Effects of supplementary feeding on bark stripping by red deer (*Cervus elaphus*)

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Abstract

Red deer (*Cervus elaphus*) are capable of causing severe damage to Norway spruce (*Picea abies*) through bark-stripping, leading to severe economic losses. It is suggested that an imbalance in the nutrient intake can lead to an increased urge to consume bark. Supplementary feeding is a very common practice. It is yet unclear how supplementary feeding effects the level of bark stripping, some studies have shown that feeding with unsuitable forage might lead to an increased urge to consume bark. However, it is also shown by other studies that feeding with suitable forage in sufficient amounts could replace bark in the diet and therefore decrease the level of bark stripping. The aim of this study is to investigate how the damage level in 68 spruce stands is affected by the distance to and the number of feeding stations, the type of supplementary feed will also be taken into count. The damage level could not be significantly related to the distance to feeding stations or the number of feeding stations. The damage level was significantly related to the number of cereal feeding stations. Our results implies that more data from spruce stands far away from feeding stations are needed to give more robust results and that maybe factors as landscape structure and alternative forage overshadows the effect of supplementary feeding. The results regarding forage type should not be used to draw any conclusions since there was no corrections made for the spatial auto-correlation between each feeding stations, a correction for this maybe would have changed the results by lowering the significance level.

Introduction

Ungulate herbivory plays an important role in forest ecology. By creating open areas, ungulates contribute to maintaining heterogeneity in the forest landscape, something that is required to support diversity of flora and fauna (Apollonio et al. 2017). However, ungulate populations have big impacts on agriculture and forestry, leading to challenges for wildlife management systems (Apollonio et al. 2017).

Red deer (*Cervus elaphus*) can cause severe damage to both forests and agriculture. Bark stripping is the main problem in forests, while foraging and trampling are the main problems in agriculture (Gill 1992, and Jordbruksverket/SCB. 2015). Bark stripping can cause severe economic losses through reduced growth and fungal infestation, leading to storm breakage, stem deformation and wood decay (Gill 1992, Verheyden et al. 2006). Red deer eat bark mainly during winter, but also during spring and summer (Gill 1992a, Ligot et al. 2013 and Jarnemo & Månsson 2011). They are known to eat bark from 21 tree species in Europe (Gill 1992a, and Verheyden et al. 2006) and Norway spruce *(Picea abies)* is one of the most affected species (Vospernik 2006, Månsson and Jarnemo 2013).

Vulnerability to bark stripping is related to different tree characters, such as bark thickness, bark adhesiveness to the stem, stem branchiness and stem diameter (Gill 1992, Vospernik 2006, Jiang & Ueda 2005, Månsson & Jarnemo 2013). The intensity of bark stripping can also vary between years and areas (Gill 1992a, Welch 1987). One explanation for between-year variations can be varying weather conditions, such as snow depth, rain fall and low temperatures, but there can also be other factors causing differences between areas (Jarnemo 2016).

Several studies have also shown a positive relationship between the level of damage and red deer density (Verheyden et al. 2006, Kiffner et al. 2008, Jerina et al. 2008, Ligot et al. 2013). However, there are also studies that have been unable to detect such a relationship (Szederjei 1957, Völk 1999, Verheyden et al. 2006, Jarnemo et al. 2014). Many authors have shown that the effect of deer density can be overshadowed by other factors, and that maybe the most important factors are the availability of alternative forage and forest structure (Gill 1992a, Verheyden et al. 2006, Vospernik 2006, Jerina et al. 2008, Völk 1999, Jarnemo & Månsson 2011). Various studies conclude that alternative forage is a key factor explaining the severity of bark stripping, and that bark stripping levels increase when more desirable forage is scarce (Welch et al. 1987, Völk 1999, Ueda et al. 2002, Nopp-Mayr et al. 2011, Jarnemo et al. 2014).

Bark stripping damage is generally worse in planted even- aged monocultures with dense crown closure, low tree diameter and low species diversity (Jerina et al. 2008, Kiffner et al. 2008, Nopp-Mayr et al. 2011, Verheyden 2006, Völk 1999, Vospernik 2006). Multi storeyed, mixed and natural forests seem less susceptible to bark stripping (Reimoser & Gossow 1996, Völk 1999, Jarnemo 2016). Increased damage in young and dense stands can be due to favourable microclimate during winter with warmer climate and less snow (Jerina et al. 2008). Dense monocultures might also have a negative effect on the vegetation in the field and bush layer, making alternative forage less available (Jarnemo 2016).

Red deer are known to be sensitive to disturbances (Sunde et al. 2009, Jarnemo & Wikenros 2014). This can be an important factor explaining the level of bark stripping (Nopp-mayr et.al 2011, Ligot 2013, Gerhardt et. al 2013, Rajsky 2008) since the hiding qualities of the cover increases with stem density, canopy cover and proportion of conifers, whereas the vegetation in field and bush layers decreases (Jarnemo 2016). One can thus conclude that red deer seek cover in dense forest stands where the availability of forage in the field layer is low, resulting in the red deer eating bark.

A different aspect is that an imbalance in nutrient intake can affect the urge to consume bark (Faber 1996). Bark may provide roughage and balance the rumen pH which will improve the digestion efficiency and ensure proper rumen function (Van de Veen 1973 in Jarnemo 2016, Faber 1996, Saint- Andrieux 2009). Studying moose (*Alces alces*) Felton et al. (2016), showed that when captive moose were given free choice of food they were consistent in reaching a balance between macronutrients. Their result is in line with other studies, stating that the objective of food selection in large herbivores is to obtain the best mix of nutrients (Westoby 1974).

Oil seed rape (*Brassica napus*) seems to be an attractive food for red deer and seems to have a high nutritional value (Jarnemo 2016). It is sometimes suggested by hunters and forest-owners that oil-seed rape may lead to higher bark stripping levels (Jarnemo et al. 2016, Jarnemo 2016). Studies show that intake of oil-seed rape generates lower pH in rumen (Barry 2013). Imbalance in nutrient intake might be a factor of great importance in Scania since red deer forage on agricultural crops, containing low amounts of fiber which could lead to an increased urge to eat bark. (Jarnemo & Månsson 2011, Allen et al. 2014). It has been concluded that an increased proportion of agriculture in the landscape will lead to an increasing risk of damage (Jarnemo & Månsson 2011). Thus, the level of damage might also be due to the deer feeding on different crops, resulting in an imbalance in the nutrient intake and therefore also an increase in the urge to eat bark.

Another factor that has to be taken into account is supplementary feeding, which is a common practice. There are many different types of feed but the most common in Sweden are silage, sugar beets, potatoes, carrots and fruits (SOU 2014:54).

Supplementary feeding is done for several reasons: to increase winter survival, to improve reproductive performance, to increase hunting possibilities and to reduce damage on forestry and agriculture (Putman & Staines 2004, Andersson 2017). The effect of supplementary feeding on bark stripping is unclear. Some studies show that bark stripping and browsing increases due to supplementary feeding (Gundersen et al. 2004, Mathisen et al. 2014, Pheiffer & Hartfiel 1984). Others show that the damage level decreased after initiation of feeding (Ueckermann 1977, Masuko et al. 2011, Rajsky et al. 2008) and some were unable to detect any effect at all (Szederjei 1957, Verheyden et al. 2006, Kiffner et al. 2008, Milner 2014).

An increase in bark stripping due to supplementary feeding can be a result of the high concentration of animals around the feeding station (Gundersen et al. 2004, Mathisen et al. 2014). It can also be due to feeding with unsuitable forage, containing large amounts of carbohydrates leading to an imbalance in the nutrient intake (Felton et al. 2016, Felton et al. 2017), and see above.

It has been suggested that supplementary feeding can reduce bark-stripping if the deer have access to a sufficient amount of suitable forage replacing bark in the diet (Ueckermann et al. 1977, Ueckermann et al. 1983, Pheiffer & Hartfiel 1984, Rajský et al. 2008, Masuko et al. 2011).

The aim of my project is to evaluate how supplementary feeding will affect the rate of bark stripping. My focus will be on how bark stripping is affected by the distance to feeding stations, the number of feeding stations around the stand and by different kinds of supplementary feed.

Method

Study area

The study area consists of different estates in the area for licensed hunt of red deer in southern Scania (Appendix 1). The area is dominated by agriculture (SCB, 2016), mixed with managed forest consisting of Norway spruce (36%), Scots pine (11%), mixed conifer (2%), Conifer/broadleaved (6%), and broadleaved (40%) (Nilsson & Cory, 2016). The most common crops are cereals such as wheat, barley and oats. Oilseeds, ley and sugar beets are also common (SCB, 2016). The landscape is flat with small hills. The mean temperature in the area is -1ºC in January and 16ºC in July (Wastenson, 1999). Average precipitation 600 mm and only 10-20% of the precipitation is snow (Wastenson, 1999). Other deer species in the area are fallow deer (*dama dama*) and roe deer (*Capreolus capreolus*), whereas moose is rare. Moose and fallow deer are also known to strip bark, however to a much lesser extent than red deer.

Inventory in spruce stands

Level of damage

My project is part of a bigger study focusing on the interactive effects of agriculture and forestry on red deer damage in the landscape, with a hypothesis that the intake of certain crops, e.g. oil-seed rape, will increase the rate of bark stripping. The spruce stands were therefore chosen based on this study design. The bigger study also included a survey of the forage availability and a pellet group survey, both in the spruce stands (figure 1) and around the stands using transects (figure 2). However, this data was not used in my study and I will therefore not describe this in detail.

Bark stripping rates were measured in 68 stands of 20-40 year old Norway spruce (*Picea abies*), with different distances from oil-seed rape and a minimum size of 1 ha (Jarnemo et al. 2016). In each stand 10 survey plots with a random starting point were distributed (figure 1), all with a radius of 5.64 m (Månsson & Jarnemo 2013). The distance between the surveys plots was determined by calculating the square root of the size of the stand. The occurrence of bark stripping was measured on the 10 stems closest to the center of the plot, there was a maximum radius from the plot centre, beyond which trees were not measured (Jarnemo et al 2014, Månsson & Jarnemo 2013). Stems were classified as damaged or undamaged and the damages were identified as fraying or stripping as well as fresh (stemming from preceding winter and spring) or old (before preceding winter) (Jarnemo et al. 2014, Månsson & Jarnemo 2013). It is possible to distinguish damage by moose and fallow deer from red deer by the height of the wounds and the width of the toothmarks. However, since moose is very rare in our study area, and the population of fallow deer is not large enough to generate bark stripping the probability of finding damage from these animals was small.

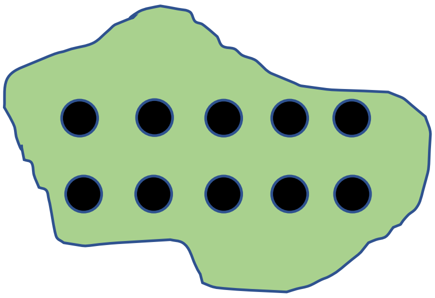

Figure 1. Ten survey plots with a random starting point were distributed in the spruce stands.

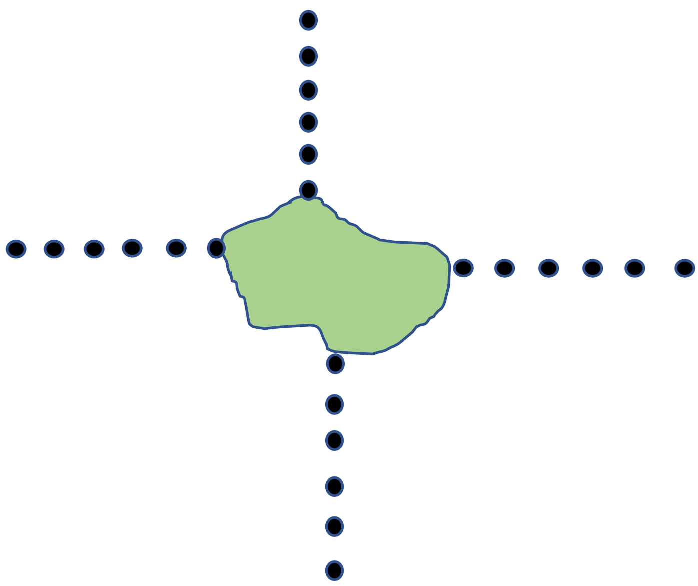

Figure 2. Vegetation cover and pellet groups were measured around the stands using 4 transects, each with 6 survey plots.

Effect of feeding stations

Feeding stations were mapped with the help of landowners, game managers and hunters and analyzed using GIS. The effect of supplementary feeding on bark stripping, was evaluated in three different ways, all of them using linear regression in SPSS.

i) Fresh damage levels in spruce stands in relation to the distance of the closest feeding station. This was done by measuring the distance from the edge of the spruce stand to the closest feeding station.

ii) Fresh damage levels in spruce stands in relation to the average distance to the four closest feeding stations. This was done by measuring the distance from the edge of the spruce stand to the four closest feeding stations and then calculating the average distance.

iii) Fresh damage levels in spruce stands in relation to the number of feeding stations in an area of 500 m around the stand. This was done by counting the number of feeding stations in a 500 m zone starting from the edge of the stand.

Effect of different kinds of forage

We also investigated the type forage used in each feeding station and the effect it had on the damage level. The different forage was divided into 7 groups; 1) Sugar beets 2) Other root vegetables 3) Cereal 4) Silage 5) Corn 6) Bread 7) Active feeding station with unknown forage Using the previously mentioned method number iii) the number of feeding stations for each forage type was counted. The other methods were not used in this analysis since the distance to the closest feeding station with a specific forage type could be very far and would therefore lead to a bias. The analysis was done using a multiple regression in SPSS.

Results

Feeding stations

The total number of feeding stations used in this study was 458. In several feeding stations multiple kinds of feed was provided, as shown in table 1. Therefore, the total sum in table 1 exceed the real number of feeding stations used.

Table 1. Feeding stations and types of forage provided.

	Beets	Root vegetables	Silage	Cereal	Corn	Bread	AO	
Number of feeding stations	227	42	94	68	93	8	16	548

<u>Tree damage</u>

As shown in table 2, a very high proportion of the trees were damaged. On average, 18% of the trees showed fresh damage, and 85% showed old damage.

Table 2. Total number of damaged trees, and proportion damaged trees per stand. In total, 8100 trees were used in the study.

	Fresh damage	Old damage
Damaged trees	1310	6879
Damaged trees (%)	16	85
Max	73	100
Min	0	24
Mean	18	85

Analysis 1 – Distance to and number of feeding stations, regardless of forage type.

<u>Distance to the closest feeding station</u>

The number of damaged trees was not significantly related to the distance of the closest feeding station ($p=0.435$, $R^2=0.009$, $t=-0.786$) (Figure 3).

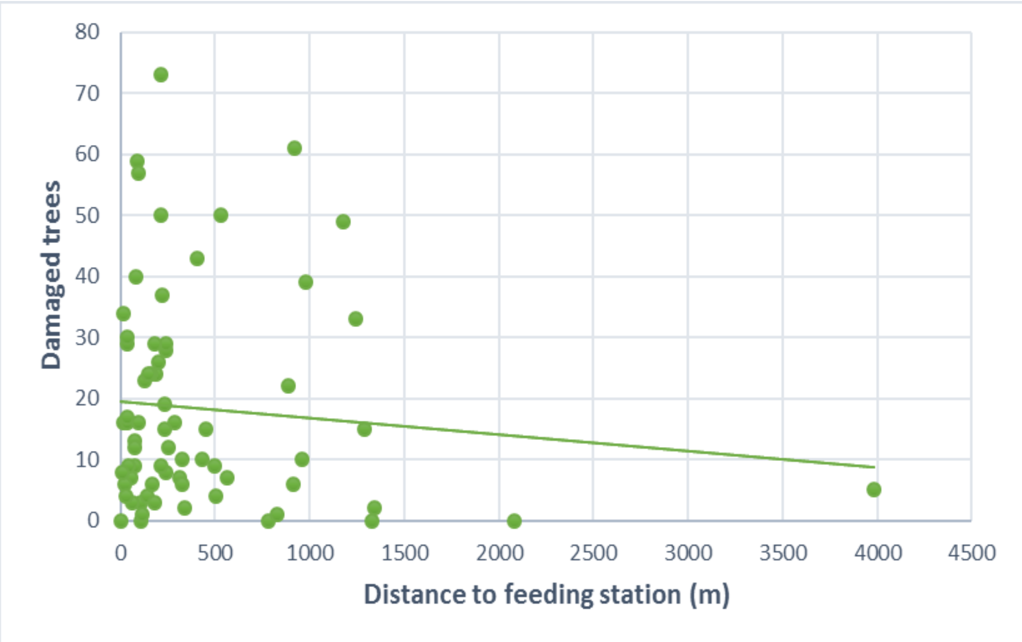

Figure 3. Number of damaged trees from preceding winter (fresh), related to the distance of the closest feeding station in m.

Average distance to the 4 closest feeding stations

The number of damaged trees was not significantly related to the average distance of the 4 closest feeding stations ($p=0.849$, $R^2=5.55E^{-4}$, $t=-0.191$) (Figure 4).

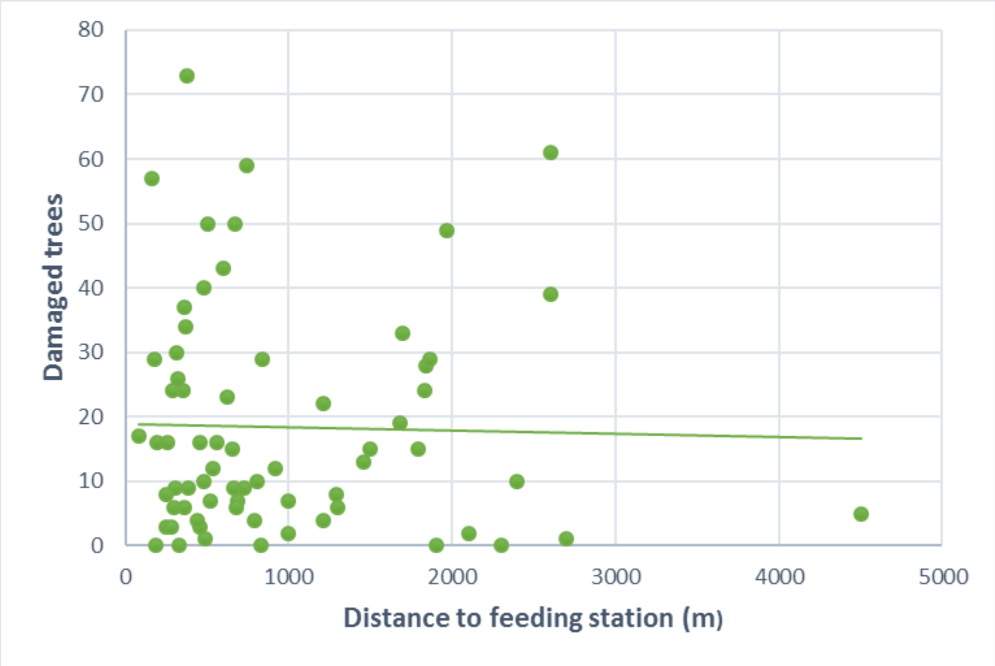

Figure 4. Number of damaged trees from preceding winter (fresh) related to the average distance of the 4 closest feeding stations in m.

Number of feeding stations in a 500 m zone around the spruce stand

The number of damaged trees was not significantly related to the number of feeding stations in a 500m zone around the spruce stands ($p=0.814$, $R^2=8.48E^{-4}$, $t=0.237$) (Figure 5).

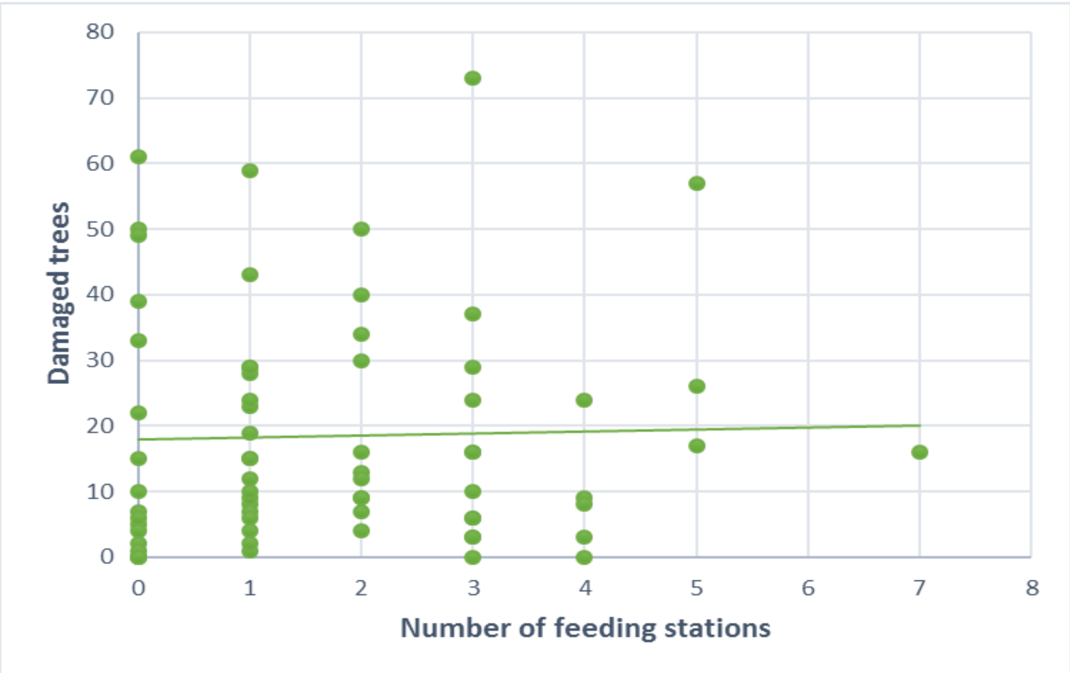

Figure 5. Number of damaged trees from preceding winter (fresh) related to the number of feeding stations in a 500 m zone around the spruce stand.

Analysis 2 – the effect of different forage types

The number of damaged trees was significantly related to the number of feeding stations in a 500m zone with the forage type cereal ($p=0.011$, $R^2=0.095$, $t=2.632$) (Figure 6). A high number of feeding stations with cereal was associated with a high damage level.

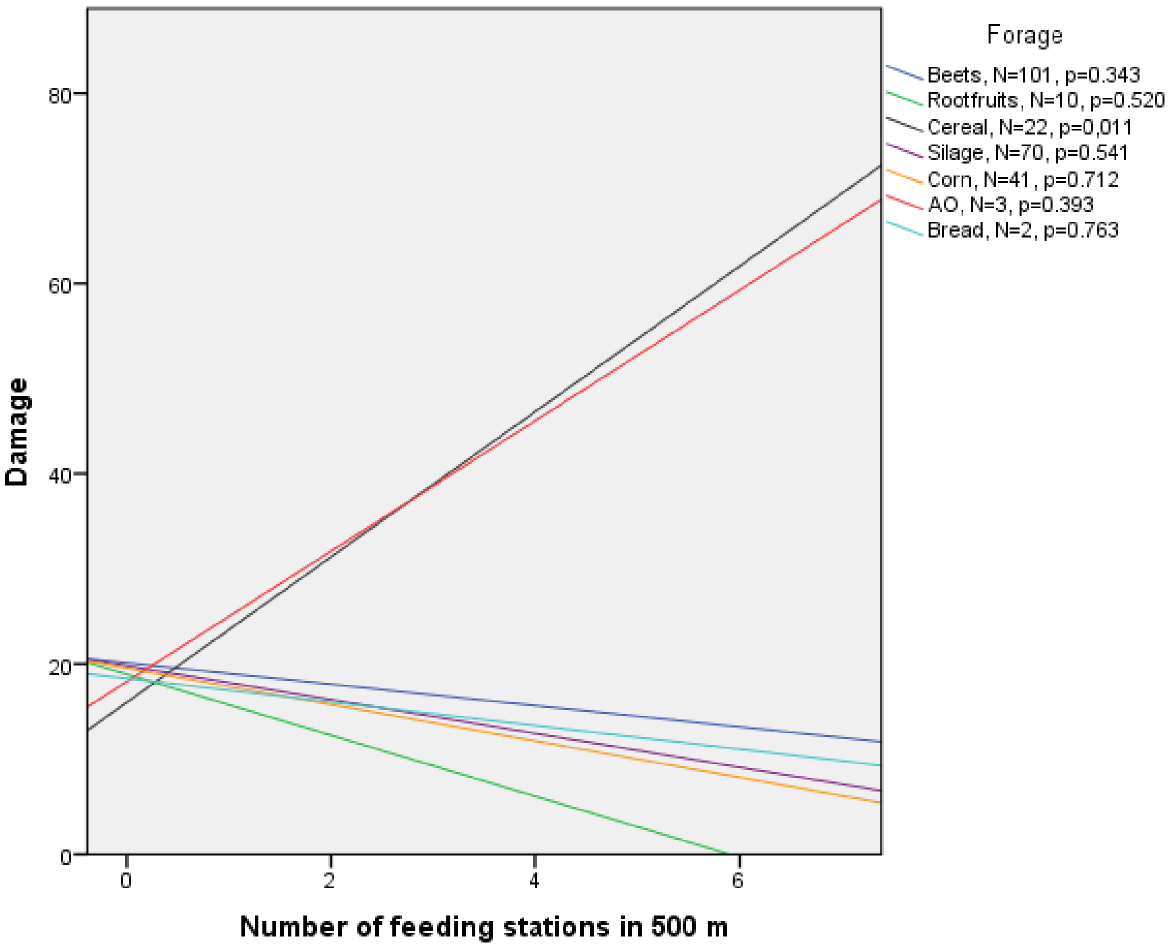

Figure 6. Number of damaged trees from preceding winter (fresh) related to the number of feeding stations in a 500 m zone from the stand, divided into different forage types. AO = active feeding station with unknown type of forage.

Discussion

Analysis 1

My study could not show that bark-stripping level was related to the distance to or the number of feeding stations around the spruce stands. This is consistent with other studies, that also concluded that supplementary feeding could not significantly be related to the rate of bark-stripping (Szederjei 1957, Verheyden 2006, Milner 2014).

However, this does not prove that supplementary feeding does not have any effect on the bark stripping level and the lack of significance could be due to several reasons.

The spatial auto correlation for each feeding station was not considered. There is a risk in not considering this, and it may have had an impact on the results. Since many of the spruce stands used in the study were close to each other, the same feeding stations were used multiple times in the analysis and one can therefore not regard the stands as independent from each other. This could have been solved by calculating a special index of auto-correlation for each feeding station. This would have been important if my results had been significant, since it would probably have reduced the level of significance. However, in this case it is unnecessary since it would most likely not change my results.

It is difficult to determine whether stands are independent from each other in this type of study since there is no information about how animals moved between the different stands, or how many individual deer were involved.

Another factor explaining our results is the high density of feeding stations in the study area and the lack of spruce stands far away from feeding stations. Since supplementary feeding is a very common practice in Scania, the majority of the spruce stands had less than 1000 m to the closest feeding stations, this distance can be related to findings of Allen et al. 2014 whom showed that red deer in Scania make several journeys from resting grounds to feeding grounds exceeding 2 km. The high density of feeding stations gives us data with very small variation, which most likely affects the results. Without data representing damage levels far away from feeding stations we cannot really conclude the effect of supplementary feeding. We could simply not find any area with low density of feeding stations to compare with.

The bark stripping level on Norway spruce in Scania is very high. Jarnemo and Månsson (2013) showed that 83-92% of the trees were damaged (both fresh and old) in their study areas in Scania. It has been shown by Jarnemo and Månsson (2011) that an increased proportion of agriculture will lead to an increasing risk in bark stripping. Thus, maybe factors such as forest structure, the amount of agriculture, deer stand usage, and disturbance overshadows any effect of feeding, or that the interactions among all these factor needs to be taken into count.

Analysis 2

The level of bark stripping could be significantly related to the number of cereal feeding stations in a 500m zone. A high number of cereal feeding stations was associated with a high level of bark stripping rate.

Our results differ from previous studies like Felton (2017) stating that feeding with forage containing large amounts of carbohydrates would increase the intake of woody browse and Faber (1996) suggesting that eating forage containing low amounts of fiber may increase the risk of bark stripping. Based on these studies one would expect that sugar beets and other root vegetables would be the variables explaining the damage level, since they both contain large amounts of carbohydrates and low amounts of fiber. However, cereals have been bred by humans to be rich in macronutrients, and compared to twigs from trees and bushes, they have relatively high amounts of easily digestible carbohydrates (Spörndly 2003). If such items are ingested by ungulates in high doses, it could induce bark stripping based on what we know about nutritional balancing today.

Every estate in the study area uses beets as supplemental feed. It is very common and difficult to find estates that do not use it. I believe that this might be one of the reasons why no effect could be found from beets.

The problem with auto correlation discussed above applies just as well to this analysis. However, in this analysis a correction for this maybe would have changed my results, reducing the level of significance. Therefore, one should not draw too many conclusions based on these results.

The low R^2 value implies that the number of cereal feeding stations does not explain all the variation in the damage level, even if there is a significance. Only two estates had several cereal feeding stations close to the stands, and these stands had very high damage levels. However, these estates also had sugar beet feeding stations close to the stands. This implies that cereal feeding stations result in high damage levels but that it cannot explain the whole variation in damage level since these two estates were also feeding with sugar beets. Another explanation can also be that these two estates had spruce stands close to oil-seed rape fields, possibly increasing the damage level in these stands, and/or that there is an interaction between the intake of sugar beets and cereal (a high combined dose) that may induce bark damage on spruce.

For future studies, it would be interesting to do some changes and corrections. To make analysis 1 more robust a bigger variation in feeding stations density would be needed. One would need study areas with similar red deer densities, similar amount of natural forage, the same landscape structure but with a larger variation of feeding station density. This would of course be difficult since supplementary feeding is such a common practice on the estates in Scania.

In this study, we did not consider the amount of feed presented at the feeding stations. We did not have that information. It would therefore be of great importance to include this in a future study. A small amount of supplemental forage during winter in an area with already large amount of alternative forage might not affect the bark stripping level. However, a relatively large amount of feed of inappropriate nutritional composition in an area were alternative forage is scarce might lead to an increase in the bark stripping rate. In this study one can assume that the number of feeding stations close to the spruce stands are a type of index on the amount of forage, 4 feeding stations inside the 500 m zone is probably more forage than 1 feeding station. However, without knowing the amount of forage at each station one cannot be sure.

From this study one can conclude that investigating the reasons behind bark stripping is complex and depends on many different factors. It is difficult to exclude one factor and analyze it without taking the other factors into account since they probably all are important and in some ways affect each other. However, like Apollonio et al. (2017) I believe that supplementary feeding should be done with caution since it has been shown that there are potential consequences of using inappropriate feed. If supplementary feeding is to take place, small amounts of appropriate feed, resembling the animals' natural diet should be used.

I believe continuing studies on this topic is important in order to reach a sustainable management of both red deer and forest management.

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Appendix 1

Map over area for licensed hunt of red deer.

http://www.lansstyrelsen.se/skane/SiteCollectionDocuments/Sv/djur-och-natur/jakt-och-vilt/karta-kronhjortsomraden.pdf