FSC Biodiversity Conservation in Sweden

- A review of biodiversity monitoring and an assessment of the contribution of FSC to conservation of forest species and habitats

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Summary

This report presents how monitoring and assessment is conducted in FSC certified forests and evaluates the value of FSC certification for biodiversity in Sweden. Monitoring and assessment are essential components in the FSCs work towards a more sustainable forest management. Data collected during monitoring can potentially be used to evaluate the state of biodiversity and environmental condition in certified forests. This report summarises the existing sources of biodiversity data and how it could be used to evaluate different environmental aspects in certified forests. Further, the report presents an analysis of biodiversity using open data on occurrence of forest indicator and red-listed species. Biodiversity assessments are important instruments in the process of assessing whether certification standards achieve their purpose, which is improving the sustainability of forest management and safeguarding forest biodiversity.

The report is structured in three parts: 1. Monitoring and assessment, 2. FSC added value for biodiversity, and 3. Biodiversity data analyses.

Part 1: Monitoring and assessment

This chapter summarises monitoring of economic, environmental and social effects in FSC certified forests in Sweden. Information on monitoring methods was collected from 17 certificate holders (CHs) and forest managers, using a web-based questionnaire and semi-structured interviews. All CHs contributed with information about their monitoring efforts either by answering the questionnaire, participating in the interview, or both. The CHs represented large forest companies, group certification associations, and a few intermediate-small forest owners.

The economic sustainability of forest management in Sweden is generally being assessed via establishment and regular revisions of the management plan. This includes implementation of management activities, policies and goals, as well as long-term forest strategy. Monitoring of environmental condition is mainly conducted via following up on implementation of actions like pre-commercial thinning and final harvesting using standardised qualitative protocols. On landscape scale, assessment of old forest and deciduous forest area, as well as prescribed burning are the main factors monitored by CHs. Social effects of forest management related to the own organisation are monitored via implementation of management systems. Effects on local communities and reindeer herding areas are followed up by documenting dialogue and co-planning activities.

Environmental monitoring in Swedish forests is strongly focused on structures and not on species. Structures are also used for nature value assessments and planning and executing conservation management. All CHs identified biodiversity monitoring using species directly as a major challenge. Incorporating species records from open databases in the management planning is the main method currently used to address biodiversity directly. Recently established and upcoming biodiversity initiatives by several large forest companies are likely to produce more species-related assessments in the future. There is also potential to make use of quantitative data from national monitoring programmes, which are used to a limited degree today, to improve biodiversity monitoring.

FSC certification was identified as the main driver of engagement in environmental monitoring and sustainability efforts. Landscape planning, conservation set asides and prescribed burning were among the areas where FSC has contributed most. The principles of FSC are also used by many CHs as guidelines, to organise and structure their sustainability work, and as a measure of societal expectations on sustainability.

Part 2: FSC added value for biodiversity

FSC criteria for sustainable forest management focus to a large degree on biodiversity conservation. According to the FSC principles, certificate holders (CHs) forest should be managed in a way that protects, promotes and creates values associated with biodiversity.

This chapter identifies aspects of biodiversity that have benefited from FSC certification. This is done by comparing legal requirements in Sweden with the requirements in the FSC standard and by compiling information from interviews with Swedish CHs. In the next step, we evaluate to what extent data from CHs and open data can be used to quantitatively assess the added biodiversity value of FSC certification.

Overall, we come to the following conclusions:

- FSC certification has a more ambitious environmental framework than the legal requirements in most aspects. The exception is cultural heritage and protected species where there is no difference to the law.
- CHs argue that certification has significantly affected their forest management and contributed to increased efforts for environmental sustainability.
- Many CHs collect detailed data on biodiversity, but data is often either simplified into a binary variable or not systematically stored. A structured way of sampling and storing data by CHs would considerably improve opportunities for quantitative evaluation of the effects on biodiversity and the environment. Standardising and combining these data into a single FSC data base could be used for large scale assessments and research. This would feed back in terms of improved and more efficient management and monitoring methods.
- Open data sources can be used to estimate the added biodiversity value of FSC. However, the quality of the analyses would improve if data from CHs could be included.

FSC added value for improvement in the abundance of forest structures, like dead wood and old trees, is supported by national monitoring data. So far, there is no corresponding improvement of conservation status of threatened forest species. Lack of positive increase in species can likely be attributed to time lags in species responses and that forests with high conservation values are harvested. Replacing natural forest ecosystems with managed ones leads to irreversible loss of some of the biodiversity. Even if forest management is conducted with environmental consideration, it cannot maintain or restore natural old-growth forest ecosystems. Therefore, a net loss of biodiversity can be expected in regions where natural forests are harvested and replaced by managed forests.

Part 3: Biodiversity data analyses

This chapter describes biodiversity analysis of open species and habitat data. The analysis evaluates the probability to find selected forest indicator and red-listed species across certified forests in central and northern Swede. We used data from an open species database and used a modelling approach to assess the occurrence of 19 species across space and over time. The species were mainly associated with different types of old-growth forests and dead wood.

The results show the distribution of each species across the studied area (distribution maps), with an estimated probability to find the species in each location. The results also show how the probability to find the species has changed over time during the last 15-20 years (occurrence trends). All the studied species showed a stable occurrence over time, i.e. there were no significant increases or decreases. This indicates that the distribution of the species has been maintained in FSC certified forests. However, the analyses do not account for population sizes and changes in species abundance.

Hence, the positive trends for structures related to biodiversity at national level is not reflected in increased occurrence of the analysed species. This lack of positive relationships could be explained by a weaker increase or decrease in availability of forest structures in the regions where the analysis was conducted (central and northern Sweden), compared to southern Sweden.

Stable species trends over a 20-year period provide an indication of maintenance of existing biodiversity and an opportunity for improvement during the coming years. More data on species occurrences is needed to produce more detailed assessments at local scales, and assessments of a larger number of forest species. Systematic collection of species data during monitoring would contribute to improved assessments in the future.

Part 4: Proposed monitoring scheme

Current monitoring efforts by certificate holders produce limited amounts of quantitative data and are not sufficient for a robust evaluation of biodiversity. This chapter proposes how a more standardised monitoring requirements could be developed for the FSC standard.

We have based our suggestions for monitoring on the methods and activities that CHs already perform in their assessments. The suggestions are focused on improved procedures for collecting, organising, and storing quantitative data from field assessments and reporting the data to a common FSC database.

In the long term, the data could be analysed to answer specific questions related to biodiversity and forest management. Building a data base over forest structures and species will allow FSC to better evaluate the positive impacts of the certification and increase visibility of environmental efforts performed by CHs.

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Part 1: Monitoring and assessment

Monitoring and assessment are essential components in the FSCs work towards a more sustainable forest management. The requirements for monitoring are specified in principle 8 in the standard, briefly stating that the implementation of the management plan and the environmental and social effects of forestry activities need to be monitored, and the results should feed back into planning processes and made available to the public.

How FSC certificate holders follow up on their efforts to meet the requirements in the standards regarding economic, environmental, and social aspects is important for continuous learning and improvement - and to achieve a positive change over time. However, the standard only sets general requirements for which aspects need to be monitored, while leaving the decision on which specific parameters to monitor and how, up to the certificate holders. For this reason, the knowledge on how the FSC principle on monitoring and evaluation is implemented, and how the monitoring results relate to the environmental condition and state of biodiversity, is rather poor.

To improve the understanding of FSCs contribution to biodiversity conservation, this project aims at summarising the ongoing monitoring efforts among FSC certificate holders in Sweden and to compile relevant biodiversity data.

1. Our Approach

Information on monitoring and assessment was collected using a web-based questionnaire to all FCS certificate holders (CHs) in Sweden and a complementary semi-structured interview for a subset of CHs. Both the questionnaire and the interview focused on identifying parameters that are being monitored and the common methods that are being used. The interviews complemented the survey with in-depth discussions about how monitoring of economic, environmental, and social effects is organised and performed by each CH. We also investigated the motivation for engaging in monitoring and the perceived challenges of interpreting FSC requirements and implementing monitoring for CHs. Seventeen FSC certificates and 14 CHs were identified in Sweden, as some CHs had more than one certificate. All CHs were invited to answer the web-based questionnaire and eleven of them were invited to participate in the interview (Table 1).

The web-based questionnaire consisted of questions grouped into six sections: 1) general questions, 2) management plan, 3) environmental effects, 4) social effects, 5) accessibility and applicability, and 6) motivation for monitoring and interpretation of FSC principles. The questions were formulated based on criteria in the standard, associated with each focus area (economic, environmental, and social). The respondents were required to identify the parameters they monitor (answer alternatives: yes/no) and to shortly describe the methods of assessment (Appendix 1).

The semi-structured interviews addressed the same categories, but focused more on how the monitoring work is organised and the type of biodiversity and environmental data that is collected and stored (Appendix 2). We also asked the respondents to describe what they perceived as the main challenges and limitations associated with monitoring and how FSC monitoring requirements are interpreted by certificate holders.

Table 1. Number of FSC certificate holders (CHs) approached for this project, according to different forest owner categories; the number of CHs in each category that participated by responding to the web-based questionnaire and by participating in a semi-structured interview.

Certificate holder type	Invited	Responded to questionnaire	Participated in interview
Large forest company	5	4	4
Group certification	5	9	3
State/municipality	2	2	1
Other	2	2	2
TOTAL	14	17	10

2. Overview of monitoring efforts

Response rate to the survey was high among CHs (93%). In total we received 17 responses to the web-based questionnaire, representing all but one CH in Sweden; some additional responses were provided by individual members/forest owners certified via group certification. Ten CHs participated in the interview (response rate 90%).

Majority of the CHs manage large forest areas (>5000 ha, 88%) and have been certified for more than 10 years (76%). Five of the CHs represented a group certification without own forest management, but several of the other CHs with own forest land provided group certification services as well. All participants stated that they are monitoring economic, environmental and social aspects of their forest management, but there was some variation in how detailed the monitoring efforts were in each of the sections and which methods were used for evaluation. In general, however, there were high similarities between CHs in how they approached monitoring and assessment. The complete response data for all CHs has been summarised in a data sheet and submitted to FSC separately.

2.1. Economic aspects

The economic sustainability of forest management in Sweden is generally being assessed via establishment and regular revisions of the management plan. A management plan is a site-specific plan for a forestry unit, which addresses how management activities and conservation will be implemented in compliance with laws and regulations. All respondents confirmed that they evaluate their management plan, and nearly all of them do it annually (88%). The part of the management plan that was monitored by most CHs was the implementation of management activities (16 out of 17), while a somewhat lower proportion of CHs regularly evaluate policies, objectives and long-term economic sustainability (11 out of 17) (Fig 1).

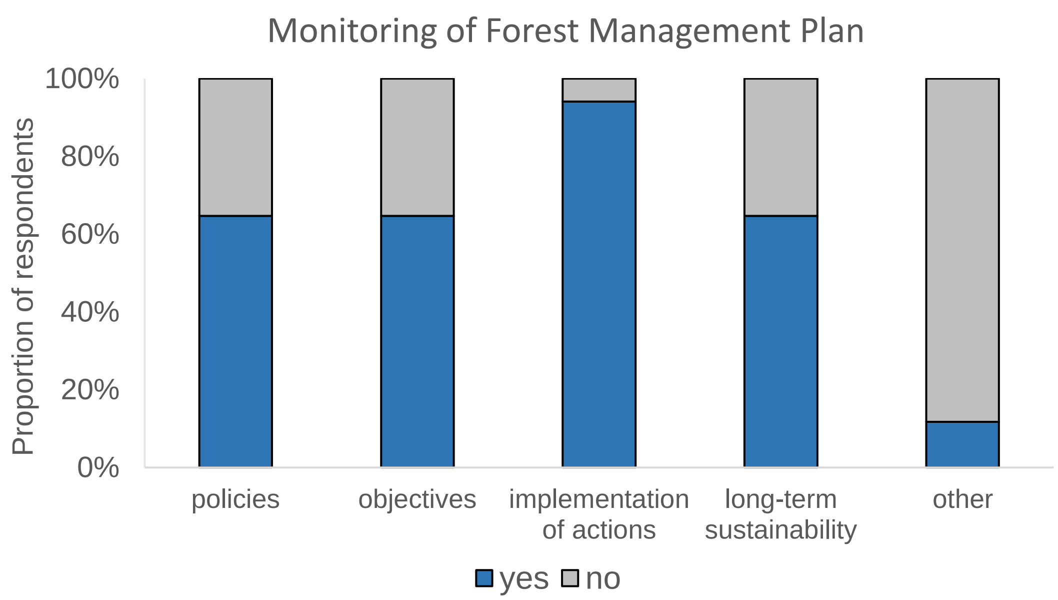


Figure 1. Economic aspects monitored by CHs related to the forest management plan.

Long-term economic sustainability is commonly assessed by CHs using the Heureka software (Wikström et al. 2011). This is a forest planning tool developed by The Swedish University of the Agricultural sciences (SLU). It performs both short- and long-term forecasting of forest development and multiple ecosystem services and allows to specify different forestry goals and objectives. Some of the group certificate holders offer Heureka-based long-term forest strategy as an optional service to their members.

2.2. Environmental aspects

The environmental impacts of forest management activities are by most CHs monitored and assessed with standardised qualitative protocols that contain multiple criteria. The aspects that are monitored include site-specific factors like retention trees, buffer zones and dead wood (Fig 2), as well as landscape factors like deciduous tree proportion, set-asides, old forests and wetlands (Fig 3).

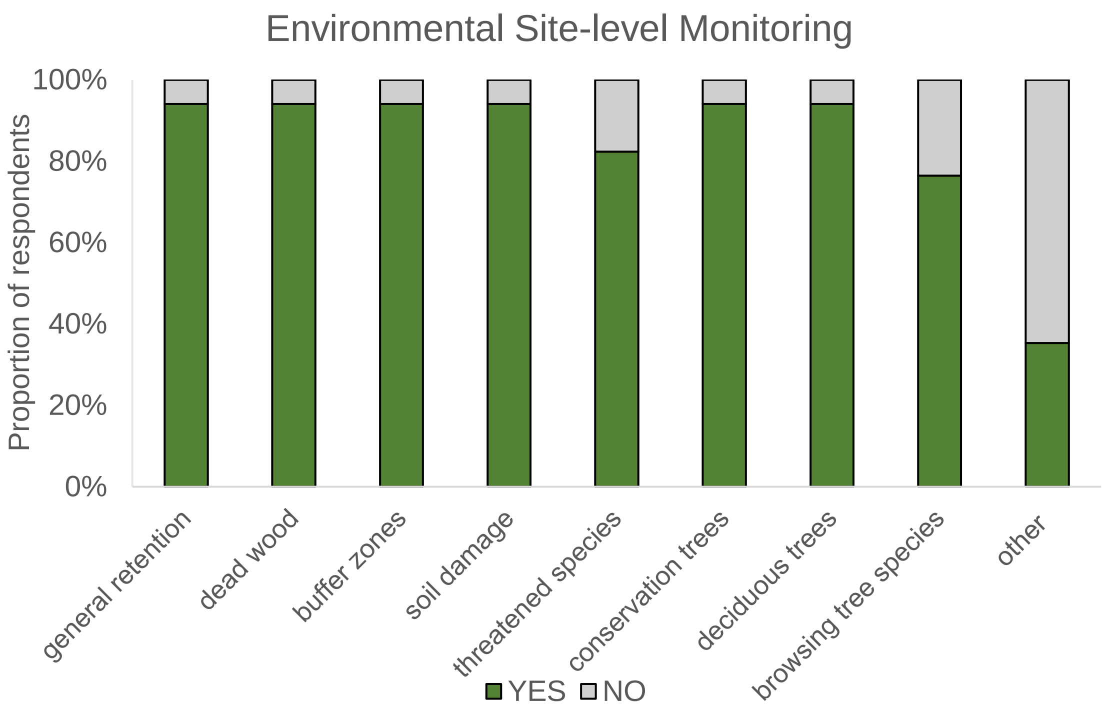


Figure 2. Environmental aspects monitored by CHs related to implementation of management activities.

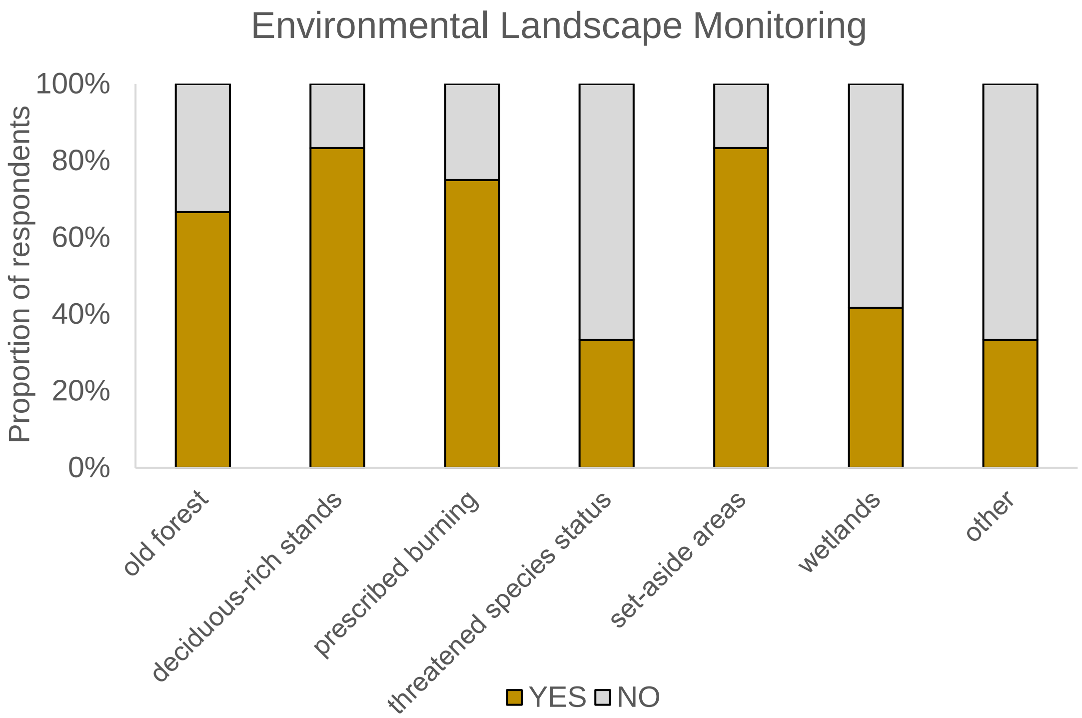


Figure 3. Environmental aspects monitored by CHs related to implementation of ecological landscape plans.

Different environmental aspects are assessed with different types of methods by CHs. These include field-assessments, internal and external revisions, ratio analyses, natural value assessments, and on-site evaluations during ongoing forestry activities. Assessments focus on whether management has been carried out in accordance with targets for good environmental consideration, which includes legal requirements, certification compliance and recommended practices by the Swedish Forest Agency. Assessment is done by grading with a “pass” or “fail” (discrepancy), occasionally with several levels of discrepancies. The great majority (82%) of CHs do yearly follow-ups on the environmental condition, generally by selecting a sample of all management activities, which is then evaluated in the field. The evaluation is done either by external consultants or by employees who have not been involved in the planning or execution of the management activity.

Environmental and nature value assessments, as well as implementation of conservation management, are strongly focused on habitat structures and not on species. The structures that are monitored include retention trees and conservation value trees, dead wood, buffer zones, and deciduous trees in coniferous forests. Even if species are not surveyed systematically by CHs, data on rare and threatened species, and conservation species is used during planning of all forestry operations and during follow-ups. In cases of species which require special consideration, the placement of buffer zones or retention patches is adapted to maintain the habitat for the species.

Species data is collected from an open database in Sweden, Artfakta, which is operated by the Swedish Species Information Centre at SLU, on behalf of the Swedish Environmental Protection Agency (EPA). Species observations of plants, animals and fungi can be registered via a website Swedish Species Observation System (Artportalen) by anyone, including the general public, professionals, public authorities and corporate enterprises (SLU Artdatabanken 2023) .

2.3. Social aspects

Monitoring of social sustainability linked to working conditions and work environment are typically implemented and documented via company's management system (82% of respondents). Use of management systems is a common practice for businesses in Sweden and many forest companies hold several ISO management system certificates, such as ISO 9001 (quality), ISO 14001 (environment), ISO 50001 (energy) and ISO 450001 (work environment). It is also important to note that the Swedish labour market has a strong tradition of union membership and worker rights are regulated by collective agreements. The responses of CHs showed that, among internal social aspects, work safety (94%) and education/competence development (100%) appear to have the highest priority, as nearly all CHs confirmed that these factors are regularly evaluated (Fig 4).

Social aspects related to impacts on local communities and indigenous rights are documented in internal revisions and follow-ups. Here the main focus is on the dialog with affected communities and on distribution of information, as 94% of the respondents confirmed that they monitor their engagement in dialog with local communities and 71% monitor engagement with Sámi villages (only some CHs practice forestry near Sámi villages). Several CHs also identify approachability as an important for assessing effects of their activities on local communities. Approachability is ensured by having contact details and contact persons available to whom community members can direct their questions and opinions. Monitoring and evaluation of social effects on local communities is done by documenting the number of events (e.g., communication, co-planning) and their outcomes. The information is often stored together with other documentation for the specific forest area that is affected. Regarding management activities in reindeer herding areas, the CHs that participated in interviews said that they evaluate the results together with affected parties, either in the field or in an office meeting.

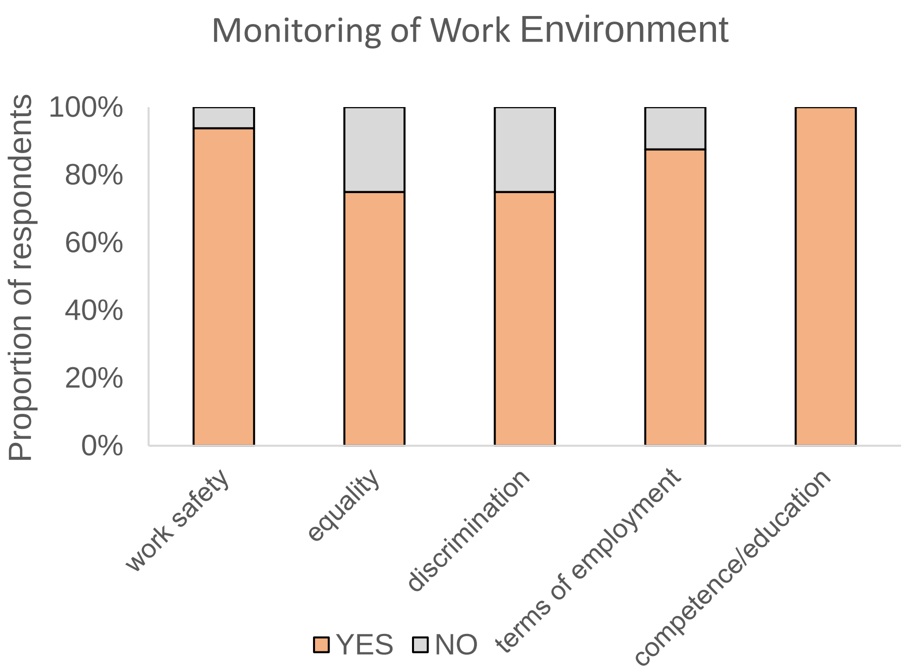


Figure 4. Social aspects monitored by CHs related to the work environment.

3. Methods and Metrics in Environmental Monitoring

3.1. General Retention

Monitoring of the environmental condition in the forest is carried out by CHs via assessing implementation of forestry activities. The activities with the highest expected impact on the forest, pre-commercial thinning and final harvesting, are given most attention. Among CHs, 88% monitor the quality of implementation of these activities via a standardised qualitative protocol. Other activities are also assessed, including soil scarification (59%), ditch management (47%) and road construction (53%), but to a somewhat lesser extent, or depending on whether discrepancies have been discovered that need to be addressed. The assessment protocols include a list of environmental criteria/elements that are evaluated, including tree retention, created dead wood, buffer zones, deciduous trees, and conservation trees (all factors monitored by 94% of respondents), as well as browsing-prone tree species, occurrence of threatened species (around 80% of respondents), and additional (unspecified) environmental metrics (35%).

The results from the qualitative protocols are summarised yearly and used to monitor frequency of discrepancies over time. Many companies have specific goals regarding acceptable discrepancy levels for environmental condition. The areas with high or increasing frequency of discrepancies are addressed by e.g., providing additional training for the field staff or planning staff, and increasing the sample of management activities that are followed up the next year.

The proportion of forestry activities that are evaluated varies among CHs. Generally, a stratified random sample of all activities is evaluated each year. The stratification is based on an even geographic distribution and even representation among different types of landowners. In addition to the selected sample, which commonly covers about 2-20% of all activities, more extensive follow-ups are performed for activities where it is difficult to reach good results. Some CHs have identified soil damage, dead wood, and buffer zones near water as areas where it is more difficult to maintain high standards for environmental consideration. In certain categories, where the number of activities is small, such as prescribed burning, all of them may be evaluated.

3.1.1 Data collection

Results from environmental monitoring are typically stored as qualitative data (“approved” or “discrepancy”). Quantitative data may also be collected but are often not stored and compiled in a systematic manner. For example, estimation of number of retention trees and dead wood is needed to perform nature value assessments. Yet, the counts that are done in the field are often transformed into a qualitative grading, while the original quantitative data (if recorded) remains on a paper protocol, which may not even be stored.

Collection and quality of quantitative data collected varies among CHs. The smaller CHs and group certification holders (with one exception) were clear about that they do not compile or store any quantitative data. The larger CHs, based on information from their digital tools and protocols, are doing several quantitative assessments during their general retention follow-ups (called internal/external audits, or green audits by CHs). These assessments include counting (or estimating) **number and volume of green trees**, **dead wood**, and **area of buffer zones** and **retention patches**. The larger CHs we interviewed could not provide a clear description of exactly which quantitative data may have been collected during the monitoring and assessment process, and none of these CHs were willing to share these data with us. Two large CHs were not available for a detailed interview, and we therefore lack precise information about their data.

In summary, CHs have very similar routines for qualitative assessments, but vary greatly in terms of quantitative data collection and systematic storage.

3.2. Landscape Planning

Ecological landscape plan has been established by about two-thirds of respondents (12 out of 17, or 71%). Interestingly, several small forest owners also confirmed that they have an ecological landscape plan, while some of the large forest owners (>5000 ha forest land) do not have one. Monitoring priorities within the landscape plan include area of set-asides and deciduous forests (>80% of CHs with landscape plan) followed by area of old forests and prescribed burning (60-70%). Relatively fewer CHs regularly monitor status of threatened species on landscape scale and proportion of wetlands (30-40%). Some CHs manage part of their set-asides to enhance biodiversity, while some do additional specific monitoring activities related to their landscape plan, register species with action programmes (guidelines for habitat management and conservation, set by the Environmental Protection Agency, to improve viability of selected threatened species), and one CH has modelled green infrastructure for species with different habitat requirements. Most CHs (70%) also regularly evaluate which natural values should be prioritised within their forest land.

3.2.1 Data collection

Data compiled by CHs include **tree species**, **tree age**, area of forest **set asides**, and areas where **conservation management** has been done. However, data on natural values within these areas (structures and species) is generally lacking. Such data could be used to assess quality of the set asides and their contribution to overall landscape scale biodiversity conservation. Several CHs have expressed that they would like to follow up on conservation management areas and be able to assess their ecological contribution but are lacking tools and/or resources for such assessments.

3.3. Gaps and Challenges

There were clearly some aspects that received less attention or were monitored less systematically. This was particularly true for environmental monitoring. All CHs who were interviewed identified species monitoring as the most challenging, and hardly any said that they are doing species surveys, apart from collecting open data records and incorporating them into activity planning, as part of their systematic environmental evaluation.

Several reasons were stated by CHs for not systematically monitoring species. For example, that it requires large amount of time and comprehensive expert knowledge that the company personnel are generally lacking. The number of species in the forest is very high, and employing species experts for all taxa would be very costly. In addition, there is an uncertainty among CHs about how species data should be interpreted and what practical relevance it would have for the day-to-day management activities. As species responses to the environment can have long time lags, and these lags differ among taxa, it is very difficult to relate ongoing activities to variation in species occurrence, and even more difficult to accurately predict time trends. For those reasons, CHs choose to rely on public species databases to identify species that have been observed in their forests and incorporate those in their planning system. Any species observations done during nature value assessments or ongoing forestry activities are also recorded and included during planning, but no systematic search for species is performed.

Another obvious gap in the environmental assessment is lack of quantitative data. Monitoring and assessment can be performed using both qualitative and quantitative methods. Qualitative methods are well-established in internal management systems to monitor social work environment and company`s relative progress towards achieving own sustainability goals. Yet, it is questionable if such methods are sufficient for monitoring environmental condition and biodiversity in the forests. This is because, by use of qualitative assessment, an assumption is made that compliance with laws and regulations and pre-defined targets equals good environmental condition. This is hopefully true, if the targets are based on scientific evidence, but not necessarily true. Therefore, in environmental monitoring, quantitative data are important for objective assessment of the environmental condition and ecological status of species and habitats.

3.4. Species and Habitats

It appears that there is a high awareness among CHs that they lack good methods for biodiversity assessment. All interviewees identified biodiversity and species monitoring as the area which they find most difficult to assess, but also as the area that they would most like to develop. Indeed, all large forest companies have different initiatives related to biodiversity, but these are often geographically limited and do not serve as standardised monitoring schemes for the entire forest management unit.

Two CHs have selected forest landscapes with valuable characteristic forest biotopes, which are managed (or conserved) with a focus to promote natural and/or cultural values in a long-time perspective. These are called “ecological parks” or “knowledge forests” and are, apart from developing natural values, also used for educational purposes, guided tours, recreation, and collaborative biodiversity research projects with universities.

Another example is a biodiversity programme for species, habitats, and water, recently initiated by another large forest CH. The programme includes a set of focus habitats and focus species, which will be specifically promoted in certain forest landscapes. Finally, at least two other CHs are working on identifying a broad range of species, both common and threatened, for which forest is an important habitat and which are likely to be affected by forestry activities. It may be expected that some sort of monitoring programmes will be implemented for these species in the coming years.

4. Opportunities for Biodiversity Monitoring

4.1. National Biodiversity Surveys and Open Data

Sweden has several national environmental monitoring programmes where different types of biodiversity data are created. These data could potentially be utilised to assess environmental condition and biodiversity in certified forests. Apart from the open species database mentioned earlier in this report, relevant monitoring programmes include the Swedish National Forest Inventory (NFI), the Swedish Bird Survey, the Swedish Butterfly Monitoring Scheme and inventories by the Swedish Forest Agency.

NFI is a standardised survey carried out by the Department of Forest Resource Management at SLU. The survey covers a grid of sample plots systematically distributed across the country, and every year a sample of about 12 000 plots is inventoried. The recorded environmental indicator variables include tree species composition, tree age and growth parameters, dead wood, as well as site characteristics and history. Summary statistics are published in a report each year and can also be explored via an interactive web-based analysis tool.

The Swedish Bird Survey is a monitoring programme carried out by the Department of Biology at Lund University (LU) for the Swedish Environmental Protection Agency (EPA). The programme includes different types of surveys and several hundred point-counts and transect counts are carried out by volunteers each year across the country, in order to estimate population trends for all common bird species. It is also part of the European network for bird monitoring (EBCC). The results are presented in yearly reports and graphics on the web.

The Swedish Butterfly Monitoring Scheme is a national monitoring programme coordinated by LU for the Swedish EPA. Point counts and transect walks are carried out by volunteers every year across the country, but the number of survey points and locations vary depending on volunteer participation. Results and statistics are published in yearly reports.

The Swedish Forest Agency has conducted a biodiversity monitoring project (UBM) between 2009 and 2022. In a series of surveys, 650 signal species of plants, lichens, mosses, and fungi, as well as red-listed species, large trees and coarse dead wood, have been inventoried in woodland key habitats (WKH) and old production forests. Woodland key habitats are a type of forest set asides with high natural values but no legal protection. Results from years 2009-2015 have been summarised and published in reports and graphics on the web. The Swedish Forest Agency also conducts yearly surveys of general retention in a sample of final harvesting sites and publishes a wide range of forest-related statistics, such as area of set-asides, dead wood, and deciduous forests.

4.2. Use of Public Data by CHs

The data collected in all the above-mentioned biodiversity surveys can be obtained upon request. Disadvantages are that frequent requests for large amounts of data may have processing charges and can take long time to process by the responsible organisations. Yet, for CHs with large management units, there is a clear potential for this data to be used for monitoring the state of environmental condition and biodiversity in their forests. For small forest owners, it is less likely that any of the survey plots or transects are located within their land. For instance, the majority of butterfly monitoring sites are located in open habitats, even if some forest sites are also surveyed. However, hardly any of the CHs have said that they use these data, apart from collecting information on species records for their management activity planning. Individual species records from the national surveys are reported to the Artportalen open species database. Thus, the CHs are already collecting this species information, but our impression is that it is not fully utilised.

Potentially, the national survey data could be used for regular follow-ups on a landscape scale. If sufficiently large forest areas are included, it may be possible to compare species occurrence across time periods of perhaps 5-10 years. At the present, this data is not compiled or analysed by CHs in any systematic way, with very few exceptions (e.g. one CH has compiled NFI data on environmental indicators in their forests). We expect, however, that with the newly established biodiversity and species initiatives (see section 4.4), also monitoring schemes will come into place and we may see more data in the coming years.

Finally, it must be mentioned that a lot of scientific biodiversity research is conducted in FSC certified forests, often in close collaboration with CHs. Research projects include testing effects of different management methods and conservation management, like dead wood creation or prescribed burning, on biodiversity. Most of this research, including datasets, is published open access, and compiling and storing the species records from the scientific surveys, which are conducted with rigorous methods, would provide a quantitative basis for CHs' biodiversity monitoring.

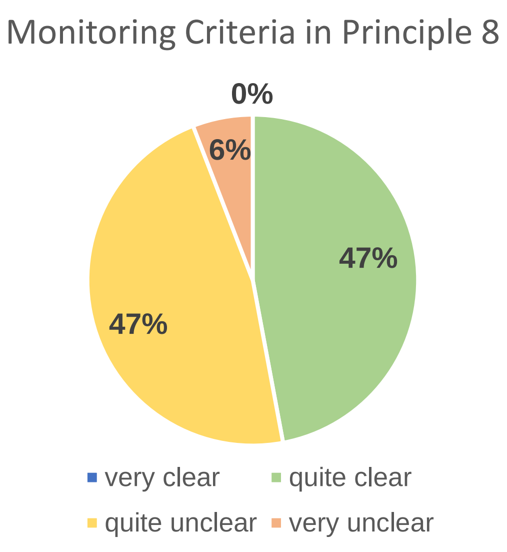
5. Motivation for Monitoring

5.1. Interpretation of the monitoring principle

The CHs found the requirements for monitoring and assessment as described in FSC principle 8 either quite easy to understand (8) or quite difficult to understand (8). During interviews, the CHs also confirmed that it is difficult to understand what precisely is expected. At the same time, however, CHs appreciated that the principle only provides very general instructions, which allow free interpretation of how monitoring should be carried out in relation to the scale and intensity of management activities.

> *"Perhaps it is a bit unclear, yes, but if the criteria were very specific it would make it difficult to adapt (monitoring) to the needs and capacity of individual forest owners" (CH, translation from Swedish).*

The balance between respondents was somewhat shifted regarding whether the monitoring principles were easy to implement (Fig 5). Here, a majority of CHs responded that it was quite difficult to implement (10), while a smaller group found it quite easy (6). The most often mentioned reasons for the difficulty to implement monitoring was that it was resource-demanding (41%) or difficulty to understand the criteria (35%). A few respondents found the monitoring requirements very difficult to implement and these CHs stated group certification or small forest ownership as the main reasons for implementation difficulty. Finally, three CHs (18%) stated that they had no difficulties at all implementing monitoring, while they still wished they could improve some aspects, like species and nature-adapted management.



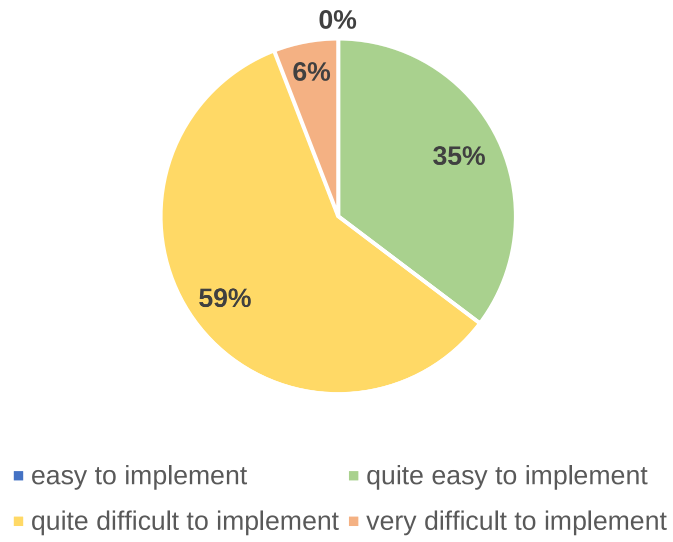


Figure 5. Interpretation of FSC monitoring and assessment principles by CHs.

5.2. FSCs role

We identified forest certification among the main drivers of monitoring work. Overall, 94% of respondents listed certification requirements as their main motivation, followed by companies' own sustainability reports (53%) and legal requirements (41%). Considerably fewer identified different types of EU legislation as their main driver (47% combined for EUDR, CSRD and SFDR). During interviews, it became clear that certification is particularly important for the monitoring efforts regarding environmental sustainability. In comparison, the economic aspects are interlinked with companies' interest to maintain long-term profitability; thus, the financial and sustainability goals overlap to a considerable degree. Similarly, there are other drivers than forest certification behind ambitious standards for social sustainability, such as Sweden's strong tradition of union membership that ensures workers' rights, and widespread implementation of ISO management systems.

A great majority of CHs stated that FSC certification has been the main driver of increased environmental sustainability in managed forests, including setting aside forest for conservation, and habitat restoration efforts, such as prescribed burning. FSC certification has been crucial for engaging in these efforts, and for broadening the understanding and appreciation of all forest values, according to CHs. External audits were mentioned as an important and positive driving force, and as being very important for motivation to maintain high quality in forest management. Many CHs viewed audits as a helpful tool of assessment.

"Landscape plans only exist thanks to FSC, otherwise we wouldn`t work with landscape planning. The same applies to prescribed burning." (CH, translation from Swedish)

"Certification sets the level for what society expects from us in terms of sustainability." (CH, translation from Swedish)

FSC standard has also provided an important framework and structure around which to organise sustainability work. Particularly, during the early years of forest certification in Sweden (late 90`s and early 2000`s), it has been the single strongest driver of increased environmental sustainability. This is because the gap between legal requirements for environmental consideration and FSC standards was quite large at that time. However, during recent years, legal requirements have become stricter regarding species and habitat protection, via EU Habitats Directive (Council Directive 92/43/EEC, 1992) and Birds Directive (Council Directive 79/409/EEC, 1979). In addition, many forest owner companies have increased their own sustainability ambitions and developed specific goals that are unrelated to the certification requirements. Indeed, among the CHs who participated in interviews, three stated that their own goals are more ambitious than certification standards in certain areas.

5.3. Ecologial knowledge

It was apparent during the interviews that both the level of ecological knowledge and the ambition for environmental sustainability has increased over time among CHs. There was also a perception that the requirements for ecological knowledge have increased along with the development of FSC standards. Competence requirements for forestry personnel on all levels are today higher, in order to comply with the principles, and understand how to implement them on the ground.

"It is not easy, and the forest managers must really know their forests well now" (CH, translation from Swedish).

The CHs who participated in interviews expressed positive attitudes towards increased availability of educational activities during recent years, such as courses for forest personnel in e.g., nature value assessment. Several CHs said that they wished there were more courses available, particularly training in species identification for non-experts. It was clear that education and competence development at all levels of forest management is highly valued, and that it is among the top prioritised social sustainability factors.

"To recognise a habitat, and based on the habitat (quality) be able to identify which species could thrive there, without necessarily needing to search around for each species – whether it is there or not. That kind of level of competence and confidence I would wish to have in my own work and for every of our forest managers out there in the field." (CH, translation from Swedish)

6. Conclusions Part 1

We conclude that the Swedish FSC certificate holders have well-established systems and routines for qualitative assessment of economic, environmental, and social aspects. Widespread implementation of management systems such as ISO among Swedish companies have contributed to establishment of these routines.

Forestry activities with high potential impacts on forest ecosystems are monitored using field-based inventories and regular follow-ups of general retention. These assessments are predominantly qualitative, which we consider to be potentially problematic for an accurate and objective evaluation of the environmental condition and biodiversity. However, there is a clear ambition for improvement of biodiversity monitoring and several large CH have ongoing or newly established initiatives related to species and habitats.

We believe that a potential to improve biodiversity monitoring also lies in better use of open data. Sweden has several long-going monitoring programmes with nation-wide coverage. These projects create quantitative data related to specific taxa like birds and butterflies, but also on environmental forest indicators, including dead wood. Compilation of these data could allow quantitative assessments of biodiversity and the environmental status.

Finally, we conclude that forest certification is probably the single most important motivation for engaging monitoring and improving sustainability of forest management in Sweden. Particularly, several aspects of environmental sustainability are tightly linked with the establishment and of FSC certification system and the implementation of FSC principles.

Part 2: FSC contribution to biodiversity conservation

This chapter evaluates the potential added value that FSC certification has for biodiversity conservation. We start by comparing the FSC standards to the national legislation (section 7) and discuss differences between the two frameworks. We discuss the added biodiversity value of FSC from our own perspective, compared to a previous evaluation, and based on interviews with certificate holders. We also present data sources that could be used to assess the added value of FSC to biodiversity quantitatively. In section 8, we evaluate whether the conclusions on FSC added value are supported by data for forest structures and habitats, for conservation status of threatened forest species, and for maintenance of functional forest ecosystems.

7. Comparing FSC standards to national legislation

To identify the added value of FSC to biodiversity, we compared the FSC standard to the legal requirements in Sweden. If the FSC standard has higher requirements than the national legislation, forest management in certified forests can be expected to have a less negative impact on biodiversity than management in non-certified forests.

In Sweden, all forest management activities are regulated by the forestry law (Skogsvårdslagen, SVL 1979:429), the Swedish species protection law (Artskyddsförordning 2007:845) and two laws on culture and historical heritage (Lag om fornminnen 1942:350; Kulturmiljölag 1988:950). The Swedish Forest Agency (SFA, Skogsstyrelsen) is the authority responsible for controlling compliance with SVL. The agency also comes with recommendations on how the law should be implemented in practice. In addition, SFA has developed a set of guidelines for good forestry practice together with the forestry sector. These are called “Målbilder för god miljöhänsyn” (approx. goals or visions). These guidelines often go beyond the strict legal requirements. They are aimed at aiding the forestry sector towards a more sustainable management, which is needed to meet Sweden`s broader environmental goals for forest biodiversity. The latest FSC standard is aligned and continuously refers to these guidelines for several environmental aspects such as buffer zones, consideration-demanding habitats, and soil protection.

The table below presents a summary of the main differences between legal requirements, SFA good-practice and FSC requirements. For each environmental aspect, the potential added value of FSC in relation to SVL is also identified in the last column.

Figure 6. Deciduous forest dominated by birch trees. Deciduous trees and patches of deciduous forest in boreal forest landscapes are important for many species, including insects and birds.

Table 2. Comparative table of the legal requirements, good-practice recommendations by SFA, and the FSC criteria for forest management, summarised for several environmental/biodiversity aspects. FSC potential added value is illustrated for each environmental aspect: ++ indicates high added value, + some added value, 0 no apparent added value, and ? that the value is unclear. The value identified by CHs is shown as / +
** - Environmental consideration cannot exceed productivity loss of 2-10% of net forest value. When all necessary measures cannot be taken within this limit, the most important values should be prioritised; these are i) consideration-demanding habitats, ii) nature value trees (old, large, dead, deciduous trees in conifer stands), iii) buffer zones to lakes and watercourses.*
[a] – Protected species listed in the Swedish species protection law (Artskyddsförordning 2007:845): all species marked with N/n in annex 1 (protected according to EU directives) and species in annex 2 that are protected according to national regulations.
[b] – FSC standard refers to management according to SFA good-practice recommendations.

Environmental aspect	Legal requirements in Sweden	Recommended management (SFA)	FSC certification requirements	FSC value
Low-productive forests (growth less than 1 m^3 ha^{-1} a^{-1})	No harvesting of areas >0.1 ha, but individual trees can be harvested	No harvesting	No forestry activities	**+**
Tree species composition	Adapt tree species to local site conditions*.	Adapt tree species to local site conditions, maintain the original composition of native species.	Proportion of deciduous trees in boreal stands at least 10%. Min 5% area dominated by deciduous trees, in addition to set asides. Promoting deciduous trees during thinning, priority for noble-deciduous trees.	**++ / +**
Consideration-demanding habitats	Adapt management to avoid damage and maintain natural values*.	Forestry activities should be avoided or minimised in consideration-demanding and high natural value habitats, except to promote natural values. Damage should be avoided.	No forestry allowed in some habitats (old-growth forests, non-productive forests, WKH). High conservation values (HCV) must be preserved. Some habitat types can be managed to increase natural values [b].	**++**
Cultural heritage elements	Adapt management to avoid damage and maintain cultural values*.	At least 3 “culture stumps” used to mark and protect cultural elements during final harvesting. Avoid soil damage/driving. Save trees with high natural/cultural values.	Cultural heritage elements must be protected from damage during soil preparation. Consideration for Sami cultural heritage. Cultural heritage sites of national interest listed as HCV 6.	**?**

Environmental aspect	Legal requirements in Sweden	Recommended management (SFA)	FSC certification requirements	FSC value
Rare, threatened, and protected species	Adapt management to avoid damage to rare and threatened species(*). All necessary consideration must be taken for protected species, according to national lists and the EU Species- and Habitats directive[a]. List of prioritised bird species.	Adapt management to avoid damage to rare and threatened species(*). All necessary consideration must be taken for protected species, according to national lists and the EU Species- and Habitats directive[a]. List of prioritised bird species.	Necessary consideration must be taken to habitat requirements and connectivity during planning and forestry activities[b]. Documentation and consideration for protected species, according to national lists and in EU Species- and Habitats directive[a]. Special consideration of nests of prioritised birds of prey, capercaillie leks, birds with small populations.	**+**
Buffer zones	Leave buffer zones to avoid damage to natural and cultural values*.	Sufficient buffer zones (min 5 m) with trees and bushes should be left adjacent to water, wetlands, farmland, non-productive forest and built areas. Generally, no harvesting in buffer zones.	Ecologically functional buffer zones must be left/created adjacent o water, wetlands and low-productive forests[b].	**+**
Retention trees and dead wood	Leave retention trees and dead wood to maintain natural values *.	Trees and dead wood should be retained during all harvesting operations. Priority should be given to old, large deciduous, dying or dead trees and unusual tree species. Nature-value trees must be retained.	On average 10 retention trees per ha must be left at final harvest. Create standing dead wood, min 3 per ha, during thinning or final harvest. Retain all dead trees and dead wood older than 1 year, dead nature-value trees, retention trees and wood in low-productive forests.	**++ / +**

Environmental aspect	Legal requirements in Sweden	Recommended management (SFA)	FSC certification requirements	FSC value
Clear-cuts	Size and shape of clearcuts should be adapted to local conditions, striving to limit the size of cut areas*. For larger properties (>50 ha), a max 50% of area may be forest <20 years.	Size and shape of clearcuts should be adapted to local conditions, striving to limit the size of cut areas.	Retention trees and patches should be left to minimise large cut areas. Maximum distance to nearest tree 70m.	+
Soil and water	Serious damage to soil and water by forestry activities should be avoided or minimised*. Some restrictions on ditching. No soil-scarification in buffer zones.	Damage to soil and water by forestry activities should be avoided or minimised. No driving 10m from water's edge, no driving through ditches, water courses and wetland buffer zones.	No new ditches and no maintenance of old ditches on sensitive sites. Several specific consideration requirements for forestry activities related to water and soil[b].	+
Forest roads	Damage to natural and cultural values should be avoided or minimised*.	Damage to natural and cultural values should be avoided or minimised.	Damage to natural and cultural values should be avoided or minimised.	+
Restoration and set asides	No requirements	Set aside 5% of the area. No forestry activities in WKH and natural-like forests.	Set aside 5% of the area for nature conservation and 5% for biodiversity-oriented management. Prescribed burning on 5% of harvested area each 5 years.	++ / +
Subalpine forests	Harvesting not allowed if natural or cultural values severely negatively affected. Clearcut size restrictions.	Recommendations for consideration-demanding habitats apply to subalpine forests with high natural values.	Limited forestry activities allowed above the nature conservation boundary and subalpine forests with high conservation values (HCV 2). Specific requirements for intact forest landscapes (IFL).	+?

Environmental aspect	Legal requirements in Sweden	Recommended management (SFA)	FSC certification requirements	FSC value
Noble-deciduous forests	Stands with at least 50% noble-deciduous trees must be managed and regenerated to maintain tree species composition	Stands with at least 50% noble-deciduous trees must be managed and regenerated to maintain tree species composition	No specific requirements, criteria for all deciduous tree species apply.	**0**
Landscape planning	No requirements	No specific recommendations	Large forest owners must have an ecological landscape plan. The plan includes e.g., targets for % old forest, % burned area, % deciduous-rich stands.	**++ / +**
Nature value assessment	No requirements	No specific recommendations	Natural values affected by forest management must be assessed before final thinning, harvest and road construction.	**++**
Exotic tree species	Planting of exotic tree species not allowed in subalpine forests. In other areas allowed under certain conditions.	Planting of exotic tree species not allowed in subalpine forests. In other areas allowed under certain conditions.	Planting of exotic tree species not allowed close to protected areas and in landscapes with <2% exotic trees. Exotic tree species are not retained during harvesting and are removed from retention patches and buffer zones. Plantations together with other transformed land use max 5% of forest land.	**+**

7.1. Qualitative assessment of FSC added value

Based on the comparison between legal requirements and FSC in table 2, FSC had a high added value in several environmental aspects related to biodiversity. These included tree species composition (figure 6), tree and dead wood retention (figure 7), habitat restoration, set asides (figure 8,9), landscape planning and nature value assessment. For these aspects, there is a clear quantitative difference between the legal requirements and the FSC standard. Therefore, compliance with FSC can be expected to have a lower negative impact on the environment and biodiversity than non-certified forest management. According to SFA, over 80% of voluntary forest set-asides are located in certified forests.

There are a few aspects for which there is no clear (or easily quantifiable) difference between the legislation and FSC standard. These include forest management in noble-deciduous forests, and consideration for cultural heritage sites and elements. In these areas, the national regulations have similar or more specific requirements. Consideration to cultural heritage is additionally regulated by two separate laws.

For the rest of the environmental aspects FSC has some added value. These are for instance low-productive forests, subalpine forests, limitation of clear-cut size, protection of soil and water, and use of exotic tree species. The FSC requirements are somewhat higher and more specific in these areas, but they either lack a quantitative component or differ from the legislation in a way that makes the resulting biodiversity benefits more difficult to predict.

On a general level, there are many similarities between the legal requirements, SFA recommendations and the FSC standard. Recommendations by the SFA on environmental consideration are in line with the FSC requirements for most aspects; yet these recommendations are not legally binding. Therefore, they are not considered in the assessment of FSC added value. It is likely that the environmental consideration implemented by non-certified forest owners lies along a spectrum between the strict legal requirements and the SFA recommendations, depending on the goals of individual forest owners. For this reason, it is difficult to make general predictions on the environmental status of non-certified forests or compare these to certified forests.

Figure 7. Clearcut in Northern Sweden with general retention. Green (living) retention trees and dead wood, including logs, snags (standing dead trees) and created dead wood like high-stumps provide habitats for biodiversity associated with early successional forest stages.

The level of implementation of the legal requirements for environmental consideration is constrained by the §30 of the SVL. The act states that the ongoing land use (i.e. forestry) cannot be negatively impacted by environmental consideration actions to a significant extent. In practice, this means that forest owners cannot be demanded to suffer economic loss of more than 2% (large forest owners) to 10% (small forest owners) of the net value of the forest stand. Such a constrain does not exist in FSC certification. An exception to §30 SVL is consideration for nationally protected and EU-protected species, which is regulated in the environmental code via Species Protection Ordinance (Artskyddsförordning 2007:845). Although, SVL still applies to threatened species that are not listed as protected on the national or EU level.

Figure 8. Old, natural-like conifer forest. Setting aside forests with high natural values contributes to protection of forest biodiversity, ecosystem functioning and increases landscape connectivity for species that depend on undisturbed forest habitats with long continuity.

Has FSC added value increased since previous evaluation?

A comparison of the national legislation and the FSC standard has been published ten years ago (FSC Sweden, 2013). In addition, a scientific assessment of differences between legislation and FSC requirements for 2012-2017 has been done for Sweden, Finland, Estonia and Latvia (Lehtonen et al. 2021). Since then, both the FSC standard and the legislation have changed, such as the implementation of the Species Protection Ordinance. Other major changes in the latest FSC standard include requirements for habitat restoration/conservation management, requirement to identify natural values that need to be prioritised at a landscape scale, specifications regarding suitable sources of data and collection of information on important habitats and species, additional consideration for forest birds, and requirements to align management with SFA recommendations.

Largely, our comparison is in line with previous evaluations of the added value of FSC. The main values identified earlier were retention trees, dead wood, set aside areas (including woodland key habitats), deciduous forests and forest fires (prescribed burning). Our evaluation shows that, in addition to previously identified values, new aspects have also contributed. The requirement of 5% forest land to be managed for increased natural or social values, in addition to the 5% set aside area, will contribute to habitat restoration in certified forests. Since this is a new requirement, the effects cannot yet be evaluated quantitatively.

In our assessment, we have also identified landscape planning as an area with high FSC added value. The previous evaluation (FSC Sweden, 2013) stated that the effects of landscape planning are difficult to estimate, which we agree with. However, we think that the combination of landscape planning, together with quantitative targets for habitat protection and restoration, provides clear opportunities for improved biodiversity conservation. It requires, however, that landscape planning is performed by competent personnel and based on ecological evidence. Developing landscape plans also encourages CHs to improve their ecological knowledge and competence. Another knowledge- and awareness-creating aspect is the requirement for nature value assessment and documentation. The added value of this requirement lies in improved methodology for identifying high natural values, which provides better opportunities for their protection.

Low-productive forests were not evaluated by the previous assessment. Our comparison suggests that FSC has positive added value for conservation of low-productive forests, as no forestry activities are allowed in these habitats according to the standard, while single tree harvesting is allowed according to national legislation. Low-productive forests often grow on wet and swampy soils, which are particularly sensitive to damage. Swamp forests host characteristic biodiversity and these habitats have declined dramatically due to forest drainage. We therefore believe that completely avoiding activities in these forests leads to improved conditions for biodiversity.

7.2. FSC added value according to the certificate holders

FSC contribution to biodiversity was also assessed from interviews with nine of Sweden's CHs. During the interviews, CHs were asked how FSC certification has influenced their forest management and their work with environmental sustainability.

All CHs stated that FSC certification has significantly affected their forest management and contributed to increased efforts for environmental sustainability. Aspects such as forest set asides, prescribed burning and landscape planning were particularly highlighted. There are no specific legal requirements for these aspects in SVL. However, the Swedish policy for the forestry sector implies that forest owners have responsibility to ensure high quality of both productivity and environmental consideration. If necessary, this must be achieved by voluntarily doing more than what the law demands. Yet, the interviewed CHs confirmed that without forest certification, setting aside forests and developing landscape plans (e.g. working towards increasing proportion of deciduous trees and implementation of prescribed burning) would not have been as common as we see today. Similarly, the amount and quality of general retention (green trees, buffer zones and dead wood) has been positively influenced by the implementation of FSC principles.

Aspects with high added biodiversity value in table 2 were also largely identified by the CHs as important for biodiversity. This means that FSC certification has been crucial for engaging the forestry sector in specific aspects of biodiversity conservation. In fact, an ongoing increase in several of the identified biodiversity factors – hard dead wood, old forest and deciduous trees – has been documented in the NFI monitoring data on a national scale (SLU 2023). In addition, CHs have said that working according to certification standards has broadened their understanding and appreciation of all forest values. FSC requirements for nature value assessments have likely contributed to this increased understanding, as well as to a higher level of ecological knowledge among CHs. In particular, the large forest companies have over time increased their own sustainability ambitions and developed new goals for natural values in their forests that go beyond certification requirements.

7.3. Quantitative assessment of FSC added value

We have identified several data sources that may be used to quantitatively evaluate the added value of FSC for biodiversity. For environmental aspects where the added value is expected to be high (table 2), we have identified 1) the data needed and 2) the data sources that may hold this data (table 3). The latter includes publicly available data from the Swedish national Forest Inventory (NFI), open species databases such as Artportalen (SLU Artdatabanken 2023), but also data from forest managers and CHs.

In the previous chapter (Monitoring and Assessment), we highlighted the lack of quantitative data compilation for CHs within their monitoring schemes. For the data sources listed in table 3, some data are generally stored by CHs, such as data on tree species or area of forest set asides. Other data may be collected but are not stored and compiled in a systematic manner (e.g. number and volume of retention trees and dead wood). Based on information from some CHs and their digital tools and protocols, quantitative assessments are done during general retention follow-ups (called internal/external audits, or green audits by CHs). These assessments include counting (or estimating) number and volume of green trees, dead wood, and area of buffer zones and retention patches. Yet, these counts are often transformed into a qualitative grading, while the original quantitative data remains on a paper protocol at best, which may not even be stored.

Collection and quality of quantitative data collected varies among CHs. The smaller CHs and group certification holders (with one exception) were clear about that they do not compile or store any quantitative data. Large forest companies store relatively more quantitative data but were not specific about which data precisely and on which spatial level. For this reason, we have listed some data sources from CH with a note on accessibility. This means that the data is (or could be) generated, but it is currently not available.

Table 3. List of environmental factors related to biodiversity with presumably high FSC added value. Relevant types of data are listed, which would be needed to run actual analyses, and potential sources of the data. Note that not all data are presently available or accessible.
** - Quantitative data from field assessments currently not stored or summarised in a systematic manner by most CHs. Counts and volume of trees and dead wood are converted into a qualitative grading for nature values (nature value assessments) or into pass/fail quality targets (general retention follow-ups).*

Environmental Aspect	Relevant Data	Potential Data Sources
Tree species composition	- Proportion/volume deciduous trees	- CHs forest stand databases - Swedish National Forest Inventory

Retention trees and dead wood	- Number/volume of green retention trees - Number/volume of nature-value trees - Number/volume of dead wood - Species records	- CHs nature value assessments* - CHs general retention follow-ups* - Swedish National Forest Inventory - Artportalen species database
Buffer zones	- Area/width of buffer zones	- CHs general retention follow-ups*
Consideration-demanding habitats	- Area of habitats - Types of habitats - Species records	- CHs nature value assessments* - CHs general retention follow-ups* - Artportalen species database
Restoration, set asides and landscape planning	- Area of set aside forest (NO) - Area of burned forest - Area of biodiversity-oriented management (NS) - Types of biodiversity-oriented management - Species records	- CHs forest stand databases - CHs nature value assessments* - CHs landscape plans - CHs sustainability reports - Artportalen species database

Figure 9. Prescribed burning in pine forest. Fire used to be a common natural disturbance in Northern Europe's boreal forests and many species of insects, plants and fungi are adapted to burned forests. Prescribed burning helps to create habitats for those species in managed forests where natural fires are rare.

8. Are conclusions on FSC added value supported by data?

8.1. Habitats and structures

Long term data on several structures and habitats identified in the present assessment is collected by the Swedish National Forest Inventory (NFI). Since a major proportion (almost 70%) of productive forests are certified in Sweden by either FSC or PEFC, the national trends are broadly applicable to certified forests. At a national level, a positive increase in large living trees, volume of dead wood, area of old forests and proportion of deciduous trees has been observed during the last 20-25 years (SLU 2023, Kyaschenko et al. 2022). Area of old forest, for example, has more than doubled since 1985 when the level was at its lowest. Even if this increase shows a positive development, the current area of old forest is still only about 55% of the area that was present in the 1920`s when the NFI monitoring started.

The magnitude of change in habitats and structures varies between geographical regions of Sweden. The positive development is most pronounced in the southern parts of the country. This is probably due to a longer history of intensive forest management in southern regions, which has degraded natural values in most forests. The changes implemented by certification and upgraded legislation to protect and promote biodiversity are therefore clearly apparent, as improved environmental condition in these forests. In the north, the increase in structures and habitats related to biodiversity is weaker or may even show a slight decrease in some regions. This is because the forest management history is shorter and large forest areas with limited forestry still exist. In this context, expansion of active forest management, even with environmental consideration measures, may not lead to improved conditions for biodiversity at larger spatial scales.

The abundance of structures like dead wood in managed forests are still below ecologically functional level. While it is certainly positive that amount of dead wood is increasing, it is still far below the amounts found in natural forests. For instance, in woodland key habitats (WKH), the average amount of dead wood is 20m^3/ha (Wijk 2017). In production forests, it is on average only 9 m^3/ha (SLU 2023). Minimum evidence-based levels required to support dead-wood dependent biodiversity are estimated around 20-30 20m^3/ha in boreal forests (Angelstam & Manton 2021). There is also a lack of diversity of dead wood, such as dense wood from slow-growing trees, burned and charred wood, highly decayed wood, and hollow dead trees. Diversity of dead wood habitats is important for sustaining a high diversity of dead wood associated species (Stockland, Siitonen & Jonsson 2012). Thus, despite that the overall amount is increasing, it will take long time until it is sufficient to protect and support all dead wood associated biodiversity. An interesting question to follow up on in the future is whether the current certification requirements are sufficient to produce a continued increase towards ecologically sustainable levels, or if the current increase will level off below the evidence-based threshold.

8.2. Species

Intensive forest management has well-known negative effects on the conservation status for many forest species. Despite that environmental consideration was incorporated in the Swedish legislation in late 1990-ies, and the above-mentioned positive developments for structures, positive effects on species have not been apparent.

A few individual species have shown improvements, especially at local and regional levels, when special actions have been taken to create and protect their habitat. For example, deciduous trees that have been spared during clearcutting in the 1990`s have positive effects on birds in spruce forests today (Lindbladh et al. 2022). Also, some species with flexible habitat requirements that can e.g., utilise fresh dead wood on clearcuts have reached more favourable status. In contrary, conservation status of many species associated with old-growth forests is worsening. In a recent synthesis (Eide et al. 2022), forest harvesting was reported as one of two main causes of species becoming threatened on national level (the other cause is overgrowth of grasslands). Tree harvesting has negative effects on about 1400 species, particularly in the Northern Sweden, where old-growth forests with high conservation values are still being harvested (Eide 2020). Forest clearcutting specifically is a threat to 394 species (Ottosson 2022), and the conservation status of this group of species has not improved since 2015 (Artdatabanken 2020).

Survey of WKH showed that many red listed species and indicator species occur in WKH (Wijk 2017). Yet, the number of records of each species per WKH was low, often a single record was made in each area. This means that the amount and diversity of e.g., dead wood habitats are too low to support large populations. Properties of dead wood like tree species, size, position (standing or lying) and degree of decay are important for individual species (Stockland, Siitonen & Jonsson 2012). Therefore, dead wood with high variation in these properties must be present in each area to support many species. Large enough amounts of different types of dead wood and sufficient time are needed to achieve this, as wood decay is a slow process. Even if the habitat quality in production forests is improving, it may take several decades to observe any positive effects on species. In addition, many natural forest species have extinction debts, which means that they can remain in areas for a long time after their habitat has been degraded or lost (Kuussaari et al. 2009). The true effects of habitat loss may therefore not be initially apparent. In the Swedish context, some species may still be declining, as a consequence of forest degradation during the 19th and 20th century, or due to current expansion of intensive forestry into natural forest areas.

Habitat restoration may halt population declines and save species from local or national extinction. It is therefore important that environmental requirements in the forest legislation and certification are based on ecological knowledge, and that their implementation and compliance is ensured.

8.3. Forest ecosystems

The state of the environment and biodiversity in Swedish forests is regularly assessed by SFA during evaluation of the national environmental target “Sustainable Forests.” The latest report from 2022 concludes that the target will not be achieved by 2030. As the main challenges are mentioned: 1) loss of HCV forests with irreplaceable biodiversity values, 2) lack of variation in forest management systems and dominance of clearcutting, 3) cessation of natural disturbances like fire and grazing, and 4) lack of green infrastructure and functional connectivity for species that are poor dispersers.

The most urgent problem is the loss of remaining old-growth forests. Currently, these forests constitute about 2.5% of forest land outside protected areas and voluntary set asides. There are many unknown and undocumented areas, where HCV forests may be lost due to lack of transparency in small-scale forestry (Swedish Forest Agency 2022). Risk of losing valuable forests is also increased by high felling pressure in Swedish forests. This is already evident as increasingly younger forests are being harvested during last 20 years, according to SFA. When old-growth forests are harvested, it leads to an irreplaceable loss of biodiversity. This is because natural forests are highly complex ecosystems, which cannot be restored just by allowing trees to reach a certain age. The current increase in area of old forest will be positive in the long term but cannot compensate for loss of existing old-growth.

9. Conclusions Part 2

- FSC certification has a more ambitious environmental framework than SVL in most aspects. The exception is cultural heritage and protected species where there is no difference to the law.
- The main identified aspects of FSC added value are supported by data on national level, as an increase of structures and habitats important for biodiversity.
- CHs argue that certification has significantly affected their forest management and contributed to increased efforts for environmental sustainability.
- Many CHs collect detailed data on biodiversity, but data is often simplified into a binary variable or not systematically stored. A structured way of sampling and storing data would result in a large data base that could be used for improved evaluations and research. This would feedback in terms of improved and more efficient methods.
- Open data sources can be used to estimate the added biodiversity value of FSC. However, the quality of the analyses would improve if data from CHs could be included.
- Data from NFI show an ongoing improvement in several forest structures important for biodiversity, like dead wood, old forests and deciduous trees, which corresponds to the areas where FSC requirements give high added value.
- So far there is no corresponding overall improvement of conservation status of threatened forest species. Some species have increased while others continue to decrease.
- Likely reasons for delayed effects on species are time lags in species response, extinction debts, and that the current availability of important structures and habitats are still below ecologically functional levels.
- While FSC has contributed to improved habitat conditions at stand level, including more old trees and dead wood, these improvements are currently insufficient to protect and prevent loss of intact forest ecosystems at landscape level.

Part 3: Biodiversity data analyses

This chapter presents results from data analyses on biodiversity in FSC certified forests. To assess the added value of FSC for biodiversity, we have analysed temporal trends of a set of forest indicator species and red listed species occurring in certified forests (Table 4). The selection of the species was focused on species associated with habitats and structures promoted by FSC certified forest management.

Table 4. List of selected species, their red-list (2023) status, indicator status according to the Swedish forest agency (Swedish Forest Agency 2023), their association to Natura 2000 habitats (i.e. classified as a typical species for a specific habitat) and their main habitat associations.

Species	Taxon	Red-list status	Forest indicator	Natura-2000 types	Habitat associations
Climacocystis borealis	Fungi	LC	Yes	Taiga 9010, Herb-rich forests with Picea abies 9050	Old growth forests, dead wood
Fuscoporia viticola	Fungi	LC	Yes	Taiga 9010	Old growth forests, dead wood
Hydnellum ferrugineum	Fungi	LC	Yes	Taiga 9010	Old growth forests
Phellinidium ferrugineofuscum	Fungi	NT	No	Taiga 9010, Herb-rich forests with Picea abies 9050, Natural forests of primary succession stages of landupheaval coast 9030	Old growth forests, dead wood
Phellinus populicola	Fungi	LC	Yes	Taiga 9010, Natural forests of primary succession stages of landupheaval coast 9030	Old aspen trees, old growth forests
Phellopilus nigrolimitatus	Fungi	NT	No	Taiga 9010	Old growth forests, dead wood
Phlebia centrifuga	Fungi	VU	No	Taiga 9010, Herb-rich forests with Picea abies 9050, Natural forests of primary succession stages of landupheaval coast 9030	Old growth forests, dead wood
Pulsatilla vernalis	Plant	EN	No	Coniferous forests on, or connected to, glaciofluvial eskers 9060	Old growth forests
Rhodofomes roseus	Fungi	NT	No	Taiga 9010, Herb-rich forests with Picea abies 9050	Old growth forests, dead wood
Sarcodon squamosus	Fungi	NT	No	Taiga 9010	Old growth forests
Aromia moschata	Insect	LC	Yes		Old growth forests
Cacotemnus thomsoni	Insect	LC	Yes		Dead wood, old forests
Callidium coriaceum	Insect	LC	Yes	Taiga 9010	Dead wood, old forests
Microbregma emarginatum	Insect	LC	Yes	Taiga 9010	Old trees
Necydalis major	Insect	LC	Yes	Taiga 9010	Old growth forests, dead wood
Nothorhina muricata	Insect	NT	No	Taiga 9010, Coniferous forests on, or connected to, glaciofluvial eskers 9060	Old trees, open forests
Peltis ferruginea	Insect	LC	Yes	Coniferous forests on, or connected to, glaciofluvial eskers 9060	Dead wood, old forests
Semanotus undatus	Insect	LC	Yes		Dead wood, old forests
Tomicus minor	Insect	LC	Yes	Coniferous forests on, or connected to, glaciofluvial eskers 9060	Old forests, dead wood

10. Biodiversity Analysis

10.1. Data

To assess species trends, we extracted species observations between year 2000 – 2023 in certified forests from open access species data (GBIF 2020). Our analysis initially selected 29 species of insects, fungi, mosses, lichens, and plants (Appendix 3). These species are associated with old growth forests, dead wood, or deciduous trees. It is known from the national forest inventory (NFI) reports that these components have increased in managed forests during the last decades (SLU 2023). The criteria for species selection were:

- Species with short life cycles that may be expected to respond quickly to changing environments.
- Indicator species of forests with high natural values (Swedish Forest Agency 2023), red-listed (SLU 2020), or typical N2000 species of boreal forest habitats
- Associated with habitats or structures with identified high FSC added value
- Sufficient number of records over the last 20 years (>1000)

The final criteria reduced the number of species to 19 as 10 species did not have enough records. The spatial data on geographical extent of certified forests covering large parts of northern and central Sweden were obtained from several CHs. To extract species records and compute analyses, we have applied a 100m hexagon grid to the certified forest area.

10.2. General description of the analyses

To determine the distribution of species associated with high natural values in certified forests, we analysed species occurrence over the last 20 years. During this time FSC certification has been implemented at large scale by the selected CHs. The biodiversity analysis focused on species of fungi, insects and plants that were either red listed or indicating forests with high natural value. Species were associated with habitats and substrates such as dead wood, old growth forests, deciduous trees and for wood, or forest fires. This analysis identified in which areas and how likely the species can be found in certified forests of central and northern Sweden.

Distribution maps and probability of occurrence over time were estimated for 19 species using a modelling approach. We obtained open data on species observations between years 2003 – 2023 and restricted to FSC certified forests only. We also obtained open data for the entire forest species community and habitat data (ground moisture and forest type) for the same forest areas. Observations were organized into hexagonal grid cells of 100m radius. An algorithm (FRESCALO) was applied to account for biased observations in the open species data. It estimates the probability of finding a species in each grid cell (per year) by considering the habitat and forest species assemblage, both within and adjacent to the grid cell. Time trends and distribution maps for each species were then created from these adjusted values.

10.3. Technical methods description

Working with species observations from open data bases comes with several challenges. Presence-only data means that while the presence of a species can be considered as true, a species that has not been reported might be because the species is not there (true absence) or because it was not detected (false absence). The recorder effort will also be unknown for each grid-cell and uneven across grid-cells, which needs to be addressed (Prendergast et al. 1993, Guillera-Arroita 2017).

To tackle these issues, we will estimate the probability of finding (or observing) each species with the Frescalo approach (Hill 2012). Frescalo is an algorithm developed to estimate unknown recording effort and species occurrence of data that is aggregated in time periods (i.e per year and grid). It is a well-established method to model the data collection process of biological recording schemes (Isaac et al. 2014, Pescott et al. 2019). As input, the algorithm requires community data and environmental data. It then estimates the expected frequency of each species in a grid-cell for each year (a value between 0 and 1) that can be converted into a species' probability to be observed.

To estimate the expected frequency, the algorithm uses a neighbourhood around each grid cell that will weight each frequencies by 1) the geographic distance between the focal cell and the surrounding cells; 2) environmental similarity between the focal and the surrounding grid-cells; and 3) the observed frequency of the species in the community. In our analysis, we used 100 m grid cells covering the area with certified forests. For each grid cell, we extracted all species observations (i.e. community data) and both humidity (SLU 2020) and forest type (Ahlkrona et al. 2019) (i.e environmental data).

As community data, we used the same taxa as our focus species (beetles, vascular plants, mosses, lichens, and fungi) using conifer, deciduous and mixed forests as their biotope according to the Swedish Species Information Centre. To reduce the size of the data set, we first removed grids with few observations (i.e. grids that only had species richness lower than 10% of the grid with the maximum value) and then species occurring in few grids (covering ≥ 0,5% of the grid cells).

Once we obtained the estimated frequency of each species from the Frescalo algorithm, we investigated the species' annual trends from 2000 to 2023. The first three years had to be excluded subsequently, because the algorithm did not work. However, when data is collected within a temporal framework, the data points are not independent from each other (Turner and Gardner 2015). This means that the risk of finding statistical significance when it does not exist, increases. To avoid this issue, we need to account for temporal autocorrelation within the data. Therefore, for each species, we ran a regression model with temporal dependency assuming that regression residuals follow a random walk process 'Rw1' (a model in itself, as described in Zuur et al. (2017)).

As outcome of the temporal trend analysis, we obtained 1) one estimated frequency per species and year (across all grid-cells) that was used to plot the general species temporal trends (figure 10); and 2) one estimated frequency per species, and grid-cell (across all years) that was used to plot the species distribution maps (figure 11). We used Integrated Nested Lapplace Approximation (INLA) for Bayesian inference (Rue et al. 2009) and the R-package R-INLA (www.r-inla.org for model execution (Rue et al. 2017, Bakka et al. 2018)) to compute the temporal trends. INLA is a method for approximate Bayesian inference for Latent Gaussian Models (such as models with temporal dependency where a dependency structure – the temporal trend – needs to be captured by the model). INLA has a high computational-cost-efficiency and allows incorporating temporal dependency with higher flexibility than other Bayesian methods, especially when modelling large datasets over large geographical areas (Blangiardo and Cameletti 2015, Zuur et al. 2017).

10.4. Results

Temporal trends were possible to estimate for 19 out of 29 species (figure 10). The remaining species had to be excluded (listed in Appendix 3), due to the filtering described in Methods (insufficient number of records resulting in grids with too few species or species occurring in too few grids).

The results show that species occurrence has been stable over time. We detected no clear increase (or decrease) of the probability of finding the species across time, but rather a random oscillation with no defined direction. That means that either the probability of finding a species has remained stable across time (with random increases and decreases) or that the trend cannot be determined with certainty (is not significant). A trend is 'significant' if the 95% CI do not overlap zero (figure 10), or the mean probability value, depending on the graphical illustration of the trend.

The species distribution maps show that different species have different distributions within the analysed forest area. Some species occur widely across the whole area, e.g., fungus *Rhodofomes roseus* and beetle *Peltis ferruginea*, while for others there are few specific regions where there is high probability of finding the species, e.g., plant *Pulsatilla vernalis* and beetle *Aromia moschata*. Overall, when seen across the entire analysed forest area, all species present a high probability to be found. The high probability is not informative per se but is due to large forest areas within the species natural ranges being included in the analyses. Important to note is that the analysis cannot account for changes in population sizes; thus, it is still possible that the abundance of species has increased or decreased within their distribution range.

The analysis does not account for species coverage or abundance but responds (or it's based) on recorded presence of the species and associated species community within a type of habitat. Therefore, regarding interpretation of the results presented here, we have the following disclaimers:

1. The analysis is only correlative, meaning that trends can be caused by variables other than certification (e.g. temporal fluctuations in climate or predation). Therefore, we cannot quantify to what extent certification is causing the observed patterns.

2. The results show the probability of finding the species, i.e. species occurrence. The probability does not describe species abundance, coverage, population size or viability. The trends cannot be interpreted as a beneficial status for the populations of the species.

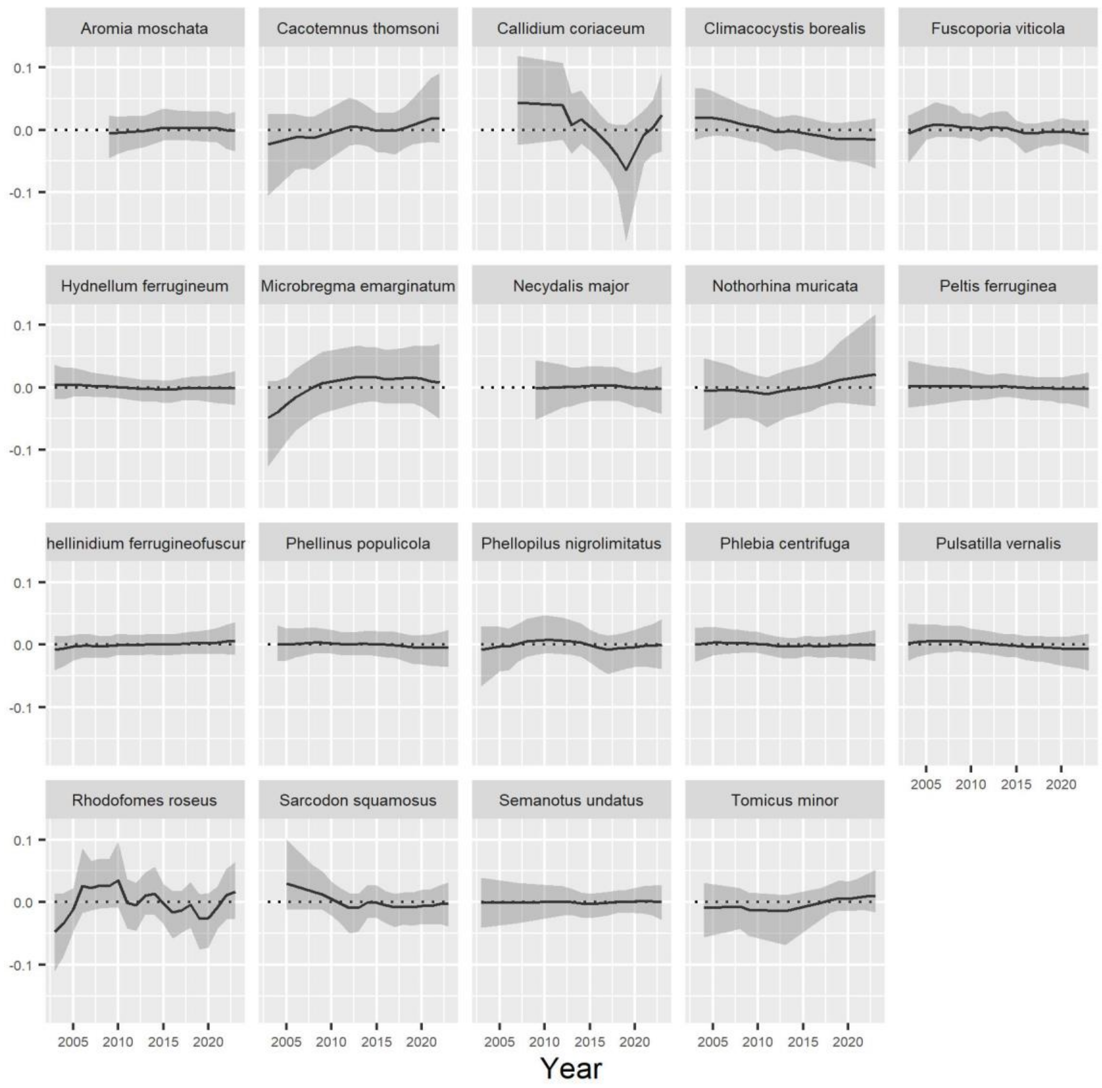


Figure 10. Estimated time trends for occurrence of 19 forest species: the Y axis shows relative changes in species occurrence over time. The black line is the probability of finding the species over time, during the last 15-20 years. The dashed line at zero illustrates the average level of species occurrence, and the grey area shows the confidence interval. Confidence intervals that overlap zero show that there has been no significant trend, i.e. no change in species occurrence.

10.5. Visualisation of results

The results from the analyses can be visualised using maps, graphics of species trends and habitat factors, and images of species and habitats. Geographically, the distribution of grid centroids can be presented, with their estimated probability to encounter each species. For each analysed species and structure/habitat we also include an image with a short description of species ecology and threat status, or habitat value for biodiversity.

Materials for visualisation submitted to FSC:

- Map images with probability of species occurrence
- Time trend over last 20 years for each species

- Short description of each species, its indicator value and red-list status
- Image for each species
- Important habitats and structures for each species
- Short description of habitats and structures and how they are promoted by implementation of the FSC standard

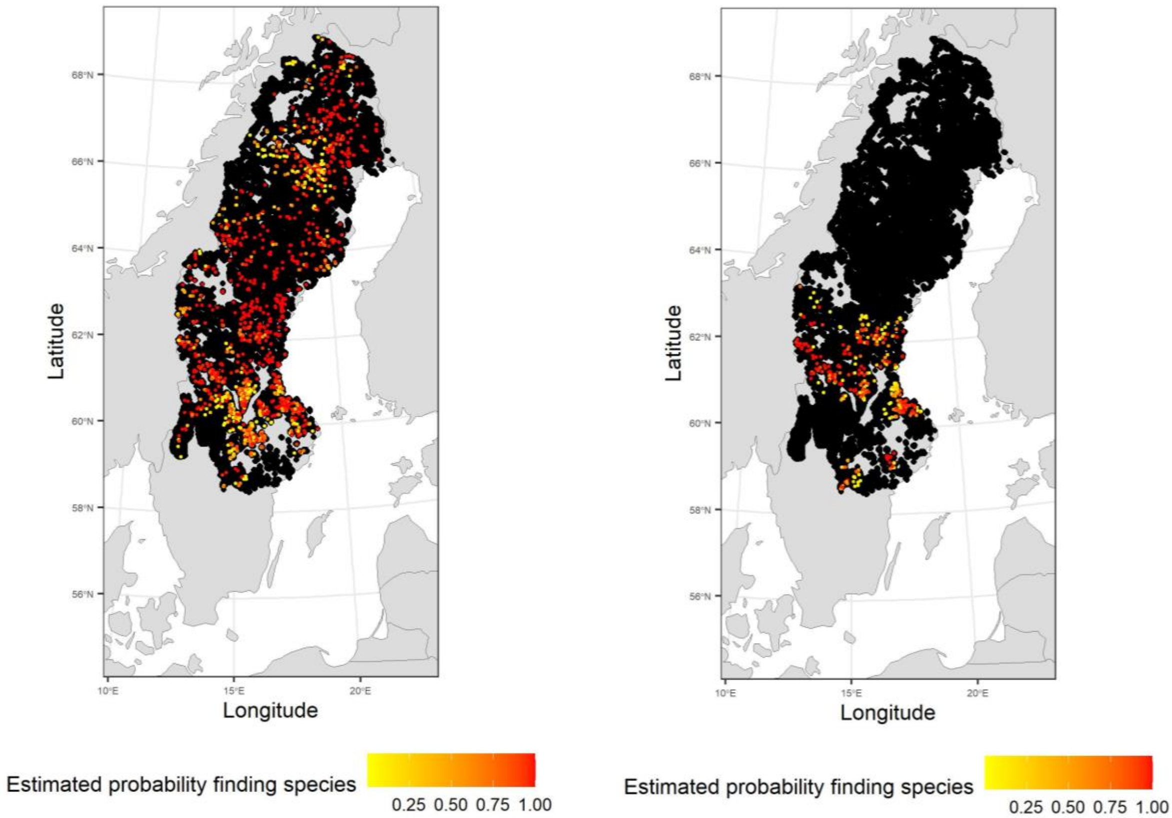


Figure 11. Spatial distribution of species occurrence. On the left wood-living fungus Rhodofomes roseus and on the right flowering plant Pulsatilla vernalis. The colour gradient (yellow to red) shows how likely it is that the species can be found in each area. The black points illustrate the distribution of certified forests that were included in the analysis. The analysis was based on open occurrence data for each species, forest species community and habitat characteristics, and was performed using the FRESCALO algorithm.

10.6. Discussion

The results indicate that the occurrence of species has been maintained in managed certified forests and we are as likely to find these species now as we were 20 years ago. One positive interpretation of these results is that the environmental consideration efforts in managed forests have contributed to maintenance of biodiversity, either by stabilising species occurrence or by reducing their decline. This interpretation is also in line with the positive developments regarding forest structures and habitats. The absence of significant positive trends might, in addition, reflect that the abundance of structures and extent of habitats have not yet reached ecologically sustainable levels.

The geographical extent of the analysed forest areas also needs to be considered when interpreting the results. Our analyses produced probability of occurrence over a large area, including central and northern Sweden. The NFI monitoring data has shown that the trends for forest structures and species vary across regions. Analysing a large area means that positive and negative small-scale trends are combined at a larger spatial scale, which may result in a stable overall trend that masks ongoing changes at smaller spatial scales. Availability of detailed monitoring data of rare and threatened forest species, and habitat data, would allow more specific time trends to be estimated for each region than what was possible in the current analysis.

Below, we exemplify how the results of the analyses could be interpreted for six focus species, by considering their ecology, geographic distribution, and the environmental aspects that FSC certification has contributed to.

The flowering plant, *Pulsatilla vernalis (EN),* has a limited distribution range and shows a stable occurrence over time. The species depends on open forest habitats and is favoured by natural disturbances, which are rare in managed forests. The red list status of *P. vernalis* has recently decreased from VU to EN, and targeted actions for the species have been implemented by a forest company in parts of its main distribution area. The stable occurrence trend that we observe is therefore a positive indication for the species and can probably be attributed to prescribed burning and set asides of open pine forests.

The longhorn beetle, *Nothorina muricata (VU),* has a wide distribution but a limited number of occurrences across the analysed area. The species shows a stable trend with a potential start of an increase during the last years. *N. muricata* depends on old, living, and sun-exposed pine trees, and its conservation status has recently improved from VU to NT. Retaining large old trees as conservation trees in managed forests, especially during harvesting, has probably benefitted the species widely across its distribution range. Additionally, prescribed burning in pine forests, which increases openness and sun exposure, has improved the habitat quality locally.

The dead wood dependent beetle, *Necydalis major,* has two main distribution areas and occurs more frequently in the southern part. The species occurrence over time has been stable. *N. major* depends on dead wood of deciduous trees in open forests. Managing forests for increased proportion of deciduous trees at landscape scale, retaining old deciduous trees and dead wood during harvesting, and using prescribed burning to increase sun-exposure, are activities that contribute to maintaining occurrences of this species in boreal forest regions.

The beetle, *Microbregma emarginatum,* has a limited distribution range and occurs in two coastal regions and shows a positively stabilising trend over time. The species has improved its conservation status from NT to LC. *M. emarginatum* depends on old, coarse living spruce trees. Retention of conservation trees throughout the forest rotational cycle has likely contributed to an improved status for the species, as many generations of beetles can use the same tree. Setting aside old spruce forests is important for maintenance and potential expansion of the limited distribution of this species.

The polypore fungus, *Phellinus populicola,* occurs throughout the area where aspen trees are present and shows a very stable occurrence probability over time. This fungus grows on large living aspen trees and requires forest with high abundance of aspen. The species conservation status has improved from NT to LC. Managing forests for increased proportion of deciduous trees at landscape scale and retaining aspen trees during harvesting and other forestry activities are actions that contribute to maintaining habitat for *P. populicola*.

The polypore fungus, *Rhodofomes roseus (NT),* has a wide distribution and occurs throughout most of the studied area. The probability of species occurrence over time has fluctuated during the last 20 years, but without a specific direction. *R. roseus* grows in natural-like forests and requires continuous supply of fresh dead wood of spruce. Retention of dead wood and setting aside old forests with high conservation values are important actions for maintaining the occurrence range of the species on a broad spatial scale and providing habitat of sufficient quality at the local scale. As all old forest-associated species, *R. roseus* depends on a continuous and stable habitat supply at a landscape scale, to avoid local extinctions and fluctuations of the overall probability of occurrence.

10.7. Comparing certified and non-certified forests

A comparison of certified and non-certified forests might be desirable to understand FSCs contribution to biodiversity conservation. However, there are aspects that make such comparisons complicated and the outcomes difficult to interpret. These results indicate that the distribution of species has been maintained in managed certified forests and we are as likely to find these species now as we were 20 years ago.

The main issue is the difficulty to find comparable control forests, i.e. forests that are managed to only meet the legal requirements. Factors that need to be controlled for in such a comparison include the size of forest management units, management intensity, geographical region, and other certification schemes (PEFC). Nevertheless, the motivation of the forest owner for belonging (or not belonging) to a certification scheme must be considered. Since the major proportion of production forests in Sweden are certified (by the FSC, the PEFC, or both), search for comparable areas would be very time consuming. In addition, the heterogeneity of the control group of “uncertified forests” makes comparisons difficult to perform and complicated to interpret.

Some scientific studies have made comparisons for certain forest owner categories (Villalobos et al., 2018). For example, no significant positive effect of certification was found for private forest owners on preservation of environmentally important areas during felling, number of trees and high-stumps, and conservation set asides. Two main issues were identified: 1) high non-compliance rates among both certified and uncertified forest owners, and 2) the requirements by certification schemes as well as the legal requirements are far below ecologically sustainable levels. The size of set asides exceeded the requirements in both groups, protection of habitats during felling and number of retained trees and high-stumps were below the required thresholds (Villalobos et al., 2018). As the study used about a decade old data and some of the underlying survey methodology has been questioned and since modified, it would be interesting to know whether any improvements have been achieved during the last decade.

11. Conclusions Part 3

- Probability to find the species and changes in occurrence over time could be estimated for 19 indicator and red listed forest species, including insects, fungi and a plant.
- The distribution area where the species are likely to be found varies between the studied species, with some species very widely distributed and others with limited core areas.
- The distribution of species has been maintained in managed certified forests and we are as likely to find these species now as we were 20 years ago.
- No significant increases in species probability of occurrence were observed, but the shape of several trends suggests stabilisation after either a decline or a slight increase.
- The geographical range of species occurrence is illustrated in maps with estimated probabilities of finding the species in each location.
- The analysis does not account for changes in population sizes; thus, it is still possible that the abundance of species has increased or decreased within their distribution range.
- Comparison between certified and uncertified forests was not done in this analysis due to many confounding factors which make such analyses difficult to perform and interpret.

Part 4: Proposed monitoring strategy

Our evaluation revealed gaps in the monitoring strategy of CHs. The predominantly qualitative methods are not suitable for assessing environmental condition and biodiversity in certified forests. This makes it difficult to evaluate whether certification is achieving its purpose of ensuring sustainability of forest management. In this chapter, we summarise our suggestions on how to improve environmental monitoring and assessment.

11.1. Factors that need to be monitored

At the stand scale, monitoring should focus on substrates favoured by the certification standard, such as fresh and decayed dead wood, conservation trees, high-stumps, retention trees and area of buffer zones. At the landscape scale, monitoring should focus on the area of set asides and forests with conservation management. These quantitative data should be measured in a standardised way and stored in a specific monitoring database, together with species records (both open data and data from CH's). Currently, data are stored together with other information for each specific forest stand making it difficult to extract specific variables.

Stands where conservation management is performed should be monitored in order to evaluate the outcome of the management. This is currently not done despite that the standard requires documentation and following up of natural values. Repeated natural value assessment 15-20 years later would show which habitats and structures have improved and whether the area has been colonised by target species. Such reassessment would provide a clear measure of improvement and help CHs and forest owners visualise the results of their conservation work.

Additional factor to consider include quality and continuity of set asides. Again, the standard has requirements for quality control and documentation regarding set asides, but most of the CHs have either just started the work of assessing their set asides or have not done it at all. To protect biodiversity in the long term, it is crucial that the forests that are set aside contribute to stable landscape connectivity networks. Currently, CHs can reevaluate their set asides, harvest existing ones and replace them with new areas. We acknowledge that sometimes this could be motivated, e.g. if exceptionally high natural values are discovered elsewhere, but we think that some caution is needed here to protect biodiversity associated with long habitat continuity and species that disperse slowly across the landscape.

We propose that 1) data from quality control and natural value assessments of set asides must be stored for long term use, and 2) the documentation and data on stability, i.e. whether each area is still a set aside and maintains its quality, is also stored long term. When a set aside area is removed or replaced, this should be based on a documented evaluation of natural values at local and landscape scale.

11.2. Proposed methods

The proposed data collection can be incorporated within the existing monitoring activities. All CHs perform sample-based assessments of final harvest and precommercial thinning (i.e.

internal audits, general retention follow-ups), where compliance with the standard is assessed for several factors. This includes variables such as amount of dead wood, retention trees and buffer zones. The only modification needed is that quantitative estimates (instead of qualitative) are recorded and stored by the CHs. Some CHs are already doing this, while others need to adjust their field protocols. Data from natural value assessments that are done before forestry activities can also be used. Again, the amount of quantitative data created in these assessments varies, but all CHs have a standardised method in place for performing nature value assessments (as this is required by the standard). We suggest a standardised template, or data sheet for storing data on selected factors.

Alternatively, it could be optional for CHs to collect the necessary data for their forest management unit from ongoing national monitoring schemes, such as NFI, the Swedish bird survey, etc. The availability of such data will depend on the size and geographic location of CHs forest area and the existing data might not be sufficient for all CHs.

11.3. Data management and reporting

Our evaluations showed inconsistencies in the way data are handled and stored by CHs. The value of collecting, managing, and storing data in the long-term does not seem to be clear to many CHs. We think that some pedagogic efforts might be needed to explain the importance of standardised data, e.g., for evaluating environmental impacts of forestry activities and for demonstrating positive effects of conservation management.

We propose that a standardised data sheet or template is introduced for storing data by CHs. The variables and measurement units should be specified, as well as the spatial and temporal scale for monitoring. The extent currently used by CHs for environmental consideration follow-ups (10-20% of all management activities each year) is probably sufficient for the purpose. For quality assessments of set asides and conservation management areas, a longer time perspective is probably more suitable, proposedly every 15-20 year period, depending on the scale and intensity of forest management.

11.4. Compliance

It was apparent that the current interpretation of CHs on how to comply with the monitoring and assessment principle of the standard did not involve data collection. Yet, data collection is a central part of any monitoring process and essential for evaluating long term effects of the monitored factors. It is unclear whether the current interpretation is due to lack of ecological knowledge, due to lack of specific requirements in the standard, or due to the way external auditing is performed. We propose that a clear definition of what is meant by monitoring and assessment is included in the standard, to ensure that it is interpreted as intended.

Final conclusions

1. Significant contribution of FSC to biodiversity, but more effort is needed.

FSC certification has significantly contributed to increased efforts for biodiversity in Swedish forests. It is the single most important motivation identified by certificate holders for engaging in monitoring and improving sustainability of forest management methods. This contribution is likely reflected in the national trends showing improvements in several forest structures important for biodiversity, such as dead wood, area of old forests and deciduous trees.

While FSC has contributed to improved habitat conditions at stand level, this is insufficient to protect and prevent loss of intact forest ecosystems at landscape level, particularly for old-growth forest associated biodiversity. In addition, there is no apparent overall improvement of conservation status of threatened forest species, which may be due to extinction debts, and that the current availability of important structures and habitats are still below ecologically functional levels.

2. The occurrence of species is maintained in FSC certified managed forests.

Analyses of forest indicator and red-listed species occurrence in FSC certified forests show that the probability to find the species has been stable over the last 15-20 years. No significant decrease or increase in species occurrence can be observed across managed forest areas of central and Northern Sweden. The species selected for analyses include several fungi and beetles that are dependent on old trees and dead wood of different tree species or require natural disturbances. That their distribution has been maintained indicates that structures and habitats that are retained or created in certified forests, like dead wood, retention trees, set asides and prescribed burning, have contributed to providing habitats and supporting occurrences of these species over time.

In the future, detailed species monitoring data might allow performing specific analyses at a smaller (local or regional) scale, to assess influence of specific structures and habitat factors on species population sizes. To maintain viable populations of forest-associated species in the long term, it is important to understand whether the current requirements in the FSC standards are sufficient to meet species habitat requirements at local and landscape scales.

3. Biodiversity is poorly monitored, but open data and a standardised protocol can produce high quality data in the future

Many certificate holders collect detailed data on factors associated to biodiversity, but the data is often simplified into a qualitative binary variable or not systematically stored. A structured way of sampling and storing data would result in a large data base that could be used for improved evaluations and research. Therefore, we propose that a standardised data sheet or template is introduced for storing data. In addition, we propose that a clear definition of what is meant by monitoring and assessment is included in the standard, to ensure that this principle is interpreted as intended.

We believe that a potential to improve biodiversity monitoring also lies in better use of open data. Sweden has several long-going monitoring programmes with nation-wide coverage. These projects create quantitative data related to specific taxa like birds and butterflies, but also on environmental forest indicators, including dead wood. Compilation of these data could allow quantitative assessments of biodiversity and the environmental status.

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Appendix 1. Questionnaire on monitoring and assessment in FSC certified forests Sweden

This questionnaire examines the types of monitoring and assessment conducted in FSC certified forests in Sweden. The project is led by FSC International. Participation in this survey is voluntary and the identity of individual respondents are anonymous. The results of the survey will be summarised on a national level.

Section 1. General questions

What is the size of your forest management unit?

1. >5000 ha
2. 1000-5000 ha
3. <1000 ha

For how long has your organisation been FSC certified?

1. <5 years
2. 5-10 years
3. >10 years

Section 2. Forest management plan

Is the implementation of the management plan monitored according to the existing management system? (Yes/No)

How often? (Yearly/ every second year/ Every third year/ Less often/ More often)

Which parts of the management plan are evaluated:

1. Policies (Yes/No)
2. Management objectives (Yes/No)
3. Implementation of planned activities (Yes/No)
4. Long-term economic sustainability (Yes/No)
5. Other parts of the management plan? (Yes/No, which ones?)

Briefly describe the methods/routines used for follow-up and evaluation of:

1. Policies (Free text)

2. Management objectives (Free text)

3. Implementation of planned measures (Free text)

4. Economic long-term sustainability (Free text)

5. Other parts of the management plan? (Free text)

Section 3. Environmental impacts of management activities and changes in the environmental condition

Is the environmental condition of the forestry unit monitored? (Yes/No)

How often? (Annually/ Biannually/ Every third year/ Less often/ More often)

Information on monitoring methods:

Some examples of monitoring methods are a) standardized survey (carried out precisely the same way at several locations/on repeated occasions), b) non-standardized survey, c) population monitoring for specific species, d) remote sensing, e) compilation of operational data, f) compilation of data from Artportalen, g) other method (describe).

Are the following aspects of the environmental condition monitored:

1. Tree retention (# trees left) (Yes/No)

Which method of a-g (described below) is used? (Free text)

2. Dead wood (Yes/No)

Which method of a-g is used? (Free text)

3. Buffer zones (Yes/No)

Which method of a-g is used? (Free text)

4. Soil/driving damage (Yes/No)

Which method of a-g is used? (Free text)

5. Trees of high biodiversity value (Yes/No)

Which method of a-g is used? (Free text)

6. Proportion of broadleaved trees in coniferous stands (Yes/No)

Which method of a-g is used? (Free text)

7. Retaining grazing-prone tree species during pre-commercial thinning (Yes/No)

Which method of a-g is used? (Free text)

8. Threatened species (Yes/No)

Which method of a-g is used? (Free text)

9. Other biodiversity values (Yes/No, specify)

Which method of a-g is used? (Free text)

Regarding the monitoring of biodiversity, which species/organism groups are monitored?

1. Birds (Yes/No, specify)

2. Insects (Yes/No, specify)

3. Lichens (Yes/No, specify)

4. Mosses (Yes/No, specify)

5. Vascular plants (Yes/No, specify)

6. Mushrooms (Yes/No, specify)

7. Mammals (Yes/No, specify)

8. Red-listed/threatened species (Yes/No, specify)

9. Conservation species (Yes/No, specify)

10. Other biodiversity (specify)

What management activities are followed up/monitored?

1. Thinning (Yes/No)

2. Final harvest (Yes/No)

3. Road construction (Yes/No)

4. Prescribed burning (Yes/No)

5. Specific species consideration (Yes/No)

6. Other conservation management (specify)

How often/what proportion of activities are followed up? (all/ about half/ a sample)

Is there an ecological landscape plan for the management unit that is followed up regularly? (Yes/No)

Are the following aspects in the ecological landscape plan monitored:

1. Proportion of old forest (Yes/No)

2. Proportion of deciduous stands (Yes/No)

3. Area with prescribed burning, (Yes/No)

4. Status of red-listed/threatened species (Yes/No)

5. Share of areas dedicated to nature conservation (Yes/No)

6. Proportion of wetlands (Yes/No)

7. Other (Yes/No, describe)

Are there regular follow-ups of nature/biodiversity values and habitats that should be prioritised? (Yes/No, describe)

Regarding questions in the environmental section above: do you have any data, ideally long-term data, that you could consider sharing with us, for an analysis on how monitoring contributes to improved environmental condition in FSC certified forests? (Describe data)

Section 4: Social effects of forest management

Are the social effects of activities on the forestry unit evaluated in accordance with the existing management system? (Yes/No)

Which social aspects within the organisation are monitored regularly:

1.The work environment:

1a. Safety (Yes/No)

1b. Gender equality (Yes/No)

1c. Discrimination (Yes/No)

2. The terms of employment (Yes/No)

3. Education and skill development (Yes/No)

4. Other (Yes/No, describe)

Which social aspects outside the organisation are monitored regarding impacts on the local communities?

1. Information (Yes/No)

2. Dialogue and consultation (Yes/No)

3. Local adaptations (Yes/No)

4. Measures to promote social and economic development (Yes/No)

5. Other (specify)

Please give short examples of monitoring methods/what data are recorded and stored.

Which social aspects outside the organisation are monitored regarding impacts on Sámi reindeer herding?

1. Information (Yes/No)

2. Dialogue and consultation (Yes/No)

3. Co-planning processes (Yes/No)

4. Local adaptations (Yes/No)

5. Other (specify)

Please give short examples of monitoring methods/what data are recorded and stored.

Section 5. Applicability and accessibility of assessment results

Are there established procedures and routines for analysing and implementing the results of monitoring/evaluation in the planning process and revision of the management plan? (Yes/No)

How well do these procedures work in practice when the management plan is implemented?

1. Very well

2. Well for certain actions, worse for others

3. Less well

4. Poorly

5. Don't know

Are the monitoring/assessment results available to the public? (Yes/No)

Where can the results be accessed?

Section 6. Interpretation and implementation of FSCs monitoring principle

Do you/your organisation feel that the criteria for monitoring and assessment according to FSC's principle 8 are:

1. Very clear
2. Quite clear
3. Quite unclear
4. Very unclear
5. Don`t know

Do you/your organisation feel that the criteria for monitoring and evaluation according to FSC's principle 8 are:

1. Easy to implement
2. Quite easy to implement
3. Quite difficult to implement
4. Very difficult to implement
5. Don`t know

What is the main reason you find monitoring/assessment difficult to implement?

1. Difficult to understand criteria
2. Lack of knowledge/competence on monitoring methods
3. Too resource-consuming
4. Too time-consuming
5. Other (specify)

Do you think there is a need for more concrete/standardized criteria for monitoring/evaluation?

1. Great need
2. Some need
3. No need
4. Don`t know

Do you think there is a need for more support regarding suitable methods for environmental monitoring?

1. Great need
2. Some need
3. No need
4. Don`t know

Do you have any other comments regarding the monitoring and assessment principle within FSC?

(Free text)

Appendix 2. Interview questions on FSC monitoring and assessment

Section 1. Biodiversity and environmental condition

How do you monitor biodiversity? What methods do you use and how often are environmental factors assessed?

Is there a focus on certain species/groups or structures?

What are the advantages/disadvantages of monitoring structures compared to species?

Which species/structures do you follow up on during internal audits?

Are nature value assessments used for monitoring biodiversity?

Do you think it is difficult to follow up/monitor biodiversity? Why?

What could facilitate your work with biodiversity monitoring?

What types of data are collected and stored from environmental monitoring?

Section 2. Social values

How do you monitor social sustainability/social effects of management activities?

What are the most important/relevant aspects for your company?

Do you evaluate the results of dialogue/consultation and local adaptations?

Does the evaluation/follow-up take place together with affected local communities/Sami villages?

What are your main challenges with monitoring social sustainability?

Section 3. Economic sustainability

What is your main forest management objective?

How is the short-term and long-term productivity and economic sustainability evaluated?

Have FSC principles and requirements affected your management objectives?

Section 4. Motivation for monitoring and assessment, and the role of FSC

Which regulations govern your work with environmental monitoring? Which has the most influence?

How important are your own sustainability goals compared to requirements from the certification in your work with monitoring?

Does the certification contribute to more ambitious sustainability work? How?

What role do the FSC principles play in developing your environmental monitoring?

Section 5. Resources and competence

What are the limiting factors for carrying out environmental monitoring/follow-up? (e.g., resources or competence)

Are you satisfied with how you currently work with monitoring? What would you like to do more/less of?

Have you changed or developed the way you work with sustainability and monitoring during the time you have been certified?

How would you like to develop your monitoring in the future?

Would it be useful to have more specific requirements and criteria for what should be monitored and how often?

How could the FSC standard be developed to facilitate certificate-holders' work with monitoring?

Interview questions adapted for group certificate holders

Section 1. Biodiversity and environmental condition

How do you as an umbrella organisation work with monitoring and assessment of biodiversity and environmental condition?

What information do you get from your members regarding which aspects are followed up and with what methods?

Are there requirements for the members to report to you how they comply with principle 8 criteria?

Do you work differently with small and large forest owners?

Do you find it easy to obtain a clear picture of the environmental condition and biodiversity?

What could facilitate your work with ensuring compliance with principle 8?

Do you have access/compile/store any data on environmental assessments from your members?

Section 2. Social values

How do you as an umbrella organisation work with monitoring and assessment of social sustainability/social effects of forest management?

What are the most important/relevant aspects from your perspective?

What are your main challenges with monitoring social sustainability?

Section 3. Economic sustainability

Which are your members main objectives of forest management?

How is the short-term and long-term productivity and economic sustainability evaluated?

Have FSC principles and requirements affected management objectives of your members?

Section 4. Motivation for monitoring and assessment, and the role of FSC

Which regulations govern your work with environmental monitoring? Which has the most influence?

What role do the FSC principles play in developing your environmental monitoring?

Section 5. Resources and competence

What are the limiting factors for carrying out environmental monitoring/follow-up? (e.g., resources or competence)

Would it be useful to have more specific requirements and criteria for what should be monitored and how often?

How could the FSC standard be developed to facilitate certificate-holders' work with monitoring?

Appendix 3 - Species included in the analysis

Aegomorphus clavipes

Aromia moschata

Cacotemnus thomsoni

Callidium coriaceum

Chimaphila umbellata

Climacocystis borealis

Crossocalyx hellerianus

Fuscoporia viticola

Hydnellum ferrugineum

Leptoporus mollis/erubescens

Lobaria pulmonaria

Microbregma emarginatum

Necydalis major

Nothorhina muricata

Peltis ferruginea

Peltis grossa

Phellinidium ferrugineofuscum

Phellinus populicola

Phellopilus nigrolimitatus

Phlebia centrifuga

Pseudographis pinicola

Pulsatilla vernalis

Rhodofomes roseus

Saperda carcharias

Saperda perforata

Sarcodon squamosus

Semanotus undatus

Tomicus minor

Tragosoma depsarium