Impact of grazing management with large herbivores on forest ground flora and bramble understorey

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1. Introduction

Woodland conservation and large herbivore grazing (or grazing management) are often reported as conflicting aims. On the one hand, livestock production and high numbers of wild herbivores are considered as a serious threat for biodiversity in native woodlands (e.g. Rackham, 1980; Steinfeld et al., 2006; Dufour-Dror, 2007; Tremblay et al., 2007). On the other hand, evidence is growing that large herbivore grazing is a key process in the dynamics of naturally grazed ecosystems, including woodland (Olff et al., 1999; Boldam, 2001; Bakker et al., 2004). In Europe, grazing by domestic herbivores in forests is mainly restricted to woodpasture remnants (Putman, 1986; Mountford and Peterken, 2003), although it is still a widespread land use form in Britain (Armstrong et al., 2003), mainly in small forests. In Flanders (N. Belgium), livestock has been gradually removed from woodland areas since early Medieval times (Tack et al., 1993). However, since the end of the twentieth century, there is growing interest in forest grazing with domestic large herbivores as part of conservation and restoration management practices (Rodwell and Patterson, 1994; Bakker and Londo, 1998; WallisDeVries et al., 1998).

Apart from the general conservation goals (concerning naturalness or increasing vegetation structure heterogeneity), grazing management in forests is sometimes used for specific reasons, in an attempt to counteract unfavourable processes (e.g. control of dominant species, Van Wieren and Bakker, 1998). In the past decades, one of the most obvious changes in many forests in Flanders is the strong expansion of the bramble understorey (in most cases Rubus fruticosus agg., below mentioned as Rubus). Rubus also invades forests with high conservation interest, such as ancient forests. Ancient forests are characterised by a species-rich ground

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Anemone nemorosa
Associational resistance
Bramble control
Competition for light
Hyacinthoides non-scripta
Treading and trampling

ABSTRACT

We investigated whether grazing management with large herbivores is appropriate to reduce expanding bramble (Rubus sp.) in an ancient forest in Flanders (N. Belgium). We further studied interaction effects of four years (all year-round) grazing and Rubus cover on the presence, cover, and flowering of five forest ground flora species (unpalatable: Anemone nemorosa and Primula elatior; palatable: Hyacinthoides non-scripta, Vinca minor and Hedera helix). We collected data on eight transects and in 412 plots in adjacent grazed and ungrazed forest and used baseline datasets of 1996 and 2002 in the same area (i.e. before grazing). In a field experiment, we simulated grazing (by clipping) and trampling (by pressing a weight) in eight homogeneous A. nemorosa vegetation stands.

Large Rubus thickets had a clear negative impact on cover and flowering of A. nemorosa due to competition for light. Four years of cattle grazing reduced bramble cover by more than 50%, but then the limiting factor for A. nemorosa cover and flowering shifted to trampling damage. We also found lower cover and flowering of H. non-scripta in grazed plots, as a consequence of direct grazing. The evergreen species V. minor and H. helix totally disappeared from the grazed forest. Simulated once-only effects of grazing and trampling had a small and short term negative impact on cover of A. nemorosa, but flowering was strongly reduced. Grazing reduced biomass with 25–30% in the following years.

Year-round grazing with large herbivores is an appropriate measure for bramble control in forests, but negative effects on ground flora are possible if grazing pressure is high. A low or moderate grazing pressure (<0.25 animal units ha⁻¹ y⁻¹) should be maintained in landscape mosaics with grassland and forest; or intermittent periods of non-grazing should be provided to maintain forest ground flora diversity.

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flora, mainly consisting of stress tolerant geophytes and hemi-cryptophytes with poor regeneration capacities (Hermey et al., 1999). McEvoy et al. (2006a) also found a trend of bramble expansion in woodlands in Northern Ireland. There is evidence that species richness declines as bramble cover increases or the species becomes dominant (Kirby, 1990; Kirby and Woodell, 1998).

There are three major factors described that may cause Rubus expansion in Flemish (and other European) forests. First, since the second half of the twentieth century, a conversion took place from coppice wood with standards to tall wood in nearly all ancient forests. Not the conversion by itself, but rather the cessation of the accompanying measures, such as repeated cutting of thickets (including Rubus, often bundled in faggots for burning) and the removal of litter, benefited the development of Rubus (Kirby et al., 2005). Second, fragmentation of ancient forest led to increased forest edge length and area and promoted Rubus cover increase (Honnay et al., 2002). Finally, increased atmospheric nitrogen deposition, caused by intensive animal husbandry and increased traffic intensity, favoured nitrophilous vegetation (including bramble species), decreased vegetation diversity and changed community composition in forests (Landmann, 1995; Bobbink et al., 2002; Skrindo and Okland, 2002; Bernhardt-Römermann et al., 2007).

Conservation practitioners are concerned about a possible shift towards a decreased species richness with dominance of plants with a competitive strategy (sensu Grime et al., 1988), such as Rubus. Grazing management in ancient forests may be a tool to affect competition between Rubus and forest ground flora (McEvoy et al., 2006b; Kirby and Thomas, 2000). Geum urbanum, Lysimachia nemorum, Potentilla sterilis, Primula vulgaris and Viola riviniana were among forest species that increased in a cutting trial when cover of R. fruticosus was removed (Kirby and Woodell, 1998). On the other hand, neither the effects of grazing nor trampling on ancient forest ground flora are studied comprehensively. It is known that herbivory can affect the physical structure, species composition and population structure of woodland communities (Jenkins et al., 2007). Trampling can alter soil processes (e.g. N-mineralisation) by increasing soil bulk density (Brelend and Hansen, 1996). Trampling effects on plants and vegetation include damage to the root system and a reduction of plant species diversity, cover, biomass and height (Cole and Bayfield, 1993; Liddle, 1997). Mesophilous forest communities are found to be susceptible to trampling (Roovers et al., 2004; Amrein et al., 2005). However, little is known about effects on forest specialists.

In this study, we investigated the effects of four years of year-round grazing on ground flora and Rubus cover in an ancient forest. We hypothesized that increasing Rubus cover has negative effects on cover and flowering of forest ground flora species. We further hypothesized that large herbivore browsing reduces Rubus cover. We hypothesized that the reduction of Rubus cover, as a consequence of grazing management, has a positive influence on presence, cover, flower abundance and growth of forest ground species. However, we expect interaction with the palatability of these species: for palatable species such as Hyacinthoides non-scripta, Vinca minor and Hedera helix, positive effects of reduced cover might be counteracted by negative effects due to grazing damage. For unpalatable species such as Anemone nemorosa and Primaulum elatior, we expect a positive effect of reduced Rubus cover through grazing.

To get an insight into the direct short term effects of grazing and trampling, we set up a field experiment with A. nemorosa, in which total grazing and trampling were simulated as a once-only and extreme event. We hypothesized that direct trampling and grazing have a negative effect on cover, flower abundance and biomass of this species and explored recovery in two consecutive years.

We discuss the relative importance of possible positive effects (as a result of bramble control) and possible negative effects of grazing management (as a result of direct damage) on forest ground flora in a context of altered competition, associational resistance and palatability of plant species.

2. Methods

2.1. Study sites and studied species

The study was carried out in two nature reserves on moist, nutrient rich soils: Bos t’ Ename (50’86’N, 3°65E; >100 ha; sandy loam) and Hayesbos (50°78’N, 3°77E; ±50 ha; loam) in Flanders (N. Belgium). Forests in these two reserves mainly consist of Carpinion (most abundant trees: Fagus sylvatica, Quercus robur and Populus x canadensis) and smaller parts of Alnion-Padion vegetation (most abundant trees: Fraxinus excelsior, Alnus glutinosa, Ulmus minor). Large areas with species-rich ground flora, flowering in early spring, are present (most abundant are A. nemorosa and H. non-scripta in the Carpinion forest and P. elatior, A. nemorosa, and V. minor in the Alno-Padion). Both study areas are among the most species-rich forests in a survey of 234 randomly chosen deciduous forest patches (0.5–5216 ha) in western Belgium and the most northern part of France (Honnay et al., 1999a). Bos t’ Ename has been the subject of both intensive historical and ecological research (Tack et al., 1993; Honnay et al., 1999b).

Since the end of the 20th century, Bos t’ Ename and Hayesbos are managed as nature reserves. In Bos t’ Ename, forest (251 ha) is grazed together with adjacent grassland (25.5 ha) and former arable land (10.7 ha) since 2004 (Fig. 1). A small herd of the local and hardy cattle breed “white and red of East-Flanders” (10–14 animals, including cows, heifers, calves and one bull) and two Konik horses were introduced in the area for year-round grazing (i.e. ±0.25 animal units (AU) ha−1 y−1). This grazing pressure is rather high (≥125 kg herbivore biomass ha−1 y−1, cf. WallisDeVries et al., 1998) and fairly constant. Both cattle and horses were introduced to trigger and guide the development of more natural vegetation patterns on formerly intensively used grassland (summer grazing) and arable land. Forest was included in the grazing block to join former agricultural land, but in particular, the managers wanted to amass knowledge concerning the effects of large herbivores on forest development (e.g. natural regeneration, bramble control, effects on ground flora). Part of the forest, adjacent to grazed parts (20.2 ha) and some isolated forest patches remained ungrazed. For grazing, browsing and resting, the forest was almost exclusively used by the cattle herd. During one year, the cattle’s time budget for foraging was 12.3% in the forest, 63.1% in grassland and 24.6% on former arable land. 88% of the grazing time in the forest occurred during winter, mainly late winter (Van Uytvanck, unpublished data of 36 observation sessions of 5 h, evenly spread over seasons and daily period). Horses did not use the forest for foraging since their introduction in the area. In Hayesbos, only spontaneous development occurs (no grazing, no other management measures). The latter study area was used for the grazing and trampling simulation experiment. Deer were absent in both study sites. An introduction trial of roe deer (Capreolus capreolus) in Bos t’ Ename in 1997 (six individuals) failed. All roe deer disappeared from the area less than 2 months after introduction.

We studied six plant species (the forbs are typical ancient forest species): R. fruticosus group (representing >95% of all Rubus species), A. nemorosa, P. elatior, V. minor, H. helix and H. non-scripta. The former five species are spread throughout the forest, with A. nemorosa forming large stands, massively flowering in spring. H. non-scripta mainly occurs in almost pure, spatially distinct stands (Fig. 1). H. non-scripta, H. helix and V. minor are known as
palatable plants. The presence of irritant and antibiotic protoanemone ine and ranunculine in A. nemorosa and the acrid tasting triterpene-saponins in P. elatior makes both species unpalatable for livestock (van Genderen et al., 1997; Grime et al., 1988; De Cleene and Lejeune, 1999; Okrslar et al., 2007).

2.2. Data collection

Four different datasets were used to study grazing management effects: (1) four permanent plots (1996–2008; Rubus) and (2) 42 relevés (2002; Rubus, ground flora) were used as baseline for (3) a fence line study with 412 plots (2008; Rubus, ground flora). A simulation study (4) with eight plots was used to underpin the mechanistic effects of defoliation and treading (2006–2008; ground flora). The sampling procedure and datasets used for the different aims of this study are summarised in Table 1.

2.2.1. Rubus cover before and after grazing management (datasets 1996–2008 and 2002)

To assess cover percentages of Rubus before and after grazing management, we acquired a dataset of 1996. This dataset (Cornelis, 1996) contains 32 relevés (decimal scale of Londo, 1984), made in 4 permanent plots, marked in the field (Fig. 1). Each plot was divided into two subplots (one roe deer enclosure and one open subplot) of 20 m × 20 m. In all subplots, 4 relevés (10 m × 10 m) were made, resulting in a total of 32 relevés. In 2004, two of the four plots were included in the grazing block. One enclosure subplot in the grazing block (near to Hyacinthoides patch 2, Fig. 1) was destroyed before cattle and horses were introduced in 2004, resulting in one more grazed subplot. From this dataset, we used Rubus cover percentages. In April 2008, we revisited all subplots and assessed cover percentage of Rubus again.

To assess the starting conditions of the study area before grazing, we used a set of 42 relevés (2 m × 2 m; decimal scale of Londo, 1984) made in the study area in August 2002, i.e. two years before the start of year-round grazing in Bos t’ Ename (Buckens, 2003). These relevés were located in the area where transects were established (Fig. 1): 19 in the forest block grazed since 2004, 23 in the permanently ungrazed forest block. From this dataset, we used cover data of Rubus (Table 1).

2.2.2. Frequency of forest ground flora before (dataset 2002) and after grazing (dataset 2008)

We used the 42 relevés (dataset Buckens, 2003) to obtain presence/absence data from three frequently occurring forest ground flora species: H. helix, P. elatior and V. minor. We used presence/absence because cover was always low (<10%). Because relevés were made in August (student’s thesis), A. nemorosa and H. non-scripta could not be accurately recorded. In the same area, we recorded presence/absence of the same species in 412 plots in April 2008 (see Section 2.2.3; Table 1).

2.2.3. Comparing Rubus and forest ground flora in grazed and ungrazed forest (dataset 2008)

We applied two different strategies for the fence line study of forest ground flora and Rubus in Bos t’ Ename, according to different species distribution: clumped (H. non-scripta) vs. scattered (all other species).

For the species, occurring scattered throughout the forest, we set out eight transects, each of them crossing adjacent grazed and ungrazed forest parcels (Fig. 1). Individual transects were parallel to the topographic contours of the main slope in the study site and were 10–30 m apart. Transect length ranged from 315 to 630 m. In each transect an equal number of plots (2 m × 2 m) in ungrazed and grazed forest was established. Distance between plots was 7.5–15 m. One transect with 56 plots was situated in Alno-Padion forest; seven transects with 356 plots were situated in Carpinion forest. Measurements on transects were conducted in the second half of April 2008. We recorded absence or presence of H. helix, P. elatior and V. minor. Apart from A. nemorosa, these were the most frequent species (present in more than 5% of all plots, but cover % was always lower than 10%). We further estimated Rubus and A. nemorosa cover with a decimal scale (Londo, 1984) and counted the number of A. nemorosa flowers in each plot. We used A. nemorosa as a model species for unpalatable ground flora in general, because it was present throughout the forest in more than 90% of all plots. On a cloudless day, we measured Rubus canopy height and photosynthetic photon flux density (μmol photons s⁻¹ m⁻²) in 64 plots (eight per transect) at four fixed points per plot. Light measurements were made at 20 cm (four fixed points) and 150 cm (one point without interfering vegetation) above ground level with a photometer (Skye Instruments LTD, SKP 200). Light penetration in the vegetation was determined as the ratio between paired measurements at 20 and 150 cm.

For H. non-scripta, mainly occurring clumped in distinct stands, we established eight grids, four in grazed forest and four in ungrazed forest. These grids (27 m × 27 m, with horizontal and vertical grid lines 3 m apart) were located in the centre of eight H. non-scripta stands and resulted in 100 cross points per stand. Measurements in grids were made in April 2008. We estimated...
2.2.4. Effects of simulated grazing and trampling on A. nemorosa (dataset 2006–2008)

At Hayesbos, we established eight plots (3 m × 1 m) in a Carpinion forest with large patches of A. nemorosa dominated vegetation (cover per patch: 80–100%; distance between plots: 20–250 m). Each plot was divided in three adjacent subplots of 1 m². Randomly, we assigned control, simulated grazing and simulated trampling treatment to the subplots. In this experiment, we tried to measure a pure, mechanical grazing and trampling effect. For this, we assumed that large herbivores forage on A. nemorosa, without selecting more palatable or nutritious food types. Before treatment, cover percentage was estimated with a decimal scale (Londo, 1984) and the number of flowers was counted (second half of April 2006). Then, we cut off all above ground biomass in the simulated grazing treatment. Collected biomass was dried at 70 °C during 48 h and weighed. Trampling was simulated with a wooden cattle paw dummy (basal “hoof” surface = 49 cm²); in each trampling-subplot we made 40 imprints by pressing the dummy on the vegetation with a weight of ± 100 kg (i.e. ± 2 kg/cm², a comparable pressure of an adult cow). This resulted in complete trampling of the vegetation and disturbance in the upper 5 (± 2) cm of the soil in each trampling-subplot. We repeated all measurements in the second half of April 2007 and April 2008 and collected biomass again in the simulated grazing subplots. Simulated trampling was not repeated in 2007 to assess recovery after a once-only trampling event. Therefore, differences between trampling and grazing effects can only be compared with the 2007 data (one grazing event vs. one trampling event), not with the 2008 data (one trampling event vs. two grazing events).

2.3. Data analysis

2.3.1. Rubus cover before and after grazing management (datasets 1996–2008 and 2002)

A comparison between Rubus cover percentages in the permanent plots of 1996 and 2008 was made using a Repeated Measurements ANOVA with mixed effects (S-plus 8.0). Because in each plot, adjacent subplots (ungrazed exclosure and open grazed) contain juxtaposed relevés, observations inside plots are not independent. For this, we entered plot as a random factor in the analysis, with relevé nested in plot. We decided not to sum the values of individual relevés per subplot to include variance within plots in the analysis. Response data were square root transformed. We entered treatment (grazed or ungrazed) and year (1996 and 2008) and the interaction between treatment and year as fixed factors. We defined a spatial correlation structure with plot as group variable. A significant impact of grazing was to be expected if the interaction term treatment-year was significant: no effect in 1996 (measurements before treatment), a possible effect in 2008. Multiple comparisons using Tukey tests, were made between years in grazed and ungrazed plots.

A comparison between Rubus cover percentages in the two blocks (one before grazing, one permanently ungrazed; dataset 2002) was made using generalised linear models (S-plus 8.0). Response variable Rubus cover was square root transformed; independent factor = treatment.

2.3.2. Presence/absence of forest ground flora before (dataset 2002) and after grazing (dataset 2008)

Comparison of presence/absence frequencies of R. elatior, V. minor and H. helix between the two blocks before grazing (dataset 2002) and between the same blocks (one permanently ungrazed and one grazed since 2004; dataset 2008) were analysed using Yates corrected χ² tests. Further comparisons between 2002 and 2008 were made in the same way.

2.3.3. Comparing Rubus and forest ground flora in grazed and ungrazed forest (dataset 2008)

We used generalised linear mixed models (S-plus 8.0) to analyse cover percentages of Rubus, H. non-scripta and A. nemorosa, number of A. nemorosa and H. non-scripta flowers, presence of flowering stems and grazing damage to H. non-scripta. We used general linear models to analyse stem height of H. non-scripta. A logit and square root transformation (giving the best results to meet conditions of normality) was performed for percentages or presence/absence data and counts, respectively. We defined a spatial correlation structure, using xy-coordinates for all plots or cross points on transects and grids, respectively.

Table 1

Overview of sampling procedure and research aims at Bos t’ Ename. G – grazed/grazing blocks; U – ungrazed blocks; BG – before grazing; comp. – comparison (including statistical testing); perm. – permanent; non-perm. – non-permanent; meas. – measurement.

<table>
<thead>
<tr>
<th>Subject/variable</th>
<th>Research aim</th>
<th>Plot type</th>
<th>Plot set up</th>
<th>Plot no.</th>
<th>Relevé/meas. type</th>
<th>Data source</th>
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<tbody>
<tr>
<td>Rubus</td>
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<tr>
<td>-Cover</td>
<td>1) comp. G–U 1996–2008 perm. (40 × 20 m) random 4, each with U &amp; G subplot (20 × 20 m)</td>
<td>Londo, 4 per subplot i.e. 32 relevés (10 × 10 m)</td>
<td>Cornelis, 1996; this study</td>
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<td>-Height</td>
<td>2) comp. blocks BG 2002 non-perm. (2 × 2 m) random 42 (19 U, 23 before G)</td>
<td>Londo</td>
<td>Buckens, 2003</td>
<td></td>
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<tr>
<td>Forest ground flora</td>
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<tr>
<td>-Frequencies of V. minor, H. helix, P. elatior</td>
<td>3) comp. G–U 2008 non-perm. (2 × 2 m) random 8 transects</td>
<td>412 (206 G, 206 U)</td>
<td>presence/absence</td>
<td>this study</td>
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<tr>
<td>-Cover</td>
<td>4) comp. G–U 2008 non-perm. (2 × 2 m) 8 transects</td>
<td>64 (32 G, 32 U)</td>
<td>meas. this study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. nemorosa</td>
<td>5) comp. blocks BG 2002 non-perm. (2 × 2 m) random + transects</td>
<td>42 (23 BG, 19 U)</td>
<td>presence/absence</td>
<td>this study</td>
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<tr>
<td>-Cover</td>
<td>6) comp. G–U 2008 non-perm. (2 × 2 m) 8 transects</td>
<td>412 (206 G, 206 U)</td>
<td>presence/absence</td>
<td>this study</td>
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<tr>
<td>-Cover</td>
<td>7) comp. BG and G–U 2002–2008 random 42 (19 U, 23 before G)</td>
<td>454 (23 BG, 206 G, 225 U)</td>
<td>presence/absence</td>
<td>this study</td>
<td></td>
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<tr>
<td>-Cover</td>
<td>8) comp. G–U 2002 non-perm. (2 × 2 m) 8 transects</td>
<td>412 (206 G, 206 U)</td>
<td>Londo</td>
<td>this study</td>
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<td>-Cover</td>
<td>9) comp. G–U 2002 non-perm. (2 × 2 m) 8 transects</td>
<td>412 (206 G, 206 U)</td>
<td>counts this study</td>
<td></td>
<td></td>
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<tr>
<td>-Cover</td>
<td>10) comp. G–U 2002 non-perm. (3 × 3 m) 8 grids (27 × 27 m) 72 (36 G, 36 U)</td>
<td>Londo</td>
<td>this study</td>
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<td></td>
<td></td>
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<tr>
<td>-No. flowers</td>
<td>11) comp. G–U 2002 non-perm. (cross point) 8 grids (27 × 27 m) 800 (400 G, 400 U)</td>
<td>counts</td>
<td>this study</td>
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<tr>
<td>-Stem height</td>
<td>12) comp. G–U 2002 non-perm. (cross point) 8 grids (27 × 27 m) 800 (400 G, 400 U)</td>
<td>presence/absence</td>
<td>this study</td>
<td></td>
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<td>-G damage</td>
<td>13) comp. G–U 2002 non-perm. (cross point) 8 grids (27 × 27 m) 800 (400 G, 400 U)</td>
<td>presence/absence</td>
<td>this study</td>
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<tr>
<td>-A. nemorosa</td>
<td>14) comp. G–U 2002 non-perm. (cross point) 8 grids (27 × 27 m) 800 (400 G, 400 U)</td>
<td>presence/absence</td>
<td>this study</td>
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</table>
Rubus cover percentages were modelled with treatment (grazed vs. ungrazed) and forest type as independent variables. The same was done for H. non-scripta and A. nemorosa analyses, but also Rubus cover was included as an independent factor. Before entering other independent variables in these models, we tested for correlations (Pearson’s correlation coefficients) between light penetration and Rubus height \((r = -0.44, P < 0.001)\), Rubus cover and light penetration \((r = -0.42, P = 0.03)\) and between Rubus cover and Rubus height \((r = 0.38, P = 0.008)\). Given the significant correlations, we only included Rubus cover (more observations than light penetration and Rubus height), treatment and forest type as fixed factors in the models. We compared light penetration (%) through Rubus understory and Rubus canopy height in ungrazed and grazed plots \((2 \times 32)\) using generalised and general linear models respectively.

Plots where A. nemorosa was absent \((8\%)\) were removed from the analysis to exclude bias (e.g. absence as a consequence of historical forest use). We controlled for stochastic variation in ungrazed vs. grazed plots. Initial models include all variables and all interactions. Non-significant factors and interactions were gradually eliminated, using a backward procedure. AIC values for goodness of model fit were used to control, whether the model was improved or not after elimination.

2.3.4. Effects of simulated grazing and trampling on A. nemorosa (dataset 2006–2008)

Simulated grazing and trampling effects on A. nemorosa cover, flower abundance and biomass were analysed using Repeated Measurements ANOVA \((S\text{-plus 8.0})\). We entered treatment (grazing, trampling or control), year \((2006, 2007 \text{ and } 2008)\) and the interaction between treatment and year as fixed factors. A significant impact of grazing or trampling was to be expected if the interaction term treatment*year was significant: no effect in 2006 \((P = 0.003)\). Light penetration was significantly higher in grazed plots \((22.0\% \pm 15.9\%\) vs. ungrazed: \(12.1\% \pm 9.2\%\); Tukey test \(P = 0.004)\).

Cover percentage and number of flowers of A. nemorosa were significantly lower in grazed plots \((Fig. 2)\). Overall, Rubus cover had a negative impact on A. nemorosa cover and flowering \((Table 3)\), but it was more clearly expressed in ungrazed plots \((significant interaction between treatment and Rubus cover, Fig. 3)\).

For H. non-scripta, cover percentage, number of flowers per individual, number of fertile plants and stem height were significantly lower in grazed plots \((Fig. 4)\). 71% of H. non-scripta individual plants showed grazing traces to leaves or stems. No significant effect of Rubus cover and no interaction with grazing was found \((Table 3)\).

In none of the analyses, did forest type \((Carpinion vs. Alno-Padion)\) have a significant effect.

3.4. Effects of simulated grazing and trampling on A. nemorosa (dataset 2006–2008)

Cover percentages of A. nemorosa were significantly lower after simulated grazing and trampling \((treatment*year: F = 8.069; P = 0.003)\). However, the reduction in cover percentages was small (less than 10\%, Table 4) for both grazing and trampling. Trampled plots recovered in the second year after disturbance. Grazed plots, that were subject to two treatments \((2006 \text{ and } 2007)\) did not recover by 2008. Flower abundance \((F = 8.247; P = 0.032)\) was lower in trampled and grazed plots, but the reduction was only significant after 2 years. Biomass decreased significantly after simulated grazing, on average with 25% after one year, with \(\pm 30\%\) after two years \((Friedman Anova \chi^2 (N = 8; \ df = 2) = 14.000; P < 0.001, Table 4)\).

Table 2

<table>
<thead>
<tr>
<th>Species</th>
<th>2002</th>
<th>2008</th>
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<tbody>
<tr>
<td></td>
<td>UG (N = 19)</td>
<td>G (N = 206)</td>
</tr>
<tr>
<td></td>
<td>BG (N = 23)</td>
<td>G (N = 206)</td>
</tr>
<tr>
<td>H. helix</td>
<td>26.32 (a)</td>
<td>23.83 (a)</td>
</tr>
<tr>
<td>V. minor</td>
<td>5.26 (a)</td>
<td>6.64 (a)</td>
</tr>
<tr>
<td>P. elatior</td>
<td>15.79 (a)</td>
<td>12.89 (a)</td>
</tr>
</tbody>
</table>

Grass cover decreased significantly \((29.6\% \pm 19.5\%\) in ungrazed plots \((P < 0.001)\). Also canopy height of Rubus was significantly lower in grazed plots \((43.7\% \pm 33.2\%\) vs. ungrazed: \(78.6\% \pm 56.8\%\); Tukey test \(P = 0.006)\).

Cover percentage of H. helix, V. minor and P. elatior are presented in Table 2. In 2002, we found no significant differences in presence frequencies of H. helix, P. elatior and V. minor between the block before grazing and the permanently ungrazed block. Frequency analysis in the same blocks in 2008 revealed a significant difference between grazed and ungrazed blocks for H. helix and V. minor. Both species had disappeared completely from the grazed block. Frequency analyses between years revealed significant differences between the “before grazing block” and the block grazed since 2004 for H. helix and V. minor. Frequencies of P. elatior did not differ between blocks before or after grazing, nor between years \((Table 2)\).

3.3. Comparing Rubus and forest ground flora in grazed and ungrazed forest (dataset 2008)

In grazed plots, Rubus cover was significantly lower than in ungrazed plots \((22.4\% \pm 25.7\%\) vs. ungrazed: \(43.6\% \pm 27.7\%\); Tukey test \(P < 0.001)\). Also canopy height of Rubus was significantly lower in grazed plots \((43.7\% \pm 33.2\%\) vs. ungrazed: \(78.6\% \pm 56.8\%\); Tukey test \(P = 0.006)\). Light penetration was significantly higher in grazed plots \((22.0\% \pm 15.9\%\) vs. ungrazed: \(12.1\% \pm 9.2\%\); Tukey test \(P = 0.004)\).

Some of the species significantly increased in the grazed plots (Table 2), but the number of flower-bearing plants was smaller \((Fig. 4)\). The frequency of Padion species was lower in the grazed plots \((4.5\% \pm 3.4\%\) vs. ungrazed: \(6.6\% \pm 3.9\%\); Tukey test \(P = 0.004)\).

In none of the analyses, did forest type \((Carpinion vs. Alno-Padion)\) have a significant effect.

4. Discussion

Large herbivore grazing \((\pm 0.25 \text{ AU ha}^{-1} \text{y}^{-1})\) reduced cover and height of Rubus and cover and presence of forest ground species in the forest. H. non-scripta cover and flowering decreased and stem height and number of flowers per individual plant was reduced.
The effects of large herbivores on cover and flower abundance of the dominant vernal, unpalatable ground flora species A. nemorosa was comparable to effects on H. non-scripta, but it was likely that the effects on A. nemorosa were mainly due to trampling. The evergreen V. minor and H. helix disappeared from grazed forest parts.

### 4.1. Rubus control

Analyses of different datasets showed that grazing reduced Rubus cover significantly (±30–50%) as compared to ungrazed control plots. In a survey of 105 woodland areas in Northern Ireland overall cover percentages of Rubus were much lower, but in grazed woods cover percentages were significantly lower than in ungrazed woods: 3.9% and 9.6% respectively (McEvoy et al., 2006b). Given the generally high regeneration capacity of Rubus spp., with even over-compensation of lost tissues (Focardi and Tinelli, 2005), grazing pressure needs to be high enough to reduce Rubus cover considerably. McInnes et al. (1992) suggest that moderate levels of shrub browsing by moose (Alces alces) may even increase production efficiency of the shrubs involved. In our study site, cattle grazing pressure in the forest increased in late winter – early spring. In this period of the year, the cattle herd spent more than 28% of its foraging time in woodland habitat, foraging (65% of the time) on the wintergreen leaves and branches of Rubus (Van Uytvanck, unpublished data). Putman (1986) and Maublanc et al. (1991) report a similar seasonal dependent forage behaviour for browsers.

Other factors that might affect Rubus cover and forest ground flora are related to the tree and shrub layer canopy. De Keersmaeker et al. (2004) showed the importance of a well developed coppice or woody shrub layer to enable suppression of Rubus in favour of ground flora. The permanent plots in our study site showed an increase in Rubus cover in ungrazed forest in the period 1996–2008. However, given the relatively short time between the observations and the non-intervention management during the past decades, important changes in shrub and tree canopy structure were not to be expected at the study site.

For conservation management, it is important to assess the importance of Rubus in the diet of large herbivores. The forage quality of Rubus is characterised as mid-low (González-Hernández and Silva-Pando, 1999), mainly because the digestibility is low. In dune ecosystems, Rubus caesius is a desired food source for horses (Cosyns et al., 2001), donkeys (Lamoot et al., 2005a), ponies and cattle (Lamoot et al., 2005b). Crude protein concentrations in Rubus are relatively high: 8.8 ± 3.8% (Heens, unpublished measurements of Rubus in the study site). These concentrations meet the minimal nitrogen requirements of cattle (¼7.2%, Agricultural Research Council, 1980, in WallisDeVries et al., 1998). However, the best forage quality for Rubus is reached in late spring. At this time of the year, Rubus is not a substantial part of the cattle’s diet. It is clear that Rubus will only be eaten if food supply in other habitats and of other, less grazer defensive plant species is too low. This may have important consequences when grazing is applied for Rubus control in forests.

### 4.2. Forest ground flora

High Rubus cover percentage had a clear negative effect on the flowering and cover percentage of A. nemorosa. Although we expected a positive effect of large herbivore grazing on both cover and flowering due to reduced competition, our data did not confirm this hypothesis. Occasional grazing of A. nemorosa is noted (personal observations; observations P. Blondé), but it is not yet clear, whether the species is a valuable food source for large herbivores. For roe deer, A. nemorosa is a constituent of the summer diet (Costa Pérez, 1992, in González-Hernández and Silva-Pando, 1999). Among a list of 33 species of trees, shrubs, forbs, grasses and ferns, A. nemorosa had the highest digestibility (68.1%) and a very high crude protein concentration (20.8%, González-Hernández and Silva-Pando, 1999), but the presence of protoanemonine makes it unpalatable for livestock (Grime et al., 1988; De Cleene and Lejeune, 1999).
Therefore, it is likely that mainly trampling by cattle inhibits growth and flowering of \textit{A. nemorosa}. Results of the grazing-trampling experiment clearly indicate that trampling can decrease cover and flowering, though simulation effects were relatively weak if compared with the transect study. Possible explanations for this are the once-only treatment in the experiment, the combined effect of grazing and trampling in the field and differences in treatment period. Once-only grazing or trampling might allow a better recovery than repeated disturbance in the field (Cole, 1995; Godefroid et al., 2003) and although \textit{A. nemorosa} is an unpalatable species, the combined effect of grazing and trampling may be larger than grazing or trampling alone, as was simulated in the experiment. Moreover, large herbivore trampling of \textit{A. nemorosa} in the field occurs mainly in late winter-early spring, when shoots are small and possibly more vulnerable than in April. Generally, soils are wetter in late winter than in April, resulting in a higher susceptibility to trampling (damaging also the root system of plants) and compaction (Kuss, 1986). Possibly, \textit{A. nemorosa} uses the energy reserves in the rhizomes to compensate trampling damage to below and above ground plant parts. These reserves are largely responsible for above ground growth and flowering and therefore, a reduction in biomass and flowering potential is likely to happen. It could take many seasons of additional irradiance to build up these reserves. In mesophilous forests communities, Roovers et al. (2004) found high recovery percentages, but mainly herbaceous species, with a relatively high resilience after trampling were involved. In our trampling experiment, we also found a rather fast recovery of \textit{A. nemorosa} leaves (conversely to grazing treatment), but flowering remained low in the following years.

For the palatable \textit{H. non-scripta}, we found no effects of \textit{Rubus} cover, though it was much higher in ungrazed forest. Probably, \textit{H. non-scripta} is more shade tolerant than \textit{A. nemorosa}. The

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{\textit{Anemone nemorosa} cover percentages and flower abundance in relation to \textit{Rubus} cover in grazed (since 2004) and permanently ungrazed forest (Bos t’ Ename). Larger dots represent more relevés with the same \textit{Rubus}/\textit{Anemone} cover ratio than smaller dots (5 frequency classes with a linear relationship).}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Characteristics of \textit{Hyacinthoides non-scripta} stands in grazed (since 2004) and permanently ungrazed forest (Bos t’ Ename); all histograms with standard error. Different letters indicate significant differences between values (Tukey test \(P < 0.05\)).}
\end{figure}
emergence and flowering period of \( H. \ non-scripta \), which are 2–3 weeks later than those of \( A. \ nemorosa \).\] When trees already have leaves and light penetration is restricted, strengthen this idea.\] Grazing had a clear negative impact on both individual plants and stands.\] McEvoy et al. (2006b) showed significant differences in cover of \( H. \ non-scripta \) in grazed (2.5%) and ungraazed (10.1%) woods. However, together with \( A. \ nemorosa \), it is not considered as a preferential food species for either grazed or ungrazed woods. In our study, we found very high percentages of grazed \( H. \ non-scripta \) individuals, resulting in reduced cover (mainly due to increased damage to leaves) and stem height. Cooke (1997) found comparable results: shorter stems and leaves due to grazing of muntjac (\( Muntiacus reevesi \)).\] The most profound impact may be on the ability to produce seeds (Littlemore and Barker, 2001).\] Our results are in line with these findings, showing a significant reduction in the number of fertile plants and the number of flowers per individual.\] From the total disappearance after four years of grazing, we can deduce that \( H. \ helix \) and \( V. \ minor \) were highly preferred forest species. Experiences with a comparable forest in the east of Flan- ders (Altenbroek – Voeren, 43 ha) are similar: in wintertime, cattle are attracted to species with wintergreen leaves and forage on it till the food source is depleted (Van Uytvanck, unpublished data).\] For \( H. \ helix \), González-Hernández and Silva-Pando (1999) showed excellent forage quality and, together with \( R. \ fruticosus \), it was the primary forage for roe deer in autumn and winter (Jackson, 1980).\] The complete removal through grazing of \( H. \ helix \), which often dominates ground flora in drier parts of deciduous forests, may trigger important changes in community composition by providing a release in competition for less vigorous forbs (McEvoy and McAdam, 2002).\] This could be of interest in N-American forests, where \( H. \ helix \) is a non-native, invasive species, having a substantial negative impact on forest ground flora (Biggerstaff and Beck, 2007).\] In our study, \( P. \ elatior \) was not eaten by cattle.\] Kirby (2001) reports grazing of this species by deer: muntjac usually eats flowers, fallow deer (\( Dama dama \) dama) additionally eats leaves.\] This appears to weaken plants such that they were less able to withstand the effects of dry summers.\] Kirby (2001) also found evidence of grazing-sensitivity for a number of forest species such as \( V. \ myrtillus \), \( L. \ sylvatica \), \( M. \ perennis \), \( D. \ dilatata \) and \( L. \ pericyclumenum \) in British woods.\] Other factors that might have influenced forest ground flora cover and flowering in the study site are changes in soil, hydrology, litter quality and quantity (Hérault et al., 2005).\] However, these changes may rather affect forest ground flora condition on the long term (Honnay et al., 1998) than in a time span of four years.\] 4.3. Rubus cover and grazing interaction\] The interaction between grazing and \( R. \) cover suggests that in grazed plots, the limiting factor for \( A. \ nemorosa \) shifts from light deficiency under large, tall and dark \( R. \) thickets to grazing and trampling damage in plots with lower \( R. \) cover. The active mechanism here, is probably related to associative resistance (Callaway et al., 2005; Bossuyt et al., 2005; Van Uytvanck et al., 2008).\] Although \( R. \) is considered as a palatable species and sometimes as a preferred food source for large herbivores (Garin et al., 2000), it has spiny stems and large thicket offers, to a certain extent, protection to ground flora such as \( A. \ nemorosa \).\] Gómez et al. (2001) showed that shrub thickets have to be large enough to function as an effective barrier for grazers.\] For \( R. \), this means that large patches, offer more protection to grazing and trampling than small ones.\] Large patches are also higher and darker due to the growth form of \( R. \ fruticosus \) agg., which has outgrowing suckers that support each other. Small \( R. \) patches are more easily eaten and entered by cattle and are probably less able to protect \( A. \ nemorosa \) from trampling.\] Larger patches are eaten as well, but they hinder movement of animals through it (Kirby and Woodell, 1998).\] For early growing and flowering woodland specialists like \( A. \ nemorosa \) (March–April), increased light penetration, due to the reduction of the shading canopy of the evergreen \( R. \ fruticosus \) agg. (dominantly present at the study site), may enhance vitality (Barkham, 1992).\] In our study site, this advantage probably was counteracted by severe trampling damage.\] The increase in light may also allow non-woodland species to establish (Kirby, 2001).\] Our data concerning large herbivore effects, only cover four years.\] Given the fact that cattle were able to reduce \( R. \) cover considerably, it is possible that the forest will gradually lose its role as winter food supply habitat. Therefore, the real grazing and trampling pressure on forest ground flora may decrease in time.\] In contrast with \( H. \ non-scripta \), rhizomatous species such as \( A. \ nemorosa \) may benefit from moderate disturbance (Grime et al., 1988; Van Staalduinen et al., 2007).\] Shoots of this species may be produced from very small broken rhizome fragments remaining in the upper surface of the soil after disturbance (Barkham, 1992).\] 4.4. Conclusions and practical applications\] Year-round grazing with cattle is an effective and quick-working measure to control \( R. \) vegetation in small forests.\] However, in the short term, mainly negative effects on forest ground flora were found.\] Trampling by cattle, mainly foraging on \( R. \) in late winter – early spring, had negative effects on cover and flowering of the unpalatable \( A. \ nemorosa \).\] Grazing clearly has a negative impact on the palatable \( H. \ non-scripta \) and evergreen ground flora species.\] The latter may disappear quickly from grazed forests.\] Extrapolation to long-term effects is uncertain, but these may include indirect effects on the whole system as well (e.g. soil compaction). Managers should try to find a balance between positive and negative effects of large herbivore grazing in ancient forests.\] We advise to maintain a low or moderate grazing pressure, i.e. below 0.25 \( \text{AU ha}^{-1} \text{y}^{-1} \) in a mosaic where also a substantial part of grassland is included.\] This grazing pressure however, may be too high for less productive ecosystems or other vegetation types and needs evaluation in the field.\] Providing temporal time gaps in grazing may prevent excessive grazing and trampling damage to vulnerable forest ground flora (e.g. in spring) and may give opportunities for recovery (e.g. a 1–2 years exclosure period).\] Both management measures are in line with guidelines provided by Mountford and Peterken (2003) for the New Forest.
(0.3 cows or 0.15 ponies ha⁻¹; short periodic reductions and increases in herbivore numbers). Seasonal grazing may prevent the loss of wintergreen species. Insight into the effects of different grazing regimes clearly needs further research. Managers should be aware that a massive flowering vernal forest most often reflects a high and long lasting cultural impact and a rather intensive forest management. Certainly, some of these massive flowering forests need preservation and an appropriate management. In large woodland areas, a more heterogeneous, patchy vegetation pattern as a result of the implementation of modern, less intensive and more natural grazing systems may be a valuable conservation alternative (Hodder et al., 2005), but it may imply a reduction in the presence, cover or flowering of forest ground flora species that often dominate the ungrazed forest.

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