Intensified grazing affects endemic plant and gastropod diversity in alpine grasslands of the Southern Carpathian mountains (Romania)

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Abstract: Alpine grasslands in the Southern Carpathian Mts, Romania, harbour an extraordinarily high diversity of plants and invertebrates, including Carpathic endemics. In the past decades, intensive sheep grazing has caused a dramatic decrease in biodiversity and even led to eroded soils at many places in the Carpathians. Because of limited food resources, sheep are increasingly forced to graze on steep slopes, which were formerly not grazed by livestock and are considered as local biodiversity hotspots. We examined species richness, abundance and number of endemic vascular plants and terrestrial gastropods on steep slopes that were either grazed by sheep or ungrazed by livestock in two areas of the Southern Carpathians. On calcareous soils in the Bucegi Mts, a total of 177 vascular plant and 19 gastropod species were recorded. Twelve plant species (6.8%) and three gastropod species (15.8%) were endemic to the Carpathians. Grazed sites had lower plant and gastropod species richness than ungrazed sites. Furthermore, grazed sites harboured fewer gastropod species endemic to the Carpathians than ungrazed sites. On acid soils in the Fagaras Mts, a total of 96 vascular plant and nine gastropod species were found. In this mountain area, however, grazed and ungrazed sites did not differ in species richness, abundance and number of endemic plant and gastropod species. Our findings confirm the high biodiversity of grasslands on steep slopes in the Southern Carpathian Mts and caution against increasing grazing pressure in these refuges for relic plants and gastropods as well as for other invertebrates.

Key words: Alpine grassland; biodiversity; Bucegi Mts; Gastropoda; grazing; Fagaras Mts; vascular plants

Introduction

Alpine grasslands are unique habitats for a variety of plant and invertebrate species (Körner 1999; Nagy et al. 2003). Seasonal pastoral activities have been practiced for many centuries on accessible areas of these natural grasslands (Messerli & Ives 1997). To increase grazing areas, semi-natural grasslands have been created in mountain areas below the tree line by forest logging (Ellenberg 1996; Coldea 2003). Although vascular plant species richness of various natural and semi-natural grasslands in general increases under moderate grazing (Collins et al. 1998; Sternberg et al. 2000), effects of grazing on biodiversity vary considerably among ecosystems and among different taxa (Niemelä & Baur 1998; Balmer & Erhardt 2000; Cremene et al. 2005; Baur et al. 2006). Moreover, patterns of biodiversity and their driving processes obviously vary with spatial and temporal scale (Crawley & Harral 2001; Dullinger et al. 2003). Pasture management should therefore be adjusted to the local conditions to identify and implement the best strategy of biodiversity conservation.

In contrast to the general trend of grassland abandonment in remote areas, land use is increasingly intensified in easily accessible mountain areas (Tasser & Tappeiner 2002). Transhumant shepherding, the seasonal migration of sheep to suitable grazing grounds, is the traditional use of subalpine and alpine grasslands in the Southern Carpathian Mts (Romania). For example, historical records document sheep grazing in the Bucegi Mts since the beginning of the sixteenth century (Barbulescu & Motca 1983). In these mountains, the sheep flocks have always been large, forcing the animals to graze also in adjacent forests, which were clearcut to extend the pastures in the 19th century (Coldea 2003). More recently, the size of the sheep flocks has increased further as a consequence of the altered socio-economic situation since 1989. Detrimental effects of overgrazing and trampling on plant diversity and vegetation structure, and eroded soils have been reported on the plateau.
of the Bucegi Mts (Barbulescu & Motca 1983; Coldea 2003). As a result, grazing pressure has increased on so far extensively used, adjacent steep mountain slopes. This is of particular concern as the Southern Carpathians harbour a high number of endemic and relic plant and invertebrate species (ICAS 1996; Ioras 2003).

The aim of the present study was to examine effects of intensified grazing on these steep slopes, so far only occasionally grazed by sheep and wildlife (chamois). As indicators of biodiversity we used vascular plants and terrestrial gastropods, which both have been shown to be sensitive indicators of habitat change (Ellenberg 1996; Labaune & Magnin 2002). We assessed the species diversity and species abundance of vascular plants and terrestrial gastropods in both intensively grazed sites and in sites only occasionally grazed by chamois in two areas in the Southern Carpathians, Romania. In particular, we addressed the following questions: (1) How are plant and gastropod diversity and abundance affected by intensified sheep grazing on steep slopes? (2) How do endemic and threatened (red-listed) species respond to intensified grazing? (3) Are responses to grazing correlated between plants and gastropods?

Material and methods

Study areas and sampling

The effect of intensified pastoral management on the alpine plant and gastropod diversity was examined in two areas in the Southern Carpathians in Romania: in the Bucegi Mts (45°24' N, 25°31' E) 30 km SSW of Brasov and in the Fagaras Mts (45°37' N, 24°37' E) 40 km SE of Sibiu. The two mountain areas are 80 km apart from each other and differ in the underlying bedrock: the investigated slopes of the Bucegi Mts consist of limestone, while the sites in the Fagaras Mts are situated on siliceous bedrock.

The Bucegi Mts are built of Mesozoic sedimentary rocks (mainly limestones, sandstones and conglomerates), which are exposed to erosion since middle Tertiary. This resulted in complex tectonic and morphological structures, with numerous small valleys and ridges on steep slopes. In the Bucegi Mts, the first protected areas were established in 1943 (www.bucegipark.ro; accessed 15.02.2006). The protected areas were several times enlarged, resulting in the Bucegi Nature Park with a total area of 326.6 km², including 13 nature reserves (ca. 90 km²) in 2000. A significant part of the nature reserves is located on the steep mountain slopes, while the gently inclined slopes on the plateau, which are heavily overgrazed at many places and contain huge areas of eroded soil, are not protected. Our study was conducted on natural alpine grasslands at the border of the Abruptul Prahovean Nature Reserve (Table 1).

The Bucegi Nature Park contains approximately 30% of the total plant diversity in Romania. The steep slopes of the Bucegi Mts harbour a most interesting flora with numerous Carpathian endemic and glacial relic plants (Coldea & Cristea 1998). At places with calcareous bedrock, the gastropod fauna is rich with several species endemic to the Carpathians (Grossu 1981, 1983).

The Fagaras Mts are a traditional area for Romanian shepherds, who have been practicing transhumant pastoralism for many centuries (Puscaru-Sorocceanu et al. 1981). Our study sites were located on crystalline bedrock with brown acid soils in subalpine, man-made grasslands in the valley north of the Balea Nature Reserve. The flora of this valley is characteristic for the alpine region of the Southern Carpathians and includes several Carpathian endemic species (Puscaru-Sorocceanu et al. 1981; Barbulescu & Motca 1983). The Balea Nature Reserve is considered as relatively species-poor in invertebrates (www.ipmsb.ro/rezervnat.htm#balea; accessed 28.02.2006). However, some Carpathian endemic invertebrates can still be found in this area, e.g. the land snail Arianta aethiops aethiops (Bielz, 1851) (Baur et al. 2000).

In both mountain areas we investigated similar sites that differed in grazing intensity. In July 2003, we surveyed the diversity and abundance of vascular plants and terrestrial gastropods on steep slopes at five sites intensively grazed by sheep (hereafter grazed sites) and at five sites only occasionally grazed by chamois (hereafter ungrazed sites) in the Bucegi Mts (Table 1). Grazed study sites were parts of pastures repeatedly visited by large flocks of sheep (> 500 individuals). Ungrazed study sites were situated on the same slopes but separated from grazed sites either by rock walls or stands of Pinus mugo (Table 1).

<table>
<thead>
<tr>
<th>Study site</th>
<th>Location</th>
<th>Elevation (m)</th>
<th>Vegetation height (cm)</th>
<th>Soil pH</th>
<th>Percentage area covered by rocks and scree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucegi Mts</td>
<td>1</td>
<td>1100</td>
<td>23.0 ± 8.0</td>
<td>5.0</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1400</td>
<td>29.0 ± 5.0</td>
<td>5.5</td>
<td>30</td>
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<td></td>
<td>3</td>
<td>1800</td>
<td>35.0 ± 10.0</td>
<td>6.0</td>
<td>50</td>
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<td>4</td>
<td>2200</td>
<td>42.0 ± 15.0</td>
<td>6.5</td>
<td>70</td>
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<tr>
<td></td>
<td>5</td>
<td>2600</td>
<td>50.0 ± 20.0</td>
<td>7.0</td>
<td>90</td>
</tr>
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</table>

For plants we compiled a species list of grasses and forbs for each site. In addition to presence/absence, we also recorded the abundance of each species in a subplot of 10 × 10 m using the Braun-Blanquet method (1964). Walking in a zigzag line over the entire study site (20 × 30 m) the list of plant species was completed by recording all new species observed. Plant identification followed Tutin et al. (1964–1980) and Ciocarlan (2000).

Species richness and relative abundance of terrestrial gastropods were assessed by visually searching for living snails and slugs and for empty shells. Five people searched in each 20 × 30 m plot for a total of 120 minutes. Fieldwork was only conducted under conditions favourable for gastropod activity (moist vegetation and high air humidity).


At each study site, the following ecological variables were measured: elevation (in metres above sea level, extracted from topographical maps; Bucegi Mts, scale 1 : 53,000; Fagaras Mts, scale 1 : 60,000), exposure (degrees from south using a compass), inclination (average of six measurements), soil pH (average of six soil samples using the Helligem method; AVM Analyseverfahren, Freiburg, Germany), two measures of vegetation height (average height of the forb and the grass layer, both based on six measurements), and the percentage area covered by rock and scree (estimated to the nearest 10%).

In the Bucegi Mts, grazed and ungrazed study sites did not differ in elevation, soil pH and area covered by rocks and scree (Table 1; t-tests, in all comparisons, P > 0.35). However, grazed sites faced slightly more to north-east, whereas ungrazed sites tended to face to south-east (Mardia-Watson-Wheeler-test, P = 0.05). Furthermore, grazed sites occurred on slightly flatter slopes than ungrazed sites (33.8° ± 3.8° (SD) vs 39.2° ± 1.9°; t = 2.94, P = 0.0188). As expected, the vegetation was shorter at grazed sites than at ungrazed ones (forb height: 7.0 ± 2.7 cm vs 23.0 ± 2.7 cm, t = 9.24, P < 0.0001; grass height: 18.0 ± 4.5 cm vs 30.0 ± 0 cm, t = 6.00, P = 0.0003).

In the Fagaras Mts, grazed and ungrazed sites did not differ in exposure, elevation, inclination, soil pH and area covered by rocks and scree (Table 1; t-tests, in all comparisons, P > 0.14). Again, the vegetation was shorter at grazed...
than at ungrazed sites (forb height: 6.8 ± 2.4 cm vs 18.8 ± 8.5 cm, t6 = 2.71, P = 0.0352; grass height: 22.5 ± 5.0 vs 37.5 ± 9.6 cm, t6 = 2.78, P = 0.0321).

Data analyses
The StatView program package (SAS Institute 1998) was used for statistical analyses. Means ± 1 SD are given unless otherwise stated. In all analyses we considered the study sites as the unit of investigation. As calcareous and siliceous soils are known to harbour a different flora and fauna, we analysed data from the Bucegi and Fagaras Mts separately. Data on species richness, number of gastropod individuals, and number of endemic and red-listed species were log-transformed (if necessary log(x + 1)).

Because the grazed and ungrazed sites examined in the Bucegi Mts slightly differed in exposure, we used analyses of covariance (ANCOVA, type III model) with grazing/no grazing as factor and exposure as covariate to examine possible differences in species richness, number of gastropod individuals, and number of endemic and red-listed species. Similarly, data from the Bucegi Mts were analysed using the same ANCOVA-model with inclination as covariate. However, in no case did inclination have a significant influence on the examined variables. Therefore, these analyses are not presented. In the Fagaras Mts, the grazed and ungrazed sites examined differed neither in exposure nor in inclination. For this area we used unpaired t-tests to examine possible differences between grazed and ungrazed sites in species richness, number of gastropod individuals, and number of endemic and red-listed species.

We used detrended correspondence analysis (DCA) to examine differences in plant and gastropod communities between grazed and ungrazed study sites (Hill & Gauch 1980). DCA was performed separately for both groups of organism and both mountain areas. For the DCA, the vegetation cover-abundance code adapted from Braun-Blanquet (1964) was applied using the following weights: 0.1 for ‘R’, 0.5 for ‘+’, 3 for the category 1, 7.5 for the category 2, 15 for the category 3, 25 for the category 4, and 40 for the category 5 (see Buschmann et al. 2005). Prior to ordination, the data were log-transformed. Species that were less frequent than the median frequency were down-weighted in proportion to their frequencies (Elertsen et al. 1990). DCA was performed using CANOCO version 4.5 (ter Braak & Smilauer 2002).

In plants, comparisons of species richness and number of endemic and red-listed species are based on the species list of each study site (20 × 30 m), whereas comparisons of communities are based on abundance data of 10 × 10 m subplots.

To examine whether grazed and ungrazed sites differed in the number of endemic plants or gastropods, we assigned each species to one of the following categories: Romanian Carpathian endemic (occurring exclusively in the Carpathians of Romania), Eastern European endemic (Balkanic, Pontic, Carpathic and/or Dacic distributions) and widespread (naturally occurring in large areas of one or more continents). Total cover of plants endemic to the Carpathians was calculated for each site as the sum of the cover values of all Carpathian endemic plants (see above). In Romania, a red list exists for plants (Boscaiu et al., 1994) but not for terrestrial gastropods.

We used Pearson’s correlations to examine possible correlations between species richness and numbers of endemic and red-listed species within and between plants and gastropods. For data of the Bucegi Mts, we calculated partial correlations, keeping exposure constant.

Results

Plant and gastropod species richness
A total of 177 plant species was recorded at the study sites of the Bucegi Mts. Grazed sites had a lower plant species richness (57.8 ± 10.9; mean ± SD) than ungrazed sites (64.2 ± 8.6; ANCOVA: F1,6 = 6.44, P = 0.0443). The exposure of the sites did not affect the number of plant species (P = 0.51), but there was a tendency for an interaction between grazing and exposure (P = 0.0573). Nineteen different gastropod species were recorded at the study sites of the Bucegi Mts. Grazed sites harboured fewer gastropod species (5.4 ± 3.5) than ungrazed sites (8.4 ± 2.3; ANCOVA: F1,6 =
Fig. 1. Ordination diagram based on detrended correspondence analysis of plants and terrestrial gastropods in grazed and ungrazed grasslands in the Southern Carpathians, Romania, displaying the major variation in species composition: A – plants in the Bucegi Mts; B – plants in the Fagaras Mts; C – terrestrial gastropods in the Bucegi Mts; D – terrestrial gastropods in the Fagaras mountains. Open dots indicate ungrazed sites and full dots grazed sites. Numbers refer to the study sites (see Table 1).

6.00, \( P = 0.0498 \)). Again, site exposure did not influence the number of gastropod species (\( P = 0.29 \)), and there was a tendency for an interaction between grazing and exposure (\( P = 0.0573 \)).

In all, 96 plant species were found in the study sites on siliceous bedrock in the Fagaras Mts. Grazed (29.3 ± 6.4) and ungrazed (30.8 ± 4.6) sites did not differ in plant species richness (\( t_6 = 0.46, P = 0.66 \)). At the same sites, a total of 9 gastropod species was recorded. Grazed sites (3.3 ± 2.2) and ungrazed sites (3.8 ± 1.3) did not differ in gastropod species richness (\( t_6 = 0.68, P = 0.52 \)).

Community structure

In plants growing in the Bucegi Mts, the DCA ordination revealed a separation of grazed and ungrazed study sites, except that one grazed site (#10) was positioned among ungrazed sites (Fig. 1A). The first axis (Eigenvalue = 0.379) explained 25.1% of the variance in species data (together with the second axis 37.7%). In plants of the Fagaras Mts, grazed and ungrazed sites were clearly separated (Fig. 1B). The first axis (Eigenvalue = 0.683) explained 28.4% of the variance in plant species data (together with the second axis 39.6%). Similarly, in terrestrial gastropods living in the Bucegi Mts, the DCA ordination revealed a clear separation of grazed and ungrazed study sites (Fig. 1C). The first axis (Eigenvalue = 0.273) explained 27.7% of the variance in species data (together with the second axis 35.7%). In gastropods of the Fagaras Mts, however, there was no separation between grazed and ungrazed sites (Fig. 1D). The first axis (Eigenvalue = 0.534) explained 40.0% of the variance in gastropod species data (together with the second axis 59.1%).

Abundance of gastropods

A total of 1,611 gastropod individuals were recorded (1,496 in the Bucegi Mts and 115 in the Fagaras Mts). In the Bucegi Mts, on average 114.6 ± 62.9 individuals were found in grazed sites and 184.6 ± 47.6 individuals in ungrazed sites. However, due to the large within-treatment variation in number of individuals the difference in gastropod abundance was not significant (ANCOVA: \( F_{1,6} = 1.16, P = 0.32 \)). The exposure of the site did not influence the number of gastropod individuals recorded (\( P = 0.80 \)) and there was no interaction between grazing and exposure (\( P = 0.52 \)). Similarly, grazed and ungrazed sites in the Fagaras Mts did not differ in the number of gastropod individuals (15.8 ± 4.0 vs 13.0 ± 9.8; \( t_6 = 0.92, P = 0.39 \)).

In the Bucegi Mts, the number of recorded gastropod individuals increased with increasing grass height (partial correlation, exposure kept constant: \( r = 0.82, n = 10, P = 0.0086 \)). No similar relationship between number of gastropods recorded and vegetation height was found in the Fagaras Mts (\( r = -0.17, n = 8, P = 0.70 \)).

The two mountain areas differed also in the proportion of slugs (gastropods without shell) found. In the Bucegi Mts, only 14 (0.9%) out of the 1496 individuals recorded were slugs, whereas in the Fagaras Mts 88 (76.5%) of the 115 gastropod individuals were slugs (chi square = 1028.8, df = 1, \( P < 0.0001 \)).
Endemism

Twelve (6.8%) of the 177 plant species recorded in the Bucegi Mts were endemic to the Carpathians (Cerastium transsilvanicum Schur, Dianthus gelidus Schott, Nyman and Kotschy, Dianthus tenuifolius Schur, Gypsophila petraea (Baumgarten) Reichenbach, Hypericum richeri ssp. transsilvanicum Celakovsky, Koeleria macrantha ssp. transsilvanica Schur, Onobrychis montana ssp. transsilvanica Simonkai, Ozytopis carpatica von Uechtritz, Phyteuma wagneri Kernner, Saxifraga demissa Scott and Kotschy, Thlaspi dacieum Heuffel and Thymus pulcherrimus Schur) and another 20 species (11.3%) were endemic to Eastern Europe. The name of plant species endemic to the Carpathians tended to be lower in grazed sites (3.0 ± 2.6) than in ungrazed sites (4.0 ± 1.4; ANCOVA: F1,6 = 5.18, P = 0.0632). The number of Carpathian endemic plant species was not affected by the exposure of the sites (P = 0.21), but there was a significant interaction between grazing and exposure (P = 0.0494), indicating that the number of endemic plant species in grazed areas was differently influenced by the combined effects of grazing and exposure. Furthermore, the total cover of Carpathian endemic plants was lower in grazed (1.0 ± 1.5%) than in ungrazed sites (3.9 ± 3.8%; ANCOVA: F1,6 = 10.03, P = 0.0194). The exposure of the sites did not influence the total cover of endemic plants (P = 0.89), but there was a tendency for an interaction between grazing and exposure (F1,6 = 5.94, P = 0.0506).

Two (2.1%) of the 96 plant species recorded in the Fagaras Mts were endemic to the Carpathians (Hypericum richeri ssp. transsilvanicum and Thymus pulcherrimus) and another nine species (9.4%) were endemic to Eastern Europe. Grazed and ungrazed sites did not differ in the number of Carpathian endemic plant species (1.3 ± 0.6 vs 0.5 ± 0.6; t6 = 1.15, P = 0.29). Neither did the grassland types differ in total cover of plants endemic to the Carpathians (grazed: 0.2 ± 0.3%, ungrazed: 0.8 ± 1.5%; t6 = 0.11, P = 0.92).

Three (15.8%) of the 19 gastropod species recorded in the Bucegi Mts were endemic to the Carpathians [Alopia canescens (Charpentier, 1852), Alopia livida (Menke, 1830) and Chondrula venerabilis (Pfeiffer, 1853)] and two further species [Oxychilus inopinatus (Ulicny, 1887) and Faustina faustina (Rossnässler, 1835)] were endemic to Eastern Europe. The number of gastropod species endemic to the Carpathians was lower in grazed than in ungrazed sites (1.5 ± 0.5 vs 2.2 ± 0.4; ANCOVA: F1,6 = 6.67, P = 0.0416). Site exposure did not influence the number of endemic gastropod species (P = 0.17), and there was no interaction between grazing and exposure (F1,6 = 5.59, P = 0.06). Considering the number of gastropod individuals endemic to the Carpathians, on average 81.4 ± 53.7 individuals were found in grazed sites and 109.2 ± 33.4 in ungrazed sites. However, because of the large within-treatment variation in number of endemic individuals, this difference was not significant (ANCOVA: F1,6 = 0.29, P = 0.61). Furthermore, there was no effect of site exposure on the number of endemic gastropod individuals (P = 0.54) nor was there any interaction (P = 0.89). Considering single species, the Carpathian endemic A. livida and the Eastern European endemic F. faustina occurred in most of the sites examined. The abundance of both species did not differ between grazed and ungrazed sites (ANCOVA, P = 0.71 and P = 0.92, respectively). However, the abundance of another Carpathian endemic, C. venerabilis was affected by sheep grazing: 5.4 ± 7.8 individuals were found in grazed sites and 70.0 ± 39.1 individuals in ungrazed sites (ANCOVA: F1,6 = 10.54, P = 0.0175). The abundance of C. venerabilis was not significantly influenced by the exposure of the site (ANCOVA: P = 0.07), but there was an interaction between grazing and exposure (F1,6 = 7.09, P = 0.0374), indicating that this species was differently influenced by the combined effects of grazing and exposure. C. venerabilis occurred in all five ungrazed sites and in two of the five grazed sites. The other two endemics (A. canescens and O. inopinatus) were only found at a single site each.

None of the nine gastropod species found in the study sites of the Fagaras Mts was endemic to the Carpathians.

Red-listed species

In the Bucegi Mts, four vulnerable and 19 nearly threatened (rare) plant species were recorded in the sites examined (no critically endangered or endangered species occurred in these sites). Grazed and ungrazed sites did not differ in the number of red-listed plant species (total of species considered as vulnerable or nearly threatened; grazed sites 10.4 ± 2.4%, ungrazed sites 8.2 ± 3.3%; ANCOVA: F1,6 = 3.86, P = 0.10). The exposure of the sites did not influence the number of red-listed species (P = 0.78), and there was no interaction between grazing and exposure (P = 0.09).

In the Fagaras Mts, one vulnerable and four nearly threatened plant species were found in the study sites. Grazed and ungrazed sites did not differ in the number of red-listed plant species (2.0 ± 1.6 vs 1.8 ± 1.0; t6 = 0.04 P = 0.97).

Correlations between plants and gastropods

Plant species richness was positively correlated with gastropod species richness in the Bucegi Mts (partial correlation, keeping exposure constant, r = 0.67, n = 10, P = 0.0480), but not in the Fagaras Mts (r = −0.48, n = 10, P = 0.25). In the Bucegi Mts, plant species richness was also positively correlated with the number of plants endemic to the Carpathians (partial correlation r = 0.91, n = 10, P = 0.0003) and the number of Carpathian endemic gastropods (partial correlation r = 0.77, n = 10, P = 0.0116). However, the number of red-listed plant species was neither correlated with plant species richness nor with the number of endemic plants or gastropods. Furthermore, none of these variables were intercorrelated in the Fagaras Mts.

Discussion

Over the past centuries, pastoralism has taken up much
of the grasslands in the Southern Carpathians (Barbulescu & Motca 1983). Due to the high grazing pressure, the grassland areas were stepwise enlarged by clear-cutting forests and areas covered by shrubs and bushes (Puscaru-Soroceanu et al. 1981). However, the problem of overgrazing by large flocks of sheep grazing in relatively small areas remained. The huge number of sheep reduced plant diversity, and subsequently, the soil became eroded, particularly on flatter parts of the mountains (Coldea 2003). As a consequence, the originally wide-spread, species-rich grasslands can today only be found on the steeper slopes, which until recently were less intensively or not at all grazed by livestock. However, since 1989, the altered socioeconomic conditions in Romania have favoured a further increase in the size of sheep flocks, which still have to graze on the same mountain pastures. As a result, grazing pressure has extended into these unique, species-rich grassland remnants on the steeper slopes.

Our study shows that in the Bucegi Mts species richness of plants and terrestrial gastropods is lower in grasslands on steep, intensively grazed slopes compared with sites only occasionally grazed by wildlife even though red-listed plant species were not affected. Management by grazing is known to alter the botanical composition and structure of grassland vegetation (Morris 2000). Intermediate levels of disturbance are assumed to increase plant species richness and reduce the dominance of competitive species (Curry 1994). However, effects on gastropod communities are less well studied. Grazing may influence gastropods indirectly by altering the amount and quality of the food supply and by changing the microclimate, or directly by trampling the snails’ shells (Baur 1986; Boschi & Baur 2007). The latter is of particular importance for gastropods, because on steep slopes grazing sheep frequently move pieces of stone that results in crushed snails (Baur et al. 2000). Our results indicate that the extent of disturbance by grazing is too high to maintain the former species-rich plant and gastropod communities in the Bucegi Mts.

The effects of intensive sheep grazing on the plant and gastropod communities of acid soils in the Fagaras Mts were less pronounced. Areas with siliceous bedrock are generally less species-rich in plants and particularly in gastropods than areas with calcareous soils (Ellenberg 1996; Wäreborn 1970, 1992). Hence, in such areas an increased grazing pressure might not so strongly affect species richness. However, in the present study, species composition and abundance in plants were altered in a characteristic and pronounced way in the Fagaras Mts (Fig. 1B), suggesting that intensive sheep grazing affects the vegetation composition also on siliceous bedrock.

On acid soils only a limited number of gastropods can cope with the calcium carbonate deficiency. Slugs (gastropods without shell) can better live under such conditions. This may explain the high proportion of slugs in the Fagaras Mts. However, gastropod abundance and species richness remained low, preventing significant differences between grazed and ungrazed sites. Furthermore, slugs are presumably less sensitive to livestock trampling than shelled gastropods (Boschi & Baur 2007).

With our sampling approach we might have missed a few rare gastropod species (cf. Cameron & Pokryszko 2005). Our focus was, however, the comparison of two types of land use. Consequently, we applied the same samling effort per plot in either land use type. The observed differences are conservative because the probability of overlooking a snail is rather higher in tall vegetation of ungrazed sites than in short vegetation of grazed sites.

Both investigated mountain areas harboured species endemic to the Carpathians, but they were more numerous in the calcareous grasslands of the Bucegi Mts than in the Fagaras Mts. In the Bucegi Mts grazed sites harboured fewer endemic gastropod species than ungrazed sites. There was also a tendency for grazed sites to contain fewer endemic plant species than ungrazed sites. Furthermore, the total cover of Carpathian endemic plants was lower on grazed slopes than on ungrazed slopes in this mountain area. Different endemic plant and gastropod species reacted differently to grazing pressure. For example, the Carpathian endemic gastropod Chondrula venerabilis is a specialized grassland species, which showed a reduced abundance in grazed sites. By contrast, the Carpathian endemic Alopia livida and the Eastern European endemic Faustina faustina, two gastropod species feeding on algae and lichens, occur mainly on vertical rock surfaces and thus are less exposed to trampling by grazing livestock. Hence, the abundance of both A. livida and F. faustina did not differ between grazed and ungrazed sites.

Plant species richness was positively correlated with that of terrestrial gastropods in the Bucegi Mts. In steppe-like grasslands and their seral stages of succession in Transylvania, Romania, no correlation between plant and gastropod species richness was found (Cremene et al. 2005). Similarly, the species richness of vascular plants was a poor indicator for species richness of gastropods in nutrient-poor, dry calcareous grasslands in Switzerland (Baur et al. 1996; Niemelä & Baur 1998). In the present study, plant diversity may not directly influence gastropod diversity, but both may respond to similar environmental conditions.

Implications for conservation and management
Our study shows that in the Bucegi Mts plant and gastropod diversity and abundance are significantly reduced by sheep grazing on formerly ungrazed, steep slopes. This is of particular concern because the plateau of the Bucegi Mts is already heavily overgrazed, which has resulted in the local extinction of numerous indigenous plant species (Barbulescu & Motca 1983; Coldea 2003). The grasslands investigated in our study belong to the last remaining refuges for several endemic and relic plant and gastropod species. If overgrazing by sheep should further extend into these particularly valuable grassland remnants, their diverse flora and
fauna would be at risk. Thus, an appropriate management should aim to protect these last refuges on steep slopes from overgrazing. Most of these valuable grasslands are part of the 13 nature reserves of the Bucegi Nature Park (www.bucegipark.ro). The findings of our study indicate that there is an urgent need to implement the protection aims of the existing nature reserve. Furthermore, the restoration of overgrazed grasslands should be promoted, even if this may require decades. At present, the situation in the Fagaras Mts appears to be less critical, but should also be observed with attention.

In conclusion, our study confirms the high biodiversity value of grasslands on steep slopes, not only for endemic and relic plant and gastropod species, but also for more widespread species in the Carpathian Mts. It also shows the detrimental effects of intensified sheep grazing on these so far unthreatened grasslands, which were only occasionally grazed by wildlife. Other taxonomic groups such as butterflies and moths may also suffer under the increasing grazing pressure. For example, populations of the moth *Grammia quenseli* Paykull, 1791, critically endangered in Romania, and a number of other arctic-alpine moth species, declined extremely during the last decades in the Bucegi Mts, and might even become extinct without conservation measures (Rakosy et al. 2003; Dinca 2006).

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