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SAMMANFATTNING

Sedan 2010 har vildsvin (*Sus scrofa* L.) uppehållit sig i den sydsvenska nationalparken Dalby Söderskog. I tidigare forskningsresultat har vildsvinens närvaro både bevisats skapa positiva och negativa effekter på mark och vegetation. I dagsläget råder dock en kunskapsbrist gällande vildsvinens bökeffekter på lövskogsvegetationen inom det ursprungliga utbredningsområdet. I denna studie har vegetationsdata, insamlat före respektive efter en vidsvinsinvasion, från 74 permanenta provytor jämförts. Mer specifikt syftar studien till att bestämma vilken effekt vildsvinsböket har på vegetationens täckningsgrad, artrikedom och artsammansättning i en tempererad lövskog. Mellan 2010 och 2013 har störningsfrekvensen ökat från 0 % till 61 % i området. Vidare har den genomsnittliga täckningsgraden minskat med 40 % respektive 30 % under vår- och sommarperioden. I de bökade ytorna har den största effekten visats på täckningsgraden hos de dominerande vårblommorna *Anemone nemorosa* (vitsippa), *Anemone ranunculoides* (gulsippa) och *Ranunculus ficaria* (svalört) vilka tillsammans minskat från 60 % till 33 %. Under studietiden har det totala artantalet ökat från 44 till 45 arter och den genomsnittliga artrikedomen har ökat från 6.3 till 6.9 arter/m^3. Avslutningsvis tycks vildsvin orsaka kraftiga skador på vegetationens täckningsgrad men även gynna mindre och konkurrenssvaga arter samt öka den totala artrikedomen. Trots att större delen av studiens resultat tycks gå i linje med tidigare forskning så bör dessa betraktas som indikatorer på möjliga korttidseffekter eftersom studietiden är begränsad till tre år.

Nyckelord: Artrikedom, Dalby Söderskog, *Sus scrofa*, lövskog, markstörning, vegetationsförändringar, vegetationstäckning, vildsvin

ABSTRACT

Inside the south Swedish national park Dalby Söderskog, wild boars (*Sus scrofa* L.) have been visiting since 2010. The presence of wild boars has earlier been proven to impact both soil and vegetation characteristics, both positively and negatively. Still, there is a lack of knowledge regarding the rooting effect on the vegetation in deciduous forest within the native range. In this study, I have compared the field vegetation collected before and after the invasion of wild boars in 74 permanent experimental plots. More specifically, the study aimed to qualify the effect of wild boar rooting on cover ratio, species richness and species composition in a temperate deciduous forest. The rooting frequency did increase from 0% in 2010 to 61% in 2013. The results indicated a general cover loss of both spring vegetation (-40%) and summer vegetation (-30%). Within the rooted areas, cover ratio of the dominant spring flowers *Anemone nemorosa* (wood anemone), *Anemone ranunculoides* (yellow) and *Ranunculus ficaria* (lesser celandine) decreased from 60 % to 33 %. The total species number increased from 44 to 45 and the average species richness increased from 6.3 to 6.9 species/m^3. In conclusion, wild boars seem to cause heavy damages on the cover ratios. Rooting appears to favour small and non-competitive species, but also to increase the species richness. Even tough most of the results are in line with previous studies, it is more preferable to consider them as indications of short-term effects as the time aspect is as short as three years.

Keywords: Broadleaved deciduous forest, Dalby Söderskog, soil disturbance, species richness, *Sus scrofa*, vegetation change, vegetation cover, Wild boar

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CONTENTS

INTRODUCTION

Background

In 1992, Sweden signed the Convention on Biodiversity Diversity (CBD), which is intended to retain and utilize the biodiversity sustainably (Swedish Environmental Protection Agency 2014). In addition, the Swedish parliament has adopted 16 environmental quality objectives (Environmental objectives portal 2013). One of theses objectives, named *Sustainable forests*, attends to protect the biological production, biodiversity and social- and cultural values in the forests (Environmental objective portal 2012). Different species are adapted to different kinds of environments, and natural disturbances are important controlling factors for the biodiversity (Götmark 2010). In the modern forestry, a large proportion of the natural disturbances are prevented to avoid economical losses. However, some disturbances are hard to prevent e.g. heavy winds and heavy rains. Another example of a natural disturbance that is quite hard to manage is the effects of wild boar (*Sus scrofa*).

Problem

Wild boars do rooting the soil when they are searching for belowground plant parts. The rooting intensity depends upon forest type and soil moisture, where deciduous forests and high soil moisture are preferred over coniferous stands and dry soils (Bratton et al.1982; Welander 1995; Welander 2000). In the last decades, only a few studies have been examining the impacts of wild boars on the forest flora in broadleaved forests. According to Barrios-Garcia and Ballari (2012), there is a demand for vegetation studies from the native range area as most of the available research is focused on impacts in introduced areas, where Great Smokey National Park is the most studied area (Bratton 1974, 1975; Howe & Bratton 1976; Howe et al. 1981; Bratton et al. 1982; Singer et al. 1984). In the native home range, studies about the rooting effects in deciduous forests have only been made in Bialowieza (Poland) and in a Swiss beech forest (Wirthner et al. 2012). With the help of data collected in native ranges, comparisons could be done with vegetation data from introduced areas and thereby assess if the impacts differ between different ranges. Such data is also needed to examine whether the native plant communities are more or less resilient to the rooting activity than the flora in the introduced areas. Since it is hard to predict where disturbance will occur, recent studies have mostly been using enclosures to enable comparison between rooted and non-rooted areas.

In this study, data is collected from permanent plots before and after an establishment of wild boar in a south Swedish national park called Dalby Söderskog. The first time wild boars were spotted here were in 2009 (Nilsson 2013), but at this time there were no visible signs of disturbance inside the experimental plots. When the animals firstly arrived to Dalby Söderskog, they mostly stayed in the northwestern part of the area. Today, the wild boar hunting is coordinated in the area of Skrylle and therefore the amount of visible tracks has been increasing in Dalby Söderskog. The increased disturbance has resulted in more and more signs of rooting in the south area of the national park. Before wild boars did enter the area, heavy ground disturbance was rather uncommon. Therefore, it is likely that the field vegetation in Dalby Söderskog has been distinctly affected after the establishment of wild boars.

The study area is covered with broadleaved forest and left for free development since 1918 (Kristensson 2007). It is a well-visited recreation area, especially during springtime when the forest offers a dense cover of spring flowers. In the last decades, Dutch elm disease and ash dieback have killed a large amount of the large *Ulmus glabra* (elm) and *Fraxinus excelsior* (ash) in the national park. As a result of the high mortality, large gaps have been created in the canopy cover, which have increased the amount of incoming sunlight. Sunlight is known to be a strongly limiting factor for plant growth (Hedwall et al. 2013). Additionally, most of the seed plant species requests some kind of soil disturbance to germinate (Welander 1995). Therefore, my assumption is that species richness has increased exceptionally in open areas.

Aim

The aim of this study is to quantify the effect of wild boar invasion on the abundance, richness and composition of the herbaceous field cover in Dalby Söderskog national park. Since the disturbance has been proved to affect the spring- and summer vegetation differently in earlier studies, I will investigate these vegetation covers separately.

In order to quantify the effects of wild boars, I will examine the following hypotheses more specifically:

- Increased disturbance caused by rooting impacts both spring- and summer flora negatively
- Rooting, as a natural disturbance, favors uncompetitive species
- Rooting activity changes the species composition

MATERIAL AND METHOD

Study organism

Wild boars are omnivore mammals native to Eurasia (Long 2003). Today, the species is distributed in all continents (except for Antarctica) because of human introductions. In Sweden, the species have a dramatic history since it has gone extinct twice. Because of domestication and intense hunting, the wild boar population got extinct for the first time in the late 1600s (Markström 2002). In 1723, it was introduced to Öland by the Swedish King to serve as prey for hunters. Once again, the population was forced to extinction in 1770. The present population originates from escaping animals during the 1900s, and since 1988 the species is considered native to Sweden by the Swedish parliament. Today, wild boars are unequally distributed over the south and middle part of Sweden. In 2005, the population size was estimated to approximately 40,000 animals (Bergström & Danell 2009) and seven years later, in 2012, the population had increased to more than 100,000 animals (Swedish Hunting Association 2012). The reason for its rapid increase is likely a combination of their plastic diet, low amount of natural enemies, high reproduction capacity and supplemental feeding (Boitani et al. 1995; Taylor et al. 1998; Thurfjell et al. 2009).

In the native home range, up to 90 % of the wild boar diet consists of vegetable food (Genov 1981; Herrero et al. 2004). The foraging is known to be highly selective both in terms of plant species and plant parts (Dardaillon 1986; Baubet et al. 2004; Herrero et al. 2004). During spring and winter, a large proportion of their food comes from belowground plant parts as bulbs, roots, rhizomes and seeds, which the pigs can get by rooting the soil. When rooting the soil, wild boars break the soil surface, turn it upside down and remove plant parts, and therefore this can be compared with plowing the ground. In recent studies, rooting activity has been suggested to change the mineral composition, pH, soil moisture and increase the decomposition rate in the soil (Singer et al. 1984; Mohr et al. 2005; Wirthner et al. 2012). In addition, the presence of wild boar has been proven to increase the species richness (Welander 1995; Milton et al. 1997; Arrington et al. 1999), decreasing the vegetation cover (Singer et al. 1984; Arrington et al. 1999; Wirthner et al. 2012) and causing seed mortality and influencing seedling recruitment (Massei & Genov 2004).

Study area

Dalby Söderskog is a national park with an area of 36 ha, situated nearly 10 km east of Lund in Skåne County (Kristensson 2007). The national park was established in 1918, in order to protect a remnant of the "pristine" forests that grew on Romeleåsen, which in fact were former wooded pastures that had been overgrown. Dalby Söderskog is located in the temperate, sub-oceanic climate zone, and mild winters and relatively long and cool summers characterize the climate. The mean annual temperature is 7-8 °C while the annual precipitation rate reaches nearly 650 mm (Germundsson & Schlyter 1999). The topography in Dalby Söderskog is gently sloping in a southwesterly direction, from 80 to 55 m.a.s.l., and it borders arable land in all directions, with the exception to the northeastern part that is bordering a semi-natural pasture.

1a)

1b)

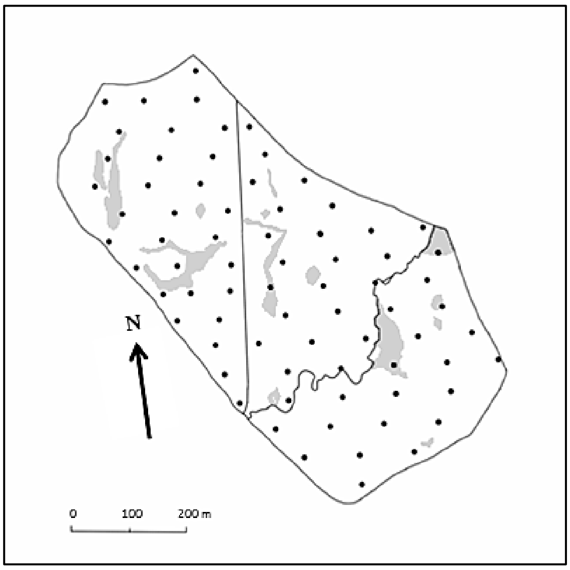

Figure 1. a) the location of Dalby Söderskog in the province of Skåne, **b)** map of Dalby Söderskog with the 74 semi-permanent sample plots. The straight path that was used to establish transect lines with sample plots is also shown. The grey areas indicate wetlands and the black crooked lines shows the small stream that runs through the area.

The soil consists of moist, lime- and nutrient rich Baltic moraine, and in the south part of the national park, there is a small stream running through the area (Ringberg 1980). There are also six smaller wetlands with ephemeral open water in winter and spring (Kristensson 2002). Since the founding of Dalby Söderskog national park, the forest has largely been left for spontaneous succession, with the exception of minor management operations as cutting dead elm trees along the hiking tracks and clearing around old oaks (Brunet & von Oheimb 2008). Today, the tree layer is dominated by *Quercus robur* (oak), *Fagus sylvatica* (beech), *Fraxinus excelsior* (ash) and *Ulmus glabra* (elm) and the shrub layer mostly consists of species as *Corylus avellana* (hazel) and *Crataegus sp.* (hawthorn) (Swedish environmental protection agency 2013; Brunet & von Oheimb 2008). In springtime, the national park is well-attended thanks to its magnificent spring flora. The ground cover is then dominated by *Anemone nemorosa* (wood anemone), *Anemone ranunculoides* (yellow anemone), *Ranunculus ficaria* (lesser celandine) and *Corydalis cava* (hollow root). During the summer, the herbaceous flora is characterized by e.g. *Mercurialis perennis* (dog´s mercury), *Aegopodium podagraria* (ground elder), *Impatiens parviflora* (small balsam) and *Geum urbanum* (bennet).

Vegetation sampling

This study is based on a system of 74 sample plots that Lindquist (1938) established in 1935 in order to document the long-term vegetation succession in Dalby Söderskog (Figure 1). Lindquist used an old paved path that runs through the national park as transect whereupon the experimental plots were placed on perpendicular lines to the transect. The average distance between the lines was about 50 meters, and 100 meters between the plots.

In 2010, the original plot system was re-established using GPS-coordinates based on Lindquist's inventory map from 1935 (Brunet et al., submitted manuscript). To enable relocation of the sample plots, the centres have been marked with plastic sticks, and trees in the surrounding were marked with ribbons (von Oheimb & Brunet 2007). In 2013, the plots where relocated using these marks, as well as GPS co-ordinates (RT90) and photographs taken during earlier investigations. All plots where re-photographed during the fieldwork in both April and June 2013. The edges of the experimental plots were marked with the help of two 2-meter rulers in north-south direction and the centres of the plots were marked with plastic sticks. The percentage cover ratio was estimated in field (except for the spring flora in 2013, which has been determined from photographs on the computer) for all herbaceous vascular species, tree species and bush species in the field layer (plants < 80 cm). Plant parts that belonged to vegetation rooted outside the experimental plot were also included in the estimation. The cover ratios are expressed as percentage, following the scale: 0.5, 1, 2, 3, 5, 8, 10, 12, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90 and 100 %. A square made of paper sized 1x1 dm, equivalent to 1 % cover, was used as reference to facilitate the estimation. The vegetation surveys were made in April and July in 2010 and April and June in 2013. The canopy closure was also estimated in June 2013. The vegetation data in 2010 and in spring 2013, and data on wild boar rooting 2010, 2011, 2012 and in spring 2013 were sampled by Jörg Brunet (Brunet, unpublished data). Plant nomenclature is according to Mossberg & Stenberg (2003).

Data analysis

In order to investigate whether wild boars have influenced the vegetation in Dalby Söderskog or not, cover estimations of the spring- and summer flora from 2010 and 2013 were compared.

Data collected in spring and summer were merged for both years in order to examine whether there have been any differences in the cover and frequency of individual species between surveys. If the same species was recorded in both spring and summer, the highest estimate was used in the calculations. The average cover (%) and frequency (%) were calculated for each species separately in Microsoft Excel for mac 2011, version 14.1.0. The number of species in each plot and the average number of species for each season was calculated with the same program.

In order to compare the average cover ratio and frequency of occurrence for each species, Minitab 16 Statistical Software was used. Since the data collected in 2010 and 2013 are related, as the experimental plots overlap each other, paired t-test was used to compare the average cover for each species. In the first step, observations from all experimental plots were used in the analysis. In a second step, all plots with double zero values (both in 2010 and 2013) were deleted before performing the paired t-tests. Since the aim of this study is to investigate if rooting activity caused by wild boars impacts the vegetation, positively or negatively, the dataset was also divided into single or non-rooted experimental plots and repeatedly rooted plots and again, paired t-tests were performed between the species in the various groups. To classify the plots, data from 2010, 2011, 2012 and 2013 were used. If a plot was rooted more than one time in total, it was classified as rooted and vice versa.

To determine if the frequency of occurrence differed between 2010 and 2013 for the present species, calculations were made with the help of a chi-squared test. The relation between canopy cover and ground vegetation cover estimates were analyzed with linear regression.
Lastly, to examine whether the species diversity differed between the years, Shannon diversity index was calculated in Microsoft Excel for Mac 2011, Version 14.1.0 as:

$$H' = -\sum_{i=1}^{R} p_i * \ln p_i$$

where p_i is the fraction of the entire population made up of species i and
R is the number of present species.

To examine possible changes in evenness it was calculated as:

$$H'_{max} = \frac{H'}{\ln S}$$

where S is the total number of species in the study area.
The species richness, which excludes evenness, was also calculated by using paired t-test calculated in Minitab 16 Statistical Software.

RESULTS

Wild boar rooting

Since the 2010, when wild boars firstly arrived to Dalby Söderskog, the rooting activity has increased every year. In 2011, disturbance was recorded in 23 plots (31%) and in 2012 the number had increased to 39 plots (53%). Recently, in both March and June in 2013, rooting activity was discovered in 45 (61%) of the 74 experimental plots. The intensity of the rooting activity is highly variable between the experimental plots. In some plots, wild boars have caused moderate disturbance while some plots are only covered by bare mineral soil due to extremely harsh disturbance (Figure 2a; Figure 2b).

2a) **2b)**

Figure 2. Examples of disturbed sample plots in Dalby Söderskog; a) shows an example of rooting around one of the plots and b) shows rooting inside one of the plots. Both pictures were taken in June 2013 and represent the summer disturbance.

Vegetation cover

The mean ground vegetation cover inside the experimental plots in Dalby Söderskog was significantly lower ($p < 0.001$) in both spring and summer during 2013 compared to 2010 (Figure 3). The average cover decreased with 40 % between spring 2010 (63.43±36.70 %) and spring 2013 (37.73±23.59 %). The cover between summer 2010 (62.77±48.95 %) and summer 2013 (44.33±36.04 %) did also decrease, but only with approximately 30 %. The relation between the canopy cover and the ground vegetation cover was fairly strong ($R^2 = 0.56$, $p=0.000$) (Figure 4).

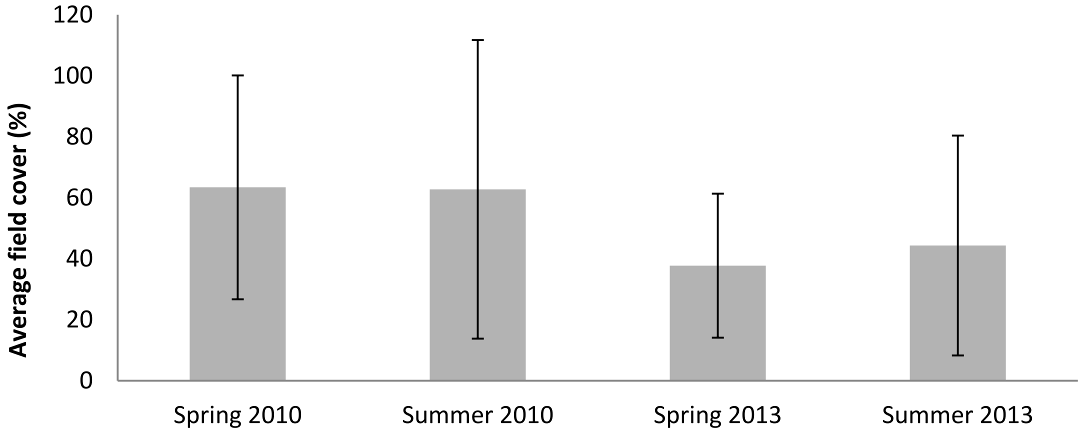

Figure 3. Average ground vegetation cover (% ± standard deviation) at the 74 sample plots during spring and summer respectively in 2010 and 2013. The cover of all species has been summarized to get the average cover of all plots.

Inside the 74 experimental plots, 51 species in total were registered during the four surveys. Only 22 species could be considered as frequently occurring in the plots, i.e. found in ≥5 experimental plots during one of the surveys (Table 1). In total, six of the frequently occurring species had significant cover change (p-value ≤0.05) (Table 1; Figure 5.). Three of the significant species are spring flowers (*Anemone nemorosa*, *Anemone ranunculoides* and *Ranunculus ficaria*), one of the flowers is a typical summer flower (*Circaea lutetiana* (enchanter's-nightshade)) and the remaining two are tree species (*Fraxinus excelsior* and *Ulmus glabra*).

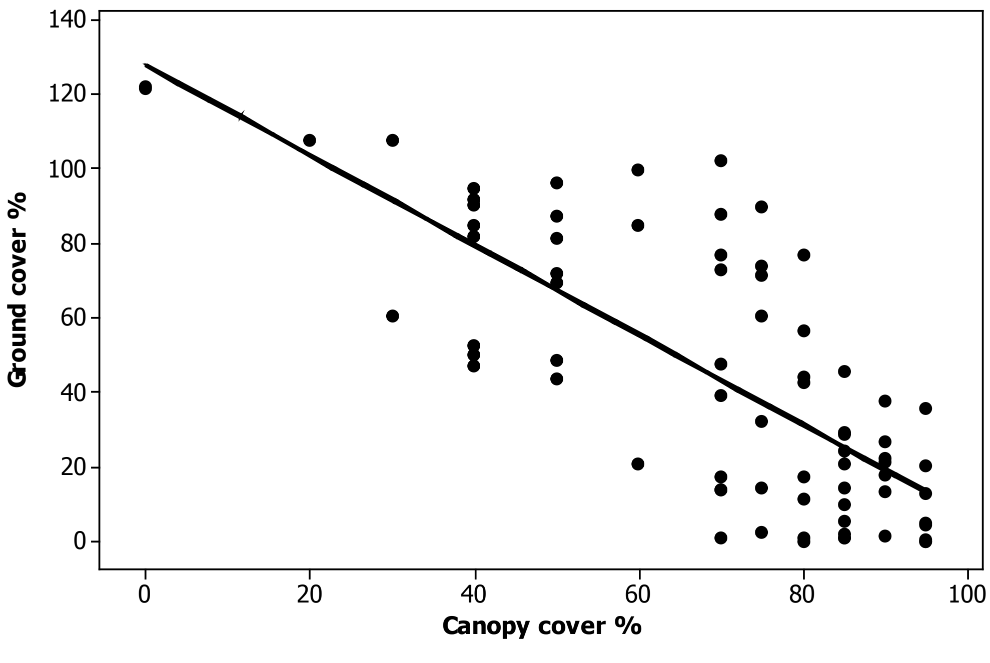

Figure 4. Linear regression between ground cover and canopy cover in the 74 sample plots in June 2013, with added linear trend line.

Table 1. Mean cover (%) and frequency of occurrence (%) of plant species in Dalby Söderskog inside the 74 sample plots. All species with a frequency of occurrence higher than five, including those with insignificant changes, are included in the table. Bold numbers indicates significant p-values (<0,05).

Species	**Mean cover (%)**			**Frequency (%)**		
	2010	2013	*p*	2010	2013	*P*
Acer platanoides	0,59	0,42	0,58	11	14	0,62
Aegopodium podagraria	11,28	11,35	0,94	24	27	0,71
Anemone nemorosa	34,03	21,99	**0,000**	91	91	1,00
Anemone ranunculoides	12,09	6,32	**0,000**	73	74	0,85
Carex sylvatica	0,02	0,11	0,066	4	8	0,302
Circaea lutetiana	5,15	0,84	**0,016**	20	22	0,84
Corydalis cava	2,92	2,45	0,21	24	26	0,85
Crataegus spp.	0,16	0,26	0,19	14	11	0,62
Fagus sylvatica	2,18	1,79	0,39	34	28	0,48
Festuca gigantea	0,09	0,53	0,12	4	12	0,071
Fraxinus excelsior	11,63	8,24	**0,03**	84	76	0,22
Galium aparine	1,16	0,66	0,40	11	15	0,46
Geranium robertianum	0,18	0,99	0,087	5	14	0,092
Geum urbanum	3,34	4,73	0,29	41	46	0,51
Impatiens parviflora	0,82	1,68	0,17	14	16	0,64
Mercuralis perennis	2,27	1,18	0,28	9	11	0,79
Poa trivialis	2,37	3,08	0,41	7	20	**0,016**
Quercus robur	0,17	0,13	0,42	22	14	0,20
Ranunculus auricomus	0,14	0,07	0,25	8	8	1,00
Ranunculus ficaria	13,58	6,36	**0,000**	76	77	0,85
Ulmus glabra	0,10	0,39	**0,016**	5	15	0,057
Urtica dioica	1,81	1,68	0,69	7	12	0,26

All species with significant cover changes decreased from 2010 to 2013 except for *Ulmus glabra*, which slightly increased. The largest percentage loss, calculated by mean cover, had *Circaea lutetiana* (-83.7 %). The largest cover ratio differences had *Anemone nemorosa* (-12.03±18.68 %) and *Ranunculus ficaria* (-7.22±13.79 %).

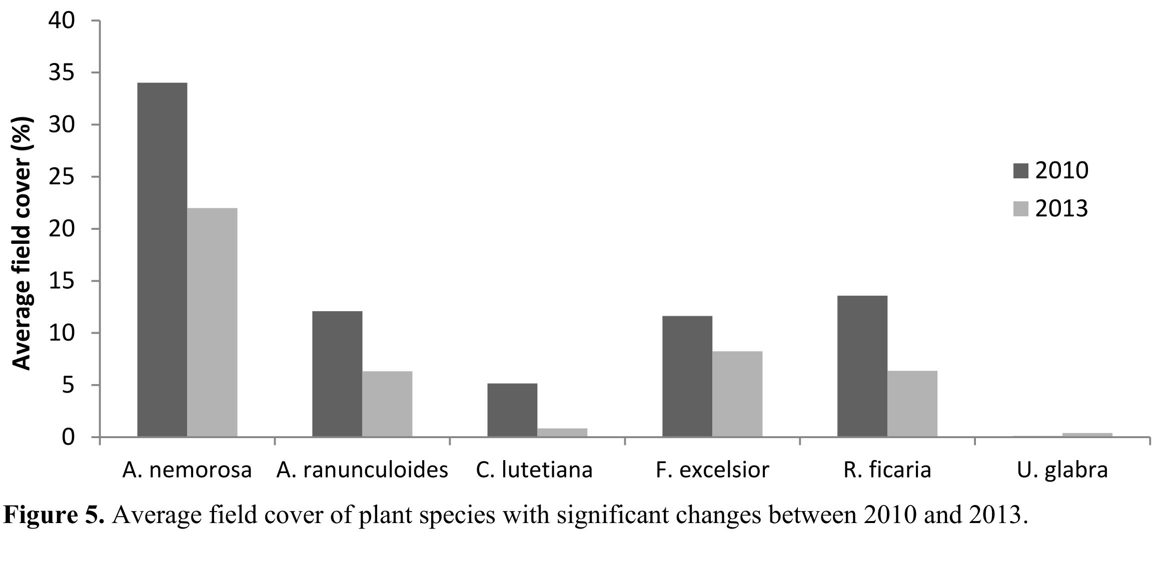

Figure 5. Average field cover of plant species with significant changes between 2010 and 2013.

Only one species, *Poa trivialis* (rough bluegrass), had significant change in frequency of occurrence between 2010 and 2013 (p=0.016), where it increased from five (7%) to 15 (20%) plots (Table 1). In the second step where all double zeroes where excluded, no more species had significant p-values. In 2010, 44 species were identified and in 2013 the number of species was 45. There were some species that were not rediscovered in 2013: *Epilobium hirsutum* (great wilowherb), *Juncus effusus* (common rush), *Orchis mascula* (early-purple orchid), *Ribes alpinum* (alpine currant), *Rubus fruticosus* (blackberry), *Veronica montana* (mountain speedwell). Some species were discovered in 2013, but not in 2010: *Chrysosplenium alternifolium* (golden saxifrage), *Euonymus europaeus* (European spindle), *Filipendula ulmaria* (meadowsweet), *Gagea spathacea* (Belgian gagea), *Neottia ovata* (common twayblade), *Malus spp.* (Apple), *Rumex sanguineus* (red-veined dock). These species had an average cover (%) lower than one percent and of these species, highest number of occurrence were three plots.

Table 2. Changes in average coverage (%) for single species between 2010 and 2013. The non-rooted plots have neither been disturbed in 2010 nor 2013, whereas the rooted plots where disturbed by wild boars in 2013. Species that occurs in less than five study plots where excluded in the calculations. Bold numbers indicates changes with significant p-values (<0.05).

Species	**Single or non-rooted plots (n=24)**			**Rooted plots (n=50)**		
	2010	2013	*P*	2010	2013	*p*
Acer platanoides	0,3	0,6	0,105	0,7	0,3	0,367
Aegopodium podagraria	23,5	29,1	0,977	5,4	5,5	0,905
Anemone nemorosa	27,6	26,7	0,668	37,1	19,7	**0,000**
Anemone ranunculoides	10,7	6,6	0,054	12,7	6,0	**0,000**
Carex sylvatica	0,0	0,04	0,328	0,03	0,1	0,103
Circaea lutetiana	1,3	1,0	0,404	6,9	0,9	**0,020**
Corydalis cava	2,8	3,3	0,587	3,0	2,0	**0,015**
Crataegus sp.	0,08	0,0	0,328	0,2	0,4	0,079
Fagus sylvatica	1,4	2,3	0,325	2,5	1,5	**0,035**
Festuca gigantea	0,2	1,2	0,250	0,02	0,2	0,080
Fraxinus excelsior	2,38	3,1	0,339	16,1	10,7	**0,018**
Galium aparine	2,9	1,9	0,580	0,3	0,04	0,251
Geranium robertianum	0,08	0,06	0,664	0,2	1,4	0,084
Geum urbanum	3,0	4,2	0,684	3,5	5,0	0,266
Impatiens parviflora	0,4	0,2	0,258	1,0	2,4	0,152
Mercurialis perennis	5,2	2,6	0,304	0,9	0,5	0,678
Poa trivialis	3,7	2,5	0,336	1,7	3,3	0,144
Quercus robur	0,02	0,02	1,000	0,2	0,2	0,411
Ranunculus auricomus	0,1	0,04	0,328	0,2	0,08	0,344
Ranunculus ficaria	12,0	5,8	**0,026**	14,3	6,6	**0,000**
Ulmus glabra	0,06	0,4	0,150	0,1	0,4	0,056
Urtica dioica	4,7	3,8	0,385	0,4	0,6	0,102

The comparison between non-rooted and rooted experimental plots resulted in significant mean cover changes of seven species (Table 2). Inside the non-rooted plots, *Ranunculus ficaria* was the only species with significant changes (-6,2%), whereas *Anemone nemorosa* (-17.4%), *Anemone ranunculoides* (-6,7%), *Circaea lutetiana* (-6%), *Corydalis cava* (-1,0%), *Fagus sylvatica* (-1,0%), *Fraxinus excelsior* (-5,4%) and *Ranunculus ficaria* (-7.7%) indicated significant cover changes inside the rooted plots.

Finally, the calculation of Shannon's diversity index resulted in very similar values in 2010 (2.91) and 2013 (3.08). As a result, the Shannon's evenness followed the same pattern (0.77 in 2010 and 0.81 in 2013). However, species richness increased significantly ($p=0.003$) from 2010 (6.28 ± 2.38 species/plot) to 2013 (6.93 ± 2.98 species/plot).

DISCUSSION

The aim of this study was to quantify the effect of wild boar invasion on the abundance, richness and species composition of the field vegetation in Dalby Söderskog national park. The disturbance has increased both in terms of frequency and intensity since the invasion in 2010. The results of this study show significant effects on vegetation cover of single species but also on the species composition. Today, Dalby Söderskog is a popular excursion goal and area for country walks, especially during springtime when the forest floor is covered by mat-forming flowers as *Anemone nemorosa* and *Anemone ranunculoides* (Kristensson 2007). As the invasion of wild boar appears to impact the spring flowers negatively, there is a risk not only for a decrease in biodiversity, but also for a decreased recreational value of the forest. Therefore, I will both discuss the impacts on ecological and social values in this section.

Wild boar rooting

Since the invasion of wild boars in Dalby Söderskog, the number of rooted plots has been increasing steadily. According to Welander (2000), rooting both varies in frequency and extent. The size of the rooting patches has been shown to vary between year, season, habitat type and soil categories. Another factor controlling the disturbance is the food selection, which is based on several factors as e.g. food quality, energy supply and seasonal variations (Howe & Bratton 1976; Barrios-Garcia & Ballari 2014). In this study, rooting activity was unevenly distributed over the study area and many of the permanent plots classified as rooted were not disturbed on a regular basis. Therefore it is hard to make assumptions about the habitat preferences of wild boars in this environment. However, a closer look at the photographs that were taken of the experimental plots during the surveys in 2013 showed that the untouched areas were mostly covered by dead wood, thorny shrubs or large weeds. Also, in some of the areas with low disturbance frequency canopy cover was dominated by beech and had a sparse field cover. Wild boars prefer mast i.e. beechnuts and acorns as they are nutritious (Markström 2002), while plant parts, e.g. roots and shoots, serves as a secondary choice (Bratton 1974). Therefore, wild boars most likely visit these areas when the mast supply is sufficient.

6 a)

6 b)

Figure 6. The pictures are taken inside and around the most severely rooted study plot; a) is taken in spring 2013 and b) is taken in the summer 2013.

Vegetation cover

During the surveys made in 2013, visible changes caused by wild boars were observed on both spring- and summer vegetation (Figure 2a, 6a, 6b). According to the calculations, field cover decreased with 40 % in spring and 30 % in summer between 2010 and 2013. This result is in line with previous studies where wild boars have been shown to reduce the vegetation cover in introduced areas (Singer et al. 1984; Arrington et al 1999; Wirthner et al. 2012). In this study, tree species as well as spring and summer flowers indicated significant cover decreases which is in line with my hypothesis that rooting affects both spring and summer flowers. However, the main result is the large cover losses of the dominant spring flowers *Anemone nemorosa, Anemone ranunculoides* and *Ranunculus ficaria,* which together decreased from 60 % to 33 % between 2010 and 2013. As wild boars selectively feed on e.g. starchy tubers, rhizomes and corms (Howe & Bratton 1976), it is reasonable that they decreased as they have this kind of storage organs. In contrast, several studies have confirmed summer flowers to be more sensitive to rooting than the spring flowers (Bratton 1974; Howe & Bratton 1976; Bratton et al. 1982; Falinski 1986). According to Bratton (1974), one possible explanation is the fact that summer flowers are larger than spring flowers and thereby more exposed to mechanical damages. The difference could also be explained by the temporal variations. In Bialowieza, Poland, rooting intensity was shown to be remarkably low during winter season but from late spring onwards the intensity was increasing and reached its maximum during June/July (Falinski 1986). In Dalby Söderskog the temporal variation goes the other way around as the highest rooting intensity has been detected during winter and springtime (pers. obs. Brunet 2014). In contrast to the above studies, agricultural lands surround Dalby Söderskog. Wild boars prefer to stay in forest edges adjacently to agriculture fields as they provide both food and shelter (Thurfjell et al 2009). Within the native home range, wild boars are known to consume large amounts of crops during summer and autumn (Genov 1981; Schley & Roper 2003; Herrero et al 2006). As food supply gets insufficient during winter and early spring, wild boars search for alternative food sources, therefore adjacently forests is caused by the highest disturbance during this time (Barret 1978; Baron 1982). According to this information, the result of only one decreasing summer flower (*Circaea lutetiana*) compared to several significant spring flowers seems reasonable. *Circaea lutetiana* has rhizomes just like *Anemone sp.* which may be an explaining factor for why it has been affected. A comparison with older vegetation data collected in 2002 indicated a slight increase in the cover ratio of the *Circaea lutetiana* between 2002 and 2010 (Brunet & von Oheimb 2008). However, it decreased with a strong significance ($p = \leq 0.020$) in this study. Interestingly, no former studies have explained rooting as a threat for *Circaea lutetiana*. The flower is mainly distributed in Europe, which is a probable reason for the lack of knowledge. Therefore, it is hard to say if this flower is more or less sensitive to rooting than other species.

When the experimental plots were divided into two different classes (non-rooted and rooted plots), the results were even more obvious. Also, the classification increased the total number of significant species with one. Together, these results can be interpreted as disturbance frequency has a large impact on the field vegetation. Because experimental plots that are rooted once are included in the non-rooted plots, it is possible that most species are able to manage moderate rooting frequencies. This assumption is also confirmed by the fact that *Ranunculus ficaria* was the only species with a significant cover change in the non-rooted experimental plots.

During the last decades, Dutch elm disease and ash dieback have killed nearly all the old elms and many ashes in Dalby Söderskog. As a result, gaps have been created in the canopy cover and as a result there has been an increased amount of light in the openings. According to Christensen et al. (2007), seed germination and plant growth are favoured by an increased amount of light. But in spite of that, the cover ratio of *Fraxinus excelsior* did significantly decline inside the rooted plots. During the survey in June 2013, the ash dieback disease had affected plenty of ash seedlings and therefore we considered these seedlings as dead. In other words, there might be a weak correlation between the decrease of ash and the rooting activity as the disease has killed a lot of plants. The other significant tree species (*Ulmus glabra*) increased significantly in the general test but inside the rooted plots it was only near significant ($p=0.056$). Wild boars might have influenced the germination of *Ulmus glabra* beneficially, but as the seedlings are light demanding (Löf et al. 2009) the changed amount of sunlight has possibly favoured both the growth and germination.

Species richness and species composition

Between 2010 and 2013, the species richness has increased significantly from 6.3 to 6.9 species/m^3. Also in previous studies, rooting has been proven to increase the species richness (Welander 1995; Kotanen 1995; Milton et al. 1997; Arrington 1999; Tierney & Cushman 2006). According to Connell (1978), the highest species richness is reached with an intermediated disturbance regime. If the disturbance regime is to low, competitive species will dominate and outcompete other less competitive species. In the opposite way, if the disturbances get to intense most of the species will be negatively affected. A moderate disturbance reduces some of the dominant species, why small and less competitive species can manage to grow in the area. In comparison, the result of both the Shannon's index and evenness indicated an enhancement of the species distribution which seems highly plausible as the most dominating species were strongly reduced at springtime.

Between 1925 and 1979, 86 different species disappeared in Dalby Söderskog due to a changed forest structure, where the area went from being open and lightly grazed to be covered by closed and multi-layered old growth forest (Kristensson 2002). A similar trend has also been documented between 1970-2002, where light demanding species have been strongly decreasing (Brunet & von Oheimb 2008). Two of the newfound species (*Chrysosplenium alternifolium* and *Gagea spathacea*) were both common in 1935, but as the forest closed up they got rare (Lindqvist 1938; von Oheimb & Brunet 2007). At the same time, matt-forming species as e.g. *Anemone nemorosa* and *Anemone ranunculiodes* became more widespread, why small flowers as the above mentioned probably got outcompeted. According to Welander (1995), rooting may benefit smaller spring flowers that have earlier been benefited by grazing. This means that a reduction of the dominant species may have favoured those two flower species in question, which is in line with my hypothesis saying increased rooting favours uncompetitive species.

As earlier mentioned, gaps have been created in the canopy layer due to the Dutch elm disease and ash dieback. Therefore, gap creation and rooting have together caused an increased amount of light in the canopy layer as well as the in the field layer. Most seed plant species (both perennials and annuals) requires some kind of disturbance within their seed dispersal area to get a successful reproduction (Welander 1995). When wild boars are rooting the soil, they create plots with exposed mineral soil and increased amount of light that favours the seed germination (Bueno et al. 2011). As the result of the linear regression confirmed a negative relation between the field- and canopy cover, rooting may have been exceptionally favourable for the species richness in the open areas. According to Barrios-Garcia and Ballari (2012), wild boars may also influence the species composition by impacting the alterations of nutrient availability and promote the seed dispersing.

There are two different possibilities for seed to be dispersed by animals, either within fur or on feet (epizoochory) or within the faecal matter (endozoochory) (Barrios-Garcia & Ballari 2012). Epizoochory is considered to be the most important source of distribution for long distance dispersal of seeds (Heinken et al. 2006). In former studies, seeds from especially *Urtica dioica, Poa pratensis, Poa trivialis, Juncus effusus* and *Rumex sanguineus* have been found in the fur of wild boars (Heinken & Raudnitschka 2002; Schmidt et al. 2004). Wild boars are often wallowing in muddy pools to cool themselves and to get rid of parasites. Afterwards, they brush the dirt of against so-called rubbing trees. In earlier studies, a higher number of seeds and seedlings and also higher species richness among those have been found close to the rubbing trees (Heinken et al. 2006; Mrotzek et al. 1999; Welander 2000). Several of these species were adapted to more open areas, indicating a dispersal of seeds from e.g. fields and pastures into the forests. In this case, I think the increase in species richness is due to a combination of a changed light amount and the seed dispersal supported by wild boars. Additionally, I believe that the resilience of the vegetation also affects the species richness at least in a more long-term perspective as most of the regrowth come from seeds, shoots and corms rather than bulbs and tubers (Bratton et al. 1982).

The recovering of the vegetation depends on its adaption to the disturbance and it can vary between six months and three years (Bratton et al. 1982; Baron 1982). But there is also a risk for single species to get problems with recovering if they become extremely reduced due to intense rooting (Bratton et al. 1982). An additional factor controlling the recovery is the mast supply. In mast-years, beeches and oaks produces large volumes of masts, why the supply of acorns and beechnuts get satisfying to the wild boars. In such conditions, additional vegetation gets a chance to recover due to an eased pressure (Bratton 1974; Groot Bruinderink & Hazebroek 1996). As the tree layer in some of the areas of Dalby Söderskog is dominated by beech, there might be an opportunity for the exposed vegetation to recover when the mast supply is satisfying.

Recreation and social values

Forests with high social values are important in many aspects. Among all, this type of forests have encouraging effects on the health and wellness of people, regional development and tourism (Swedish Forest Agency 2014). Within the municipality of Lund, the amount of forest is only 16 %. The amount of urban woodlands is highly variable among the conurbations in the municipality. Some of the urban communities have a sufficient access to urban woodlands while both Lund city and Stångby are completely surrounded by agricultural lands (Blomberg 2007). Therefore, recreational areas as Dalby Söderskog, Dalby Norreskog and Skrylle are of considerable value for the citizens. Approximately, Dalby Söderskog is visited 100.000 times a year, especially during spring when the forest floor is covered by spring flowers as *Anemone sp., Ranunculus ficaria* and *Corydalis cava* (von Sydow 2015). In a recent study, 33 % of the respondents were afraid of meeting wild boars in the forest (Eriksson et al. 2010). As wild boars have been proven to cause damages on the forest flowers and scare people, there is a conflict between the wild boars and the recreational values of the national park. In 2013, protective hunting was performed two times in Söderåsen national park with the motive of wild boars where causing damages on the values that the national park are aimed to protect (The County Administration Board of Skåne 2013). There are two purposes for protective hunting. Firstly, it decreases the population number and secondly it creates a feeling of uncertainty within the herd of animals which keeps the animals from the disturbed areas for a while (Swedish Protection Agency 2010). Since the 1st of January 2015, protective hunt will be plausible even in Dalby Söderskog (NFS 2014:5, 5). Hopefully, the hunting will reduce the damages of the vegetation cover as well as increase the tolerance for wild boars.

Source of error and potential improvements

The experimental plots were supposed to be marked by plastic sticks but unfortunately there is a tendency for markers to disappear. Hence, it was hard to find the exact area of these plots but with the help of our aerial photographs, plots could be relocated with an estimated error less than 10 cm. However, the vegetation is fairly homogeneous throughout the study area (Brunet & von Oheimb 2008), why these margins should not have a notably affect on the results. Also, if the experimental plots were placed 10 cm differently there is a risk that small species had been excluded or included to the data.

In his study, calculations of species richness, diversity index and evenness only issues the overall differences. Unfortunately, it is hard to determine if rooting is the underlying cause for the changed species richness in Dalby Söderskog. To get more detailed results, further studies should make calculations for non-rooted and rooted areas separately. More preferably, classification could be classified as non-rooted, single rooted and repeatedly rooted plots. Additionally, spring and summer flowers could be calculated separately to qualify the rooting effect upon the different herb groups. This study does also have a short time frame, why it is hard to separate the vegetation changes caused by natural variation from those who have been caused by environmental changes (Milberg 2003). Repeated studies are therefore needed, as they would facilitate the disjunction and contribute with data needed for the investigation upon long-term effects. Because of the size of the study area, it is hard to put the results in relation to a higher geographical scale (Tyler 2007). Furthermore, a northern distribution of wild boars are expected in Sweden due to the on going climate change (Melis et al. 2006). Therefore, further studies should also focus on different vegetation types in different regions of the country.

Inside Dalby Söderskog, about 15 lichen species and nine moss species classified as red-listed were found in the beginning of the 21th century (Gärdenfors 2000; Kristensson 2002). As the national park aims to protect such species, there is also a reason for quantifying the effects on the ground flora. Vegetation studies upon the moss and lichen flora have been made in 1940 (Waldheim 1944), 1990s (Hallingbäck 1989; Hallingbäck 1992; Tyler 1999) and in 2002 (Kristensson 2002). Therefore, there shall be enough data to perform studies similar to this one.

Conclusion

According to the results of this study, rooting affects the cover ratio on spring flowers and summer flowers, the species richness and the species composition in Dalby Söderskog. This means that none of the hypotheses that were stated in the introduction could be rejected. However, as the time span of this study only amounts to three years, it is important to remember that these results only reflect possible short-term effects on the field vegetation in a deciduous forest. Disregarding the short time set, this result contributes new information regarding the response on the deciduous forest vegetation after an introduction of wild boars. My expectation is that further long-term analyses hopefully can be based on the results of this study.

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APPENDIX 1

Appendix A. Mean cover (%) and frequency of occurrence (%) of plant species in Dalby Söderskog inside the 74 sample plots. Species included in less than five experimental plots are included in the table. * indicates p-values that could not be calculated because the frequency was the same in all plots.

Species	**Mean cover (%)**			**Frequency (%)**		
	2010	2013	*p*	2010	2013	*p*
Athyrium filix-femina	0,040	0,054	0,321	1	1	0,321
Carex remota	0,068	0,007	0,321	1	1	0,321
Chrysosplenium alternifolium	0,000	0,180	0,170	0	3	0,170
Cornus sanguinea	0,013	0,068	0,321	1	1	0,321
Corylus avellana	0,100	0,240	0,209	4	4	0,209
Dactylis glomerata	0,840	1,080	0,242	3	5	0,242
Elymus caninus	0,013	0,027	0,321	1	1	0,321
Epilobium hirsutum	0,040	0,000	0,321	1	0	0,321
Epilobium montanum	0,040	0,110	0,228	2	4	0,228
Euonymus europaeus	0,000	0,068	0,321	0	1	0,321
Filipendula ulmaria	0,000	0,040	0,321	0	1	0,321
Gagea spathacea	0,000	0,013	0,159	0	3	0,159
Geum rivale	0,027	0,450	0,205	1	3	0,205
Juncus effusus	0,027	0,000	0,321	1	0	0,321
Lamiastrum galeobdolon	0,540	0,200	0,167	3	3	0,167
Lathraea squamaria	0,013	0,007	0,321	1	1	0,321
Listera ovata	0,000	0,040	0,181	0	3	0,181
Malus sp.	0,000	0,013	0,321	0	1	0,321
Orchis mascula	0,013	0,000	0,321	1	0	0,321
Paris quadrifolia	0,013	0,013	1,000	1	1	*
Polygonatum multiflorum	0,130	0,110	0,321	1	1	0,321
Ribes alpinum	0,013	0,000	0,321	1	0	0,321
Rubus caesius	1,220	2,500	0,263	3	4	0,263
Rubus fruticosus	0,950	0,000	0,321	1	0	0,321
Rubus idaeus	1,081	0,880	0,516	4	4	0,516
Rumex sanguineus	0,000	0,054	0,103	0	4	0,103
Stachys sylvatica	0,470	0,203	0,208	3	3	0,208
Veronica montana	0,013	0,000	0,321	1	0	0,321
Viola reichenbachiana	0,081	0,020	0,344	3	3	0,344

APPENDIX 2

Appendix B. Changes in average coverage (%) for single species between 2010 and 2013. The non-rooted plots have neither been disturbed in 2010 nor 2013, whereas the rooted plots where disturbed by wild boars in 2013. All species occurred in less than five experimental plots. * p-values that could not be calculated because the cover of the specific species was the same in all plots.

Species	**Single or non-rooted plots (n=24)**			**Rooted plots (n=50)**		
	2010	2013	*p*	2010	2013	*p*
Athyrium filix-femina	0,12	0,17	0,328	0,00	0,00	*
Carex remota	0,00	0,00	*	0,10	0,01	0,322
Chrysosplenium alternifolium	0,00	0,00	*	0,00	0,26	0,171
Cornus sanguinea	0,00	0,00	*	0,02	0,10	0,322
Corylus avellana	0,083	0,00	0,328	0,11	0,36	0,123
Dactylis glomerata	2,50	3,21	0,270	0,04	0,06	0,659
Elymus caninus	0,04	0,083	0,328	0,00	0,00	*
Epilobium hirsutum	0,12	0,00	0,328	0,00	0,00	*
Epilobium montanum	0,12	0,29	0,328	0,00	0,02	0,322
Euonymus europaeus	0,00	0,00	*	0,00	0,10	0,322
Filipendula ulmaria	0,00	0,00	*	0,00	0,06	0,322
Gagea spathacea	0,00	0,00	*	0,00	0,02	0,159
Geum rivale	0,00	0,33	0,328	0,04	0,50	0,322
Juncus effusus	0,00	0,00	*	0,04	0,00	0,322
Lamiastrum galeobdolon	0,83	0,42	0,328	0,40	0,10	0,322
Lathraea squamaria	0,00	0,00	*	0,02	0,01	0,322
Listera ovata	0,00	0,12	0,185	0,00	0,00	*
Malus sp.	0,00	0,00	*	0,00	0,02	0,322
Orchis mascula	0,00	0,00	*	0,02	0,00	0,322
Paris quadrifolia	0,04	0,04	*	0,00	0,00	*
Polygonatum multiflorum	0,42	0,33	0,328	0,00	0,00	*
Ribes alpinum	0,00	0,00	*	0,02	0,00	0,322
Rubus caesius	3,75	4,38	0,588	0,00	1,60	0,322
Rubus fruticosus	2,92	0,00	0,328	0,00	0,00	*
Rubus idaeus	0,42	0,21	0,328	1,40	1,20	0,659
Rumex sanguineus	0,00	0,083	0,328	0,00	0,04	0,159
Stachys sylvatica	0,62	0,42	0,328	0,40	0,10	0,322
Veronica montana	0,00	0,00	*	0,02	0,00	0,322
Viola reichenbachiana	0,20	0,00	0,328	0,10	0,03	0,453

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