Linköping University | Department of Physics, Chemistry and Biology
Type of thesis, 60 hp | Educational Program: Physics, Chemistry and Biology
Spring or Autumn term 2020 | LITH-IFM-A-EX—20/3811--SE

Boxes with artificial habitats support saproxylic beetles in green areas near and within cities

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Division, Department

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Department of Physics, Chemistry and Biology
Linköping University

Datum
Date

Språk
Language

☐ Svenska/Swedish
☒ Engelska/English

☐ _______________

Rapporttyp
Report category

☐ Licentiatavhandling
☒ Examensarbete
☐ C-uppsats
☐ D-uppsats
☐ Övrig rapport

☐ ____________

URL för elektronisk version

ISBN

ISRN: LITH-IFM-A-EX--20/3811--SE

Serietitel och serienummer
Title of series, numbering

ISSN
____

Titel
Title

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Sammanfattning
Abstract

The highest terrestrial biodiversity in Sweden is connected to old grown deciduous trees with tree trunk hollows and dead wood, such as oak and maple. A reduction of deciduous forest and old grown trees from anthropological activities has left many habitats wanting in size and fragmented. Many saproxylic species that are dependent on old grown trees with tree trunk hollows are now threatened. The aim of this study was to further develop artificial habitats (boxes) used for conservation of saproxylic beetles. The boxes were made larger, placed in cities' green areas and filled with produce from the surrounding areas. The study assessed the effectiveness of these boxes, regarding species richness and composition, compared with earlier studies and tree trunk hollows. The study also aimed to assess what variables might affect the species richness and family and species composition. During April to August 2019, 3454 individuals of 105 saproxylic species were collected in 55 boxes. Of the species dependent on tree trunk hollows, 45% were found in the boxes, compared with tree trunk hollows. Of the variables included shading of the box, the amount of buildings surrounding the box and the amount of forest surrounding the box were found to affect species richness. More shading and a larger forest area increased the species richness in the boxes, and a higher concentration of buildings decreased species richness in the boxes. Conclusively, this study showed that boxes placed in cities' green areas could act as an alternative habitat for saproxylic beetles.

Nyckelord
Keyword
Artificial habitats, conservation, saproxylic beetles, tree trunk hollows, wood mould boxes

Contents

1 Abstract

The highest terrestrial biodiversity in Sweden is connected to old grown deciduous trees with tree trunk hollows and dead wood, such as oak and maple. A reduction of deciduous forest and old grown trees from anthropological activities has left many habitats wanting in size and fragmented. Many saproxylic species that are dependent on old grown trees with tree trunk hollows are now threatened. The aim of this study was to further develop artificial habitats (boxes) used for conservation of saproxylic beetles. The boxes were made larger, placed in cities' green areas and filled with produce from the surrounding areas. The study assessed the effectiveness of these boxes, regarding species richness and composition, compared with earlier studies and tree trunk hollows. The study also aimed to assess what variables might affect the species richness and family and species composition. During April to August 2019, 3454 individuals of 105 saproxylic species were collected in 55 boxes. Of the species dependent on tree trunk hollows, 45% were found in the boxes, compared with tree trunk hollows. Of the variables included shading of the box, the amount of buildings surrounding the box and the amount of forest surrounding the box were found to affect species richness. More shading and a larger forest area increased the species richness in the boxes, and a higher concentration of buildings decreased species richness in the boxes. Conclusively, this study showed that boxes placed in cities' green areas could act as an alternative habitat.

Keywords: Artificial habitats, conservation, saproxylic beetles, tree trunk hollows, wood mould boxes

2 Introduction

Biodiversity is the variety of nature types, habitats and organisms that exists in the landscape, for example in old pastures and forests. The highest terrestrial biodiversity in Sweden is found in association with old grown trees, such as oaks, small-leaved lime trees and maple trees, both on the countryside and in the cities (Nilsson et al. 2010). The trees could be the key for survival for many threatened species, but old grown trees are a scarce commodity (Ranius, 2002; Stenbacka, 2009; Bergman et al. 2012). Deciduous trees have during a long time been subject to anthropogenic exploitation (Ranius, 2002; Bergmeier et al. 2010; Bergman et al. 2012). In Europe, old grown deciduous trees were abundant until the late 19th century (Kirby et al. 1995; Jansson et al. 2009a). Since then, there has been a change in land use, where a combination of intense forestry, agriculture, urban expansion and reforestation of old pastures has left the old grown deciduous forests severely lacking in size, abundance and connectivity (Jansson et al. 2009a, 2009b; Bergmeier et al. 2010). In Sweden, about 6% of the total tree volume comprise of deciduous trees. Continuously, less than 1% of the tree volume in Sweden is regarded as old grown trees, where oak comprise about 45% of that volume (SLU, 2017). This creates a great deficiency of habitats for species dependent on deciduous forest and old trees. Additionally, there is an age gap amongst oaks, where there are a lot of younger trees, but not that many middle-aged trees. When the older trees eventually die, there are no trees to take their place, creating an even greater lack of habitats (Ranius, 2002; Höjer et al. 2004; SLU, 2017).

Old grown deciduous trees offer a wide range of microhabitats, including tree trunk hollows, cracks, scars and sun-exposed bark and branches. Tree trunk hollows provide habitats for birds, mammals, and many invertebrates. They also provide refuge from predators and extreme weathers (e.g. heat) (Ranius et al. 2009; Sverdrup-Thygeson et al. 2010; O'Connell and Keppel, 2016). Further, they provide insects and other fauna with a safe environment for their offspring (Ranius et al. 2009; Sverdrup-Thygeson et al. 2010; O'Connell and Keppel, 2016). Tree trunk hollows are created when the tree decays from the inside. This is initiated when various specialist fungi (e.g. *Laetiporus sulphureus* and *Phellinus robustus*), which break down lignin and cellulose, colonize the dead internal woody tissue of the tree. The remaining debris accumulates in the base of the created hollow, where it slowly decomposes with other organic matter (e.g. dead insects and dead leaves), creating a nutritious porous material called wood mould (Jansson et al. 2009b; Ranius et al. 2009).

The wood mould and the tree trunk hollows creates a very specific microhabitat, which has been identified as the most important habitat for an ecological group of beetles called saproxylic beetles (beetles dependent on dead or decaying wood) (Davies et al. 2008; Jansson et al. 2009a; IUCN, 2010; Bergman et al. 2012; Sánchez-Bayo and Wyckhuys, 2019).

Saproxylic beetles play a major role in forest ecosystems, where they pollinate plants and, together with fungi, break down dead wood and contributes to processes of decomposition and recycling of nutrients (IUCN, 2010; Mestre et al. 2018). They are regarded as a highly threatened ecological group in Europe. In Sweden, about 40% of the saproxylic beetles are threatened by extinction, and similar numbers can be seen all through Europe (Djupström, 2010; Irmler et al. 2010; IUCN, 2010). This is a result of the vast loss of old deciduous trees, which is estimated to affect more than half of the saproxylic beetle population (Stenbacka, 2009; IUCN, 2010; Sánchez-Bayo and Wyckhuys, 2019).

In a Swedish study by Jansson et al. (2009a), with an aim to support saproxylic beetles like alleculid beetles (Alleculidae), chafer beetles (Cetonini) and click beetles (Elateridae), artificial habitats were constructed. These artificial habitats consisted of wooden boxes filled with oak sawdust and oak leaves to mimic the habitat in real hollow trees. The boxes were then attached onto big hollow oak trees, about four meters above ground, in an oak landscape. Almost 70 % of the saproxylic beetle species that usually resides in hollow trees were also found in the boxes (Jansson et al. 2009a). The boxes may provide an alternative habitat for tree trunk hollows, which take a long time to develop. They may also be used as steppingstones to facilitate dispersal between different populations (Jansson et al. 2009a).

The aim of this study was to further develop these artificial habitats with bigger boxes, which were placed on the ground in green areas in or near different cities and filled with wood and compost, produced in the maintenance of the green areas. Here the boxes could act as an alternative habitat for tree trunk hollows. In this study, the effectiveness (species richness and number of species dependent on tree trunk hollows) of the bigger boxes was assessed and compared with the study on boxes attached to tree trunks, by Jansson et al. (2009a) and a study of species found in tree trunk hollows, by Ranius and Jansson (2000). Furthermore, to assess what might impact the effectiveness, i.e. species richness and family and species composition, several variables were included in the study.

3 Material and methods

3.1 Study sites

In 2014, 60 boxes (artificial habitats) were deployed in different city parks and green areas near cities. This included regular city parks, with easily accessible areas, nature reserves, and regular forest areas, which were not classed as nature reserves. The boxes were equally divided between the cities of Lund, Göteborg (Gothenburg), Linköping, Motala, Örebro and Uppsala, with ten boxes in each city. Five boxes were not included in this analysis since they were invaded by ants and had large anthills in them. This resulted in a box distribution of eight boxes in Linköping and Motala, nine boxes in Göteborg and ten boxes in Lund, Örebro and Uppsala. All six cities are located in the southern part of Sweden, with Uppsala being the most northern city and Lund the most southern city (Figure 1).

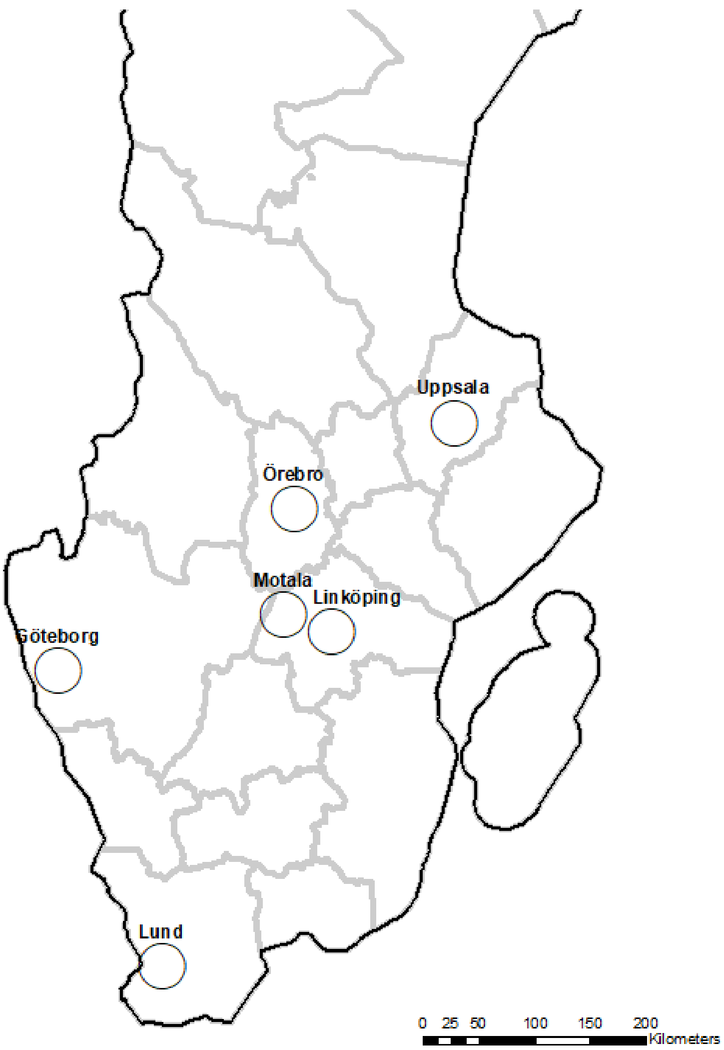

Figure 1. *Overview map of southern part of Sweden and the included cities of this study. Map developed in ArcGis, content from Lantmäteriet (2020-03-19)*

3.2 The boxes

The boxes were designed to resemble conditions of the microclimate inside hollow oak trees and were constructed with 25 mm thick wooden walls and a lid. The box size was 1.0m x 1.0m x 1.0m, with a total volume of 1000 litres. Two holes, with a diameter of about 20mm, were drilled on each side of the box. A cross was milled on the lid, and in each end of the cross a 20mm hole was drilled to let small amount of rainwater enter the box (Figure 2). Each box was filled with 400 litres of leaves from the surrounding area and 400 litres of wood chips (2-5cm in diameter) from deciduous trees. The contents were then soaked with 25 litres of water to benefit decomposition. The bottom of the box was covered with tarpaulin to prevent leakage, keep moisture in the box, and aid the decomposition process.

Figure 2. *Picture of a wooden box with visible, milled cross on the lid and the drilled holes on each side of the box. Image by Caroline Ryding, 2019*

3.3 Collecting invertebrates

To collect invertebrates (e.g. beetles and pseudoscorpions) from the boxes, pitfall-traps were used. The pitfall-traps were plastic jars with a top diameter of 65 mm. The traps were filled to

80 % with preservation fluid. The fluid contained a mixture of 50 % water, 50 % propylene glycol and a few droplets of dish soap to reduce surface tension.
To include different types of microclimate in the study, two pitfall-traps were placed in each box. One was placed in the most humid area and the other was placed in the driest area. This was decided by an ocular assessment of the box. First a hole, fitting the trap (jar), was dug. A cloth was then placed in the hole to keep the sawdust in place, since the material in the box was quite coarse-grained. The jar was placed in the hole. The hole was then filled with sawdust to stabilize the jar and make it more accessible for the smallest invertebrates. Finally, two wooden strips were placed upon the trap to lead the fauna to the jar (Figure 3). The pitfall-traps were first deployed in April 2019. Collection and exchange of traps took place every four weeks, during May, June, July, and August.

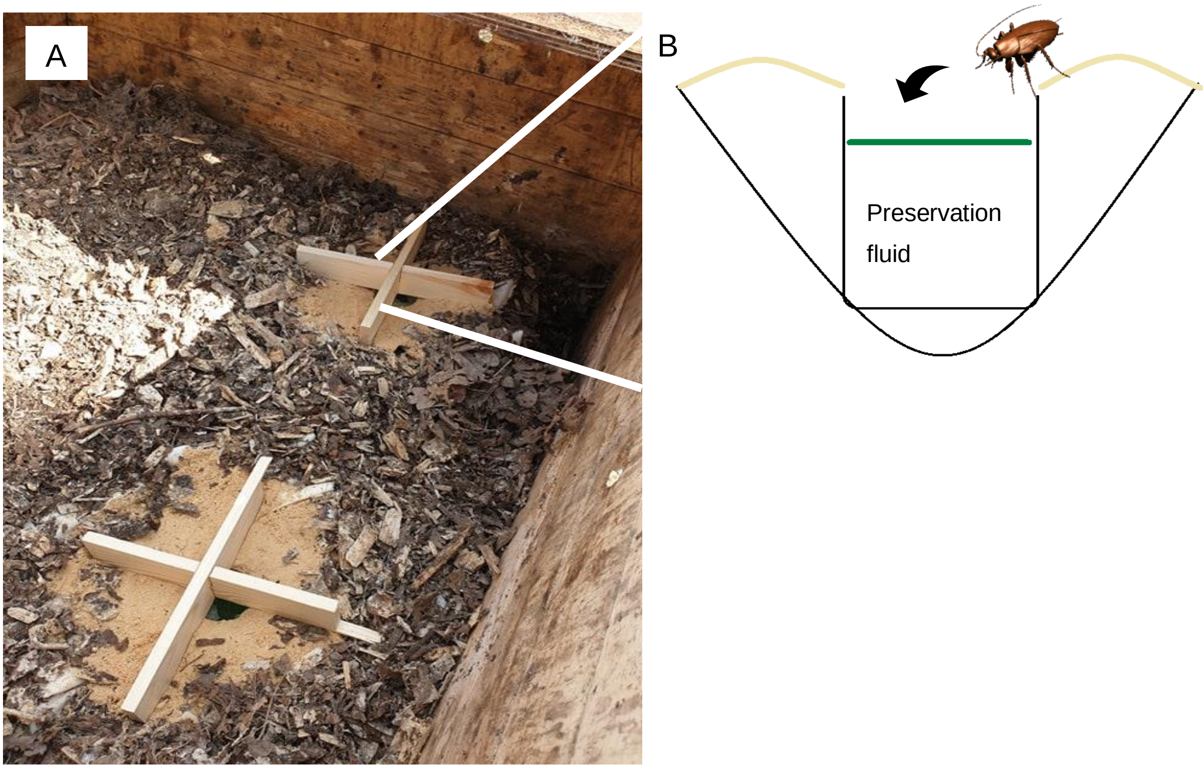

***Figure 3**. The trap construction. A) the traps inside the box, with one trap placed near the most humid area, and the other trap placed in the driest area and B) animation of the trap construction*

3.4 Identification and classification

This study focused on saproxylic beetles, but saproxylic pseudoscorpions were also identified. Saproxylic refers to organisms that are dependent on dead wood or of other dead wood species, such as fungi, in some or most part of their lives. There are obligate saproxylic species, which are species that are completely dependent on dead wood through all their life stages. There are also facultative saproxylic species, which are dependent on dead wood through some of their life stages. Facultative species may also use other habitats, such as compost or piles of leaves (Økland et al. 1996; IUCN, 2010). The beetles were identified by Gunnar Sjödin, and the pseudoscorpions were identified by Stanislav Snäll. The nomenclature was based on information from Dyntaxa (2017). Classification of obligate or facultative saproxylic species were made according to Dodelin et al. (2008).

3.5 Included variables

To assess the effectiveness of the boxes on species richness, several variables were included in this study (Table 1). Three circular zones were set up around the boxes with the radiuses: 2500m, 500m and 100m (mentioned as L, M and S zone in ordination plot). The size of the largest zone was a modified approach, based on result from Jansson et al. (2009a) and Bergman et al. (2012), where few saproxylic beetles colonized boxes that were located farther than 2284m from hollow oaks.

Table 1. *Included variables, their units, and at what scale they have been estimated*

Variable	Unit	Scale
City		
Concentration of buildings around the box	m^2	All zones
Concentration of deciduous forest area around the box	m^2	All zones
Concentration of coniferous forest area around the box	m^2	All zones
Shading of box	*%	Box level
Level of decomposition	**%	Box level
Hollow trees	amount	100m zone
Moisture in box	***Scale of 1-3	Box level

*estimated with 5 different scales, 0-4, where 0% = no shade, 25% = more sun than shade, 50% = equal sun and shade, 75% = more shade than sun, 100% = full shade

** starting content in box (%) – present content (%) = decomposed content (%)

*** 1 = dry, 2 = moist, 3 = wet

The variables buildings (concentration of buildings around the box), coniferous forest area (concentration of coniferous forest area) and deciduous forest area (concentration of deciduous forest area) were estimated with the geographical information program ArcGIS 10.7 (ESRI, 2018). Shading, moisture, decomposition, and hollow trees were all estimated on site. To be able to use all variables in the same analysis, the variables from the smaller zones were subtracted from the larger zones (e.g. the amount of buildings in the medium and small zone was subtracted from the largest zone).

3.6 Data analysis

A comparison between the species found and identified in this study and in Jansson et al. (2009a) and Ranius and Jansson (2000) was conducted. This was, to assess how many species that reside in tree trunk hollows and that also reside in the boxes of this study. The families Nitidulidae, Latrididae, Ptiliidae and most part of Staphylinidae were left out for the comparison since they were left out in the earlier studies as well. An ANOVA test was conducted to compare species richness in the boxes between the cities.

To evaluate the variables' effect on species richness, a linear mixed effects model analysis was conducted in R with the "SADS" package by Prado et al. (2018). This analysis is used on nested data and combines fixed and random effects (see 3.5.1). To assess the variables relationship to the families' and species' composition, a Redundancy analysis (RDA) was conducted from the package "VEGAN" by Oksanen et al. (2019) in R. The RDA extracts the variation of response variables and summarizes it. This way the variation can be explained by a set of independent variables (Ramette, 2007).

3.6.1 Linear mixed effects model

Since the species were collected from the same boxes during different occasions the data was nested. This implies that the data was not independent of each other (Zuur et al. 2009; Delattre et al. 2014; UCLA: Statistical Consulting Group, 2016; Seltman, 2018). To counter this effect, a linear mixed effects model was used.

This type of model works like an extension of linear regression. The model can explain relationship between an independent variable and a response variable despite of the data being nested. This is possible since linear mixed effects model use fixed and random effects. Fixed effects are the factors of interest in a study (Zuur et al. 2009; Delattre et al. 2014). In this study the fixed effects were coniferous/mixed forest area, deciduous forest area, shading, moisture, decomposition, hollow trees and buildings. The random effects are factors whose levels were sampled at random from a larger population, which we wish to generalize from, but whose specific level values are not of interest (Zuur et al. 2009; Seltman, 2018). In this study, "city" was the only random effect since the cities were sampled from all cities in Sweden.

Since the purpose was to interpret each variable's effect on species richness, a maximum likelihood (ML) approached was used for variable estimation. This approach compares different models with the variables, and a model that has a higher likelihood has a lower BIC-value (Bayesian Information Criterion). This results in an initial mixed effects model with a, expectantly, higher BIC-value than the final model. The final model is the one with the lowest BIC-value, and its estimation of the variables is supposed to be more accurate (Zuur et al. 2009; Delattre et al. 2014; UCLA: Statistical Consulting Group, 2016; Seltman, 2018).

In the mixed effect model analysis in this study, the variables coniferous/mixed forest area in the 2500m radius zone and buildings in the 2500m radius zone were highly correlated ($\rho = 0.662$). A correlation in mixed effect models is the expected correlation of the regression coefficients. This could imply multicollinearity, where the variables probably share some overlapping effects. This could lead to misleading or skewed results, and to solve this issue coniferous forest area from the 2500m zone was not included in the analysis.

3.6.2 Ordination

Before conducting RDA, the raw data was modified to exclude very rare species that only occurred in less than three boxes and in a fewer number than five per species. This was a modified approach based on Poos and Jackson (2012), who removed species that occurred in less than 10% of the collected data. Furthermore, to down-weight outliers, $\log_{10}$-transformation was used for the number of species.

One RDA was conducted on species composition and one on family composition. Furthermore, one RDA was conducted with City as the only variable. This was to assess the impact on the communities in response to different locations in the country, disregarding local and regional variations. The RDA plots presented in the result, only show the most significant variables, this was to make the plots easier to interpret.

4 Results

From the boxes, a total of 3659 individual beetles and 172 different species were collected. The species and the individuals were greatly dominated by saproxylic species, with 94% (3454 individuals) of the individuals and 61% (105 species) of the species categorized as saproxylic species (see full saproxylic species list in appendix 1). Of these, 48.6% (51 species), were classified as obligate saproxylic. Five of the saproxylic beetles were red-listed: *Trinodes hirtus, Mycetophagus quadriguttatus, Ptenidium gressneri, Aderus populneus* and *Uloma culinaris* (SLU, 2019). Additionally, two species of pseudoscorpions, *Chernes cimicoides* and *Dinocheirus panzer,* were found in the boxes. They had an abundance of 6 and 253 individuals, and a presence in 5 and 15 of all the boxes, respectively. A total of 27 saproxylic beetle families were found in the boxes (Figure 4). The most species rich family was Staphyhylinidae, with an average of 10.2 species in each city, and the most common family was Latridiidae, with at least one species present in all 55 boxes. The most common species were *Aridius nodifer, Dienerella elongata* and *Epuraea unicolor* with a presence in 46, 34 and 34 boxes, respectively, out of the 55 boxes.

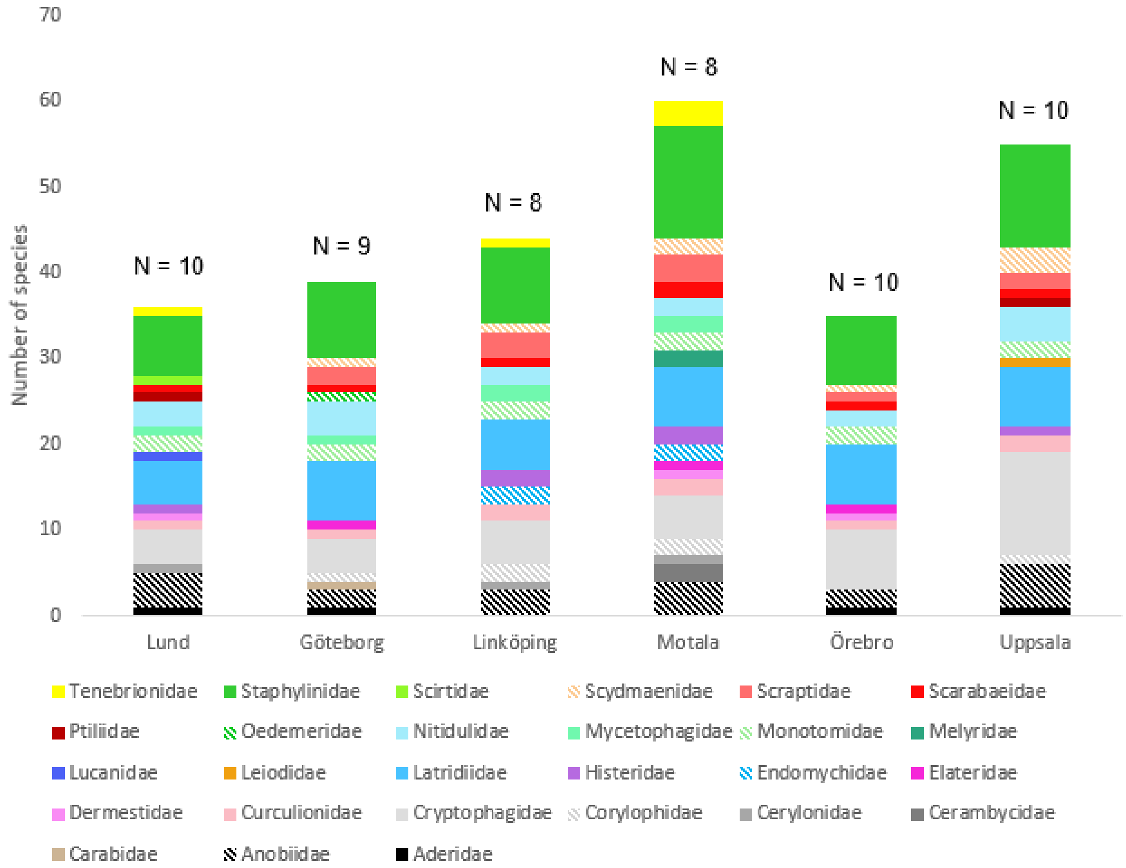

***Figure 4**. The number of species categorized into their respective family in each city. The y axis shows the number of species and the x axis shows the cities included in this study. N = 55*

There was a difference in species richness in the boxes between the cities, where the boxes of Uppsala and Linköping (P = 0.002 and P = 0.014) had a significantly higher species richness per box compared to the boxes in the remaining cities (Figure 5).

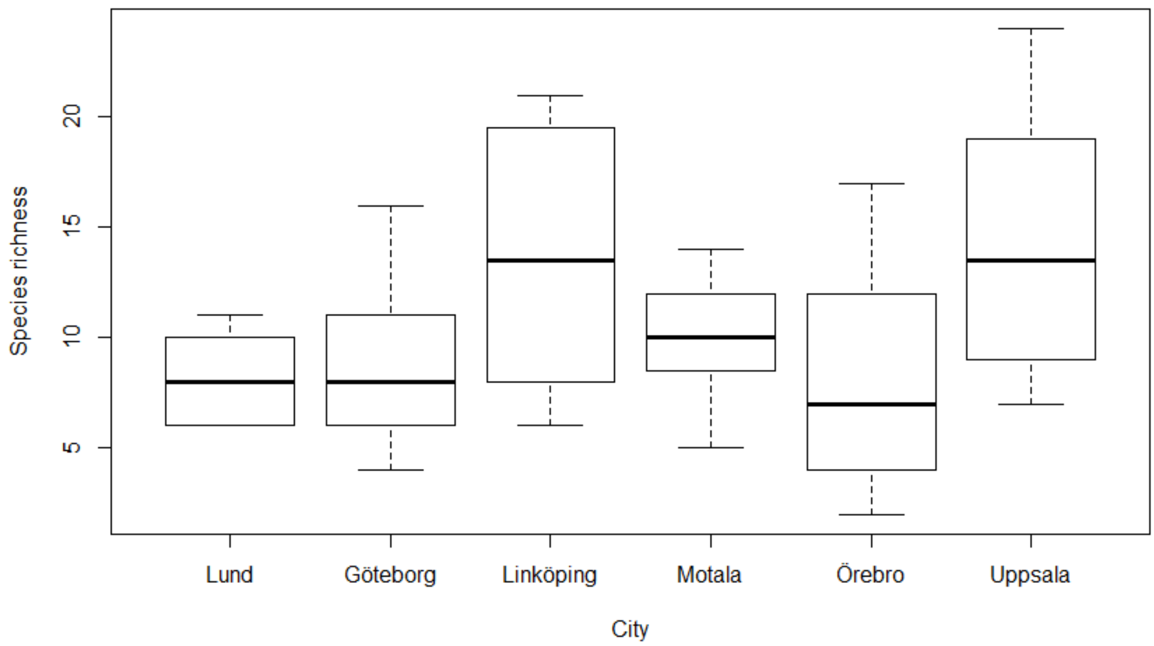

Figure 5*. Species richness of the boxes in the different cities. Median, min, max, ± sd, N = 55, n = 440*

The proportion of species dependent on tree trunk hollows was 35% of the species found in the boxes. Compared to the species found in tree trunk hollows, 45% were also found in the boxes of this study, and compared to the smaller boxes the proportion was 65% (Table 2).

Table 2. *Compilation of identified species concerning saproxylic species that are dependent on tree trunk hollows from the boxes in this study, the boxes from the previous study and tree trunk hollows*

Category	In the boxes from this study (N = 55)	Boxes in Linköping attached to trees (N = 47) (Jansson et al. 2009a)	Natural oak cavities (N = 90) (Ranius and Jansson, 2000)
Total number of beetle individuals in microhabitat categories hollows, rot, and nest	620	1862	2496
Total number of saproxylic beetle species in microhabitat	37	57	82

categories hollows, rot and nest			
Mean number of beetle species in microhabitat categories hollows, nest, and rot	2.8 (SD 1.8)	8.1 (SD 4.0)	9.9 (SD 4.6)
Quantity of saproxylic species in the most species rich box	24	27	
Saproxylic species on Swedish Red list	4	7	15
Pseudoscorpions	2	5	7

4.1 Variables affecting species richness

Results from the linear mixed effects model showed, that the amount of buildings in the 500m zone, shading and forest area in the 100m zone had significant effects on species richness. Shading, coniferous forest area and deciduous forest area all had a positive effect on species richness, where an increased amount of these variables increased species richness (Table 3). The amount of buildings in the 500m zone showed to have a negative effect on species richness.

Table 3. *Linear mixed effects model result of the included variables' effect on species richness, with initial model with a higher BIC-value and the reduced model with a lower BIC-value. The random effect's (City) intercept SD was 3.04 and residual SD was 3.84*

Variables	Coefficient	SE	DF	T-value	P-value
Initial linear mixed effects model (BIC = 556.04)					
Buildings 2500m zone	$-1.7*10^{-7}$	$9.7*10^{-8}$	36	-0.220	0.827
Buildings 500m zone	$-3.7*10^{-5}$	$1.7*10^{-5}$	36	-2.182	0.036*
Buildings 100m zone	$-4.7*10^{-4}$	$4.7*10^{-4}$	36	0.997	0.325
Deciduous forest 2500m zone	$-3.5*10^{-6}$	$2.1*10^{-6}$	36	-1.690	0.100
Deciduous forest 500m zone	$1.2*10^{-5}$	$1.9*10^{-5}$	36	0.642	0.525
Deciduous forest 100m zone	$1.1*10^{-4}$	$1.1*10^{-4}$	36	0.980	0.334
Coniferous forest 100m zone	$2.6*10^{-4}$	$1.1*10^{-4}$	36	2.280	0.029*
Hollow trees	0.043	0.065	36	0.656	0.516

Decomposition	-0.075	0.072	36	-1.043	0.304
Shading	1.053	0.516	36	2.042	0.049*
Moisture	1.277	1.299	36	0.983	0.332
Final linear effects model (BIC = 389.21)					
Buildings 500m zone	$-1.9*10^{-5}$	$1*10^{-5}$	45	-1.921	0.061
Shading	1.001	0.467	45	2.144	0.038 *
Deciduous forest 100m zone	$1.7*10^{-4}$	$7.4*10^{-5}$	45	2.272	0.028 *
Coniferous forest 100m zone	$2*10^{-4}$	$7.8*10^{-5}$	45	2.526	0.015 *

*significant effect on species richness

4.2 Variables affecting family composition

The RDA of the family composition in response to the included variables showed, that the variables explained 44.7% of the total variation of the families' composition. The city variable (P = 0.009) explained about 17% of the total variation. Furthermore, shading (P = 0.010) and coniferous/mixed forest area (P = 0.026) had a significant impact on the families' composition. More shade and a larger area of coniferous forest surrounding the boxes increased the number of species included in the families Latridiidae, Staphylinidae, Cryptophagidae, Monotomidae, Endomychidae and Nitiludiae (Figure 6). Also, most families seemed to avoid boxes with a larger area of buildings surrounding them.

The families Endomychidae, Nitidulidae and Latridiidae had deviating variation from the remaining families. Latridiidae seemed to be more frequent where the boxes were more shaded and had a higher level of moisture. Nitidulidae and Endomychidae also seemed to be influenced by shade and moisture in a positive way. They also, seemed to be positive influenced by a larger amount of coniferous forest area surrounding the boxes.

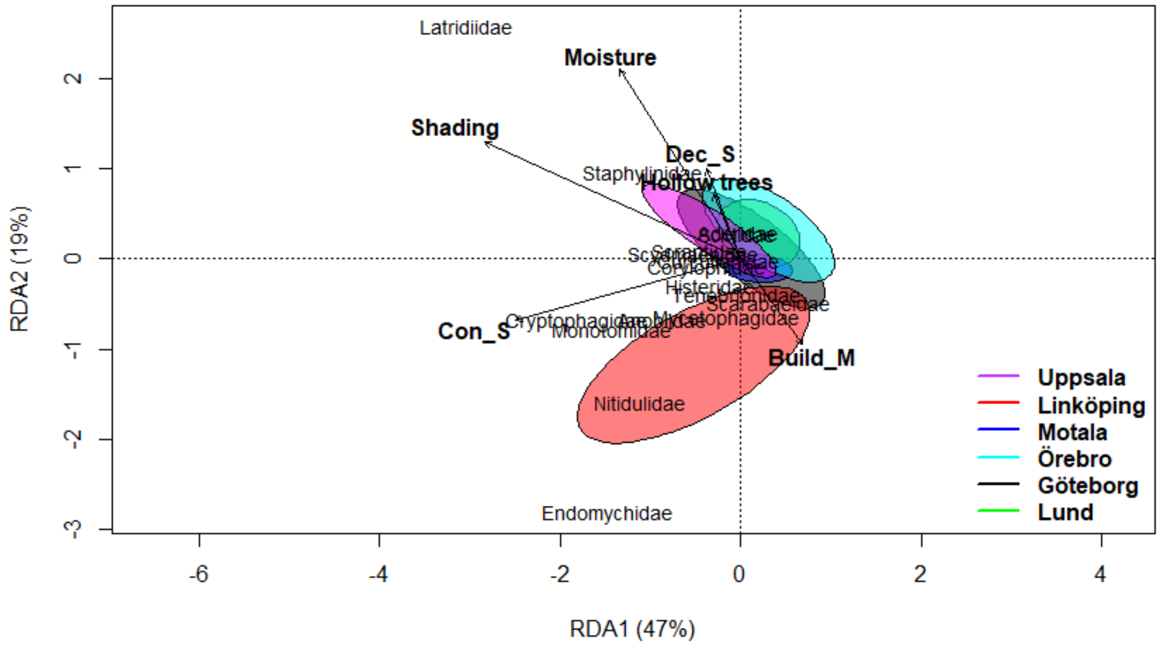

Figure 6. *RDA plot of the family composition in response to the included variables, where RDA1 axis accounted for 21% of the total variation, and RDA2 axis accounted for 8% of the total variation. The values on the RDA1 and RDA 2 axis shown in the plot is the amount of variation explained by the axes on the constrained variation.*

4.3 Variables affecting species composition

The RDA of the included cities showed, that the species composition was similar between the cities Lund, Göteborg, Motala and Örebro (Figure 7). Uppsala and Linköping seemed to have a different species composition, both compared to each other and compared to the remaining cities.

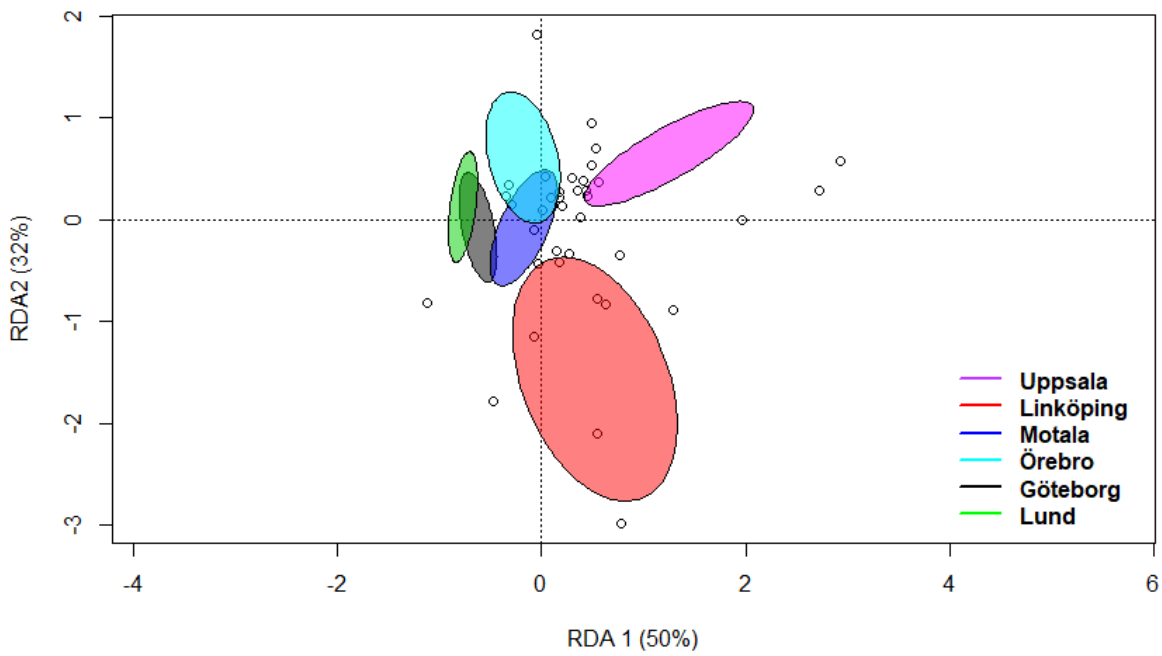

Figure 7. *Visualization of the city effect on species composition, where the colored circles represent the boxes' composition based on species identified in them and the dots are different species. The RDA1 axis accounted for 10% of the total variation, and the RDA2 axis accounted for 6% of the total variation. The values on the RDA1 and RDA 2 axis shown in the plot is the amount of variation explained by the axes on the constrained variation.*

The RDA on the included variables and species composition showed, that the variables explained 48.3% of the variation in species composition. The city variable (P = 0.001) explained 19.6% of the variation in species composition. Moisture (P = 0.037) and shading (P = 0.002) had a significant effect on species composition (Figure 8), where more shade or moisture seemed to increase the number of species in the boxes. Coniferous forest area (P = 0.06) tended to influence species composition in a positive way. Furthermore, boxes with a larger area of buildings around them, tended to have a lower number of species. Also, the species composition had a clear longitudinal gradient, where the composition of species in Lund and Göteborg differed from Uppsala and Linköping.

The species *Latridius minutus, Corticaria longicollis, Epuraea marseuli*, *Aridius nodifer* and *Diernella elongata* all deviated from the other species. The species *D. elongata* seemed to be positively correlated with moisture and shading, where an increase in these variables increased the abundance of the species. The species *L. minutus, C. longicollis, E. marseuli* and *P. fur* all seemed to be positive correlated with coniferous forest area, shading and moisture. Furthermore, *A. nodifer* seemed to have a positive correlation with hollow trees and deciduous forest.

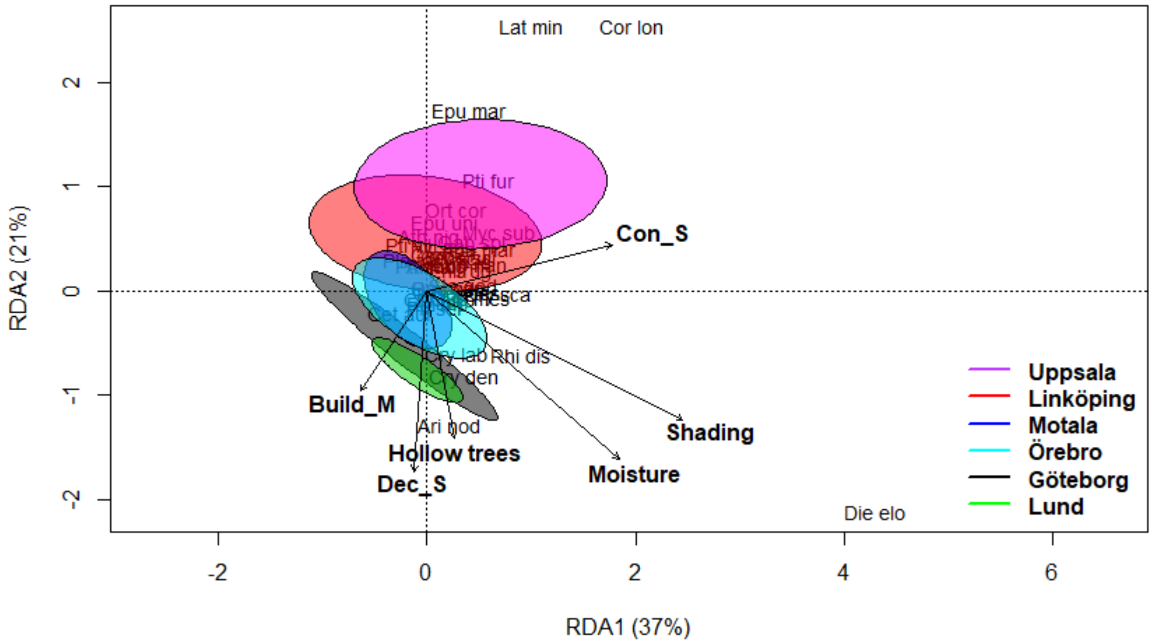

Figure 8*. RDA of the included variables on the species. RDA1 axis accounted for 18% of the total variation, and RDA2 axis accounted for 11% of the total variation. The values on the RDA1 and RDA 2 axis shown in the plot is the amount of variation explained by the axes on the constrained variation.*

5 Discussion

Using boxes as an alternative habitat for saproxylic beetles, in green areas near and within cities, proved to be effective since a much greater proportion (61% of the species and 94% of the individuals were saproxylic) of the beetle species found in the boxes were saproxylic species. The boxes contained five red-listed species, however, in a very low number. But, the presence of them showed that the boxes are in some cases a suitable habitat for these specialists. The most common species found in the boxes were *A. nodifer, D. elongata and E. unicolor*. Both *A. nodifer* and *D. elongata* belong to the family Latridiidae, or commonly known as Minute brown scavenger beetles or Fungus beetles (Robinson, 2005). These beetles feed on spores and hyphae of moulds, fungi, and mildews, and they depend on moisture

(Robinson, 2005). Therefore, one can assume that most boxes were quite moist, at least in some parts of the box, which attracted these species and families.

The difference in species richness between the cities' boxes are an outcome of different regional and local variables. Some of the variables are included in this study, but there could be other variables, e.g. substrate, that could affect species richness in the boxes. Shading had a tendency to increase species richness in the boxes. This is contradicting compared to other studies where more sun-exposed habitats generally hosted a greater species richness (Ranius and Jansson, 2000; Jansson et al. 2009a; Müller et al. 2015). One reason for this contradiction could be that a more shaded box had a higher level of moisture, which several species and families are dependent on. The moisture variable was, however, not significant. This could be because it was estimated and not measured with a proper tool, i.e. moisture meter. As mentioned earlier, the family Latridiidae is dependent on moisture, but the families Endomychidae, Cryptophagidae, Mycetophagidae, Scirtidae and Cerylonidae are also dependent on a moist habitat. Furthermore, if a more sun-exposed box would lead to a drier habitat it could affect larvae negatively. Some larvae require moisture for their growth, since they feed off of fungi hyphae and mould (Punzo, 1975, Robinson 2005). Also, the climate in the shaded boxes might be more stable. Tree trunk hollows provide a very stable microclimate compared to other dead wood habitats, such as logs and stumps (Jansson et al. 2009a). Some species might therefore reside in shadier boxes since the microclimate, e.g. temperature and moisture, might be more stable.

The amount of buildings surrounding the boxes had a negative impact on species richness. Buildings may act as barriers against the beetles, which might hinder the dispersal of species (Fattorini, 2011; Matteson et al. 2013). Also, with a higher concentration of buildings there is going to be a lower area of forest, with more fragmented habitats for beetles. Deichsel (2006) showed, that an increase in habitat fragmentation, as a result of urbanisation, increased the loss of flightless species. Additionally, Mestre et al. (2018) showed, that a more isolated and poorly connected habitat had a lower biodiversity of saproxylic beetles than well connected ones. The negative effect of a larger building area, on saproxylic beetle species, could also be seen in the RDA of species composition. Boxes with a higher concentration of buildings surrounding them had fewer species in them. The RDA also showed that the species composition differed with a clear longitudinal gradient, where, for example, Lund and Uppsala had completely different species composition. This is reasonable, since there is a difference in where species colonize in the country (SLU, 2019). Sobek et al. (2009) showed, that species composition changed based on distance between habitats, which could be explained by an increase in habitat heterogeneity. Thus, the farther apart the habitats (in this case the cities) are from each other, the greater the structural differences are going to be between the habitats.

The comparison of species dependent on tree trunk hollows in this study and species found in oaks by Ranius and Jansson (2000) showed, a 55% lower species richness in the boxes than in tree trunk hollows. This could be compared to the smaller boxes, from Jansson et al. (2009a) study, which had only 30% lower species richness than tree trunk hollows. However, the boxes in this study did have a higher number of, for example, *Cryptophagus badius, C. dentatus* and *C. scanicus* compared to the boxes in Jansson et al. (2009a). Furthermore, *Cryptophagus labilis* and *Melanotus villosus* were absent from the boxes in Jansson et al. (2009a) and at that time *C. labilis* was classed as “Near Threatened” on the red-list, this is not the case anymore. Lund had the most individuals of *C. labilis*. This could be explained by the fact that the tree species *Fagus sp*, which is the tree species that the beetle is mostly found in, is mainly found in the southern parts of Sweden, with a large population in Skåne, where Lund is located. The tree species distribution could also explain the absence of *C.labilis* in Jansson et al. (2009) study, which was conducted in Östergötland.

A reason for the lower species richness of tree trunk hollow dependent species could be the distance from a dispersal source. Jansson et al. (2009a), Bergman et al. (2012) and Ranius et al. (2011) all saw a decrease in species richness as the distance from a dispersal source grew. Jansson et al. (2009a) also discussed, that some species are more likely to colonize when the substrate is older and more decomposed, this could also be a reason for the lower species richness in the boxes of this study. The substrate in the boxes was very coarse-grained, with larger wood fragments, which take longer to decompose and turn in to suitable material for the larvae to feed on. Based on this, suitable substrate for these boxes should be further studied, to determine what substrate is best suited for saproxylic beetle colonization. According to Jansson et al. (2009a), a difference between fungi flora between boxes and tree trunk hollows could also decreased species richness in the boxes. Another reason for the lower species richness could be the height of the box. Ranius (2002) showed, that species richness was greater in tree trunk hollows whose entrances was situated higher up on the tree than compared to the hollows whose entrances were situated lower on the trees.

Nevertheless, one should keep in mind that the boxes are placed in different cities and environments making a comparison like this difficult to interpret. However, there are no other studies to compare the boxes' species richness to species richness in tree trunk hollows. But, these results may give an inkling of the boxes' efficiency as an alternative for species dependent on tree trunk hollows.

5.1 Conclusion

The boxes were effective as an alternative habitat for saproxylic beetles since the boxes were greatly dominated by saproxylic beetles. The boxes contained more species when they were shaded and had a larger forest area surrounding them. Furthermore, the species richness decreased when the concentration of buildings increased, which could imply that buildings act as barriers for species dispersal or take up space and reduce suitable habitat. Species composition is affected by variables as well as the location in the country, and the further away habitats are, the larger the differences are going to be. The lower number of species dependent on tree trunk hollows in the boxes could be affected by numerous reasons and should be studied further. Continuously, despite the lower species richness of tree trunk hollow dependent species in these boxes. They are still an easy and effective way to support saproxylic beetles in green areas near and within cities, since they are filled with produce from the green area and easily managed. And, with some modifications, of placement and substrate, the boxes could be more effective. Lastly, it could be a good idea for cities, in general, to use boxes like these in the surrounding green areas to support the highly threatened saproxylic beetles.

6 Societal and ethical consideration

The purpose of this study was to expand the possible means of saproxylic conservation to green areas and city parks. The collection of fauna in this study always resulted in the organisms dying in the preservation fluid. However, to be able to use these boxes for conservation and to make them more effective this was necessary for the assessment of the boxes. Alternative ways of collecting fauna where the fauna does not die are difficult to conduct, since the fauna is versatile and ranges from flying to crawling species. Therefore, pit-fall traps were needed. Also, since the study was conducted in different cities, and some of the species feed on each other, there was a need for preservation fluid so as many species as possible were collected and preserved. Furthermore, the number of individuals that were not collected far outweighs the number of individuals that did get collected. Lastly, it is important with a well-designed study, where the fauna collection does not need to be redone because of errors in the design.

7 Acknowledgements

This study could not have been conducted without the help of my supervisor Nicklas Jansson. He helped me design this study together with Thomas Ranius. Nicklas also designed the traps and supported me throughout the writing process. A special thank you goes out to Lars Westerberg for helping me with the statistic. Thanks to the cities' municipalities and management of city parks and green spaces for the assistance with construction, placement, and filling of the boxes. Also, a big thank you to Gunnar Sjödin and Stanislav Snäll for species identification.

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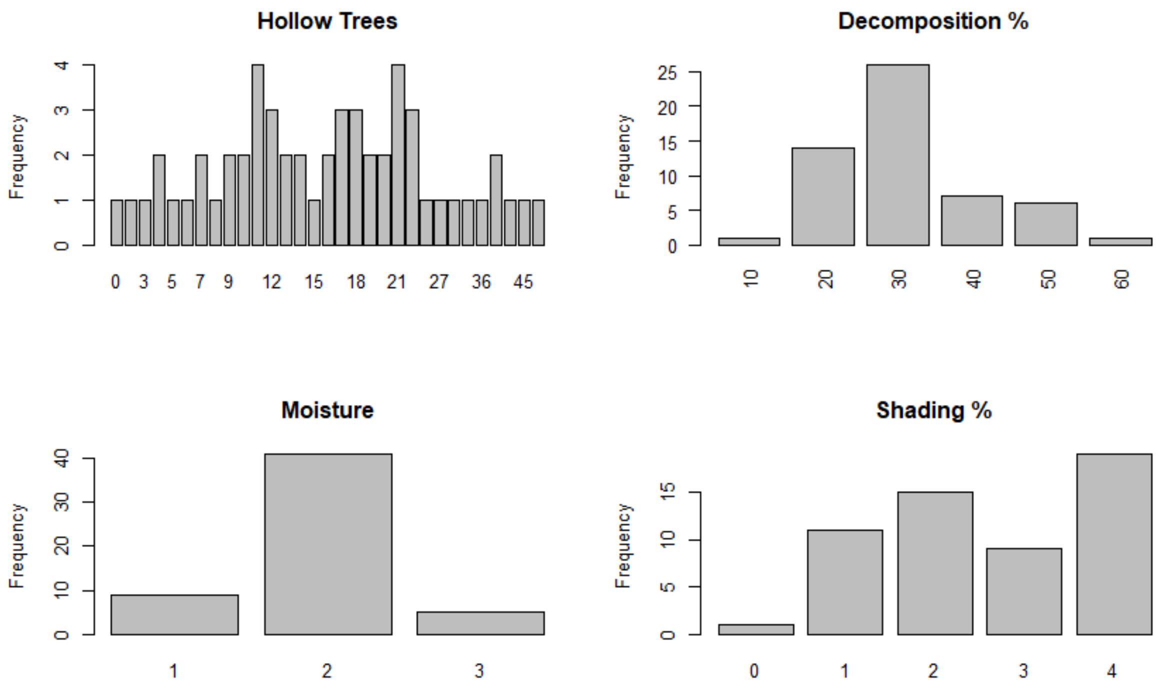
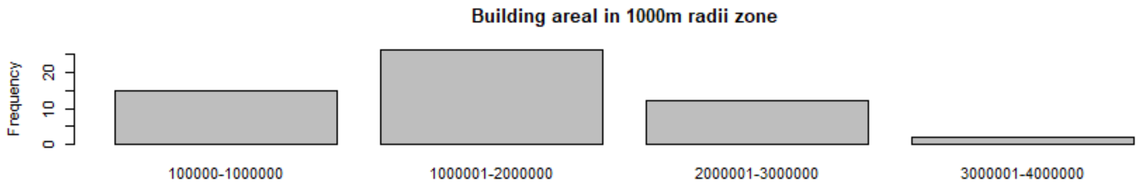
Appendix 1. Species list

Species	RL	Cat	Number of individuals in the boxes	Species	RL	Cat	Number of individuals in the boxes
Abraeus perpusillus		O	1	Glischrochilus quadripunctatus		O	4
Aderus populneus	NT	F	1	Hadrobregmus pertinax		O	7
Alosterna tabacicolor		O	1	Hylobius abietis		O	1
Anaspis marginicollis		O	31	Hylurgops palliatus		O	9
Anaspis rufilabris		O	1	Latridius minutus		F	95
Anaspis thoracica		O	4	Leptusa fumida		O	3
Anidorus nigrinus		O	10	Litargus connexus		O	3
Anisostoma glabra		O	1	Megatoma undata		F	2
Aridius nodifer		F	243	Melanotus castanipes		O	1
Atheta nigricornis		F	93	Melanotus vilosus		O	2
Atomaria bella		O	2	Micrambe abietis		F	1
Atomaria fuscata		F	1	Mycetaea subterranea		F	234
Atomaria morio		F	2	Mycetina cruciata		O	1
Atomaria umbrina		O	1	Mycetophagus quadriguttatus	NT	F	4
Atomaria wollastoni		F	4	Omalium rivulare		F	1
Bajkalicus dispar		O	1	Orthoperus corticalis		O	19
Cartodere constricta		F	1	Orthoperus punctatus		F	1
Cerylon histeroides		O	4	Palorus depressus		F	4
Cetonia aurata		F	27	Paromalus flavicornis		O	3
Chernes cimicoides			6	Phloeocharis subtilissima		O	2
Chrysanthia geniculata		O	1	Phloeonomus pusillus		O	5
Corticaria longicollis		F	228	Phloeonomus sjobergi		O	10
Corticaria rubripes		F	1	Phyllodrepa gracilicornis		F	1
Corticaria serrata		F	27	Pitinus villiger		F	10
Cortinicara gibbosa		F	4	Placusa tachyporoides		O	12
Cryptophagus badius		O	8	Platynus assimilis		F	3

Cryptophagus dentatus	F	90	Prionocyphon serricornis		O	15
Cryptophagus labilis	F	16	Prionychus ater		O	2
Cryptophagus micaceus	O	1	Protaetia marmorata		O	4
Cryptophagus pilosus	F	6	Ptenidium gressneri	NT	O	1
Cryptophagus saginatus	F	11	Pteryx suturalis		O	1
Cryptophagus scanicus	F	96	Ptilinus pectinicornis		O	3
Cryptophagus scutellatus	F	12	Ptinus fur		F	100
Dasytes aeratus	O	2	Ptinus raptor		F	1
Dasytes cyaneus	O	1	Ptinus subpillosus		O	6
Dendrophilus corticalis	F	8	Quedius invreae		F	1
Diaperis boleti	O	1	Quedius maurus		O	1
Dienerella elongata	F	1435	Quedius mesomelinus		F	13
Dinocheirus panzeri		253	Quedius scitus		F	6
Dorcus parallelipipedus	O	1	Quedius xanthopus		F	7
Enicmus rugosus	O	13	Rhizophagus bipustulatus		O	27
Enicmus testaceus	O	2	Rhizophagus dispar		F	75
Epuraea marseuli	O	66	Scraptia fuscula		O	5
Epuraea melanocephala	F	2	Scydmaenus hellwigii		F	3
Epuraea pallescens	O	1	Sepedophilus marshami		F	1
Epuraea unicolor	O	191	Sepedophilus testaceus		F	9
Eupauloecus unicolor	F	1	Stenichmus godarti		O	6
Euplectus bescidicus	O	1	Strictipleura rubra		O	1
Euplectus karstenii	F	1	Trinodes hirtus	NT	O	1
Euplectus mutator	O	5	Uloma culinaris	NT	O	1
Euplectus nanus	F	8	Xestobium rufovillosum		O	1
Euplectus punctatus	O	1	Xyleborinus saxesenii		O	1
Gabrius splendidulus	F	48	Zyras lugens		F	1
Glischrochilus hortensis	F	2				

Appendix 2. Distribution of variables in relationship to the boxes




Building areal in 1000m radii zone
Frequency
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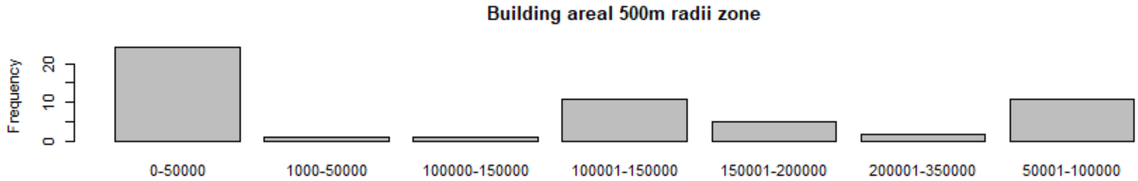
10
20
100000-1000000
1000001-2000000
2000001-3000000
3000001-4000000


Building areal 500m radii zone
Frequency
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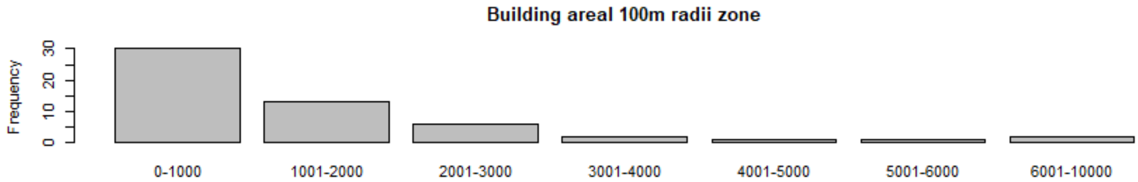
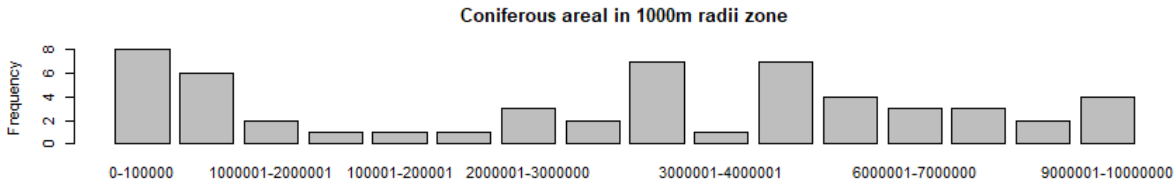
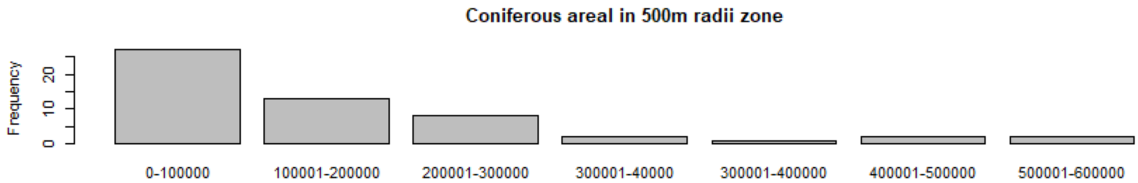
10
20
0-50000
1000-50000
100000-150000
100001-150000
150001-200000
200001-350000
50001-100000


Building areal 100m radii zone
Frequency
0
10
20
30
0-1000
1001-2000
2001-3000
3001-4000
4001-5000
5001-6000
6001-10000


Coniferous areal in 1000m radii zone
Frequency
0
2
4
6
8
0-100000
1000001-2000001
100001-200001
2000001-3000000
3000001-4000001
6000001-7000000
9000001-10000000


Coniferous areal in 500m radii zone
Frequency
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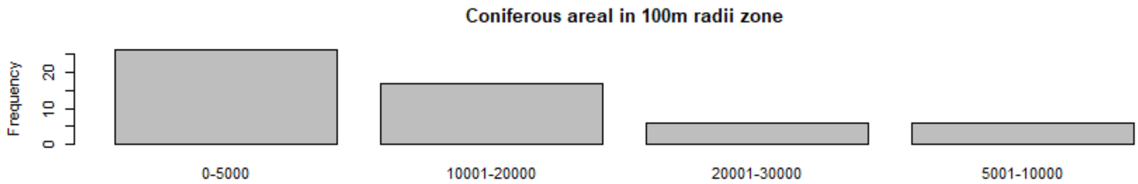
10
20
0-100000
100001-200000
200001-300000
300001-40000
300001-400000
400001-500000
500001-600000


Coniferous areal in 100m radii zone
Frequency
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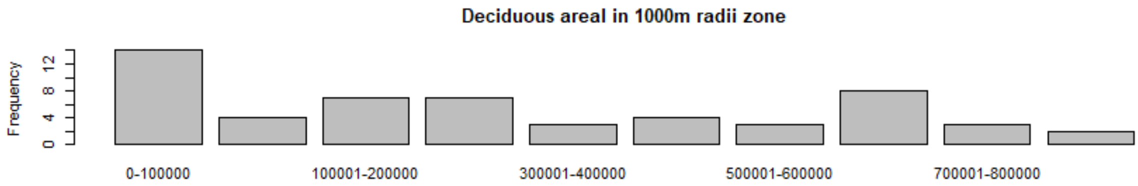
20
0-5000
10001-20000
20001-30000
5001-10000


Deciduous areal in 1000m radii zone
Frequency
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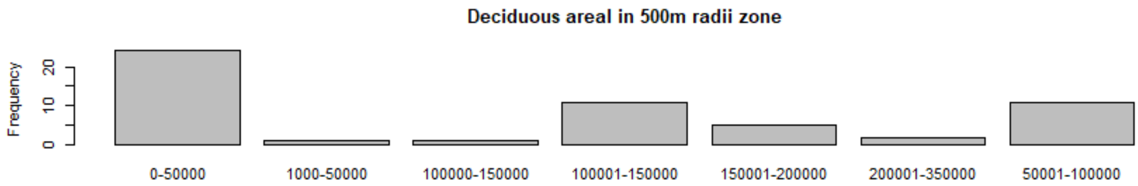
4
8
12
0-100000
100001-200000
300001-400000
500001-600000
700001-800000


Deciduous areal in 500m radii zone
Frequency
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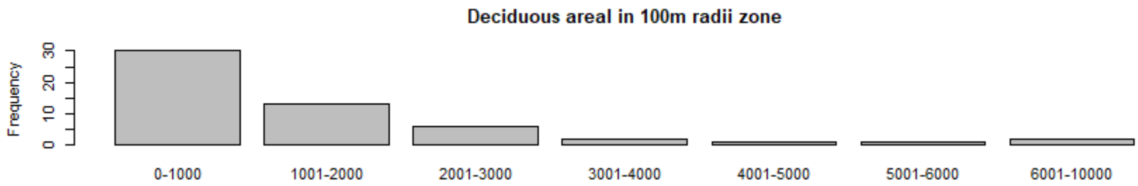
10
20
0-50000
1000-50000
100000-150000
100001-150000
150001-200000
200001-350000
50001-100000


Deciduous areal in 100m radii zone
Frequency
0
10
20
30
0-1000
1001-2000
2001-3000
3001-4000
4001-5000
5001-6000
6001-10000