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Cook-book for water ecosystem service assessment and valuation

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Abstract

This work proposes a methodological framework for the biophysical assessment and the economic valuation of water ecosystem services at the water body, the catchment and the European scale. It suits the intent of understanding how changes in pressures may affect the delivery and the value of these services. We integrated the existing knowledge with experience of experts and operational needs (collected through a consultation), to propose practical methodologies able to address specific objectives. This report is organized as follows. The first section analyses the objectives of an ecosystem services assessment, explains how and why we selected and designed the methodology proposed, and discusses the concepts of ecosystem services and their integrated assessment and valuation. The results of the consultation of the experts are presented in the second section. The third section ('cook-book') exposes, in a concise and practical way, the approach and methodologies proposed to assess and value water ecosystem services. Finally, some major issues related to this methodology are discussed in the last section.

This report is a deliverable for the MARS (Managing Aquatic ecosystems and water Resources under multiples Stress) research project funded by the Seventh Research Framework Programme (FP7) of the European Commission. Project number : 603378.

This report is the Part 2 of the MARS deliverable D2.1
"Four manuscripts on the multiple stressor framework"

Cook-book for ecosystem service assessment and valuation in European water resource management

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Content

Non-technical summary

MARS (Managing Aquatic ecosystems and water Resources under multiples Stress) is a research project funded by the Seventh Research Framework Programme (FP7) of the European Commission (project number: 603378). It aims to analyse the effects of multiple stressors on the status of European waters and on the ecosystem services provided by aquatic ecosystems.

This work proposes a methodological framework for the biophysical assessment and the economic valuation of water ecosystem services at the water body, the catchment and the European scale. It suits the intent of understanding how changes in pressures may affect the delivery and the value of these services.

To this end, we integrated the existing knowledge with experience and needs of the partners of the project (collected through a consultation), to propose practical methodologies able to address the project specific objectives.

This report is organized as follows. The first section analyses the objectives of the ecosystem services assessment in MARS, explains how and why we selected and designed the methodology proposed, and discusses the concepts of ecosystem services and their integrated assessment and valuation. The results of the consultation of the project partners are presented in the second section. The third section ("cook-book") exposes, in a concise and practical way, the approach and methodologies proposed to assess and value water ecosystem services in MARS. Finally, some major issues related to this methodology are discussed in the last section.

The work presented in this report tries to link the assessment and valuation of water ecosystem services to the ecosystem status and to the analysis of the impacts of pressures at different spatial scales (water body, catchment and European scale).

1. Introduction

1.1 Objective

The project MARS aims to analyse the effects of multiple stressors on the status of European waters and on the ecosystem services provided by aquatic ecosystems. While the *ecological status* expresses the quality of the structure and functioning of the aquatic ecosystems (Directive 2000/60/EC), *ecosystem services* refer to the benefits that people obtain from them (MA, 2005), the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). In MARS the analysis will be conducted considering three spatial scales: the water body, through field experiments, such as river flumes and mesocosms, where stressors changes are controlled; the catchment, studying the effect of multiple pressures across different climatic conditions in 16 European catchments, ranging from Southern to Nordic catchments; and the European scale, where the effects of multiple pressures will be assessed on the whole continent.

The purpose of the research presented in this report (MARS Task 2.2) is to develop a methodology to assess and value the ecosystem services provided by aquatic ecosystems, with the aim to study the effect of multiple stressors on ecosystem services at the three scales of interest for the project. The methodology will be then applied in the course of the project at the water body, the catchment and the European scale.

1.2 Strategy to design the assessment methodology

To develop the methodology we combined two approaches. On the one hand, we analysed the framework and concepts of ecosystem services to provide definitions, indicators and methods for assessing and valuing ecosystem services in water ecosystems for the specific application in MARS, based on literature review and on-going initiatives in Europe (MAES, Maes et al. 2014; EU FP7 OpenNESS and OPERAs projects). On the other hand, we collected the experience, knowledge, and needs of the MARS partners through a web questionnaire, to select the relevant ecosystem services and target the methodology. We considered this research as a learning process, where previous experiences in the MAES working group and information available through literature review had to be combined with the knowledge and expertise of the project consortium, independently from previous experience in ecosystem service assessments. We integrated the outcomes of our analysis and partners' consultation to propose a methodology that addresses the objectives of the project and can be applicable in practice.

In the development of the research, the interaction with the MARS partners that will apply the methodology at the different spatial scales (water body, catchment, European scale) has been organised around two major events. The first in May 2014, when the web questionnaire for partners' consultation was sent, and the second in October 2014, when we presented the results of the questionnaire and circulated a draft of the proposed methodology for partners' comments and feedback (Figure 1.1).

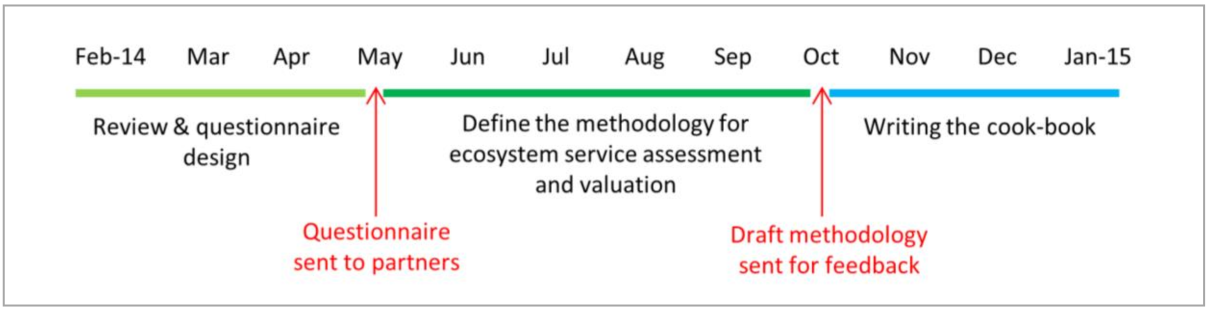


Figure 1.1 Main steps in the development of the MARS methodology for assessing and valuing ecosystem services.

This report presents the results of this research. It is organised in four parts. After a thorough analysis of the objectives of the assessment, the document explains how and why we selected and designed the methodology proposed (Chapter 2), discussing the concepts of ecosystem services and their integrated assessment and valuation in MARS. Then, the results of the consultation of the project partners are presented (Chapter 3). Chapter 4 (the cook-book) shows in a concise and practical way the methodology proposed to assess and value water ecosystem services for MARS. Finally, some major issues related to this methodology are discussed (Chapter 5).

To improve the readability of the document and the practical application of the methodology most of the results (data, information and tools) on which chapters 2-4 are based are presented in the Annexes 1-6, and Annex 7 provides definitions of some key terms used in the report.

2. Analysis

This section presents the results of the analysis and literature review conducted for developing the methodology for assessing and valuing ecosystem services in MARS. We start from the analysis of the purposes of the assessment in the project to shape the methodology and we then present and elaborate the concepts of ecosystem services (definition, classification) in the context of the project. We propose an integrated framework for the assessment of water ecosystem services and discuss the challenges of a valuation. Finally, the methodologies for the biophysical and economic assessment of water ecosystem services are presented.

2.1 Scope and scale of the assessment

The first step in developing the methodology for assessing and valuing ecosystem services is an attentive analysis of the purpose of this methodology in the project MARS. What do we want to achieve in the project? What should the methodology fulfil? Clearly identifying the objectives is essential for developing a suitable and targeted approach. It is also necessary as the field of "ecosystem services" is broad and in part undefined.

The overall objective of the project MARS is to study the effects of multiple-stressors on the ecological status and the delivery of ecosystem services in surface water and groundwater, to support managers and policy makers in the practical implementation of the Water Framework Directive (WFD, Directive 2000/60/EC). It will analyse and predict multiple stressor-impact relationships at three scales: water bodies (WP3), river basins (WP4) and Europe (WP5). The project will define overall concepts and methodologies for the assessment and valuation of ecosystem services with the aim of demonstrating the practical use in multiple-stressor problems for river basin managers (WP2). Specifically, the project refers to the **biophysical quantification** and **economic valuation** of ecosystem services. (Box 1 summarises the main research activities related to ecosystem services per different project work packages, as described in the DOW).

The ecosystem services of interest are those related to the water bodies covered by the WFD and relevant for the river basin management. The methodology should 1) address ecosystem services at different scales, 2) represent the effects of multiple stressors, and 3) support the integrated river basin management.

Box 1 - Ecosystem services in the DOW

WP2 will review existing approaches and methods of ecosystem service assessment and valuation at various spatial scales, and will provide guidelines for service valuation in WPs 3-6 and more generally for the use in river basin management. It will provide an overview of concepts and criteria for indicators (water quality, water quantity, ecological quality and ecosystem services) applicable in integrated river basin management and will select benchmark indicators to be applied within other WPs.

WP3 will assess the combined impacts of extreme climatic events (floods, low flow, thermal extremes, extreme mixing and pulsed DOM loading), nutrient loading and morphological alterations on selected core indicators, including ecological status, ecosystem structure, function and resilience in ecosystem service delivery.

WP4 will link catchment models, benchmark indicators and risk assessment to appraise how multiple stressors affect water quantity and quality, ecological status, ecological functions and ecosystem services under contrasting scenarios of water resource management, land use and climate change. The work interfaces directly with river basin and regional environmental management. It will demonstrate how the improved models can be used to guide River Basin Planning and Programmes of Measures through enhanced policy support related to EU water resources.

WP5 will describe patterns of multiple stressors, ecological status, water quantity, water quality and ecosystem services at the European scale for lakes, rivers, groundwater and transitional waters to be displayed in a series of maps; to analyse linkages between multiple stressors, status and services at the European scale for lakes, rivers, groundwater and transitional waters; in specific, Subtask 5.1.4 will carry out a spatial assessment of services delivered by European aquatic ecosystems.

WP6 will synthesise the results from WPs 3-5, enhance understanding of stressor interactions and stressor-response relationships across scales, including the sensitivity of particular species, water-body types, or ecosystem services to common stress combinations identify indicator and tool gaps for improving Integrated River Basin Management across Europe. Task 6.4 Integrated River Basin Management: evaluation of the MARS conceptual model. The benefits of sustaining ecological flows and the value of green infrastructure for natural water retention measures (flood regulation and drought mitigation).

WP7 will integrate the results from WP2-6 into practical, easy-to-use tools to support water resources management. The tools will contribute to designing cost-effective programmes of measures to extend and improve existing tools to detect and diagnose changes in chemical, ecological and quantitative status of water bodies, and to identify the risks for ecological functioning and capacity for provision of ecosystem services. A set of benchmark indicators addressing water quantity, water quality, ecological status, ecosystem functioning and ecosystem services will be presented

WP8. A set of benchmark indicators addressing water quantity, water quality, ecological status, ecosystem functioning and ecosystem services will be presented interacting with the most relevant WFD-CIS groups to provide timely inputs to guidance documents concerning impacts of multiple stressors on water status and related ecosystem services, and the best mitigation measures.

2.1.1 Address ecosystem services at different scales

Considering the case studies of the project at the three different spatial scales, water body, catchment and the European scale, we can identify specific objectives and opportunities of the assessment of ecosystem services (Annex 1).

At the water body scale (Annex 1 Table A1.1), in confined experimental conditions, the main focus is the analysis of specific functions of the ecosystem that support certain ecosystem services, and the study of their alteration under different combinations and changes of stressors (which in the experiments are controlled). In these experiments the functions supporting the ecosystem services can be assessed, while the demand side is not directly taken into consideration (preventing the full application of the ecosystem service assessment).

The case studies at the catchment scale offer the relevant spatial scale for the application of ecosystem services concepts in river basin management (possibly through River Basin Management

Plans). Within the catchment, the aquatic ecosystems and their services can be further mapped at the water body scale or by sub-catchments or regions, depending on the data availability and the resolution desired for the assessment. The catchment is the appropriate scale to observe and quantify processes related to the water cycle, to implement monitoring and management plans, and to test and downscale scenarios of multiple-pressures. The 16 catchments of MARS represent a great variability of pressures and ecosystem services across Europe (Annex 1 Table A1.2). In addition, in these case studies the research will involve the local stakeholders, which is relevant for the application of ecosystem service concepts in the development of management plans.

The assessment and valuation of ecosystem services at the European scale allows to address regional trends, identify hot spots in the delivery or degradation of services, test the effectiveness of regional policies (such as EU Directives) and scenario analysis at the large scale (Annex 1 Table A1.3). Data issues are related to the availability of homogeneous and consistent data across Europe, which is possible when data are based on satellite images but more difficult when monitoring data are collected by national and regional agencies. In terms of resolution, aquatic ecosystems at the European scale can be mapped as water bodies, river basins or sub-catchments, or areas, and generally rely on the catchment as the meaningful spatial unit for processes related to the water cycle.

2.1.2 Represent the effects of multiple-stressors

The methodology developed by the project MARS should be able to describe the impacts of multiple-stressors on the delivery of ecosystem services, under different scenarios. Based on the description of the case studies at the different scales, we can summarise that the main pressures that affect the aquatic ecosystems are related to alterations of water quantity and quality, and to changes in the habitat and the biological components (Table 2.1).

An important aspect in this respect is that the excessive exploitation of ecosystem services can turn into a pressure for an ecosystem. It is important that the conceptual framework of the methodology correctly addresses the inherent link between ecosystem services and pressures. For this reason we would like to include the concept of sustainability in the assessment of ecosystem services (this will be discussed in Section 2.4).

Table 2.1 Main pressures that affect aquatic ecosystems. The pressures can be the consequence of different drivers, such as changes in population, economic activities, land use and climate.

<table>
<tr><th colspan="2">Alteration of:</th></tr>
<tr><td>Water quantity

Flow modifications (hydrological alterations):
Quantity and frequency (dams, water abstractions, irrigation, transfers)
Groundwater abstractions
Changes in precipitation and temperature
Changes in runoff</td><td>Water quality

Diffuse and point pollution:
Nutrients
Chemicals (pesticides, endocrine disrupting compounds, nanoparticles, etc.)
Metals
Pathogens
Litter
Groundwater salinization

Sediments, increased turbidity and brownification</td></tr>
<tr><td>Habitat

Hydromorphological alterations (physical alteration of channels, bed disruption, dams, etc.)</td><td>Biota and biological communities

Alien species

Overfishing</td></tr>
</table>

2.1.3 Support integrated river basin management

The final aim of the project MARS is to support managers and policy makers in the practical implementation of the Water Framework Directive (WFD). With respect to the methodology for assessing ecosystem services two levels of objectives can be identified. A specific level of application for analysing the link between ecosystem services and multiple-stressors, and a more general level for assessing and valuing ecosystem services to support the development of River Basin Management Plans (RBMP) foreseen under the WFD, that is relevant for the catchment and European scale analysis.

Indeed, the ecosystem service approach could be appealing for policy makers and river basin managers to quantify and justify the cost of maintaining and restoring ecosystems (conservation), to set target of sustainable use of natural resources, to highlight co-benefits of certain measures, and to analyse trade-offs between different stakeholders' needs or different scenarios.

The application of the ecosystem service approach in river basin management means that the methodology should make use of appropriate data (such as data already available by monitoring) and tools for water management, such as hydrological models. It should be spatially explicit, to the extent possible, to support the spatial planning, and should include the interests and perspectives of all stakeholders involved.

Above all, to support the implementation of the WFD, the methodology should be applicable in practice. This means in several cases to opt for pragmatic solutions and delimit the context of application. We will discuss further the link between the ecosystem service approach and Integrated Water Resource Management (IWRM) in Section 2.2.

2.1.4 Characteristics of the methodology

To summarise, based on the previous analysis of the scope we can identify some requirements that the MARS methodology for assessing ecosystem services should fulfil:

- define the ecosystem services relevant for aquatic ecosystems and water resource management;
- provide quantitative information on the benefits people obtain from nature including economic value, with the focus on biophysical quantification and monetary valuation;
- be sufficiently simple and flexible to be applied for the analysis at the different spatial scales (water body, catchment, Europe) by different users across Europe (not site-specific);
- capture the effect of multiple stressors and scenarios on ecosystem services delivery;
- support the river basin management process, which means offering an approach that considers sustainability (and conservation) of natural resources, is sufficiently pragmatic (using data and tools that are available and suitable for river basin management), is linked to valuation (cost-benefit analysis, trade-off analysis) and proves effective in communication with stakeholders involved in river basin management planning.

We have considered these elements as guiding principles in the development of the methodology, which is discussed in the rest of the document.

2.2 Ecosystem services and water management

2.2.1 Ecosystem services

Ecosystem services are the benefits that people obtain from ecosystems (MA, 2005), the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010) (for definitions of terms see also Annex 1 of Maes et al. 2014). One of the goals of the conceptualization of ecosystem services is to make more visible the key role that biodiversity and ecosystem functions play to support multiple human benefits, such as nutrition or safety. Understanding the linkages between the natural and socio-economic systems can lead to appreciation and, consequently, to an improved protection and management of ecosystems (Alahuhta et al., 2013).

Several classifications and **conceptual frameworks** have been proposed to analyse ecosystem services, such as the Millennium Ecosystem Assessment (MA, 2005a), the Economics of Ecosystems and Biodiversity (TEEB, 2010), and the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin, 2013). The Working Group on Mapping and Assessment of Ecosystems and their Services (MAES), which was set up to support the implementation of the EU Biodiversity Strategy to 2020, has developed an analytical framework to ensure that consistent approaches are used by the EU and its Member States (Maes et al. 2013). The conceptual framework is based on the CICES v4.3 and has been tested in several pilot studies, including one on freshwater ecosystems and another on marine ecosystems. To be consistent with the assessments carried out in the EU we propose to use the CICES v4.3 as reference for the MARS methodology. In CICES, ecosystem services are considered through the 'cascade model', which links the structure and the functions (processes) of the ecosystem to the service, which can be translated into benefits and values associated to human well-being (Figure 2.1).

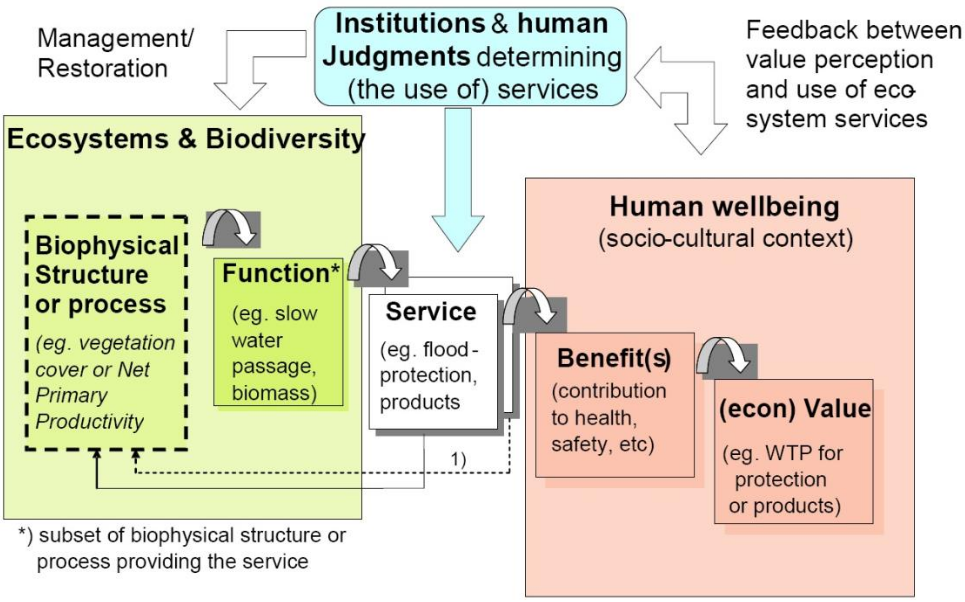


Figure 2.1 Illustration of the cascade model, a conceptual model to analyse ecosystem services, from De Groot et al. (2010).

2.2.2 Water related ecosystem services

A large variety of ecosystem services have been addressed by ecosystem services assessments such as MA, TEEB, MAES, and national assessments (Pereira et al., 2006; UK NEA, 2011). In MARS we are interested to study ecosystem services related to water and aquatic ecosystems. Maes et al. (2014) have analysed the **ecosystem services per typology of ecosystem**, considering the services delivered by rivers, lakes, groundwater and wetlands in the freshwater pilot study, and those provided by transitional waters, coastal waters, shelf waters and open ocean in the marine pilot study. With a slightly different approach, Brauman al. (2007) discussed the '**hydrologic ecosystem services**', defined as the ecosystem services that "encompass the benefits to people produced by terrestrial ecosystem effects on freshwater", each hydrological service being characterised by the hydrological attributes of quantity, quality, location and timing. Keeler et al. (2012) described in detail water-quality related ecosystem services. Recently, Guswa et al. (2014) have addressed more generally the 'water related ecosystem services', discussing the link between hydrological modelling and the ecosystem services relevant for river basin management. From these studies we can observe two approaches in the organisation of the analysis, one per ecosystem typology (Maes et al. 2014) and the other per hydrological relevant services (Brauman et al. 2007). Both approaches consider the integration of the processes, the first by accounting for all the ecosystems in the analysis, the second by integrating the processes in the river basin.

In the DOW of MARS, the ecosystem services of interest are referred as: ecosystem services at the water body, river basin and European scale; ecosystem services of surface and ground waters; ecosystem services for lakes, rivers, groundwater and transitional water; ecosystem services delivered by aquatic ecosystems; ecosystem services associated with riparian areas; ecosystem services relevant for water resource management. In MARS there is primarily a focus on the ecosystem services delivered by the aquatic ecosystems, which can be linked to the water body status, and secondary an interest in the hydrological ecosystem services relevant for river basin management, which may include processes related to the interaction of water and land in different ecosystems, such as forest, agriculture, riparian areas, wetlands, and water bodies.

To address the principal focus of the project, starting from the experience of MAES pilot studies, we developed a classification of ecosystem services based on the CICES v4.3 and we linked it to the classifications of the Millennium Ecosystem Assessment (MA, 2005a) and the Economics of Ecosystems and Biodiversity (TEEB, 2010) (for users more familiar with other classifications). The idea was to offer a coherent terminology relevant for MARS partners, sufficiently simple for stakeholders, and meaningful for river basin managers. The **list of ecosystem services** relevant for water systems we proposed for MARS is presented Annex 2 Table A2.1. In the analysis we considered the following aquatic ecosystems: lakes, rivers, transitional waters, coastal waters, groundwater, freshwater wetlands, coastal wetlands, riparian areas, floodplains. Providing a list of ecosystem services for the aquatic ecosystems can support the practical implementation of the methodology, but of course the list has not to be considered exhaustive and more services can be included, especially hydrological services relevant for river basin planning and decision making. We tested the list of ecosystem services in the partners' consultation. The results are discussed in Section 3 of this report.

The list of ecosystem services proposed in Annex 2 was developed to facilitate the analysis of the effects of multiple-stressors on the delivery of aquatic ecosystem services. If the objective is to carry out a comprehensive trade-off analysis using the ecosystem service approach at the river basin scale, we recommend using the original CICES v4.3 where a longer list of ecosystem services is provided (including terrestrial ecosystem services), considering the specific characteristics of the region under study.

2.2.3 Ecosystem services and water resource management

The interest of MARS in providing support to the implementation of the WFD and **River Basin Management Plans** (RBMP) brings in the discussion on the use of the ecosystem service approach in water management and the relationship between ecosystem services and Integrated Water Resource Management (IWRM).

IWRM is defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2000). Before the ecosystem service approach (see definition in Annex 7), IWRM already insisted on the need of connecting environment and human well-being and proposed the integration of multi-disciplinary knowledge from different sectors and stakeholders in the water management.

There are significant similarities between the ecosystem services approach and IWRM. Cook and Spray (2012) argue that the two concepts are ‘nearly identical’. Both aim at a management of natural resources that optimises the economic and social welfare and contemporary insure the ecological sustainability, integrating the knowledge of stakeholders and multiple disciplinary perspectives. As IWRM has a longer history in concepts development and in the implementation, they suggest that learning from the criticisms to IWRM would help improving the adoption of the ES approach.

These criticisms are related to several aspects. First of all the lack of a consistent definition and the difficulty of developing a holistic approach, for analysing all the links between sectors needed in the management and integrating all the range of knowledge involved. Similar criticisms on the lack of clear definitions have been moved to the ecosystem service approach, and considering the boosting of the scientific publications (and communities) now adopting the terminology there is also some confusion and the risk of an inconsistent use of terms (Jax et al. 2013). The concept of IWRM has also been considered quite broad, so that can be interpreted to suit opposite societal visions, from resisting to supporting neoliberalisation of water resources (Cook and Spray 2012). The Ecosystem Service approach aims at making explicit the value of ecosystem services, but this might involve the risk of creating economic markets for provisioning, regulating and cultural services. The challenge is to recognise the value of ecosystems and their services, especially for those not considered so far, without let them being managed only by the markets. The third main criticism to IWRM according to Cook and Spray (2012) is the failure to incorporate the principles in the governance, for the inherent difficulty in the implementation of concepts into practice, because of the barriers to change in the mentality of governments and water managers, and the inability to reconcile the social and ecological systems of water management. The ‘implementation gap’ is also an important challenge for the ecosystem service approach, and the main goal of entire research projects, such as MAES, OpenNESS, OPERAs, or current national assessments.

Ecosystem services and IWRM both share the goal of negotiating the trade-offs between different human and ecosystem needs, while supporting sustainability, and require the involvement of stakeholders for making explicit the whole range of values (not only economic values). The ecosystem service approach offers a framework for analysing the trade-offs among different services and the links to beneficiaries (Brauman et al. 2007). But importantly, in river basin management the main goal is the state of receiving waters, which have some target state to be achieved by a combination of measures to be implemented in the catchment in a cost-efficient way, while in the ecosystem services approach the emphasis is on ecosystems not specifically on target values, which however could be included in the analysis.

In our opinion IWRM used more the term “environment” while the ecosystem service approach used the term “ecosystem”, with environment referring more to resources and physical conditions, and ecosystem inherently making more explicit the dimension of the relationships between physical conditions, biota, biodiversity and functions.

The concept of human-ecological system advocated by the ecosystem service approach is very powerful in linking biophysical processes and human benefits, and allows ecosystem services to be valued and integrated in the river basin decision making process. There are high expectations from the use of the ecosystem services approach to capture and integrate all the effects (economic, environmental and social) associated with new plans and investments (in a way similar to the Environmental Impact Assessment). Hydrological modelling can provide knowledge and tools to integrate the water related ecosystem services into the land management decisions, such as in scenarios analysis, payments for ecosystem services, and strategic spatial planning (Guswa et al. 2014).

Finally, we have also to notice that the WFD refers to economic valuation in decision-making to support the RBMP in the identification and selection of a cost-effective Programmes of Measures (PoM, WFD Article 11). The development of the PoM can be improved integrating all relevant ecosystem services, for example considering the co-benefits of different Natural Retention Measures on different ecosystem services. In addition, the WFD (under Article 9) requires Member States to implement the cost-recovery principle in the water supply system, and benefits of ecosystem services could be included in the Cost-Benefit Analysis. Some recent studies have been reflecting on the potential of the ecosystem service approach in the application of the WFD and RBMPs, highlighting the opportunity of the holistic system thinking to understand the co-benefits of measures (Vlachopoulou et al. 2014; COWI 2014; ESAWADI 2013).

2.3 Integrated assessment

The reflections on ecosystem services and water management reveal the potential of the ecosystem service approach for integrated analysis and the evaluation of trade-offs, and bring us to the next step of our analysis: the development of an integrated assessment framework and the discussion on the valuation of ecosystem services. In this context it is important to mention that there are two ongoing EU FP7 projects, OpenNESS[3] and OPERAs, both started in 2013, specifically dedicated to the study of the concepts of ecosystem services and natural capital and their operationalization. The approach proposed in this document is functional to the purpose of the project MARS and makes reference to the work developed so far by these projects, but has not the ambition to completely resolve the methodological issues relative to ecosystem services.

2.3.1 Linking pressures, status and ecosystem services

In MARS the methodology for assessing and valuing ecosystem services has to be able to capture the effects of multiple stressors on the delivery of the services, as well as to consider the relationship between aquatic ecosystem status and services.

The approach proposed by MAES for the pilot studies (Maes et al 2014) was based on the assumption that the delivery of ecosystem services depends on both the spatial accessibility of ecosystems and the ecosystem condition. Following this hypothesis, the working structure proposed in MAES consisted of four steps: 1) the spatial mapping of the ecosystems; 2) the assessment of the conditions of the ecosystems; 3) the quantification of the ecosystem services; and 4) the integration of these two components in an integrated assessment, considering the range of ecosystems and services and their relationships in space and time. MAES put a great emphasis on the spatial dimension of the analysis and on the use of data already collected through the current EU policy frameworks.

In the case of aquatic ecosystems this working structure corresponds to analyse on one side the (ecological) status of water bodies and on the other side the ecosystem services delivery. Multiple pressures and their changes can result in the alteration of both the status and the services. Analysing these variations is at the core of the project MARS, with scenarios of multiple stressors tested by experiments or modelling. The challenge is to disentangle the complex relationships between stressors, status and services, and correctly distinguish between indicators of condition and service.

Integrated assessment means as well analysing the synergies and conflicts between different services in the current situation and under different future scenarios (trade-offs). In addition to changes in pressures, MARS will investigate a number of scenarios of possible future development, which will involve specific combinations of multiple pressures. In this regard the possibility of quantifying the changes in the delivery of services by biophysical and hydrological models appears crucial.

[3] The authors of this report are participating to the project OpenNESS, supporting synergies and reciprocal learning between MARS and OpenNESS on the ecosystem services related to aquatic ecosystem and water resource management. They are also collaborating with the project GLOBAQUA on economic valuation of ecosystem services.

To summarise, the working hypothesis of MARS that will be tested throughout the project is that the multiple stressors affect the status of the aquatic ecosystem (the ecological status and more generally the ecosystem status), which in turn could result in a change in the ecosystem services and in their economic value, schematically:

Change in Pressures[4] → Change in Ecosystem Status →Change in Ecosystem Services → Change in Value

The methodology for assessing and valuing ecosystem service in MARS should be able to explore the nature of these linkages. To this purpose, we developed a **conceptual framework for the integrated assessment** of water related services to support the users in making explicit the links between pressures (and scenarios) and ecosystem services. The framework is presented in Annex 3.

In the framework, we identify the main pressures affecting aquatic ecosystems (according to Table 2.1) and the possible links to the alteration of four ecosystem/hydrologic attributes: 1) water quantity (including seasonality); 2) water quality; 3) biological quality elements; 4) hydromorphological & physical structure. The attributes are different from those proposed by Brauman et al. (2007), to include in the analysis the biological and hydromorphological aspects and to make the link to the WFD elements explicit (so that the relationship to ecological status should be in principle more easy and the analysis based on similar data). For each attribute we selected a number of representative indicators and identified the possible relationships with the ecosystem services suggested for the methodology (taken from the list presented in Annex 2). The indicators of ecosystem status can be linked to the benchmark indicators proposed by the Task 2.3.
The purpose of this framework (Annex 3) is to support the users in describing the logical relationships in the assessment of ecosystem services and design a conceptual scheme of the research. The arrows are examples. Each case study could select the relationships under analysis and complete and adapt the framework to the specific case study.

2.3.2 Valuation

Once the assessment framework is established, the following step is the quantification and valuation of ecosystem services, and here there is another dimension of integration to be taken into account that regards the valuation. Before discussing the methodology for assessing and valuing ecosystem services we need to explore the concept of ‘valuation’ of ecosystem services.

The value is “the contribution of an action or object to user-specified goals, objectives, or conditions” (MA, 2005). Valuation is the process of attributing a value. The value of ecosystem services is the relative contribution of ecosystem to the goal of supporting sustainable human well-being (Costanza et al 2014). Any decision involving trade-offs of ecosystem service implies valuation (Costanza et al 2014).

There are multiple values and multiple valuation languages (metrics). Drawing from environmental ethics, Jax et al. (2013) discuss the different values in the relationship of human and non-human nature, including inherent, fundamental, eudaimonistic and instrumental values. The values that are

[4] See the definition of the terms *stressor* and *pressure* and their use in this report provided in Annex 7.

captured by the ecosystem service concept depend on how the concept is operationalised and implemented (approaches and methodologies used). Different stakeholders have different value systems and perspectives. Therefore involving all the stakeholders (not only politicians, managers and scientists) in the valuation process is necessary to consider the plurality of values, while neglecting some values would exclude the people who embrace these values (Jax et al. 2013).

The notion of value should not be restricted to the merely monetary value but embrace a larger range of values. If restricting the value of ecosystem services to economic value, we risk to fail accounting all value dimensions and environmental components (trade-offs) of policy decision (Keeler et al 2012). The criticism to the commodification of ecosystem services is that the non-monetary values of nature, such as inherent, fundamental and eudaimonistic values, can be neglected in the assumption that the natural capital can be substituted by other capital. Other valuation methods (non-monetary) should be adopted to account for values other than instrumental values (Jax et al 2013).

'Value pluralism' refers to the idea that there are multiple values, including economic (monetary), sociocultural and ecological values. An integrated valuation should endorse the value pluralism (Gomez-Baggethun et al. 2014). This is the approach currently developed in the project OpenNESS. The valuation techniques vary with the typology of values to be elicited and the scope of the valuation exercise, the geographical scale, spatial resolution, and reliability and accuracy required. The purpose of the valuation can range from awareness raising, to accounting, priority setting, instrument design and litigation (Gomez-Baggethun and Barton 2013).

We recognise the importance of integrating the different dimensions of value. The challenge is the difficulty of integrating different valuation languages (metrics). Projects like OpenNESS are investigating the use of different techniques for valuation of ecosystem services, including non-monetary techniques and Multi Criteria Analysis, in addition to the traditional monetary methods. However, when the study is targeted on few services at the local scale and involves stakeholders (without the ambition to cover all ecosystem services and all possible value dimensions) the risks associated to neglecting the multiple values are lower (Jax et al 2013).

MARS will not perform integrated valuation studies, including economic, social and ecological values. The project will focus on the biophysical and the economic (monetary) dimensions of ecosystem services. In any case, we think it is important to consider the notion of value pluralism in the analysis and to interpret the economic valuation in monetary terms *sensu* Costanza et al. (2014), i.e. for awareness raising about relative changes over a period in time. This excludes the intent of treating all ecosystem services as substitutable. In the valuation in MARS we are interested mainly in the change of value as the result of the effects of multiple stressors changes.

What the MARS methodology should aim for is the integration between biophysical and economic valuation. This highly depends on the method used for the assessment. Economic models to value ecosystem services related to water quality are often poorly integrated with the biophysical models describing the underpinning natural processes (ecological and hydrological models) (Keeler et al. 2012). We will discuss how to improve the integration in the following section, which presents the methodology for biophysical and economic valuation of ecosystem services proposed for MARS (Section 2.4 and Section 4).

2.4 Biophysical and economic assessments

2.4.1 Biophysical assessment

Methodology and tools

There are several approaches to assess and map ecosystem services, from land cover maps combined with scoring factors (e.g. Burkhard et al. 2009) to specific ecosystem service models based on ecological production functions (Sharp et al. 2014). There are also some specific decision support tools, available in literature, for assessing and valuing ecosystem services, that follow specific methodology. Bagstad et al. (2013) reviewed 17 tools for assessing and valuing ecosystem services, including InVest (http://www.naturalcapitalproject.org/InVEST.html) and ARIES (http://www.ariesonline.org/). These tools usually combine ecology and economics, considering the spatial dimension.

The EU FP7 project OpenNESS (Dec 2012 - May 2017) is studying methodologies for mapping and modelling the biophysical control of ecosystem services and approaches for the valuation of the demand of ecosystem services. The application of a number of methods in 27 case studies is ongoing. The methods for assessing the biophysical control that are under study in OpenNESS are reported in Table 2.2. The approaches for the valuation of the demand of ecosystem services include monetary, non-monetary and deliberative methods (e.g. multi-criteria and Bayesian approaches).

Name of the method	Reference
Spreadsheet/GIS methods	Burkhard et al. (2012); Vihervaara et al. (2012)
QUICKScan	http://www.quickscan.pro/
Bayesian Belief Networks (BBNs)	Bayesian Belief Networks: A Cross-Cutting methodology in OpenNESS: Briefing Note
State and transition models (STMs)	Bestelmeyer et al. (2011)
ESTIMAP	Zulian et al. 2013
InVEST	http://www.naturalcapitalproject.org/InVEST.html

Table 2.2 Methodologies for mapping and modelling the biophysical control of ecosystem services under study in the project OpenNESS (2013).

Considering the current and impellent challenge of the implementation, i.e. being able to translate the concepts of ecosystem services into practice, the need to be operational constituted one of the leading criteria in the development of the methodology. This means as well to simplify and accept some compromise. We also wanted to assure the **flexibility and feasibility** to users, to be able to further apply/adapt the methodology to their specific case of application. For this, in developing the biophysical methodology, we focused on the concepts, while leaving the tools to the choice of the users.

The water quantity and quality, and the water related ecosystem services, are affected by the complex interactions of climate, topography and geology, land cover and management, and other anthropogenic modification of the landscape. Incorporating water related ecosystem services in the decision making process requires the capacity to predict the effects of land use changes on the water resources, which can be offered by the **hydrological models** (Guswa et al. 2014). Hydrological and biogeochemical catchment models are appropriate tools for dealing with water related ecosystem services (Guswa et al. 2014; Vigerstol and Aukema 2011; Brauman et al. 2007). They can represent the dynamic of the river basin and the temporal (lag time) and the spatial distance between beneficiaries and impacts, and they can be used in scenario analysis for testing multiple stressors (the core element of MARS). They also allow describing the connection to the hydrologic/ecosystem attributes presented in the integrated assessment framework (Annex 3), that are key for establishing any physical relationship between stressors, status and services.

Following this line and considering the wealth of knowledge in hydrological modelling available in the project MARS, we have featured a methodology that could profit and enhance this capacity. For this reason for the biophysical assessment we propose to base the assessment on **indicators of ecosystem services** rather than tools, proposing indicators of ecosystem services that are directly related to water bodies or to water-land interaction in the watershed (hydrologic ecosystem services). To assure the maximum flexibility and stimulate the creative application of different biophysical models and data analysis we leave the choice of the tool to the user, while we concentrate on the common methodology. Similar to Maes et al. (2014) and Layke et al. (2012), we propose the selection of appropriate indicators or proxies, as flexible and handy approach to measure ecosystem services. We started testing this option through the partners' consultation in May 2014, where we offered a list of indicators per ecosystem service type extracted from Maes et al. (2014) (see questionnaire template Annex A6.1).

Proposed conceptual framework for the indicators

To support the correct understanding and appropriate use of the indicators for ecosystem services, and more generally to structure the assessment, we have to analyse which dimension of the ecosystem service is captured by the indicators (this is particularly relevant in the project MARS, where indicators will be used also for the assessment of the status of ecosystems, and the relationship between conditions and services will be investigated).

To this purpose we propose a simplified conceptual framework based on the cascade model (shown in Figure 2.1) for structuring the analysis and the classification of indicators of ecosystem services to be used in MARS. The framework, presented in Figure 2.2, includes the **Capacity** of the ecosystem to deliver the service, the actual **Flow** of the service, and the **Benefits**. Capacity refers to the potential of the ecosystem to provide ecosystem services, while flow is the actual use of the ecosystem services. The capacity relies on biophysical data, while flow requires the acquisition of socio-economic data. Benefits are associated to the human well-being and the value system (other studies discussing the concepts of capacity and flow: Schroter et al 2014; Layke et al 2012; Villamagna et al 2013; Maes et al. 2013). This framework is coherent with the MARS conceptual model.

Services are often associated with high exploitation of the ecosystem; the risk is an unsustainable use of nature. For this reason we are interested in looking at the sustainable flow of services. This is considered in the conceptual framework by including indicators informing about the **sustainability**, i.e. indicator combining capacity and flow. In many cases, the information on capacity and flow is lacking, or the full capacity of the ecosystem is unknown or unaccountable. In these cases we can try to collect indicators about the **efficiency** of processes, for comparing two different scenarios or ecosystem performances in delivering services.

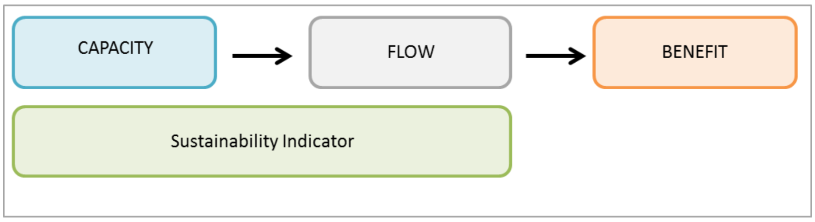


Figure 2.2 Conceptual framework to classify indicators of water ecosystem services in MARS.

Review of indicators for water ecosystem services

To help the partners selecting the best indicator for each situation, we compiled a list of potential proxies/indicators[5] for water ecosystem services and classified them according to the categories of the conceptual cascade model: capacity, flow and benefit (the category of 'sustainability' and 'efficiency' were not explicitly used in the classification, but the user is invited to consider when the proxies/indicators provide this kind of information). Here, we present some conclusions from our literature review.

The specific studies of the Millennium Ecosystem Assessment dealing with freshwater systems (MA 2005b, c) settle down the basis for the analysis and its interpretation, but they do not provide specific indicators to be monitored. Following the MA process, UNEP (2009) focuses on the relevance of water security and UNEP-WCMC (2011) collects the lessons learnt in sub-global assessments reviewing 137 indicators of ecosystem services. However, despite the valuable information, the full list of indicators analysed in UNEP-WCMC (2011) is not publicly available. A similar situation (i.e. very good analysis without raw data access) is found in the studies of Feld et al. (2009, 2010). TEEB (2010) is a good introduction of indicators for many uses (not only ecosystem services) but it does not enter into the detail of listing them. Vigerstol and Aukema (2011) and Clerici et al. (2014) offer practical assessments of freshwater ecosystem services and evaluate different approaches, although they do not provide new indicators for ecosystem services.

Our compilation and classification of water ecosystem services indicators is presented in Annex 4 Table A4.1. It includes a total of 206 proxies and is based on Maes et al. (2014), Egoh et al. (2012), Layke et al. (2012), Russi et al. (2013) and Liquete et al. (2013). Minor modifications from the original authors like re-phrasing or re-allocation were required to avoid duplications and to respect our conceptual framework (and also our list of ecosystem services).

Table 11 of Maes et al. (2014) comprises all the indicators proposed in the deliberative process of implementation of the EU Biodiversity Strategy around the freshwater pilot. Since Maes et al. (2014) was the basis to build the MARS questionnaire, we include all their indicators except only

[5] See Annex 7 for the definition of the terms *proxies* and *indicators*

few[6].Appendix 1 of Egoh et al. (2012) summarises an extensive literature review. The Ecosystem Service Indicators Database of the World Resources Institute (www.esindicators.org, Layke et al. 2012) compiles metrics and indicators from numerous sources that have been identified and applied by individuals from varied organizations. We reviewed a selection of over 400 indicators from this database. Russi et al. (2013) highlights the relevance of water and wetlands and links it to decision-making. It also provides a few examples of indicators for freshwater ecosystem services in Table 3.1 and Box 3.1. We reviewed also Liquete et al. (2013), which includes a systematic compilation of 476 marine and coastal ecosystem services' indicators, in order to cover additional aspects specifically related to transitional and coastal waters.

In the MARS cookbook, we will try to guide the user step-by-step in the process of assessing water ecosystem services (Section 4.3). However, whenever a new practitioner is presented with a list of indicators such as Annex 4, it is worthwhile to recall the key messages of UNEP-WCMC (2011):

- Ensure objectives are clear
- Adopt a small set of specific, policy-relevant indicators
- Go beyond provisioning services
- Utilise existing data and proxies (but recognise limits)
- Think about sustainability – include indicators for both ecosystems and benefits
- Include biodiversity
- Be sensitive to scale
- Assess trends and consider synergies and trade-offs
- Engage stakeholders early
- Focus on communication

[6] The proxies excluded are:

- Number and efficiency of treatment plants: this is human technology, not an ecosystem-based function.
- Waste water treated: it depends only on human, not natural, capabilities.
- Number of sites for CO2 deep injections and volumes of CO2 injected: this is human technology, not an ecosystem-based function.

2.4.2 Economic valuation methods

Valuation methods and policy instruments

To propose the methodology for the economic valuation of ecosystem services for MARS, we first reviewed the economic valuation techniques and consulted the project partners on their specific needs and knowledge in the field. In this phase it was important to understand the availability of trained economists in the consortium and the intention of the case studies to perform an economic valuation (case study research plan), as well as to target the suggested methodology.

There are several ways to estimate values of ecosystem services (see for instance Koundouri et al. (2014) for a recent implementation of the ecosystem service approach to valuing freshwater goods and services to humans). Broadly speaking, there are three categories of approaches: cost-based, revealed preferences and stated preferences approaches.

- **Cost-based approaches** consider the costs that arise in relation to the provision of services.
- **Revealed preferences** approaches refer to techniques that use actual data regarding individual's preferences for a marketable good which includes environmental attributes
- **Stated preferences** approaches refer to methods based on structured surveys to elicit individuals' preferences for non-market environmental goods.

Another practical way to value ecosystem services under non-availability of site-specific data or funding constraints is the **benefit transfer approach.** This approach consists in using economic estimates from previous studies to value services provided by the studied ecosystem (see Navrud and Ready, 2007).

Table A5.1 in Annex 5 provides a detailed list of methods for economic valuation, making the distinctions between the different approaches.

To mitigate the impact of multiple stressors, different policy instruments may be implemented or may be relevant. In Table A5.2 in Annex 5 we provide a list of the typical available policy instruments, making the distinction between economic instruments, voluntary approaches, regulations and information tools. Knowledge which policy instruments are to be implemented is important since it helps choosing among the different valuation approaches.

Tables A5.1 and Table A5.2 have been used in the partners' consultation for understanding their needs and research plan for the MARS case studies regarding economic valuation. The results of the consultation are presented in Section 3. The intention of performing economic valuation is also summarised per case study in Annex 1.

Based on further analysis and feedback from partners, we have developed the methodology to be applied in MARS, which is presented in details in Section 4.4 (Cook-book).

3. Partners' consultation

3.1 Approach

To inform and target the methodology for assessing and valuing ecosystem services (WP2.2) we included the consultation of the users in the process. We designed an on-line questionnaire to collect the needs, experience and knowledge of the MARS partners and consider them in the development of the methodology. The consultation took place in May 2014 through the questionnaire, which included some parts of the analysis presented in the previous section (Section 2). The questionnaire form is reported in Annex 6 (A6.1).

In MARS the effects of multiple stressors on the delivery of ecosystem services will be studied at three different scales: water body (WP3), catchment (WP4) and at the European scale (WP5). For this reason we designed the questionnaire in a way to receive input from the groups working on the different scales (case studies). The list of people that were contacted for each scale is reported in Annex 6 (A6.2), together with the names of the actual respondents.

The following part presents a critical analysis of the results of the questionnaire and provides some indications on the methodology for assessing and valuing ecosystem services based on the responses to the questionnaire. The complete statistics on the responses from partners are reported in Annex 6 (A6.3). It is important to notice that the answers to the questionnaire reflect the knowledge and research plan of the case studies in May 2014, which might change and evolve in the course of the project.

3.2 Results

3.2.1 Case studies in MARS: scale, ecosystems and their services

Respondents and scale of application

We sent 37 questionnaires: 9 to WP3 partners, 16 to WP4, 8 to WP5, and 4 to partners from other WPs. In total we received 27 responses (see Annex 6). In some cases the questionnaire has been filled referring contemporary to two different scales. Figure 3.1 presents the distribution of the respondents to the questionnaire according to the three different scale of study of the project.

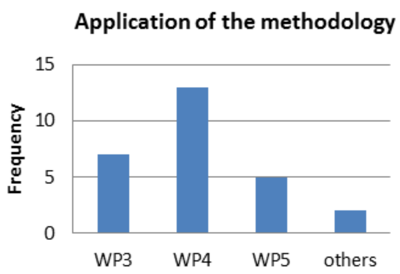


Figure 3.1 Distribution of the respondents to the questionnaire according to the three different scales of study of the project. Legend: water body (WP3), catchment (WP4), European scale (WP5), others (the partner was consulted but is not involved in the application of the methodology).

In MARS most of the users will apply the methodology at the catchment scale (WP4), while doubts were reported on the sense of applying ecosystem services approach to flume experiments (WP3) (Question 2.1). We consider that the most relevant scale for the methodology will be the catchment scale, as the European scale (WP5) can be considered as the aggregation of all the river basins in Europe.

Ecosystem types

The assessment of ecosystem services and their value under multiple-stressors will be focused mainly on rivers and lakes, with some interest as well for transitional waters, groundwater and riparian areas (Figure 3.2, Question 2.2). This is especially the case when considering only the response from the catchment scale (WP4) (Figure 3.3).

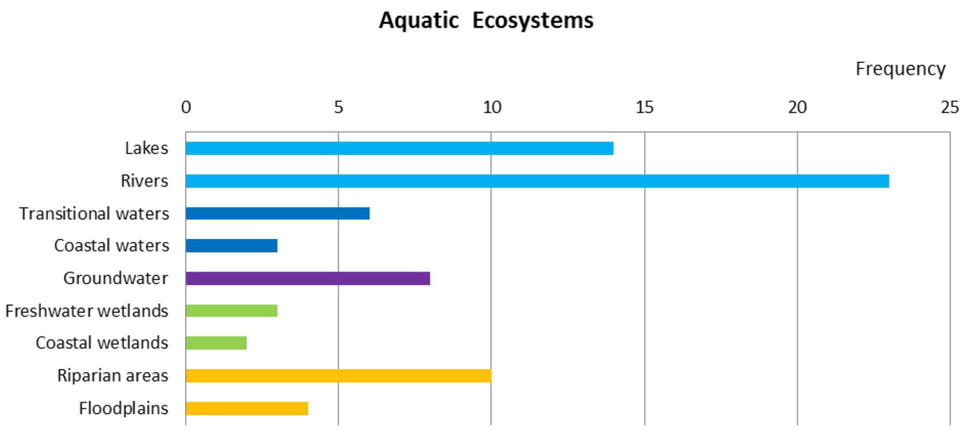


Figure 3.2 Aquatic ecosystems relevant for the delivery of ecosystem services that will be assessed in the project (all responses).

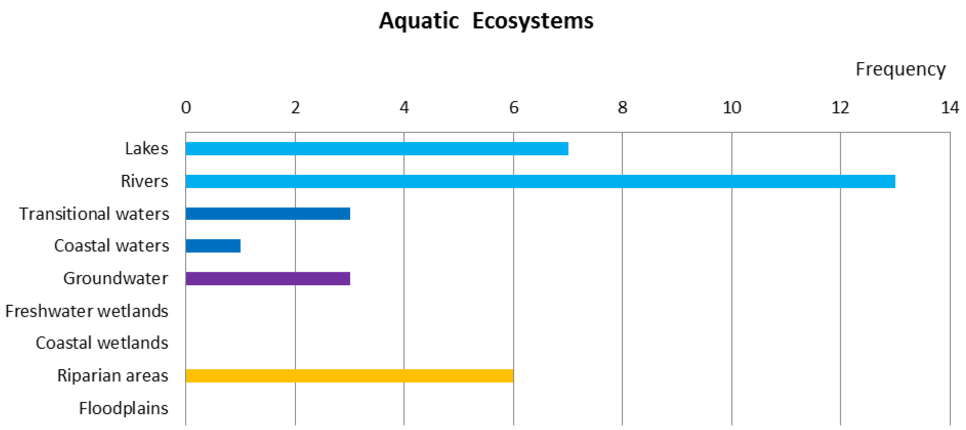


Figure 3.3 Aquatic ecosystems relevant for the delivery of ecosystem services that will be assessed in the project at the catchment scale.

Ecosystem services

The ecosystem services considered in the research will be mainly (Figure 3.4, Question 2.3):

- *Provisioning services*: fish provisioning, water provisioning for drinking and other purposes
- *Regulating services*: water purification, flood protection, maintaining population and habitats
- *Cultural services*: recreation

Some partners indicated the interest in considering also extra abiotic environmental services, such as extraction of reed for building roofs, navigation (transport and shipping) and hydropower.

Figure 3.5 presents the results specifically for the catchment scale. In most of the cases the ecosystem services that are considered relevant for the catchment will be studied in the project, except for recreation that, although is acknowledge as an important service by many partners, in half of the cases will not be assessed.

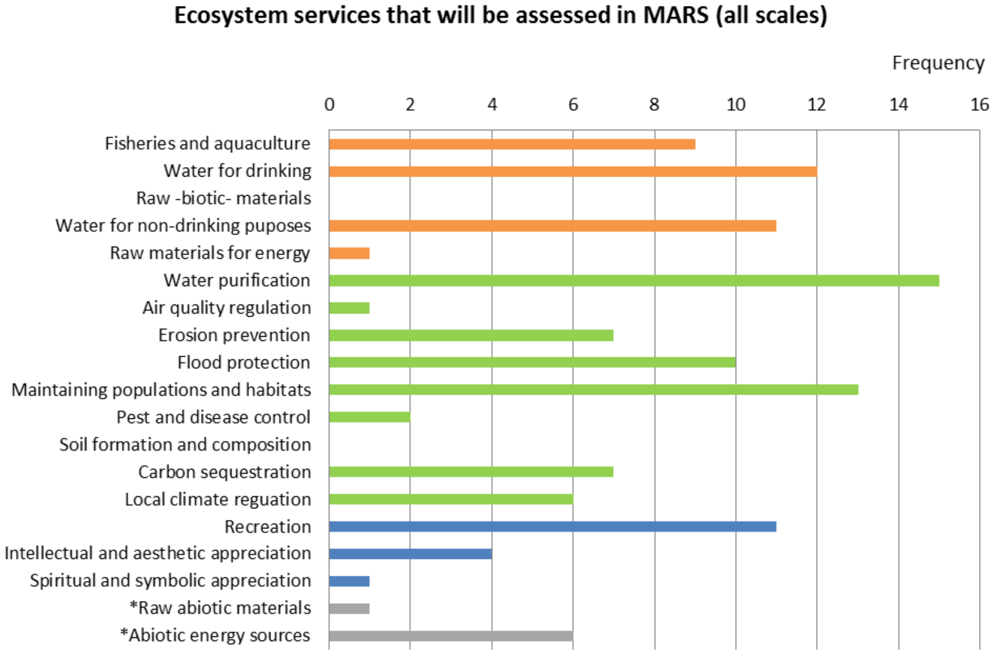


Figure 3.4 Ecosystem services that will be assessed in the project (according to the questionnaire results). *indicates extra abiotic environmental services.

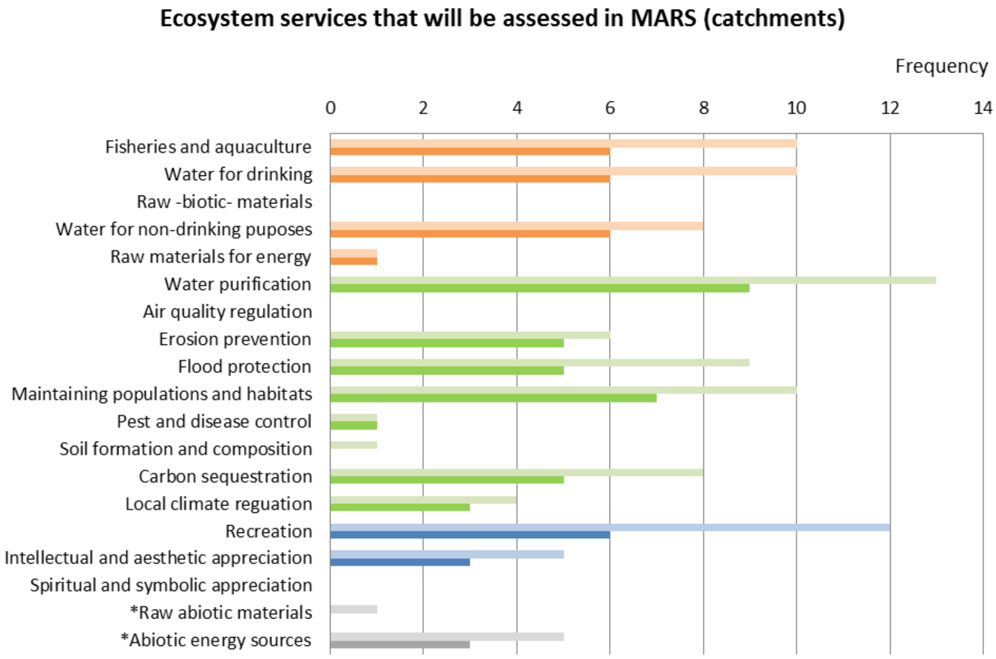


Figure 3.5 Ecosystem services that are considered relevant (light colours) and will be assessed (dark colours) in the project at the catchment scale. *indicates extra abiotic environmental services.

3.2.2 Needs and resources of the partners for the assessment

Indicators for ecosystem services

In the questionnaire, for the ecosystem services selected, the partners were asked if the proposed indicators were appropriate for assessing the delivery of the ecosystem services in their study, and if they had the possibility to assess them by data or modelling (Question 2.5). As list of indicators we provided those proposed by the MAES Working Group in the Freshwater Pilot (Maes et al. 2014; Maes et al. in preparation) with some revision. Considering that the respondents to the questionnaire represent the opinion of aquatic ecosystem experts across the whole Europe, the answers to this question offer a valuable feedback of MARS to the MAES WG.

As already discussed in Maes et al. (2014) that list includes both indicators of status (conditions) of water bodies and indicators of delivery of ecosystem services.

The results for provisioning services, regulating services and cultural services are reported in Figure 3.6, 3.7 and 3.8 respectively.

Considering all responses and all indicators together, on average 53% of the indicators provided are relevant and can be assessed in the project MARS (Question 2.5).

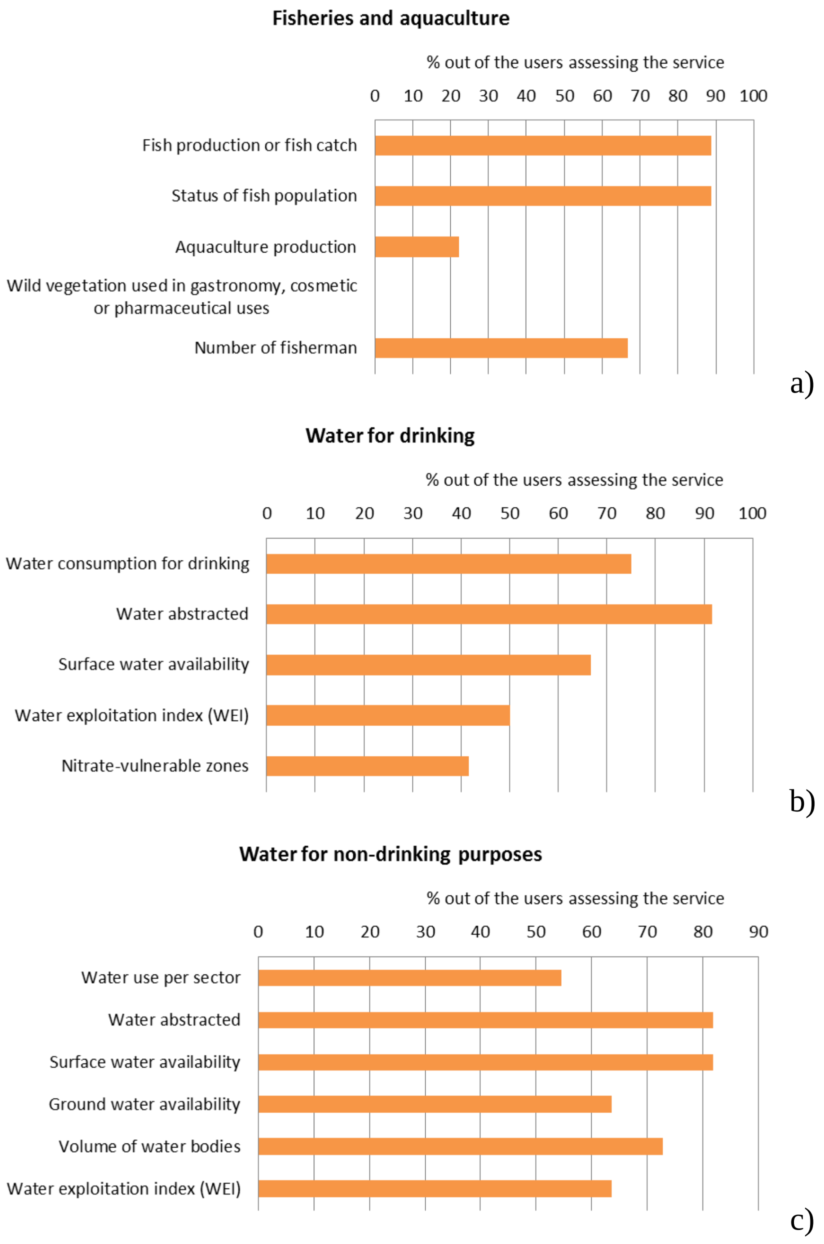


Figure 3.6 Percentage of responses that considered the indicator relevant for the assessment of the PROVISIONING ecosystem service: a) fish provisioning, b) water provisioning for drinking, c) water provisioning for non-drinking purposes. The percentage is calculated out of the total number of responses that declared the intention to assess the ecosystem service in the project.

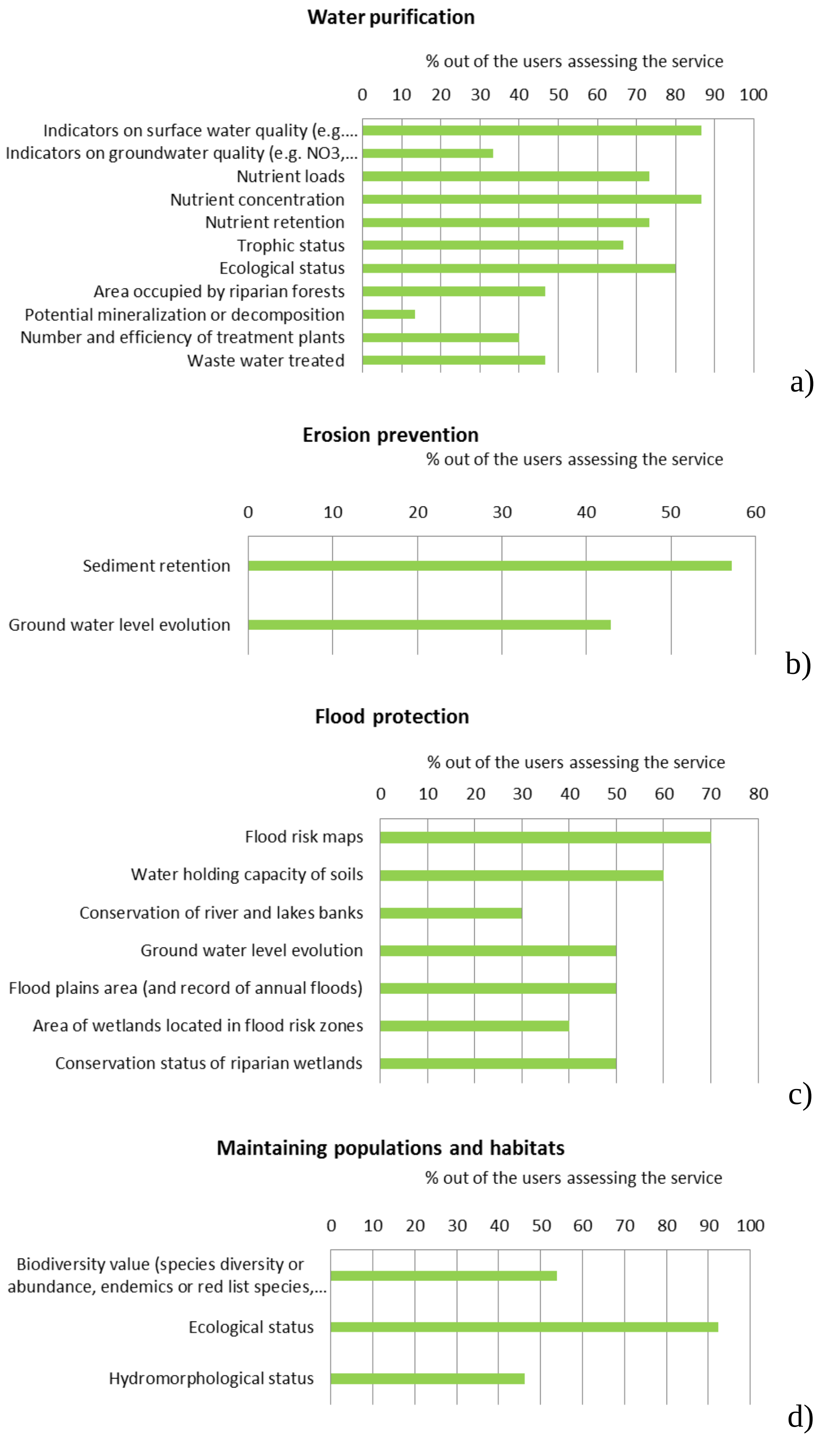
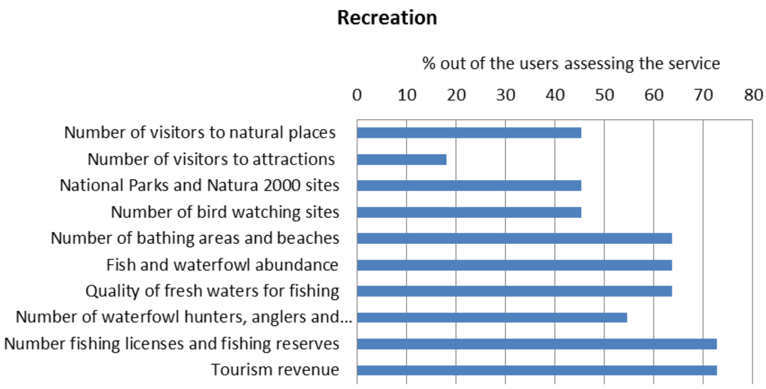
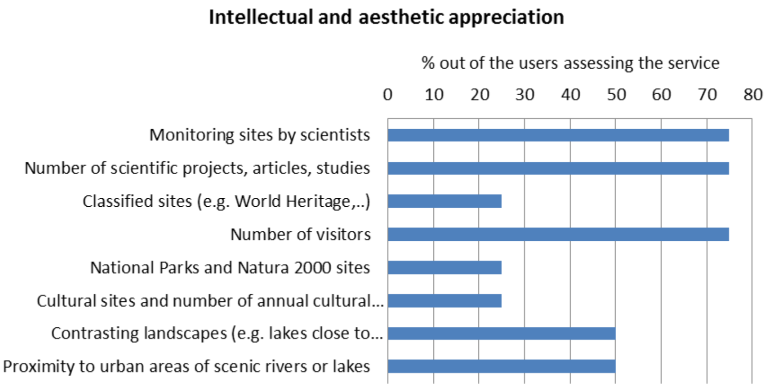


Figure 3.7 Percentage of responses that considered the indicator relevant for the assessment of the REGULATING ecosystem service: a) water purification, b) erosion prevention, c) flood protection, d) maintaining population and habitat. The percentage is calculated out of the total number of responses that declared the intention to assess the ecosystem service in the project.



a)



b)

Figure 3.8 Percentage of responses that considered the indicator relevant for the assessment of the CULTURAL ecosystem service: a) recreation and tourism, b) Intellectual and aesthetic appreciation. The percentage is calculated out of the total number of responses that declared the intention to assess the ecosystem service in the project.

Economic assessment

In MARS, four partners will carry out an economic assessment at the catchment scale (AZTI-Tecnalia, Aarhus University, NIVA, Cardiff University) and one at the European scale (JRC).
The ecosystem services they will value are mainly "fisheries and aquaculture", "recreation" and "intellectual and aesthetic appreciation" (Figure 3.9, Question 2.7).

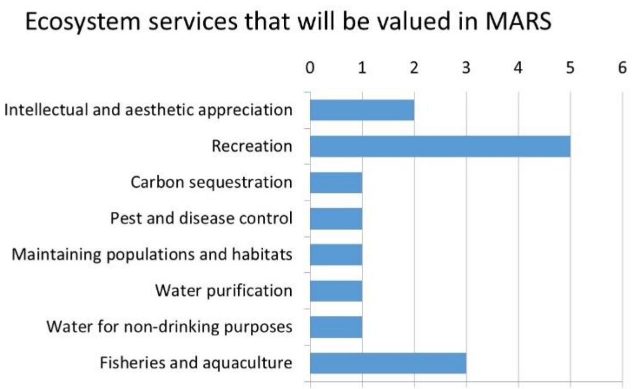


Figure 3.9 Ecosystem services that will be valued in the project (according to the questionnaire results)

Three partners (AZTI, NIVA and Cardiff) plan to collect economic data (e.g. conducting surveys) while the others (Aarhus University and JRC) will use existing databases (Question 2.9).

They will apply cost-based, stated preferences and benefit transfer approaches (no revealed preferences will be applied) (Figure 3.10, Question 2.10).

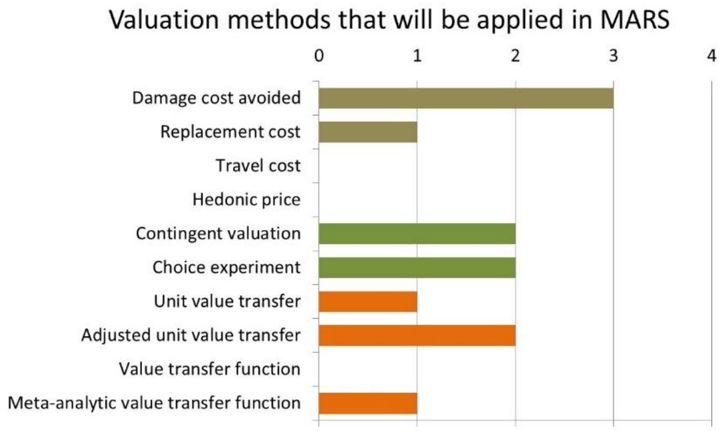


Figure 3.10 Economic methodologies that will be applied in the project (according to the questionnaire results)

The questionnaire also asked respondents which policy instruments (to face the impact of multiple stressors) have already been implemented / would be relevant to implement in their case study. Results show that there is no dominant instrument (Question 2.12 and 2.13).

Previous studies and expertise available in the consortium

The assessment and valuation of aquatic ecosystem services foreseen in the project will produce new knowledge, as studies already published on the topic relative to the MARS case studies were reported only in 37% of the responses (Question 3.1). At the same time, the fact that some studies are already available in some areas is an important knowledge base for the future development of the project and has to be taken into consideration.

Importantly, 44% of the respondents declared to have direct experience in mapping and assessing ecosystem services (Question 3.2) but the percentage falls to 33% regarding the specific experience in economic valuation. However, all partners (5/5) that will perform an economic assessment already have experience in the valuation of ecosystem services and they know which method to use in their case study.

Feedback from partners on the questionnaire

Feedback on the questionnaire was given by 93% of the respondents. The large majority considered the background information provided with the questionnaire useful and clear (Figure 3.11, Question 4.1).

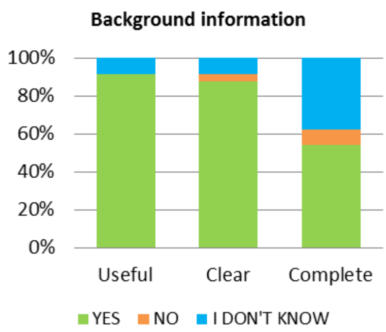


Figure 3.11 Feedback of the respondents on the background information document provided with the questionnaire.

A similar opinion was expressed regarding the list of ecosystem services, with almost 70% of the respondents also keen in using the list with their stakeholders (Figure 3.12, Question 4.3). This confirms that the list of ecosystem services was considered useful and clear not only for researchers (like the partners of the projects) but also for stakeholders involved in the river basin management. Some doubts were reported on the completeness of the list, highlighting the need to be more explicit about the services provided by groundwater and transitional/coastal waters, and on some conceptual aspects, such as the service "maintaining population and habitat" or the inclusion/exclusion of "hydropower and navigation". The latter are not considered as ecosystem services in the framework, but rather as extra abiotic environmental services. In addition, there is a need to clarify to which extend the analyses of ecosystem services will be applied in flume experiments. The large majority of respondents judged also the list of indicators in the questionnaire as useful and clear, but about 20% think it is incomplete (Figure 3.12, Question 4.5). This is in part explained by the fact that new indicators also for ecosystem services will be developed in the course of the MARS project (such as indicators of the contribution of the groundwater baseflow to the surface water ecology, or for examples the use of the number of ships for transport and for tourism).

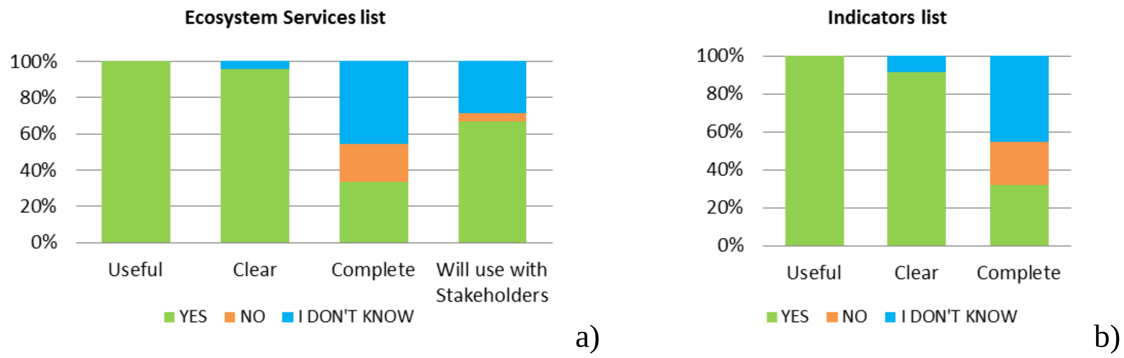
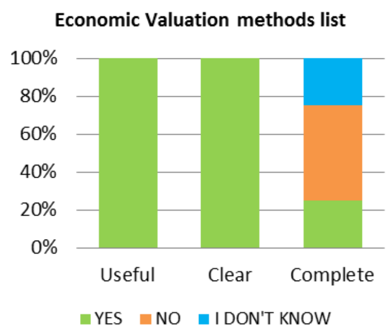
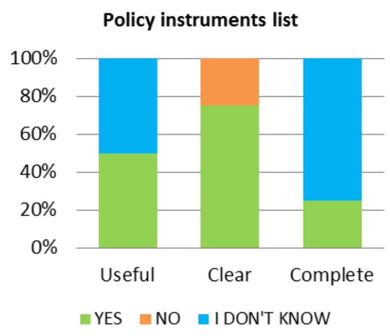


Figure 3.12 Feedback of the respondents on a) the ecosystem services list and b) the indicator list per ecosystem service provided in the questionnaire.

The questions on the economic valuation of ecosystem services were answered by 5 respondents (that will carry out the economic valuation in their case studies), and the feedback on this part was provided by 4 of them. All respondents on the economic part agreed that the list of economic valuation methods made available in the questionnaire was useful and clear, although half of them think it is incomplete. They suggested including market methods and multi criteria analysis. With regards to the policy instruments list, half of the respondents found it useful and clear, but most of them were not sure about the completeness, although no additional instruments were suggested.



a)



b)

Figure 3.13 Feedback of the respondents on a) the economic valuation methods list and b) the policy instruments list provided in the questionnaire.

Finally, two important comments were reported. First, the WFD assessment of the quality status should not be questioned as an overall objective. Second, there is a need to reflect on the indicators used to measure ecosystem services, especially to avoid the use of state indicators for process-related ecosystem services. These points are completely taken into account in the methodology of Task 2.2.

3.3 Possible benchmark indicators for ecosystem services

Based on the responses to the questionnaire, some possible candidates for benchmark indicators (developed by Task 2.3 of MARS) for ecosystem services can be suggested at the time of writing this report. They are the following:

- Fish provisioning: fish production or fish catch;
- Water provisioning: water abstractions for different purposes; water availability;
- Water purification: nitrogen retention (mainly based on modelling); area occupied by riparian forests;
- Finally, an indicator based on e-flow statistics.

4. The cook-book for MARS

On the basis of the concepts and research analysis discussed in Section 2 and the consultation of the project partners presented in Section 3, we propose a methodology for the biophysical assessment and economic valuation of water ecosystem services to be applied in the MARS case studies at the water body, catchment and European scale.

The methodology, also called cook-book for is pragmatic intent, is organised in four main steps (Figure 4.1):

- Scoping of the analysis
- Development of the integrated assessment framework
- Biophysical quantification of ecosystem services
- Economic valuation of ecosystem services

In the following paragraphs we describe each step and the intermediate stages in the application. (Notice that according to partners' consultation in May 2014 only five case studies will perform the economic valuation, the step 4 of the methodology. See Annex 1 for an overview of the analysis and economic valuations planned in MARS).

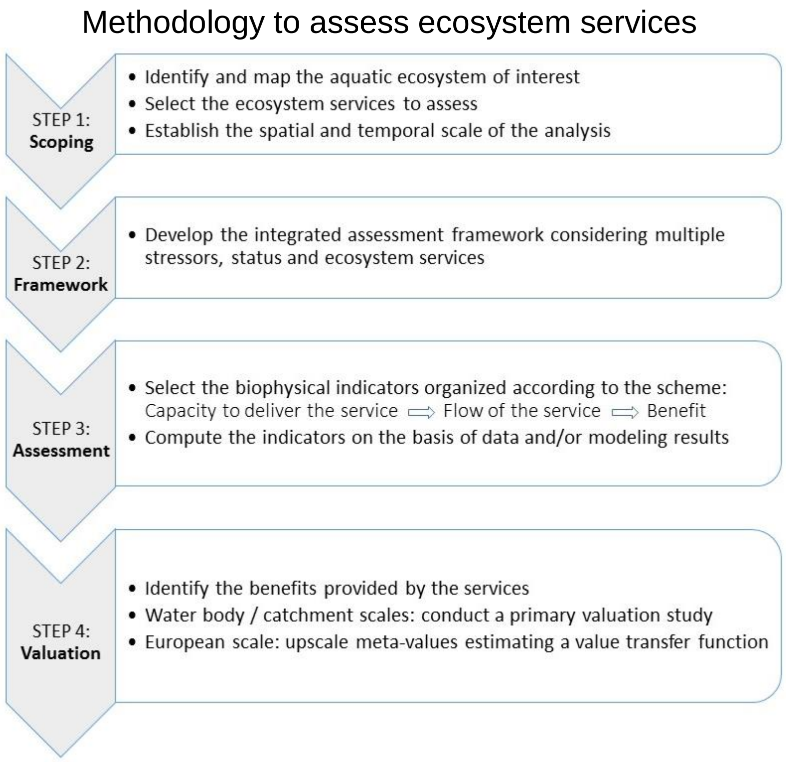


Figure 4.1 Schematic representation of the main steps of the methodology for assessing and valuing ecosystem services.

4.1 Scoping (Step 1)

First of all the scope of the assessment has to be clearly formulated. This clarifies the ambitions and limitation of the study and is needed to establish the scale of the analysis and select the appropriate methodology/tools. In MARS the final aim is analysing the effects of multiple pressures on the ecosystem service delivery at different scales but specific goals are established by each case studies (see Annex 1 for details). It is important to establish whether the case study plans to involve the stakeholders, reflect on RBMP and water management in general, and perform the economic valuation.

Overall, we noticed that in the field scale studies the focus will be on the biophysical functions responsible for the delivery of the services, while at the catchment and the European scale both the supply and demand sides of ecosystem services will be assessed, therefore including biophysical and socio-economic data, and in some cases also performing an economic valuation. At the three scales the research will focus on the relationships between multiple stressors and the delivery of ecosystem services, the outcomes from the catchment scale could be relevant for river basin management while at the European scale for understanding trends and effects of EU policies (see Section 2.1).

As a general indication the scheme proposed by Gomez-Baggethun and Barton (2013) or other can be used. According to this scheme the purpose of the valuation can be:

- awareness raising
- accounting
- priority setting
- instrument design
- litigation

The next elements of the scoping involve:

a) selection of the ecosystems of interest
b) selection of the ecosystem services of interest
c) temporal and spatial scale of the analysis

The order of these actions depends on the case study. For users working on specific aquatic ecosystems, probably it is easier to identify first the ecosystems and then the relevant services. On the contrary, for users focused on hydrological services (see discussion on water related services in Section 2.2 for definition) generally at the river basin scale, it might be simpler to select the ecosystem services first and then include the relevant ecosystems (in this case not only aquatic ecosystems).

a) Selection of the ecosystems of interest

The aquatic **ecosystems** of interests for the study are mainly those relevant for the WFD:

- Lakes
- Rivers
- Transitional waters
- Coastal waters
- Groundwater
- Freshwater wetlands
- Coastal wetlands
- Riparian areas
- Floodplains

The mapping is important for the catchment and the European scale, while for field experiments only a local analysis will be conducted.

b) Selection of the ecosystem services of interest

For each aquatic ecosystem a number of **ecosystem services** of interest have to be selected using the list of ecosystem services provided in Annex 2. This list is the same made available in the questionnaire, and was considered useful and clear by the respondents (93%).

With regard to hydropower generation, we classified it as extra abiotic environmental service, to be consistent with the CICES classification. However, some partners of the projects mentioned it as an ecosystem service (in the questionnaire), while others include it as a pressure. We suggest to consider dams as pressures and water provisioning for hydropower generation as the contribution of the ecosystem, therefore under the class water provisioning for non-drinking purposes.

If the objective of the analysis is to carry out a comprehensive trade-off analysis using the ecosystem service approach at the river basin scale, we recommend consulting also the original CICES v4.3 (Haines-Young and Potschin 2013), where a longer list of terrestrial and aquatic ecosystem is provided.

c) Temporal and spatial scale of the analysis

A crucial element for the assessment is to establish the **spatial and temporal scale** of the analysis. This strongly depends on general scope of the analysis, the availability and resolution of temporal and spatial data and modelling capabilities. The temporal and spatial scale has to be established taking into account the scenario analysis. A possible resolution could be for example the sub-catchment scale or main water bodies, and annual or seasonal temporal values.

4.2 Integrated assessment framework (Step 2)

After the scoping the following step is the development of the integrated assessment framework for the case study. In this step the users are invited to develop the expected links between multiple stressors, ecosystem status and services relevant for their case study, using the integrated assessment framework presented in Annex 3 as support (see Section 2.3 as rationale). The users have to select the stressors under study, consider the expected impacts on the ecosystem/hydrological attributes, check if the indicators of status under analysis capture the effects of the stressors, and link the attributes (and indicators) to the ecosystem services of interest.

All ecosystem services can be affected by multiple stressors. The users should attempt to describe the possible links between the stressors and the ecosystem services. In addition to the scheme of integrated assessment (Annex 3) Table 4.1 could inspire this reflection. The idea is to think about the relationships between the selected services and selected stressors as a matrix and reflect on the expected links. This will help in designing the assessment and the scenario analysis.

Table 4.1 Matrix of multiple stressors and expected qualitative effect on different ecosystem services.

	Ecosystem services proposed in MARS	Flow modifications	Diffuse and point pollution	Groundwater salinisation	Erosion/ Brownification	Hydromorphological alterations	Alien species	Overfishing
Provisioning	Fisheries and aquaculture	high	high	low	high	medium	high	high
	Water for drinking	high	high	high	high	medium	low	low
	Raw (biotic) materials	medium	high	low	medium	high	high	medium
	Water for non-drinking purposes	high	high	high	high	medium	low	low
	Raw materials for energy	high	high	low	low	high	medium	low
Regulation & Maintenance	Water purification	high	high	medium	high	high	medium	low
	Air quality regulation	high	high	low	low	medium	low	low
	Erosion prevention	high	low	low	low	high	medium	low
	Flood protection	high	low	low	low	high	medium	low
	Maintaining populations and habitats	high	high	low	medium	high	high	high
	Pest and disease control	high	high	low	medium	high	high	high
	Soil formation and composition	high	medium	low	high	high	low	low
	Carbon sequestration	medium	low	low	medium	high	medium	low
	Local climate regulation	high	low	low	low	high	low	low
Cultural	Recreation	high	high	low	high	high	medium	high
	Intellectual and aesthetic appreciation	high	high	high	high	high	high	high
	Spiritual and symbolic appreciation	high	high	high	high	high	high	high

Legend: Expected impact of each pressure over the ESS ● high, ● medium, ● low.

4.3 Biophysical assessment (Step 3)

To ensure the flexibility of the methodology and the use of the wealth of hydrological models and data analysis techniques available in the project consortium, for the biophysical quantification of ecosystem services we propose to select ad hoc indicators. To this purpose we have prepared a **list of proxies/indicators** based on literature review. The list of indicators is presented in Annex 4 (see Section 2.4 for rationale).

In the list the indicators are classified (as much as possible) according to:

- Capacity
- Flow
- Benefits

This classification of indicators follows the conceptual framework developed in Figure 2.2 (Section 2.4). The user is also invited to consider if indicators of ecosystem services providing information on the sustainability or efficiency can be included (Section 2.4).

Notice that the biophysical assessment will probably include in most of the case **only indicators of capacity and flow**, while indicators of benefits might already be connected to the economic valuation, the forth step of the methodology (presented in Section 4.4).

In Table 4.2 we show an application of the proposed methodology to the European scale case study, showing which indicators can be proposed for capacity, flow and sustainability/efficiency.

Each partner is invited to:

- Select from Annex 4 the most significant and feasible proxy/indicator for the ecosystem service and category they want to measure,
- or get inspired by the list of proxies and re-interpret a new one (see Table 4.2 for an example).
- Apart from the ecosystem service characterisation, the estimation of sustainability/efficiency indicators and the temporal evolution are particularly interesting.
- Keep in mind that the final goal of this exercise is to compare the delivery of ecosystem services under multiple stressors, thus the effects of the stressors have to be captured by the selected indicators (the integrated framework - Annex 3 - should help in design the assessment correctly).
- Calculate the selected proxy/indicator with data coming from the best available sources (models, measurements, national statistics, scientific literature, etc.).
- Present the information stating clearly the ecosystem service analysed, the water body at stake, the type of information (capacity, flow, benefit or sustainability/efficiency) and, if possible, the scale and the time frame.

The users that have opted for specific tools for assessment of ecosystem services, such as Invest, will follow the methodology proposed by the tools but are prompt to integrate their results in the proposed conceptual framework (see discussion in Section 2.4 and Figure 2.2).

Table 4.2 Proposal of proxies/ indicators to quantify some relevant ecosystem services, using indicators of capacity, flow and sustainability or efficiency according to the cascade model proposed for MARS. The example is based on the research plan proposed by JRC at the European scale.

Ecosystem services	Natural capacity	Service flow	Sustainability or efficiency
Fisheries and aquaculture	Biomass of commercial species	Fish catch	% of catch within sustainable limits (catch below the Maximum Sustainable Yield)
Water for drinking	Surface runoff Groundwater recharge	Water used by different sectors	Water Exploitation Index +; Falkenmark index
Water for non-drinking purposes	Surface runoff Groundwater recharge	Water used by different sectors	Water Exploitation Index +; Falkenmark index
Water purification	Area or coverage of wetlands	Nitrogen removal Persistent Organic Pollutant degradation	Total mass removed vs. total input
Erosion prevention	Area or coverage of vegetated riparian areas	Sediment retention	Sediment retention vs. sediment yield
Flood protection	Natural retention capacity Area covered natural floodplains	Proportion of the water volume retained for a flood with 100 yr return time	Trend in flooding frequency
Maintaining populations and habitats	Mapping nursery areas (e.g. trout)	Minimum requirements like e-flow Habitat change	Recruitment rate
Carbon sequestration	Total carbon stored in a riparian zone or in wetland soils	Carbon sequestration (accumulation rate) per year	% of total carbon accumulated or emitted per year
Recreation and tourism	Mapping protected areas (national parks, Natura 2000…)	Number of visitors	Density of visits % of neighbour population (100 km) visiting the site

4.4 Economic valuation (Step 4)

4.4.1 A scale-specific approach

This section presents approaches and methodologies for monetary valuation of water ecosystem services in MARS. It shows how this value can be estimated in order to be integrated into the decision making process of the RBMP. Cost-efficient program of measures supposes to carry-out a cost-benefit analysis of these measures including benefits such as ecosystem services. In this respect, the monetary valuation exercise contributes to take into consideration the benefits the humans get from the ecosystems into the implementation of policies.

We limit our analysis to the ecosystem services that are planned to be valued in the project MARS. In the consultation carried-out among the MARS partners in May 2014, five research teams have expressed their interest for the valuation of 8 ecosystem services in their case study. The information is summarized in Table A1.2 and Table A1.3.

We propose an economic valuation of ecosystem services that is scale-specific, targeted at the water body/catchment scale and at the European scale. The steps of the economic valuation are outlined in Figure 4.2 and described in more detail in the following paragraphs. The first two stages of the assessment are common to both scales.

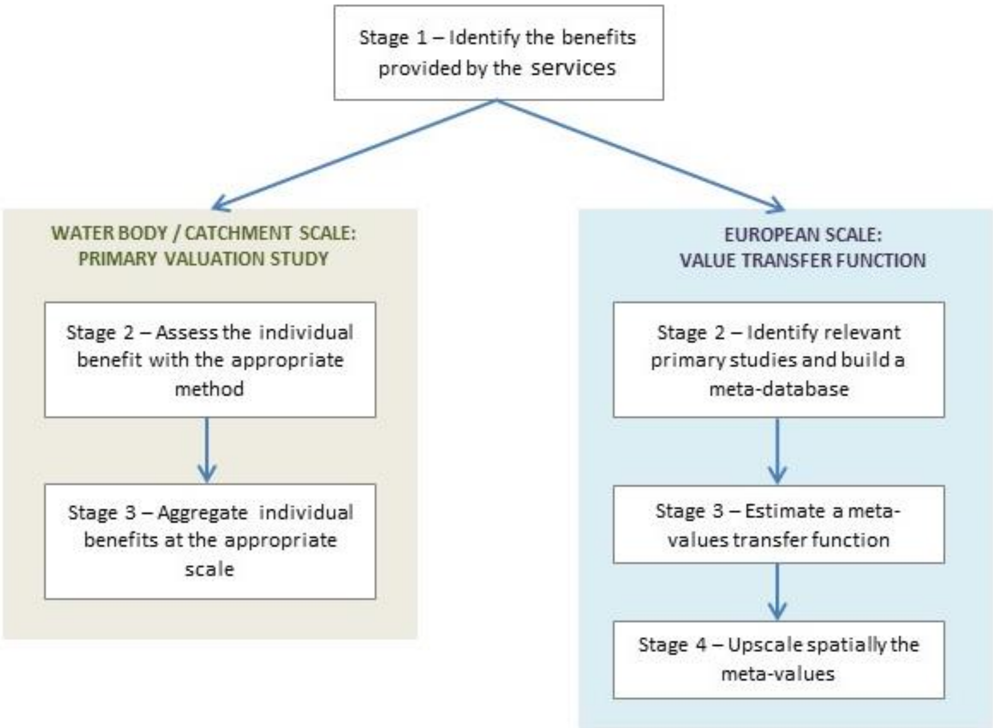


Figure 4.2 Steps of the methodology for the economic valuation of ecosystem services.

STAGE 1 – Identify the benefit provided by the service

The first step of an economic assessment consists in identifying the benefits provided by the ecosystem service to be valued. Fisher et al. have argued that it is the easiest way to perform a valuation exercise avoiding any double counting (Fisher and Turner 2008, Fisher et al. 2009). Following this approach, only the services that have a direct impact on welfare are valued.

In their seminal paper Potschin and Haines-Young propose a conceptual delineation between function, service, benefit and value:

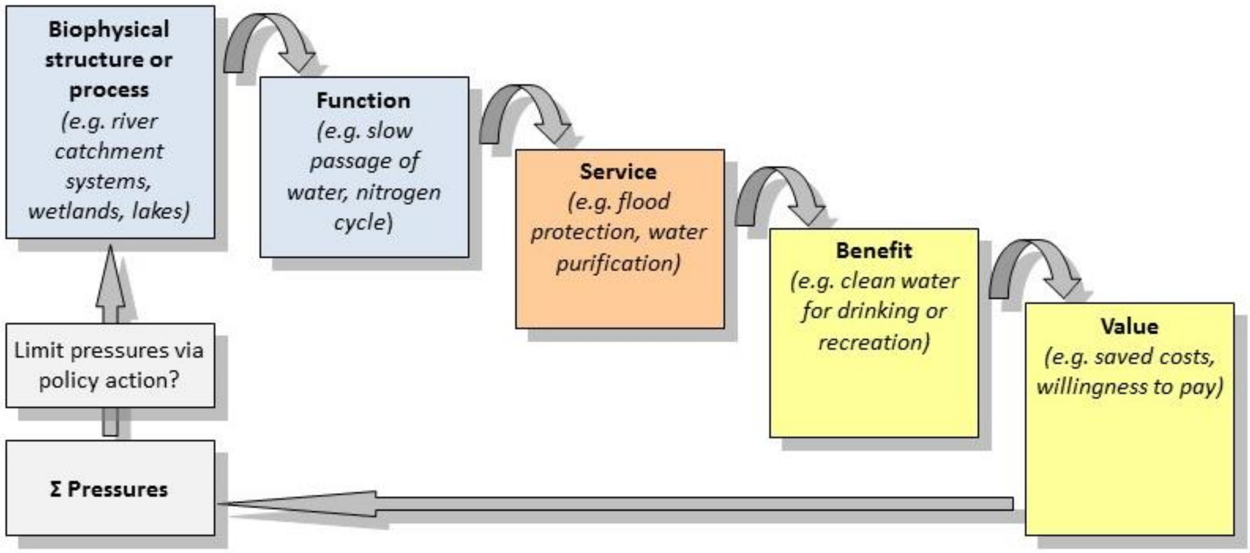


Figure 4.3 Relationships between ecosystem services, benefits and values (modified from Potschin & Haines-Young, 2011).

Services are separated from benefits because gains in welfare generated by ecosystems may vary depending on the final uses and users. An ecosystem service can provide different benefits depending on its location and the socio-economic characteristics of the environment. Figure 4.3 gives an example of the benefits provided by water purification service: clean water for swimming (recreation) or potable water for drinking (provision) are two different benefits. Benefits are created by the flow of services (even if the flow may depend on the size of the stock) while the value of the stock should be seen in the context of the natural capital concept. Therefore, we have limited the methodologies to the valuation of the flow of services. Within the MARS project, we aim to measure the change in economic benefits resulting from the effect of stressors. An assessment consists then in estimating the variation in the value of the flow of services resulting from the realization of a given scenario.

The benefits are obviously higher when more beneficiaries get advantage of it. It is therefore crucial to identify the beneficiary population. We examine this point later on (stage 2).

4.4.2 Economic assessment at the water body and catchment scales

This section presents various techniques that have been developed to value water ecosystem services at small or medium scales. A first subsection introduces the appropriate method to be used to assess the individual benefits (stage 2). A second subsection explains how to aggregate individual benefits at the appropriate scale (stage 3).

One should point out that there are other on-going initiatives related to the development of methodologies for the economic assessment of water ecosystem services. For instance, MARS works closely with the GLOBAQUA project which intends to incorporate valuation of ecosystem services into an approach for sustainable management of water-related resources (Koundouri et al., 2014). In line with the Driving forces, Pressures, States, Impacts and Responses (DPSIR) framework, they propose a methodology to assess the level of cost recovery of a water infrastructure that includes the costs associated with the depletion of water ecosystem quality. They suggest to use monetary valuation to transpose in economic terms the effects of ecological and biological characteristics of water on human welfare. The valuation technics delivered in MARS also offer a chain of tools to estimate the environmental damage resulting from a change in ecological conditions. This integrated approach for the management of freshwater resources, by monetizing environmental cost through valuation of ecosystem services, is an example of the mutual synergies that can benefit both projects.

STAGE 2 – Assess the individual benefit with the appropriate method

Water ecosystems provide a wide range of services, very different in their biophysical functions and in the way they impact human welfare. There are many valuation methods, the relevance of each depending on the service to be valued. An extensive overview of methods can be found in Annex 5.

They are usually classified into two main categories, namely *revealed* and *stated* preference methodologies. *Revealed* methods take into account observable market information, which can be adjusted and used for revealing the individual's preference and thus quantifying the associated welfare benefits. With *stated* preference methods, consumers are proposed some hypothetical markets for which they have the opportunity to pay or accept compensation for the environmental good or service in question (Bateman et al 2003).

In addition to these two main categories, *cost-based* methods and *benefit transfer* approaches may be considered. The *cost-based* methods include the damage cost avoided, the replacement cost, and the substitute cost methods. These methods do not provide strict measures of economic values. Instead, they assume that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services. A *benefit transfer* takes pre-existing values from a study case (or cases) to develop a customized benefit estimate for a new policy case.
The choice of the primary valuation method to be applied is crucial. It depends both on the ecosystem service to be valued and on the beneficiary population. In the following, we give the correspondence between services and the appropriate valuation method to be applied for the ecosystem services valued in MARS.

The following tables provide the valuation method suggested per ecosystem service:

- Fisheries and aquaculture (Table 4.3)
- Water for non-drinking purposes (Table 4.4)
- Water purification (Table 4.5)
- Carbon sequestration (Table 4.6)
- Recreation (Table 4.7)
- Intellectual and aesthetic appreciation (Table 4.8)

Table 4.3 **Fisheries and aquaculture**

Potential case studies: Nervion-Ibaizabal catchment, Welsh basins, Vansjø-Hobøl and Otra catchments	
Valuation method suggested	**Market-price**
Potential beneficiaries	Fishing industry (fishermen, commercial sector)
Approach	Use the (adjusted) market-price of fish as a proxy for the value of the fish provisioning service
Example	Assess the total value of the fish provisioning service through the revenue generated by fish sales net of the cost of fishing
Procedure	1. Collect information on fish price, fish demand (approximated by fish sales) and production costs of the fishing industry 2. Value the service as the total market value of catches minus the cost of production
Marginal change value	Net profit (value of sale minus cost of production) from an additional ton of fish
Data requirement	▪ Price of fish on the wholesale market (eventually by specie) ▪ Demand for fish (can be approximated by current fish catches) ▪ Production cost of the fishing industry
Benefit of the approach	▪ Market price and fish catch data are easily available
Limitation of the approach	▪ Market price may not reflect the economic value in case of market imperfections (e.g. disproportionate subsidies) ▪ The method is only valid if the fishery / aquaculture production is sustainable (for an unsustainable fishery, the value is higher than the market price)

Table 4.4 **Water for non-drinking purposes**

	Potential case studies: Vansjø-Hobøl and Otra catchments	
	Agriculture / Industry	***Hydropower***
Valuation method suggested	**Production function**	**Market-price**
Category	Revealed WTP	Market-based
Potential beneficiaries	Farmers, industries	Households, industries
Approach	Value the resource provisioning service as its impact on the production of a marketed output	Use the (adjusted) price of electricity as a proxy for the value of the abiotic energy provision service
Example	Assess the value of the water provisioning service for agriculture/industry as the change in the net value of the total output production resulting from the use of the resource	Assess the annual value of water produced by a watershed as the net value of the hydropower production generated by this quantity of water
Procedure	1. Estimate the agricultural / industrial production technology (production function, profit function or cost function) 2. Apply the marginal productivity approach to estimate the value of water	1. Estimate the annual quantity of water produced by a watershed (e.g. biophysical modeling, primary data) 2. Compute the amount of electricity generated at the dam for the water supplied by the watershed 3. Assess the annual value of the abiotic energy provision service as the market value of the energy generated by the dam, net of the annual cost of production
Marginal change value	Marginal profit resulting from the use of one additional cubic meter of water by the farm/industry	Market value of the energy generated by an additional cubic meter of water produced by the watershed, net of the average annual cost of production (cost per cubic meter per year)
Data requirement	▪ Quantity and cost of production factors (including water) ▪ Level of production (agricultural/industrial output), cost of production or profit realized ▪ Market-price of the produced good	▪ Annual average quantity of water produced by a watershed ▪ Price of electricity ▪ Building and operating costs of the dam ▪ Lifetime of the reservoir ▪ Power production technology of the dam
Benefit of the approach	▪ Well-know and applied methods ▪ Approach is grounded on reliable statistical and economical technics	Allows value mapping by attributing a specific value to the water yield in the different parcels of the water basin
Limitation of the approach	▪ Data can be difficult to obtain (amount of data needed is important) ▪ The method requires that a change in the use of water does not affect the market price of the final good	Seasonal variations in energy production and energy price are not taken into account

Table 4.5 **Water purification**

Potential case study: Welsh basins	
Valuation method suggested	**Replacement cost**
Potential beneficiaries	Population benefiting from clean water
Approach	Use the cost of a built infrastructure able to provide the water purification service as a proxy for the value of the water purification service provided by the ecosystem
Example	Assess the value of the water purification service through an estimation of the construction and operating cost of artificial wetlands
Procedure	1. Identify all the possible technical solutions for achieving the require pollution removal 2. Estimate the cost of all alternatives and select the cheapest one 3. Value the purification service as the unit cost of the cheapest alternative
Marginal change value	Cost of the purification process for one cubic meter of water
Data requirement	▪ Quantity of water purified by the ecosystem ▪ Beneficiary population from the clean water ▪ Cost of providing clean water (quantity purified by the ecosystem or quantity used by the beneficiaries) with an alternative built infrastructure
Benefit of the approach	▪ Allow to assess the value of the service through a technical-economic approach which is less time and resources demanding than measuring the value of the benefits
Limitation of the approach	▪ Do not consider individual or social preferences for clean water and cleaning systems ▪ Replacement cost is a poor proxy for the benefit value (cost of substitute is not a good measure of the benefit) ▪ Overestimate the value of the water purification service

Table 4.6 **Carbon sequestration**

Potential case studies: Vansjø-Hobøl and Otra catchments	
Valuation method suggested	**(Adjusted) market-price**
Potential beneficiaries	Society
Approach	Use the CO_2 price on the emission trading markets as a proxy for the value of the carbon sequestration service
Example	Assess the total value of the carbon sequestration service applying the price of the emission permits to the amount of carbon sequestered by the ecosystem
Procedure	1. Determine the amount of carbon sequestered by the ecosystem (carried-out in the biophysical assessment) 2. Depending on the time scale of the assessment, choose the market price or an estimation of this price (e.g. European Union Emission Trading Scheme) for a one-ton emission permit 3. If necessary, select a value for the discount factor (when the time scale of the assessment is a long period, benefits of the sequestration service should be discounted on time) 4. Compute the value of the sequestration service as the discounted sum of the values of emission permits corresponding to the carbon sequestered each year within the assessment period
Marginal change value	Change in the amount of carbon sequestered (with respect to the Business as Usual case) x price of the corresponding emission permits on the market (for future emissions, the price is an estimation)
Data requirement	▪ Quantity of carbon sequestered by the ecosystem for each year of assessment period ▪ Market-prices of a one-ton emission permit for each year of the assessment period ▪ Discount factor to use for long term assessments
Benefit of the approach	▪ Carbon market prices and discount factors data are easily available
Limitation of the approach	▪ To date, carbon market-price has been very volatile ▪ Carbon price may be impacted by policies or subsidies

Table 4.7 **Recreation**

Potential case studies: Nervion-Ibaizabal catchment, Odense, Welsh basins , Vansjø-Hobøl and Otra catchments, Europe				
Valuation method suggested	**Contingent valuation**	**Choice experiment**	**Travel cost**	**Hedonic prices**
Potential beneficiaries	Visitors	Visitors	Visitors	Residents
Approach	Survey-based technique in which respondents answer questions regarding their willingness to pay for an ecosystem service or a change in this ecosystem service	Survey-style technique in which respondents are asked to state their choice over different hypothetical alternatives ("alternatives" consist in a combination of attributes of an ecosystem and a price associated to this combination)	Survey-based technique that uses the cost incurred by individuals taking a trip to a recreation site as a proxy for the recreational value of this site	Method that estimates the value an environmental characteristic of an ecosystem by looking at differences in property prices
Example	Assess the value of recreational swimming in a lake by asking individuals how much they are ready to contribute for it (e.g. to have clean, swimmable water)	Assess the recreational value of a lake by the choice respondents make between different options (accessibility, possibility to practice activities such as swimming or boating, water quality) associated with different prices to be paid for each combination.	Assess the value of the recreational service of a lake based on the number of visitors and the money they spend to visit the lake	Assess the value of lake amenities by comparing real-estate prices located at different distances of this lake
Procedure	1. Design the survey (survey mode, target population, services valued, development of scenarios, questions and visual support, treatment of protest answers) 2. Implement the survey (selection of the population sample, realization of the survey) 3. Compile and treat data (apply appropriate statistical technics), analyze the results	1. Design the experiment (target population, choice sets, attributes, questions and visual support) 2. Implement the experiment (selection of the population sample, realization of the experiment) 3. Compile and treat data (apply appropriate statistical technics), analyze the results	1. Design the questionnaire that will be addressed to the visitors 2. Collect information from the visitors (see the row "data requirement" below) 3. Estimate by regression the relationship between the decision to visit, the travel cost and the ecosystem services variable 4. Estimate the demand function for the ecosystem (including the socio-economic characteristics of the visitors and biophysical	1. Collect data on residential property sales in the area of the ecosystem for a given time period (price and property characteristics) 2. Estimate a function stating the relationship between the property price and its characteristics (including characteristics of the ecosystem) 3. Estimate the value of the amenities provided by the

			features of the ecosystem) 5. Estimate the ecosystem services benefits from the (consumer) surplus of the visitors	ecosystem (which is the change in real estate value resulting from a change in an attribute of the ecosystem)
Marginal change value	WTP of people to open the site one extra day / to open an extra site (e.g. a lake) to the public	WTP of people to improve the quality of water such that it can be swimmable one extra day in the year	Marginal (individual) travel expenses people are willing to spend when the water quality (e.g. of a lake) increase from a class to an upper one	WTP of a resident to live one meter closer to the ecosystem (e.g. a lake)
Data requirement	▪ Physical and ecological characteristics of the ecosystem ▪ Scenario of change of the ecosystem (e.g. change in the water quality or ecological status) ▪ (Declared) individual willingness to pay for the service ▪ Socio-economic characteristics of the respondents ▪ Socio-economic characteristic of the beneficiaries (e.g. population around the area)	▪ Physical and ecological characteristics of the ecosystem ▪ Scenario of change of the ecosystem (e.g. change in the water quality or ecological status) ▪ Choices made by the participants during the experiment ▪ Socio-economic characteristics of the respondents ▪ Socio-economic characteristic of the beneficiaries (e.g. population around the area)	▪ Visitors' travel costs (including the value of time spent travelling) ▪ Other travel expenses (e.g. accommodation) ▪ Visitors' socio-economic characteristics ▪ Distance from visitors' hometown to the ecosystem visited ▪ Other locations visited during the trip ▪ Distance of the site from substitute ecosystems ▪ Biophysical and ecological characteristics of the ecosystem	▪ Data on property sales (price, property characteristics, including location) ▪ Data on the ecosystem itself (size, quality, ecological status) ▪ Size of the beneficiary population
Benefit of the approach	▪ Allows to measure the value of non-market services ▪ Able to capture use and non-use values	▪ Allows to measure the value of non-market services ▪ Able to capture use and non-use values ▪ Allows to value separately the outcomes of one or several policy option ▪ Respondents do not directly state their WTP (values are inferred from hypothetical choices they made) which limits bias	▪ ESS value estimates are based on the actual choices of beneficiaries and not on what they declare (no strategic behaviour) ▪ Results can be easily interpreted	▪ ESS value estimates are based on the actual choices (and not on answers) of beneficiaries (no strategic behaviour possible) ▪ Allows to estimate separately the value of several non-market attributes (e.g. distance from the ecosystem, quality of the ecosystem)
Limitation of the approach	▪ Answers can be biased by	▪ Discrete choice experiment cannot be	▪ ESS value may be overestimated if the	▪ Housing prices may be explained by

	respondents (they can lie) ▪ Values of non-use services are not consistent with those estimated through other approaches (e.g. hedonic prices or travel cost method)	used with too many attributes ▪ Designing the questionnaire requires a specific expertise	visitors also travelled for other reasons (in addition to visit the ecosystem) ▪ The travel cost is only a lower-bound measure of the ESS value (value can be underestimated), e.g. for local visitors ▪ Value of some components of the travel cost are controversial (e.g. value of time)	factors subject to bias the results (e.g. taxes, interest rates) ▪ Environmental benefits should be of common knowledge to be reflected in home prices

Table 4.8 **Intellectual and aesthetic appreciation**

Potential case studies: Welsh basins, Vansjø-Hobøl and Otra catchments

Valuation method suggested	**Contingent valuation**	**Choice experiment**	**Hedonic prices**
Potential beneficiaries	Visitors	Visitors, residents	Residents
Approach	Survey-based technique in which respondents answer questions regarding their willingness to pay for an ecosystem service or a change in this ecosystem service	Survey-style technique in which respondents are asked to state their choice over different hypothetical alternatives ("alternatives" consist in a combination of attributes of an ecosystem and a price associated to this combination)	Method that estimates the value of an environmental characteristic of an ecosystem by looking at differences in property prices
Example	Assess the value of a water environment landscape by asking individuals how much they are ready to contribute for preserving it	Assess the intellectual/aesthetic value of being in a protected wetland by the choice respondents make between different options (combinations of water quality, number of species and vegetation) associated with different prices to be paid for each combination.	Assess the value of lake amenities by comparing real-estate prices located at different distances of this lake
Procedure	1. Design the survey (survey mode, target population, services valued, development of scenarios, questions and visual support, treatment of protest answers) 2. Implement the survey (selection of the population sample, realization of the survey) 3. Compile and treat data (apply appropriate statistical technics), analyze the results	1. Design the experiment (target population, choice sets, attributes, questions and visual support) 2. Implement the experiment (selection of the population sample, realization of the experiment) 3. Compile and treat data (apply appropriate statistical technics), analyze the results	1. Collect data on residential property sales in the area of the ecosystem for a given time period (price and property characteristics) 2. Estimate a function stating the relationship between the property price and its characteristics (including the distance to the ecosystem) 3. Estimate the value of the amenities provided by the ecosystem (which is the change in real estate value resulting from a change in an attribute of the ecosystem)
Marginal change value	WTP of people to open the site one extra day / to open an extra site (e.g. a lake) to the public	WTP of people to improve the quality of water such that the frequency of alga bloom is reduced by one day in the year	WTP of a resident to live one meter closer to the ecosystem (e.g. a lake)

Data requirement	▪ Physical and ecological characteristics of the ecosystem ▪ Scenario of change of the ecosystem (e.g. change in the water quality or ecological status) ▪ (Declared) individual willingness to pay for the service ▪ Socio-economic characteristics of the respondents ▪ Socio-economic characteristic of the beneficiaries (e.g. population around the area)	▪ Physical and ecological characteristics of the ecosystem ▪ Scenario of change of the ecosystem (e.g. change in the water quality or ecological status) ▪ Choices made by the participants during the experiment ▪ Socio-economic characteristics of the respondents ▪ Socio-economic characteristic of the beneficiaries (e.g. population around the area)	▪ Data on property sales (price, property characteristics, including location) ▪ Data on the ecosystem itself (size, quality, ecological status) ▪ Size of the beneficiary population
Benefit of the approach	▪ Allows to measure the value of non-market services ▪ Able to capture use and non-use values	▪ Allows to measure the value of non-market services ▪ Able to capture use and non-use values ▪ Allows to value separately the outcomes of one or several policy option ▪ Respondents do not directly state their WTP (values are inferred from hypothetical choices they made) which limits bias	▪ ESS value estimates are based on the actual choices (and not on answers) of beneficiaries (no strategic behaviour possible) ▪ Allows to estimate separately the value of several non-market attributes (e.g. distance from the ecosystem, quality of the ecosystem)
Limitation of the approach	▪ Answers can be biased (respondents can lie or may have strategic behaviours) ▪ Values of non-use services are not consistent with those estimated through other approaches (e.g. hedonic prices or travel cost method)	▪ Discrete choice experiment cannot be used with too many attribute ▪ Designing the questionnaire requires a specific expertise	▪ Housing prices may be explained by factors subject to bias the results (e.g. taxes, interest rates) ▪ Environmental benefits should be of common knowledge to be reflected in home prices

STAGE 3 – Aggregate individuals benefits at the appropriate scale

The WFD requires to conduct some economic analyses and assessments of the associated environmental and resource costs and benefits. As the population who benefits from an improvement of aquatic ecosystem services may be spread across a wide geographical area, one of the key parameters when aggregating benefits of improved water ecosystem quality is the spatial distribution of these benefits.

One of the main difficulties in environmental economic valuation is then to decide on the size of the benefiting population (beneficiaries). This issue is important since aggregate benefits depend on estimates of both individual benefits and of the number of beneficiaries. As mentioned in Hanley et al. (2003), errors made in estimating the number of users and non-users affected by an environmental change can easily swamp errors in estimates of individual benefits (obtained in STAGE 2) when aggregate values are calculated.

The general rule is that the beneficiaries should be the households/persons aggregated at the relevant geographic scale. The beneficiaries should include both users and non-users impacted by the ecosystem service considered. For services which are only of local importance, the relevant population is the population of the site (e.g. the users). For ecosystems of national or global importance with a few substitute sites (e.g. protected area for endangered species), a larger population should be used (e.g. users and non-users).

When spatially aggregating individual benefits, it is usually considered that the willingness to pay decreases with the distance from water body providing ecosystem services. A first rationale behind distance decay is that the opportunities of taking advantage of improvements in ecosystem provision are greater the closer one lives considered water body, Jørgensen et al. (2013). A second rationale is related to the existence of possible substitutes. Indeed, as the number of available substitute sites is expected to increase with increasing distance to the site of interest, it is expected that individual values decrease as the distance to the water body increases.

There are a lot of empirical evidence supporting this view. Among others, Georgiou et al. (2000) have found a negative, significant relationship between the willingness to pay to clean up the River Tame in Birmingham (UK) and the distance respondents live from the river. Based on their estimates, the implied willingness to pay to clean up the River Tame declined to zero at a distance of 16 miles (for a 'small' improvement) and 36 miles (for a 'big' improvement). Bateman and Langford (1997) have measured the willingness to pay for protecting the Norfolk Broads (UK). They report that the willingness to pay declines from a mean value of £39/household/year at a distance of 20 km, to £13.90 at a distance of 110–150 km away from the Broads area.

The usual method to take into account the fact that the willingness to pay decreases with the distance to the water body providing ecosystem services is to use a *distance decay function* in order to weight the willingness to pay according to the distance to the ecosystem, Bateman et al. (2006). This distance determines the boundaries of the geographical area, or so-called economic jurisdiction, over which the individual WTP-values can be aggregated over the population of beneficiaries to calculate the total economic value of a proposed scenario of environmental change, Schaafsma et al. (2012)

The specification of the distance decay relations has been highly debated among economists. A number of studies have examined in particular how the distance decay relation differs between users and non-users of the ecosystem service. Among others, Bateman *et al.* (2006) find that distance decay is stronger for non-users than users, and Hanley *et al.* (2003) find that while distance decay is significant for both users and non-users, users of a water body show stronger distance decay than non-users.

4.4.3 Economic assessment at the European scale

For the valuation at the European scale, we propose a methodology consisting in upscaling values of primary studies (value transfer), accounting for the biophysical and socio-economic heterogeneity in the water environments.

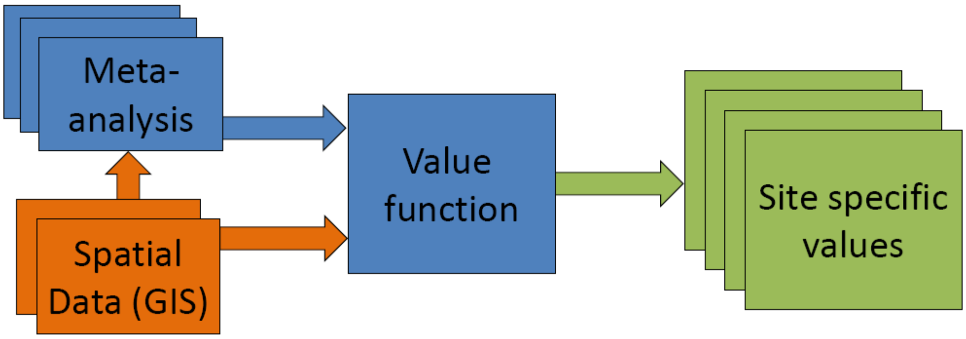


Figure 4.4 Methodology for economic assessment at the European scale

This approach first builds on a ***meta-analysis*** using the results of available past studies for various water bodies to estimate a function able to represent the relationship between the features of water ecosystems and the value of the services they provided. Ecosystem features include their geomorphological and ecological characteristics but also the characteristics of their beneficiaries such as income, distance to the ecosystem or to substitute ecosystems. From a methodological point of view, the meta-analysis is view as a mean to estimate benefit functions that synthesize information from multiple primary studies having valuated aquatic ecosystem. The interested reader may refer to Brander, Florax and Vermaat (2006) or to Brander, Beukering and Cesar (2007) for some examples of meta-analysis in the context of valuation of ecosystem services.

The second stage consists in ***upscaling*** the results of the meta-analysis. The economic values that have been estimated in the regression analysis must then be transferred and aggregated at larger geographic areas through a scaling-up procedure. This procedure allows to value multiples ecosystem sites at the continental scale, accounting for the change in the global stock of the resource. Recent examples of upscaling values of ecosystem services include Ghermandi *et al.* (2010) and Ghermandi and Nunes (2013).

STAGE 2 – Identify relevant primary studies and build of the meta-database

<u>*STAGE 2a – Identifying primary studies*</u>

This step consists in ***searching and selecting studies*** (most often in online databases) valuing services provided by ecosystems similar to those of the policy site[7] (this methodology will be applied in MARS at the European scale for valuing European lakes). The scientific references must be selected through systematic searches on various search engines and on the web sites of major publishers of academic journals. The grey literature must also be included, in particular to reduce the influence of a potential publication bias in the meta-regression analysis.

Validity tests have shown that studies closer spatially and in time tend to have lower transfer errors. However, relevant primary studies (in terms of ecosystem or ecosystem services) may not be available for the same area or countries as the policy site and gathering a sufficient amount of studies may require expanding the bibliography at a larger scale (worldwide).

<u>*STAGE 2b – Collect relevant information from primary sources in a meta-database*</u>

In stage 2b, all relevant information from primary sources must be ***collected into in a meta-database***. This stage consists in including in the database information on methods applied in the primary study, ecosystem services valued, biophysical characteristics of the ecosystem (water quantity, water quality, ecological status), and the characteristics of the beneficiaries (income, age, education level). All this information will serve as controls in the meta-regression.

<u>*STAGE 2c- Standardize primary values*</u>

Economic values have been reported in the literature in many different metrics (i.e. willingness to pay per unit of area or volume, marginal values, capitalized value), using different currencies and for different period of time. In order to enable a comparison across studies all these values must be standardized. As explained by Ghermandi et al. (2010), the standardization of different and heterogeneous metrics used to value ecosystem services is a difficult and controversial task.

Accounting for heterogeneity in space and in time. The observed economic values have been obtained for different countries and for different period of time. This requires some normalization procedures. First, to account for differences in purchasing power among countries, a purchasing power parity indexes has to be applied to the original values. Second, the problem of having different years of observation is usually solved by using appropriate price deflators, see Ghermandi and Nunes (2013) for a recent example.

Normalizing values for valuation studies. Economic values produced by various methods may be expressed in different metrics (currency, year, value, price) and cannot be directly compared. For example, some methods produce estimates of willingness to pay (e.g. contingent valuation) whereas others produce estimates of capitalized value (e.g. hedonic prices). In order to make adjustments for a comparison across studies (common metric, currency and time period), a specific standardization

[7] *Policy site* is the site where the benefit transfer is applied based on the primary information from the *study sites*.

procedure must be used. Two approaches may be followed. First, some previous studies have used a normalized value expressed in monetary units per unit of area per unit of time Ghermandi et al. (2010), Brander et al. (2012), Ghermandi and Nunes (2013). The second normalization procedure consists in expressing ecosystem service values in monetary units per visit per unit of time (Brander, Beukering and Cesar, 2007) or in monetary units per household/respondent per unit of time Brouwer et al. (1999), Johnston et al. (2005).

STAGE 2d - Augment the amount of information from secondary sources

This stage consists in including additional data for each primary study site from secondary sources (e.g. database or GIS files) with relevant information on population density around the ecosystem, income of the population or presence of substitute ecosystems (e.g. density of lakes).

STAGE 3 – Estimate a meta-values transfer function

Ecosystems features include their geomorphological and ecological characteristics but also the characteristics of their beneficiaries such as the income, the distance to the ecosystem or to substitute ecosystems. The data analysis of the meta-database does not allow for interactions between the various potential explanatory variables. Indeed, ***a meta-regression analysis*** allows to control for the variation in the characteristics of an ecosystem (e.g. biophysical surrounding, income, population density or availability of a substitute ecosystem) when conducting the value transfer. In order to attain marginal effect, we use a meta-regression analysis to assess the relative importance of all potentially relevant factors simultaneously. The regression technique allows accounting for the biophysical or socio-economical differences between the study sites and our case study (Europe).

This approach consists in using the results of available past studies for various water bodies to estimate a function able to represent the relationship between the features of water ecosystems and the value of the services they provided. The dependent variable in our meta-regression equation is the economic value of the ecosystem service considered. The explanatory variables are grouped in different matrices that include the ecosystem services provided (with potential interactions across ecosystem services), the water body characteristics (i.e., type of water body, size of water body, etc.), the study characteristics (i.e., survey method, payment vehicle, elicitation format, etc.) and context-specific explanatory variables.

There are two popular panel-data models which can be used for estimating the meta-regression model, e.g. the fixed-effect model and the random-effect model. The crucial difference between these two models lies on the assumptions used to define the error variance. In the fixed-effect model it is assumed that all studies included in the meta-analysis share a common true effect size, differences in observed effects arise only due to sampling error. However because studies commonly differ in implementation and underlying population, among others, the assumption of the fixed-effect model is often implausible. The random-effects model allows the true effect size to differ from study to study and this is the approach usually recommended.

STAGE 4 – Upscale spatially the meta-values

The values that have been estimated for localized changes by the regression analysis should then be transferred and aggregated at larger geographic areas through a scaling-up procedure. Scaling-up is value transfer across a larger geographic scale. This procedure allows to value multiples ecosystem sites at the continental scale, accounting for the change in the global stock of the resource (while the valuation of a specific water body is isolated from the rest of this stock).

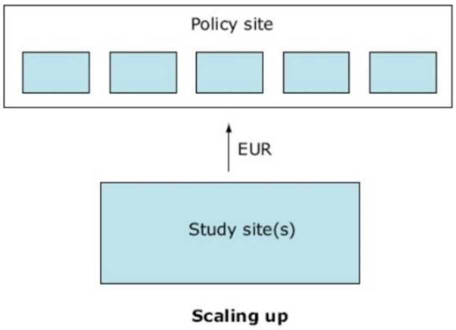


Figure 4.5 Schematic representation of the scaling up procedure (EEA, 2010)

The meta-database gathers studies at small scales (mainly water body scales). The information on value of services provided by these small ecosystems is synthetized by a meta-regression. The estimated meta-value function may then be used to scale-up the information at the European level, allowing to transfer and aggregate values of individual water bodies to the multiple-ecosystems European case study. However, the valuation of the flow of services provided by each ecosystem is not isolated from the other water ecosystem of the case study. The scaling-up procedure accounts for the abundance of ecosystem through the impact of the substitution effect on the individual value of the services they provide individually.

Following Germandhi and Nunes (2013), we propose the following steps. First, the most appropriate transfer function among the different meta-regression specifications must be selected. This choice may be based on explanatory power of the model, sign and significance of the coefficients estimated. Second, one must define the appropriate geographic scale for transferring values. Third, an ecosystem service grid must be built, each cell of the raster map being treated as a policy site, to which values are transferred by estimating the local value of the transfer function by means of map algebra. This requires an extensive use of GIS.

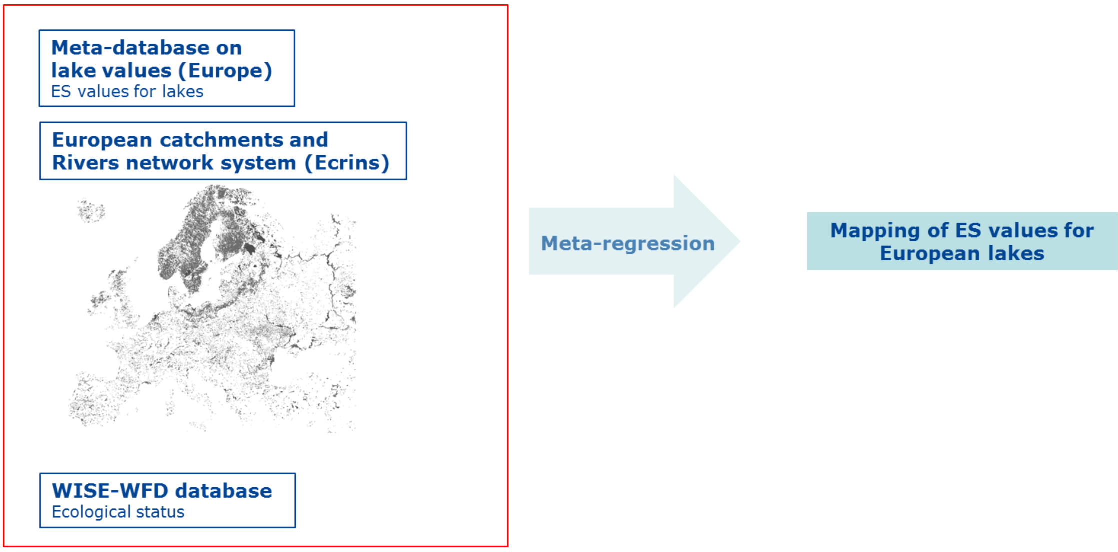


Figure 4.6 Example of scaling up procedure (upscaling of lake values at the European scale, on-going work at the JRC).

As discussed by Germandhi and Nunes (2013), when analyzing the results of the study, it is important to evaluate the accuracy of the value transfer model and to take into consideration the multiple sources of errors and uncertainties involved (uncertainty in the primary valuation data, uncertainty is involved in the estimation of the meta-analytic value transfer function, representativeness of the study sites).

4.5 Example of integration of biophysical and economic analyses

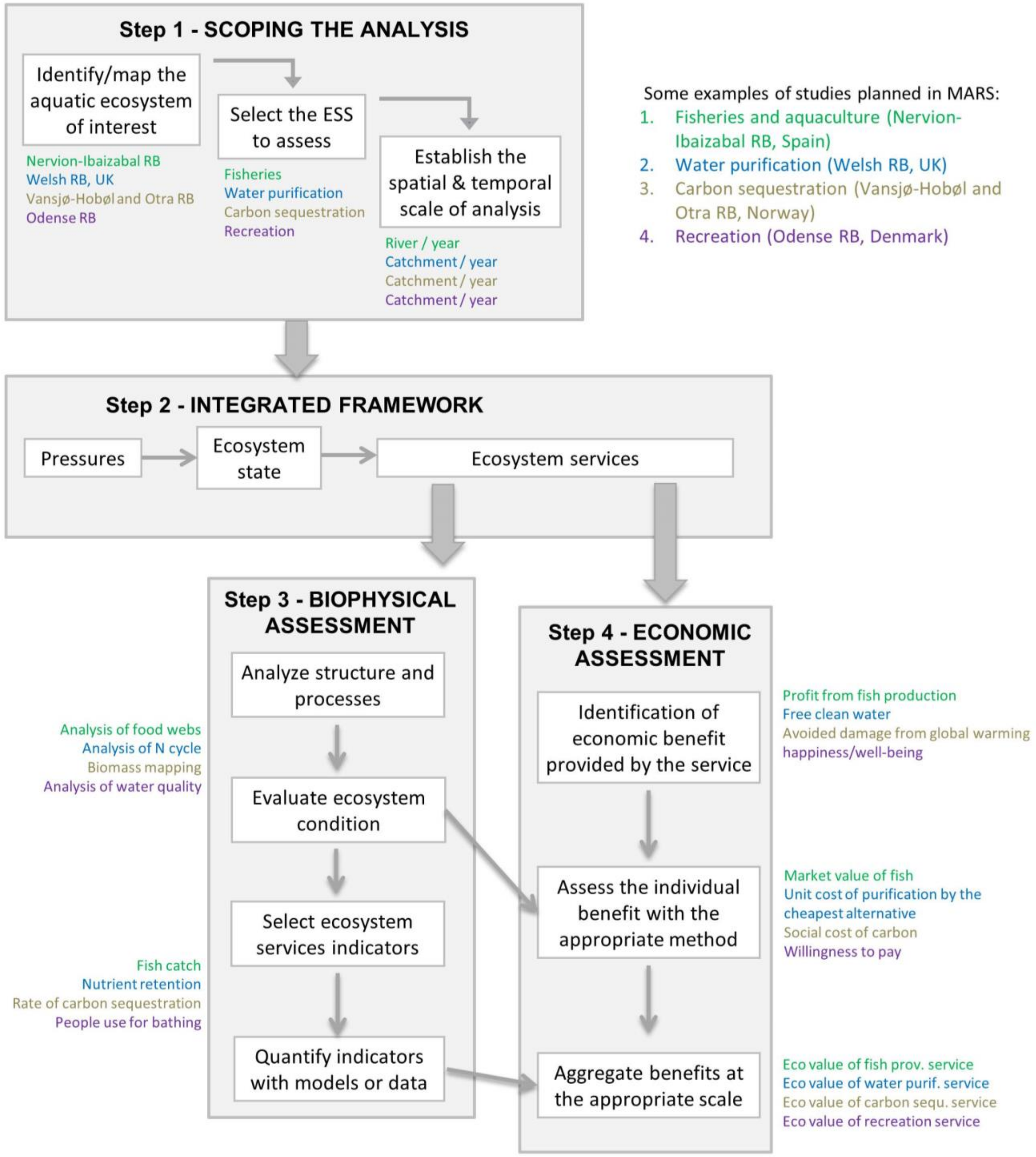


Figure 4.7 Scheme of integration of biophysical and economic analyses.

5. Discussion

In this report we have presented a pragmatic approach for assessing and valuing ecosystem services that builds on the expertise of the MARS partners, making use of the relevant knowledge on hydrological modelling, data analysis, monitoring and indicators, available in the MARS consortium (and in general in European research institutes). The methodology proposed fulfils the MARS main objective of analysing how multiple stressors may affect the delivery of ecosystem services. It is flexible and can be applied at different scales (experiments/catchments/continents) and in different locations in Europe, as required by the MARS project. It covers both the biophysical quantification and the economic valuation of water ecosystem services.

The methodology has been designed to be easy to follow. It presents the basic concepts and assumptions to be established before the analysis, and provides a “shopping bag” to select the appropriate tools to assess and value ecosystem services.

For the development and targeting of the methodology, a consultation of the project partners was carried out by a web-questionnaire in May 2014. The questionnaire was an opportunity for learning the main research issues of each case study, collecting knowledge and needs of partners, testing the ecosystem service list and having a preliminary discussion on indicators. Similarly, for partners the questionnaire requested reflecting on the definition and classification of ecosystem services (especially for those new to the topic) and writing a preliminary research plan. Touching upon ecology and economics, the questionnaire aimed to an interdisciplinary discussion in the research teams, which is necessary when working on ecosystem services.

The link between biophysical and economic assessments, which is an objective of the methodology, was challenging not only for the questionnaire but for the whole development of the methodology. The competence and knowledge needed to apply biophysical and economic methods are often in the hands of different experts. Similarly the valuation process, especially integrated valuation, which integrates ecological, social and economic values, is complex and requires an interdisciplinary team.

Therefore we recognise that the task of MARS is ambitious and the methodology proposed in this work has also some limitations. It simplifies and standardizes the objectives and tools to be used by the MARS partners. Still, a lot of research effort is needed to apply them, in particular to quantify the biophysical indicators and the economic values. For these reasons, most of the partners may select indicators and values easily calculated by their existing capabilities, without exploring the more complex or innovative ones.

The final aim of MARS is getting a holistic view of the aquatic environment in Europe. But in order to get a correct overview, this methodology requires compartmentalizing each natural or socio-economic factor at stake. The users of this methodology should be very clear about (1) what natural process or function they measure, (2) what are the feedbacks (pressure-state-service), and (3) what kind of ecosystem service assessment they accomplish (capacity-flow-benefit).

We have also to acknowledge that we (MARS consortium) are in the process of applying the methodology, but we had to develop the cook-book before completing testing the methodology, while it would have been better to adjust the methodology based on the implementation experience. This is what we expect happening in the course of the next years in the project MARS.

The scale of the analysis in the project involves several opportunities. The field scale studies will consider the effect of multiple stressors on the biophysical and the ecological processes underpinning the ecosystem services, the catchment scale will consider the ecosystem services integration and trade-offs, including management consideration. The European scale will address trends in regional changes and effects of EU policies. The barriers could be that when looking at the hydrological and ecological processes the relevant spatial scale are the catchment and the landscape, while data and statistics regarding the socio-economic development, needed for the studying the demand side of ecosystem services, are mainly available at the national and regional administrative scale.

Another risk that we can anticipate is the conceptual misunderstanding of the relationship between ecosystem services and anthropogenic pressures. High exploitation of the ecosystem can turn an ecosystem service into a pressure (ex. recreation, water use), this creates difficulties in identifying ecosystem services only as benefits. Confusion in the understanding and definition of ecosystem services could lead to a misuse of the concepts and be used against the objectives of protecting and enhancing the water ecosystem services.

We think that MARS and this work can contribute to the reflection on the use of ecosystem services in the water resource management. The application of ecosystem service concepts in RBMP is appealing and could reveal very powerful for the development of the green economy. A society that recognises the contribution of nature and the interest of protecting and restoring the environment is spending better and investing in green economy. The challenge is to integrate social equity and environmental elements in the management of the resources and the environment (Cook & Spray 2012).

Differently from ecosystem status, the concept of ecosystem service involves an anthropocentric perspective on nature and its resources, but at the same time recognises the fundamental interdependence between humans and nature (called the human-ecological system). Ecosystem services assessments look at the human benefits from nature. This approach could however be adopted with contrasting underpinning intentions. On the one hand to protect nature highlighting how precious and convenient are the services provided by nature; on the other hand to exploit nature, reducing nature to market goods. We adopt the first approach. Our working hypothesis is that ecosystem services do not substitute the information (indicators) of status of an ecosystem, but highlight the specific benefits that humans receive from it, with the intent of protect and enhance the ecosystem to continue assuring these natural benefits. Thus we consider status and services are complementary information for basin management.

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Annexes

Annex 1 – Scope of ecosystem service assessment in MARS case studies

Table A1.1 - Assessment at the water body scale

Experiments at the water body scale in the project MARS (WP3). *Indicates the research plan as reported in the partners' consultation in May 2014; - no answer to the questionnaire.

WP3 Task	Case study	Leading Institute	Brief description (based on the DOW text)	Ecosystem services*	Economic valuation*
3.1 Lake experiments	3.1.1 Extreme rainfall	NERC	(location UK) Study of the effects of extreme rainfall (32 mesocosms); mimic enhanced runoff into lakes. Ecosystem metabolism and biodiversity will be monitored. Biological and chemical analysis (bacteria by molecular methods, phytoplankton as clorophyll a, zooplankton, macroinvertebrates, macrophytes and fish)	No	No
3.1 Lake experiments	3.1.2 Extreme heatwaves	AU	(location DK) Study of the effect of extreme heatwaves (mesocosm). Biological and chemical analysis (bacteria, phytoplankton as clorophyll a, zooplankton, macroinvertebrates, macrophytes and fish)	-	-
3.1 Lake experiments	3.1.3 Extreme mixing and DOM loading	FVG-IGB	(location DE) Study of the effect of extreme mixing and DOM loading (24 mesocosms). Phytoplankton will be used as indicator of lake ecological status, in addition to physico-chemical indicators, including cyanobacterial toxins, Secchi depth, nutrients, and DOC. Variables capturing trophic and competitive relationships will serve to explain variation in phytoplankton and harmful algae.	-	-
3.2 River experiments	3.2.1 Extreme flow in Nordic rivers	NIVA	(location NO) Study of the effect of extreme flow (4 stream side flumes); effects on primary production and periphyton consumption in relation to trait composition of primary producers and consumers; combined effects of hydrology and nutrient loading; relative importance of primary production and allochthonous inputs for secondary production. Additional functional indicators include leaf breakdown rate and stable isotope signatures.	No	No

3.2 River experiments	3.2.2 Peak flow in Alpine rivers	BOKU	(location AU) Study of the effect of peak flow (HyTEC 2 large channels). Responses to hydraulic and other stressors will be habitat and behavioural shifts of larval and juvenile fish; drift of fish, macroinvertebrates and algae; water chemistry	Water purification, maintaining populations and habitats, abiotic energy sources	No
3.2 River experiments	3.2.3 Water scarcity in Mediterranean rivers	UTL	(location PT) Study of the effect of low flow in Mediterranean rivers (indoor flume). Responses addressed include hydraulic conditions, physico-chemical water quality, substrate composition, fish movement and behaviour, and invertebrate persistence, density and position in the substrate.	Maintaining populations and habitats	No
3.2 River experiments	3.2.4 Low flows in Nordic rivers	AU	(location DK) Study of the effect of low flow in Nordic rivers (12 outdoor flumes). Community composition of all biological elements, ecosystem functioning and food web structure will be determined.	Water for non-drinking purposes, water purification, maintaining populations and habitats	No
3.3 Analysis of time series	3.3.1 Lakes	EMU	Analyse existing time series from lakes in terms of multi-stressor effects on physico-chemical water quality parameters, biological quality elements, and measures of ecosystem functioning and services	Fisheries and aquaculture, water for drinking, recreation	No
3.3 Analysis of time series	3.3.2 Rivers	CU	Analyse existing time series from streams in terms of multi-stressor effects on physico-chemical water quality parameters, biological quality elements, and measures of ecosystem functioning and services	Fisheries and aquaculture, water for drinking, water for non-drinking purposes, water purification, erosion prevention, maintaining populations and habitats, pest and disease control, local climate regulation, intellectual and aesthetic appreciation	No

Table A1.2 - Assessment at the catchment scale

Figure A1.1 Location of the 16 catchments under study in the project MARS (WP4).

Table A1.2 - Case studies at the catchment scale in the project MARS (WP4). * Indicates the research plan as reported in the partners' consultation in May 2014.

WP4 Task	Case study	Leading Institute	Main pressures (from DOW)	Brief description (based on the DOW text)	Ecosystem services*	Economic valuation*
4.2 Southern river basins	Sorraia (7,611 km^2, PT)	UTL	Widespread transfers, regulation and abstraction of surface and groundwaters climate change	Models of fluxes of water, nutrients, sediments and organic pollutants will be used to assess the impact of these multiple stressors on water resources and quality and focus on identifying optimal management solutions to water conflicts, restoration, and the effects of climate warning	Water for drinking; Water for non-drinking purposes; Raw materials for energy; Water purification; Flood protection; Maintaining populations and habitats; Carbon sequestration; Recreation	No
4.2 Southern river basins	Nervion-Ibaizabal (1,755 km^2, ES)	AZTI	Water quality, morphological changes	Investigate how various discharge and morphological change scenarios may affect ecological quality, recreation (bathing) and estuarine biodiversity and what are the preferred management strategies to improve water resource and ecological status	Fisheries and aquaculture; Recreation	Yes. Ecosystem services that will be valued : Fisheries and aquaculture, Recreation Methods they want to apply: damage cost avoided, replacement cost.
4.2 Southern river basins	Pinios (9,500 km^2, GR)	NTUA	Desertification agriculture	A hydrological model will link multiple water quality stressors to benthic macroinvertebrate data, and the consequences for management options related to the improvement of natural hydrological cycles, water supply and water purification will be appraised	Water for drinking; Water for non-drinking purposes; Erosion prevention; Flood protection; Carbon sequestration	No
4.2 Southern river basins	Beysehir (4,080 km^2, TR)	METU	Abstraction for irrigation Climate changes eutrophication	Examine the conflicting demands of water use for crops, people and ecosystems in this setting, and investigate how these multiple stressors can be effectively reconciled with good water resource and ecological status outcomes. Particular attention will be given to surface water-groundwater interaction and the optimal use of all water resources within the catchment	Water for non-drinking purposes; Local climate regulation; Recreation	No

4.2 Southern river basins	Lower Danube (RO)	DDNI	Flood risk and water quality are already major problems, exacerbated by increasing urban land use, floodplain development, reduced river-bed capacity and deforestation. Hydro-morphological pressures include 255 reservoirs, 80% embankment on the lower reaches, regulation (6,600 km) and abstraction (138 significant abstractions).	Flow and quality alterations will be modelled, and land use change scenarios tested on order to evaluate the implications for ecosystem services within the Basin	Fisheries and aquaculture; Flood protection	No
4.3 Central river basins	Thames (9,948 km^2, UK)	NERC	Stressors include agricultural nutrients, organic pollutants, endocrine disrupting compounds, nanoparticles and metals, invasive species and pathogens, extensive regulation, high and growing water demand and regular droughts.	Linked abiotic and biotic models will be used to quantify response to multiple drivers using mechanistic and Bayesian approaches and so to characterise i.) the effects of climate change, land use changes and population growth on response surfaces describing nutrients stress, toxic compounds, temperature and pathogens, and ii.) the impact of a range of management scenarios on environmental services and outcomes under various multistressor conditions	Water for drinking; Water purification; Flood protection; Maintaining populations and habitats	No
4.3 Central river basins	Regge and Dinkel (1,350 km^2, NL)	DELTARES	Agriculture has caused large hydromorphological alterations, base flow reductions and water quality deterioration. Droughts and groundwater abstraction lead to water scarcity affecting biological quality	Work will focus on surface-groundwater interactions, ecological flows, drainage and irrigation strategies, Natural Water Retention Measures and HABITAT GIS assessment for selected BQEs	Water for drinking; Water for non-drinking purposes; Water purification; Maintaining populations and habitats	No
4.3 Central river basins	Odense (1,100 km^2, DK)	AU	Agriculture has caused large hydromorphological alterations, base flow reductions and water quality deterioration. Droughts and groundwater abstraction lead to water scarcity affecting biological quality.	Mechanistic models will examine abiotic effects on phytoplankton, zooplankton, submerged vegetation and fish to understand consequences for key ecosystem services (water supply, nutrient retention, recreation and angling). Climate change and land use scenarios will be applied, and nutrient and sediment retention using new ten metre riparian buffers will be investigated as these will become mandatory from 2012 onwards	Fisheries and aquaculture; Water purification; Recreation	Yes Ecosystem service that will be valued: recreation Method used: Damage cost avoided, Contingent valuation

4.3 Central river basins	Elbe, Havel and Saale (DE)	FVB-IGB	Major stressors include eutrophication, hydromorphological alterations by damming, land use regulation structures, loss of bank vegetation and intensive shipping	Model applications will focus on services for flood risk reduction, fisheries, recreation and water purification (N and P-retention)	Water purification; Local climate reguation	No
4.3 Central river basins	Ruhr (DE)	UDE	Agriculture urbanisation	Models for nutrients and discharge will address ecosystem services including self-purification and biodiversity protection using empirical dose-response relationships to examine future scenarios of land use and restoration	Water purification; Erosion prevention; Maintaining populations and habitats; Carbon sequestration	No
4.3 Central river basins	Drava (2,600 km^2, AT)	BOKU	hydropower and associated morphological alteration are key stressors affecting fisheries and recreation	Empirical models will link hydromorphology to fish, invertebrates and phytobenthos. Faced with new hydropower plants, scenarios will address the conflicting ecosystem service effects on fisheries, recreation and hydropower	Water purification; Maintaining populations and habitats; Abiotic energy sources (e.g. hydropower generation)	No
4.4 Northern river basins	Welsh basins (4,000 km^2, UK)	CU	Stressors combinations	Scenarios and modelling will explicitly address links between land-use, climate and ecosystem service resilience (fish production, water quality regulation, decomposition and cultural values)	Fisheries and aquaculture; Water for drinking; Water for non-drinking purposes; Water purification; Erosion prevention; Maintaining populations and habitats; Pest and disease control; Local climate regulation; Intellectual and aesthetic appreciation	Yes Ecosystem services that will be valued: Fisheries and aquaculture, Water purification, Maintaining populations and habitats, Pest and disease control, Recreation, Intellectual and aesthetic appreciation Methods they will use: Contingent valuation, Choice experiment

4.4 Northern river basins	Vansio-Hobol (690 km^2, NO)	NIVA	Diffuse agricultural pollution Flow regulation	Empirical studies will link macrophytes, macroinvertebrates and fish to nutrients and temperature, while lake process models will address consequences for chlorophyll a.	Fisheries and aquaculture; Water for drinking; Water for non-drinking purposes; Erosion prevention; Flood protection; Maintaining populations and habitats; Carbon sequestration; Recreation; Intellectual and aesthetic appreciation; Abiotic energy sources (e.g. hydropower generation)	Yes. For the Vansio Hobol and Otra catchments. <u>Ecosystems services that will be valued</u>: Fisheries and aquaculture, Water for non-drinking purposes, Carbon sequestration, Recreation, Intellectual and aesthetic appreciation. <u>Methods applied:</u> Damage cost avoided, Choice experiment, Unit value transfer, Adjusted unit value tranfer
4.4 Northern river basins	Otra (3,740 km^2, NO)	NIVA	hydropower, acidification, metals, invasive species and nuisance macrophytes	(Provides hydroelectric power, salmon habitat, recreation, and protected habitat for important biota). Long-term data on hydrology, hydrochemistry and biology allow empirical and mechanistic relationships between stressors and status of fish and benthic invertebrates.		
4.4 Northern river basins	Kokemaenjoki (27,040 km^2, FI)	SYKE	stressors combine eutrophication and pathogens from agriculture, hydromorphological change from hydropower and flood defence, climate change and brownification	Dynamic and hybrid modelling will assess stressor effects from forestry and agriculture on macrophytes, phytoplankton, concentrating particularly on 'brownification'.	Erosion prevention	No
4.4 Northern river basins	Vortsjarv (3,104 km^2, EE)	EMU	level fluctuations affecting ecosystem structure and CO2 emissions, while catchment agriculture results in eutrophication. Climate change is further affecting hydrology, water level, temperature, ice regime brownification and carbon balance. Large commercial fisheries are both ecosystem service and important pressures.	Modelling within MARS will focus on climate change effects on water temperature and ice regime, brownification and carbon balance alterations.	Fisheries and aquaculture; Water purification; Carbon sequestration; Recreation; Intellectual and aesthetic appreciation; Abiotic energy sources (e.g. hydropower generation)	No

Table A1.3 - Assessment at the European scale

Assessment at the European scale in the project MARS (WP5). * Indicates the research plan as reported in the partners' consultation in May 2014.

WP5 Task	Case study	Leading Institute	Brief description (based on the DOW text)	Ecosystem services assessment*	Economic valuation*
5.1 European matrix of stress and impact	5.1.4 Spatial assessment of services delivered by European aquatic ecosystems	JRC	We will assess the spatial distribution of both the biophysical and economic values of the services delivered by aquatic ecosystems (i.e. food provision, water regulation, water purification, recreation) and their changes under multi-stressor scenarios. Models will be applied to analyse scenarios on future land use, climate and mitigation / restoration. Models will be applied to analyse scenarios on future land use, climate and mitigation / restoration.	Fisheries and aquaculture, water for drinking, water for non-drinking purposes, water purification, air quality regulation, erosion prevention, flood protection, maintaining populations and habitats, carbon sequestration, local climate regulation, recreation, abiotic energy sources	Recreation
Task 5.2 Multiple stressors in large rivers		BOKU	This task will focus on the effects of multiple stressors on phytoplankton, macrophytes, macroinvertebrates and fish, and on ecosystem services. Though parts of the task will use data from a wide range of European rivers, a focus will be on the Danube, the largest river in Central Europe. We will survey the main historical waves of alterations related to overfishing, pollution, channelization, dam construction, navigation, invasive species and climate change, and we will relate the stressors to documented changes in the aquatic communities and ecosystem services.	-	-
5.3 Multiple stressors in lakes		NIVA	We will analyse the impacts of multiple stressors on lake ecosystems over large spatial scales. We will examine ecological responses of primary producers in large populations of lakes, assess the impacts of future multiple stressor scenarios. The biological responses examined (phytoplankton indices, macrophyte indices) will be selected as indicators of the quality of ecosystem services such as drinking water quality, bathing water quality and recreation.	-	-
5.4 Multiple stress effects on European fish assemblages		IRSTEA	We will comparatively analyse the effects of multiple stress on fish in rivers, lakes and transitional waters using statistical and modelling approaches and recent Europe-wide databases. The information can be used to identify the most threatened ecosystems across Europe with respect to services derived from fish (angling and fisheries), biodiversity (risk of local extinction due to increase of niche overlap), and ecosystem functioning (loss of function supported by endangered species). We will study the effects of multiple stressors on the establishment of exotic species and subsequent effects on native fish assemblages and services (e.g. recreational activities/angling and food resources, and management of fish communities dominated by exotic species)	-	-

Annex 2 - Ecosystem services classification

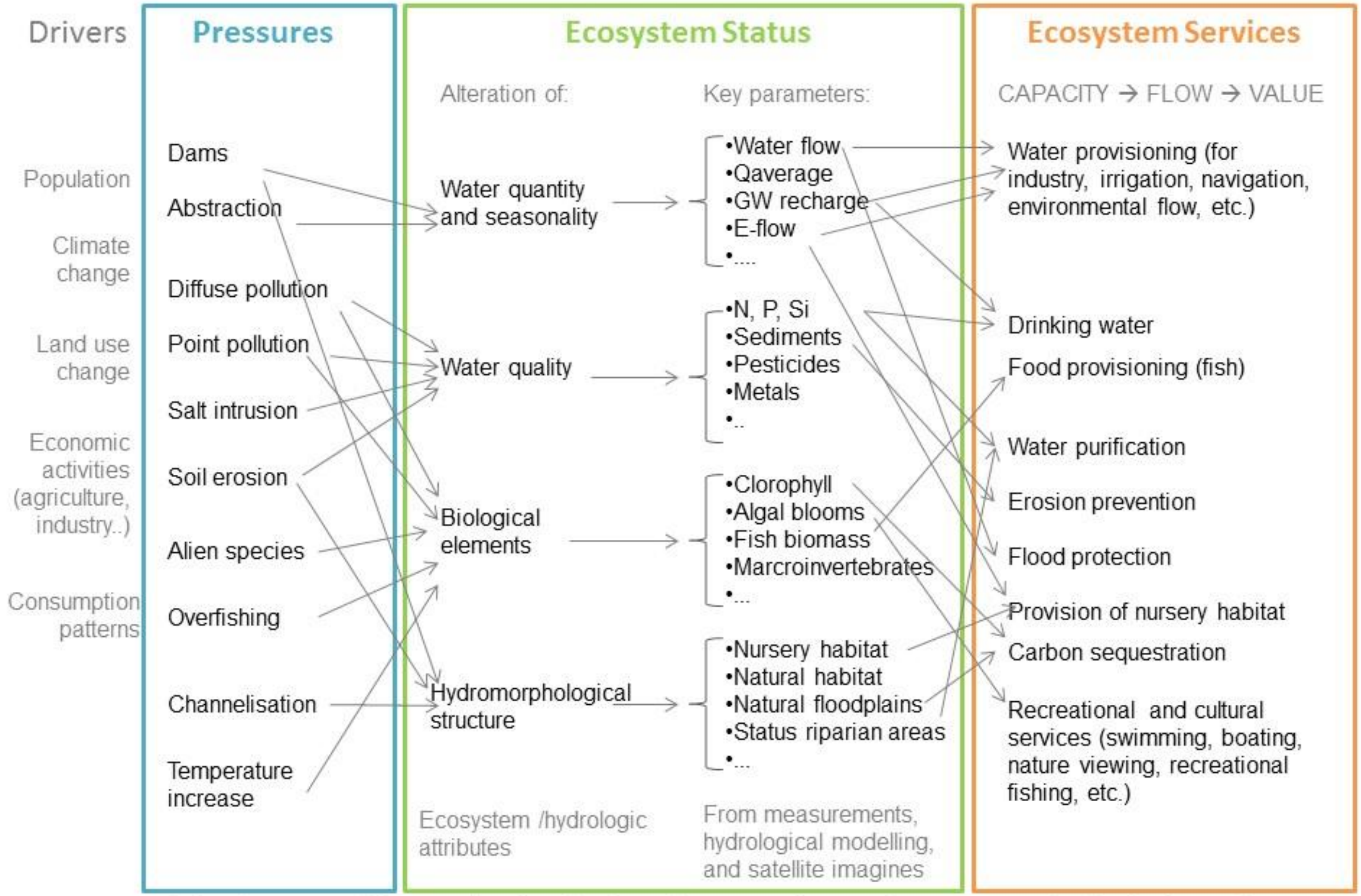
Table A2.1 – List of ecosystem services relevant for water systems

	Ecosystem services terminology proposed in MARS	Examples	Ecosystem services from CICES	Ecosystem services from TEEB
Provisioning	Fisheries and aquaculture	e.g. fish catch	Food - Biomass	Food
	Water for drinking	e.g. provision of water for domestic uses	Drinking water	Fresh water
	Raw (biotic) materials	e.g. algae as fertilisers, vegetal compounds for cosmetics	Materials - Biomass	Raw materials, Medicinal resources
	Water for non-drinking purposes	e.g. provision of water for industrial or agricultural uses	Non-drinking water	Fresh water
	Raw materials for energy	e.g. wood from riparian zones	Energy - Biomass	Raw materials
Regulation & Maintenance	Water purification	e.g. excess nitrogen removal by microorganisms	Mediation of pollution in water	Waste-water treatment
	Air quality regulation	e.g. deposition of oxides of nitrogen on vegetal leaves	Mediation of pollution in air	Local climate and air quality
	Erosion prevention	e.g. vegetation controlling soil erosion on river banks	Mediation of mass flows and erosion	Erosion prevention and maintenance of soil fertility, Moderation of extreme events
	Flood protection	e.g. vegetation or floodplains trapping and slowing down the water flow, coastal habitats protecting from inundation	Flood protection	Moderation of extreme events
	Maintaining populations and habitats	e.g. key habitats use as reproductive grounds, nursery, shelter… for a variety of species	Maintaining populations and habitats	Habitats for species, Maintenance of genetic diversity
	Pest and disease control	e.g. diseases and parasites are better controlled in the wild (by natural predation on weakened individuals)	Pest and disease control	Biological control
	Soil formation and composition	e.g. rich soil formation in floodplains or in wetlands borders	Soil formation and composition	Erosion prevention and maintenance of soil fertility
	Carbon sequestration	e.g. carbon accumulation in vegetation or sediments	Global climate regulation	Carbon sequestration and storage
	Local climate regulation	e.g. maintenance of humidity and precipitation patterns by wetlands or lakes, shading effect	Micro and regional climate regulation	Local climate and air quality
Cultural	Recreation	e.g. swimming, recreational fishing, sightseeing, boating	Experiential interactions with nature	Recreation and mental and physical health, Tourism
	Intellectual and aesthetic appreciation	e.g. subject matter for research, artistic representations of nature	Intellectual and aesthetic interactions with nature	Aesthetic appreciation and inspiration for culture, art and design
	Spiritual and symbolic appreciation	e.g. existence of emblematic species like *Lutra lutra* or sacred places	Spiritual and symbolic interactions with nature	Spiritual experience and sense of place

*Extra abiotic environmental services**	*Raw abiotic materials*	*e.g. extraction of sand & gravel from river bed or river banks*	*Abiotic materials*	
	Abiotic energy sources	*e.g. hydropower generation*	*Renewable abiotic energy sources*	

*See discussion in Section 4.1

Annex 3 – Integrated framework for water ecosystem services assessment



The list of pressures and the arrows describing the relationships are not exhaustive, the users are invited to develop the specific relationships at stake in their case study

Annex 4 – Biophysical assessment of ecosystem services: list of indicators

Table A4.1 - Biophysical indicators based on literature review

Potential proxies/indicators for water ecosystem services based on literature review (sources are listed below) and organised in three categories: natural capacity, service flow and social benefit, according to the type of information they provide. The proxies/indicators refer mainly to the ecosystem services delivered by lakes, rivers, groundwater, riparian areas, floodplains, wetlands, transitional and coastal waters.

Sources

[1] Maes et al. 2014 (Table 11)
[2] Egoh et al. 2012 (Appendix 1)
[3] Layke et al. 2012 (World Resources Institute database www.esindicators.org)
[4] Russi et al. 2013 (Table 3.1 and Box 3.1)
[5] Liquete et al. 2013 (Table S3)

Legend

- **in bold** = ecosystem services that will be assessed by the MARS partners according to the questionnaire of May 2014
- highlighted = indicators considered relevant by more than 6 respondents to the questionnaire of May 2014
- in red = this indicator is more appropriate for ecosystem condition or integrity than for the delivery of a particular service

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Ecosystem services	Natural capacity	Service flow	Social benefit
Fisheries and aquaculture	Status of fish population (species composition, age structure, biomass) [1,5] Abundance of fish [2,5] Relative fish abundance based on catch per unit effort (CPUE) [5] Condition of fish stocks [3] Food web structure and robustness [5] Number of wild species used for human food [3]	Fish catch [1,2,5] Aquaculture production [1,3] Sea food productivity [5] Wild vegetation used in gastronomy [1] Fish production from sustainable sources (e.g. proportion of fish stocks caught within safe biological limits, certified/viable fisheries…) [4,5]	Number of fishermen [1] Employment in fishing, mariculture and related sectors [3,5] Fish products as a percent of total animal protein in people's diet [3] Value of fish and sea food landings, or value of aquaculture sales [3,5] Marginal value of a change in fisheries management [5]
Water for drinking	Surface water availability [1,2] Total freshwater resources [1,4] Nitrate-vulnerable zones [1] River salinity [2] Renewable water supply accessible to humans [3] Water storage capacity [3]	Water consumption for drinking [1] Water abstracted [1] Water exploitation index [1] Consumptive water use by end user [3]	Proportion of population using an improved drinking water source [4] Proportion of cities obtaining water supplies from protected areas [4] Water-stressed population [3] Total water requirements [3]
Raw (biotic) materials	Land cover [2] (Wood) biomass production over stem diameter classes [5]	Wild vegetation used in cosmetic or pharmaceutical uses [1,5] Surface of exploited wet forests (e.g. poplars), coastal forests (e.g. mangroves) and reeds cutting [1,2,5] Timber produced by riparian forest [1] Timber from sustainable managed forests [4] Organisms from which drugs have been derived [3] Number of species that have been the subject of major investment or have become a commercial product [3]	Value of pharmaceutical products developed in natural systems or from marine organisms [3,5] Investment into natural products prospecting [3] Value of (wet or coastal) timber forest products [3,5] Net value added of raw materials: seaweed, fishmeal, fish oil, ornamental [5]
Water for non-drinking purposes	Surface water availability [1,2] Ground water availability [1,2] Total freshwater resources [1,4] Salinity levels [2,3] Renewable water supply accessible to humans [3] Water storage capacity [3]	Water use per sector [1,4] Water abstracted [1] Water exploitation index [1] Area water-logged by irrigation [4] Volume of water desalinated [3]	Cost of water and water delivery [3] Total water requirements [3] Net value added: desalinated water supply [5]
Raw materials for energy	(Wood) biomass production over stem diameter classes [5]	Production of peat [1] Surface of exploited wetlands for peat and biofuels [1] Firewood produced by riparian or coastal forests [1,5]	Net present value of clearance logging and of fuelwood under different management scenarios [5]

Ecosystem services	Natural capacity	Service flow	Social benefit
Water purification	Indicators on surface water quality (e.g. microbiological data, BOD, phosphate concentration, oxygen conditions, saprobiological status, suspended matter) [1,4,5] Indicators on groundwater quality (e.g. NO3, pesticide, trace metals, emerging pollutants) [1] Nutrient concentration [1,5] Trophic status [1] Ecological status [1] Area occupied by riparian forests [1] Presence of floodplains, wetlands, estuaries or mangroves [5] Presence/distribution of nitrophilous macroalgae or macrophytes [5] Potential mineralization or decomposition [1]	Nutrient loads [1] Nutrient retention [1,2] Nutrient uptake by organisms [5] Removal of nutrients by wetlands [4] Amount of waste processed by ecosystems [3] Sedimentation and accumulation of organic matter [5]	Access to safe water [3] Value of ecosystem waste treatment and water purification [3] Cost of effluent treatment or nutrient abatement [5]
Air quality regulation	Tree cover [2] Pollutant concentration [2] Atmospheric cleansing capacity [3]	Deposition velocity [2] Flux in atmospheric gases [3]	
Erosion prevention	Ground water level evolution [1] Soil erosion rate by land use type [4] Geomorphology [2] Vegetation distribution and properties (of riparian or coastal zones) [2,5] Area affected by erosion [3] Presence of seagrass meadows or kelp [5]	Sediment accretion /soil retention [1,2,5] Siltation [3]	Willingness-to-pay of local residents [5] Loss in property values from declining shoreline protection [5]
Flood protection	Water holding capacity of soils [1,2,3,4] Conservation status of river banks, lake banks and riparian zones [1,2] Floodplain area [1,2] Area of wetlands located in flood risk zones [1] Ground water level evolution [1] Soil capacity to transfer groundwater [3] Infiltration capacity of an ecosystem [4] Floodplain water storage capacity [3,4] Area of intact wetlands, floodplains, coral reefs,	Flood risk maps [1] Record of annual floods [1,2] Trends in number of damaging natural disasters [3,4] Probability of incident [4] Wave attenuation or surge reduction [5]	Percentage of population living in water hazard prone areas [4] Population in floodplain/coastal area [3] Spending on disaster assistance for floods [3] Construction and/or maintenance cost of sea defences [5] Avoided damage per storm condition [5]

Ecosystem services	Natural capacity	Service flow	Social benefit
	mangroves, sandbars or barrier beaches [3,5] Vegetation distribution and properties (of riparian or coastal zones) [2,5]		
Maintaining populations and habitats	Biodiversity value (species diversity or abundance, endemics or red list species, spawning areas) [1,2] Ecological status [1] Hydromorphological status [1] Coverage, condition and structural complexity of nursery and feeding areas (e.g. coral, mangrove) [5] Macrophyte species richness [5]	Habitat suitability [2] Species abundance and richness [5] Habitat change [5] Juvenile density [5] Postlarvae production per hatchery [5]	Community perception on the importance of habitat provision [5] Economic value of the annual juvenile fish production based on the price of aquaculture growth [5]
Pest and disease control	Alien species introduced in aquatic environments and riparian zones [1] Disease vector predator populations [3]	Pest density [2] Control of aquatic disease bearing invertebrates and plants by fish [5] Occurrence of problems limiting crop and livestock productivity [3] Increase in disease vectors mosquitoes [3] Estimated change in disease burden as a result of changing ecosystems [3]	Population affected by water-related diseases [4] Waterborne and water related disease incidence [3]
Soil formation and composition	Presence of hydromorphic soils [1] Surface of floodplains [1] Potential mineralization or decomposition [1] Decomposition of dissolved and particulate organic matter by bacteria and funghi in the sediments [5]	Fluvisols surface [1] Nutrients stored in the sediments [5]	
Carbon sequestration	Organic carbon stored or carbon stock [1,4,5] Above and below-ground biomass [2,5] Carbon in soil or sediments [2,5] Dissolved organic matter [5]	Carbon sequestration or carbon change [1,4,5] Carbon uptake [3,5] Soil carbon accumulation [5]	Quantity of carbon fixed combined with the marginal damage costs of carbon emissions [5] Market value of carbon [5]
Local climate regulation	Riparian zone [2] Ground water level [1] Temperature & Precipitation [2] Evapotranspiration [3] Cloud formation [3] Canopy stomatal conductance [3]	Drought frequency [3]	

Ecosystem services	Natural capacity	Service flow	Social benefit
Recreation and tourism	National Parks and Natura 2000 sites [1] Number of bird watching sites [1] Number of beaches [1] Fish and waterfowl abundance [1,2] Condition of fish stocks [3] Quality of fresh waters for fishing [1] Accessibility [2] Footpaths [2] Size of marine leisure and recreation hotspots [5] Cover and smell of decomposing algae [5] Presence of coralligenous community or cetacean population [5]	Number of visitors to natural places (e.g. to National Parks, lakes, rivers, protected wetlands) [1,2,3,4] Number of visitors to attractions (e.g. thermal, mineral and mud springs and balnearies, speleology sites, species watching) [1,4] Number fishing licenses and fishing reserves [1] Beach closure due to bacteria limit, discolored or turbid water [5] Number of bathing areas[1] Number of waterfowl hunters, anglers and amateur fishermen [1,3]	Tourism revenue [1] Traffic census [2] Amount or spending on nature tourism [3,4,5] Beach visitors and travel cost [5] Tourists' perception in a marine protected area [5]
Intellectual and aesthetic appreciation	National Parks and Natura 2000 sites [1] Contrasting landscapes (e.g. lakes close to mountains) [1] Proximity of scenic rivers or lakes to urban areas [1,2] Monitoring sites by scientists [1] Fish studies as a source of information [5] Seabird populations [3]	Cultural sites and number of annual cultural activities organised [1] Classified sites (e.g. World Heritage, label European tourism) [1] Number of visitors [1,2] Number of scientific projects, articles, studies, patents [1,4] Number of educational excursions at a site [4] Number of TV programmes, studies, books etc. featuring sites [4]	Changes in the number of residents and real estate values [4] Comparative value of real estate nearer to nature/ cleaner water bodies [3,5] Price of a hotel room with sea views [5] Willingness to pay for improvement in the environment/ improved water quality [2,3] Taxes and subsidies that support maintaining open space [3] Financial expenditure in research [5]
Spiritual and symbolic appreciation	National species or habitat types [1] Rare species [2] Cultural landscape intactness [3]	Sacred or religious sites (e.g. catastrophic events, religious places) [1] Number of sites or species fundamental to performance of rituals [3] Number of visitors [1] Number of (environmental) associations registered [1]	Changes in the number of residents and real estate values [4] Incentives to maintain traditional cultural landscapes [3]

Annex 5 – Economic valuation of ecosystem services: list of techniques

Table A5.1 – Economic valuation methods

Approach	Valuation method	Description of the method	Examples of ESS value assessment
Cost-based	*Damage cost avoided*	Method that values an ecosystem service estimating the damage that might be incurred if this service disappears	Assess the value of the storm protection service provided by wetlands through an estimation of avoided damage in case of a storm
	Replacement cost	Method that uses the cost of a substitute for an ecosystem as a proxy for the value of services provided by this ecosystem	Assess the value of the water purification service through an estimation of the construction cost of artificial wetlands
Revealed preferences	*Travel cost*	Survey-based technique that uses the cost incurred by individuals taking a trip to a recreation site as a proxy for the recreational value of this site	Assess the value of the recreational service of a lake based on the number of visitors and the money they spend to visit the lake
	Hedonic price	Method that estimates the value an environmental characteristic of an ecosystem by looking at differences in property prices	Assess the value of lake amenities by comparing real-estate prices located at different distances of this lake
Stated preferences	*Contingent valuation*	Survey-based technique in which respondents answer questions regarding their willingness to pay for an environmental service or a change in this environmental service	Assess the value of an aquatic species by asking individuals how much they are ready to contribute for preserving it
	Choice experiment	Survey-style technique in which respondents are asked to state their choice over different hypothetical alternatives (alternatives consist in a combination of attributes of an ecosystem and a price associated to this combination)	Assess the value of services provided by a river by the choice respondents make between different options (combinations of water quality, number of species and vegetation) combined with different prices to be paid for each combination.
Benefit transfer	*Unit value transfer*	Method that values an ecosystem service by transferring a monetary value derived from another study (and from another site)	Assess the value of the recreational service of a lake applying a constant value per unit of ecosystem (e.g. the surface area) taken from another study
	Adjusted unit value transfer	Method that values an ecosystem service by transferring a monetary value derived from another study, this value being adjusted using an ad-hoc factor to account differences between the two sites	Assess the value of the recreational service of a lake applying a value per unit of ecosystem (e.g. the surface area) that depends on the income level of the local population
	Value transfer functions	Method that values an ecosystem service using a value function estimated from another site	Assess the value of the recreational service of a lake by plugging site-specific parameters into a value function estimated from another study
	Meta-analytic value transfer functions	Method that values an ecosystem service from a function estimated through statistical regression analysis of many primary valuation studies	Assess the value of the recreational service of a lake by plugging site-specific parameters into a value function estimated from a meta-analysis

Table A5.2 – Policy instruments relevant for ecosystem services

Category	Policy instruments	Examples / Explanations
Economic instruments	▪ *Taxes* ▪ *Markets* ▪ *Subsidies* ▪ *Payments for ecosystem services*	▪ Effluent taxes, water withdrawal fees. ▪ Tradable water pollution permits. ▪ Subsidies for low water consumption equipment. ▪ "Contract for services" i.e. voluntary payment for the delivery of specified ecosystem services. In France payment by the Vittel company to farmers who adopt less intensive farming techniques, in UK angler's payment for improvements to river water quality (angling passport).
Voluntary approaches	▪ *Private agreements* ▪ *Public voluntary schemes* ▪ *Negotiated agreements*	▪ Unilateral commitments made by polluters or resource users, multilateral agreements between polluters and pollutees or between resource users. ▪ Voluntary programs developed by public bodies such as environmental agencies, to which economic agents (individuals, farmers, firms) are invited to participate. ▪ Agreements usually created out of a dialogue between government authorities and economic agents (individuals, farmers, firms) typically containing a target and a timetable for reaching that target.
Regulations	▪ *Norms and standards* ▪ *Restrictions on use and access* ▪ *Liability rules*	▪ Minimum water flows, maximum pollutant concentrations in watersheds. ▪ Legal possibility for public authorities to restrict or to limit access or use of water resources. ▪ Legal obligations for the responsible party to bear the costs of restoring the environment.
Information tools	▪ *Education campaign* ▪ *Use of media* ▪ *Eco labelling of products*	▪ Campaigns to raise awareness of children about water issues. ▪ Use of any kind of media for informing populations about water issues. ▪ Water saving labelling program for products and services which are helping to reduce water use (Smart WaterMark in Australia).

Annex 6 – Questionnaire on ecosystem services

A6.1 Questionnaire form

MARS Task 2.2 - Questionnaire on Ecosystem Services

Fields marked with * are mandatory.

The **aim** of this questionnaire is to collect the needs, experience and knowledge of the MARS partners to inform and target the methodology to be developed by Task 2.2 for assessing and valuing ecosystem services.

We ask you to carefully read the **background information** before taking the questionnaire.

Background information can be found here:
Background_information.pdf

A pdf copy of the questionnaire can be found here:
copy_questionnaire_Mars.pdf

The **questionnaire** is organized in four sections. We will ask information about:

1. the respondent (4 questions)
2. the ecosystem services of interest (13 questions)
3. previous experience and studies on ecosystem services (5 questions)
4. feedback on the questionnaire (6 questions)

You can save your answers anytime with the button "Save as Draft" at the bottom of the page.

This questionnaire has been prepared by Grizzetti B., Lanzanova D., Reynaud A., Liquete C., Cid N., Cardoso A.C.
(If you have any question about this questionnaire please contact denis.lanzanova@jrc.europa.eu)

1. Information about the respondent

In this section we ask you information about the **respondent** of the questionnaire and the involvement in the MARS project.

1.1 Name of the institution:*

1.2 Names of the respondents (people in your team that will be involved in assessing and valuing the ecosystem services in MARS. More than one name possible):*

1.3 Contact email:*

1.4 Type of involvement in Ecosystem Services in MARS (more than one option possible):*

- ☐ WP2
- ☐ WP3
- ☐ WP4
- ☐ WP5
- ☐ Other WP

Please specify (e.g. name of the study):*

2. Selection of relevant ecosystem services

In MARS we will study the effects of multiple stressors on the delivery of ecosystem services at three different scales: water body, catchment and the European scale. Task 2.2 will develop methodologies for assessing and valuing ecosystem services at these three scales. In this session we will ask you information about the ecosystem services that are of interest for you, considering first their biophysical assessment and then their economic valuation.

2.1 For which **scale** will you apply the methodology?*

- ○ I will apply the methodology developed by Task 2.2 at the water body scale (WP3)
- ○ I will apply the methodology developed by Task 2.2 at the catchment scale (WP4)
- ○ I will apply the methodology developed by Task 2.2 at the European scale (WP5)
- ○ I will not apply the methodology directly

In this case please specify for which scale you would like to take the questionnaire: water body, catchment, European scale.*

2.2 Within your study which **water bodies or ecosystems** (relevant for the delivery of ecosystem services) will you assess? (more than one option possible)

Please tick the relevant box(es)

	I will assess in MARS
Lakes	☐
Rivers	☐
Transitional waters	☐
Coastal waters	☐
Groundwater	☐
Freshwater wetlands	☐
Coastal wetlands	☐
Riparian areas	☐
Floodplains	☐

2.3 From the following list of **ecosystem services** which ones do you think are relevant (and you plan to assess in MARS) for your study? (more than one option possible)

Provisioning services

Please tick the relevant box(es)

	Are relevant for my study	I would like to assess in MARS
Fisheries and aquaculture *(e.g. fish catch)*	☐	☐
Water for drinking *(e.g. provision of water for domestic uses)*	☐	☐
Raw -biotic- materials *(e.g. algae as fertilizers, vegetal compounds for cosmetics)*	☐	☐
Water for non-drinking puposes *(e.g. provision of water for industrial or agricultural uses)*	☐	☐
Raw materials for energy *(e.g. wood from riparian zones)*	☐	☐

Regulation & Maintenance services

Please tick the relevant box(es)

	Are relevant for my study	I would like to assess in MARS
Water purification *(e.g. excess nitrogen removal by microorganisms)*	☐	☐
Air quality regulation *(e.g. deposition of oxides of nitrogen on vegetal leaves)*	☐	☐
Erosion prevention *(e.g. vegetation controlling soil erosion on river banks)*	☐	☐
Flood protection *(e.g. vegetation acting as barrier for the water flow, lakes or floodplains trapping and slowing down the water flow)*	☐	☐
Maintaining populations and habitats *(e.g. key habitats use as reproductive grounds, nursery, shelter... for a variety of species)*	☐	☐
Pest and disease control *(e.g. diseases and parasites are better controlled in the wild (by natural predation on weakened individuals) than in fish farms, biodiversity may control mosquito population and prevent malaria outbreaks)*	☐	☐
Soil formation and composition *(e.g. rich soil formation in floodplains or in wetlands borders)*	☐	☐
Carbon sequestration *(e.g. carbon accumulation in vegetation or sediments)*	☐	☐
Local climate reguation *(e.g. maintenance of humidity and precipitation patterns by wetlands or lakes, shading effect)*	☐	☐

Cultural services

Please tick the relevant box(es)

	Are relevant for my study	I would like to assess in MARS
Recreation *(e.g. swimming, recreational fishing, sightseeing, boating)*	☐	☐
Intellectual and aesthetic appreciation *(e.g. subject matter for research, artistic representations of nature)*	☐	☐
Spiritual and symbolic appreciation *(e.g. existence of emblematic species like Lutra lutra or sacred places)*	☐	☐

Extra abiotic environmental services

Please tick the relevant box(es)

	Are relevant for my study	I would like to assess in MARS
Raw abiotic materials *(e.g. extraction of sand and gravel from river bed or river banks)*	☐	☐
Abiotic energy sources *(e.g. hydropower generation)*	☐	☐

2.4 Are there any other ecosystem services not included in the list that you think are relevant and you plan to assess in MARS for your study?

2.5 For the ecosystem services you have selected in question 2.3, we would like to know which **indicators** you think are appropriate for assessing the delivery of the ecosystem service in your study and if you have the possibility to assess them by data or modelling (the list of indicators is also provided in the background document).

PROVISIONING SERVICES: Fisheries and aquaculture

Please tick the relevant box(es)

	Are appropriate	I can estimate
Fish production or fish catch	☐	☐
Status of fish population (species composition, age structure, biomass)	☐	☐
Aquaculture production (e.g. sturgeon and caviar production)	☐	☐
Wild vegetation used in gastronomy, cosmetic or pharmaceutical uses	☐	☐
Number of fisherman	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

PROVISIONING SERVICES: Water for drinking

Please tick the relevant box(es)

	Are appropriate	I can estimate
Water consumption for drinking	☐	☐
Water abstracted	☐	☐
Surface water availability	☐	☐
Water exploitation index (WEI)	☐	☐
Nitrate-vulnerable zones	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

PROVISIONING SERVICES: Raw (biotic) materials

Please tick the relevant box(es)

	Are appropriate	I can estimate
Timber produced by riparian forest	☐	☐
Surface of exploited wet forests (e.g. poplars) and reeds	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

PROVISIONING SERVICES: Water for non-drinking purposes

Please tick the relevant box(es)

	Are appropriate	I can estimate
Water use per sector	☐	☐
Water abstracted	☐	☐
Surface water availability	☐	☐
Ground water availability	☐	☐
Volume of water bodies	☐	☐
Water exploitation index (WEI)	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

PROVISIONING SERVICES: Raw materials for energy

Please tick the relevant box(es)

	Are appropriate	I can estimate
Production of peat	☐	☐
Surface of exploited wetlands for peat and biofuels	☐	☐
Firewood produced by riparian forests	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Water purification

Please tick the relevant box(es)

	Are appropriate	I can estimate
Indicators on surface water quality (e.g. microbiological data, BOD, phosphate conc, oxygen conditions, saprobiological status)	☐	☐
Indicators on groundwater quality (e.g. NO3, pesticide, trace metals, emerging pollutants)	☐	☐
Nutrient loads	☐	☐
Nutrient concentration	☐	☐
Nutrient retention	☐	☐
Trophic status	☐	☐
Ecological status	☐	☐
Area occupied by riparian forests	☐	☐
Potential mineralization or decomposition	☐	☐
Number and efficiency of treatment plants	☐	☐
Waste water treated	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

For **air quality regulation**, if you want to suggest indicators for ecosystem services, please use this space:

REGULATION & MAINTENANCE SERVICES: Erosion prevention

Please tick the relevant box(es)

	Are appropriate	I can estimate
Sediment retention	☐	☐
Ground water level evolution	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Flood protection

Please tick the relevant box(es)

	Are appropriate	I can estimate
Flood risk maps	☐	☐
Water holding capacity of soils	☐	☐
Conservation of river and lakes banks	☐	☐
Ground water level evolution	☐	☐
Flood plains area (and record of annual floods)	☐	☐
Area of wetlands located in flood risk zones	☐	☐
Conservation status of riparian wetlands	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Maintaining populations and habitats

Please tick the relevant box(es)

	Are appropriate	I can estimate
Biodiversity value (species diversity or abundance, endemics or red list species, spawning areas)	☐	☐
Ecological status	☐	☐
Hydromorphological status	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Pest and disease control

Please tick the relevant box(es)

	Are appropriate	I can estimate
Alien species introduced in aquatic environments and riparian zones (e.g. plants, invertebrates, vertebrates)	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Soil formation and composition

Please tick the relevant box(es)

	Are appropriate	I can estimate
Fluvisols surface	☐	☐
Presence of hydromorphic soils	☐	☐
Surface of floodplains	☐	☐
Potential mineralization, decomposition, etc.	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Carbon sequestration

Please tick the relevant box(es)

	Are appropriate	I can estimate
Carbon sequestration or carbon change (e.g. in riparian forests, Populus plantations)	☐	☐
Organic carbon stored or carbon stock (e.g. in fluvisols)	☐	☐
Number of sites for CO2 deep injections and volumes of CO2 injected	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

REGULATION & MAINTENANCE SERVICES: Local climate regulation

Please tick the relevant box(es)

	Are appropriate	I can estimate
Ground water level	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

CULTURAL SERVICES: Recreation

Please tick the relevant box(es)

	Are appropriate	I can estimate
Number of visitors to natural places (e.g. to National Parks, to lakes or rivers, to protected wetlands)	☐	☐
Number of visitors to attractions (e.g. thermal, mineral and mud springs and balnearies, speleology sites, etc)	☐	☐
National Parks and Natura 2000 sites	☐	☐
Number of bird watching sites	☐	☐
Number of bathing areas and beaches	☐	☐
Fish and waterfowl abundance	☐	☐
Quality of fresh waters for fishing	☐	☐
Number of waterfowl hunters, anglers and amateur fishermen	☐	☐
Number fishing licenses and fishing reserves	☐	☐
Tourism revenue	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

CULTURAL SERVICES: Intellectual and aesthetic appreciation

Please tick the relevant box(es)

	Are appropriate	I can estimate
Monitoring sites by scientists	☐	☐
Number of scientific projects, articles, studies	☐	☐
Classified sites (e.g. World Heritage, label European tourism)	☐	☐
Number of visitors	☐	☐
National Parks and Natura 2000 sites	☐	☐
Cultural sites and number of annual cultural activities organised	☐	☐
Contrasting landscapes (e.g. lakes close to mountains)	☐	☐
Proximity to urban areas of scenic rivers or lakes	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

CULTURAL SERVICES: Spiritual and symbolic appreciation

Please tick the relevant box(es)

	Are appropriate	I can estimate
National species or habitat types	☐	☐
Number of visitors (e.g. to places where springs and streams with groundwater origin made them historic and religious sites)	☐	☐
Sacred or religious sites (e.g. catastrofic events, religious places)	☐	☐
Number of wildlife associations registered	☐	☐

If you have additional comments on indicators, or you want to suggest indicators for ecosystem services not present in the list please use this space:

EXTRA-ABIOTIC ENVIRONMENTAL SERVICES - For **raw abiotic materials**, if you want to suggest indicators for ecosystem services, please use this space:

EXTRA-ABIOTIC ENVIRONMENTAL SERVICES - For **abiotic energy sources**, if you want to suggest indicators for ecosystem services, please use this space:

2.6 In your MARS study, will you carry-out an **economic valuation** of ecosystem services?*

- ○ YES
- ○ NO

Economic valuation

2.7 Which **ecosystem services will you value** in the MARS project?

Provisioning services

Please tick one box for each row

	I will value	I will not value	I don't know
Fisheries and aquaculture *(e.g. fish catch)*			
Water for drinking *(e.g. provision of water for domestic uses)*			
Raw -biotic- materials *(e.g. algae as fertilizers, vegetal compounds for cosmetics)*			
Water for non-drinking puposes *(e.g. provision of water for industrial or agricultural uses)*			
Raw materials for energy *(e.g. wood from riparian zones)*			

Regulation & Maintenance services

Please tick one box for each row

	I will value	I will not value	I don't know
Water purification *(e.g. excess nitrogen removal by microorganisms)*			
Air quality regulation *(e.g. deposition of oxides of nitrogen on vegetal leaves)*			
Erosion prevention *(e.g. vegetation controlling soil erosion on river banks)*			
Flood protection *(e.g. vegetation acting as barrier for the water flow, lakes or floodplains trapping and slowing down the water flow)*			
Maintaining populations and habitats *(e.g. key habitats use as reproductive grounds, nursery, shelter... for a variety of species)*			
Pest and disease control *(e.g. diseases and parasites are better controlled in the wild (by natural predation on weakened individuals) than in fish farms, biodiversity may control mosquito population and prevent malaria outbreaks)*			
Soil formation and composition *(e.g. rich soil formation in floodplains or in wetlands borders)*			
Carbon sequestration *(e.g. carbon accumulation in vegetation or sediments)*			
Local climate reguation *(e.g. maintenance of humidity and precipitation patterns by wetlands or lakes, shading effect)*			

Cultural services

Please tick one box for each row

	I will value	I will not value	I don't know
Recreation *(e.g. swimming, recreational fishing, sightseeing, boating)*	○	○	○
Intellectual and aesthetic appreciation *(e.g. subject matter for research, artistic representations of nature)*	○	○	○
Spiritual and symbolic appreciation *(e.g. existence of emblematic species like Lutra lutra or sacred places)*	○	○	○

Extra abiotic environmental services

Please tick one box for each row

	I will value	I will not value	I don't know
Raw abiotic materials *(e.g. extraction of sand and gravel from river bed or river banks)*	○	○	○
Abiotic energy sources *(e.g. hydropower generation)*	○	○	○

2.8 Are there any other ecosystem services not included in the list that you will value or for which you would like to add a comment?

2.9 Do you plan to collect by yourself **economic data** (that is conducting field surveys for instance by interviewing water users with specific environmental valuation technics) to conduct the economic valuation? (The alternative consists in using existing databases or economic valuation data from the literature)*

- ○ YES
- ○ NO
- ○ I DON'T KNOW

2.10 From the following **methods**, which one will you be interested to apply for the economic valuation? Please consider the background information document for an explanation of the methods

Cost-based approach

Please tick the relevant box(es)

	I know this method	I would like to apply this method
Damage cost avoided	☐	☐
Replacement cost	☐	☐

Revealed preferences approach

Please tick the relevant box(es)

	I know this method	I would like to apply this method
Travel cost	☐	☐
Hedonic price	☐	☐

Stated preferences approach

Please tick the relevant box(es)

	I know this method	I would like to apply this method
Contingent valuation	☐	☐
Choice experiment	☐	☐

Benefit transfer approach

Please tick the relevant box(es)

	I know this method	I would like to apply this method
Unit value transfer	☐	☐
Adjusted unit value tranfer	☐	☐
Value transfer function	☐	☐
Meta-analytic value transfer function	☐	☐

2.11 Are there any other methods not included in the list that you will be interested to use and for which you would like to add a comment?

2.12 To face the impact of multiple stressors which **policy instruments** have already been implemented in your case study? Please consider the background information document for the examples of policy instruments.

Category: economic instruments

Please one box for each row

	Already implemented	Not yet implemented	I don't know
Taxes	○	○	○
Markets	○	○	○
Subsidies	○	○	○
Payments for ecosystem services	○	○	○

Category: voluntary approaches

Please one box for each row

	Already implemented	Not yet implemented	I don't know
Private agreements	○	○	○
Public voluntary schemes	○	○	○
Negociated agreements	○	○	○

Category: regulations

Please one box for each row

	Already implemented	Not yet implemented	I don't know
Norms and standards	○	○	○
Restrictions on use and access	○	○	○
Liability rules	○	○	○

Category: information tools

Please one box for each row

	Already implemented	Not yet implemented	I don't know
Education campaign	○	○	○
Use of media	○	○	○
Eco labelling of products	○	○	○

2.13 To face the impact of multiple stressors which **policy instruments** would be relevant in your context for managing ecosystem services? Please consider the background information document for the definition of policy instruments.

Category: economic instruments

Please tick the relevant box(es)

	Would be relevant for testing in future scenario	I don't know
Taxes	☐	☐
Markets	☐	☐
Subsidies	☐	☐
Payments for ecosystem services	☐	☐

Category: voluntary approaches

Please tick the relevant box(es)

	Would be relevant for testing in future scenario	I don't know
Private agreements	☐	☐
Public voluntary schemes	☐	☐
Negociated agreements	☐	☐

Category: regulations

Please tick the relevant box(es)

	Would be relevant for testing in future scenario	I don't know
Norms and standards	☐	☐
Restrictions on use and access	☐	☐
Liability rules	☐	☐

Category: information tools

Please tick the relevant box(es)

	Would be relevant for testing in future scenario	I don't know
Education campaign	☐	☐
Use of media	☐	☐
Eco labelling of products	☐	☐

3. Previous experience and studies on assessing and valuing ecosystem services

In this section we would like to have some information about previous studies on assessing and valuing ecosystem services in your case study and on your personal experience in the field.

3.1 Have ecosystem services already been assessed in **previous studies in your case study** (literature review)?*

- ○ YES
- ○ NO
- ○ I DON'T KNOW

Could you please provide on or two references:

3.2 Do you (or somebody in your team who can contribute/be involved in the MARS project) have direct experience in MAPPING and assessing the delivery of ecosystem services (**biophysical quantity**) at the water body, catchment or the European scale?*

- YES
- NO

3.2.1 Please indicate which ecosystem services you have already assessed and which methodology you have used:

3.3 Do you (or somebody in your team who can contribute/be involved in the MARS project) have experience in **economic valuation** of ecosystem services at the water body, catchment or the European scale?*

- YES
- NO

Economic valuation

3.3.1 Please indicate which ecosystem services have you already assessed and which methodology you have used for the economic valuation:

4. Feedback on the questionnaire

In this session we would like to have your feedback on this questionnaire.

4.1 Do you think that the **background information** we have provided in this questionnaire was:

	YES	NO	I don't know
Useful	○	○	○
clear	○	○	○
Complete	○	○	○

Do you have any additional comments on the background information?

4.2 Do you think that the **ecosystem service list** we have provided in this questionnaire was:

	YES	NO	I don't know
Useful	○	○	○
clear	○	○	○
Complete	○	○	○
Could be used with your stakeholders	○	○	○

Do you have any additional comments on the ecosystem service list?

4.3 Do you think that the **indicator list** (also available in the background document) we have provided in this questionnaire was:

	YES	NO	I don't know
Useful	○	○	○
clear	○	○	○
Complete	○	○	○

Do you have any additional comments on indicators?

4.4 Do you think that the **list of methods for economic valuation** we have provided in this questionnaire was:

	YES	NO	I don't know
Useful			
clear			
Complete			

Do you have any additional comments on the methods for economic valuation?

4.5 Do you think that the **list of policy instruments** we have provided in this questionnaire was:

	YES	NO	I don't know
Useful			
clear			
Complete			

Do you have any additional comments on the policy instruments?

4.6 Do you have any specific **comments/suggestions/wishes** on the methodology for assessing and valuing ecosystem services in the project MARS what you would like to tell us?

A6.2 Contributors to the questionnaire

The project MARS analyses the relationship between multiple stressors and the delivery of ecosystem services related to the aquatic ecosystems at three different scales: water body (WP3), catchment (WP4) and the European scale (WP5). For this reason in the questionnaire we refer to studies at these three scales.

Through the questionnaire we collected relevant information from MARS partners to be considered in the development of the methodology. We received one questionnaire per each case study of WP4 and 7 out of 9 replies for the case studies of WP3. For the European scale (WP5), we asked the Task 5.2, 5.3 and 5.4 and all the partners of Task 5.1.4 to fill in the questionnaire. In addition, we were interested in the input of some partners of MARS who will not directly apply the methodology. These few partners not directly involved in WP3, WP4 or WP5 studies were asked to indicate for which scale they answered the questionnaire, according to their field of expertise (water body, catchment or the European scale).

The final list of contributors to the questionnaire is provided in the following table:

Table A6.1 - Contributors to the MARS questionnaire on Ecosystem services (Task 2.2).

Task	Sub task	PartNo.	Institute
WP3			
3.1 Lake experiments	3.1.1 Extreme rainfall, location UK	14	NERC
3.1 Lake experiments	3.1.2 Extreme heatwaves, location DK	2	AU
3.1 Lake experiments	3.1.3 Extreme mixing and DOM loading, location DE	10	FVG-IGB
3.2 River experiments	3.2.1 Extreme flow in Nordic rivers, location NO	15	NIVA
3.2 River experiments	3.2.2 Peak flow in Alpine rivers, location AU	4	BOKU
3.2 River experiments	3.2.3 Water scarcity in Mediterranean rivers, location PT	19	UTL
3.2 River experiments	3.2.4 River-low flow in Nordic rivers, location DK	2	AU
3.3 Analysis of time series	3.3.1 Lakes	9	EMU
3.3 Analysis of time series	3.3.2 Rivers	6	CU

WP4			
4.2 Southern river basins	Sorraia	19	UTL
4.2 Southern river basins	Nervion-Ibaizabal	3	AZTI
4.2 Southern river basins	Pinios	16	NTUA
4.2 Southern river basins	Beysehir	13	METU
4.2 Southern river basins	Lower Danube	7	DDNI
4.3 Central river basins	Thames	14	NERC
4.3 Central river basins	Regge and Dinkel	8	DELTARES
4.3 Central river basins	Odense	2	AU
4.3 Central river basins	Elbe, Havel and Saale	10	FVB-IGB
4.3 Central river basins	Ruhr	1	UDE
4.3 Central river basins	Drava	4	BOKU
4.4 Northern river basins	Welsh basins	6	CU
4.4 Northern river basins	Vansio-Hobol	15	NIVA
4.4 Northern river basins	Otra	15	NIVA
4.4 Northern river basins	Kokemaenjoki	17	SYKE
4.4 Northern river basins	Vortsjarv	9	EMU
WP5			
5.1 European matrix of stress and impact	5.1.4 Spatial assessment of services delivered by European aquatic ecosystems	12	JRC
5.1 European matrix of stress and impact	5.1.4 Spatial assessment of services delivered by European aquatic ecosystems	10	FVB-IGB
5.1 European matrix of stress and impact	5.1.4 Spatial assessment of services delivered by European aquatic ecosystems	14	NERC
5.1 European matrix of stress and impact	5.1.4 Spatial assessment of services delivered by European aquatic ecosystems	16	NTUA
5.1 European matrix of stress and impact	5.1.4 Spatial assessment of services delivered by European aquatic ecosystems	8	DELTARES
5.2 Multiple stressors in large rivers		4	BOKU
5.3 Multiple stressors in lakes		15	NIVA
5.4 Multiple stress effects on European fish assemblages		11	IRSTEA
Other			
2.3 Identification of benchmark indicators		1	UDE
2.4 Elaboration of the MARS model		14	NERC
		1	UDE
		AB	HMUELV

A6.3 Results of the questionnaire

This section provides the detailed results of the questionnaires that are discussed and displayed by graphs in the text of the report. The compilation of comments from partners has not been included here, but all comments have been taken into consideration in the analysis for the report.

1. Information about the respondents

Number of questionnaires sent out: 37
Number of questionnaire responses: 27

2. Selection of relevant ecosystem services

2.1 For which scale will you apply the methodology?

WP3	7
WP4	13
WP5	5
others	2

2.2 Within your study which water bodies or ecosystems (relevant for the delivery of ecosystem services) will you assess?

Lakes	14
Rivers	23
Transitional waters	6
Coastal waters	3
Groundwater	8
Freshwater wetlands	3
Coastal wetlands	2
Riparian areas	10
Floodplains	4

2.3 From the following list of ecosystem services which ones do you think are relevant (and you plan to assess in MARS) for your study?

Ecosystem Service		Relevance	%	MARS	%
Provisioning services:	Fisheries and aquaculture	20	74	9	33
	Water for drinking	21	78	12	44
	Raw -biotic- materials	3	11	0	0
	Water for non-drinking purposes	18	67	11	41
	Raw materials for energy	5	19	1	4
Regulation & Maintenance services:	Water purification	23	85	15	56
	Air quality regulation	2	7	1	4
	Erosion prevention	10	37	7	26
	Flood protection	17	63	10	37
	Maintaining populations and habitats	22	81	13	48
	Pest and disease control	5	19	2	7
	Soil formation and composition	3	11	0	0
	Carbon sequestration	15	56	7	26
	Local climate regulation	9	33	6	22
Cultural services:	Recreation	21	78	11	41
	Intellectual and aesthetic appreciation	10	37	4	15
	Spiritual and symbolic appreciation	3	11	1	4
Extra abiotic environmental services:	Raw abiotic materials	5	19	1	4
	Abiotic energy sources	12	44	6	22

2.4 Are there any other ecosystem services not included in the list that you think are relevant and you plan to assess in MARS for your study?

(Comments provided)

2.5 For the ecosystem services you have selected in question 2.3, we would like to know which indicators you think are appropriate for assessing the delivery of the ecosystem service in your study and if you have the possibility to assess them by data or modelling (the list of indicators is also provided in the background document).

Indicators on Provisioning services

Ecosystem services	Proposed indicators from MAES	ES will be assessed in MARS	Indicator is relevant	%	Indicator can be assessed in MARS	%
Fisheries and aquaculture	Fish production or fish catch	9	8	89	5	56
	Status of fish population (species composition, age structure, biomass)	9	8	89	7	78
	Aquaculture production (e.g. sturgeon and caviar production)	9	2	22	0	0
	Wild vegetation used in gastronomy, cosmetic or pharmaceutical uses	9	0	0	0	0
	Number of fisherman	9	6	67	4	44
Water for drinking	Water consumption for drinking	12	9	75	6	50
	Water abstracted	12	11	92	6	50
	Surface water availability	12	8	67	6	50
	Water exploitation index (WEI)	12	6	50	4	33
	Nitrate-vulnerable zones	12	5	42	3	25
Raw (biotic) materials	Timber produced by riparian forest	0	0		0	
	Surface of exploited wet forests (e.g. poplars) and reeds	0	0		0	
Water for non-drinking purposes	Water use per sector	11	6	55	3	27
	Water abstracted	11	9	82	6	55
	Surface water availability	11	9	82	8	73
	Ground water availability	11	7	64	4	36
	Volume of water bodies	11	8	73	4	36
	Water exploitation index (WEI)	11	7	64	4	36
Raw materials for energy	Production of peat	1	0	0	0	0
	Surface of exploited wetlands for peat and biofuels	1	0	0	0	0
	Firewood produced by riparian forests	1	0	0	0	0

Indicators on Regulation & Maintenance services

Ecosystem services	Proposed indicators from MAES	ES will be assessed in MARS	Indicator is relevant	%	Indicator can be assessed in MARS	%
Water purification	Indicators on surface water quality (e.g. microbiological data, BOD, phosphate concentration, oxygen conditions, saprobiological status)	15	13	87	9	60
	Indicators on groundwater quality (e.g. NO3, pesticide, trace metals, emerging pollutants)	15	5	33	3	20
	Nutrient loads	15	11	73	9	60
	Nutrient concentration	15	13	87	11	73
	Nutrient retention	15	11	73	8	53
	Trophic status	15	10	67	7	47
	Ecological status	15	12	80	9	60
	Area occupied by riparian forests	15	7	47	4	27
	Potential mineralization or decomposition	15	2	13	0	0
	Number and efficiency of treatment plants	15	6	40	2	13
	Waste water treated	15	7	47	4	27
Air quality regulation						
Erosion prevention	Sediment retention	7	4	57	1	14
	Ground water level evolution	7	3	43	0	0
Flood protection	Holding capacity flood risk maps	10	7	70	2	20
	Water holding capacity of soils	10	6	60	5	50
	Conservation status of river and lake banks	10	3	30	1	10
	Ground water level evolution	10	5	50	3	30
	Floodplain area (and record of annual floods)	10	5	50	1	10
	Area of wetlands located in flood risk zones	10	4	40	1	10
	Conservation status of riparian wetlands	10	5	50	1	10
Maintaining populations and habitats	Biodiversity value (species diversity or abundance, endemics or red list species, spawning areas)	13	7	54	5	38
	Ecological status	13	12	92	8	62
	Hydromorphological status	13	6	46	2	15

Pest and disease control	Alien species introduced in aquatic environments and riparian zones (e.g. plants, invertebrates, vertebrates)	2	1	50	0	0
Soil formation and composition	Fluvisols surface	0	0		0	
	Presence of hydromorphic soils	0	0		0	
	Surface of floodplains	0	0		0	
	Potential mineralization, decomposition, etc.	0	0		0	
Carbon sequestration	Carbon sequestration or carbon change (e.g. in riparian forests, *Populus spp.* plantations)	7	7	100	4	57
	Organic carbon stored or carbon stock (e.g. in fluvisols)	7	2	29	0	0
	Number of sites for CO_2 deep injections and volumes of CO2 injected	7	1	14	1	14
Local climate regulation	Ground water level	6	2	33	0	0

Indicators on Cultural services

Ecosystem services	Proposed indicators from MAES	ES will be assessed in MARS	Indicator is relevant	%	Indicator can be assessed in MARS	%
Recreation and tourism	Number of visitors to natural places (e.g. to National Parks, to lakes or rivers, to protected wetlands)	11	5	45	1	9
	Number of visitors to attractions (e.g. thermal, mineral and mud springs and balnearies, speleology sites, etc)	11	2	18	0	0
	National Parks and Natura 2000 sites	11	5	45	2	18
	Number of bird watching sites	11	5	45	1	9
	Number of bathing areas and beaches	11	7	64	5	45
	Fish and waterfowl abundance	11	7	64	3	27
	Quality of fresh waters for fishing	11	7	64	3	27
	Number of waterfowl hunters, anglers and amateur fishermen	11	6	55	2	18
	Number fishing licenses and fishing reserves	11	8	73	4	36
	Tourism revenue	11	8	73	5	45

Intellectual and aesthetic appreciation	Monitoring sites by scientists	4	3	75	2	50
	Number of scientific projects, articles, studies	4	3	75	3	75
	Classified sites (e.g. World Heritage, label European tourism)	4	1	25	0	0
	Number of visitors	4	3	75	2	50
	National Parks and Natura 2000 sites	4	1	25	0	0
	Cultural sites and number of annual cultural activities organised	4	1	25	0	0
	Contrasting landscapes (e.g. lakes close to mountains)	4	2	50	1	25
	Proximity to urban areas of scenic rivers or lakes	4	2	50	2	50
Spiritual and symbolic appreciation	National species or habitat types	1	1	100	0	0
	Number of visitors (e.g. to places where springs and streams with groundwater origin made them historic and religious sites)	1	1	100	0	0
	Sacred or religious sites (e.g. catastrofic events, religious places)	1	1	100	1	100
	Number of associations registered on animals, plants, environment, naturism, etc	1	1	100	1	100

2.6 In your MARS study, will you carry-out an economic valuation of ecosystem services?
5 respondents said YES (19%)

2.7 Which ecosystem services will you value in the MARS project?

Ecosystem Services		**Will value**	**Will not value**	**Don't know**	**Sum of answers**
Provisioning services:	Fisheries and aquaculture	4	1	1	6
	Water for drinking	0	3	1	4
	Raw -biotic- materials	0	4	0	4
	Water for non-drinking puposes	1	2	1	4
	Raw materials for energy	0	4	0	4
Regulation & Maintenance services:	Water purification	1	2	2	5
	Air quality regulation	0	2	1	3
	Erosion prevention	0	1	2	3
	Flood protection	0	1	2	3
	Maintaining populations and habitats	1	2	1	4
	Pest and disease control	1	2	1	4
	Soil formation and composition	0	2	1	3
	Carbon sequestration	1	1	1	3
	Local climate reguation	0	3	0	3
Cultural services:	Recreation	5	0	0	5
	Intellectual and aesthetic appreciation	2	1	1	4
	Spiritual and symbolic appreciation	0	3	0	3
Extra abiotic environmental services:	Raw abiotic materials	0	4	0	4
	Abiotic energy sources (e.g. hydropower generation)	0	4	0	4

2.8 Are there any other ecosystem services not included in the list that you will value or for which you would like to add a comment?

No answers

2.9 Do you plan to collect by yourself economic data (that is conducting field surveys for instance by interviewing water users with specific environmental valuation technics) to conduct the economic valuation? (The alternative consists in using existing databases or economic valuation data from the literature)

YES 3 respondents, NO 2 respondents

2.10 From the following methods, which one will you be interested to apply for the economic valuation? Please consider the background information document for an explanation of the methods

Economic valuation method	**know the method**	**know the method and will apply**	**would like to apply**	sum of answers
Cost-based approach: Damage cost avoided	1	3	0	4
Cost-based approach: Replacement cost	2	1	0	3
Revealed preferences approach: Travel cost	3	0	0	3
Revealed preferences approach: Hedonic price	3	0	0	3
Stated preferences approach: Contingent valuation	3	1	1	5
Stated preferences approach: Choice experiment	2	1	1	4
Benefit transfer approach: Unit value transfer	2	1	0	3
Benefit transfer approach: Adjusted unit value tranfer	1	2	0	3
Benefit transfer approach: Value transfer function	3	0	0	3
Benefit transfer approach: Meta-analytic value transfer function	2	1	0	3

2.11 Are there any other methods not included in the list that you will be interested to use and for which you would like to add a comment?

(Comments provided)

2.12 To face the impact of multiple stressors which policy instruments have already been implemented in your case study? Please consider the background information document for the examples of policy instruments.

		Already implemented	Not yet implemented	Don't know	Sum of answers	Relevant for testing in scenario
Economic instruments:	Taxes	4	0	0	4	3
	Markets	1	2	0	3	2
	Subsidies	5	0	0	5	3
	Payments for ecosystem services	3	2	0	5	3
Voluntary approaches:	Private agreements	2	0	1	3	1
	Public voluntary schemes	4	0	1	5	2
	Negociated agreements	0	1	3	4	1
Regulations:	Norms and standards	3	0	2	5	3
	Restrictions on use and access	3	0	2	5	2
	Liability rules	0	0	4	4	2
Information tools:	Education campaign	3	0	2	5	1
	Use of media	3	0	1	4	1
	Eco labelling of products	2	1	1	4	0

3. Previous experience and studies on assessing and valuing ecosystem services

3.1 Have ecosystem services already been assessed in previous studies in your case study (literature review)?

YES	10	(37%)
NO	14	(52%)
I DON'T KNOW	3	(11%)

(References provided)

3.2 Do you (or somebody in your team who can contribute/be involved in the MARS project) have direct experience in MAPPING and assessing the delivery of ecosystem services (biophysical quantity) at the water body, catchment or the European scale?

YES	12	(44%)
NO	15	(56%)
I DON'T KNOW	0	(0%)

(References provided)

3.3 Do you (or somebody in your team who can contribute/be involved in the MARS project) have experience in economic valuation of ecosystem services at the water body, catchment or the European scale?

YES	9	(33%)
NO	18	(67%)
I DON'T KNOW	0	(0%)

(References provided)

4. Feedback on the questionnaire

Feedback (any type) provided by 25 (out of 27) respondent (93%)

4.1 Do you think that the **background information** we have provided in this questionnaire was:

	Useful	Clear	Complete
YES	22	21	13
NO	0	1	2
I DON'T KNOW	2	2	9
blank	3	3	3
sum of answers	24	24	24
	% (out of sum of answers)		
YES	92	88	54
NO	0	4	8
I DON'T KNOW	8	8	38

4.2 Additional comments provided on the background information:
(Comments provided)

4.3 Do you think that the **ecosystem service list** we have provided in this questionnaire was:

	Useful	Clear	Complete	Will use with Stakeholders
YES	24	22	8	14
NO	0	0	5	1
I DON'T KNOW	0	1	11	6
blank	3	4	3	5
sum of answers	24	23	24	21
	% (out of sum of answers)			
YES	100	96	33	67
NO	0	0	21	5
I DON'T KNOW	0	4	46	29

4.4 Additional comments provided on the ecosystem service list:
(Comments provided)

4.5 Do you think that the **indicator list** we have provided in this questionnaire was:

	Useful	Clear	Complete
YES	23	21	7
NO	0	0	5
I DON'T KNOW	0	2	10
blank	4	4	5
sum of answers	23	23	22
	% (out of sum of answers)		
YES	100	91	32
NO	0	0	23
I DON'T KNOW	0	9	45

4.6 Additional comments provided on indicators:
(Comments provided)

4.7 Do you think that the **list of methods for economic valuation** we have provided in this questionnaire was:

	Useful	**Clear**	**Complete**
YES	4	4	1
NO	0	0	2
I DON'T KNOW	0	0	1
blank	23	23	23
sum of answers	4	4	4
	% (out of sum of answers)		
YES	100	100	25
NO	0	0	50
I DON'T KNOW	0	0	25

4.8 Additional comments provided on the methods for economic valuation:
(Comments provided)

4.9 Do you think that the **list of policy instruments** we have provided in this questionnaire was:

	Useful	Clear	Complete
YES	2	3	1
NO	0	1	0
I DON'T KNOW	2	0	3
blank	23	23	23
sum of answers	4	4	4
	% (out of sum of answers)		
YES	50	75	25
NO	0	25	0
I DON'T KNOW	50	0	75

4.10 Additional comments provided on the policy instruments:
(Comments provided)

4.11 Do you have any specific comments/suggestions/wishes on the methodology for assessing and valuing ecosystem services in the project MARS what you would like to tell us?
(Comments provided)

Annex 7 – Glossary of terms

We provide below some definitions that clarify the use of certain terms in this report. Different disciplines may use different definitions; the ones we propose reflect the meaning we agreed in this work.

Ecosystem approach	It is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems (CBD, 2015)
Ecosystem service approach	It is a mechanism for integrating ecosystem services into public and private decisions. An ecosystem services approach seeks to integrate ecosystem services into decision-making by (a) using scientific c assessment tools to understand people's dependence and impact on the services provided by ecosystems and (b) applying policy mechanisms that incorporate ecosystem service values into the decisions made by governments, businesses, NGOs and individuals (McKenzie et al., 2008).
Integrated assessment	In the context of this report, it is a holistic evaluation of pressures, ecosystem state and ecosystem services in a certain case study, analysing in particular the links and interdependence among them. Here, ecosystem services can be quantified from a biophysical and/or economic perspective.
Ecosystem state or condition	The physical, chemical and biological condition of an ecosystem at a particular point in time (Maes et al. 2014)
Ecosystem service flow	*De facto* used set (bundles) of ecosystem services and other outputs from natural systems in a particular area within a given time period (Burkhard et al. 2014)
Inland waters	All standing or flowing water on the surface of the land, and all groundwater on the landward side of the baseline from which the breadth of territorial waters is measured (Directive 2000/60/EC). Depending on the position of that baseline in each country, inland waters may include transitional and coastal waters.
Water ecosystem services	In the context of this report, they are ecosystem services delivered by water bodies (the so-called aquatic ecosystem services) or water-dependant habitats (i.e. riparian zones, floodplains, wetlands)
Hydrologic ecosystem services	Ecosystem services that encompass the benefits to people produced by terrestrial ecosystem effects on freshwater (Brauman al. 2007). That is, they comprise all ecosystem services linked to a river basin or catchment area, thus joining water ecosystem services and some terrestrial ones.
Indicator	An indicator in ecology and environmental planning is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals (Heink and Kowarik, 2010)
Proxy	A figure that can be used to represent the value of something in a calculation (Oxford dictionary). Proxy data: data used to study a situation, phenomenon or condition for which no direct information - such as instrumental measurements - is available (EEA, 2015). Proxies are used as indirect indicators.

Stressors & Pressures	In MARS we refer to *stressor* as any environmental change in a factor that causes some response by the system of interest, e.i. organism, population, ecosystem (Odum, 1985). A *pressure* is the direct effect of a *driver*, which is any anthropogenic activity that may have an environmental effect (CIS guidance IMPRESS 2002). In this report we have used the terms *pressures* and *stressors* almost as synonymous, but we have tried to prefer the term *pressures* when the emphasis was on effects originated by anthropogenic causes (*pressures* are *stressors* originates by anthropogenic causes) or we wanted to make more explicit the link to the DPSIR scheme adopted by the WFD.

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