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Creating a landscape of management: Unintended effects on the variation of browsing pressure in a national park

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ABSTRACT

The principle objective of management in strictly protected areas, such as national parks, is to reduce human intervention as much as possible to secure natural assemblages and processes. As wildlife management in many national parks has to deal with increased ungulate populations and a broad lack of predators, park managers need to know how their wildlife management, including feeding and hunting, disturbs ungulate behaviour, which in turn might affect natural processes. One measure for this effect is the spatial distribution of browsing pressure in the landscape. Here we measured the browsing activity of ungulates on 5841 vegetation plots in the montane Bavarian Forest National Park to test the hypothesis that browsing in the landscape is mostly influenced by environmental covariables not related to park management. The survey revealed a browsing intensity that allows regrowth of tree species most palatable for ungulates. A comparison of different predictor sets in our spatial additive logistic regression models for silver fir, common rowan and European beech revealed that management activities and space are most important in explaining the variation in browsing level. These quantitative results underline that management activities are of major relevance for the variation of browsing intensity. Thereby, these activities shape a landscape of management that strongly contrasts the aims of the national park to reduce anthropogenic influence on natural processes. We therefore urge all park managers to carefully reconsider the necessity and effect of their management activities, especially of winter feeding, deer control areas and hiking trails.

1. Introduction

Large herbivores are vectors of important processes that significantly influence the structure, composition and development of forest ecosystems. Therefore, the management of large faunal elements in a landscape not only is decisive in assuring the completeness of the respective biocenosis, but also has a considerable effect on the ecosystem itself (Gill, 1992b, 2006; Fuller, 2001; Fuller and Gill, 2001; Russell et al., 2001; Schütz et al., 2003; Selva, 2004; Ray et al., 2014).

The impact of deer browsing on forest ecosystems has attracted the interest of both foresters and conservationists during the last decades because the abundance of deer has increased rapidly owing to protection from human persecution, the lack of natural predators and the change of land-use practices (Côté et al., 2004; Ripple and Beschta, 2012; Hagen et al., 2014). Numerous studies have shown that ungulate browsing has a profound impact on forest ecosystems (Gill, 1992a,b; Ammer, 1996; Reyes and Vasseur, 2003; Rooney and Waller, 2003; Cailleret et al., 2014). Deer, as selective browsers or grazers, affect the growth and survival of many herb, shrub, and tree species and modify patterns of relative abundance and vegetation dynamics. Furthermore, over-browsing in forests reduces plant cover and diversity, which can change the successional pathways in forest ecosystems with consequences for the diversity of insects, mammals and birds and changes in nutrient and carbon cycling (Hobbs, 1996; Pastor and Cohen, 1997; Feber et al., 2001; Fuller, 2001; Côté et al., 2004).

Most recent studies have focused on the negative influence of ungulate browsing on the density and species composition of regenerated trees in managed forests. The aim of management is often to optimize opportunities for hunters while minimizing complaints of farmers and foresters (Porter and Underwood, 1999). The

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findings of these studies have been transferred to protected area management (Hothorn and Müller, 2010; Kamler et al., 2010). But within protected areas, such as national parks, management objectives are different. According to the definition of the International Union for the Conservation of Nature (IUCN), protection of ecological processes (i.e. natural process management), is – in addition to species protection, education and recreation – one of the most important management objective of national parks (IUCN, 1994). These designated goals of national parks require that human manipulation of the populations of large herbivores should be reduced to a minimum so that the natural dynamics of the system have more room to unfold (Wright, 1992). However, the species composition of ungulates and their predators in national parks is often incomplete. Furthermore, the area covered by national parks in productive areas may be too small to encompass the full natural spatial–temporal distribution of large herbivores or carnivores (Boyce, 1991). As a consequence, only some of the processes can be influenced by park managers, such as control measures, park zonation and position of hiking trails. Other processes cannot be directly addressed, such as land use and hunting outside the protected area. Therefore, park authorities often have to intervene to compensate for unfavourable framing conditions (Schonewald-Cox, 1988; Wright, 1992; Porter and Underwood, 1999; Heurich et al., 2011; Hurley et al., 2012).

One important intervention tool is the control of herbivore populations. Examples are the culling of elephants in African national parks (van Aarde et al., 1999) and deer control in Central European and North American national parks to compensate for the absence of large predators, such as wolf, lynx and bear (Huff and Varley, 1999; Bradford and Hobbs, 2008; Günther and Heurich, 2013; Grignolio et al., 2014). Through deer control, authorities try to prevent a high browsing pressure with its unintended effects on vegetation composition (Mysterud and Østbye, 2004) and damages caused by deer in adjacent privately owned forests and fields (Heurich et al., 2011). But even if the control measures succeed in reducing the deer populations to densities that allow natural forest regeneration, they could cause anti-predator behaviour (Brown et al., 1999; Frid and Dill, 2002) that modifies the time–space behaviour of the animals (Laundré et al., 2010). Recently, it was shown that these effects can be even larger than effects caused by natural predators (Ciuti et al., 2012). Management measures other than direct wildlife control also could influence the distribution of browsing pressure. For example, winter feeding (van Beest et al., 2010) or a high touristic pressure via park roads and hiking trails might affect the distribution of browsing pressure, especially if the deer population is controlled and the animals therefore show an adaption to human-induced predation risk (Herbold, 1995; Frid and Dill, 2002; Coulon et al., 2008).

The distribution of browsing pressure is influenced by abiotic and biotic environmental factors. On the landscape scale, topography is an important factor that determines the distribution of herbivores. Altitude, slope and aspect are the major characteristics that influence meteorological parameters, such as radiation, temperature, precipitation and snow height (Coughenour, 1991; Mysterud, 1999; Mysterud et al., 2001; Heuze et al., 2005). The structure of the forest stand, a biotic parameter, could influence the chance of a tree sapling being browsed because the structure greatly influences two important habitat variables, food and cover, which determine ungulate distributions (Mysterud et al., 1999; Mysterud and Østbye, 1999; Kramer et al., 2006; Vospernik and Reimoser, 2008). The composition and structure of the regenerated trees themselves also play an important role in the browsing risk. The palatability, nutrient content and taste of different plant species, but also their height, density and distribution affect their browsing risk (Augustine and McNaughton, 1998; Schulze, 1998). Also the physical and chemical characteristics of surrounding vegetation determine the risk of being browsed (Bergman et al., 2006; Miller et al., 2006). According to Miller et al. (2006), plants are more at risk of being browsed among less-palatable or short neighbouring vegetation or when neighbouring vegetation is lacking. This is mainly because neighbouring vegetation is a potential alternative food resource and provides cover for tree saplings (Moser et al., 2006).

Here, we examine the influence of biotic and abiotic environmental and management-related factors on the variation of browsing pressure in forest regeneration areas. We measured lead shoot browsing of common rowan (*Sorbus aucuparia*), silver fir (*Abies alba*) and European beech (*Fagus sylvatica*) on 5841 systematically distributed sample plots in the Bavarian Forest National Park. Our aims were to judge whether the objective of the park administration to allow natural processes with as little interference as possible is achieved, and to test the hypothesis that the distribution of browsing in the landscape is mostly influenced by environmental factors such as topography, forest regeneration, forest stand and ground vegetation and to a lesser extent by park management.

2. Study area and design

2.1. Natural conditions

The Bavarian Forest National Park covers an area of 244 km^2 in south-eastern Germany along the border with the Czech Republic (49°3′19″N, 13°12′9″E). Together with the adjacent Bohemian Forest, the area comprises one of the largest contiguous forested areas in central Europe. The park was accredited by the International Union for Conservation of Nature (IUCN) in 1978 as category II.

The area is mountainous, with elevation varying between 600 and 1453 m a.s.l. Mean annual temperature varies between 6.5 °C in the valleys and 3 °C along the ridges and at higher elevations. Mean annual precipitation varies between 830 and 2230 mm, a considerable amount of which occurs as snowfall. Snow cover persists for seven to eight months at higher elevations and for five to six months in valleys.

Three major forest types are found within the national park. Above 1100 m a.s.l. (16% of the area), sub-alpine spruce forests with Norway spruce (*Picea abies*) and some common rowan prevail. On the slopes, between 600 and 1100 m a.s.l. (68% of the area), mixed montane forests with Norway spruce, silver fir, European beech and sycamore maple (*Acer pseudoplatanus*) occur. In wet depressions at the bottom of valleys (16% of the area), often associated with cold air pockets, spruce forests with Norway spruce, mountain ash and birch (*Betula pendula*, *Betula pubescens*) predominate. Since the mid-17th century, the area of the current national park was managed, which led to a dramatic change in tree species composition. Silver fir originally accounted for at least 30% of the mixed mountain forests and decreased to the current <3% (Heurich and Englmaier, 2010). In the mid-1990s, spruce trees of the national park were massively attacked by the spruce bark beetle (*Ips typographus*). By 2006, this resulted in the death of mature spruce stands over an area amounting to 6000 ha (Heurich and Neufanger, 2005).

2.2. Park and wildlife management

One guiding principle of wildlife management in the national park is to reduce human intervention as much as possible. However, because of the lack of natural predators and the additional aim of protecting privately owned forests and private property bordering the national park from damages, red deer and roe deer are controlled by hunting. To keep disturbances to a minimum, these measures have been spatially limited to a deer control area.