TESSA valuation of effects on ecosystem services from the ecological restoration of river Billstaån

Susanne Tellström

Department of Ecotechnology and Sustainable Building Engineering

Mittuniversitetet

2016
Abstract
In the Swedish river Billstaån an ecological restoration project is planned. To assess the expected outcomes of the project in terms of ecological and socio-economic effects ecosystem service assessment is pursued. As ecosystem services describe benefits acquired from nature for human well-being such an endeavour can help increase understanding for the full impact of the restoration process for the local community as well as illuminate possibilities for rural development.

This study assessed ecosystem services by applying parts of Toolkit for Ecosystem Service Site-based Assessment (TESSA), testing the usability of the framework for the Billstaån case. TESSA provided a structured framework to assess several services currently provided by Billstaån and estimate some of the expected effects on them from the planned restoration measures quantitatively. Ecosystem services connected to nature-based recreation and global climate regulation could be converted into monetary values, while the water related services assessed could not be converted. Due to the limited amount of services covered by TESSA, and this assessment, the monetary valuation do not express a total value of services from Billstaån. The monetary valuation established indicate that increased values connected to the restoration measures mainly will be generated in services connected to recreation and tourism. The restoration effects on ecosystem services were also captured in qualitative description of an alternate state of Billstaån, including fauna passages to restore migration routes in the river, a current dam having been reverted to streaming water and reintroduction of freshwater pearl mussels to the river ecosystem. In the alternate state a larger brown trout population is expected in the river and more visitors are attracted to the area for recreational fishing as well as interests founded by the restoration efforts.

TESSA was found usable to assess some of the ecosystem services connected to Billstaån. The assessment procedure was relatively fast and rewarding. The extensive guidelines and quality of the methodologies makes TESSA very interesting for pursuing knowledge of impact on ecosystem services from various changes to landscape and land-use, which should be both helpful and provide valuable material in many cases. For the Billstaån case TESSA provide a methodological basis that could be directly transferred into monitoring work, after the restoration has been finished, to trace development of the ecosystem services covered in the toolkit.

TESSA included no tools to assess if the services covered in the framework are the most relevant for the investigated site and the number of services covered by the toolkit was limited. This indicates that working with TESSA as a stand-alone tool can make it hard to determine if the assessed services are the services most relevant for the investigated site, its beneficiaries and the prospected development. Such material is suggested to be included in the future updates of TESSA, by e.g. steps for attaining a qualitative overview of services at a site, along with methodological cover of more regulating ecosystem services, cultural values, and how to value service input to industrial systems.
1 Introduction

In this study *Toolkit for Ecosystem Service Site-based Assessment* (TESSA) is applied to river Billstaån, Sweden, to better describe the expected outcomes of a planned restoration project. The restoration aims to increase the ecological status in Billstaån, which currently is low due to impact from hydropower extraction. In this report findings from ecosystem service assessment based on TESSA are presented in terms of an overview of assessment results, impressions from working with TESSA, and evaluation of framework applicability for the Billstaån case.

2 Background

In Sweden hydropower production has great importance as energy source, producing about 67.5 TWh yearly and representing half of the total Swedish electricity production (Jonsson, 2015). About 75% of Swedish rivers are regulated and water regulation have a major impact on Swedish rivers and their biodiversity by direct changes to water surfaces and river courses, effects from migration barriers and alterations to natural water flows (Jonsson 2015; Sveriges Riksdag, 2012). Common issues are related to how the shifting water levels caused by hydropower regulation deplete bottom fauna and remove nutrients, which in extension affect organisms in the entire food chain, decreasing fish populations and the general biological production in river ecosystems (Jonsson, 2015). Hydro-electrical production furthermore requires a reverted water flow opposite to the natural flows over the year, as reservoirs are drained in the cold months when the energy demand is high, affecting fish and bottom fauna as they are less active during winter. The reverted flows can also decrease the spring flood, important in habitats such as seasonally flooded wetlands.

The European Water Framework Directive as well as the Swedish national environmental goals means higher political demands on ecologically sustainable river management (Renöfält and Nilsson, 2005). A committee appointed by the Swedish Parliament to investigate stakeholder responsibility for the effects on biodiversity from hydropower found that even though both small-scale and larger hydropower facilities affect biodiversity, effects from smaller plants are more easily mitigated. Furthermore, in relation to the amount of energy produced small-scale plants have higher environmental impact (Sveriges Riksdag, 2012). The committee also established that there is a consistent understanding of the negative impact from hydropower on biodiversity, applying to both small and large hydropower plants, but that measures taken to mitigate the impacts are limited.

To increase the environmental performance of hydropower production it must be adapted towards increased use of fauna passages and environmental flows (Jonsson, 2015). Ecologically adapted flows have been suggested as an important instrument that can be combined with physical measures to restore river habitats. (Renöfält and Nilsson, 2005). It has also been established that restoration measures in Swedish rivers could substantially improve the economic value in rural areas, both as an effect off the labour needed for the restoration as well as the improvement in e.g. recreational fishing (Jonsson, 2015).
2.1 **The restoration of Billstaån**

One river affected by hydropower is Billstaån in Jämtland, flowing from the Natura 2000 lake Näkten to lake Storsjön over a stretch of 4.4 km (Länsstyrelsen Jämtlands län, 2012). In Swedish conditions Billstaån is a smaller water course. River Billstaån has been used for hydroelectric production since the early 1900’s, but has also been previously affected by timber floating and milling. Currently, the yearly energy production in Billstaån is 6.5 GWh per year, which is generated from three small-scale hydropower plants in Lillå, Strömbacka and Billsta (Jämtkraft AB, 2015c). The main environmental impacts on the river are connected to the hydropower use, including migration barriers, disrupted flow continuity and effects from flow regulation (Länsstyrelsen Jämtlands län, 2011). According to Water Information System Sweden (VISS) the status of Billstaån is *poor*, which is the second lowest status on a five grade scale under the classification of the European Water Framework Directive (2000/60/EC) (VISS, 2015; European Commission, 2015).

To mitigate environmental impact from hydropower the owner of the power plants in Billstaån, Jämtkraft AB, together with the County Administrative Board in Jämtland and other stakeholders have started a restoration project (Jämtkraft AB, 2015a; Jämtkraft AB, 2015b). The main restoration measures can be seen in Figure 1. The restoration of Billstaån is part of the larger watershed management program *Triple Lakes*, set to maintain and safeguard the ecological status of lake Näkten and two nearby lakes (LIFE, 2015). The restoration measures planned in Billstaån includes: construction of three fauna passages to restore migration routes, for e.g. brown trout (*Salmo trutta*), and to create extended freshwater habitats; deconstruction of an unused reservoir to revert a presently dammed area, Ävjan, to streaming water; reintroduction of freshwater pearl mussels (*Margaritifera margaritifera*); and several other measures to create new spawning beds, remove...
smaller migration barriers and putting removed boulders back into the river to increase river diversity (Triple Lakes, 2015). To address the risk of invasive species, e.g. Arctic char (*Salvelinus alpinus*), and disease spread from lake Storsjön to the Natura 2000 area lake Näkten a permanent migration barrier will be constructed by the hydropower plant in Lillå, meaning fish from lake Storsjön will not be able to migrate into lake Näkten (Jämtkraft AB, 2015a). The restoration measures will enhance local biodiversity, increase river accessibility for migratory fish and procure a restored stream habitat with improved ecological status. After the restoration Billstaån is expected to be part of Natura 2000, as the ecological potential in the river is deemed high in terms of water quality and topographic properties (Jämtkraft AB, 2015b).

### 2.2 Assessment of effects on ecosystem services

To understand more of the restoration impacts in river Billstaån and the local area, ecosystem service assessment is used to assess the planned measures and expected results. Ecosystem services are benefits humans acquire from the ecosystems, representing natural resources and ecological maintenance processes as well as softer values connected to experiences of nature for recreation, inspiration, etc. (TEEB, 2010; MEA, 2005).

In the restoration of Billstaån ecosystem services have not been considered in the restoration planning process, but ecosystem service assessment might be a complement in describing more levels of impact from restoration of riparian ecosystem, including socio-economic factors possibly affected. Assessing ecosystem services can thus give opportunities for a wider, more diverse monitoring, including more development factors into what is considered as restoration results. Describing the restoration effects in terms of ecosystem services can also create more options for external communication of the restoration results.

#### 2.2.1 Toolkit for Ecosystem Service Site-based Assessment

Toolkit for Ecosystem Service Site-based Assessment (TESSA) is a framework for ecosystem service assessment on site-scale, directed towards sites important to preserve based on values for biodiversity (Peh et al., 2014; Peh et al., 2013). The framework provides a collection of methodologies for ecosystem service assessment and extensive guidelines, compiled into a step-wise approach adaptable to the assessment prerequisites of the site of interest. The ecosystem service categories covered in the current version of the framework are: *global climate regulation, water-related services, harvested wild goods, cultivated goods* and *nature-based recreation*. The range of ecosystem services covered in the toolkit is based on general significance of these services at many sites, and the traceability of measurements related to assessing them (Peh et al., 2013). TESSA was used to define some factors in a future alternate state for Billstaån, when the river is restored, and to generate quantitative values on some ecosystem services. TESSA was also deemed adequate for setting up the assessment in a structured manner that can be directly replicated in future restoration monitoring work.
3 Purpose and scope

This study applies Toolkit for Ecosystem Service Site-based Assessment (TESSA) for evaluating the expected outcomes of the restoration efforts in river Billstaån, generating both assessment results and investigating the usability for the TESSA framework in this specific case. The objectives are to describe the alternate state of Billstaån, as it might be after the river is restored, and evaluate monetary values on some ecosystem services impacted by the restoration measures.

The services assessed in this study, according to the categories used in TESSA, are nature based recreation; global climate regulation; and water related services. The impacts of the freshwater pearl mussel reintroduction on ecosystem services is also investigated, but done outside the scope of TESSA. Out of the services incorporated in TESSA the goods based services harvested wild goods and cultivated goods have been deemed less interesting to assess for Billstaån as they are not addressed by the restoration efforts. Due to the small size of the investigated site there is also a lack of data and possibilities to do estimations are limited.

4 Method

To be able to do a larger study four research teams, with no previous experience of ecosystem service assessment, have been working alongside each other relying on guidance provided by TESSA materials. Four teams of 5-6 people were assembled, the team members being bachelor students in environmental science and environmental engineering from various backgrounds, most of them second year students at Mid Sweden University. The TESSA evaluation was performed as a project in the course Ecosystem Services (MX019G) and TESSA was used as guiding framework to plan assessment methodology, collect data and calculate quantitative values on some ecosystem services.

Identification of ecosystem services suitable for assessment within this study was based on discussions among the research teams, material provided from the restoration project group and the laboratory resources available at Mid Sweden University. The material available from the restoration project group was considered sufficient information in terms of understanding the main stakeholder interests, even though further input from some stakeholders was collected as part of the assessment. Most of the research was conducted during a field week, which limited possibilities to arrange some activities, e.g. stakeholder meetings, but some such material was already available from the consultation steps in the restoration project planning process. In total, the teams had about five weeks available, the field week on full time; the others on part time.

As TESSA includes several methods to assess each service not all of them were used, nor manageable in the Billstaån case. The methodologies from TESSA that were selected for the study are presented in table 1, including comments on implementation (for full methodological descriptions, refer to the toolkit: Peh et al., 2014). Additional to this, one research team made an overview table to compare ecosystem services at the current and alternate based on other TESSA material (similar to p. 7 in CCI and BirdLife International, 2011). Some mind maps for describing the current state and the alternate state of river Billstaån were also constructed to capture the patterns of possible positive and negative effects from the restoration (see further in appendix 3).
Table 1. Applied methodologies, according to TESSA naming, and comments on assessment proceedings in the study of Billstaån. The assessment scopes are cited from respective chapters in the toolkit (Peh et al., 2014).

<table>
<thead>
<tr>
<th>Method</th>
<th>Scope</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate M1</td>
<td>Classifying areas of different levels of disturbance, within a habitat type.</td>
<td>Used in combination with QGIS and orthophoto.</td>
</tr>
<tr>
<td>Climate M2</td>
<td>Estimating above-ground live biomass carbon stock using IPCC tier 1 estimates.</td>
<td>Also tested based on data from field measurements with relascope. Complementary calculations on carbon sequestration based on a method presented by the Alabama Forestry Commission were carried out (Alabama Forestry Commission, 2015).</td>
</tr>
<tr>
<td>Climate M7</td>
<td>Estimating soil organic carbon stock in mineral and organic soils.</td>
<td>Temperatures and time in the oven for soil samples were altered, as follows: soil samples dried at 105°C for 24 hours, were weighed; then placed in the oven for one more hour and weighed again to make sure all water was evaporated; the samples were then put in the oven at 550°C for 6 hours and weighed again.</td>
</tr>
<tr>
<td>Water M1</td>
<td>Obtaining information on flooding, water use and water quality from stakeholder meetings.</td>
<td>No stakeholder meeting was held. The assessment was based on project planning material.</td>
</tr>
<tr>
<td>Water M3</td>
<td>Assessing flood protection services.</td>
<td>Hydrological data was attained from databases and modelling tools provided online by Swedish Meteorological and Hydrological Institute (SMHI, xxxx).</td>
</tr>
<tr>
<td>Water M5</td>
<td>Assessing water quality services.</td>
<td>Criteria for evaluation of the water sample results taken from Swedish Environmental Protection agency, report 4913. [TESSA evaluation?]</td>
</tr>
<tr>
<td>Wild goods M4</td>
<td>Estimating the value of timber.</td>
<td>The potential economical timber value in connection to new forest in Ävjan was estimated, based on statistics on productivity and prices of timber in this type of forest, but not considering the harvesting costs.</td>
</tr>
<tr>
<td>Recreation M1</td>
<td>Census for estimating numbers of site visits.</td>
<td>Since there is no entrance or fees to count visitors, number of fish permits (amount sold per year and related income) is used, along with visitor numbers to the local restaurant and events.</td>
</tr>
</tbody>
</table>

4.1 Methodology for assessing services from freshwater pearl mussels

As the reintroduction of freshwater pearl mussels was considered an important aspect in the restoration and there is no method in TESSA covering impacts and values of reintroduction of species to an ecosystem, separate methodology was developed. Literature studies were made to identify ecosystem services connected to freshwater pearl mussel populations. Experts from the County Administrative Boards in Jämtland and in Västernorrland were also contacted for input. In Västernorrland a restoration project including reintroduction of mussels is carried out in the river Vindeläven, being further underway than the Billstaån project. In Vindelälven the mussels have been planted into the river ecosystem and primary results are available to suggest a possible development in Billstaån. To assess a monetary value a small web survey measured willingness to pay for the presence of freshwater pearl mussel and visits to mussel waters (further details in Appendix 3).
5 Results
This section compile and expand the work of the research, divided into service status as the current state and proposed service development in the alternate state of a restored river ecosystem. The material is also considered in terms of monetary valuation. Details on the material generated by the research teams, as per team, are presented in Appendix 1-4 (p. 19-35). Impressions of working with TESSA and the framework usability for the Billstaån case are presented in the discussion section (p.13-16).

5.1 Current state

5.1.1 Recreation and tourism
The area around Billstaån is available as recreational area for the residents in the small town Hackås, just north of the river, as well as by the outspread residential houses and holiday homes along the river. The distance from Hackås to Billstaån is about 1.5 km, resembling what is commonly considered as within walking distance. Considering the vicinity to Billstaån, and possible visit numbers from local residents, there are about 500 residents in Hackås (SCB, 2014) and about 7 000 residents in the local municipality of Berg (SCB, 2015).

There are two main motives for visits to Billstaån: the restaurant in Strömbacka, open in summer; and the yearly music competition Årets Näck, taking place in an area similar to an outdoor museum with an old water mill. In terms of recreational activities Billstaån provides a bathing spot with picnic area, a marina at the river outlet in lake Storsjön, and is connected to the hiking trail Närktenleden. The restaurant in Strömbacka is situated in an old mill and several other old buildings are preserved and used in the same business. This indicates several cultural ecosystem services connected to the river and the specific settings in Strömbacka are important for the restaurant and its visitors in terms of e.g. the river as part of the visual impressions. As the river has been used as a power supply for the mill and other similar purposes for a long time, the place also gives the natural connection between different use of rivers from ancient time until today. Cultural services are also important for the music competition, taking place in the river itself as the musicians perform in the river to portray the Neck: a water spirit from Swedish folk lore, known for playing the violin. This event is very strongly connected to Billstaån and has happened each summer in the same location for about 20 years.

Recreational fishing is another interest connected to Billstaån, but as fishing permits are sold for larger areas than the river itself it is hard to estimate to which degree the permits are used for river fishing. As illustrated in Figure 2, Billstaån is divided between two fishing management organisations corresponding to the two nearby lakes: Näkten FVO and Storsjön-Berg FVOV.

The assessment of the amount of recreational fishing in Billstaån is further complicated by how the fishing management of Storsjön-Berg includes the longest stretch of the river, while recreational fishing connected to Näkten currently is more popular. Based on contact with the fishing management organisation in Näkten, 320 fishing permits were sold for that area in 2014. According to information from the County Administrative Board in Jämtland, about 50 fishing permits were sold in Storsjön-Berg in the same year (see further details in appendix 2). That gives a total number of 370 fishing permits that could have been used in river Billstaån, even though fishing in the lakes might have been prioritised among the anglers.
5.1.2 Visitor numbers
Since the area around Billstaån lacks a natural entrance visitor numbers or visit frequency are hard to determine and no such data is monitored on regular basis. Based on visit numbers stated by local stakeholders and reasonable estimations related to local population numbers, as shown in Table 2, about 3 500 visitors per year is suggested. This is probably a considerable underestimation in terms of total visits per year, as reoccurring visits from local residents are not included but probably common as the distance to Hackås is short. Neither visitors nor visits coming from people outside the local municipality, considered tourists, are included in the estimation as working with regional tourism data would be difficult as Billstaån is not situated in the popular skiing areas of Jämtland.

Table 2. Estimation of visitor numbers to river Billstaån.

<table>
<thead>
<tr>
<th>Category of visitors</th>
<th>Visitors</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunch guests at the restaurant</td>
<td>1 200</td>
<td>Information from the restaurant: 30 guests/day for 8 weeks</td>
</tr>
<tr>
<td>Årets Näck spectators</td>
<td>300-350</td>
<td>From information from event planner</td>
</tr>
<tr>
<td>Anglers visiting the river (not necessarily for fishing)</td>
<td>100</td>
<td>1/3 of the permits sold in 2014</td>
</tr>
<tr>
<td>Residents in Hackås</td>
<td>500</td>
<td>One visit per resident and year</td>
</tr>
<tr>
<td>Visitors from the municipality</td>
<td>1 400</td>
<td>1/5 of the total residents in the municipality of Berg</td>
</tr>
</tbody>
</table>

5.1.3 Global climate regulation
One research team assessed the carbon stock of the currently standing forest around Billstaån in an area of 77 ha of forest (Appendix 4). In the current state this forest has the capability to bind about 1 900 tonnes carbon totally, including both above and below ground carbon stock, according to IPCC standard values (IPCC, 2006). Based on field work the area was considered as mixed forest, approximately between 50-100 years old (Appendix 1).
5.1.4 Water quality

To assess the current water quality, water samples were collected at the inlet and outlet of Billstaån (further description in Appendix 2). In general the water quality measured was good, according to criteria from the Swedish Environmental Protection agency representing close to neutral pH, minimal turbidity, and low to moderate COD (Naturvårdsverket, 2007). The values of biological as well as chemical oxygen demand indicates low chemical oxygen consumption in the river, while the oxygen levels shows Billstaån is an oxygen rich environment (see Appendix 2 for all sample data values). Measurements of total nitrogen show very high to extremely high values, suggesting eutrophication, but this is considered a deviation caused by contaminated samples as no other signs of eutrophication have been found. The water samples made thus fortify previously attained information on Billstaån as having good water quality.

5.2 Alternate state

As the restoration measures will increase the ecological status of Billstaån impact on ecosystem services is deemed as mainly positive. An expected increase in value and increased use of several ecosystem services in Billstaån is suggested, which can increase monetary flows through more visitors and related income for local businesses. See general considerations for the alternate state of a restored river Billstaån in Table 3.

Table 3. Description of alternate state for river Billstaån, based on the planned restoration measures and the expected impacts on ecosystem services and connected socio-economic factors.

<table>
<thead>
<tr>
<th>Restoration measure</th>
<th>Ecological impact from restoration measure</th>
<th>Expected ecosystem service effects</th>
<th>Socio-economic factors connected to restoration impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna passages</td>
<td>Removal of migration barriers. Increased possibilities for fish migration. Boosting river biodiversity. Opportunities for new species to establish in the system (e.g. otter).</td>
<td>Increased populations of migratory fish. Opportunities for recreational fishing. Increased chances to see, photograph, etc. (new) species.</td>
<td>Increasing visitor interests for recreational fishing and nature tourism. Increasing income from fishing permit sales. Opportunities for local business development.</td>
</tr>
<tr>
<td>Reservoir deconstruction</td>
<td>Extended, new river habitat environment. Extended, new land habitat environment where the reservoir is currently situated. New ecosystem(s). More streaming water. Increased oxygenation of water.</td>
<td>New landscape in the area that is currently the reservoir. Changes to visual values in the area. Removal of lake-like environment and its recreational uses.</td>
<td>Changed vista for some properties in the area. Decreased risks connected to dam safety. Opportunities to create desirable landscape type, e.g. a wet meadow, to increase visitor interest and ecological value.</td>
</tr>
<tr>
<td>Reintroduction of freshwater pearl mussels</td>
<td>Reintroduced key-specie to the ecosystem. Increased water filtration. Opportunities for better water quality. Food source for other species. Opportunities for more thriving river biodiversity.</td>
<td>Opportunities for better water quality. Positive effects for populations of fish and other species. Educational value from mussel shells as environmental archive (future research possibilities).</td>
<td>Increasing visitor interest for nature tourism. Opportunity to educate people on the importance of freshwater pearl mussels for the river ecosystem. Possibility to fulfil the Swedish national environmental goals.</td>
</tr>
</tbody>
</table>
5.2.1 Recreation and tourism

In the alternate state the restoration project can provide publicity to the Billstaån area and generate increased interest from visitors locally as well as in the region of Jämtland as a whole. This will be further extended if Billstaån is included in Natura 2000. As a result the restoration can increase the number of visits for current recreational activities and events as well as add visitor interests created by the restoration itself and generate new categories of visitors. This means new recreational activities directly connected to the restoration measures can be planned and marketed, e.g. the possibility to watch migrating trout in the fauna passages. Possibilities to attract tourists to Billstaån will thus increase.

Benefits to recreational fishing is one of the emphasised outcomes for the restoration project as the fauna passages allows brown trout to migrate more freely in Billstaån. An increasing trout population is expected to live and reproduce in the river in the alternate state, opening up for a higher quality recreational fishing than at the current state, as brown trout is more desirable than species now common in the river system. The value increase for recreational fishing will probably be larger for the area managed by the fishing management organisation of Storsjön-Berg since they are responsible for the area where brown trout is supposed to migrate upstream to spawn.

It should be noted that there may be some negative effects for local residents from increased visitor numbers in the area, as it can present social effects in terms of disrupted privacy, etc. In a more long term perspective most local residents should be positively affected by the development by creation of new recreational activities, job opportunities, raised property values and a better infrastructure if access to some areas around the river is increased.

5.2.2 Global climate regulation

As the hydro-electrical production in Billstaån will not be affected by the restoration, the main change to services connected to global climate regulation in the alternate state is the dam deconstruction in Ävjan. As the water is drained more ground be available for carbon capturing processes, in an area where carbon capture currently is limited due to being water covered and assumedly also having a low biological productivity which is common in hydropower reservoirs. When the water surface is decreased new land for e.g. forest growth will be available, including low vegetation carbon stocks and, over time, soil storage in dead matter. As the research teams considered the area of possible additional forest in the Ävjan differently, the estimated carbon captures differ. The possible above ground carbon stock from additional forest in the Ävjan area based on IPCC tiers was estimated to be about 6 tonnes carbon stock in 2.4 ha additional forest younger than 20 years (Appendix 2); approximately 18 tonnes carbon in 5.2 ha forest younger than 20 years; and 129 tonnes carbon in 5.2 ha forest older than 20 years (Appendix 4). To achieve a value of total carbon more directly based on the prerequisites on site in Billstaån one team calculated the carbon stocks in trees, soil and low vegetation based on field measurements and samples from the Ävjan area (details in Appendix 1). This estimation suggests 513 - 793 tonnes carbon can be stored in an additional forest of 3.2 ha in the Ävjan area.

One research teams raised concerns for how the draining of water in the dam may initially mean effluents of methane now stored in the reservoir sediments. Methane is a greenhouse gas, but the extent of such problems and data for how to convert it into carbon stock (which in that case has to rebuild before the Ävjan area stores more carbon than as a dam) has not been pursued in this study.
5.2.3 Flood protection

Two of the research teams assessed flood protection properties connected to river Billstaån. Currently there are no wetlands connected to Billstaån, which is the provider of flood protection as presented by TESSA. This led to one team concluding that there is no natural flood protection, from ecosystem services, in Billstaån (Appendix 1). The other team pursued further investigations in terms of flood risks in connection to the reservoir deconstruction in Ävjan (Appendix 4). From this was established that the area most impacted by increased water flow in conjunction with the reservoir draining is the river stretch between Ävjan and the small lake Flon, where no residential houses are situated. The hydropower plant in Lillå is placed just upstream lake Flon, which may require some extra caution when planning the water flow to safeguard the plant. A holiday cottage and a wooden bridge are also situated just upstream lake Flon but due to the controlled flow, and distance from the river to the holiday cottage, flood risks are probably low for these constructions. In general the flood risks are small due to the regulation of the river system. The team advised a step-wise approach to the draining procedure to increase control of the water flow, suggesting it may take place in springtime as the water flow is slow at that time of the year. An additional note is how draining the reservoir during spring would make possible a form of spring flood for some parts of the river, which can be beneficial for some habitats connected to river ecosystem.

5.2.4 Freshwater pearl mussels

By researching the properties of freshwater pearl mussels, three main ecosystem services connected to the specie was found (Appendix 1; Appendix 3) (Degerman et al., 2009; Smith and Jepsen, 2008; Wildscreen Arkive, 2015):

- Water purification, through filtration of water and storage of nutrients and heavy metals
- As a provider of more beneficial habitat for other species, e.g. brown trout, as freshwater pearl mussels are considered an umbrella species in river ecosystems
- As a provider of nutrition for other species, as mussel faeces contain nutrients for algae and detritus eaters in the bottom fauna, indirectly providing sustenance for fish and other organisms eating invertebrates
- Educational values connected to the function as environmental archive as the mussel shells grow similarly to annual rings and can be analysed for information on historical environmental development, that can be used in environmental research; but also in connection to the indicator role of freshwater pearl mussels in the Swedish environmental goals Flourishing lakes and streams and A rich diversity of plant and animal life

These represent services that will be added to Billstaån in the alternate state, when freshwater pearl mussels have been reintroduced to the river ecosystem.

In the survey to establish a monetary value on freshwater pearl mussels, the willingness to pay for having freshwater pearl mussels in a stream nearby was determined to an average of 76 SEK per person and year (Appendix 3). The survey also captured a willingness to pay for visiting such a stream at 50 - 100 SEK per visit.
5.3 Monetary values connected to ecosystem services at Billstaån

From the quantitative values generated by TESSA some monetary values for ecosystem services connected to river Billstaån have been estimated, as described in Table 4. Based on these values, the current state of Billstaån has a turnover up to 1.1 million SEK per year in connection to recreational activities. In the alternate state of a restored river about 1 million SEK/year can be added from values connected to the new forest in the Ävjan area and the reintroduction of freshwater pearl mussels. The current turnover is mainly connected to the restaurant business in Strömbacka, so this indicate that the restoration will add new monetary interests and business opportunities to the area. Note that this do not represent a total value of services from the river ecosystem, nor all services in this study, as more services are present at river Billstaån than those covered by TESSA. The water related services covered by TESSA, water quality and flood protection, are important in the ecological restoration setting of Billstaån but could not be translated into a monetary perspective.

An interesting part of the valuation is that most of the monetary values considered are generated as per year, which indicates that the restoration project in Billstaån actually has a pay-back time at least at a society level. If 1 million SEK could be generated per year the costs for the construction of fauna passages and the reservoir deconstruction, estimated to 8,94 million SEK (Jämtkraft AB, 2015a), a corresponding amount of money could be achieved within ten years. In extension this means the restoration also can be seen as an investment in the local economy and its capability to maintain business through creating new income and employment possibilities. As the area around Billstaån is rural changes to visitor numbers and related business opportunities can have great effects to the total local economic turnover.

Table 4. Monetary values connected to ecosystem services of Billstaån estimated from working with TESSA.

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Monetary unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation</td>
<td>Strömbacka restaurant turnover</td>
<td>1 000 000 SEK/year</td>
</tr>
<tr>
<td></td>
<td>Ticket sales to Årets Näck</td>
<td>24 000 - 28 000 SEK/year</td>
</tr>
<tr>
<td></td>
<td>Sold fishing permits in Näkten 2014</td>
<td>50 150 SEK</td>
</tr>
<tr>
<td></td>
<td>Sold fishing permits in both Näkten and Storsjön-Berg (estimated value)</td>
<td>72 600 SEK/year</td>
</tr>
<tr>
<td>Global climate regulation</td>
<td>Carbon dioxide emission licenses representing the new forest in Ävjan</td>
<td>320 000 - 496 000 SEK/year</td>
</tr>
<tr>
<td>Timber provisioning</td>
<td>Timber value representing the new forest in Ävjan</td>
<td>55-600 SEK/year</td>
</tr>
<tr>
<td>Freshwater pearl mussels</td>
<td>Speculative harvesting</td>
<td>98 000 SEK/3 000 pearls</td>
</tr>
<tr>
<td></td>
<td>Average willingness to pay for freshwater pearl mussel presence</td>
<td>76 SEK/survey recipient</td>
</tr>
<tr>
<td></td>
<td>Willingness to pay for visit to mussel river</td>
<td>50-100 SEK/visit</td>
</tr>
</tbody>
</table>
The turnover of the Strömbacka restaurant has a dominating share in the current monetary value established for ecosystem services from Billstaån, as presented in Table 4. The restaurant is connected to ecosystem services provided by river Billstaån due to its location in direct proximity to the water surface, affecting the restaurant experience by vista, sounds, etc. Since the restaurant also supplies food it is hard to measure how much of the generated SEK is actually connected to the ecosystem services, vs. factors such as the quality of the food and local competition from other restaurants. What is expressed as yearly turnover thus can be related to cultural ecosystem services provided by the river, but a great extent of human interference also affects the visitors experience and willingness to pay.

The freshwater pearl mussels reintroduced in the alternate state are interesting in a monetary terms. Based on the willingness to pay for visiting mussel water in the survey the presence of mussels could generate 175 000 – 350 000 SEK for the 3 500 visitors estimated at the current state if all of them paid e.g. an entrance or parking fee. In relation to other monetary values acquired this represents values higher than both the ticket sales to Årets Näck and the fishing permit sales. In a speculative scenario the possible economic benefit of harvesting freshwater pearl mussels for pearls, as ornamental resource, was evaluated. Such harvest is not allowed at the present as freshwater pearl mussel is a protected species, but the calculation was done because ecosystem service values as per definition do have to be harvested to be assessed. Based on USD prices on cultivated pearls it was estimated that harvest of 3 000 mussels per year could generate 98 000 SEK, as seen in Table 4. As the USD pricing is connected to other species it must be considered that this value can be an underestimation as well as an overestimation. None the less the valuation indicates pearl harvest can be of economic interest, e.g. in connection to souvenirs, should it be allowed in the future.

The monetary valuation of recreational fishing in Billstaån is problematic, since it is not measureable to what extent or how many of the sold fishing permits are used in the river and not the corresponding lakes whose fishing management organisations sells them. The monetary value presented in Table 4 thus encompass the monetary value of the possibility to engage in recreational fishing in Billstaån, as well as in lake Nääken and the part of Storsjön addressed in the valuation. The actual value of the activity stands unknown and is hard to estimate, as it stands vs. the same type of values in the lakes which probably is higher and more used in the current state of Billstaån. In the alternate state this can be altered as the restoration intends to enhance the value of the catch available in the river from changes to species composition in favour of recreational fishing interests.

Altogether, the TESSA monetary valuation of Billstaån points at some difficulties when evaluating ecosystem services as potential economic outputs, as the ecosystem studied is connected to surrounding ecosystems and their services. This indicate how the services of a single system are hard to single out in a small locality such as the site used in this study, as they glide over into surrounding systems since the human beneficiaries do not limit their use of ecosystem services to the service as it is provided from one single system.
Discussion

Out of the 27 methodologies covered by TESSA, nine were used to assess the restoration of Billstaån in terms of ecosystem services connected to recreation, global climate regulation, water quality and flood protection. TESSA indicated the expected restoration outcomes for these services in relation to their current status, but more results for the ecosystem services in the current state of the river were generated than results for the future alternate state. Some of the TESSA methods were altered, by e.g. complementary calculations, to better suit the settings of Billstaån. All tested methods resulted in quantitative data of some sort, which could be translated into monetary values in some sense for all services covered in the assessment except for the water related services. This is considered successful as the study had limitations in terms of time and lack of data in connection to the site.

As TESSA is meant for assessment of sites prospected for exploitation, with removal or damage to ecosystem services as a result, the study of Billstaån meant testing TESSA for another scope. This made it very clear how it generally is harder to measure what we will gain from changes to an ecosystem than what we could lose by changing it. In Billstaån ecosystem services will benefit from the restoration and probably increase in value, but to estimate by how much in monetary terms is hard based on available knowledge and the results in this study. This is emphasised by how the monetary assessment do not include the full range of ecosystem services from Billstaån but rather is a mapping of values connected to certain services covered in TESSA. Because of this the alternate state of Billstaån is described less in detail, in an entirely qualitative way, than was expected at the start of the study. As the scenario thinking aspect was one of the reasons for setting up the study this outcome can suggest some limitations for TESSA when applied to cases outside the suggested scope.

TESSA illustrated how various types of information are relevant for measuring and assessing ecosystem services. The range of results attained from TESSA was diverse, including e.g. calculated numbers on carbon stock, data measured in the field and opinions from stakeholders in recreational activities. This made managing the presentation of the cohesive assessment results challenging, but it is suggested as an issue not unique for this study but a reoccurring problem when presenting results from ecosystem service assessment (as the considered output from any ecosystem should be considered diverse).

6.1 TESSA benefits

From a supervisor point of view, working with TESSA was overall positive and rewarding. The toolkit made it possible for the research teams to work independently during the assessment, as the framework guidelines offered basic support for the different assessment steps. TESSA also clearly helped the teams in learning some common methodology for ecosystem service assessment, and some of the issues and problems related to such procedures. Because of this the teams could produce their own assessments within reasonable time and pursue methodological development as well as deeper interpretations of their results.

The research teams described TESSA as user-friendly and overall providing a good platform for analysis of the site, providing a systematic action plan in terms of methodological choices. The stepwise approach made it rather easy to collect information and achieve transparent results and conclusions.
In terms of methodological development some of the research teams arranged their methodology to better suit the site of Billstaån and Swedish ecosystem conditions, evidently basing it on TESSA. They studied the TESSA guidelines and added complementing calculations as well as used other data references, in a way that would not have been possible without the framework as starting point for their assessments. As the methodological choices generally required less arrangements than if the research teams had been set to arrange methodology of their own, discussions on how to interpret and evaluate the results were lifted during the actual assessment rather than after it was finished. This created more possibilities for methodological development and for discussing general issues in ecosystem service assessment and monetary valuation of nature. Through this, the research teams got a deeper understanding of their results and what it may implicate.

6.2 TESSA limitations

The main issue discovered during this study is how to determine the relevance of the selection of ecosystem services covered in TESSA for the Billstaån case. This is directly connected to the currently limited number of services covered by the framework and how services determined as important for the restoration outcome in previous studies are not covered (e.g. habitat values, energy production and erosion control). It was thus clearly demonstrated that TESSA do not provide a complete assessment of ecosystem services at a site, but a sample of services. In itself this is not a problem, as TESSA still provide valuable material for starting to understand ecosystem services from a site, but it is hard to evaluate the importance of the material TESSA provided in the Billstaån case. Mainly it can be discussed if the new information from TESSA provides valuable input to the restoration or if it is too much of a sample related to what is already known. This also indicate possible issues if the assessor has little knowledge of ecosystem services from start, as it can be hard to relate the services assessed in TESSA to the actual demand on a site and the needs from its beneficiaries. E.g. an area providing important regulating services, presently not covered by TESSA, can be assessed in terms of provisioning of goods and recreation towards an unfair, under-estimated, assessment not including main positive impacts the site has for nearby communities.

In TESSA great emphasis in terms of available methodologies are placed on services connected to global climate regulation, covering 14 out of the 27 methodologies in the toolkit. This did not suit the setting of the restoration in Billstaån, both since such effects are limited in the alternate state but also since the ecological restoration measures have no direct intentions in relation to global climate regulation. Through this dominance in the framework global climate regulation services acquired a lot of the time available in this study, even though they do not represent major values in the development of Billstaån. In extension this aspect of the current framework construction limited assessment efforts for other services that might had been more valuable to assess, e.g. wild foods.

6.3 Improvement suggestions

6.3.1 For similar studies

This study was limited in sense of time, but still gave possibilities to work with TESSA and establish what in can provide in the Billstaån setting. Through the course of the study it became evident how the assessment would have benefitted from a longer planning phase, with more involvement from stakeholders in the restoration project group. This would have provided a better, more finalised, scoping appraisal and a more transparent starting point for the research teams in terms of assessment expectations and already available information.
A more general mapping of ecosystem services possible to include in the assessment should have been made before the research teams were introduced to the services covered by TESSA. This might have affected the choice of assessed services, directing it more towards interesting aspects of the Billstaån site than methodology available. Such material could have been prepared by the supervisors, or as a joint effort to start the research project, to enhance the understanding of the full range of services Billstaån provides.

A more arranged collaborative approach in general would have meant a more stable research process for the teams, by e.g. making a joint definition of the alternate state, which in turn could have provided less confusion and more assurance in terms of results quality. Despite efforts to maintain a high level of collaboration between the research teams, by several seminars for general progress discussions and sharing information, the wished for united action was not fully achieved. Having a clearer outline to start from and follow through the study could have reduced the stress, which was pointed out as the main reason for not contacting other teams, and increased understanding for the task. This could have been achieved by setting up shared milestones or dividing the assessment into subprojects to keep all teams up to pace and working more in parallel with the different steps in the research process.

6.3.2 For further development of TESSA
As TESSA is still under development, more ecosystem services will be covered in future versions. In the light of the assessment of Billstaån, especially more regulating services and cultural values should be included to be able to cover services important at this specific site. E.g. methodology to assess the value of natural water treatment, the input to industrial systems (hydropower in the Billstaån case), and assessment of possible changes to property values could be interesting in many other cases. Suggestions for how to assess the value of reintroduction of a specie, increased biodiversity, and the cultural aesthetic value of a vista would also be interesting for cases similar to Billstaån.

In terms of transparency and accuracy of ecosystem service assessments carried out based on TESSA, tools for how to consider or present services not covered by the current toolkit are needed. Such tools could be a qualitative overview of more services from the site or a step of risk assessment of services possibly lost in the alternate state. Through this, TESSA assessment results could be related to what can be accounted for and not within the quantitative methodologies in the framework. This would extend the range of assessments based on TESSA and make it possible to include services that are important at the site, but currently not covered in the quantitative assessments.

A cohesive way for comparing results to other TESSA studies to determine plausibility, through e.g. having access to other case studies through a web portal, would help greatly in understanding the study outcome. The research teams in general expressed a lack of suggestions on how to interpret, contrast and evaluate their results. Guidance in how to generate such material, through e.g. converting numbers on carbon stock into monetary values related to carbon taxation, should be available in future versions of the toolkit. From an academic point of view such efforts may present itself naturally, but as the toolkit addresses practitioners such steps can be missed or left out if the suggestions for them are not provided directly. It would also help in communication efforts if more commonly known factors such as ecological footprint, etc. can be considered.
Conclusions

In the study of the ecological restoration of river Billstaån TESSA has provided a structured framework to assess several ecosystem services currently provided by Billstaån and estimate some of the expected effects on them from the planned restoration measures quantitatively. Ecosystem services connected to nature-based recreation and global climate regulation could be converted into monetary values, while the water related services assessed could not be converted. Due to the limited amount of services covered by TESSA, and this assessment, the monetary valuation do not express a total value of services from Billstaån. The monetary valuation established indicate that increased values connected to the restoration measures mainly will be generated in services connected to recreation and tourism. The restoration effects on ecosystem services were also captured in qualitative description of an alternate state of Billstaån, including fauna passages to restore migration routes in the river, a current dam having been reverted to streaming water and reintroduction of freshwater pearl mussels to the river ecosystem. In the alternate state a larger brown trout population is expected in the river and more visitors are attracted to the area for recreational fishing as well as interests founded by the restoration efforts.

TESSA was found usable to assess some of the ecosystem services connected to Billstaån. The assessment procedure was relatively fast and rewarding. The extensive guidelines and quality of the methodologies makes TESSA very interesting for pursuing knowledge of impact on ecosystem services from various changes to landscape and land-use, which should be both helpful and provide valuable material in many cases. For the Billstaån case TESSA provide a methodological basis that could be directly transferred into monitoring work, after the restoration has been finished, to trace development of the ecosystem services covered in the toolkit.

TESSA included no tools to assess if the services covered in the framework are the most relevant for the investigated site and the number of services covered by the toolkit was limited. This indicates that working with TESSA as a stand-alone tool can make it hard to determine if the assessed services are the services most relevant for the investigated site, its beneficiaries and the prospected development. Such material is suggested to be included in the future updates of TESSA, by e.g. steps for attaining a qualitative overview of services at a site, along with methodological cover of more regulating ecosystem services, cultural values, and how to value service input to industrial systems.
References


Jämtkraft AB. (2015a). *Miljökonsekvensbeskrivning angående anläggande av vandringsvägar och utrivning av damm i Billstaån* [Environmental impact assessment concerning construction of fauna passages and deconstruction of reservoir in Billstaån].

Jämtkraft AB. (2015b). *Samrådsunderlag angående anläggande av vandringsvägar och utrivning damm i Billstaån: Billsta kraftverk, Strömbacka kraftverk, Åvandammen och Nåktens regleringsdamm* [Consultation paper concerning construction of bypass channels and deconstruction of dam in Billstaån: Billsta power plant, Strömbacka power plant, the Åvjan dam and regulating dam of Näkten].


Appendix 1: Study details for team 1
Alm F., Österud T., Lundblad N., Vestlund G., Souri C., Johansson B.

Study scope
Assessment of global climate regulation services, connected to the reforestation of the area that is now the reservoir of Ävjan, and flood protection. Identification of ecosystem services connected to freshwater pearl mussels.

Method
Team 1 based their study on TESSA methods:

- Climate M1: using QGIS and the boundary of Swedish shoreline protection (100 m from the water line) to determine levels of disturbance and possible area of re-growing forest at Ävjan
- Climate M2: using IPCC formulas for carbon and data from own site measurements
- Climate M5
- Climate M7: oven temperatures and procedure was changed to 105 °C for 24 hours, followed by weighing and one more hour in the oven to make sure all water was evaporated before weighing again, the samples were then placed in 550 °C for 6 hours before last weighing
- Water M1

Calculating the total carbon stock was done in three different ways to get a span of results to contrast to each other and the other teams. The results from TESSA were used as input in those calculations. The freshwater pearl mussel services were identified by interviews with experts.

Additional methodology: Low vegetation carbon content
To estimate the carbon content in low vegetation site samples were made. Three samples of low vegetation of 1 dm$^3$ (0.00001 ha) each were taken at two different locations. The samples were weighed and dried at 50°C for 5 days and then weighed again. 50% of the remaining dry weight was assumed to be carbon. The carbon content/dm$^3$ was converted to carbon content/hectare.

Additional methodology: Carbon dioxide uptake and its economical value
To be able to convert carbon (C) to carbon dioxide (CO$_2$) the conversion factor of (44/12) was applied. The conversion factor is based on the ratio between the molecular weight of C (12g/mole) and CO$_2$ (44g/mole).

Formula: (44/12) * carbon content

To convert the carbon dioxide into an economical value, the sum of the different carbon storages were added together and converted into carbon dioxide. The carbon dioxide sum was multiplied with the cost of buying a carbon dioxide emission license (170 SEK/ton) from the Swedish Society for Nature Conservation.

Formula: total carbon dioxide equivalent * 170 SEK

This gives a value in SEK/hectare. To get the value of the forest that can grow in the Ävjan area the SEK/hectare is multiplied with the hectare new forest (gained from calculating the area in QGIS).

Formula: (Value SEK/hectare) * (total hectare)
Results

Global climate regulation

Figure 3. Sketch of Ävjan and surroundings, representing the area where most changes to the current landscape will occur in the restoration of Bilstaán. The turquoise field show the area of water surface that will disappear as the dam is removed. The pink field is the current beach like area, with low vegetation. These two areas combined represents the possible area where a new forest can grow around the river after the dam is removed. This represents 3,2 hectare of possible new forest. The squares show points of investigation: yellow being the sample site for low vegetation and soil; white where deciduous trees were counted; and, orange where pines were counted.

As further described in figure 3, Alm et al. estimated the new possible forest in the Ävjan area to 3,2 hectare. From the field measurements to count trees and species in the surrounding forest, the forest was estimated to be between 50-100 years old. From working with three different ways to calculate carbon capture capability of forest it was found that the area of new forest would be able to capture between 513-793 ton, including stored carbon in trees, soil and low vegetation. This represents 320 000 - 496 000 SEK in carbon dioxide emission licenses from the Swedish Society for Nature Conservation (Naturskyddsföreningen, 2015). For more details, see table 5.

Table 5. Assessment of carbon capture capability in the possible new forest in the Ävjan area. The data set is based on three different methodologies for calculating carbon capture in trees and includes capture in soil and low vegetation.

<table>
<thead>
<tr>
<th>Method</th>
<th>Parameter</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPCC (TESSA Climate M2)</td>
<td>Ton carbon</td>
<td>382</td>
</tr>
<tr>
<td></td>
<td>Ton CO₂</td>
<td>1 400</td>
</tr>
<tr>
<td></td>
<td>Value (SEK)</td>
<td>240 000</td>
</tr>
<tr>
<td>From Praktisk skogshandbok</td>
<td>Ton carbon</td>
<td>227</td>
</tr>
<tr>
<td>(Hamilton, 1992)</td>
<td>Ton CO₂</td>
<td>831</td>
</tr>
<tr>
<td></td>
<td>Value (SEK)</td>
<td>140 000</td>
</tr>
<tr>
<td>Alabama Forestry Commission</td>
<td>Ton carbon</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>Ton CO₂</td>
<td>374</td>
</tr>
<tr>
<td></td>
<td>Value (SEK)</td>
<td>64 000</td>
</tr>
<tr>
<td>Soil samples (TESSA Climate M5)</td>
<td>Ton carbon</td>
<td>385</td>
</tr>
<tr>
<td></td>
<td>Ton CO₂</td>
<td>1 413</td>
</tr>
<tr>
<td></td>
<td>Value (SEK)</td>
<td>240 000</td>
</tr>
<tr>
<td>Low vegetation</td>
<td>Ton carbon</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Ton CO₂</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Value (SEK)</td>
<td>16 000</td>
</tr>
</tbody>
</table>
Flood protection
Absence of wetlands was determined during field studies in the area around Billstaån. Team 1 did not pursue further assessment of flood protection services due to defiance within the toolkit.

Freshwater pearl mussels
Team 1 found the main ecosystem service connected to freshwater pearl mussels is water filtration. One mussel can filtrate up to 70 l water/day from particulate matter, and store nutrients. Furthermore, freshwater pearl mussels are considered an indicator specie in terms of water quality, due to its sensitivity to changes in habitat. Thus, large mussel populations in extension indicate flourishing water biodiversity. Additional to this, freshwater pearl mussels provides food for plankton and microorganisms, from their excrement (psuedofeces), which favours further steps in the food chain (such as brown trout). Freshwater pearl mussels are also edible for humans but are considered tough and with no special appeal to the palate.

In a speculative scenario, if pearls from freshwater pearl mussel would become harvestable, the pearls produced in Billstaån could generate about 12 300 USD/year (98 000 SEK/year). This is based on retail prices on pearls from other freshwater systems (Pearl Paradise, 2015), with a mean value of 41 USD, and an estimated harvest from 10% of the planned introduction of 3 000 pearl mussels in Billstaån. However, since freshwater pearl mussels in Sweden are currently red-listed, there is no current market for such goods.

The team suggested TESSA method Water M5 to assess water quality when the mussels have been established in the river to monitor possible improvement from the current state.
Appendix 2: Study details for team 2
Bengtsson A., Ericsson L., Hedman L., Gjerdrum A., Wärn S.

Study scope
To assess the recreational value of fishing in Billstaån, the river water quality, carbon storage capability of the possible new forest in the Ävjan area and the economical value of this forest.

Method
Team 2 based their study on TESSA methods:

- Recreation M1: instead of counting visitors, a count of fishing permits was done to determine sold permits per year and related income for the fishing management organisations
- Water M5: water samples from two points (one close to the inlet and one by the outlet), three samples from each point to be able to use mean values per sample point, temperature and dissolved oxygen were measured on site, while pH, nutrients and COD were measured in a lab environment, COD was converted to BOD and the measured oxygen saturation was converted into oxygen content using an online converter, data on Coliform bacteria was attained from the local municipality (of Berg)
- Climate M2: applying IPCC methodology and formulas to an estimated area of new forest in the area of Ävjan based on QGIS and topographic maps from Lantmäteriet

Additional methodology: Forest value
To estimate an economic value of future forest in the Ävjan area, statistics about forest productivity in the region of Jämtland (from SLU) and timber prices from the company Norrskog was used.

Results
Recreational fishing
Team 2 found out that Billstaån is split between two fishing management organisations; Storsjön-Berg FVOF and Näkten FVOF. As can be seen in figure [F], the division point is situated upstream lake Flon. The FVOF of Näkten is responsible for the river upstream this point, including lake Näkten, and the FVOF of Storsjön-Berg is responsible for the downstream stretch and parts of Storsjön.

Figure 4. Map of Billstaån and the boundary between the FVOF’s of Näkten and Storsjön- Berg (blue line).
Based on the data in table 6 and 7, the total economic value of the fishing permits connected to Billstaån was estimated to 72 600 SEK in 2014. However, the lakes are probably the primary fishing points and to which degree these permits were used for fishing in the river is unknown.

**Table 6.** Permit prices in the FVOF’s of Näkten and Storsjön-Berg.

<table>
<thead>
<tr>
<th>Type of permit</th>
<th>Price in Näkten FVOF (SEK)</th>
<th>Price is Storsjön-Berg FVOF (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week permit</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Month permit</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Year permit</td>
<td>200 (including 5 nets)</td>
<td>600</td>
</tr>
<tr>
<td>Year permit, trolling</td>
<td>400</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 7.** Number of sold fishing permits and total economic value in the FVOF’s of Näkten and Storsjön-Berg.

<table>
<thead>
<tr>
<th>Number sold permits</th>
<th>Näkten FVOF</th>
<th>Storsjön-Berg FVOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day permits</td>
<td>319</td>
<td>48</td>
</tr>
<tr>
<td>Average cost (SEK)</td>
<td>187,50</td>
<td>266,70</td>
</tr>
<tr>
<td>Total (SEK)</td>
<td>59 812,50</td>
<td>12 800</td>
</tr>
</tbody>
</table>

**Water quality**

The results from the water sample in Billstaån are shown in table 8. They were complemented with measurements of Coliform bacteria from the local municipality of Berg, at the two closet measuring points (Näcksta and Side), with levels not indicating any notable risks.

**Table 8.** Water samples from Billstaån, taken at inlet and outlet, 2015-09-29.

<table>
<thead>
<tr>
<th>Sample point</th>
<th>Sample</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet (B)</td>
<td>Phosphorus (ug/l)</td>
<td>-11 *</td>
<td>-26</td>
<td>-8 *</td>
</tr>
<tr>
<td></td>
<td>Total Nitrogen (ug/l)</td>
<td>1940</td>
<td>3100</td>
<td>18300 **</td>
</tr>
<tr>
<td></td>
<td>COD (mg/l)</td>
<td>38,7</td>
<td>19,30</td>
<td>27,3</td>
</tr>
<tr>
<td></td>
<td>BOD (mg/l)</td>
<td>25,5</td>
<td>12,7</td>
<td>18,0</td>
</tr>
<tr>
<td></td>
<td>Turbidity (FNU/FTU)</td>
<td>0,25</td>
<td>0,29</td>
<td>0,19</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>7,4</td>
<td>7,4</td>
<td>7,4</td>
</tr>
<tr>
<td></td>
<td>Oxygen (%)</td>
<td>88-95</td>
<td>88-95</td>
<td>88-95</td>
</tr>
<tr>
<td>Outlet (A)</td>
<td>Phosphorus (ug/l)</td>
<td>133</td>
<td>-11 *</td>
<td>50 *</td>
</tr>
<tr>
<td></td>
<td>Total Nitrogen (ug/l)</td>
<td>3320</td>
<td>2200</td>
<td>972 *</td>
</tr>
<tr>
<td></td>
<td>COD (mg/l)</td>
<td>20,1</td>
<td>17,80</td>
<td>16,3</td>
</tr>
<tr>
<td></td>
<td>BOD (mg/l)</td>
<td>13,3</td>
<td>11,7</td>
<td>18,0</td>
</tr>
<tr>
<td></td>
<td>Turbidity (FNU/FTU)</td>
<td>0,25</td>
<td>0,24</td>
<td>0,21</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>7,4</td>
<td>7,4</td>
<td>7,4</td>
</tr>
<tr>
<td></td>
<td>Oxygen (%)</td>
<td>86-91</td>
<td>86-91</td>
<td>86-91</td>
</tr>
</tbody>
</table>
The sample results were compared to criteria from the Swedish Environmental Protection agency. According to these criteria, the samples in Billstaån have close to neutral pH, minimal turbidity, and low to moderate COD. The measurements on COD and BOD show low chemical oxygen consumption in the river, while the oxygen levels shows Billstaån is an oxygen rich environment. The data on total nitrogen shows very high to extremely high values, on levels suggesting eutrophication. This is probably not the case as such issues are otherwise not suggested as normally occurring in Billstaån, but due to contaminated samples. Overall, it is hard to determine whether these samples show on normality or not as the water samples are not further compared to other samples from the area, or repeated over time.

Above ground carbon stock and timber value
Team 2 estimated the possible new forest in the Ävjan area to be 2,4 hectare. Based on IPCC values of 5 metric tonnes dry matter/hectare European forest under 20 years of age, this additional forest represent above ground living biomass of 11, 95 tonnes storing 5,975 tonnes carbon totally.

This result was related to the possible timber value, based on average forest productivity in the region of Jämtland (3.4 m³ sk / ha forest and year) and prices from the main regional forestry company, as shown in table 9. The total value from this estimation is about 1 300 SEK in the 2,4 hectare new forest in the Ävjan area.

Table 9. Timber value of potential forest growth in the Ävjan area per year and commodity (based on prices from Norrskog).

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Price (SEK/m³ fub)</th>
<th>Value at the site (SEK/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous pulpwod</td>
<td>217</td>
<td>583</td>
</tr>
<tr>
<td>Birch pulpwod</td>
<td>242</td>
<td>55</td>
</tr>
<tr>
<td>Saw logs</td>
<td>215</td>
<td>600</td>
</tr>
<tr>
<td>Fuel wood (conifer and deciduous)</td>
<td>135</td>
<td>77</td>
</tr>
</tbody>
</table>
Appendix 3: Study details for team 3
Eklund A., Rydén I., Carlsson S., Karlsson I., Franzén W.

Study scope
Assessment of the economic value of Billstaån for recreation and tourism and indicating important points in the alternate restored state. Establishing visitor numbers in the area and values of reintroducing freshwater pearl mussels.

Method
Team 3 considered TESSA methods:

- Recreation M1 and M2: instead of counting visitors at the site, stakeholders in terms of visitor interest and numbers were determined and contacted to collect numbers on visitors and related income, along with opinions on what the restoration can mean for local tourism.

To map the current situation and alternate state of Billstaån an overview table similar to one used within TESSA presentation material was made.

Additional method: Mind maps
To achieve further understanding of the possible development in Billstaån from current state to alternate restored state, the team worked with mind maps to describe scenarios and correlations between the factors considered in their study. The probable development was based on studies and contact with a similar restoration project in Vindelälven (Sweden) and analysis of the Environmental Impact Assessment of the project in Billstaån.

Additional method: Survey to estimate value of freshwater pearl mussels
To get a valuation of freshwater pearl mussels and their effects on their environment from the public, a short digital survey was created by using Google Forms. The survey was spread on personal Facebook profiles and was available for 6 days.

The following starting information was given in the survey:

“Freshwater pearl mussels can purify water from emissions and heavy metals. One mussel can purify 50 l water per day. It also helps other species thrive.”

This was done to provide the respondents with a starting point, since freshwater pearl mussels is not a specie commonly known. The information was found in literature studies and from expert contacts.

The following questions were used in the survey:

1. Knowing this, how do you feel about having populations of freshwater pearl mussels in streams in your area?
   
   [Alternatives: Positive; Negative; Neutral]
2. Would you be prepared to pay anything for the existence of freshwater pearl mussels in your area? If yes, how much money per year would you be willing to pay to have freshwater pearl mussels in a stream closeby? (For comparison, a study in Sweden has shown a willingness to pay 12 SEK per person and year to preserve White-backed woodpecker.)

[Field for free writing]

3. Would cleaner water and increased biodiversity due to freshwater pearl mussel make you visit an area?

[Alternative: Yes; No; Unsure]

4. If yes, how much would you be willing to pay for such a visit?

[Field for free writing]

The survey also included a field for comments.

The information about White-backed woodpecker is from a study from Swedish University of Agricultural Sciences, made 15 years ago (Fredman, 2000). The result of that study was a willingness to pay 10 SEK per person and year, which has been adjusted by using an inflation calculator to relate it to current economy.

To calculate how much the survey respondents in average were willing to pay for freshwater pearl mussels the total SEK sum in respective category from the survey was divided with the number of respondents.

Results

Recreation

The restaurant in Strömbacka is open in summer, eight weeks per year, and serves about 30 lunch guests a day and additional dinner guests. At the time of the study the yearly turnover was estimated to be about 1 million SEK in 2015. In connection to the restoration a cottage will be moved, which cause additional costs. Generally, the restaurant owner expects the restoration to increase the business in Strömbacka.

Based on information from the event planner, the competition Årets Näck has had between 300 - 350 visitors over the last five years, presenting a revenue of 24 - 28 000 SEK/year from ticket sales.

Through contact with the fishing management organisation in Lake Näkten, the team found that recreational fishing in the area around Billstaån included 320 visitors in 2014, about 180 of them locals. This presented a total income of 50 150 SEK in 2014 from sold fishing permits, from which about 42 000 SEK were permits bought by local residents.

The team also investigated the effects to a snowmobile track passing one of the areas that will be made into fauna passage, and if the possibility to use it may be affected. Through contact with the project leader at Jämtkraft AB it was found that usability of the track is not expected to change.
Alternate state

At the current state, visitors to Billstaån go there for recreational activities such as fishing, bathing, hiking, snowmobiling or dining in the restaurant in Strömbacka. In the alternate state the visitor numbers are expected to increase since the restoration project means more people become aware of the area but also due to interest in the reintroduced freshwater pearl mussels and the site becoming part of Natura 2000. This is beneficial for the restaurant, as they can get more guests, but can also increase recreation in the area in general and boost the reputation of Jämtkraft AB. The table also assigned some global losers, which is due to the project investments coming from EU level.

In terms of economical gain, the stakeholder in the area most related to this is the restaurant. In the alternate state tourism to the area is expected to increase, giving added economical gains to the restaurant. More fishing licenses may also be sold as the fishing gets better when fish populations in the river increase. Thus, both the restaurant owner and fishing license vendors will profit from the restoration. In short term, property owners close to the river are possible losers as they have to adapt to more visitors in the area. In a more long term perspective they can be positively affected by increased visitor numbers to the area.

For the services connected to freshwater pearl mussels, the reintroduction into Billstaån means added services to the area. This creates new values in connection to visitor interest as well as other ecosystem services that may be better performed as mussel populations are restored in the area.

These differences between current and alternate state is illustrated in table 10, which shows that visitor numbers and economical gain is expected to increase in a way that generally benefits local and regional stakeholders. Differences between the states are further described in the mind maps in figure 5 and 6.

Table 10. Comparison of present and alternate state of ecosystem services, beneficiaries and project results of the restoration in Billstaån.

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Current state</th>
<th>Alternate state</th>
<th>Who gains</th>
<th>Who loses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation and tourism - Visitor numbers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation and tourism - Economical gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of freshwater pearl mussel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Local scale  Regional scale  Global scale
Figure 5. Description of current state of Billstaån. Red frames indicate negative effects.

- Blocked migration routes
- Decreasing fish populations
  - Less fishing visitors
  - Decreasing populations of freshwater pearl mussel
    - Less water purification
    - Decreasing knowledge and lost research potential
  - Less possibility to fulfil the Swedish Environmental Goals, as freshwater pearl mussels is an indicator specie for two of these goals
Figure 6. Description of alternate, restored, state for Billstaän. Red frames indicate negative effects, while green indicates positive.

- Free migration routes
- Increasing fish populations
  - Increased publicity due to increased biodiversity, preservation of species and Natura 2000
  - More fishing visitors
    - More paying visitors
    - Visitors for education and research
  - Increasing freshwater pearl populations
    - Indicator for the Swedish Environmental goals
- Project costs
- Possible effect on snowmobile track
  - Less snowmobile visitors
  - Increased publicity due to increased biodiversity, preservation of species and Natura 2000
    - More paying visitors
    - Visitors for education and research
  - Increasing fish populations
    - More fishing visitors
      - More paying visitors
**Freshwater pearl mussels**

The team found the following ecosystem services connected to freshwater pearl mussels:

- Water filtration: removing nutrients and particulate matter
- Environmental archive: as the mussel shell store heavy metals, and since freshwater pearl mussels can be very old, they can be analysed to track historical environmental impact
- Umbrella specie: populations of freshwater pearl mussels indicate beneficial conditions for other species

The survey to establish the value of freshwater pearl mussels got 55 recipients in the time available, mainly friends and relatives of the research team. To increase credibility of the survey a larger survey spread is required, in terms of answered surveys as well as demographics.

As can be seen in figure 7, a great majority of the recipients considered freshwater pearl mussels as a positive element in nearby ecosystems. In the following questions how much money they would be willing to pay to have them in a near stream the average value was 76 SEK per year and person, spanning from 1 SEK for a few recipients up to 500 SEK for a few others.

**Figure 7. How do you feel about having populations of freshwater pearl mussels in streams in your area?**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>51</td>
<td>92.7%</td>
</tr>
<tr>
<td>Neutral</td>
<td>4</td>
<td>7.3%</td>
</tr>
<tr>
<td>Negative</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Visitor interest connected to the presence of freshwater pearl mussels were less unanimous, as shown in figure 8. Among those who showed interest to visit such areas the willingness to pay for such a visit was generally about 50-100 SEK per visit. Several recipients interested to visit such an area did not want to pay anything, while one recipient was willing to pay 10 000 SEK.

**Figure 8. Would cleaner water and increased biodiversity due to freshwater pearl mussel make you visit an area?**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>24</td>
<td>48%</td>
</tr>
<tr>
<td>No</td>
<td>10</td>
<td>20%</td>
</tr>
<tr>
<td>Unsure</td>
<td>16</td>
<td>32%</td>
</tr>
</tbody>
</table>
Appendix 4: Study details for team 4
Purins R., Homoly J., Eriksson-Norman E., Stigblom E., Olsson M., and Johansson S

Study scope
Testing how useful TESSA is for investigating effects on tourism from the removal of the reservoir in Ävjan, assessing risk for flooding and estimate carbon stock in the new forest in the Ävjan area.

Method
Team 4 based their study on TESSA methods:

- Recreation M1: instead of counting visitors at the site, based on web research and contact with tourism stakeholders and the local municipality
- Water M1 and M3: using data on water bodies and dams from SMHI
- Climate M2 and M5: applied to an area determined from using QGIS, orthophoto and a boundary of 200 m from the river, by using IPCC values for European boreal coniferous forest younger than 20 years in the area that currently is Ävjan

Results
Tourism
Data on visitor numbers and income was collected from the arranger of Årets Näck, an employee at the restaurant in Strömbacka and a seller of fishing permits in lake Näkten. By this, the team found out that the restaurant is only open over summer, that the ticket price to Årets Näck has been 80 SEK/visitor, and they also got details on fishing permits as shown in table 11. In the interviews, none of stakeholders expected their visitor numbers or income to change in connection to the removal of the reservoir in Ävjan. Furthermore, the team established that the tourism in Hackås in general is limited due to the size of the village as there are few events where visitors can participate.

Table 11. Sold fishing permits in Näkten 2014.

<table>
<thead>
<tr>
<th>Permit type</th>
<th>Price/permit (SEK)</th>
<th>Number sold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>200</td>
<td>154</td>
</tr>
<tr>
<td>Month</td>
<td>100</td>
<td>18</td>
</tr>
<tr>
<td>Week</td>
<td>50</td>
<td>119</td>
</tr>
<tr>
<td>Trolling</td>
<td>400</td>
<td>29</td>
</tr>
</tbody>
</table>

Flood protection
According to data from SMHI, the reservoir in Ävjan has an area of 0.36 km² and an average depth of 3-4 m, storing about 100 000 m³ water. Based on the SMHI data in table 12, the team calculated the average yearly water flow through Ävjan as 3, 97 m³/sec. The flow is controlled upstream by the regulation dam at the inlet of Billstaån from Lake Näkten as well as downstream through the damming of Ävjan itself. At the moment there is no risk for flooding in connection to Ävjan, but as the reservoir is removed water flow will increase over a period of time.
Table 12. Average monthly water flows between the reservoir in Ävjan and lake Flon in 1981-2013.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Okt</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow speed (m$^3$/sec)</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
<td>0.66</td>
<td>1.68</td>
<td>3</td>
<td>2.1</td>
<td>2.7</td>
<td>2.7</td>
<td>1.9</td>
<td>4.1</td>
<td>7.2</td>
</tr>
</tbody>
</table>

The team established that during the reservoir draining the area most impacted, having the highest risk for flooding due to increased water flow, is the river stretch between Ävjan and the small lake Flon. There are no residential properties in this area that can be affected, but the hydropower plant of Lillå is situated in connection to this stretch of river Billstaån. To safeguard the hydropower plant and its production, some adjustment to the draining procedure may be required.

In a speculative scenario, the team estimated that Ävjan could be emptied in 7 hours (based on an average inflow of 4m$^3$/s and outflow of 8-10 m$^3$/s), not including draining of water stored in soil, groundwater etc. As this is probably not a preferable choice considering the high possibility of flooding riverside areas directly downstream Ävjan, the team advised a more stepwise approach. This would limit flooding risks substantially, as the flow speed would increase slower and leave less impact on the surroundings. To fit into the variation of precipitation and flow speed in the river over the year, further illustrated in figure 9, the spring was suggested as most suitable for undertaking the procedure as the water flow is slow during that time of year.

![Figure 9. Chart over average temperature, precipitation and flow speed of Billstaån.](image-url)
Carbon stock

The area of forest studied by this team included 77 hectare forest surrounding Billstaån and was chosen from ortophoto application to QGIS. In the current state this forest has the capability to bind about 1 900 tonnes carbon totally, including both above and below ground carbon stock. In an alternate state, with additionally 5,2 hectare forest growing where now is the water surface of Ävjan, the carbon capability will be increased by about 18 tonnes carbon in the first 20 years of forest growth and 129 tonnes carbon after 20 years. The total carbon stock in 20 years in the forest around Billstaån will thus be at least 2 040 tonnes, adding the new forest in Ävjan to the current stock.

To better understand the carbon stock results the team calculated how the carbon stock relates to average emissions per person in Sweden. They found that the carbon stock in the forest they investigated represent carbon emissions from 370 people, even though the area is small compared to many other forested areas in Sweden.