Preface

This thesis, written at the Department of Ecology and Natural Resource Management (INA) at the Norwegian University of Life Sciences, completes my master degree in Natural resource management. The field work for my thesis was conducted in eastern and southern Norway in 2009, 2010 and 2011 as a project financed by Statnett. This theme was relevant for my study and up to date topic which is educational and interesting to be part of.

I want to thank my supervisor Katrine Eldegard researcher at INA for taking me in on the project, and all the help, ideas and guidelines through the entire process of writing my thesis. Professor Stein Ragnar Moe and Professor Vidar Selås was also a huge help with comments, spelling and ideas on the drafts of the thesis. A thank to Sindre Ligaard for the identification of all the different beetle families and species collected and giving course on how to identify the different beetle species and families.

Then I would like to thank Are Endal Rognes and Dag Slettebø for assistance on the collecting of the field data, sharing a coffee and a good laugh around the fire, and thank to all the assistants that helped on this project.

Ås, May 14th 2012.

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Abstract

Since the start of industrial forestry in the 1700 century Norwegian boreal forests have gone true a dramatic change. Modern forestry practices have made the forests more homogenous, due to clear cutting of old forest, which reduces the number of old and dead trees. Because of a frequent maintenance cutting of trees, power-line corridors may constitute a reservoir of dead wood, litter biomass, enhanced shrub cover and especially in the edge zones also increased grass cover. Question raised in this thesis are as follows: 1) Does the frequent cutting of tree vegetation under the power-line, increase beetle (*Coleoptera*) species richness, biodiversity and species abundance? 2) Is there a difference in species richness, composition, functional feeding groups and biodiversity between the edge and the interior habitat, and if this difference is the same in early i.e. power-line corridor and later successional stages of forest? To capture beetles sweep nets were used on 20 sites in 2009 and 31 other sites in 2010. Within each of the 51 x 20 plots, sweep netting was carried out in a systematic manner so that the whole area was covered once, in five different habitat types A) power-line corridor, B) edge of power–line corridor, C) forest edge, D) forest, distance into forest equal to one half of the corridor width, and E) 100 m into the forest from the corridor/forest edge. In addition, data on field layer vegetation, trees and habitat characteristics were sampled in 2009 and 2010. In 2011, additional data on forest characteristics and habitat characteristics were sampled at the same 51 sites. A total of 3048 individuals belonging to 210 species of 32 beetle families were collected. Main findings where that beetle species composition varied significantly between different habitats. Detritivores where more associated with forest habitats, while herbivores were more associated with early succession habitats. Species richness was higher in the centre of the early succession habitat the power-line corridor than along the edge of the early succession, whereas the forest edge had higher species richness than the forest interior. Early succession stages appeared to be positively affected by the frequent clearing of vegetation, because of increases in the cover of grass, deciduous shrubs and dwarf shrubs. Beetle species diversity was higher in the power-line corridor than in the forest interior. Whereas biodiversity in the forest edge zone was intermediate. The relative proportion of individuals and species within different ecological groups differed among the five different habitats. Interestingly, the herbivore/predator ratio shifted from strong herbivore-bias in the center of the power-line corridor (early successional stage forest) to a strong predator-bias 100 m into the later successional stage forest, with gradual change in the ratio in the plots in between these different habitats. In conclusion, I found that regular maintenance cutting of trees in power-line corridors, with associated changes in field layer vegetation, influenced biological diversity of beetles and may increase biological diversity on a local scale.

Sammendrag

Siden starten av 1700 århundret har det industriale skogbruket i Norge gått igjennom en radikal forandring. Praktisen til det moderne skogbruket har gjort skogene mer homogene, fordi flathogst av gammelskog, har redusert antallet av gamle døde trær. På grunn av kontinuerlig hogst av trær, kan kraftgate korridoren være et reserve for tilgang til død ved, biomasse etter død vegetasjon, mer busk dekke og spesielt i kantsonen økt gress dekke. Spørsmålene stilt i denne oppgaven er som følgende: 1) Gjør den hyppige fjerningen av trevegetasjon under kraftlinja, økning i billenes (Coleoptera) arts rikhet, biologisk mangfold og arts tetthet? 2) Er det en forskjell i billenes artsrikhet, samensetting, næringsgrupper, og biologisk mangfold mellom kanten og skogen, og hvis denne forskjellen er den samme som i tidlig, det vil si kraftgate korridoren og senere suksesjonsstadier av skogen. For å fange billene ble det brukt slaghåv på 20 lokaliteter i 2009 og 31 andre lokaliteter i 2010. Innenfor hver av de 51 x 20 plotene, ble slaghåven brukt på en systematisk måte slik at hele området ble gått igjennom en gang, i de fem forskjellige habitat typene A) korridor under kraftledningen, B) kanten til korridoren under kraftledning, C) kanten til skogen, D) skogen, som har distansen inn i skogen lik en halv av korridorens bredde, og E) 100 m inn i skogen fra korridoren/kanten til skogen. I tillegg, ble data av feltsjiktets vegetasjon, trær og habitat karrekteristisk, samlett inn i 2009 og 2010. I 2011, ble ytterlige data av skogens karrekteristisk og habitat karrekteristisk samlet inn i de 51 lokalitetene. Tilssammen ble det fanget 3048 individer tilhørende til 210 arter av 32 bille familier. Hovedfunnene var at billenes arts samensetning var signifikant forskjellig mellom de forskjellige habitatene. Nedbrytere var mer assosiert med skogen, mens plantespiserne var mer assosiert med de tidlige suksesjons habitatene. Artsrikheten var høyere i senter av den tidelige suksesjons habitatet i kraftgate korridoren, enn langs kanten til den tidelige sukksesjonsfasen, mens kanten til skogen hadde større artsrikhet enn skogen. De tidelige suksesjonsstadiene ser ut til å være positivt påvirket av den hyppige ryddingen av vegetatsjon, på grunn av det økte dekket av gress, lyng og løvbusker. Bille artsmangfoldet var størst i kraftgate korridoren, enn i skogen. Mens det biologiske mangfoldet i kanten til skogen var middels. Den relative andelen av individ og arter innenfor forskjellige økologiske grupper var forskjellige mellom de fem habitatene. Interesangt var det at forholdet mellom plantespiserne og predatorene forandret seg fra sterkt plantespisende-fordeling i kraftgate korridoren (tidlig suksesjons skog) til en sterk predator-fordeling 100 m inn i den senere suksesjons skogen, med gradvis forandring i fordelingen i plottene mellom de forskjellige habitatene. I konklusjon, fant jeg at hyppig hogst av trærne i kraftgate korridoren, med assosiert forandringer i feltsjiktets vegetasjon, påvirket det biologiske mangfoldet av biller og kan øke det biologiske mangfoldet på en lokal skala.

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1. Introduction

The boreal conifer forest is rather homogenous, due to the low number of tree species. A few species dominate the field layer, mainly dwarf shrubs and small tree saplings (Esseen et al. 1997). However, natural disturbances such as wildfires and storms create a dynamic mosaic of different successional stages, which is important to species dependent on environmental heterogeneity (White 1979; Esseen et al. 1997; Buddle et al. 2006). Since industrial forestry was introduced in the early 1700s, Norwegian forests have gone through a radical structural change, resulting in increased fragmentation of old forest stands (Esseen et al. 1997) few old trees and low availability of dead wood (Hansson 1992). Today, the human impact on the forests is visible almost everywhere (Hansson 1992). These transformations have in particularly affected invertebrates that need coarse woody debris and old growth forests (Niemelä 1997), but there will usually also be a low shrub density in production forests (Esseen et al. 1997).

Because of frequent clearing of trees, power-line corridors may constitute a reservoir of dead wood production, enhanced shrub cover (King & Byers 2002) and especially in the edges also increased grass cover (Magura 2002). Early successional forests under power-lines are more frequently disturbed than those in production forests (Luken et al. 1992). In order to avoid trees from reaching the lines, all trees in the power-line corridors are cut down frequently, whereas at least selected trees in the production forest can grow freely until they reach the age of maturity (Luken et al. 1992; Esseen et al. 1997). Here, I use the definition of disturbance given by (Dornelas et al. 2011): "Disturbance is considering both anthropogenic and natural, and there is no classification whether the disturbance is good or bad for biodiversity, and focus merely on measuring their effects". The nonequilibrium hypothesis says that the highest diversity is obtained with intermediate frequencies of disturbance, with low diversity at both very high and very low frequencies of disturbance (Connell 1978; Huston 1994). Periodical disturbance can enhance biodiversity, because of more release of nutrients (Holt 2008) and reduced competition exclusions (Menge & Sutherland 1987). It can also explain a coexistence of species with different adaptations, that live in the same ecosystem (Connell 1978).

Power-line corridors are characterized by a high proportion of forest edges. Small and patchy diversity can enhance regional biodiversity (Huston 1994). In this study, I am going to study the effect of a two-sided edge response, i.e., both in the early succession forest in the power-line corridor and in the adjacent forest interior (Fonseca & Joner 2007), and I define edge as the boundary separating the early succession forest under the power-line from the forest interior (Cadenasso et al. 2003; Ries et al. 2004). The forest edge is dynamic, because damages caused by wind and other processes increase tree mortality (Heliölä et al. 2001; Ewers & Didham 2008). Species respond differently to the edge depending on how sensitive they are to edge effects (Ries & Sisk 2010). Early succession species and forest interior species have different sensitivity to the forest edge (Koivula et al. 2004). Ries et al. (2004) explained four fundamental mechanisms that may explain the sensitivity for beetle (*Colepotera*) species to edge effects: (1) ecological flows, i.e. movement of materials, energy and organisms through the edge (Wiens et al. 1985; Cadenasso et al. 2003), (2) access to spatially separated resources i.e. resources are different in the two patches and the edge (McCollin 1998; Fagan et al. 1999), (3) resource mapping, i.e. resource distribution change closer to the edge and species changes thereafter (Ries et al. 2004), and (4) species interactions, such as predation avoidance and predation dynamics (Ries et al. 2004). Therefore the edges can be beneficial for some species and represent barriers to others (Lidicker 1999).

Among invertebrates, beetles are especially well suited for studies of biodiversity, because of the large number of species and broad range in adaptations with regard to habitats and trophic levels (Stork 1988; Pearson & Cassola 1992; Allison et al. 1993). Previous studies have found that beetle species richness is lower in continuous forests than in clearcuts, because of increased number of early successional species occupying open habitats (Halme & Niemelä 1993; Heliölä et al. 2001). However, some species are positively influenced by the extent of canopy closure (Magura 2002). Beetles that primary feeds on fungi and dead wood have highest abundance in the forest interior (Bruns 1984; Similä et al. 2003), whereas herbivores have highest abundance in the matrix and declines towards the forest edge (Ewers & Didham 2008). Since predators are not directly associated with plants, the diversity of herbivore beetles is often high in open habitats due to the combination of much food and low predation risk (Halme & Niemelä 1993). Sparse ground vegetation will reduce the invertebrate prey for predators, such as carabids (Niemelä et al. 2007). Beetle species that have a low natural abundance and are specialists are vulnerable for extinction in disturbed patches (Davies et al. 2004). In general, non-flying beetles

are less associated with disturbed patches, since they are less mobile than are flying beetles (Driscoll & Weir 2005; Wimp et al. 2011). Many beetle species respond positively to habitat edges (Ewers & Didham 2008), but specialized herbivores that do not use any complementary resources have been found to decline towards the edge (Wimp et al. 2011).

In this study, the main research question was if biological diversity of beetles captured in the field layer vegetation was influenced by ecological disturbances caused by repeated cutting of trees in power-line corridors, and creation of edge habitats. Beetles were sampled in plots located in five different habitats in a gradient ranging from the center of the power-line corridors, via both sides of the edge between power-line corridors and forests, to one-half corridor-width into the forest, and finally to 100 m into the forest interior. More specifically, I investigated if these five habitats differed with respect to species composition, species richness, biodiversity, species abundance distributions and functional diversity. I also investigated potential edge effects 1) by comparing the difference in species richness between edge plots and plots located in the 'main habitat' for both the two main habitat types, i.e. respectively power-line corridor and forest, and 2) by comparing edge plots located in respectively power-line corridors and forest. Because creation of power-line corridors represent a substantial habitat change, from closed-canopy forest to relatively open and sun-exposed habitats with a regular supply of new biomass through maintenance clearing, I predicted a significant change in species composition and functional diversity, with a higher relative proportion of herbivores in the power-line corridors. Based on previous studies, I also predict that species richness and biodiversity would be higher in the centre power-line corridors than in the forest interior (Halme & Niemelä 1993; Heliölä et al. 2001). Whereas for the possible edge effect, I predict based on previous studies that the proportions of herbivores declines towards the edges from the center of the early succession habitat, and the proportions of predators declines towards the edges from the forest interior (Hunter 2002; Elek & Lövei 2007; Ewers & Didham 2008). I also predict that the species richness is higher in the forest edge than the edge to the power-line corridor. Based on previous studies that open habitat species and forest interior species moves to the forest edge and increases the species richness in the forest edge (Magura et al. 2001; Baker et al. 2007; Roume et al. 2011).

2. Materials and methods

2.1 Study area

The study was carried out in southeastern Norway in the counties Akershus, Aust-Agder, Buskerud, Hedmark, Oppland, Oslo, Telemark, Vestfold and Østfold. The different sites are located between latitudes 58° and 61°, longitudes 8° and 11°, and at altitudes of 25 to 1055 meter above sea level. The different sites were chosen by placing 84 crosses, evenly distributed, over a coarse-grained overview map of Statnett's power-line network. Out of the 84 crosses, 51 were randomly chosen by drawing lots. At every site there was a power-line crossing and there was either conifer or/and leaf forest, on both sides of the power-line. At each site, the forested area adjacent to the power-line was at least 200 m wide, perpendicular from the power-line (Figure 1).
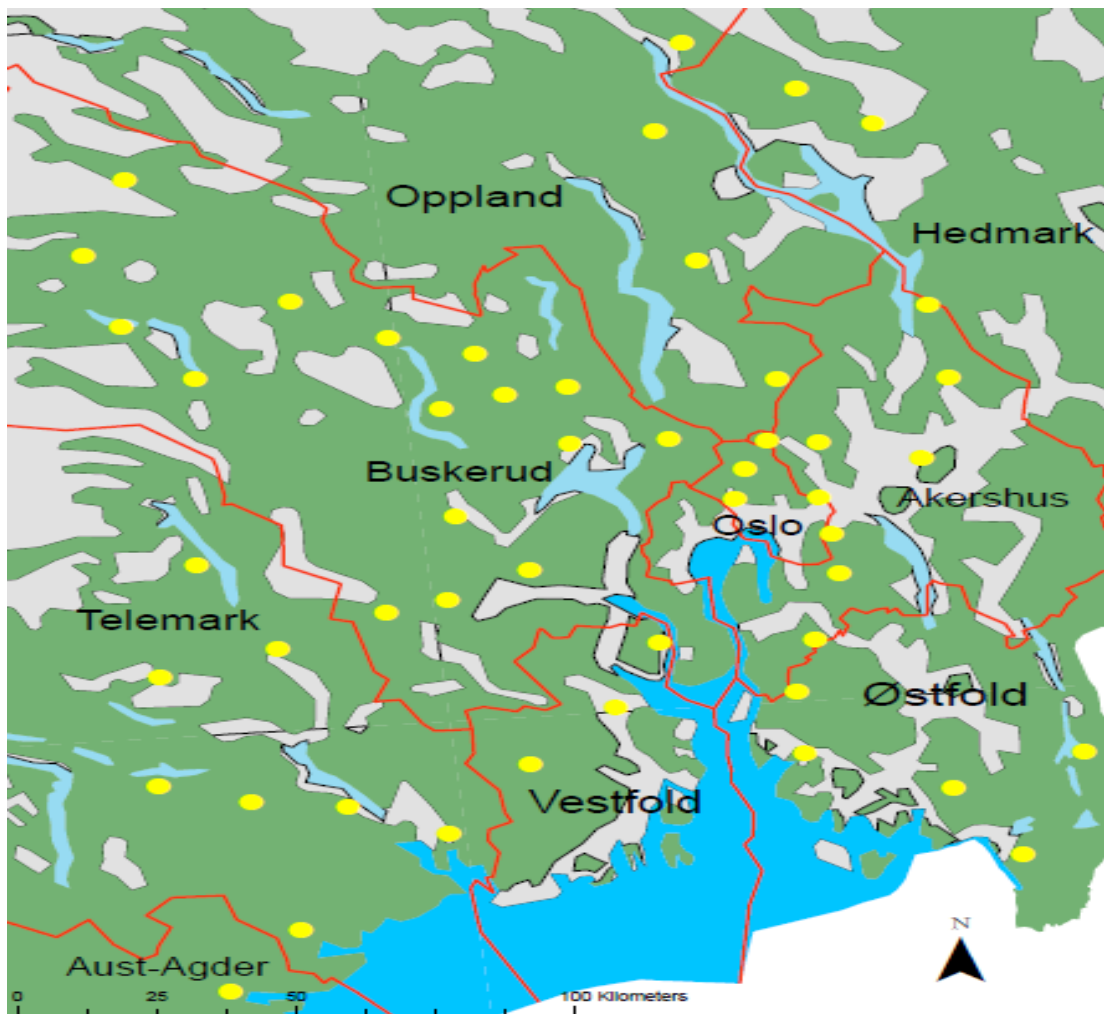

Figure 1 The nine counties that the data was collected from. A yellow circle shows the location of one site, a total of 51 sites (map data: Kartverket (2012)).

2.2 Study design - Terminology

Each of the 51 study sites consisted of areas that contained 20 plots (4 m x 5 m rectangles) in the forest and in the power-line corridor (Figure 2). Four plots were placed in each of the following five habitats: A) power-line corridor, B) edge of power–line corridor, C) forest edge, D) forest, distance into forest equal to one half of the corridor width, and E) 100 m into the forest from the corridor/forest edge. Every plot was GPS marked in the southwestern corner of each subplot 1 (Figure 2) by use of a hand-held GPS (Garmin CSx60, datum WGS84, UTM32).
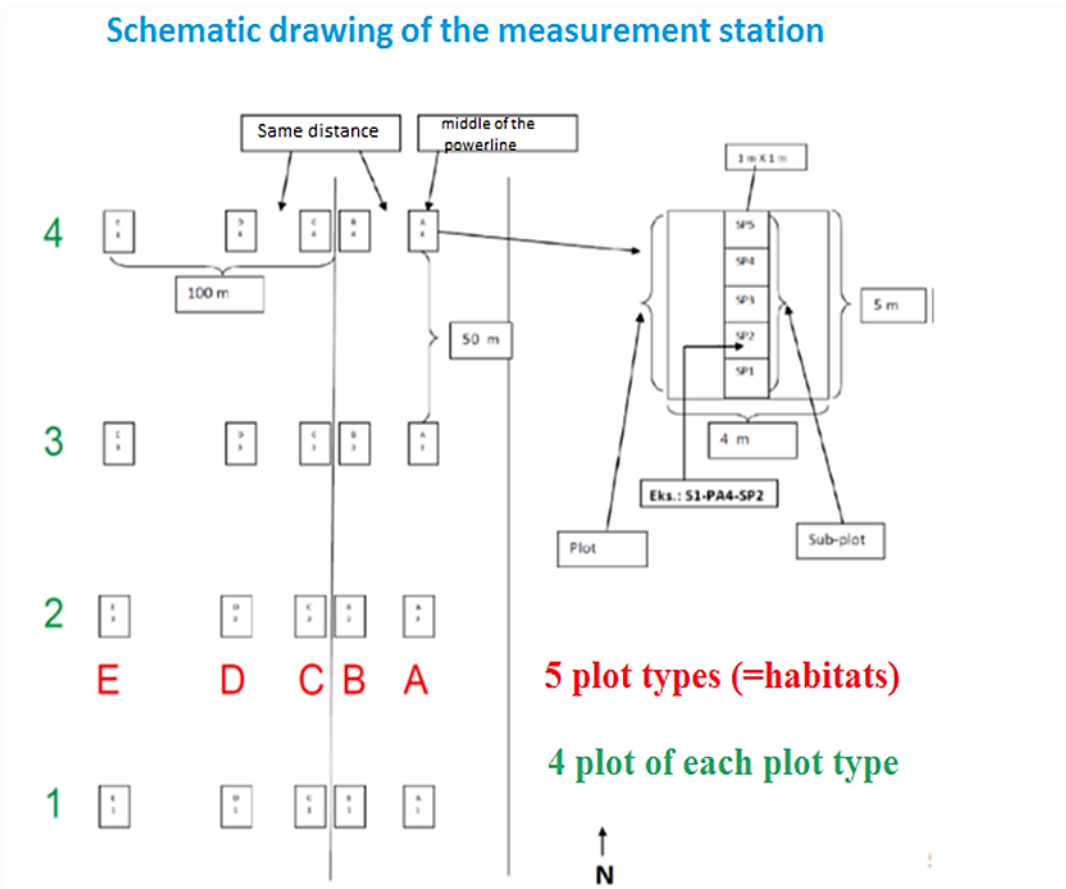

Figure 2 Schematic illustration of a site. Each site had five plot types of habitats: in the center of the power-line (A), edge of the early succession stage (B), edge of the forest interior (C), forest plots (D) and 100 m into the forest from the corridor/forest edge (E). There were four plots (replicates) of each plot type. The plots were arranged in a regular pattern: Plots A1-A4 was placed along the center line of the power-line corridor, with a distance of 50 m between each plot. Plots B1-B4 were placed within the power-line, along the forest edge. Plots C1-C4 were placed along the forest edge. Plots D1-D4 were placed within the forest, at a distance equal to the distance between plots of type A and B (i.e., one half of the corridor width). Plots E1-E4 were placed in the forest 100 m from the edge between the power-line corridor and the forest. Herbs, grass, deciduous shrub and dwarf shrubs were collected in five subplots (1 m x 1m squares), placed along the center line of the 4 x 5 m plot.

2.3 Field work – collection of beetles

Beetles were sampled at 20 sites in 2009 and at 31 other sites in 2010. Within each of the 51 x 20 plots, sweep netting was carried out in a systematic manner so that the whole area was covered once. All invertebrates captured were transferred to a container and covered with a 70-80% ethanol solution. Site number, plot number date, year and the signature of the collector was noted with pencil on a piece of paper placed inside the container along with the collected material.

2.4 Lab work – sorting, species identification and categorization of beetles

In the lab, beetles were sorted out from each individual sample. Thereafter, the beetle material was handed over to a taxonomist and beetle expert (Sindre Ligaard), who carried out species identification (Silfverberg 2004). Each species found in the collected material was also assigned by the expert to one of the following categories (Appendix 1), according to its primary ecological function: DE (general detritivore), FU (fungivore), HB (herbivore), PR (predator), and DW (dead wood feeder).

2.5 Field work environmental data: vegetation and habitat characteristics

In 2009 and 2010, data on field layer vegetation (percentage cover of each species of vascular plant), was sampled in subplots, whereas trees and habitat characteristics were sampled at plot level. In 2011, additional data on forest characteristics (vegetation type, site index, development class and forest edge type) and habitat characteristics (slope and aspects of individual plots) were sampled at plot level.

Forest registrations were conducted on each site, and each plot was marked with a GPS. All trees > 5 cm diameter breast heights were identified to species. In addition, development class, soil debt, terrain determination, edge type and exposition were registered. Slope was measured at the steepest point within each plot. A SUUNTO clinometer was used to find the gradient. A compass was used to determine the aspect of the slope. Soil depth was determined on a 100 m^2 surface (radius 5.64 m). It was conducted by putting a premeasured marking stick in the ground. It was registered in two classes: 0) soil depth < 30 cm and 1) soil depth > 30 cm. Edge between forest and power-line was registered in three classes: sharp, intermediate and gradual. Terrain slope

was also determined on a 100 m^2 (radius 5.64 m), and it was registered either of two classes: 0) slope ≤ 5 degrees, 1) slope > 5 degrees.

A vegetation site index was defined based on dominating tree species, vegetation type, soil depth, terrain slope, height above sea level, and northern latitude. The vegetation type that dominated on an area of 100 m^2 (radius 5.64 m) was classified after these codes (Fremstad 1998):

A1 – Lichen woodland

A2 – Cowberry – bilberry woodland

A3 – Heather – bog bilberry woodland

A4 – Bilberry woodland

A5 – Small – fern woodland

B1 – Low – herb woodland

C1 – Tall – fern woodland

C2 – Tall – herb, downy birch and Norway spruce forest

2.6 Statistics analyses

The total dataset amounted to 51 (sites) x 20 (plots), i.e. 1020 plots, minus 8 plots with missing data. All statistical analyses were conducted by using the statistic softwares SAS/STAT® 9.2 (SAS Institute 2008) and R 2.14.1 (R Development Core Team 2011). Packages used in R was biodiversity R (Kindt & Coe 2005) and vegan (Oksanen et al. 2011).

2.6.1 Differences in species composition

Canonical Correspondence Analysis (CCA) and Monte-Carlo permutation tests were used to determine if the variation related to the categorical variables site (51 levels = sites) and habitat (five levels; A) power-line corridor, B) edge of power–line corridor, C) forest edge, D) forest, distance into forest equal to one half of the corridor width, and E) 100 m into the forest from the corridor/forest edge), were larger than a random variable. In order to find significant additional variation explained by habitat after the variation related to site had been explained, a partial constrained ordination was performed. First the variation related to site, and then the residual variation related to habitat was determined. Because many of the 4 m x 5 m plots had zeros individuals captured, data from all four plots within each habitat and site were pooled, yielding one data row per habitat per site in the species matrix. Before fitting the CCA, all species with ≤ three individuals were excluded, and thus 58 species were included in the CCA. In addition seven data rows without any individuals i.e., row sum = 0 were excluded before fitting the CCA. The species data were square root transformed to down weigh the influence of highly abundant species.

2.6.2 Differences in species richness

Differences between habitats were investigated by use of species accumulation curves: A species accumulation curve is a plot of the cumulative number species of discovered in the different sites, as a function of the effort to collect the data. In this case 51 sites, each with five habitat types, and four plots in each habitat equal 204 pooled plots in each habitat type (i.e. equal sampling effort in each habitat type). The sample order was randomized (McGill 2010). However, as there was substantial among-site variation in species richness (Appendix 5), species richness was also analyzed by generalized mixed models with species richness as response variable, habitat (five levels: A) power-line corridor, B) edge of power–line corridor, C) forest edge, D) forest, distance into forest equal to one half of the corridor width, and E) 100 m into the

forest from the corridor/forest edge) as fixed effect explanatory variable, and site as a random effect. The species richness data were counts (number of species), and therefore we fitted a model with log link function, Poisson distribution, and Gauss-Herimite Quadrature (GHQ) technique for parameter estimation (Bolker et al. 2009). Inspection of the graphical diagnostics and the Pearson Chi-Square/df value revealed that this model provided a good fit to the data.

In addition to the fixed effect habitat, I explored potential influence of other environmental variables measured at the site or plot level. First, I fitted a model for each environmental variable separately, and site as random effect. The following environmental variables measured on the site level were tested: elevation, width of power-line corridor, age of power-line corridor (number of years since establishment), sharpness of the edge (sharp, intermediate, and gradual) and aspect of the edge (N, S, E, and W). In addition, as the beetles were collected in the field layer vegetation, we tested the field layer environmental variables measured at the plot level, that is, percentage cover of 1) deciduous shrubs, 2) grass, 3) dwarf shrubs, 4) herbs, 5) soil, 6) stones and 7) bryophytes. Only environmental variables for which $p<0.10$ when tested individually were included in the global (most complex) statistical model. In addition to habitat, only grass cover, herb cover, dwarf shrubs cover and deciduous shrubs cover had $p<0.10$. Pairwise correlation tests between these field layer variables revealed that they were not substantially correlated ($p<0.5$), and thus they were included in the same model. After fitting the full model, model selection was performed by backward elimination, i.e. by sequentially removing terms with the highest p-value, and removing interaction terms before main effects. We provided Wald F tests of fixed effects, and likelihood ratio (LR) tests of random effects for the model best supported by the data.

2.6.3 Differences in biodiversity

The Renyi diversity profiles were used to compare different habitats with respect to biodiversity. If the calculated Renyi profiles of different habitats do not intersect at any point, they can be used to rank habitats with respect to biodiversity (Kindt & Coe 2005). The profile value (Hα) on the x-axis, shows the component species and a scale parameter (α) ranging from zero to infinity (Kindt et al. 2006; R Development Core Team 2011). The x-axis value 0, 1, 2 and infinitive are related to species richness S, the Shannon diversity index H, the Simpson diversity index D^{-1} and the Berger-Parker diversity index d^{-1} (Kindt et al. 2006).

As for species richness, there was considerable among-sites variation in biodiversity, but because the number of species and individuals were zero in a large number of the plots, a very large proportions of the biodiversity index values calculated was either '0' or '1', and no analyses at the plot-level resolution, with 'site' as random effect, could be carried out. Thus, biodiversity was only investigated by inspection of Renyi profiles with aggregated data over all 51 sites.

2.6.4 Differences in species abundance distributions

The empirical cumulative distribution function (ECDF) was plotted to compare the species abundance distribution of the five habitats types (McGill et al. 2007; Magurran et al. 2011). The ECDF plots were calculated from the collected data. A Kolmogorov-Smirnov test was used to test if the distributions differed among habitats (Lilliefors 1967).

2.6.5 Changes in functional diversity

The number of individuals and number of species within each functional group were counts and generalized linear mixed models (GLMMs) for analyses of the functional groups data, following procedures recommended by Bolker et al. (2009) were used. First, a full (most complex) model including the fixed effects habitat, functional group, and the interaction habitat × functional group was fitted. The interaction term was included because the purpose was to find out whether there was a difference between habitats with respect to the relative number of individuals and species in each functional group. Site was modeled as random effect. Initially, a model with log link function, Poisson distribution, and Gauss-Hermite Quadrature (GHQ) technique for GLMM parameter estimation was fitted (Bolker et al. 2009). However, inspections of graphical diagnostics and the scaled Pearson statistic for the conditional distribution suggested that there was substantial over-dispersion. Therefore, the model was adjusted by changing from a Poisson to a negative binomial distribution. All information criteria, inspections of graphical diagnostics, and the scaled Pearson statistic indicated that the negative binomial distribution provided a better fit.

3. Results

3.1 Species composition

In 2009 and 2010, 3048 individuals belonging to 210 species of 32 beetle families were collected, using sweep nets. Four predator species; *Anthophagus Omalinus, Malthodes Guttifer, Malthodes Fuscus and Malthodes Brevicollis* and two herbivore species; *Micrelus Ericae* and *Absidia Schoenherri* comprised 65% of all the individuals collected. The three largest families; *Cantharidae*, *Curculionidae* and *Staphylinidae* contituted 81% of the total individulas. Species composition varied significantly between different habitats: A) power-line corridor, B) edge of power–line corridor, C) forest edge, D) forest, distance into forest equal to one half of the corridor width, and E) 100 m into the forest from the corridor/forest edge. The results of the CCA showed that Site explained 34 % of variation (Monte-Carlo permutation test: Pseudo-$F_{50,197}$: 2.02, $p < 0.001$, 999 permutations). In order to find significant additional variation by habitat after the variation related to site had been explained, the partial constrained ordination was performed. The results of the CCA showed that the variable habitat explained 2.4 % (Monte-Carlo permutation test: Pseudo-$F_{4,193}$: 1.84, $p < 0.001$, 999 permutations). Plots in the center of the power-line corridor A) had a species composition very different from plots in the forest (D, C and E), and plots on each side of the edge (B and C), also differed substantially in species composition (Figure 3). Detritivores as *Cryptophagus abietis*, *Acrotrichis rugulos and Corticarina obfuscata* were most associated with forest habitat (C and D). Predator *Dasytes niger* and herbivores as *Polydrusus undatus,* Rhampus pulicarius and Lochmaea suturalis where most associated with early succession habitats (A and B).
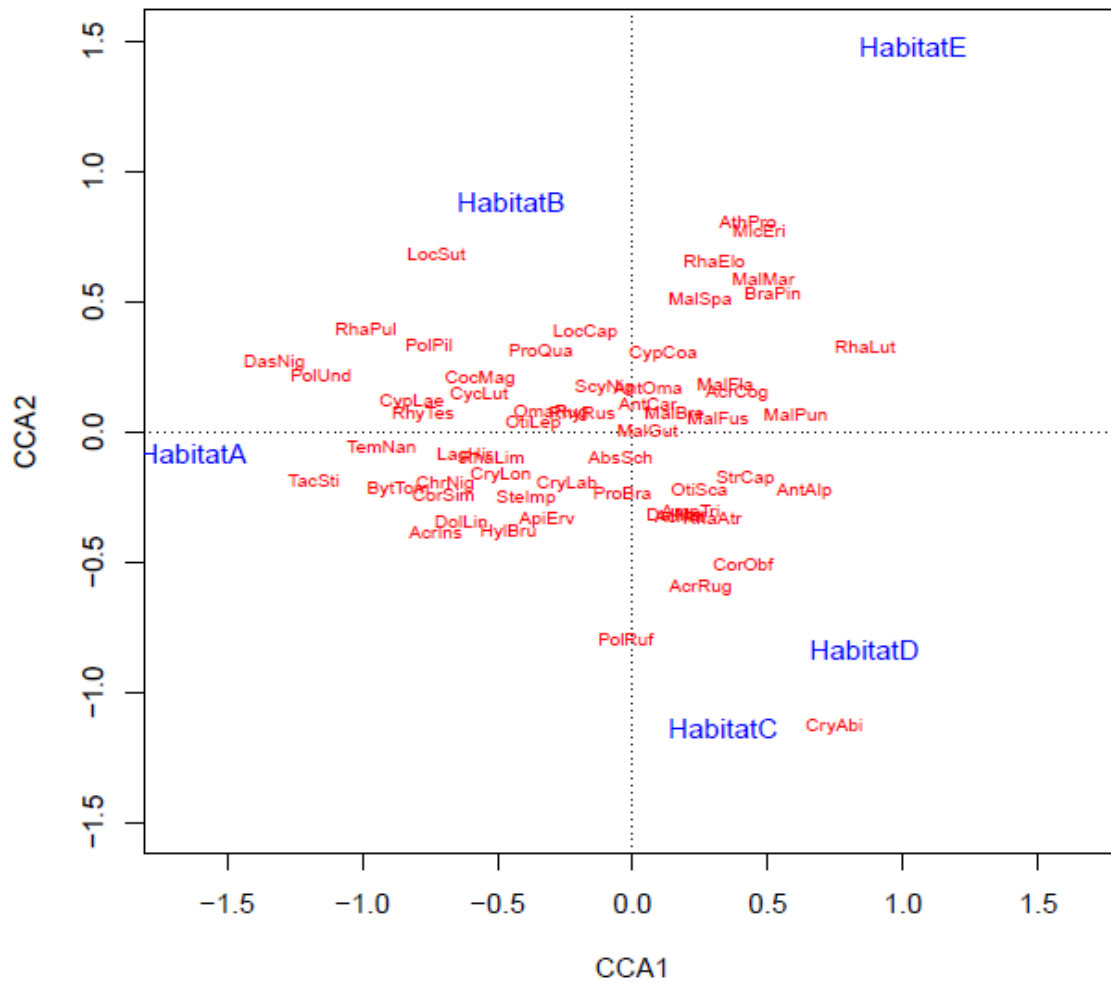
Figure 3 CCA plot showing differences in species composition of beetles captured in the field layer between five different habitats. Beetles captured with sweep nets in 51 different locations, in five different habitats (power-line corridor (A), edge of power–line corridor (B), forest edge (C), forest, distance into forest equal to one half of the corridor width (D), and 100 m into the forest from the corridor/forest edge (E)). The diagram shows abbreviated species names (red) and centroids of habitats types (blue).

3.2 Species richness

The species accumulation curves of the different habitats A, B, C, D and E did not seem to level off (Figure 4). This indicates that not all available species were collected in any of the habitats. The early succession stage (A) had higher species richness than the edge to the early succession stage (B), wheareas the forest edge (C) was higher in species richness than the forest interior (D). The early succession forest (A and B) has higher species richness than the later forest succession (C and D).
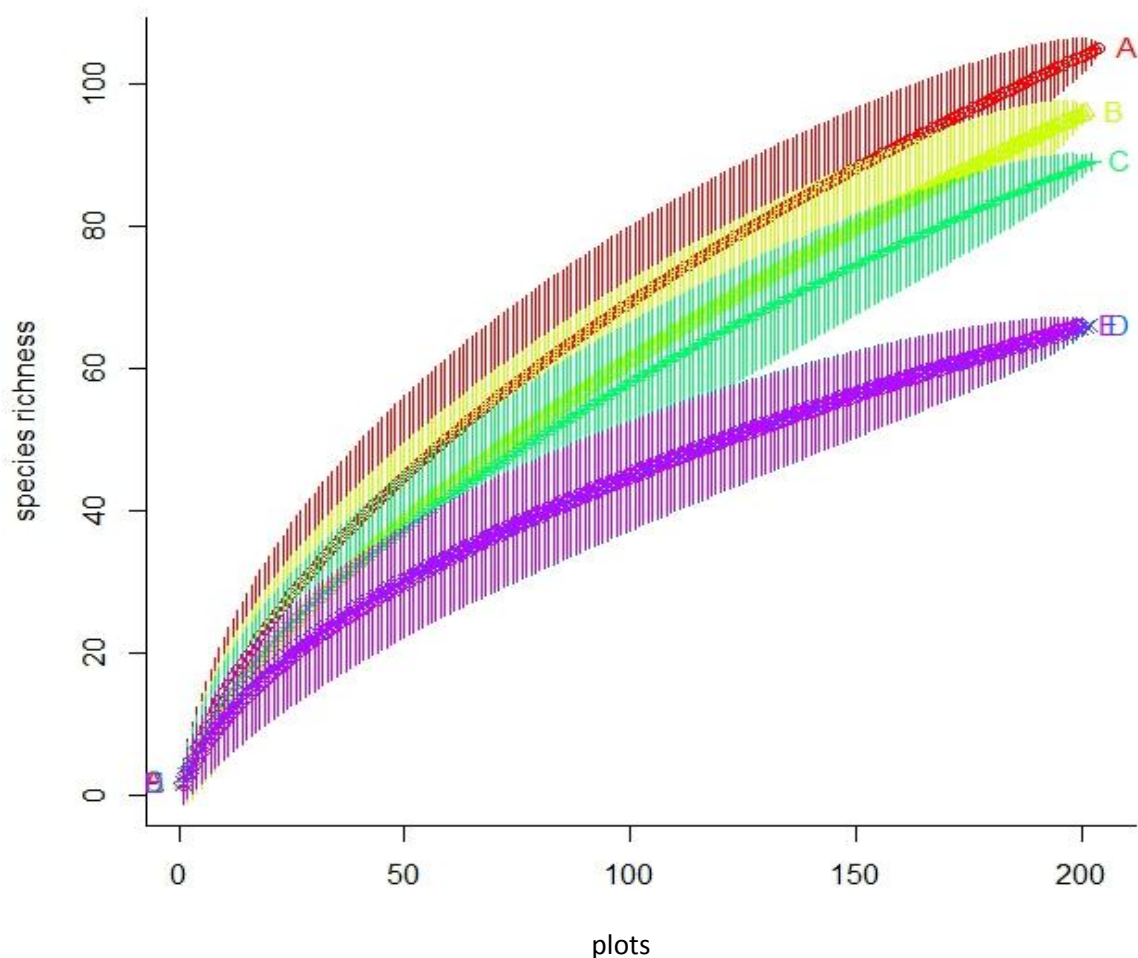

Figure 4 Species accumulation curves plotted for the five habitats. The x-axis shows the number of plots for collecting of beetles by sweep nets (see Figure 2). The y-axis show the cumulative numbers of species recorded. The habitat under the power-line (A) had the largest species richness and the lowest was in the forest habitat 100 m from the center of the power-line (E) and the forest habitat (D). The edge of the early succession habitat (B) had higher richness than the forest edge (C). The largest differences in species richness were found between the habitat in the center of the power-line had larger species richness, than the forested habitats (D and E). The vertical lines show the corresponding standard deviation.

In the family accumulation plots, most of the curves seem to approach an asymptote (Appendix 2). This is natural since there are fewer beetle families than beetle species, and thus easier to collect all or most of the families. The edge plots of the early succession stage (B), i.e. power-line corridor, had the highest beetle family richness. The early succession forest, i.e. center of power-line corridor and interior forest has approximately the same family richness.

Habitat and the field layer explanatory variables grass, dwarf shrubs and deciduous shrubs individually influenced the species richness ($p < 0.05$; Table 2), whereas there was no significant effect of herb (Table 1). Further analyses were performed using the variables with $p<0.10$ in Table 1. Pairwise correlation tests showed that none of the field layer variable were correlated ($r>0.5$). The full (most complex model) included these variables and second order interactions between these field layer variables and habitat. Model selection was performed using backward elimination by sequentially removing terms with the highest p-value, and always removing the interaction term before main effects. Habitat, grass and dwarf shrub were the only variables that significantly enhanced species richness (Table 2).

Table 1 Relationships between species richness and individually tested field layer vegetation explanatory variables, using log link function and Poisson distribution. Beetle species captured in 2009, in 20 different locations and 2010 in 31 different locations. Random effect: site $p < 0.0001$ in all analyses.

Explanatory variables	Df	Log (likel)	χ^2	F	p
Habitat	4,953			3.13	0.0143
Grass	1,956			12.6	0.0004
Dwarf shrubs	1,956			4.92	0.0269
Deciduous shrubs	1,956			18.3	<.0001
Herbs	1,956			2.52	0.1126

Table 2 Results of relationships between species richness and explanatory variables. Response variable was number of beetle species. Results of generalized linear models, with log link function and Poisson distribution. **a)** Only field layer vegetation as explanatory variables. **b)** Field layer vegetation and habitat as explanatory variables. Field layer variables were measured as percentage cover within subplots in Figure 2. Beetles were sampled at 51 different sites, and site was modeled as random effect. Habitat was power-line corridor (A), edge of power–line corridor (B), forest edge (C), forest, distance into forest equal to one half of the corridor width (D), and 100 m into the forest from the corridor/forest edge (E).

Explanatory variables	Df	Log (likel)	χ^2	F	P
a)					
Fixed effects					
Grass	1,954			11.1	0.0009
Dwarf shrubs	1,954			11.1	0.0009
Deciduous shrubs	1,954			12.4	0.0004
Random effect					
Site	1	-1700	120		<.0001
b)					
Fixed effects					
Habitat	4,950			3.06	0.0160
Grass	1,950			12.2	0.0005
Dwarf shrubs	1,950			10.9	0.0010
Deciduous shrubs	1,950			13.8	0.0002
Random effect					
Site	1	-1694	121		<.0001

Type Ⅲ Wald–F tests of fixed effects. Log likelihood tests of random effect.

Table 3 Parameter estimates and associated standard errors for model b) in Table 2.

	Estimate (β)	SE
Habitat A	0.26	0.080
Habitat B	0.15	0.080
Habitat C	0.41	0.075
Habitat D	0.29	0.078
Habitat E	0.26	0.083
Grass	0.0075	0.0021
Dwarf shrub	0.0063	0.0019
Deciduous shrub	0.0266	0.0071

Frequency plots of grass, dwarf shrub and deciduous shrub cover is shown in Appendix 3. In the early succession forest (A and B) deciduous shrub and grass were most abundant, while in the later succession forest (C and D) dwarf shrub were more abundant (Figure 5).

Estimated mean species richness was highest in forest edge plots (C), followed by plots in center of the power-line corridors (A), with the lowest richness in edge plots in power-line corridors (B) and forest interior (D) (Table 3, Figure 6, 7 and 8). Species richness increased with increasing cover of grass (Table 3, Figure 6), deciduous (Table 3, Figure 7) and dwarf shrubs, (Table 3, Figure 8).
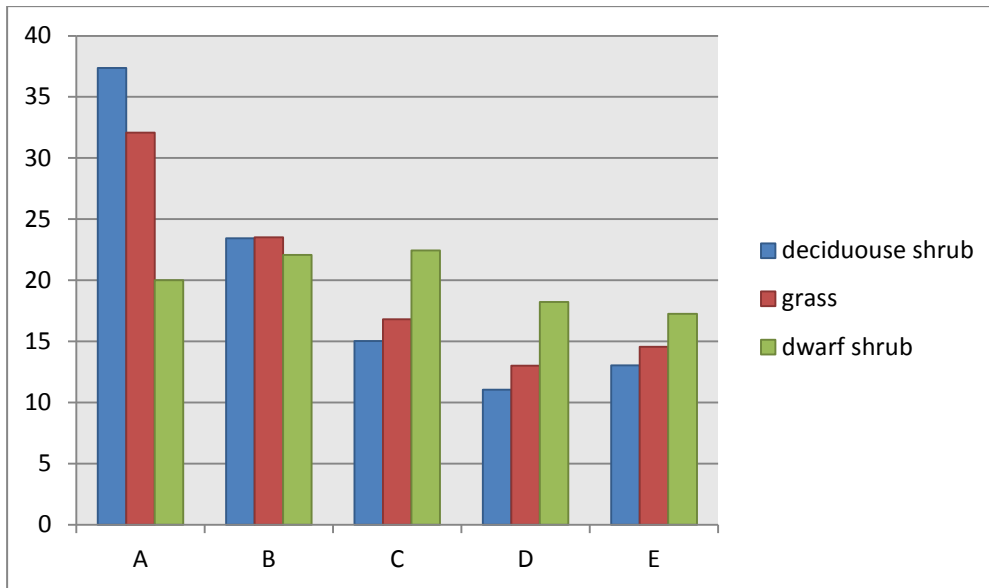
Figure 5 Percentage cover of environmental variables (deciduous shrub, grass and dwarf shrub) within each habitat (power-line corridor (A), edge of power–line corridor (B), forest edge (C), forest, distance into forest equal to one half of the corridor width (D), and 100 m into the forest from the corridor/forest edge (E).
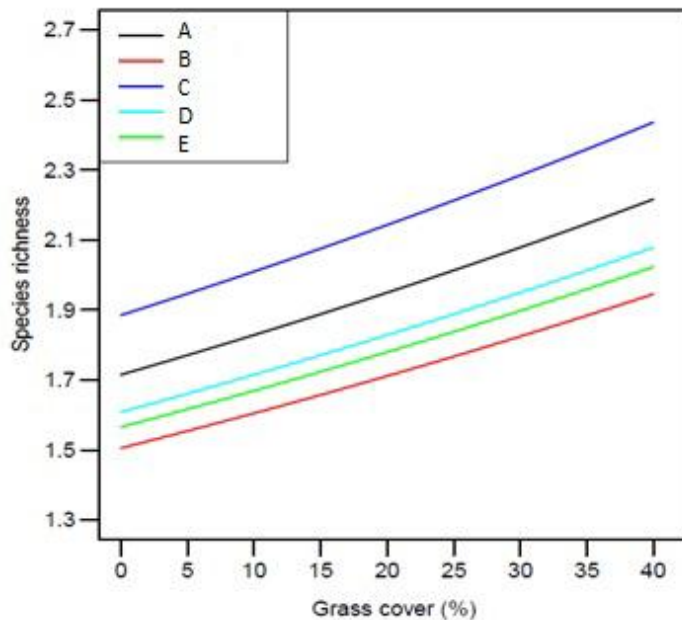

Figure 6 Species richness increased with increasing amount of grass cover. Predicted average species richness increased with higher density of grass cover up to 40 %. The center of the power-line (A) and the forest edge (C) had the largest average increase in species richness, respectively. The forest (D), the power-line edge (B), and the habitat 100 m in the forest from the power line (E), had approximately the same increase in species richness.

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Figure 7 Species richness increased with increasing amount of deciduous shrub cover. Predicted average species richness increased with higher density of deciduous shrub cover up to 12 %. The center of the power-line (A) and the forest edge (C) had the largest average increase in species richness, respectively. The forest (D), the power-line edge (B), and the habitat 100 m in the forest from the power line (E), had approximately the same increase in species richness.
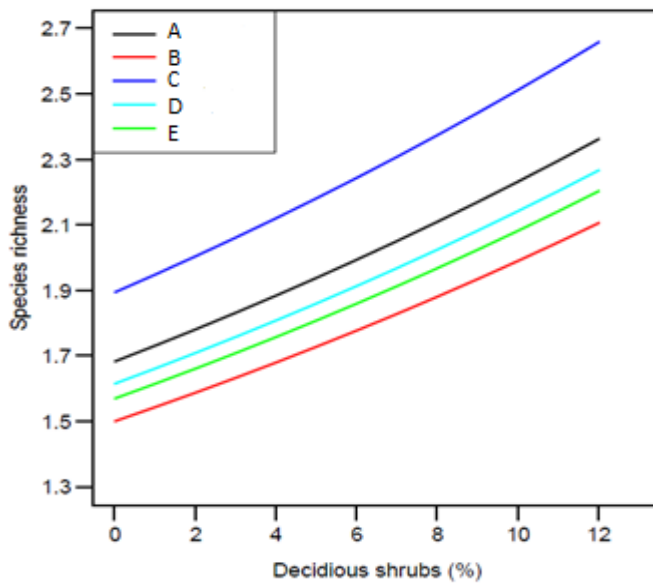

Figure 8 Species richness increased with increasing amount of dwarf shrubs cover. Predicted average species richness increased with higher density of dwarf shrub cover up to 60 %. The center of the power-line (A) and the forest edge (C) had the largest average increase in species richness, respectively. The forest (D), the power-line edge (B), and the habitat 100 m in the forest from the power line (E), had approximately the same increase in species richness.
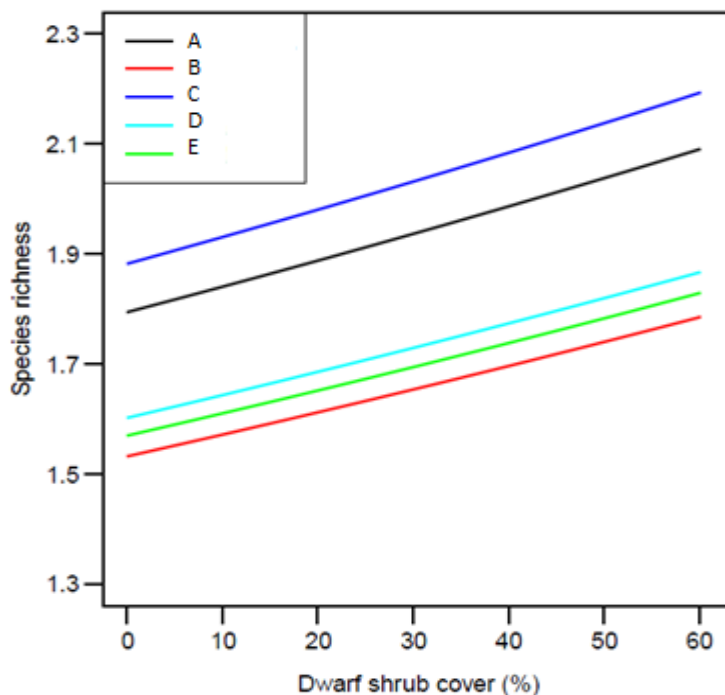
3.3 Edge effects on both sides of the edge (early and later successional stages)

The mean species richness in the center of the power-line (A), i.e. in the center of the early successional stage forest, had on an average 0.25 species more per plot than the edge to the early succession forest (B). The forest edge (C) had on an average 0.29 species more per plot, than the forest habitat situated at the same distance from the forest edge as of the width of the corridor (i.e., habitat D) (Figure 9).
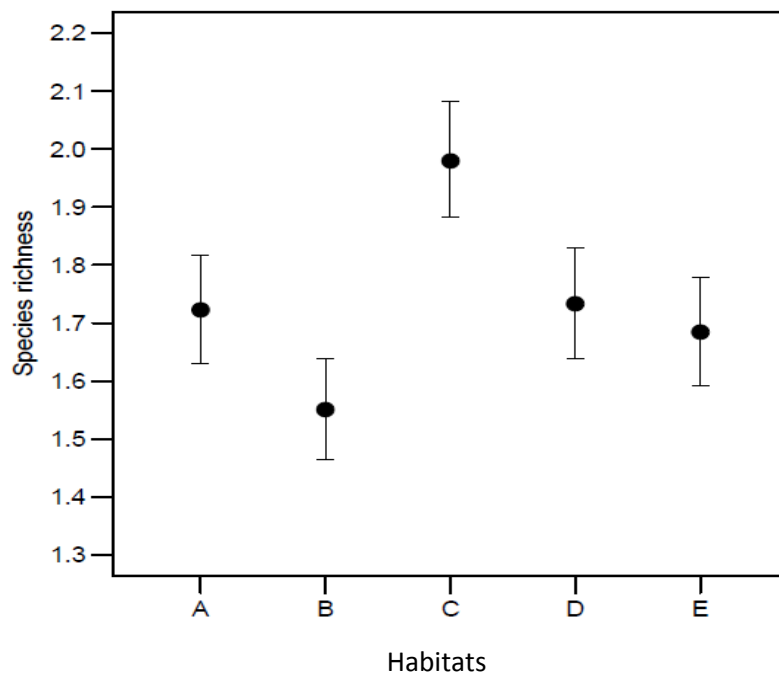

Figure 9 Estimated mean species richness (number of species) and associated standard errors. Beetles were captured by sweep netting in plots of 4 m x 5 m in five different habitats: species richness in the centre of the power-line, early succession habitat (A), the early succession edge habitat (B) the forest edge habitat (C), and in plots located one half corridor width into the forest (D), and in plots 100 m into the forest (E). Plots in the forest edge zone had higher richness than plots located farther within the forest, whereas the opposite was found for early successional stage forests in power-lines, in power-line corridors, plots along the forest edge had lower species richness than plots in the center of the corridor.

When comparing only the two types of edge plots (B and C in Figure 10), was the mean number of beetle species on an average 0.32 higher in the forested edge (C) plots than in the early power-line edge (B) plots. Grass and dwarf shrub significantly enhanced spices richness in these two plots (Table 4).

Table 4 The average species abundance was greater in the forested edge habitat (C) ($e^{(0.4441-0)}$= 1.56 species), than in the early succession forest edge (B) ($e^{0.4441+(-0.2311)}$= 1.24 species), with an average 0.32 species per plot (a total of 51 x 4 plots). Grass and dwarf shrubs were the only significant environmental effects that enhanced species richness in the edge effect habitats (B and C). Results of generalized mixed models with response variable species richness, log link function and poison distribution. Type 3 Wald F-test of fixed effects and log likelihood test for random effects are reported.

Explanatory variables				df	F value	*Pr > F*	Log (likel)	χ^2
Fixed effects		Estimate	Standard error					
Habitat	B	0.2130	0.0757	1,349	9.32	0.0024		
Habitat	C	0.4441	0.0995	.	.	.		
Grass		0.0070	0.0035	1,349	4.02	0.0458		
Dwarf shrubs		0.0070	0.0030	1,349	5.48	0.0198		
Random effect								
Site				1			-686	32

3.4 Biodiversity

The early succession forest habitat (A) had higher beetle species diversity than the other habitats except from the forest edge (C). Habitat C had higher diversity than the forest habitat (D) and the forest habitat 100 m from the center of the power-line (E). Steep curves indicate a large variation in abundance among different beetle species, i.e. lower evenness (Figure 10). For the family richness, the diversity for the early succession stage edge (B) was higher than other habitats except the early succession forest (A). Habitat (A) was more diverse then the forest edge (C) and the forest habitat a 100 m from the center of the power-line (E). The diversity for beetle families was lowest for the forested habitat 100 m from the center of the power-line (E) (Appendix 4).
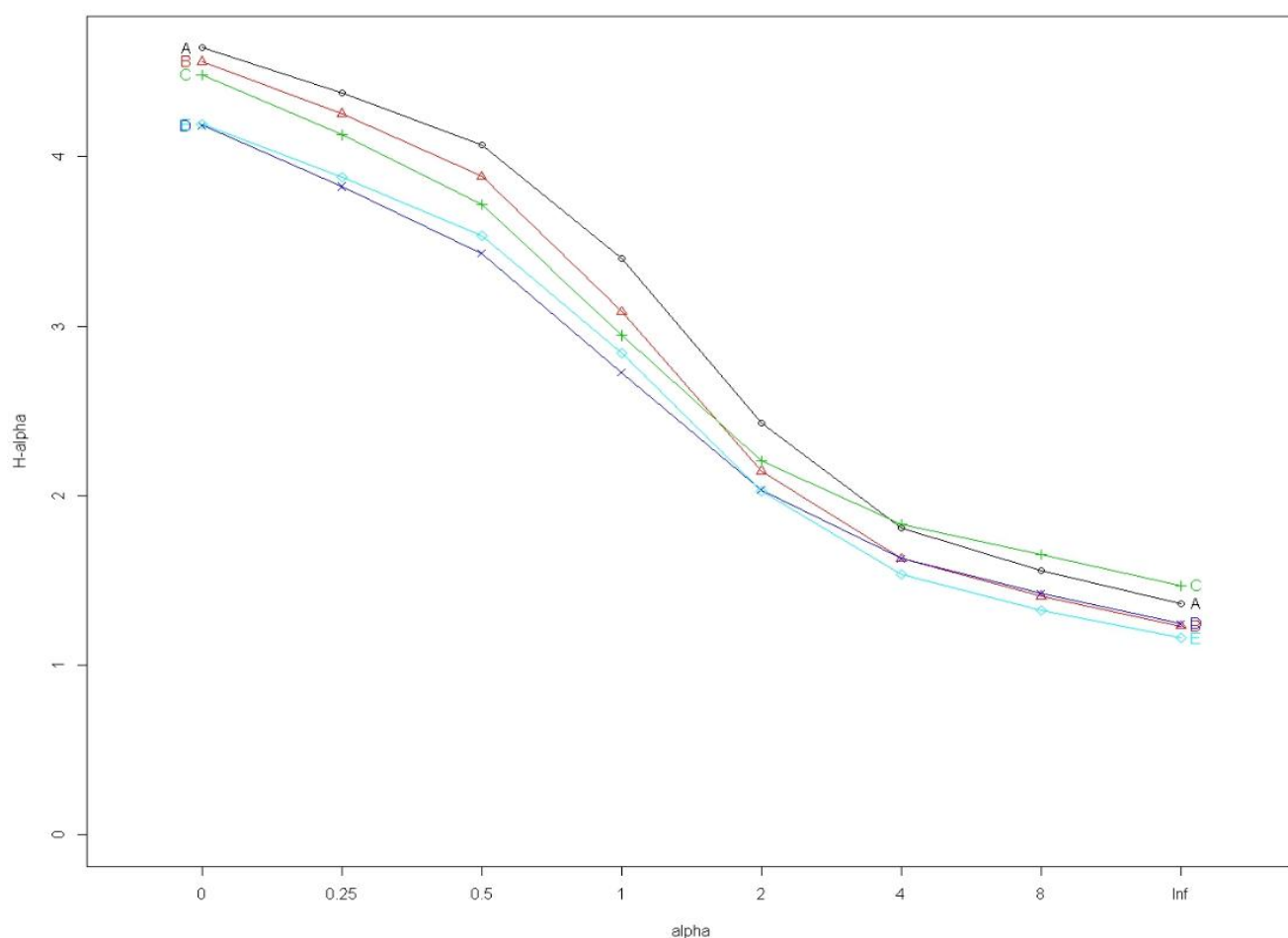
Figure 10 The Renyi diversity profile shows the difference in evenness, species richness and biodiversity among species between the different plots, based on aggregated data from 51 sites. The figure shows Renyi diversity profiles for each habitat. Steep curves indicate lower evenness among beetle species. The starting position on the left (alpha = 0) indicate that A, B and C has the largest beetle species richness, ranked in respective order. It is not possible to separate E and D. The antilog ($e^{H\text{-value}}$) for alpha = 0, shows the number of species richness. It is not possible to decide which site was the most diverse since the lines were crossing. Alpha = infinitive shows that the later forest edge habitat (C) had the least number of the most dominating species and the forest habitat a 100 m from the center of the power line habitat (E) had the largest number of dominating species. The forest habitat (D) and the early succession forest edge (B) have approximating equal numbers.

3.5 Species abundance distribution

The empirical cumulative distribution function plot (ECDF, Figure 11) shows that approximately 85% of the species had abundance less than $10^{-2} = 0.01$, i.e. 1% of all captured beetle individuals. This shows that most species had low abundance for all habitats. There was no significant difference in species abundance between the two distributions that appear to be most dissimilar in Figure 11, i.e. between forest edge (C) and forest interior (E) (Kolmogorov-Smirnov test: D = 0.147, p = 0.337).
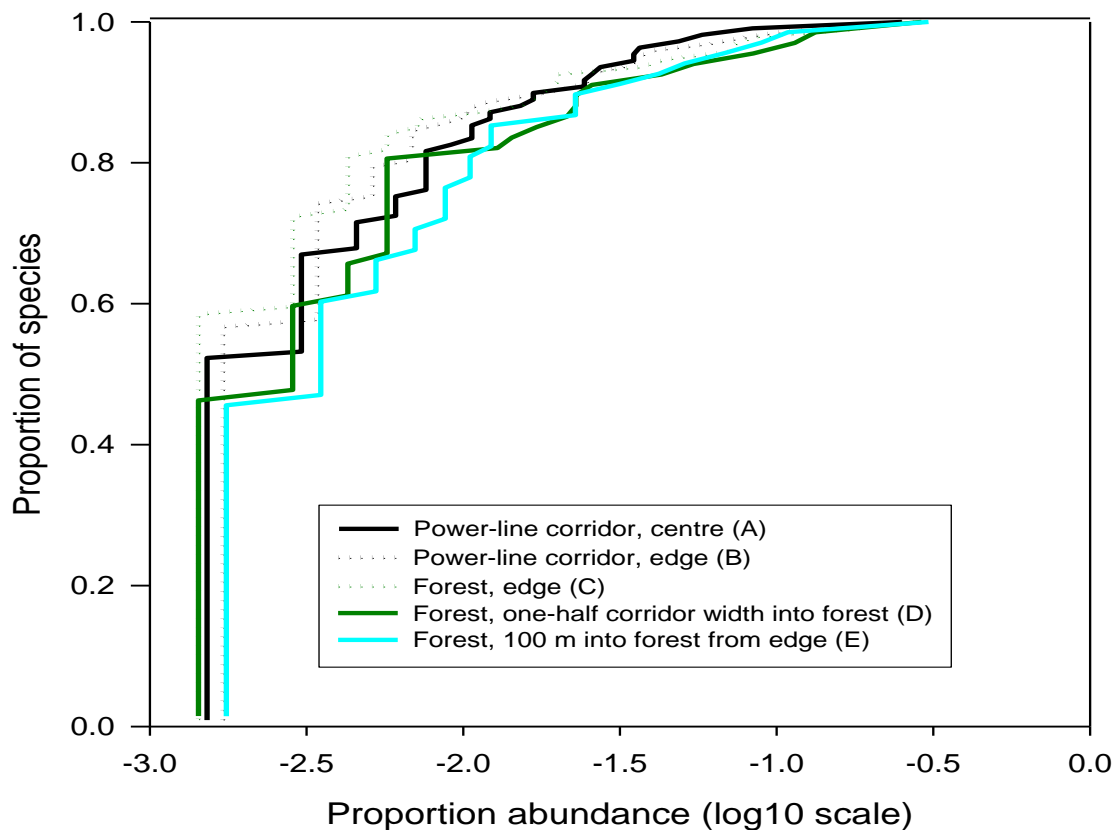
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Figure 11 The empirical cumulative distribution function (ECDF) with the beetle abundance showed in proportions of all individuals observed for the given habitats: A) power-line corridor, B) edge of power–line corridor, C) forest edge, D) forest, distance into forest equal to one half of the corridor width, and E) 100 m into the forest from the corridor/forest edge, in all sites. The species abundance divided by total number of individuals on a log10 scale is shown on the x-axis. Species is ranked from highest to lowest abundance, and the ranks (divided by total species richness within each habitat) is shown on the y-axis. The slope is indicative of evenness, and as the slopes is sharply vertical, this implies that the evenness is high.

3.6 Functional groups

Number of individuals and number of species differed between habitats and between functional groups. There was also a significant interaction between habitat and functional group (Table 5 and 6, Figure 12 and 13). This means that the relative proportion of individuals and species within different functional groups differed among habitats. Interestingly, the herbivore/predator ratio shifted from strong herbivore-bias in the center of the power-line corridor (early successional stage forest) to a strong predator-bias 100 m into the later successional stage forest, with gradual change in the ratio in the plots in between these different habitats (Figure 12 and 13).

Table 5 Factors influencing the number of beetle individuals captured per 4 m x 5 m plot with sweep netting in the field layer vegetation. Wald F test of fixed effects and likelihood ratio tests of random effects. Individuals captured in 2009, in 20 different locations and 2010 in 31 different locations. Generalized mixed models with log link function, negative binomial distribution, and Gaussian hermite quadrature approximation to the likelihood.

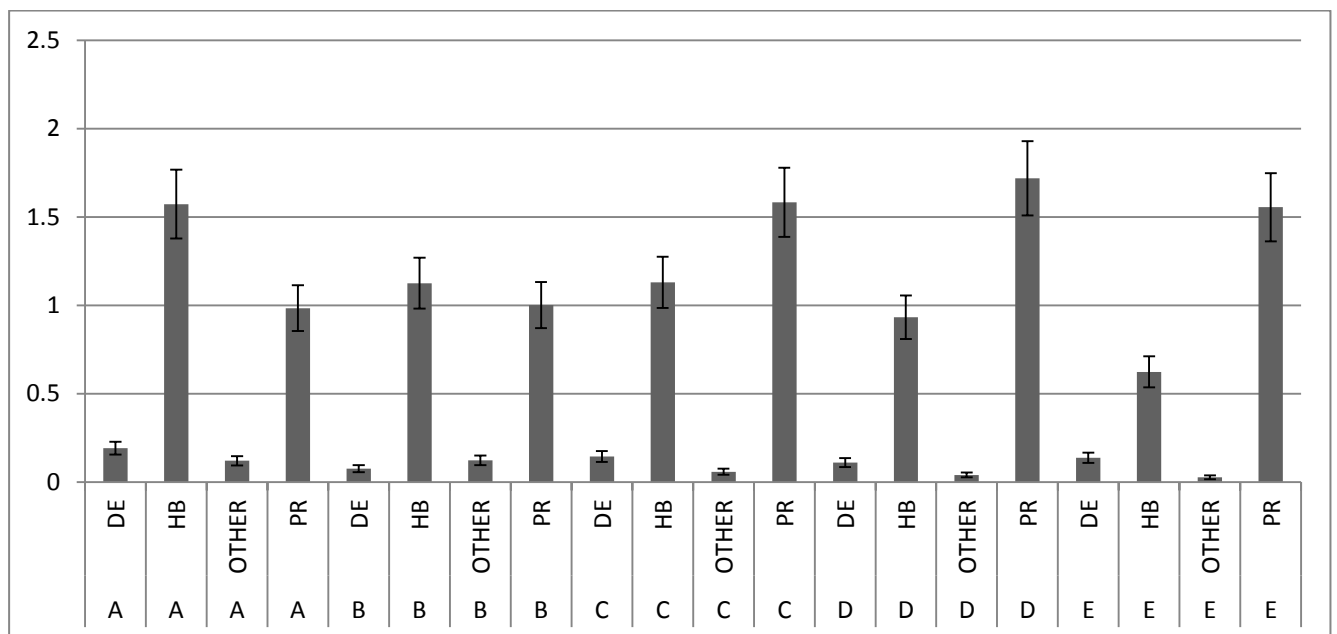| Explanatory variables	df	Log (likel)	χ^2	F	P
Fixed effects					
Habitat	4,397			5.16	0.0004
Functional group	3,397			292	<.0001
Habitat×functional group	12,97			6.92	<.0001
Random effect					
Site	1	-3929	176		<.0001

Figure 12 Estimated mean (±SE) number of individuals within different functional groups of beetles. Beetles were captured by sweep netting within 4m x 5m plots (see Figure 2) at 51 sites, in five different habitats: The center of the power-line habitat (A), the early succession edge habitat (B), forest edge habitat (C), forest habitat (D) and the forest habitat, a 100 m from the center of the power-line (E). PR = predators, HB = herbivores, DE = general detritivore and dead wood feeders and fungivores are grouped into the category 'OTHER'.

Table 6 Factors influencing the number of beetle species captured per 4 m x 5 m plot, with sweep netting in the field layer vegetation. Wald F test of fixed effects and likelihood ratio tests of random effects. Species captured in 2009, in 20 different locations and 2010 in 31 different locations. Generalized mixed models with log link function, negative binomial distribution, and Gaussian hermite quadrature approximation to the likelihood.

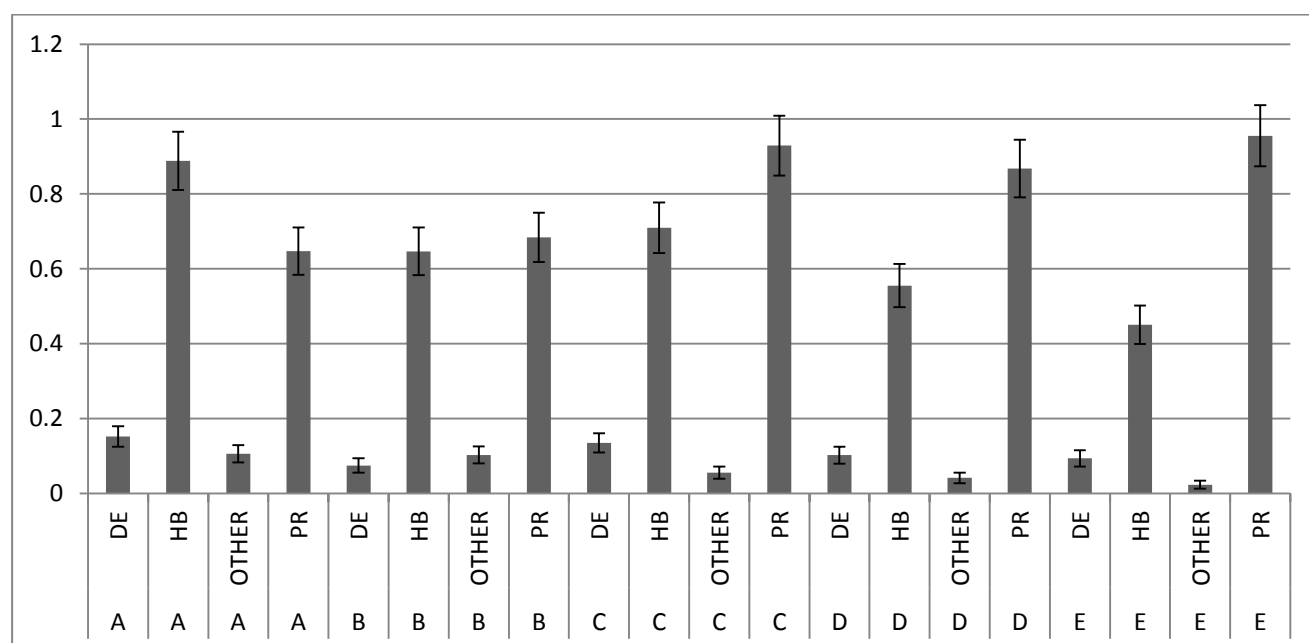| Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	4,397			4.79	0.0007
Functional group	3,397			230	<.0001
Habitat×functional group	12,97			5.59	<.0001
Random effect					
Site	1	-2970	117		<.0001

Figure 13 Estimated mean (±SE) number of species within different functional groups of beetles. Beetles were captured by sweep netting within 4m x 5m plots (see Figure 2) at 51 sites, in five different habitats: The center of the power-line habitat (A), the early succession edge habitat (B), forest edge habitat (C), forest habitat (D) and the forest habitat, a 100 m from the center of the power-line (E). PR = predators, HB = herbivores, DE = general detritivore and dead wood feeders and fungivores are grouped into the category 'OTHER'.

4. Discussion

4.1 Species composition and functional groups

As predicted, there was a significant effect of habitat in analysis of beetle species composition. The positions of the centroids of the different habitats in the CCA plot, and the arrangement of the different species (Figure 3), show that plots in the centre and along the edge of the power-line corridor had a species composition that differed substantially from plots in the forest. The greatest difference was between plots in the center of the power-line corridors, and plots in the forest interior. This is not surprising, as they reflect the greatest contrast in habitat conditions. Interestingly, plots along the edge of the power-line corridor differed substantially from plots in the edge zone within the forest. Kaila et al. (1997) found a similar trend that the early and later successional forest stages varied significantly, due to various environmental factors and access to resources. Hansson (1994) found that the vertebrate species composition varied between clearcut and forest interior, because some species have different adaption to disturbance.

Detritivores as *Cryptophagus abietis*, *Acrotrichis rugulos and Corticarina obfuscata* were most associated with edge to the forest interior and forest interior. Predator *Dasytes niger* and herbivore as *Polydrusus undatus, Rhampus pulicarius* and *Lochmaea suturalis* where most associated with the early succession power-line corridor and the edge to the early succession power-line corridor. This correspond well with Ewers & Didham (2008) that found highest abundance of detritus feeders in the forest interior and that they declines closer to the edge, and herbivores are more abundant in open habitat.

There was a significant interaction between habitat and functional group. That the proportion of different beetles functional groups differed among habitats. This is probably because of the different ways of utilizing food resources. Various functional groups are strongly related to their feeding habits (Lassau et al. 2005). Interestingly, the herbivore/predator ratio shifted from strong herbivore-bias in the center of the power-line corridor (early successional stage forest) to a strong predator-bias 100 m into the later successional stage forest, with gradual change in the ratio in the plots in between these different habitats. This is the same as Ewers and Didham (2008) found for herbivore beetles, i.e. they were abundant in the clear cut and declined towards

the forest interior. There is less chance to be depredated in the open habitat (Halme & Niemelä 1993), i.e. predators are more associated with forest interior (Hunter 2002; Elek & Lövei 2007) and a more complex habitat in the early succession stage gives more shelter from predators (Lassau et al. 2005), and there is more plant food available (Halme & Niemelä 1993).

4.2 Species richness

I found substantial differences in species richness among habitats. When looking at total species richness in each habitat aggregated over all sites and plots, species richness was higher in power-line corridors, i.e. in early successional stage forest, than in forest. Within power-line corridors, species richness was higher in the center than along the edges, whereas the opposite pattern was found for forest, in forest, species richness was higher in the forest edge than in plots located farther into the forest.

The beetle species richness in the early succession stages appeared to be positively affected by the frequent clearing of vegetation, which increases the cover of grass, deciduous shrubs and dwarf shrubs. It has been found that clearcuts, urbanized areas and small forest fragments have larger species richness, than forest interior, because of many open habitat species (Heliölä et al. 2001; Elek & Lövei 2007; Gagné & Fahrig 2011). Lassau et al. (2005) found that in higher complex habitats will create more different niches that can be utilized for the different beetle species, i.e. the clearance of vegetation under the power-line disturbed the habitat such as, more food is available.

Species in indigenous forest are lost after disturbance, but overall spices richness and diversity increases (Lewis & Whitfield 1999). Specialist beetle species in the interior forest do not cope well in disturbed patches, since they are more specialized, with large body sizes, and more affected by synergistic effects, such as fragmentation and edge effects (Collinge & Forman 1998; Davies et al. 2004). In contrast, beetle species in the clearcuts are in general small sized and generalists (Collinge & Forman 1998; Gibbs & Stanton 2001; Elek & Lövei 2007).

4.3 Edge effects

When analyzing mean species richness per plot, controlling for among site effects, a different pattern emerged for species richness, than when looking at total species richness in each habitat aggregated over all sites and plots aggregated data, as above: The forest edge had the highest estimated mean species richness. Thus, the forest edge had higher mean species richness than the forest interior habitats. In contrast in the power-line corridors, plots along the edge had lower mean species richness than plots in the centre of the corridor. When comparing only the edges, the forested edge had significant higher species richness than the early succession forest edge. Grass and dwarf shrub cover enhance the species richness in the two edges. The early succession forest had larger beetle species richness than the later forest succession. Some open habitat species move through the edge and into the forest interior (Niemelä et al. 1993; Spence et al. 1996). Open habitat species and forest interior species moves to the forest edge and increase the species richness in the forest edge (Magura et al. 2001; Baker et al. 2007; Roume et al. 2011). The sensitivity to edge is different for early succession species and forest interior species (Ries & Sisk 2010), because resource distribution in relation to edge differs between the two habitats. Different species utilize different resources (Ries et al. 2004).

Beetle species needs different habitats during their life cycles, because different feeding resources are needed at the different stages (Law & Dickman 1998). In general edges are therefore positive for the beetle fauna, since they create different habitats, within reach, for the beetles to utilize during different stages of the life cycles (Kremsater & Bunnell 1999). Magura (2002) found that species richness was higher in the forest edge, because of the presence of forest beetle species and enhanced grass cover, whereas Heliölä et al. (2001) found the highest species richness in clearcuts, and that the forest edge and interior forest did not differ in species richness. Beetle species that are small and disturbance adapted can penetrate through the edge from the open habitat, but wind shear forces that damage trees near edges might make the permeability for open habitat beetles more severe (Laurance 2000; Laurance 2008). Thus enhanced shrub cover in the interior forest caused by disturbance of the edge may give more herbivore prey for the forest predators (Spence et al. 1996; Magura 2002). Some rare specialized beetle species need to be exposed to the sun, and dead wood in the early succession stages to survive (Kaila et al. 1997).

4.4 Diversity and species abundance

The main findings was that beetle species diversity in the early succession stage under the power-lines corridors was larger than in the forest habitats, except for forest edge, which could not be separated with respect to diversity.

Jennings et al. (1986) found in landscape with forestry that logged the forest interior into strips of open habitat and forest, had larger diversity than continuous forest. This was due to more habitat heterogeneity, i.e. open habitat and forest close to each other. Open habitat beetles significantly enhanced species richness in the early succession habitats (Heliölä et al. 2001), and beetles moves to the forest edge from both the early succession forest and forest interior community (Spence et al. 1996; Magura 2002), thus some forest interior specialist species are lost after logging (Niemelä et al. 1993). Simberloff (1999) state the importance of the biological diversity in stable forest interior, since biological diversity is not only species richness, but also ecosystems and genetics, the fauna in this ecosystem and species composition is unique (Simberloff 1999; Buddle et al. 2006). Selonen et al. (2005) found higher diversity in the open-habitat due to rapid increase in dead wood. In the old forest there are some unique elements not found in the disturbed forest, that is important to some specialist species (Buddle et al. 2006).

The beetle diversity in the early succession edge and forest interior was lower than in the early succession habitat. This might be because most forest interior species usually do not get close to the edge (Barberena-Arias & Aide 2003; Ewers & Didham 2008), or avoid edges (Lidicker 1999), and thus will avoid open habitats. This might be due to traits as no wings, because they don't cope well in disturbed patches (Driscoll & Weir 2005; Wimp et al. 2011), more exposure to sun, lack of preferred food (Ries et al. 2004), and dependence on the extent of canopy closure (Magura 2002), and beetle species richness decreases in dense homogenous forests, due to less plant diversity and vegetation structure (Ponel et al. 2003). In conclusion, frequent clearing of vegetation under the power-line corridor may enhance the biodiversity, but forest interior species are likely to be negatively affected by this type of disturbance.

The response by beetle species to the frequent clearing of vegetation, high disturbance or the less disturbed more stable production forest, depend on how individual species respond to habitat

fragmentation or habitat loss. Habitat loss has a much greater effect on species diversity than habitat fragmentation, and habitat fragmentation can have both positive and negative effects (Fahrig 2003). Intermediate disturbance enhance the biodiversity, abundance and richness, on a local scale (Connell 1978; Selonen et al. 2005), but when combined, the total anthropogenic disturbances have reached a threshold that make the global diversity to decline, and many species faces local extinctions as a consequence (Novacek & Cleland 2001; Thomas et al. 2004), such as stenotopic specialized beetle species are vulnerable (Elek & Lövei 2007). The disturbance under the power-line corridor may have a positive influence on the biological diversity because the frequent clearing of vegetation may lead to a higher diversity of food resources, which again gives more diversity for beetles that utilizes different food sources, (Haila et al. 1994; Selonen et al. 2005), such as dead wood (Kaila et al. 1997), grass (Elek & Lövei 2007), deciduous shrubs and dwarf shrubs (King & Byers 2002). In this study there was no effect of dead wood, which is similar to the study of Selonen et al. (2005). I suggest that this is mostly due to the trapping method, i.e. sweep netting, which probably only captures a few wood-dependent species (Buffington & Redak 1998).

4.5 Conclusion

The frequent cutting of power-line corridors, and thus maintenance of edge zones, influenced biological diversity in the field layer vegetation, both with respect to species composition, functional diversity, species richness and biodiversity. Species richness and biodiversity was generally higher in the centre of the power-line corridor than in the forest interior, but species richness was highest in the forest edge zone. Species richness was positively related to cover of grass, dwarf shrubs and deciduous shrubs in all habitats, but power-lines had more well-developed cover of grass and deciduous shrubs. The relative proportion of herbivores was highest in the centre of the corridor and decreased via both sides of the forest boarder to a lowest level in the forest interior. Edge habitat in the forest was relatively richer in species richness than forest interior habitat. In contrast, edge habitat in the power-line corridors were poorer than in the centre of the corridor. In conclusion, power-line corridors may increase local biological diversity of field-layer dwelling beetles, but forest interior species are likely to be negatively affected.

5. References

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Appendix 1

Literature ecological functions

Die Käfer Mitteleuropas Freude, H., Harde, K.W. & Lohse, G.A. 1964-79. Die Käfer Mitteleuropas. Band 1-12. Krefeld.

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Bd. 34. Vandkalve og hvirvlere (Hansen, 2. opplag 1973).

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Bd. 58. Rovbiller 2 (Hansen 1952).

Bd. 59. Rovbiller 3 (Hansen 1954).

Bd. 77. Adselbiller, stumpbiller m.m. (Hansen, ny utgave 1968).

Bd. 44. Blødvinger og klannere m.m. (Hansen, 2. opplag 1973).

Bd. 74. Smældere og pragtbiller (Hansen, ny utgave 1966).

Bd. 55. Clavicornia 1 (Hansen 1950).

Bd. 56. Clavicornia 2 og Bostrychoidea (Hansen 1951).

Bd. 50. Heteromerer (Hansen, 2. opplag 1973).

Bd. 29. Torbister (Hansen 1925).

Bd. 73. Træbukke (Hansen, ny utgave 1966).

Bd. 31. Blad- og bønnebiller (Hansen 1927).

Bd. 69. Snudebiller (Hansen, ny utgave 1965).

Bd. 62. Barkbiller (Hansen 1956).

Fauna Entomologica Scandinavica.

Vol. 10. The Buprestidae (Coleoptera) of Fennoscandia and Denmark (Bily 1982).

Vol. 15. The Carabidae (Coleoptera) of Fennoscandia and Denmark (Lindroth 1985-86).

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Vol. 20. The Aquatic Adephaga (Coleoptera) of Fennoscandia and Denmark. I.

Gyrinidae, Haliplidae, Hygrobiidae and Noteridae. (Holmen 1987).

Vol. 22. Longhorn beeties (Coleoptera, Cerambycidae) of Fennoscandia and Denmark
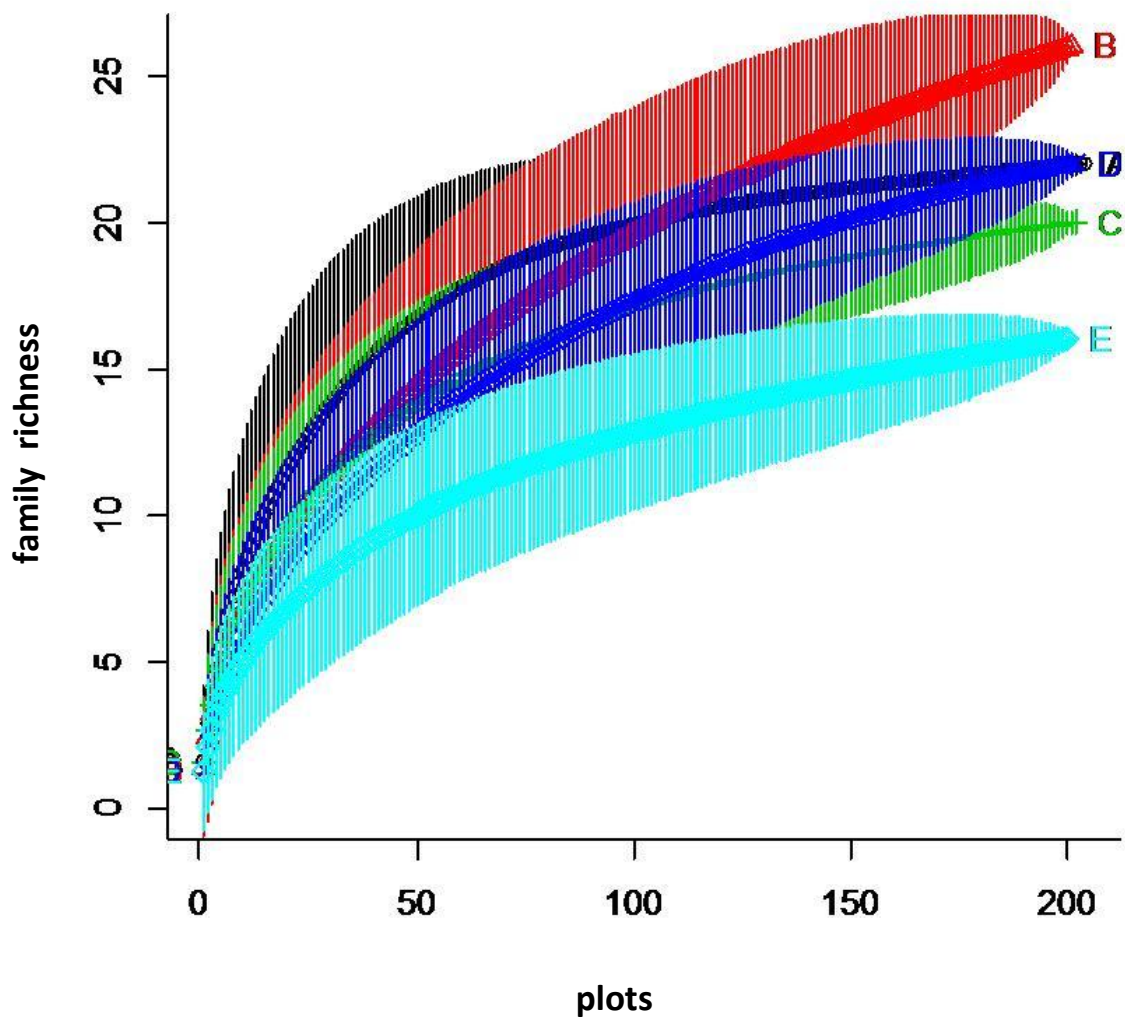
(Bily & Mehl 1989).

Nationalnyckeln:

Skalbaggar: Långhorningar, Coleoptera: Cerambycidae

Text: Bengt Ehnström, Bild: Martin Holmer

Appendix 2

Family accumulation curves

Family accumulation curves for the different habitat types. The x-axis shows the number of plots where beetles were collected by sweep nets. The y-axis shows the cumulative numbers of beetle families recorded. The forested plot (E) has the lowest species richness and the early succession stage edge (B) the highest. Vertical lines show the corresponding standard deviation. Habitats (A-E), is described in Figure 4.
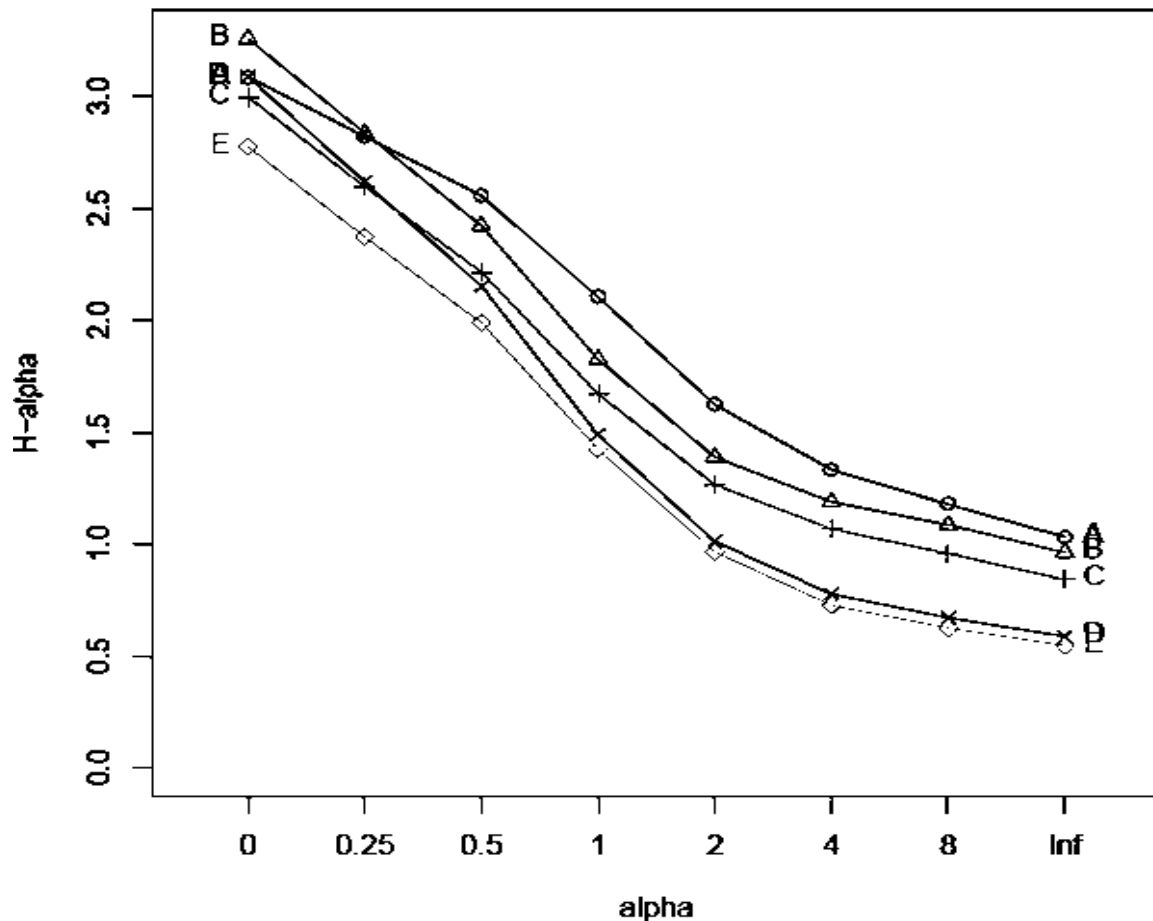
Appendix 3

Frequency of vegetation in the field layer
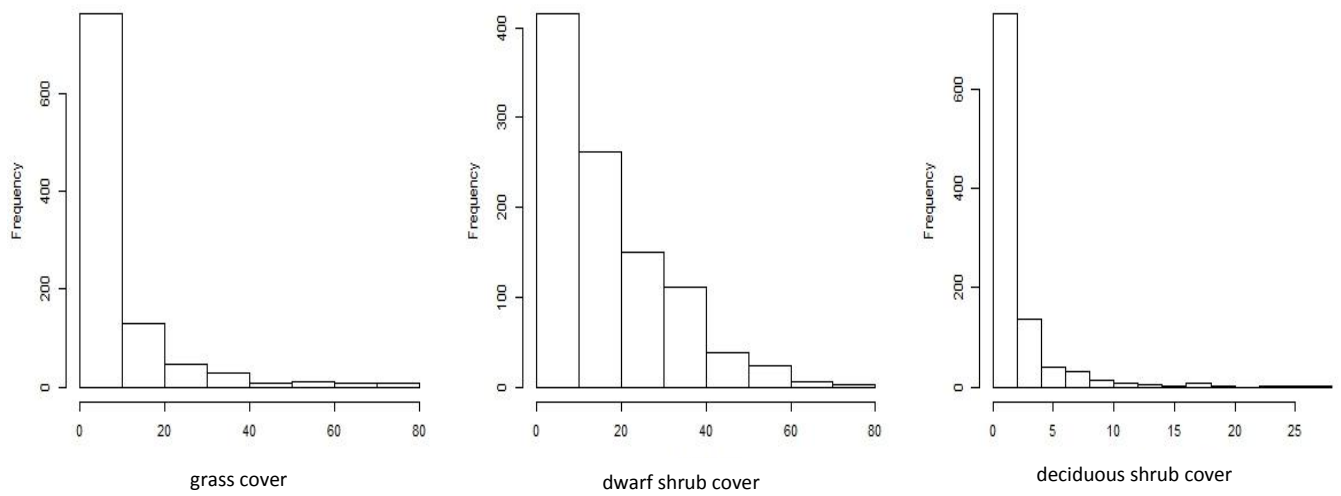
Histogram showing the frequency of plots on categories of grass cover, deciduous shrub cover and dwarf shrub cover.

Appendix 4

Beetle family diversity

The Renyi diversity profile shows the difference in evenness, family richness and biodiversity among families between the habitats, based on aggregated data from 51 sites. The steeper slopes indicates lower evenness among beetle families. The starting position on the left (alpha = 0) indicate that the edge to the early forest succession habitat (B) has the largest family richness, the forest habitat (D) and the early succession forest (A), has the same family richness and was larger than, the later forest edge habitat (C) and the lowest family richness was in the forest habitat a 100 m from the center of the power line (E). The antilog ($e^{H\text{-value}}$) for alpha = 0, shows the number of family richness. It was not possible to decide which site were the most diverse since the line is crossing, except for the forest habitat (E), who is the least diverse. Alpha = infinitive shows that habitat (A) has the least number of the most dominating species and (E) has the largest.

Appendix 5

Variation and trapping effort in species richness between the 51 sites