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Faculty of Environmental Science and Technology
Department of Ecology and Natural Resource Management

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How do management practices in power-line corridors affect species richness and abundance of solitary bees?

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M. Sc. Thesis

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Preface

The study presented in this thesis was conducted at the Department of Ecology, Norwegian University of Life Sciences (NMBU) and it marks the end of my master studies in Ecology, specialization General ecology.

I want to thank my supervisor, Katrine Eldegard, for the valuable guidance she offered to me through comments and suggestions on my master thesis. I express my deep gratitude to my co-supervisor, Markus Sydenham, for statistical support, lab assistance and comments on thesis drafts. Both have permanently shown patience towards me and encouraged me all along the way of thesis writing. They were always giving quick and useful responses to my questions related to my work project.

I also want to thank the field assistants Irene Hermansen and Jenny Benum Lorange for trapping of the bees during the collection period, 2013.

The project for my master thesis was funded by Statnett and it is part of "Biodiversity in power line corridors", a larger research project on the impact of habitat management on biodiversity.

Norwegian University of Life Science (NMBU)

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Diana Nicoleta Stanescu-Yadav

Abstract

In order to identify opportunities for biodiversity conservation, it is important to understand how current land use patterns threaten the integrity of ecosystems and the services they provide. The aim with this study was to test how the experimental manipulation of the habitat conditions under power-line corridors affects species richness and abundance of solitary bees.

Nineteen sites situated under the power-line strips transecting boreal forests in south-eastern Norway were selected. In each one of them were placed three experimental units: one cleared and the debris removed from the experimental unit (removal), another one cleared following standard management practice where the debris is left on the ground (standard) and last left uncleared acting as a control. Three flight interception traps were placed in each experimental unit.

A total number of 613 individuals and 63 species of solitary bees were collected.

Clearing of power-lines corridors led to an increase in diversity of solitary bees in both cleared experimental units, but the highest species richness and abundance of solitary bees was observed in the management areas cleared of woody debris. In almost half of sites there was a higher solitary bees' species richness in removal experimental unit than other two experimental units. A positive response of solitary bee species richness to total forbs' species richness was observed in same type of experimental unit.

The results of this experiment suggest that clearing of forest in the power-line corridors may create new habitats that enhance the diversity of solitary bees.

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1.0 INTRODUCTION

Current land use patterns threaten the integrity of ecosystems and the services they provide (Hadley & Betts 2012). Pollination, an important ecosystem service, is ensured, in addition to wind, by many major groups of pollinator animals (Ollerton et al. 2011). Bees (Hymenoptera, Apiformes) are one of the most studied groups of pollinators (Greenleaf et al. 2007). They are considered being "a key component of global diversity" because they enhance the reproduction of natural vegetation (Potts et al. 2010). Bees are regarded as a better alternative to plants' self-pollination, which often leads to inbreeding depression (Michener 2007; Ollerton et al. 2011).

Worldwide are more than 20,000 known species of bees, majority solitary and they are often oligoleges, meaning that they gather pollen and are dependent on particular plant species (Michener 2007). Functional name for the taxonomic category of non-social bees, solitary bees do not interact with their kin. They do not live in colonies and, lack worker caste and are more specialized to certain species of flowering plants by comparison to social bees (Totland 2013).

The introduction in Europe of different mites that parasitize honeybees has increased the importance of solitary bees as pollinators (Potts et al. 2010; Michener 2007). Due to their specific traits, solitary bees become very effective as specialist pollinators (Michener 2007). Some of solitary bee species are considered as being better pollinators than honeybees for a certain range of crops, such as alfalfa (Michener 2007). For particular plants, solitary bees ensure a higher quantitative (Bischoff et al. 2013) and qualitative (Holzschuh et al. 2012) effectiveness of pollination than honeybees, becoming indirectly beneficial for other insects and animals that depend on the set fruit of these plant species (Michener 2007).

In Norway approximately one third of all bee species are on the national red list (Kålås et al. 2010a). In order to promote species richness and abundance of solitary bees in anthropogenic habitats, studies on the drivers of bee diversity are required. Bees depend on food resources being available within foraging ranges of the nesting place (Michener, 2007). Both, the type of nesting and foraging resources bees utilize may be species specific. For instance, some species nest in dead wood (above-ground nesting solitary bees) and others in sandy soil (ground-nesting solitary bees) (Westrich 1996). Solitary bees' food requirements vary in the range of entomophilous plants, meaning flowering plants pollinated by insects (Michener, 2007). A high richness and abundance of floral plants is associated with a high richness of solitary bees (Michener 2007). Thus a high diversity of resources promotes a high diversity of consumers in insect communities (Price 1984) through pollen availability. In addition, pollen quality is important as determinant of larval development which ensures the persistence of solitary bees in a certain area (Potts et al. 2003). Fundamental factor in the organization of bee community structure is floral community composition (Potts et al. 2003).

A certain degree of disturbance by land conversion could, in some cases, enhance bee diversity (Winfree et al. 2007). Habitat fragmentation for example, may drive the abundance of solitary bees by increasing the sun exposure of the soil that enhances nesting and the growth of entomophilous plants (Klein et al. 2007; Wojcik & Buchmann 2012). Solitary bees are poikilothermic insects, so their activity level depends on sunlight that warms their body while not flying (Winfree 2007). Consequently, within a shaded forest habitat their activity will be decreased.

Lack of long-term monitoring of pollinators' richness and abundance in the Northern hemisphere, makes difficult to assess declines in bee populations (Michener 2007), and thus discussions about future protection may be based on insufficient knowledge. Strong global land-use conversion affects bees negatively (Potts et al. 2010), but the response of each pollinator category depends directly on the selected study design (Winfree et al. 2011).

Studies correlating altitudinal and latitudinal parameters with the number of bee species in different countries of the world (Michener 2007) proved a greater faunal abundance and richness in temperate areas than in tropical ones. The result is explained by a lower larvae predation and by a higher lower competition with highly social bees (Michener 2007).

Many correlative studies in Netherlands and United Kingdom analyzing only life-history strategies of different bees suggest that land conversion has led to a decline up to 60% in local bee diversity between 1980 and 2006 (Biesmeijer et al. 2005; Ollerton et al. 2014).

Habitat conversion modifies landscape composition. Clearing of landscape in a habitat forest modifies also the configuration of landscape and increases open-canopy habitat area (Steckel et al. 2014). Open canopy favours germination and growth of plants that bees depends on. Power-line corridors are one of the open-canopy habitat types where the plants must adapt to survival in different environmental conditions. There is a growing interest in preserving these habitats as valuable areas for pollinators (Wojcik & Buchmann 2012).

A study conducted in Great Britain in 1970s showed that pollinators' diversity was much higher than the hypothesized one in the landscapes with overhead electrical transmission corridors (Free 1975). Another study developed in U.S. identified power-line corridors as being a better habitat for native bees than the mowed grassy fields found in neighborhood (Russel et al. 2005). Moreover, high-mobility insect species are associated with power-line corridors that offer possibilities for suitable habitats for pollination (Berg et al. 2011). Furthermore, power-line corridors have a high range of flowering plants and enhance the presence of ground-nesting bees and wasps (Wojcik & Buchmann 2012). Solitary bees' response to change in land-use is explained by the habitat type that they prefer and by the floral resources they find in a certain area (Winfree et al 2011).

All above mentioned correlative studies present knowledge about the potential value of power-line clearings for pollinators, but there was not conducted any field experiment before. This indicates a lack of knowledge concerning the best management practice for solitary bees. Therefore the current study is an experiment which chooses to analyze power-line strips because they are great nesting habitats and they provide foraging resources for bees (Russell et al. 2005). The focus on solitary bees was chosen because many studies have shown that they are more sensitive to land conversion than other bees because their more specialized floral and nesting requirements (Steffan-Dewenter et al. 2002; Biesmeijer et al. 2006) and their low reproductive rate (Tepedino and Parker 1983). Because of it, unfavorable conditions which last for several years may affect their abundance and species richness.

The purpose with this study was to investigate how various management practices under electrical power-lines affect solitary bee diversity. In addition, forbs' plant community is considered as a driver for variations of treatment's effect among sites. A field experiment with three different treatments – mimicking three different management practices – was carried out to investigate how experimental habitat management affects solitary bees' diversity. I predict that:

- Solitary bees' abundance and species richness will be higher in both cleared experimental units (with and without debris) than in un-cleared control (with substantial re-growth of trees).
- The highest abundance and species richness of solitary bees will be found in experimental areas where the woody debris has been removed.
- Solitary bees' richness will increase with the increase of floral complexity.

2.0 METHODS

2.1 Site selection

There were identified as best candidate areas the ones situated in boreal forests within the main power-line grid in Southeast Norway. They had a stretch of minimum 200 meters with substantial regrowth of trees below the power-lines. Among them, 19 sites were selected to capture a range of abiotic and biotic conditions. Their selection was based on two criteria. The first, to ensure that within site effects were comparable all power-line strips were homogeneous enough, in terms of successional stages. The second criteria referred to the possibility of placing at each site three similar experimental units at least 20 meters apart, considering successional stage and vegetation type. The experimental units were 30 meters long following the direction of the power-line strip and as broad as the power-line strip (i.e. circa 40 m for single lines and 80 for double lines).

The above mentioned experiment is part of "Biodiversity in power line corridors", a larger research project on the impact of habitat management on biodiversity. The experimental units were either (a) cleared following standard management practice where the debris is left on the ground, (b) left uncleared acting as a control or (c) cleared and the debris removed from the experimental unit thereby exposing the ground direct sun-light (Figure 1).

For each experimental unit within each site, the experimental treatment was ramdomly allocated by drawing Lego bricks of different colors out of a non-transparent box. A foresting company was contacted in autumn 2012 to clear one of the experimental units to do carry out the experimental treatments (treatment (a) and (c) in Figure 1).

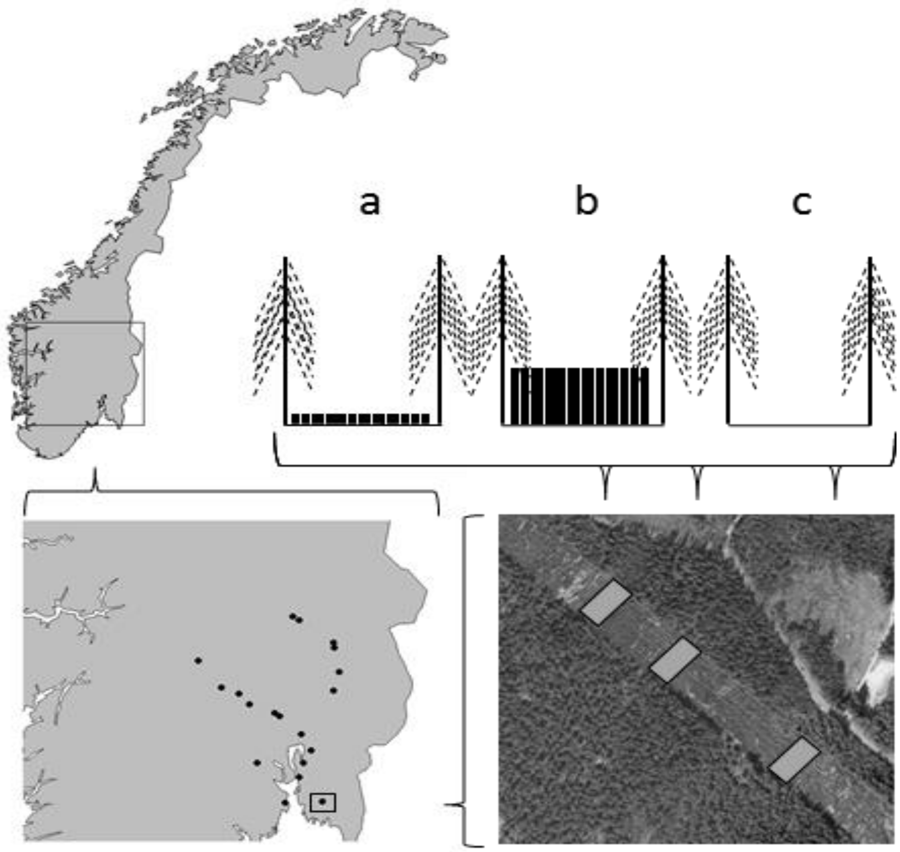

Figure 1 - Geographic location of the 19 study sites located within power-line strips. Each study site consisted of three experimental units visualized as a cross section of the power-line strip. The experimental units were either (a) cleared following standard management practice where the debris is left on the ground, (b) left uncleared acting as a control or (c) cleared and the debris removed from the experimental unit thereby exposing the ground to direct sunlight.

2.2. Bee sampling

Bees were sampled in 2013 during the entire flowering season (from snow-melt April to September) that coincide with bees' activity period. The sampling was made using flight interception-traps that were emptied four times during the experiment period. Three flight interception traps in each experimental unit were placed. Two traps were placed in either site of the power-line strip and one in the center. The flight interception-trap consisted of two transparent Plexiglas screens, and assembled to form a cross with a white funnel underneath. Flying insects were intercepted by the screen and collected in a bottle attached to the bottom of the funnel. The bottles were previously filled up with a 50:50 mixture of green propylene glycol and H_2O with a drop of detergent to break the surface tension.

Figure 2 – Localization of flight interception traps within each experimental unit

Foto 1 – Flight interception trap (source: Jenny Benum Lorenge)

After emptying the traps, insects were brought back to the entomological laboratory at the Norwegian University of Life Sciences. Laboratory selection was made following a definition of solitary bees (Steffan-Dewenter et al. 2002) which excludes the honey bee (*Apis melifera*) and all *Bombus* species, but includes cleptoparasitic species of solitary bees. After this selection, solitary bees were stored in 80 % ethanol before they were sent to pinning and identification.

The most used passive method for sampling bees is the pan-trap (Westphal et al. 2008). But flight interception-traps were also used in previous studies (Moretti et al. 2009; Ulyshen et al. 2010). The choice of flight interception-traps as sampling method for this study because it has the advantage of sampling communities over an extensive area at the same time and of a good efficiency independent of the complexity of floral community across the space and time (Rubene et al. 2014).

2.3 Statistical analyses

The purpose with experiment is to collect relevant data to test if partial and total clearing of power-line strips increases species richness and abundance of solitary bees.

In order to analyze the experiment effect on bee species richness and abundance, I have used generalized linear mixed model (GLMMs) assuming Poisson distributed errors and a log-link function in the R library 'lme4'. Response variable were bee species richness (number of species) and bee abundance (number of individuals) within each of the treatment unit pooled across all traps and sampling period in 2013. The effect of clearing power-line strips counted treatment type as the independent variable and site identity as random effect. Random effect states that there is some variation in the data that is site specific. Different sites are statistically independent because of their specific traits, such as geology, elevation and latitude (Figure 1). This model accounts then for the variation between sites. I have used the total number of traps successfully sampled within each treatment unit throughout the sampling period as an offset. Maximum number of traps per experimental unit was 12 and minimum was 9. The variation in number of traps appeared because some of them were lost or bestroyed by wind and it resulted in an average of 11.49 traps months per experimental unit at the level of the entire experiment.

2.3.1 Experimental effect on solitary bees' species richness and abundance

In order to analyze effects of the experimental treatments of species richness, I fitted a GLMM with species richness as the response variable, and the type of treatment as fixed effect explanatory variable. In addition to this, I have included forbs species richness as an explanatory variable for variations of treatment effect among sites. To account for differences in sampling intensity due to occasional destroyed traps, I included number of trap months as an offset variable. To account for among-site differences, site identity was included as random effect.

I have use the same model for solitary bee species abundance, so I expect that this response variable will be affected by the same elements as solitary bee species richness.

The effect of management areas under the power-line strips in 19 selected locations on species richness and abundance of solitary bees was estimated as significant of insignificant for this experiment by different obtained "P" values. Reference value was 0.05.

3.0 RESULTS

A total number of of 613 individuals and 63 species of solitary bees were collected. There was a considerable among site variation in the number of sampled bees. These values fall in the diversity pattern used in community ecology according to which few species are common, while many are rare (Andrewartha & Birch 1954; Darwin, C. 2004 (1859).

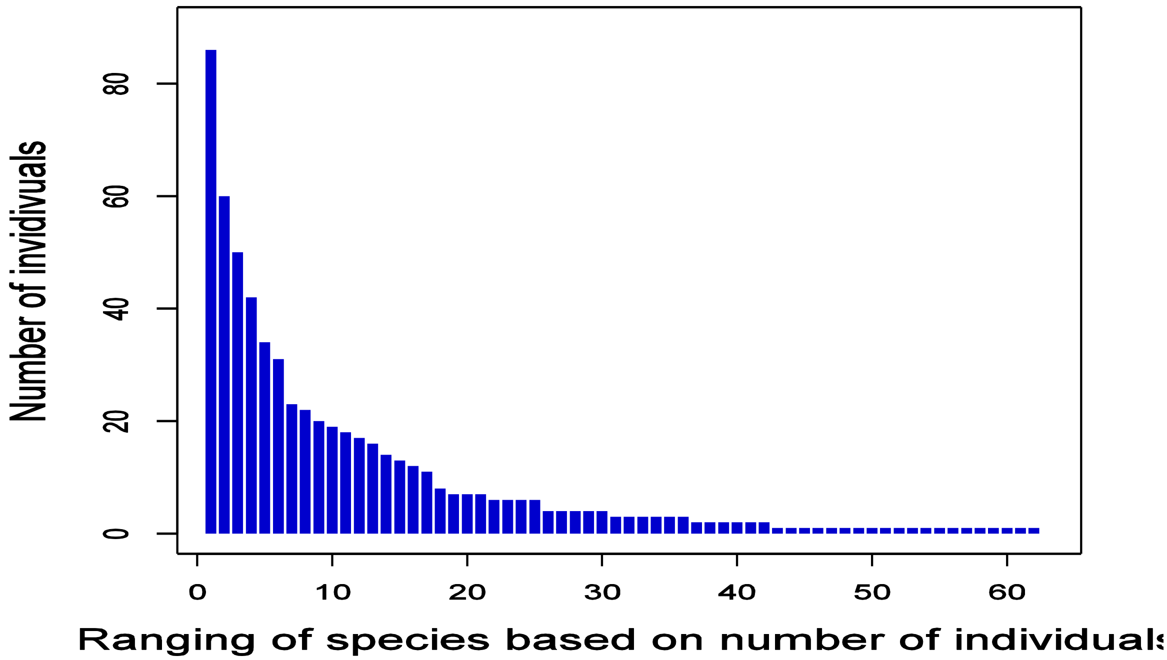

Figure 3 – Rank abundance distribution of solitary bee species.

The most abundant genera of solitary bees species were *Andrena* (*Andrena Subopaca* 86 individuals, *Andrena lapponica* 63 individuals), *Hylaeus* (*Hylaeus confusus* 50 individuals) and *Lasioglossum (Lasioglossum fratello* 42 individuals) (Figure 3).

3.1 Experimental effect on solitary bees' species richness and abundance

As a result of the statistical analysis, important data for this experiment was delivered.

It was observed a significant effect of removal and standard management practices on solitary bee species richness (Table 1, $z = 3.993$, $p = <0.001$ and , $z = 3.133$, $p = 0.002$). "Z" value for both types of management practices are positive, which means that they have a positive effect on solitary bee species richness as response variable, compared to the intercept (control).

As in the case of species richness, for abundance also "z" values were positive for the removal and standard management practices (Table 1, $z = 7.075$, and , $z = 2.861$) and "P" value for both of them showed a significant relation (Table 1, $p = 0.001$ for removal; $p = 0.004$ for standard).

The effect of control treatment on both species richness and abundance of solitary bees was negative, being expressed in negative values (Table 1, $z = - 6.832$ for species richness; $z = 4020$ for abundance).

Total species richness of forbs was included in the previous statistical model (Tabel 2). While comparing the effect of the interaction between forbs species richness and removal and standard treatments on solitary bee species richness, "p" values (Table 2, $p = 0.001$ for removal and, $p = 0.258$ for standard) have shown a significant relationship only for removal treatment. The value of "p" <0.001 (Table 2) was also found for the effect of the interaction between forbs species richness and both, removal and standard treatments on solitary bee abundance. This result shows a significant relationship compare to the effect of their interaction, while the value for standard treatment (Table 2, $p = 0.7437$) shows a non-significant relationship.

Table 1 - Effects of habitat mangement on the species richness and abundance of solitary bees in powerline corridors. The effects were analyzed using Generalized linear mixes effect models to account for the nested structure of the experimental setup. Site identities were used as random effects and the number of traps successfully collected per experimental unit were used as an offset variable.

Solitary bee species richness	Estimate	SE	z	p
Intercept(Control)	-1.3293	0.1946	-6.832	<0.001
Removal	0.5897	0.1477	3.993	<0.001
Standard	0.4710	0.1503	3.133	0.002
Random effects:	σ	SD	obs	Groups
	0.4325	0.6576	57	19
Solitary bee abundance	Estimate	SE	z	P
Intercept(Control)	-0.9113	0.2267	-4.020	<0.001
Removal	0.7355	0.1040	7.075	<0.001
Standard	0.3198	0.1118	2.861	0.004
Random effects:	σ	SD	obs	Groups
	0.8069	0.8983	57	19

Table 2 - The effect on solitary bee species richness of experimental clearing of power line strips depended on the floral community within the power-line.

Solitary bee species richness	Estimate	SE	z	p
Intercept(Control)	-1.12762	0.24437	-4.614	<0.001
Removal	-0.33465	0.29667	-1.128	0.259
Standard	0.19710	0.29015	0.679	0.497
Forbs Richness	-0.01392	0.01838	-0.757	0.449
Removal: Forbs Richness	0.07283	0.02153	3.383	0.001
Standard: Forbs Richness	0.02333	0.02064	1.131	0.258
Random effects:	σ	SD	obs	Groups
	0.3034	0.5509	57	19
Solitary bee abundance	Estimate	SE	z	P
Intercept(Control)	-0.590835	0.256741	-2.301	0.021
Removal	-0.292158	0.234321	-1.247	0.213
Standard	0.336249	0.230641	1.458	0.145
Forb Rich	-0.024784	0.014112	-1.756	0.079
Removal: Forb Rich	0.075587	0.015886	4.758	<0.001
Standard: Forb Rich	0.004922	0.015052	0.327	0.7437
Random effects:	σ	SD	obs	Groups
	0.7253	0.8517	57	19

Solitary bees' species richness and solitary bee abundance values are infuenced by sampling intensity. Species richness increases with an higher number of traps per experimental unit. Solitary bees' species richness had higher median value in standard treatment than in removal and control ones (Figure 4A), while in case of solitary bee abundance median values were similar for all three type of managemement units (Figure 4C).

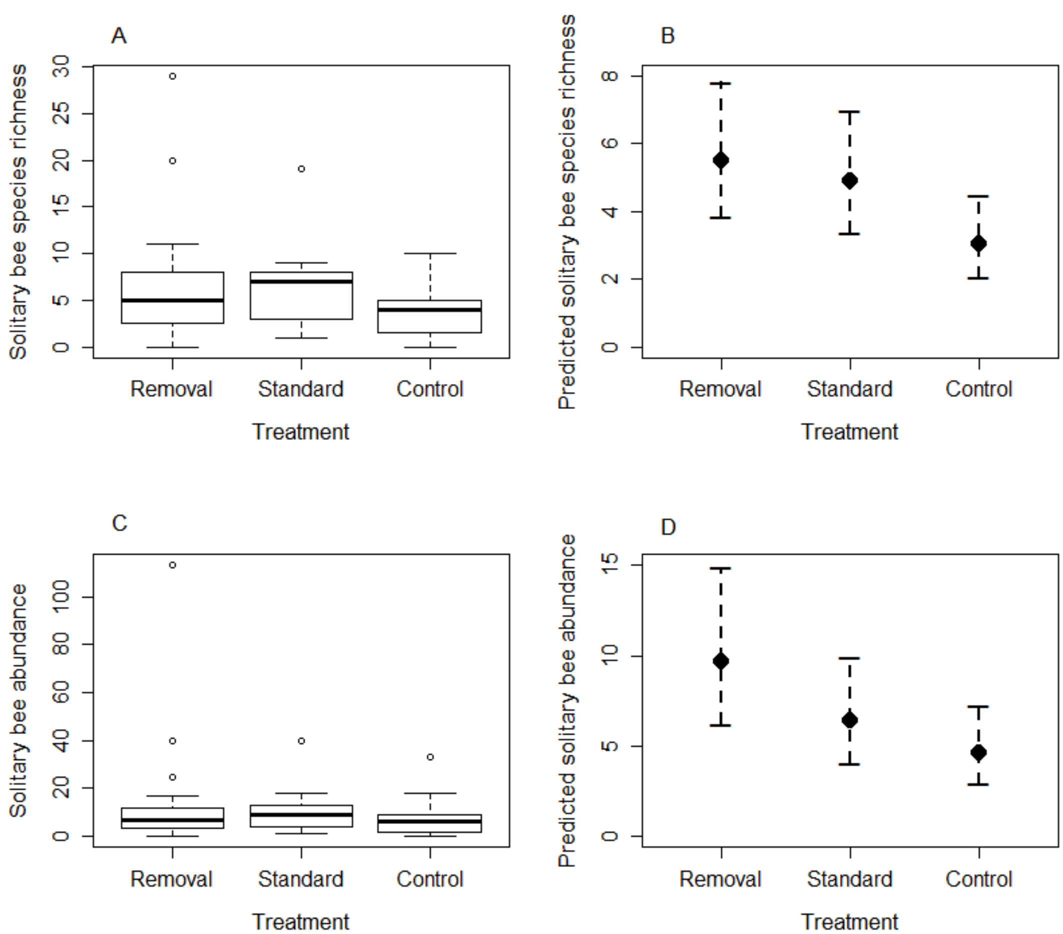

Figure 4 – The effect of treatments on solitary bee species richness and abundance - median based on observed values (A, C). Predicted solitary bee species richness (B) and predicted solitary bee abundance (D).

The highest difference concerning the effect of management practices on both response variables was in removal treatment. In addition, this increase was highlighted by two outliers' values for solitary bees' species richness and three for solitary bees' abundance. One of the sites that had very high values in removal experimental unit for both, bee abundance and species richness, was identified as having outlier values in case of standard treatment regarding the abundance of bees.

While medians based on observed values pointed on the distribution of solitary bee number of species and number of individuals for each treatment, predicted values for both response variables offer a complete picture of the general impact of each management practice on them. The highest solitary bee species richness was observed in removal treatment units (Figure 4B). For the same response variable, there was found a lower value for standard treatment than for removal. But this value is closer to the one from removal treatment than to the one for control (Figure 4B). The effect of removal treatment on solitary bees' species richness was greater than the effect of standard and control.

The highest solitary bees' abundance value was observed in removal treatment. Total number of solitary bees found in standard treatment areas was closer to the one found for control one, than the one for removal (Figure 4D).

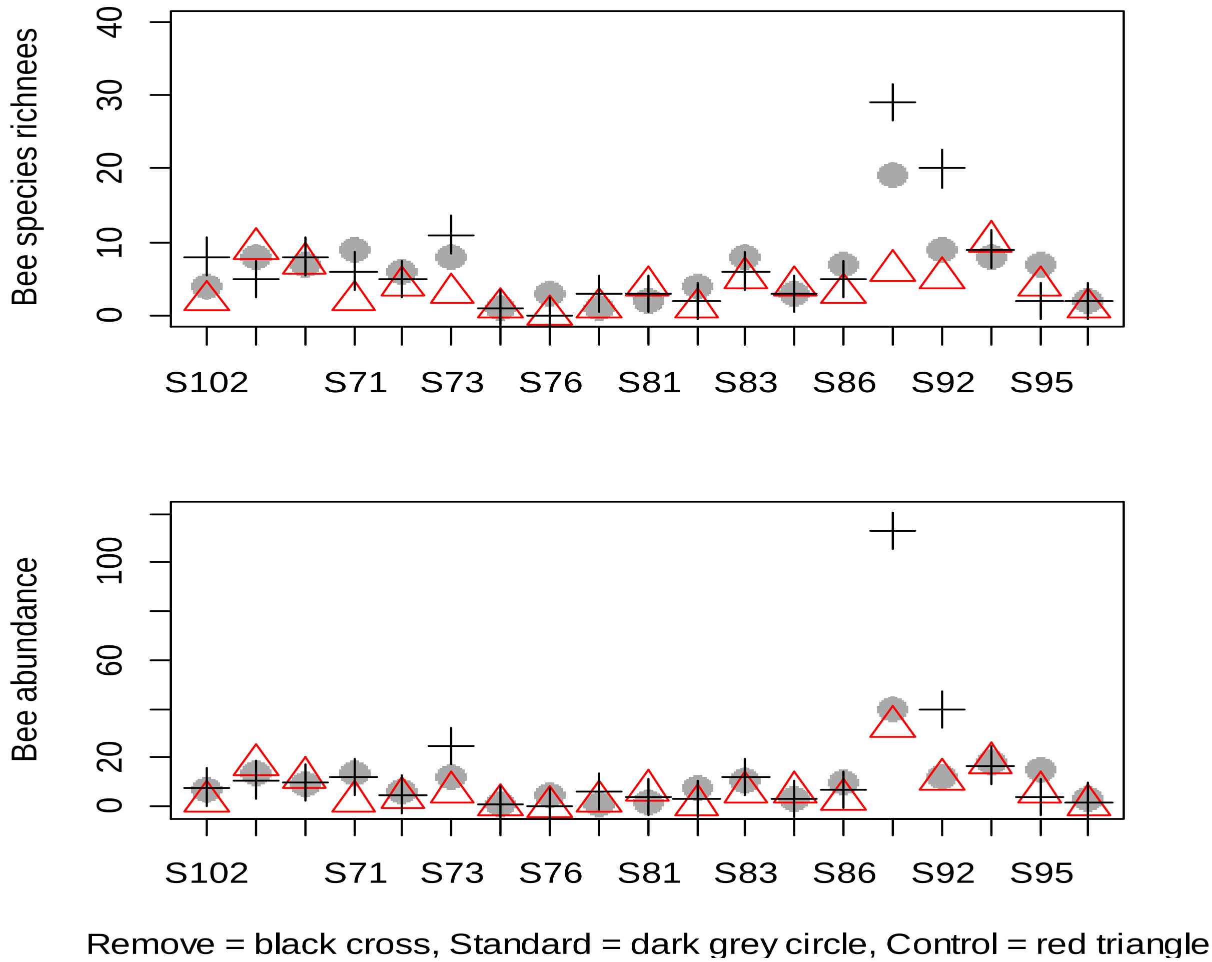

Figure 5 - Variation in species richness and abundance of solitary bees in terms of site identity (n = 19) and the three experimental units.

Totally there were sampled 49 species of solitary bees in all removal management units, 43 in standard and 28 in control one. Total number of individuals sampled in all removal management units was 286, decreasing to 193 individuals in standard and 138 in control ones.

A low variation was observed in total solitary bee species richness between removal (49 species) and standard treatment (43 species), with the specification that in more than half of locations removal treatment seemed to better enhance bee species richness (Figure 5).

In both removal and standard management areas, the values of total species richness were closer to each other and higher than in control (20 species) management areas.

There were observed two outliers (Figure 5), at site 87 and site 92, where the effect of remove treatment on solitary bee species richness was greater than the effect of standard and control treatments. Solitary bee species richness value at site 87 was 29 solitary bee species and 20 species at site 92. Those are extremly high values comapare to the values found at all other sites.

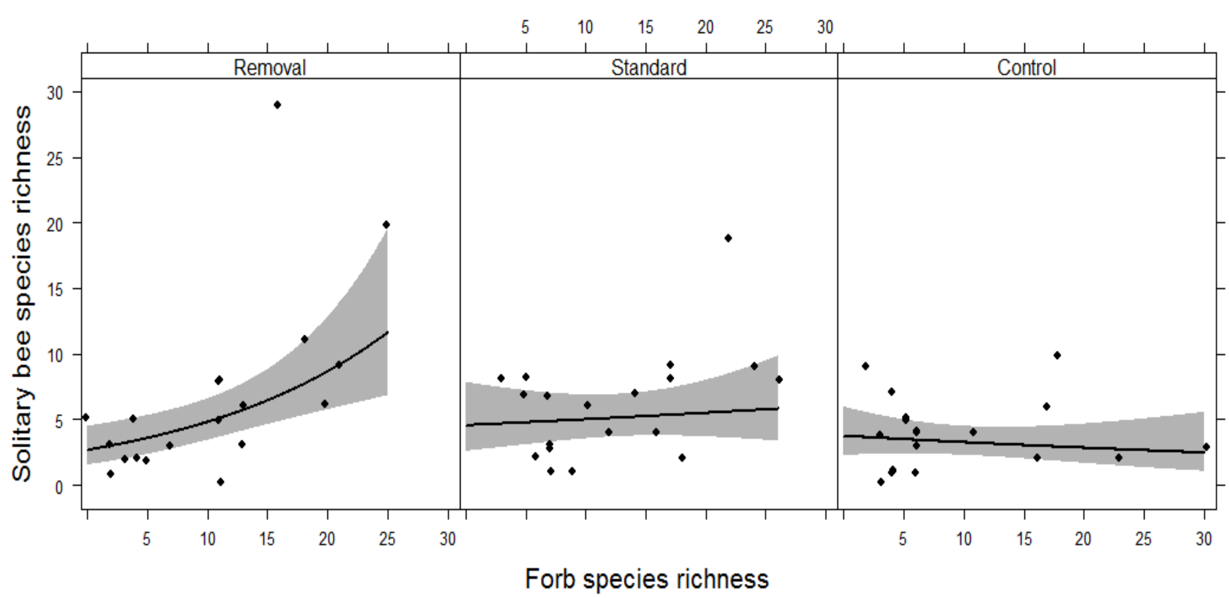

Figure 6 - Solitary bee species richness with total species richness of forbs in each experimnetal unit. Dots are observed species richness at 19 sites. Fitted lines and 95% confidence intervals from simple GLMMs.

The interaction effect of treatment and forbs species richness showed that largest effect of removing the woody debris from soil was gained in the experimental units with a high forb species richness (Figure 6, table 2).

In standard management areas solitary bee species richness seemed not to be strongly affected by the treatment, even total species richness of forbs incresed. It was observed only a slightly increase of solitary bee species richness in standard management areas (Figure 6), but it is too low to be counted as an effect. This is rather a similarity to control treatment.

4.0 DISCUSSION

Clearing of power-lines corridors led to an increase of solitary bees' species richness and abundance in both cleared experimental management areas (i.e., respectively with and without woody debris left to decay on the ground). The highest increase was observed in management areas where the woody debris was removed from the experimental unit. Richness of solitary bees increased with total species richness of forbs in the removal experimental units.

The results regarding solitary bees' species richness and abundance showed that very few species of solitary bees were highly abundant, while most of other species had a very low abundance (Figure 3). The most abundant genera of solitary bees species were *Andrena*, *Hylaeus* and *Lasioglossum* and they were trapped at two location where site identity is the explanatory for their high abundance. This finding is consistent with the ecological biodiversity pattern mentionned more than 150 years ago by the naturalist Charles Darwin. He observed that a low abundance is a specific to many species belonging to different classes (Darwin 1859).

4.1 Experimental effect on solitary bees' species richness and abundance

As I predicted, the abundance and richness of solitary bees was higher in both cleared experimental units (with and without woody debris left on soil) than in control unit (Figure 4B and 4D). This suggests that there are better microclimatic conditions in these habitats that enhance solitary bee diversity. It seems that solitary bees' diversity in these two experimental units is driven by changes in habitat, underlying changes in environmental conditions that affect their nest and food resources. Clearing in power-line corridors requires continuous management for accessibility that maintains the vegetation at an early successional level. This will promote the abundance of bee species that cannot compete in forest environment.

The management of natural areas could, in some cases, promote local species richness and abundance of bees (Winfree et al. 2007). Previous studies on power-line clearings have identified and measured only the negative effects of the open power-line corridors on forest species (Brown 1995; Clarke & White 2008). This is because land conversion was generally associated with pollinator decline (Kremen et al. 2004, Murray et al. 2009).

But recent scientific studies have proved different positive values of power-line corridors for early successional species (Russel et al. 2005; Clarke et al. 2006). Moreover power-lines are proved to enhance pollinator bees (Wojcik & Buchmann 2012). In condition of open-canopy habitat the values of environmental parameters are different than the closed canopy habitat. In open canopy habitats, evaporation and shading decrease, while moisture, light intensity and openness increase. Precipitation reaching directly to soil modifies its texture. Increased sunlight could increase air and soil temperature. As poikilothermic insects, solitary bees increase their activity with temperature increase (Winfree 2007). Moreover soil exposed directly to sunlight is proved to be preferred by solitary bee as nesting place (Totland, 2013).

A study developed in Sweden has shown that highest abundance and species richness of red listed flying insects was found in power-line corridors. Rare bee species (Russel et al. 2005) and other pollinating species (Lensu et al. 2011) consider power line corridors as alternative habitats because of a higher dryness level. Modification in environmental conditions resulted from clearing of habitats in power-line corridors areas was proved to sustain a high pollinator abundance and species richness (Berg et al. 2011).

Another result of this study showed that the highest solitary bee abundance and species richness were observed in cleared habitats where woody debris was removed from soil (Figure 5). The highest value of both response variables was found at sites 87 and 92 (Figure 5) as the consequence of site specific variation. Both sites are located in very sandy areas and the direct sunlight reaching to soil makes it favourable for below-nesting solitary bees. The correlation between the type of soil and nesting is even stronger when the most abundant nesters trapped at these two locations were the ones having the highest abundance at experiment level (*Andrena subopaca, Andrena lapponica*,and *Lasioglossum fratello*).

Many studies proved that sandy soils enhance the presence of solitary bees and many of them are ground-nesters (Westrich 1996; Michener 2007). The result of this study confirm the last statement because all the above mentioned solitary bees species are ground-nesters. Nest availability is one of the reasons why solitary bees' diversity increases (Westrich 1996).

In contrast, those solitary bee species which prefer shaded habitats will avoid areas directly exposed to sunlight. Above-ground nesters, the one nesting in tree trunks for example, are susceptible to be found in a higher number in control areas, while ground-nesters abundance is expected to increase in cleared areas where debris was removed from soil.

Solitary bees' diversity is not enhanced only by the availability of nesting places, but also by food resources. The result of this study indicates that solitary bee diversity increases with the increase in floral diversity and indicated removal treatment as the habitat with highest quality for solitary bee abundance and species richness (Figure 6). The variation in solitary bee species richness is higher among the sites than within sites, in part because the effect of treatment depends on the dominating plant community found within the power-line strip.

As in this study I focus on solitary bee diversity, is important to connect these insect species with dominant plant community they interfere mostly. The environmental conditions in cleared areas where debris was removed enhance the growth of flowering plants. Flowers serve as a source of nectar and pollen for bees (Russel et al. 2005) and their offspring. Thus, a high richness of forbs will indirectly ensure future abundant generations of solitary bees. This happens because entomophilous plants benefit a lot from the increase in air and soil temperature (Klein et al., 2007; Wojcik & Buchmann 2012). Due to this, the removal treatment is considered an abundant and high quality food resource for solitary bees. It is proved that richness of plants' community drives solitary bees' diversity for food resources (Norfolk et al. 2015, Michener 2007). While the purpose with analyzing forbs community plants was to understand the underlying factors that enhance solitary bee diversity, there are also other studies that mentioned the relationship between solitary bee diversity and forbs richness. But they all focused on pollination of forbs as main services ensured by solitary bees (Buchman & Nabham 1996; Ollerton et al. 2011).

In addition to forbs richness as an explanatory variable for solitary bee diversity, recent literature identified new factors that abundance and species richness of solitary bees depends on.

A German study found that solitary bee species richness increases with the increase of habitat area (Krauss et al. 2009). According to the current development of power-line network across the country, the creation of new power-line corridors could enhance solitary bee diversity. Elevation has also impact on solitary bee diversity being considered a site specific parameter. Richness of solitary bees is expected to decrease with increasing altitude. Elevation is a limiting factor because it modifies other environmental parameters, such as temperature and moisture.

The impact of power-line corridors management can be seen in the response of species (Wojcik & Buchmann 2012). Some of the plants and pollinators have the ability to adapt to the new environmental conditions found in cleared areas. Removal areas support a lower richness of solitary bees nesting in trunks of dead wood because of higher distance between nesting and food resource place.

An interesting factor to be studied because of its potential influence on solitary bee diversity in power-line corridors is the electromagnetic field created by the high-voltage wires. This one was proved to have impact on bees (Wojcik & Buchmann 2012). According to anecdotal and published literature honey bees became aggressive and their productivity decreased (Wellenstein 1973; Rogers et al. 1982; Lee & Reiner 1983). Dense vegetation such as forest has the capacity to absorb the radiation emitted by power-line wires (Wojcik & Buchmann 2012). I assume that in the condition of a cleared vegetation patch, this capacity of radiation absorption will be canceled or reduced to minimal values. This could determine the bees to migrate to new areas with lower or absent electromagnetic field. The electrical field may have a negative impact, firstly as a decreased pollination service offered to plant species and secondly, effect on pollinator insects wishing to colonize new territories in their search for food and nest resources. There is no data regarding the impact of electromagnetic field coming from power-lines on solitary bees' diversity, but there are expected the same consequences as for honeybee.

5.0 CONCLUSION

The results of this experiment suggest that solitary bees are enhanced by the clearing of landscape under power-line in Southeast Norway. The highest solitary bee abundance and species richness was observed in cleared treatment where debris was removed. The creation of open canopy habitats modifies the environmental factors in favor of solitary bees' requirements for nesting and food resources. A few sites had very high values of solitary bee abundance and species richness, and I would recommend these areas as best candidates for conservation of solitary bee diversity. As part on future management plans, Norwegian authorities responsible for protection of biological diversity should be informed about these bee diversity "hotspots''.

The findings of this experiment increase the interest for further monitoring and for development of appropriate management practices that could enhance solitary bees' richness and abundance in power-line corridors in Norway.

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