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Vegetation changes after cessation of grazing management in the Jizerské Mountains (Czech Republic)

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Vegetation changes following the cessation of grazing of highly productive pasture in the Jizerské Mountains in 1997 were studied. The experiment included three replicate pairs of plots and data were collected before and after grazing was ended. Cover was estimated in 1-m^2 permanent plots. Abandonment of the pasture resulted in a significant decrease in plant species diversity. Annuals and perennials such as *Trifolium repens* and *Poa trivialis* disappeared within three years of the end of grazing. Species scores on the first ordination axis of RDA analyses, where time was the only explanatory variable were highly positively correlated with species heights obtained from the local flora and species height was the single parameter that best explained the reaction of species to the cessation of grazing. Within five years of abandonment, differences among swards caused by continuous stocking and rotational grazing had disappeared and tall grasses and shade-tolerant forbs dominated all swards. No new species were recorded after the abandonment of the pasture. If the abandoned grasslands will not reforest, alternative management regimes must be practiced in order to prevent their degradation and spread of tall dominants.

Key words: abandonment, ecology, grassland, plant species diversity, sward, temperate pasture

Introduction

Abandonment of low-production grassland is currently a problem in many European countries. In the Czech Republic, there were two main periods of cessation of grassland management in the last century. After World War II, abandonment of marginal grassland in mountain areas followed forcible resettlement of German inhabitants out of the former Czechoslovakia (Krahulec *et al.* 1996). Many marginal low-production grasslands were not suitable for the management of large areas, which was practised by socialistic agriculture from the 1950s to 1989. After the political change that occurred in the former Czechoslovakia in 1989, state farms collapsed and highly productive grasslands that previously had been intensively managed were abandoned. Numbers of cattle, for instance, decreased from 3 360 000 in 1990 to 1 127 000 in 2003 (Anonymous 2004). Despite reforestation of low-production grasslands, the total area of permanent grasslands increased from 833 000 ha to 961 000 during this period, because part of the arable land in less favoured areas was reseeded by grasses. Expected further conversion of cropland to grassland and low EU quotas for ruminants will support extensification of grassland utilization in the future. Extensification could be useful on account of either the reduction or avoidance of mineral fertilization, as well as association change in timing and frequency of sward utilization. On the other hand such changes could be dangerous due to the risk of temporal or permanent abandonment of the marginal areas.

Recently, it was estimated that 30% of the total grassland area in the Czech Republic consisted of non-utilized meadows and pastures (Hrabě & Müller 2004). Absence of grazing or cutting frequently leads to a decrease of plant species diversity (Bakker 1989, Smith & Rushton 1994, Pecháčková & Krahulec 1995, Losvik 1999, Gaisler *et al.* 2004). A denser and taller vegetation canopy was observed by Křenová and Lepš (1996) after abandonment of a meadow. Also species with a short turnover period disappeared from highly productive sites, except in dry plant communities with low productivity (Lennartsson & Svensson 1995). An increase of tall grasses and nitrophilous herbs was observed by Krahulec *et al.* (2001) after interruption of sheep grazing in the Giant (Krkonose) Mountains, whereas Rosset *et al.* (2001) recorded a decrease in plant species diversity, and a strong increase in *Ranunculus aconitifolius* in abandoned mountain meadows compared with plots mown once a year in the Swiss Alps. The higher reduction in the number of plant species at a small scale than large scales indicated development of more patchy vegetation under abandoned grassland (Persson 1984).

The aim of this study was to analyse vegetation changes in a highly productive pasture after the cessation of management, and to answer the following questions:

1. Does pasture abandonment influence plant species diversity and sward structure?
2. Can the responses of plant species to grazing cessation be predicted from their heights?
3. Does diversification of vegetation decrease under no management?

Material and methods

Study site

The experiment was carried out 5 km west of Liberec, in the Jizerské Mountains (51°20´N, 15°02´E), Czech Republic. The site is 420 m a.s.l., with an annual average temperature of 7.2 °C and an average precipitation of 803 mm (meteorological station in Liberec). The bedrock is a biotic granite underlying medium deep brown soil (cambisol) with pH 4.8, 3% C_{ox}, 43 mg kg^{-1} available P, 70 mg kg^{-1} K, and 68 mg kg^{-1} Mg. The vegetation of the experimental pasture was classified as *Cynosurion* with some elements of *Arrhenatherion* (Moravec 1995). Nomenclature of vascular plant species was taken from Kubát *et al.* (2002). The dominant species were *Agrostis capillaris*, *Lolium perenne*, *Taraxacum* spp. and *Trifolium repens*.

Experimental design

Three pairs of permanent plots of 1×1 m were established in 1993. To eliminate the effect of

pseudoreplication, the distance between the paired plots was 60 m. These plots were used to compare the effect of continuous and rotational heifers grazing between the years 1993 and 1997. A detailed description of the design and results of the previous experiment were published by Pavlů *et al*. (2003). Relevés were collected in a continuous grid of nine 0.33×0.33 m subplots in each permanent plot. Botanical observations collected in the last grazing season of the previous experiment in 1997 were used as a baseline data. The percentage canopy cover (Whalley & Hardy 2000) of all vascular species was estimated in May each year of the study.

Data analysis

Redundancy analysis (RDA) in the CANOCO package (ter Braak & Šmilauer 1998), followed by a Monte Carlo permutation test, were used to analyse the data. The data form included repeated observations with the baseline (measurements performed before cessation of grazing). An interaction of time and treatments corresponds to the effect of previously practiced continuous and rotational grazing and time to development within years after abandonment.

To test the hypothesis that time development leads to spread of tall species that are able to better compete for light after abandonment, the height of species (the average height recorded in local flora, Kubát *et al*. 2002) was used and the scores for each species on the first ordination axis of the RDA analyses, where time was coded as one continuous explanatory (environmental in CANOCO terminology) variable and the other factors as covariables. Spearman's rank correlation was used to evaluate this relationship. Repeated ANOVA was used to evaluate species diversity data (number of plant species).

Results

Plant species composition

Trifolium repens, *Bellis perennis*, *Lolium perenne*, *Veronica serpyllifolia* and *Leontodon autumnalis* were more abundant under continuous grazing, while *Dactylis glomerata*, *Poa trivialis*, *Aegopodium podagraria*, *Alopecurus pratensis*, *Holcus mollis* and *Veronica chamaedrys* were more abundant under the rotationally grazed treatment in 1997.

Pasture abandonment resulted in significant changes in sward composition. The marked successional development of vegetation (Table 1, hypothesis A1) and the reaction of the main species (Table 2 and 3) were recorded. The majority of vegetation changes occurred within two years after the abandonment of the pasture (Fig. 1). The annual weeds, *Capsella bursa-pastoris*, *Plantago major* and *Cirsium vulgare* recorded in

Table 1. Results of the RDA analyses of cover estimates. C = previously practiced continuous grazing; R = previously practiced rotational grazing; PlotID = plot identificator; % explained variability = species variability explained by all ordination axes (measure of explanatory power of the explanatory variables); *F* = *F* statistics for the test of particular analysis; *P* = corresponding probability value obtained by the Monte Carlo permutation test.

Tested hypothesis	Explanatory variables	Covariables	% expl. variables	*F*	*P*
A1: Is there a successional trend in species composition?	Year	Year × C, Year × R, R, C, PlotID	16.0	15.1	0.002
A2: Is there a difference in development between treatments?	Year × C, Year × R	Year, PlotID	11.5	20.7	0.004
A3: Is there a difference between treatments in 1997?	C, R		29.8	21.2	0.002
A4: Is there a difference between treatments in 2001?	C, R		12.4	13.6	0.202

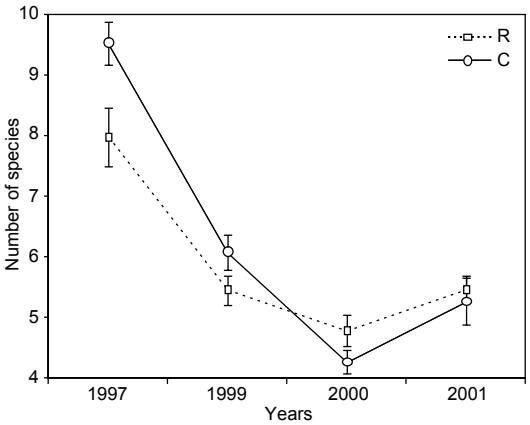

Fig. 1. Changes in plant species diversity of abandoned pastures managed between 1993 and 1997 by continuous (C) and rotational (R) grazing.

1997, were not observed in the pasture in 1999, two years after abandonment. Other annuals, *Veronica arvensis*, *Poa annua* and the perennial rhizomatous grass *P. trivialis*, were last recorded in 2000, three years after the cessation of the grazing. *Trifolium repens*, a common pasture legume had a mean coverage of 32.3% in 1997, but was not detected in 1999. Substantial reduction in abundance was observed for *Lolium perenne* and *Cerastium holosteoides* (Table 2). On the other hand, tall perennial grasses such as *Holcus mollis*, *Elytrigia repens*, *Dactylis glomerata* and *Alopecurus pratensis* increased in abundance after the cessation of grazing. The mean coverage of *H. mollis* was only 1.9% in 1997 but increased to 24.8% in 1999 (Table 3).

The significant interaction of time and treatments indicates (Table 1, hypothesis A2) a non-parallel change in continuous and rotational treatments after the cessation of grazing; while there were differences in species composition in 1997, no differences were detected in 2000 (Table 1, hypotheses A3 and A4). Differences in vegetation composition due to different grazing systems disappeared within the study period.

Potential sward height

There was a significant positive Spearman's rank correlation of species heights with their scores on the ordination axis representing time devel-

Table 2. Mean coverage (%) ± standard error of the plant species, which decreased after cessation of continuous and rotational grazing treatments.

Plant species	1997	1999	2000	2001
Capsella bursa-pastoris	0.1 ± 0.1	0	0	0
Cerastium holosteoides	3.1 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.2
Cirsium vulgare	0.2 ± 0.2	0	0	0
Lolium perenne	29.5 ± 4.6	2.1 ± 0.8	0.1 ± 0.1	0.1 ± 0.1
Plantago major	0.5 ± 0.1	0	0	0
Poa annua	2.8 ± 0.6	6.3 ± 1.2	0	0
Poa trivialis	8.4 ± 1.2	2.5 ± 0.5	0	0
Trifolium repens	32.3 ± 4.0	0	0	0
Veronica arvensis	1.0 ± 0.2	0.1 ± 0.1	0	0

Table 3. Mean coverage (%) ± standard error of the plant species, which increased after cessation of continuous and rotational grazing treatments.

Plant species	1997	1999	2000	2001
Alopecurus pratensis	0.9 ± 0.6	1.2 ± 0.4	1.3 ± 0.5	3.1 ± 1.6
Dactylis glomerata	0.7 ± 0.5	3.6 ± 1.6	2.6 ± 1.4	2.6 ± 1.3
Elytrigia repens	12.8 ± 2.7	11.2 ± 2.3	13.3 ± 2.2	28.3 ± 5.5
Holcus mollis	1.9 ± 1.2	24.8 ± 5.4	10.2 ± 2.5	12.2 ± 3.1
Plantago lanceolata	0.9 ± 0.3	1.7 ± 1.1	2.2 ± 0.7	2.3 ± 0.8
Ranunculus repens	1.3 ± 0.3	4.3 ± 1.6	7.3 ± 1.6	5.0 ± 1.1
Veronica chamaedrys	2.9 ± 1.1	10.8 ± 2.3	19.1 ± 3.8	26.1 ± 4.3

opment ($R = 0.67$, $P < 0.001$). This result indicates the importance of plant height as a simple vegetative trait that is able to explain species response to the cessation of grazing.

Species diversity

The abandonment of the pasture resulted in a significant decrease of species diversity (Fig. 1). While there was higher species diversity in the continuous treatment in 1997, there were no differences detected between continuous and rotational treatments two years after cessation of grazing. The mean numbers of species per plot (without categorization according to treatments) were 15.2, 11.7, 8.5 and 9.2 in 1997, 1999, 2000 and 2001, respectively.

Discussion

Plant species composition and diversity

Both species composition and diversity changed after the abandonment of pastures. Reductions in species diversity have been documented in many other similar studies (Smith & Rushton 1994, Bakker 1998, Losvik 1999). The majority of annuals disappeared within two years after the cessation of grazing. This fact suggests a strong decrease in gap formation rate. The persistence of annuals, but also of some perennials with a turnover period of just a few years is strongly dependent on the creation of gaps (Davies & Snaydon 1976, Rush 1988, Křenová & Lepš 1996, Smith *et al*. 2000). No new species were recorded after the abandonment of the pasture. The probability of colonization by species that are valuable from a nature conservation point of view and present in the neighbourhood is, therefore, decreased. The results are in accordance with a study by Hill *et al*. (1992) describing effect of sheep exclusion from hill pastures in upland Britain.

Trifolium repens completely disappeared and the abundance of *Lolium perenne* substantially decreased. This corresponds with results of Bakker (1989), Marriott and Bolton (1998) and Marriott *et al*. (2003) and can be ascribed to changes in the height of the sward. Both species were able to persist under frequent defoliation of species in the pasture (Pavlů *et al*. 2003), but they were not able to compete for light under tall dominants in abandoned or extensively managed grasslands (Hofmann *et al*. 2001, Correll e*t al*. 2003). *Cerastium holosteoides* decreased dramatically and *Poa trivialis* disappeared after the abandonment. The former is a low-growing species that can benefit from frequent defoliation, mainly due to the small proportion of its biomass being removed, but it is not able to compete for light under a closed canopy. Bakker (1989) recorded the retreat of *P. trivialis* after cessation of biomass removal. He concluded a high sensitivity of *P. trivialis* to litter accumulation. In contrast, Smith and Rushton (1994) demonstrated an increase in standing crop of *P. trivialis* in the ungrazed mesotrofic meadow. Similarly, Krahulec *et al*. (2001) observed an increase in *P. trivialis* after cessation of sheep grazing. Differences in plant community composition in trophic structure seem to be a reasonable explanation of these opposite results. There is evidence that successional changes in abandoned grasslands are strongly dependent on the soil conditions and initial plant species composition.

Disappearance of shorter-growing grass species (*Lolium perenne* and *Poa* spp.) with high grazing tolerance correspond to Grime *et al*.'s (1988) concept of species strategies in relation to biomass removal. Abundance of tall dominants (*Elytrigia repens* and *Holcus mollis*) characterized by vegetative regenerative strategies and rhizomatous life form as well as slight increase of tufted, polycarpic, perennial grasses (*Alopecurus pratensis* and *Dactylis glomerata*) having moderately grazing tolerance and regenerative strategies by seed is in accordance with Grime *et al*.'s (1988) description of plant species. Different habitats select for plant species with different life strategies (Grime 1987).

Potential sward height

Species height is a simple predictor of species reaction to the cessation of grazing. Tall species compete better for light, but they are more sensitive to frequent defoliation. Species heights have frequently been studied from the reverse point

of view — grazing response. According to Diaz *et al*. (2001), prediction of grazing response on the basis of several easily measurable traits is feasible but nevertheless the plant height was revealed as the best single predictor.

Tall grasses (*Alopecurus pratensis*, *Elytrigia repens*, *Dactylis glomerata* and *Holcus mollis*) increased in coverage after the abandonment of the pasture. This corresponds to an experiment by Ryser *et al*. (1995), where three times higher standing biomass of grasses was recorded in unmanaged compared to regularly mown plots. Similarly Kahmen and Poschlod (2004) observed an increase in number and abundance of tall species (> 0.6 m) at the expense of smaller species in abandoned grasslands. Bullock *et al*. (2001) recorded that *Elytrigia repens* was nearly 20 times more abundant in non-spring grazed paddocks compared with paddocks that were heavily grazed in the spring. Fertile habitats with low disturbance benefit a high allocation to stem due to competition for light (Tilman 1990). The present study indicates a rapid increase in *Holcus mollis* due to the cessation of grazing. Similarly, Bakker (1989) recorded the spread of *H. mollis* in lightly grazed patches and Hill *et al*. (1992) observed a massive spread of this species in unmanaged plots. In the present study, this species produced a large amount of biomass after abandonment mainly during the first two years and caused litter accumulation. *Veronica chamaedrys*, *Plantago lanceolata* and *Ranunculus repens* were the only forbs that increased in abundance after the abandonment. Under abandonment, all these species adopted a tall growth form with large leaves, probably as a response to shading. Spatial dispersion of *V. chamaedrys* was more regular under grazing, whereas patchiness developed after cessation of grazing. The change in plant species composition occurred so quickly after cessation of grazing probably due to relatively fertile habitat and initial presence of competitors in term of Grime's theory (Grime 1988). However we cannot expect such a quick change in oligotrophic sites.

Conclusions

Intensive grassland management encourage coexistence of a wide range of species. Cessation of defoliation resulted in a decrease of plant species diversity and increased uniformity of grassland communities with previously differing species composition arising from different grazing systems. No new species were recorded after the abandonment of the pasture. If the abandoned grasslands will not reforest, alternative management regimes must be practiced in order to prevent their loss of species diversity, degradation and spread of tall dominants.

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