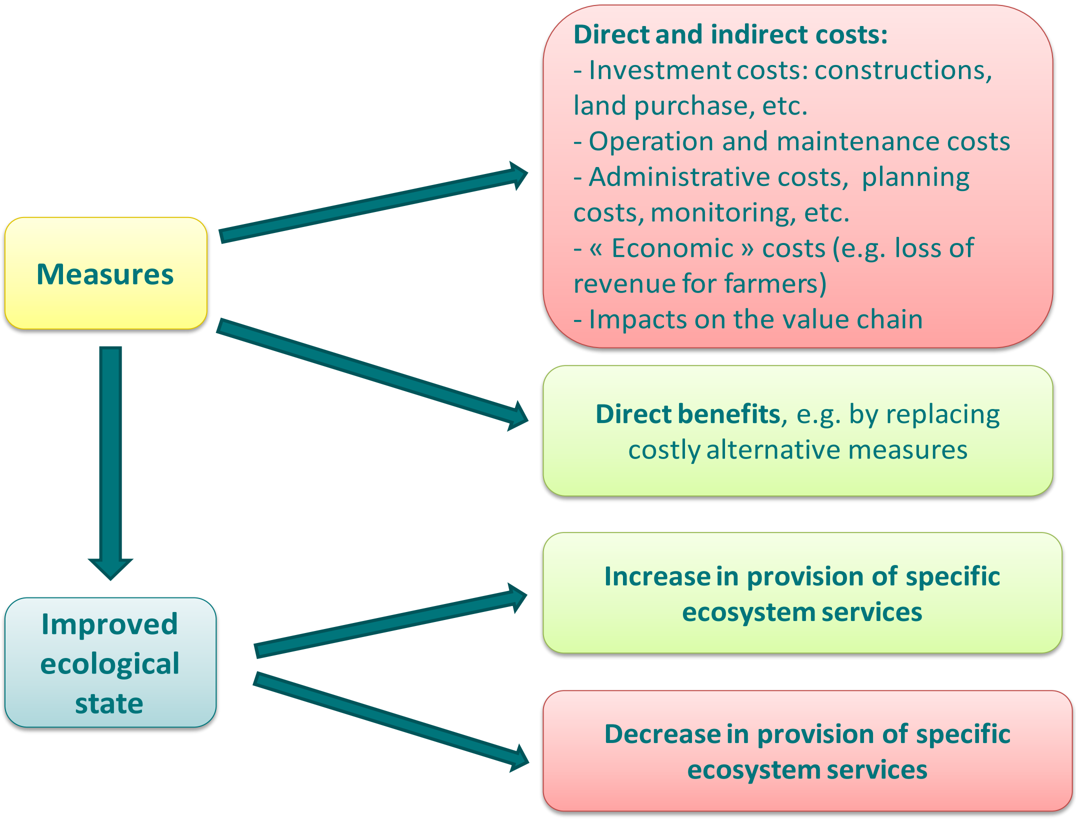

Figure 1 Costs and benefits to be considered for the evaluation of efficiency of proposed EBM approaches

Another way of integrating efficiency reflections within the AQUACROSS planning process is through a cost-effectiveness analysis (CEA), which ranks a list of measures aiming at the same environmental pressure either by choosing the most effective measures under budget constraint, or by choosing the least costly measures to reach a given target level. Although very practical for prioritising among a set of measures, this approach does not consider the resulting benefits (beyond reaching the environmental target).

The evaluation of equity and fairness, finally, looks at how costs and benefits linked to the proposed approaches are distributed amongst different groups of the society.

What is important for the evaluation of all three criteria is that the expected performance of the EBM plan is compared to the correct baseline. In order to be able to specify the added value of the proposed approach, it is important not to compare its performance against the situation today, but to compare it to the expected performance of the management approaches which are planned so far.

1.2 Main content of the report

After introducing the background of the work in the previous sub-chapter and providing an overview of the AQUACROSS case studies in chapter 1.3, the main objective of this report is to introduce the EBM approaches that have been developed within the AQUACROSS case studies, to present the methods applied to evaluate their expected performance for the three criteria and against the baseline, as well as to show and discuss the results of this evaluation. Before concluding, preconditions for a successful uptake of the proposed approaches are discussed. Accordingly, the structure of the report is as follows:

1. Introduction
1.1 Background
1.2 Structure of the report
1.3 Overview of case studies
2. What management approaches are proposed in the AQUACROSS case studies?
2.1 Introduction and framing
2.2 Case Study EBM Plans and Context
2.3 Discussion
3. What is the added value of EBM?
3.1 How have proposed approaches been evaluated?
3.2 Which results of the evaluation?
4. Which pre-conditions for ensuring a successful and effective implementation of EBM?
5. Summary and conclusions

1.3 Overview of case studies

The methodological framework developed within AQUACROSS is put in practice in eight case studies, which are distributed all over Europe. They were selected to cover the range of different aquatic ecosystems as well as to showcase specific elements of the objectives of the EU 2020 Biodiversity Strategy relevant for the management of aquatic ecosystems. The following table provides an overview of the AQUACROSS case studies. Their proposed EBM approaches as well as their evaluation are presented in the following main chapters of the report.

Table 2 Overview of AQUACROSS case studies

Case study	Location	Aquatic realm	Relevant biodiversity strategy targets	Environmental issue(s) targeted by the case study	Main approach
CS 1	North Sea	Marine	Target 1, 2, 4 & 6	Reconciling societal goals aiming for sustainable seafood, clean energy and nature conservation	Use of a risk-based approach to assess the cumulative effects of multiple impact chains
CS 2	Intercontinental Biosphere Reserve of the Mediterranean (Andalusia (Spain) – Morocco)	Freshwater, coastal, marine	Focus on Target 2, but also impact on Target 1, 3 & 4	Restoring degraded ecosystems and establishing green and blue infrastructure	Multi-zoning modelling approach for spatial optimisation
CS 3	Danube River Basin	Freshwater (river, floodplains)	Target 1 & 2	Balancing multiple biodiversity and ecosystem services targets for river restoration and conservation.	Modelling approach for a spatially optimised selection of restoration sites along the Danube main stem
CS 4	Lake Lough Erne – between Northern Ireland and the Republic of Ireland	Freshwater (lake)	Target 5	Invasive alien species and nutrient pollution	Analysis of the SES using the linkage framework and stakeholder-based fuzzy cognitive mapping
CS 5	Ria de Aveiro Natura 2000 site, Portugal	Coastal and freshwater (river, wetland)	Target 2	Mitigating the effects of dredging and counteracting saltwater intrusion	Quantitative modelling and co-development of responses using spatial multi-criteria analysis
CS 6	Lake Ringsjön and Rönne å Catchment in Kattegat, Sweden	Freshwater (lake)	Target 2	Eutrophication from agriculture and untreated wastewater inflow	Coupled agent-based, system dynamics model; collaborative scenario building
CS 7	Swiss Plateau	Freshwater (river)	Target 2	Morphological alterations of rivers, continuity interruption, pollution with micro-pollutants and pesticides	Modelling for spatially optimised site selection
CS 8	Marine protected area Faial-Pico Channel in the Azores	Marine	Target 1, 2 & 4	Extraction of species by commercial fishermen and touristic uses	Qualitative approaches involving stakeholders for the selection of policy instruments

Note The EU Biodiversity Strategy to 2020 consists of the following targets: Target 1: Protect species and habitats. Target 2: Maintain and restore ecosystems. Target 3: Achieve more sustainable agriculture and forestry. Target 4: Make fishing more sustainable and seas healthier. Target 5: Combat invasive alien species. Target 6: Help stop the loss of global biodiversity. Detailed information on case studies and the results of their work can be found in the AQUACROSS Deliverable 9.2.

2 Which management approaches are proposed in the AQUACROSS case studies?

2.1 Introduction and framing

EBM plans aim to restore and preserve the resilience and the sustainability of the whole Social-Ecological-System, while at the same time achieving other societal goals. In this chapter, we introduce the concept of EBM plans and describe how they have been applied in the AQUACROSS Case Studies to improve management of aquatic ecosystems for the protection of aquatic biodiversity. In section 2.1 we first introduce and define what is an EBM plan, which is made up of a combination of management measures and policy instruments. In section 2.2 we summarise each AQUACROSS Case Study's EBM plan, as well as the case study context and relevant research questions. We also assess how far each case study's EBM scenario progresses beyond baseline management relative to different characteristics of ecosystem-based management, making reference to the components of EBM presented in Box 2 (section 1.1.1). Section 2.3 summarises to what extent each AQUACROSS case study has gone beyond baseline management.

Following Piet et al. 2018 (D8.1), an AQUACROSS, EBM plans consist of two elements:

- Measures, which are integrated into a Programme of Measures
- Policy instruments, which are integrated into an Implementation Plan

A measure is any action with the potential to contribute to a predetermined environmental objective, i.e. to bridge the gap between the current and the desired status of the ecosystem. The impacts of these measures over ecosystems can either be direct, such as in the restoration or protection of ecosystems. They can also be indirect, as a result of targeting pressures, the regulation of the activities of co-producing ecosystem services, or drivers. Multiple interconnected measures that have the same aim can feed into a Programme of Measures. A Programme of Measures encapsulates the changes required to move the status of ecosystems to the level required to achieve desired societal goals. 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 welfare gains.

A policy instrument is any action with the potential to help put a Programme of Measures into practice, as well as to improve the capacity of the social system to improve the overall governance of ecosystems. These policy instruments encompass any action designed to improve decision support systems (i.e. integration of scientific knowledge, improved monitoring), overcome institutional lock-ins (i.e. by breaking institutional silos, improving policy coordination), adapt the legal framework (i.e. redefining permits, licences and use rights, etc.),change water users' behaviour (i.e. incentivising resource saving decisions), foster cooperation among stakeholders (to agree on conservation targets and share benefits), develop alternatives to improve the financial feasibility of the Programme of Measures (i.e. through direct subsidies, compensation to potential losers, cross subsidies between ecosystem services' users to restore fairness and increase the social acceptability of the PoM), or to promote the adoption and swift diffusion of alternative technologies or enforce regulations. These policy instruments should then be integrated into an Implementation Plan, which is a suite of multiple policy instruments.

Together, the Programme of Measures and the Implementation Plan make up the Ecosystem-Based Management Plan (EBM plan).

2.2 Case Study EBM Plans and Context

In this section, we describe the EBM plan in each case study. As EBM Plans are site and situation specific, to understand them we must understand the local decision-making context. Accordingly, we also introduce key elements of the case study context. This also helps to assess transferability. Detailed information on each case study and its EBM Plan can be found in the Case Study Reports (McDonald et al. 2018 (D9.2)). As discussed in section 1, EBM is reflected not only in the EBM plan, but also in the process that leads to it. Each case study description also includes information on the extent to which the process reflected EBM. In the sections indicating how far each case study goes beyond current management practices, reference is made to the components of EBM (see Box 2, chapter 1.1.1).

2.2.1 CS 1 – North Sea

Relevant context: The North Sea is one of the busiest seas with many (often growing or newly emerging) sectors laying claim to a limited amount of space. The main human activities include fishing, shipping, oil and gas extraction, and newly emerging activities such as the renewable energy sector. In particular, offshore wind farms are increasingly demanding space. These combined human activities and their associated pressures on the environment have hindered the achievement of the ecological goals for the North Sea. Important societal goals for local stakeholders and policymakers for the North Sea Case Study included sustainable food (fisheries), clean energy (renewables) and a healthy marine ecosystem. In particular, EU targets for renewable energy are driving off-shore wind farm expansion, which can have negative effects (bird mortality, noise, physical loss of the seafloor) but also potentially positive ones (promote marine biodiversity through a ban of fishing within the offshore wind farms (OWF) or through additional hard substrate) in marine ecosystems.

Case Study Aim and EBM Plan: The North Sea case study aimed to provide a more integrated, ecosystem-based approach to marine spatial planning and management, considering diverse (and potentially conflicting) societal goals, included several sectors (fisheries and offshore renewable wind energy), and considered their impacts on the entire ecological system. The EBM Plan aimed to deliver integrative management by considering different policy objectives – i.e. sustainable food supply, clean energy and a healthy marine ecosystem. Additionally, the EBM Plan aimed to assess and improve the knowledge base to support a more informed decision-making process toward the conservation of biodiversity and the ecosystem services it supports. Case Study 1's EBM Plan included (1) reducing fishing effort in the North Sea, (2) habitat banking, (3) fishing technology substitution: pulse trawl, (4) banning extractive activities in Marine Protected Areas, (5) redesigning off-shore wind farms to reduce bird mortality and (6) off-shore wind farms design to promote biodiversity.

Table 3 Main differences between the baseline and the management / EBM scenario in CS 1

Main differences or commonalities	Baseline	EBM / Management scenario
Environmental ambition / policy target	Targets are defined by policy objectives: – Fishing effort to achieve maximum sustainable yield (CFP/MSFD) – Enhance economic importance of the North Sea (Dutch Integrated Management Plan for the North Sea 2015) – Offshore wind power to increase from 1.2 GW in 2015 to 5.2 GW in 2020 (Dutch National Renewable Energy Action Plan) to achieve EU Renewable Energy Directive target of 14% by 2020	Pertaining to the fisheries management scenarios we consider the same (i.e. quota) management as under the baseline but with different targets (i.e. more ambitious toward biodiversity conservation) as well as some novel management approaches based on novel scientific findings. For the planning and management of the OWFs we work from the baseline in which some OWFs are already planned or even implemented but management options are still being discussed but also consider different planning scenarios.
Measures		– Reduction of fishing effort or capacity – Implementation of catch quota toward more precautionary goals – Implementation of habitat credits – Technological gear change: beam trawl to pulse trawl – Banning (or not) of fishing within the OWFs – Applying (additional) hard substrate for the construction of the OWFs to promote biodiversity – Redesigning OWFs to reduce bird mortality
Policy instruments	– Conventional regulatory instruments for catch quota management – Management plans for Natura 2000 sites to comprise fishing restrictions (quotas), regulating the extraction of species from fishing pressures within those areas. – Outside protected areas, status improvement will depend mainly on the ongoing sustainable exploitation of fisheries within the framework of revision of the CFP (2013-2022).	The same as in the baseline, but in addition these are considered: – Further regulations (bans, stringent quotas) to further reduce fishing effort in the North Sea beyond current legislation. – Habitat credits are applied to incentivize fishers behaviour in order to avoid areas with high(er) biodiversity value
Sites	Fishing activities covering most of the North Sea. Planned MPAs and OWFs.	Potential new MPAs have been identified to fulfil Natura 2000 requirements. Additional OWFs are planned.

How far did CS1 go beyond current management practices?

1. EBM considers ecological integrity, biodiversity, resilience and ecosystem services

CS 1 considers ecological integrity and biodiversity. With its focus on many different ecosystem components, including both species and habitats, this is a clear improvement to conventional management focussing on a single species or component.

The case study's integrated perspective also requires a consideration of all potential ecosystem connections. Even though the focal SES covers only a subset of the comprehensive SES, it is a major improvement, as it includes many more ecosystem connections than existing single-sector or single-species approaches. For example, typical fisheries management consists of only a single impact chain in this linkage framework, e.g. fishing (benthic towed gears) - Extraction of flora and/or fauna - Fish & Cephalopods.

CS 1 considers furthermore cumulative impacts, by explicitly considering different societal goals and how their achievement is potentially compromised by several human activities and their pressures. Current management in the North Sea is usually focussed on a single sector (e.g. fisheries management).

2. EBM is carried out at appropriate spatial scales

The case study developed and applied a knowledge base at the scale of the whole North Sea ecosystem as required by the policy frameworks (see point 5 below) instead of the member state perspective involving only their exclusive economic zone.

4. EBM builds on social-ecological interactions, stakeholder participation and transparency

CS 1 has elaborated the relationship between biodiversity status and the supply of ecosystem services which link the ecological system to the social system. The case study attempted to seek agreement amongst stakeholders with potentially conflicting interests on the setting of a threshold that determines the MSFD policy goal of Good Environmental Status by building consensus on a shared understanding of the current indicators in relation to concepts such as "undisturbed" or "sustainably exploited".

5. EBM supports policy coordination

CS 1's EBM Plan considers multiple objectives, and developed the knowledge base such that it can guide towards the achievement of multiple different policy objectives simultaneously. As such it has explored various trade-offs to inform decision-making.

6. EBM incorporates adaptive management

Adaptive management should be part of CS 1's EBM plan as it is unclear if the proposed management measures aimed at reducing the human-induced pressures are adequate to achieve the desired ecological status. This requires an ongoing process of analysing the results of the environmental monitoring programs and (further) adjust the management according to how the ecological status advances towards its targets.

2.2.2 CS 2 – Intercontinental Biosphere Reserve of the Mediterranean

Relevant context: Human activities are causing species to disappear at an alarming rate in the IBRM area and its area of influence. Significant changes in aquatic ecosystems are already visible in the area, and are expected to become more intense in the future. Losses of this magnitude affect the entire ecosystem balance, and its valuable resources used for food provision, drinking water supply, energy inputs, medicines, and materials contributing to human well-being. The Intercontinental Biosphere Reserve of the Mediterranean (IBRM) aims to manage biodiversity and ecosystems in an integrative manner across an area located between Spain and Morocco. The EU Biodiversity Strategy 2020 target 2 with an aim to restore at least 15% of degraded ecosystems by 2020 is driving interest in Green and Blue Infrastructure in the IBRM. Limited budgets and stakeholder and government desire to exploit the areas economic potential mean that prioritisation of restoration sites and ecosystem protection that minimises costs is needed.

Case Study aim and EBM plan: This case study aimed to optimally locate green and blue infrastructure (GBI) to maintain healthy ecosystems, reconnect fragmented habitats and restore degraded ecosystems, so they can provide society with more and better goods and services, whilst allowing multiple use. The case study considered the whole Intercontinental Biosphere Reserve of the Mediterranean, which covers parts of Spain and Morocco and the marine area in between. The EBM Plan consisted of designating areas as one of four types of zones: two with conservation aims (the core zone and conservation zone), which limit activities that would pressure the ecosystem, one that allows sustainable use, and a fourth zone that allows exploitation. Within the conservation and core zones, activities that cause pressures are limited, and ecosystems are to be restored. A mix of policy instruments (legislation, permits, payments, and education) was envisioned.

How far did CS 2 go beyond current management practices?

2. EBM is carried out at appropriate spatial scales

CS 2's EBM plan goes beyond traditional management, which is typified by borders, and instead manages ecosystems in multiple regions in Morocco and Spain as one unit. This enables more effective linking of protected areas, which achieves greater environmental outcomes for the same cost. CS 2 worked closely with international and local stakeholders to promote cooperation and management at appropriate spatial scales.

3. EBM develops and uses multi-disciplinary knowledge

CS 2 combines multiple scientific sources of ecological and socio-economic information, and uses this to optimise selection of restoration sites within their case study area. This integration of interdisciplinary science, supported and validated by stakeholder involvement, goes significantly beyond standard management. It achieves greater efficiency and effectiveness, as management can scientifically consider a greater range of ecosystem services valued by society.

Table 4 Main differences between the baseline and the management / EBM scenario in CS 2

Main differences or communalities	Baseline	EBM / Management scenario
Environmental ambition/policy target	EU Biodiversity Strategy 2020 Target 2, which "aims to maintain and restore ecosystems and their services by including green infrastructure in spatial planning". Baseline GBI network is based on the current policies.	Same ambition as baseline in addition to "restoring at least 15 % of degraded ecosystems by 2020"
Measures	A number of measures are implemented to achieve environmental ambitions, though fewer Green and Blue Infrastructure approaches than in EBM scenario (see right column)	The EBM scenario includes EBM measures that are expected to restore the main degraded aquatic ecosystems in the IBRM case study area, namely: **Reduce key pressures** - Reduce the fishing pressures - Reduce the recreational activities pressures -Reduce the urban and commercial development pressures **Restoration of degraded habitats** -Restoration of damaged components of riparian zone habitats; - Restoration of marine degraded seafloor habitats - Restoration of coastal wetlands - Restoration of coastal dunes
Policy instruments	Monitoring and research instruments; Legislative instruments: MSFD, Coastal protection plans, WFD, CFP, sustainable tourism strategy; Payments to farmers for implementation Awareness-raising: farm advisory services, training, stakeholder participation, innovation groups and stakeholder workshops Training and qualification Public information programs Permits /quotas	Same instruments as in the baseline, but incorporating restoration of habitats and optimal allocation of key areas to increase ES potential within GBI
Sites	According to the baseline scenario, there are different sites (or Zones) that address different conservation targets to establish an optimal GBI design.	In the EBM scenario, the spatial GBI design is based on a future scenario where the implementation of EBM measures is assumed to be successful in restoring degraded ecosystems. In this EBM scenario, in addition to the zones identified under the baseline scenario, restoration zone has been identified where EBM measures are expected to restore 15 % of the degraded ecosystems. The EBM measures are applied to specific sites and further studies will be necessary to detail the appropriate measure. Optimal sites are selected considering environmental objectives, restoration potential, maximising ecosystem services, and increasing networks/connectedness.

2.2.3 CS 3 – Danube

Relevant context: Relevant context: The Danube River Basin is the most international river basin in the world. The International Commission for the Protection of the Danube River (ICPDR) coordinates the conservation, improvement and rational use of Danube waters. However, currently, each country on the Danube selects their own restoration sites without ICPDR guidance. Multiple human activities, including the construction of hydropower plants, expansion of agricultural use, and large-scale river regulation measures designed to improve navigation and flood protection, have resulted in this ongoing loss of habitat and biodiversity; in particular, hydro-morphological alterations such as river fragmentation or disconnection of wetlands threaten riverine ecosystems and their biodiversity. Stakeholders are concerned about affordability of restoration. In addition to biodiversity, flood retention, and recreational value, stakeholders also demanded consideration of nutrient retention.

Case Study Aim and EBM Plan: The Danube Case Study aimed to improve management of river-floodplain systems along the Danube by considering multiple policy targets, multiple ecosystem services, and aiming to maximise their joint value. By linking available multi-disciplinary information in an innovative way, they created a basis for more integrated management and restoration planning of river-floodplain systems in line with the principles of ecosystem-based management (EBM). In particular, the case study aimed to identify optimal sites for hydro-morphological restoration. The following EBM measures were identified and evaluated in the Case Study: (1) re-flooding of floodplains through removal, relocation, lowering, slotting or other alteration of dyke structures, (2) re-connection of floodplains to the main river through the creation of bypasses, reconnection of floodplain channels, and creation of secondary channels, and (3) bank-restoration and stabilisation through the removal of hard artificial material.

How far did CS3 go beyond current management practices?

2. EBM is carried out at appropriate spatial scales

CS 3 fosters transboundary coordination and cooperation by considering the whole navigable main stem of the River Danube (ecosystem scale) independent from jurisdictional, administrative and political scales (e.g. country scale). In contrast to the baseline scenario, where restoration sites are selected country by country, CS 3 optimally selects sites considering the Danube as a whole. The approach cannot replace local planning of specific projects but as a flexible large-scale planning tool it can support the integration across policies, targets and countries in line with EBM. CS 3's optimisation across the whole of the Danube should increase efficiency.

3. EBM develops and uses multi-disciplinary knowledge

CS 3 utilised Bayesian Network modelling approach to understand the complex socio-ecological system to be managed. The network shows linkages between hydropower and navigability and alterations to hydro-morphology, as well as urbanization and agriculture. This allows for a greater characterisation and understanding of the whole system, relative to baseline management, and thus allows for new, balanced consideration of its management.

5. EBM supports policy coordination

Relative to baseline management, where restoration site selection was predominantly determined under Water Framework objectives, CS 3's EBM plan also considers additional policy objectives (including the Habitats and Birds Directives, Flood Directive, and Biodiversity Strategy). This supports overall policy coordination, and increases efficiency (i.e. overall benefits, including environmental, for the same costs).

Table 5 Main differences between the baseline and the management / EBM scenario in CS 3

Main differences or commonalities	Baseline	EBM / Optimisation scenario
Environmental ambition / policy target	The Danube River Basin Management Plan (DRBMP) includes river restoration sites, with the aim of reaching good ecological status for all water bodies (i.e. in accordance with the Water Framework Directive (WFD)). The DRBMP includes specific goals for hydro-morphological restoration of river-floodplains systems, which is considered a measure of basin-wide importance to conserve biodiversity (EC, 2011, Target 2), ensure the good status in the river stretch, flood protection, pollution reduction and climate adaptation by 2021 (chapter1 and 2, ICPDR, 2015). However, despite these goals, few countries have already implemented or planned restoration projects to meet the 2021 target; the baseline includes those already foreseen or implemented in the 2015 DRBMP.	Next to the targets of the EU WFD, also considers other policy targets to select optimal river restoration sites (including the Birds and Habitats Directive, the Biodiversity strategy and the Floods Directive). The EBM Plan meets the 2021 goals.
Measures	Restoration measures are all aiming to reduce the direct effect of hydro-morphological alteration of the river-floodplain system due to artificial structures. Re-flooding, re-connection and bank restoration are considered for all scenarios. The added value of the optimisation scenario lies in the selection methods of the sites to be restored with these measures.	
Policy instruments	Restoration sites are implemented through a variety of policy instruments.	No change from baseline. The results of the evaluation might lead to the identification and proposition of additional, more specific policy instruments, including economic policy instruments.
Sites	River restoration sites are selected by individual countries. Site selection processes are unclear. The sites and restoration form part of the national river basin management plans established under the WFD. They are listed in the second DRBMP (from 2015). Only sites where restoration measures are foreseen or already planned are included in the evaluation.	River restoration sites are selected optimally across the whole of the Danube, based on potential effectiveness and efficiency. As well as considering WFD objectives, site selection also considered Birds and Habitats and Floods Directives, and Biodiversity Strategy (as well as related ecosystem services)
Governance / Institutional context	It is assumed that the governance / institutional context is the same in all scenarios.	It is assumed that the governance / institutional context is the same in all scenarios, although stakeholders were involved in EBM optimisation process.

2.2.4 CS 4 – Lough Erne

Relevant context: Lough Erne sustains multiple competing activities each with different demands from the system in terms of ecosystem services and physical resources. Lough Erne is a heavily modified water body according to WFD status labels, and contains a range of non-native species. Most recently, there has been an invasion and proliferation of the Nutall's Pond Weed (*Elodea nutalli*), which is listed as an Invasive Alien Species of Union Concern. This new arrival is able to colonise deep areas of the Lough and has clogged many areas of the lake interfering with popular recreational activities, in particular boating. Managing Elodea is complicated by the transboundary nature of the Lough and catchment, which cross the Northern Ireland/Republic of Ireland border.

Case Study Aim and EBM Plan: CS 4 examined the implications of the regulation on Invasive Alien Species (IAS) for practical management in Lough Erne, Northern Ireland, in the context of existing EU environmental commitments. Stakeholder-informed qualitative modelling predicted a decline in future water quality in the Lough due to agricultural activities in the catchment, which would also fuel Elodea growth. The case study EBM plan considered two management approaches to the mechanical removal of Elodea included in the baseline: 1) limiting agricultural nitrogen pollution through a set of on-farm management measures (e.g. reduce fertiliser and manure application), and 2) raising lake levels in summer to limit Elodea growth and allow recreational activities.

How far did CS 4 go beyond current management practices?

2. EBM is carried out at appropriate spatial scales

The innovative proposal of raising water levels in Lough Erne CS 4 to manage invasive species (*Elodea Nuttalli*) targets environmental and recreation opportunities. The proposed EBM Plan includes a combination of recreation, environmental, and agricultural aspects to facilitate cooperation and collective action across different stakeholder and policy domains to share the array of ecosystem services obtained not only at the Lough level, but across the whole transboundary catchment, which considers recommendations across Northern Ireland/Republic of Ireland border.

5. EBM supports policy coordination

CS 4 Facilitates cooperation and collective action across different stakeholder and policy domains to share the array of ecosystem services obtained: CS 4's EBM Plan includes recreation, environmental, and agricultural aspects.

Table 6 Main differences between the baseline and the management / EBM scenario in CS 4

Main differences or commonalities	Baseline	EBM / Management scenario
Environmental ambition / policy target	Currently Elodea nutalli is proliferating uncontrolled around Lough Erne, the Loughs have "Moderate Environmental Potential" Regulation on Alien Invasive Species, WFD	The specific aim as discussed with stakeholders is to reduce input of Agricultural Phosphorus to Lough Erne by 30%
Measures	The first explosive outbreak of Elodea occurred in 2010. The weed was so abundant that it interfered significantly with recreational activities in the lake through clogging of outboard motors as well as physical interference with entry to the Lough and the pursuit of recreational activities such as kayaking. The management cost associated with physical removal of a small proportion of the weed was €91k (Kelly, 2013).	Increase lake water levels Implement Best Management Practices on farms to decrease nitrogen and phosphorus runoff.
Policy instruments	The voluntary Environmental Farming Scheme (EFS) provides subsidy for construction of Riparian Buffers. The Nitrates Action Plan for Northern Ireland mandates some nutrient management activities	Same as baseline
Sites	Lough Erne only	All sub basins of Lough Erne catchment with water quality not meeting "Good" Ecological Status
Governance / Institutional context	Fragmented cross-border cooperation	More regionally coordinated approach

2.2.5 CS 5 – Aveiro

Relevant context: CS 5 comprises the freshwater to marine continuum of the Vouga River coastal watershed protected as part of the Natura 2000 network, i.e., the Ria de Aveiro Natura 2000 site. Local stakeholders value the area, whose rich natural capital supports a wide variety of economic, cultural and recreational activities, and is rich in biodiversity. There are a complex variety of land and water uses and potential conflicts, and a number of anthropogenic pressures that impact local hydro-morphological conditions. The region is also vulnerable to ocean storm surges, rain flooding, and coastal erosion, meaning that it often requires human intervention for protection or to enable economic activities. In particular, two major interventions will be implemented in 2018/2019: 1) a dredging programme to enable hydrodynamic equilibrium and navigability in Ria de Aveiro coastal lagoon, and 2) the extension of a flood bank to decrease surface saltwater intrusion into agricultural areas.

Case Study Aim and EBM Plan: CS 5 applies ecosystem-based management to minimise the negative side-effects of the dredging programme and the flood bank extension. The case study also aims to make use of the best available information in a trans-disciplinary context, drawing on stakeholder input, detailed ecosystem mapping, ecosystem services indicators, and links between biodiversity and ecosystem services. Their proposed EBM plan includes measures and policy instruments: 1) Restoration of saltmarshes through revegetation and by fostering elevation through accretion, 2) restoration of seagrasses by applying coconut fibre mats, transplantation of plants; 3) Harmonising monitoring frameworks across the Water Framework Directive and Habitats Directive; 4) Incorporate stakeholders and integrate various territorial management instruments to develop estuary management plan.

Table 7 Main differences between the baseline and the management / EBM scenario in CS 5

Main differences or commonalities	Baseline	EBM / Management scenario
Environmental ambition / policy target	Protect biodiversity in line with Natura 2000 objectives. Whilst enabling economic and other activities in the area, aim to mitigate negative impacts of interventions and economic activity.	Same as in baseline.
Measures	Two measures are to be implemented in 2018/2019, which will have foreseen but unintended negatives impacts on biodiversity 1) a dredging programme to enable hydrodynamic equilibrium and navigability in Ria de Aveiro coastal lagoon, and 2) the extension of a flood bank to decreases surface saltwater intrusion into agricultural areas	The same as baseline, but, to minimise negative side effects, the following measures are additionally proposed: - restoration of saltmarshes through revegetation and elevation - restoration of seagrasses through transplantation and coconut-fibre mats
Policy instruments	Many policy instruments are implemented to achieve biodiversity goals, including protected areas.	- Harmonise monitoring across Water Framework/Birds and Habitats Directives - Incorporate stakeholders into planning - Integrate territorial management institutions (and their multiple goals) into planning
Sites	Ria da Aveiro river and neighbouring Baixo Vouga Lagunar.	Same as in baseline. - Seagrass and saltmarsh restoration sites will be selected considering multiple ecosystem services and with stakeholder input.
Governance / Institutional context	-Many separate institutions -Limited, inconsistent stakeholder involvement in management	-Coordinated input from multiple institutions into integrated Estuary management plan -Ongoing, coordinated stakeholder engagement in management

How far did CS 5 go beyond current management practices?

1. EBM considers ecological integrity, biodiversity, resilience and ecosystem services

Relative to baseline management, CS 5's EBM Plan considers a wider variety of ecosystem services. This leads the Case Study to propose restoration of tidal wetlands, which along with supporting provisioning ecosystem services such as food provisioning (e.g. fish), also offers cultural services through increased recreation opportunities. The CS 5's EBM Plan also focuses on increasing ecosystem resilience: alongside seagrass and saltmarsh restoration, their proposal for harmonising Water Framework Directive and Habitats Directive monitoring programmes along the water continuum, with increased stakeholder participation, will increase the local ecosystem's health.

4. EBM builds on social-ecological interactions, stakeholder participation and transparency

CS 5's EBM plan was co-created with input from local stakeholders and policy-makers, and considers their values and priorities, specifically regarding the unintended pressures present in the baseline scenario and their valuation of ecosystem services through Spatial Multi-criteria Analysis. The EBM Plan involves greater stakeholder engagement than baseline management, specifically by better integrating CIRA, the Inter-municipal Community of the Aveiro Region, to better understand different stakeholder priorities and support identification of trade-offs and synergies.

5. EBM supports policy coordination

CS 5's EBM Plan supports policy coordination beyond traditional management by harmonising monitoring across the Habitats Directive and the Water Framework Directive i.e. across aquatic realms and EU Directives. Additionally, rather than focus on individual policy objectives, CS 5 proposes achieving multiple objectives by managing at the estuary scale to achieve different sectoral concerns simultaneously (e.g. shipping, biodiversity, agriculture, tourism).

2.2.6 CS 6 – Sweden

Relevant context: The Rönne å catchment is located in Southern Sweden in a landscape that is witnessing a transition from an agricultural to a multi-functional landscape. The main pressures affecting freshwater quality are agricultural activities and insufficient sewage treatment. Swedish regulations are implemented from river basin to county to municipal levels. Water councils, a group of stakeholders including municipalities and water users, have developed bottom up solutions in the past, and are increasingly incorporated in the governance system through the Water Framework Directive. Stakeholders identified three key challenges to be overcome: 1) legacy nutrient pollution in the catchment, 2) effective ecosystem management across different spatial scales, and 3) cost sharing among beneficiaries and those who bear costs under future policies.

Case Study Aim and EBM Plan: The Swedish case study aimed to develop scenarios in co-design with stakeholders, decision makers, civil servants and practitioners, complemented by stylised social-ecological modelling, to investigate how water governance might be improved. Resilience aspects of the Assessment Framework were used to assess social aspects of policymaking and implementation – particularly the governance-related resilience principles and processes of change. The EBM plan developed in the case study includes the following aspects: (1) wetland extension, (2) modernization of sewage treatment systems in summer houses that are not connected to the central sewage system, (3) increased stakeholder collaboration through water councils.

Table 8 Main differences between the baseline and the management / EBM scenario in CS 6

Main differences or commonalities	Baseline	EBM / Management scenario
Environmental ambition / policy target:	Effective implementation of the WFD with a view to meet the Environmental Quality objectives. Reduce nutrients in the lake with a target of 100% properties meeting requirements of Swedish Environmental Code for private sewage treatment. At the local level, municipalities have developed comprehensive plans and local environmental objective programmes containing action strategies The enforcement of the upgrades to private sewage treatment systems that is required from the Environmental Code is heterogeneous among municipalities.	Same as baseline, except: - increase compliance of private sewage treatment systems.
Measures	At the local level, municipalities use multiple measures to meet local environmental targets, including biomanipulation of the lake (extraction of certain fish to reduce nutrient levels), measures to control agricultural nutrient pollution, etc.	- Same as baseline but also consider additional, novel options, such as reduction in pike fishing and different planning horizons.
Policy instruments	Many policy instruments are used to implement measures and meet environmental. goals. These include for example, standards and regulations in the Swedish Environmental Code, CAP subsidies, etc.	The same as baseline but with cross-boundary management plans
Sites	Lake Ringsjön & Rönne å	Management occurs at local level as well as and integrated across catchment and neighbouring areas.
Governance / Institutional context	Within the structure of the national and local institutions that govern and manage water quality, there is a gap in the ability to make ecosystem service improvements benefit a larger catchment society, such as those stakeholders downstream. This is likely due to the separation of the two water councils - Lake Ringsjön, which undertakes more activity around water management such as the biomanipulation projects, and the Rönne å water council.	The three water councils (Rönne å, Ringsjön and Kattegatt coastal water council) improve collaboration and develop comprehensive management plans together. The planning horizon has increased from roughly five to 10 to 20 years.

How far did CS 6 go beyond current management practices?

1. EBM considers ecological integrity, biodiversity, resilience and ecosystem services

CS 6's EBM Plan targets cultural, provisioning, and regulating ecosystem services. Relative to baseline management, the CS 6 EBM proposal considers the dynamic nature of ecosystem services, and how these differ over space and time, considering feedback processes and long-term trends, which can improve fairness of measures implemented.

4. EBM builds on social-ecological interactions, stakeholder participation and transparency

CS 6's EBM Plan reflects their research finding that baseline management in the catchment is marked by relatively weak connections between stakeholder-driven, bottom-up "water councils" to the important water authorities, county administrative boards, and municipalities. The CS 6 EBM Plan supports strengthening the integration of water councils, and links between stakeholders and other institutions more generally. Water councils are well prepared to consider trade-offs among ecosystem services and to form new alliances in support of currently undervalued regulating ecosystem services, which other services depend on in the long term. Additionally, CS 6's development of co-created narrative scenarios supports communication and consensus of shared visions for the future.

6. EBM incorporates adaptive management

Relative to baseline management, CS 6 use the resilience principles to identify feedback processes and social-ecological interactions that determine long-term outcomes - both due to current trends and from restoration measures. The CS 6 focus on managing slow variables, understanding feedbacks between social processes and ecological outcomes, and the importance of applying the precautionary principle maintain diversity and redundancy keep open the option of future management changes, and avoid short-termism. The CS 6 EBM plan's increased involvement of stakeholders through the water councils also supports regular evaluation of management and adaptation to new information or goals.

2.2.7 CS 7 – Swiss Plateau

Relevant context: The Swiss Plateau is densely populated, and maintaining or restoring biodiversity and good state of freshwater ecosystems is challenging due to pressures from anthropogenic land use (e.g. agricultural, urban, industrial), energy production, traffic infrastructure (roads, railroads, etc.), recreational activities, among others. Switzerland decided to fund the morphological restoration of one quarter of all morphologically degraded rivers over the next 80 years, to upgrade the 100 most important wastewater treatment plants to remove micropollutants, and to reduce agricultural pollution. In the context of river restoration, cantonal authorities had to deliver a strategic planning of the morphological restoration of rivers for the next 20 years, which will be revised every 12 years. The management challenge is a spatial and temporal prioritisation of river restoration measures that maximizes the ecological status of each catchment as well as of the co-benefitting ecosystem services (such as recreation), while minimising changes in the provision of those services that lead to trade-offs with the good ecological state of freshwater ecosystems, without exceeding the established budget. Within this case study, methods that aim for supporting this strategic planning process have been developed.

Case Study Aim and EBM plan: The Swiss case study aimed to develop methods to support the spatial and temporal prioritisation of river restoration measures in the Swiss Plateau by maximising the ecological status of catchments under a given budget constraint, while considering other societal needs and other sources of impairment. This includes the development of spatially explicit criteria to assess the ecological status of catchments based on an integration of existing methods to assess the chemical, physical and biological status of river reaches (see Kuemmerlen et al., 2019) and a consideration of barriers to fish migration. The second step includes a development of optimization algorithms to identify combinations of restoration measures that maximize the ecological status, while considering budget and other societal constraints. The assessed management measures covered: (1) ecological restoration of stream sections, (2) the removal of barriers to fish migration, (3) the upgrade of wastewater treatment plants, and (4) a reduction of pesticide pollution from agriculture.

Table 9 Main differences between the baseline and the management / EBM scenario in CS 7

Main differences or commonalities	Baseline	EBM / Management scenario
Environmental ambition / policy target	To restore some of the rivers that are currently in a bad morphological state according to the cantonal strategic planning, to upgrade selected wastewater treatment plants to remove micropollutants and to reduce the pesticide input from agriculture by 50%.	Same as in baseline, but in addition maximizing the ecological state of the catchments by selecting the river reaches to be restored and barriers to be removed based on an optimization of spatial ecological criteria.
Measures	River restoration, removal of barriers, upgrade of waste water treatment plants with a 4th treatment step, improving agricultural practice	Same as in baseline, but with different site selection strategy for river restoration and removal of barriers.
Policy instruments	A number of measures that aim to restore riverbed connectivity, by rehabilitating modified river streams. The measures are financed by subsidies that are regionally developed and implemented by the cantons. Financing is provided by the federal government.	Same as in baseline
Sites	Reaches to be restored were defined according to the first round of the cantonal strategic planning	Reaches are selected based on the spatial optimization assuming the same budget and other constraints as in the baseline
Governance / Institutional context	The strategic planning for river restoration and water quality management measures are done largely independent of each other, often by different departments of the cantonal authorities	The strategic planning for river restoration takes into account the planned management actions regarding water quality.

How far did CS 7 go beyond current management practices?

5. EBM supports policy coordination

In the setting of CS 7, trade-offs between costs, provision of ecosystem services and maintaining or re-establishing a good ecological state have to a large degree been decided politically by establishing and financing the action plans listed. For this reason, the main challenge faced by the case study was to support the identification of combinations of measures that maximise the ecological state of the catchment resulting from the investment. The integrative planning of all measures can help to increase the efficiency of this process. This case study developed methods to facilitate better coordination across different sectors and policies.

2.2.8 CS 8 – Azores

Relevant context: The Faial-Pico Channel is a richly biodiverse Marine Protected Area (MPA), covering 240km^2 of North Atlantic coast and ocean in the Azores, an EU Outermost Region. Recreational and commercial fishing place pressure on local biodiversity, while swiftly growing tourism fuels local economic growth but increases competition for use of the Channel, and also drives future pressures on biodiversity. Local stakeholders all value the Channel's biodiversity, and although they have some competing management objectives, the small, interconnected stakeholder community wants to cooperate on management to ensure the Channel's long run health. Channel management is complicated by multi-level and overlapping responsibilities, with policy development and implementation split across five institutions. Stakeholders were concerned about low compliance with regulation, in part due to unclear regulations. Additional stakeholder priorities included increasing scientific monitoring of Channel biodiversity and regular, holistic evaluation of current management.

Case Study Aim and EBM Plan: The aim of the Azores Case study was to collaborate with local stakeholders and policy-makers and apply the AQUACROSS Assessment Framework to understand social and ecological aspects of the Faial-Pico Channel, and identify actions to efficiently and equitably ensure the Channel's long-term sustainability, balancing the objectives of commercial and recreational fishers, tourism operators, and other local stakeholders. The case study EBM Plan consisted of five local policy solutions: (1) increased scientific monitoring, (2) increased stakeholder participation through a Stakeholder Advisory Group, (3) integrating and coordinating management of the Channel, (4) clearly communicating and enforcing fishing and biodiversity regulations, and (5) sharing costs through a sustainability tax or diving fee.

Table 10 Main differences between the baseline and the management / EBM scenario in CS 8

Main differences or commonalities	Baseline	EBM / Management scenario
Environmental ambition / policy target	– Environmental target of "conserving biological resources" (Ordinance 53/2016) and "protect and soundly manage marine protected areas for marine environmental reasons" (Decree 15/2007/A) are undershot due to low compliance, little awareness of regulations, sectoral focus on fisheries	– Same ambition, but achieved through full enforcement of existing legislation, better knowledge, greater awareness, adaptive management, and coordinated approach across fisheries and tourism sectors.
Measures	– Many measures are implemented in line with the Common Fisheries Policy and the Azores Legal Framework for Fisheries to achieve environmental and fisheries goals, includinge.g. gear restrictions, quotas, bans, etc., and measures related with the designation of MPAs (e.g. activities restrictions)	– Same measures as the baseline (no change in gear or location/size of MPA) – Change in delivery mechanisms of existing regulations (e.g. more stringent enforcement, monitoring, etc.).
Policy instruments	– Numerous policy instruments implement environmental goals (including fishing quotas, subsidies, etc.)	– Per-night tax on hotels and/or fee on divers, earmarked for biodiversity measures – Full enforcement of existing laws through surveillance cameras and change in management – Increase in monitoring – Measures to increases awareness/ knowledge (signs, leaflets, education, help-line, simplification of laws)
Sites	– Faial-Pico Channel	– Same
Governance / Institutional context	– Overlapping and uncoordinated local policies and four responsible institutions for management, littleintegrationfromenvironmental regulatorswithotherregionaldirectorates (e.g. fisheries, tourism) – Low transparency and stakeholder participation – Lack of knowledge of environmental state and biodiversity trends; no stakeholder monitoring	– Coordinated, integrated government approach to managing the Channel (feat. regular coordinating meetings between ministries, shared monitoring and enforcement); regular revision of targets/measures based on monitoring (adaptive management) – High transparency and participatory management of the Channel through Stakeholder Advisory Group; regular revision of targets/measures based on monitoring (adaptive management) – Consistent long-term monitoring of environmental state and biodiversity;

How far did CS 8 go beyond current management practices?

1. EBM considers ecological integrity, biodiversity, resilience and ecosystem services

Relative to standard management, the increase in monitoring as part of CS 8's EBM Plan increases knowledge and ability to understand and protect biodiversity and the ecological system. Policy coordination and incorporation of multiple policy objectives (including biodiversity, fishing, and tourism goals) encourages integrative planning to maximise multiple ecosystem services at once. This, along with stakeholder participation and sustainable financing, increases ecological and social resilience.

4. EBM builds on social-ecological interactions, stakeholder participation and transparency

CS 8 EBM plan was co-created with stakeholders, representing their priorities of increased enforcement, simplification and communication of laws. Additionally, the plan's Stakeholder Advisory Group formally increases stakeholder participation and transparency. Stakeholders believe that increased stakeholder engagement, relative to baseline levels, will increase stakeholder cooperation and decrease conflict, lead to greater biodiversity protection, and increase knowledge, all increasing overall resilience of the SES. The proposed sustainability tax and/or diving fee would fund biodiversity protection and address equity issues.

5. EBM supports policy coordination

CS 8 baseline management of the Faial-Pico Channel is characterised by complex, overlapping management, with five separate institutions developing, implementing, and monitoring and evaluating policy that affects biodiversity, tourism, and fishing. The CS 8 EBM plan proposes managing the Channel as one unit under an integrated policy coordination group featuring representatives from each policy/implementing authority. This group will be able to collaborate across Directorates and islands to manage the Channel together, increasing ability to recognise and meet multiple objectives.

6. EBM incorporates adaptive management

CS 8's proposed increased monitoring will provide essential knowledge for adaptive management, supporting regular evaluation. The EBM Plan includes a stakeholder advisory group and integrated policy coordination group, tasked with regularly evaluating management, establishing integrated, representative objectives, and implementing responses. CS 8 also proposes a bed tax and/or diving fee to finance biodiversity protection, ensuring sustainable funding for biodiversity protection actions.

2.3 Discussion

In this section, we summarise to what extent each case study has gone beyond baseline management. While ideally each case study would significantly progress toward each component of EBM, in practical terms, the underlying research needs and scope of each Case Study mean they have different specific strengths and focus on furthering particular components of EBM more than others. We assess each case study against each of the components using a 0 – 1 – 2 – 3 scale: 0 indicates that this was not a focus of the case study's EBM plan and process; 1 indicates that this case study progressed this component beyond baseline management but this was relatively incidental; 2 indicates that the case study proposal significantly progresses this component of EBM relative to baseline management; 3 indicates that the case study's approach in this area is a clear exemplar for others trying to progress this component of EBM beyond baseline. This serves two purposes: first, readers of this report who are interested in particular aspects of EBM can see which case studies will be the best source of information. Second, this allows us to identify especially interesting measures or policy instruments that address each EBM characteristic, which we discuss in chapters 3 and 4 and the conclusions section.

Table 11 Application of EBM in the case studies

	CS 1	CS 2	CS 3	CS 4	CS 5	CS 6	CS 7	CS 8
1. EBM considers ecological integrity, biodiversity, resilience and ecosystem services	3	3	3	2	3	3	3	1
2. EBM is carried out at appropriate spatial scales	3	3	3	3	1	1	2	2
3. EBM develops and uses multi-disciplinary knowledge	2	3	3	3	3	2	2	2
4. EBM builds on social-ecological interactions, stakeholder participation and transparency	2	2	2	3	3	3	2	3
5. EBM supports policy coordination	2	2	2	2	3	3	2	3
6. EBM incorporates adaptive management	2	1	1	1	1	2	2	2

Legend: 0 indicates that this was not a focus of the case study's EBM plan and process; 1 indicates that this case study progressed this component beyond baseline management but this was relatively incidental; 2 indicates that the case study proposal significantly progresses this component of EBM relative to baseline management; 3 indicates that the case study's approach in this area is a clear example for others trying to progress this component of EBM beyond baseline.

3 What is the added value of EBM?

Once case studies defined their EBM approaches (see chapter 2), based on their understanding of the socio-ecological system (framework (see Costea et al. 2018 (D4.2) and Teixeira et al. (D5.2)), the next step within the AQUACROSS assessment framework (see Gomez et al. 2017 (D3.2) and Piet et al. 2017 (D8.1)) consists in the evaluation of the proposed approaches against the following three criteria – effectiveness, efficiency and equity & fairness – in order to determine the performance of the proposed EBM approach compared to the baseline situation (see also chapter 1 and 2). Given the project context of AQUACROSS, only an ex-ante evaluation is possible.

The present chapter describes in a first part how the different case studies evaluated their proposed EBM approaches against the baseline situation for the three criteria, and presents and discusses in a second part the results of this evaluation. If not indicated differently, all case study specific information provided in the following results from the work undertaken within AQUACROSS, for which more information can be found in the case study reports. These are compiled in McDonald et al., 2018 (D9.2).

3.1 How have proposed approaches been evaluated?

The three outcome-oriented criteria of the AQUACROSS assessment framework have been evaluated by the case studies to varying degrees. The table below provides an overview of the case studies which have worked in particular on a specific assessment criterion.

Table 12 Overview of case studies applying the evaluation criteria

Evaluation criteria	Case studies
Effectiveness	CS 1; CS 2; CS 3; CS 7; CS 8
Efficiency	CS 1; CS 2; CS 3; CS 4; CS 7
Equity and fairness	CS 2; CS 3; CS 6; CS 7; CS 8

The diversity of case studies in terms of different institutional contexts, different environmental issues, different aquatic realms, etc. is also reflected in the **diversity of tools which have been mobilised for the evaluation exercise**. These will be quickly discussed in the following. The results of the evaluation will be presented in the chapter thereafter.

How was effectiveness evaluated in the case studies?

For evaluating the effectiveness of a proposed (alternative) management approach, its expected performance to achieve the CSs objectives is compared to that of the current (baseline) management approach. Ideally some framework to assess this performance exists, e.g. through risk-based approaches or based on indicators and a target. This assessment framework is necessarily case study specific. Within AQUACROSS, any evaluation of effectiveness refers to the **environmental objectives** of the case study (see chapter 1.1 and Piet et al. 2017 (D8.1)). In the case studies, which have a strong modelling component (in particular CS 2, CS 3 and CS 7),

effectiveness indicators are included in the modelling approach, and are an important part of the optimisation criteria. Improving effectiveness is in these cases the major intrinsic objective of the modelling exercise.

In CS 7, the main environmental objective is to attain a good ecological state of catchments by selecting river reaches to be ecologically restored. The proposed assessment of the ecological state of catchments is based on the ecological state of river reaches and the position of barriers to fish migration within the river network. The ecological state of river reaches is an integration of the physical, chemical, and biological state, which each have their own indicators, including near-natural morphology and near-natural nutrient concentrations, among others. The assessment results are provided in values ranging from 0 to 1, which can be divided into 5 quality classes, indicating bad, poor, moderate, good or high status, similar to the Water Framework Directive. Ecological restoration measures target the morphological properties of river reaches including the river channel, banks and the riparian zone, previously modified through anthropogenic causes. However, the morphological restoration is frequently insufficient to attain a good ecological state, as it does not consider other aspects of ecological state that may be deficient (e.g. high nutrients). Furthermore, the approach implemented in the case study can be used to assess whether restoration alone serves the purpose of raising the ecological state of the reach to a good state or whether complementary management measures would be necessary. The catchment scale assessment can be used to identify the river reaches where restoration measures would be most effective to improve the ecological state of the whole catchment. In CS 2, the Intercontinental Biosphere Reserve of the Mediterranean, a multizoning approach is applied in which targets are verified for each planning unit. Targets are translated into conservation features (biodiversity, ecosystem services and protected areas) and compared for all scenarios. The indicator used to measure the general progress of the implementation of the green and blue infrastructure is the ecosystem condition. The ecosystem condition was defined using the Human Footprint Index (HFI), which shows the anthropogenic cumulative pressures on the aquatic ecosystem in the case study area. Then, three different conservation categories were established from the quantiles of the HFI values, namely unfavourable-bad, unfavourable-inadequate, and favourable.

In CS 1, another approach for evaluating effectiveness was applied (Piet et al. 2018 (D9.2, CS1)). This is a **(semi-quantitative) risk-based approach** building on the AQUACROSS linkage framework (see Costea et al. 2018 (D4.2) and Teixeira et al. (D5.2)). This approach uses the reduction of risk to evaluate effectiveness. The linkage framework includes impact chains, which are defined by human activities, pressures and ecosystem components. Different management measures aim to mitigate the threats caused by different impact chains, and the risk-based approach estimates the degree to which they succeed in reducing these threats. As a result, by using the risk-based approach, effectiveness reflects the degree to which the implementation of a measure potentially contributes to reduce impact risk and hence contributes to biodiversity conservation compared to the baseline situation. Effectiveness is calculated as the cumulative reduction (%) of impact risk on the combined biodiversity components (within the part of the socio-ecological system on which the case study is concentrating).

Box 3 Evaluating effectiveness using the risk-based approach

Applying the risk-based approach in the North Sea (CS 1)

The risk-based approach as applied in the North Sea estimates impact risk as the likelihood that ecosystem components are impacted by specific human activities and that therefore the achievement of policy objectives aiming to conserve biodiversity is compromised. Thus, those management measures that succeed in reducing most of the impact risk can be considered most effective. Below is an overview of the management measures that were evaluated and the reduction in impact risk per ecosystem component.

The evaluation of the effectiveness of the ecosystem-based management measures, in terms of reducing the risk that biodiversity is impacted, shows that other management measures (i.e. targeting fisheries or offshore windfarms) than those intended to conserve biodiversity (i.e. MPAs) may result in comparable, if not bigger, reductions in total impact risk and can hence be considered more effective.

Goal	Management measures: code and description	
Sustainable food supply	1.1	Extension of regular fisheries management to achieve MSY through a reduction in fishing effort or capacity
	1.2	More precautionary fisheries management that results in bigger reduction of fishing effort or capacity than 1.1 and results in less than the maximum sustainable food supply.
	1.3	Using incentives to change fishers' behaviour in order to reduce physical disturbance of the seabed habitats.
	1.4	Applying new technology, i.e. gear substitution of conventional beam trawl to pulse trawl, to reduce the impact of fishing on the ecosystem.
Healthy ecosystem	2.1	A ban on all extractive human activities in existing MPAs.
Clean energy	3.1	Using turbines that reduce bird mortality in OWFs
	3.2	Erecting the OWFs in locations where bird mortality is lower
	3.3	Banning fishing with benthic trawls in the OWFs
	3.4	Building OWFs such that their additional hard substrate enhances marine biodiversity

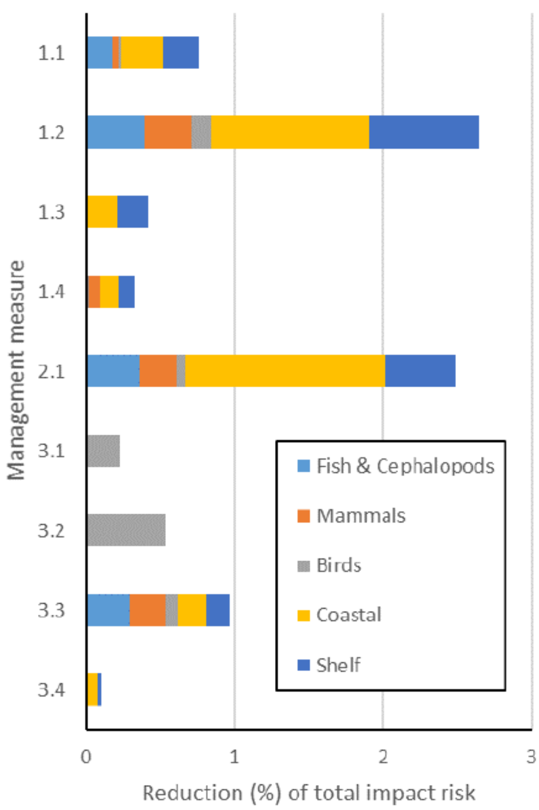

Figure 2 Overview of the management measures that were evaluated in CS 1 and the reduction in impact risk per ecosystem component (Piet et al. 2018 (D9.2, CS1))

Based on the outcomes of the risk-based approach, the North Sea case study went even further and applied a **quantitative indicator-based approach**, focussing on a single impact chain (fishing with benthic towed gears→ physical disturbance → sub-littoral sediment) in order to evaluate the effectiveness of two management measures (a ban on all extractive human activities in existing marine protected areas (MPAs) versus banning fishing with benthic trawls in the offshore wind farms). Two indicators are used for the assessment, in which the proposed measures are compared to the baseline situation: average fishing intensity and proportion of areas fished (Piet et al. 2018 (D9.2, CS1). Now effectiveness was expressed in terms of its ability to decrease the proportion of area fished (or increase the area unfished) as this is considered to represent a better status of the seabed habitats and hence biodiversity.

In other case studies the knowledge base on biophysical relationships and the missing information on expected impacts of measures did not allow for a proper evaluation of effectiveness. This is the case, for example, in the Irish CS 4, where the effect of one of the proposed measures to combat the proliferation of invasive alien species – namely altering lake levels – remains unknown. In this case, no ex-ante assessment of effectiveness is possible (O'Higgins et al. 2018 (D9.2, CS4)).

In CS 8, which proposes the introduction of new policy instruments for the management of a marine protected areas in the Azores, available data and information also limited a quantitative evaluation of effectiveness. Instead, a qualitative approach based on the linkage framework has been chosen in order to identify the drivers and pressures, which will be influenced by the policy instruments (McDonald et al. 2018, (D9.2, CS8)).

Which evaluation of efficiency in the case studies?

The evaluation of efficiency aims at ensuring that the proposed management approaches increase and/or maximise human wellbeing compared to the current management alternatives (*see chapter 1 and Piet et al. 2017 (D8.1)*). The evaluation of efficiency looks at the (financial and economic) costs of measures and at the (positive and negative) changes in supply of ecosystem services resulting from the implementation of measures within the ecological system. The latter requires information on the biophysical effects of the measures as a basis for the evaluation of benefits (or costs – in the case of a decrease of ecosystem services).

Within the AQUACROSS case studies, **estimates of financial costs of measures** have been made in several cases. In the context of the Intercontinental Biosphere Reserve of the Mediterranean (CS 2), relative **restoration costs have been included in the modelling exercise**. Restoration costs have been derived from values reported for previous projects and studies, and then weighted according to the ecosystem condition of the habitats in the area to be restored. It was assumed that habitats in worse ecosystem condition required larger restoration investments (e.g. unfavourable-bad compared to unfavourable-inadequate).

In CS 4 and CS 7, a **cost-effectiveness-analysis** (CEA) has been carried out. A cost-effectiveness analysis can be applied in two contexts (see for example Martin-Ortega and Balana 2012): It is either applied to reach a given (environmental) target with the least possible costs – or to maximise an (environmental) output under a specific cost limit (budget constraint). Both contexts for cost-effectiveness analysis were present within AQUACROSS:

- In CS 4 (Lough Erne), measures for reducing agricultural diffuse pollution up to a certain target level have been ranked according to their cost-effectiveness. This allows choosing the least costly measures in the first place.
- In CS 7 (Swiss Plateau), the optimisation exercise takes place under budget constraints, as the amounts available for future investment in river restoration are known and relatively fixed. The case study aims therefore at maximising the improvement of the ecological status of the river with the available budget.

In the case of the Danube (CS 3), a **cost-benefit approach** has been followed, which is further specified in the illustration box below.

Box 4 Evaluating efficiency in the Danube case study (CS 3)

Cost-benefit considerations in the Danube case study

Costs

Financial costs for the proposed restoration measures have been estimated based on a literature review that focused on western European countries. These were complemented with estimates of economic costs, namely the expected loss of agricultural land as a result of the restoration activities. Also included is the financial gain from removing dykes, as they will no longer require maintenance costs.

To determine the size of the measures, the status quo and target levels of hydro-morphological alteration were compared to estimate the amount of restoration required. Land use data provided information on the share of agricultural land per site, allowing to calculate the economic cost.

Benefits

The efficiency analysis focused on three main ESS: recreation, flood protection, and nutrient retention, the last of which was identified as a key ESS by stakeholders. The other two ESS were included based on literature and expert opinions. Values for these benefits once again came from a literature review and included some estimates specific to the Danube River Basin. Benefit dimensions are based on population sizes or area of agricultural land that is converted to natural uses through restoration. Monetary values were given in annual terms, so discounting was applied to find the present value of 30 years of benefits.

The ARIES modelling platform was able to provide information on current provision of ESS, including the accessibility and provision levels for recreation. It was assumed that all ESS would return to full provision after restoration.

The efficiency analysis is not without limitations; there is large uncertainty regarding the monetary value of benefits, as well as uncertainty about how ESS will change, and the size of the populations that will be affected. There is also some uncertainty on the cost side as there is no precise information about the proposed measures. Nevertheless, the efficiency analysis provided very useful insights, as it allowed for the consideration of trade-offs between different options in a systematic way.

In CS 2, **ecosystem services** have not been assessed in monetary terms, but have been **taken into account quantitatively** in the optimisation exercise through the use of the ARtificial Intelligence for Ecosystem Services modelling platform (ARIES) (Martinez-Lopez et al., *forthcoming*)). This is the case for spatial ecosystem services indicators on flood regulation, carbon sequestration, pollination, soil retention and potential recreational opportunities. The case study aimed at providing cost-effective spatial solutions based on the minimum area covered by green and blue infrastructure achieving specific conservation targets (in terms of biodiversity and ecosystem services),and on EBM restoration action costs, by an optimal spatial allocation of conservation features, ecosystem services and allowed human activities among zones with different managing schemes.

Which evaluation of equity and fairness in the case studies?

The evaluation of equity and fairness of proposed EBM approaches builds on the evaluation of efficiency. Once all positive and negative impacts of management alternatives have been identified, the allocation of these costs and benefits among different groups of the society can be assessed.

All case studies, which reflected on the implications of the EBM scenarios in terms of **equity and fairness,** did this **in a qualitative way**. The main sub-criteria which have been applied were on the one hand the **spatial allocation of the measures** which have been proposed compared to the baseline situation (CS 2, CS 3 and CS 7 in particular), and on the other hand reflections on the main **stakeholder groups which would either need to bear the costs of the proposed measures – or benefit from the improved ecosystem services** (CS 6 and CS 8 in particular). The results of these evaluations are described in more detail in the following section.

From a process point of view the evaluation of equity and fairness is necessarily a later step in the evaluation as it follows the efficiency analysis, but it is indispensable for correctly considering the implementability of EBM proposals. It builds the basis for reflections on policy instruments (see also chapter 4).

3.2 Which results of the evaluation?

The following presents some results of the evaluations undertaken in case studies, with specific discussions on their performance regarding the three evaluation criteria. The results of the evaluations are discussed with the aim to identify and specify the added value of proposed EBM approaches compared to the baseline situation in the case studies, as well as to identify aspects which might require further adaptations.

Results regarding effectiveness

As mentioned above, evaluating the expected effectiveness of measures in reaching environmental improvements requires sound knowledge on biophysical links as well as good data availability for the case study area. Uncertainty linked to the best choice of methods and the availability of data is omnipresent in the exercise. Having this in mind, all evaluation results from the case studies which were able to evaluate their approaches show a better overall performance for their EBM solutions compared to the baseline situation in terms of effectiveness.

In order to be able to make the link between the performance of the proposed approach and the added value of EBM, it is also important to acknowledge that the AQUACROSS EBM approaches often build on previous management which already applied one or more of the EBM principles. This is not always an easy exercise. In the case of the Danube for example (CS 3), the proposed optimised selection strategy for river restoration projects along the main stem is compared to the current selection at country level in the context of the implementation of the EU Water Framework Directive. However, it is unclear which specific criteria countries apply to choose these sites and which processes they follow. Nonetheless, comparing the sites selected by both strategies clearly show that a better effectiveness (a better degree of reaching the environmental targets) is achieved in the EBM scenario (see figure below). In this case, the increased use of scientific knowledge (which is one of the EBM principles), is hence able to propose more effective solutions.

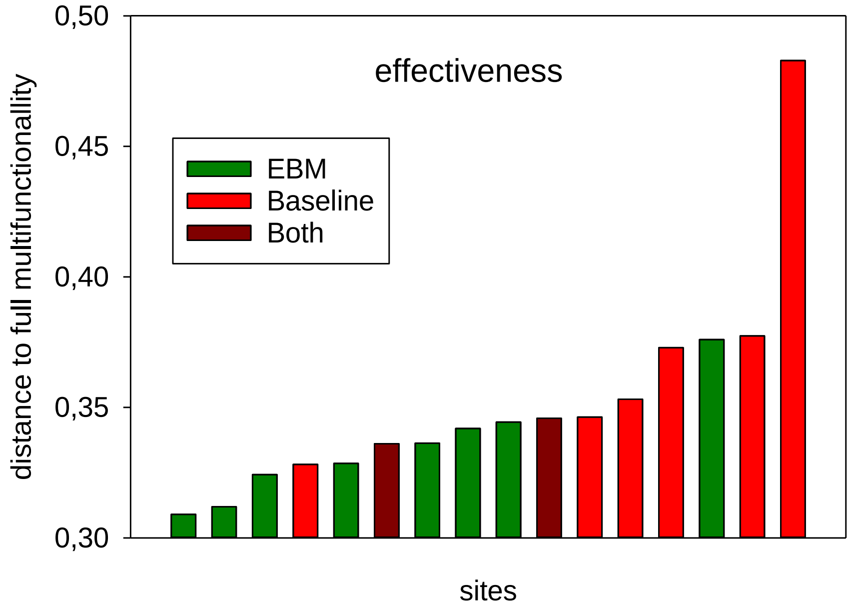

Figure 3 Effectiveness related to biodiversity calculated for the different sites of the EBM (green) and baseline (red) scenario for CS 3 (Funk et al. 2018)

Note: Values are ordered from lowest to highest, dark red bars show sites that are part of both scenarios. The closer the sites are to multifunctionality, the better they perform.

In the case study of the Swiss Plateau (CS 7), the optimized restoration strategy outperforms the cantonal strategy (baseline scenario) in the indicators for good ecological state of river reaches and for good ecological state of catchment (see figure below). "The latter, represents the overall ecological state of the catchment, being the most important indicator that summarizes all information in the catchment, while balancing the different ecological processes taken into account" (Kuemmerlen et al. 2018 (D9.2, CS7)). The better performance of the baseline scenario with regards to the near-natural fish migration potential shows, however, that the cantonal planning provides a quite good strategy already.

In cases where data availability did not allow for clear-cut statements on the expected performance of EBM approaches compared to currently applied and planned management approaches (e.g. CS 5 and CS 8), starting reflections on potential consequences of measures, bringing in more (even if imperfect) information, clearly identifying uncertainties, etc. still turns out to be very useful in the process of improving management, as it allows stakeholders to take more informed decisions.

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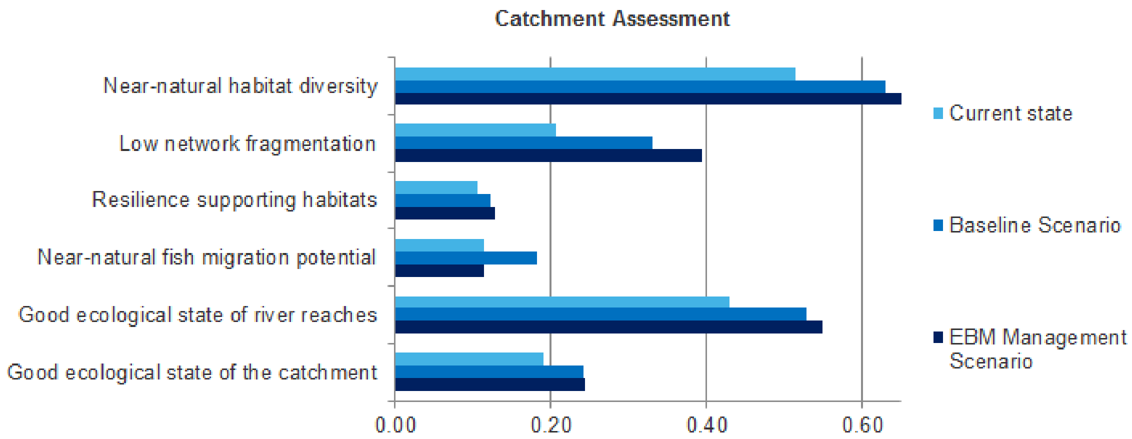

Figure 4 Catchment assessment in terms of ecological state and several ecological processes for the Mönchaltdorfer Aa catchment in CS 7 (Del. 9.2, CS 7 report)

Results regarding efficiency

The results of the cost-effectiveness analyses show that the EBM approaches allow for a **better budget allocation** while either accounting (quantitatively) for ecosystem services within the optimisation modelling (CS 2), or when at least different biodiversity aspects are included (CS 7). In the Intercontinental Biosphere Reserve of the Mediterranean (CS 2), the implementation of EBM measures allows conserving biodiversity, maintaining ES capacity, and restoring degraded ecosystems (at least 15%), and improving the connectivity while costs are minimised.

In the case of the Danube (CS 3), results indicate that restoring sites proposed through the optimised selection strategy are both more effective in reaching the environmental objectives and less costly (see figure below).

These results from CS 3 mainly go back to the fact that the optimisation scenario selects sites which are already closer to a near natural state, which tends to leave land used for agriculture, for example, aside. Even if expected changes in ecosystem service provision could not be quantified or simulated, better (qualitative) knowledge on ESS that will be impacted by proposed measures helped to improve efficiency. As in the Danube case study, the modelling exercise undertaken for the Intercontinental Biosphere Reserve of the Mediterranean (CS 2) optimised conservation and restoration targets, while keeping at the same time as much as possible space for current exploitation to take place. This approach implicitly **considers trade-offs between ecosystem services which are a) considered “compatible” with nature conservation objectives (e.g. recreation, or partially flood protection) versus b) extractive / provisioning ecosystem services,** which are considered incompatible, as they intervene with the ecosystem. These trade-offs are “commonly found between individual provisioning services and between provisioning services and the combined regulating, cultural, and supporting services and biodiversity” (Millennium Ecosystem Assessment 2005). Taking these trade-offs into account reduces costs imposed on those which currently cause pressures on the environment, by maintaining, for example, agricultural production sites. The need to consider negative trade-offs and/or to provide positive synergies between ESS is highlighted also in CS 5.

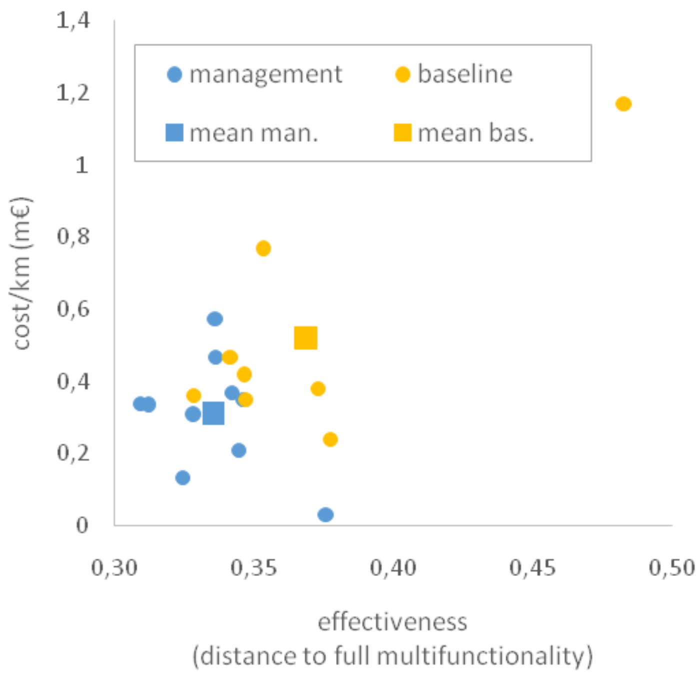

Figure 5 Effectiveness related to biodiversity and cost of restoration measures calculated for the different sites of the management and baseline scenario in the AQUACROSS Danube case study (CS 3)

Note: The different dots indicate each a specific restoration site, either belonging to the baseline scenario (orange) or to the EBM scenario (blue). The squares indicate the mean values, considering all restoration sites of one scenario.

In the Irish CS 4, the cost-effectiveness analysis illustrated that some measures have not only benefits through their effects on the environment (changes in ESS), but that efficiency gains can also be reached just by changing management practices (e.g. when integrating fertiliser and manure nutrient supply, or reducing fertiliser application rates). These win-win-measures should be implemented anyway, and do not require any quantitative assessment of the environmental benefits.

Any ambition to look at a management problem from a more holistic perspective, taking both the ecological and the social system and their interactions into account, necessarily increases complexity (Piet et al. *forthcoming*; DeFries and Nagendra 2017). As mentioned above, in particular the consideration of different ecosystem services renders the possibility to make sound evaluations of efficiency difficult, due to methodological constraints and important data needs. In CS 4 (Lough Erne), for example, the EBM perspective led to reflections moving away from the current physical extraction of invasive alien species to the consideration of measures that target (part of) the source of the problem: diffuse agricultural pollution. When only looking at the financial cost side, the current measure of physical extractions of weed is cheaper than the measures proposed to reduce agricultural diffuse pollution up to a certain target level. However, whereas physical extractions only serve the purpose of removing weed and do not target the source of the problem, reducing pollution from agricultural land has a multitude of co-benefits. As introduced in chapter 1, the evaluation of efficiency should look at both costs and benefits of management approaches. Ecosystem services are defined as the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005), and of which the supply may be enhanced by proposed measures. Accordingly, to get a comprehensive evaluation of the efficiency of the proposed EBM approach, one should consider (i.e. quantitatively or possibly monetary) the entire spectrum of ecosystem services that are promoted by the measure. Given the complexity of the exercise, this has not been possible as part of the case study. Nonetheless, developing and discussing the possible solutions in stakeholder processes still helps to support the decision-making process, even if information cannot be backed up quantitatively.

Results regarding equity and fairness

Evidence from case studies with regards to the evaluation of equity and fairness emphasised the importance of **two main dimensions**: (1) **equity between those who would pay for the measures and those who benefit**, and (2) **spatial equity.**

(1) Equity between those who would pay for the measures and those who benefit

Reflections in case studies on equity and fairness show that there is a strong link to ecosystem services: making them explicit (as it is done within an EBM approach), means that they can be taken into account in decisions. Accounting for ecosystem services allows starting reflections on balancing costs and benefits between different social groups. Often proposed measures are particularly costly for those social groups causing the current pressures, whereas other groups of the population may benefit from the improvements in the environment.

A key focus of the Azores case study (CS 8) has been to decrease conflicts between different stakeholders, by involving them in the process of elaborating the EBM plan. The question of who will finance conservation measures has been identified as a main issue with regards to equity and fairness:

> *"Current MPA [Marine Protected Area] management and the proposed EBM plan place costs on fishers (who could already no longer fish in valued MPA locations, and now face increased enforcement and compliance costs), while tourists, tourism operators, and other local stakeholders benefit (both from exclusive access to diving locations and positive environmental impacts). Financing can be used as a way to share the costs between those who benefit and those who bear cost" (McDonald et al. 2018, (D9.2, CS8)).*

Based on these insights, two alternative policy instruments have been identified with stakeholders: a per-dive fee or a per-night tourism tax, with the proceeds earmarked to fund biodiversity protection. These instruments can be further considered by the responsible authorities in the future.

Equity and fairness issues, and in particular financing of measures, also play an important role in the Swedish case study (CS 6). Within the case study, social exchanges are fostered for improving governance and in particular finding solutions for the current eutrophication problem of the lake Ringsjön. Trade-offs between ecosystem services and how different parts of the society are concerned by different ESS play a central role. In particular, the CS seeks to consider ecosystem trade-offs to improve fairness over space (catchment vs. subcatchment), over sectors (producing vs. regulating services), and over time (among generations, considering different planning horizons). Current policies do not address those ESS trade-offs yet. Eutrophication of the lake is caused in particular by private households (in addition to agriculture), through insufficient wastewater treatment. Upgrading households with private sewage treatment installations, and hence improving lake water quality, is costly. Improved lake water quality is assumed to lead to an increase of ecosystem services provided by the lake. However, these ESS would benefit other groups of the population, not necessarily the ones paying for the improvements. During stakeholder exchanges, this situation has received particular attention and is perceived to be unfair. This perception by stakeholders will need to be taken into account when looking for future solutions to the problem. The case demonstrates that any results of the assessment of the socio-ecological system need to be considered from the perspective of stakeholders. Thus, in the Swedish case this led to the fact that reflections moved from an initial point of view of the polluter-pays-principle to a potential beneficiary pays principle, which might change the type of management solutions which are considered. A comparable statement can also be found in Förster et al. (2015), who emphasises that considering ESS within the political process clearly increases transparency, which can change the perception of stakeholders of what is a fair solution. In this regard, the assessment of ESS can contribute to solutions, but can also trigger new conflicts (Förster et al. 2015).

(2) Spatial equity

In the case studies that concentrated on the spatial optimisation of restoration measures, it is this spatial allocation of efforts which received most attention. Shifting proposed restoration sites often means shifting efforts, as other countries (e.g. in CS 3), or other regions (e.g. in CS 2) would pay for the restoration. In the Danube (CS 3), restoration efforts would shift from Slovakia and Serbia in the baseline to Hungary, Croatia, and Bulgaria in the EBM scenario. Austria and Romania are supposed to provide restoration effort in both scenarios, although their efforts are less costly in the EBM scenario.

In general, evidence from the AQUACROSS case studies does not allow saying whether EBM approaches improve equity. However, it shows that the approaches allow changing the perspective on a given problem. Considering the optimal spatial location of measures and explicitly considering ecosystem services is important for the management process, as it provides indications on who will benefit from the proposed changes and who might bear the costs. Even in the absence of quantitative and monetised information, this allows further reflections on the pre-conditions for success of proposed management approaches (see chapter 4) and reflections on potentially needed policy instruments to make propositions more socially acceptable.

Discussion of evaluation results

In general, the work undertaken in the case studies shows that, as with traditional management approaches, a quantitative evaluation of EBM approaches is currently difficult. As mentioned before, this is due to uncertainty linked to the choice of methods, unavailability of data and missing knowledge on causal relationships in the biophysical system. For any conclusions on the added value of EBM based on the evaluation undertaken within the case studies it has to be taken into account that EBM is considered to be a cyclical approach (see chapter 1). Any evaluation can hence only provide information on the expected performance of the first cycle of EBM management. The full EBM approach foresees that several cycles are necessary, with each of them being further shaped based on the lessons learned from the previous cycle. The exercise provided here can hence only provide a first idea for each case study of the potential advantages of following an EBM approach compared to the baseline situation. A longer term investigation would be necessary in order to make some more general conclusions. However, even though evaluating an EBM approach faces the same analytical constraints as the evaluation of alternative approaches, the involvement of stakeholders under an EBM approach for the elicitation of integrated societal objectives (rather than prescribed, single policy targets under the baseline), or the identification of joint solutions (rather than policy lead miraculous cures) are elements that need to be taken into account in here.

Furthermore, an ideal evaluation of the performance of a proposed EBM approach would include a **sensitivity analysis**, specifically undertaken in order to estimate the impact of the consideration of certain EBM principles. This sensitivity analysis would consist in assuming alternative scenarios of how the system would perform if a specific EBM criterion would not be taken into account (e.g.: What would have been the management decision without the involvement of stakeholders? What would have been the proposed solution without consideration of ecosystem services?). Only such an exercise would allow indicating the added value of considering specific EBM principles in a given situation. A sensitivity analysis could also be applied for the way how EBM principles are applied. For example, a case study which is improving the involvement of stakeholders in the decision-making process could also make assumptions on how results of the process would change not only if no stakeholders would have been involved, but also in the case that other stakeholders (e.g. different persons, different representativeness of sectors) would have been present for example at organised workshops which supported the case study work.

Regarding the evaluation of efficiency in particular, several points can be highlighted: **administrative costs** (e.g. costs for planning and monitoring) of proposed EBM approaches are not considered in detail in any of the case studies. However, for implementing authorities, it might be interesting to check whether significant differences in administrative costs exist between the baseline and the EBM scenario. Administrative effort might in particular influence the lapse of time necessary to come to an effective implementation of a proposed approach. On the one hand, policy coordination, for example, which is fostered by the EBM approach, can limit costs of measures, by favouring alternatives which target different policies at once. On the other hand, higher coordination effort is needed and translates to more meetings between administrations and more need for exchanges. Also, the increased involvement of stakeholders is linked to some costs, which should be accounted for: meeting facilities, information material, time spent by participants, etc. Increased consideration of expected administrative costs in future work will decrease some of the uncertainty linked to the evaluation of efficiency, and might help to better appraise and anticipate potential administrative barriers to the implementation of either current or proposed EBM approaches. Furthermore, one of the major arguments put forward for EBM is that it promotes management solutions which are multifunctional, and which improve the status of several ecosystem components and/or provision of several ecosystem services simultaneously (while considering trade-offs) (see Gomez et al. 2017 (D3.2)). However, evidence from the work in the AQUACROSS case studies shows that **methodological limitations exist for predicting changes in the ecological system**

induced by the management measures. These changes, however, and the changes in the provision of ecosystem services which are linked to it, are needed in particular for the assessment of benefits. These difficulties are also confirmed by other studies (Newton et al. 2018; Pascual et al. 2010; de Groot et al. 2010). Compared to mapping of ecosystem services which are directly linked to land occupation, which is quite straightforward, assessment for fresh water or marine ecosystem services is more complex. Land-water interactions as well as the hydrological cycle need to be taken into account (Grizzetti et al. 2016).

The linkage framework which is applied in AQUACROSS allows identifying potential impacts on ESS, but does not yet enable the quantification of these potential impacts. Also, modelling **did not allow predicting how the provision of ESS will change** with the introduction of measures, either for the baseline or EBM approaches. While estimates can be made more easily for provisioning ecosystem services (e.g. water, food, raw materials), which are often traded in markets and for which extracted quantities are usually known, making reliable assumptions for regulating or maintenance services, for example, is much more difficult (see also Grizzetti et al. 2016). In fact, "there are major gaps in information on nonmarketed ecosystem services, particularly regulating, cultural, and supporting services" (Millennium Ecosystem Assessment 2005). However, it is this change in ESS provision – together with estimates of the financial costs of measures – which is the basis for a proper evaluation of efficiency. These methodological limits explain why evaluations linked to impacts on ecosystem service provision remain qualitative in the AQUACROSS case studies – or are addressed together with stakeholders (see for example CS 4 and CS 5).

However, while it is important to recognise uncertainty within the evaluation process which concerns in equal measure the evaluation of EBM and of existing baseline approaches, it is also important to emphasise that available information indicates a better performance of proposed EBM approaches, both with regards to effectiveness and efficiency.

4 What are the pre-conditions for ensuring a successful and effective implementation of EBM?

This section takes stock of all reflections undertaken in the different case studies within AQUACROSS to present a comprehensive evaluation on the specific enabling conditions for the successful take-off and implementation of "qualified" EBM approaches as different from traditional or conventional management alternatives, both measures and the process to select and encompass them.

This chapter, though, does not build on case study work alone but also on *ad-hoc* thoughts. As a result of that, it combines (a) some of the work carried out in the case studies on enabling factors – sometimes emerging from discussions with stakeholders that took place during the case study process – and (b) an analysis of the governance context of these case studies – reflecting on limiting factors and opportunities in prevailing institutional setups, and how these could be adapted for enhanced uptake, design, and implementation of EBM.

Hence, it emphasises on the adaptations and other changes in the institutional setup that might be required to pave the way for the uptake of EBM, to improve its design and to facilitate its successful implementation as opposed to business as usual (Gómez et al. 2017). Based upon information provided by the project's case studies a wide diversity of alternatives has been identified to address two basic questions:

- "Which factors could hinder the successful take-off and implementation of your proposed approach?"
- "Which changes would need to be introduced, which pre-conditions need to be ensured or reinforced to ensure a successful implementation of your proposed approach?"

Our main purpose consists in informing on what particular factors allow progressing further towards EBM, as an incremental piecemeal process characterised not only by its sequential nature but also by its transitional costs. With this resolve, we tried to identify enabling conditions in the social system that may either preclude or facilitate further adoption of EBM approaches and therefore to figure out the institutional changes that would be required to facilitate its uptake and successful implementation.

This section therefore builds on information and lessons learnt in the different study sites, where the project's assessment framework (Gómez et al. 2017) has been applied to a different extent, regarding the design and implementation of EBM within prevailing institutional settings to identify the factors that may boost further adoption of innovative EBM approaches and the institutional and policy changes that would need to be made to realize the full potential of EBM.

As foreseen in the assessment framework, the experience gained in the case studies confirms the general research hypothesis as per the main challenge for EBM implementation. To different levels of detail, all case studies show the potential EBM approaches may play as cost-effective solutions to tackle specific environmental problems while contributing to the sustainability of the whole social-ecological system. Under these two criteria, EBM convincingly appear as superior to business as usual. After all, an EBM approach may unveil potential win-win situations often discarded or simply overlooked in the policy process since proposed measures under the baseline are somewhat limited, as they tend to focus on tackling partially individual issues. Nevertheless, better outcomes, lower costs and enhanced contributions to sustainability, while necessary, are seemingly insufficient conditions for the uptake of EBM alternatives at first instance and to go beyond in finding a suitable way for their design and implementation.

Despite substantial evidence about their technical superiority (effectiveness), their cost advantages, the size and variety of co-benefits entailed and their contribution to the robustness and resilience of the biophysical system (e.g. Jaffe 2011; Palm et al. 2014; Lorenz et al. 2016; Nurmi et al. 2016; reviewed in Delacámara et al. 2018), EBM alternatives still need to go through a policy making environment that is better shaped for facilitating standard technological choices, supported by well-established and commonly accepted assessment methods (e.g. the interest in the contribution of nature-based measures for EU policies on biodiversity, freshwater or the marine environment [EC 2012]; the implementability of management measures framed by the Common Fisheries Policy and the MSFD, supported by coordination and an appropriate science-policy-society interface [Ramírez-Monsalve et al. 2016]).

EBM implementation is a social and political challenge rather than merely a technical one. Focusing either on ecosystems themselves and not on the management of the activities that benefit from these ecosystems (such as agriculture, fishing, power generation, manufacturing, etc.), or on the services provided by those ecosystems (such as freshwater provision, food security or supply of raw materials) entails a critical departure from traditional practice in environmental policy and resources management. Institutions, technological choices, assessment methods and criteria and even the science-policy dialogue to date have been mostly shaped by an intense path dependency and past management practices that are not necessarily well suited to let innovations get through (e.g. Polasky 2011a, b; Marshall & Alexandra 2016), even if they come along with promising advantages in terms of effectiveness, costs, and sustainability.

Basing management on the ecosystem means picking comprehensive alternatives able to deliver beneficial outcomes across a range of economic activities and services rather than on specialised sectoral policies or service regulation and management. Comparisons between traditional and EBM approaches can be presented in terms of single benefits vs. simultaneous co-benefits (e.g. EC 2015b). In this context, the main factor hampering the adoption of EBM comes from institutional, technical choices and scientific traditions that tend to specialise in particular policy areas, *ad-hoc* solutions, and circumscribed knowledge domains both in natural and social sciences. Some effort to break these silos has already been done, and is (partially) visible in the design of current EU policy (e.g. WFD, MSFD), even if the outcomes of those process can be said to be disputable.

The very nature of EBM, as an integral response to restore and enhance ecosystems, implies a series of challenges for institutions, technology, and knowledge. On the institutional side, the selection, effective design and successful implementation of EBM entail breaking institutional silos and building effective coordination mechanisms within (vertical coordination) and across policy domains (horizontal coordination). On the technology side, EBM requires seamless, comprehensive solutions rather than individual techniques to cope with one problem at a time.

On the knowledge side, EBM faces us with the challenge of mobilizing and integrating a meaningful body of transdisciplinary scientific knowledge in a way that can be taken by stakeholders to represent the complex links between society and nature and support collective policy responses.

In the end, institutions, technology and knowledge are means to the ends of building collective decisions that, from an EBM perspective, are also peculiar as they demand cooperation across a variety of stakeholders to reach commonly agreed objectives in terms of ecosystem conservation and build agreements to somehow share the benefits and bear financial and other opportunity costs involved.

One way or the other, the prospects for further adoption of EBM instead of its traditional alternatives are positively correlated with the degree of institutional coordination in place, the ability to assess and compare the effectiveness of integral responses, the capacity to integrate knowledge on the social-ecological system in a way that can actually be taken up by stakeholders and, last by not least, on the social ability to put all this at the service of social debate in order to build cooperative decisions that are perceived as superior and legitimate by all social agents, even if political will is not always strong. The AQUACROSS case studies convey important lessons learnt on these four important dimensions.

Institutions: EBM barriers or facilitators?

Institutions are shaped by social and policy practice. Innovative practice may require innovative institutions. Activity-based management have led to activity specialised policy units (such as the government divisions of agriculture, nature conservancy, energy, food, etc.). Services-based management have led to dedicated service departments (such as water, hydropower, fishing, etc.); Impact-based management may lead to specialised impact management units (air pollution control, sanitation and water quality, river restoration). Nevertheless, there are not adequate policy units so far to place EBM. The mismatch between institutional setups in place and EBM is a common concern in all AQUACROSS case studies and many of them identify conditions that might pave the way for the transition towards an EBM enabling institutional system.

Institutions are seen as a factor hindering the implementation of EBM. This is widely illustrated by the situation in the North Sea (CS 1), where despite overarching EU strategies and regulations, the scale of the ecosystem contrasts with action plans defined at national scales where responses are shared by mid-level administrative units in charge of managing activities, services, and impacts. A better coordination at both national and international scales may be the basis for a comprehensive response to the North Sea challenges.

Bureaucratic divisions are convenient ways to organize management, expertise, science, and the public debate. Yet, compartments may evolve into closed communities of interest endowed with their own specialized jargon, scientific domains, data, assessment methods, etc. Bureaucratic expedience may come at the expense of overlooking consequences outside the apparently well-defined management domains and the outcome of institutional silos may lead to what has been dubbed, for instance, as "energy-blind" water policies, "water-blind" industrial development or to downplay when not ignoring at all biodiversity concerns in areas such as water, energy, spatial development, tourism, fishing, etc. (e.g. Dieperink et al. 2016;

Gómez et al. 2016; Laborde et al. 2016). EBM brings these dysfunctionalities of the institutional system to the spotlight.

Working against the need for applying an integrated approach is the need to pigeonhole subsets of the full SES in order to avoid inaction from overwhelming complexity, one of the many traps that may hinder resolving a "wicked problem" such as EBM (DeFries and Nagendra 2017).

This proposed division into discrete sections, however, should not result in the prevailing two development pathways of EBM research identified by Borgstrom et al. (2015): one focusing on the social and institutional processes linked to EBM as reflected in policy documents such as Shepherd (2004) and CBD (2014)[1], the other focusing on the ecological aspects as required by the main European policy frameworks for all ground and surface water bodies (up to one nautical mile offshore), i.e. Water Framework Directive (WFD, Directive 2000/60/EC), and marine waters, i.e. Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC).

Though EBM has been initially proposed as a suitable option to reach a well-defined objective in one policy domain (such as the WFD or the MSFD), its distinctive character relies on its contribution to tackle simultaneously and in an integrative fashion different policy targets (biodiversity, wider nature conservation, etc.). This is for instance illustrated by those green infrastructures proposed in the Intercontinental Biosphere Reserve of the Mediterranean (CS 2), between Spain and Morocco, or the measures proposed to deal with invasive species in the Lough Erne (CS 4), in Northern Ireland. In the latter, for instance, the EBM plan to tackle alien invasive species in Lough Erne goes beyond their physical removal to target the driving factors: the generation of Elodea. In doing so, other policy targets (such as the abatement of nutrients from agriculture or even transboundary cooperation) come into play.

Therefore, on the positive side, AQUACROSS case studies provide evidence on the significant welfare enhancing opportunities associated to synergies between water management, food security, energy conversion, flood control, climate change adaptation, biodiversity protection and many other areas. Reaping these opportunities requires breaking out of institutional silos so as to allow the build-up of coordinated responses. Therefore, every request for advice will focus on that specific topic/component/sector/discipline without any consideration of how this sits in the wider social-ecological system and encumbering the development of an integrated approach such as EBM.

Coordination becomes a hard challenge when policy compartments without policy leverage are each one charged of the compliance of an EU Directive. The lowest the level of the public administration at which environmental policy areas is handled (i.e. in addressing the subsidiarity principle), the highest the risk of being caught into the bureaucratic honeycomb (e.g. Battisti and Fanelli 2015). At the intermediate levels of government problems are perceived as technical, rather than as social challenges demanding political will and public involvement and higher attention is paid to procedural and legal compliance rather than to the content and purpose of the changes delivered by the government to their constituencies (Termeer et al. 2016). While monitoring and enforcement is adequately placed at these levels,

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[1]Ecosystem approach sourcebook. Retrieved from https://www.cbd.int/ecosystem/sourcebook/default.shtml.

coordinating objectives and means across policy domains is only possible at the highest levels of government and it is there where the advantages of EBM could be fully appreciated.

The mismatch between the proper scale at which ecosystem management must be dealt with and the government level at which responsibilities are placed can be traced back as one of the main factors hindering further implementation of EBM. This explains the relative success of the Danube transboundary management system (CS 3), and the weakness of the coordination of the North Sea basin countries (CS 1). Though synergies between the EU Biodiversity Strategy, the Water Framework Directive, Birds and Habitat Directives, the Marine Strategy Framework Strategy, etc. are largely appreciated, responsibilities on each of the domains are still placed in specialised institutions, at intermediate levels, focusing on dedicated compliance targets with little coordination at national scales and weak approaches to sectoral policy coordination.

Consequently, the highest the level at which ecosystem concerns are handled the highest the possibilities of effective coordination. This explains the contrasting outcomes of the Danube (CS 3), where there is a dedicated coordination body - the ICPDR, with limited legal powers, anyway - at the international river basin scale and the North Sea (CS 1) where these coordination mechanisms are still very much work in progress.

Handling water topics internationally as in transboundary river basins or international waters (i.e. at the highest level, whichever the case) has the twofold advantage of facilitating coordination on one side and scaling water and biodiversity issues up in the policy agenda. This facilitates framing management discussions directly on policy relevant outcomes (such as mutual water security, as in the Danube, CS 3) or eventually in empowering civil society to deal with social concerns (such as plastic pollution or halting overfishing in the oceans) or support stakeholders' investments (in wind energy developments while recovering ocean habitats in the North Sea (CS 1) etc.).

Nothing of this is within reach of social and policy actors when responsibilities for ecosystem management are placed in the intermediate levels of government and biodiversity, discussions tend to focus only on technical issues and formal compliance objectives without much regard of welfare and socially relevant outcomes. The highest the level in the government (i.e., Central Government), once the necessary resources are provided, hierarchy where ecosystem issues are placed, the lowest the risk of having uncoordinated policies (on water, biodiversity, land use, energy, etc.), and the highest the level of an outcome-oriented policy, informed by transparent and independent knowledge and data. It is relevant to note that there is a permanent tension, from a governance perspective, between the need for further integration and subsidiarity, between centralised decisions and decentralisation or devolution. It is important to emphasise that what is really critical is to provide rational criteria to ascertain at what level should policy (and new policy approaches such as EBM) be delivered: on one side, higher levels of government may be essential to raise the profile of ecosystem-based management; on the other, this should come along with enhanced accountability processes. As a matter of fact, what matters is the allocation of risks, responsibilities, and benefits.

Natural protected areas (NPAs) can do a lot to cope with the institutions affecting ecosystems management. These advantages are not only clear in transboundary ecological units (such as in the Intercontinental Biosphere Reserve of the Mediterranean, CS 2) but also at most local levels where ecosystems are collectively managed so that social dialogue results in the setting of both ecosystem conservation and social development objectives that serve to articulate the duties and responsibilities of public entities. This is generically the case of Biosphere Reserves, both national and international ones, which require strategic plans to hit conservation targets that are compatible with human development and serve to build public alliances and coordinated actions[2]. This is of paramount importance to develop appropriate outcome-oriented strategies and measures for the conservation of biodiversity, function and services that focus on the system's resilience as a whole rather than on preserving specific sites or charismatic species.

At a different scale, institutional coordination is easiest when administrative units are adapted and coordinated within a scheme of institutional coordination across relevant ecosystem boundaries (and not the other way around). This is, for instance, the case of the Vouga coastal watershed in Portugal (CS 5), Lough Erne in Northern Ireland (CS4) or Lake Ringsjön - Rönne (CS 6) in Sweden where there still are agreements to jointly manage an environmental asset and the contribution of the different administrative units is asked for. This is not to say, though, that prevailing institutions in those study sites fit the scale (on spatial, temporal and organisational grounds) that would be needed for EBM. The situation is different, for instance, from the North Sea (CS 1), where different units at a national level struggle to coordinate policies locally without a national plan being available, and when these national plans do exist (as it is the case of the Dutch North Sea 2050 Spatial Agenda) they are neither yet part of an overall EU planning exercise at the proper ecosystem scale nor have the necessary legal powers.

As the Intercontinental Biosphere Reserve of the Mediterranean (CS 2) shows, UNESCO's Man and the Biosphere programme, launched in 1971, focuses directly in making the most of natural preservation to human development which gives a dimension to natural protection that goes beyond preserving natural reference conditions, to find the proper balance between the social system (humans) and the ecological one (the Biosphere) -this helps put welfare concerns upfront and provides a framework for policy coordination across policy realms.

AQUACROSS case studies leave doubts as to whether a bottom-up strategy to build up coordinated action among institutional silos could succeed in bridging the institutional mismatch. Success stories, like joint management of natural assets, protected areas, biosphere reserves, transboundary water planning, etc. seem to suggest that policy coordination must be the result of a cooperation agreement among stakeholders, or even countries. Those settlements are to be designed to agree upon a set of welfare relevant objectives that can be reached through enhancing and protecting ecosystems (such as improving the ecological status of Lough Erne, CS 4, or the Danube, CS 3). Further, they require as a means (not as an end in itself), the coordination of different actions based on voluntary agreements. If gains from cooperation are properly perceived, all parties (countries, stakeholders and public entities) may become interested in building a reputation of loyalty and subsequently to accept monitoring and transparent enforcement instruments (and in the definition of discernible targets, the acceptance of independent monitoring, etc.), setting the diplomatic discussions directly on

[2]Technical Guidelines for Biosphere Reserves (UNESCO)

substantial issues and on demonstrable outputs rather than on ticking boxes and formal (as opposed to meaningful) compliance.

Technical choices: supporting or breaking the status quo?

EBM entails many distinctive technical alternatives. In general, they are multi-purpose solutions, able to deliver outcomes in many relevant areas (such as in the case of green infrastructures, river restoration, etc.) rather than highly engineered solutions primarily designed to cope with single purpose problems (such as pumps, desalination and wastewater plants, turbines, fishing gears, etc.). At first sight, such advantages may result in multiple co-benefits, synergies among policy domains, avoided costs and contributions to sustainability through better-preserved ecosystems. Nevertheless, the apparent comparative advantage comes out with some relevant hindrances that may bias technical choices towards traditional alternatives.

The making of technical choices is heavily conditioned by tradition, institutional inertia and the assessment methods in place that were originally designed to assess and compare non-EBM, single-purpose approaches (e.g. Marshall 2013; Lukasiewicz et al. 2015). That is why it is interesting to analyse what factors explain why a given set of technical options (either traditional or innovative), come first in the policy arena.

In several Case Studies, this technical choice is framed as the problem of choosing between an option to remediate the impact of ecosystems' degradation on one side (such as, for instance, mechanical weed removal to control alien invasive species in Lough Erne, CS 4, or the bioremediation in the Ringsjön and Rönne å lakes in Sweden, CS 6), and ecosystem renaturalisation on the other (such as the increase in the water level in Lough Erne or the management of pollution sources in the above-mentioned Swedish lakes). Alternatives are mutually exclusive; remediation does not tackle the causes but rather only deals with their consequences and does not come with any ancillary benefit. Nonetheless, the burden of proof falls on the innovative side, and institutional inertia may end up by locking communities into traditional choices.

Among the factors that may impede the adoption of EBM is the impression that single-purpose, traditional options solve problems without creating new ones (weed removal is costly but does not create relevant conflicts of interest between its potential beneficiaries: tourists, tourism entrepreneurs, locals that enjoy recreational services, and those responsible for water diffuse pollution (if the case the preferred option is to act up on the use of fertilizers) or over third parties (if the option rather consists in increasing the water level which results in increased flood risk in the surrounding area).

Remedial solutions, while only partially effective to deal with outcomes and not with causes, can be seen as preferable options to avoid facing diverging stakeholders' concerns and grant social acceptability. For this very same reason, structural engineered alternatives, provided they are financed from public budget, are easier to gain social acceptance than, for instance, ecosystem restoration (as in the case of banks to prevent saline intrusion rather than extending the protected area and reducing agricultural land in the Vouga lagoon in Portugal, CS 5).

Notwithstanding this, as recognised in many Case Studies, EBM options in many areas, due to their innovative character and the fact that they need to be tailored for particular places and problems, still lack a conclusive test for a solution and are not one-size-fits-all solutions, may still be in disadvantage with more explicit traditional solutions

EBM options are newcomers to a large extent, with little or no previous records of effectiveness, which compete with well-established technical alternatives, backed with documented success records. For instance, green and blue infrastructures and their optimal location to cope with ecosystem restoration in the Intercontinental Biosphere Reserve of the Mediterranean (CS 2) and the increase of the water level at Lough Erne (CS 4), are effective in the short term, but their implementation may trigger adaptive physical processes that may reduce effectiveness and even increase the scale of the problem in the medium and long term. For instance, weed may grow up in size favoured by water clarity and float causing new detrimental impacts on navigation and tourism. As EBM deals with reshaping ecosystem processes and functions and the outcomes of these processes are uncertain, the promise to deliver better outcomes in the long term could be perceived as a handicap with respect to traditional practice (e.g. Sanon et al. 2012; Rodríguez-Entrena et al. 2014).

In many cases, tradition and EBM may well not be mutually exclusive, but rather a transition, whereEBM options are proposed as complementary means to mitigate the impact of traditional practices and hopefully align output and financial objectives of the access to ecosystem services with the preservation of the integrity of those ecosystems. This is the case of the control of trawling devices as a means to reduce the physical disturbances in the North Sea (CS 1) adapting pressures and activities rather than protecting and restoring ecosystems themselves (through fishing fleet scrapping, zoning, or enacting new marine protected areas). Balance between sets of alternatives is driven by trade-offs among the differing views and interests of stakeholders rather than on synergies between alternative objectives (such as guaranteeing net primary production through enhancing conservation, thus improving fishing grounds sustainability and contributing to energy security through wind farms in the North Sea). When conflicts between competing objectives (sustainable fishing and power generation) are not explicitly set and balanced, technology choices might result in three management plans (one for managing the marine environment, another one for sensible fishing and the third one for responsible wind farm development) without too much regard for their mutual interactions.

On the bright side of things, EBM has an enormous potential for using ecosystem interactions and processes to enhance the effectiveness of technical choices. Ideally, as in the North Sea, a network of marine protected areas, when properly designed (in location, size, organisational structures, etc.) may support reaching biodiversity targets while increasing net primary production along the North Sea (CS 1). The selection of priority stretches for river restoration can take advantage of upstream-downstream, river basin restoration to enhance the effectiveness of restoration efforts, reduce costs, and might be the source of positive interactions that feed back into more effective actions as in the Danube river basin (CS3). Similarly, spatial planning, when ecosystem interactions are properly factored in, may support the identification of optimal sizes and types of green and blue infrastructures to consolidate a network as the one proposed for the Intercontinental Biosphere Reserve of the Mediterranean (CS 2) or in the Swiss plateau (CS 7) where planned restoration can be considered effective to improve the morphological state of most reaches only after considering mutual interactions and the combined effect of all restoration measures.

Knowledge: further than the scientific challenge.

Informing comprehensive ecosystem decisions, rather than activity or service-focused actions, is the source of important challenges both for science and stakeholders. Science to guide EBM should explicitly apply a transdisciplinary and integrated perspective and consider the whole social and ecological system to inform actions that are linked to multiple outcomes, that might trigger adaptive processes, require institutional adaptations and other changes on both spheres of social-ecological systems.

That being said, besides its undisputable intrinsic value, the role of science consists in informing social choices and, in the policy arena, it is to be judged by its relevance rather than by its detail and mostly by its ability to help stakeholders and policy makers form a shared vision of the environmental challenges they face, the welfare and nature enhancing opportunities they have, the options available and the likely consequences of alternative courses of action.

Science must be backed by an effective communication strategy. Indeed, terms such as complex adaptive systems, non-reducible uncertainties, resilience and so forth are not first-hand candidates to foster a fluent social dialogue and to avoid the risk of inaction from overwhelming complexity (Gómez et al. 2016 (D3.1)).

Knowledge uptake in the social system is driven by its capacity to represent and answer questions that belong to the policy arena, rather than being a state-of-the-art research question. Scientists are somehow responsible for creating the social demand for knowledge, but the policy arena is for them a pretty unfamiliar and inhospitable place (e.g. Kahn 2018). The better the communication strategy the likelier the demand for scientific knowledge from the social system.

Relevance for improving social responses that are better informed by knowledge and data is the overarching screening criterion for an effective science-policy dialogue. Despite the soundness of comprehensive frameworks, whose details belong to the scientific community, social dialogue must be based only on those links that are relevant and able to inform social choices.

Screening, linkage frameworks for relevant variables and knowledge are therefore a first necessary step as demonstrated in all case studies, but the final selection is still technical knowledge out of reach of most social actors. This is not because of the lack of technical skills or familiarity with scientific jargon, but because of the lack of a compelling explanation about how one thing leads to another (causal relationships) and basically how decisions they make (their activities and policy choices) explain the problems they see in their surrounding environment and the positive and negative outcomes they receive from it.

Besides data, metrics and indicators, science has the responsibility to provide consequential knowledge on why things happen and how they could be improved. Knowledge is more conducive when integrated in evidence-based storylines and narratives that support the comparison of alternative courses of action (Gómez et al. 2017 (D3.2)). The importance of a meaningful science-policy dialogue is demonstrated in the Lough Erne (CS 4) where detailed data and indicators have been compressed into shared cognitive maps and which were not only able to conduct policy choices but also to send knowledge demands back to scientists to support collective learning and the progressive development of restoration alternatives.

Demand for knowledge is also higher when citizens perceive problems as a matter of choice with meaningful welfare consequences and not just as mandatory obligations to comply with high-level regulations (in that context it is critical the discussion over the nature and the convenience to eradicate alien invasive species in the Lough Erne, CS 4). Contrariwise, though important at the technical level, science is in limited demand when stakeholders do not perceive that their welfare is somehow at stake – it is in those situations when they seem more willing to leave decisions to technical experts. Although improving knowledge for decision-making is put forward by nearly all case studies, Rönne å (CS 6) and Azores (CS 8), provide examples of what could be considered, according to the available information, as inclusive decision-making processes.

Social decision processes: building cooperative solutions

EBM implies multiple co-benefits that spread across different sectors and benefit various groups of stakeholders. This distinctive character of ecosystem-based management may be a powerful case to increase policy acceptance and to build broader social agreements to favour their effective implementation (see, for instance, the wide range of stakeholders involved in the discussion of green and blue infrastructures, in river restoration options or in the enactment of new marine protected areas).

Nevertheless, on the other side, EBM is also unique in its aim to rebalance human interventions and ecosystems conservation and, one way or another, the benefits of enhanced conservation are outweighed by some opportunity costs borne by the activities explaining previous detrimental trends such as fishing effort and wind power generation in the North Sea (CS 1), diffuse pollution from agriculture in Lough Erne (CS 4), agriculture in the Vouga (CS 5), etc. Hence, EBM may recognise the need to deal with potential conflicts of interest among stakeholders (Dietz et al. 2003; Nelson et al. 2006). The way these potential conflicts are handled and adjudicated may have profound consequences on the final configuration of the management plan, where policy instruments play a key role as mechanisms contributing to make measures operational.

EBM approaches are easier when there is a pre-existing agreement to jointly manage the ecosystem at hand (as in the Danube river basin district, CS 3) and this agreement is self-enforceable by the mutual interest of the parts in sharing the benefits of ecosystems' improvement. Limitations emerge when there are not mechanisms in place, for instance, to implement the spatial optimisation approach proposed in the Danube (CS 3) that would imply that financial resources provided by one country are used for river restoration in another country. These agreements provide an institutional frame that places policy at a level of ecosystems (the entire river basin, the biosphere reserve, or the marine protected area). Else, the potential costs of individual actions (by one country or some farms adopting sustainable agricultural practices) will not be offset by benefits that spread over all beneficiaries across the ecosystems. The imbalance between national and private costs and external benefits still precludes coordinated actions in the North Sea (CS 1) and favours piecemeal approaches (to biodiversity, marine conservation, wind farm development and fishing), instead of a comprehensive EBM plan. The issues of who would bear the cost of the EBM approach and who would benefit from it play also an important role in the Ringsjön and Rönne å lakes in Sweden (CS 6) and in the Azores (CS 8).

The required social agreement may also be an integral part of the EBM plan. Social concerns and the way they are dealt with in the social process may determine the set of measures that are acceptable, thus making the adoption of the EBM plan feasible. Voluntary agreements to promote soil conservation in farming may deliver a definite solution to lake degradation (in Northern Ireland and Sweden, CS 4 & CS 6) but the lack of appropriate agri-environmental schemes and the likely negative impacts on rural income and employment may favour solutions that despite not addressing the cause of the problem (increasing the water level of bioremediation) but leave behind a lower number of stakeholders (e.g. a limited number of plots flooded in the surroundings of Lough Erne), hence limiting the damages to a level that can be compensated from the gains of the wide number of winners (such as recreational boats in Lough Erne) and opening the option to finance the cost of the intervention by collecting a permit or use fee from the beneficiaries (as in the diving tax proposed in the Azores, CS 8). None of these social concerns appears when the solution consists in a structural approach, that does not harm economic activities and is not financed either by local stakeholders (like in the case of the flood bank designed to prevent saltwater intrusion into agricultural areas in the confluence of the river Vouga and the Aveiro coastal lagoon, CS5).

5 Summary and conclusions

EBM proposals developed in AQUACROSS case studies to reach EU biodiversity targets

Following the assessment framework previously developed within the AQUACROSS project, AQUACROSS case studies investigated how the concept of EBM could be made operational for supporting the achievement of the objectives of the EU Biodiversity Strategy.

The detailed assessment of the socio-ecological system in the case study areas led to tailored propositions, aimed at making a more effective contribution to reaching biodiversity objectives. The work undertaken within the case studies confirmed the prevailing view that with the ambition to implement EBM for aquatic realms, no standard solutions are conceivable. Whereas AQUACROSS assessments in some case studies led to the proposition of different types of measures compared to current plans (e.g. CS 1, CS 4), other case studies propose the same measures as current plans, but allocated differently following a spatial optimisation approach (e.g. CS 2, CS 3, CS 7), accounting in particular for ecosystem services delivered. Again, in other case studies (e.g. CS 8), the need for adapted policy instruments seems to prevail as the most important change needed to reach biodiversity targets. Innovation is promoted in all cases, but taking different forms.

As already stated in literature, there "is no single or best solution to wicked problems in ecosystem management" (DeFries and Nagendra 2017). Instead, incremental, partial improvements with possibilities for adaptations should be aspired, which is also reflected in the EBM approach adopted within AQUACROSS. It is acknowledged that EBM is a complex endeavour, requiring cyclical adaptive approaches, and a stepwise advancement on EBM principles. This is done by all AQUACROSS case studies (see chapter 2). The fact that not all case studies are able to advance on all EBM principles confirms the challenges linked to the approach and the value of its iterative philosophy. Being too ambitious in wanting to change too many parameters at once might be too challenging for a real life situation, but also for the multidisciplinary research required to address EBM as carried out in AQUACROSS. Advancing in steps is more feasible and realistic.

Within the approaches they developed, and in comparison to currently ongoing management practices and planned management proposals for the same area, case studies advanced on various EBM principles (see chapter 1). This includes in particular the consideration of ecological integrity, biodiversity, resilience and ecosystem services, the development of multi-disciplinary knowledge, and the building on social-ecological interactions, stakeholder participation and transparency (see chapter 2). The CS altogether – in particular through the diversity of conditions they cover in terms of aquatic realms, important threats to biodiversity, ecological status, etc. – provide good examples for others aiming at progressing towards (more) EBM.

Evaluation of expected performance of EBM approaches proposed in case studies

As varied as the alternative management solutions proposed in the case studies are the methods used to evaluate them. In line with the ambition of the project to mobilise stakeholders and to co-develop and guide AQUACROSS research activities, stakeholder and expert knowledge has been integrated into the assessment of aquatic ecosystems at different stages throughout the case studies. However, work in case studies emphasises the need for finding an equilibrium regarding the involvement of stakeholders in the evaluation process – compared to the use of scientific knowledge. Involving stakeholders is very important to make use of additional knowledge and of different existing perspectives, to increase acceptability of proposed approaches, to define (evaluation) indicators that are (policy/real-life) relevant and more generally to ensure that produced knowledge is useful to guide the decision-making process. In case of insufficient scientific datasets, or incomplete information, for example, on the current status of aquatic ecosystems or on the causal relationships between management measures and induced changes, stakeholders can provide precious information and/or legitimacy to decisions taken in situations of high uncertainty. There is still some leeway to reinforce stakeholder involvement in future EBM cycles in some of the AQUACROSS CS. At the same time, too much reliance on stakeholders also bears some risks, and the emphasis laid on the need for involving stakeholders in research projects should be accompanied by a critical look at results and assessments being made based on them. Stakeholder participation cannot replace, but complements scientific analysis of the system.

Ecosystems are complex, and it is not possible to “foresee all consequences of interventions across different spatial, temporal, and administrative scales” (DeFries and Nagendra2017). This is confirmed by the work undertaken in the AQUACROSS case studies. Evaluating in all details expected effectiveness, efficiency and equity and fairness implications, in particular *ex-ante*, requires important assumptions to be made – or remains challenging in some cases if uncertainty is too high. However, the exercise is still very important and useful. Information generated – even if imperfect – helps provide a critical look at different options for addressing biodiversity and water management issues. It then informs decision making, and can be used in an adaptive management process which encompasses a learning-by-doing component and an incremental approach to move to the final solution.

The knowledge produced in AQUACROSS is particularly useful and relevant for describing and critically analysing the current situation of the knowledge base of the social-ecological system. This is, amongst other things, due to the use of the linkage framework, which has also been further developed and used for a risk-based assessment of effectiveness of proposed EBM approaches. However, generated knowledge is less developed for assessing the dynamics of the system, indicating how ecosystem services and benefits would change when the status of specific ecosystem components is affected. This reduces its potential for supporting *ex-ante* assessment of scenarios, although some effort has been put in forecasting exercises for addressing this challenge (see Kakouei et al. 2018 (D7.3)).

Because of the absence of (socio-economic) modelling of "stakeholder decisions" and choices, methods used by case studies were well adapted to assess (biophysical) impacts of *measures*. They turned out to be more challenging to assess the expected impact of *policy instruments*, and of their socio-economic consequences. As emphasised for example also by Grizzetti et al. (2015), considering both dimensions of biophysical assessment and economic valuation remains one of the main challenges in the field of ecosystem services research. AQUACROSS has provided some input on how to advance with this integration, but still some further improvements are possible.

Whereas advanced possibilities for quantifying (changes in) ecosystem services would bring more insight in the evaluation of efficiency and the impact on human wellbeing, it would also allow for more reflections regarding the evaluation of equity and fairness. In future iterations of the EBM management cycle, efficiency and equity and fairness issues should receive increased attention. Results of these reflections could then be linked to the proposition of policy instruments, which could round of the EBM plans and accompany the implementation of measures.

Despite important uncertainties and limitations mentioned above, some insights can be gained when looking at the results of the evaluation exercise in the AQUACROSS case studies. Evaluations of effectiveness show that AQUACROSS EBM approaches are more effective in reaching a wide range of biodiversity targets, in particular by more effectively choosing where to place measures and where to invest available financial resources. The more holistic perspective which is taken requires a consideration of different trade-offs, e.g. involving societal goals or specific ecosystem services, when assessing effectiveness. Evidence from case studies indicates that solutions proposed following the application of the AQUACROSS assessment framework seem to be more efficient as well (although, as mentioned above, only part of the costs and benefits could be considered and estimated in monetary values in the evaluations carried out in individual case studies).

Results of the AQUACROSS work also emphasise the need to more systematically differentiate between different types of ecosystem services. Due to existing trade-offs, in particular between some provisioning ESS and other types of ESS, the overall goal of enhancing and protecting ESS services needs further refinement. Some ESS seem less compatible with biodiversity conservation objectives, and their excessive exploitation can turn into a pressure for the ecosystem supplying them (see also Grizzetti et al. 2016).

Evidence from case studies regarding the evaluation of distributional aspects is not sufficient to state whether the proposed approaches are more equitable and fair than more traditional approaches to water management. However, case study work shows that a more holistic approach, including in particular the consideration of ESS, allows for more transparency and for more informed views on water management challenges and the connections between water and biodiversity. Even in cases where no clear evaluation results are presented, it is assumed that any additional information on ecosystem services will contribute to more informed decisions: going through the steps of the evaluation exercise widens the base on which decisions are taken, clarifies areas of uncertainty, contributes to the transparency of decisions and allows adapting them in future management cycles, when more information becomes available[3].

As emphasised by Piet et al. (*forthcoming*), after the evaluation phase ascertaining the feedback into the next EBM cycle is crucial to make the adaptive EBM process work. This is true also for the AQUACROSS case studies. The feedback provided from the ex-ante evaluation now needs to be used to improve what is proposed, and needs to be included as part of a better description of the knowledge base. The stepwise advancement on specific EBM principles in AQUACROSS

[3] The benefits of a shared understanding of in particular the role of ESS within the social-ecological context is also emphasised by Förster et al. (2015).

CS also has implications on the interpretation of the evaluation results presented in case studies. It is not the added value of EBM as such which could be evaluated, but only the first step of the iterative process that is central to EBM.

Pre-conditions for ensuring a successful and effective implementation of EBM

AQUACROSS work has been done in the framework of a research project, but with the aim to provide practical input for management in the case study sites. It is hence important to be clear about the pre-conditions which are necessary for EBM to be implemented, with the ultimate aim of reaching the targets of the Biodiversity Strategy. Reflections stemming from individual case study work and from the project process in general indicate that EBM can only be successfully implemented where institutional cooperation can take place, allowing for the joint consideration of different policy objectives when (a) planning, (b) evaluating and (c) finally choosing, solutions. This tends to suggest that EBM should rather be considered in higher-level institutions, which have the possibility to take a more global vision on management decisions. Cooperation agreements among stakeholders, which define a set of welfare-relevant objectives that can be reached through enhancing and protecting ecosystems, seem to be a suitable tool to support the implementation of EBM approaches.

Among the factors that may impede the adoption of EBM is the impression that single-purpose, traditional options solve problems without creating new ones. EBM deals with reshaping ecosystem processes and functions and the outcomes of these processes are often uncertain. Data limitations and the required understanding of the complex SES link the (ex-ante) evaluation of effectiveness to important uncertainties. The promise to deliver better outcomes (only) in the long term could be perceived as a handicap with respect to traditional practice. Although framed by this context, to inform complex EBM approaches, scientific knowledge needs to apply a transdisciplinary and integrated perspective and consider the whole social and ecological system. Science needs to provide consequential knowledge on why things happen and how they could be improved, and should clearly target the practical needs of decision makers.

By definition through its comprehensive approach, EBM aims at benefitting various groups of stakeholders. This could be an advantage for its implementation, if all societal concerns are taken into account when determining the set of measures that are (most) acceptable, thus making the adoption of the EBM plan feasible. At the same time, the more comprehensive assessment provides increased transparency about who pays and who benefits, revealing possibilities of financial compensation. In current practice, these social concerns are often overlooked or not considered at all, if technical solutions are chosen to tackle a specific problem, which neither harm economic activities nor are financed by local stakeholders.

Outlook

The results of the work undertaken within AQUACROSS case studies seem to highlight that the failure to meet the Biodiversity Strategy objectives is in addition to an institutional failure largely due to the lack of inter- or transdisciplinary knowledge and suitable assessments to inform policy choices on ecosystem restoration options. There is a real need for change in the way policy decisions are informed and institutions organised to make these changes happen. To inform biodiversity protection choices we need to understand how ecological systems work and interact with humans. Only from the understanding of how nature organises itself, we will be able to design effective policy/restoration action that will bring real ecological benefits. In a second step, if public policy really seeks to achieve efficiency across the board, the right analytical instruments need to be developed in order to come up with reliable advice.

What is missing is the inability of policy to realise that biodiversity is impacted by almost every other societal choice that we make. Without this realisation, “no net loss” or restoration targets are nothing but dreams. Instead of biodiversity proofing policy and assessments or advertising the need to protect nature, certain requirements could be directly embedded in the information needs to evaluate any societal choices. This requires that we evaluate the scales, scope and objectives that we apply in regulatory impact assessments (if at all applied to inform decisions by the different EU countries). Unfortunately, in terms of biodiversity protection or environmental protection in general, this requires an understanding of the whole system under evaluation (as an EBM approach dictates). Coherence in public policy is achieved when the final decision has considered ALL potential impacts. Any policy choice involves compromises. The balance of decisions could change with a higher effort in the identification of co-benefits that are often ignored because the system fails to acknowledge them due to narrow focus policy assessments or political decisions.

What the comprehensive analysis done in AQUACROSS has shown, is that it is possible to identify win-win situations, which should be the top priority for the next phase of the biodiversity strategy. These solutions should be rendered compulsory, if there are no arguments, financial, economic, fairness, etc. that could challenge the introduction of this change. This ultimately involves questions about political resolve and the weight that environmental protection policy really holds in (European) public policy.

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