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Influence of primitive Biłgoraj horses on the glossy buckthorn (*Frangula alnus*)-dominated understory in a mixed coniferous forest

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ABSTRACT

Changes in the understory dominated by glossy buckthorn *Frangula alnus* via the influence of primitive horses were analyzed in a 28-year-old enclosure in the village of Szklarnia at the Biłgoraj Horse-Breeding Centre near Janów Lubelski (eastern Poland). The analysis was conducted in 20 circular plots (30 m^2) defined in adjacent, similar forest stands (enclosed and control). Disturbance by the horses, mainly through trampling, caused numerous paths to form within the glossy buckthorn-dominated understory and led to a decrease in density of stems of lower height classes (30–80 and 81–130 cm, respectively). An increase in species diversity at the expense of glossy buckthorn density was also observed. The horses' trampling caused an increase in *Padus avium* density and the encroachment of other woody plant species that were less shade-tolerant and grew well in soils rich in nutrients. An increase in the density of woody plants over 180 cm above ground was observed within the enclosure, which was probably the result of the horses' excretion of feces. The results presented here provide new insight into the ecological role that horses play in forest-meadow landscape mosaics, which, via altering the development of vegetation, may contribute to an increase in biodiversity within forest habitats.

1. Introduction

Glossy buckthorn (*Frangula alnus*) is one of the most common species in openings and moderately shaded forest habitats in temperate Europe (Hampe et al., 2003). This species constitutes an essential part of the diet of roe and red deer (Gębczyńska, 1980), but rather due to its common presence than preference (Dzięciołowski, 1967, 1970). The local domination of buckthorn is a characteristic feature of this typical understory species. It often occurs in the form of dense thickets highly dominating the shrub layer and limiting the occurrence of other plant species (Johnson et al., 2006; Sugier and Czarnecka, 2010). High density of buckthorn patches may restrict the growth of tree seedlings and the development of forest stands (Fagan and Peart, 2004).

The domination of selected plant species may thus be limited by how the habitat is used by large herbivores, which may modify it in several ways, e.g. feeding on selected plant species (depending on the season and spatial distribution of patches), modification of physical and chemical conditions through reduction of tall plants, excretion of feces, and trampling (Newman, 2000). This also pertains to woody plants, among which browsing may reduce the dominant species of shrubs and bring about ecological consequences (da Silveira Pontes et al., 2016; Pajunen et al., 2012; Pekin et al., 2014; Prévosto et al., 2006). Primitive horses also have an influence on woody species, as their grazing limits shrub and tree seedling development and slows down succession processes in meadow areas (Borkowski, 2002; Kuiters and Slim, 2003). The horses may also modify shrub species composition and, as a result, this may cause higher species diversity (Darinot and Morand, 2001; Merckx and Pereira, 2014). Nevertheless, little is known about primitive horses' influence on the forest habitat (Klich and Grudzińska, 2016; Kuiters and Slim, 2003; Skiwski and Klich, 2012). Gaining more data in this area may help understand the horses' role in forest-meadow landscape mosaics and explain the effect of traditional wood-pastures (Hartel et al., 2013). This issue is currently valid due to the increasing role of natural grazing in the face of land abandonment (Gielarek et al., 2011; Navarro and Pereira, 2012; Poyatos et al., 2003).

Wild equines known as Tarpans, which inhabited the forested areas of Europe in the past, were also called "forest horses" (Pasicka, 2013). Primitive contemporary horses that are their descendants constitute a substitute for the wild grazers that became extinct and disappeared from the natural landscapes of Europe (Vereshchagin and Baryshnikov, 1989). Wild large grazers are believed to have played an important ecological role in forest ecosystems in historical times (Vera, 2000) and could possibly have been a crucial (now lacking) factor contributing to their higher biodiversity (Navarro and Pereira, 2012). Horses, because of their specific digestive system, are able to digest grassy forage with a high fiber content that is not preferred by ungulates. Their foraging on grasses and sedges stimulates their regrowth, which increases the attractiveness of grassland communities to other grazers (Vera, 2000).

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Apart from playing an important ecological role in open areas, horses that inhabit forests can also modify the development of ground flora in such habitats. Today's substitutes for extinct equines, i.e. primitive horses, can spend even 50% of the daytime within the forest (Szaj, 2011; Popp and Scheibe, 2014). Even if consumption of woody species by horses is not high (Cosyns et al., 2001), they may influence the dynamics of plant formation not only through consumption of browse and bark but also due to other types of interactions, such as trampling, excretion of feces, etc. (Borkowski, 2002).

The aim of this study was to assess the Biłgoraj horses' influence on the understory dominated by glossy buckthorn in a mixed coniferous forest. It was hypothesized that the horses would have a significant influence on understory structure and species diversity. Although primitive horses forage more willingly in open sites within the forest stand, they also look for places that are abundant in browse (Klich and Grudzień, 2013; Klich and Grudzińska, 2016). Glossy buckthorn is one of the preferred woody species to be consumed by primitive horses (Klich and Grudzień, 2013) and can be reduced in the sapling phase by this herbivore (Newton et al., 2013).

2. Methods

2.1. Study site

The study was conducted in September 2014 in the village of Szklarnia at the Biłgoraj Horse-Breeding Centre near Janów Lubelski (50°38′37″N, 22°24′26″E). A ca. 30 ha area had been enclosed by wooden poles in 1986 and was reduced to 20 ha in 2007 (Butryn, personal comm.). The area of forest stands within the enclosure currently consists of approximately 7 ha. A group of mares of primitive Biłgoraj horses (closely related to the Polish *Konik*) was free to use this area during most of the vegetation period (Grudzień, 2012). The group comprised 20–25 individuals during most of the breeding period, but the numbers gradually declined to 17 individuals in 2014 (Butryn, personal comm.). The livestock unit for the whole area of enclosure was *ca.* 0.85–1.00. The area of the Breeding Centre along with the village of Szklarnia is surrounded by the "Lasy Janowskie" forest complex. The area is characterized by dominant sandy soils covered mainly by fresh mixed coniferous forests (Radwan et al., 1997). *Pinus sylvestris* is the dominating tree species which constitutes ca. 86% of the main canopy trees (Wediuk, 2005). The study site is located at an altitude of approximately 200–210 m a.s.l. The region has a continental climate of hot summers (mean 18.4 °C in July), cold winters (mean −3.1 °C in January) and a mean annual temperature of 7.9 °C. The sum of annual precipitation is equal to 526 mm (www.globalspecies.org).

2.2. Experimental design

The comparison pertained to the differences between the common management of forest habitats and areas managed with the presence of primitive horses; this type of study design had also been implemented in former studies (e.g. Angassa and Oba, 2008; Mureithi et al., 2014). An assessment of the shrub layer structure was conducted within two forest stands with a fresh mixed coniferous habitat: a) enclosed - located inside the enclosure with the horses, b) control - outside the enclosure. A control stand, outside the enclosure, presented a development of the shrub layer under low wild ungulate browsing pressure. The area is occupied mainly by red deer and other species of less importance, e.g. roe deer (1.1–1.5 ind/100 ha) and moose (1.9 ind/1000 ha). The abundance of red deer in this area is not precisely known, but available data show that the density can be estimated to be at a low level, i.e. 12.3 ind/1000 ha (Rążewski, unp. data), after a slight increase from ca. 11 ind/1000 h in the 1980s and 1990s (Drozd, 2001). The current density, ca. 14.5 ind/100ha per forest area, is much lower as compared to other regions in Poland (Bobek et al., 2013) and below the recommended level for red deer density (NRŁ nr 57/2005). The density of all wild ungulates, based on the method provided by Fruziński (1989), can be assessed at ca. 24 deer units per 1000 ha of forest area. This value is also below the carrying capacity of forests in Poland (Głowaciński, 2007), where the lowest value (25 deer units per 1000 ha of forest) was assessed for habitats of the lowest productivity; in this study the forest habitats are regarded as moderate (Drozd, 2001). Thus the influence of wild ungulates on forest ecosystems in this area can be regarded as inconsiderable.

The two stands (enclosed and control) were similar in the domination of pine (69 years), canopy cover, soil type, and altitude, and with a high domination of glossy buckthorn. The stands were closely located (100 m) and constituted one patch of glossy buckthorn within a forest habitat that was crossed by a small river. The field study was based on 20 circular plots (30 m^2) which were defined along transects at 10 m intervals within each forest stand. The understory species were analyzed within the plots. The area of the plots was delimited with a steel tape measure with a 3.09 m radius from the centre of the plot. Each woody species with a trunk that was at least half-way inside the plot area was included in the analysis. A tree or shrub with a stem which was growing from the soil with no visible connection with any other specimen was treated as an individual.

2.3. Data collection and statistics

Within each plot, all trees and shrubs 30–450 cm high were counted, categorized by species and measured for their exact height. Individuals up to 30 cm were excluded from the analysis to avoid the miscounting of seedlings in dense undergrowth. Individuals up to 2 m were measured for height with a steel tape measure with an accuracy up to 1 cm. Higher specimens were measured for height with a clinometer with an accuracy up to 25 cm. The measurements were performed by two people. To compare the differences in the soil's natural fertility between the stands, the DBH (diameter at breast height) of the main canopy trees within the plots were measured with a tree caliper with an accuracy up to 1 cm.

The measured individuals were grouped into four height classes: 30–80, 81–130, 131–180, and 181–450 cm above ground. Shannon's index of diversity was calculated for each plot in order to compare the horses' influence on species diversity in the shrub layer. The index was calculated based on the proportional abundance of each woody species within each plot regardless of the height class. Statistical analyses were performed using SPSS 3.1 software. A comparison of the mean DBH of the main canopy trees, mean number of shrubs and trees within the plots and height class, and mean Shannon's index was performed by using the unpaired *t*-test.

3. Results

The stands presented a similar DBH of the main canopy pine trees ($t = 0.398$, $p = 0.693$) (Fig. 1). Although a stand within the enclosure presented a significantly lower density of all woody plants within the plots, species that were other than glossy buckthorn were more abundant within the enclosure ($t = 2.115$, $p = 0.043$). Species diversity in the stands was also statistically different ($t = 3.088$, $p = 0.004$); the enclosure presented a much higher Shannon's index ($H = 0.73$) than the control stand ($H = 0.46$).

The mean density of *F. alnus* was much lower within the enclosure and statistically different from the control stand ($p < 0.05$) (Table 1). A higher density of *P. avium* (statistically different: $t = 2.179$, $p = 0.036$) and the occurrence of other species which were not present within the control stand (*S. nigra, E. europaeus)* were also observed. Among the trees (of the understory), three species were present within the enclosure which were not observed within the control stand, i.e. *P. sylvestris* (statistically different $p < 0.05$), *U. laevis* and *P. communis.* On the contrary, *P. abies* was not found within the enclosure, but this species was found within the control stand (statistically different: