Preface

This thesis marks the end of my studies in Natural Resource Management at the Department of Ecology and Natural Resource Management (INA) at the Norwegian University of Life Sciences (UMB). It has been two great years and I want to thank everybody sharing it with me.

Norwegian University of Life Science

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Abstract

Compared to closed-canopy forest, power-line corridors are more frequently disturbed through regular cutting of all trees. The habitat is thus maintained in an early successional stage, with much sun exposed ground. This habitat resembles clear cuts created by modern forestry practices, but differs from clear cuts in that it is maintained in an early successional stage over time (i.e. not allowed to develop into later development classes). After clearing of the corridor the biomass is not removed from the habitat and this may lead to an accumulation of dead wood in the power-line corridors. In this study I investigated how regular disturbance of boreal forest habitats, in the form of maintenance cutting of trees in power-line corridors, influenced biological diversity of beetles (Coleoptera). More specific, I wanted to study if; 1) species composition differed between power-line corridors and closed canopy forests; 2) functional diversity differed between power-line corridors and forest, i.e. if the relative proportion of beetles and species within functional groups, differed between the two habitats; 3) species richness and/or biodiversity was higher in power-line corridors compared to forest; 4) amount of dead wood increases species richness and/or biodiversity in the power-line corridor and the forest and 5) distribution of rare versus common species, (species abundance distribution) differed between power-line corridors and forests. In total 14215 beetles were trapped with 160 interception traps from 20 sites in power-line corridors and forests during the summer season 2010 and 2011 in the Oslo fjord region of Norway. Species composition differed significantly between power-line corridors and forests. A total of 19 red-listed species were trapped and eight of these were threatened. The relative proportion of individuals and species within different functional groups also differed between the two habitats, with a relative higher proportion of dead wood feeders in power-line corridors. Species richness and biodiversity were significantly higher in the power-line corridor. I found a positive relationship between both species richness and biodiversity and the amount of dead wood in the habitats. This relationship was relatively stronger in power-line corridors. The species abundance distribution did not differ significant between the two habitats. Power-line corridors may help maintaining higher local biological diversity in otherwise managed forest stands and it functions as supplementary habitat for some threatened species.

Table of Contents

1. Introduction

Disturbances have a strong influence on ecosystems and species composition (White & Pickett 1985), but have not received as much attention as for example habitat change and climate change (Turner 2010). Disturbance disrupts community structure and function (White & Pickett 1985; Smith & Smith 2006) and is recognized by a continuously frequency with a certain interval of time (Turner 2010). Disturbance may be natural or human caused and forestry are with clear cut the most important ecosystem change in fennoscandian boreal forests (Esseen et al. 1997).

There is approximately one million recorded species of insects in taxonomic publications, but the number is uncertain because of biased classifications and unrecognized species variations (Gullan et al. 2010). There are more than 350 000 described species of beetles, making beetles to the most species rich group of insects known so far (Gullan et al. 2010). Beetles play a huge role in ecosystems and their diversity are reflected in different functional groups based on the role they perform in ecosystems (Blondel 2003). Functional groups are often linked to a general foraging behavior as e.g. they may act as predators, fungivores, dead wood feeders or detritivores (Lawrence & Britton 1994 cited in Lassau et al. 2005) and that change in functional group composition may come from change in food supply (Lassau et al. 2005). In Norway, 3558 beetle species have been recorded, but the total number of beetle species has been estimated to be approximately 3800 (Ødegaard et al. 2010). Of the recorded species, 61 are considered to be regionally extinct and 444 are categorized as threatened on the 2010 Norwegian red list for species (Kålås et al. 2010). Regionally extinct species are mainly attached to the old-established cultural landscape or to old forest or woodland (Ødegaard et al. 2010). Among all red listed beetle species, 360 have an affinity to woodland (Kålås et al. 2010), and most of these are attached to dead wood (Ødegaard et al. 2010). Forestry is one of the main reasons for threatened beetle species because of the changed tree composition, low amount of dead wood and lack of tree species mixture in uniform stands (Haila 1994).

Norwegian forests are mainly boreal forests with a belt of boreonemoral forests along the coast from east to south-west of Norway (Moen 1998). The forests cover approximately 40% of the mainland (Statistics Norway 2012), but only 1.6% are older than 160 years (Hobbelstad et al. 2004). According to the Norwegian nature index, the forests in Norway are in medium to low condition for maintaining biodiversity (Storaunet & Gjerde 2010) and it is especially the lack of dead wood and old trees, including the insects and fungus inhabiting these habitats,

which reduces the condition. Modern forestry is considered to be the main factor for the reduced amount of dead wood (Storaunet & Gjerde 2010).

When modern stand forestry with clear cutting started around the middle of the 20th century (Storaunet & Gjerde 2010), the composition of the forests changed to a mosaic of stands of different age, density and tree species (Gjerde et al. 2009). In forestry, most of the timber is transported out of the forest after logging, which means that the amount of dead wood does not necessarily increase or decrease (Selonen et al. 2005). In contrast, power-line corridor maintenance leaves the logged trees in the corridors, resulting in an increase in the amount of dead wood, in addition to increased sun exposure to the ground.

When gaps from either clear cuts or power-line corridor maintenance are created, new conditions are applied to the habitats. There is an increase in soil temperature and decrease in soil humidity, and the light favors sun-adapted species and growth of small trees (Smith & Smith 2006). Also the temperature fluctuations in such gaps are more extreme than in a forest, because forest reflects heat at day and traps heat at night (Primack 2006)

In Norway forest production has been stable during the last 60 years (Statistics Norway 2012), and the amount of dead wood is increasing according to national forest inventory data (Storaunet et al. 2011). In 2010, the mean amount of dead wood in forests dominated by Norway spruce *Picea abies* and Scots pine *Pinus sylvestris* was 16.9 $m^3 ha^{-1}$ and 11 $m^3 ha^{-1}$, respectively (Storaunet et al. 2011). In the southern and middle boreal zones in Fennoscandia, a spruce dominated old growth forest could have an average amount of dead wood from 90 to 120 $m^3 ha^{-1}$ and a pine dominated old growth forest an average of 60 to 120 $m^3 ha^{-1}$ (Siitonen 2001).

Old-growth forests contain more threatened forest specialists species and more abundant generalist species than managed forest (Koivula & Niemela 2002) and especially many of the threatened dead wood living species are beetles (Jonsell et al. 1998). Beetle species specialized on dead wood of spruce and birch are significantly more abundant in areas with higher volumes of dead wood (Siitonen 1994). Siitonen (1994) also state that number of saproxylic species (Species' dependent of dead wood in some parts of its life) increase with increasing amount of dead wood. Several other studies emphasize the importance of dead wood and the fact that species richness increases for saproxylic beetles with increasing amount of dead wood (Økland et al. 1996; Sverdrup-Thygeson & Ims 2002; Similä et al. 2003). Composition of dead wood is also very important (Similä et al. 2003) and especially

dead wood in sun exposed habitats are important to maintain populations of species dependent on natural disturbance (Kaila et al. 1997). Species richness of beetles are known to be significantly higher in old growth forests (>160 year) than in mature forests (95-120 years) (Martikainen et al. 2000). Many beetles are dependent on dead wood and it may take up to 20 years for some beetle species to emerge out of dead wood (Gullan et al. 2010).

Many species adapted to disturbed conditions may respond positively if non-commercial dead wood and damaged old trees, are left in logging areas (Kaila et al. 1997) because there is a large variation between micro habitats like different size and type of wood, different nutrition availability and a variation in water capacity which makes many habitats for beetles (Esseen et al. 1997). Invertebrates linked to wood decay are known as one of the largest contributor to species richness (Kaila et al. 1997), and in Norway 17 % of the red listed species depends on dead wood (Kålås et al. 2010).

In this study, I investigated whether disturbance of boreal forest, in the form of maintenance of early successional stage forest and accumulation of dead wood in power-line corridors, influenced biological diversity of beetles. More specific, I wanted to investigate if: 1) species composition differed between power-line corridors and forests (Kaila et al. 1997); 2) functional diversity differed between power-line corridors and forests, i.e. if the relative proportion of beetles and species within functional groups differed between the two habitats (Lassau et al. 2005); 3) species richness and/or biodiversity was higher in power-line corridors than in forests (Niemela et al. 1993; Kaila et al. 1997); 4) dead wood increased species richness and/or biodiversity in the power-line corridors and the forests (Økland et al. 1996) and 5) distribution of rare versus common species, (species abundance distribution), differed between power-line corridors and forests (Haila et al. 1994).

2. Methods

2.1 Site selection and design

2.1.1 Study area

The sampling sites were located in south eastern Norway. First, a total of 84 sites were randomly distributed on a map showing the power-line network operated by Statnett, the company responsible for all high voltage electricity transmissions and distribution in Norway. Subsequently, 54 out of the 84 sites were randomly selected. Of these 54 sites, 20 sites (Figure 1) were selected for this study. In 2010 ten sites (site; 1-4, 7, 10-13 and 18; Figure 1) where chosen and eight flight interception traps (Figure 2) were placed in each site (Figure 3). In 2011 ten new sites (site; 14-15, 26, 32, 35, 42, 44, 46, 50 and 51; Figure 1) where chosen and eight interception traps were placed in each of the new sites.

Figure 1. Geographical distribution of the 20 sites where I collected data on beetles by use of intersection traps (Figure 2).

All sites were chosen by the criteria: The sites had been examined for habitat characteristics (in 2009 for the 2010 sites or during 2009 or 2010 for the 2011 sites), the site was available in April (lack of snow, closed roads, etc.) and the site was not planned to be maintained by Statnett during the study period. A main maintenance clearing are conducted every tenth year and a follow-up maintenance every fifth year by Statnett.

Figure 2. Tripod of slanted bamboo poles holding the interception trap. Plexiglas in a cross above the funnel with the storage container at the bottom. Flying beetles collide with the plexiglas and fall down into the funnel leading into the container with conservation fluid (photo: Jogeir Engeset Mikalsen).

All sites were in power-line corridors with conifer or deciduous forest vegetation. There was always at least 200 m distance perpendicular from the power-line to an area without forest, preventing unwanted edge effects. If a site did not fulfill the requirement it was moved along the power-line corridor until the requirements where fulfilled (Satellite/aerial view in "Norgeibilder.no" was used).

The sites were located as exact as possible ± 200 m from a preliminary GPS position (Datum: WGS84, UTM32).
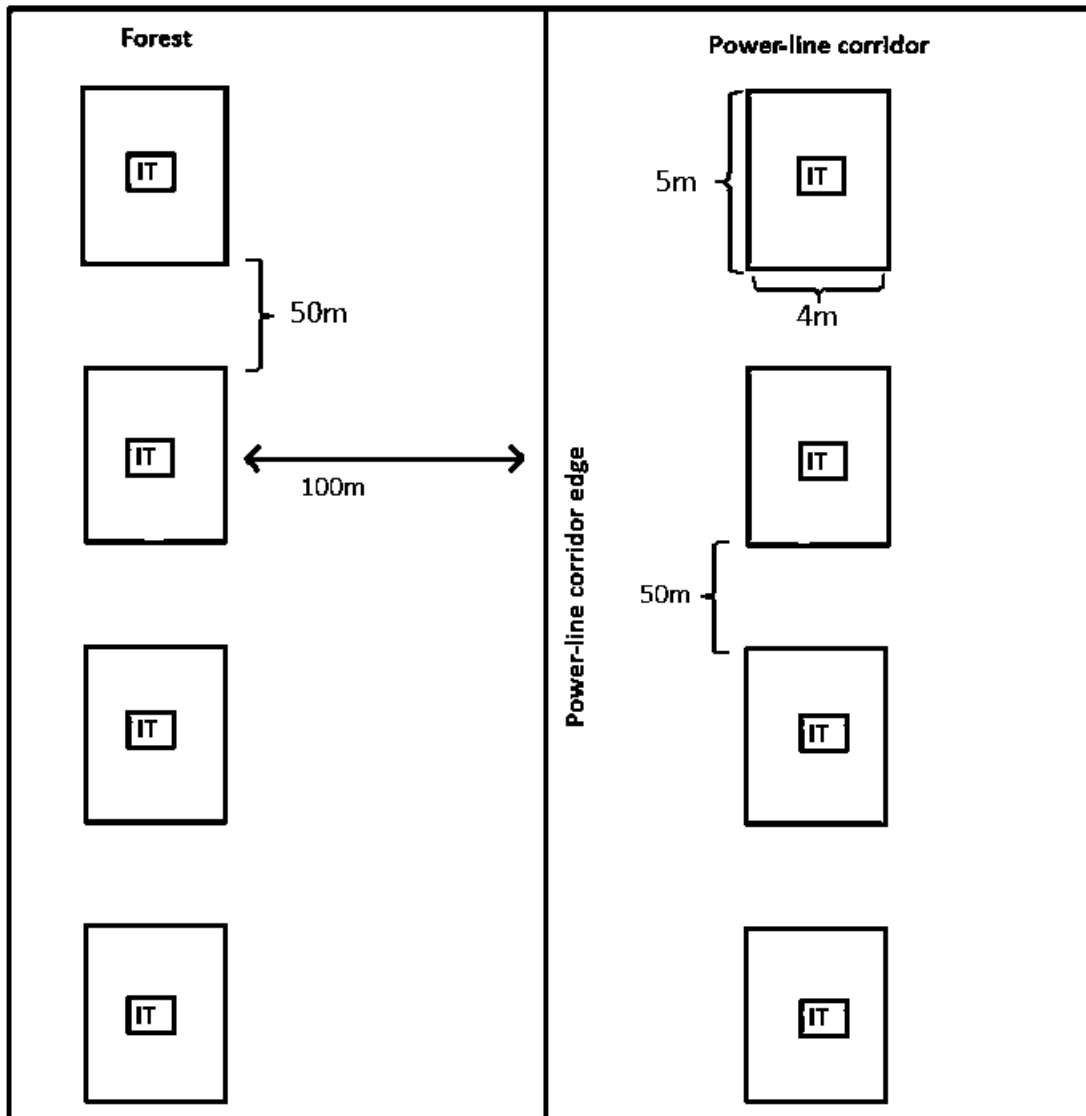
Figure 3. Site with plots and placement of interception traps (IT). Four plots were placed in the power-line corridor with 50 m between each plot, and four plots were placed in the adjacent forest perpendicular from each power-line plot and 100 m into the forest from the edge of the power-line corridor.

2.1.2 Site design – terminology

Each of the 20 sites consisted of 8 plots of 4 m x 5 m, four in closed canopy forest and four in the power-line corridor. Although there was some variation within each of these two habitats, for example in mean tree height, the power-line corridor habitat represented in general early successional stages of boreal forest. Forest habitats represented in general later successional stages of boreal forest. Power-line plots were located along the center line of the power-line

corridor with a distance of 50 meters between each plot. All power-line plots at each site were placed between two power poles, with at least 50 m distance from a power pole. Each forest plot was located 100 m into the forest from the edge of the power-line corridor, perpendicular on each of the power-line plots in the power-line corridor (Figure 3).

2.2 Data collection – environmental variables

2.2.1 Data collection on habitat characteristics

Data on elevation of each plot was determined by use of digital maps, Ar5 (Nilsen 2011) in ArcGIS (ESRI 2009). The total width of each power-line corridor was measured with "Norge i bilder" (Norge digitalt). Data on number of years since the power-line was established was provided by NVE (Norwegian Water Resources and Energy Directorate). The following climatic variables were extracted from eKlima (The Norwegian Meteorological Institute); January mean temperature, July mean temperature, difference between January and July temperature, mean temperature in the growing season (June, July, August September) and mean annual precipitation for the last 30 years. In 2009 and 2010, the number of dead logs with diameter >3cm on the thickest part of the log was recorded, the number of dead standing trees was recorded on plot level, whereas the percentage of dead wood was recorded within five 1 m x 1 m subplots placed along the center line of the 4 m x 5 m plots in Figure 3. I calculated the average cover of dead wood within the five plots and used this as a measure of dead wood cover within the 4 m x 5 m plot. The steepest slope within each plot was measured in percent with a clinometer (Suunto), and aspect of each individual plot was measured where the plot was steepest.

2.2.2 Interception traps

The interception traps (Figure 2) were formed by two rectangular Plexiglas plates (21.5 cm x 39.5 cm), both Plexiglas plates were split halfway from the short end and to the middle and mounted together forming a cross. A funnel (21.5 cm diameter) with a container at the bottom where placed under the Plexiglas plates and the container was filled with 2.5 dl conservation fluid (propylene glycol). The upper part of the bottle had 1-4 small holes to let out excess rainwater. The holes were small enough to prevent small beetles from escaping the container. The whole device was hung with some thin steel wire or thin rope from a tripod of slanted bamboo poles. The bamboo poles were stuck into the ground and the trap hang freely in the air, 58-93 cm above ground. All traps were put up in the center of each plot (Figure 3).

2.3 Data collection - beetles

2.3.1 Beetles
The flight interception traps were placed out in the field at the end of April and beginning of May both years and emptied each month until August/September. Thus each trap captured beetles continuously from spring to early autumn and beetles were collected four times during this period. Ten sites in both 2009 and 2010 and eight traps per site, gives a total of 640 containers of collected material. At each collection round, the containers were replaced with a new container with uncontaminated preservation fluid.

2.3.2 Lab work and species identification
In the lab, content from each container were emptied in a fine-meshed plankton cloth and rinsed for conservation fluid before it was transferred to new pre-labelled storage glass with 80% ethanol. Thereafter, the material was sent to an expert in beetle species identification, Sindre Ligaard, who identified the beetle species, following the nomenclature of Silfverberg (2004). Ligaard also categorised all the collected species into one of the following six functional groups: DW (dead wood feeders), FU (fungivores), HB (herbivores), LW (live wood feeders, PR (predators), DE (general detritivores, not dead wood, but including plant material, excrement's and carcasses) and NA (ecological function unknown) following literature listed in Appendix 1. Only ecological function for imago beetles were used when classified into functional groups.

2.4 Statistical analyses
Before analyses, the data from each plot, i.e. from the four different collecting rounds, were pooled together, because each trap was trapping beetles continuously from April/May to September/October.

2.4.1 Species composition
To analyze the difference in species composition I used a Canonical Correspondence Analysis (CCA) and Monte-Carlo permutation tests to determine if the variation from the categorical variables site (20 levels = sites) and habitat (two levels; power-line corridor, forest) were larger than from a random variable. In order to find additional variation explained by habitat, after the variation explained by site had been accounted for, I performed a partial constrained ordination: First the variation from site was partial led out and then the remaining variation bound to habitat was found. A square root transformation was applied to the beetle species data to down-weight the effect of abundant species.

2.4.2 Functional groups

The data on number of beetles in each functional group were counts (number of individuals or species per group respectively). Before analysis the group NA (ecological function unknown) with 62 individuals was excluded. Furthermore the LW (live wood feeders) had only 56 individuals and was pooled together with DW (dead wood feeders). I used generalized linear mixed models (GLMMs) for analyses of the functional groups data, following procedures recommended by Bolker et al. (2009). Response variables were number of individuals and number of species. I fitted full (most complex) models including the fixed effects habitat, functional group, and the Habitat×Functional group. The interaction term was included because the purpose was to find out whether there was a difference in the relative number of beetles/species within each functional group between the power-line corridors and forest. The interaction term was significant in both of the two models, and thus no model reduction was carried out. Site was modeled as random effect. I fitted a model with log link function, Poisson distribution, and Gauss-Hermite Quadrature (GHQ) technique for GLMM parameter estimation (Bolker et al. 2009). However, inspections of graphical diagnostics and the scaled Pearson statistic for the conditional distribution suggested that there was sustainable over-dispersion. Therefore, I adjusted the model 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. I provide Wald F tests of fixed effects, and likelihood ratio (LR) tests of random effects for the model best supported by the data. I report estimated least squares means and associated standard errors.

2.4.3 Species richness

In order to compare the difference in species and family richness between power-line corridors and forests I made species and family accumulation curves based on data from all 20 sites. Method "exact" was used to avoid the randomization and curve modeling which may overlook heterogenic sites in other types of accumulation curves (Ugland et al. 2003). The method focuses on site-frequency for each species, so the curve will only change when the frequencies of species change (Kindt et al. 2006). Accumulation curves for each site separately indicates site variation in biodiversity (Appendix 2). Because of this, I decided to fit generalized mixed models with species richness as response variable, habitat (Power-line corridor, Forest) as fixed effect explanatory variable and site as random effect. The species richness data were counts (number of species), and therefore I fitted a model with log link function, Poisson distribution, and Gauss-Hermite Quadrature (GHQ) technique for parameter

estimation (Bolker et al. 2009). However, inspection of the graphical diagnostics and the Pearson Chi-square/df value revealed that there was over-dispersion. Therefore, I adjusted the model by changing from Poisson to a negative binomial distribution, which provided a better fit to the data. In addition to the fixed effect habitat, I investigated the influence from dead wood variables measured at the plot level. Initially, I also fitted separate models for each environmental variable with site as random effect. The following environmental variables on the site level were tested: Elevation, total width of power-line corridor, angel of inclination, aspect, number of years since power-line was established, January mean temperature, July mean temperature, difference between January and July temperature, mean temperature in the growing season (June, July, August September), mean year precipitation for the last 30 years, number of dead logs, number of dead stands and dead wood coverage in percent. Only habitat, percent cover of dead wood and number of dead logs were included as explanatory variables in further analysis, because the rest were not significant $p > 0.10$ when individually tested.

I provide Wald F tests of fixed effects, and likelihood ratio (LR) tests of random effects for the model best supported by the data.

2.4.4 Biodiversity

I used Renyi diversity profiles for species and family diversity to compare the different diversities between power-line corridors and forests. Renyi profiles for each site separately indicated substantial variation in biodiversity among sites (Appendix 3). Because of this, I decided to fit generalized mixed models with biodiversity as response variable, habitat (Power-line corridor, Forest) as fixed effect explanatory variable and site as random effect. The analysis results were presented with Shannon biodiversity index as response variable, but the choice of biodiversity index did not qualitatively influence my results. I fitted a generalized mixed model with identity link function, normal distribution, and Restricted Maximum Likelihood (REML) technique for parameter estimation. In addition to the fixed effect habitat, I investigated the influence from dead wood variables measured at the plot following procedures from species richness analysis above. Number of dead standing trees was not significant when individually tested (P-value = 0.18), and was rejected from further analyses.

2.4.5 Species abundance distribution

An empirical cumulative distribution function (ECDF) was created to compare commonness and rarity of species in their habitat (i.e. species abundance distribution) as recommended by

McGill et al. (2007) and Magurran et al. (2011). This form of index is more mathematic powerful than many other indexes presenting species abundance as they are not influenced by species richness, making it possible to compare two habitats that differ in total species richness. Kolmogorov-Smirnov test were used to determine if the distributions (ECDF's) from the two habitats differed significantly from each other. In the ECDF the abundance is sorted in increasing order an divided by total abundance in each habitat and used as values on the x-axis. The ranks from lowest to highest abundance are divided by the total number of species richness (S) and placed on the y-axis, giving values ranging from 1/S to 1 (Magurran et al. 2011).

Data were analyzed using SAS (SAS/STAT® 9.2) and R (R development core team 2011) statistical software.

3. Results

3.1 Beetle abundance and species composition

The total dataset contained 14215 beetles from 641 species and 61 families. In the power-line corridors, 10514 beetles from 535 species and 54 families were collected, and in the closed canopy forests, 3701 beetles from 408 species and 57 families were collected. The ten most common species constituted 5547 of the individuals, which is approximately 39% of the total material. The ten most common families constituted 11574 of all beetles, which is approximately 81% of the total. The three most common species was *Amischa analis, Dasytes niger* and *Scaphisoma agaricinum* which together comprised approximately 17.3% of all beetles. These species were also most common in the power-line corridors where they comprised approximately 23.5% of all beetles there (Table 1). In the forests *Athous subfuscus, Acrotrichis intermedia* and *Scaphisoma agaricinum* were most common with approximately 12% of all beetles there (Table 1). The three most common families were Staphylinidae, Elateridae and Curculionidae with 3396, 2390, 1585 beetles, respectively, and 23.9%, 16.8% and 11.2% of the total. Together these three families covered approximately 52% of all beetles captured.

Table 1. The most common species' in power-line corridors and adjacent forests. Functional groups (FG) are: DE (general detritivores), DW (dead wood feeders), FU (fungivores), HB (herbivores), PR (predators).

Power-line corridors				Forests			
Species	Family	FG	Beetles (No.)	Species	Family	FG	Beetles (No.)
Amischa analis	Staphylinidae	PR	1136	*Athous subfuscus*	Elateridae	HB	169
Dasytes niger	Melyridae	PR	737	*Acrotrichis intermedia*	Ptiliidae	DE	144
Scaphisoma agaricinum	Staphylinidae	FU	593	*Scaphisoma agaricinum*	Staphylinidae	FU	130
Ampedus balteatus	Elateridae	DW	393	*Dalopius marginatus*	Elateridae	DW	123
Curtimorda maculosa	Mordellidae	FU	389	*Triplax russica*	Erotylidae	FU	122
Potosia cuprea	Scarabaeidae	DE	382	*Ampedus balteatus*	Elateridae	DW	94
Pityogenes chalcographus	Curculionidae	HB	361	*Dryocoetes autographus*	Curculionidae	HB	93
Leptura melanura	Cerambycidae	DW	341	*Nicrophorus vespilloides*	Silphidae	DE	92
Ampedus nigrinus	Elateridae	DW	316	*Ampedus nigrinus*	Elateridae	DW	90
Dalopius marginatus	Elateridae	DW	261	*Bibloporus bicolor*	Staphylinidae	PR	88

The functional group with most beetle individuals were the predators (PR) with 4134 individuals (29% of all) followed by dead wood feeders (DW) with 3168 individuals (22%), herbivores (HB) with 2745 individuals (19.4%), fungivores (FU) with 2195 individuals (15.4%), general detritivores (DE) with 1846 (13.0%), live wood feeders (LW) with 56 individuals (0.4%) and the group with unknown ecological function (NA) had 62 individuals (0.4%) (Table 2).

Table 2. Number and percent of beetles in the power-line corridors and in the forests for each of the functional groups: DE (general detritivores), DW (dead wood feeders), FU (fungivores), HB (herbivores), LW (live wood feeders), PR (predators), and NA (ecological function unknown).

Functional group	DE	DW	FU	HB	LW	PR	NA	Total
Power-line corridor (No.)	1240	2569	1584	1909	56	3126	30	10514
Forest (No.)	606	599	611	845	0	1008	32	3701
Power-line corridor (%)	11.8	24.4	15.1	18.2	0.5	29.7	0.3	100.0
Forest (%)	16.4	16.2	16.5	22.8	0.0	27.2	0.9	100.0

Nineteen species from my dataset are listed in the 2010 Norwegian red list for species (Ødegaard et al. 2010). Four species; *Corticeus fraxini, Cryptocephalus coryli, Hylis procerulus* and *Sphaeriestes bimaculatus* were categorized as endangered (EN) and contained eight individuals. Four species; *Anthribus scapularis, Atomaria fuscipes, Cidnopus pilosus* and *Paranopleta inhabilis* were categorized as vulnerable (VU) and contained six individuals. Ten species were near threatened (NT); *Agrilus betuleti, Atomaria subangulata, Cis fagi*, *Hylis cariniceps, Meligethes corvinus*, *Microrhagus Lepidus*, *Mycetophagus fulvicollis, Oxypoda recondite, Platysoma lineare* and *Stagetus borealis* and comprised 36 individuals together. One species, *Meligethes ochropus* were placed in the category data defiency (DD) and contained five individuals. Together the red listed species comprised 55 individuals (Table 3). Most of these species are threatened by human development, forestry and modern farming (appendix 4).

Table 3. Species trapped in this study, which are listed in the 2010 Norwegian red list for species (Ødegaard et al. 2010). Red list categories are: EN (endangered), VU (vulnerable), NT (near threatened) and DD (data deficiency). Functional groups are: DE (general detritivores), DW (dead wood feeders), FU (fungivores), HB (herbivores), LW (live wood feeders), PR (predators), and NA (ecological function unknown).

Species	Family	Functional group	Red list categori	Beetles (No.)
Cryptocephalus coryli	Chrysomelidae	HB	EN	1
Hylis procerulus	Eucnemidae	DW	EN	5
Sphaeriestes bimaculatus	Salpingidae	PR	EN	1
Corticeus fraxini	Tenebrionidae	DE	EN	1
Anthribus scapularis	Anthribidae	HB	VU	2
Atomaria fuscipes	Cryptophagidae	DE	VU	1
Cidnopus pilosus	Elateridae	HB	VU	2
Paranopleta inhabilis	Staphylinidae	PR	VU	1
Stagetus borealis	Anobiidae	DW	NT	3
Agrilus betuleti	Buprestidae	LW	NT	1
Cis fagi	Ciidae	FU	NT	1
Atomaria subangulata	Cryptophagidae	DE	NT	1
Hylis cariniceps	Eucnemidae	DW	NT	3
Microrhagus lepidus	Eucnemidae	DW	NT	1
Platysoma lineare	Histeridae	PR	NT	2
Mycetophagus fulvicollis	Mycetophagidae	FU	NT	2
Meligethes corvinus	Nitidulidae	HB	NT	20
Oxypoda recondita	Staphylinidae	PR	NT	2
Meligethes ochropus	Nitidulidae	HB	DD	5

The variation from site gave the largest effect and the results of the CCA showed that the variable site explained approximately 17% of the variation (Monte-Carlo permutation test: Pseudo-$F_{19,140}$: 1.46, p = 0.001, 999 permutations). In order to find additional variation explained by habitat, after the variation from site had been explained, I performed a partial constrained ordination: The results of the CCA showed that the variable habitat explained approximately 2 % of the variation which was not also explained by site (Monte-Carlo permutation test: Pseudo-$F_{1,139}$: 3.34, p = 0.001, 999 permutations).

3.2 Functional groups

The number of beetles and species in power-line corridors were influenced by habitat, functional groups and the interactions between them (Table 4 and Table 5). The significant habitat x functional group interaction indicates that the relative number of beetles and species within the functional groups differed between the power-line corridors and the forests. The number of individuals and species within the dead wood group increased, whereas the other groups were relatively even or declining in power-line corridors (Figure 4 and Figure 5).

Table 4. Functional groups analyzed with the variables; habitat, functional group and their interaction influencing number of beetles captured. A general linear mixed model (GLMM) was used. Site was included as a random effect. Wald F tests were used for fixed effects and likelihood ratio test for the random effect.

Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	1,771			307.77	<0.0001
Functional group	4,771			17.92	<0.0001
Habitat×functional group	4,771			4.69	0.0010
Random effect					
Site	1	-2953.5	60.2		<0.0001

All functional groups had significant higher number of both beetles and species in the power-line corridors than in the forests, based on estimated mean numbers (Figure 4 & Figure 5). Dead wood feeders (DW) had an estimated mean number of 32.5 (26% of total) beetles per plot in the power-line corridors and 7.56 (17% of total) beetles per plot in the forests. Predators (PR) were more evenly distributed with 34.0 (27%) beetles per plot in power-line corridors and 12.4 (28%) beetles per plot in forests. General detritivores (DE) had 15.0 (12%) and 6.9 (16%), fungivores (FU) 19.7 (16%) and 7.3 (16%) and herbivores (HB) 22.8 (18%) and 10.3 (23%) beetles per plot in power-line corridors and forests, respectively (Figure 4)
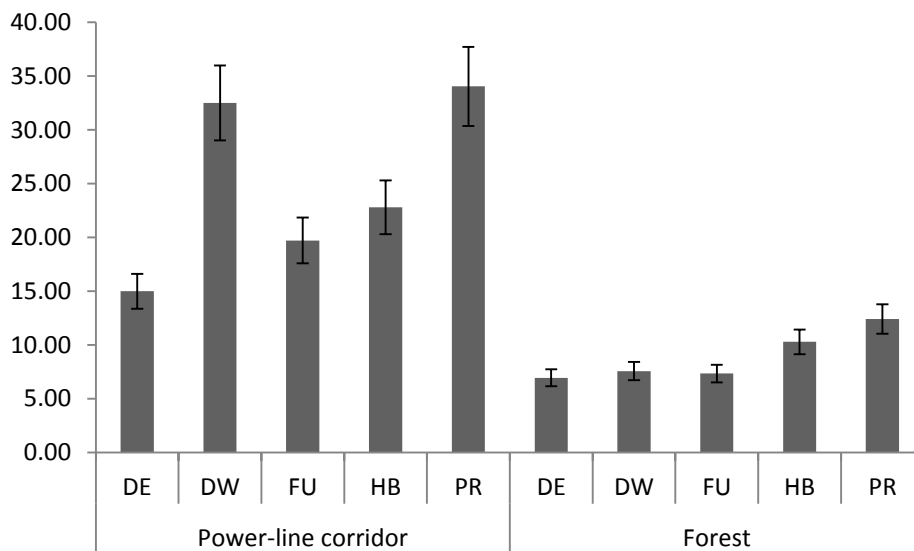

Figure 4. Estimated mean numbers of beetles (±SE) per plot of different functional groups in power-line corridors and in adjacent forests. Functional groups: DE (general detritivores), DW (dead wood feeders), FU (fungivores), HB (herbivores) and PR (predators).

Table 5. Functional groups analyzed with the variables; habitat, functional group and their interaction influencing number of species captured. A general linear mixed model (GLMM) was used. Site was included as a random effect. Wald F tests were used for fixed effects and likelihood ratio test for the random effect.

Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	1,771			227.29	<0.0001
Functional group	4,771			58.60	<0.0001
Habitat×functional group	4,771			8.34	<0.0001
Random effect					
Site	1	-2037.8	40.47		<0.0001

Dead wood feeders (DW) had an estimated mean number of 9.5 (23% of total) species in the power-line corridors in contrast to 3.7 (15% of total) species in the forests. Herbivores (HB) were more evenly distributed with 8.5 (20%) species in the power-line corridor and 5.1 (21%) in the forest. General detritivores (DE) had 5.8 (14%) and 3.6 (15%), fungivores (FU) 6.1 (15%) and 4.0 (16%) and predators (PR) 11.5 (28%) and 7.9 (33%) species in the power-line corridors and the forests, respectively (Figure 5).

The functional group with the largest increase in percent from forest to power-line corridors was the dead wood feeders (DW). The power-line corridor contained 9% more beetles and 8% more species of dead wood feeders (DW) compared with the forest (Figure 4 and Figure 5).

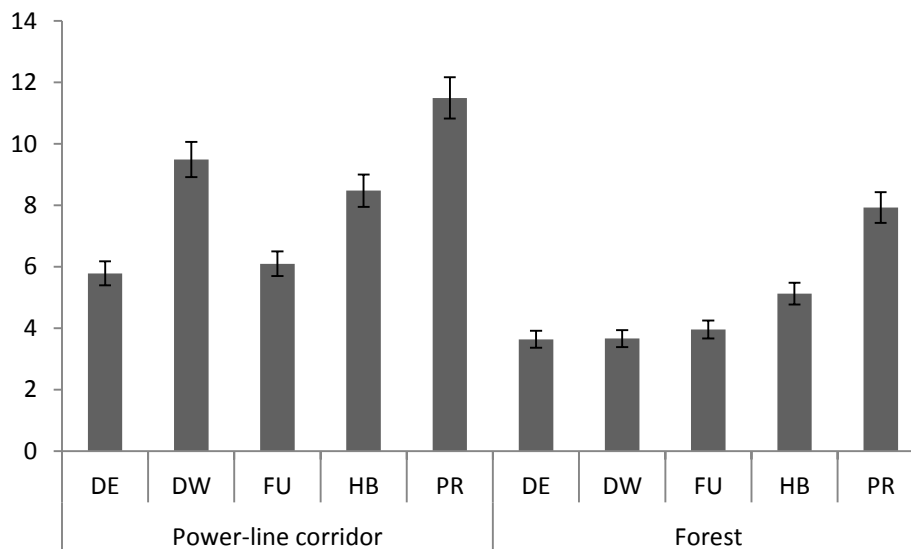
Figure 5. Mean numbers of species (±SE) of different functional groups in power-line corridors and in adjacent forests. Functional groups: DE (general detritivores), DW (dead wood feeders), FU (fungivores), HB (herbivores) and PR (predators).

3.3 Species richness in relation to habitat and amount of dead wood

Species accumulation curves (Figure 6) show that overall species richness, as calculated for aggregated data from 20 sites, was higher in power-line corridors than in forests and that the curve has not leveled off (i.e. number of species would increase if I had increased number of sites/plots). A similar accumulation curve was made for families (Appendix 5), were the curve leveled off, indicating that most families had been sampled.
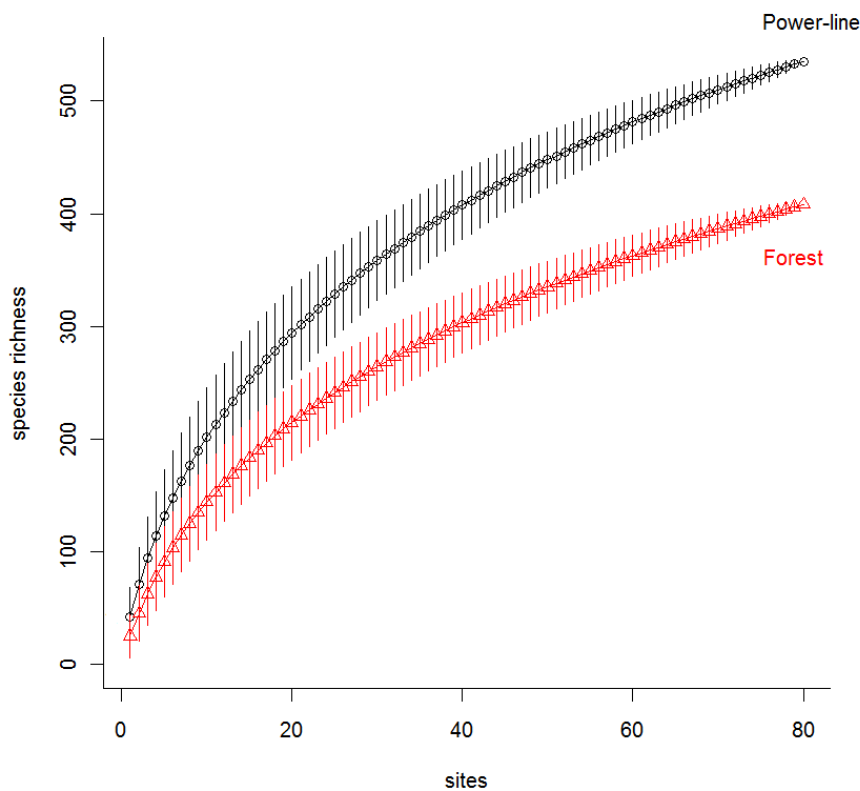

Figure 6. Accumulation curves for beetle species collected along the center line of power-line corridors and 100 m inside the adjacent forests. Data are aggregated from 20 sites. Method used; "exact". Beetles were collected at the sites described in (Figure 3) by use of interception traps (Figure 2).

The Estimated mean number of species per trap (see Figure 3) was 41.7 (SE±1.90) in power-line corridors and 33.3 (SE±1.18) in forests (Figure 7). Habitat alone had a significant influence on species richness ($F_{1,139} = 110.2$, P = <0.0001). The environmental variables percentage of dead wood ($F_{1,139} = 6.44$, P =0.012) and number of dead logs ($F_{1,139} = 7.09$, P =0.0087) had significant positive effects on species richness when tested individually.
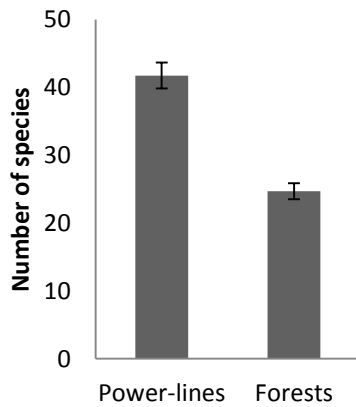
Figure 7. Estimated mean species richness per plot for power-line corridors and adjacent forests (±SE).

Per one percent increase in dead wood cover, richness increased with 1 species (estimate dead wood cover: $\beta = 0.0203$, $\pm SE = 0.00798$; $e^\beta = 1.02$) and per one dead log more present, richness increased with one species (estimate dead logs: $\beta = 0.0179$, $\pm SE = 0.00673$; $e^\beta = 1.02$).
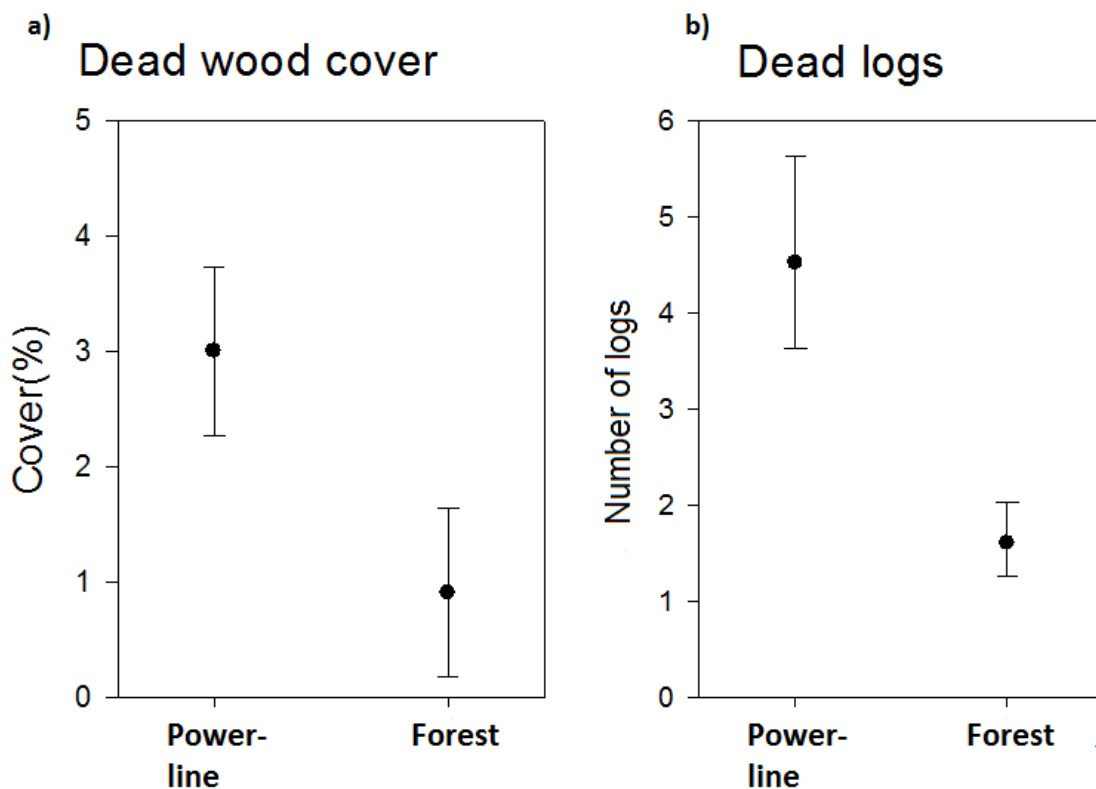
Figure 8. Mean number of percent coverage of dead wood (a) and number of dead logs (b) in the power-line corridors and adjacent forest (95% confidence interval). Dead logs were measured as number of dead logs >3 cm on the thickest part within each of the 4m x 5m plots shown in Figure 3. Dead wood cover was measured as the percentage of dead wood covering the ground within subplots located along the center line of the 4m x 5m plots shown in Figure 3. The data on dead wood from each plot are an average based on counts from five 1 m x 1 m subplots within each plot.

Mean number of dead wood cover in percent was 3.0% in power-line corridor and 0.91% in the forest and mean number of dead logs was 4.5 in the power-line corridors and 1.6 in the forests (Figure 8). The number of beetles increased significantly with the number of dead wood and dead logs (see above), but there was also a significant effect of the interaction between habitat and percentage of dead wood (Table 6) and habitat and dead logs (Table 7), with relatively stronger positive effects of amount of dead wood for power-line corridors than for forest (parameter estimates; Habitat x percent of dead wood: $\beta_{power-line} = 0.0429$, $\beta_{forest} = 0$; Habitat x Number of dead logs: $\beta_{power-line} = 0.034$, $\beta_{forest} = 0$)

Table 6. Species richness of beetles analyzed with the variables; habitat, percentage of dead wood and their interaction influencing number of species captured. A general linear mixed model (GLMM) was used. Site was included as a random effect. Wald F tests were used for fixed effects and likelihood ratio tests of random effect.

Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	1,137			68.01	<0.0001
Percent of dead wood	1,137			1.79	0.1834
Habitat × Percent of dead wood	1,137			3.99	0.0479
Random effect					
Site	1	- 606.1	9.11		0.0013

Table 7. Species richness of beetles analyzed with the variables; habitat, number of dead logs and their interaction influencing number of species captured. A general linear mixed model (GLMM) was used. Site was included as a random effect. Wald F tests were used for fixed effects and likelihood ratio tests of random effect.

Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	1,137			50.87	<0.0001
Number of dead logs	1,137			3.18	0.0768
Habitat × Number of dead logs	1,137			6.31	0.0132
Random effect					
Site	1	- 604.6	8.31		0.0020

3.4 Biodiversity in relation to habitat and amount of dead wood

The Renyi profiles for power-line corridors and forests intersected, and thus they did not provide a clear result with regard to which habitat had the highest biodiversity (Figure 9). Beetle species from the forest were more evenly distributed than beetle species from the power-line corridors (less steep curve in Figure 9). A similar Renyi profile was made for families (appendix 6).
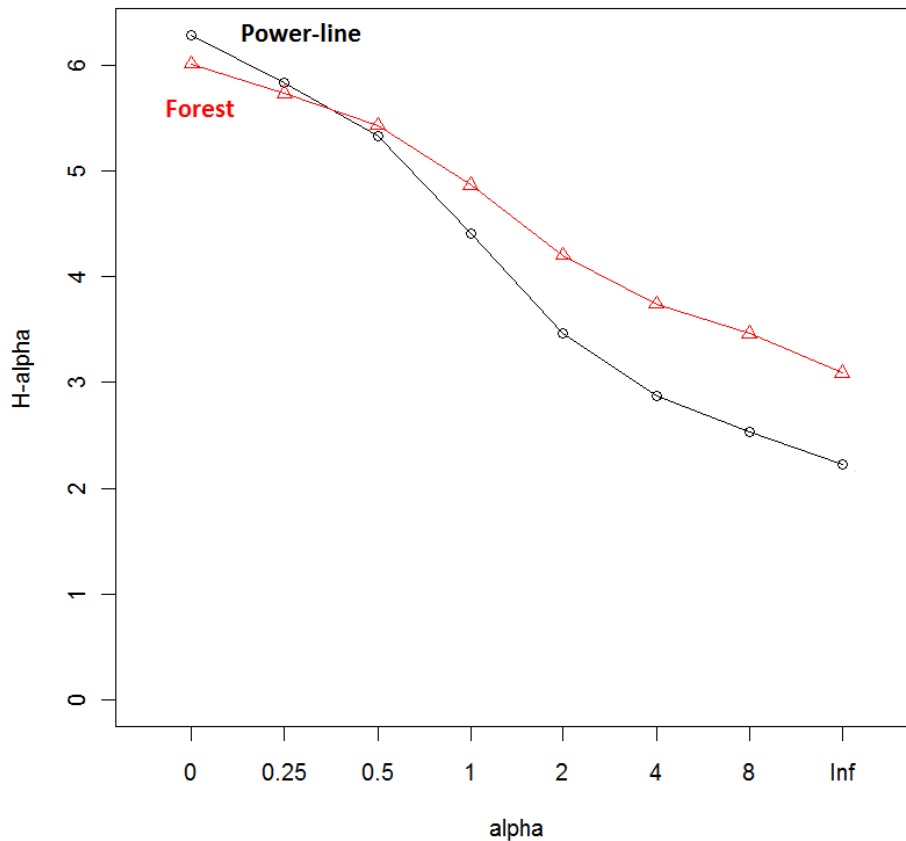
Figure 9. Comparison of biodiversity of beetles collected along the center line of power-line corridors and 100 m inside adjacent forests. Data are aggregated from 20 sites. The two curves show a diversity profile for each habitat and starting point for each curve indicates species richness (total number of species from 20 sites). The anti-logarithm ($e^{\text{H-alpha value}}$) for alpha = 0 gives species richness (Power-line: 535 species; Forest: 408 species). Alpha = infinity (inf) is a Berger-Parker index and shows information on the proportion of the most abundant species. The anti-logarithm ($e^{\text{H-alpha value}}$) for alpha = inf gives proportion of the most abundant species (Power-line: 0.108 = 10.8%; Forest: 0.046 = 4.6%). Profile value for alpha = 1 is Shannon index and for alpha = 2 it is the logarithm of the reciprocal Simpson diversity index. Steepness in curve indicates the share within the different species of beetles. The relatively steep curve indicates that evenness is low in both habitats. Because of intersecting curves it is not possible to decide whether the power line or the forest habitat has the highest total diversity. Beetles were collected on sites described in (Figure 3) with interception traps (Figure 2). 100 permutations were conducted.

The Renyi profiles were based on aggregated data from all 20 sites, and each plot was treated as an independent sampling site. When I analyzed the data with general linear mixed models with site as random effect, and thus controlling for the repeated sampling within each habitat within each site, I found that estimated mean biodiversity (Shannon index) was 3.11 (SE±0.050) in power-line corridors and 2.89 (SE± 0.064) in forests (Figure 10), and the difference was significant (Habitat: $F_{1,139} = 14.09$, P = 0.0003).
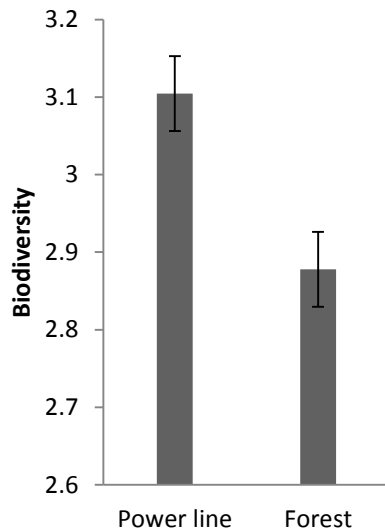
Figure 10. Estimated mean diversity of beetles based on the Shannon index for power-line corridors and adjacent forests (±SE).

Percentage of dead wood ($F_{1.139} = 0.79$, P =0.38) and number of dead logs ($F_{1.139} = 0.30$, P =0.59) did not influence biodiversity significantly when they were tested individually. However, when dead wood measures were included as explanatory variables in the models, together with habitat, the Habitat x Dead wood interactions (Table 8 and Table 9) indicated that dead wood influenced biodiversity, with a relatively stronger positive influence of dead wood in power-line corridors (parameter estimates; Habitat x Percentage of dead wood cover: $\beta_{power-line} = 0.051$, $\beta_{forest} = 0$; Habitat x Number of dead logs: $\beta_{power-line} = 0.029$, $\beta_{forest} = 0$).

Table 8. Biodiversity of beetles analyzed with the variables; habitat, percent of dead wood and their interaction influencing number of beetle species captured. A general linear mixed model (GLMM) was used. Site was included as a random effect. Wald F tests were used for fixed effects and likelihood ratio tests of random effect.

Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	1,137			5.98	0.016
Percent of dead wood	1,137			2.93	0.09
Habitat × Percent of dead wood	1,137			4.60	0.034
Random effect					
Site	1	-86.3	2.14		0.072

Table 9. Biodiversity of beetles analyzed with the variables; habitat, number of dead logs and their interaction influencing number of beetle species captured. A general linear mixed model (GLMM) was used. Site was included as a random effect. Wald F tests were used for fixed effects and likelihood ratio tests of random effect.

Explanatory variables	df	Log (likel)	χ^2	F	p
Fixed effects					
Habitat	1,137			4.68	0.032
Number of dead logs wood	1,137			2.59	0.11
Habitat × Number of dead logs	1,137			3.67	0.058
Random effect					
Site	1	-87.1	2.27		0.066

3.5 Species abundance distribution

The calculated Empirical Cumulative Distribution Functions (ECDFs) (Figure 11) for power-line corridors (535 species) and forests (408 species) were not significantly different (Kolmogorov-Smirnov test: D = 0.058, p = 0.41). In both habitats, most species were rare and 68.5 % of the species in power-line corridors had five or less individuals which constitute only seven percent of all individuals there. In forests 77.5 % of the species had five or less beetles which constitute 15.5 % of all beetles there. Only 22 (4%) and 27 (6.6%) species from the power-line corridor and forest respectively, had an abundance of more than one % of the total in each habitat (Figure 11)
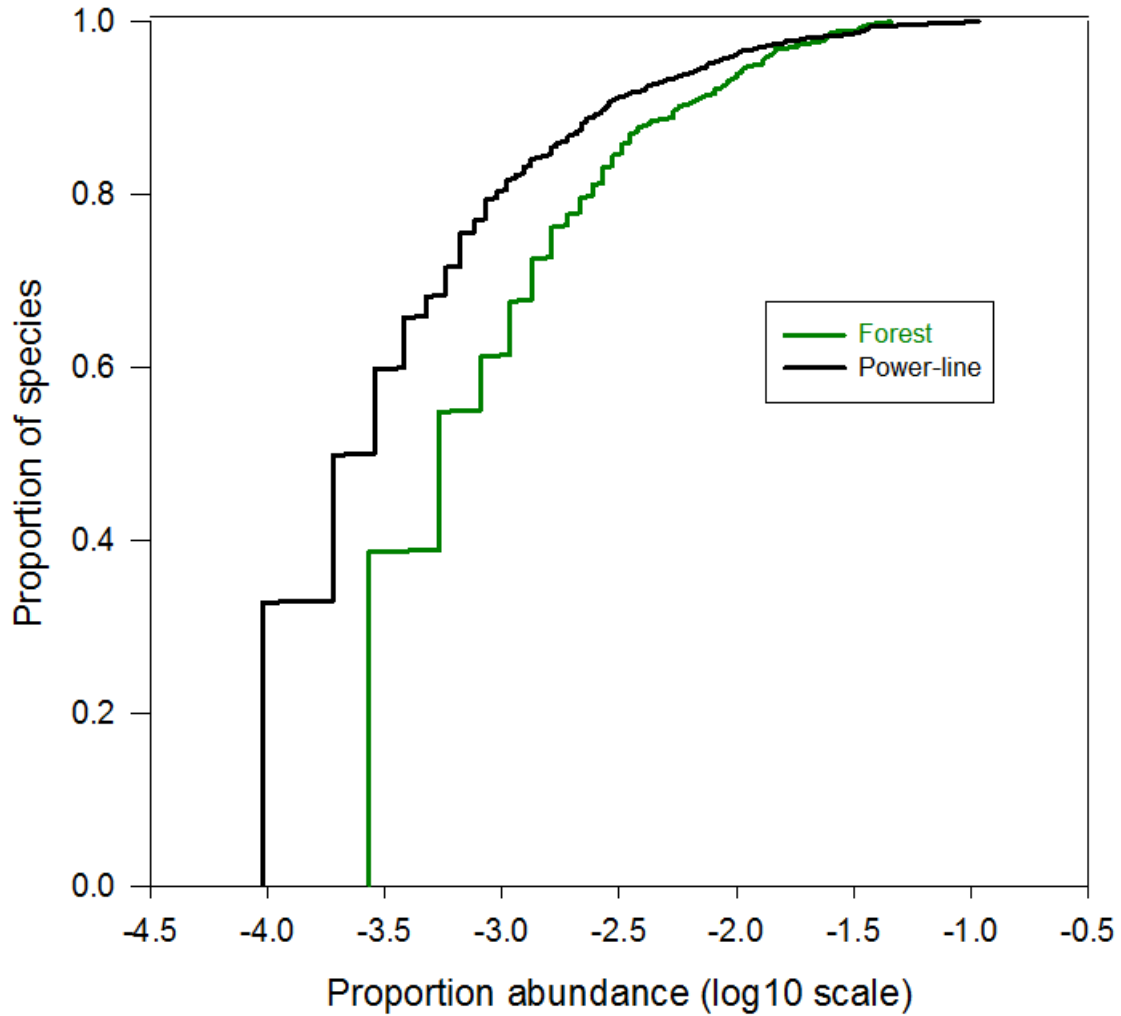
Figure 11. Empirical Cumulative Distribution Functions (ECDF) of species collected along the center line of power-line corridors and 100 m inside adjacent forests. Species are plotted from least to most abundant. X-axis is proportion abundance on a log10 scale. Value 0 is equivalent to abundance 10^0, = 1, i.e. 100%. Value -1 is equivalent to 10^{-1}, = 0.1, i.e. 10%, Value -2 is proportion 0.01, i.e. 1%, -4=0.01%. Y-axis is a proportion of species richness (S) (created by dividing each species rank by total number of species) and plots the values S^{-1} to 1. The curve indicates that there are high dominance of some species and that most species are rare. Beetles were collected on sites described in (Figure 3) with interception traps (Figure 2) from 20 sites.

4. Discussion

The majority of previous studies on beetles in boreal forest have looked at beetles in old-growth forests (Siitonen 1994; Martikainen et al. 2000; Similä et al. 2002; Similä et al. 2003; Janssen et al. 2009) and clear-cuts (Kaila et al. 1997; Martikainen 2001; Koivula 2002; Koivula & Niemela 2002; Similä et al. 2002; Selonen et al. 2005; Gibb et al. 2006; Gustafsson et al. 2010). In this study I have looked at how power-line corridors and closed canopy forests affected beetles. Power-line corridors are similar to clear-cuts in that they are followed by an early successional stage of forest after disturbance, i.e. after cutting of the tree layer. However, whereas clear-cuts gradually develop into older succession stage forest, power-line corridors are maintained at an early successional stage through frequents cutting, and the cutting also leads to an accumulation of dead wood in the corridors.

4.1 Beetle abundance and Species composition

The number of trapped beetles was 2.8 times higher in power-line corridors than in closed-canopy forests. As I predicted, I found that the species composition differed significantly between the power-line corridors and forests. This is unsurprising, given the substantial differences in habitat characteristics between the two habitat types. However, whereas the proportion of total variance explained by between-site differences amounted to 17%, the variation attributed to between-habitat (power-line *versus* forest) differences was only 2%. Thus, among-site variation was more important than between-habitat variation for beetle community composition. Of the ten most common species in the forest, four were also found among the top ten most common species in the power-line corridor. Three of the species had a proportional increase between 25-63% in the power-line corridor, whereas *Dalopius marginatus* had a proportional decrease of 38% in the power-line corridor.

Closed-canopy forests have more shade, moist and lower temperature compared to power-line corridors and species that prefer forest interior probably decline or are substantially reduced in power-line corridors. In contrast, species that prefer sun-exposed, drier, and typically warmer habitats will probably increase in abundance in power-line corridors. Another important difference in habitat characteristics, which probably influenced community composition, was the higher amount of dead wood in power-line corridors compared to forests. The number of individuals and species within the functional group, dead wood feeders, were relatively higher in power-line corridors (see discussion below), and this may explain a large part of the significant difference in species composition. Saproxylic species have been found to differ

significantly in species assemblage between clear-cuts and older forests (Stenbacka et al. 2010). However, not all dead wood feeders will benefit from increased amounts of dead wood in the corridors. Many species are dependent of coarse dimensions of dead wood and moist habitats (Esseen et al. 1997). *D. marginatus,* a dead wood feeder which was abundant in my study, has also found to be common in wet plant communities by Pawlega (2010). This suggests that the relatively lower abundance of this species in the power-line corridors could be due to lack of moist areas.

In the carabid family some generalists are distributed through successional stages with no preference in tree layer (Haila et al. 1994). Furthermore, many non-saproxylic species have been found to be unaffected by forest management (Martikainen et al. 2000; Stenbacka et al. 2010), and some are even attracted to clear-cuts, probably because of changes in microclimate (Stenbacka et al. 2010).

4.2 Functional groups

For all functional groups, a larger number of individuals and species were trapped in power-line corridors than in forest, but the relative proportion of individuals and species within each of the functional groups differed between the two habitats. The dead wood feeders had the greatest difference between the two habitat with a positive increase of 9% more individuals and 8% more species in the power-line corridors than in the forests. The relative increase in dead wood feeders in power-line corridors is probably related to the fact that there was more dead wood available in power-line corridors compared to forests. The proportion of predator beetles were evenly distributed between the two habitats, whereas the proportion of species was 5% higher in the forests compared with power-line corridors.

Changes in functional groups are related to changes in food supply, either between-habitats or between-seasons and have also been found in previous studies. For example, many beetles species bound to wood and bark are dominant in early season (Jukes et al. 2002) whereas for example detritivores and fungivores are more dominant in autumn (Choi et al. 2010). For mammals it is suggested that complex habitat increases present guild sizes more than the impact of additional guilds (August 1983). Indicating that dead wood feeders increase with more wood and that functional groups change with food supply as also found by Lassau et al. (2005). Thus, food supply change, during for example season or disturbance, could be a reason for changes in functional group composition. This is because the groups are classified

from their ecosystem function (Blondel 2003) and foraging habit (Lawrence & Britton 1994, cited in Lassau et al. 2005)

4.3 Species richness and biodiversity

The number of trapped beetles was higher in power-line corridors than in forests and the number of trapped species was 31% higher in the power-line corridors. Also, the species accumulation curve showed clearly a higher species richness in the power-line corridors versus the forests, whereas the Renyi profile was ambiguous on which habitat having the highest biodiversity. Both the estimated species richness and estimated biodiversity was significantly higher in the power-line corridors.

Vegetation heterogeneity is often greater in early successional stages, and has been suggested to be to be the dominant factor for higher species richness in early succession when compared with mature forests of different age (Haila et al. 1994). A higher species richness has been found in clear-cuts (Koivula 2002; Pawson et al. 2008) and in openings in forest compared with mature forest (80-120 years) (Koivula 2002) whereas Stenbacka et al. (2010) found that species richness was lowest in clear-cuts compared with different forests. When old-growth forests (> 160 years) compared with mature forests (95-120 years), species richness are significantly higher in the old-growth forests (Martikainen et al. 2000). This may to some extent be due to the large amount of dead wood in old-growth forests (Siitonen 2001).

One reason for high abundance of beetles in the power-line corridor versus the forests could be that insects lack the ability to maintain a constant temperature, and depend on external or internal heat to increase body temperature (Gullan et al. 2010), so that activity and thus the possibility for trapping is highest in sun exposed habitats (Kaila et al. 1997; Sverdrup-Thygeson & Ims 2002). Another factor that affects the number of beetle individuals trapped is resource availability (Gotelli & Colwell 2001). My results may thus reflect that the resource availability was higher in the power-line corridors than in the forests and increased possibility for trapping of beetles in power-line corridors and thus, higher species richness. More dead wood in power-line corridors versus forest could also be a resource that increases species richness.

4.4 Species richness and biodiversity increase in relation to dead wood

Species richness and biodiversity was higher in power-line corridors compared with forest and increased when the amount of dead wood (percentage cover of dead wood and number of

dead logs) increased. There was a relatively stronger positive relationship between biodiversity and amount of dead wood in power-line corridors compared with the forests.

Many studies have found a positive effect of dead wood on beetles (Økland et al. 1996; Martikainen et al. 2000; Grove 2002; Similä et al. 2003; Brin et al. 2009; Stenbacka et al. 2010). Gibb et al. (2005) found a significantly difference in both standing dead wood and lying dead wood in old growth forest versus managed forest and clear-cuts, but no difference between managed forest and clear-cuts. The similarity in amount of dead wood in clear-cuts and managed forest is also reported by Selonene et al. (2005). One study found that clear-cut areas had significantly lower species richness than old-growth forest and marginally lower than mature forest (Stenbacka et al. 2010) whereas Martikainen (2000) found an strong correlation between saproxylic species and dead wood in mature to old-growth forests. Often the amount of dead wood is emphasized as important for species richness (Økland et al. 1996) and several other studies also emphasize the importance of different types of dead wood for species richness, as saproxylic species often specialize on different types of dead wood (Økland et al. 1996; Siitonen 2001; Similä et al. 2003; Gjerde et al. 2009). In old-growth forests the amount of dead wood may be ten times as high as the mean number of dead wood in Norway (Siitonen 2001; Storaunet et al. 2011). The forests in my study are mainly managed forest which more or less differ from old-growth forests in tree age composition, amount and composition of dead wood (Hofgaard 1993; Gjerde et al. 2009).

The difference between power-line corridors and clear-cuts is the larger amount of dead wood left behind in the power-line corridors and the repeated cutting of trees in the corridors.

When the higher species richness in power-line corridors are compared with studies on clear-cuts versus forest, there is a trend that power-line corridors confine a better habitat than clear-cuts. On clear-cuts there is a poor continuity in dead wood because the cutting are followed by replant a long time before dead wood are produced. For example in a 5-7 years old clear-cut area there are small amounts of heavily decomposed wood and early successional stages of forest stands contains even less dead wood than clear-cuts (Stenbacka et al. 2010). In power-line corridors the continuity in dead wood may be better with maintenance of the power-line corridor and fresh dead wood accumulating each tenth year but a power-line corridor will off course lack the large logs of dead wood.

Power-line corridors probably have higher species richness because of the higher amounts of dead wood compared with the forests in this study. If the species richness from power-line

corridors had been compared with old-growth forest, the difference would probably have been lower or even higher in the forests. Similä et al. (2002) emphasize the need for naturally originated young stands with lots of dead wood in addition to old-growth forests to fulfill the succession gradient in boreal forests. This is very close to the role the power-line corridors play in the ecosystem, even though it lacks large and coarse dead wood. Still rare species that depends on interior forest conditions in old-growth forest may suffer (Jonsson et al. 2005) even when large amounts of dead wood are left in power-line corridors and clear-cuts. A further study could consist of investigating only saproxylic beetles from the same data in this study, to see how much effect the dead wood explaining increased species richness and biodiversity on the dead wood living species.

The fact that I got an increased species richness from the effect of dead wood on all species together and not only from for example saproxylic species, indicates that dead wood should have an even higher effect on groups of species living of dead wood if I had tested them alone.

4.5 Red listed species

I found a total of 19 red listed beetle species with 55 individuals were eight of these species are threatened in Norway (Ødegaard et al. 2010). Approximately 90% of these beetles were found in the power-line corridor and thus, a sun exposed habitat. In Sweden, red listed insects that depend on dead wood and prefer shade constitute a small group. In three stages of recently dead wood (≤2 years, 2-5 years and 5-15 years), the shade preferring species covered only 4-16% of the total number of species (Jonsell et al. 1998). Martikainen (2001) found higher numbers of threatened saproxylic beetle species connected to aspen *Populus tremula* in clear-cuts than in old-growth forest whereas Stenbacka et al. (2010) found most red list species in old-growth forest compared with clear-cuts and young forests. Even so, clear-cuts may be beneficial for some saproxylic species if suitable substrate is available (Stenbacka et al. 2010). Interception traps seems suited for trapping red listed species, which also are documented by Hyvarinen et al. (2006) and the threatened species indicates that the power-line corridors provide a suitable habitat for those species or at least a more suitable habitat than managed forests.

4.6 Species abundance distribution

I found no difference in the empirical cumulative distribution functions (ECDF) of the two habitats, which suggest that the two habitats were relatively similar with respect to the

distribution of rare versus common species. Both the ECDF curves showed that there were some very dominant species whereas most species were rare. In my study some of the most common species are found in both habitats, like *Scaphisoma agaricinum* who were the third most common species in both habitats and *Ampedus nigrinus*, comprising 3% and 2.4% in power-line corridors and forests respectively. *A. nigrinus* are known to become more abundant with decreasing successional stage (Stenbacka et al. 2010). The distribution of species similar to my findings is found in all natural ecosystems (Magurran & Henderson 2003; Stenbacka et al. 2010; Magurran et al. 2011).

4.7 Interception traps

Interception traps are documented as a good trapping method for accumulation of beetle species (Hyvarinen et al. 2006; Achterberg et al. 2010) and this trapping type is good for trapping wood living beetles (Økland et al. 1996). The main disadvantage with these traps are that they do not distinguish beetles living in the area from immigrating beetles (Stenbacka et al. 2010), giving a probability of increased trapping in warmer habitats because of increased mobility (Gullan et al. 2010). Compared to Martikainen et al.(2000), who trapped beetles with interception traps in forest, I trapped a larger number of beetle species even though I had only slight above half the number of traps deployed in the field. One reason for this could be that I trapped from two habitat types, whereas they trapped from different mature forests (95-160+years).

4.8 Conclusion

Both habitat type (power-line corridor or forest) and amount of dead wood in the habitat influenced biological diversity of beetles, and the number of red listed species and individuals was higher in power-line corridors. In addition to a significant difference in species composition, there was a significance between habitat difference in proportion of individuals and species within different functional groups. The most pronounced difference was a relative higher proportion of dead wood feeders in power-line corridors. Both species richness and biodiversity was higher in power-line corridors, and this was probably at least partly due to the fact that there was more dead wood in power-line corridors than in forests.

As an overall conclusion power-line corridors may help maintaining a higher local biological diversity in otherwise managed forest stands, and provide a supplementary habitat for some threatened species. As a management advice I emphasize the importance of leaving the cut trees in power-line corridors after maintenance.

5. Litterature

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Appendix
Appendix 1

Literature used by Sindre Ligaard when determining the beetle species functional groups:

Die Käfer Mitteleuropas

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

Volumes describing the species ecology

Swedish insectfauna:

Landin, B.O. 1957. Bladhorningar - Lamellicornia. Fam. Scarabaeidae. Svensk Insektfauna. Ent. Föreningen i Stockholm.

Lindroth, C.H. 1933. Olikfotade baggar. Heteromera. Svensk Insektfauna. Ent. Föreningen i Stockholm. 158 s.

Lindroth, C.H. 1942. Sandjägare och jordlöpare. Fam. Carabidae. Svensk Insektfauna. Ent. Föreningen i Stockholm.

Lindroth, C.H. (ed.) 1960. Catalogus Coleopterorum Fennoscandiae et Daniae. Ent. sällsk., Lund.

Lindroth, C.H. 1961. Sandjägare och jordlöpare. Fam. Carabidae. Svensk Insektfauna. Ent. Föreningen i Stockholm. 209 s.

Lindroth, C.H. 1967. Våra skallbaggar, del 1, 2 och 3. Bonniers, Stockholm. (New edition)

Palm, T. 1948-70. Kortvingar. Fam. Staphylinidae 1-5. Svensk Insektfauna. Ent. Föreningen i Stockholm.

Denmarks insectfauna:

Bd. 76. Sandspringere og løbebiller (Hansen 1968).

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

Bd. 57. Rovbiller 1 (Hansen 1951).

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).

Vol. 18. The Hydrophiloidea (Coleoptera) of Fennoscandia and Denmark (Hansen 1987).

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).

The Encyclopedia of the Swedish Flora and Fauna (Nationalnyckeln):

Skalbaggar: Långhorningar, Coleoptera: Cerambycidae

Text: Bengt Ehnström, Photo: Martin Holmer

Appendix 2
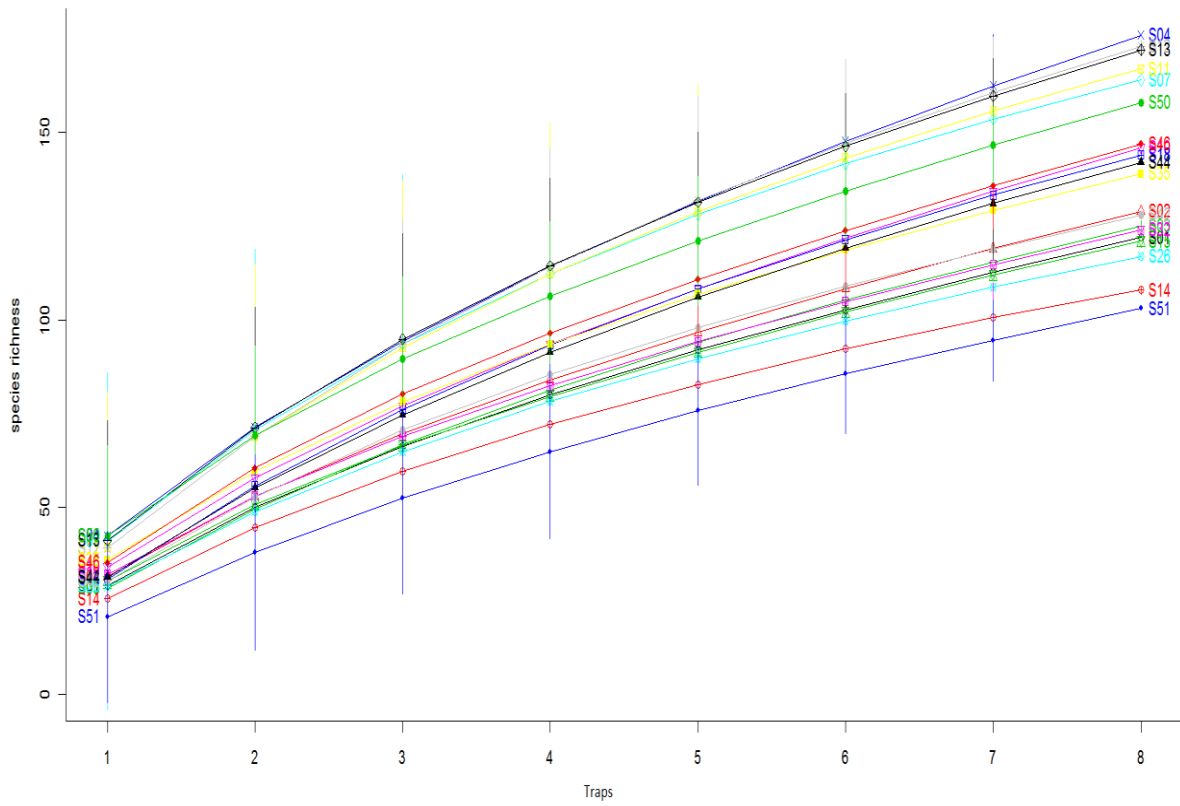
Accumulation curves for beetle species from different sites. Beetles were collected along the center line of power-line corridors and 100 m inside adjacent forests. Data are aggregated from 20 sites. Method used; "exact". Beetles were collected at the sites described in (Figure 3) by use of interception traps (Figure 2).

Appendix 3
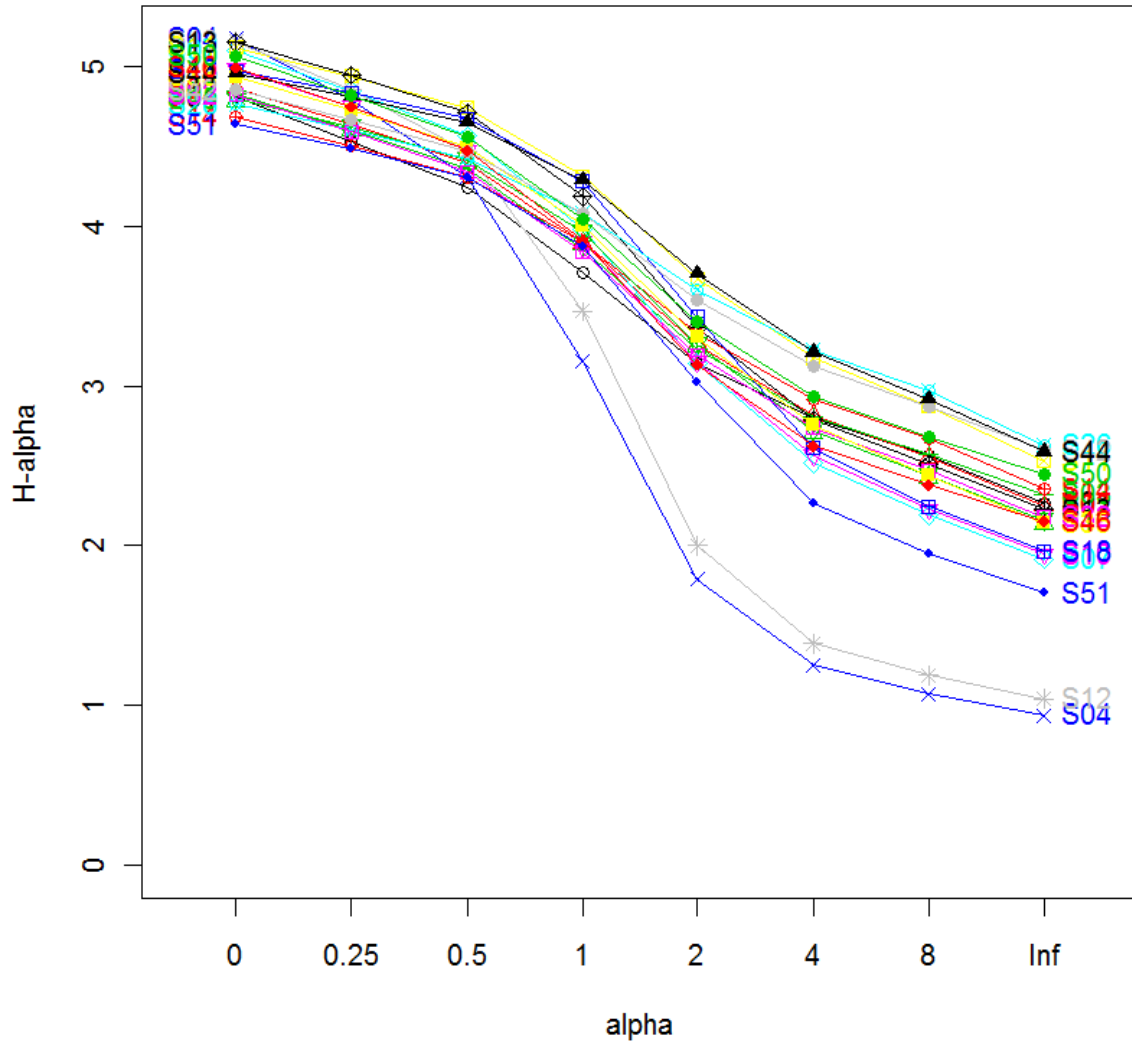
Comparison of biodiversity on beetles from different sites. Beetles were collected along the center line of power-line corridors and 100 m inside adjacent forests. Data are aggregated from 20 sites. The curves show a diversity profile for each site and starting point for each curve indicates species richness. The anti-logarithm ($e^{H\text{-alpha value}}$) for alpha = 0 gives family richness. Alpha = infinity (inf) is a Berger-Parker index and shows information on the proportion of the most abundant family. The anti-logarithm ($e^{H\text{-alpha value}}$) for alpha = inf gives proportion of the most dominant family. Profile value for alpha = 1 is Shannon index and for alpha = 2 it is the logarithm of the reciprocal Simpson diversity index. Steepness in curve indicates the share within the different species of beetles. The evenness for sites is low. Beetles were collected on sites described in (Figure 3) with interception traps (Figure 2). 100 permutations were conducted.

Appendix 4

Description on each of the threatened species based on information found at:

http://www.artsportalen.artsdatabanken.no

| Species	Red list categori	Habitat / ecology	Criteria	Factors influecing habitat
Cryptocephalus coryli	EN	Solid ground woodland Deciduous forest of hazel, birch and goat willow (Salix spp.). Yong forest. Likes it very warm	Only found in counties around the Oslo fjord. Heavily decrease also in Sweden. May be overlooked in Norway because of a large possible natural habitat. Species are easy to find but probably fragmented heavily and in decrease.	Human development and extraction Selection cutting wood chopping are believed to affect the habitat, but in which extent are unknown
Hylis procerulus	EN	Solid ground woodland Living in huge logs of much degraded wood of spruce.	Eight discovery's of the species in Norway. Probably very local and very fragmented	Human development and extraction Forestry and logging
Sphaeriestes bimaculatus	EN	Solid ground woodland, Old growth forest dominated by pine. In little or medium degraded bark or wood.	Bound to pine forests, living under the bark. Found on eight localities in Norway. Probably very fragmented extensiveness. Probably some number of unrecorded species.	Human development and extraction Clear-cutting Selection cutting, thinning and wood chopping Removal of dead wood Forest roads Forest fire flameout and replanting on fire surface Cutting of special trees (old, hollow and burn damaged)
Corticeus fraxini	EN	Solid ground woodland Old growth forest dominated by pine. Living in bark or wood of newly dead pine	About 10 older registrations, in newer time only found in old growth spruce forest Extensiveness is very fragmented and the places the species are found are decreasing.	Human development and extraction Clear-cutting Selection cutting, thinning and wood chopping Removal of dead wood Cutting of special trees (old, hollow and burn damaged) Forest fire flameout and replanting on fire surface
Anthribus scapularis	VU	Wetland, coastal landscapeand solid ground. Ombrotrophic mire Dune meadow In wood on dead heath and bushes.	Information on lifestyle is incomplete But often connected with bog myrtle in mire	Drainage Infrastructure House-building
Atomaria fuscipes	VU	Disturbed ground Grazed Anthropogenic	Bound to feces and rotting plants. Found in the whole country but species are	Change in houses (lack of stables and dirt cellars etc.)

		grassland. Animal and bird feces	strongly decreasing	Change in waste handling (lack of compost, sawdust, slaught trimmings etc.)
Cidnopus pilosus	VU	Costal landcape Solid ground woodland Anthropogenic

Open, dry habitats with deciduous forest. Grazed or manually light forest cleaning. Cultural meadow, grazed or cut. | Common species in south Sweden and Denmark. Probably decreasing in Norway because of overgrown habitats and build outs. | Modern farming Human development and extraction |
| Paranopleta inhabilis | VU | Solid ground woodland dominated by birch. Live under the bark of burned trees, especially birch. | Only known from Karasjokk in Norway but are more common than earlier expected in Sweden. Probably over looked in Norway but habitat are decreasing. Unknown if the species are heavily fragmented | Clear cutting Selection cutting, thinning and wood chopping Forest fire flame out and replanting on fire surface |

Appendix 5
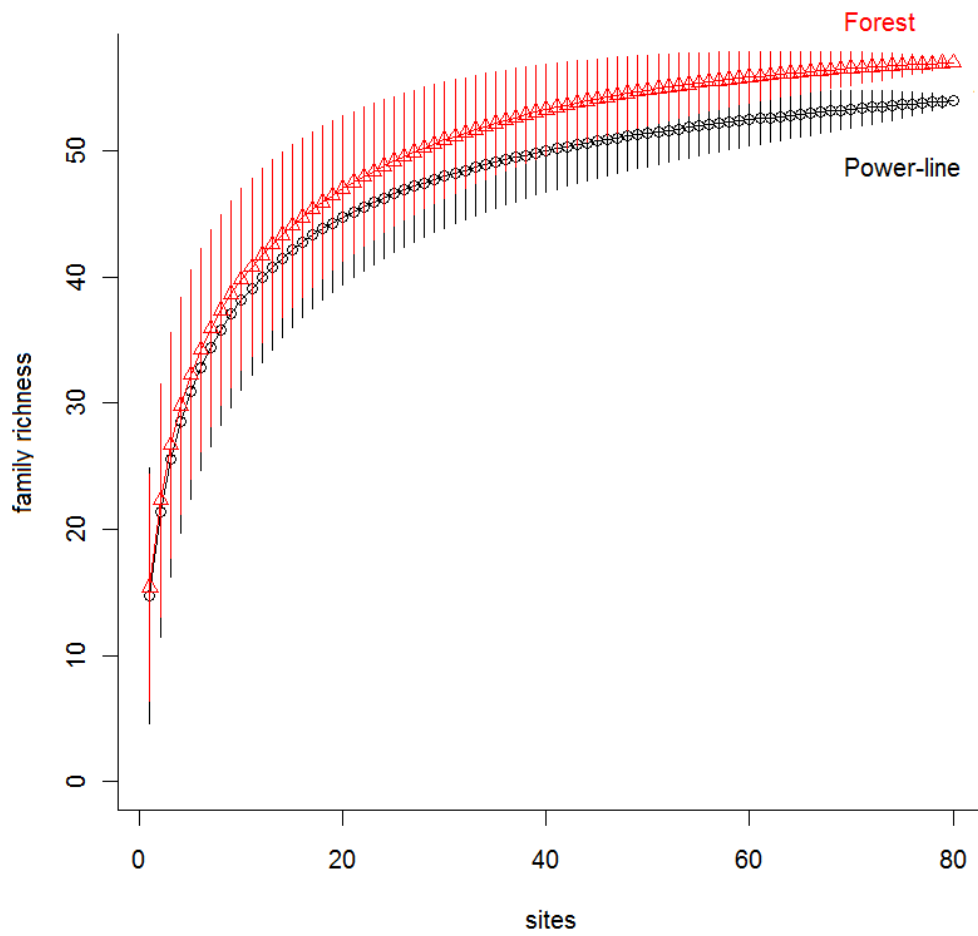
Accumulation curves for beetle families collected along the center line of power-line corridors and 100 m inside adjacent forests. Data are aggregated from 20 sites. Method used; "exact". Beetles were collected at sites described in (Figure 3) by use of interception traps (Figure 2).

Appendix 6
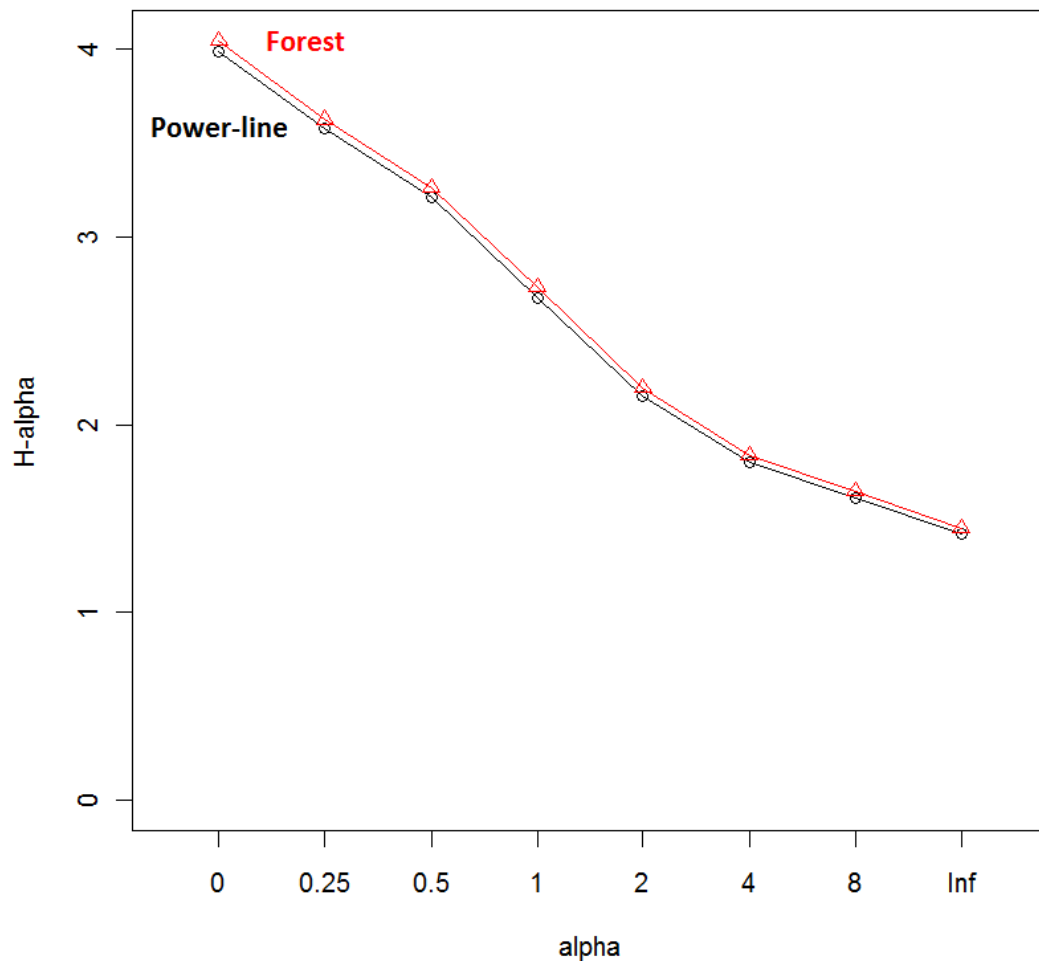
Comparison of biodiversity on family richness of beetles collected along the center line of power-line corridors and 100 m inside adjacent forests. Data are aggregated from 20 sites. The two curves show a diversity profile for each habitat and starting point for each curve indicates species richness. The anti-logarithm ($e^{\text{H-alpha value}}$) for alpha = 0 gives family richness (Power-line: 54 families; Forest: 57 families). Alpha = infinity (inf) is a Berger-Parker index and shows information on the proportion of the most abundant family. The anti-logarithm ($e^{\text{H-alpha value}}$) for alpha = inf gives proportion of the most dominant family (Power-line 0.245 = 24.5%; Forest: 0.221 = 22.1%). Profile value for alpha = 1 is Shannon index and for alpha = 2 it is the logarithm of the reciprocal Simpson diversity index. Steepness in curve indicates the share within the different species of beetles. Steepness in curve indicates the share within the differen beetle families. The evenness for families is low, but almost similar compared with each other. The forest habitat had higher diversity than the power-line habitat because the curve for forest were always higher. Beetles were collected on sites described in (Figure 3) with interception traps (Figure 2). 100 permutations were conducted.