Available online at www.sciencedirect.com
SCIENCE DIRECT
Forest Ecology and Management 222 (2006) 1–8
Forest Ecology and Management
www.elsevier.com/locate/foreco

Selective bark-stripping of beech, *Fagus sylvatica*, by free-ranging horses

A.T. Kuiters *, L.A.M. van der Sluijs, G.A. Wytema

Centre for Ecosystem Studies, Alterra Green World Research, Wageningen University and Research Centre, P.O. Box 47, NL-6700 AA Wageningen, The Netherlands

Received 8 March 2005; received in revised form 10 August 2005; accepted 26 September 2005

Abstract

Incidence and intensity of bark-stripping by horses was surveyed in stands and tree lanes of European beech (*Fagus sylvatica* L.) in Veluwezoom National Park, by using transects. Damage was apparent on 38% of beech trees, and 11% were seriously damaged (score 3 or more). Susceptibility to bark-stripping was found to be strongly size dependent, with highest damage rates occurring at the smaller DBH classes ($\leq$40 cm). Another significant factor affecting damage rate was bark structure, albeit this factor was confounded with tree size. Beech trees with a smooth bark were significantly more damaged compared to individuals with a rough bark structure. Occurrence pattern was another significant factor. Stand trees had higher damage rates compared to trees occurring in lanes along roads and paths. Mean rate of fungal infection of bark-stripped beeches was much higher in stands (46%) than in tree lanes (11%), and strongly increased with increasing damage class. We also analysed beech bark for several macronutrients and compared these with those of several other commonly occurring tree species. Macronutrients in bark tissue could not explain horses' preference for beech.

Keywords: Horses; Bark-stripping; Beech; Tree bark preference; Bark macronutrients

1. Introduction

Ungulates may have a profound effect on forests by grazing, browsing, trampling, rooting, and bark-stripping (Gill, 1992; Kuiters et al., 1996; Weisberg and Bugmann, 2003). Grazing the herbaceous ground layer improves conditions for woody regeneration by reducing competition for light with vigorous herb and grass species (Mitchell and Kirby, 1990). It can also change the species composition of the ground vegetation in forests (Chytry and Danihelka, 1993; Kirby, 2001). Rooting may improve or impede regeneration by either creating favourable conditions for seed germination or de-root small seedlings or saplings. The net effect depends on rooting frequency (Groot Bruinderink and Hazebroek, 1996). Browsing of seedlings and saplings may have a serious impact on tree regeneration by impeding sapling growth or by filtering out browsing-sensitive species (Kuiters and Slim, 2002; Rooney, 2001).

The impact of bark-stripping can be severe because it affects not only saplings but also canopy trees. Debarking may potentially impair growth, and could result in partial or total crown die-back. Trees that have incurred heavy damage, especially after ring-barking, are likely to die (Welch and Scott, 1998). This may eventually change forest structure.

Damage caused by deer, including bark-stripping, has been reviewed by Gill (1992). Red deer (*Cervus elaphus*), sika deer (*Cervus nippon*) and fallow deer (*Dama dama*) are known to remove bark from woody species, usually in winter. Bark-stripping on European beech occurs mainly in summer, because bark is then more easily stripped (Gill, 1992). To our information no literature is available on bark-stripping by horses. It is a well-known phenomenon in Dutch nature reserves where free-ranging horses are introduced for nature conservation purposes.

This study was aimed to quantify the extent of beech stem damage in Veluwezoom National Park, The Netherlands, caused by bark-stripping of free-dwelling horses, and factors affecting damage rate. In this area beech occurs either in stands or in old-growth beech lanes. From 2002 onwards beech in the area showed seriously stem damage due to bark-stripping by the horses. Especially the beech lanes are particularly loved for their attractiveness and cultural–historical value. For this reason the site manager wanted a survey of the damage rate of beech lanes and beech stands, and wanted insight in the factors

* Corresponding author. Tel.: +31 317 478754; fax: +31 317 424988.
E-mail address: loek.kuiters@wur.nl (A.T. Kuiters).

0378-1127/$ – see front matter
doi:10.1016/j.foreco.2005.09.019

affecting incidences and intensities. Beech was by far the most attacked tree species in the national park. It has often been suggested that nutrient deficiencies might be a main reason for bark-stripping behaviour of ungulates and smaller mammals such as rabbits, hares, squirrels and voles (Gill, 1992; Miquelle and Van Ballenberghe, 1989), but evidence is largely lacking. Selective bark-stripping could then be related to differences in nutrient contents. We therefore also analysed macronutrients in beech bark and compared these with the contents in bark tissue of several other commonly occurring woody species in the research site.

2. Materials and methods

2.1. Study site

This study was conducted in Veluwezoom National Park, centrally situated in The Netherlands (30–100 m a.s.l., 52°05′N, 6°00′E). Mean annual precipitation is approximately 780 mm and the mean annual temperature is 9.5 °C. The original vegetation in this area, with a substrate of loam-rich sandy soil, is thought to have been mixed deciduous forest, dominated by *Fagus sylvatica* and *Quercus robur*. However, old-growth forest has over the centuries been replaced by tree plantations of *Pinus sylvestris*, *F. sylvatica*, and *Q. robur* and by heaths (Kuiters, in press). In 1930, the area was designated as National Park after most agri- and silvicultural activities had stopped.

Icelandic horses were introduced in the south western part of Veluwezoom National Park in 1986. Horse-grazing is used as a management tool to maintain and develop a half-open forest landscape. Accordingly, the free-ranging horses in the park are considered as a natural form of disturbance. A 420 ha compartment was fenced, encompassing woodland stands (220 ha), heaths (170 ha) and former pastures. Woodland stands cover 63% of the area. Of the total woodland cover, 14% is composed of mono- and mixed-species stands with beech. Other important tree species are *Quercus robur* (33%) and *Pinus sylvestris* (28%). The number of horses is held at a more or less constant level (45–55 horses). Besides horses the area is inhabited by wild ungulates, i.e. red deer, roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). The management of the park allows natural processes to prevail in this area and no silvicultural activities have been carried out since the 1980s (Kuiters, in press). If the structure and species composition of the beech stands will alter in the long run due to debarking activities of the horses, this will be acceptable and fits in the non-intervention strategy of the area.

2.2. Field measurements

Data on bark-damage were collected in a survey carried out in February 2003. The relevance of tree occurrence pattern was incorporated in this study by comparing beech stands with tree lanes. In beech stands, assessments of incidence and intensity of stem damage were made on individual trees at each of 24 randomly selected locations with mono- or mixed-species stands, with beech as dominant tree (canopy cover >50%). Mean tree density in the beech stands varied from 45–300 stems per ha. Each location was systematically surveyed to determine the frequency of affected trees and intensity of stem damage. From a random starting point at the border of a stand, a transect of 20 m wide was chosen with an orientation to the central part of the stand. The length varied between 30 and 80 m, depending of the size of the stand. We aimed to have at least 20 trees on each transect. Besides stands, 16 old-growth beech lanes along roads and paths were examined for stem damage. Mean distance between trees in these lanes amounted to 5–6 m. Mean length of the lanes averaged 305 m, and varied from 55 to 800 m.

Each individual tree in a transect or row was assessed for damage intensity according a five-point scale from Mountford and Peterken (1999) (Table 1). The relative amount of bark removed within the susceptible height range, i.e. between stem-foot and maximum browse-height of the horses (0–2.0 m), determined the damage rate. Six diameter classes were distinguished: ≤20, 21–40, 41–60, 61–80, 81–100 and 101–120 cm. For each tree we checked whether bark structure was smooth, moderate or rough. Bark structure type was assigned arbitrarily and documented by photos. Of all trees with stem damage, we also examined if the wound in the trunk was infected by fungi (presence or absence).

2.3. Chemical analysis

Bark samples of beech were collected in the spring of 2003 throughout the surveyed locations for all DBH classes. Several other commonly occurring woody species were also sampled to allow a comparison with beech. These were *Amalanchier lamarckii, Castanea sativa, Frangula alnus, Pinus sylvestris, Populus tremula, Quercus robur, Q. rubra* and *Sorbus aucuparia*. For these species only one DBH class (<20 cm) was sampled. The composition of bark samples for various macronutrients, i.e. Ca, Mg, K, Na and P was assessed. These minerals are essential for bone formation (Ca, Mg and P), enzyme activation (Ca, Mg and K), lactation (Ca), nerve and muscle function (Ca, Mg and K) and regulation of body fluid volume and osmolarity (Na and K) (Robbins, 1993). It is known that horses and other ungulates often suffer from mineral deficiencies, especially Na (Kinnaird et al., 1979; Van Soest, 1994).

Each sample consisted of a piece of bark of 5 × 5 cm and included outer and inner bark and cambium from the tree trunk at breast height. Bark samples were taken by using a wood chisel. For each tree type and DBH class (beech) five samples were taken from different trees. A total of 80 bark samples were

Table 1
Five-point scale applied for scoring stem-damage to beech (from: Mountford and Peterken, 1999)

Score	Category (damage)	Description
0	No	No bark removed
1	Limited	<10% bark removed
2	Moderate	10–50% bark removed
3	Severe	>50% bark removed
4	Very severe	Ring-barked