Forest succession on Nørholm heathland in relation to wildlife grazing

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Master Thesis no. 162
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Master thesis in Forest Management,
SLU course code EX0503, Advanced level (E) 30ECTS (HEC)

ACKNOWLEDGEMENTS

“When you want something, entire universe conspires in helping you to achieve it.”

© Paulo Coelho

The road on achieving the Masters degree wasn't easy for me. It was a road with lots of side turns, bumps and barriers both in studies and in personal life. But at the end, I think I managed to do it, I managed to achieve what I really wanted – a Masters degree in Forestry from a terrific international program – SUFONAMA (Erasmus Mundus), that I started in far away 2008☺

I want to express full gratitude to my wonderful Danish supervisor – Inger Kappel Schmidt for her constant support in this project, for her belief in me and my abilities, for her patience and funding. Without her I would not be able nor to start, nor to finish this project ☺

My special thanks to the wildlife expert Rita Buttenschøn for guiding us through Nørholm heathland area and helping me to start out the field work.

I also want to express my special thanks to my best friend and hardworking field assistant Andrea Goepfrich for her time and knowledge during the exhausting, but nevertheless exciting week of field work.

My big thanks to my SLU supervisor Jörg Brunet for his understanding and time, especially during the summer vacation.

Last, but not least, I want to mention an amazing person, who once pushed me forward in striving for excellence and searching for my own spot in this life, my former employer from PARC Canada, David Sauchyn. Thank you, Dave!

I devote this thesis to my wonderful parents – my father Sergej, who unfortunately will not be able to see me finishing this degree and share the happiness, but who is always in my heart for his love and guidance, and my mother Galina, for her constant support, caring attitude and positive energy.

ABSTRACT

The succession processes of a forest, their speed and direction depend on various disturbance factors among which are: storms, wildfires, wildlife grazing/browsing, and in case of heathlands – also human management. The study of this Master thesis, however, was carried out in an area, where human management had been restricted since 1913.

The site of Nørholm heathland has been studied since 1921, with 9 vegetation surveys and vast amounts of data available. With ever since increasing deer population in the area (up to 130 roe deer individuals in 2005), the necessity of a new study appeared where the accent would be put on the influence of deer population on the forest succession on heathland. The specific aim of this study was to analyze the relationship between the amount of deer and young tree saplings, especially in the height class up to 0.5m.

The amount of deer per square kilometer was calculated using several techniques discovered during literature review. Dependences between presence of deer tracks and deer pellets on plots, deer presence and main tree species in height classes 0.5m, 1m and 2m were analyzed, but no statistical significance was discovered. The reasons for that will be discussed in this master thesis with suggestions for further steps and research.

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CHAPTER 1: INTRODUCTION

Nørholm Heathland is a NATURA2000 site, where forest succession has been studied since 1921, with data from 9 vegetation surveys now available. Heathland has been and still remains unmanaged from 1895, which makes this site an extraordinary study area for tree colonization and forest succession research (Figure 1.1).

High biodiversity of this ecosystem, Mountain Pine forest and agricultural fields situated around create specific conditions, which can significantly influence habitat selection of animal species living there. These characteristics of habitat confirm heterogeneity of the food available for herbivore species such as Roe and Red deer, and a high density of these animals might be expected.

Both deer species migrated to heathland back in the 1900s and their numbers were increasing ever since (from 1 roe deer in 1900 to 130 in 2005) (Schmidt & Riis-Nielsen 2010)

Browsing damage from these animals may be significant and influence the distribution of species (predominantly deciduous) in height classes, especially in $H<0.5m$, and slow down the forthcoming tree colonization.

It therefore was the objective of my Master thesis research to identify the number of deer present on the estate through dung estimation technique and find out whether there are any correlations between deer abundance and forest succession.

1.1 Forest succession on heathland

The percentage of lowland heathlands in Europe has declined significantly for the last century, increasing their conservation value and public concern.

In Denmark heathland area has declined by 60-70% by the 1960s, which corresponds to 120 000 ha (Newton *et al*. 2009, DMU terrestrial overvågning 2010). The remaining heathlands are fragmented and about 80 % are small heathlands under 5 ha, with a total of 80 000 ha (1.9% of Danish territory). (Schmidt & Riis-Nielsen 2010)

There are several reasons behind such major decrease of heathland area. But the key factor here is that heathland is mostly a semi-natural environment which survival depends on human activities. Heathlands in the Western part of Denmark are located on acid sandy soils. The traditional heathland farming with a constant removal of nutrients resulted in over-exploitation of the soil and formation of heather vegetation. When heathland farming ceased, the areas were used for more modern farming with addition of commercial fertilizer or used for plantation of mostly Norway spruce. The end of the human nutrient removal, together with increased N-deposition from the air allows heathlands to set off a succession, which over time, depending on the site fertility, develops into grassland-shrubland and later to forest. As mentioned in the report by Schmidt & Riis-Nielsen

Figure 1.1 Nørholm Heathland with visible tree colonization in the background. (Photo Krestyanska, M. 2010)

(2010)-*“Heathlands have become more susceptible to threats from the surrounding environment such as tree colonization and eutrophication due to the fragmentation”*.

Tree colonization (forest succession) on heathland develops in several stages (heathland →shrub land →forest, or heathland → grassland → forest) and depends on several factors, among which are: potential seed sources of woody species, seed dispersal, open patches, nutrient and water availability (Schmidt & Riis-Nielsen 2010), and presence of grazing animals. Seed production, seed dispersal into gaps in vegetation, favorable climate and precipitation conditions are determining successful establishment of the woody species (DeSteven 1991).

Pioneer woody species such as oak (*Quercus robur*), birch (*Betula spp.*), rowan (Sorbus spp) and pine *(Pinus sylvestris* & *Pinus mugo*) establish themselves easily on heathlands. As soon as those establish on heathland, more favorable conditions are being created for the establishment of other secondary species. (Schmidt & Riis-Nielsen 2010)

The general distance to mother seed trees has also diminished during the last century due to the general decrease in the size of heathlands and also conversion of heathlands into forests or plantations.

It has also been mentioned in the scientific literature that tree roots may break through the iron pan layer, which is common on heathland soils, and as a result increase nutrient availability and decomposition (LePage et al. 2000).

1.2 Increasing deer population

It is a common fact that natural threats to deer such as wolf, lynx etc. are no longer available in many parts of Europe, including Denmark. And even though human impact on the environment of these mammals is significant, the deer populations are still increasing.

Roe deer (*Capreolus capreolus*) are among those mammals that are very adaptable to man-made environments and occur at high density both on agricultural and commercial forestry lands (Pielowski 1984, Ratcliffe & Rowe 1985). Several Scandinavian studies have shown that deer are able to tolerate orienteering events, hunting and recreational activities. The results of these studies have also shown, that in all cases the animals returned to their home range shortly after the disturbance (Jeppesen 1987, Herbold 1990, Cederlund & Kjellander 1991), and with sufficient amounts of food resources available, were able to breed and increase the population numbers on several sites.

Land fragmentation, especially of woodland, into many small isolated patches in the modern agricultural landscape poses problems for woodland animals (Wiens 1990, Zhang & Usher 1991). But nevertheless, population isolation is not a problem for large, mobile mammals like roe or red deer, which cross open fields. And indeed, in many cases fields become essential feeding grounds (Zejada & Homolka 1980) that support high deer densities (Linnell & Andersen 1995).

Browsing pressure at any site will depend on deer species and numbers, the local abundance of seedlings, their palatability, and the availability of alternative food sources. Accordingly the density, below which deer populations need to be maintained to allow successful free regeneration, will vary substantially between sites. A number of studies indicates that deer population densities of <4–7 km^2 allow successful regeneration of birch and Scots pine. Regeneration can occasionally be achieved at densities of 15–25 km^2. But with the absence of control, deer populations can easily increase to between 30 and 100/ km^2 and effective deer control is essential for successful regeneration of sensitive species (Harmer & Gill 2000).

The changes in woodland vegetative structure and species composition could be beneficial to the types of woodlands depending on management objectives. Browsing can maintain or enhance the conservation interest of habitats (Putman & Moore 1998). For other wildlife, however, shrubby woodlands tend to provide habitat for more species for a greater part of the year than woodlands that have a thin under storey. Woodlands with greater hiding cover are also preferred by the deer themselves (Mysterud & Østbye 1999). Putman (1998) also states that, "browsing of small farm woodlands by roe deer could be negatively impacting the conservation value and aspects of woodland's commercial value by reducing the amount of shrubby cover."

1.3 Problem formulation and hypothesis

Nørholm Hede is a 350 ha lowland heathland that belongs to the NATURA 2000 network. It has been chosen as the research area due to the vast amounts of data available, and also due to the increasing conservation concern about heathlands, which requires a very diverse research about them. But in spite of much research attention, very little is known about the impact of grazing on lowland heath vegetation (Newton *et al*. 2009). Therefore focus of the research is in the area of wildlife grazing and its influence on forest succession on Nørholm Hede that has been unmanaged since 1895. Forest succession has been studied by counting of trees to species and their height distribution. The data has shown changes in tree height structure, probably due to the increasing deer population.

The basic hypothesis is that wildlife grazing, specifically by Roe deer (*Capreolus capreolus*) and Red deer (*Cervus elaphus*), significantly slows down the succession of forest on Nørholm heathland. Another assumption was that coniferous species and shrubs with spikes are able to protect deciduous trees from herbivores. (Schmidt & Riis-Nielsen 2010). It therefore has been decided to carry out applied research with fieldwork involved. Apart from data collected in the field (survey-count of animal drops), *Forest and Landscape* has kindly provided me with data on forest succession (age classes of trees in different height classes) for 88 years (10 surveys were done since 1921, with the latest carried out in 2009).

The main objective of my Master thesis research was to identify animal-grazing pressure and how it influences presence of trees and their distribution on heathland. This was supplied with data-analysis of distribution of trees on the heath in height classes over time in relation to the rough estimate of deer population in the same period.

CHAPTER 2: MATERIALS AND METHODS

2.1 Case study area – Nørholm Heathland

2.1.1 General information and historical background

Nørholm heathland (in danish "*hede*") is situated 10km northeast from the Varde city southwestern Jutland, Denmark) (Figure 2.1). The heath covers an area of over 350 ha and was abandoned and left without management since 1895 (Schmidt & Riis-Nielsen 2010). It was legally protected in 1913 and studied for free succession since 1921.

Figure 2.1 Map of the study areas in southwestern Denmark, a) overview of study area location defined by red rectangle (adapted from google earth), b) Study area aerial view (adapted from google earth).

In 1913 when heathland became protected, it was demanded that the area had to remain as heathland, but it had to stay untouched without any form of management. Today the area is seen as a mosaic of heathland, grassland and different successional stages of forest and shrub land.

As mentioned above, since 1921 till 2009 the area has been monitored by Statens Forstlige Forsøgsvæsen (later Forest and Landscape), creating vast amounts of data from 10 surveys that included count of all trees and their distribution in height classes. At the very beginning of research, the heathland was subdivided into 33 quadrates of 400 x 400 meters that covered all the 350 hectares (Figure 2.2 & 2.3). In those squares the immigration of every single tree has been registered until 1974. But since the amount of trees was too high for a total count due to the doubling every 10 years, the further analysis was done based on representative subplots. The ground vegetation was also monitored in 20 permanent vegetation plots of 10 x 10 m and vegetation was registered at the same interval as for the trees (Riis-Nielsen *et al.* 2005). In 2009-2010, about 100 new plots were added to the 20 permanent plots and used for both measurements of trees and ground vegetation. Nowadays the Nørholm Hede is one of the Natura 2000 sites under protection of the Habitat Directive of European Union. That means the owner of the area has to ensure the cultural heritage and the protection of species that are connected to this nature type.

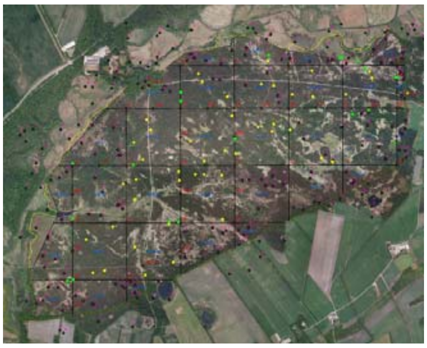


Figure 2.2. Aerial photograph of Nørholm heathland with marked permanent sample plots. (Photo Google maps, 2010).

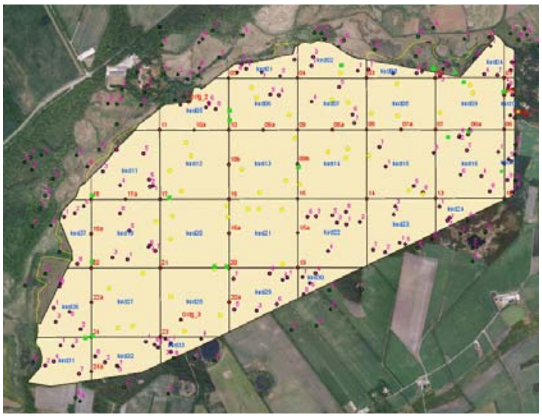


Figure 2.3. Aerial photograph with marked permanent plots. (Photo Forest and Landscape, 2010).

2.1.2 Climate

The research area is relatively close to the west coast of Denmark, which may explain relatively high precipitation. The average annual precipitation measured from 1873-1996 is 778 mm but the annual average precipitation measured from 1961-1990 is about 10 % higher.

The average temperature measured from 1873-1996 is 7.6 C, where the annual summer temperature is 14.9 C and the winter temperature is 1.1 C. Even though the precipitation has increased from 1961-1990, the temperature has remained the same (Riis-Nielsen *et al.* 2005).

2.1.3 Vegetation

Ground vegetation is comprised of heather (*Calluna vulgaris* and *Erica tetralix*), dense grasses (such as D*eschampsia flexuosa* and *Molinia caerulea*) and also dense Black crowberry vegetation (*Empetrum nigrum*). Among tree species present on heathland, the most dominant are Mountain Pine (*Pinus mugo*) and Birch (*Betula* spp.)

2.1.4 Soil types and hydrology

The soil on Nørholm heathland is sandy podzol. There are few spots with drifting sand in the Western part of the area. In the middle, the terrain is slightly hilly. The Eastern part of the heath includes low areas. On the Northern part there are areas with periodical wet meadows.

2.2 Methodology

2.2.1 Wildlife grazing/browsing (Roe deer)

"Browsing is a natural ecological process that can maintain or enhance the conservation interest of habitats." (Putman & Moore 1998).

Figure 2.4 Male roe deer. (Photo British Deer Society, 2010).

Roe Deer (*Capreolus capreolus*) is a highly secretive animal, visual counting of which is normally too inaccurate to be useful. However, some basic estimates of density state that suitable woodland can hold 0.51-0.72 animals per hectare (The Deer Initiative 2010). Size of an adult animal is from 10 up to 25 kg, with width of 60 to 75 cm at shoulder (with bucks usually larger than females, Figure 2.4) (The British Deer Society 2010). Colouration varies from summer to winter season – summer, reddish brown; winter grey, pale brown, might be even black. Maximum lifespan is up to 16 years, but bucks rarely exceed 5 years. High mortality is recorded at/and shortly after birth and within 1st winter, even though roe deers main predators (such a lynx, for example) no longer exist. Roe deer can produce up to 3 offspring, but usually the number does not exceed 1-2, with time of birth May-June (The British Deer Society 2010).

The most common habitat is woodland and forest, but may occupy fields as well, when the density of animals is too high or if other habitat is not available. Activity period for roe's is throughout 24-hours but open spaces are used more often during the hours of darkness, if populations are experiencing any kind of disturbances. Peak times of activity come at sunset and sunrise. A lot of time is spent "lying up", which is when the deer lies down to ruminate between feeding periods.

Roe’s are selective browsers, and usually prefer such food types as herbs, brambles, ivy, heather, bilberry and coniferous tree shoots, with most damage to seedlings occurring during spring and early summer, when shoots are young and most palatable (Harmer & Gill 2000). There are major differences in diet between deer species that could influence their impact on vegetation. Red deer are partially grazers, containing 30–70% of grasses in their diet, whereas roe deer typically eat shrubs, trees and forbs, with less than 20% of grasses in the diet. These preferences may, however, vary significantly depending on the location and food resources available. Both species of deer, roe and red, focus most feeding on vegetation from 30 to 60 cm in height, with roe deer usually remaining closer to woodland edges, while red move further out when grazing in fields.

Since roe deer are browsing tree shoots and agricultural crops, it puts these animals in conflict with farmers and foresters due to economic damage. Though, many land owners and forest managers can achieve significant income from recreational hunting and/or meat production. Whether in conflict or used as a resource, roe deer populations require careful management to maintain health and quality and to ensure a sustainable balance with their environment.

2.2.2 Deer estimation method

The purpose of my fieldwork was to identify the amount of animals on the research area. The animals to consider were Red deer and Roe deer (if applicable), description of which is provided in the above section of this paper. But before the fieldwork, the choice of the most suitable method for carrying it out had to be made.

Deer pellets estimation is an “indirect” method for estimating amount of deer on the territory that avoids the difficulty of having to see deer to count them directly (The Deer Initiative, 2008).

There are two major factors to be taken into account, when doing this kind of research:

1. Pellets persist for some time, but the rate at which it decays (decay rate) is highly variable;
2. The rate at which deer produces dung (defecation rate) is quite constant, but can vary.

There are two main techniques for pellets’ counting, and both consider the decay and defecation rates. The difference between the main two methods (Faecal Standing Crop and Faecal Accumulation Rate) is that the first one does not require pellet clearance of the sample plots and can be done within one visit, while the second one require to revisit the territory. (Acevedo *et al* 2010). It was decided to carry on with the FSC, due to the very limited amount of time for fieldwork.

Figure 2.5 Two fresh deer pellets with one old, but still visible pellet. (Photo Krestyanska, M. 2010).

Faecal Standing Crop (FSC) is an indirect method for estimation of numbers of deer on the territory with only a single visit to the research area required (The Deer Initiative 2008). The basic principle is that plots are being marked and the pellet groups counted on each of them. By doing so, it is possible to identify the relative number of deer on the territory. Pellet group areto be identified as an accumulation of four or more faecal pellets within 2 cm from each other (Bailey & Putman 1981). Approximate number of deer on the territory had to be obtained from the owner of the land/hunters for comparison analysis.

In order to avoid errors in estimation, it was decided to divide pellet groups according to their decomposition rate. Firstly, three groups (fresh, older, but still intact and old but still visible) are to be considered in the calculations. A pellet group was defined to be fresh if it was still damp on the surface (See Figure 2.5). Further, the decay rate is believed to be influenced by length of the bare-ground season (snow-free period), precipitation and also by the ground substrate (Wallmo et al. 1962; Harestad & Bunnell 1987; Persson 2003).

Figure 2.6. Fresh and very visible deer tracks on the wet ground in Nørholm Heathland. (Photo Krestyanska, M. 2010).

Deer species had to be identified according to the shape of pellets, whether possible (see *Appendix 1*. Deer pellets identification).

On each sample plot browsing damage has to be carefully studied, and noted according to the categories listed in the “Field work sheet” (See

Appendix 2. Field work sheet). Deer tracks had to be noted as well, but they are usually considered to be unreliable in terms of deer abundance calculations, still they do show deer activity (Mayle et al. 2000) (see Figure 2.6).

Calculation of deer density is estimated as:

$$D = \frac{m}{(t * r)},$$

where D is the deer density (deer/km^2), m is the mean number of pellet groups observed per plot, t is the dung persistence period/mean time to decay, r is the defecation rate (Smart 2004; Tsaparis 2009).

Or

$$D = \frac{m * sitearea}{r * plotsize} \bigg/ t,$$

where D is the deer density (deer/km^2), m-mean number of pellet groups per plot, r-defecation rate, t-time to decay (Bailey & Putman 1981).

Figure 2.7 Pellet group of more than 25 pellets belonging to one adult deer (Photo Krestyanska, M. 2010).

Defecation rates for certain species are necessary to know in order to carry out the calculation. They are estimated as red (25 pellet groups per day) and roe (20 pellet groups per day) (Figure 2.7) (The Deer Initiative 2008; Mitchell et al. 1985).

On the basis of literature review, decay level is accepted to be from 4 up to 6 months (130-180 d).

When the calculations for each plot will be done, and a number of deer per km^2 shall be obtained, the comparison analysis between amount of animals and distribution of trees in height classes is to be carried out. It will be discussed in the further chapter of this paper.

2.3 Field work

Field work on Nørholm Hede was carried out within 2 consecutive weeks starting from 30th of March until 10th of April, 2010. The first two days I was accompanied by my supervisors Inger Kappel Schmidt and Rita Butteschøn to make sure that the selected technique for counting animal droppings would work on site, and also to make sure that I would be able to find GPS positions of sample plots from previous years´ research. Further on, I received enormous amount of help from my friend and field assistant Andrea Goepfrich in the second week of fieldwork.

Accommodation, transportation and equipment was provided by Forest and Landscape and included: GPS, measuring tape, metal detector, maps, centre pin with 4 radial lines, metal stick to position in the centre of the pin, 5 visible sticks and water proof field sheets to collect field data. Field data sheets were composed by me before the fieldwork and checked by Inger Kappel Schmidt for their relevance to the research.

Since Nørholm Hede is located in a remote area, it was necessary to study aerial photographs of the area before hand. Photographs were provided both by Forest and Landscape and obtained via Internet.

As mentioned in the Methodology part, dung counting techniques vary greatly. But since the vegetation surveys in preceding years were done in 5 and 10m circular plots (in diameter), I continued within the same range of size and form of plots. That was done in order to enable direct comparison of the tree growth (height classes) to the amount of deer present on the site (grazing pressure).

Apart from GPS, we used a metal detector to find the precise position of sample plots from summer 2009, which were marked by a metal stick in the ground. But unfortunately, we were able to localize only a very small amount of those metal sticks due to dense ground vegetation.

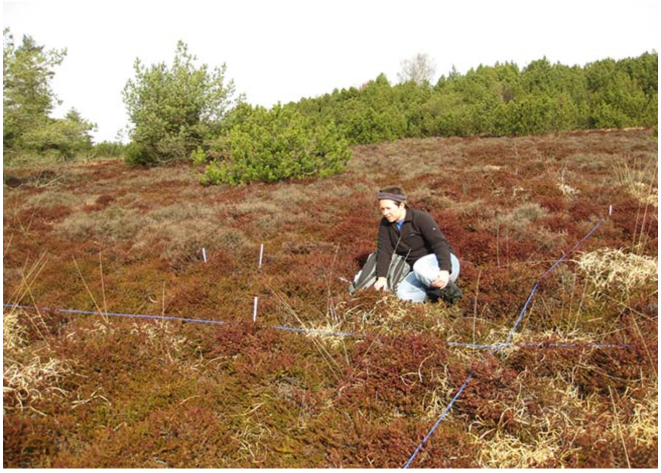


Figure 2.8 Sample plot where deer pellets are marked with white sticks.

When counting dung on each single plot, it was extremely hard to identify, in most of the cases, where pellets belong to adult male roe deer or red deer. Only 3 observations of red deer were thought to be recognized, but those were still put in the category with roe deer, to eliminate the potential errors.

50 plots in total were studied and analysed during the 2 weeks of fieldwork. Some of them were eliminated during the data analyses stage due to the absence of vegetation survey from 2009 to which the major comparison had to be done.

Counting of dung was carried out from the early morning until evening, when sunlight was still available. Weather conditions varied during the 2 weeks of the field work.

During the 1st week heavy rain events occurred, but the 2nd week pleased with sun, and temperatures above +13C.

2.4 Data analysis

After two weeks of field work all the collected data was sorted out and entered into Microsoft Excel spread-sheets. All the calculations were carried out using this program. All the diagrams were built afterwards to see possible trends and dependencies. The statistical analysis was run in the program SPSS v16.0 to find out if any of the results were statistically significant and see the possible correlations.

The following relationships were explored:

i: Deer tracks presence and total pellets per plot

ii:Main species in height class H>0.5m and deer/plot/km^2

iii:Main species in 3 height classes 0.5, 1, 2m and deer/plot/km^2

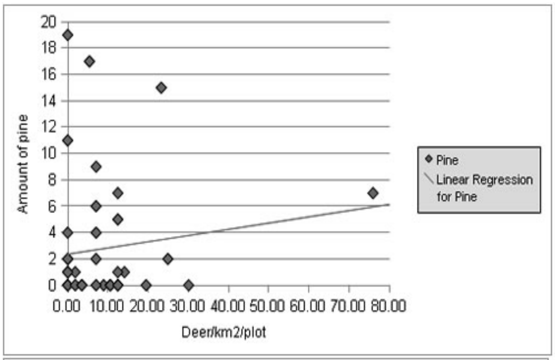
The tests were carried out using a one-way Analysis of variance procedure (ANOVA), with p-values varying from 0.032 to 0.981. Further details will be discussed in the Results and Discussion sections.

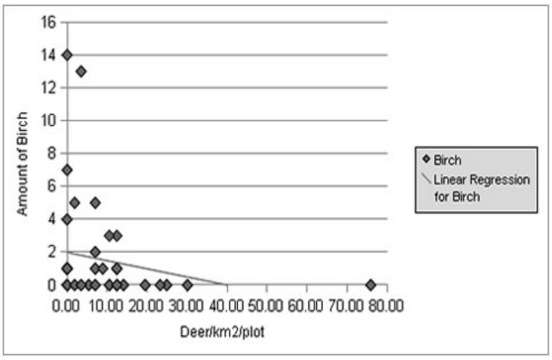
CHAPTER 3: RESULTS

I have tried to combine several options while calculating deer abundance on Nørholm Hede (with dung persistence period from 130 to 160 days), and after several rounds of different calculations I came with numbers varying from 25-30 deer per km^2, with the mean average of 8.35 deer per/km^2 per plot.

3.1 Deer presence vs. main tree species in height class H<0.5m

While analysing field data and calculations in Excel, I was able to notice a trend - a dependence between deer pellets (deer presence) on the plots and the amount of main species distribution (birch, mountain pine and oak) in height class H<0.5m. In most of the cases, where high amount of pellets was recorded, very little or no trees in height class H<0.5m were found. And the opposite - where no pellets were found, diagram curves would show a high number of main species in H<0.5m height class. But only Pine in the height class >0.5m showed statistical significance ($p=0.032$) in one-way ANOVA. For the rest of the trees (birch and oak) p-values were statistically insignificant (0.708 and 0.972 respectively). See below Figure 3.1 - Main Species in Height class H<0.5 in relation to the presence of deer per plot.





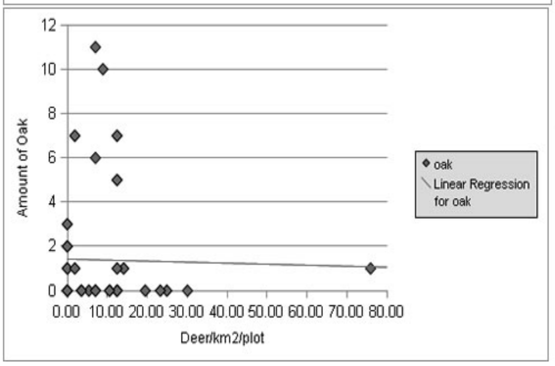


Figure 3.1 Main tree species in Height class H<0.5 in relation to the presence of deer per plot

At the beginning of the field work, based on some previous research and the data available, it was assumed that among main tree species Pine, Birch and Oak, deer will give their food preferences to young Oak saplings, which would also explain the reason of disappearance/nearly absence of young oak trees in height class >0.5m or 1-2m. But it does not seem to be the case, since we can notice on the diagram that there are still oak trees present on the plots where the amounts of deer are peaking (plots from 17.3 to 22.3 on the diagram), while when looking at birch – it is not present at all on the same plots. And at last, amounts of deer on the same plots with peak of deer activity does not seem to influence, to the same extent, the amounts of young pine trees.

3.2 Deer tracks presence vs. presence of pellets on the plot

Another trend was found between deer tracks on each plot vs. presence of pellets on the plots – in several cases where no tracks were observed, no pellets were found, but the evidence of damage to *Calluna vulgaris* due to deer browsing was noted. (See Figure 3.2)

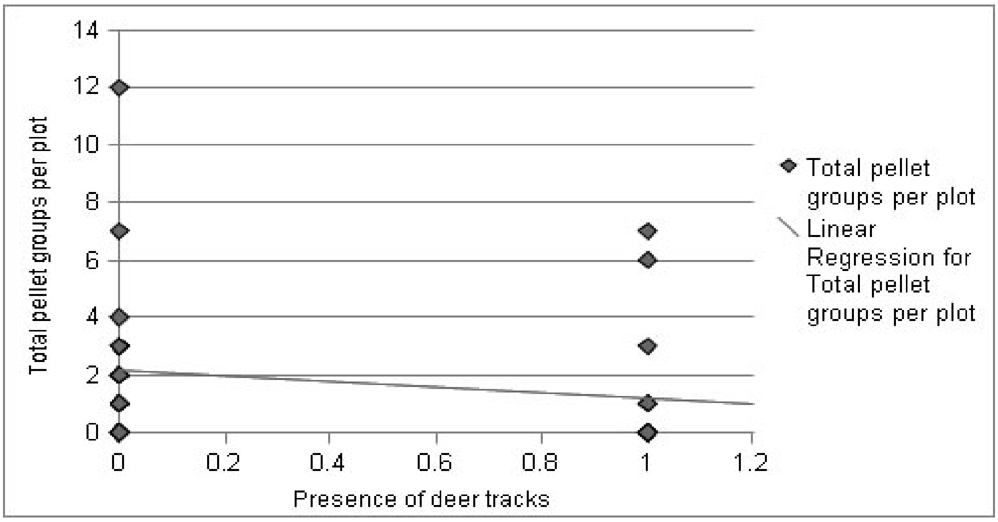
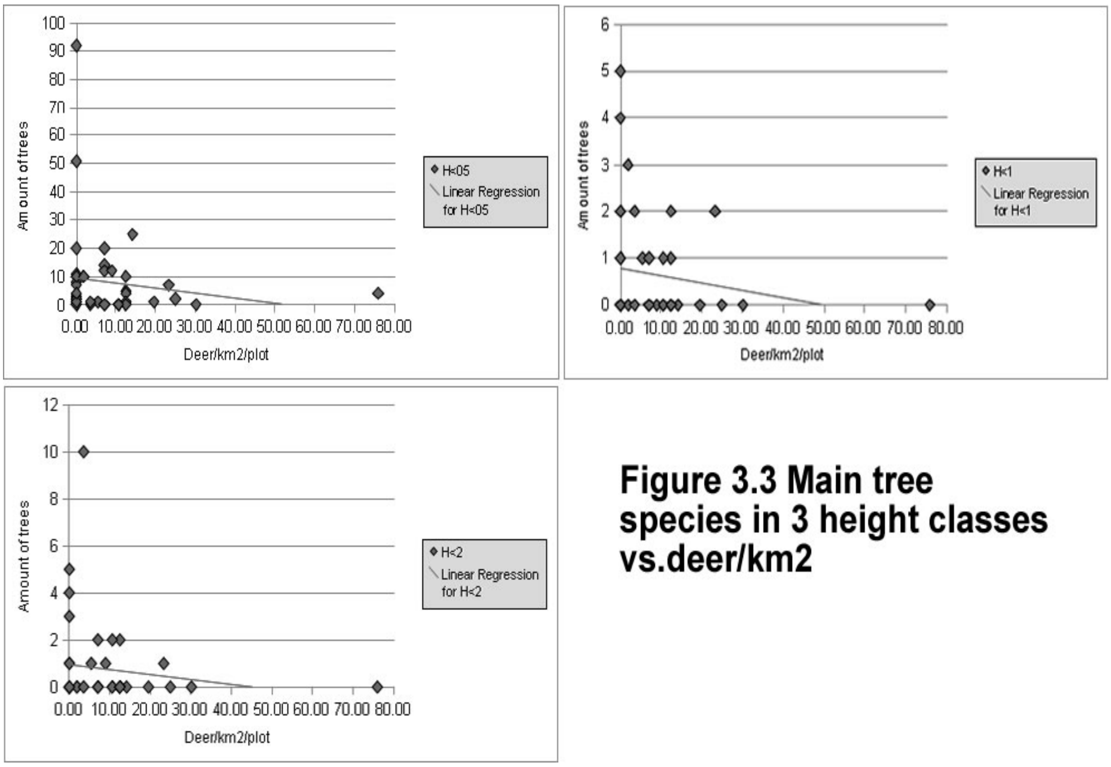


Figure 3.2. Deer tracks presence and total pellet groups/plot

3.3 Main tree species in 3 height classes vs. deer/km2

As we can see on Figure 3.3, there is a very distinct evidence of absence/very little amount of trees in all three height classes (>0.5, 1, 2 m) where the amount of deer/plot/km^2 is predominating. It was also assumed at the beginning of this Master thesis work that the amounts of deer will most probably affect trees in >0.5 m class, which is not necessarily the case when looking at the diagram below. It seems that even with an amount of deer such as 10-15 deer/km^2, the amount of trees in >0.5m class remains very high, reaching its peak in one of the plots up to almost 90 individual young saplings.

Figure 3.3 Main tree species vs. deer/km^2



CHAPTER 4: DISCUSSION

4.1 Why so less deer visible?

As mentioned in the paper *"Tree colonization on unmanaged heathland-succession during the first 100 years"* by Schmidt & Riis-Nielsen (2010), there were about 130 roe deer, and 35 red deer, on heathland in the year 2005. During the two weeks of fieldwork only 1 single roe deer was observed on the area. The major reason for "not seeing" the deer, may be the big river restoration project that was carried out on the heathland during my field work, and involved heavy machinery present on the territory all the time, producing very loud noise from early morning until late evening. And even though, I mentioned in one of the first chapters that deer, especially roe, are able to adapt to human-made environment, the disturbance like big trucks was enormous when compared to the amounts of roads and size of whole heathland. I therefore assume that deer was trying to hide in remote locations with much more trees, as shelter, available.

4.2 Rain – a disturbance factor to my research?

Due to the fact that there were several heavy rain events during the first week of field work, I assume that those might have influenced my perception of some of the pellets in terms of "fresh" look and also might speeded up the decomposition of dung. But unless further analysis on water content/decomposition rate was carried out, it otherwise would simply be impossible to differentiate between the fresh pellets or wet pellets after rain event (see *Chapter 2.2.1* for definition of fresh pellets).

4.3 Not random plots – a right choice?

As mentioned in one of the chapters above, I've collected data from 50 plots on Nørholm Hede, with only 44 of which were selected for further study and analysis. Those plots were not random, but pre-selected based on the vegetation survey from previous years. And plots with no vegetation survey data available were therefore eliminated from my research.

Not randomly selected plots are bound to certain locations, which, in some cases, may not be suitable or preferred by deer populations. Among such plot locations are roadsides, cross-sections, locations on very wet grounds which are hardly accessible.

4.4 Where did the statistical significance go?

It was an unfortunate discovery at the end of the work to find out that there is no statistical significance in the results of this work. It is assumed that there was not enough plots evaluated to give the results the statistical power. And as mentioned above, the non-random plot choice might have influenced it as well. When evaluating results and the p-value for the 3 main tree species in 3 height classes versus the amount of deer/km^2, the p-value seems to be decreasing from the value of 0.981 to the value of 0.480 (from H>0.5, 1 and 2m height classes accordingly). But it cannot presume that the statistical significance will appear when evaluating similar results for trees in higher height classes.

CHAPTER 5: CONCLUSION

The main objective of this Master thesis was to find out whether the wildlife grazing is influencing the forest succession on the Norholm heathland and to what extent. The research results provided certain evidence that the low amount of trees in 3 height classes (0.5, 1, 2m) on several plots is connected with the prevailing amount of Roe deer on the territory (Figure 3.3.).

Several other trends-relationships were studied in order to see which main tree species were affected most on which plots by deer browsing compared to the amount of deer on those plots (Figure 3.1).

One specific assumption that was made at the beginning of this research, was that deer prefers young oak saplings rather than any other sapling of the main tree species (pine, birch, oak). However, the results show that oak and pine in height class H>0.5m are less influenced than birch (Figure 3.1). It is therefore advised to carry out research on deer diet preferences on the territory in order to check whether deer prefers certain species of trees more than the others and to what extent.

With the increasing deer population, limitations due to the NATURA2000 network and management regulations, the researchers will face more challenges on the site in the future. This research provides certain evidence that could enhance future studies about forest succession processes and wildlife and thus help manage and preserve the unique heathland sites all over Europe.

With the several limitations to the study, such as shortage of time available for the field research, limited human resources etc., it is therefore strongly advised to continue the multidisciplinary research on the site, increasing the amount of plots, their random choice and studies of deer diet preferences on heathland through stomach analysis of the animals killed during hunting, as well as year-to-year surveys of the amounts of animal-grazers should be obtained.

Since these types of studies are fairly new on the Norholm heathland, new methods of calculating amount of deer on the territory should be studied and evaluated in their relevance to the Norholm heathland case, in order to develop the right approach and produce comparable and statistically significant results.

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APPENDICES

Appendix 1. Deer pellets identification

Droppings provide a useful indication that deer are present, and may even help identify the species. Size is a crucial clue, whilst other characteristics help build a more complete picture. Unfortunately, though, not all droppings exhibit the standard characteristics popularly associated with each species. Diet, condition and size of the animal all have an influence, but used in combination with other field signs, knowledge of dropping characteristics can be a useful tool in evaluating and identifying animals on the site.

Droppings	Roe Deer	Red deer
Size	Small droppings: 1-1.4 centimetres x 0.7-1 centimetres 	Large (the largest among all deer species) droppings: 2-2.5 centimetres x 1.3–1.8cm 
Colour	Shiny, nearly black and glossy when fresh	Black and shiny, gradually becoming duller and more dark brown
Shape	Cylindrical pellets often pointed at one end, the other end rounded	Cylindrical/acorn-shaped, often pointed at one end, rounded or slightly concave at the other

Appendix 2. Field work sheet

Sample plot #			Coordinates			Date										
Observation	Pellet groups #			Pellet groups decomposition rate/Deer Species(Red, Roe)					Browsing damage/plant species				Deer tracks		Pellets of other animals
	Less than 4 per group	5 to 10	More than 10	Fresh	Older,but still intact	Old, but still visible	Nearly decomposed	Damaged	No browsing-0	Little browsing-1	Medium browsing-2	High browsing-3	Present	Not present	

code	No pellets	< 4	5 to 10	>10	TPG/plot	Mean pellets/plot	fresh	old intact	old visible	nearly dec.	No brows	Little	Medium	High	Deer trac	Not pres.	Deer per km2
P1-P1	0	1	1	1	3	26,5	0	1	1	1	1	0	0	0	1	0	21,2
P2-P2	0	1	1	1	3	26,5	0	1	1	0	0	1	0	0	1	0	21,2
P13-P13	0	1	1	1	3	26,5	0	0	1	0	1	0	0	0	1	0	21,2
P14-P14	0	1	1	2	4	41,5	0	1	1	0	1	0	0	0	1	0	28,2
P15-P15	0	1	1	1	3	26,5	0	1	1	0	1	0	0	0	1	0	21,2
P16-P16	0	0	1	1	2	22,5	0	0	1	0	1	0	0	0	1	0	14,1
P17-P17	0	0	1	0	1	7,5	0	0	1	0	1	0	0	0	1	0	7,1
P19-P19	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
P20-P20	0	1	1	1	3	26,5		1	1	0	0	1	0	0	1	0	21,2
8-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
8-2	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0,0
8-3	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
9-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0,0
9-2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
9-3	0	0	0	1	1	15	0	0	1	0	1	0	0	0	1	0	7,1
10-1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0,0
10-2	0	0	0	1	1	15	1	0	0	0	1	0	0	0	1	0	7,1
10-3	0	0	2	1	3	30	0	1	1	1	1	0	0	0	1	0	0,0
14-3	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0,0
15-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
15-2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
15-3	0	2	4	1	7	53	0	0	1	0	1	0	0	0	0	1	0,0
15-4	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
16-1	0	1	1	0	2	11,5	1	1	0	2	0	0	1	0	1	0	0,0
16-2	0	0	0	1	1	15	0	1	0	0	1	0	0	0	1	0	0,0
16-3	0	0	0	1	1	15	0	1	0	0	1	0	0	0	1	0	0,0
16-4	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0,0
17-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
17-2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0,0
17-3	0	1	0	1	2	19	1	0	1	0	0	1	0	0	1	0	0,0
20-2	0	3	3	1	7	49,5	1	1	1	0	0	1	0	0	1	0	0,0
20-3	0	1	1	1	3	26,5	0	1	1	0	1	0	0	0	0	1	0,0
20-4	0	1	1	10	12	161,5	0	8	10	0	0	1	0	0	1	0	84,7
21-1	0	0	1	1	2	22,5	2	1	1	1	0	0	0	1	1	0	14,1
21-2	0	0	0	1	1	15	0	1	0	0	1	0	0	0	0	1	7,1
21-3	0	1	2	3	6	64	0	3	3	0	1	0	0	0	0	1	42,3
21-4	0	0	1	1	2	22,5	3	3	3	0	0	0	0	1	1	0	14,1
22-3	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0,0
23-1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0,0
23-2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0,0
24-1	0	1	0	0	1	4	0	0	1	0	1	0	0	0	1	0	7,1
24-2	0	1	1	1	3	26,5	0	1	1	0	0	1	0	0	1	0	21,2
24-3	0	1	0	0	1	4	0	1	0	0	1	0	0	0	0	1	7,1
24-4	0	0	1	0	1	7,5	0	1	0	0	1	0	0	0	0	1	7,1
	17	**19**	**26**	**34**	**79**	**781**	**9**	**30**	**34**	**5**	**34**	**6**	**2**	**2**	**28**	**16**	**8,5**

Appendix 3. Field work sheet with data