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Floristic structure and temporal changes of the association *Helictotricho planiculmis-Nardetum strictae* in the Veľká Fatra Mts (central Slovakia)

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Abstract: The present study deals with the species composition pattern of the mat-grass swards (phytosociological association *Helictotricho planiculmis-Nardetum strictae*) in the Veľká Fatra Mts. These low-productive pastures occupy only north-facing slopes of the main ridge. Their floristic variation was recorded at the variant level – variant with *Hieracium alpinum* and *Ligusticum mutellina*. The major environmental gradients were interpreted based on Ellenberg's indicator values for vascular plants. The principal component analysis revealed the importance of soil nutrients and grazing type for species composition variability. The comparison of the sampled periods (1953, 1987/1988 and 2001) also indicated these floristic changes, which most likely reflected different sheep and cattle grazing patterns in particular periods.

Keywords: dynamics, *Nardo strictae-Agrostion tenuis*, ordination, phytosociology, species composition, the Western Carpathians.

Introduction

Medium species-rich pastures of the alliance *Nardo strictae-Agrostion tenuis*, firstly described by SILLINGER (1933) from the Nízke Tatry Mts, represent semi-natural habitats on low-productive and acidic soils. Their distribution area involves Western and Eastern Carpathians mountain ranges (e.g. KLIKA 1934, GREBENŠČIKOV et al. 1956, MRÁZ 1956, ŠOMŠÁK 1971, HADAČ et al. 1988, BLAŽKOVÁ & BŘEZINA 2003, ŠKODOVÁ et al. 2015), including Moravia region and Poland (PAWŁOWSKI et al. 1960, KRAHULEC 1990, 1997). Outside the Carpathians, this vegetation also occurs in the Krkonoše Mts (Sudetes; KRAHULEC et al. 1997, 2007), Alps (ELLMAUER 1993, THEURILLAT et al. 1994, STEINBUCH 1995) and Jura Mts (DE FOUCALT 1994, 2012). In Ukraine, similar grassland vegetation is classified within the broadly defined alliance *Potentillo ternatae-Nardion strictae* Simon 1958 (cf. MALYNOVSKI & KRICSFALUSY 2002, VELEV & APOSTOLOVA 2009, but see also ŠKODOVÁ et al. 2015). Previous research pointed out an important effect of discontinuous geographic pattern of high mountains on floristic variation of mat-grass swards (KRAHULEC 1985, KLIMENT & UJHÁZY 2014). This geographical isolation is usually coupled with environmental peculiarities (geological substrate, altitude, climate), differences in regional species pool and agricultural practices (KLIMENT & JAROLÍMEK 2010).

In Slovakia, low productive pastures of the *Nardo strictae-Agrostion tenuis* were relatively widespread vegetation types in the past. They developed in secondary deforested montane and supramontane areas as artificial vegetation of acidophilous beech forests, mixed fir-beech forests and spruce forests. These pastures were established during the colonization of the mountains (KLIMENT & UJHÁZY 2014) and were maintained through a combination of traditional management practices such as cattle and sheep (occasionally also horse) grazing accompanied by a one-off mowing (KLIMENT 1992). Their species composition was significantly affected by socio-economic changes in the second half of the 20th century (PECHÁČKOVÁ et al. 2010). Although the low-intensity sheep grazing is considered to be a more suitable management for these stands (HEJCMAN et al. 2004), it was partially altered by cattle grazing. More recently, human activities have resulted in the reduction and degradation of oligotrophic short-stem *Nardus* grasslands due to abandonment (and subsequent secondary succession) or afforestation. This pattern is more pronounced in lower mountains at altitudes up to 1200–1300 m (e.g. Kremnické vrchy Mts, Skorušinské vrchy Mts, Volovské vrchy Mts) where vegetation of the *Nardo strictae-Agrostion tenuis* belongs to threatened habitats (KLIMENT & JAROLÍMEK 2010). Large-scale stands most often occurred on the flat parts of higher mountain ranges with altitude up to 1500 (1600) m (e.g. Lúčanská Malá Fatra Mts, Veľká Fatra Mts; KLIMENT & UJHÁZY 2014). However, the recent cessation of traditional management considerably modifies their species composition. Many of these typically developed stands are changing towards treeless vegetation dominated by the dwarf shrubs *Vaccinium myrtillus*, *V. vitis-idaea*, *Calluna vulgaris* or tall grass *Calamagrostis villosa*. Abandonment is also commonly accompanied by a loss of species diversity and a decline of graminoids cover (PECHÁČKOVÁ & KRAHULEC 1995, KLIMENT & JAROLÍMEK 2010, KLIMENT 2015a, b).

The same is also true for vegetation belonging to the association *Helictotricho planiculmis-Nardetum strictae* (alliance *Nardo strictae-Agrostion tenuis*). This vegetation is characterized by a mixture of common acidophilous and oligotrophic dominant species and constant presence of montane species growing on carbonates. It was firstly described by GREBENŠČIKOV et al. (1956) as broadly defined vegetation type *Avenastrum planiculme-Nardus stricta* from southern part of the Veľká Fatra Mts. While the area of these low-productive pastures was retained or increased by grazing in the past, socio-economic changes during the 1980s negatively affected intensity of agricultural activities (KLIMENT & UJHÁZY 2014). The aim of the present study was to analyse i) species composition of the mat-grass swards (association *Helictotricho planiculmis-Nardetum strictae*) in the Veľká Fatra Mts, and ii) floristic changes after 35–48 years.

Material and methods

Study area

Mat-grass swards were studied in the Veľká Fatra Mts, situated in the central Slovakia. The study area belongs to the Inner Western Carpathians and its altitude ranges from 420 to 1592 m a.s.l. Flat and smoothly modelled relief is typical for central and southern part of the mountain, whereas considerably rugged relief is dominant in the northern part. Crystalline and sedimentary rocks of different ages (mostly Mesozoic) are the most common types of the geological bedrock (POLÁK et al. 1997). Vegetation sampling was done in north-facing slopes of the main ridge plateau at altitudes from 1340 to 1490 m (southern part of the mountain), between Kráľova studňa Saddle and Suchý vrch Mt. These pastures were long-term managed by extensive grazing, but type of grazing animals differed between periods (KLIMENT 1992). They were initially grazed by sheep (1950s; GREBENŠČIKOV et al. 1956), but cattle have grazed there almost exclusively since 1960s (KLIMENT 1986). Their numbers varied between periods – from 1.22 (1980s) to 0.49 (2000s) livestock units per hectare (KLIMENT 1986, MILAN 2003).

Field sampling and data analyses

Phytosociological relevés of the association *Helictotricho planiculmis-Nardetum strictae* were sampled using standard principles of the Zürich-Montpellier approach (BRAUN-BLANQUET 1951; WESTHOFF & van der MAAREL 1978). The cover of plant species was recorded with the extended nine-degree Braun-Blanquet cover/abundance sampling scale (BARKMAN et al. 1964) in period of 1987–1988 and 2001 (original author's relevés). Relevés published by GREBENŠČIKOV et al. (1956) were sampled using the seven-degree Braun-Blanquet sampling scale. All relevés were stored in the TURBOVEG database software (HENNEKENS & SCHAMINÉE 2001) and processed in the Juice program (TICHÝ 2002). The data set was classified with the SYN-TAX 2000 package (PODANI 2001) using the Ružička`s coefficient of dissimilarity and β-flexible clustering method (β = -0.25). Differential species of vegetation units (in Tab. 1) followed study by HEGEDÜŠOVÁ VANTAROVÁ & ŠKODOVÁ (2014). In addition to numerical classification, phytosociological material was divided into three groups of samples according to the sampling period (1953, 1987/1988, 2001). Differential species of each group of relevés (cluster/sampling period; Tab. 2) were determined using a combined concept of frequency and fidelity. Number of relevés belonging to a target cluster was virtually standardized to an equal size (TICHÝ & CHYTRÝ 2006). Differential species were defined as species showing simultaneously frequency ≥ 40%, *phi* coefficient > 0.40 (Fisher's exact test $P < 0.05$) and difference of frequencies among clusters > 30%. We have to be aware that re-sampling was not conducted strictly on the same plots, but all analysed relevés were restricted to the stands of *Helictotricho planiculmis-Nardetum strictae*.

Major environmental gradients (differences) in species composition were analysed by the linear method of unconstrained ordination in the CANOCO for Windows package (ver. 4.5, Microcomputer Power, Ithaca, NY, USA), as the length of the gradient in detrended correspondence analysis was 1.84 SD units. Principal component analysis (PCA) was done with square-root transformation of species cover values (see LEPŠ & ŠMILAUER 2007 for the methodological details). Unweighted means of Ellenberg indicator values (EIV) for vascular plants (Light, Temperature, Moisture, Soil reaction, Nutrients; ELLENBERG et al. 1992) and grazing type were used to interpret variation in species composition. They were plotted into the PCA ordination diagram as supplementary variables (Fig. 1). Statistical significance of relationship between the first two PCA axes and EIVs was calculated with the modified permutation test ($P < 0.05$, 999 permutations; ZELENÝ & SCHAFFERS 2012) using the R software (R Foundation for Statistical Computing, Vienna, AT, USA). Grazing type (cattle vs. sheep grazing) entered the analysis as binary variable and its statistical relevance ($P < 0.05$) was tested using the Pearson correlation coefficient in the Statistica program (ver. 7.1; StatSoft Inc., Tulsa, OK, USA).

Species taxonomy and nomenclature were unified using the concept of broadly defined taxa according to the checklist of non-vascular and vascular plants of Slovakia (MARHOLD & HINDÁK 1998). The species names of subspecies are replaced by an asterisk (*). List of vascular plants merged to aggregate (agg.), genus (sp. div.) or subspecies levels in the data set includes *Achillea millefolium* subsp. *alpestre* (incl. *A. millefolium*, *A. *alpestre*), *Alchemilla* sp. div. (*Alchemilla* sp., *A. crinita*, *A. monticola*), *Luzula campestris* agg. (*L. campestris*, *L. sudetica*), *Luzula luzuloides* subsp. *rubella* (*L. luzuloides*, *L. *rubella*). In a few cases, some deviations from this checklist were necessary following current knowledge about distribution pattern of vascular plants in the study area –

Anthoxanthum alpinum (incl. *A. alpinum*, *A. odoratum*), *Leucanthemum margaritae* (*L. margaritae*, *L. vulgare*) and *Pyrethrum clusii* (*P. clusii*, *P. corymbosum*). This nomenclatural approach was applied for the purpose of numerical classification. All names of plant communities and diagnostic species of vegetation units followed the contemporary revised survey of Slovak grassland vegetation (HEGEDÜŠOVÁ VANTAROVÁ & ŠKODOVÁ 2014).

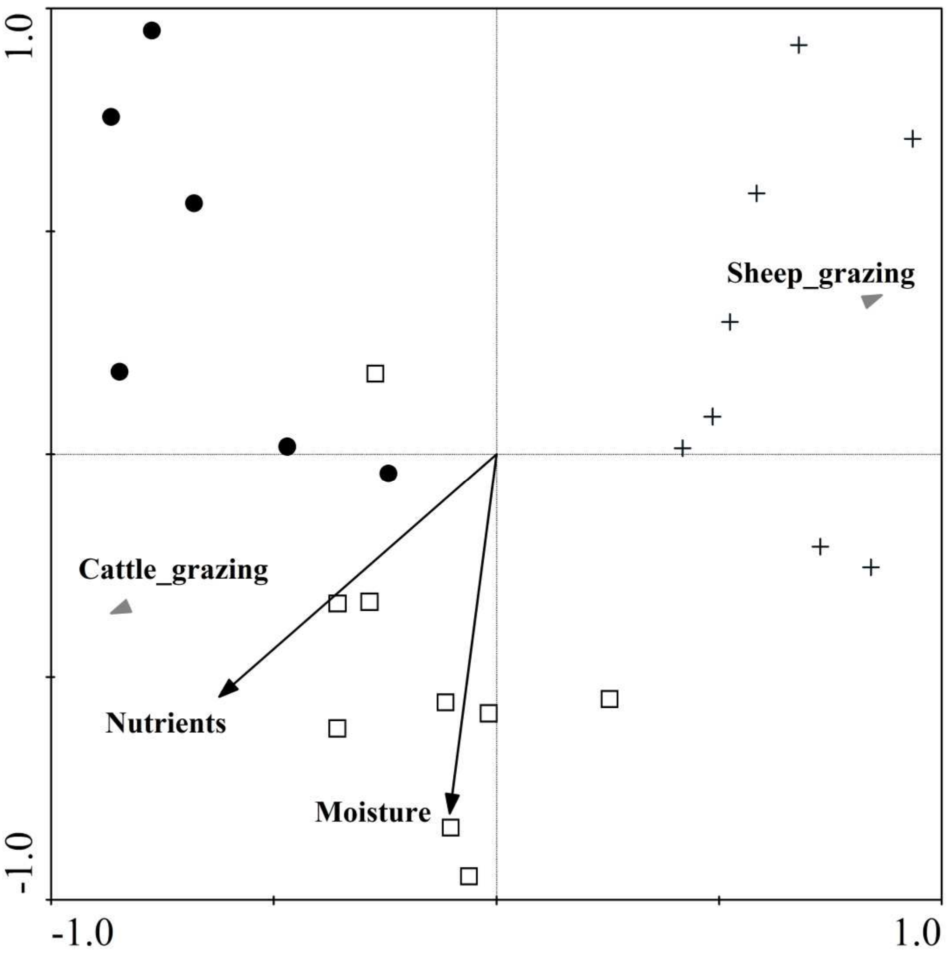

Fig. 1. PCA ordination biplot showing first two ordination axes, significant variables (for more detail see Material and methods) and vegetation plots sampled in 1953 (crosses), 1987-1988 (black circles) and 2001 (squares). The first two ordination axes explain 31.9% and 18.0% of the total species variability, respectively. Species with only one presence in data set were removed before analysis.

Tab. 1. Phytosociological table of the association *Helictotricho planiculmis-Nardetum strictae* in the Veľká Fatra Mts. Frequency (C in %) and mean cover values (upper index) of individual species are shown. Variant with *Hieracium alpinum* represents relevés 1–8 (GREBENŠČIKOV et al. 1956) and variant with *Ligusticum mutellina* relevés 9–22 (Kliment ined.), respectively.

Relevé No.	1	2	3	4	5	6	7	8		9	11	19	20	21	23	10	13	12	14	15	18	16	17	22		
Number of plant taxa	11	15	11	20	31	19	13	26	C %	30	25	20	21	24	30	28	33	36	35	29	32	28	20	19	C %	Ctot %
Differential taxa of association																										
Avenula planiculmis	2	1	2	2	2	+	1	3	**100^{2}**	b	+	+	1	a	+	+	1	1	a	1	1	+	+	+	**100^{1}**	**100^{1}**
Soldanella carpatica	.	.	+	.	+	+	+	.	**50^{+}**	a	+	+	+	+	1	1	1	1	+	+	1	+	.	.	**87^{1}**	**74^{+}**
Ligusticum mutellina	.	.	.	.	.	.	.	.	**-**	+	.	.	.	1	1	.	.	.	+	.	.	.	.	1	**33^{1}**	**22^{1}**
Polytrichum formosum (E_0)	.	.	.	.	.	.	.	.	**-**	1	a	+	.	.	+	a	1	.	.	.	.	.	+	+	**53^{1}**	**35^{1}**
Differential taxa of the variants																										
Hieracium alpinum agg.	.	.	.	.	+	+	+	+	**50^{+}**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**-**	**17^{+}**
Antennaria dioica	.	.	.	+	.	+	+	.	**38^{+}**	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	**7^{+}**	**17^{+}**
Hieracium prenanthoides	.	.	.	+	+	.	.	.	**25^{+}**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**-**	**9^{+}**
Galium anisophyllon	.	.	.	.	r	.	+	.	**25^{+}**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**-**	**9^{+}**
Phleum rhaeticum	.	.	.	.	+	+	.	.	**25^{+}**	1	1	1	1	1	+	+	1	a	+	+	+	1	1	+	**100^{1}**	**74^{1}**
Anthoxanthum alpinum	.	.	.	+	+	.	.	.	**25^{+}**	+	a	.	+	+	1	1	1	1	.	+	+	.	+	+	**80^{1}**	**61^{1}**
Poa alpina	.	.	.	.	.	.	.	.	**-**	+	+	+	+	+	+	+	+	+	.	.	.	+	.	.	**67^{+}**	**43^{+}**
Hieracium lachenalii	.	.	.	.	.	.	.	.	**-**	r	+	.	.	.	.	+	r	r	+	.	.	r	.	+	**53^{+}**	**35^{+}**
*Solidago *minuta*	.	.	.	.	.	.	.	.	**-**	r	.	.	.	.	.	r	r	.	+	+	r	+	+	.	**53^{+}**	**35^{+}**
Stellaria graminea	.	.	.	.	.	.	.	.	**-**	.	+	.	+	+	+	.	+	+	.	+	.	+	.	.	**53^{+}**	**35^{+}**
Acetosa arifolia	.	.	.	.	.	.	.	.	**-**	+	.	.	.	.	+	.	.	.	.	+	.	1	1	a	**40^{1}**	**26^{1}**
Allium victorialis	.	.	.	.	.	.	.	.	**-**	.	+	.	.	.	.	+	+	.	.	.	+	+	+	.	**40^{+}**	**26^{+}**
Poa chaixii	.	.	.	.	.	.	.	.	**-**	.	.	.	.	.	+	.	.	+	+	.	+	+	+	.	**40^{+}**	**26^{+}**
Omalotheca sylvatica	.	.	.	.	+	.	.	.	**13^{+}**	r	.	.	r	.	+	.	.	+	.	.	.	.	.	+	**33^{+}**	**26^{+}**
Cerastium holosteoides	.	.	.	.	.	.	.	.	**-**	+	.	.	.	.	.	+	.	+	.	.	.	.	+	.	**27^{+}**	**17^{+}**
Festuca rubra	.	.	.	.	.	.	.	.	**-**	.	.	+	.	.	.	.	.	+	.	+	.	.	+	.	**27^{+}**	**17^{+}**
Carex ovalis	.	.	.	.	.	.	.	.	**-**	.	.	.	+	+	+	.	.	.	.	.	.	+	.	.	**27^{+}**	**17^{+}**
Rhytidiadelphus squarrosus (E_0)	.	.	.	.	.	.	.	.	**-**	b	1	1	1	1	1	+	.	+	+	a	1	1	1	.	**87^{1}**	**57^{1}**
Nardo strictae-Agrostion tenuis																										
Homogyne alpina	.	+	+	2	2	+	+	+	**88^{1}**	b	1	a	1	b	b	b	b	b	1	+	+	+	+	b	**100^{2}**	**96^{2}**
Vaccinium myrtillus	+	1	.	2	3	3	2	3	**88^{2}**	b	b	a	1	1	1	1	1	+	1	1	+	+	.	b	**93^{2}**	**91^{2}**
Avenella flexuosa	.	2	.	1	+	+	.	.	**50^{1}**	b	3	3	a	a	a	4	5	3	3	3	4	a	3	a	**100^{3}**	**83^{2}**
Vaccinium vitis-idaea	+	+	.	+	.	r	+	.	**63^{+}**	+	+	.	.	.	.	.	+	.	a	1	+	.	.	.	**40^{1}**	**48^{+}**
Gentiana asclepiadea	.	.	.	.	.	.	.	.	**-**	.	.	.	.	r	.	.	.	.	.	.	.	.	.	1	**13^{+}**	**9^{+}**

Tab. 1. – cont.

Relevé No.	1	2	3	4	5	6	7	8		9	11	19	20	21	23	10	13	12	14	15	18	16	17	22		
Number of plant taxa	11	15	11	20	31	19	23	16	**C %**	30	25	20	21	24	30	28	33	36	35	29	32	28	20	19	**C %**	**Ctot %**
Nardetea strictae, Nardetalia strictae																										
Nardus stricta	3	3	3	3	3	2	1	2	**100^{2}**	3	3	4	4	4	5	1	a	b	3	4	b	5	4	4	**100^{3}**	**100^{3}**
Potentilla aurea	.	.	+	+	+	+	+	+	**75^{+}**	a	b	a	a	a	a	3	a	b	1	a	a	a	a	1	**100^{2}**	**91^{2}**
*Luzula *rubella*	+	1	+	1	1	1	+	+	**100^{1}**	1	.	+	+	+	.	+	+	1	+	+	+	+	.	+	**80^{+}**	**87^{+}**
Luzula campestris agg.	.	.	.	.	+	.	+	+	**38^{+}**	.	.	+	.	+	+	+	+	+	+	+	+	.	.	.	**60^{+}**	**52^{+}**
Veronica officinalis	+	.	.	.	.	.	r	+	**25^{+}**	.	+	+	.	.	+	.	.	+	+	.	.	+	.	.	**40^{+}**	**35^{+}**
Carex pallescens	.	.	.	.	.	.	.	.	**-**	.	.	.	.	+	.	.	.	r	.	.	.	.	.	.	**13^{+}**	**9^{+}**
Mulgedio-Aconitetea																										
Campanula serrata	.	.	.	r	+	r	+	+	**63^{+}**	1	+	+	+	+	+	+	1	a	+	+	1	.	.	.	**80^{1}**	**74^{+}**
*Achillea *alpestris*	.	+	+	.	+	+	+	.	**63^{+}**	r	.	.	+	+	+	+	+	1	+	+	+	.	.	.	**67^{+}**	**65^{+}**
Pyrethrum clusii	.	.	.	+	+	.	.	.	**25^{+}**	+	.	.	.	.	.	.	.	1	+	.	r	.	.	.	**27^{+}**	**26^{+}**
Phleum hirsutum	.	+	.	+	.	.	.	.	**25^{+}**	.	.	.	.	.	.	.	+	.	+	.	1	.	.	.	**20^{+}**	**22^{+}**
*Veratrum *lobelianum*	.	.	.	.	.	.	.	.	**-**	r	.	.	.	.	.	.	.	.	.	.	.	r	.	.	**13^{+}**	**9^{+}**
Other taxa																										
Deschampsia cespitosa	2	1	1	+	+	+	1	1	**100^{1}**	+	1	1	1	1	1	1	+	b	1	1	+	1	1	1	**100^{1}**	**100^{1}**
Hypericum maculatum	.	+	+	1	2	+	2	+	**88^{1}**	b	a	1	a	b	a	1	1	b	a	+	1	1	+	1	**100^{2}**	**96^{2}**
Agrostis capillaris	1	.	.	+	+	1	+	+	**75^{+}**	3	b	a	b	b	a	1	a	3	a	a	b	b	a	1	**100^{2}**	**91^{2}**
Alchemilla sp. div.	.	.	.	.	+	+	r	.	**38^{+}**	.	.	.	.	+	+	.	1	+	r	+	+	+	.	.	**53^{+}**	**48^{+}**
Ranunculus nemorosus	.	.	.	+	+	.	.	.	**25^{+}**	.	+	.	.	.	.	.	+	1	+	+	.	+	.	.	**40^{+}**	**35^{+}**
Luzula sylvatica	1	+	.	.	+	.	.	.	**38^{+}**	+	.	.	.	.	.	.	.	.	+	.	.	+	.	+	**27^{+}**	**30^{+}**
Thymus alpestris	.	.	.	.	r	.	+	+	**38^{+}**	.	.	.	.	.	.	+	.	.	+	+	1	.	.	.	**27^{+}**	**30^{+}**
Leucanthemum margaritae	.	.	.	.	+	.	+	+	**38^{+}**	.	.	.	.	.	.	+	.	.	+	.	+	.	.	.	**20^{+}**	**26^{+}**
Lotus corniculatus	.	+	.	.	.	.	+	+	**38^{+}**	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	**13^{+}**	**22^{+}**
*Viola *sudetica*	.	.	.	.	r	.	.	+	**25^{+}**	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	**13^{+}**	**17^{+}**
Bryophytes (E_0)																										
Pleurozium schreberi	+	.	.	4	1	.	.	.	**38^{2}**	+	1	1	+	.	.	.	+	.	b	1	1	.	+	.	**60^{1}**	**52^{1}**
Hylocomium splendens	.	.	.	2	.	.	.	.	**13^{2}**	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	**13^{+}**	**13^{1}**

Plant taxa present in one or two relevés (except for differential species):

E_1: *Anemone narcissiflora* + (relevé no. 14); *Briza media* + (12, 18); *Carlina acaulis* + (18); *C. vulgaris* r (2); *Crepis conyzifolia* + (14); *C. mollis* + (12); *Crocus discolor* + (1, 8); *Cruciata glabra* + (7, 18); *Heracleum *trachycarpum* + (12); *Leontodon *hispidus* + (12, 14); *Leontodon* sp. + (2); *Linum extraaxillare* + (9); *Phyteuma spicatum* r (13); *Picea abies* r (6); *Pilosella officinarum* r (6), + (14); *Primula elatior* + (3); *Prunella vulgaris* + (11); *Ranunculus pseudomontanus* + (13); *Senecio subalpinus* + (12); *Sesleria albicans* + (5); *Trifolium pratense* + (12); *Veronica chamaedrys* + (13); *Viola biflora* 1 (18)

E_0: *Amblystegium varium* + (12); *Barbilophozia barbata* + (23); *Brachythecium velutinum* + (11); *Bryum caespiticium* + (10); *Calliergonella cuspidata* + (23); *Cephalozia bicuspidata* + (15); *Dicranum scoparium* + (15, 16); *Ditrichum heteromallum* + (16, 21); *Lophocolea heterophylla* + (13); *Plagiothecium curvifolium* + 17); *Polytrichum juniperinum* + (6); *Tortella tortuosa* + (10)

Localities of the phytosociological relevés:

Relevés no. 1–8 (variant with *Hieracium alpinum*): GREBENŠČIKOV et al. (1956, Tab. 5, rels 6–9, 11, 13–15)
Relevés no. 9–23 (variant with *Ligusticum mutellina*): Kliment (1987–2001, ined.)

9. Mt. Kráľov grúň, near the tourist path below Kráľova skala; 1 350 m a.s.l., aspect NNE, slope 15°, area 5 × 5 m, cover E_1 100 %, E_0 20 %, height 50/30 cm, date 1. 10. 1987.
10. Mt. Malá Krížna (1 497 m a.s.l.), near the tourist path below the top part of a ridge; 1 480 m a.s.l., aspect N, slope 20°, area 5 × 5 m, cover E_1 95 %, E_0 15 %, height 90/45 cm, date 14. 8. 1987.
11. end of the Rovne Valley below the Krížna Mt., margin of spruce forest; 1 360 m a.s.l., aspect NNE, slope 20°, area 5 × 5 m, cover E_1 95 %, E_0 15 %, height 80/45 cm, date 18. 8. 1988.
12. Mt. Veľká Pustalovčia (1 585 m), western slopes; 1 340 m a.s.l., aspect WNW, slope 20°, area 5 × 5 m, cover E_1 100 %, E_0 1 %, height 140/45 cm, date 21. 8. 1987.
13. end of the Vrátna dolina Valley, lateral ridge of Suchý vrch Mt., near Biela skala Mt., below the cliff; 1 450 m a.s.l., aspect WNW, slope 10°, area 5 × 5 m, cover E_1 100 %, E_0 5 %, height 40 cm, date 12. 8. 1987.
14. Kráľova studňa Saddle, northern slopes above the end of Malé Studienky Valley; 1 340 m a.s.l., aspect NNE, slope 15°, area 5 × 5 m, cover E_1 100 %, E_0 15 %, height 90/40 cm, date 24. 8. 2001.
15. Mt. Krížna, northern slopes of the ridge between geographical points 1 557 and 1 497 m a.s.l., above the end of Dedošova dolina Valley; 1 430 m a.s.l., aspect NNW, slope 15°, area 5 × 5 m, cover E_1 100 %, E_0 10 %, height 60/30 cm, date 15. 8. 2001.
16. Mt. Krížna, northern slopes of the geographical point 1 557 m a.s.l., above the end of Dedošova dolina Valley; 1 440 m a.s.l., aspect N, slope 15°, area 5 × 5 m, cover E_1 100 %, E_0 5 %, height 90/45 cm, date 15. 8. 2001.
17. Mt. Krížna, northern slopes of the ridge between Krížna Mt. and geographical point 1 557 m a.s.l.; 1 460 m a.s.l., aspect N, slope 10°, area 5 × 5 m, cover E_1 100 %, E_0 5 %, height 55/30 cm, date 15. 8. 2001.
18. Mt. Ostredok, north-western slopes, lateral ridge near Štrochy, near the tourist path (green mark from Drobkov); 1 380 m a.s.l., aspect WNW, slope 20°, area 5 × 5 m, cover E_1 100 %, E_0 5 %, height not recorded, date 13. 8. 1987.
19. Mt. Ostredok, western ridge (green tourist mark), north-western slopes above the Vrátna dolina Valley, near forest margin; 1 370 m a.s.l., aspect N, slope 15°, area 5 × 5 m, cover E_1 98 %, E_0 10 %, height 70/30 cm, date 16. 8. 2001.
20. Mt. Ostredok, northern slopes of the ridge above Vrátna dolina Valley (green tourist mark); 1 370 m a.s.l., aspect N, slope 15°, area 5 × 5 m, cover E_1 95 %, E_0 5 %, height 70/30 cm, date 16. 8. 2001.
21. Mt. Ostredok, northern slopes above a forest margin, above the end of Vrátna dolina Valley; 1 370 m a.s.l., aspect NNW, slope 15°, area 5 × 5 m , cover E_1 98 %, E_0 5 %, height 60/30 cm, date 16. 8. 2001.
22. Mt. Suchý vrch, northern slopes of the ridge near Biela skala Mt., above the end of a Revúcky mlyn Valley; 1 490 m a.s.l., aspect NNE, slope 25°, area 5 × 5 m, cover E_1 95 %, E_0 1 %, height 80/35 cm, date 16. 8. 2001.
23. Mt. Suchý vrch, mild convex ridge of valley below saddle between geographical points 1 551 and 1 545 m a.s.l., below a slope terrace; 1 440 m a.s.l., aspect NNW, slope 15°, area 4 × 6 m, cover E_1 98 %, E_0 5 %, height not recorded, date 16. 8. 2001.

Tab. 2. Comparison of species composition of the association *Helictotricho planiculmis-Nardetum strictae* among three periods (column no. 1 – 1953; 2 – 1987/88; 3 – 2001). Frequency and fidelity (phi coefficient × 100 in the upper indices) values of individual species are shown. Species with a presence only in one or two relevés were omitted (see Tab. 1).

Number of column	1	2	3
Number of relevés	8	6	9
Differential taxa of each period			
Hieracium alpinum agg.	**50** $^{63.2}$	0 $^{-}$	0 $^{-}$
Hieracium lachenalii	0 $^{-}$	**83** $^{64.5}$	33 $^{-}$
Allium victorialis	0 $^{-}$	**67** $^{57.4}$	22 $^{-}$
Anthoxanthum alpinum	25 $^{-}$	**100** $^{53.2}$	67 $^{-}$
Poa alpine	0 $^{-}$	**83** $^{52.5}$	56 $^{-}$
Cerastium holosteoides	0 $^{-}$	**50** $^{52.0}$	11 $^{-}$
Acetosa arifolia	0 $^{-}$	17 $^{-}$	**56** $^{52.1}$
Carex ovalis	0 $^{-}$	0 $^{-}$	**44** $^{59.0}$
Differential taxa of association			
Avenula planiculmis	100 $^{-}$	100 $^{-}$	100 $^{-}$
Soldanella carpatica	50 $^{-}$	100 $^{-}$	78 $^{-}$
Ligusticum mutellina	0 $^{-}$	17 $^{-}$	44 $^{-}$
Polytrichum formosum (E_0)	0 $^{-}$	67 $^{-}$	44 $^{-}$
Nardo strictae-Agrostion tenuis			
Phleum rhaeticum (char.)	25 $^{-}$	100 $^{-}$	100 $^{-}$
Poa chaixii (char.)	0 $^{-}$	33 $^{-}$	44 $^{-}$
Crepis conyzifolia (char.)	0 $^{-}$	0 $^{-}$	11 $^{-}$
Homogyne alpina (dif.)	88 $^{-}$	100 $^{-}$	100 $^{-}$
Vaccinium myrtillus (dif.)	88 $^{-}$	100 $^{-}$	89 $^{-}$
Avenella flexuosa (dif.)	50 $^{-}$	100 $^{-}$	100 $^{-}$
Vaccinium vitis-idaea (dif.)	62 $^{-}$	67 $^{-}$	22 $^{-}$
*Solidago *minuta* (dif.)	0 $^{-}$	67 $^{-}$	44 $^{-}$
Gentiana asclepiadea (dif.)	0 $^{-}$	0 $^{-}$	22 $^{-}$
Nardetalia strictae*, *Nardetea strictae			
Nardus stricta	100 $^{-}$	100 $^{-}$	100 $^{-}$
*Luzula *rubella*	100 $^{-}$	83 $^{-}$	78 $^{-}$
Potentilla aurea	75 $^{-}$	100 $^{-}$	100 $^{-}$
Luzula campestris agg.	38 $^{-}$	67 $^{-}$	56 $^{-}$
Veronica officinalis	25 $^{-}$	33 $^{-}$	44 $^{-}$
Carex pallescens	0 $^{-}$	17 $^{-}$	11 $^{-}$
Other taxa			
Deschampsia cespitosa	100 $^{-}$	100 $^{-}$	100 $^{-}$
Hypericum maculatum	88 $^{-}$	100 $^{-}$	100 $^{-}$
Agrostis capillaries	75 $^{-}$	100 $^{-}$	100 $^{-}$
*Achillea *alpestris*	62 $^{-}$	83 $^{-}$	56 $^{-}$
Campanula serrata	62 $^{-}$	100 $^{-}$	67 $^{-}$
Ranunculus nemorosus	25 $^{-}$	50 $^{-}$	33 $^{-}$
Thymus alpestris	38 $^{-}$	33 $^{-}$	22 $^{-}$
Luzula sylvatica	38 $^{-}$	17 $^{-}$	33 $^{-}$

Tab. 2. – cont.

Number of column	1	2	3
Number of relevés	8	6	9
Pyrethrum clusii	25^{-}	50^{-}	11^{-}
Leucanthemum margaritae	38^{-}	33^{-}	11^{-}
Phleum hirsutum	25^{-}	33^{-}	11^{-}
Omalotheca sylvatica	12^{-}	33^{-}	33^{-}
Antennaria dioica	38^{-}	17^{-}	0^{-}
Lotus corniculatus	38^{-}	17^{-}	0^{-}
*Viola *sudetica*	25^{-}	17^{-}	0^{-}
Stellaria graminea	0^{-}	50^{-}	56^{-}
Alchemilla sp. div.	0^{-}	50^{-}	56^{-}
Festuca rubra	0^{-}	17^{-}	33^{-}
Galium anisophyllon	25^{-}	0^{-}	0^{-}
Hieracium prenanthoides	25^{-}	0^{-}	0^{-}
*Veratrum *lobelianum*	0^{-}	17^{-}	11^{-}
Bryophytes (E_0)			
Pleurozium schreberi	38^{-}	67^{-}	56^{-}
Rhytidiadelphus squarrosus	0^{-}	83^{-}	89$^{45.0}$
Hylocomium splendens	12^{-}	17^{-}	11^{-}

Results and discussion

Numerical classification divided phytosociological material of mat-grass swards in the Veľká Fatra Mts into two floristically well-defined groups of relevés. They were interpreted at variant-level of the *Helictotricho planiculmis-Nardetum strictae* association (Tab. 1). Variant with *Hieracium alpinum* is differentiated primarily by *Hieracium alpinum* agg., *H. prenanthoides*, *Galium anisophyllon* and *Antennaria dioica*. These stands, originally grazed by sheep, were documented only by GREBENŠČIKOV et al. (1956). Vegetation of the variant with *Ligusticum mutellina* is distinguished by diverse plant functional groups including numerous graminoids (*Anthoxanthum alpinum*, *Carex ovalis*, *Festuca rubra*, *Phleum rhaeticum*, *Poa alpina*, *P. chaixii*), broadleaved herbs (e.g. *Acetosa arifolia*, *Allium victorialis*, *Ligusticum mutellina*, *Solidago *minuta*) and mosses (*Polytrichum formosum*, *Rhytidiadelphus squarrosus*). This cluster includes more recent stands sampled in the years of 1987/88 and 2001, which were used for cattle grazing at that time (MILAN 2003). The most common species with increasing cover values within the analysed period were some small grass and herb species. We suppose that micro-site disturbances and selective consumption resulting from differences between sheep and cattle grazing promote especially growth and development of *Avenella flexuosa* and *Potentilla aurea* (but see also KRAHULEC et al. 2001) and at the same time, reduced the cover of *Vaccinium myrtillus* (cf. GREBENŠČIKOV et al. 1956). This vegetation is classified within the alliance *Nardo strictae-Agrostion tenuis* based on presence of montane and oligotrophic species such as *Avenella flexuosa*, *Gentiana asclepiadea*, *Homogyne alpina*, *Vaccinium myrtillus* and *Vaccinium vitis-idaea*.

The present floristic pattern corresponds to the main outcomes of the national synthesis (KLIMENT & UJHÁZY 2014).

The stands of *Helictotricho planiculmis-Nardetum strictae* inhabit only the north-facing slopes of the main ridge plateau. The narrow distribution context of the suitable vegetation type and sampling design allowed us to compare changes in species composition of the mat-grass swards, i.e. phytosociological relevés were grouped according to the three sampling periods (Tab. 2). The plots sampled by GREBENŠČIKOV et al. (1956) differed only by presence of *Hieracium alpinum* agg. (cluster 1), whereas abundant set of species such as *Hieracium lachenalii*, *Allium victorialis*, *Anthoxanthum alpinum*, *Poa alpina* and *Cerastium holosteoides* showed highest fidelity to the period of 1987/88 (cluster 2). The floristic peculiarity of the last period (cluster 3) was driven mainly by species *Acetosa arifolia* and *Carex ovalis*. Two EIVs and grazing type showed significant relation (P < 0.05) with first two PCA ordination axes (Fig. 1). The main factors controlling floristic differences were connected with soil nutrient (PCA axis 1) and moisture gradient (PCA axis 2). Although PCA analysis showed positive response of vegetation plots recorded in 2001 to moisture gradient, our data did not allow us to directly disentangle its role in variation of species composition. These plots differed mainly by the occurrence of species *Carex ovalis*, *Acetosa arifolia*, *Ligusticum mutellina* and *Gentiana asclepiadea*, which are characterized by relatively higher EIV for moisture (ELLENBERG et al. 1992). We do not consider inter-annual fluctuation of precipitation (2000/2001) to be relevant for this pattern, as annual plant species with higher moisture requirements were not found in the studied pastures. There was observed evident shift in availability of nutrients between initial (cluster 1) and more recent vegetation plots (cluster 2 and 3). This trend most likely results from higher input of nutrients associated with cattle grazing which is also indicated through increase in some mesotrophic and acidic-tolerant species (e.g. *Acetosa arifolia*, *Allium victorialis*, *Phleum rhaeticum*, *Poa alpina*, *Omalotheca sylvatica*). Different grazing patterns probably induced the changes in species composition and affected division of vegetation material into the sheep and cattle grazed plots (Tab. 1, Fig. 1). This pattern was already proved from grasslands (e.g. SEBASTIÀ et al. 2008). Both grazing animals similarly act through grazing, trampling and nutrient addition, but their effect is a species-specific. A sheep grazing causes a lower degree of soil and plant cover disturbance than a cattle grazing, which is more pronounced at mountain areas with higher precipitation. Sheep as highly selective grazers prefer species from lower vegetation layers and avoid tall grasses (HEJCMAN et al. 2002, SEBASTIÀ et al. 2008). They can also effectively suppress weeds and help restrict their spread. In contrast, a cattle grazing suppresses a succession of tall grasses and supports higher cover of small grasses. Local disturbances created by cattle enable a successful seedling establishment and development of moss layer (GREBENŠČIKOV et al. 1956, PÁTKOVÁ & KRAHULEC 1997, HEJCMAN et al. 2004, POUROVÁ 2009, see also Tab. 1). Large herbivores, such as cattle, are an important driver in the nutrient cycling (e.g. phosphorus, nitrogen) in pastures. They ingest large quantities of plant biomass, but return most nutrients to the pasture via excreta deposition (POUROVÁ 2009). Changes in grazing management are thus generally considered to be significant processes modifying vegetation structure (HEJCMAN et al. 2002, 2004).

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