"HERE, THERE OR EVERYWHERE?" DO SAPROXYLIC BEETLES UTILIZE DEAD WOOD OF ASPEN (*POPULUS TREMULA*) REGARDLESS OF WHERE IT IS SITUATED IN THE FOREST LANDSCAPE?

"HER, DER ELLER OVERALT?" UTNYTTER SAPROXYLE BILLER DØD OSP (*POPULUS TREMULA*) UAVHENGIG AV HVOR DEN BEFINNER SEG I SKOGLANDSKAPET?

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Preface

This thesis is part of a collaboration between the Norwegian Institute for Nature Research (NINA) and NORSKOG under the project *"Hverdagshensyn eller reservater?" Relativ betydning for biologisk mangfold av skogbrukets Levende Skog-hensyn, i forhold til betydningen av vernede skogmråder.* The thesis provides 30 study points and is based on field studies in three different parts of southern Norway during the summer of 2006.

First of all, I would like to thank my supervisors Sigmund Hågvar at the Department of Ecology and Nature Management at the University of Life Science, and Anne Sverdrup-Thygeson at the Norwegian Institute for Nature Research for inspiration and encouragement, and for helping me through the whole process.

As the data material providing the basis for my analyses was collected in 2006, I attended fieldwork during the 2009 summer season to justify the use of previously collected data in my thesis. I had a great time during fieldwork, and would very much like to thank Espen Wandaas and Kjell Erik Hansen for making those rainy and warm days a memorable time.

I would also like to thank Sindre Ligaard for identifying all those beetles, Ørjan Totland for helping me out of the confusing field of statistics and Torfin Andersen for coming up with smart ideas of dealing with excel.

At the end, I would like to thank the Research Council of Norway for funding the research, and NINA for printing of this masters thesis.

Special thanks to Kristian and Ragnhild. I could not have done this without you.

"Du ska itte trø i graset.
Spede spira lyt få stå.
Mållaust liv har og e mening
du lyt sjå og tenkje på"
(Einar Skjæraasen)

Abstract

Forestry is reducing the diversity of forest-dwelling species through fragmentation of habitats and removing of large-sized trees such as aspen (*Populus tremula*). There is a considerable difference in the quantity of dead wood in managed and unmanaged forests of Fennoscandia. For many insects forestry has played a central role in the decline in number of species, mainly by reducing the volume and changing the composition of dead wood. Especially saproxylic (wood-living) beetles, species that are contributing to nutrient recycling and decomposition, have suffered vastly from forest management, and are now constituting one of the largest groups of red-listed species. For many of these species, aspen is the most important wood substrate. Forest certificates have been established as an answer to the reduction of forest species. The Norwegian standard for logging methods preserving species diversity, “Levende Skog”, is criticized for having relatively vague recommendations, and it is therefore crucial to find more precise techniques. This thesis investigates the utilization of dead aspen wood by two groups of saproxylic beetles: aspen associated and non-aspen species, in three different areas and three management categories. Beetle traps were attached to dead aspen logs and placed in biological important areas, reserves and tree retention areas to study whether saproxylic species used dead aspen regardless of habitat. We found that the tree retention areas had a significantly higher number of non-aspen species, and that aspen associated species utilized dead wood in spite of where it was located in the forest landscape. This means that aspen trees are used by a variety of saproxylic beetles, both generalists and specialists, and that the position of trees are less important for the aspen species. This study thereby provides a clear recommendation: forest owners may contribute to beetle diversity by preserving the volume of aspen trees throughout the forest landscape.

Sammendrag

Skogbruket reduserer det biologiske artsmangfoldet i skog ved å fragmentere habitater og fjerne trær med store dimensjoner, som blant annet osp (*Populus tremula*). Det er nå en betydelig forskjell i andelen døde trær i kulturskoger sammenliknet med vernede skogsområder i Fennoscandia. Skogbruket har vært med på å redusere antallet arter for mange insektgrupper ved å fjerne et stort volum av trær, i tillegg til å forandre treslagssammensetningen og begrense andelen døde trær. Dette har vært av spesielt stor betydning for de saproxyle (vedlevende) billene, arter som bidrar til næringssirkulasjon og nedbrytning, og som et resultat utgjør de nå en av de største gruppene av rød-listede arter. Osp er et av de viktigste substratene for mange saproxyle arter. Skogsertifisering har blitt etablert som et tiltak for å redusere tap av arter. Den norske malen ”Levende Skog” som blir benyttet i skogbruket har blitt kritisert for å ha for diffuse anbefalinger, og det er derfor av betydning å finne konkrete retningslinjer for en bærekraftig hogst. I denne studien undersøker vi utnyttelsen av død osp hos ospe-avhengige og ospe-uavhengige billearter i de tre forvaltningskategoriene biologisk viktige område, reservat og kulturskog. Studiet ble gjennomført i Losby, Oslo og Selvik. Vi fant at kulturskogen hadde signifikant høyere mangfold av ospe-uavhengige arter, og at ospeartene utnyttet dødt ospevirke uavhengig av hvilken kategori det befant seg i. Dette betyr at ospetrær blir benyttet av en rekke vedlevende billearter, både generalister og spesialister, og at området ospevirket befinner seg i ikke er av betydning for ospeartene. Dette studiet bidrar dermed til en klar anbefaling: skogeiere kan bidra til et variert artsmangfold av biller ved å ivareta volumet av ospetrær.

Contents

Introduction

Norwegian timber and timber products are competing on the international market with raw material bases like concrete, aluminium and oil-based products, and has earlier been able to compete with and even outcompete such inventions under the argument of being "environmental friendly" and renewable (Sanness 2003). Today the picture is quite more complex as forest products are loosing market shares as a result of decreased timber consumption. It is also no longer satisfactory to claim that the timber products are advantageous for the environment through renewability. Consumers, governments and environmental organisations raise questions about whether the main logging is done in an acceptable way, preventing life threatening damage on nearby environments or if it destroys important habitats and diversity of different species (Auld et al. 2008). Environmental certificates, like "Living Forest standards" have been established in Norwegian forestry's to "promote ecologically sustainable forestry with a good balance between wood production, environment protection and social interests" (Levende Skog 2009). Whether this strategy has been efficient or not, or if this method is the most beneficial regarding preservation of species has not yet been sufficiently documented, especially for the group of insects.

The Norwegian Institute for Nature Research (NINA) is collaborating with NORSKOG (organization for the larger forest owners) on a project investigating the ecologic and economic effect of the Norwegian forestry's environmental strategy. The program's objective is to study whether the "Living Forest standards" are sustainable for biological diversity, or if new assessments are needed (NINA 2009).

Habitat fragmentation

A major issue regarding loss of biodiversity is habitat fragmentation. When areas are fragmented, large continuous habitats are reduced in area and divided into two or more fragments (Harper et al. 2005; Siitonen & Siitonen 2005), and in varying degree, the remaining forest patches are isolated from each other (Weynand 2002). Many species are dependent on the ability to move freely across landscapes in search of feeding resources, and if their habitat is fragmented they may be prevented from migrating when looking for food in their normal home range (Primack 2006). In addition, fragmented habitat may limit species' chances for dispersal and colonization (Bhattacharya et al. 2003; Bauer et al. 2005). When areas are fragmented, long-lived species are disfavoured, and short-lived ones are favoured. Fragmentation can thus result in severe effects on ecosystems and ecosystem services (Mooney et al. 1995; Vogt et al. 1997).

Together with urbanization and agriculture, intensive forestry is in a significant way causing alteration of the spatial and temporal structure of forests and forested landscapes (Helms 1998; Perry 1998). Studies by Didham et al. (1996) and Gibb and Hochuli (2002) have shown that forest fragmentation not only disturbs diversity and abundance, but it can also influence the interactions between insects and other organisms. In Finland, it is estimated that forestry-induced changes alone will lead to the gradual extinction of approximately 1000 species (Hanski 2000). For the group of insects, forestry has played an important role in the reduction in number of species. This is mainly a result of reduction in the volume and changes in the composition of dead wood (Grove 2001; Lämås & Fries 1995; McGee et al. 1999; Fridman & Walheim 2000). There is a large difference in the quantity of dead wood in Fennoscandian managed and unmanaged forests. According to Siitonen (2001), managed forests in Fennoscandia contain about 30% of dead wood compared with unmanaged forests. Studies by Harmon et al. (1986), however, estimated that the volume of coarse wood debris in temperate forests (standing or lying dead wood with a diameter >10 cm) has been reduced by as much as 90-98% as a consequence of forestry.

Why study beetles?

Numerically, insects constitute a large part of biodiversity (May 1988; Wilson 1992) and are important components in ecosystem functioning and for ecological processes (Hyvärinen et al. 2006). Beetles represent a large part of biodiversity in both tropical and boreal ecosystems, and have recently begun to play a central role when estimating global biodiversity patterns (Gaston & Hudson 1994). In forests, saproxylic (dead-wood-depending) beetles have central ecological functions, contributing to nutrient recycling and decomposition (Samuelsson et al. 1994). Many of the saproxylic beetles have suffered vastly from forest management, and this group represents one of the largest groups of red-listed species (Berg et al. 1995; Jonsell et al. 1998; Rassi et al. 2001). In the last version of the Norwegian National Red Lists of rare and threatened species, 20% of the species listed as forest dwelling were saproxylic (Gundersen &

Rolstad 1998), and the proportion is probably rather similar after the 2006 revision. In fact, together with fungi (19%) insects (45%) represent 64% of red-listed species in Norway (Artsdatabanken 2006). This is the situation of saproxylic beetles throughout Europe, and they have status as a highly threatened taxonomic group (Berg et al. 1994; Read 2000; Alexander 2004). About 50% of the German saproxylic beetles are considered to be endangered (Geiser 1998 in Davies et al. 2007), and among the Finnish saproxylic beetles, 196 species are categorised as threatened (Rassi et al. 1992). Among the about 1000 beetle species confined to dead wood in Sweden, about 400 are red-listed (Ehnström and Waldén 1986; Jonsell et al. 1998; Gärdenfors 2000). In Norway there are about 3000 beetle species, and of these, 700 are obligate saproxylic, which means that they are dependent on dead wood or wood-living fungi for breeding. Additional, 200 are so-called facultative saproxylic. These species can breed on alternative substrates as well (Palm 1959; Stokland1994).

Until recently, few studies have been performed on saproxylic invertebrates, other than for pest species of economic importance (Sverdrup-Thygeson & Ims 2002). In Fennoscandia, an increasing amount of few studies on the relationship between saproxylic beetles and forest characteristics (e.g. Økland et al. 1996), and amount of habitat at the patch level in the surrounding landscape (e.g. Økland et al. 1996; Ranius 2000; Sverdrup-Thygeson & Lindenmayer 2002) has been conducted. Only in the last few decades have decline in saproxylic species diversity been acknowledged (Gustafsson et al. 2010). Studying beetles is difficult, due to the fact that many species are small, and because of their high species richness. It is especially difficult with adequate sampling of rare and threatened species since they form only a small fraction of the total sample, but still constituting a considerable part of the whole fauna (Muona 1999; Martikainen & Kouki 2003). In recent years, a few studies have revealed interesting news about the positive effects of “Living Forest standards” in clear cut areas (Sverdrup-Thygeson et al. 2005), and the importance of retention trees on red-listed beetles (Martikainen 2001).

Importance of aspen trees and biodiversity

In Fennoscandia the number of threatened saproxylic species associated with aspen (*Populus tremula*) is high (Ehnström & Waldén 1986; Rassi et al. 1992; Samuelsson & Ingelög 1996; Siitonen 1999). At the same time, aspen is known to have low economic value (Martikainen 2001), and has been regarded as a pest species resulting in extensive killing with herbicides. This has been going on until recently (Sahlin & Schroeder 2010). Aspen trees are known to have a low rate of seed regeneration, and fire suppression and high browsing pressure has resulted in slow renewal in many areas (Sahlin & Schroeder 2010; Kouki et al. 2004).

When talking about biodiversity it is important to make significance to the value of ecological services. Although for example aspen trees are of low value from an anthroposophical view, they truly represent a valuable habitat for many organisms. The core of survival of life lies in the biodiversity of organisms, and each species is dependent on other species services to ensure survival. Such services cannot be provided without the interaction between organisms, populations and communities, and loss of biodiversity reflects the sensitivity of ecological services to both the deletion and depletion of species (Perrings 1995). There are still few documents available on the worldwide patterns of biodiversity, and the studies that have been performed to assess general patters so far have mainly been investigated on large-sized species such as birds, mammals and vascular plants that are easy to collect (di Castri 1996; ICBP 1992; Myers et al. 2000). With a very vague estimate saying there are 5 000 000 species worldwide, the vertebrates and vascular plants would make up only 5% of the total amount of species, and other groups like single-celled organisms, fungi, cryptogams and invertebrates would compose 90-95% of the total. Insects alone represent more than half of the presently known species. Many invertebrate taxa are even still unknown (Franklin 1993).

Certification standards

With the Rio Convention on Biological Diversity from 1992, Agenda 21 of 1992 and the Bern-convention of 1986 (Convention on the Conservation of European wildlife and natural habitats) countries like Norway has obliged to prevent species extinction, and to protect and maintain vital populations of species in their natural habitat (Engan et al. 2008). As a result, during the last decade there has been an explosively growth of forest certification to promote biodiversity conservation of industrial logging (FSC 2002; WWF 2002; CWC 2003). The standard of “Living forest”, the Norwegian template for sustainable forestry, was established in 1998 and was a historic event gathering actors from both the forestry sector, environmental organisations and trade union movement with a joint agreement of sustainable management of forests (NSS 2010). The purpose of forest certification is to advance the forestry in such a way that producers operating with high standards can classify their products in the marketplace, leaving consumers with two choices; either buying products from forests with conventional management, or products from companies who are logging in a way which generates greater environmental benefits, preferably choosing the last option (FSC 2002; WWF 2002). Today almost all Norwegian forestry is certified by the ISO 14001 standard.

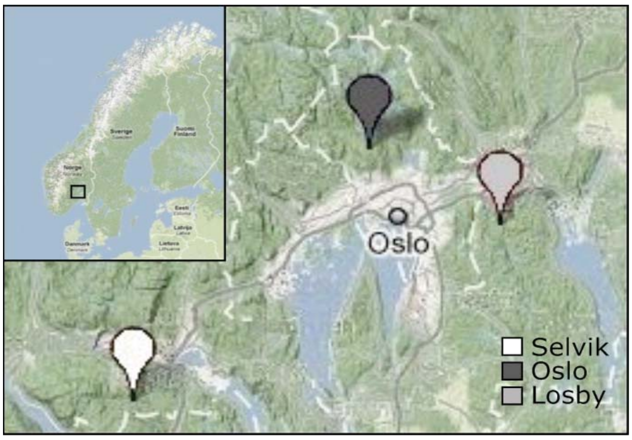
Main objective of the study

Although the "Living forest standard" has existed for twelve years and has been evaluated during these years, we still do not know what would be a sensible combination between management based conservation, more comprehensive conservation and full protection (Vatn et al. 2005). It is for instance important to determine whether saproxylic beetles utilize wood regardless of where the dead material is situated in the forest. Because aspen is an important tree species for saproxylic beetles, we chose to study whether the environment around dead aspens influenced the beetle community colonizing the wood. Forest with three different management regimes were compared; biological important areas, reserves and tree retention areas in three study areas in southern Norway, testing if habitat, study area or both affected the number of saproxylic species.

Material and methods

Study Area

The study was conducted in three different study areas of southern Norway; Losby Bruk in Østmarka (Lat. 59.89 - Long. 10.97), Nordmarka in Oslo (Lat. 60.00 - Long. 10.71) and Selvik Bruk in Drammen (Lat 59.68 – Long. 10.12) (Picture 1) in 2006. The altitudes in Losby varies from 150-300 m above sea level, in Oslo they vary between 200-500 m above sea level, and for Selvik it varies between 130-200 m above sea level (Statens kartverk 2010). Within each area, three different habitats were selected for trapping saproxylic beetles: a biological important area (BIA), a reserve (R) and a tree retention area (TRA) (see map example in Appendix). All areas were carefully selected being certain they had as similar compositions of tree species and weather conditions as possible. The areas lie within the southern boreal vegetation zone (Moen 1998), and consist of mixed forests with elements of both coniferous and deciduous trees in different succession stages. The annual mean precipitation is 760 mm, 839 mm and 975 mm for Losby, Oslo and Selvik respectively (eKlima 2010). The areas are certified by ISO 14001 and “Living Forest Standard”, and have digital forest management plans.



Picture 1. Map of the study areas and location in Norway (left inset). Each of the study areas contains three different management categories.

Fieldwork design

Within each of the three landscape categories, eight study plots were established. In each of these study plots two logs with traps were placed, making a total of 16 logs/traps positioned in each category (Picture 2) and thus 144 logs/traps for the three study areas together. The logs were

Picture 2. Fieldwork design.

intended to imitate natural dead, standing wood, and act as bait for saproxylic beetles The logs were made of aspen trees and were cut into lengths of 1 m having a diameter of average 20 cm. All logs were produced in the same operation to prevent from variation in wood quality. In order to keep the logs in a vertical position, an iron bar of 30 cm was hammered 15 cm into the centre of one end. The remaining 15 cm of the bar was then forced into the ground. Logs that were placed in tree retention areas situated on logged areas were placed in close relation to retention trees to make sure of accurate sun exposure.

In each plot the logs were placed with a distance of approximately 1.5 m in an east- west line at the highest point of every single plot. The intention of using two logs is to be able to investigate and compare the beetle fauna produced in and attracted to the logs by covering one of the trunks with insect net. However this problem is beyond the scope of this study, and hence the collection of beetles from both two logs were pooled and analysed together in this study.

Picture 3. Window trap attached to a log in Selvik.

Each log was secured with steel wire around the trunk to prevent bark from falling off when drying. Then window traps were attached at the top of each log using the installed wires (Picture 3). The top position was chosen to avoid cover vegetation hindering insects to be captured. There are many different methods of capturing insects, but window traps were selected because of their capability of sampling a large amount of insect species (Alinvi et al. 2007; Hyvarinen et al. 2006; Økland 1996). They are also known to collect red-listed species in an effective manner (Kaila 1993; Martikainen & Kouki 2003). Traps were made of two Perspex plates (20 x 40 cm), united in a cross and placed in a funnel leading to a collection bottle (Picture 1). The bottles were filled half full with 20% ethylenglycole in water to prevent the liquid content from evaporating, and a few drops of detergent (Zalo) to make trapped insects able to break the water surface membrane. Beetles swarm from the beginning of May and traps were therefore in function from this month to the end of August. Since different beetle species swarm at various times, the advantage of using a permanent installation like window traps, is the possibility of collecting at the precise time of a swarm without having to be present (Sigmund Hågvar pers. comm.). During summer the traps were checked and emptied once every month (June, July and August).

One pair of logs was destroyed by beaver (*Castor fiber*), and therefore only seven study sites were included in tree retention areas in the Losby study area. Curious cattle (*Bos taurus*) sometimes pushed the logs out of their positions leaving the content of the trap leaking out on the ground. The sample of insects on logs that were pushed by cattle was collected and included in the statistics, since most of the content was intact.

In each study plot, the number of living and dead (both standing and downed) aspen trees within a radius of 30 m from the centre of the plot was recorded. Only trees with a diameter > 15 cm at breast height were counted.

Data and Statistical analysis

The beetles were identified and counted by Sindre Ligaard. His lists were then compared with an extensive list of saproxylic beetles compiled by Jogeir Stokland (Stokland, unpubl.). The book of Ehnström & Axelsson (2002) was also used to double-check information on habitat preferences of beetles. First, "tourist" species of no interest to the present study (i.e. species that are not dependent on deciduous and coniferous trees as habitat) were excluded. The material contained 13 species lacking information about habitat preference, and they were therefore not included in the data material to prevent "noise" in the statistics (Appendix 1). The remaining species were divided into three partly overlapping groups; non-aspen, aspen-associated and red-listed species. Non-aspen species were defined as saproxylic species that do not use aspen trees. Aspen-associated species use aspen trees, but may also use other deciduous or coniferous trees. Since larger sampling sizes will give safer conclusions, the two groups of non-aspen and aspen-associated species were not divided into obligate or facultative wood-living species (obligate = dependent on dead wood to fulfil their lifecycle, facultative = dead wood is one of several possible habitats jf. Stokland).

There were too few species and individuals of red-listed species to be able to run any separate statistical tests, so this group was not divided into different classifications of non-aspen or aspen-associated species, and no further statistical analyses were performed. The data material of aspen-associated species was a bit scarce, and non-aspen species were therefore included in the data material and the statistics, and separate tests were conducted for the two groups. They do tell us something about species richness and species composition in the three areas and categories, and should consequently not be left out of the results.

The computer programs used for statistical analyses were Minitab (Version 15) and Microsoft Excel 2007. All datasets were checked for normal distribution using Anderson-Darling test for normality. As the data for non-aspen species and non-aspen individuals were highly skewed and not normal distributed the data was square root- or log10 transformed prior to statistical analyses. The non-parametric test Kruskal-Wallis was used to analyse distribution of living and dead aspen trees, as normal distribution could not be achieved with any transformation methods. When analysing data, General Linear Models (GLM) and One-way ANOVAs were used to see if the variation in species and individuals could be explained by the three different areas Losby, Oslo and Selvik, and/or by the categories biological important areas, tree retention areas and reserves and the interaction between area and category. Pearson's r correlation was used to determine the relationship between number of species and number of individuals. The minimum level of significance was set at $P \leq 0.05$.

Results

Out of the 71 traps 7097 individuals were captured, and the total number of species was 423. This accounts for 1.8% of the Norwegian insect fauna, and 13% of the entire known Norwegian Coleopteran fauna. Of these, 4969 individuals (70%) belonging to 230 species (54%) were saproxylic (Stokland, unpubl.), including 36 individuals of 13 (6%) red-listed species. A total of 92 species were non-aspen species and 125 were aspen-associated. Only one species was a true aspen specialist (*Trypophloeus bispinulus.*). Two of the red-listed species were registered as vulnerable, and 11 as near threatened (Artsdatabanken 2006). Only three of the red-listed species were also listed as near threatened in the Swedish Red List (ArtDatabanken 2010), and none of the species were red-listed in Finland (Evaluation of Threatened Species in Finland 2000 report) (Table 1). Further, none of the red-listed species are registered in the IUCN Red List of Threatened Species (IUCN 2010). *Enicmus planipennis* Strand dominated the collection of red-listed species with 10 individuals in 7 different sites. The combination of deciduous and coniferous trees dominated as habitat (Stokland, unpubl.). Two species preferred coniferous trees and four species were dependent on deciduous trees (Table 1).

Table 1.
The total number of individuals, description of habitat and distribution (number of appearance on sites) of red-listed saproxylic beetles. *Decid.= mainly deciduous trees, Conif.= mainly coniferous trees. (NT= Near Threatened, VU=Vulnerable).

Species	Family	Habitat	Status Norway	Status Sweden	Status Finland	Individuals	Sites
Atomaria subangulata Sahlberg	Cryptophagidae	Decid.	NT			7	6
Corticaria cateritia Mannerheim	Corticaridae	Conif.	VU			1	1
Cis dentatus Melliè	Ciidae	Decid./conif.	NT	NT		1	1
Cis quadridens Melliè	Ciidae	Decid./conif.	NT	NT		2	2
Dorcatoma robusta Strand	Anobiidae	Decid.	NT			1	1
Enicmus planipennis Strand	Corticaridae	Decid./conif.	NT	NT		10	7
Euglenes pygmaeus Degeer	Aderidae	Decid./conif.	NT			1	1
Hadreule elongatula Gyllenhal	Ciidae	Decid./conif.	NT			5	4
Mycetophagus populi Fabricius	Mycetophagidae	Decid.	VU			4	4
Pissodes harcyniae Herbst	Curculionidae	Conif.	NT			2	1
Plegaderus vulneratus Panzer	Histeridae	Decid./conif.	NT			1	1
Rhizophagus picipes Olivier	Monotomidae	Decid.	NT			1	1
Scydmoraphes minutus Chaudoir	Scydmaenidae	Decid./conif.	NT			1	1
No. of individuals/sites with red-listed beetles						37	31

Population density

Number of individuals per species gives an estimate of the population size, and indicates whether the studied groups of insects have similar species-abundance distribution or not (Martikainen & Kouki 2003). The total number of saproxylic species correlated positively with the number of saproxylic individuals, both for non-aspen species (Pearson's r = 0.839, p = 0.000) (Figure 1a), aspen-associated species (Pearson's r = 0.892, p = 0.000) (Figure 1b) and red-listed species (Pearson's r = 0.943, p = 0.000) (Figure 1c). The majority of the traps (67%) contained zero red-listed species.

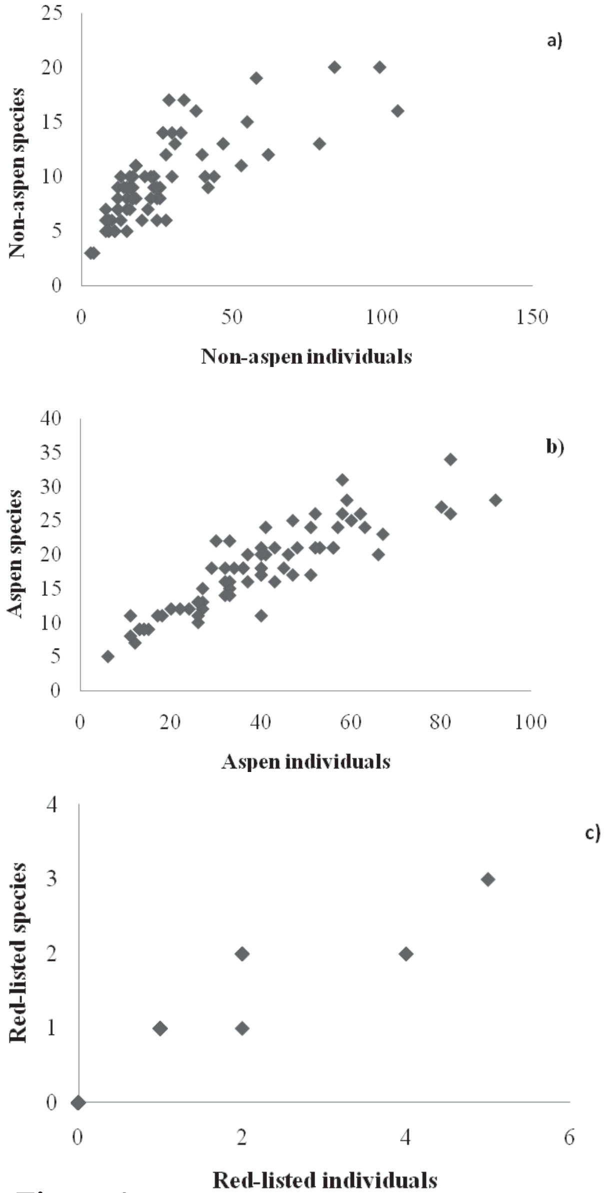


Figure 1.
The relationship between total number of species and total number of individuals captured in traps (n=142) for non-aspen (a) aspen-associated (b), and red-listed species (c).

Variation between areas and categories

Study area and category significantly affected the number of non-aspen species, but the interaction between area and category was not significant. Similarly, area and category was significant for non-aspen individuals, but there was no significant interaction between area and category (Table 2). For aspen-associated species study area was significant and thereby explains the variation in number of species that was found. Category was not significant. The interaction between study area and category was not significant, but displays a tendency towards significance. When it comes to aspen-associated individuals study area was significant, but there was no significant effect of category or any interaction between study area and category (Table 2).

Table 2.
General Linear Models (GLM) testing the effect of Study Area and Category and interactions on abundance of non-aspen and aspen-associated species and individuals

	Non-aspen species (df=70, r^2=42.45)*			**Aspen-associated species (df=70, r^2=38.73)**		
Source	Seq. SS	F	P	Seq. SS	F	P
Area	0.72	16.03	0.000	809.15	13.99	0.000
Category	0.23	5.23	0.008	51.6	0.92	0.405
Area*Category	0.05	0.62	0.651	265.42	2.31	0.068
Error	1.36			1781.59		
Total SS	2.37			2907.77		
	Non-aspen individuals (df=70, r2=48.31)*			**Aspen-associated individuals (df=70, r2=39.67)**		
Area	2.36	19.97	0.000	8907.4	16.56	0.000
Category	0.97	8.14	0.001	996.1	1.84	0.168
Area*Category	0.06	0.24	0.915	1041.9	0.97	0.430
Error	3.62			16646.2		
Total SS	7.01			27591.6		

* Data is log10 transformed for non-aspen species and individuals

For both non-aspen species (One-way ANOVA, F = 14.87, p = 0.000) (Figure 2), non-aspen individuals (One-way ANOVA, F = 17.27, p = 0.000), aspen-associated species (One-way ANOVA, F = 13.11, p = 0.000) (Figure 3) and aspen-associated individuals (One-way ANOVA, F = 16.21, p = 0.000), Selvik had a significant higher number of species than Losby and Oslo. There was no significant difference between Losby and Oslo in number of species (Figure 2 and 3) or number of individuals for non-aspen or aspen-associated species.

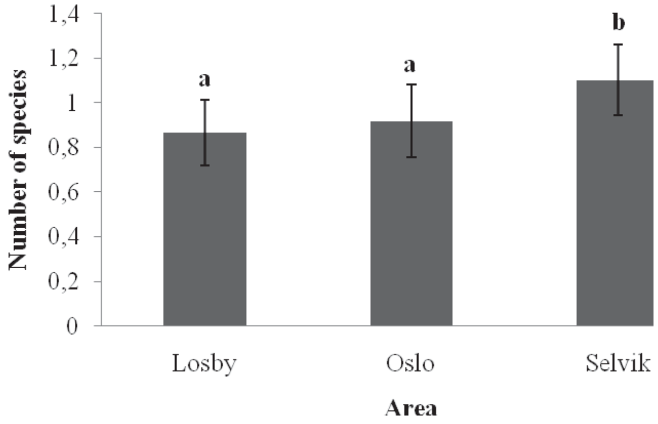


Figure 2.
Mean number of non-aspen species in traps (n=142) in Losby, Oslo and Selvik. Data is log10 transformed.

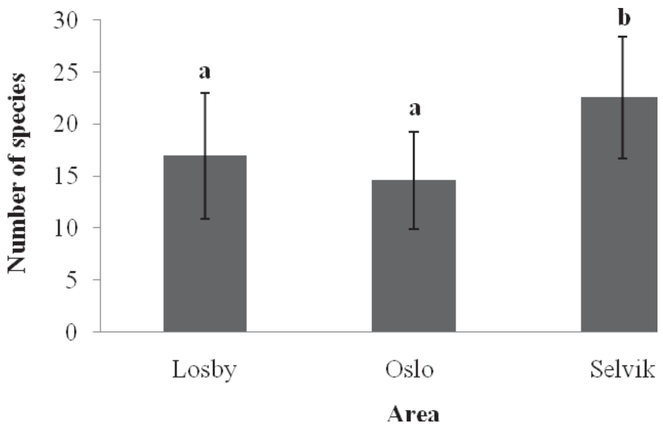


Figure 3.
Mean number of aspen-associated species in traps (n=142) in Losby, Oslo and Selvik.

When looking at the three areas together the tree retention areas had significant higher number of non-aspen species (One-way ANOVA, F = 3.93, p = 0,024) and non-aspen individuals (One-way ANOVA, F = 5.27, p = 0.005) than both biological important areas and reserves, but there was no significant difference between biological important areas and reserves (Figure 4).

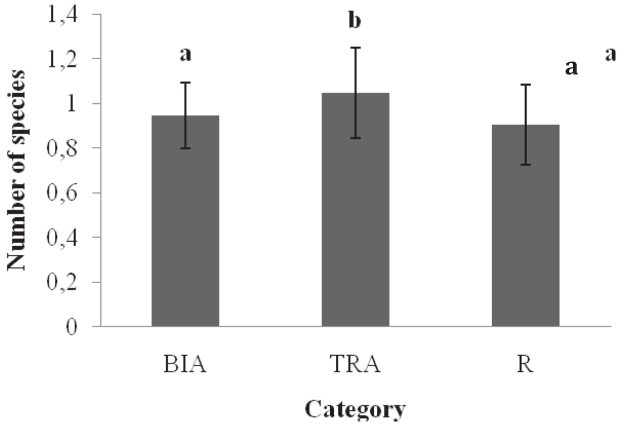


Figure 4.
Mean number of non-aspen species in the three different categories biological important areas (BIA), tree retention areas (TRA) and reserve (R). Data is log10 transformed.

The result that the tree retention areas had a higher number of non-aspen species than the other categories may be explained by looking at the distribution in the three different areas. For Losby there was no significant difference in number of species (One-way ANOVA, F = 2.35, p = 0.121) (Figure 5) or individuals (One-way ANOVA, F = 1.56, p = 0.234) between the categories. In Selvik there was no significant difference in number of species between the categories (One-way ANOVA, F = 1.37, p = 0.276) (Figure 5), however there were more individuals in the tree retention areas than in the reserves, but no difference between reserves and biological important areas (One-way ANOVA, F = 1.37, p = 0.041). In Oslo the tree retention areas had significant higher number of species (One-way ANOVA, F = 4.39, p = 0.026) (Figure 5) and individuals (One-way ANOVA, F = 6.53, p = 0.006) than reserves. There was no significant difference between biological important areas and reserves for either species or individuals in Oslo.

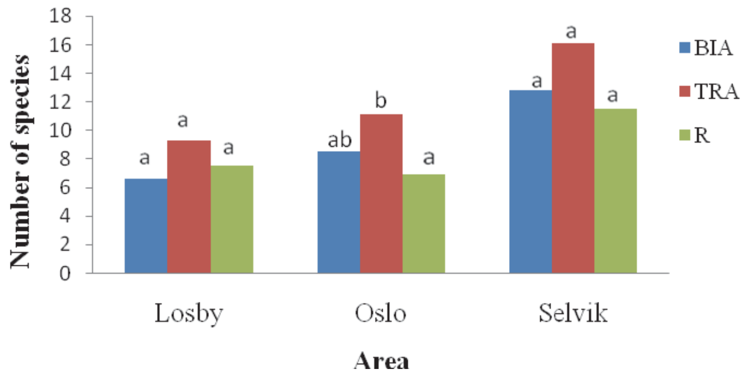


Figure 5.
Mean number of non-aspen species in traps (n=142) in the three different areas and categories. Different letters show which categories that are significantly different.

Category could not explain the difference in number of aspen-associated species and individuals for either Losby (One-way ANOVA for species: $F = 1.78$, $p = 0.195$; individuals: $F = 1.06$, $p = 0.364$), Oslo (One-way ANOVA for species: $F = 0.67$, $p = 0.521$; individuals: $F = 0.01$, $p = 0.988$) or Selvik (One-way ANOVA for species: $F = 2.78$, $p = 0.085$; individuals: $F = 1.88$, $p = 0.178$) (Figure 6).

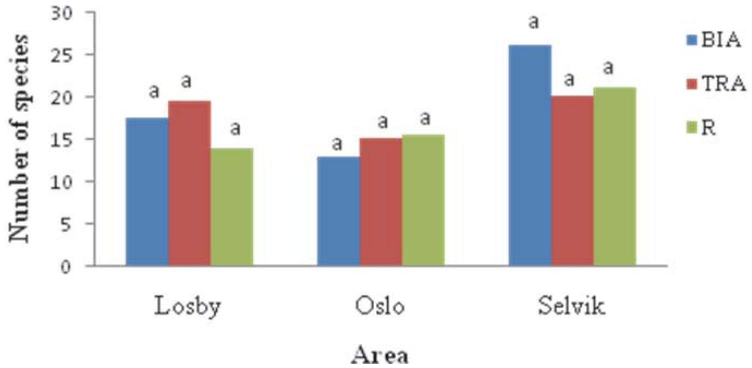


Figure 6.
Mean number of aspen-associated species in traps (n=142) in the three different areas and categories.

The distribution of red-listed species was quite irregular in the three different areas and categories. The only area where red-listed species were found in all categories was Selvik (Figure 6).

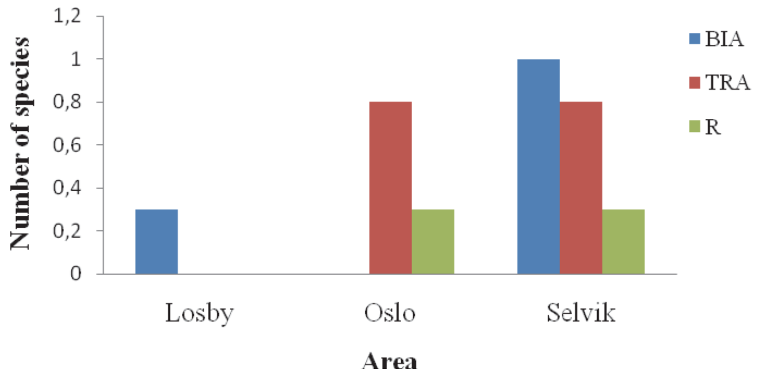


Figure 6.
Number of red-listed species in traps (n=142) in the three different areas and categories.

Access to aspen trees

Looking at distribution of aspen trees in the three different areas, Losby had significantly higher number of living aspen trees than Oslo and Selvik (Kruskal-Wallis, $H = 7.51$, $p = 0.023$) (Table 3). There was no significant difference in distribution of dead aspen trees between the three areas (Kruskal-Wallis, $H = 0.10$, $p = 0.950$). Category did not explain any of the variation in either living aspen trees (Kruskal-Wallis, $H = 0.40$, $p = 0.818$) or dead aspen trees (Kruskal-Wallis, $H = 0.09$, $p = 0.958$) (Table 3).

Table 3.
Distribution of living and dead aspen trees in the three different areas and categories

Area/category	Median and mean (in brackets) number of living aspen trees	Median and mean (in brackets) number of dead aspen trees
Losby	1.0 (1.4)	0.0 (0.13)
Oslo	0.0 (0.5)	0.0 (0.04)
Selvik	0.0 (0.4)	0.0 (0.04)
BIA	0.0 (0.8)	0.0 (0.04)
TRA	0.0 (0.7)	0.0 (0.04)
R	0.0 (0.9)	0.0 (0.13)

Discussion

Effects of study sites and landscape categories

In this study we found evidence that study sites explain some of the variation in the number of species present of both aspen associated and non-aspen associated species and individuals. Selvik had a significantly higher number of both species and individuals of non-aspen and aspen-associated beetles than Oslo and Losby. The annual mean precipitation in Selvik was slightly higher than in the other study sites, but this alone can not explain the variation. An alternative explanation of the higher number of species and individuals can be that Selvik is situated farther south than Oslo and Losby. Many beetle species, especially those that are red-listed, prefer warmer climate and therefore occur more frequently in southern areas (Sverdrup-Thygeson pers. comm.). Since we do not have sufficient background material of climatic factors such as mean number of days with sun, snow depth and mean temperature, it is difficult to say anything precise about the source of the higher number of beetles in Selvik.

Category affected the variation in non-aspen beetles, as the number of species and individuals was higher in tree retention areas than in biological important areas and reserves. However, there was no significant difference between biological important areas and reserves. Tree retention areas are areas that have been disturbed, and the environment of such habitat is very different from the environment in undisturbed, and less disturbed areas such as reserves and biological important areas. Assuming that areas where logging activity is strictly prohibited have high number of species because such areas preserve the species living in them may sound logical, but this may not be the case. The “Intermediate disturbance hypothesis” (Connell 1978) predicts that the highest biological diversity is found in environments with intermediate levels of disturbance. According to this hypothesis intermediate intervals of disturbance alter competitive conditions thereby preventing domination by a few species, eventually leading to variation and high diversity (Ekstam & Forshed 2000). Reserves protect the species living here, but species inhabiting these stabile systems have often evolved and specialized over a long period of time (Ekstam & Forshed 2000). In protected forests, many species are excluded through competition, leading to a reduction of diversity over time (Ekstam & Forshed 2000), and this may be the reason why there was more diversity in the tree retention areas than in the two other categories. Another important factor that can have influenced the number of species in tree retention areas is that such cultivated habitats, like ecotones, represent a transition zone between habitat types where a variety of species from surrounding habitats meet, thus increasing diversity (Murcia 1995; Foggo et al. 2001). Biological important areas resemble reserves in that the environment is stable, however to a lower extent than reserves as gentle logging can be performed. The size of the biological important areas and reserves can also influence the outcome since these habitats have a small proportion of core area compared with the edge area. These factors may explain why the biological important areas and reserves did not differ in number of non-aspen species and individuals.

Category did not affect the variation in aspen-associated species and individuals, a result that indicates that these beetles utilize dead aspen trees regardless of the habitat in which the dead wood is situated. A surprising result perhaps, was that there was a higher number of non-aspen species than aspen-associated species in the traps attached to aspen logs. This may highlight the importance of dead aspen trees not only for aspen specialists, but also for a variety of different beetle species. Alternatively, a high number of non-aspen beetles were vagrant species (i.e. “tourists”) that were brought there randomly by the wind or only passing through, without any further affiliation with the aspen substrate. The lower number of aspen species and the occurrence of only one true aspen specialist may be due to the fact that the aspen logs, in this first year of field study, were recently cut. Aspen-associated beetles prefer older, dead wood that is beginning to decompose, rather than fresh timber (Palm 1951; Speight 1989). According to Sverdrup-Thygeson & Birkemoe (2009) the diversity of aspen associated species in dead wood increases during the first three years after cutting and then declines.

Losby had a significant higher level of living aspen trees than the two other areas, but there was no difference in the access to dead aspen trees. This result, however, did not affect the number of aspen-associated species in Losby, and this might be due to the fact that it is the dead aspen trees that are of interest to most saproxylic beetles, also according to Schroeder et al. (1999).

Red-listed species

Sampling rare species is challenging (Martikainen & Kouki 2003). In fact, it can be twice as difficult to catch threatened forest beetles as other beetle rarities in the forests (Muona 1999). With insufficient data material on red-listed species found in this study it was impossible to analyze the recordings statistically and find trends on e.g. preferred category, as the outcomes could be a result of coincidence rather than a result of real habitat preferences. Preston (1948) & Hughes (1986) found by theoretical models that chance alone dictates the presence of rare and threatened species in small samples. Samples with less than 200 trapped species are found to be almost useless when searching for threatened and near threatened beetle species in boreal forests (Martikainen & Kouki 2003). The same authors recommend a collection of at least 300-400 beetle species, or about 4000 individuals to be able to find threatened species with certainty (Martikainen & Kouki 2003). Muona (1999) is convinced that not even samples of up to 20 000 individuals is satisfactory in surveying threatened species. In small samples most of the threatened species will be missed, and it is likely to believe that such samples mostly consist of common species that can be found in most parts of the forests. Such data is therefore not adequate to use for determination of conservation priorities since it might give random results (Martikainen & Kouki 2003). Martikainen & Kouki (2003) collected six threatened beetle species from a sample of 400 species in their study of sampling rare beetles. In this study we found 423 saproxylic species, and of these 2 were threatened and 11 were near threatened, a quite high number compared with the findings by Martikainen & Kouki (2003). Nevertheless, this number is still not enough to say something precise about their distribution and preference of habitat.

Nevertheless, since there was a significant higher level of non-aspen species in tree retention areas, it is likely that we would find more red-listed species here if the total sample size of saproxylic beetles had been larger. Berg et al. (1994, 1995) have suggested that there is substantial variation in the tolerance to different kinds of cutting and light exposure of threatened species, and Jonsell et al. (1998) found that out of the red-listed saproxylic beetles in Sweden, only 9% prefer shaded conditions. In fact, many red-listed saproxylic species prefer sun-exposed dead wood (Martikainen 2001; Sverdrup-Thygeson & Ims 2002), a susbtrate that occur frequently in old, late-successional forests as a result of burning, storms or insect attacks. Although the present forestry regime likely improves light conditions through removing tree biomass, at the same time potential host trees for threatened beetles are eliminated. To improve the situation, Martikainen (2001) suggests that retention of living and dead aspens in clear cuttings can be suitable for providing a key structure for saproxylic beetles in managed stands. Indeed, several studies show that red-listed wood-living beetles are able to find and utilize the available dead wood in managed forest (Martikainen 2001; Svedrup-Thygeson & Ims 2002; Lindhe & Lindelow 2004).

Sources of error

There are some factors that may have influenced the variation in number of species and individuals. Some variation can be due to local conditions where the samples were collected. Further, the trunks that were pushed by cattle might have lost some of their trap content, perhaps resulting in that some beetles were lost. There are also certain challenges connected to using window traps. Firstly, these traps are measuring flight activity, and as the activity of beetles increases with warm temperatures and solar radiation, the number of species caught may be higher in plots with high sun exposure. This source of error was attempted eliminated by placing logs in areas with similar sunlight conditions. Analyzes of the base sum showed that there was no significant difference in sun exposure between traps in the three management categories all together, thus this method has proven to be successful. Secondly, window traps may sample insects inaccurately, collecting both species that are actively utilizing the material (insects hatching in the substrate) and vagrant species with no particular preference for the substrate.

Advices to forestry

Even though there are uncertainties in the research method, the main findings in this study seem to be relatively clear. Dead aspen trees are an important habitat for a variety of beetles, and for aspen-associated species they are used independent of where they are situated in the forest. This means that all the aspen trees in a forest landscape are valuable. It is likely that the quantity of dead aspen trees will be critical to the number of aspen-associated species and their population size. The total number of protected forests and key habitats in Norway is very low (1.8% reserves; Framstad et al. 2010), and constitute a little share of the total forest area. This means that the amount of dead aspen wood in managed forests will be crucial for the survival of aspen-dependent beetles. Forestry can contribute in the preservation of biodiversity of beetles related to aspen trees by increasing the proportion of dead aspen throughout the forest landscape. This will also benefit woodpeckers and birds and animals that use abandoned woodpecker holes as nesting sites, such as ducks, owls and martens. Our results have shown that all aspen trees are important. Consequently, an advise for the forest owners should be to save living aspen trees from logging, making them able to die naturally. Finding exact measures on how many aspen trees pr daa that should be left when logging would perhaps be helpful, and this could be an interesting research question for further studies.

Forest certification: Good enough for preserving biodiversity?

Giving general advises based on short-term studies of single group of organisms is challenging. There was no significant difference in the number of living and dead aspen trees between biological important areas, reserves and tree retention areas in this study. Thus, it is by any means difficult to say whether a sufficient number of aspen trees have been left in the forest landscape after logging to sustain the communities of saproxylic species. However, it seems that tree retention areas logged under the ISO 14001 certification are of importance to the preservation of non-aspen species.

Forest certificates are becoming more and more important as a tool for preserving biological diversity, but the market for forest products being certified exists mostly in countries of North America and Western Europe (Gullison 2003). Compared to other countries, the implementation of forest certification standards has come a long way in Norway (Bass et al. 2001; Rametsteiner 2001 in Gullison 2003). In Japan, being one of the largest importers of tropical wood, certified products account for 0.2% of the total volume, and in Brazil, where the market has shown poor interest in knowing the origin of timber, the use of Amazonian timber represents about 86% of total wood use (Smeraldi & Verrisimo 1999). The study of Gullison (2003) is questioning whether forest certification actually benefits species diversity or not. He is worried that the certification process simply recognizes companies already having good practices favouring the environment, and that it does not require poorly managed companies to improve their standards to be able to achieve a certification license. Fortunately, in most cases this is not the situation for Norwegian forestry, but the Living Forest Standard still has a potential of improvement (Hobbelstad et al. 2004). Studies such as this can hopefully contribute to clearer advisements.

Conclusion

Aspen is vital for a variety of species, and this study showed that aspen associated beetles are able to find dead aspen wood in spite of where it is situated in the forest. These findings stress the importance of preserving the volume of aspen throughout the forest landscape. Forest managers may contribute to sustain attractive habitats for saproxylic beetles by leaving living and dead aspen trees evenly throughout the forest landscape when logging. It is important to bear in mind that this study was conducted for one single group of taxa. To be able to give any certain advice on the preservation of species diversity, several studies should be conducted for different species groups and compared before it is possible to say anything in general about the effect of logging on the forest biodiversity as a whole.

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Appendix

Example of study design; map from Losby showing the distribution and location of study plots in the field. LB = Biological Important Area in Losby, LK = Tree Retention Area in Losby, and LN = Reserve in Losby.