Do we protect the right forests?
– A case study of representativeness of protected forests in Östergötland, Sweden, and identification of tracts of value.

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**Sammanfattning/Abstract:**

Protected forests need to be a representative selection of the natural proportion of forest types, including distribution of productivity levels, age classes and nature types. This is important for the possibility to preserve biodiversity. In addition, the protected areas has to be of sufficient size and not isolated from each other, to function as effective biodiversity preservers. The question is, how does it look in reality? The objective with this study was to get an overall picture of the current forest protection situation in Östergötland, Sweden, and how it has changed the last 60 years. Are all ecologically relevant forest habitat types represented in appropriate proportions in protected forests? To evaluate where the protected areas are located in relation to each other, a connectivity index was calculated for each patch of protected area. Together with a value for size, a value index was created and applied to all protected areas, and it turns out that the protected areas of Östergötland is not totally representative when it comes to nature types, age classes and levels of productivity. For example, there is an underrepresentation of both pine and spruce forests on high-productivity soils. However, areas with higher productivity levels have been protected over time. The age distribution seems to be skewed towards older forests in protected areas. There are some underrepresented nature types, as well as overrepresented ones in nature reserves, a small overrepresentation of unproductive impediments, and only spruce and mixed forests seems well connected in the landscape. The greatest differences in protected and unprotected forests is the productivity level, were focus should be on protecting higher productivity areas in order to succeed in preserving the biodiversity of forests as intended.

**Nyckelord/Keyword:**

Forest representativeness, connectivity, protected forests, forest productivity
1 Abstract

Protected forests need to be a representative selection of the natural proportion of forest types, including distribution of productivity levels, age classes and nature types. This is important for the possibility to preserve biodiversity. In addition, the protected areas has to be of sufficient size and not isolated from each other, to function as effective biodiversity preservers. The question is, how does it look in reality? The objective with this study was to get an overall picture of the current forest protection situation in Östergötland, Sweden, and how it has changed the last 60 years. Are all ecologically relevant forest habitat types represented in appropriate proportions in protected forests? To evaluate where the protected areas are located in relation to each other, a connectivity index was calculated for each patch of protected area. Together with a value for size, a value index was created and applied to all protected areas, and it turns out that the protected areas of Östergötland is not totally representative when it comes to nature types, age classes and levels of productivity. For example, there is an underrepresentation of both pine and spruce forests on high-productivity soils. However, areas with higher productivity levels have been protected over time. The age distribution seems to be skewed towards older forests in protected areas. There are some underrepresented nature types, as well as overrepresented ones in nature reserves, a small overrepresentation of unproductive impediments, and only spruce and mixed forests seems well connected in the landscape. The greatest differences in protected and unprotected forests is the productivity level, were focus should be on protecting higher productivity areas in order to succeed in preserving the biodiversity of forests as intended.

2 Introduction

In the last decades only, there has been hundreds of species that are believed to have become extinct. The fact is that the extinctions we see today, is considered to result in one of the great mass extinctions of history (Barnosky et al., 2011, Dirzo & Raven, 2003, Pievani, 2013). The by far greatest reason for the large number of threatened species is considered to be habitat loss and habitat degradation. Habitat loss does not only consists of total loss of areas or nature types in a region, it also includes fragmentation of natural areas. In addition, pollution, introduction of alien species, overexploitation of resources and climate change seem to have an effect on the high rate of extinctions (Barnosky et al., 2011, Dirzo & Raven, 2003, Pievani, 2013). A habitat type strongly affected by fragmentation is forests, caused by the intensive forest management (Svensson, 1996). One of the most important factors that influences the landscape patterns of forests are the forestry management, which in Sweden is dominated by clear-cutting (Axelsson & Östlund, 2001). Formal protection of valuable forest areas is one way to prevent further loss and fragmentation of this habitat. For this to be a successful strategy, it is urgent to protect the right areas, i.e. the areas which has the highest possibility to preserve biodiversity. In the year 2010 Sweden was one of the countries to sign the Nagoya protocol for protection of our environment and biodiversity. After that, 20 more specific goal has been set, called the Aichi targets. The participating countries needs to apply the agreement by (among other things) establishing an ecologically representative and well connected network of protected areas. By using a strategy to protect representative proportions of different nature types, age classes and productivity levels in forests, there is a higher possibility that ecologically valuable forest habitats is included.

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Forests naturally harbour a large variety of habitats, which in turn increases the possibility of a high biodiversity. A well-functioning ecosystem is of vital importance to provide us with ecosystem services, which in forests includes for example pollination, pest controls of productive forests, flood prevention and more (MEA, 2005, Ninan & Inoue, 2013). A high biodiversity means a high amount of ecosystem services, and it has been shown that a decrease in biodiversity means changes in function of the ecosystem (Cardinale et al., 2011). Preservation of a high biodiversity is therefore a priority when protecting forest areas. Unfortunately, the biodiversity in forests (and also other habitats) is decreasing globally, as indicated by the IUCN red list of threatened species (International Union for Conservation of Nature and Natural Resources). A new red list of threatened species in Sweden has recently been presented, and a summary of conditions and trends about these species (Swedish Species Information Centre [Artdatabanken], 2015, Sandström et al., 2015), showing that more than 1800 species (which means 43 % of the red listed species) has forests as an important habitat. A total of 53 % (around 2250 species) of the red listed species occur in the forests. Furthermore, well over a 1000 species live in hardwood forests. Looking at the county of Östergötland alone, almost 600 of the red listed species connected to forests occur in the county. Of these over 400 are endangered (EN), critically endangered (CR) or even nationally extinct (RE) (Swedish Species Information Centre [Artdatabanken], 2015). So what is the reason for this large number of threatened species? In forests, the by far greatest reason for negative effects is logging, which is estimated to affect 1800 red listed species (Sandström et al. 2015).

Naturally, there have been preferable to conduct forestry on productive land. Protected areas are more often situated in low productive areas, instead of being representative of the forest landscape (Andrew et al., 2011, Babu Shrestha et al., 2010, Nilsson & Götzmark, 1992, Scott et al., 2001, Branquart et al., 2008). Productive areas have been shown to host a higher biodiversity amongst trees (Belote & Aplet, 2014, Erskine et al., 2006, Paquette & Messier, 2011, Piotto, 2008, Vilà et al., 2013) and fauna such as birds, amphibians and reptiles (Báldi & Vörös, 2006) A low representativeness of forest habitat types in protected areas has been shown to be inefficient in preserving a high biodiversity. Even though almost 25% of the land area in Thailand was under protection in year 2006, the proportions of protected nature habitat types was not representing the proportion of these nature habitat types in the country, making a lot of ecologically important habitats being underrepresented (Trisurat, 2007). This means, that the traditional strategy of forest protection (resulting in protection of low productive areas) does not favor a high biodiversity. These areas are therefore not enough when one wants to protect threatened species. The practise of protecting low productive, and not always representative forests applies to Sweden as well (Nilsson & Götzmark, 1992, Fridman, 2000). A Swedish report by Jasinski and Uliczka (1998) has demonstrated the importance of high productive forests to keep a higher biodiversity. The report highlighted the low number of species detected in or depended on wooded forest impediments in Sweden. Many of the species found in these habitats were not even linked to the trees as such. Cederberg et al (1997) has also described the importance of productive forest, with a report concluding that only 2% of the red listed species of Sweden used the wooded forest impediments as their main habitat. If forest areas chosen for protection is not selected on productivity and representativeness, one is likely failing to protect forest dependent threatened species that requires a specific forest habitat. Swedish Species
Information Centre [Artdatabanken] (2013) points out in a conservation status report that the biggest shortcoming in protection of biodiversity in forests is the lack of enough protected areas with high ecologically values. At the same time, it has been concluded that specialized species needs a certain amount of cohesive habitat in the landscape to have a chance of survival in the long run (Harrison & Bruna, 1999). When also isolating habitats through fragmentation, it is a higher risk that habitats become unutilized by these specialized species. The choice of forest for protection therefore need to be based on several characteristics, such as productivity, representativeness of the landscape, size and connectivity to other similar habitats.

When striving towards higher representativeness of protected forests, one should also consider distribution of age. Forestry in large parts of the world has led to areas of monocultures and often even aged forests. Since forest habitat structures differ through age classes (Spies & Franklin, 1991), an even age forest lack many important habitats. It is therefore important to strive towards protection of many different age classes. However, when working towards a representative distribution in both age and nature types, it’s not really what proportion we have today that is the important to try and live up to. One has to look at the estimated pre-industrial proportions (MVB, 1997). This since the pre-industrial time represents a more natural occurrence of different forest habitats, before comprehensive effects from human activities in the forest landscape.

Efficient conservation management of threatened forest specific species and their habitats, needs up-to-date knowledge of the protected forests. The objective of this study is to present an overall picture of the forest areas of Östergötland, with regard to representativeness of nature types, productivity level and age distribution in formally protected forests of Östergötland. Are all types of forests represented proportionally, based on the proportion of the county as a whole? Are some nature type, age classes under or over represented? How well are productive woodlands represented in the protected areas? A further objective of this study is to analyze the connectivity between valuable forest areas in Östergötland (such as protected forests, biotope protection areas, nature conservation agreement areas and identified key habitats), using model organisms with different dispersal abilities. Which regions provides the highest possibility of dispersal? On this basis, tracts of value should be identified, and subsequently of possible support in future conservation management and establishment of new nature reserves.

### 3 Material & methods

To compare protected areas with the county of Östergötland as a whole, several parameters were considered. Analysis of representativeness included distribution of age in all forests, distribution of nature types, and a comparison of unproductive impediments and productive woodland. In the analysis of connectivity the patch distance and patch size were considered and several analysis were performed for different forest types. This to take account of the different preferences of different forest living species. Protected areas included in the study is nature reserves, identified key habitats, biotope protection areas and areas with nature conservation agreements. Areas bought by the County Administration Board of Östergötland [Länsstyrelsen Östergötland] from a forestry company to establish as nature reserves, were also included as protected areas. The connectivity analysis was used to pick out tracts of value of different forest types.
3.1 Used data

The county of Östergötland has a total of 238 nature reserves, which all were included in the analysis of nature types and age distribution. Only 222 were included in the comparative analysis of productivity. The excluded ones were not found in the archives, and hence has no information on productivity. 347 areas bought as upcoming reserves, 5962 identified key habitats, of which 838 are data received from forestry companies, 395 biotope protection areas and 273 areas with nature conservation agreement, were used in the analysis of nature type distribution and connectivity.

Evaluations of forest areas from the establishment of nature reserves, containing information about productivity, age and surface area has been digitalised from the archives of the County Administration Board of Östergötland [Länsstyrelsen Östergötland]. To identify forest types of areas with sparse information, the habitat mapping data (KNAS) has been used. Data on identified key habitats has been collected from several forestry companies operating in the county, alongside data from the Forestry Commission [Skogsstyrelsen]. Data concerning nature types and amounts of forest areas of the county of Östergötland has been collected from the National Forest Inventory [Riksskogstaxeringen] of Swedish University of Agriculture [SLU] (2014) and CORINE land cover data from the Ordnance Survey [Lantmäteriet]. An overview of used data is presented in Table 1. All analysis were performed with ArcMap 10.1.

Table 1: Used data and included areas in the different analysis of this study.

<table>
<thead>
<tr>
<th>Analysis</th>
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<td>-Data from National Forest Inventory</td>
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<td>Productivity level over</td>
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<td>(from the University of Linköping, Sweden)</td>
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<td>Nature types</td>
<td>-Land cover CORINE data</td>
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<td>-All of the county of Östergötland</td>
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<td>Age distribution (ha)</td>
<td>-Evaluations of forest areas</td>
<td>-Nature reserves</td>
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<td>-Data from National Forest Inventory</td>
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<td>-Productive forests of Östergötland</td>
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1 Maps collected 2015-01-19 from https://maps.slu.se/get/
### 3.2 Analysis of representativeness

To evaluate if the protected forests of the county of Östergötland is representative in comparison with the county as a whole, proportions of productivity levels, nature types of forests and age classes has been compared. When comparing productivity levels, evaluations of forest areas from the establishment of nature reserves for the protected areas were used, and data from National Forest Inventory [Riksskogstaxeringen] for the county of Östergötland. The productivity levels were compared using site indices (SI). A site index is an estimate of average tree height at a certain age of reference. For pine, spruce and oak the age is 100 years, for birch it is 50 years. Since site indices are only presented in even numbers in the National Forest Inventory, the site indices with uneven numbers that occur in the forest evaluations were grouped according to current practice\(^2\). This means that uneven site indices are added to the site index closest below itself. Hence, T12 both includes T12 and T13, and so on.

Comparing nature types in forest areas, only land cover CORINE data were used (exact divisions into nature categories is given in Appendix 1). This to be able to ensure a fair comparison, since the habitat mapping data (that only represents the nature reserves) have different nature categories than the land cover CORINE data. Doing the age comparison, evaluations of forest areas from the establishment of nature reserves were used for the protected areas, and data from the National Forest Inventory [Riksskogstaxeringen] for the county of Östergötland. When comparing age, only the established nature reserves were compared to the county as a whole, simply because almost all other areas lack information about age. Also, only productive forests are included in this analysis. This is because this is the only areas with specified ages in the nature reserves. Totally 189 ha of the nature reserves were with no age specified. This is considered as negligible, as it is solely 0.0001 % of the county, and 0.004 % of the nature reserve areas. A comparison of both volume and area was made between the protected areas and the county as a whole. Unfortunately, only the reserves established from year 2002 and later has information about volume. This gives a representation of the reserves of 70.5 % (in terms of surface area) in that particular analysis. When comparing age proportions using area instead, all reserves are included.

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\(^2\) Pers. comm. Magnus Wadstein, the Forestry Comission of Östergötland [Skogsstyrelsen-Östergötlands distrikt], 2015-04-01.
### 3.3 Analysis of connectivity

It is hard to estimate how well different patches are connected in a landscape since species differ in dispersal ability and habitat use. Fragmented regions create metapopulations of present species, more or less connected in the landscape. Every species has its own threshold of metapopulation capacity, and above this value the population has a great chance to persist in that particular landscape (Hanski & Ovaskainen, 2000). But since these values are species specific, a general method to rank all valuable patches in the landscape of Östergötland is needed. Using a butterfly species as a model, another study has shown the link of patch size, location and quality with expansion of the population. The larger area, patches with suitable habitats available and higher quality of the fragments, the larger expansion of the species in the landscape (Wilson et al., 2009). This study gets support from Soga and Koike (2012), who argue that larger fragments is better than small, and has a positive effect on species richness. Since the data used in this study does not value the quality of patches, only size is taken into account. But how much is enough? When not using any particular species or even group of species as a model for this analysis, this is of course even harder to answer. The general rule is; the larger patch, and the shorter distance to another patch, the higher value of that specific patch. Several studies of different butterfly species (which should be considered not the most mobile group of species), shows very different minimum areas and distances between patches. The minimum area to obtain good survival of the butterfly *Euphydryas aurinia* is according to a study in Great Britain 80-142 ha (Bulman et al., 2007). Another study suggests that the minimum patch size for survival of another butterfly (*Icaricia icarioides fender*, The Fender’s blue butterfly) is 2 ha, and not more than 1 km between patches. But, this study also showed that a high number of small patches close to each other could be even better, which indicated that patch size and connection to other patches are equally important (Schultz & Crone, 2004). An earlier study by Hanski and Ovaskainen (2000) showed the similar, namely that populations living in well-connected forest patches are subjected to lower risk of extinction and inbreeding depression.

However, survival rate of a species in a fragmented landscape also depend on its mobility. Thomas (2000) argues that a more mobile species is less affected by longer distances, whilst a species of intermediate mobility is affected the most. Butterfly species of intermediate mobility (most often 1-3 km, and more seldom up to 10 km) are declining the most, followed by low mobile species (generally >100 m, but sometimes up to 1 km). The butterfly species that has a high mobility (several kilometers, or much further) survives in greater degree, probably because they migrate farther away. Longer distances between patches in the landscape is therefore less of a problem. The intermediate species needs larger areas (a mean of 12 ha as a minimum), were they can move locally to new areas. Small patches is not enough, and longer distances between patches means that they more often end up in the matrix in between and have a low survival rate because of that. More sedentary butterfly species doesn’t need as large habitats (a mean of 2 ha as a minimum) to maintain a good survival rate (Thomas, 2000).

The connectivity analysis was made for all valuable forests in the county of Östergötland. This includes identified key habitats, biotope protection areas, nature reserves and valuable areas bought from a forest company by the County Administration Board of Östergötland. All collected data does not have the same
information about nature type or amounts of different tree species. In order to give all areas some comparable information, the dataset was supplemented with land cover CORINE data for some undefined key habitat areas from one of the forest companies, and the habitat mapping data (KNAS) was used for nature reserves. Areas purchased by the County Administration Board of Östergötland had information about percentage of tree species. The highest percentage was used to define the forest type of a particular area. If the highest percentage was lower than 65%, the area was classified as a mixed forest. This based on the definition by the National Forest Inventory [Riksskogstaxeringen] of Swedish University of Agriculture [SLU] (2012), although the definition is based on volume, and the proportion division of the dataset is not specified. In order to not miss any larger proportions of tree species in an area, all specified species with a representation of more than 20% was put as an own category.

All included data were divided in forest classes, based on earlier identified tracts of value (County Administration Board of Östergötland [Länsstyrelsen Östergötland]); spruce and mixed forest; pine forest; boreal deciduous forest; and hardwood forest. An additional class was also used; swamp forest. To see the exact division of forest types into classes; see the appendix (Appendix 2). When generating a table with information on which patches are located near each other, only patches within 6000 m were included as having any connecting effect on each particular patch (and therefore included in the table and further analysis). This was done in purpose not to get too much information on each patch to analyze.

A connectivity index for each patch area from a simple connectivity model by Moilanen and Nieminen (2002) was calculated, using the formula

$$S_i = \sum_{j \in i} \exp(-\alpha d_{ij}) A_j^b$$

where $S_i$ is the connectivity of a patch, $1/\alpha$ is the average migration distance, $d_{ij}$ is the distance between patches i and j, $A_j$ is the area of j, and $b$ is the effect from the amount of surrounding habitat (how much the area of nearby patches matter). $b$ is set between 0-1, where 0 means no effect at all from surrounding areas (it does not matter whether a nearby patch is small or large), and 1 means a linear relationship between nearby patch size and migration from the same. Moilanen and Nieminen (2002) argues neither is correct, since the size of nearby patches should have an effect on immigration from that patch, but it is very unlikely that there should be a linear relationship. Therefore, the value of $b$ is set to 0.5 in the analysis of this study, as suggested by Moilanen and Neiminen (2002). Each patch in the analysis got a connectivity index, which in term was divided into categories between 0 and 3 (for details, see Appendix 3). All patch areas were also categorized between 0.5-4, were areas over 500 hectares has the highest value (Appendix 3). These assigned values were then added to form a value index, between 0.5-7. The difference in value level of connectivity and surface area, makes the patches own size the most important factor affecting its value index the most. This method is used with drawn inspiration from a similar survey of the County Administration Board of Västerbotten [Länsstyrelsen Västerbotten] (Uppsäll (red.), 2012). But instead of taking into account the shape of an area, and the percentage of valuable land in a circle around each patch, the connectivity index mentioned above is used.
Two different connectivity analysis were run in parallel. One for more short distance dispersal species (with a mean dispersal capacity of 700 m), and one for more long distance dispersal species (with a mean dispersal capacity of 5000 m). These two parallel analysis represents two model organisms, and no species in particular.

3.4 Selection of tracts of value

The selection of tracts of value is based on the national strategy for formal protection of forests of Sweden [Nationell strategi för formellt skydd av skog] (2005). But since this study is limited to only the county of Östergötland, no data of occurring red listed species or information of industrial development, soil conditions or other similar data are used. The choice of tracts of value is only based on density of different forest types. This in turn is based on the connectivity analysis, which has given landscape overview of the most valuable areas (i.e. the areas with highest potential to preserve biodiversity).

4 Results

4.1 Representativness

4.1.1 Productivity level

The protected forests of Östergötland, does not represent the county as a whole when it comes to productivity level (presented as site indices, SI), as the average productivity level in protected areas is lower. Protected spruce forest were considerably skewed towards lower productivity compared with the county as a whole (Figure 1). The median of the protected areas is at SI G26 (31 %), followed by G28 (26 %). When comparing with the county of Östergötland, the differences at this productivity levels are huge, with only 2 and 9 % respectively. Instead, the median in productivity level of Östergötland is at G30 and G32 (both 30 %). The protected areas on the other hand, only have 18 and 5 % in these levels, respectively. Östergötland has as much as 20 % of all forest areas with a productivity of G34, whilst the protected areas have less than 2 %. In the productivity level of G36 the difference are not as noteworthy (less than 0.5 % for protected areas, and 4 % in the county), but there is still an underrepresentation in the protected forests. Since there are no overall data on the productivity levels of oak and birch of Östergötland, only spruce and pine are compared between county and protected areas.
Protected pine forests are not as much skewed towards low productivity as spruce forests, but still it’s not representative of the productivity of the county (Figure 2). Both protected areas and the county as a whole peaks at a site index of T24, but with 28 versus 34 % of the total area. The county has higher percentage in T22, T24 and T26, while the protected areas has higher percentage in T12-T20. In T28 the proportion is almost the same (2 % in protected areas and 1 % in the county). Hence, there is an overrepresentation of lower productive levels, and an underrepresentation of the higher productive levels. At SI T18 the protected areas almost has the double proportion (11 to 6 %) compared with the county and at SI T16 the proportion is actually three times larger (9 to 3 %) than in the county.

Figure 1. Occurrence of different productivity levels in protected and unprotected spruce forests of Östergötland.

Figure 2. Occurrence of different productivity levels in protected and unprotected pine forests of Östergötland. The protected areas are a bit skewed towards lower productivity then in the county as a whole.
When comparing means of site indices (productivity levels) in nature reserves of Östergötland over time, the last years shows a positive trend towards higher indices (Figure 3). The site index mean of pine has only increased modestly since the period of 1996-2002, but has still increased the most in total compared to the other site indices. The site index mean of pine is above the prioritized site index of the county (Administration Board of Östergötland [Länsstyrelsen Östergötland], 2006), which is T20. For spruce site index G26 or more is prioritized, for oak E22 and for birch B22. Also for these three tree species the site index means are above the prioritized level, but have not increased much over time. But when considering what is regarded as high productivity by the County Administration Board of Östergötland (2006) (G30, T28), and by Löf et al. (2009) (E24) and Rytter et al (2008) (B22), only the mean site index of birch is above that level.

![Figure 3. Means of site indices in nature reserves of Östergötland over time, from the first established nature reserve up until today.](image)

4.1.2. Nature types

The distribution of nature types of forest areas in the protected forests compared to the county shows a very small underrepresentation of coniferous and mixed forests (57.9 and 60.6 %, 6.2 and 7.6 % respectively), and a large underrepresentation of younger forests (6.5 and 18.1 respectively). One can also see a small overrepresentation of deciduous forests (12.7 and 8.9 respectively) and coniferous swamps (4.1 and 2.7 % respectively) in the protected areas, as well as a large overrepresentation of wetlands (10.4 and 1.6 % respectively) compared to the county. The unproductive impediments are also overrepresented in the protected areas, even though the bars are very small (1.9 and 0.2 % respectively) (Figure 4).
When only comparing unproductive impediments with productive woodland, one can see an overrepresentation of impediments in the protected forests (Figure 5), even though the differences are not that large.

Figure 4. Distribution of nature types of forest areas in protected areas compared to the county of Östergötland. Areas of water, grasslands and areas classified as other are excluded in the analysis.

Figure 5. Comparison between protected forest lands and the county of Östergötland with regard to proportion of unproductive impediments and productive land. Productive forest land includes areas classified as productive forest (both valuable and not valuable), and impediments includes areas classified as unproductive forest, unproductive flat rock, forest boglands, barren land and unproductive three and bush land. Land area considered as other than this are not included in the analysis.
4.1.3. Age distribution

The distribution of ages in forest areas is presented in two different ways (area and volume) (Figure 6 and 8), and compared to the estimated pre-industrial proportions of age distribution of Sweden, using boreal successional forests as an example (MBV, 1997). Looking at the county as a whole, a visualisation with proportions of area gives a more or less steep curve, with a peak of middle aged forests (31-80 years) as the largest category. Presented as proportions of volume (m³sk) the distribution is quite alike, but with an even higher percentage of middle age forests (31-80 years), and a lower percentage of young forests (<3 years and 4-30).

The most notable difference between the county of Östergötland and the estimated pre-industrial proportions of age distribution (Figure 7), is the low level of old forests (>110 years) in the county. The pre-industrial estimation also show a bit more even distribution of the young and middle aged forests (up to 109 years old), compared to the county of Östergötland today. The age categories differ slightly between the county and the estimates pre-industrial proportions, but even if one only compares the forest >120 years in the county, with the estimates amounts of forests >150 years old, the county has a low proportion.

Figure 6. Distribution of age in the county of Östergötland, presented as percent of hectares of forest area and as percent of forest cubic meters (m³sk). Only productive land is included.
Presented in proportions of areas, the distribution in the protected areas seems totally different than in the county as a whole (Figure 6 and 8), getting two different medians in the reserves of both old forest (>120 years old) and some of the youngest forests (5-30 years old). The protected areas has thus a higher level of both younger and older forests. The categories of 5-30 years and >110 years in nature reserves are more common than the categories of 4-30 years, and 81-120 years and >120 years in the county. The category of 30-70 years in nature reserves on the other hand is much lower represented than the 31-80 years of the county. Since some of the data of protected areas are only presented in categories, all data of these areas are presented in the already existing categories. Unfortunately, since all data of the county of Östergötland are presented in categories which differ from the categories of protected areas, only a rough comparison can be made. When data is compared using volume (m$^3$sk), the differences between protected forest and the forests of the whole county is much smaller than in percentage of area. But it seems as if one can detect a skewed distribution towards older forests in protected areas compared with the county as a whole. The categories of 70-110 years and >110 years in nature reserves are considerably larger than the categories of 81-120 years and >120 years in the county.
4.2 Connectivity and tracts of value

The connectivity analysis show varying results for the different forest types. The most well-connected set of value indices is of spruce and mixed forests (which is put in the same analysis). For species with high dispersal ability (mean 5000 m) the distribution of protected areas are quite well connected through the county, with maybe a small exception for the middle and middle-west region (Figure 9). For the species with low dispersal ability (mean 500 m) the distribution is still spread over most of the county (Figure 10).
Figure 9. Distribution of value indices for spruce and mixed forest for species with high dispersal ability (mean 5000 m). Value index varies between 0.5-7, where 0.5 means that the patch is not well connected or of particular good size, whilst 7 means that the patch is very well connected in combination with its size.

Figure 10. Distribution of value indices for spruce and mixed forest for species with low dispersal ability (mean 700 m). The value index is specified in Figure 9.

A comparison with earlier established tracts of value, defined by the County
Administration Board of Östergötland, shows that some hot spots in the county are still left out from the defined tracts (Figure 11). Particularly the eastern region has many clusters of high value index patches. Suggested tracts of value is shown in Figure 12.

Figure 11. Distribution of value indices for spruce and mixed forest (dots) and the defined tracts of value by the County Administration Board of Östergötland (black). Value indices for species with high dispersal ability (mean 5000 m) to the left, and for species with low dispersal ability (mean 700 m) to the right. Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.
Figure 12. Suggested tracts of value for spruce and mixed forests in Östergötland (black). Figure shown with value index dots for species with low dispersal ability (mean 700 m). Red and orange dots are considered as high value patches, whilst yellow and green dots are not as well connected or small patches.

The connectivity of hardwood forest for species with high dispersal ability is more stable over larger areas and generally of middle to high value indices. This is especially pronounced in a continuous region from the south to the east. In the west parts of the county there is a large continuous area with higher connectivity (Figure 13). For the species with low dispersal ability the hot spots are few, even though the distribution follows the same pattern (Figure 14). For a species with low dispersal ability the areas of hardwood forests with high value indices are very fragmented.
When looking at the distribution of value indices of both long and species with low dispersal ability together with earlier identified tracts of value, the most noticeable is
that very few hot spots are included (Figure 15). There is actually a large part between the tracts of value to the east that has patches with the highest index values. The larger tracts include mostly patches with very low value indices. Suggested tracts of value is presented in Figure 16.

Figure 15. Distribution of value indices for hardwood forest (dots) and the defined tracts of value by the County Administration Board of Östergötland (black). Value indices for species with high dispersal ability (mean 5000 m) to the left, and for species with low dispersal ability (mean 700 m) to the right. Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.
Figure 16. Suggested tracts of value for hardwood forests in Östergötland (black). Figure shown with value index dots for species with low dispersal ability (mean 700 m). Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.

The connectivity for deciduous forests is higher than that of hardwood forests, both for species with low and high dispersal ability (Figure 17-18). But for species with low dispersal ability the landscape of high value patches is still quiet fragmented (Figure 18). The highest concentration of high value indices is located in the north and south-west parts of the county, which is most pronounced for species with high dispersal ability. There is also more scattered hot spots in the middle and east parts of the county as well, both for species with high and low dispersal ability.
Figure 17. Distribution of value indices for deciduous forest for species with high dispersal ability (mean 5000 m). The value index is specified in Figure 9.

Figure 18. Distribution of value indices for deciduous forest for species with low dispersal ability (mean 700 m). The value index is specified in Figure 9.

The earlier identified tracts of value also here include mostly low or middle high value indices (Figure 19), whilst the hot spots are located more to the west and north parts of the county. To include these areas, tracts of value for deciduous forests are suggested in Figure 20.
Figure 19. Distribution of value indices for deciduous forest (dots) and the defined tracts of value by the County Administration Board of Östergötland (black). Value indices for species with high dispersal ability (mean 5000 m) to the left, and for species with low dispersal ability (mean 700 m) to the right. Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.

Figure 20. Suggested tracts of value for deciduous forests in Östergötland (black). Figure shown with value index dots for species with low dispersal ability (mean 700 m). Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.
The connectivity for pine forest is very dispersed and bare, for both species with low and high dispersal ability (Figure 21-22). The only hot spot area is located in the north, and is much clustered. Except for this area, the valuable patches are scattered in the county, and with low value indices.

*Figure 21. Distribution of value indices for pine forest for species with high dispersal ability (mean 5000 m). The value index is specified in Figure 9.*
**Figure 22.** Distribution of value indices for pine forest for species with low dispersal ability (mean 700 m). The value index is specified in Figure 9.

The earlier established tracts of value include this hot sport area in the north, and some other very small clusters of middle high value indices in the landscape. The largest tract only includes a few areas of middle high value indices, and then patches with low value index (Figure 23). Some adjustments of tracts of value for pine is presented in Figure 24.

**Figure 23.** Distribution of value indices for pine forest (dots) and the defined tracts of value by the County Administration Board of Östergötland (black). Value indices for species with high dispersal ability (mean 5000 m) to the left, and for species with low dispersal ability (mean 700 m) to the right. Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.
Figure 24. Suggested tracts of value for pine forests in Östergötland (black). Figure shown with value index dots for species with low dispersal ability (mean 700 m). Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.

Swamp forests, including both deciduous and coniferous ones, show a divided clustering of hot spots for species with high dispersal ability, located in the north and the south to south-west of the county. Middle high value index areas are spread through the rest of the county, mostly following the outskirts of the county (Figure 25). Species with low dispersal ability does not have more than one hot sport area, and a couple of small clusters of middle high value index areas. The rest of the county contains scattered low value index areas (Figure 26). For a species with low dispersal ability the available habitats are thus very fragmented.
Figure 25. Distribution of value indices for swamp forests (both deciduous and coniferous) for species with high dispersal ability (mean 5000 m). The value index is specified in Figure 9.

Figure 26. Distribution of value indices for swamp forests (both deciduous and coniferous) for species with low dispersal ability (mean 700 m). The value index is specified in Figure 9.

There is no existing tracts of value for swamp forests identified by the County Administration Board of Östergötland today. Figure 27 shows a suggestion of where these tracts could be placed.
Figure 27. Suggested tracts of value for swamp forests in Östergötland (black). Figure shown with value index dots for species with low dispersal ability (mean 700 m). Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.

To get an overview of which tracts of value for different forest types are located in the same regions, a collected figure (Figure 28) shows all suggested tracts of value. Both parts of the south-west and south-east, as well as the north-east of the county contains tracts of value of several of the forest types.
Figure 28. Collected view of suggested tracts of value (black). From the upper left corner; spruce and mixed forest; hardwood forest; deciduous forest; pine forest; and swamp forest. Red and orange dots is considered as high value patches, whilst yellow and green dots are not as well connected or small patches.

5 Discussion

This study shows that there is an underrepresentation of high productivity forest in the protected forests of Östergötland in both spruce and pine forests (with emphasis on spruce forests). But, more areas of higher productivity level have recently been protected, contributing to an overall increase of the productivity level means, even
though the mean site index for birch is the only one above the level of what is considered as high productivity. There are some misrepresentation of nature types in nature reserves, for example both unproductive impediments and older forests is overrepresented in the protected areas. However, compared with the estimated pre-industrial proportion of old forests (17%), the percentage of protected old forests in the county of Östergötland is too low (about 3%). The overall proportion of forest area under protection is only 2% of the total forest area in the county, making the amounts of protected old forest even lower. In addition, the proportion of middle aged forests (30-110 years) under protection is relatively low, compared to the estimated pre-industrial proportion. A total landscape analysis using connectivity and patch size to find hot spots of high value areas, shows that only spruce and mixed forest seems well connected and has a stable distribution in the whole county for both organisms with high and low dispersal ability.

5.1 Representativeness

5.1.1 Productivity level

The skewed distribution towards lower productive forest in the protected areas is of great concern. The low representativeness today of areas with high productivity (especially of spruce) are probably rather inefficient in this sense, just as it has been shown to be in other countries, even with about a quarter of the forest areas under protection (Trisurat, 2007). The connection between high productive areas and a higher biodiversity amongst trees (Belote & Aplet, 2014, Erskine et al., 2006, Paquette & Messier, 2011, Piotto, 2008, Vilon et al., 2013) and fauna such as birds, amphibians and reptiles (Balódi & Vörös, 2006) makes protection of high productive areas a priority. The County Administration Board of Östergötland (2006) has pointed out areas of spruce with a site index of G26 and higher as to be prioritized, and 82% of the protected areas of spruce are actually at this level or higher. However, the County Administration Board also note that it is a site index of G30 and higher that is considered as high productivity in spruce forests in the southern region of Sweden. A level of productivity that exists in large proportions in the county, as 84% of spruce forests have a site index of G30 or more, whilst only 25% of the protected areas are at this levels. Thus, there is a possibility for protecting higher productivity levels, in terms of available high productive spruce forests. But there could of course be a conflict of interest with the forestry industry, making these forest areas expensive to purchase. The consequence of that will be smaller forest areas for the same amount of money.

For pine forests the priority in the county is site indices of T20 or above. When comparing all areas with a site index of T20 or above, the protected areas have 75% of the surface area at this level, whilst the county has a total of 89%. Thus, the productivity levels below T20 represents a quarter of all protected areas, and more than twice as much in proportion as in the county (11%). This overrepresentation of low productivity levels in the county, makes it essential to try to protect as high levels as possible, in order to have a higher probability of protecting biodiversity. However, though a site index of T28 or more is regarded as high productivity in the southern region of Sweden, this is a productivity level with very low proportions in the county (only 1%). Therefore, it’s even more important to redirect the priority to the productivity levels of T22-T26 (which compared to T20, is underrepresented in protected areas). There is no existing collected information for the whole county.
about the site indices for oak and birch, so a comparison between the county and the protected areas was not possible. However, the County Administration Board of Östergötland has declared prioritized levels, which for oak is E22 and for birch is B22. When only looking at the distribution of site indices in protected areas of these forest types, the proportions of surface area of these site indices or higher is actually quite high (Appendix 4).

It is not too surprising that it seems hard to fulfill the criteria of representativeness and productivity even though there are written strategies for selection of forest for protection (County Administration Board of Östergötland [Länsstyrelsen Östergötland], 2006). Branquart et al. (2008) has shown that only about a quarter of all reserves in Europe are chosen based on the three important criteria; representativeness, spatial design and site quality. In reality, many forest areas are simply selected for protection when that particular area are under threats of logging. This means that in practice the protection of forests my not be as effective as it is intended to be. One can see the same tendencies in other countries outside of Europe as well. A study by Andrew et al. (2011) showed that the distribution of the protected forests of Canada are slightly biased to lower productive areas compared to the distribution of different productivities in the country. Also in this case, the authors find the reason for this skewed distribution to be due to human activities, where we favor high productive forest for our forestry.

Yet another study from inside and outside the Yellowstone national park in USA, has shown that nature reserves often are located at higher elevations, where private land is rarer and the productivity lower due to less rich soils (Hansen & Rotella, 2002). The focus of the study was abundance of birds, which was higher in high productive hot spots on low elevation lands, and lower in the low productive, high elevation lands under protection as nature reserves. The consequence in this case is, according to the authors, the high risk of species loss when intense forestry is conducted in high productive areas. This may isolate birds in low productive, high elevation areas where the breeding is less successful. Because of a shorter breeding season due to climate, less available food etc. The authors also point out that an intense forestry in the, by the birds favorable, productive landscapes may also lower the possibility for them to migrate from the high productive hot spots and breed in the areas chosen for protection. Thus, if we cannot reach the levels of representativeness of productive land in protected areas, the areas under protection may not be successful for preservation of biodiversity. This despite its otherwise desirable qualities such as for example dead wood, old trees and so on. Also in Nepal, the same pattern of protection of high elevation areas has been noticed. A study by Babu Shrestha et al. (2010) showed that more than two thirds of the total protected areas in Nepal was located in the high mountains, although only less than a quarter of the country contains this landscape type. This should result in similar problems in preservation of biodiversity.

But it’s not only an intense forestry that is conducted in the most productive areas. Human settlements is most often established in these types of areas (O’Neill &

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Abson, 2009). This goes for nature types all over the world, from tropical forests and boreal forests to temperate grasslands, deserts and tundra. The pattern of settling in the most productive parts of the landscape, is most pronounced in regions with very low average productivity. Not surprisingly, socioeconomic forces will always influence what humans will do where, including locations of forest protection. Formulating a strategy for forest protection, locally, nationally and internationally is necessary, but setting word in to practice is also necessary to reach the goals set.

The means of site indices for protected areas has improved some over time, but the differences are small, with exception for pine (Figure 3). When looking at the difference since the earliest periods in the forty’s to the seventy’s, the site index mean of pine is the one that has increased the most. But still neither spruce nor pine is close to the levels of high productivity. According to Löf et al. (2009) a sit index of E24 is considered as oak forest with high productivity enough for production. On this basis, the mean site index of oak is not that high either. According to Rytter et al. (2008) the site index of birch should not be any less than B22 in a production forest. This may therefore be considered as high productivity. This makes birch the only category of tree species to have a mean over the high productivity level. The protection efforts in the county should perhaps be targeted towards slightly higher productivity levels than today. It's worth pointing out though, that neither of the oak or birch site indices are specified for the southern region of Sweden. It can therefore be both higher and lower site indices that is corresponding as high productivity in this particular region. One also have to keep in mind that this is site index means, showing first and foremost changes over time, which in this case is showing a positive trend towards higher productivity levels. Even though the mean site index for pine has improved the most, it is still the category furthest away from what is considered high productivity. Efforts should perhaps be focused on protection of high productive pine forest, followed by high productive spruce forest.

5.1.2 Nature types

The protected forests of Östergötland are not totally representative of the county, with both over- and underrepresentations of different nature types that exists in the county today. The small overrepresentation of deciduous forests and coniferous swamps, and the large overrepresentation of wetlands is probably due to nationally and internationally targeted actions to protect these kind of areas (Swedish Environmental Protection Agency [Naturvårdsverket] & the Forestry Commission [Skogsstyrelsen], 2005). There is also a small underrepresentation of coniferous and mixed forests, which may also be linked to the nationally prioritized forest types. Of the coniferous forest types, only limestone coniferous forest are prioritized nationally (Swedish Environmental Protection Agency [Naturvårdsverket] & the Forestry Commission [Skogsstyrelsen], 2005). These prioritizations has several reasons. The landscape has changed due to both agricultural needs and forestry management. Compared with pre-industrial proportions, the amounts of forests (mainly deciduous in the region of which Östergötland is a part of) turned into arable land is estimated to be somewhere around 40-60 % (MVB, 1997). There is therefore in fact a shortage in remaining deciduous forest. Also, only about a fifth of all swamp forest areas that existed a 100 years ago is still remaining (Society for Nature Conservation [Naturskyddsföreningen], 2009). Because of about a 100 years of drainage of forest with a purpose of constructing fields, these small overrepresentations are in line with
the goal to protect the biodiversity of these habitats. Deciduous forest have not been, and are not highly valued in forestry, even though they provide many organisms with important habitats. Well over 1500 red listed species in Sweden uses deciduous forests as a habitat, and for more than a 1000 it is even important for their survival (Sandström et al., 2015). Many species of birds depend on both old or dying deciduous forest, and successional deciduous forest developing after forest fires (Society for Nature Conservation [Naturskyddsföreningen], 2009). The productive forests of Sweden are totally dominated by coniferous forest, by more than 80% (Swedish University of Agriculture [SLU], 2014). The success of the national and international targets are therefore dependent on regions like the county of Östergötland to keep these forest and nature categories. A small overrepresentation in protected areas compared to the county of these forest types is therefore to be considered to be positive.

The large underrepresentation of young forests has to be considered with some caution. The category also includes cutting areas, an environment promoting only a small part of the many threatened species. As mentioned, many species are affected negatively by logging, since they often are dependent on continuity and therefore have a hard time surviving the clear-cut phase (Dynesius, 2015, Khaleghizadeh et al., 2014, Kuuluvainen et al., 2012, Sandström et al., 2015). These environments are thus not in any need of increased protection. But, it is very important to consider what the young forests have that is positive for protecting a high biodiversity. A young forest in a natural state has high levels of decaying wood, gaps with sunlit glades, natural disturbances such as fires and more, which is often not represented in many of the young forests we have today. More on age distribution in chapter 5.1.3.

There is a small overrepresentation of unproductive land in the nature reserves. This is not very surprising considering the practice to protect this areas throughout history, and to use the ones with higher productivity to forestry (Andrew et al., 2011, Babu Shrestha et al., 2010, Nilsson & Götmark, 1992, Scott et al., 2001, Branquart et al., 2008). This also correlates with the results above considering site indices, where the protected areas has lower site indices than the county. However, neither the productivity level nor most of the differences in proportions of nature types between protected area and the county as a whole are very large. Giving space for the prioritized forest types may result in an uneven proportion in the county, but may be positive in a bigger perspective. Comparisons of representativeness should maybe be conducted in a larger scale, like the country of Sweden, or the Scandinavia as a whole, to get a clearer picture of weather the protected areas are representative or not. The biodiversity we try to protect are not limited to county or land boarders. Even so, efforts should be focused on evening out these differences, in order to increases the chances of protecting more ecologically valuable forest areas and thus also maintain or even increase biodiversity.

5.1.3 Age distribution

The most frequent occurring age class in forests in Sweden is 41-60 years old (Swedish University of Agriculture [SLU], 2014). Both age analysis shows a higher proportion of old forests in protected areas compared to the county as a whole. But compared with the estimated pre-industrial levels in boreal successional forest (MBV, 1997), the amounts of old forest under protection is still too low, and the proportions should be more evenly distributed between age classes. Old trees contributes to
microhabitat in different ways, making it possible for many species to persist in an area. Because of this, there has been a focus towards protecting old-grown forests.

However, the potential of younger forest in preserving biodiversity may often be overlooked. The proportions of 19% of middle aged forests (30-70 years) is also to low in the protected areas, compared with pre-industrial proportion of 32%. And since the age class 41-60 years is the most represented in the county, the possibility to protect more of this areas should be good. But after all, it’s not just depending on what age a forest has (even if continuity often is important), it’s the quantity of different habitats and substrates that makes the difference. It has actually been shown to be higher values (in terms of biodiversity indicators) in young forests than old. Lundström et al. (2011) used 17 indicators of higher biodiversity, such as dead wood, large, old or dead trees, gaps, forests affected by water, uneven age and more, to determine were the representation of possible high biodiversity was the highest. In more than half of the 17 indicators the highest representation was in forest younger than 100 years. Even though this was an indirect survey of biodiversity, it still shows the great possibility for the same in younger forests, which often is seen more as the next generation of valuable forest areas. Also, for some red listed species the early successional stages are very important (Tikkanen et al., 2006). Swanson et al. (2010) also point out the important role of a young, successional forest when it comes to biodiversity in many plant species (including many herbs and shrubs) and to theme connected species of fauna. The richness that a young forest provides is partly because of the not yet dominating tree canopies. However, the importance of disturbance in forests are essential to make the different age classes contribute as much as possible in preservation of biodiversity. In a boreal successional forest, fires is considered one of the most important factors affecting the age structures (Lehtonen and Kolström, 2000; Kuuluvainen et al., 1998; Ryan, 2002). Having more nature conservational fires could therefore be an important and rather easy tool to redirect the proportions of age classes in the county. And as a complement to the protection of the already too few old forests that is in focus for protection, perhaps a more clear strategy to also include young, successional forests should be used. Together with appropriate conservation measures (natural development, constructed wetlands, tree fellings to create dead wood), young forests can contribute with important habitats to preserve biodiversity.

If there is in fact, an underrepresentation of middle-aged forests in nature reserves, we may lose a lot of possible biodiversity in this slightly younger forests which then is used for forestry instead. The strategy must be to try and protect a representative proportion of age classes, but on the basis of the estimated pre-industrial proportions. The formulated strategy of protecting forests of Östergötland today (County Administration Board of Östergötland [Länsstyrelsen Östergötland], 2006), uses a point system to grade stands of trees, where stands over 99 years has the lowest value, and stands over 139 years the highest value. This value was added to points given for valuable elements, occurrence of red listed or signal species (species indicating high probability of finding other demanding and sensitive species), and continuity of the forest. Maybe a more adjusted model for the strategy should be used, where middle aged forest either gives higher score, or in some other way is given attention. Otherwise one might devalue a forest of middle age that should be prioritized before another forest area.
Before modifying the strategy of forest protection according to age, one must consider the fact that the categories used in the age analysis were not exactly the same for the county, the protected areas and the estimated pre-industrial proportions. There may therefore be an over- or underestimation of some categories of age when making the comparison. However, the age analysis gives good enough estimations on what age classes is represented in the county, what is protected, and compared to the pre-industrial levels; what we should prioritize.

5.2 Identification of tracts of value
This study identifies new important hot spot areas with high value patches that were not included in many of the earlier identified tracts of value for the county. With the suggested tracts of value, the chance of protecting a higher biodiversity and more threatened species increases.

Hardwood forests and boreal deciduous forests are rather well connected for species with high dispersal ability, but for species with low dispersal ability the high value patch areas may be a bit isolated. For species having pine and swamp forest as their habitat, the regions with high value patch areas are very small and isolated. The pine category does however only include patches that surely includes pine in some way. Areas only labelled with coniferous is only included in the spruce and mixed forest category. There may therefore be an underestimation of small or large proportion, and thus the pine habitats may not be as scattered as the result of this study indicates. Of course, one also have to bear in mind, that not all obstacles are alike. Even if the county mostly consist of small, more scattered patches, the matrix between them may work better or worse for different species to move through. And also, fragments close to each other is not the best choice in all cases. With only a large cluster of patches, the risk of extinction of one or several species due to diseases, weather catastrophes, forest fires or else is higher with all fragments in one place and close to each other (Cabeza, 2001). It may therefore not be the best choice to prioritize patches in a single tract exclusively. Even if large fragments are better than small when looking at species richness, it has also been shown that a higher quality (such as richness of nectar sources for butterflies) in small fragments can improve biodiversity to the same scale as larger fragments (Soga & Koike, 2012). When doing additional studies, this may be included in the value index if possible. Hence, a small area should not be discounted as a contributor to protection of biodiversity. Even so, many species demand a certain amount of habitat area to persist in the region (Hanski & Ovaskainen, 2000), which is why larger areas still should be prioritized. At least when habitat restorations is possible in the area. A study from Canada, also showed that protected, productive areas often are small, compared to the protected, low productive areas (Andrew et al., 2011). This pattern should be counteracted by including both quality, productivity level, connectivity and size when choosing areas for protection. However, all parts of Sweden do not have the possibility of protecting large connected areas, simple because they do not exist in the region. However, the goals of protecting higher productive areas should be run together with a goal of protecting well connected areas.

The distribution of spruce and mixed forest seems well spread and well connected in the whole county, both for species with high and low dispersal ability. Of course one has to keep in mind that this is a mixed habitat, which may not be specific enough for a lot of species. The reason for mixing spruce together with mixed forest (both
coniferous and deciduous) was the already existing tracts of value, which includes spruce and coniferous mixed forests. Many mixed forest patches were labelled with only coniferous, not specifying whether it is spruce, pine or other. The value index map may have looked a lot different excluding the mixed areas, with the risk of a large underestimation.

5.3 Conclusions

The results of this study can be used as important background knowledge when working with forest protection in the county, and also in the country as a whole. One can use the identification of productivity levels, forest nature types and age classes that there is a lack of, and in which parts of the county we have sufficient amount or are lacking certain nature types to focus on areas for protection that gives the best potential for preservation of biodiversity.

The most important factor to work on is the productivity level, with focus on protecting higher productivity areas in order to succeed in preserving the biodiversity of forests as intended. A representative selection of protected forests is important to catch the biodiversity of the county. The protected areas of Östergötland is not totally representative when it comes to protected nature types, age classes and levels of productivity. The somewhat skewed representation of nature types is maybe the most acceptable, taking into account other national and international priorities. The small underrepresentation of coniferous and mixed forests should however be kept in mind when planning for new protected areas, as should the probable underrepresentation of middle age forests. The low levels of old forest still available in the county compared to the estimates pre-industrial proportions should also be highlighted and prioritized, as it already is in the existing strategy.

The work of the County Administration Board of Östergötland regarding protection of forests is a very important contribution to reach the national environmental quality objectives [Miljökvalitetsmålen] of sustainable forests and a rich flora and fauna. None of this objectives are believed to be met in year 2020 (Swedish Environmental Protection Agency [Naturvårdsverket], 2014a, 2014b). This study could contribute to improving the chances of reaching the set goals in the future.

6 Acknowledgement

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7 References


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## 8 Appendix

*Appendix 1: Classification of nature types of the land cover CORINE data.*

<table>
<thead>
<tr>
<th>Class</th>
<th>CORINE data designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous forest</td>
<td>Coniferous forest on lichen field</td>
</tr>
<tr>
<td></td>
<td>Coniferous forest on not lichen field</td>
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<tr>
<td></td>
<td>Coniferous forest on not lichen field, 7-15 m</td>
</tr>
<tr>
<td></td>
<td>Coniferous forest on not lichen field, &gt;15 m</td>
</tr>
<tr>
<td></td>
<td>Coniferous forest on flat rock</td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>Deciduous forest, not on lichen field or flat rock</td>
</tr>
<tr>
<td></td>
<td>Deciduous forest on flat rock</td>
</tr>
<tr>
<td>Coniferous swamp forest</td>
<td>Coniferous forest on morass</td>
</tr>
<tr>
<td>Deciduous swamp forest</td>
<td>Deciduous forest on morass</td>
</tr>
<tr>
<td>Mixed forest</td>
<td>Mixed forest, not on lichen field or flat rock</td>
</tr>
<tr>
<td></td>
<td>Mixed forest on morass</td>
</tr>
<tr>
<td></td>
<td>Mixed forest on flat rock</td>
</tr>
<tr>
<td>Cutting area/Young forest</td>
<td>Cutting area</td>
</tr>
<tr>
<td></td>
<td>Young forest</td>
</tr>
<tr>
<td>Wetland</td>
<td>Wetlands influenced by lake water</td>
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<tr>
<td></td>
<td>Soaked morass</td>
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<tr>
<td></td>
<td>Other morass</td>
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<tr>
<td></td>
<td>Salt marshes</td>
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<tr>
<td>Unproductive land</td>
<td>Area with sparse vegetation</td>
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<tr>
<td></td>
<td>Flat rock areas</td>
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<tr>
<td></td>
<td>Bushland</td>
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<tr>
<td>Grasslands</td>
<td>Pasture land</td>
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<tr>
<td></td>
<td>Natural grassland</td>
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<tr>
<td></td>
<td>Moorland</td>
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<tr>
<td></td>
<td>Moorland (grass)</td>
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<tr>
<td></td>
<td>Herb meadow</td>
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<tr>
<td>Water</td>
<td>Streams</td>
</tr>
<tr>
<td></td>
<td>Lakes and ponds, open areas</td>
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<tr>
<td></td>
<td>Lakes and ponds, overgrown area</td>
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<tr>
<td></td>
<td>Coastal lagoon</td>
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<td></td>
<td>Estuarie</td>
</tr>
<tr>
<td></td>
<td>Coastal seas and oceans, open areas</td>
</tr>
<tr>
<td></td>
<td>Coastal seas and oceans, overgrown areas</td>
</tr>
<tr>
<td>Other</td>
<td>Agricultural land</td>
</tr>
<tr>
<td></td>
<td>Cultivation of fruits and berries</td>
</tr>
<tr>
<td></td>
<td>Shores, dunes and sand plains</td>
</tr>
<tr>
<td></td>
<td>Fire field</td>
</tr>
<tr>
<td></td>
<td>Peatery</td>
</tr>
<tr>
<td></td>
<td>Glaciers and permanent snow covered fields</td>
</tr>
</tbody>
</table>
Appendix 2: Classification of forest types in the connectivity analysis. Data from land cover CORINE data, data from the Forestry Comission [Skogsstyrelsen], habitat mapping data (KNAS) and data collected from forestry companies of Östergötland.

<table>
<thead>
<tr>
<th>Sprunce and mixed forest</th>
<th>Coniferous, mixed coniferous forest, coniferous natural forest, coniferous natural forest – young forest-like, coniferous forest, coniferous forest – partly affected, coniferous swamp, coniferous tree, stands with yew tree, mixed conifer, mixed forest swamp, spruce, spruce forest, spruce swamp, deciduous-coniferous, deciduous mixed coniferous forest, coniferous natural forest rich in deciduous trees, natural forest-like coniferous forest, sandy coniferous forest, lime coniferous forest, mixed forest.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Swedish headlines:</td>
<td>Barr, Barrblandskog, Barrnaturskog, Barrnaturskog ungskogslik, Barrskog, Barrskog delvis påverkad, Barrsump, Bartrad, Bestånd med idegran, Blandbarr, Blandsumpskog, Gran, Graneskog, Gransumpskog, Lövbarr, Lövblandad barrskog, Lövrik barrnaturskog, Naturskogsartad barrskog, Sandbarrskog, Kalkbarrskog, Blandskog.</td>
</tr>
<tr>
<td>Pine forests</td>
<td>Pine, pine forest, pine swamp.</td>
</tr>
<tr>
<td>Original Swedish headlines:</td>
<td>Tall, Tallskog, Tallsumpskog.</td>
</tr>
<tr>
<td>Swamp forests</td>
<td>Swamp forest with alder, coniferous swamp, mixed swamp forest, spruce swamp forest, deciduous swamp forest, fens and calcareous fens, pine swamp forest, hardwood swamp forest, alder fens, herb-rich swamp forest.</td>
</tr>
<tr>
<td>Original Swedish headlines:</td>
<td>Alsumpskog, Barrsump, Blandsumpskog, Gransumpskog, Lövsumpskog, Rikkårr eller kalkkärr, Tallsumpskog, Ädellövsumpskog, Alkärr, Örtrika sumpskogar.</td>
</tr>
<tr>
<td>Boreal deciduous forests</td>
<td>Herb-rich alder grove, swamp forest with alder, aspen forest, mixed forest, mixed swamp forest, coarse deciduous trees, deciduous, deciduous-coniferous, deciduous mixed coniferous forest, burnt deciduous forest, burnt deciduous forest – succession land, deciduous grove, deciduous natural forest, deciduous residue, coniferous natural forest rich in deciduous trees, deciduous-rich (at least 2/20 deciduous trees), deciduous-rich forest edge, deciduous wooded meadow, deciduous wooded meadow – recently</td>
</tr>
</tbody>
</table>
grazed, deciduous wooed meadow residue – overgrowing, deciduous wooed meadow residue with pollarded trees, natural forest-like deciduous forest, secondary deciduous natural forest, deciduous forest – aspen, deciduous forest with hardwood trees, deciduous forest – other, deciduous trees – other, alder fens, hazel grove, hazel groves and hazel-rich forests, herb-rich alder grove.

**Original Swedish headlines:**

**Hardwood forests**
Coarse hardwood trees, moorland hardwood forest, secondary hardwood natural forest, hardwood, hardwood natural forest, hardwood forest, hardwood forest – oak, hardwood forest – other, hardwood swamp forest, hardwood tree.

**Original Swedish headlines:**
Grova ädellövträd, Hedädellövskog, Sekundär ädellövnatskog, Ädellöv, Ädellövnatskog, Ädellövskog, Adellövskog ek, Ädellövskog övrigt, Ädellövsumpskog, Ädellövträd.
Appendix 3: Assigned values based on connectivity index and patch size creating value indices, used to select tracts of value in Östergötland, Sweden.

<table>
<thead>
<tr>
<th>Connectivity index</th>
<th>Value</th>
<th>Area (ha)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;25</td>
<td>0</td>
<td>&gt;1</td>
<td>0.5</td>
</tr>
<tr>
<td>25-150</td>
<td>0.5</td>
<td>1-5</td>
<td>1</td>
</tr>
<tr>
<td>150-500</td>
<td>1</td>
<td>5-10</td>
<td>1.5</td>
</tr>
<tr>
<td>500-1000</td>
<td>1.5</td>
<td>10-25</td>
<td>2</td>
</tr>
<tr>
<td>1000-2500</td>
<td>2</td>
<td>25-50</td>
<td>2.5</td>
</tr>
<tr>
<td>2500-5000</td>
<td>2.5</td>
<td>50-100</td>
<td>3</td>
</tr>
<tr>
<td>&gt;5000</td>
<td>3</td>
<td>100-500</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;500</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix 4: Distributions of pine, spruce, oak and birch in nature reserves of Östergötland, Sweden.

Figure 1. Occurrence of different productivity levels in pine forests. Blue bars are considered low productive levels, grey and green are prioritized for protection by the County Administration Board of Östergötland (2006), and green bars are considered high productive levels.

Figure 2. Occurrence of different productivity levels in spruce forests. Blue bars are considered low productive levels, grey and green are prioritized for protection by the County Administration Board of Östergötland (2006), and green bars are considered high productive levels.
Figure 3. Occurrence of different productivity levels in boreal deciduous forests. Blue bars are considered low productive levels, grey are prioritized for protection by the County Administration Board of Östergötland (2006).

Figure 4. Occurrence of different productivity levels in oak forests. Blue bars are considered low productive levels, grey are prioritized for protection by the County Administration Board of Östergötland (2006).