Deliverable D6.4

Version: FINAL
Date: 02/07/2013
Author: ECOLOGIC/JRC/UFZ
Dissemination status: PU
Document reference: Deliverable_D6.4

Manuscript on the Composite Ecosystem Services Approach to be applied to the BioFresh portal (M39)

STATUS: FINAL VERSION

Project acronym:	BIOFRESH
Project name:	Biodiversity of Freshwater Ecosystems: Status, Trends, Pressures, and Conservation Priorities
Call and Contract:	FP7-ENV-2008-1
Grant agreement no.:	226874
Project Duration:	01/11/2009 – 30.04.2014 (54 months)
Co-ordinator:	Leibniz-Institute of Freshwater Ecology and Inland Fisheries at Forschungsverbund Berlin e.V., Germany
Partners:	RBINS, Royal Belgian Institute of Natural Sciences, Belgium BOKU, Universität für Bodenkultur Wien, Austria ICLARM, International Center for Living Aquatic Resources Management, Malaysia IRD, Institut de Recherche pour le Développement, France UDE, Universität Duisburg-Essen, Germany IUCN, International Union for Conservation of Nature, Switzerland UOXF.AC, Oxford University, UK UB, Universitat de Barcelona, Spain UFZ, Helmholtz Zentrum für Umweltforschung, Germany UCL, University College of London, UK UCBL, Université Claude Bernard - Lyon 1, France UPS, Université Paul Sabatier- Toulouse 3, France ECOLOGIC, Ecologic GmbH Institut für Internationale und Europäische Umweltpolitik, Germany EC-ERC, Commission of the European Communities - Directorate General Joint Research Centre, Italy UD, University of Debrecin, Hungary NRM, Naturhistoriska riksmuseet, Sweden FIN, FishBase Information and Research Group, Inc.

BIOFRESH

Biodiversity of Freshwater Ecosystems: Status, Trends, Pressures, and Conservation Priorities

Project no. 226874

Large scale collaborative project

Deliverable number	D6.4
Deliverable name	Manuscript on the Composite Ecosystem Services Approach to be applied to the BioFresh portal
WP no.	WP6
Lead Beneficiary (full name and Acronym)	ECOLOGIC, Ecologic GmbH Institut für Internationale und Europäische Umweltpolitik, Germany
Nature	Manuscript
delivery date from Annex I (proj. month)	**M39**
Delivered	yes
Actual forecast delivery date	
Comments	See version history

Project funded by the European Commission within the Seventh Framework Programme Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

This project is supported by funding from the specific programme 'Cooperation', theme 'Environment (including Climate Change)' under the 7th Research Framework Programme of the European Union.

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This deliverable has been used as the basis for an article, which is currently under review by the 'Ecosystem Services: Science, Policy and Practice' journal (submission date: 25.3.13).

Version history

<table>
<tr><th>Version</th><th>Date</th><th>Author</th><th>Status and description</th><th>Distribution to</th></tr>
<tr><td>0.1</td><td>10/05/2012</td><td>McKenna Davis, Gerardo Anzaldua, Manuel Lago, Mathias Scholz, Wanda Born</td><td>Concept note presented at Oxford annual meeting</td><td>BioFresh consortium (task 6.4 side meeting)</td></tr>
<tr><td>0.2</td><td>10/10/2012</td><td rowspan="5">McKenna Davis, Gerardo Anzaldua, Manuel Lago, Núria Cid Puey, Mathias Scholz, Wanda Born, Ana Cristina Cardoso</td><td>Working draft</td><td>JRC (Núria Cid Puey and Ana Cristina Cardoso)</td></tr>
<tr><td>1.0</td><td>01/03/2013</td><td>Draft final</td><td>Jörg Freyhof, Daniel Hering, Christian Feld, Carla Pinho</td></tr>
<tr><td>1.1</td><td>16/04/2013</td><td>Request for input from Biodiversity Matrix (WP4), Climatic Vulnerability Index (WP5), Species Conservation Status (WP7) and other partners (case studies) at Leipzig annual meeting</td><td>BioFresh consortium</td></tr>
<tr><td>2.0</td><td>15/06/2013</td><td>Revised draft final</td><td>Jörg Freyhof, Daniel Hering, Christian Feld, Carla Pinho</td></tr>
</table>

Executive Summary

This deliverable of the FP7 BioFresh project investigates the **ecosystem services approach** (ESA) within a freshwater context. Specifically, four freshwater species and habitats (i.e. the beaver, peatlands, floodplains and lakes) are looked at in more depth to assess the practical application of the ESA at several scales. Following an extensive literature review, we identified the status quo of current research on the relationships between freshwater biodiversity, the provision of ecosystem services (ESS) and their integration into the ESA (chapter 2) as well as the knowledge gaps necessitating further research. Deliverable 6.4 responds to the identified need to account for the role of the cultural, economic and policy contexts in which ecosystem service assessments occur. In doing so, this report answers the question of how these contextual factors influence the holistic application of the ESA and impact the conservation of freshwater species and habitats.

The continued degradation of freshwater ecosystems and the loss of their biodiversity pose a major global threat to the sustainability of human livelihoods. The ESA has emerged as one response to accomplish more informed decision-making by which the objectives and efforts in nature conservation can be reframed to gain efficacy. However, the intended holistic character of the approach can be hindered by contextual factors influencing its practical application, i.e. elements leading to the prioritization or omission of certain ecosystem service types.

While individual components of the ESA and the relationship between biodiversity and ESS have been a central focus of scientific research, studies addressing variations in the application of the approach and the related contextual factors that lead to this variation remain elusive, particularly within a freshwater context. This report accordingly aims to address this important gap and - in doing so – to provide an impulse leading increased awareness and consideration of this topic and, ultimately, to improved implementation of the ESA.

This report therefore deals with the influence of contextual factors on ESA application in a freshwater context and subsequent impacts on decision-making. It begins by a targeted literature review to position the role of contextual factors within the broader discussions of ESA. Research to date on biodiversity and ESS provisioning, and particularly the lack of knowledge on freshwater biodiversity and ecosystems, is then outlined to provide the reader with an overview of the available knowledge on these topics. Finally, current relevant research being conducted within the European Union is presented in an effort to help conceptualize the important niche being addressed in this report, i.e. focusing on a *freshwater* context, investigating *how* the ESA is being applied in practice and highlighting the *factors affecting this application*.

The remainder of the report aims to find gaps between the practical application of the ESA in freshwater ecosystems studies and the relationship with contextual factors, as well as the perception of practitioners and scientists when identifying the ESS provided by such ecosystems. Accordingly, the results of a consultation exercise gathering the perceptions of a sample of practitioners and scientists working in a freshwater species conservation context is presented. The outcomes of this exercise are utilized within an analysis of the application of the ESA in four freshwater-focused case studies, illustrating evidence where ecosystem services assessment has helped to resolve management issues in practice and demonstrating in theory the level of consideration given to each ESS type when applying the ESA.

Several novel findings have been elucidated within this report, contributing to filling the previously identified knowledge gaps in this field. Three main contextual factors were found to exert an influence on the application of the ESA, namely: (1) individual perceptions and/or choices, (2) lack of data availability for ESS valuations and (3) scale of the ESA application. The report further elucidates a correlation between the contextual factors

surrounding the application of the ESS approach and the weight given to the different service categories. Whether intentional or subconscious, contextually induced biases have been shown to result in the under representation or omission of certain ESS categories and overestimation of others in applying the ESA. These possible biases can have important consequences for freshwater ecosystem and/or species conservation efforts by creating a scientifically unsubstantiated partiality in decision-making processes. Recommendations on how to more holistically apply the ESA and optimally account for contextual factors are presented, laying the foundation to support a more conscious freshwater management and sustain multiple, complementary services while minimizing negative trade-offs.

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1 Introduction

This deliverable investigates the **ecosystem services approach** (ESA) within a freshwater context, aiming to assess its practical application by focusing on four select species and habitats of particular relevance and therein also illustrates several scales at which the approach was applied. Following an extensive literature review focused at the European level, but also taking into account the global and local/regional scales, we were able to identify the status quo of current research on the relationships between (freshwater) biodiversity, the provision of ecosystem services (ESS) and their integration into the ESA (chapter 2) as well as the knowledge gaps necessitating further research.

The development of this task has been informed by the outcome of other Biofresh deliverables. Consultation of the biodiversity matrix[1] (from WP4), for example, supports our selection of beaver as a focus species within this deliverable. For those elements not directly addressed within this deliverable, we have explicitly highlighted where this information can be found within the context of published studies (chapter 2.1 and 2.2) and parallel ongoing European research efforts (see chapter 2.3).

In order to maximize the utility of this deliverable within the BioFresh project, we have focused on investigating the application of the ESA within a freshwater context. The literature review and emerging knowledge gaps highlight the need to more explicitly consider the role of the cultural, economic and policy contexts in which ecosystem service assessments occur (RUBICODE project: Harrison, 2009 and Reyers et al., 2013). Deliverable 6.4 responds to this need and answers the question of how these contextual factors influence the holistic application of the ESA and thereby impact the conservation of freshwater species and habitats. In answering this research question, we have outlined the ESS provided by the beaver as well as peatlands, floodplains and lakes in four in-depth case studies, also highlighting differences in assessments resulting from the respective scales analyzed.

1.1 Overview

The continued degradation of freshwater ecosystems and the loss of their biodiversity pose a major global threat to the sustainability of human livelihoods (Vescovi et al., 2009) and represent a growing need for more effective policy frameworks for nature conservation. The concept of *ecosystem services* (ESS) has emerged as a novel framework for approaching these trends due to its potential to explicitly link conservation and human well-being. While the concept was first used in the 1960s to refer to the benefits people obtain from ecosystems (MEA, 2003), research on the subject has increased significantly in the past two decades. In spite of this, only a very limited proportion of this new research has been dedicated to the exploration of contextual factors that influence the practical application of the ESA. This topic is of high relevance within the field of ESS and biodiversity since these contextual factors (the elements leading to the prioritization or omission of certain ecosystem service types) can play a significant role in reducing or facilitating the effectiveness of the approach by inter alia impacting its intended holistic character.

[1] The BioMatrix is a data repository of contemporary distributions of freshwater biodiversity created by the BioFresh project, largely drawn from species range maps, a range of environmental variables, species trait data and IUCN Red List species assessments, and mapped to the latest catchment layer; HydroBASINS. http://www.iucn.org/about/work/programmes/species/our_work/about_freshwater/what_we_do_freshwater/bio_fresh/

Given the extensive diversity of research currently being conducted in the field of ESS and biodiversity, this report aims to address an important gap within the discussions and – in doing so - provide an impulse leading increased awareness and consideration of this topic and, ultimately, to improved implementation of the ESA. Accordingly, this report is organized as follows.

- **Setting the frame**: A targeted literature review serves to position the role of contextual factors within the broader discussion of the ESA. Research to date on biodiversity and ESS provisioning, and particularly the lack of knowledge on freshwater biodiversity and ecosystems, is then outlined to provide the reader with an overview of the available knowledge on these topics. Finally, current relevant research being conducted within the European Union is presented in an effort to help conceptualize the important niche being addressed in this report, i.e. focusing on a *freshwater* context, investigating *how* the ESA is being applied in practice and highlighting the *factors affecting this application*.

- **Exploring the role of contextual factors in ESA application:** The remainder of the report aims to find gaps between the practical application of the ESA in freshwater ecosystems studies and the relationship with contextual factors, as well as the perception of practitioners and scientists when identifying the ESS provided by such ecosystems. Accordingly, we first analyze the application of the ESA and identified ESS provision in four freshwater-focused case studies, elucidating monetary values where feasible.

- **Results**: As a holistic application of the ESA entails consideration of the full range of ESS provided by the ecosystem or species in question, the ESS identified in each case study were enumerated according to the list provided in the consultation questionnaire. The results have been synthesized into a comparable tabular format and are subsequently clarified.

- **Discussion and conclusion:** The rationale behind why certain ecosystem service types are prioritized or omitted in applying the ESA is discussed, addressing an important gap within current research on the ESA, ESS and biodiversity. This report thus lays the foundation to support a more conscious management and application of the ESA in order to sustain multiple, complementary services and minimize negative trade-offs.

2 Setting the frame: ESA/ESS (freshwater) research to date

2.1 The ecosystem services approach

Recognition of shortcomings within the field of biodiversity conservation has led to the development of new ideas which extend beyond the traditional, single-sector conservation boundaries (Maes et al., 2012; TEEB Foundations, 2010) and instead recognize the potential for common ground between biodiversity conservation and ESS provision (Reyers et al., 2012). Given this background, the ESA has received significant attention for its potential to support multiple objectives and increase the embedding of nature protection issues into the political agenda, thereby facilitating more informed and impartial decision-making within relevant sectors (Haines-Young and Potschin, 2010), such as urban and regional planning, water, agriculture, energy, fishery, forestry, health, nature protection and tourism.

The Millennium Ecosystem Assessment (MEA, 2005) offered an initial structure for classifying both the tangible and intangible ESS derived by humans. The original categories included provisioning, regulating, cultural and supporting services.[2] Provisioning services, encompassing the products obtained from ecosystems, consist of e.g. food, water, fuel and medicines. Regulating services refer to, for example, air quality, climate and flood regulation as well as pollination and disease/pest control. The third category – cultural services – refers to the non-material benefits humans obtain from ecosystems, such as recreational opportunities, aesthetic enjoyment and spiritual enrichment. Finally, supporting services refer to e.g. photosynthesis, nutrient/water cycling and soil formation, which serve as the building blocks for the production of the other three classes of ESS.

Since the time of the MEA publication, numerous variations have been produced on this approach (Haines-Young and Potschin, 2011). For example, the TEEB Initiative (The Economics of Ecosystems and Biodiversity) – which aims to draw attention to the economic benefits of biodiversity – introduced the category of 'habitat services' to the established groups of provisioning, regulating and cultural services. Additional frameworks have also been discussed, for example in Wallace (2008), Costanza (2008), Fisher and Turner (2008), which serve to reevaluate the proposed categories and revise the utility of the current approaches based on the new knowledge currently being rapidly generated. Currently, a standardised classification system (Common International Classification of Ecosystem Services – CICES) is being developed with support from the European Environment Agency to assist their work in the area of land and ecosystem accounts and assist the development of support tools for managing natural capital (Haines-Young and Potschin, 2011).

2.2 Biodiversity and ecosystem service provisioning

The direction in which current environmental policies and scientific efforts are pointed suggests a growing recognition of the potential linkages between freshwater biodiversity and ecosystems and the continuity of crucial ESS. The Convention on Biological Diversity's Strategic Plan, for example, outlines the need to protect waters of importance to biodiversity and ESS (Target 11[3]) and the EU 2020 Biodiversity Strategy's headline target is to halt "the loss of biodiversity and the degradation of ESS in the EU by 2020, and restor[e] them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss"[4]. However, while the value of protecting ESS is widely acknowledged, the precise correlation between biodiversity and ESS provisioning remains a topic of debate (e.g. Elmqvist et al., 2010). One central outstanding question relates to the importance of biological richness to the functioning and thereby the provisioning of ESS within a given habitat (Fitter et al., 2010). While many examples exist that document the role of biodiversity in primary production, regulation, provisioning and cultural services (see e.g. Fitter et al., 2010; MEA, 2005), the mechanisms by which the delivery of these services are enhanced remain a topic of contestation (EASAC, 2009).

Consequently, numerous research projects and an extensive body of literature have arisen with the aim of increasing the knowledge basis of this relationship and furthering the discussion. Within the BiodivERsA network, for example, a European call on *"biodiversity and ecosystem services"* was launched in November 2010, through

[2] See www.millenniumassessment.org for additional information and examples.
[3] *Implementation of the Conference of the Parties to the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011–2020* (Decision X/2, Target 11: "at least 17 per cent of terrestrial and inland water areas,…especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of PAs and other effective area-based conservation measures, and integrated into the wider landscapes…"
[4] European Commission (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020 (COM(2011) 244). Brussels 3.5.2011. URL: http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7%5b1%5d.pdf

which 7 projects were selected for €9.5M[5]. Additional examples of relevant projects and initiatives are outlined in Table 2, providing a setting for this report's focus area and approach.

ESS and biodiversity from a freshwater perspective

Despite the aforementioned growing body of research on ESS and their correlations with biodiversity, the application of these concepts for the study and conservation of freshwater contexts remains more limited than is the case for other ecosystem types. Current evidence on the relationships between freshwater biodiversity and ecosystem functioning has been deemed "insufficient or equivocal, and the science is not sufficiently mature to allow detailed predictions of precise outcomes of biodiversity loss or management needs for fresh waters" (Cowx, 2011). Several of the limitations and knowledge gaps are outlined here.

To begin, there is a lack of information regarding the functional roles and ecology of many freshwater species, and in particular groundwater species (Boulton, 2009). Furthermore, there is a lack of established indicators integrating key structural and functional aspects of the ecosystems under study (Schneiders et al., 2011) and the majority of existing evidence stems from theoretical, controlled-environment and small scale field studies instead of from mature, natural systems (EASAC, 2009).

While effects on provisioning services are more straightforward, changes on regulating and supporting services remain difficult to quantify (Kettunen and ten Brink, 2006). Added complications arise from the "longitudinal nature of river systems and the associated connectivity, which make rivers act as conduits for threats emanating from upstream" (Amis et al., 2009). Rivers are further constrained by catchments, which results in them being affected by both local and upstream conditions and water flows between catchments.

Finally, the issue of scale and accordingly the relationship between ESS provided by specific freshwater species and the habitats in which they exist are lacking. One challenge is to distinguish between species value versus biomass in fish production; for example, threatened or endemic species are very often more valuable in a cultural or ethical perspective, which is difficult to measure.

Taking these challenges into account, the most comprehensive study which has been produced on freshwater biodiversity and ecosystem service provision to date is that of Cowx (2011). Utilizing the Millennium Assessment goals categorization (2005), Cowx identified 26 ESS supported by freshwater fish conservation and highlights the services provided by freshwater ecosystems to society (see Table 1).

[5] See http://www.biodiversa.org/2 for more information.

Table 1. Provision of ecosystem services by freshwater fish conservation

Category	Ecosystem services
Provisioning services	Food provision: extraction of aquatic organisms for human consumption
	Raw materials: extraction of minerals and organisms not for human consumption
	Transport and navigation: user of waterways for shipping and communication
	Energy: non-consumptive use of the aquatic environment for energy generation, i.e. hydropower
	Water resources: abstraction of water for agricultural, domestic and industrial purposes
Regulation services	Climate regulation: balance and maintenance of the atmosphere, e.g. flooded forests and plant production
	Disturbance prevention: flood and storm protection by natural flooding processes
	Bioremediation of waste: effluent cycling and removal of pollutants by capture in sediments; fishes may maintain healthy aquatic systems that favour these processes
	Fish as bioindicators
Cultural services	Religious symbols
	Dietary symbols, particularly demonstrating wealth
	Cultural heritage and identity: value associated with freshwater environments themselves
	Cognitive values: education and research resulting from the freshwater ecosystems
	Leisure and recreation: ornamentals and pleasure and sport fishing
	Leisure and recreation: active and passive use of aquatic systems for non-consumptive human pleasure, stimulation and well-being
	Psychological and physiological values
	Existence: value derived from the aquatic environment without using it
Support services	Control of pest organisms
	Resilience and resistance: life support by the freshwater environment and its response to pressures, including maintenance of ecosystem balance
	Biologically mediated habitat: habitat provided by aquatic organisms
	Physical habitat: habitat provided by the physical (non-living) environment
	Flood retention: management and control of flood risk
	Flood forests: carbon capture
	Nutrient cycling: the storage, cycling and maintenance of nutrients by aquatic environment
	Nutrient transfer upstream migration by anadromes in nutrient poor regions
	Food base for many mammalian, bird and reptilian predators

Several further studies have been produced which concentrate on ecosystem service provision in relation to *specific types of freshwater ecosystems* (e.g. Born et al., 2012; Dugan et al., 2010; Ghermandi et al., 2009; O'Higgins, 2010; Sethogile, 2011; Wilson et al., 1999; Engelhardt and Ritchie, 2001; Kettunen and ten Brink, 2006; Lecerf and Richardson, 2009) or *species* (e.g. Anderson and Rosemond, 2007; Boulton et al., 2008; Covich et al., 1999; Covich, 2004; Collen and Gibson, 2001; Dumbauld, 2009; Gamfeldt, 2008; Smith, 2010; Canni, 2002; Kettunen and ten Brink, 2006; Holmlund and Hammer, 2004; Taylor et al., 2006; Vaughn and Hakenkamp, 2001; Vaugh, 2010). Kettunen and ten Brink (2006), for example, highlighted the negative impacts of both sudden and gradual species declines on ESS. Frequently lost or degraded services were identified as: food and fresh water supply, nutrient cycling, water purification, waste management and recreation and tourism (cultural services).

2.3 The context of EU research on ESS/ESA

In addition to the outlined academic exercises investigating the relationship between biodiversity, ESS and the ESA, numerous ongoing research projects are being conducted on these topics. In order to position our work within this framework, Table 2 highlights the most relevant European research projects focusing on ESS/ESA and biodiversity.

Table 2. The context of EU research on ESS/ESA

Project or initiative title	Brief description	Time-frame
TEEB (The Economics of Ecosystems and Biodiversity)[6]	A global initiative focused on drawing attention to the economic benefits of biodiversity. Its objective is to highlight the growing cost of biodiversity loss and ecosystem degradation. TEEB presents an approach that can help decision-makers recognize, demonstrate and capture the values of ecosystems & biodiversity, including how to incorporate these values into decision-making	2007 - ongoing
Biodiversity & Ecosystem Service Sustainability (BESS)[7]	Research program designed to reduce uncertainty about the functional role of biodiversity in key ecosystem processes and the delivery of ecosystem processes at the landscape scale and how these are likely to change in an uncertain future	2011-2017
Urban Biodiversity and Ecosystem Services (URBES)[8]	Addresses significant scientific knowledge gaps on the role of urban biodiversity and ecosystem services for human well-being	2011-2014
CONNECT[9]	Linking biodiversity conservation and ecosystem services: advancing insights in tradeoffs and synergies between biodiversity, ecosystem functionning and ecosystem service values for improved integrated biodiversity strategy.	2012-2014
RUBICODE - Rationalising Biodiversity Conservation in Dynamic Ecosystems[10]	Aiming to develop and apply concepts of dynamic ecosystems and the services they provide and explore relationships between service-providing populations, ecosystem resilience, function and health, and socio-economic and environmental drivers of biodiversity change	2006-2009

[6] http://www.teebweb.org/
[7] http://www.nerc-bess.net/
[8] http://urbesproject.org/
[9] http://www.connect-biodiversa.eu/
[10] http://www.rubicode.net/rubicode/index.html

OPENNESS (Ecosystem services – from concepts to real-world applications)[11]	Aims to translate the concepts of Natural Capital and Ecosystem Services into operational frameworks that provide tested, practical and tailored solutions for integrating ES into land, water and urban management and decision-making	2012-2017
POLICYMIX[12]	Assessing the role of economic instruments in policy mixes for biodiversity conservation and ecosystem services provision	2010-2014
OPERAs[13]	An initiative to define whether, how and under what conditions the concepts of Ecosystem Services and Natural Capital can be transferred and applied to the actual management of a variety of ecosystems in order to enhance human well-being.	2012-2016

As evidenced by the above table as well as the preceding literature review, individual components of the ESA as well as the relationship between ESS and biodiversity have been or are currently being extensively researched, However, the interactions between natural and social systems remain more elusive and have only been looked at in a limited number of studies (e.g. Bennett et al, 2009; Martin-Lopez, 2012; Rodríguez et al, 2011) and are only touched upon in the RUBICODE and OPENNESS projects.

To effectively incorporate the ESA into policy, the RUBICODE project outlines that research on the relationships between governance, public perceptions and attitudes, planning and communication is necessary; more specifically, the role of the cultural, economic and policy contexts in which ecosystem service assessments occur should be more explicitly considered (Harrison, 2009). In order to maximize the breadth of knowledge being generated at this nexus, this report fills a clear gap within current research activities and in the literature published to date by looking at the role of contextual factors in applying the ESA in a freshwater context.

2.4 Policy-led initiatives: Working Group MAES

The Working Group on Mapping and Assessment on Ecosystems and their Services (MAES) was set up under the Common Implementation Framework (CIF) to support the implementation of Action 5 of the EU 2020 Biodiversity Strategy. The Group is composed of Member State representatives, scientific experts, the EEA and EU staff members. Action 5 is one of the keystones of the strategy providing a knowledge base for Europe's green infrastructure, the restoration of 15% of degraded ecosystems and the No Net Loss of biodiversity.

The WG MAES works on a conceptual framework for mapping and assessment linking human well-being to biodiversity and proposals for a typology of ecosystems and ecosystem services. It includes description of the ecosystem function both at present and in the future. Biodiversity is the focus of the ecosystem description. It addresses the linkage between ecosystems and socio-economic systems.

The MAES includes six thematic pilots to test the framework, including one focused on the freshwater environment. The objective of the pilots is to provide a set of recommendations by end 2013, which will help Member States with their assessments. Each pilot will examine and report data needs to complete the ecosystem assessments. Each pilot is led by a Member State and an EC service and draws on the active contributions of EU and MS working together. The project will continue until 2020. Deliverables include an EU report on how far MS were able to map and assess ecosystems and their services in 2014/15 and a mid-term report in 2016.

[11] http://www.openness-project.eu/
[12] http://policymix.nina.no/
[13] http://operas-project.eu/operas/index.html

3 Exploring the role of contextual factors in ESA application

Given this framework, this chapter addresses current gaps in freshwater research by concentrating on the importance of social considerations in applying the ESA. More specifically, the different perspectives existing in the identification of ESS types are focused on (Martin-Lopez et al., 2012). Within a freshwater context, for instance, a lake can be valued by conservationists for habitat provision, by fishermen for supporting desirable fish populations and by outdoor enthusiasts for providing recreational opportunities and aesthetic beauty. This can result in an under- or over-representation of certain ecosystem service categories when applying the ESA (e.g. in not quantifying or valuing certain ecosystem service types or not incorporating them in scenario developments) and subsequently threaten ecosystem and species conservation efforts in decision-making processes.

In this context, environmental management decisions predominantly occur between provisioning services and regulating/cultural services while supporting and cultural services are more often ‘taken for granted’ (Martin-Lopez, 2012; Rodríguez et al., 2006; Schaich et al., 2010; Molnar and Kubiszewski, 2012). The different perspectives on this topic can be expected to result in variations in the prioritization of certain ecosystem service types over others and thus in inconsistencies in the application of the ESA.

In applying the ESA, the interactions between natural and social systems are central as they can serve to highlight conflicts of interest between different stakeholders in the use and delivery of different ecosystem service types (Castro et al., 2011) and present trade-offs and synergies between the provisioning of different ESS. Although individual components of the approach are a central focus of scientific research (e.g. biophysical functioning, the provisioning of ESS and their economic valuation), knowledge on the consideration of contextual factors in the application of the ESA in conservation management remains elusive (i.e. the elements surrounding ESA implementation which lead to the prioritization or omission of certain ecosystem service types).

The interplay between these aspects has primarily been looked at in utilizing social preferences[14] to value ESS (e.g. Castro et al., 2011; Garcia-Llorente et al., 2012), but few studies have addressed the biases towards the selection of ecosystem service types using a non-economic approach focusing on contextual factors (Martin-Lopez, 2012) and none have been identified which adopt a freshwater perspective. Attention is therefore drawn here to the role of contextual factors in the application of the approach and the potential consequences for freshwater conservation efforts.

The following sections thus aim to find gaps between the practical application of the ESA in freshwater ecosystems studies and the perception of practitioners and scientists when identifying the ESS provided by such ecosystems. First, we performed a consultation exercise on a sample of scientists and practitioners working with freshwater ecosystems. Second, we analyzed the application of the ESA and identified ESS provision within four freshwater-focused case studies. Third, we compared the ESS from the case studies with those identified in the consultation. The rationale behind why certain ecosystem service types are prioritized or omitted is discussed, laying the foundation to support a more conscious management and application of the ESA in order to sustain multiple, complementary services and minimize negative trade-offs.

[14] The term *social preferences* “incorporates individual perceptions, knowledge and associated values” (Martin-Lopez et al., 2012: 2) into ecosystem service management discussions.

3.1 Methodology

3.1.1 Consultation of scientists and practitioners

A consultation exercise exploring the perceptions of scientists and practitioners on the ESS provided by freshwater organisms and ecosystem types was performed. The methodology of the consultation followed the questionnaire sampling technique applied to gather information on England's terrestrial habitats by Haines-Young and Potschin (2008). This involved distributing a questionnaire to approximately 35 BioFresh consortium members and 15 external European experts active in the field of freshwater conservation, policy or research. Information on what these individuals perceived to be the main types of services and wider benefits delivered by 5 freshwater species (groups) and 5 freshwater ecosystem types (see Table 7) was requested. Ultimately, 22 individuals provided input on the questionnaire.

While numerous frameworks and opinions exist regarding the categorization of ESS (Bastian, 2013), the ecosystem service classification of TEEB (2010) was used to build the questionnaire provided to respondents. The species (groups) and ecosystem types were selected for their relevance to the work and expertise of the survey sample and to the chosen case studies in order to facilitate enhanced comparability of the results. Accordingly, amongst the species and ecosystems investigated are those explored in the four case studies (i.e. beaver, peatlands, floodplains and lakes).

The case study analysis is the complementary part of this work and provides a quantitative and qualitative overview of the ESS taken into in the examined case studies. Findings of the comparative analysis between the consultation of practitioners and scientists and the case studies is then presented in Table H and discussed in the final section of the report.

3.1.2 Selection of freshwater case studies

Four case studies have been collected for analysis, covering a range of criteria of relevance for freshwater conservation discussions. The selected studies look at peatland conservation in Belarus, beaver reintroduction in Germany, maintenance of active floodplains in Germany and lake district management in the US. Each of these case studies has been selected for (1) its application of the ESA within a freshwater context and (2) its inclusion of sound quantitative data in at least part of the analysis, including economic values where applicable. Given the extremely limited availability of studies meeting these criteria, it must be acknowledged that the chosen cases focus on either management, conservation or restoration efforts at the local or regional scale. Furthermore, three case studies look at ecosystems while only one is concerned with a species (group). This could be seen as confirmation of the lack of literature on freshwater species and their role in ecosystem service provision. These case studies nevertheless provide an array of valuable insights into the various potential applications of the ESA and the contextual factors surrounding them. A brief background to each case study is provided below, as well as a description of how the ESA was applied.

It should be noted that the debate on the legitimacy of the ESA for biodiversity conservation, as well as that of the various monetary valuation techniques applied within each case study has been and continues to be extensively discussed in the literature as well as in current research projects (see Table 2 and e.g. Atkinson et al, 2012; Helm and Hepburn, 2012), and thus has deliberately been left outside the scope of our research in order to focus our efforts on the less explored, more elusive aspects of the ESA. On this basis, differences in the application of the approach are the focus of this analysis, serving to highlight the influence of contextual factors on political decision-making processes and subsequently on continued ESS delivery. Furthermore, while the contextual factors highlighted in the results are limited to those of relevance to the case studies, it is also important to recognize the numerous additional factors which can potentially influence the application of the ESA. These supplementary points also warrant further research and are thus highlighted in the conclusion.

Rewetting and sustainable peatlands management in Belarus (from Anzaldua and Gerdes, 2011; Naumann et al., 2011)

Given the existing dichotomy between two of the main services provided by peatland ecosystems, namely carbon sequestration and fuel provision, a vibrant discussion about the management of these habitats is currently taking place both in national and international fora. In an attempt to identify the costs and benefits of peatland restoration efforts, the Belarus Project introduced a valuation exercise from an ESA perspective using market prices and applying the avoided damage costs method (calculating the cost of avoiding CO_2 emissions and peatland fires). By lending weight to the ecological and socio-cultural values in addition to the economic aspects, the diverse user demands on the peatland habitats could be more accurately evaluated in order to weigh trade-offs and successfully deliver multiple functions in the long-term. The values of carbon storage and the other ESS enhanced or maintained through the project activities were accordingly assessed and provided the foundation for informed decision making for the management of the area.

Background
Peatland covers an extensive area of the Belarus territory. Around half of this area has been affected by drainage and peat extraction activities, resulting in extensive fragmentation and negative consequences for numerous species. Accordingly, the Belarus Project was undertaken by an international consortium of environmental organizations with an overall budget of €2.5 million. These organizations combined their experience in peatland restoration and management with an innovative methodology to assess carbon emissions reductions from such ecosystems. The key project objectives of this case study were to rewet 14,000 ha of degraded peatland, quantify greenhouse gas emissions from degraded and re-wetted sites, increase carbon storage in re-wetted sites, increase the number and abundance of wetland species and develop a framework that allows for the sustainable use of peatland.

Ecosystem services provided and their benefits
An initial analysis suggests that carbon emissions reduction via sequestration and storage are estimated at 2.9 t CO2/ha/year. In addition to mitigation, the project also contributes to climate change adaptation through micro-climate regulation, soil degradation prevention, water regulation and retention and peat fire prevention. In the short-term, the project is expected to provide jobs through the research, construction, supervisory, maintenance and monitoring work. In the long run, biomass harvesting jobs could emerge and the Academy of Sciences of Belarus plans to set up a laboratory for GHG emission measurements. At the time the study was conducted, about 25 management jobs were being provided through the project. In the future, the project might also have a positive impact on eco-tourism in the region. These aspects and an estimation of their values in monetary terms where relevant are presented in Table 3 below.

Table 3. Ecosystem services and, where appropriate, valuations of peatlands

Service Type		Benefits provided	Valuation Method	Value
Provisioning	Food	a) Cranberry, Blueberry, Mushrooms, Fish, Game (respectively)	1 ton/yr at market price: 1.67 €/kg; 0.5 ton/yr: 0.84 to 1.12 €/kg; --; 5kg/day: 0.84 €/kg; --	1,670 €/yr; 490 €/yr; --; 222 €/yr; --
	Genetic resources	b) Estimated 200-300% increase in biodiversity (Dokudovskoe)		
	Ornamental resources	-		
	Raw materials	c) Biomass and organic fertilizer production		
	Transport and navigation	-		
	Human habitat	-		
	Fresh water	d) Water regulation and retention through the construction of dams and reservoirs (stabilization of the water level)		
	Medicinal resources			
	Water			
Regulation	Air quality regulation	e) Carbon emissions reduction via sequestration and storage f) Avoided emissions from peat fires	ca.50% of peat composition is C): estimated 2.9 tCO2e/ha*year	
	Soil formation /conservation	g) Protection from soil degradation		
	Moderation of extreme events	h) Prevention of peat fires (Dokudovskoe)	Avoided expenditure from peat fire prevention and reduced frequency of peat fires	4,725 € 6,871.17 €
	Erosion control	i) Erosion and peat storm control		
	Bioindicator			
	Climate regulation	See e) and f) j) Micro-climate regulation (control of frost and humidity)		
	Pest regulation			
	Water purification, waste treatment, pollution control	See d)		
	Biocontrol	k) Maintenance of suitable conditions for species		
	Pollination			

	Regulation of waterflows/hydrological regimes	See d)		
Cultural	Aesthetic value	l) Enhanced aesthetic conditions of the area (Dokudovskoe)		
	Spiritual & religious value	-		
	Cultural heritage and identity	m) Peatlands in the region are seen by locals as "the lungs of Europe"		
	Information for cognitive development			
	Recreation & tourism/ Ecotourism, Wilderness	n) Establishment of two ecological paths for education and bird-watching purposes (Dokudovskoe)		
	Cultural heritage, sense of place, inspiration value	o) World War II partisans used peatland as a hideout		
	Educational values	p) Planned establishment of a museum with peatlands exposition		
Habitat	Biodiversity and nursery	See k) q) Increased habitat connectivity and ecosystem resilience		
	Gene pool / endangered species protection	r) Insurance of active and effective population dispersal and exchange		
	Nutrient cycling	See d) and g)		

Conservation of floodplains in Germany (from Scholz et al., 2012a)

This case study utilized the ESA to support decision making processes regarding the preservation and expansion of active floodplains in Germany. By focusing on the provisioning of four ESS (nutrient retention, carbon sequestration, flood prevention and habitat provision), the case aimed to highlight the value of German floodplains at the landscape scale based on an extensive ecological data base, which has often been neglected in the case of evaluating ESS in economic terms (Carpenter et al. 2009, Kremen 2005).

Background

The floodplains of rivers in Germany, and particularly freshwater floodplains, have been recognized for their ability to provide various ESS. Services include supporting biodiversity hotspots and recreational activities, serving as freshwater reservoirs, carbon sinks and retention areas during floods, and providing space for farmland and settlements (Scholz et al. 2012). Today, however, only 30% of the floodplains of larger rivers in Germany are still active (i.e. inundated frequently) and 54% of the former floodplains have been severely or completely modified (Brunotte et al. 2009). Alongside large rivers like the Rhine, Elbe, Danube or Odra, currently only 10-20% of active floodplains can be found. One third of the remaining active floodplain area is shaped by intensive agriculture, 46% are grasslands and only 13% are covered by wetland forests (ibid). This large usage pressure from provisional services like agriculture, gravel mining, urbanization and transport on the one hand and the importance of intact areas for delivering regulating services (e.g. flood water detention, carbon sequestration, nutrient retention and habitat function) and contributing to human well-being on the other hand has led to a critical discussion on how to preserve and best extend the remaining active floodplains.

Table 4. Ecosystem services and, where appropriate, valuations of floodplains

Service Type		Benefits provided	Valuation Method	Value
Provisioning	Food			
	Genetic resources			
	Ornamental resources			
	Raw materials			
	Transport and navigation			
	Human habitat			
	Fresh water			
	Medicinal resources			
	Water			
Regulation	Air quality regulation	Carbon emissions reduction via sequestration (Mehl et al. 2012b) and storage above ground in forests and in soils (Scholz et al. 2012b)	Quantification of carbon stocks by use of case studies and soil maps, Assessment of the potential GHG emissions based on emission rates of CO_2 on different land use intensities on organic soils (Mehl et al. 2012b) Avoided damage cost approach: Environmental damage costs (external costs) for one t CO_2 = 13.82 €/t CO_2 and 70 € t-1 CO_2 (damage price) (Born et al. 2012)	Carbon stocks of alluvial soils in active floodplains = 158 million t C (equivalent to 578 million CO2e; e = equivalent) Organic soils of peatlands (70%) = 107 million t C) (Scholz et al. 2012b) Degraded peatlands' emissions = 2.53 million t CO2-equivalents/yr (equivalent to between 35 million €/yr (market price of 13.82 €/t CO2) to 177 million €/yr (damage costs of 70 €/ t CO2) (Born et al. 2012)
	Soil formation/ conservation			
	Moderation of extreme events	Flood control	Qualitative assessment procedure establishing the degree of retention loss caused by anthropogenic activities Asset estimation (for values in floodplains -housing, infrastructure, etc.) (Born et al. 2012)	Value of built assests in (Born et al. 2012): Inactive floodplains behind dykes = approx. 267 billion € Active floodplains = 35 billion €

	Erosion control			
	Bioindicator			
	Climate regulation			
	Pest regulation			
	Water purification, waste treatment, pollution control			
	Biocontrol			
	Pollination			
	Regulation of waterflows /hydrological regimes			
	Nutrient cycling	Nutrient retention Phosphorus retention Nitrogen reduction	Phosphorus retention derived from sedimentation rates based on proxies (e.g. roughness values, derived proxy values) Replacement cost approach (60 € t^{-1} P per year); Average value is 155 € ha^{-1} per year (Born et al. 2012) Nitrogen retention based on denitrification rates determined for water bodies and soil for active floodplains (Schulz-Zunkel et al. 2012) Replacement cost approach (6 € t N per year); Average values from 646 €/ha to 788 €/ha/yr	Phosphorous retention = 1,200 tons a^{-1} in floodplains and 278 tons a^{-1} in riparian zones Nitrogen retention = 42,000 t a^{-1} (Schulz-Zunkel et al. 2012) Annual marginal costs for nitrogen and phosphorous retention in active floodplains = ca. 252 million € and 72 million €, respectively Potential between 370 Mio. € $^{y-1}$ (max) and 451 Mio. € y^{-1} (min) for river and floodplain retain together (Born et al. 2012)
Cultural	Aesthetic value			
	Spiritual & religious value			
	Cultural heritage and identity			
	Information for cognitive development			
	Recreation & tourism/			

	Ecotourism, Wilderness			
	Cultural heritage, sense of place, inspiration value			
	Educational values			
Habitat	Biodiversity and nursery	Habitat value	Ascertained by linking characteristics of sites belonging to Natura 2000 areas, wetland habitats and protected biotopes, land use intensity and backwater areas, providing an index for species and habitat biodiversity typical of floodplains in man-made and natural landscapes (Scholz et al. 2012c)	In Germany, 4 % of remaining active floodplains are very highly significant for the species and habitats found in floodplains, compared to 27% of active floodplains that are highly significant and 22% that are of medium significance. 47 % of active floodplains were found to have a low or very low significance as habitats for species communities typically found in floodplains (Scholz et al. 2012c).
	Gene pool and endangered species protection			

Beaver reintroduction in Germany: Restoring ecosystem services by reintroducing a keystone species (from Bräuer, 2002)

This case study provides an analysis of the benefits arising from the restoration of an ecosystem and its services via the reintroduction the European beaver to the river-floodplain system in Hesse, Germany. It deals with the integration of environmental goods in economic decision processes, evaluating the conservation of an endangered species and its biosphere, the floodplains and the resulting changes in the surrounding landscape, ecosystem functions and biodiversity. Quantitative data was gathered via monitoring exercises and aerial images and models (Behrend and Optitz, 2000); additional methodological details can be found in Bräuer (2002).

Background

European beavers (*Castor fiber*), a keystone species of aquatic ecosystems, once occurred throughout Europe, but were exterminated or heavily reduced by over-hunting and, to a lesser extent, habitat destruction in many countries (Nolet and Rosell 1997). Through the building of dams, burrows, lodges and canals, they can significantly modify the structure and dynamics of aquatic ecosystems. This natural disturbance of ecosystems contributes to a higher level of biodiversity both on a species as well on an ecosystem level[15]. The reintroduction program investigated in this study is a combination of species and habitat conservation programs as designed by conservation experts. The program was launched in 1987/88 by the Naturschutz und Landesforstverwaltung Hessen and is located in the Spessart Mountains in Hesse, Germany. The program consists of two parts: (i) an introduction and (ii) measures to revitalize flood plains. In the context of this scheme, 18 beavers were released and buffer strips were purchased and managed. Since the introduction, population numbers have been seen to consistently increase and the population is now viable.

Ecosystem services provided and their benefits

The social benefit of the beaver and floodplain conservation are substantial. From an economic point of view, the Hessian Program for the Reintroduction of Beavers has to be considered as efficient. This efficiency means that within the framework of the program, public money was spent according to the taxpayers' preferences. Of special interest in this case study is that the estimated benefits of the altered ecosystem service as a product of a species conservation program offset a significant part of its overall costs; however, the results of this analysis have to be carefully transferred to other regions as the consequences of a beaver reintroduction depend on the local conditions.

[15] Moderate levels of disturbances within an ecosystem can lead to greater diversity by generating a patchwork of species populations and successional stages which are more fully able to use the available environmental resources.

Table 5. Ecosystem services and, where appropriate, valuations of beaver

Service Type		Benefits provided	Valuation Method	Value
Provisioning	Food			
	Genetic resources			
	Ornamental resources			
	Raw materials			
	Transport and navigation			
	Human habitat			
	Fresh water			
	Medicinal resources			
	Water			
Regulation	Air quality regulation			
	Soil formation / conservation			
	Moderation of extreme events	Flood protection (lower running velocity)		
	Erosion control	Erosion control (riverine vegetation)		
	Bioindicator			
	Climate regulation			
	Pest regulation			
	Water purification and waste treatment, pollution control	Nitrogen retention (2800 kgN/a in the river; 1900 kgN/year in the floodplains)	Equivalent cost via manmade technical solutions (€2.56 /kgN agri-env schemes; €7.68 /kgN in sewage plants)	€12,000/year (agri-environmental measures) or €36,000/year (sewage plants) = €250,300
	Biocontrol			
	Pollination			
	Regulation of waterflows/ hydrological regimes	Additional space for retention		
al	Aesthetic value	Altered landscape appearance		€17 million (for assumed project duration of 25 years)
	Spiritual & religious value			

	Cultural heritage and identity	Conservation of endangered species and ecosystem: rearrangement of rivershore	Contingent valuation method	
	Information for cognitive development			
	Recreation & tourism/ Ecotourism, Wilderness	Alteration in the structure of the river bed (increase of river surface by 17%)	Contingent valuation method	
	Cultural heritage, sense of place, inspiration value			
	Educational values	Observation of species	Contigent Valuation method	
Habitat	Biodiversity and nursery	Increased level of biodiversity Creation of new habitats	WTP ranged from €0.74 to €1.11 per person per day's visit	at least €550,000 per year
	Gene pool and endangered species protection	Maintenance of endangered species	Contingent valuation method	
	Nutrient cycling	see "water purification"		

Assessing the consumer surplus of angling to promote better management of less-visited lakes in the US (from Chizinski et al., 2005)

This case study is based on the article by Chizinski et al. which presents the potential for achieving more cost-effective lake district management by assessing the economic value of less-known water bodies. The article provides an outline of the consumer surplus levels of recreational anglers in Lake Kemp, Texas. Calculations were based on a year-long survey program to gather data from the reservoir's visitors. The surveys used for the exercise were those from respondents whose main recreational activity during their stay at the lake was angling.

Background

Large, well known water bodies which are commonly visited by the more than 27 million freshwater anglers in the US have frequently been the subject of economic valuation studies. On the other hand, lakes, rivers and fisheries which are lesser in size and popularity among sports fishermen have been generally left out of the picture. This type of water bodies provide recreational/cultural ESS which are distinct from those offered by their counterparts precisely due to their secluded, local character. These traits cater to the preferences and motivations of specific users, who may attach a significant value to the benefits obtained from less-visited reservoirs. Visitors of Lake Kemp, on the Wichita River in Texas, were surveyed between May 2000 and May 2001 by a team of the Texas Tech University and the US Army Corps of Engineers. Information on lodging costs, transportation costs, and recreational costs inter alia was gathered throughout the year to conduct a valuation of the lake's fishery using the single site travel cost model (Huppert 1989; Whitehead 1992).

Ecosystem services provided and their benefits

Lake Kemp provides freshwater resources for agricultural, industrial and municipal use and also functions as a means of flood protection for the area. In addition, the average per-day consumer surplus for recreational anglers calculated by Chizinski et al. ranged from US$61 to US$122. Given the larger number of small reservoirs like Lake Kemp found throughout the US in comparison to larger ones, factoring in the economic value of benefits obtained by their users could allow for a better planning of the expenditure dedicated to the management of water bodies across the country.

Table 6. Ecosystem services and, where appropriate, valuations of Lake Kemp

Service Type		Benefits provided	Valuation Method	Value
Provisioning	Food	-		
	Genetic resources	-		
	Ornamental resources	-		
	Raw materials	-		
	Transport and navigation	-		
	Human habitat	-		
	Fresh water	-		
	Medicinal resources	-		
	Water	Used by agriculture, industry, and municipalities	-	-
Regulation	Air quality regulation	-		
	Soil formation / conservation	-		
	Moderation of extreme events	Flood control	-	-
	Erosion control	-		
	Bioindicator	-		
	Climate regulation	-		
	Pest regulation	-		
	Water purification and waste treatment, pollution control	-		
	Biocontrol	-		
	Pollination	-		
	Regulation of waterflows/hydrological regimes	-		
Cultural	Aesthetic value	-		
	Spiritual & religious value	-		
	Cultural heritage and identity	-		
	Information for cognitive development	-		

	Recreation & tourism/ Ecotourism, Wilderness	Recreational angling, boating, swimming	Travel cost method (single-site travel cost model)	Average per-day consumer surplus for recreational anglers: $61–122 (depending on the wage rate fraction assigned to the opportunity cost of time).
	Cultural heritage, sense of place, inspiration value	-		
	Educational values	-		
Habitat	Biodiversity and nursery	-		
	Gene pool and endangered species protection	-		
	Nutrient cycling	-		

3.2 Results

As a holistic application of the ESA entails consideration of the full range of ESS provided by the ecosystem or species in question, the ESS identified in each case study were enumerated according to the list provided in the consultation questionnaire. The results have been synthesized into a comparable format (see Tables 7 and 8) and are subsequently clarified.

3.2.1 Consultation exercise on the perceptions of practitioners and scientists working with freshwater ecosystems

The results of the conducted questionnaire are provided in Table 7. More specifically, the filled in squares in the figure represent at least 16 responses that identified an association between a given service type and the different freshwater groups and ecosystems. These results indicate that peatlands and floodplains are perceived as providers of a higher number of ESS (25 out of the 30 listed) than rivers and lakes, while groundwater bodies are associated with less than one-third of the ESS listed. In addition to (the expected) habitat services, cultural services were the most frequently associated with the listed ecosystem types, excluding groundwater. Free flowing rivers were generally seen as providing only 1 out of 11 listed regulation services (i.e. water purification and waste treatment, pollution control). Regarding freshwater groups, macrophytes, fish and birds were generally identified as providing the most ESS (13, 12, and 11 out of 30, respectively), while beavers and invertebrates were related to less than one-fourth of the ESS listed. The predominant ESS associated to these groups were habitat services (for the beaver and macrophytes) and cultural services (for fish and birds). At the same time, neither provisioning nor regulation services were seen as being provided by beavers.

The findings from this exercise provide a pilot framework by which to evaluate the application of the ESA within the case studies. Additionally, the exercise helps to illustrate inconsistencies between the stated perceptions of the sample and the practical integration of the different ecosystem service types in the assessments carried out in the case studies (see Table 9).

Table 7. Association between ecosystem service provision and select freshwater species (groups) and ecosystems*

		Freshwater species (group)					Freshwater ecosystem type				
	Service Type	Fish	Beaver	Invertebrates	Macrophytes	Birds	Peatlands	Floodplains	Free flowing rivers	Lakes	Groundwater
Provisioning	Food	■			■	■	■	■	■	■	
	Genetic resources			■	■		■	■	■	■	■
	Ornamental resources	■			■	■	■	■	■	■	
	Raw materials						■	■			
	Transport and navigation								■	■	
	Human habitat								■	■	
	Fresh water						■	■	■	■	■
	Medicinal resources				■		■	■	■		
	Water						■	■	■	■	■
Regulation	Air quality regulation						■	■		■	
	Soil formation and conservation						■	■			
	Moderation of extreme events						■	■		■	
	Erosion control				■		■	■			
	Bioindicator	■		■	■						
	Climate regulation				■		■	■		■	
	Pest regulation	■									
	Water purification and waste treatment, pollution control			■	■		■	■	■	■	■
	Biocontrol					■					
	Pollination						■	■			
	Regulation of waterflows/hydrological regimes						■	■		■	■
Cultural	Aesthetic value	■	■	■	■	■	■	■	■	■	
	Spiritual & religious value	■				■	■	■	■	■	
	Cultural heritage and identity	■				■	■	■	■	■	
	Information for cognitive development						■	■	■	■	
	Recreation & tourism/ Ecotourism, Wilderness	■	■			■	■	■	■	■	
	Cultural heritage, sense of place, inspiration value	■	■			■	■	■	■	■	
	Educational values	■	■	■	■	■	■	■	■	■	■
Habitat	Biodiversity and nursery		■		■		■	■	■	■	■
	Gene pool and endangered species protection	■	■	■	■	■	■	■	■	■	■
	Nutrient cycling	■	■	■	■	■	■	■	■	■	■

**Note: filled in boxes represent at least 16 responses*

While the evaluated perceptions of practitioners and scientists regarding freshwater ecosystem service provision are interesting on their own, their implications as a contextual factor could potentially bias the application of the ESA and consequently influence conservation action, offering additional insights to be discussed within the context of the selected case studies.

3.2.2 Ecosystem services identified and monetised in the reviewed case studies

Table 8 lists the full range of ESS as defined in the TEEB (2010) categorization (in the horizontal rows, as done in Table 1) and the selected case studies (in the vertical columns). Circle outlines - ○ - represent ESS for which qualitative descriptions of the benefits were provided, but no economic values; full circles - ● - represent ESS for which monetary values were attached to the identified benefits.

Table 8. Association between ecosystem service provision and identified freshwater case study*

		Case study			
Service Type		**Peatlands in Belarus**	**Floodplains in Germany**	**Beaver reintroduction in Germany**	**Lake in the U.S.**
Provisioning	Food	●			
	Genetic resources	○			
	Ornamental resources				
	Raw materials	○			
	Transport and navigation				
	Human habitat				
	Fresh water	○			
	Medicinal resources				
	Water				○
Regulation	Air quality regulation	●	●		
	Soil formation and conservation	○			
	Moderation of extreme events	●	●		○
	Erosion control	○		○	
	Bioindicator			○	
	Climate regulation	○			
	Pest regulation				
	Water purification and waste treatment, pollution control	○		●	
	Biocontrol	○			
	Pollination				
	Regulation of waterflows/hydrological regimes	○		○	
Cultural	Aesthetic value	○		●	
	Spiritual & religious value				
	Cultural heritage and identity	○		●	
	Information for cognitive development				
	Recreation & tourism/ Ecotourism, Wilderness	○		●	●

	Cultural heritage, sense of place, inspiration value	○			
	Educational values	○		●	
Habitat	Biodiversity and nursery	○	●	●	
	Gene pool and endangered species protection	○		●	
	Nutrient cycling	○	●	●	

**Note:* ○ *- provision of ESS was identified and benefits were described qualitatively, but no economic values were provided;* ● *- Provision of ESS was identified and benefits are quantified using monetary values*

The analysis showed that the peatlands case study acknowledged all four ecosystem service categories in the application of ESA whereas the other three case studies left at least one category out of their analysis (provisioning services were not recognized in the beaver case study, habitat services were not acknowledged in the Lake Kemp case study and both provisioning and cultural services were not considered in the floodplains case study). Additionally, a closer look at the peatlands assessment showed that while 20 ESS were distinguished in total, only 3 were described with monetary values. On the other hand, while the floodplains and beaver case studies considered a smaller number of ecosystem service categories and ESS, most or all of the services studied were also monetized (4 out of 4 ESS in the floodplains study and 8 out of 11 in the beaver study). The Lake Kemp case study was the least inclusive, acknowledging only three ESS and monetizing one of them.

Table 9. Ecosystem services included in the ESA in each case study and results of comparative analysis

Case study	Ecosystem services included in the application of the ESA	Comparative analysis with the consultation
Peatlands in Bealrus	• Inclusion of all services • Lack of economic values attached to the majority of services	Strong consistencies in provisioning, regulation, cultural and habitat services Regulatory and habitat ESS were almost a perfect match, while two of the ESS listed under the cultural services category were omitted from the case study
German floodplains	• Omission of provisioning and cultural services • Focus on regulating and, to a lesser extent, habitat services • Monetary values calculated for all services identified	Inconsistencies in provisioning and cultural services (strong acknowledgement in consultation, but omission in the case study) Only one quarter of the regulation services recognized in the questionnaire were distinguished in the case study
Beaver reintroduction in Germany	• Omission of provisioning services • Emphasis on cultural services • Monetary values calculated for the majority of the services identified	Strong consistencies regarding provisioning, cultural and habitat ESS types No regulating services acknowledged in the consultation, but identification of four regulatory ESS in the case study
Lake Kemp in the US	• Omission of habitat services; provisioning and regulating	Full discrepancy in habitat services (all ESS under this category were acknowledged in the

	services mentioned only in general terms • Deliberate focus on a single ecosystem service: recreational angling (cultural service) • Monetary values calculated for the single service analyzed	consultation, none were included in the case study) Only one seventh of the total number of ESS recognized in the questionnaire were discussed in the case study

The findings of the comparative analysis between the consultation of practitioners and scientists and the case studies are presented in Table 9. These findings identify both consistencies and discrepancies between the ESS acknowledged in the case studies and those raised by the consultation. For instance, while provisioning and cultural services were frequently associated with floodplains in the consultation, these were not at all present in the case study's application of the ESA. Furthermore, the regulation and habitat services identified in the case study were only a limited number of those acknowledged in the consultation. Similarly, the case of Lake Kemp disregarded all habitat services, which were frequently acknowledged in the consultation. Also, numerous ESS from other categories were commonly associated with lakes by the participants of the consultation, contrasting with the very limited range of ESS mentioned in the case study. In the case of the beaver, three of the categories were fully consistent (provisioning, cultural and habitat services), while regulation services were included in the case study but not acknowledged at all in the consultation. Regarding peatlands, full convergence was found in the regulation and habitat categories and only minor discrepancies emerged in the other two ESS types. While the root causes of these similarities and differences may vary, the effect of contextual factors as highlighted throughout this report serves as a useful starting point to explain such variations and is accordingly explained in the discussion to the extent possible.

4 Discussion and conclusions

Three main contextual factors were identified in the present report as exerting influence on the application of the ESA: (1) individual perceptions and/or choices, (2) lack of data availability for ESS valuations and (3) scale of the ESA application. While this report acknowledges further possible contextual factors (e.g. individual value systems, socio-economic considerations, policy measures and political situation, existence of appropriate assessment/valuation methods), they are not explored here given their lack of relevance to the selected case studies. Further research on these and other relevant contextual factors is deemed as valuable and necessary for future studies.

Regarding the examined case studies, the first and most evident contextual factor to emerge is the role of individual perceptions and choices. Even amongst groups of individuals who are well acquainted with the ESA, it is challenging to find consistent answers when inquiring about the association of ESS and specific biodiversity and/or ecosystem components. While bias resulting from one's individual perceptions is generally thought to be excluded from scientific exercises, a lack of consensus regarding a certain issue can heighten the role of such perceptions by changing the boundaries which dictate the scope and manner of exploratory analyses. In the context of freshwater nature conservation, the existence of such uncertainty may represent a drawback of the ESA which - if not properly recognized or accounted for - could produce a further incapacity to implement the approach as intended and, in doing so, compromise the utility of findings for conservation purposes. Additionally, while studies that are deliberately dedicated to the analysis of a single ecosystem service can be very efficient in obtaining detailed results, it is likely that more services are being provided by the ecosystem under scrutiny and that these are interrelated with the service being assessed in isolation. For this reason, results emerging from these focused studies should be treated carefully and analyzed not only in isolation, but also in relation to their respective settings.

A second contextual factor observed is the lack of existing valuations to serve as a reference in establishing quantitative figures. When the consideration of the ESS provided depends on the capacity to attach monetary or numerical values to them, this can be a major obstacle to conducting a complete evaluation of all ecosystem service types. Furthermore, while a large array of ecological and economic assessment tools exist to describe ecosystem functions and services in various freshwater habitats, it is important to have sufficient and appropriate ecological data to conduct process-based quantifications of the chosen ecosystem functions and services. For instance, ecological data quality inevitably shapes the quality of subsequent economic assessment results. In reality however, data quality and appropriate assessment tools are frequently not the norm (Born, 2009). Access to qualitative and quantitative data, e.g. from market values or prior studies, that can be used as proxies to describe the (economic) value of the ESS under scrutiny are thus integral contextual factors. The lack of such values for select ESS can have a significant influence on the tendency to favor some ESS types over others.

For example, in the case study on floodplains, the ESA focused on regulating and habitat services while cultural and provisioning services were omitted due to a lack of available social empirical tools which are necessary for compiling monetary quantifications. Values for such ESS types are often not explicit, but exist as a conglomerate of implicit values (e.g. tourist visits to a certain area reflect not only a recreational value, but also its aesthetical, inspirational and cultural heritage value, however in an implicit way) (Hartje et al., 2003).

The beaver study also omitted certain ESS due to the contextual factor of lacking data availability. For instance, the value of erosion control was mentioned in the study as a valuable ESS, but not economically quantified. More specifically, while beaver ponds can retain water to buffer extreme weather events better than areas without these ponds (e.g. Johnston and Naiman, 1987; Naiman et al., 1994; Gurnell 1998; Nyssen et al., 2011), this regulating service was not considered as the existing data was not sufficiently accurate to serve as an input to a fine-scale run-off model for the catchment.

Finally, the third conceptual factor observed was the scale of the ESA application. This factor is closely linked to the lack of data availability for ESS valuations. For case studies being conducted at different spatial scales, results can differ due to a higher or lower availability of precise data. Improving the input data and backing it up with specific event-based case studies on the individual functions could lead to a further improvement of the assessment results available and thus the more complete application of the ESA in the future. This was true in the peatlands case study, as the locally-focused application of the ESA allowed for a more thorough conduction of the exercise, in contrast to what would have been an evaluation on a larger spatial scale. Conversely, the reduced sample size of recreational anglers in Lake Kemp is associated with smaller, less-visited lakes. In this specific case, the smaller sample size constrained the conduction of an economic valuation by limiting the statistical methods available.

The issue of scale was also a factor in the application of the ESA in the beaver case study. While genetic resources are valuable for beaver reintroduction on a European scale to enlarge the subspecies of the Elbe beaver (e.g. Halley, 2011), this value was not included within the approach or evaluation due to the difficulties in quantifying this effect and thereby also in calculating its economic value on the scale of the case study. It should be noted that while indicators have been developed for many ESS, a lack of available data prevents the indicators from being applied, thus eliminating their value. Thus, the abundance or lack of specific data in relation to the scale of the study can also be defined as a contextual factor. In this context, it must be noted that a more holistic application of the ESA at a broader spatial scale will generally also require large time and financial resource investments, which could in turn influence the way the approach is applied.

An additional advantage of applying the ESA is that it also supports the identification of potential or forgone benefits of ESS that are not yet considered yet in decision making (if, for example, the focus of a study is too narrow). A holistically applied ESA makes the ESS explicit and thus helps to avoid them being rashly overlooked or neglected. The approach further helps to show which ESS have been considered to date and which have not. Thus, the ESA can function as an analysis structure, which is the essential precondition for every economic assessment, i.e. Cost Benefit Analyses (Born, 2009).

This study elucidates a correlation between the contextual factors surrounding the application of the ESS approach and the weight given to the different service categories. Whether intentional or subconscious, contextually induced biases have been shown to result in the under representation or omission of certain ESS categories and overestimation of others in applying the ESA (e.g. either in not quantifying or valuing certain ESS types and not incorporating them in scenario developments, or in double counting services which are provided by the ecosystem as a whole or a combination of its parts, and not by its individual components). These possible biases can have important consequences for freshwater ecosystem and/or species conservation efforts by creating a scientifically unsubstantiated partiality in decision-making processes.

In some cases, biases can be detrimental in the effort to achieve conservation objectives. For example, if the contextual factors result in a situation in which only the benefits provided by a specific service or selection of services are considered, the resultant effect will be a biased discussion and judgments/decisions being taken on the basis of incomplete assessments. This is especially problematic when, e.g., investment decisions are based on the costs and benefits of multiple scenarios. Incomplete representation of the range of benefits provided by a given species or ecosystem would weaken the weight of conservation arguments (e.g. when provisioning and cultural ESS were not included in the floodplains study). Where empirical tools, quantitative data, proxies or valuation references are not available, qualitative descriptions of the ESS provided should nevertheless be presented as a valuable alternative in order to ensure that all relevant ESS are acknowledged within decision-making processes. For instance, the identification of recreation services by using a set of proxies (e.g. naturalness of the landscape or the presence of water), has been validated using case studies having data on visitor statistics and confirmed to be useful when validating recreation (Maes et al., 2011).

Potential biases or conscious omission of select ESS or ecosystem service categories in applying the approach should therefore be clearly acknowledged when presenting outcomes. This will facilitate increased transparency and effective management and enable decision-makers to more accurately interpret the results (Reyers et al., 2013). In parallel, a consideration of trade-offs and the integration of relevant information about the ways in which the exploitation of or damage to one type of service may affect the functioning of others is essential to minimize unintended trade-offs and/or missed opportunities for synergies when trying to achieve multiple objectives.

Accordingly, we propose that natural ecosystems are to be managed through a conscious consideration of the full array of services and processes taking place inside their boundaries as well as of the relationships with their surroundings. Here, the risks posed by adopting a holistic view (i.e. sacrificing the more in-depth scrutiny possible in focused evaluations) should be regarded as being equally relevant to the risks posed by focusing ecosystem service assessments on single ecosystem building blocks (i.e. potentially overestimating the aggregate value of the services provided). In order to achieve the challenging freshwater conservation goals currently outlined across European and international environmental policy, the ESA should be applied according to these recommendations and be more fully incorporated into planning and decision-making processes.

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