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Abstract

Disturbances, such as fire and wind, are important for saproxylic beetles (= beetles depending on decaying wood) to gain substrate in boreal forests. Clear-cutting is an example of a man-made disturbance. Measures such as prescribed burning have been made to resemble natural disturbances. The aim of this study was to see which clear-cut characteristics are important for the occurrence of the saproxylic beetle *Upis ceramboides*. This is a species favored by open habitats and is said to respond positively to forest fires. The distribution area in Sweden for this species has decreased during the last two centuries and I wanted to see if there were differences between clear-cuts in Hälsingland, where it is very rare and decreasing, and Norrbotten where this study was conducted. I found that a large area of dead birch wood had a positive effect on the occurrence per clear-cut. The larger area of dead wood in Norrbotten was the only parameter that could explain the higher frequence of occurrence of *U. ceramboides* in Norrbotten. Prescribed burning might have a positive influence on the occurrence of *U. ceramboides* if there is a high amount of substrate left, but further research should be made to investigate this. On substrate level, it is important that the substrate is sun exposed and decayed by white-rot fungi, preferably *Fomes fomentarius*. It also seems that the substrate should not be too wet since the beetle was found on logs with a low degree of contact with the ground. It is important to leave enough substrate, i.e. dead birch wood, after clear-cutting. This is done by leaving both dead and living birches, and if possible birches decayed by white-rot fungi.

Sammanfattning

Störningar såsom brand och vind är viktiga för att skapa substrat för vedlevande skalbaggar i den boreala skogen. Slutavverkning är ett exempel på mänsklig störning och i anslutning till slutavverkning kan hyggesbränning utföras för att efterlikna naturliga störningar. Syftet med denna studie var att undersöka vilka faktorer i samband med avverkning som var viktiga för förekomsten av den vedlevande skalbaggen *Upis ceramboides* (större svartbagge). Arten har bara hittats i öppna miljöer, t.ex. efter skogsbränder. Utbredningen i Sverige för denna art har minskat under de senaste århundradena och jag ville undersöka om det fanns några skillnader mellan hyggen i Hälsingland där arten verkar minska, jämfört med hyggen i Norrbotten där denna studie genomfördes. Jag fann att en stor yta med förekomst av död björkved har positiv effekt på förekomsten av *U. ceramboides* per hygge. En större yta med död björkved i Norrbotten var den enda parameter som kunde förklara en högre förekomst av *U. ceramboides* i Norrbotten. Hyggesbränning kan ha en positiv påverkan på förekomsten av *U. ceramboides* om det finns det finns mycket substrat, men detta behöver studeras ytterligare. På substratnivå är det viktigt att substratet är solexponerat och vitrötat, framför allt av *Fomes fomentarius* (fnöskticka). Det verkar som om substratet inte bör vara för blött eftersom arten var mer frekvent i substrat med en låg andel av stammen i kontakt med marken. Det är viktigt att lämna tillräckligt med substrat, d.v.s. död björkved, i samband med avverkning. Detta kan göras dels genom att lämna tillräckligt med både döda och levande björkar och om möjligt björkved som är vitrötad.

Contents

Introduction

Different types of disturbances, such as fire and wind, are important for the regeneration of trees in the boreal forest (Engelmark 1999). These disturbances are also important for many saproxylic insects (insects that are dependent on dead or decaying wood at least some time during their life cycle) to obtain appropriate dead wood substrate (Wikars 1992). During the last 150 years, fires have become less frequent in Swedish boreal forests (Niklasson and Granström 2000; Zackrisson 1977) leading to changes in dead wood composition. In addition to this, clear-cutting became a common method in Swedish forestry during the 20th century and replaced other kinds of forest management, such as selection cutting, which often led to less radical changes to the local stand (Kuuluvainen 2009). Clear-cutting affects the local stand in various ways. It leads to changes in the local climate due to changes in sun exposure and evaporation (Keenan and Kimmins 1993). It has also been found that forest management reduces the amount of coarse dead wood (Fridman and Walheim 2000; Siitonen 2001; Sippola et al. 1998) which is essential for saproxylic insects. The increased usage of wood fuel as a bioenergy-source during the last twenty years (Swedish Forest Agency 2012) has added to the decrease of dead wood substrate used by saproxylic beetles (Jonsell et al. 2007; Dahlberg et al. 2011).

It has been said that modern forestry result in disturbances similar to natural ones. For example, clear-cutting has been said to resemble forest fire. One resemblance that has been suggested is the regeneration time, which is about 100 years in boreal forestry, and the frequency of natural fires which historically have been about the same in many boreal areas (Zackrisson 1977), but this is not applicable everywhere. Studies have shown that saproxylic insects typically adapted to disturbances can benefit from clear-cutting (Kaila et al. 1997; Ahnlund and Lindhe 1992). However, even though clear-cutting can influence many saproxylic insects positively, there are still those which are dependent, or at least favored, by burned substrate (Wikars 1992) and this is one reason that many clear-cuts are subjected to prescribed burning. Many forest companies have undertaken themselves to perform prescribed burning to a certain degree according to the FSC (Forest Stewardship Council) program (Anonomys 2010). Prescribed burning can have a positive effect on saproxylic insects, especially if there are enough standing trees left after clear-cutting (Toivanen and Kotiaho 2007). It is nevertheless important to recognize the differences between natural fires and prescribed burning on clear-cuts. In a natural fire the majority of the trees are left standing, at least immediately after the fire, and there is usually a larger amount of dead wood following a natural fire. It has also been shown that severe forest fires are naturally less frequent in the boreal forest compered to smaller but more frequent disturbances, and thereby less important in the unmanaged forests of northern Europe (Kuuluvainen 2009).

In this study I have investigated habitat requirements of the beetle *Upis ceramboides*. This is a beetle favored by fire and open habitats (Pettersson et al. 2006), and is nowadays primarily found on clear-cuts. Earlier studies made in central Sweden (Hälsingland) showed that *U. ceramboides* could be found on clear-cuts but did not seem to be favored by prescribed burning (Wikars and Orrmalm 2005). These studies were made near the southern limit of the

Swedish distribution and the beetle was only found on 20 out of 76 studied clear-cuts. Field studies made in the same area in 2010 showed a declining number of clear-cuts with *U. ceramboides* (D. Rubene, pers. comm.). This beetle was earlier found in the majority of the Swedish counties, but its distribution area has decreased during the last two centuries and it is now only found in the northern part of Sweden from Hälsingland and northwards (Ehnström and Axelsson 2002; Pettersson et al. 2006). The fragmentation and ongoing reduction of the distribution area has led to the listing of *U. ceramboides* as vulnerable (VU) in the Swedish red list (Gärdenfors 2010). An action plan has been made by The Swedish Environmental Protection Agency in order to find measures to preserve *U. ceramboides* and two other red listed beetles, *Lepturalia nigripes* (Endangered) and *Melandrya dubia* (VU), that develop in birches (Wikars 2008).

In order to understand why the distribution area of *U. ceramboides* in Sweden has decreased, this study was made in northernmost Sweden, in a region which still has a relatively high abundance of *U. ceramboides* (Norrbotten) (Ehnström and Axelsson 2002; Pettersson et al. 2006). The aims of this study were to find out:

(1) which clear-cut characteristics that are important for the occurrence of *U. ceramboides,*
(2) which substrate characteristics that are important for the occurrence of *U. ceramboides*
(3) if there are differences between clear-cuts in Norrbotten and Hälsingland that can explain the differences in occurrence of *U. ceramboides* between these parts of Sweden.

Materials and methods

Study species

As a study species I used a saproxylic beetle, *Upis ceramboides* (Coleoptera: Tenebrionidae), which has been found circumpolar in boreal forests (Pettersson et al. 2006). It is famous for its ability to tolerate low temperatures (Miller 1978). The development of the larvae (Figure 2) takes up to three years and occurs in inner bark of dead deciduous trees, primarily birch, decayed by fungi (Ehnström and Axelsson 2002; Pettersson et al. 2006). The larvae are usually found on lying dead birches, often close to fruiting bodies of *Fomes fomentarius* (Ehnström and Axelsson 2002). The adult beetle (Figure 1) hatches during summer. It can live for several years and is often found under coarse bark of standing birches, but also on other trees, for example goat-willow (*Salix caprea*) and aspen (*Populus tremula*) (Ehnström and Axelsson 2002; Pettersson et al. 2006; Wikars and Orrmalm 2005).

Six other beetle species were also noted during the search for *U. ceramboides*. Two of them are red listed in Sweden, *Platysoma deplanatum* (NT, Near Threatened) and *P. minus* (NT) (Gärdenfors 2010). These two are predators and I wanted to see if this could affect the occurrence of *U. ceramboides*. The other four species, *Rhagium mordax*, *R. inquisitor*, *Schizotus pectinicornis* and *Trichius fasciatus*, are more common and can also be found in other habitats such as closed forests. Previously, it has been suggested that *R. mordax* and *R. inquisitor* are competing with *Upis ceramboides*, and I wanted to see if there was any correlation between *U.ceramboides* and the other species and if they have similar requirements.

Figure 1. One adult beetle, *Upis ceramboides*, in its pupation chamber. (*Photo: Jörgen Naalisvaara*)

Figure 2. One larva of the beetle *Upis ceramboides.*

Study area

The study was made in the northern part of Sweden (Figure 3), in the county of Norrbotten, near the border between the central and the northern boreal zone (Ahti et al. 1968). The altitude of the studied sites varied between 200 and 350 m above sea level. The soil in the area is primarily of moraine type (Sveriges geologiska undersökning (1)) and the bedrock consists mostly of granite, but in some parts greywacke and mica schist is dominating (Sveriges geologiska undersökning (2)).

The forests in the area are dominated by two coniferous tree species, Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), but with relatively high abundance of birch (*Betula pubescens* and *B. pendula*). Other deciduous trees fairly common are aspen (*Populus tremula*) and goat-willow (*Salix caprea*). The area has been subject to forestry since the mid nineteenth century (Linder and Östlund 1992) mainly by Domänverket (now Sveaskog), which is the biggest landowner in the area. Other owners are forest companies such as SCA, and small private owners. The study plots in this study are all located on land owned by Sveaskog or SCA. Data concerning time of clear-cutting and area was received from these companies.

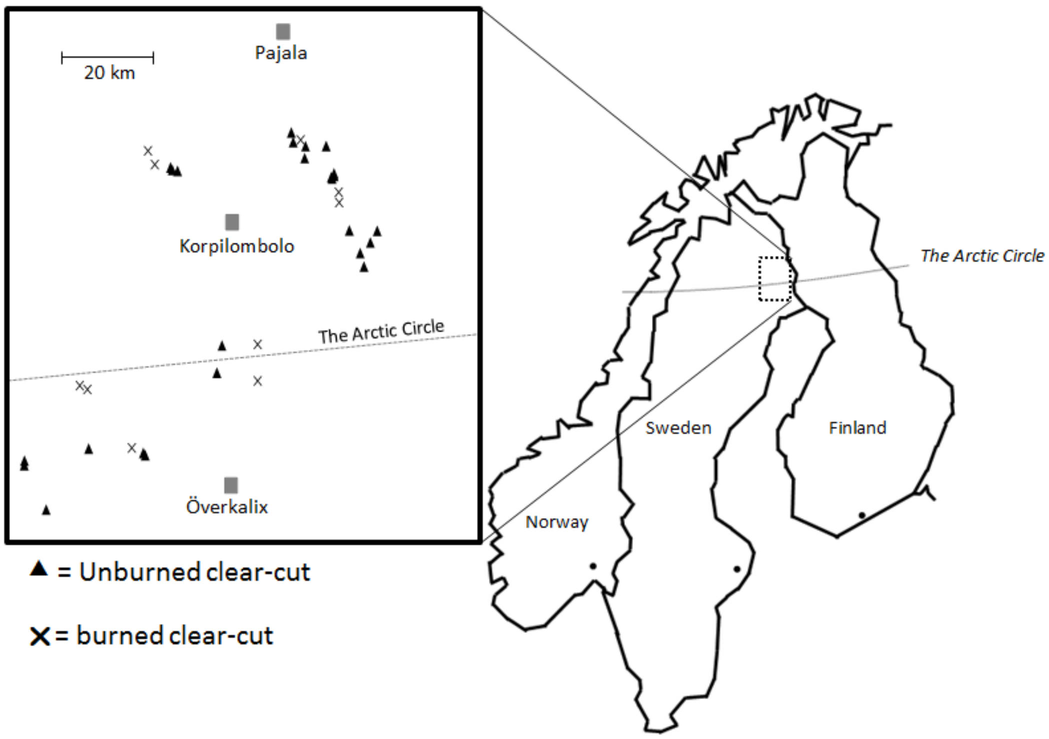

Figure 3. Map covering the study area.

The study area consisted of three landscapes. These landscapes were chosen since *U. ceramboides* had been found within these landscapes in earlier surveys (Bohman and Wedman 2006). Sveaskog and SCA helped me to find clear-cuts from each of the three age categories (5 to 9, 10 to 14 and 15 to 19 years since clear-cutting) and of these, prescribed burning should have been carried out on clear-cuts in each age category.

The study sites were all located on clear-cuts made between 1992 and 2006. Soil scarification had been carried out on all the studied clear-cuts and 10 out of 35 had been subjected to prescribed burning. Replanting had been made on all clear-cuts, in most cases with Scots pine (*P. sylvestris*) or Norway spruce (*P. abies*) but some were planted with lodge-pole pine (*Pinus contorta*) and one was partially planted with larch (*Larix sp.*), which both are exotic species.

Method

A total number of 38 clear-cuts were visited during field work in June and July 2011 and July 2012. Three of these were not included in the study due to lack of dead wood of birch. On each of the 35 studied clear-cuts a study plot with an area of 5 ha was investigated (except for one of the clear-cuts with a total area of 4.8 ha). Logs were searched by peeling off 0.25 m^2 bark at a height of approximately 1.3 m (measured from the thickest end) on each log. Logs with a total bark area of less than 0.25 m^2 were not investigated. On each study plot, 20 logs were searched for larvae of *U. ceramboides* and three other beetle species (*R. inquisitor*, *R. mordax, S. pectinicornis* and *T. fasciatus*) and for adults of *P. minus* and *P. deplanatum.*

A number of parameters were noted for each log: length, diameter, bark coverage, ground contact, degree of decay, shading, ground moisture and occurrence of fruiting bodies of fungi. The length of each log was measured with an accuracy of 0.5 m. The diameter was measured at the height of 1.3 m from the thickest end. Bark coverage was estimated in ten steps from 10% to 100%, while logs without bark were not investigated. The proportion of the log's length in contact with the ground was also estimated in eleven steps from 0% (for example if the log rested on other logs) to 100%. The degree of decay was estimated in six steps by pressing a knife into the wood (Siitonen and Saaristo 2000). Logs belonging to the classes 1 (newly dead) and 6 (partly fully decayed) were not searched for beetles since earlier studies have shown that these are rarely used by *U. ceramboides* (Wikars and Orrmalm 2005). Shading was estimated in four steps: 1 = fully exposed, 2 = mostly exposed, 3 = partly shadowed, 4 = totally shadowed (as in a closed forest). Shading caused by all kinds of vegetation was included, for example by annual plants, not just by trees or bushes. Estimation of ground moisture, made by studying vegetation, was noted according to the following scale: dry (1), mesic (2), moist (3) or wet (4). The presence of fruiting bodies of different species or genus of fungi was noted and the presence of mycelium was also noted (without concern to genus).

A number of parameters were estimated for each clear-cut. Some of these, such as total clear-cut area, time of clear-cutting and whether the clear-cut had been burned or not, were retrieved from data received from the forest companies. The area of possible habitat on each study plot (area dead lying birch wood) was estimated by dividing the 5 ha into 25 x 25 m squares where every square holding a total length of dead lying birch wood 3 m or more, was noted as a possible habitat. Only substrates with a length of 1 m and a diameter of 5 cm or more were included. The number of standing birches, both living and dead, were counted on each study plot. These values were then used to estimate the total area of possible habitat and the total number of standing birches, on each clear-cut.

Parameters on clear-cut level were analyzed with multiple logistic regression. Models were selected by a backward stepwise procedure, based on LR (Likelihood Ratio) statistics (from here and onwards, logistic regression) to find which parameters had a significant effect on the occurrence of *U. ceramboides* and on other beetle species. The parameters included on clear cut level were age (ln transformed), clear-cut area (ln transformed), total dead birch wood area (ln transformed), burned/not burned and number of standing birches left after clear cutting.

Data on clear-cut level from Hälsingland was analyzed together with clear-cut data from Norrbotten in order to investigate possible differences between these different parts of Sweden. To do that, another run with logistic regression was made which included data on clear-cut level from field work made in Hälsingland in 2010 (unpublished data). The parameters were the same as the previous analysis except for the parameter "Norrbotten or Hälsingland" and number of standing birches after clear cutting which was not noted in Hälsingland.

Logistic regression was also used to analyze parameters on dead wood object level. The parameter clear-cut identity (clear-cut ID) was used to see if there were any uninvestigated parameters that could affect the occurrences of the different species. Chi-square tests were made between each pair of beetle species in order to see if the occurrences of the different beetle species were dependent on any of the others.

Results

Of the 35 studied clear-cuts, *U. ceramboides* larvae were found on 20. The number of investigated birch logs was 603 (there was not enough suitable birch logs on some of the study plots) and *U.* ceramboides was found on 88 of them. Only one specimen of *P. deplanatum* was found and consequently the species was excluded from analysis (Table 1).

Table 1 *Proportion (%) of studied clear-cuts and logs harboring beetle species and the total number of larvae or adults (for the Platysoma species) found for each species.*

Species	Prop. of clear-cuts (%)	Prop. of logs (%)	Total number larvae/adults* found
Upis ceramboides	57.1	14.6	155
Rhagium mordax	68.6	20.7	324
Rhagium inquisitor	34.3	2.3	19
*Platysoma minus**	45.7	4.6	42
*Platysoma deplanatum**	2.9	0.2	1
Trichius fasciatus	82.9	16.6	259
Schizotus pectinicornis	91.4	27.9	436

Four of the species, *U. ceramboides, R. mordax, R. inquisitor* and *T. fasciatus,* showed positive correlation to an increasing area of dead birch wood. The two beetles that did not show any correlation with dead birch wood area, *P. minus* and *S. pectinicornis*, are mainly predators (Table 2).

When analyzing combined data from Norrbotten and Hälsingland with logistic regression, I found that *U. ceramboides* showed positive correlation with burned clear-cuts (log. regr B = 1.362, $p < 0.001$) and with Norrbotten (log. regr. B = 2.410, $p = 0.039$). When I analyzed the parameter Norrbotten/Hälsingland pairwise with the other parameters, the significant differences I found between Norrbotten and Hälsingland was total area per clear-cut and dead birch wood area per clear-cut. Both these parameters showed larger values in Norrbotten. Total clear-cut area: (F = 14.036, $p < 0.001$, One-way ANOVA test), mean (Hälsingland) = 18.6 ha, SD = 19.1, mean (Norrbotten) = 29.3 ha, SD = 19.9. Dead birch wood area: (F = 220.730, $p < 0.001$, One-way ANOVA test), mean (Hälsingland) 1.2 ha, SD = 1.6, mean (Norrbotten) = 15.7 ha, SD = 13.0. Prescribed burning had been performed more frequently on the studied clear-cuts in Norrbotten (Chi-square = 15.5, $p < 0.001$, Pearson's R = 0.321).

Table 2. *Effects of clear cut characteristics on the occurrence of beetle species per clear cut. Analyzed with logistic regression. Values are logarithmic B from final equation, which was obtained by backward elimination. Significance level is noted with *=p<0.05. — = Parameter not included in the final equation.*

	Upis ceramboides	*Rhagium mordax*	*Rhagium inquisitor*	*Platysoma minus*	*Trichius fasciatus*	*Schizotus pectinicornis*
total areal	—	—	-5.013*	—	—	—
areal dead birch wood	0.928*	1.147*	4.792*	—	1.019*	—
burned	—	-1.885*	—	—	—	—
age	—	—	—	—	—	—
standing birches	—	—	—	—	—	—

Table 3. *Effects of different parameters on the occurrence of beetle species on object level. Analyzed with logistic regression. Values are logarithmic B from final equation, which was obtained by backward elimination. Significance level is noted with *=p<0.05, **=p<0.01 and ***=p<0.001. — = Parameter not included in the final equation.*

	Upis ceramboides	*Rhagium mordax*	*Rhagium inquisitor*	*Platysoma minus*	*Trichius fasciatus*	*Schizotus pectinicornis*
clear-cut ID		-0.046***		-0.062**		-0.032***
length	—	—	—	—	—	—
diameter	—	—	—	7.606*	—	-5.233**
bark cover	—	—	—	—	—	—
ground contact	-0.017***	0.016***	—	0.020**	0.016***	—
degree of decay	—	-0.351*	—	—	—	—
shading	-0.523**	—	—	—	—	—
ground moisture	0.690**	—	—	—	—	—
fruiting bodies	0.879**	-0.748**	—	—	—	—

On dead wood object level, four of the studied parameters showed significant effects on the occurrence of *U. ceramboides*: ground contact, shading, ground moisture and presence of fruiting bodies (Table 3). The presence of fruiting bodies of fungi, without concern to fungi species, had a positive correlation with *U. ceramboides.* To study the effect of different fungi species on the occurrence of *U. ceramboides*, logistic regression was done with the same parameters as noted in Table 3 except for substituting the presence of fruiting bodies (of any fungus) with the different fungi species. The only fungus with a significant effect on the occurrence of *U. ceramboides* was *F. fomentarius* (log. regr. B = 0.626, $p = 0.010$). The other species (or genera) were: *Trametes* sp.*, Pycnoporus cinnabarinus, Daldinia loculata, Hypoxylon multiforme, Piptoporus betulinus, Lenzites betulina, Phellinus igniarius, Tremella* sp.*, Polyporus* sp.). The other parameters with significant effect on *U. ceramboides* together with *F. fomentarius* were the same as in the first analysis: ground contact (log. regr. B = -0.018, $p < 0.001$), shading (log. regr. B = -0.534, $p = 0.001$) and ground moisture (log. regr. B = 0.599, $p = 0.018$).

The only beetle species on dead wood object level with which *U. ceramboides* showed significant correlation (negative) was *T. fasciatus* (chi-square = 5.546, $p = 0.019$, Pearson's R = - 0.096). No correlation was found between *U. ceramboides* and the other species on clear-cut level.

Discussion

I found that large areas of lying dead birch wood is important for the occurrence of *U. ceramboides* per stand (Table 2). This was the only parameter on clear-cut level which had significant effect on the occurrence of *U. ceramboides*. It also had a significant positive effect on the occurrences of the other herbivorous species *R. mordax*, *R. inquisitor* and *T. fasciatus*. The other two studied species, *P. minus* and *S. pectinicornis*, are predators and apparently the amount of dead wood is not what is most important for their occurrences. None of the studied parameters on clear-cut level had any significant effect on the occurrence of these two species. Wikars and Orrmalm (2005) also concluded that a high density of dead birch wood was important for the occurrence of *U. ceramboides* and this is obviously important regardless of where in Sweden the clear-cut is located.

It is not surprising that the amount of dead wood correlates with the occurrence of saproxylic beetles but the quality of the substrate is also important. The logs that were considered to be suitable as substrate in this study were at least 5 cm thick and with a length of at least 1 m, and even though *U. ceramboides* was found in logs as small as this, most of them were found in logs with a greater diameter. This shows the importance of leaving enough dead wood and of right quality during forest management. In addition to this you must take into consideration measures like soil scarification that can destroy possible substrate and the increasing usage of wood fuel which further reduces the amount of dead birch wood.

Figure 4. One of the studied clear-cuts where *Upis ceramboides* was found.

One measure that can be made to get suitable substrate is retention of trees. Trees left in clear-cuts increases the resemblance to natural disturbances such as forest fire since natural disturbances usually leave more trees. When I studied the occurrence of *U. ceramboides* on dead wood object level, I found that substrate with little ground contact was preferred (Table 3). Because of this, stems of wind felled trees, supported by the trees' crown, should make suitable substrates as the stem will not rest on the ground. The branches can also keep the stem above ground vegetation, making it more exposed to sun light which was another parameter with a positive effect on the occurrence of *U. ceramboides*. In this study I did not find any significant correlation between the number of standing birches and the occurrence of *U. ceramboides* but Toivonen and Kotiaho (2007) showed that an increasing number of retention trees are beneficial to saproxylic beetles. Many studies have shown that retention of aspen contributes to the species richness of saproxylic beetles associated with aspen (Sverdrup-Thygeson and Ims 2002; Schroeder et al. 2011; Martikainen 2001). It has also been shown that retention of deciduous trees, such as birch and aspen, is a cost-effective way to increase the amount of substrate for saproxylic species (Jonsson et al. 2010). Observations during field work indicated that *U. ceramboides* often is found in logs that have fallen after clear-cutting, and this was especially evident on burned clear-cuts. My results did not show any significant correlation between prescribed burning and the occurrence of *U. ceramboides*. This was however possibly due to lack of appropriate substrate on many of the burned clear-cuts. On burned clear-cuts with none or few birches standing after clear-cutting (and during the fire), there were few if any larvae of *U. ceramboides.* Logs that had been burned while lying on the ground seldom held any larvae. Larvae were often found on trees that had fallen after burning. It seemed as if prescribed burning only had a positive effect on *U. ceramboides* if there were enough standing birches after clear-cutting. When Toivanen and Kotiaho (2007) studied the effects of burning and tree retention they found that burning only had a significant effect on saproxylic beetles if there were enough retention trees prior to burning. Observations made during field work suggested that this is also applicable on *U. ceramboides*. Further investigations should be made to see how different amounts of standing birches left prior to burning, affects the occurrence of *U. ceramboides*.

The correlation with ground contact was negative for *U. ceramboides* (Table 3) but the three species *R. mordax*, *P. minus* and *T. fasciatus* showed a positive correlation with ground contact. It is clear that measures made to improve the conditions for one species might make conditions worse for others. Different species require various kinds of substrate. Species adapted to open habitat, such as *U. ceramboides*, can benefit from dead wood left after clear-cutting, while other species require more shaded habitats (Jonsell et al. 1998). Perhaps the other species are favored by wetter substrate with another composition of fungi. There was, as an example, a negative correlation between *U.ceramboides* and *T. fasciatus* on dead wood object level and *T. fasciatus* seemed to be found in logs that were more decayed (even if it did not show in analysis). If the object is to make suitable substrates for *U. ceramboides* then it might be an option to gather logs in piles during thinning and logging, rather than letting them lay separately on the ground. By doing this you get logs higher up in the pile to stay off the ground. This also makes logs on top of the piles more sun exposed which, as earlier mentioned, was another positive parameter for the occurrence of *U. ceramboides*. Logs left on the ground should not be shaded by shrubs and since *U. ceramboides* could be found up to at least nineteen years after clear-cutting, thinning of shrubs should be made in order to keep substrates sun exposed. It is however important to leave birches to mature in the stand in order to get substrate further in the future.

The occurrence of fruiting bodies of fungi showed a positive correlation with *U. ceramboides* (Table 3). *F. fomentarius* was most important when I analyzed the different fungi species. The correlation with the fungus *F. fomentarius* is noted in literature (Ehnström and Axelsson 2002) but *U. ceramboides* is not exclusively bound to this fungus. In this study I found it with other white-rot fungi such as different *Trametes*-species and *Pycnoporus cinnabarinus*. It is however possible that there might be mycelium of *F. fomentarius* present without any visible fruiting bodies and therefor there can be an even stronger correlation with *F. fomentarius*. In the study made in Hälsingland, *U. ceramboides* showed a stronger correlation with *Trametes zonatella* than with *F. fomitopsis* (Wikars and Orrmalm 2005). This is perhaps due to the difference in abundance of the two fungi species. In Hälsingland, *T. zonatella* was the most abundant of the two species whereas in Norrbotten *F. fomitopsis* was far more abundant (N=239) than all *Trametes* species together (N=123). Since the presence of white-rot is essential for *U. ceramboides*, a conservation measure during clear-cutting might be to leave birches with fruiting bodies of fungi. Many of the white-rot species have fruiting bodies that develop only after the tree is dead or even not until it is lying down, and cannot be observed during clear-cutting. The fruiting bodies of most of the found fungi species are annual and cannot always be observed though mycelium of the fungus might be present. *F. fomentarius* on the other hand is perennial and is often found on standing trees, and can therefore be taken into account during clear-cutting. This makes it an important species when deciding which trees to leave.

I found no sign of any competition between *U. ceramboides* and the other beetle species. Four of the other analyzed species also showed positive correlation with increasing area of dead birch wood (Table 2) but they prefer substrates with other qualities (Table 3). *U. ceramboides* seems to be more of a specialist than the other beetle species since it correlates with many of the parameters. This shows the importance of finding right measures to preserve the species.

Conclusions

There are several measures that can be made during clear-cutting and afterwards in order to improve the conditions for *U.ceramboides.* It is clear that the amount of dead birch wood is important for the occurrence of *U. ceramboides* per stand. This has been shown in both this study and in the study made by Wikars and Orrmalm (2005). It is therefore important to leave enough birch wood after clear-cutting, both standing and lying. Another important point is that the lying dead wood should be sun exposed and preferably not lying directly on the ground. The wood must also be of appropriate quality, that is, in proper decay stage and decayed by white rot fungi. Prescribed burning can possibly have a positive effect but only if enough wood, both lying and standing, is left after clear-cutting.

This seems to be true both in Hälsingland and Norrbotten, so why is the distribution area of *U. ceramboides* decreasing and why is it seemingly disappearing from Hälsingland? I found a higher frequency of burning in Norrbotten but this was due to initial planning, I wanted a high proportion of burned clear-cuts in my study to see any possible effects. The study in Hälsingland only included five burned clear-cuts (out of totally 76 clear-cuts). I also found higher total clear-cut area and dead lying birch wood area in the studied clear-cuts in Norrbotten in comparison to Hälsingland. Since neither prescribed burning nor total clear-cut area showed to be significant for the occurrence of *U. ceramboides*, dead lying birch wood area was the only apparent difference I could find. Is then the significant difference in area of dead lying birch wood an explanation to the difference in occurrence of *U. ceramboides*? It is probably so and the future for *U. ceramboides* might therefore be dim. Deciduous trees have been suppressed during a long time in order to increase the amounts of fir and spruce, which has led to fewer birches in many stands. There are however areas in Sweden where birch still is very common such as the studied areas in Norrbotten, but since the amount of dead wood is crucial, the increasing usage of wood fuel might be a threat to the beetle even in this region. The clear-cuts included in this study all had rather large amounts of dead birch wood, but during field work it was noticed that more recently made clear-cuts (the last couple of years) held very little dead wood. Large amounts of logging residues had been removed from them. To stop the distribution area of *U. ceramboides* from continuing to decrease, and eventually risk extinction in Sweden, it is important that forest management in all stages favors the creation of proper substrate for saproxylic beetles that are dependent on birch and other deciduous trees.

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