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Modelling browsing of deer on beech and birch in northern Germany

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ABSTRACT

Food selection by cervids is of high interest for forest management as they tend to browse on trees, causing severe damage and shifts in the regeneration capacity of certain preferred tree species. This behaviour could contradict forestry management strategies as deer may browse on target species, e.g. beech or oak, which are of high economic value for forestry and nature conservation. The choice of feeding habitat is influenced by a variety of different parameters, ranging from forest characteristics to human impacts. Therefore, we focused on factors influencing browsing of roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) on two different plant species: beech (*Fagus sylvatica*), which is an important species for forestry, and birch (*Betula* spp.), which may be an alternative food resource to beech. We measured browsing damage in relation to, variables such as tree density, tree height, ground cover vegetation, possible human impacts and landscape features in the Lüneburger Heide, Germany, for our modelling approach. As expected, our results revealed that browsing on beech is positively influenced by the availability of young beech and surprisingly by birch trees, whereas browsing on birch was influenced by the availability of birch trees only. Furthermore, the occurrence of blueberry (*Vaccinium myrtillus*) was positively and significantly related to browsing damage on both plant species, but a negative relationship was found for old Norway spruce stands (*Picea abies*). Surprisingly, other tree species, landscape features and human impacts had no significant influence on the feeding damage of either tree species. Our results indicate that the availability of stands exclusively consisting of birch (preferably young birch) might decrease the proportion of browsed beeches in neighbouring stands, or even favour the selection of birch over beech for food, which would consequently lead to increased future beech regeneration. Our modelling approach is applicable to forest management, providing an overview of interactions between browsing by cervids and young tree regeneration processes.

1. Introduction

The regeneration of natural woodland has become a major priority of sustainable forestry management globally over the last few decades and this is especially true in Europe (Zerbe, 2002; NMELV, 2011). Nowadays, nature conversion issues in Germany and other north-western European countries are focused on changing contemporary, monocultural coniferous forest stands into mixed stands with indigenous, deciduous tree species (Kuiters and Slim, 2002; Scherer-Lorenzen et al., 2005; Heinze et al., 2011). In our study area, the aim of modern and sustainable forest management is therefore the alteration of these coniferous monocultures into birch-oak (*Betulo-Quercetum*) and beech-oak (*Fago-Quercetum*) forest communities (Kuiters and Slim, 2002).

Browsing by large herbivores on tree seedlings and saplings is considered a problem for forest regeneration worldwide (Chouinard and Filion, 2005; Côté et al., 2004; Moser et al., 2006). Browsing pressure by cervids is considered an influential factor in the success of forest regeneration and has been well investigated (Gill, 1992a; Reimoser and Gossow, 1996; Kuiters et al., 1996). Many studies assume that continuous, selective browsing by cervids has a retarding effect on shrub and tree growth and negatively affects natural regeneration in forests throughout Europe (Gill, 1992a; Kuiters and Slim, 2002; Moser et al., 2006). Cervids can influence vegetation regeneration in various ways (Gill, 1992a): e.g. browsing may inhibit sapling growth rate and survival, leading to a modification of species composition in the understory and tree layer (Edenius et al., 2002).

Furthermore, feeding behaviour may change tree morphology (e.g. enhanced or simplified branching pattern, compensation or slowed growth, e.g. Bergström and Danell, 1987; Bergquist et al., 2003; Hester et al., 2004; Stolter, 2008; Myking et al., 2013), resulting in reduced timber quality (Vila et al., 2003).

The diet selection of cervids is influenced by food quality and quantity (Hagemoen and Reimers, 2002; Dussault et al., 2005;

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Stolter et al., 2005, 2013; Ferretti et al., 2008; Bjørneraas et al., 2012). However, food quality is related to vegetation composition, which depends not only on abiotic factors (e.g. soil parameters, climate), but also on forest management plans (Morrison et al., 2006). Factors like the spatial arrangement of plant species (Bergman et al., 2005), cover and visibility (Mysterud and Østbye, 1999) and human impact (e.g. hunting strategies and distance to human settlements (Dussault et al., 2005; Newton et al., 2011)) may have an important role in forage selection by cervids. Therefore, the probability that a particular tree will be browsed may not only depend on its own characteristics, such as chemistry and morphology (Stolter et al., 2013), but also on the relative quality and abundance of surrounding vegetation (e.g. herbs and shrubs) (Gill, 1992b; Verheyden-Tixier et al., 1998) and the frequency of disturbance (Cross, 1998).

Bee et al. (2009) showed that browsing on individual plant species is influenced by the availability of alternative forage plants in the surrounding environment. They suggested that browsing by deer on a focal plant is simply related to the lower palatability of the surrounding vegetation (Bee et al., 2009). Furthermore, plants with a lower nutritional quality e.g. lower concentration of plant secondary metabolites often received less damage than those of higher quality (e.g. Stolter et al., 2013). Many studies suggest that the availability of diverse food resources is a key factor for the amount of feeding damage on trees (Welch et al., 1991; Gill, 1992b; Vila et al., 2003; Moser et al., 2006).

In this study we chose beech (*Fagus sylvatica*) as the most important forest regeneration species in our study area and birch (*Betula* spp.) as a species which might be of interest as an alternative food source because it is a common food plant for cervids, but is irrelevant for forestry. Improved knowledge about factors influencing browsing behaviour of both deer species on these trees is likely beneficial for the development of forest regeneration management strategies and could help minimise browsing damage on forest target species like *F. sylvatica*. Additionally, it may help identify management alternatives, such as enhancing the browsing damage on non-target species like *Betula* spp. Therefore, we addressed the following research questions:

(1) Which tree species is utilised the most by cervids in relation to tree abundance and height?
(2) What are the factors influencing browsing on *F. sylvatica* and *Betula* spp. saplings in relation to surrounding vegetation, geographical features and human impact?
(3) Are there differences in the influence of these factors on browsing between *F. sylvatica* and *Betula* spp.?

In detail, we hypothesised that:

(a) Deciduous trees are more used than coniferous trees by red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), due to their higher palatability and digestibility (i.e. plant tissues tend to contain lower amounts of secondary metabolites) (Bryant and Kuropat, 1980).
(b) Smaller trees are more frequently browsed than larger trees as they are more accessible.
(c) Presence of ground cover vegetation such as blueberry (*Vaccinium myrtillus*), blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*) favours browsing on young deciduous trees, as they provide additional food resources, which might attract animals.
(d) Geographical features influence feeding habitat selection by cervids. For example, human settlements, different road types (paths, hiking trails, roads for forestry, country roads and highways) and raised hides have a negative impact on the feeding habitat choice of the animals, while mineral licks have a positive impact.

2. Materials and methods

2.1. Study sites

The study was conducted at Wilsede, Forestry Department Sellhorn (539′N, 959′E, 100 m above sea level), located southeast in the conservation area "Lüneburger Heide", Lower Saxony, Germany. The study area is characterised by a yearly precipitation of 800 mm and a mean annual temperature of 8C. Most of the 1240 ha study site is forested; the vegetation composition is dominated by coniferous trees, planted in monocultures over 200 years ago. Dominant overstory tree species are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), Douglas fir (*Pseudotsuga menziesii*) and European larch (*Larix decidua*). The existing deciduous forest stands, such as beech (*Fagus sylvatica*), birch (*Betula* spp.) and oak (*Quercus* spp.), are relatively small and often mixed with other deciduous trees (alder buckthorn (*Frangula alnus*), hackberry (*Prunus padus*), holly (*Ilex aquifolium*), rowan (*Sorbus aucuparia*) and willow (*Salix* spp.)). Dominant ground cover vegetation species include blueberry (*Vaccinium myrtillus*), blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*) and fern (*Pteridium aquilinum*).

The nature conservation area "Lüneburger Heide" has ideal local site conditions; different forest succession stages (including early succession stages) and free-ranging red deer (*C. elaphus*) can be found here. This is relatively unique in Germany because red deer distribution ranges are usually restricted to declared "red deer areas".

The dominant large herbivores in the site are roe deer (*C. capreolus*) at an estimated density of 20 individuals per 100 ha. Red deer density is estimated at 0.2 individuals/ha and the sex ratio is 1:1 (K. Sierk, pers. comm.). At the time of the study we had no information on large predator presence in the study area, although wolves have been observed in other parts of the Lüneburger Heide since 2007.

2.2. Data collection

Fieldwork was conducted between February and March 2012. A systematic design was used for data collection. Using ET Vector Grid in ArcView (Version 3.2; 1999), the position of the sampling grid was randomly selected and the sampling plots were regularly distributed 100 m apart (Fig. 1). Each intersection point represented a 2 × 2 m sampling plot. A total of 1309 plots were investigated covering 5236 m^2. Within each sampling plot (1) tree species, (2) tree height, (3) browsing damage and height and (4) ground cover vegetation were recorded. We restricted our recordings to the ten most common tree species (Stolter, unpublished data). To avoid identification errors of winter-dormant trees, *Betula pubescens* and *Betula pendula* were not separated and were treated as *Betula* spp. *Rubus fructicosus* and *Rubus idaeus* were also not seperated and were treated as *Rubus* spp. Tree height categories (HC) were recorded to determine vegetation composition and occurrence of tree browsing since the animals forage preferentially on tree species up to 150 cm (*C. elaphus*) and 75 cm (*C. capreolus*) in height (Heroldova et al., 2003). All trees were classified at height categories: HC1: 40–100 cm, HC2: 101–150 cm and HC3: >150 cm. Tree heights under 40 cm were commonly browsed by rodents and lagomorphs and were therefore excluded.

We estimated feeding damage in each 2 × 2 m plot by counting browsed species in each of the three height categories. We recorded overall browsing damage and divided trees into two further categories: browsed (b) and unbrowsed (ub). This categorisation was less subjective than assessing browsing scores for tree species and was conducted to minimise observer bias.