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I The effect of a wind farm on native vegetation and area use of three cervid species – A case study into the planning and ecological effects of constructing a wind power plant in Southern Norway

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Photo taken by author, June 2015

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Abstract

Wind energy is increasingly popular globally, with numerous wind farms also being planned and constructed in Norway. Wind production is considered to have a low impact on the environment, yet research on local ecological impacts is lacking. Wind farms can lead to disturbances for animals, fragmentation of landscapes, and loss of wilderness areas. Wind farm construction also implies building access roads as well as turbines, powerlines and power stations. An important stage of this building process should be the restoration of disturbed areas. I studied vegetation succession along roadsides and the area use of three cervid species within the Lista wind farm in southern Norway. The results show that roadside diversity match undisturbed diversity 3 years after disturbance, and that introduced species migrate to undisturbed areas 3 years after revegetation. Introduction of new plant material is not recommended in restoration after construction, and could lead to lower fitness, genetic pollution and lower plant diversity. Space use by red deer and roe deer showed avoidance towards roads under construction of the wind farm, and subsequent habituation 3 years after construction. Results also show a general decrease in their populations for all study species in the wind farm area. Increased pedestrian activity and hunting may be important factors for this decline in use of the wind farm area. Continuing and combining these data-series in future studies can provide a unique opportunity to assess the ecological impacts of wind farms.

Sammendrag

Vindkraftverk øker globalt, og flere vindparker er under planlegging og bygging i norge. Vindkraft er regnet for å være miljøvennlig, men forskning på lokale økologiske konsekvenser mangler. Vinkraftverk kan være forstyrrende for dyr og kan lede til fragmentering av landskap og tap av inngrepsfri natur. Anlegging av vindkraftverk betyr også anlegging av veier, samt turbiner, kraftlinjer og trafostasjoner. Økologisk restaurering vil være nødvendig etter anleggsperioden. Jeg har undersøkt vegetasjonssuksesjon i veikanter og habitatbruk av tre hjortehviltarter i Lista vindkraftverk i sørnorge. Resultatene viser at diversitetsindeksene i de forstyrrede områdene er nesten like høye som de uforstyrrede områdene 3 år etter anleggsperioden og at introduserte arter migrerer til uforstyrrede områder 3 år etter revegeteringen. Introduksjon av nytt plantemateriale er ikke anbefalt i økologisk restaurering og kan føre til lavere fitness, genetisk forurensning og lavere vegetasjonsdiversitet. Arealbruk for hjort og rådyr viste at de unngikk veien under anleggsperioden og at de ble vant til forstyrrelsene 3 år etter anleggsperioden. Resultatene viser også en generell nedgang i populasjonen i vindkraftområdet. Økt menneskelig aktivitet, og friluftsbruk samt jakt kan være viktige årsaker til denne nedgangen i habitatbruk. Det anbefales en videreføring av dataseriene samt inkludering av dataset for fisk og fugl som finnes for vindparken for videre studier.

Index

Introduction

In a world experiencing anthropogenic climate change, population growth and technological revolutions, the demand for "clean" energy is increasing. Politicians and society as a whole are facing the fact that our fossil fuel reserves are finite and are looking for alternative ways to harvest more environmentally friendly energy. Renewable wind power is one of the solutions to this, and is expected to produce up to 28% of the energy need in Europe by 2030 (Zervos & Kjær 2008). Although the production of wind power is regarded as clean and contributing to positive impacts on a global level, wind farms often meet opposition from the local community over concerns about the noise and visual pollution they pose. There are also rising concerns about the possible negative impacts on the local ecosystem, in particular amid reports of bird fatalities and other impacts on wildlife (Leung & Yang 2012; Saidur et al. 2011; Tabassum et al. 2014). It seems unlikely that energy production on a commercial level could be without any ecological footprint.

Much research has been done on mortality and population level consequences of wind farms for birds and bats that collide into turbines (Telleria 2009; Voigt et al. 2012). Less research has been done on terrestrial mammals (Walter, Leslie Jr., & Jenks, 2006), and even less on *overall ecological impacts* of wind farms and their effects on biodiversity, including vegetation (personal communication, Jonathan Colman, March 2014). Although wind turbines occupy relatively little space on the ground, a wind farm, with many turbines, internal roads, power lines and maintenance buildings represent a potential severe disturbance and habitat fragmentation, especially during the construction period. Wind turbines need access roads for construction, maintenance and operation, so the landscape will inevitably be permanently altered. Habitat loss and fragmentation is one of the largest threats to biodiversity today (Primack 2012; Vegdirektoratet 2014). Access roads also open an area to an increase in human recreational activities in the form of walking, bicycling, hunting and more. These activities may further influence vegetation communities and space use by large herbivores after the establishment of a wind farm.

In Norway, wind power presently generates approx. 1.7% of total energy produced annually (energidirektorat 2015). Norway is not optimal for wind farms (personal communication, Tom Halland October 2015) as the winds are not stable, but often too strong for optimal operation. Nevertheless, many new farms are being planned and built in Norway (https://www.nve.no/konsesjonssaker/, accessed 28 Oct 2016).

When planning and building a wind farm, there are usually large discrepancies between the contributions from ecologists versus engineers in regards to design and construction issues. Road engineers are often concerned about erosion and want to plant fast growing plants in roadsides to prevent erosion and improve esthetics. Although ecological restoration is a relatively modern term, the concept of revegetation after construction projects have a long history, and are unfortunately the reason for several ecologically catastrophic incidents due to introduction of new species that have become invasive. A relevant and popular example is the introduction of *Lupinus* to Norway by the Norwegian road and train authorities (Elven & Fremstad 2000). In those times, the primary impetus for revegetation was not maintaining biodiversity, but avoiding erosion and providing quick easthetical value. The Nature diversity act (2009) prohibits introduction of alien species in Norway, and much less invasive techniques are being implemented, such as removal and storage of local topsoil to be returned to the exact same site when the construction period is over.

In order to mitigate potential loss and fragmentation of the landscape in light of large construction projects, ecological restoration is often implemented. In fact, ecological restoration is becoming increasingly popular, as we are facing the consequences of habitat loss and degradation, extinction of species and the consequences of extensive anthropogenic altering of the ecosystems. Restoration ecology is viewed as one of the best possible ways to actively do something about an otherwise potentially negative ecological situation, or to mitigate the potential detrimental effects of habitat loss (Shackelford et al. 2013). According to the Society of Ecological Restoration (SER), Ecological Restoration "is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration 2004). In connection with roads and wind farms, this is often done simply by planting or revegetating areas that have been disturbed. Either by seeds, plants, propagules or organic topsoil that has been removed carefully prior to the disturbance. Ecological restoration may also include "rewilding" in form of reintroducing animal species that have gone extinct in an area (Society for Ecological Restoration, 2004). In Norway, the Nature Diversity Act (Naturmangfoldloven 2009) is the main tool for conserving nature and all construction projects need in order to get permission from the state to proceed with its plans, a plan for how to mitigate negative impacts on nature and biodiversity accordingly. This includes a holistic protection of all animals and their living space; i.e. the habitats necessary for an entire population to thrive. Specifically for Lista, this included populations of large herbivores, and the necessary planning to mitigate potential negative consequences at the population scale.

This thesis will look at the ecological planning of a wind power plant in Norway, *Lista Wind Power Plant* (Lista WPP). Lista WPP was built in 2012-2013 by Fred. Olsen Renewables on an approximately 10 km^2 area divided in two by a county road. The area was very inaccessible for humans before the construction. During the construction, new access roads to all the turbine sites had to be constructed. The company Naturrestaurering AS was hired prior to construction as ecological consultants. Naturrestaurering AS developed a plan (Naturrestaureringsplan -> NRP) to minimize potential negative environmental impacts according to the nature diversity act (Naturmangfoldloven 2009). As they state themselves in the plan, "nature will be damaged to some extent by construction […] and it is more efficient to plan the restoration measures before construction is started (Flydal, Colman, Eftestøl, & Ryvarden, 2010).

The plan included among other things, management of the surface masses, revegetation, placement of the access roads to minimize disturbance on the ecosystem, and monitoring of potential wildlife disturbance. The NPR advised to not actively revegetate (Flydal et al. 2010), but active revegetation was nevertheless done. The roadsides were revegetated by hydroseeding (a technique were the seeds are sprayed out with water and mulch) with three species common in southern Norway (Mossberg & Stenberg 2007), but not before found on the Lista WWP site by Leon (Leon 2014). They are therefore introduced, and possibly invasive. *Trifolium* is even in the fabaceae family and lives in symbiosis with nitrogen fixating bacteria, and may therefore have competitive benefits in the otherwise nutrient poor habitat found here on Lista.

Up until the 1970s, the dominating vegetation type for Lista was coastal heathland, a cultural landscape type subject to regular burning and subsequent grazing by sheep mainly on the young heather (*Calluna vulgaris*). Most of these areas are now being covered by bushes and trees, with only a small area next to Lista Wind Farm now classified as coastal heathland. Coastal heathlands have become a severely threatened nature type in Norway (Flydal et al., 2010). The dominating vegetation type in the area today is nutrient poor heaths, bogs and poor Betula-Sorbus forest (personal communication, Klaus Høiland 24/4/15). Large mammals in the area include the ungulates red deer (*Cervus elaphus*, roe deer (*Caproleus caproleus*) and moose (*Alces alces*) from the family *Cervidae* (hereafter referred to as cervids). One of the goals in the plan was to minimize impact on the cervid area use, and monitoring of cervid area use was done prior to, during and after construction between 2010 and 2013 (Flydal et al. 2010; Leon 2014). Monitoring of vegetation distribution, and introduced species migration trends was started in 2013, after construction.

My main goal was to test possible effects the Lista WPP might have on the landscape and ecosystem, and contribute to the understanding of ecological impacts of wind power plants. I investigated the vegetation succession in the disturbed roadsides and tested if and how fast the native plant community recolonize the disturbed, hydroseeded road sides. I also tested how and if the hydroseeded species migrate into outlying, undisturbed areas. Furthermore, I sampled cervid area use and tested the animals' potential avoidance towards the construction of roads and turbines in the wind farm.

Predictions

1. The roadsides, or disturbed areas will have a lower vegetation diversity than the undisturbed area 3 years after construction. The introduced species will to some extent migrate into and colonize the undisturbed area, and likewise, the native vegetation will slowly recapture the disturbed, seeded areas.
2. Cervids will avoid the heightened amount of disturbances and human activities along the roads and turbines during and shortly after construction compared to before construction. If there is avoidance, this will likely decrease as the years pass and the cervids become more accustomed to the wind farm.

Materials and methods

Study area

Fieldwork was conducted during summer in 2015 at Lista Wind Farm in Lista, Vest Agder county, Farsund municipality (58° 9,5'N 6° 42,6'E). The area is approx. 10 km^2 and has 31 turbines and many km of access roads. The highest top in the area is 346 meter above sea level Figure 1. The wind farm area is divided into two sections by a public road. The western section is facing the ocean, while the eastern section is closed off to public traffic by a gate open only to employees and the landowners.

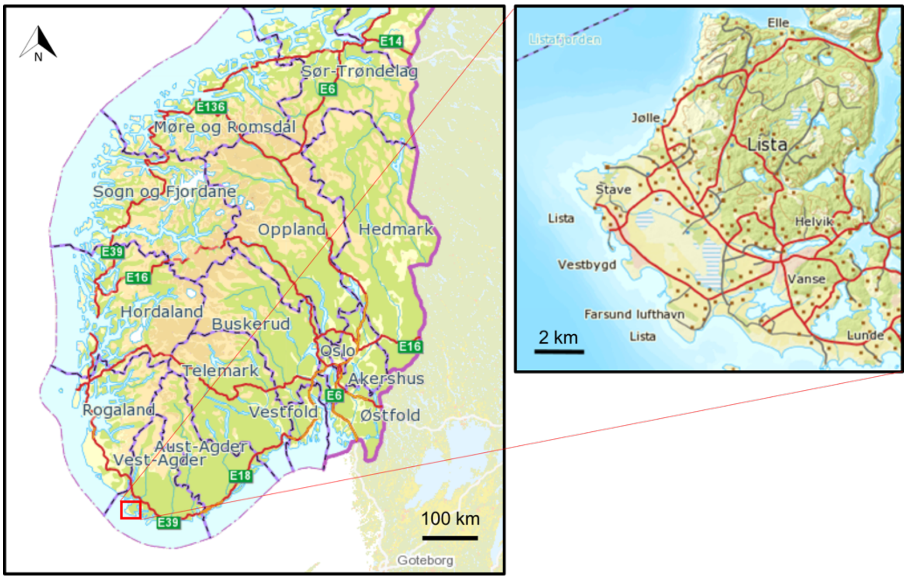

Figure 1. Map over the area, Statens kartverk. www.norgeskart.no

The wind park is characterized by nutrient poor heathland, bog and forest. The eastern part of the area has few grazing livestock, no sheep grazed there in 2015, only a small area with cows. The western part is more accessible to the public, as a county road passes through the area. There was also grazing sheep here during summer 2015. There are roe deer, moose and red deer in the park.

Vegetation

The vegetation was sampled over 2 periods in 2015; first in the end of June and then again in early October. Three transects that were studied in 2013 (Leon, 2013), were re-sampled at the same GPS coordinates. The second sampling included 6 new transects, as the first 3 were thought to be too little data. Each transect was 20 metres long, and each location had one transect 3-5 metres from the road, representing the disturbed area, and one transect 10-15 metres from the road, representing the undisturbed area (Figure 3). In each transect, four 1x1m plots were laid, 5 metres apart, giving a total of 72 plots, half from disturbed, and half from undisturbed areas. Inside the plots, the percentage of foliar coverage for each species was counted.

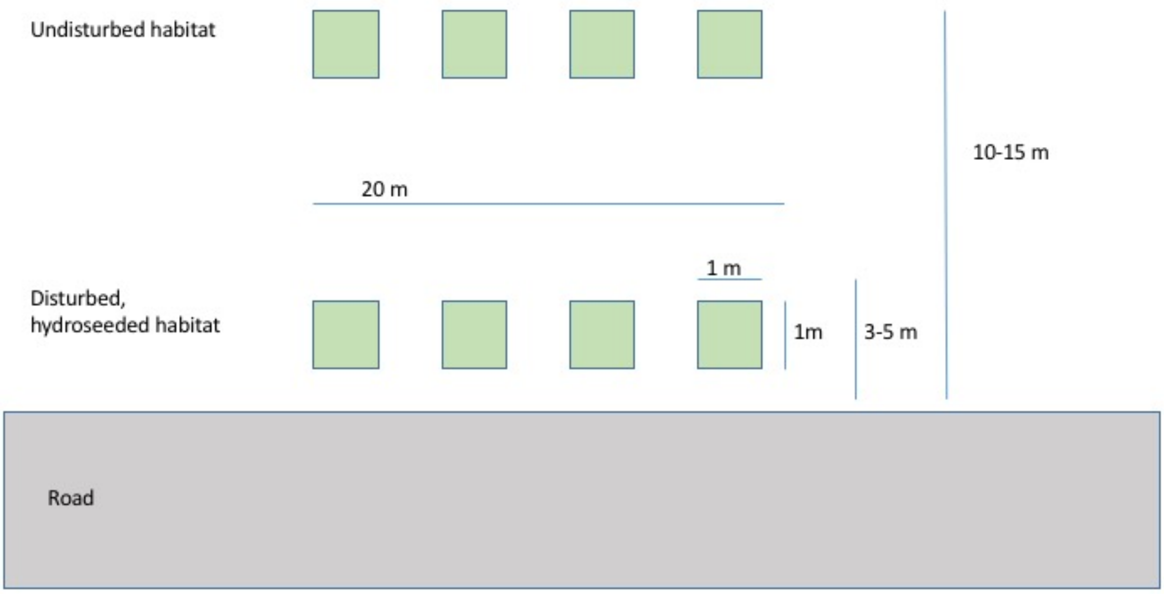

Figure 2. Model of vegetation study design. 4 plots in each transect, disturbed and undisturbed habitat.

Cervids

Cervid space use was sampled by counting faecal pellet groups in June 2015 along 34 transects, placed in a north/south and east/west grid system (Figure 2), similar to (Colman et al. 2013). This was pre-designed by Naturrestaurering AS in 2011 before the construction of the Wind farm. Faecal pellet groups were recorded by walking the 34 transects with a handheld GPS, counting the droppings that were 1 m to each side of the feet. The transects varied in length, and in total, they comprised 15 km long and within varying vegetation types, elevations and distances from the planned roads and turbines (Figure 3).

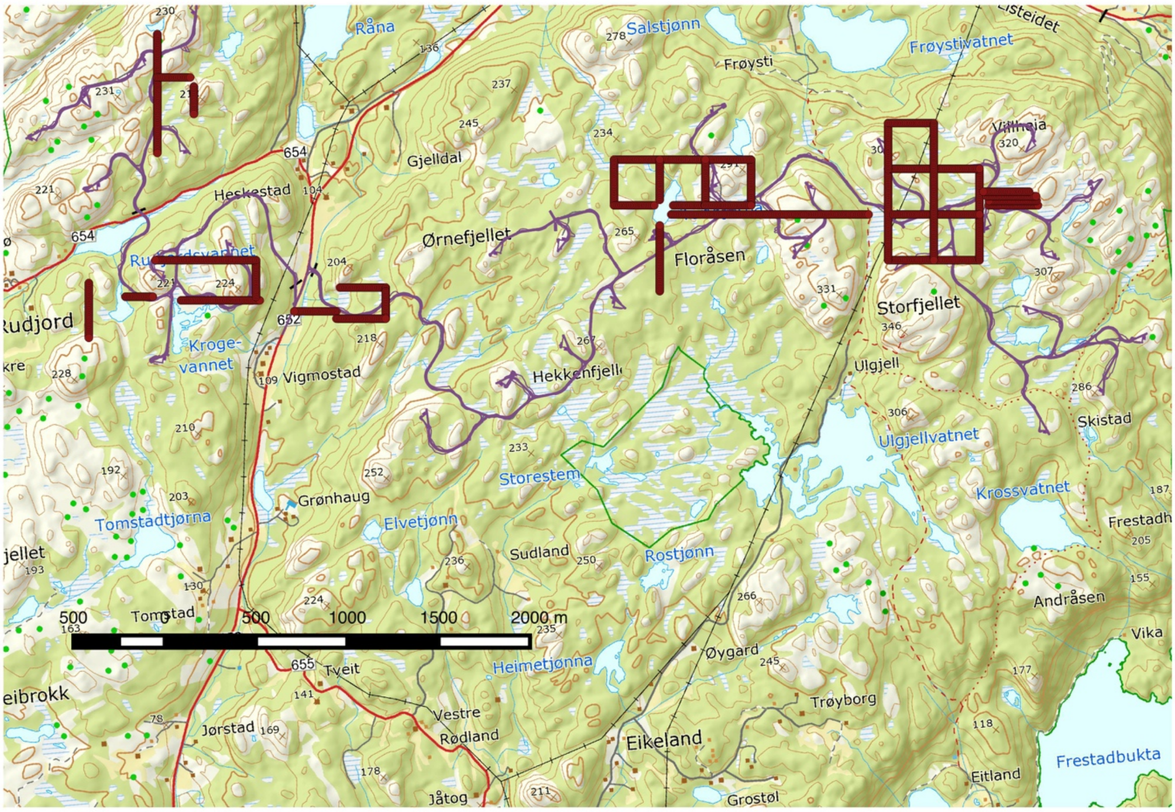

Figure 3. Map showing the access roads in purple and the transects in red.

Data analysis

The statistical analyses were done in R version R 3.3.0 (R Core Team 2014)

Vegetation data

The foliar coverage of each species from data collected in 2013 and 2015 was analysed using the package vegan: Community Ecology Package in R. The plots were designated as disturbed or undisturbed, and the diversity indices species richness (Shannon diversity number) and entropy (Shannon entropy number) were calculated for all the plots (Eldegard et al. 2015). The mean richness and entropy with the disturbance levels as the explanatory variable was plotted for the years 2013 and 2015. The species were also grouped into the categories introduced and native. As the introduced species were not observed in the area before the hydroseeding, it was assumed that all the specimens of those species originated from the hydroseeding in 2012. The introduced and native groups were then plotted as separate categories with their percentage coverage as the explanatory variable. One graph was made for the disturbed area and another for the undisturbed area to visualise the migration of the introduced plants and the succession of the native flora into the disturbed areas, respectively.

Cervid data

The transects had a start and an end UTM position originally decided by Naturrestaurering AS. As the transect grid was placed in a north/south or east/west direction, it was easy to make an empty dataset with points or positions in the transects for every 10 metres. The distance to roads and turbines for every point was then assessed with GIS (QGIS 2.10.1-Pisa). The datasets from all the years, 2011, 2012 (Naturrestaurering AS), 2013 ((Leon 2014) and the present dataset from 2015 were assigned to their geographical nearest point in the transect dataset by using NNjoin Near tool in QGIS. The dataset then consisted of 1530 geographical points, their distance to the disturbances (road and turbines) were generated, and the droppings (by year and species) corresponding to the points were organized before testing.

General population data for each cervid species was obtained from http://www.settogskutt.no, a database based on hunters' reports of the animals they observe and shot during the hunting season. Lista storvald, including the wind farm, was used as the reference area. For moose and deer, I used the total observed number of animals for the hunting season, but this data is not available for roe deer, as the hunters are not encouraged to report these observations. For the roe deer, hunting quota was used as a reference population. A graph showing the development of the general population over the relevant years, with the development in the droppings in the transects was made to compare the development in the wind farm with the overall population development in the area.

Vegetation type was also included, obtained from the transect dataset from the first year. The vegetation types were grouped into 3 groups, open, closed and disturbed. Open included bog, heather, stone, water; closed included forest (deciduous and coniferous) and disturbed included turbines and roads. The points in the dataset was assigned a vegetation type.

The lme4 package (R Core Team 2014) was used and several alternative generalized linear mixed-effects models were tested, with distance to disturbance (as continuous explanatory variable), vegetation (as categorical explanatory variable with three levels: closed, open and disturbed), year (as categorical explanatory variable with four level; 2011, 2012, 2013 and 2015), and number of faecal pellet groups as response variable with binomial distribution (the response variable had two possible outcomes). Transect number was included as a random variable to account for variation among the 34 transects. I also included population as an offset/or weight variable and fitted separate models for each species. I then identified the most parsimonious final models based on Akaike's Information Criterion (AIC; Burnham and Anderson 2002), a model with lowest AIC was selected for each species (see Table 1).

Results

Vegetation

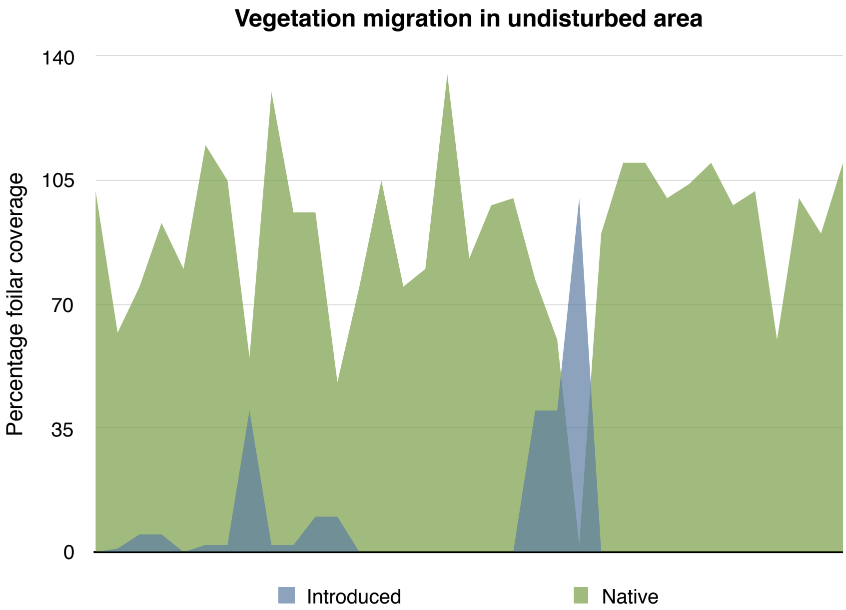

Figure 2 Graph showing the percentage foliar coverage of the different species groups in the plots in undisturbed transects, illustrating migration of introduced species. Undisturbed transects are approx. 10 meters from the hydroseeded road side. X axis shows the different plots, the two lines in darker (introduced) and lighter (native) represent the introduced species from the hydroseeding, and the native species.

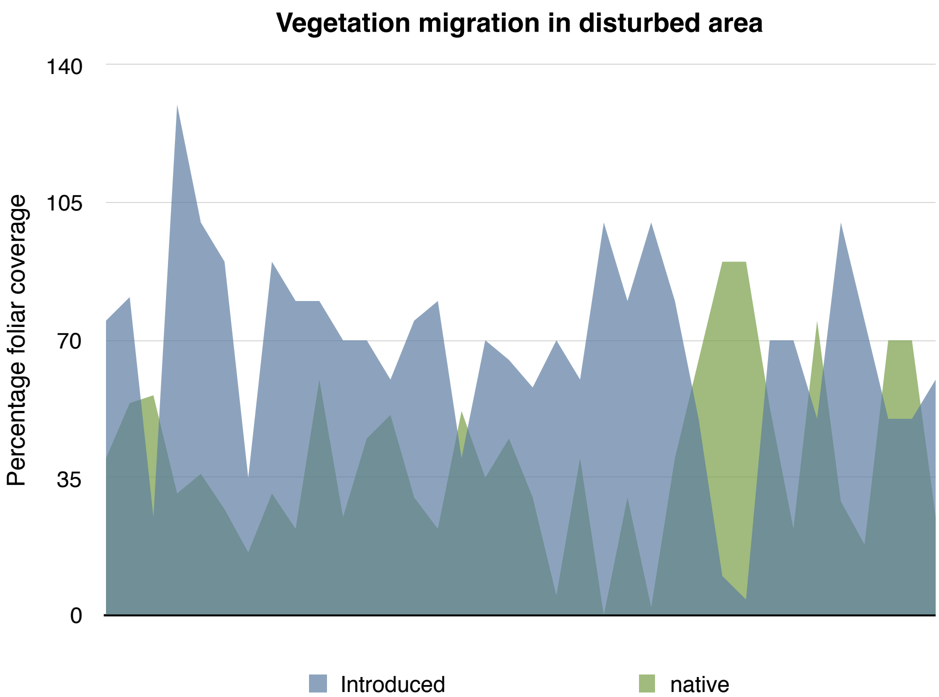

Figure 5 Graph showing the percentage foliar coverage of the different species groups in the plots in the disturbed area, illustrating succession of native species. Disturbed area was hydroseeded with the introduced species in 2012. X axis shows the different plots, the two lines in darker (introduced) and lighter (native) represents the introduced species from the hydroseeding, and the native species.

The introduced (hydroseeded) species from 2012 have to some extent migrated to the undisturbed area (Figure 4). One or more of the introduced species were found in approximately half of the plots in the undisturbed transects. The native species have also established themselves in the disturbed area, but the introduced species still dominate in most plots (Figure 5).

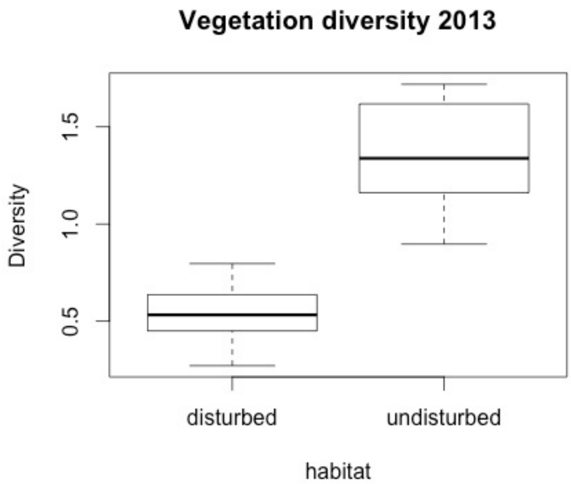

Figure 6 Mean shannon diversity number in disturbed and undisturbed transects in 2013, 1 year after construction.

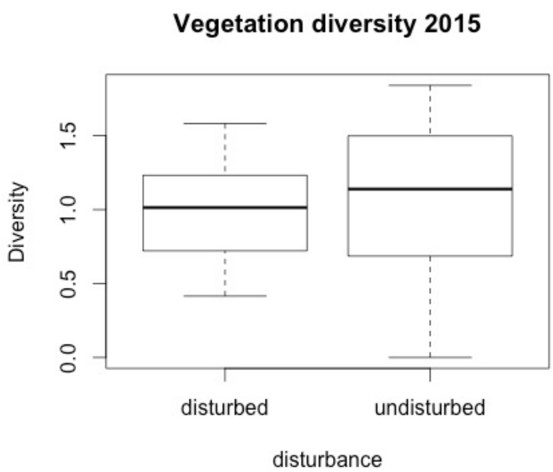

Figure 7 Mean Shannon diversity number in disturbed and undisturbed transects in 2015, 3 years after construction.

The diversity was substantially lower in the disturbed habitat compared to the undisturbed habitat in 2013 (Figure 6). However, the diversity number in the disturbed and undisturbed habitats are much closer to each other in 2015, and closer to the level of diversity measured in the undisturbed areas in 2013 (Figure 6 and 7).

Cervids

Model testing

Table 1. Selection of the best model using AIC selection criteria.

	Alternative models	AIC values		
		Red deer	Roe deer	Moose
1	Number~Year*Road+Vegetation, family=binomial	2167,058	1503,297	1519,036
2	Number ~Year*Road.s+Vegetation, family=binomial	2167,058	1503,297	1519,036
3	Number~Year*Road.s+Vegetation+(1ǀTransect)	1965,850	1472,857	1446,308
4	Number~Year*Road.s+Year*I(Road.s^2)+Vegetation+(1ǀTransect)	**1945,230**	1472,077	**1438,587**
5	Number~Year*Road.s+I(Road.s^2)+Vegetation+(1ǀTransect)	1949,681	**1467,174**	1448,252
6	Number~Year+Road.s+I(Road.s^2)+Vegetation+(1ǀTransect)	1995,318	1467,915	1456,544
7	Number~Year*Road.s+Year*I(Road.s^2)+Vegetation+(1ǀTransect), weights = Population	347727,585	971061,555	45827,595
8	Number~Year*Road.s+Year*I(Road.s^2)+Vegetation+ offset(log(Population))	2134,178	1498,166	1510,633
9	Number~Year*Road.s+I(Road.s^2)+(1ǀTransect)	1946,896	1467,281	1442,153

For red deer and moose, the model 4 had the lowest AIC value, and for roe deer, model 5 had the lowest AIC value (Table 1).

Red deer

Table 2. Number of red deer pellet groups (response variable) in relation to distance to road and turbines before (2011, intercept), under (2012) and after (2013 and 2015) construction of the wind farm and to vegetation types analyzed using generalized linear mixed model fit by maximum likelihood (Laplace approximation) family = binomial (logit).

Fixed effects	Roads			
	Estimate	SE	Z value	P value
Intercept	−2,853	0,315	−9,057	<0,001
Open vegetation	−0,266	0,152	−1,751[A]	0,080
Disturbed vegetation	−0,761	0,391	−1,947[B]	0,052
Year 2012	−1,405	0,237	−5,925	<0,001
Year 2013	−1,038	0,213	−4,87	<0,001
Year 2015	−0,674	0,225	−2,996	0,003
Distance from Road	0,060	0,184	0,325	0,744
I(Road^2)	−0,076	0,088	−0,864	0,387
Year 2012 : Road	1,530	0,317	4,826	<0,001
Year 2013 : Road	1,087	0,289	3,758	<0,001
Year 2015 : Road	0,515	0,277	1,86	0,063
Year 2012 : I(Road^2)	−0,269	0,131	−2,051	0,040
Year 2013 : I(Road^2)	−0,340	0,152	−2,239	0,025
Year 2015 : I(Road^2)	−0,590	0,25	−2,361	0,018

The occurrence of red deer droppings increased with distance from the road, indicating that red deer generally avoid the roads (Table 2). There was no significant difference between vegetation types.

With increasing distance from the road, probability of feces occurrence increase in 2012 and 2013 compared to 2011 (intercept) (Table 2). The avoidance was, however, up until 200 m (Figure 8). The avoidance is highest in 2012, and then still there but lower in 2013 and 2015, indicating that the animals avoided the road less as the years go by.

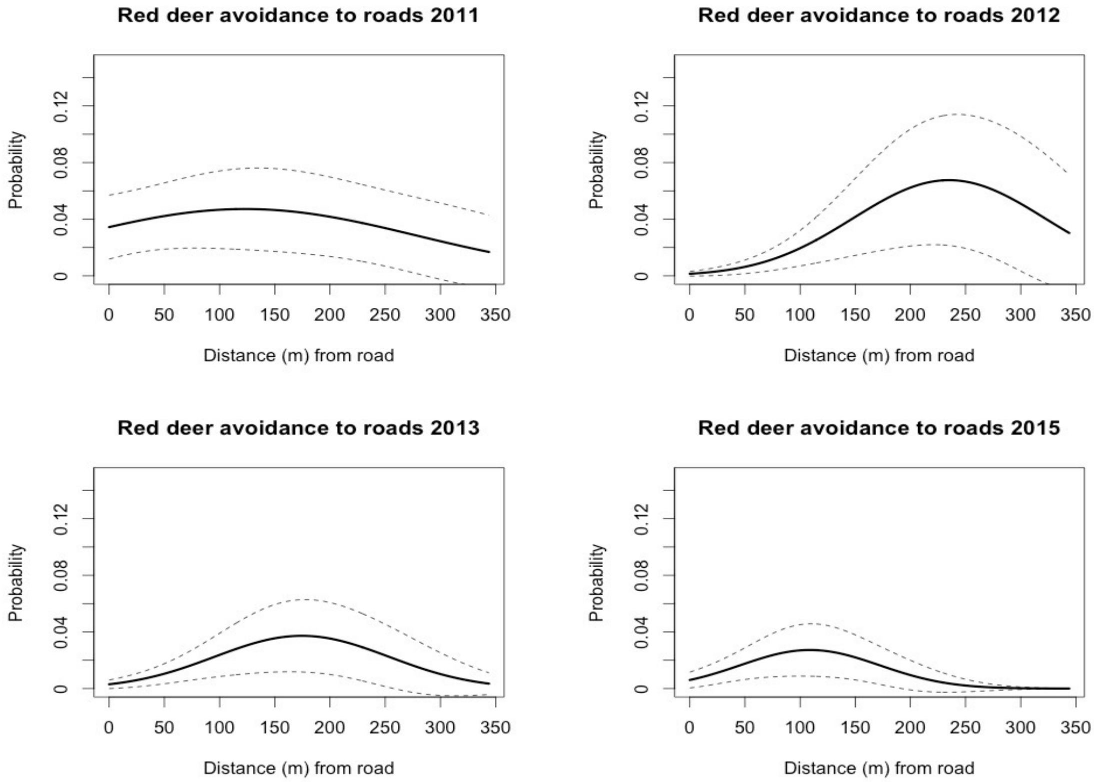

Fig. 8 Visualization of red deer avoidance to the wind farm road before (2011), during (2012) and after (2013 and 2015) construction by predicted number of faecal pellet groups (mean per plot ±95 % CI) in relation to distance to road for the different years. The prediction was based on the models from Table 1 omitting the vegetation variable.

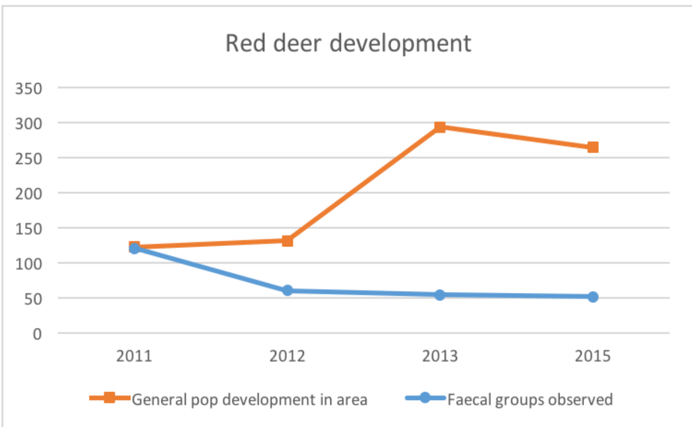

Fig 9. Red deer population development from before, during and after the construction of the wind farm. The square dots indicating the general red deer population development in the area obtained from hjorteviltregisteret.no and the round dots indicating the observed pellet groups.

There is also significantly less occurrence of droppings in 2012, 2013 and 2015 compared to 2011, but the trend is increasing, indicating that the population drops in the construction year, and then increases again the years after (Table 1). There was an overall increase in the red deer population from 2011 - 2015 in the Lista area, with a decrease in observations in the park (Figure 9).

Roe Deer

Table 3 Number of roe deer pellet groups (response variable) in relation to distance to wind farm road and turbines before (2011, intercept), under (2012) and after (2013 and 2015) construction of the wind farm and to vegetation types analyzed using generalized linear mixed model fit by maximum likelihood (Laplace approximation) family = binomial (logit).

Fixed effects	Roads			
	Estimate	SE	Z value	P value
Intercept	−2,893	0,228	−12,687	<0,001
Open vegetation	0,194	0,198	0,98	0,327
Disturbed vegetation	−0,511	0,426	−1,199	0,230
Year 2012	−1,152	0,223	−5,165	<0,001
Year 2013	−1,977	0,309	−6,404	<0,001
Year 2015	−0,774	0,192	−4,022	<0,001
Distance from Road	−0,044	0,184	−0,238	0,812
I(Road^2)	−0,233	0,089	−2,625	0,009
Year 2012 : Road	0,496	0,23	2,152	0,031
Year 2013 : Road	0,524	0,303	1,73	0,084
Year 2015 : Road	0,011	0,229	0,048	0,962

There was a significant (p=>0,05) avoidance towards the roads by roe deer in 2012, but not significant in 2013 or 2015 (Table 3). There was no significant differences between vegetation types. There was a significant decrease in the overall population in the wind farm area in the years 2012, 2013 and 2015 compared to 2011, but the trend is increasing (the occurrences are increasing again, the population builds up).

Figure 10 shows that the avoidance is until around 150 meters in 2012 and 2013, and decreased to 100 meters in 2015. The observations in the park fall 2012 to 2013, but increase again towards 2015, while the general population in the area is stable (Figure 11)

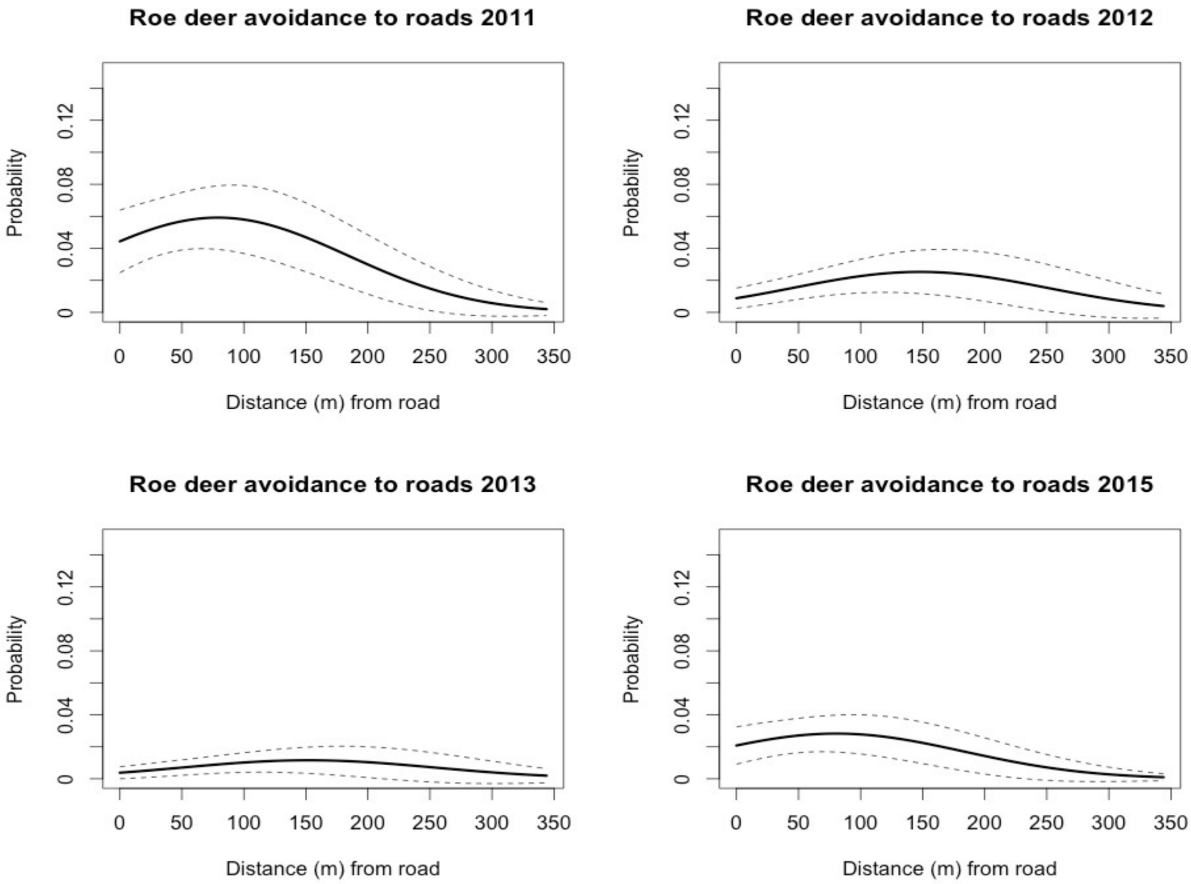

Fig. 10 Visualization of roe deer avoidance to road before (2011), during (2012) and after (2013 and 2015) construction by predicted number of faecal pellet groups (mean per plot ±95 % CI) in relation to distance to road for the different years. The prediction was based on

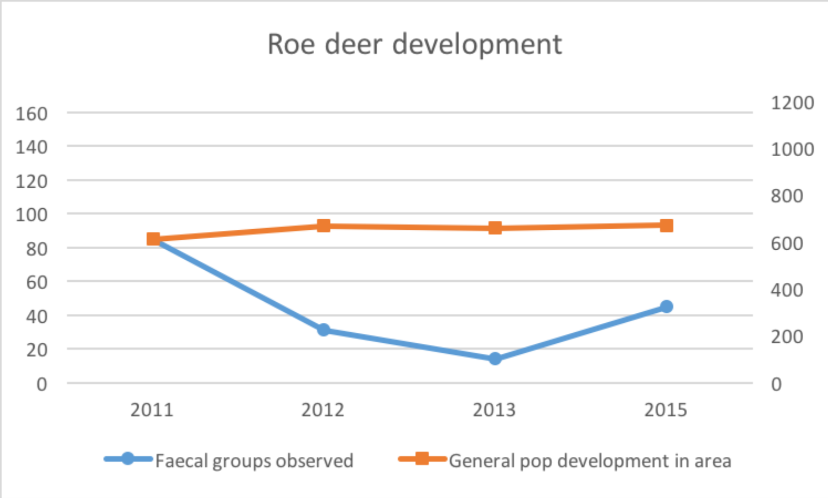

Fig 11. Roe deer population development from before, during and after the construction of the wind farm. The square dots indicating the general red deer population development in the area obtained from hjorteviltregisteret.no and the round dots indicating the observed pellet.

Moose

Table 4. Number of moose pellet groups (response variable) in relation to distance to road and turbines before (2011, intercept), under (2012) and after (2013 and 2015) construction of the wind farm and to vegetation types analyzed using generalized linear mixed model fit by maximum likelihood (Laplace approximation) family = binomial (logit).

Fixed effects	Roads			
	Estimate	SE	Z value	P value
Intercept	–3,608	0,308	–11,713	<0,001
Open vegetation	0,301	0,285	1,429	0,153
Disturbed vegetation	–0,619	0,428	–1,447	0,148
Year 2012	–0,906	0,248	–3,657	<0,001
Year 2013	–2,994	0,495	–6,052	<0,001
Year 2015	–0,157	0,246	–0,641	0,522
Distance from Road	–0,289	0,196	–1,475	0,140
I(Road^2)	0,135	0,097	1,388	0,165
Year 2012 : Road	0,553	0,285	1,939	0,053
Year 2013 : Road	0,701	0,57	1,23	0,218
Year 2015 : Road	1,112	0,296	3,754	<0,001
Year 2012 : I(Road^2)	–0,111	0,146	–0,758	0,448
Year 2013 : I(Road^2)	0,068	0,212	0,321	0,748
Year 2015 : I(Road^2)	–0,820	0,257	–3,187	0,001

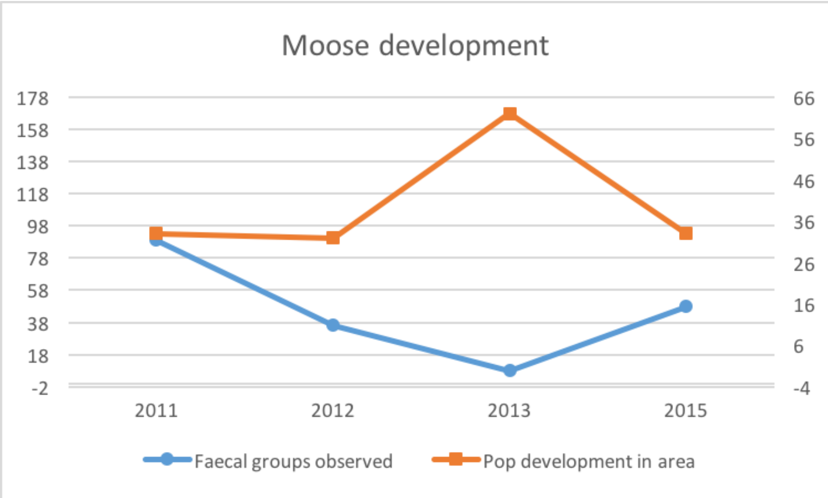

Fig 12. Moose population development from before, during and after the construction of the wind farm. The square dots indicating the general moose population development in the area obtained from hjorteviltregisteret.no and the round dots indicating the observed pellet groups.

There was a significant increase in occurrence of moose with increasing distance to the road in 2012 (p=0,05) and 2015 (p=0,001) compared to 2011 (Table 4). There was no significant result for 2013. The overall population was also significantly smaller in 2012, 2013 and 2015 compared to 2011, suggesting the population has gone down (Figure 12).

Discussion
Vegetation

Diversity

As a parameter of a healthy vegetation community, diversity indices were used. and Shannon diversity index includes the relative percentage of abundance and cover of the species (Nagendra 2002). In secondary succession, as after a disturbance, the disturbed area will usually be colonized first by few, rapidly growing pioneer species. In the present case study, these species were actively spread by humans. Pioneer species are often light loving species, and can be outcompeted by more slow growing, shadow tolerant species after some time. The diversity will typically be low at the start of the succession, and increase as years pass. Looking at figure 6 and 7, this is similar to my results for the development along the roadsides (the disturbed areas). One Year after construction, in 2013, the diversity was much lower in the disturbed area compared to the undisturbed area. However, in 2015, the diversity index number has increased and is almost as high as the undisturbed area, which only partially supports my hypothesis.

Migration

The native communities establish in the disturbed area, but what about the introduced species? The diversity index increased, and the native plant community is starting to reconquer the roadsides, but the hydroseeded grasses *A. capillaris* and *F. rubra* were still dominating in most plots. *F. rubra, A. capillaris* and *T. repens* are all common species in southern Norway (Mossberg & Stenberg, 2007), but (as mentioned earlier) not found in the wind farm area before construction. I had most concerns about *T. repens* competitiveness, since they are in the fabeceae family and have nitrogen fixating bacteria in their root nodules, but *T. repens* was not found in any of the undisturbed transects and only a few specimens in the disturbed transects. In the undisturbed areas, the diversity index was about the same in 2013 and 2015, which was expected, but the two species *A. capillaris* and *F. rubra* had migrated to the undisturbed area in 50% of the transects.

Invasive species are defined as species occurring outside their natural ranges, that spread at the expense of native species. Invasive species are one of the 7 big threats to biodiversity today (Primack, 2012). Roadside planting has traditionally been one of the major gateways for invasive species, but developers and ecologists are learning from each other and according to the Nature Diversity Act (2009), introducing exotic species is now illegal. Some developers may still often want to revegetate, with native vegetation. But how are native populations defined? A population that is native to the area will have a different genotype than a population of the same species cultivated in a nursery, and introduction of this new genotype may lead to genetic pollution of that population. Genetic pollution may in turn lead to lower fitness of that population (Aamlid et al. 2014). Although passive revegetation is encouraged to reduce the possibility of introducing foreign populations (Hagen 2010; Aamlid et al. 2014), the legislation is not clear, the Nature Diversity Act only refers to general precaution (The principle of precaution) (14 2015–2016; Naturmangfoldloven 2009), and developers must refer to advice given through reports and ecologists.

Coastal heathlands

Coastal heathlands, an important vegetation type in Lista is threatened, and a vegetation type Norway has international responsibility for protecting. Terrestrial wind farms in Norway will often be developed in areas with coastal heathlands, and thus fragment and reduce this vegetation type. However, coastal heathland is a cultural landscape, and the vegetation type needs burning and grazing to be sustained. Burning is not regarded as an efficient agricultural method anymore, so the vegetation type is in strong decline. Restoration of coastal heathland inside the wind farm was suggested as a goal in NPR (Flydal et al. 2010). Coastal heathlands could be facilitated within the Lista wind farm with use of the new road system, allowing landowners to remove trees (Canadian spruce), herd livestock and promote proscribed burning with the road as a fire shield. In many areas within the wind farm, this can already be observed (pers. Obs.).

Cervids

Area use (Space use)

The data collected before the construction of the wind park provides an optimal chance for studying avoidance towards this type of disturbance, the access roads, without potentially seeing effects of random area variables. This is the first study for all three cervid species spanning before, during and multiple years after the establishment of a wind farm.

Cervid area use is affected by many factors such as food availability, hunting pressure, disturbances and area use etc. All the cervid species in the study showed some degree of avoidance towards the constructed road after it was built, and this trend also decreased over the years with red deer and roe deer, suggesting they got used to the disturbance. Moose actually had an opposite effect, they avoid roads more in 2015 than 2012, but the sample size is small, so the effect might be random and therefore not so relevant.

Red deer is the species that consumes a larger amount of grass, included the hydroseeded species *F. rubra* and *A. capillaris*, so it could be expected that they forage on the roadsides.

Roe deer was the species in my study that showed least avoidance to the roads. Roe deer forage on herbs, bushes, heather and even grass. They are especially fond of young sprouts in spring (Hjeljord 2008) and may like foraging on the open roadsides where pioneer vegetation is growing. Edges are considered good browsing habitat for roe deer (Saïd & Servanty 2005), and the road certainly increased the amount of edges in the area. Roe deer are also known to eat *F. rubra*, but in smaller amounts (Gębczyńska 1980).

Moose forage mainly on trees and structurally larger plants. They have long legs, and short necks, and actually have to kneel to eat plants close to the ground. Their mere size and nutritional requirement make them more prone to eat coarse vegetation and they are often found in closed areas, and less likely to forage in the roadsides. Moose eat in the bush layer. The dataset on moose is relatively small (n=25 in 2011), much smaller than the other species. This makes the dataset more sensitive to random variables.

Since vegetation was removed at construction, the vegetation was very scarce the year of construction and the next year, thus not providing very interesting habitat for the cervids, as there is neither much food or hiding areas. Another hypothesis for the avoidance of the roads can simply be that it does not pay off to spend time in those areas.

In the construction year, there was a lot of activity in an area with no prior activity, humans and noisy and big machines, avoidance of the new stimuli is therefore expected. In the following years, the only regular motorized traffic was connected to operations and maintenance by the employees at the wind park. Pedestrian activity has increased substantially in the area (mostly people walking), though, and this might even be a more severe disturbance for the cervids than motorized activity or the turbines themselves (Reimoser 2012; Stankowich 2008).

The access roads to the turbines are not open to public vehicles, except the more than 100 landowners. These access roads may lead to more hunting in that specific area. Populations that have been hunted are shown to be more responsive to human disturbances than populations that are not hunted on (Rost & Bailey 1979), so this may add to the effect of the disturbance. One local landowner confirmed that hunters were indeed using the wind farm roads to improve access and gather their meat during the hunting season (Arnold Vigmostad, pers. com).

My results were very similar to Veiberg and Pedersen's (2010) «before and after» study of area use by red deer on Hitra in connection with the wind farm Hitra 1 (24 turbines). They also counted feacal pellet groups along transects in early summer and found possible avoidance towards the wind farm area during the construction period, and no apparent avoidance afterwards. This was further supported by hunting statistics for the area and interviews with locals (Veiberg & Pedersen 2010). Flydal et al. (2004) conducted an experimental study of reindeers' reactions towards the wind farm (3 turbines) on the island of Ytre Vikna. During their fieldwork, they made daily observations of flocks of roe deer and numerous moose grazing and occupying the wind farm and adjacent areas (Colman pers. com.). They also interviewed local hunters, landowners and walkers who provided confirmation that both roe deer and moose on the island were evidently uninfluenced by the wind farm.

The observed droppings went down in all species compared to before the park was built. I interpret this as a decline in the population in the park, or an avoidance towards the entire area where the turbines are built. The decline in the overall population density for all of Lista could also influence where the animals chose to be on a large scale, including avoiding the wind farm.

A potential source of error in the cervid study is that the 4 field registrations were done by different people, that have different experience, and thus, some of the differences could be attributed to this. Although pellet group count is a common method for studying area use by mammals (Campbell et al. 2004; Colman et al. 2016; Neff 1968), the method has some possible flaws (Neff 1968). The method does not discriminate between types, or importance of areas. The animals may spend more time and thus defecate more in an area with dense vegetation that the animals use for rumination, and less time in important foraging areas. Thus, the pattern of use will be misinterpreted. However, the overall, relative use by each species should not have been influenced by these flaws, as I compared before and after data.

Overall local ecological impact

Habitat fragmentation

Habitat fragmentation is considered a major threat for biodiversity, the decline in the cervid population could be attributed to fragmentation by the roads and infrastructure in the park. If the animals do avoid the roads, their habitat becomes smaller when roads are constructed and the population may decline. Habitat fragmentation may also affect vegetation negatively (Eldegard et al. 2015). Roads create sharp edges and corridors that may alter the natural vegetation spreading barriers, and fragmented landscapes are more vulnerable for invasion (Hansen & Clevenger 2005).

Loss of wilderness areas

A topic related to fragmentation is loss of wilderness areas. Wilderness areas are defined as an area that lies more than 1 km from any heavy technical intervention. Although Norway is considered to be a country with “a lot of wilderness”, the area that falls under the definition of “wilderness areas” is in strong decline. (Figure 13) and the Norwegian Environmental Agency states that “wind farms with associated infrastructure often comes in conflict with wilderness areas" (http://www.miljostatus.no/tema/naturmangfold/inngrepsfri-natur/, accessed December 12th 2016).

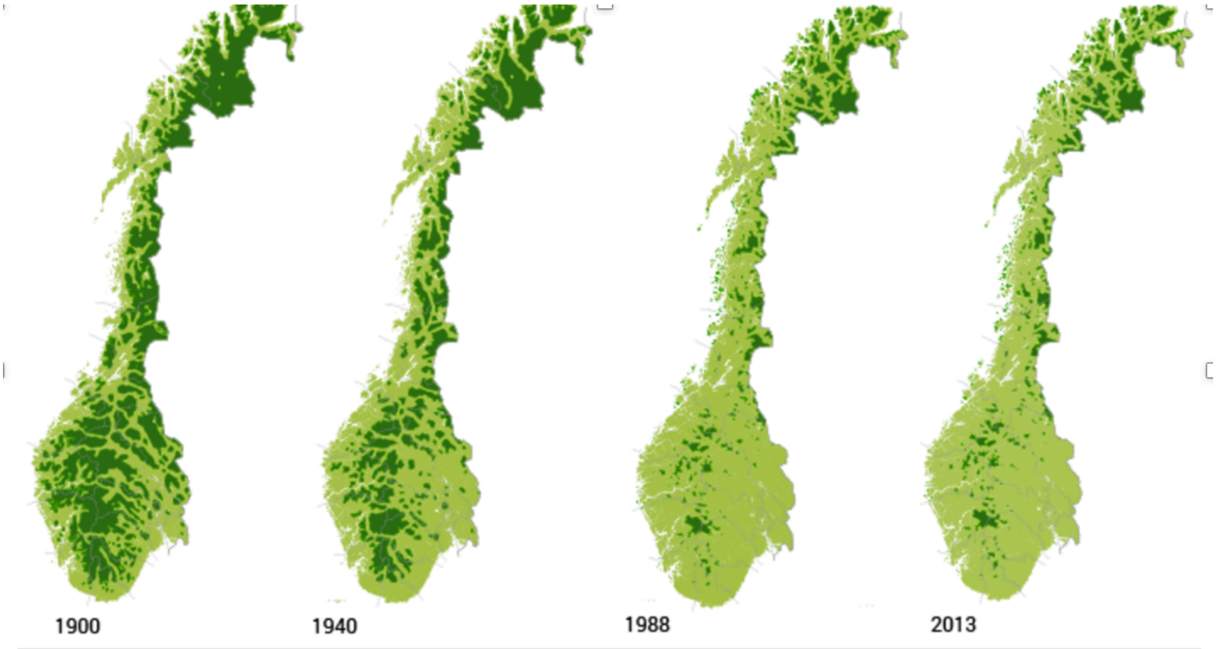

Figure 13. Wilderness areas that are 5 km or more from heavy technical installations. Source: Miljødirektoratet/miljøstatus http://www.miljostatus.no/tema/naturmangfold/inngrepsfri-natur/

Increased pedestrian use and hunted population effect may suggest that the disturbance effect would have been smaller if the access roads was closed off to public pedestrians and landowner vehicle use. Development of wind farms will disturbe the local ecosystem, but may also protect the area from potentially more disturbing development. Important vegetation and habitat types may be fragmented, but wind farm development may also provide opportunities for restoring over grown coastal heathland as mentioned above.

This study has combined datasets for 3 cervid species and vegetation from before, during and after the construction of a wind farm. Datasets for bird and fish population also exist from the wind farm (Flydal et al. 2010). Continuing and combining all datasets would provide an excellent opportunity for assessing the overall ecological impact of wind farms.

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