CHANGES IN FLORISTIC COMPOSITION OF DEGRADED STANDS OF MOUNTAIN MEADOWS AT LIMITED CONTINUAL SHEEP GRAZING

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The effect of limited continual grazing of ewes and lambs on floristic composition was studied on a degraded stand of a mountain meadow with prevalence of bistort (*Polygonum bistorta*). During five years radical changes were recorded in the stand composition. The degree of coverage of the dominant bistort decreased from 28.64 to 0.59% and the degree of coverage of dicotyledonous plants was reduced from 57.97 to 17.91%. The tussock-grass (*Deschampsia cespitosa*), whose degree of coverage increased from 14.09 to 28.28%, became the dominant plant species. The degree of coverage of grasses (*Poaceae*) increased from 37.42 to 69.44%. The index of qualitative floristic similarity (IS_S) from the period 1999/1994 was 75% and the index of quantitative floristic similarity ($IS_{S/M}$) amounted to 53% . The intensity of quantitative changes was almost double the intensity of qualitative changes as the index of quantitative dissimilarity of the stands from 1999/1994 was on average 9.4% per year while the index of qualitative dissimilarity only 5.0 % per year. The dominance of species composition tended to grow; indexes of dominance (D and D_S) were, however, affected by changes of the dominant (in 1996) and subdominant (in 1998).

mountain meadows; effect of grazing; sheep; floristic composition; similarity and dissimilarity of stands, dominance of species

INTRODUCTION

In the years 1994–1999 the changes in floristic composition of mountain meadows not cultivated for several decades were studied after the introduction of sheep grazing. As reported by Krahulec et al. (1997), the original plant stands of these meadows were transformed into a mosaic of a few

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species, or, even worse, there is only a dominant with scarce undergrowth. In the effort to utilise grazing it is necessary to consider a different reaction of plant species to grazing, even within the same genus (C o l e m a n , 1992). As reported by S l a v í k o v á (1986), grazing animals influence the species composition both directly (browsing, trampling) and indirectly (supply of N and P included in faeces). The nitrogen supply supports the expansion of nitrophilous flora and the animal cenosis of the plant stand and soil is altered (R y c h n o v s k á et al., 1985). A n d r e w (1988) reports on the distribution of some species through seeds contained in faeces of grazing animals; their expansion is, apart from the transfer of seeds, supported also by the affluent supply of nutrients contained in faeces of grazing animals (H u n t l y , 1991). The fertilising efficiency of faeces in case of continual grazing on production pasture was determined by R a i s and K r á l o v e c (1992) as 100 $kg.ha^{-1}$. M a t c h e s (1992) mentions the fact that thiamine comprised in saliva of grazing animals supports subsequent growth recovery of grasses. The dependence of changes in floristic composition on grazing intensity is analysed by G r a n t et al. (1982). H a b o v š t i a k (1983) stated that some plant species expanded even if they were intensively grazed by lambs. J e n í k (1987), who studied changes in permanent grasslands in the Poloniny, reports that in absence of wild herbivores and after prohibition against pasture of domestic animals, favourable conditions for gradual succession of pioneer tree species occurred together with gradual disappearance of flowery meadows. G o o d et al. (1990) inform how sheep on pastures in North Wales restrict the distribution of hawthorn. The presence of sheep is favourably evaluated also by M i l l e r et al. (1999) as they help to maintain the colonies of alpine gentian (*Gentiana nivalis*) in the grass cover. G a l l o et al. (1995) studied the effect of grazing on the floristic composition of yet unutilised plant stands. They reported the increased proportion of grasses and clover crops and the decreased representation of the other herbs; the degree of stand closure increased and the proportion of bare places decreased.

The aim of the study was to determine the character and dynamics of changes in the floristic composition of degraded stands of mountain meadows with the dominant species of *Polygonum bistorta* continually grazed by sheep. Knowledge of mentioned changes is an important presumption for determining the optimal regime of pasture focused on maintenance and restoration of species diversity of unused grass covers.

MATERIAL AND METHODS

The experimental site is situated in the territory of the Krkonoše National Park, at an average altitude 1 250 m (the locality of Zadní Renerovky). At present, plant stands occur here with prevailing bistort (*Polygonum bistorta*) which are classified as independent phytocenological units (P e c h á č k o v á , K r a h u l e c , 1998). These are associations of *Polygono – Deschampsietum flexuosae* and *Junco filiformis – Polygonetum*.

The soil consists mostly of a shallow layer of mountain cambisol podzol on silicate substrate with an accumulated layer of raw humus (K r a h u l e c et al., 1997).

Ewes with their lambs (still suckling at the beginning of the pasture period) were used for the experimental grazing. For the whole grazing season they were located on the unfertilised pasture equipped with the electric fencing without any shelters. In the seasons 1994–1996, crosses of Stavropol Merino and East Friesian breeds were used while in the years 1997–1998 the animals were of Caucasian Merino and Suffolk breeds and their crosses. The data referring to the beginning, end and duration of different seasons are given in Table I which contains also data characterising basic meteorological conditions (air temperature and sum of precipitation). These data were obtained using measuring instruments directly on the pasture. Stocking rates – number of ewes and average live weight of animals per 1 ha in different seasons (including lambs) – are shown in the table as well.

The floristic composition of the plant stand was observed prior to the beginning of grazing season using the point method determining the degree of coverage of plant species. As reported by e.g. S t a m p f l i (1991), this method is more appropriate for studying the changes in plant communities than visual estimates of the degree of coverage of plant species. The method was modified in such a way that individual points were placed all over the

I. Values of some biotic and abiotic factors affecting the composition of vegetation

Year	Season: data on beginning and end	Season: length (days)	Load of pasture per 1 ha: number of ewe (animals/ha)	Load of pasture per 1 ha: live weight (kg/ha)	Average air temperature (°C)	Sum of precipitation (mm/day)	Ratio of precipitation and temperatures (mm/°C)
1994	7.7.–31.8.	55	4.9	440	13.2	4.2	0.32
1995	29.6.–6.9.	69	5.4	529	12.0	4.5	0.38
1996	13.6.–17.9.	96	3.2	191	6.7	6.0	0.90
1997	17.6.–15.9.	90	3.9	254	10.2	8.7	0.85
1998	10.6.–31.8.	82	5.6	313	7.2	4.8	0.67

pasture in rows 20 m apart and the points in a row were 2 m apart. To quantify the occurrence of plant species, the basal degree of coverage was determined (basal area – Mueller et al., 1974). It represents the area covered by plants at the level of soil surface (mostly the base of stems without leaves). This method was chosen as there is only a little change in the basal degree of coverage during the growing season in comparison with the projective dominance (projective degree of coverage) which is strongly fluctuating in dependence on the development of the above-ground organs of plants (Slavíková, 1986).

To evaluate the changes in the plant stand composition, it was impossible to use the method of randomised squares due to very uneven terrain and great differences in site conditions (even in direction of contour lines). The comparison with the development on neighbouring not grazed stands would be mainly the matter of pseudoreplication. With respect to necessity to involve the whole variability of the stand composition development in the grazed area, the comparison with the state at the beginning of pasture period (autoreplication) was used.

To evaluate the development of floristic composition, classes of species stability were determined based on the calculation of Moravec et al., (1994):

$$C_i = \frac{a_i}{n} \cdot 100$$

where: C_i – stability of species i (in %)
a_i – number of records with the occurrence of species i
n = total number of records in the set

For the same purposes, the indexes of qualitative and quantitative floristic similarity of records from different seasons were calculated as reported by Moravec et al. (1994). To determine the qualitative floristic similarity, the Steinhaus's (Sørensen) index was used:

$$IS_S = \frac{2c}{A + B} \cdot 100$$

where: A – number of species in record A
B – number of species in record B
c = number of common species

$$IS_{S/M} = \frac{2\,\Sigma\, c_i\, min.}{\Sigma A_i + \Sigma B_i} \cdot 100$$

The quantitative floristic composition was determined using the modified Steinhaus's formula,

where: ΣA_i – sum of degrees of coverage (in %) of species from record A
ΣB_i – sum of degrees of coverage (in %) of species from record B
$\Sigma c_i\, min.$ – sum of lower degrees of coverage of common species

The dynamics of changes during the experimental period of several years was evaluated by the calculation of average indexes of qualitative and quantitative floristic dissimilarity (Slavíková, 1986):

$$D_{\bar{x}} = \frac{\Sigma\, 1 - S_i}{n}$$

where: S_i – respective similarity index
n – number of seasons

As S_i, the values of similarity indexes given above were used.

In addition, the index of dominance of two species (D) and the Simpson's index of dominance (D_S) were calculated as reported by Slavíková (1986):

$$D = \frac{N_{i=1} + N_{i=2}}{N} \cdot 100$$

where: $N_{i=1} + N_{i=2}$ – sum of significance (in our case the basal degree of coverage) of two species with the highest values (dominants and subdominants)
N – sum of significance values (basal degree of coverage) of all species

$$D_S = \sum \left(\frac{N_i}{N}\right)^2$$

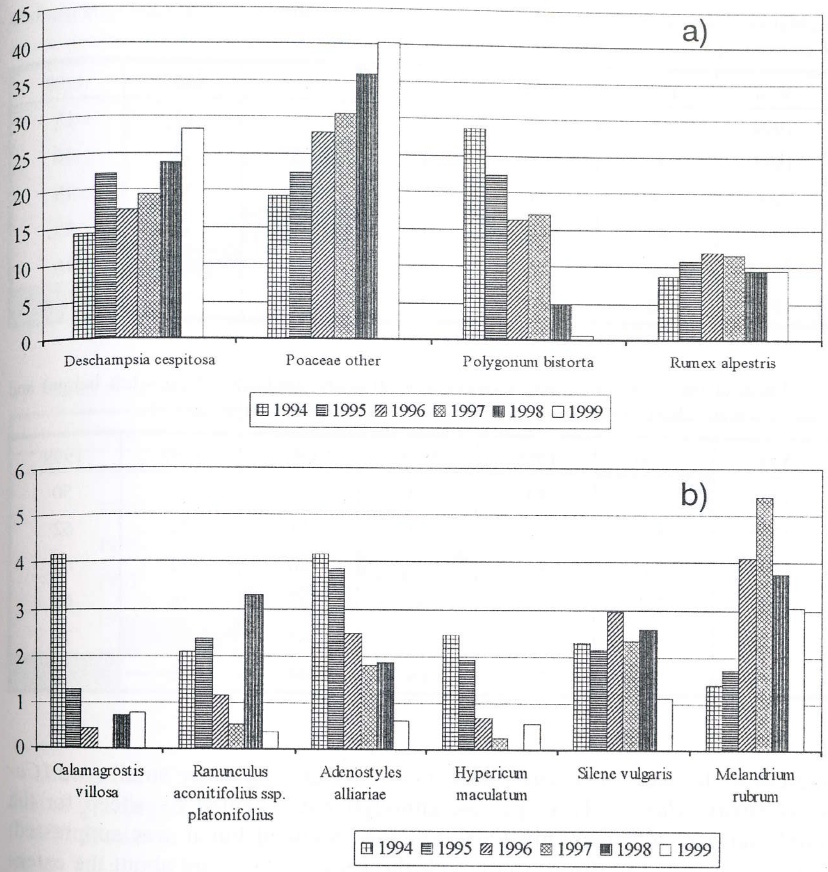
where: N_I – significance (basal degree of coverage) of i-th species
N – sum of significance (basal degree of coverage) of all species

RESULTS AND DISCUSSION

The character and intensity of changes which occurred due to the continual grazing during five years can be assessed from the data presented in Table II and Fig. 1. In contrast to the initial state at the beginning of the season 1994, a fundamental change in the degree of coverage of decisive plant species occurred. The degree of coverage of originally dominant bistort (*Polygonum bistorta*) decreased from 28.64 to 0.59%, the degree of coverage of tussock-grass (*Deschampsia cespitosa*) increased from 14.09 to 28.28% and other grasses (Poaceae) from 19.7 to 40.37%. Bistort ceased to be dominant in 1996 and subdominant in 1998. Tussock-grass became a dominant species and nitrophilous alpine sorrel (*Rumex alpestris*) became a subdominant species. The degree of coverage of dicotyledonous plants was reduced from 57.97 to 17.91%. These changes occurred basically due to grazing up bistort in time of the greatest development of its above-ground parts. It resulted not only in the opening of stand for suppressed grass species but above all in the limited development of underground parts of bistort and the release of nitrogen pre-

II. Composition of the stand and classes of stability of species

Species (group)	Basal dominance (%)						Class of stability
	1994	1995	1996	1997	1998	1999	
Deschampsia cespitosa (L.) P.B.	14.09	22.22	17.27	19.38	23.71	28.28	V
Calamagrostis villosa Chaix	4.16	1.28	0.45		0.71	0.79	V
The other grasses (Poeceae)	19.17	22.44	27.95	30.49	35.92	40.37	
Grasses (Poeceae) in total	37.42	45.94	45.67	49.87	60.34	69.44	
Chaerophyllum hirsutum L.				0.26	0.47		II
Juncus filiformis L.	0.92	1.07	0.45	1.03	1.41	1.13	V
Luzula luzuloides (Lamh.) Dandy et Wilmott	0.46		0.23		0.47	0.19	IV
Carex nigra L.			0.23			0.75	II
The other monocotyledonous species	1.38	1.07	0.91	1.29	2.35	2.07	
Monocotyledonous in total	40.18	48.08	47.49	52.45	65.04	73.58	
Polygonum bistorta L.	28.64	22.44	16.36	17.05	4.93	0.59	V
Rumex alpestris Jacq.	8.55	10.96	12.05	11.63	9.39	9.38	V
Rumex alpinus L.	0.69	0.64	2.05	0.26			IV
Ranunculus platanifolius L.	2.08	2.35	1.14	0.52	3.29	0.38	V
Adenostyles alliariae (Gouan) Kerner	4.16	3.85	2.50	1.81	1.88	0.61	V
Veratrum lobelianum Bernh.	0.46	0.64		0.26	0.47		IV
Hypericum maculatum Crantz	2.77	1.92	0.68	0.26		0.56	V
Silene vulgaris (Moench) Garcke	2.31	2.13	2.95	2.32	2.58	1.13	V
Melandrium rubrum Garcke	1.39	1.71	4.09	5.42	3.76	3.06	V
Achillea millefolium L.	0.69	1.07	0.23	0.26	0.23	0.40	V
Chamaenerion angustifolium (L.) Scop.			0.45				I
Imperatoria ostruthium L.	2.08	1.07	1.36	0.78	0.23	0.40	V
Geranium sylvaticum L.	1.15	1.07	1.14	0.26	0.47	0.40	V
Alchemilla spec.	2.08	1.92	2.50	1.03	0.47		V
Polygonatum verticillatum (L.) All.	0.23		0.23	0.26	0.23		IV
Solidago virgaurea L.			0.23		0.23	0.19	III
Potentilla aurea L.		0.43	0.23	0.26	0.23		IV
Urtica dioica L.	0.69						I
Crepis paludosa (L.) Moench		0.21				0.20	II
Galeopsis tetrahit L.				0.26		0.61	II
Viola sudetica (Willd.) Nyman					0.23		I
Stellaria nemorum L.					0.71		I
Dicotyledonous in total	57.97	52.41	48.19	42.64	29.33	17.91	
Bryophyta		0.21		0.26	0.47	0.56	IV
Blank places	3.23	0.43	5.23	5.42	7.04	10.02	



1. Changes in representation of plant species (% of basal dominance) at the beginning of vegetation in the years 1994-1999

a) species with greatest distribution
b) other significant species

viously bound in these parts (Pecháčková, Krahulec, 1998). A part of nitrogen bound in the above-ground biomass was in the form of faeces released for the other plant species. A majority of grasses from grasses family (Poaceae) was included into the joint group "other grasses" due to a very similar reaction to the studied effect of pasture. The only exceptions are the

III. Matrix of the values of index of qualitative floristic similarity (IS_S – left below) and numbers of common species (right above)

Year	1994	1995	1996	1997	1998	1999
1994		17	18	17	17	15
1995	85		17	18	17	16
1996	86	81		17	16	16
1997	83	88	79		17	15
1998	79	79	71	77		16
1999	75	80	76	73	74	

IV. Matrix of the values of index of quantitative floristic similarity ($IS_{S/M}$ – left below) and sums of lower values of degree of coverage of common species (right above)

Year	1994	1995	1996	1997	1998	1999
1994		84	73	69	59	50
1995	85		81	81	71	62
1996	76	84		86	72	63
1997	72	83	91		76	68
1998	62	74	77	82		78
1999	53	69	69	74	86	

aggressive tussock grass and unacceptable by grazing hairy small-reed (*Calamagrostis villosa*). This species, although not accepted by sheep for the rough surface of leaves, not only was not extended but it was suppressed. This is somewhat in discrepancy with the general statement about the extension of the species unacceptable by grazing (S l a v í k o v á , 1986). Although the total degree of coverage of dicotyledonous plants decreased, the reaction of individual species of this group was different. The total recess was recorded in *Adenostyles alliariae*, spotted St. John's wort (*Hypericum maculatum)*, and plane-leaved buttercup (*Ranunculus aconitifolius* ssp. *platanifolius*). Stagnation was manifested in common catchfly (*Silene vulgaris*) while in red campion (*Melandrium rubrum*) rather higher degree of coverage was recorded. In these and other herbs, irregular fluctuations were shown in different years which were caused by changed external factors, either abiotic (quantity and distribution of precipitation, course of temperatures) or biotic (stocking rate, interaction between plant species etc.). Therefore it is impossible to interpret them unambiguously.

V. Matrix of average annual values of index of quantitative (left below) and qualitative (right above) floristic dissimilarity (D_x)

Year	1994	1995	1996	1997	1998	1999
1994		15.0	7.0	5.7	5.3	5.0
1995	15.0		19.0	6.0	7.0	5.0
1996	12.0	16.0		21.0	14.5	8.0
1997	9.3	8.5	9.0		23.0	13.5
1998	9.5	8.7	11.5	18.0		26.0
1999	9.4	7.8	10.3	13.0	14.0	

VI. Values of index of dominance of two species (D) and Simpson's index of dominance (D_S)

Year	D	D_S
1994	44.2	19.2
1995	44.9	19.1
1996	35.5	16.9
1997	38.5	20.4
1998	35.6	21.7
1999	41.9	36.6

The recess of herbs and the increase of the degree of coverage of grasses due to grazing is in agreement with the results reported by G a l l o et al. (1995). However, we did not observe reduction of the bare places area, similar to T h i l e n i u s and B r o w n , 1987).

The group of "other grasses" includes 10 grass species which could be recorded and quantified by the used method. These are common pasture species with a high forage value, e.g. meadow foxtail (*Alopecurus pratensis*), smooth-stalked meadow grass (*Poa pratensis*), red fescue (*Festuca rubra*) as well as less extended or specific mountain species like alpine vernal grass (*Anthoxantum alpinum*), bent grass (*Agrostis capillaris*), tussock grass (*Deschampsia flexuosa*), creeping soft grass (*Holcus mollis*), Chaix' meadow grass (*Poa chaixii*), or alpine timothy (*Phleum alpinum*). Composition changes in this group will be a subject of a separate analysis.

Data of stability measurement (Table II) show that in 14 of 29 mentioned species a high stability of their presence in the stand was found (class V, i.e. 81–100%). These were not only the species with greatest expansion but also less frequent species. The average stability during the 5 years period reached 69 ± 30,8% which corresponds to class IV.

Indexes of qualitative and quantitative floristic similarity (Table III and IV) show that while qualitative similarity and the number of common species decreased or stagnated during the experimental period, quantitative changes were more distinct. It was caused predominantly by radical changes in the degree of coverage of the decisive species (groups) – by the recess of bistort and the expansion of tussock grass and other grasses.

Annual dynamics of mentioned changes is evident from the development of average annual indexes of qualitative and quantitative floristic dissimilarity (Table V). Both types of differences had the same range (15%) after the first year of grazing, the quantitative changes were, however, almost double-quick as the qualitative ones. The average annual intensity of qualitative changes reached 5% while the intensity of quantitative changes was 9,4%.

With respect to the radical character of changes, their impacts on dominance of species composition were determined using the indexes of dominance given in Table VI. The tendency of dominance index of two species (D) to grow was affected in 1996 by the exchange of the dominant (*Deschampsia cespitosa* instead of *Polygonum bistorta*) and in 1998 by the exchange of subdominant (*Rumex alpestris* instead of *Polygonum bistorta*); in both cases the index decreased in the given period. The fall of the Simpson's index (D_S) was displayed only in the year of the exchange of dominant (1996) while the exchange of subdominant caused only growth deceleration of the index. It results from the way of construction of the index because its value is significantly influenced not only by two but all the most distributed plant species (with the occurrence higher than 2%).

The results show that experimentally used limited continual sheep grazing radically influenced the floristic composition of the degraded plant stand of the former mountain meadow. The dominant species bistort (*Polygonum bistorta*) almost disappeared after five years of grazing, the proportion of dicotyledonous herbs decreased to less than one third and the proportion of grasses (*Poaceae*) was almost doubled.

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Změny floristického složení degradovaných porostů horských luk při limitované kontinuální pastvě ovcí.

Scientia Agric. Bohem., *31*, 2000: 221–232.

Na degradovaném porostu s převahou rdesna hadího kořene (*Polygonum bistorta*), ležícím v nadmořské výšce 1 250 m, byl v letech 1994–1999 sledován vliv limitované

kontinuální pastvy bahnic s jehňaty na jeho floristické složení. Ovce byly umístěny na elektricky ohrazené pastvině bez přístřešku a bez příkrmu. Bylo použito bahnic-křříženek plemen stavropolské merino a východofríská ovce (v letech 1994–1996), později bahnic plemen suffolk, kavkazské merino a jejich kříženek. V průběhu pokusu, za podmínek uvedených v tab. I, byl zaznamenán radikální vliv pastvy na skladbu porostu (tab. II). Pokryvnost původně dominantního rdesna se snížila z 28,64 na 0,59 % a pokryvnost dvouděložných bylin poklesla z 57,97 na 17,91 %. Dominantním druhem se stala metlice trsnatá (*Deschampsia cespitosa*), jejíž pokryvnost vzrostla ze 14,09 na 28,28 %. Pokryvnost lipnicovitých se zvýšila z 37,42 na 69,44 %. Index kvalitativní floristické podobnosti porostu (IS_S) z let 1999/1994 činil 75 %, zatímco počet společných druhů se téměř neměnil (tab. III). Kvantitativní změny ve složení porostu byly radikálnější, neboť index kvantitativní floristické podobnosti ($IS_{S/M}$) porostů z let 1999/1994 činil pouze 53 % a součet nižších hodnot pokryvnosti společných druhů jen 50 % (tab. IV). Intenzita kvantitativních změn byla téměř dvojnásobná ve srovnání s intenzitou kvalitativních změn, neboť průměrný roční index kvantitativní floristické rozdílnosti činil 9,4 %, zatímco tentýž ukazatel kvalitativní rozdílnosti 5,0 %. Byla zaznamenána tendence růstu dominance druhového složení porostu. Indexy dominance (tab. VI) však byly ovlivněny výměnou dominanty (v roce 1996) i subdominanty (v roce 1998).

horské louky; vliv pastvy; ovce; floristické složení; podobnost a rozdílnost porostů; dominance druhů

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