22nd International Sustainable Development Research Society Conference, School of Science and Technology, Universidade Nova de Lisboa, Lisbon, Portugal, 13 – 15 July 2016

Ecosystem Service Assessment of Measures to Mitigate Small-scale Hydropower Ecological Impact

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Abstract

Hydropower is important for provisioning of renewable energy, but the ecological effects to watersheds and rivers used for hydro-electrical production has gained increased attention in recent years. Concerns in connection to small-scale hydropower plants are particularly pointed out, as small plants causes several issues for aquatic biodiversity while the energy output remains limited. Hydropower dams poses as migration barriers, e.g. limiting reproduction of migratory fish; the flow regulation regimes disturbs the natural seasonal flows and damages bottom fauna; and rivers adapted to hydropower have altered biotic factors removing entire ecosystems, such as seasonally flooded wetlands. Projects to mitigate such impacts while maintaining hydro-electrical production are presently discussed and in some cases start to be undertaken. One such project is planned in river Billstaån, Sweden, affected by three small-scale hydropower plants and historically also by timber floating. The main measures in the ecological restoration process include construction of fauna passages, deconstruction of an unused reservoir and reintroduction of freshwater pearl mussels. The restoration project is carried out by the company owning the hydropower plants in Billstaån, in a joint effort including local authorities and stakeholders, to benefit local biodiversity and strengthen the ecological status of Billstaån towards the European Water Framework Directive. In this study, the expected outcomes of the Billstaån river restoration project has been assessed in terms of ecosystem services. Note that ecosystem services were not considered in the project planning of the restoration project itself, but were suggested for later monitoring efforts and for enabling inclusion of indicators of economic and social development connected to the restoration results. As ecosystem services describe the value of ecosystems through their interaction with society, this is done to complement ecological monitoring with effects on human residents in the area. Two frameworks for ecosystem service assessment have been tested: *Corporate Ecosystem Service Review* (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA). Both frameworks have been useful for assessing the expected development of Billstaån, but each of them have specific limitations. While ESR was good for qualitative scoping and defining important ecosystem services, the corporate focus made the later steps of the ESR framework hard to implement in this type of case. TESSA worked well for providing tools for quantitative assessment, but at present the number of services covered by the toolkit was limited. This indicates that different methods for ecosystem service assessment provide different levels of understanding of the assessed system. The two frameworks used to assess Billstaån do complement each other in terms of scope, but combined they point at gaps in coverage. This study has shown that ecosystem service assessment provides a complementary perspective of the value of increasing ecological status in rivers affected by small-scale hydropower, but also that the ecosystem services methodology needs further development for this type of case.

Keywords: ecosystem service assessment, hydropower, ecological restoration, Corporate Ecosystem Service Review, Toolkit for Ecosystem Service Site-bases Assessment

1. Introduction

1.1. Ecosystem services

Ecosystem services are ecosystem functions used by humans, including harvestable goods as well as softer values connected to nature as base for recreation and culture, along with underlying processes for ecosystem maintenance and regeneration (MEA, 2005; TEEB, 2010; Fakari Rad et al., 2012). The ecosystem service concept thus interprets more benefits from nature than those commonly considered as natural resources. Through describing more of the links between ecosystems and human society more of the needs and demands on nature for human well-being can be understood. In the last decade ecosystem services have been academically explored as well as integrated into decision making and policy development on all levels (Gomez-Baggethun et al., 2010).

The European Environment Agency has proposed a nomenclature for Ecosystem Services, CICES, dividing them into three *sections* of services, namely: provisioning services, including water and material supply; regulating and maintenance services, including natural processes and flows affecting the balance of the ecosystems, and; cultural services, including human experience and perceptions of nature (CICES, 2013). According to other systems there is also an additional category of supporting services, including e.g. habitat services, underlying all other services (MEA, 2005; TEEB, 2010). In CICES such supporting services are considered as part of the underlying structure for the ecosystems, which cannot be directly used or consumed but are part of the ecosystem supply for ecosystem services. Since supporting services are not final outputs from the ecosystems, CICES excludes them and considers them better dealt with using other methods, e.g. environmental accounting.

1.2. The ecological restoration project in Billstaån

The river Billstaån is a water course situated in Jämtland County, Sweden. The river connects the lake Näkten with the lake Storsjön, see Figure 1. The area is a cultural landscape with ancient remains of human settlements since the Iron Age (Swedish National Heritage Board, 2016). Billstaån is a water course about 4.4 km long (Länsstyrelsen Jämtlands län, 2012) with an average flow speed of 4 m^3/s (Jämtkraft AB, 2015a). Today the main human use of river Billstaån is as provider of hydropower for electric production, which causes several ecological issues and limts e.g. recreational fishing.

The ecological status of Billstaån is considered as *poor* under the classification in the EU Water Framework Directive (2000/60/EC), representing the second lowest grade on a five graded scale where only the two highest steps, *high* and *good*, are in line with the framework goals (European Commission, 2015). The main environmental issues are the existing migration barriers, deficient continuity, and effects from the flow regulation (VISS, 2015; Länsstyrelsen Jämtlands län, 2012). These issues limit the value of river Billstaån as habitat for e.g. brown trout (*Salmo trutta*) despite a high habitat potential in terms of water quality, stream properties, etc. (Jämtkraft AB, 2015b).

To improve the ecological status an ecological restoration project will be performed in river Billstaån (Jämtkraft, 2015a). The restoration project is conducted by Jämtkraft AB, the owner of the three hydropower plants in Billstaån; the County Administrative Board in Jämtland; and local stakeholders, including the local municipality (Bergs municipality) and the fishing management organisations in the lakes connected to river Billstaån.

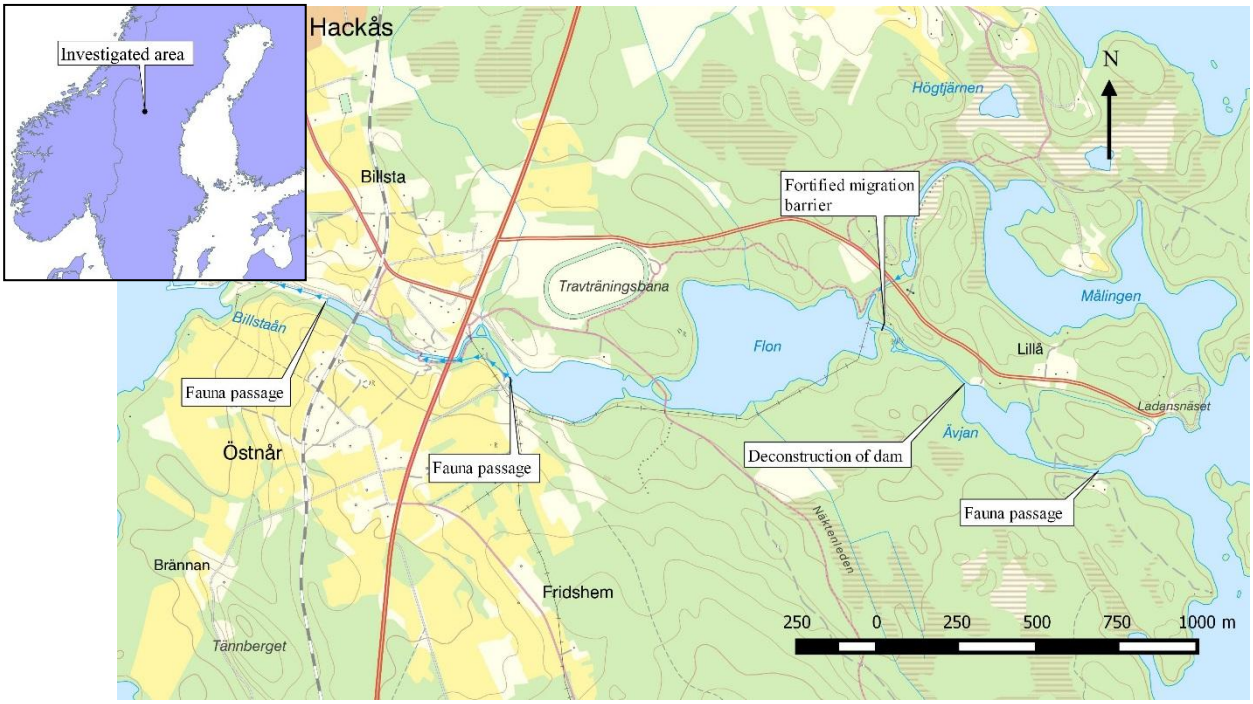

Figure 1. Map of river Billstaån and the planned restoration measures. The flow direction is from the right of the map, where lake Näkten is, to left of the map where the outlet in lake Storsjön is.

The river restoration project is part of the *Triple Lakes* program*,* a watershed management program including lake Näkten and two other nearby lakes. Triple Lakes works to address both historical and current environmental impacts so that the characteristic ecosystems of the three lakes can be better maintained in the face of global warming (LIFE, 2015; Triple Lakes, 2015). The main restorative measures in Billstaån includes construction of fauna passages at three of the dams in the river (see Figure 1), deconstruction of an unused dam restoring, a current lake-like area to streaming water, and reintroduction of freshwater pearl mussels (*Margaritifera margaritifera*).

Currently there are three small-scale hydropower plants situated in Billstaån, generating approximately 6.5 GWh a year (Jämtkraft AB, 2015c). There is a migratory brown trout population in Billstaån with good genetic status, which makes it plausible their spread will increase if the migration barriers can be removed. Due to topography and area limits to the construction sites available, traditional fish ladders have been deemed less efficient in connection to the hydropower dams included in the project (Jämtkraft AB, 2015a). Hence three fauna passages in the form of bypass channels are planned, since they enable migration for more aquatic species than just jumping migratory fish and fit better into the locality in Billstaån. Another benefit of bypass channels is that they are less demanding in terms of maintenance compared to fish ladders. Bypass channels are constructed to mimic smaller streams than the main water course and are less steep than fish ladders, making them available as migration routes for more species of fish and insects (Nöbelin, 2014). This type of fauna passages is also considered more interesting for Billstaån as it generates new aquatic environments and extended habitat areas, which gives substantially higher benefits to biodiversity compared to fish ladders.

One dam will be demolished in the restoration project which means lowering the present water levels in the currently dammed area in Ävjan (see Figure 1) by 2.5 m and affecting stream conditions and restoring about 300 m of river habitat.

The project also includes the reintroduction of freshwater pearl mussel, to be seen as bringing back a native species to the river. The freshwater pearl mussel is an indicator

species for the Swedish national environmental goal *Flourishing lakes and streams* and *A rich diversity of plant and animal life* (Naturvårdsverket, 2015a; Naturvårdsverket, 2015b). Freshwater pearl mussels are documented as beneficial for wild brown trout populations and river ecosystems in general as they provide properties of water purification through their water filtration and are considered an umbrella species (Degerman et al., 2009; Smith and Jepsen, 2008). Pseudo faeces from mussels provide nutrients for algae and detritus eaters, indirectly providing more sustenance for fish and other organisms eating invertebrates (Degerman et al., 2009; Smith and Jepsen, 2008).

Additional efforts to remove migration barriers connected to culverts, restoring waterways and breeding grounds (e.g. by moving back boulders removed to facilitate historical timber floating), reducing sludge and nutrient transport, and strengthening endangered species will also be undertaken. To safeguard the *Natura 2000* area of lake Näkten upstream the river, a partial migration barrier will be fortified to limit spread of planted Arctic char (*Salvelinus alpinus*), as well as diseases, from lake Storsjön downstream. This will allow migrating fish to migrate upstream to spawn, but not spread into lake Näkten and endanger its valuable habitat environment. After the restoration Billstaån is expected to be a Natura 2000 site. Based on information from both Jämtkraft AB and the County Administrative Board in Jämtland the ecological restoration efforts in Billstaån are expected to have both economic and social impact on the rural area where Billstaån is situated. This is connected to the high recreational fishing interest in brown trout, as well as a general need for rural development in the area.

1.3. Assessing ecosystem services

Two ecosystem service assessment frameworks were applied to the restoration project of river Billstaån: *Corporate Ecosystem Service Review* (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA). ESR was used to assess the expected restoration effects on ecosystem services provided by river Billstaån based in initial scoping and qualitative analysis, and for defining important services to consider in monitoring efforts and further assessment attempts. TESSA was used to assess some services quantitatively, towards monetary values, and introduce scenario thinking towards exploring the possible alternate state of river Billstaån after the restoration has been carried out.

The purpose of this report is to assemble the impressions of the frameworks for contrasting what ecosystem services have been assessed, the types of results achieved and the functionality of the frameworks for assessing the Billstaån case.

2. Methods

Corporate Ecosystem Service Review (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA) were chosen as methodological frameworks for assessing impact on ecosystem services from the ecological restoration of river Billstaån. As neither of these two frameworks are meant to assess ecological restoration efforts adjustments and alternations to their standard procedures were made to better fit the Billstaån case and the methodological choices are further described in this section.

2.1. Corporate Ecosystem Service Review, ESR

To conduct an initial assessment of the expected effects on ecosystem services from the restoration ESR was used, applying the first and second step of the framework to determine a study scope and generate an inventory of ecosystem services impacted by the restoration and defining ecosystem services important for the restoration outcome. ESR has been deemed feasible for immediate widespread use as a screening tool suitable for scoping assessments prior to more detailed studies (Bagstad et al., 2013), as well as suggested as a

good starting point for exploration of ecosystem services and their relation to business performance (WBCSD, 2013). The requirements on expertise and input data for ESR are relatively low, being mainly user-based; accessible from internal company knowledge, or being relatively easy to access in published research. ESR was thus considered as a good choice for assessing the ecological restoration in Billstaån, even though Jämtkraft AB is not the only stakeholder in the project.

ESR is developed for assessing dependence and impact on ecosystem services from an activity, directed towards the business world (Hanson et al., 2012; WBCSD, 2013). The assessment is qualitative and defines priority services, which are further investigated towards business planning and company policy making to limit unsustainable use of resources and benefit marketing, etc. ESR defines priority services based on connections to business results but as the focus of assessing Billstaån was the expected restoration outcomes, the weighting to define important services was instead based on future monitoring interest and possibilities for monetary valuation of services (Tellström, 2015). While assessing the river restoration the later steps of ESR, directed towards concrete business operations, were not included as they were not relevant for the restoration setting.

The ESR assessment was conducted within a system boundary including the water body and 100 m from shoreline (Tellström, 2015), based on Swedish shoreline protection legislation (Swedish Environmental Code, 2009:532). This area represents the area where restoration measures will take place and ecosystem services directly related to the river are present, including some parameters from the surrounding landscape while maintaining focus on the river ecosystem. The option to review the river catchment area was discussed, as that level is sometimes suggested as most accurate for investigating water habitats, but it was dismissed as the restoration measures will only have direct impacts on a local level.

2.2. Toolkit for Ecosystem Service Site-based Assessment, TESSA

TESSA was used to quantify values on some ecosystem services in connection to the restoration and to start exploring the future alternate state of Billstaån as a restored river. TESSA is intended for assessment of sites important for biodiversity, under threat from exploitation, to provide material that can inform decision makers and impact development plans (Peh et al., 2013; Peh et al., 2014). The framework includes a number of services commonly interesting and important for such cases. The method was used as it might have been used on a consultant basis. The time limit was set to three weeks. Time, available data and laboratory resources at Mid Sweden University gave which methods that were used out of the available ones in the TESSA toolkit. Nine of the 27 methodologies in the framework were used, several of them being slightly altered to better suit the setting and information available for the site in Billstaån (further details in Tellström, 2016). Material from the restoration project funding application was used as a basis for collecting information and was further complemented with literature studies, field measurements, and interviews with stakeholders directly involved in the restoration project as well as stakeholders in the local vicinity of Billstaån.

2.3. Scope: Assessed ecosystem services

The ESR assessment of Billstaån included the 29 ESR framework standard services, covering provisioning, regulating, cultural and supporting services. Two additional services were added due to importance in the restoration setting: *energy provisioning*, to be able to indicate the importance of the current hydro-electrical production taking place in Billstaån; and *recreational fishing*, to directly address the fishing interest used as a main argument for the restoration efforts and not only include it as one of many activities included in the ESR service recreation and ecotourism (Tellström, 2015). Energy provisioning is not commonly considered as an ecosystem service, e.g. in CICES it is included as a *benefit* that can be

acquired from ecosystem but requires input from technical inventions for extraction (Turkelbloom et al., 2014), but it was added within the frame of ESR to represent the business interests of Jämtkraft AB. In the TESSA assessment of Billstaån, ecosystem services connected to global climate regulation, water, wild goods and nature-based recreation were included. Data on carbon storage, water quality, flood protection, timber value, visitor numbers and visitor interests were collected and assessed (Tellström, 2016). Services included in TESSA but not assessed for Billstaån are found in the TESSA categories cultivated goods and harvested wild goods, which were hard to assess due to the small size of the assessed area and lacking information.

As further described in Table 1 the two assessment frameworks have some overlap in terms of assessed ecosystem services, but all services were not directly transferrable between the frameworks.

Table 1. Ecosystem services included in ESR and TESSA, respectively, and notation on what services were included in this study and assessed by both frameworks.

Ecosystem services assessed in the ESR of the restoration in river Billstaån	**Corresponding ecosystem service category in TESSA**	**Services included and assessed by both frameworks**
Crops	Cultivated goods	
Livestock	Cultivated goods	
Capture fisheries	Harvested wild goods	
Aquaculture	Cultivated goods	
Wild foods	Harvested wild goods	
Timber and other wood fibres	Cultivated goods / Harvested wild goods	Yes
Fibres and resins	Cultivated goods / Harvested wild goods	
Animal skins	Cultivated goods / Harvested wild goods	
Sand	Harvested wild goods	
Ornamental resources	Cultivated goods / Harvested wild goods	
Biomass fuels	Cultivated goods / Harvested wild goods	
Freshwater	Water-related services	Yes
Genetic resources	-	
Biochemicals, natural medicines, and pharmaceuticals	Cultivated goods / Harvested wild goods	
Maintenance of air quality	-	
Global climate regulation	Global climate regulation	Yes
Regional/local climate regulation	-	
Regulation of water timing and flows	Water-related services	Yes
Erosion control	-	
Water purification and waste treatment	Water-related services	Yes
Disease mitigation	-	
Maintenance of soil quality	-	
Pest mitigation	-	
Pollination	-	
Natural hazard mitigation	-	
Recreation and ecotourism	Nature-based recreation	Yes
Ethical and spiritual values	Nature-based recreation	Yes
Educational and inspirational values	Nature-based recreation	Yes
Habitat	-	
Energy provisioning	-	
Recreational fishing	Nature-based recreation	Yes

3. Results

3.1. Assessment of restoration project efforts in terms of ecosystem services

Two frameworks for ecosystem service assessment have been tested: *Corporate Ecosystem Service Review* (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA). Both frameworks have been useful for assessing the expected development of Billstaån, but each of them have specific limitations. While ESR was good for qualitative scoping and defining important ecosystem services, the corporate focus made the later steps of the ESR framework hard to implement in this type of case. TESSA worked well for providing tools for quantitative assessment, but at present the number of services covered by the toolkit was limited.

Table 2 gives a summary of the results from the ESR and the TESSA assessments of the river Billstaån restoration project, including priority services identified in ESR and the selected services assessed by TESSA. Full results can be found in the two assessment reports, concerning ESR and TESSA, respectively (Tellström, 2015; Tellström, 2016). As can be seen in Table 2, only four services could be assessed from qualitative information in ESR into monetary values endpoints using TESSA tools. This was partly because TESSA did not provide assessment methodologies for all ESR priority services. The present toolkit for water-related services covered by TESSA does not include methodologies that generate results that can be transferred into monetary values.

The four services that was possible to follow through the table (both assessing their qualitative importance for the project and giving approximate monetary values of their potential change) was *timber and wood fibres*, *global climate regulation*, *recreation and ecotourism*, and *recreational fishing*. Out of these, only the recreational services were considered as a priority service in ESR. Out of the services assessed by TESSA, freshwater was also a priority service in ESR, but the measurements on water quality was not transferable into a monetary value. Thus, we could identify that that TESSA at the time of this assessment did not cover all services suggested as priority services by the ESR assessment.
When applied in the assessment settings of the restoration of river Billstaån, ESR was found basically to process existing internal knowledge and complement it with general research, while TESSA addressed collection of external information from e.g. site measurements and stakeholders outside the assessors group. Compared to TESSA, ESR provided a greater opportunity for capturing the importance of factors which had not been considered earlier (and transfer them into ecosystem services) by initially suggesting inclusion of a large number of services into the assessment. TESSA, on the other hand, provided a more developed methodological basis which could be directly transferred into monitoring of ecosystem service development at the site, after the restoration has been finished. The TESSA alternate state perspective also supports to consider and to present expected restoration outcomes in a more structured way than from working with ESR.

3.2. Observations on usability of the frameworks

In the ESR assessment several issues related to the framework scope emerged during the study, partly relating to how the restoration project is not company-owned and includes stakeholders with low direct economic interest in the outcome (but are more aligned towards ecological and possible social benefits). The ownership situation was known in advance, but was not considered as the obstacle it turned out to be. As a tool for initial ecosystem services assessment ESR helped in the process of starting the translation of expected restoration outcomes into ecosystem services thinking, but the strong business focus in ESR led to final results that do not apply to the information needs in an ecological restoration context. Choice of assessment perspective for the ESR turned out to be a challenge,

indicating how both dependency and impact related to ecosystem services and such analysis depends on both timeframe and scale considered (in turn depending on the viewpoints of the assessor/s). Another problem encountered due to the strict form of working with the ESR impact matrix is how some services could not attain a priority service status due to gaps in knowledge, posing as risk factors in projects at this scale. Relating to this is the difficulty in knowing when the ESR impact matrix could be considered complete in terms of information quality, indicating a need for internal as well as external knowledge connected to the assessed activity.

TESSA is meant for application in areas threatened by exploitation, which is not the case for river Billstaån as the intent behind ecological restoration is to directly enhance and fortify biodiversity. As such, for the Billstaån case, this made some of the TESSA process and guidelines less obvious in terms of interpretation. The reversed approach in terms of expected development for the assessed site also indicated how it generally is much harder to establish gains from changes to an ecosystem than valuing the losses from removed ecosystem services. Describing the alternate scenario thus turned out more speculatively than expected, suggesting some limitation for such efforts when applied to cases outside the scope suggested by TESSA.

As the TESSA toolkit does not include support to weigh the importance of the ecosystem services included in the framework methodology compared to other services in the ecosystem as a whole, the relevance of the assessment results compared to the total ecosystem service output from the system was hard to establish. This became evident since the ESR, covering a larger number of services, had been done and most of the services pointed out as important by ESR was not included in TESSA. Furthermore, this indicates assessments based on TESSA alone can have problems to determine if the assessed services are the services most relevant for the investigated site, its beneficiaries and the prospected development. TESSA is still very usable for making an assessment of some values on the certain ecosystem services included in the framework and for capturing the alternate state as a future scenario for the investigated site.

4. Discussion

The ESR and TESSA frameworks differs both in terms of number of ecosystem services assessed and how they are categorised. ESR is based on the nomenclature used in the Millennium Ecosystem Assessment, while TESSA divides ecosystem services into categories based on types of services that can be assessed using similar methodologies. ESR aims to sort available information into the ecosystem service concept and to provide an overview of plausible impacts from an activity on ecosystem services. TESSA is more focused on making measurements on site and collect quantifiable data directly from stakeholders. These differences give different levels of ambition driving the information collection processes and for necessary structure of such efforts, even though both ESR and TESSA are intended for use by non-experts in ecosystem service assessment.

The results of this study indicate that ESR and TESSA mainly are suitable for different types of assessment goals. In an ecological restoration setting, as the project in river Billstaån, neither of them provided all the information desired. By combining ESR and TESSA an overview of expected restoration impact on ecosystem services and more detailed studies on certain services could be managed. It should be noted that in another case the services covered by TESSA could have been more the same services as the ESR priority services making the quantitative assessment from TESSA more interesting.

Table 2. Total ecosystem service assessment efforts towards describing the expected ecological restoration outcomes in river Billstaån as ecosystem service effects.

ESR					**TESSA**			
Ecosystem services	**Assessed levels of dependence and impact**	**Identified monitoring interests**	**Identified market connectors**	**Considered as priority service**	**Corresponding TESSA service category**	**Tool used**	**Generated quantitative values**	**Generated monetary value**
Timber and wood fibres	Medium / Unknown	Not investigated further (since not high/high regarding dependence/impact)	-	No	Harvested wild goods	Wild goods M4	Yes	55 - 600 SEK/year based on type of extracted goods from 2.4 ha future forest in the Ävjan area
Freshwater	High/ High	Water quality; freshwater pearl mussel population	Prices on drinking water	Yes	Water-related services	Water M5	Yes	Quantitative values for this service were water sample data, not estimated into monetary terms
Global climate regulation	High / High	Carbon capture capability; energy production	Carbon taxation	No	Global climate regulation	Climate M1, M2, M5, M7	Yes	320 000 – 496 000 SEK/year in CO_2 emission licenses representing carbon capture of 3.2 ha future forest in Ävjan
Regulation of water timing and flows	Unknown/ High	Not investigated further (since not high/high regarding dependence/impact)	-	No	Water-related services	Water M1, M3	Only qualitative assessment of flood protection was carried out	No quantitative data for monetary valuation accessible
Erosion control	High / High	River depth; soil removal rate	Costs for restoring river depth or riverside	Yes	No correspondence with TESSA services	-	-	-
Recreation and ecotourism	High / High	Visitor numbers; fishing licenses; local business development	Guest nights; general local turnover; property price development; maintenance costs for bridges, parking lots, etc.	Yes	Nature-based recreation	Recreation M1	Yes	1 000 000 SEK/year from turnover of restaurant in old mill; 24 000 – 28 000 SEK/year from ticket sales to *Årets Näck*
Habitat	High / High	Observed species (populations and/or individuals); biological indicators	SEK/kg caught fish; savings from not implanting fish	Yes	No correspondence with TESSA services	-	-	-
Energy provisioning	High / High	Energy production; efficiency changes	Energy prices; maintenance costs at hydropower facilities	Yes	No correspondence with TESSA services	-	-	-
Recreational fishing	Medium / High	Not investigated further (since not high/high regarding dependence/impact)	-	No	Nature-based recreation	Recreation M1	Yes	73 000 SEK/year estimated value on sold fishing permits

The importance of the services that presently are not covered by tools in TESSA would have been less evident if the ESR had not been carried out. The results of the total effort for assessing restoration outcomes as ecosystem services in the Billstaån case show how a combination of ESR and TESSA can provide deeper understanding of ecosystem service assessment results, in terms of interpretation, and how ecosystem service impact can be presented in different manners towards various interested parties.

Ecosystem service assessment seems to be potentially useful in terms of considering impact for more stakeholders and adding socio-economic factors to what is considered as the total restoration project results. Through this departing from common ecological monitoring it is also possible to increase and expand communication of restoration results to include material more easily approached by various stakeholders and decision makers. It has thus been proved how ecosystem service thinking generates new information that gives a more balanced picture of the planned activities in terms of restoration effects on the river ecosystem while including people as beneficiaries in addition to biodiversity in general. A main use for the assessment results probably will be in future communication of the restoration outcome and in relation to monitoring the restoration impact on the local area.

ESR and TESSA address different issues, sustainable business development and sustainable land use respectively. Put together the assembled results provide an interesting scale in terms of the various levels of investigation, intended uses and possible future application for the ecosystem service concept. Both ESR and TESSA provided new information for the restoration project in Billstaån, but not in a way directly transferrable into operational practice within the project. ESR contains steps for business planning, but those steps were not pursued due to no direct business motivation for the restoration. TESSA contains sections on how to present assessment results to decision makers, but as the decision makers in the Billstaån case already have decided to do something capturing the usability of the assessment results is more complex. The results this far is thus a complementary part of analysing the expected restoration impact, which could be further developed into direct actions included in the restoration to improve its performance in ecological as well as socio-economic terms. Further research efforts can be directed towards how the assessment results from ESR and TESSA can be presented and integrated in the restoration of river Billstaån for the benefit of the assessed area.

5. Conclusions

Hydropower is important for provisioning of energy, but the ecological effects to watersheds and rivers used for hydro-electrical production has gained increased attention in recent years. Projects to mitigate such impacts while maintaining hydro-electrical production are presently discussed. One such project is planned in river Billstaån, Sweden.

By assessing the expected outcomes of the restoration of river Billstaån as ecosystem services knowledge about the restoration impact has been transferred into the ecosystem service concept. The two frameworks used, ESR and TESSA, was manageable for arranging already existing information about the restoration project into ecosystem services as well as collecting new information to estimate some service values. Both ESR and TESSA provided interesting results, but both frameworks also lacked inclusion of important factors in the ecological restoration setting.

ESR was used to get an overview of ecosystem services in relation to the expected restoration outcomes and for identification of five priority services, having high impact on the restoration outcomes as well as having high dependence on the service to achieve the desired results. As the restoration of Billstaån is outside the business focus of the ESR framework, several of the later steps in ESR were not applicable.

TESSA worked well for providing tools for quantitative assessment, and some TESSA results could be translated to monetary values, but at present the number of services covered by the toolkit was limited. TESSA included no tools to assess if the services covered in the framework are the most relevant for the investigated site. Several of the ecosystem services indicated as priority services for the Billstaån case by ESR was not covered by TESSA. It is possible that in other cases the identified priority services could align better with the services covered in TESSA.

Both frameworks indicate that negative impacts on the ecological status of river Billstaån can be mitigated by the restoration measures as studied when using the concept of ecosystem services. The estimated monetary values from TESSA indicate that at least at society level there actually is a pay-back time for the river Billstaån restoration project, meaning the project is not solely a cost to achieve better ecological standard in the river.

This study has shown that ecosystem service assessment provides a complementary perspective of the value of increasing ecological status in rivers affected by small-scale hydropower, but also that the ecosystem services methodology needs further development for this type of case.

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