Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Forest Sciences

Artificial gap creation and the saproxylic beetle community:

The effect of substrate properties on abundance and species richness

Luckhuggning och vedlevande skalbaggar i frivilliga avsättningar:

Trädslag och dödvedstypens inverkan på skalbaggarnas abundans och artrikedom

Nils Bodin

Examensarbete i ämnet biologi
Department of Wildlife, Fish, and Environmental Studies
Umeå
2016

Artificial gap creation and the saproxylic beetle community:

The effect of substrate properties on abundance and species richness

Luckhuggning och vedlevande skalbaggar i frivilliga avsättningar:
Trädslag och dödvedstypens inverkan på skalbaggarnas abundans och artrikedom

Nils Bodin

Supervisor: Joakim Hjältén, Dept. of Wildlife, Fish, and Environmental Studies

Assistant supervisor: Ruaridh Hägglund, Dept. of Wildlife, Fish, and Environmental Studies

Examiner: Jean-Michel Roberge, Dept. of Wildlife, Fish, and Environmental Studies

Credits: 30 HEC
Level: A2E
Course title: Master degree thesis in Biology at the Department of Wildlife, Fish, and Environmental Studies
Course code: EX0764
Programme/education: Forest Science programme

Place of publication: Umeå
Year of publication: 2016
Title of series: Examensarbete i ämnet biologi
Number of part of series: 2016:11
Online publication: http://stud.epsilon.slu.se

Keywords: Boreal forest, nature conservation, saproxylic beetle, artificial gap creation, restoration measure, coarse woody debris

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Forest Sciences
Department of Wildlife, Fish, and Environmental Studies

Abstrakt

Grövre död ved (CWD) och gläntor är strukturer som minskat i svenska skogslandskap under det senaste århundradet och utvecklingen tros vara en bidragande faktor till Sveriges minskande biodiversitet. I enlighet med politiska åtaganden rörande bevarandet av biodiversitet vill nu myndigheter och skogsbolag återskapa dessa och andra strukturer genom särskilt tilltagna restaureringsåtgärder.

En sådan åtgärd är artificiellt skapande av luckor i skogen, vilket även ämnar lokalt öka mängden CWD. Åtgärden innebar i detta försök att man högg upp ett antal luckor per hektar och bestånd, samtidigt som man skapade fyra slags substrat inom ett antal luckor: Tippade träd, kapade träd, ringbarkade träd samt högstubbar. Under följande år samlades fångstdata in från kläckfällor som monterats till ett urval av substraten. Därtill samlades även data in rörande bestånds- och substrategenskaper.

I den här studien ville man analysera vilken effekt som olika substrategenskaper har på saproxyla skalbaggars *artrikedom* och *abundans*. GLMM-modeller konstruerades för de båda responsvariablerna och olika substrategenskaper användes som förklarande variabler. Studiens resultat visade bland annat att substrattypen hade en stor inverkan på abundansen, medan artrikedomen påverkades kraftigast av ett positivt förhållande till substratdiameter.

Den kraftiga skillnaden i abundans mellan olika substrattyper kan antyda att olika arter förökar sig i olika substrat. Den positiva effekten av ökad substratdiameter på artrikedomen skulle kunna vara en följd av att ett större substrat kan husera större skalbaggesamhällen – men då ingen effekt av diameter kunde kopplas till den totala abundansen av skalbaggar skulle detta även kunna peka på olika substratpreferens mellan arter.

Abstract

Coarse dead wood (CWD) and gaps are structures that have become sparse in Swedish forests as a result of forestry. This is believed to be one factor contributing to diminishing biodiversity. Because of political undertakings to preserve biodiversity, Swedish agencies and forestry companies now aim to restore these and other structures. To do so prescribed measures of nature conservation are today being practiced.

One such measure is artificial gap creation. This study analyzes the effects of this measure on saproxylic beetle communities. The measure involve the cutting of several gaps per hectare and stand, as well as creating four CWD substrates in several gaps: Tipped trees, cut trees, girdled trees and high stumps. Data was collected from substrate traps as well as on substrate- and stand properties.

In this study the effects that different substrate properties have on the *abundance* and *species richness* of the saproxylic beetle community were analyzed. GLMM-models were constructed for each of the two response variables, using several explanatory variables. Results indicate that abundance was most affected by the type of substrate, while species richness was most affected by its positive relationship to substrate diameter.

The difference in abundance between substrate types could indicate that different species breed in different substrates. The positive effect that increased diameter have on species richness could be a result of how a larger substrate house larger communities of beetles – but since substrate diameter had no significant effect on abundance it could also indicate differences in inter-species substrate preferences.

1. Introduction

1.1. Structural change

More than half of the land area of Sweden is covered by forest which is a well-known provider of many important ecosystem services. Prior to the intense logging of boreal forests in Sweden during late 1800: s, Swedish forests where composed of relatively heterogenic landscapes largely consisting of largely unmanaged forest shaped by natural disturbance regime factors such as fire, storms, gap dynamics and time (Linder & Östlund, 1998; Esseen *et al.*, 1997). These forests featured substantial amounts of structures important to biodiversity such as coarse woody debris (CWD), mixed forest stands with old trees, glades and standing sunlit dead wood (Niklasson & Nilsson, 2005).

Compared to the diversity of historical forests, the forest landscapes of Sweden are today highly homogenous (Esseen *et al.*, 1997). Because of production oriented forestry a large part of Sweden's forests are now managed to be even aged monocultures of economically important tree species, with limited amounts of dead wood (Larsson & Danell, 2001). Other anthropogenic impacts are also removing forest landscapes away from their structurally natural state, e.g. today's highly effective fire suppression (Ericsson *et al.*, 2005; Linder *et al.*, 1997; Zackrisson, 1977). Even if a disturbance does occur and areas of production forest is harmed, the land owner is by the Swedish Forestry Act 5§ required to reduce the volume of fresh windfall timber to a specific amount per hectare as well as remediate the areal production (Skogsvårdslagen, 1993). All in all, the forest landscapes of Sweden have been severely structurally altered (Larsson & Danell, 2001; Linder & Östlund, 1998; Fries *et al.*, 1997; Berg *et al.*, 1994) and this is generally believed to be one cause of the dwindling of Swedish biodiversity. CWD is sparse and of the approximately 25 000 multicellular forest species found in Sweden at least 6 500 are dependent of dead wood and according to the most recent red-list a large amount (750) of all red-listed forest species (2 300) of Sweden are saproxylic (wood inhabiting) (Sandström *et al.*, 2015). CWD exposed to sunlight is a substrate believed to be of great importance to many saproxylic species (Jonsell *et al.*, 1998; Speight & de l'Europe, 1989). Unfortunately the occurrence of forest gaps of different successional stages that house such structures have been greatly reduced as a result of human management (Esseen *et al.*, 1997).

1.2. Political undertakings

It is difficult to compare the non-monetary values of a naturally functioning ecosystem to the economical values of forestry production. There is however no doubt that the invaluable profits of ecosystem services or the intrinsic value of biodiversity must be preserved (Groom *et al.*, 2006; Costanza *et al.*, 1998). An important event in Swedish nature conservation history was the 1993 year edition of the Swedish Forestry Act (Skogsutredningen, 2004) – which defined natural values to be equally important to monetary production values. Another event of great importance was the Environmental Objectives project adopted by the Swedish parliament in 1999, which has ever since been further developed (Annerberg *et al.*, 2009). Initially there where 15 “objectives” to be reached by 2020, but in 2005 a 16th objective was added – “A Rich Diversity of Plant and Animal Life“, aiming to preserve biodiversity.

Consequently, to comply with Swedish law and other nature conservation policies, certifications and international commitments the practice of nature conservation is becoming more and more common (Larsson & Danell, 2001). Today, nature conservation practice is known both as the recognized “general conservation consideration” concurrently applied to ordinary forestry practices, as well as the less common “prescribed restoration measures”. General conservation consideration is well known as having single trees or small areas of forest set aside for nature conservation purposes, as the rest of it is harvested. However, even though this passive measure is now common practice, much due to forestry certification requirements (FSC, 2013) – much of the already diminished Swedish biodiversity is not recovering (Sandström *et al.*, 2015). This indicates perhaps a need for a more active nature conservation such as prescribed methods of restoring natural forest structures!

1.3. Aim of the study

This study will contribute to an already ongoing project of the Forest BIOCORE research group, of the Swedish University of Agricultural Sciences. The project, “Restoration of natural forest dynamics: a test of different strategies at stand and substrate level in forest set-asides” aims to assess two cost effective prescribed methods of restoring natural forest structures; i) selective cuttings to restore gap dynamics and ii) restoration burnings. This unique study was initiated in 2010 and the study stands are located in boreal forests of Sweden (Hägglund *et al.*, 2015). In Sweden 30 voluntary set-aside stands of the forest company Holmen Skog was randomly but evenly (10 of each) selected for either: i) burning, ii) artificial gap creation or iii) being left unaltered as reference stands. This study will focus solely on the ten stands subjected to artificial gap creation.

As trees are felled or killed the forest canopy opens up and the sunfleck frequency, -distribution and -daily duration is increased which affects underlying microclimates. The ecology of saproxylic beetles is well-studied, but regarding their response to forest restoration measures much is still unknown (Hägglund *et al.*, 2015). Differences in breeding substrate microclimate is believed to greatly affect the community of saproxylic beetles that end up breeding in it and direct sunlight is likely an important factor (Sandström *et al.*, 2015). Previous studies indicate not only that sun-exposed dead wood attract species of saproxylic beetles, but is also preferred as substrate for breeding by many red-listed species (Lindhe *et al.*, 2005). The aim of this study will be to further evaluate microhabitat level effects, by analyzing the effects that differences in substrate properties have on the saproxylic beetle community. The following hypothesis will be tested:

1) The abundance of saproxylic beetles breeding in a specific CWD substrate can be explained by the variables: substrate type, substrate diameter, and calculated amounts of total sunlight exposure.

2) The species richness of saproxylic beetles breeding in said substrates can be explained by the variables of substrate type, substrate diameter, proportion of substrate bark remaining and calculated amounts of total sunlight exposure.

2. Method

2.1. Study design

The stands relevant to this study were the 10 stands selected for artificial gap creation (Fig. 1). Stand size varied from 3.5 to 15.3 ha and they were mixed forests either dominated by pine (*Pinus sylvestris* L.) or spruce (*Picea abies* L.).

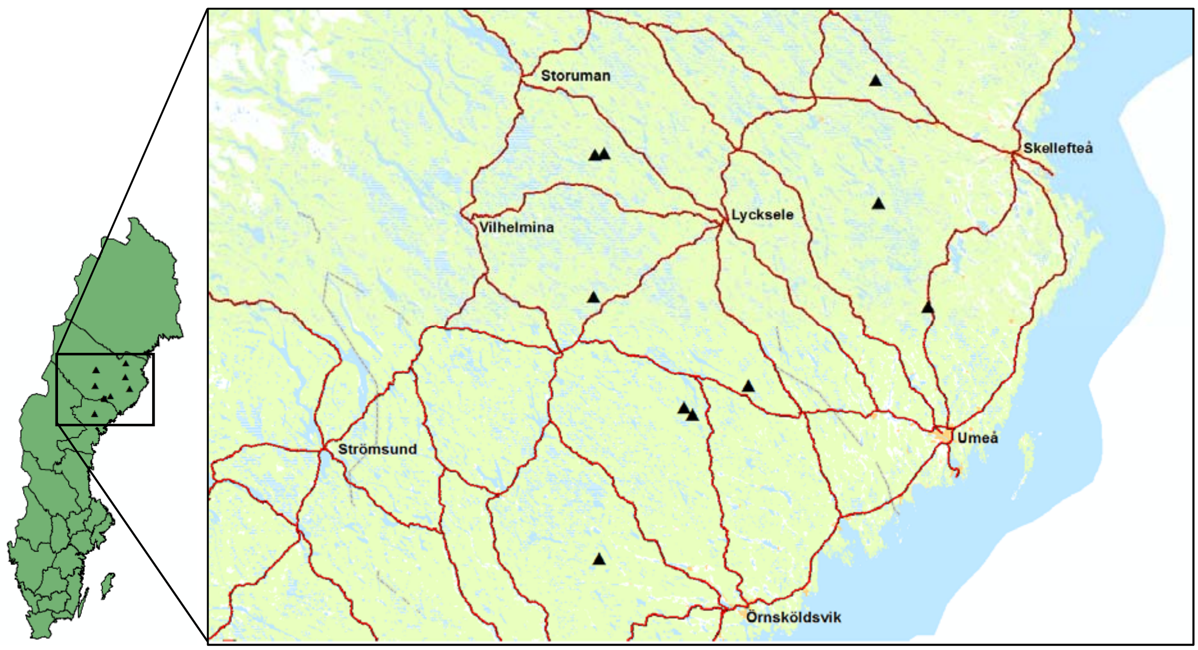

Fig. 1: The location of ten stands where selective cutting for artificial gap creation was performed. Översiktskartan 2014 © Lantmäteriet.

During early spring of 2011 the process of selective cutting was initiated. Six gaps with a diameter of 20 m where created per hectare at each study stand. Within every second gap trees were killed in four different ways and left in the gaps as dead wood. The four methods of killing trees resulted in 4 different types of dead wood, namely; i) cut logs, ii) pushed over logs, iii) high stumps and iv) girdled trees. In the remaining gaps the trees were cut at the base and extracted from the forest for two reasons; i) cover the cost of restoration and ii) reducing the risk of surpassing the legal amount of fresh dead wood left in the forest according to Swedish forestry legislation, i.e. $5m^3ha^{-1}$. When gaps had been created, substrate specific data relevant to this study (e.g. substrate type and diameter) was collected and emergence traps to collect saproxylic beetle breeding data (species richness and abundance) were mounted to randomly selected tree substrates (Fig 2). This trapping method is preferable not only as it provides quantitative data on the production of saproxylic beetles in a specific substrates, but also; as the substrate is not destroyed resampling can be performed another year and the risk of trapping “tourist” beetles randomly moving through the area is minimized.

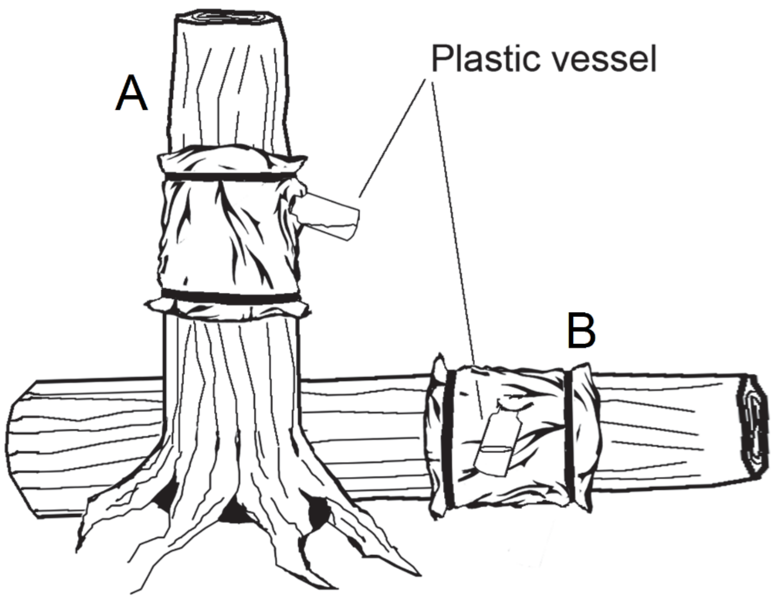

Fig. 2: Two kinds of artificially created substrates, each with a mounted emergence trap. Original illustration from Andersson et al. (2015).

The traps were left mounted from early June to late September, 2013. On trees that were cut at the base or tipped over the traps were mounted horizontally to the lying down stems and on trees that were girdled or made into high stumps the traps were mounted vertically at a height of 1,3 m (Fig. 2). As beetles hatched within a substrate and emerged through its bark they were confined by a black cloth wrapped around the tree. Searching for an exit the beetles were attracted to the sun light emitted through the transparent plastic vessels. When falling into a vessel the beetles were killed and preserved by a solution of propylene glycol/water and a small amount of detergent. For more information on this method of trapping saproxylic beetles see Andersson *et al.* (2015).

During July 2015 the study stands were visited to collect additional data on substrate level light conditions. Each substrate that previously held a trap was located using a GPS. Using a high quality DSLR camera mounted to a tripod and equipped with a 180 degree fish eye lens pictures of the canopy above each trapping position were taken. In order for the pictures to be analyzed in a software the north orientation of the camera in each picture was noted.

2.2. Analysis

Canopy photography analysis was conducted in Gap Light Analyzer (GLA) (©1999 Cary Institute, New York). Each substrate specific canopy photograph was analyzed to calculate the total amount of sunlight exposure at the position of each trap. Initially during the analysis of an image the software registers image specific north direction as well as the stand centrum coordinates and height above sea level of its stand. Then using the intrinsic image editing tools of the software the canopy photography is transformed into a completely black and white image, where white represents open sky and black represents everything else. Each photography analysis produces substrate specific values of canopy openness and sunfleck frequency, -distribution and -daily duration.

The remaining statistical analyses of this study were performed solely on substrates of spruce, as these trap data sets were more complete than those of other tree species. It was important to be aware of correlated variables as a generalized linear model is to be constructed. Initial analyses were hence performed to detect significant correlations variables to be included in the models. This was done using the "lmer"-tool of the "LME4" R-software package and the "lsmeans"-tool of the "lsmeans" R-software package (Bates *et al.*, 2016).

Secondly, generalized linear mixed effects models (or GLMMs) were created to explain the recorded variations of both abundance and species richness within the saproxylic beetle community. To do so, the "glmmADMB"-tool of the "AD Model Builder" R-software package was used for fitting models to the data (Bolker *et al.*, 2013). Variables believed to be relevant to the model were; i) the total amount of total sunlight exposure (calculated by GLA), ii) the 4 kinds of substrate, iii) substrate diameter, iv) proportion of bark coverage retained on the stem, as well as v) the unknown effects from the stands being different from one another. An initial model was created using these variables. Using the "Dredge" tool of the "MuMIn" R-software package (Barto´n, 2016) a final selection of variables was then performed by comparing the AIC-values of possible models (lowest AIC of possible models indicates the most correct model). Final models were then created using the selected variables. To further compare the effects of different substrate type a multiple comparison analysis was conducted using the "GLHT"-tool of the "multcomp" R-software package (Hothorn *et al.*, 2016).

3. Results

When visualizing the substrate means of the original data, the abundance varied much more (reaching from 87.1 to 22.4 individuals per substrate) than the species richness data did (reaching from 4.5 to 5.1 species per substrate) (Fig 3).

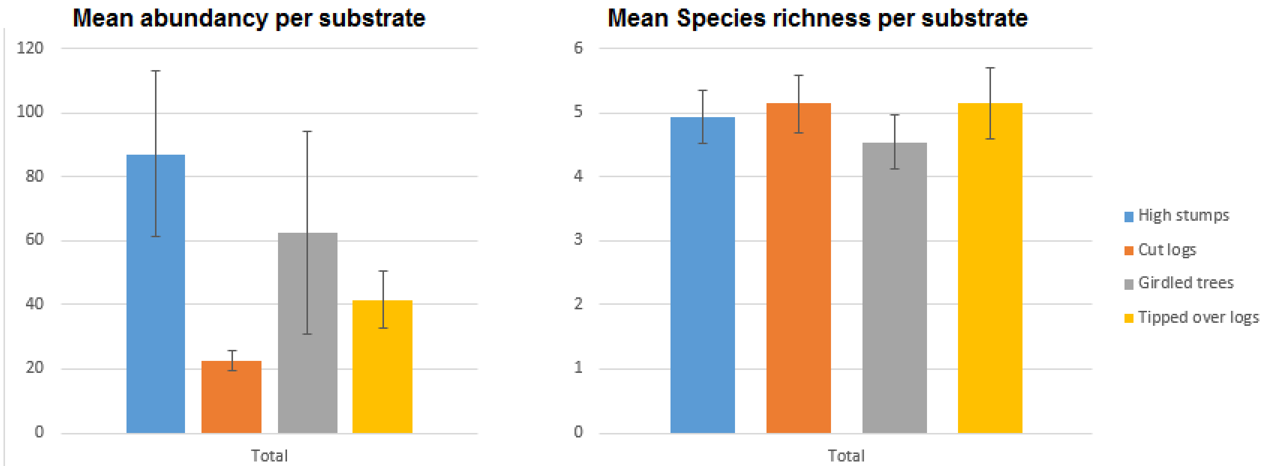

Fig. 3: Comparison of the variance in means per substrate, of the abundance data and the species richness data. Respective standard error visualized per bar.

Initial analyses indicated no significant correlations between the different explanatory variables. This ensures that the possible effects of a variable e.g. sunlight exposure, is not erroneously attributed to the type of substrate being systematically exposed to more sunlight. It could also cause what is actually one variable to be included more than once to the model.

3.1. Abundance

The per-substrate and stand abundance means of saproxylic beetles varied greatly (Fig. 4), and the overall distribution of the abundance data was heavily skewed to a negative binomial distribution due to a few but very powerful abundancy samples. (Fig. 5). An initial GLMM-model was constructed consisting of several possible variables but after optimizing it using the “Dredge” tool, it was the categorical variable of *substrate type* in combination with *proportion of bark coverage* that best explained the variation of the abundance data (Tab. 1). An ANOVA analysis comparing the two effects (Tab. 2) was also performed. To narrow down the effect of substrate type a multiple comparison analysis identified a significant ($p < 0.05$) difference between *cut down trees* and *high stumps*, with a p-value of 0.0156 (Tab. 3).

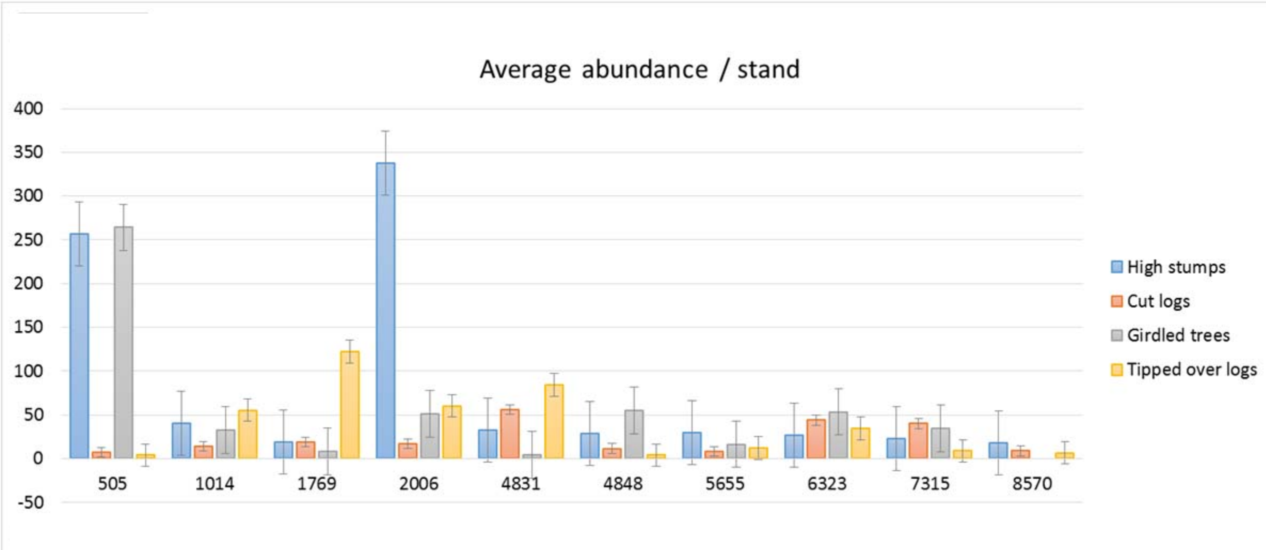

Fig. 4: Average abundance per stand and method of substrate type, with respective standard error visualized per bar.

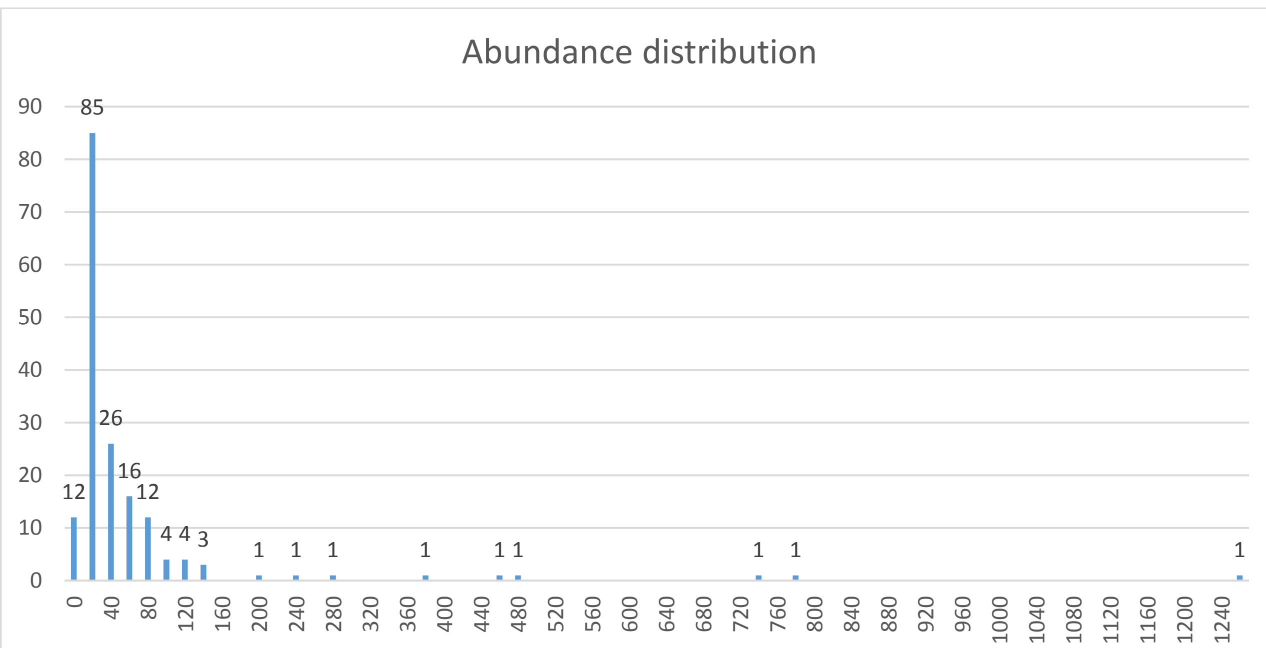

Fig. 5: The abundance data histogram, revealing a highly skewed negative binomial distribution.

Tab. 1: The GLMM-model fitted to the saproxylic beetle abundance data.

Variable	Estimate	Std. error	Pr(>|z|)
(Intercept)	2.656	0.470	<0.001
Prop. remaining bark	0.016	0.004	<0.001
Cut down trees	-1.054	0.304	<0.001
Girdled trees	-0.251	0.290	0.387
Pushed over trees	-0.443	0.317	0.162

Tab. 2: An ANOVA-analysis of the generalized mixed effects model fitted to saproxylic beetle abundance data.

	Degrees of freedom	Chisq	Pr(>Chisq)
Bark	1	13.277	<0.001
Substrate type	3	14.080	<0.001

Tab. 3: When comparing the categorical variable of substrate type, there was a significant difference between the methods of cut down trees and creation of high stumps.

Substrate type	Estimate	Std. error	Pr(>|z|)
Cut down trees / High stump	-0.936	0.311	0.016
Girdled trees / High stump	-0.259	0.303	0.785
Pushed over trees / High stump	-0.427	0.323	0.745
Girdled trees / Cut down trees	0.677	0.441	0.623
Pushed over trees / Cut down trees	0.509	0.426	0.745
Pushed over trees / Girdled trees	-0.168	0.466	0.785

3.2. Species richness

The per-substrate species richness did not vary as greatly as the abundance (Fig. 6). To explain the variation in species richness the “Dredge”-tool was again used to produce an optimized “glmmADMB”-model (Tab. 4). The variables now significant were *substrate diameter*, *proportion of remaining bark* and the *measured amount of sunlight* *exposure*. *Diameter* had both the most significant as well as the most powerful (positive) effect on the model. Both proportion of remaining bark and sunlight exposure had minor influence on the model outcome and will not be further commented on.

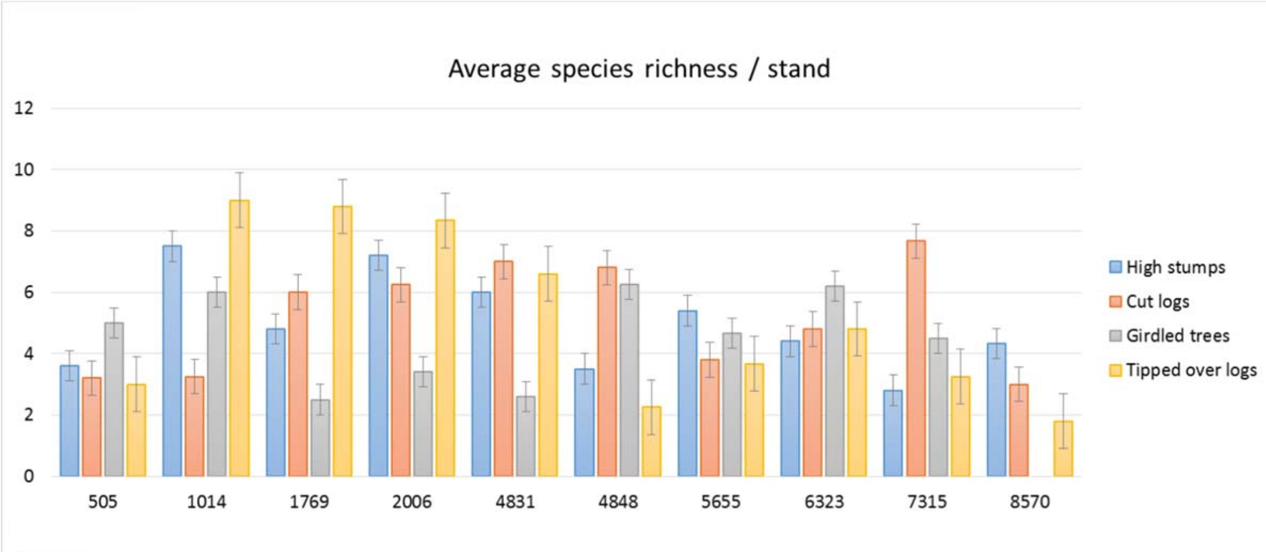

Fig. 6: Average species richness per stand and substrate type, with respective standard error visualized per bar.

Tab. 4: A generalized mixed effects model of saproxylic beetle species richness.

Variable	Estimate	Std. error	Z value	Pr (>|z|)
Intercept	0.635	0.323	1.96	0.050
Diameter	3.632	0.888	4.09	<0.001
Sunlight inlet	-0.052	0.027	-1.97	0.049
Prop. remaining bark	0.007	0.002	3.42	0.001

4. Discussion

4.1. Results

The results suggest that the combined effects of substrate type and proportion of remaining bark were best for explaining the variance in saproxylic beetle abundance (Tab. 1). The explanatory power of the substrate type originated from the difference in abundance between cut down trees and high stumps. This is likely much due to a few samples with very high abundance of beetles in high stumps which affects the model outcome. The effect that these samples have on stand treatment means (stand 505 and 2006) are visible when charted (Fig. 4). The occurrence of locally extreme abundancies was to be expected as it coincides with the ecology of many saproxylic beetle species that occasionally express extreme reproduction patterns and even can become pests (Jonsell et al., 1998). Because of this ecological trait single abundance samples, however extreme they are, cannot be considered outliers and be removed. This results in sets of data that fits well to a negative binomial distribution (Fig. 5). The occurrence of extreme abundance in only high stumps suggest that; the saproxylic beetle species that express this ecological trait prefer that substrate to others, e.g. cut down logs, this not only coincides with previous studies (Andersson *et al.*, 2015) but could also indicate that different species are attracted to different substrates. The relatively powerful effects of substrate type on the saproxylic beetle community corresponds to the results of previous studies (Hjältén *et al.*, 2007; Jonsell & Weslien, 2003).

The results further suggest that the combined effects of substrate diameter, proportion of remaining bark and measured amounts of total sunlight exposure was best for explaining the variance in species richness. In the optimized GLMM-model (Tab. 4), there was a powerful and highly positive effect from the substrate diameter variable on species richness. This could be a result of how a larger substrate can house a larger amount of breeding beetle species, but as substrate diameter had no significant effect on beetle abundance this could also indicate differences in substrate preference of beetle species. The minor and even negative effect from sunlight exposure does however not coincide with the results of previous studies, which indicated overall positive effects of increased sunlight exposure (Lindhe *et al.*, 2005; Jonsell *et al.*, 1998). The study by Lindhe *et al.* however analyzed the effects of light conditions ranging from that of a fully enclosed forest to that of a heavily thinned one – which ought to identify more differences, and that the study by Jonsell *et al.* solely analyzed the substrate preferences of red-listed saproxylic beetles. This intuitively contradictory result is therefore perhaps not that odd, as this study did not include reference material from outside the gaps and also included every saproxylic beetle species breeding in the killed trees into analyses.

4.2. Sources of error

The GLA software was set to compute the total sunlight exposure of an entire year. This could possibly cause the light exposure of winter and spring months to gloss over the light exposure of summer and autumn months, when saproxylic actually select substrate for breeding.

5. Conclusions

A factor that has yet to play its role at these stands is time. Immediately after being killed, the wood of the tree starts to decompose and depending on a multitude of factors (i.e. exposure to sun, tree species, humidity and ground contact) the decay process is either faster or slower. As saproxylic species often are very specific in their substrate preferences not only to tree species but also to its decompositional stage, the substrates will in time present a wider spectrum of substrates suitable to many more organisms (Jonsell *et al.,* 1998). So as the successional stages of the ten stands of artificially created gaps advance, the results of this study may be much more informative. Future studies hence ought to include a variable of substrate decompositional stage, as well as a categorical variable to the beetle trap data: separating species into ecological groups and into red-list status (or the lack of it), could present much explanation power and result in better comparability to previous studies that focus on red-listed species. An all-including species richness of saproxylic beetles is a very blunt tool for analyzing the effects of a stand level measure.

This study did not include reference data sets from forest stands that had not been subjected to artificial gap creation. Including such material in analyses could present much more explanatory power and would allow deducting if there are effects from artificial gap creation – compared to “normal”, non-restored forest landscapes. It is however clear that substrate level differences within artificially created gaps and CWD substrates affect the community of saproxylic beetles. The negative effect that sunlight exposure had on species richness was small and previous studies indicate sunlight exposure having positive effects on especially red-listed species, which are much more important to nature conservation. A slightly negative effect on the entire saproxylic beetle community should therefore not discourage measures that increase sunlight inlet. Since artificial gap creation is also striving to be cost neutral my recommendation is to through information make it a more common practice within the nature conservation of Sweden.

6. Acknowledgements

I would like to thank my supervisor Joakim Hjältén and my assistant supervisor Ruaridh Hägglund for excellent continuous guidance and feedback!

7. References

Andersson, J., Hjältén, J. & Dynesius, M. (2015). Wood-Inhabiting Beetles in Low Stumps, High Stumps and Logs on Boreal Clear-Cuts: Implications for Dead Wood Management (vol 10, e0118896, 2015). *Plos One,* 10(4).

Annerberg, R., Ericsdotter, S., Bergström, H., Budh, E., Körsén, P. & Palmstierna, A. (2009). *Sweden's Environmental Objectives – New Perspectives (SOU 2009:83)*. Stockholm.

Barto´n, K. (2016). *Package 'MuMIn'*. CRAN.

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R.H.B., Singmann, H., Dai, B., Grothendieck, G. & Green, P. (2016). *Package 'lme4'*. CRAN.

Berg, A., Ehnstrom, B., Gustafsson, L., Hallingbäck, T., Jonsell, M. & Weslien, J. (1994). Threatened plant, animal, and fungus species in Swedish forests - distribution and habitat associations. *Conservation Biology,* 8(3), pp. 718-731.

Bolker, B., Skaug, H., Magnusson, A. & Nielsen, A. (2013). *Getting started with the glmmADMB package*. CRAN.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. & van den Belt, M. (1998). The value of the world's ecosystem services and natural capital (Reprinted from Nature, vol 387, pg 253, 1997). *Ecological Economics,* 25(1), pp. 3-15.

Ericsson, T.S., Berglund, H. & Östlund, L. (2005). History and forest biodiversity of woodland key habitats in south boreal Sweden. *Biological Conservation,* 122(2), pp. 289-303.

Esseen, P.-A., Ehnstr, xf, m, B., Ericson, L., Sj, xf & berg, K. (1997). Boreal Forests. *Ecological Bulletins*(46), pp. 16-47.

Fries, C., Johansson, O., Pettersson, B. & Simonsson, P. (1997). Silvicultural models to maintain and restore natural stand structures in Swedish boreal forests. *Forest Ecology and Management,* 94(1-3), pp. 89-103.

FSC (2013). *FSC®-certifieringens bidrag till biologisk mångfald*.

Groom, M.J., Meffe, G.K. & Carroll, C.R. (2006). *Principles of conservation biology*. 3rd. ed. Sunderland, Mass.: Sinauer Associates.

Hjältén, J., Johansson, T., Alinvi, O., Danell, K., Ball, J.P., Pettersson, R., Gibb, H. & Hilszczanski, J. (2007). The importance of substrate type, shading and scorching for the attractiveness of dead wood to saproxylic beetles. *Basic and Applied Ecology,* 8(4), pp. 364-376.

Hothorn, T., Bretz, F., Westfall, P., Heiberger, R.M., Schuetzenmeister, A. & Scheibe, S. (2016). *Package 'multcomp'.* . CRAN. .

Hägglund, R., Hekkala, A.-M., Hjältén, J. & Tolvanen, A. (2015). Positive effects of ecological restoration on rare and threatened flat bugs (Heteroptera: Aradidae). *Journal of Insect Conservation,* 19(6), pp. 1089-1099.

Jonsell, M. & Weslien, J. (2003). Felled or standing retained wood - it makes a difference for saproxylic beetles. *Forest Ecology and Management,* 175(1-3), pp. 425-435.

Jonsell, M., Weslien, J. & Ehnstrom, B. (1998). Substrate requirements of red-listed saproxylic invertebrates in Sweden. *Biodiversity and Conservation,* 7(6), pp. 749-764.

Larsson, S. & Danell, K. (2001). Science and the management of boreal forest biodiversity. *Scandinavian Journal of Forest Research*, pp. 5-9.

Linder, P., Elfving, B. & Zackrisson, O. (1997). Stand structure and successional trends in virgin boreal forest reserves in Sweden. *Forest Ecology and Management,* 98(1), pp. 17-33.

Linder, P. & Östlund, L. (1998). Structural changes in three mid-boreal Swedish forest landscapes, 1885–1996. *Biological Conservation,* 85(1–2), pp. 9-19.
Lindhe, A., Lindelöw, Å. & Asenblad, N. (2005). Saproxylic beetles in standing dead wood density in relation to substrate sun-exposure and diameter. *Biodiversity and Conservation,* 14(12), pp. 3033-3053.
Niklasson, M. & Nilsson, S.G. (2005). *Skogsdynamik och arters bevarande*: Studentlitteratur AB.
Sandström, J., Bjelke, U., Carlberg, T. & Sundberg, S. (2015). *Tillstånd och trender för arter och deras livsmiljöer – rödlistade arter i Sverige*. (ArtDatabanken Rapporterar, 17).
Skogsutredningen (2004). Mervärdesskog. Del 1. Förslag och ställningstaganden. *Stockholm (Statens offentliga utredningar 2006:81)*.
Skogsvårdslagen (1993). (SFS 1993:553). Stockholm.
Speight, M. (1989). *Saproxylic invertebrates and their conservation*. Council of Europe, Strasbourg.
Zackrisson, O. (1977). Influence of Forest Fires on the North Swedish Boreal Forest. *Oikos,* 29(1), pp. 22-32.

SENASTE UTGIVNA NUMMER

2015:16	Restoration of natural disturbances: impact on distribution and performance of dominant ants (*Formica spp.*) by fire and gap dynamics Författare: Rebecca Larsson
2015:17	Life History Trade-offs in Anadromous Burbot Lota Lota (*Linnaeus 1758*) from Rickleån and Sävarån, Northern Sweden Författare: Mikael Sandberg
2015:18	Laxens uppströmsvandring i den restaurerade och flödesreglerande Umeälvens nedre del Författare: Joakim Johansson
2016:1	Moose (*Alces alces*) browsing patterns in recently planted clear-cut areas in relation to predation risk of the gray wolf (*Canis lupus*) in Sweden Författare: Suzanne van Beeck Calkoen
2016:2	Ecological requirements of the three-toed woodpecker (*Picoides tridactylus L.)* in boreal forests of northern Sweden Författare: Michelle Balasso
2016:3	Species Composition and Age Ratio of Rock Ptarmigan (*Lagopus muta*) and Willow Grouse (*Lagopus lagopus*) Shot or Snared in The County of Västerbotten: Possible Implementations For Grouse Winter Management Författare: Alisa Brandt
2016:4	Prevalence of Puumala virus (PUUV) in bank voles (*Myodes glareolus*) after a major boreal forest fire Författare: Seyed Alireza Nematollahi Mahani
2016:5	Dispersal of young-of-the-year brown trout (*Salmo trutta* L.) from spawning beds - Effects of parental contribution, body length and habitat Författare: Susanna Andersson
2016:6	Intra and interhabitat migration in junvenile brown trout and Atlantic salmon in restored tributaries of the Vindelriver Författare: Matti Erikoinen
2016:7	Skogsarbete i björnområde – en pilotstudie om arbetsmiljöfrågor Författare: Moa Walldén
2016:8	Älgavskjutning och slaktviktsutveckling Malingsbo-Klotenområdet Författare: Sofie Kruse
2016:9	Immediate effects on the beetle community after intensive fertilization in young Norway spruce *(Picea abies)* stands Författare: Martin Johansson
2016:10	Effectiveness of a fish-guiding device for downstream migrating smolts of Atlantic salmon *(Salmo salar L.)* in the River Piteälven, northern Sweden Författare: Linda Vikström

Hela förteckningen på utgivna nummer hittar du på www.slu.se/viltfiskmiljo