Saproxylic beetles in artificially created high stumps of spruce and birch three years after cutting

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Abstract

According to the FSC and PEFC certification standards in Sweden, high stumps should be created during thinning and regeneration felling to reduce the negative effect of intensive forest management on biodiversity, especially for the ca. 1000 species of wood dependent (saproxylic) beetles.

To study the importance of high stumps for saproxylic beetles the fauna of 120 three-year old mechanically created high stumps of Norway spruce and Silver birch were sampled in the provinces of Halland, Kronoberg and Kalmar in Southern Sweden. Using bark peeling and sieving, 4179 individuals of saproxylic beetles were found, belonging to 66 species. Nine of the species were on the Swedish red-list. Of all caught beetle species the most common were *Crypturgus pusillus*, *Phloeocharis subtilissima* and *Crypturgus hispidulus*. The number of species was significantly different between spruce and birch high stumps, on average spruce stumps hosted 4.6 saproxylic species and birch stumps 5.5. Also the beetle assemblage on spruce and birch were different, implying that high stumps of both deciduous and coniferous species should be left, if possible. Other ecological variables like presumed diversity ‘rich-poor’ landscapes, geographical location and stump diameter (within the range of 20-58 cm and 21-40 cm for spruce and birch stumps, respectively) did not affect the species richness on stumps.

Nevertheless, the 66 found species show the biological value of making high stumps. Furthermore, the occurrence of nine red-listed species indicates that high stumps are not only important for trivial species but contribute also to protection of threatened beetles. I conclude that mechanically created high stumps are important and valuable habitat supplement for saproxylic fauna.

Keywords: Biodiversity; Saproxylic beetles; High stumps; Sieving; *Picea abies*; *Betula pendula*

1 Introduction

Finding the balance between forest production and forest protection has been and is one of the main goals of contemporary silviculture. In several studies it is stressed that in Fennoscandia intensive forest management, suppression of forest fires and prevention of other disturbances have caused a situation where dead wood has become much more scarce compared to the primeval situation (e.g., Siitonen et al., 2001; Lindhe et al., 2004; Schroeder et al., 1999; Similä et al., 2003; Martikainen et al., 2000; Kolström and Lumatjärvi, 1999). Due to those threats to biodiversity certain measures have been taken in Scandinavian forestry to decrease the negative impact on various organisms (Jonsell and Weslien, 2003). According to the Swedish Forestry Act (Skogsstyrelsen, 1999) and the FSC and PEFC certification standards in Sweden retention and intentional creation of dead wood is recommended (FSC-council, 2000; PEFC, 2000). Standing dead wood, such as high stumps, of common deciduous and coniferous trees should be created during thinning and regeneration felling. The importance of those high stumps to saproxylic beetle diversity is studied in this work.

Data of habitat preference and population biology for many saproxylic beetles is restricted (Lindhe, 2004). At present only few of such studies (Hansson, 1998; Nitteus, 1998; Jonsell et al., 2003), which investigated the fauna of artificially created high stumps, have been done following felling operations (Jonsell et al., 2003).

Where different species exist and where they do not exist as well as the specific requirements of individual species are necessary and important information in order to practice successful conservation (Kaila et al., 1997). In many studies it is stated that various environmental factors, dead wood variables and stand characteristics appears to affect the occurrence of both common and rare saproxylic insect species and also the need for widely different habitats is emphasized (e.g., Kaila et al., 1997; Schroeder et al., 1999; Jonsell and Weslien, 2003; Schiegg, 2001; Similä et al., 2003). Some studies like Similä et al. (2003) showed that stump coarseness and continuity of dead wood is highly important for beetle diversity. However, other studies, like Jonsell et al. (2004), find that variables like decay stage, sun exposure and diameter might also not influence the beetle diversity very much.

All the stumps in the present study were sampled by bark sieving. The advantages and disadvantages of different beetle sampling methods are discussed in many studies (Sverdrup-Thygeson and Ims, 2002; Jonsell and Weslien, 2002; Siitonen, 1994). Compared with window traps, bark sieving gives more direct measure of the species that really dwell, and probably reproduce, within the wood (Jonsell and Weslien, 2003).

There is an ongoing discussion (see Nilsson et al., 2001; Jonsell et al., 1998, 2002; Kaila et al., 1997) whether leaving dead wood for preserving saproxylic insects should be allocated in high diversity areas or throughout the landscape. Many threatened saproxylic species are exclusively found in a limited number of high diversity hotspots in the landscape (Nilsson et al., 2001). But also many species are found on managed stands and leaving dead wood on clear cuts is a way to increase the amount of habitat for many species including red listed species preferring or indifferent to sun-exposure (Jonsell et al., 1998, 2002; Kaila et al., 1997)..

The present study is a comparison between five landscapes concerning man-made high stumps on clear cuts and saproxylic beetles. I investigated the saproxylic beetle fauna in man-made high stumps of Norway spruce (*Picea abies* (L.) Karst) and Silver birch (*Betula pendula* Roth) three years after cutting. Both these tree species support a large number of saproxylic species (Kaila et al., 1994, 1997; Schroeder et al., 1999; Jonsell et al., 1998, 2003, 2004; Lindhe and Lindelöw, manuscript.). But it is important to know, when creating high stumps, which tree species to prefer in order to benefit more saproxylic species.

The main questions raised in this study are:

- Are artificially created high stumps important for the diversity of saproxylic beetles? Which saproxylic beetle species use the high stumps?
- Is there a difference regarding the saproxylic beetle fauna between birch (*Betula pendula*) and spruce (*Picea abies*) high stumps?
- Is the diversity and composition of saproxylic beetle fauna in high stumps influenced by diameter of the stump, site geographical location and/or surrounding landscape?

2 Materials and methods

2.1 Study sites (areas)

Attacks of bark- and wood- boring beetles were studied on mechanically created (forest machinery) high stumps of Norway spruce and Silver birch in the provinces of Halland, Kronoberg and Kalmar in Sweden (Figure 1). Five sample areas were chosen from each mentioned province (Table 1). According to their geographical location the study areas were divided into: ‘west’ (W), ‘mid-west’ (Mid-W), ‘mid’ (Mid), ‘mid-east’ (Mid-E) and ‘east’ (E). In each area there were four sub-areas: two “rich” and two “poor” areas, divided according to biological/ecological values. Rich sub areas are considered to be more biological diverse than compared to the poor sites that are located in the normal landscape of production forest. There are no quantitative data supporting this division, with exception of the west areas (see below), but the selection of rich sub areas are based upon known hotspot locations for saproxylic beetles (Nilsson, 2001), and in general these areas have a larger occurrence of old broadleaved trees than in the normal production forest.

Abrahamsson (2002) studied the west areas Tönnersjöheden and Biskopstorp. He found that although Tönnersjöheden is not documented as a poor landscape it can be regarded as poor due to the low amount of dead wood, the domination of spruce monocultures (78.3% of area), the lack of forest continuity and low proportion of broadleaf forest (1.5% of the area). Biskopstorp on the contrary is a new nature reserve, with many former key-habitats. Beech and oak forests are common in the reserve (23.8% of area). According to Abrahamsson’s personal observations the amount of large trees and dead wood are considerable in the broadleaf dominated stands but not that frequent in the spruce stands.

Table 1
The study area differentiation.

Geographical location	**Area**	**Sub-area**	
		Rich	Poor
‘west’ (W)-	Biskopstorp/	**B-** Silverberget	**D-** Trakt 67
	Tönnersjöheden	**A-** Styrestad	**E-** Illrahultsvägen
‘mid-west’ (Mid-W) -	Toftaholm	**G-** Rödjan	**K-** Schedingsnäs
		H- Kors	**J-** Gylteboda
‘mid’ (Mid) -	Möckeln	**Alfa-** Stenbrohult	**Delta-** Skateboda
		Z- Läng	**Gamma-** Holmsjön
‘mid-east’ (Mid-E) -	Åsnen	**S-** Munkanäs	**X-** Bastaremåla
		T- Slagestorp	**V-** Vieboda
‘east’ (E) -	Hornsö	**M-** Böta kvarn	**P-** Venningehult
		N- Hornsö	**Q-** Skogsholm

All the stumps were created in the winter 2001/2002, with exception of sub-areas A and D that were stumps created one year earlier. The stand characteristics are not available at present. All together 120 stumps were sampled. Half of those high stumps were spruces and the other half were birches. The diameter range in spruce stumps was 20-58 cm and range in birch stumps was 21-40 cm (Figure 3).

Detailed information concerning stump numbers, diameters, tree species, for each locality and number of sampled species and their abundance in clear-cuttings are given in *appendix B.*

2.2 Sampling of the beetles

The fieldworks were carried out in September and October of 2004. For each stump, tree species (spruce/birch) and diameter was recorded. I sampled beetles using the bark peeling method: a 50*50cm area (0.25 m^2) of bark was stripped from each stump with an axe and then sieved in a bark sieving tool (Figure 2). The samples included bark and most of the loose material under the bark square, material which was possible to reach and scrape with axe. The great majority of the samples were taken at breast height, if the bark at that area was fallen the sample was taken as close as possible. The sieved bark samples were preserved in textile bags and transported to the laboratory within max. 36 hours. The sample was placed for at least 24 hours on a wire mesh over funnels under the heat from a lamp. The beetles and other living organisms fell down to ethanol dilution (50%) after which they were picked out from the sample.

Sverdrup-Thygeson (2002) states that beetle sampling with window traps reflects activity and does not provide a random sample of the total pool of beetles. Jonsell and Weslien (2003) state also that window traps measure the activity of insects around the trunk and only to some degree reflects the fauna that reproduce in the wood, but to a large extent encompasses many species that are transient visitors. In the present study for sampling bark sieving was used. According to Siitonen (1994) bark peeling destroys much of the habitat and the species inside the wood are under-represented.

Figure 1
The study areas (Southern Sweden).

Furthermore peeling yields mostly sub-corticulous species. Contrary to Siitonen (1994) Jonsell and Weslien (2003) state that bark sieving gives more direct measure of the species that really dwell, and probably reproduce, within the wood. To a large extent the two methods complement each other.

2.3 Beetle identification

The beetles were sent to entomologist Rickard Andersson, who identified them to species level. He only identified saproxylic (wood living, dependent) species. (Nomenclature following Lundberg and Gustafsson, 1995) Red-list categories follows Swedish Red list (Gärdenfors, 2000).

Figure 2
Peeling the high stump and sieving the material. (Photo: Matts Lindbladh)

2.4 Data analysis

General Linear Model (GLM) was used to perform univariate analysis of variance with balanced and unbalanced designs, for each response variable. Correlation between number of beetle species and tree species, stump diameter, rich and poor sites and geographical (east-west) location was tested both, for non pooled stumps data and pooled sites data. The statistical software used for analysis was MINITAB Release 14.

Also non-metric multidimensional (NMS) scaling was performed (Clark 1993). This is an ordination method that is well suited to data that are nonnormal or are on arbitrary, discontinuous, or otherwise questionable scales. The software used for scaling was PCord.4.

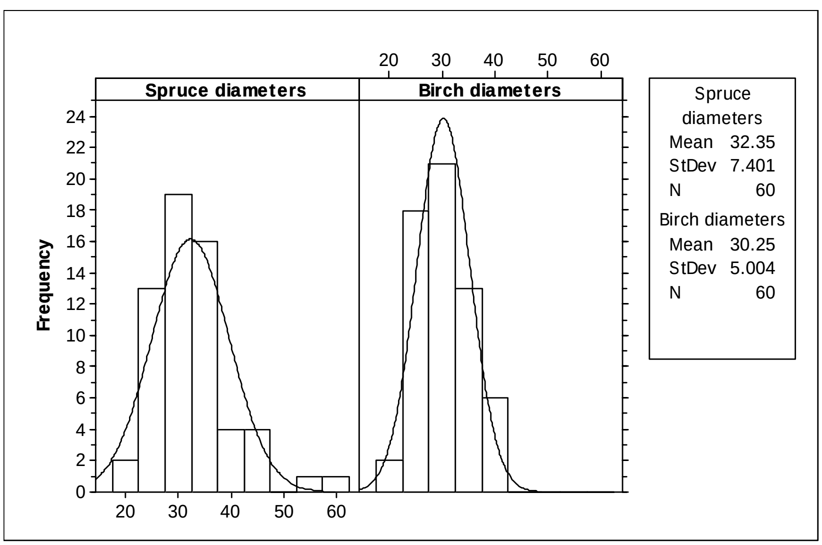

Figure 3
Histogram of Spruce and birch diameters.

3 Results

3.1 General results

3.1.1 Number of species and individuals

In total, 4179 individuals of saproxylic beetles were found, belonging to 66 species. Nine of these species (13.6%) are on the Swedish red-list (Gärdenfors, 2000).

22 species were found on one stump only and six of those were red-listed. 47 saproxylic species were found on spruce stumps and 49 on birch. Spruce high stumps hosted 17 and birch high stumps 19 unique species and 30 of the species were common to both tree species. The stumps 'Alfa 2' and 'V 3' had no wood living species. For a complete species list consult Appendix A.

Using non pooled stumps data (each stump treated separately) it was shown that the number of saproxylic species was significantly different ($p<0.05$) between spruce and birch high stumps, on average spruce stumps hosted 4.6 and birch stumps 5.5 saproxylic species per stump. Using pooled sites data (saproxylic species in three spruce stumps on one site treated together, same with birch stumps), the number of occurred species was also statistically different ($p<0.05$) between tree species. On average the three spruce stumps on a clear-cut hosted 9.6 saproxylic species and the three birch stumps 11.9 species.

Table 2
Species which occurred more than on 10 high stumps. Number of high stumps on which species occurred on, overall abundance is given within parentheses.

species	number of stumps species occurred on/ birch	number of stumps species occurred on/ spruce	number of stumps species occurred on
Anomognathus cuspidatus	38 (202)	17 (43)	55 (245)
Bibloporus bicolor	4 (10)	8 (19)	12 (29)
Bitoma crenata	9 (17)	6 (11)	15 (28)
Cis punctulatus	3 (5)	10 (26)	13 (31)
Crypturgus hispidulus	4 (5)	23 (406)	27 (411)
Crypturgus pusillus	14 (29)	37 (1989)	51 (2018)
Dacne bipustulata	14 (35)	2 (2)	16 (37)
Endomychus coccineus	12 (33)	2 (2)	14 (35)
Euplectus punctatus	8 (15)	13 (47)	21 (62)
Hadreule elongatula	10 (32)	24 (204)	34 (236)
Leptusa fumida	20 (46)	13 (29)	33 (75)
Nudobius lentus	12 (19)	11 (19)	23 (38)
Pachygluta ruficollis	12 (16)	5 (5)	17 (21)
Phloeocharis subtilissima	29 (164)	35 (261)	64 (425)
Phloeopora angustiformis	9 (22)	1 (2)	10 (24)
Rhizophagus bipustulatus	26 (72)	1 (2)	27 (74)
Rhizophagus dispar	19 (99)	9 (15)	28 (114)
Salpingus ruficollis	20 (37)	4 (5)	24 (42)
Litargus connexus	14 (34)	–	14 (34)
sum of individuals	(892)	(3087)	(3979)

The 19 species which occurred more than on ten high stumps counted up 3979 individuals (892 in birch and 3086 in spruce) which makes 95% of all records (Table 2). Of those species only one (*Litargus connexus*) was found on birch stumps only. *Anomognathus cuspidatus* was inhabiting 38 different birch stumps and *Crypturgus pusillus* 37 different spruce stumps, both being species which occurred on highest number of different stumps.

The most common species, *Crypturgus*

pusillus (2018 indiv.) was found on 51 (42.5%) of the 120 high stumps, mainly (1989 indiv.) on spruce high stumps (Table 2). The second most common species *Phloeocharis subtilissima* (425 indiv.), was found on 64 (53.3%) high stumps and 61% occurred on spruce high stumps. *Crypturgus hispidulus* was the third common species (411 indiv.), it was found on 27 high stumps and with only five individuals on birch.

3.1.2 NMS ordination

Axis 1 plotted with axis 2 and axis 1 plotted with axis 3 did not show any obvious patterns. It should be noted that in NMS all the axis are ranked equal in how much they explain. When plotting axis 2 and 3 spruce and birch were clearly separated (Figure 4). The birch plots (clear-cuts) are located above zero value on axis 3. With exception of one East plot, the spruce plots are below zero value of axis 3. Many of same geographical location plots are located close. For example three of East spruce plots are close, three Mid-west plots are close and same tendency occurs with many other sites. Grouping of rich and poor areas could not be seen.

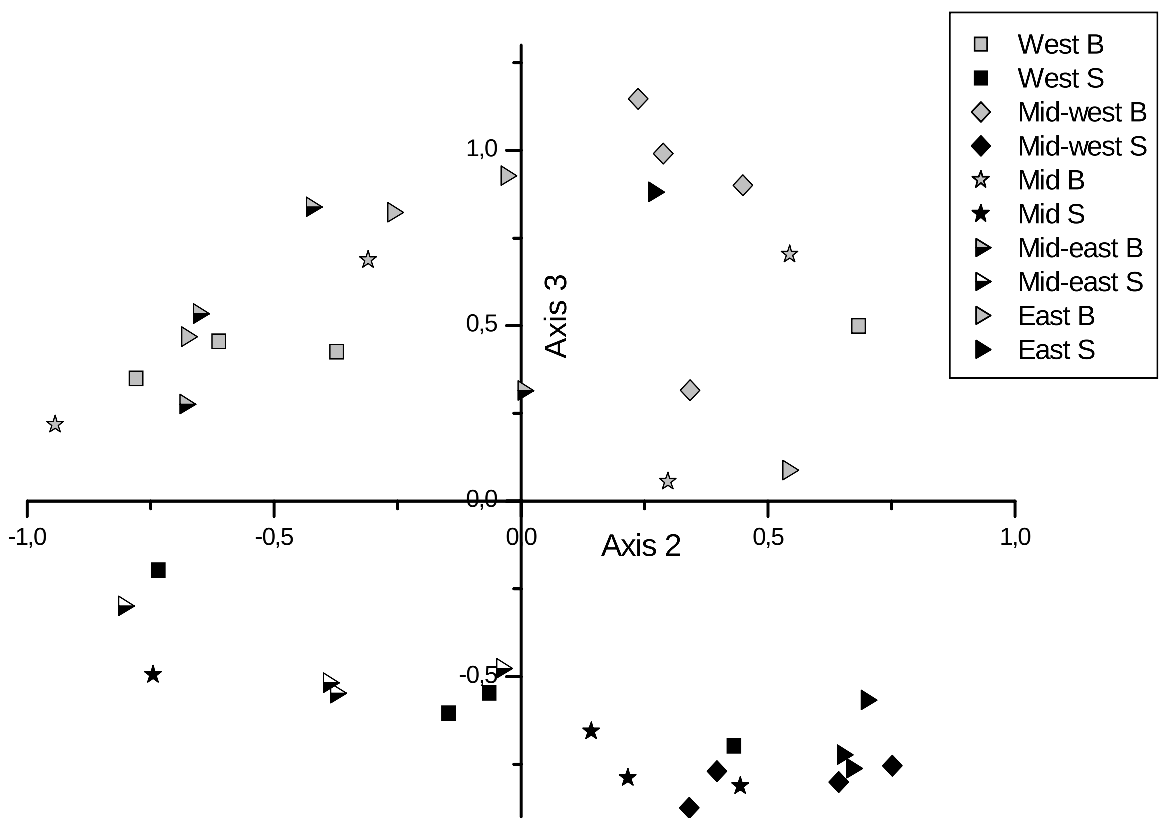

Figure 4
Non-metric Multidimensional Scaling, axis 2 and 3. B- birch plots (gray), S- spruce plots (black). See table 1 for site location.

3.1.3 The sites

The number of species on spruce and birch in different sites was not statistically different. The spruce high stumps in rich sites hosted more species than on poor sites, 36 and 35 respectively (Table 3). In case of birch, the opposite occurred, the poor areas had more species compared with rich areas, 40 and 37 respectively. When looking at saproxylic species on both tree species, there was also more species in poor areas than on rich, 53 and 48 respectively.

In rich areas the highest number of species was in 'west' clear-cut 'A' with 17 species on spruce and 20 in birch (Table 3). In poor spruce areas the highest number of species (14) was in 'west' clear-cut 'D'. In poor birch areas, sites 'J', 'Q' and 'X' all had all 15 different species. Lowest number of species (2) was on poor clear-cut 'V' spruce high stumps. Lowest number of species (6) in rich areas was in site 'T' spruce high stumps.

When looking at the number of species in bigger scale (landscape), summarizing species on neighboring areas, the species richness on spruce and birch was not statistically different. Sites A+B birch stumps hosted most species (24) (Table 3). The lowest number of species (8) was in area V+X spruce stumps.

Table 3
Number of species in different sample areas, number of individuals is given within parentheses. Summarized species on neighboring areas are highlighted in gray.

	rich areas			poor areas	
site	***spruce***	***birch***	**site**	***spruce***	***birch***
B	10 (50)	11 (34)	D	14 (150)	11 (43)
A	17 (485)	20 (47)	E	11 (138)	10 (146)
A+B	19 (535)	24 (81)	D+E	18 (288)	16 (189)
M	10 (235)	8 (33)	P	12 (287)	13 (24)
N	10 (65)	11 (34)	Q	9 (513)	15 (57)
M+N	16 (271)	12 (67)	P+Q	16 (800)	20 (81)
Alfa	7 (19)	11 (38)	Gamma	8 (170)	7 (27)
Z	8 (55)	15 (52)	Delta	8 (45)	7 (48)
Alfa+Z	11 (74)	17 (90)	Gamma+Delta	12 (215)	10 (75)
G	7 (36)	15 (76)	J	10 (119)	15 (83)
H	9 (27)	10 (34)	K	12 (101)	9 (17)
G+H	12 (63)	16 (110)	J+K	16 (220)	20 (100)
S	13 (117)	11 (16)	V	2 (33)	12 (45)
T	6 (15)	11 (24)	X	8 (559)	15 (109)
S+T	16 (132)	19 (40)	V+X	8 (592)	19 (154)
total	36 (1077)	37 (388)	total	35 (2115)	40 (599)
common	48 (1465)		common	53 (2714)	

There was one more unique species on rich spruce areas than on poor, 11 and 12 respectively. Rich birch areas hosted less unique species than poor, 9 and 12 respectively. Birch had more species (28) found in both rich and poor areas than spruce (24).

3.1.4 Diameter

The regression analyses showed no correlation between the high stump diameter and species richness, for both spruce and birch (Figure 5 and 6).

On spruce highest number of species (12) was found on two stumps, 23 and 34 cm stumps respectively. The coarsest spruce high stump (58 cm) hosted only 7 species.

On birch highest number of species (11) was found on the thinnest birch (21 cm) high stump. The coarsest stump (40 cm) had 9 species and the second coarsest stump (39 cm) had only 4 species.

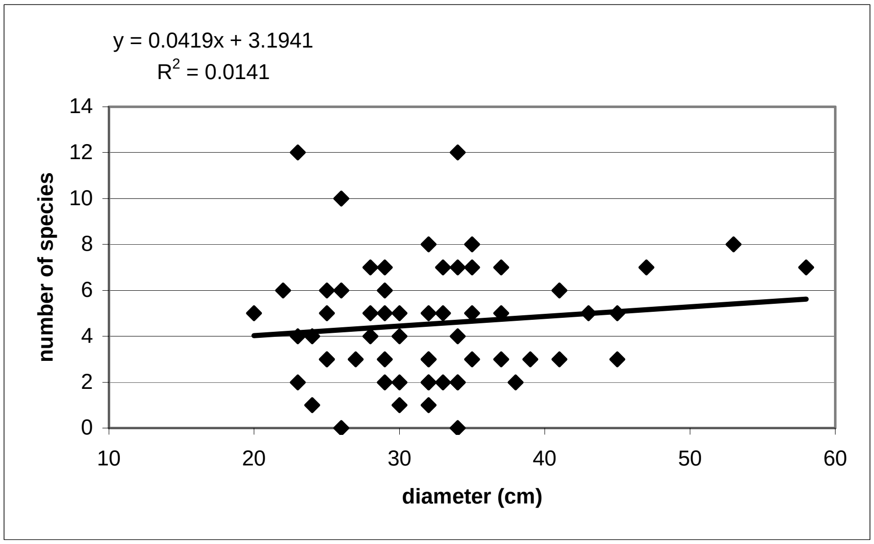

Figure 5. Diameter and number of species on the 60 spruce high stumps.

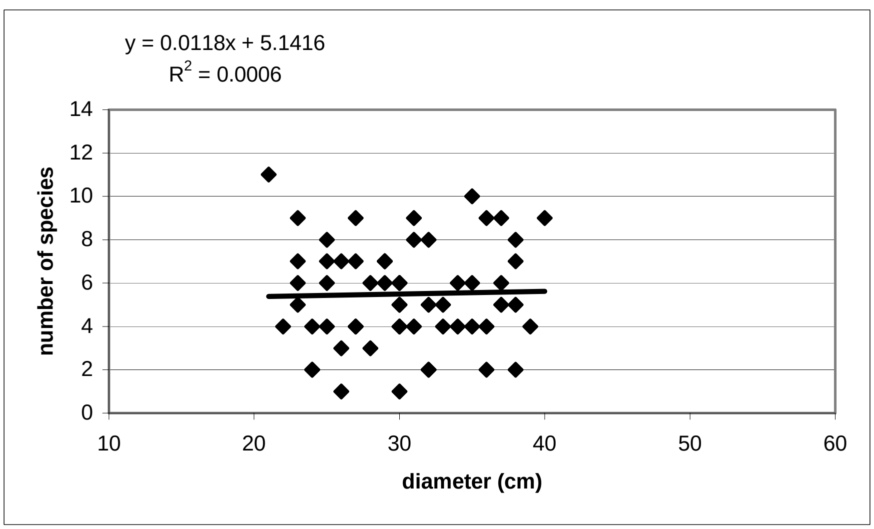

Figure 6. Diameter and number of species on the 60 birch high stumps.

3.1.5 Geographical location

When testing the influence of geographical location to number of species on spruce and birch no significant differences were found ($p>0.05$).

Spruce samples had the highest number of species (27) in ‘west’ and the lowest number (17) in ‘mid’ plots (Table 4). On birch high stumps the highest number of species (29) occurred in ‘mid-east’ location and the lowest (19) in ‘mid’ area samples (Table 5).

Summarizing beetle species on both tree species the ‘west’ area had 42 species being the richest and ‘mid’ area with 24 species the lowest in species number.

Table 4
Number of species in different geographical locations.

	west	*mid-west*	*mid*	*mid-east*	*east*
spruce	27	20	17	19	22
birch	27	28	19	29	24
birch & spruce	42	35	24	33	33

3.2 Red-listed species

In general the number of red listed species was high. In total nine red listed saproxylic species were found (13.6 % of all species) in this study: One endangered (EN), one vulnerable (VU) and seven near threatened (NT) (Table 5). The overall number of red listed individuals was low (19). Of those species seven were found on birch and four on spruce stumps.

Six of the red listed species were found in poor sites and four on rich sites, *Cis rugulosus* (NT) occurred in both. *Cis castaneus* (NT) was found in poor east site on both spruce and birch high stump. Also *Tetratoma fungorum* (NT) was found on both tree species on the poor east stand. Only vulnerable species found was *Ipidia binotata* (VU), on poor west site on a 35 cm spruce.

Geographically the most rich in red listed species were the costal areas ‘east’ and ‘west’ with four species followed by mid-east and mid-west areas with only one species. No red listed species were found on ‘mid’ areas.

The most abundant red-listed species was *Euryusa castanoptera* (NT) (5 indiv.) found on thin (23cm) birch high stump in rich west area Styrestad. The same stump, the only stump where more than one red listed species occurred, hosted also *Phyllodrepoidea crenata* (EN) (3 indiv.).

Table 5
Red listed species, their occurrence and ecology.

Name	Stump number	Tree species	Dia-meter	Loc-ation	Rich/ poor	Indivi-duals	Ecology (acc. to ArtDatabanken)
Cis rugulosus (NT)	N5	Birch	33	E	Rich	1	Among other places lives on fungi *Polyporys versicolor* on deciduous stumps. Not very well known.
Cis rugulosus (NT)	V5	Birch	37	Mid-E	Poor	1	
Cis castaneus (NT)	P2	Spruce	43	E	Poor	2	Larva development occurs in wood fungi on deciduous trees. Found in mycel of svavelticka in oak wood, also found in wet-loose (swab) beech wood.
Cis castaneus (NT)	P5	Birch	30	E	Poor	1	
Corticeus unicolor (NT)	P 4	birch	27	E	Poor	1	Under loose spruce bark on beech stumps, rarely on birch. Also occurs on dead beech stumps attacked by the fungi *Hylecoetus detmestoides*.
Dendrophagus crenatus (NT)	D 1	spruce	26	W	Poor	1	Under the bark on both conifers and deciduous trees. Feeds on cambium of trees dead for a couple of years. Can be found on standing dead trees and winters under the bark.
Euryusa castanoptera (NT)	A 5	birch	23	W	Rich	5	Found on old deciduous trees, several times on newly dead birch in dense natural forests, also on birch in grazed stands and on other newly dead trees.
Globicornis marginata (NT)	G 5	birch	35	Mid-west	Rich	1	Larva eats dead insects under the bark and in the wood of dead trees. Found in old dead sun exposed pine logs, also in the wood of dead birch and alder stumps.
Ipidia binotata (VU)	E 1	spruce	35	W	Poor	1	Very rare and local. Found on wood fungi of under the bark of dead trees. Most occurrences in Sweden on spruce stumps with *Fomitopsis pinicola* also on pine, birch, aspen and beech. Several times on clearcuts i.e. not a virgin forest relict. Often in fire killed pine and spruce. Usually on trees dead 2-5 years.
Phyllodrepoidea crenata (EN)	A 5	birch	23	W	Rich	3	Under the bark of several deciduous trees as salix sp., aspen, oak, beech and maple. Rarely on conifers. On newly dead bark (moist) on logs and standing trees.
Tetratoma fungorum (NT)	Q 1	spruce	35	E	Poor	1	Larva in fungi or in bark and wood with mycel. On deciduous trees like beech, oak, aspen, *salix caprea*, linden and apple. Most common on birch attacked by birch fungi. Frequently on standing dead trees.
Tetratoma fungorum (NT)	Q 4	birch	23	E	Poor	1	

4 Discussion

In the present study total species number was 66, which is in accordance with earlier findings of similar studies. For example Jonsell and Weslien (2003) studied spruce stumps by sieving bark samples four years after creation and found 43 saproxylic species (47 on spruce in this study). Jonsell also (2004) studied birch and aspen stumps two and five years after creation by bark sieving and found 42 saproxylic species on man-made birch high stumps (49 in this study).

'Tree species' was the only variable affecting the species richness, birch stumps hosted significantly more species than spruce stumps. Furthermore, the species composition was also different on spruce and birch, since they had 17 and 19 unique species, respectively. Not more than half of the saproxylic beetles found where common to both tree species. This was an expected result as the faunal differences between tree species are well known. Jonsell et al. (1998) found that the insect fauna is clearly different in conifers and deciduous trees. Also Abrahamsson (2002) found differences between beetle assemblage in spruce and birch when studying beetle fauna of one year old high stumps with window traps.

The results from the non-metric ordination furthermore strengthen the other performed statistical analysis. Differences between the two studied tree species are clearly seen and many of same geographical location plots are located close (Figure 4). That shows most probably the similarities in species assemblage on those areas. The rich and poor areas are scattered around the ordination sample and do not show any grouping.

As the rich areas where chosen close to known beetle hot-spots and in areas with a high amount of deciduous trees, I had expected to find more species there. In particularly species dependent on deciduous trees, as earlier studies like Martikainen et al. (2000) show that the invertebrate fauna clearly differs between mature managed and old-growth forest, old-growth forest had significantly more species than managed forest, especially regarding the saproxylic species. In this study the comparison of species richness between rich and poor landscapes gave unexpected results. The spruce high stumps had only one more species in rich areas than on poor. The opposite situation was found regarding birch stumps, in rich sites there was even less species than on poor (Table 3). However, the beetle assemblage in rich and poor areas were different as both type of areas hosted several unique species. Evidently, even stumps in the normal production forests with spruce dominance are widely used by many different beetles. The division into rich and poor areas in this study is perhaps not totally dependable and accurate. Some kind of quantitative data would have been preferable in order to investigate whether there really are important differences on landscape levels, for instance some measurement of the amount of broadleaved trees, tree age, etc.

Saproxylic fauna of Biskopstorp and Tönnersjöheden areas were also studied by Abrahamsson (2002), using window flight traps. Tönnersjöheden is located in an area dominated by spruce with low amount of dead wood and Biskopstorp is a large nature reserve (800 ha) where beech and oak are common. Both more species and individuals were collected from Biskopstorp. Same tendency occurs in present study, Biskopstorp (areas A and B) hosts more species than Tönnersjöheden (areas D and E) (Table 4). He concluded that not only trivial species may benefit from artificially created high stumps, the same conclusion can be drawn from this study.

The reason that the differences between different landscapes were small can be because the high stumps are not late enough in the succession and perhaps in the future the beetle assemblages and richness will differ more. The small differences can also be due to underestimating the potential of high stumps in production forests. Furthermore, areas regarded as rich in present study have higher abundance of deciduous trees, mostly oak and beech and the birch stumps might not be enough attractive for beetles. It could also be possible that the sample areas are not close enough to hot-spots and therefore do not host more species.

That there was no effect of 'stump diameter' to species richness was somewhat surprising, as the coarseness of the substrate has been found to be an important factor in many studies (Lindhe, et al., 2004; Jonsell, 1998). Even the rare and red-listed species did not show any preferences towards larger stumps, *e.g.* the endangered species *Phyllodrepoidea crenata* was found on one of the thinnest (23cm) birch stumps. Therefore the availability of even small size substrate in managed forest can be important for the beetle fauna and even for red listed species.

The fact that same bark area size was stripped from all stumps can decrease the diameter effect. The small effect can also be caused by the small diameter range in studied stumps, 20-58 in spruce with only 3 coarser stumps and 21-40 in birch (Figure 1, 5 and 6). Jonsell (2004) argues that more extreme diameters would probably give more effect. As a matter of fact, in the present study the three spruce stumps above 45 cm in diameter all harboured a somewhat larger number of species. Other probable cause can also be that the importance of size is more relevant in hardwood deciduous trees like oak and beech. In the long run the courser stumps should be preferred as their decay process takes longer time. Kruys et al. (1999) states that the smaller trees with smaller volume will "rot out of the system" faster. Also the bigger stumps have a bigger usable area.

The three mid-geographical locations can be seen relatively similar from ecological viewpoint as they are close to each other. But the east coast and west coast areas are different. The west coast of Sweden has lower temperature and higher precipitation. The east coast is warmer and with lower precipitation, and the areas around the study sites are dominated by oak and pine. Hornsö (east areas) is an outstanding hot-spot with 218 recorded red listed beetles (Nilsson, 2001). Nevertheless, in this study there were more species in the west coast (42) than on east (33), and less (24) species were found on middle areas (Table 4). Although there are differences in species number and assemblage in different locations, it is not possible to describe them according to available data.

No pattern could be seen in the red-listed species occurrence regarding rich/poor areas and on stumps with different diameter. Even the known beetle hot-spot Hornsö did not give higher number of red-listed species.

There was more red listed species on birch high stumps (5) than on spruce (2), two species occurred in both. The latter were *Tetratoma fungorum* and *Cis castaneus*, species which are previously found on deciduous trees. Their occurrence on both tree species could be a result of sampling with the same sieving tool but most likely they were just 'travellers' using the stump as a resting place. It is unlikely, but not impossible, that they inhabited spruce stumps.

During conservation of saproxylic species and promotion of dead wood the risk of outbreaks of bark beetles is often emphasized (Similä et al., 2003). In this study the stumps were three years old which can explain the absence of phloem- and bark-feeding beetles, as they are the first insects who colonise dead trees shortly after tree death (Weslien and Schroeder, 1999). There was one exception, *Pityogenes chalcographus*, but it was found only on two stumps and just four individuals. According to the present study there are no signs of possible outbreaks which could be a threat to neighbouring stands. That result is in accordance with earlier findings of, for example, Schroeder et al. (1999) who found that mechanically created high stumps are not ideal breeding substrate for *Ips typographus* and that the insect damage to living trees should not be expected when creating high stumps. Furthermore, bark beetles have an important role for forest biodiversity, rather than being a potential problem for living trees (Similä et al. 2003). They open the dead wood for subsequent colonisers (Schroeder and Eidmann, 1993).

4.1 Conclusions

The tree species was the only variable which influenced beetle assemblage and richness. The beetle fauna clearly differed between spruce and birch. Birch also hosted more species and therefore can be regarded more valuable. But there was only slightly less species on spruce high stumps. Both spruce and birch had many unique species and therefore, if possible, to leave high stumps of both speices can be beneficial for the overall biodiversity. Present study on saproxylic beetles also revealed some unexpected results. The rich areas did not host more species than poor. Surprisingly the stump diameter did not influence either species richness or abundance in high stumps. The fact that the most threatened species *Phyllodrepoidea crenata* was found on a thin (23 cm) birch stump shows that even small size substrate can be valuable. Geographical location influenced the beetle assemblage but species richness between areas was not statistically different. The fact that relatively high number (13.6%) of red listed species were found, and also in spruce dominated areas, highlights the importance of man made high stumps in the normal production forest for many endangered beetle species. Results of the study clearly show that artificially created high stumps are valuable for beetle conservation and protection.

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Appendix A

The complete species list. Abundance of species and number of stumps species were found on. Species which occurred on both tree species are highlighted in gray.

Species	Spruce	Birch	Sum	Nr. of stumps species was found on
Abdera triguttata	1		1	1
Anomognathus cuspidatus	43	202	245	55
Aradus betulae	1		1	1
Atomaria umbrina		1	1	1
Bibloporus bicolor	19	10	29	12
Bibloporus minutus	6		6	3
Bitoma crenata	11	17	28	15
Cerylon ferrugineum	3	4	7	5
Cerylon histeroides	1	10	11	3
Cis bidentatus		2	2	2
Cis boleti		1	1	1
Cis castaneus	2	1	3	2
Cis comptus		2	2	1
Cis fagi	2	1	3	3
Cis hispidus		3	3	3
Cis punctulatus	26	5	31	13
Cis rugulosus		2	2	2
Corticaria longicollis	4	7	11	4
Corticaria rubripes		4	4	2
Corticeus unicolor		1	1	1
Crypturgus hispidulus	406	5	411	27
Crypturgus pusillus	1989	29	2018	51
Crypturgus subcribrosus	23		23	3
Dacne bipustulata	2	35	37	16
Dadobia immersa	3		3	3
Dendrophagus crenatus	1		1	1
Dinaraea aequata	1	1	2	2
Endomychus coccineus	2	33	35	14
Enicmus rugosus		7	7	3
Ennearthron cornutum	7	3	10	7
Euplectus fauveli	2		2	2
Euplectus karsteni		5	5	2
Euplectus nanus		1	1	1
Euplectus punctatus	47	15	62	21
Euryusa castanoptera		5	5	1
Gabrius splendidulus	12		12	2
Glischrochilus quadripunctatus		1	1	1
Globicornis marginata		1	1	1
Hadreule elongatula	204	32	236	34
Hapalarea gracilicornis	2		2	1
Hylurgops palliatus	1	1	2	2
Ipidia binotata	1		1	1
Leptusa fumida	29	46	75	33
Leptusa pulchella	1	1	2	2

Appendix A (Continued)

Species	**Spruce**	**Birch**	**Sum**	**Nr. of stumps species was found on**
Litargus connexus		34	34	14
Nudobius lentus	19	19	38	23
Pachygluta ruficollis	5	16	21	17
Phloeocharis subtilissima	261	164	425	64
Phloeonomus pusillus	1		1	1
Phloeopora angustiformis	2	22	24	11
Phloeopora testacea	2	8	10	9
Phyllodrepoidea crenata		3	3	1
Pityogenes chalcographus	4		4	2
Plegaderus vulneratus	13		13	4
Ptinus subpilosus	1		1	1
Rhizophagus bipustulatus	2	72	74	27
Rhizophagus dispar	15	99	114	28
Rhizophagus nitidulus	1	10	11	5
Rhyncolus sculpturatus	1		1	1
Salpingus ruficollis	5	37	42	24
Stenichnus bicolor	5		5	1
Stenichnus godarti		1	1	1
Synchita humeralis		1	1	1
Tetratoma fungorum	1	1	2	2
Trypodendron domesticum		6	6	3
Tyrus mucronatus	2		2	1
sum	3192	987	4179	

Appendix B
Stump numbers, tree species, rich poor belonging and diameter for each locality, number of sampled species and their abundance.

Stump	Tree specie	Rich/ Poor	Diameter	Number of species	Abundance
A 1	spruce	R	35	8	338
A 2	spruce	R	23	12	51
A 3	spruce	R	34	12	69
A 4	birch	R	32	5	8
A 5	birch	R	23	9	21
A 6	birch	R	21	11	18
Alfa 1	spruce	R	32	3	16
Alfa 2	spruce	R	26	0	0
Alfa 3	spruce	R	35	3	3
Alfa 4	birch	R	28	3	3
Alfa 5	birch	R	23	5	14
Alfa 6	birch	R	40	9	21
B 1	spruce	R	33	7	21
B 2	spruce	R	29	3	9
B 3	spruce	R	26	6	20
B 4	birch	R	29	7	10
B 5	birch	R	30	6	18
B 6	birch	R	27	4	6
D 1	spruce	P	26	10	95
D 2	spruce	P	23	4	26
D 3	spruce	P	53	8	29
D 4	birch	P	29	7	20
D 5	birch	P	35	4	9
D 6	birch	P	30	5	14
Delta 1	spruce	P	25	5	11
Delta 2	spruce	P	34	4	24
Delta 3	spruce	P	32	3	10
Delta 4	birch	P	34	4	7
Delta 5	birch	P	37	5	36
Delta 6	birch	P	38	2	5
E 1	spruce	P	35	5	19
E 2	spruce	P	25	6	94
E 3	spruce	P	22	6	25
E 4	birch	P	26	3	11
E 5	birch	P	25	8	34
E 6	birch	P	29	7	101
G 1	spruce	R	25	3	5
G 2	spruce	R	38	2	26
G 3	spruce	R	32	2	5
G 4	birch	R	38	8	21
G 5	birch	R	35	6	36
G 6	birch	R	31	8	19
Gamma 1	spruce	P	45	5	133
Gamma 2	spruce	P	30	4	23

Appendix B
(continued)

Stump	Tree specie	Rich/ Poor	Diameter	Number of species	Abundance
Gamma 3	spruce	P	37	5	14
Gamma 4	birch	P	32	2	8
Gamma 5	birch	P	30	4	14
Gamma 6	birch	P	31	4	5
H 1	spruce	R	32	5	12
H 2	spruce	R	30	2	3
H 3	spruce	R	28	5	12
H 4	birch	R	33	4	8
H 5	birch	R	38	7	13
H 7	birch	R	38	5	13
J 1	spruce	P	29	6	40
J 2	spruce	P	34	7	66
J 3	spruce	P	25	3	13
J 4	birch	P	23	7	43
J 5	birch	P	30	6	13
J 6	birch	P	27	9	27
K 1	spruce	P	33	5	9
K 2	spruce	P	28	7	55
K 3	spruce	P	37	3	37
K 4	birch	P	30	4	4
K 5	birch	P	29	6	11
K 6	birch	P	32	2	2
M 1	spruce	R	29	7	215
M 2	spruce	R	32	1	5
M 3	spruce	R	27	3	15
M 4	birch	R	24	2	2
M 5	birch	R	25	4	27
M 6	birch	R	24	2	4
N 1	spruce	R	34	2	25
N 2	spruce	R	32	8	38
N 3	spruce	R	24	1	2
N 4	birch	R	26	7	10
N 5	birch	R	33	5	6
N 6	birch	R	34	6	18
P 1	spruce	P	41	6	246
P 2	spruce	P	43	5	37
P 3	spruce	P	32	2	4
P 4	birch	P	27	7	12
P 5	birch	P	30	5	9
P 6	birch	P	30	1	3
Q 1	spruce	P	35	7	143
Q 2	spruce	P	20	5	304
Q 3	spruce	P	29	5	66
Q 4	birch	P	23	6	21
Q 5	birch	P	31	9	25
Q 6	birch	P	37	6	11
S 1	spruce	R	45	3	95

Appendix B
(continued)

Stump	Tree specie	Rich/ Poor	Diameter	Number of species	Abundance
S 2	spruce	R	58	7	8
S 3	spruce	R	47	7	14
S 4	birch	R	39	4	7
S 5	birch	R	28	6	7
S 6	birch	R	36	2	2
T 1	spruce	R	41	3	4
T 2	spruce	R	30	1	9
T 3	spruce	R	33	2	2
T 4	birch	R	24	4	11
T 5	birch	R	26	1	1
T 6	birch	R	25	6	12
V 1	spruce	P	34	2	7
V 2	spruce	P	29	2	26
V 3	spruce	P	34	0	0
V 4	birch	P	27	4	9
V 5	birch	P	37	9	31
V 7	birch	P	36	4	5
X 1	spruce	P	28	4	111
X 2	spruce	P	37	7	424
X 3	spruce	P	39	3	24
X 4	birch	P	36	9	53
X 5	birch	P	22	4	14
X 6	birch	P	32	8	42
Z 1	spruce	R	24	4	9
Z 2	spruce	R	23	2	8
Z 3	spruce	R	30	5	38
Z 4	birch	R	30	6	12
Z 6	birch	R	25	7	19
Z 7	birch	R	35	10	21