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Vegetation characteristics of species-rich grasslands in the National Park Slovenský raj, Slovakia

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Abstract

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The paper presents phytosociological data of grassland communities in Kopanecké lúky in the National park Slovenský raj. Regarding the species richness, the studied meadows are extraordinary valuable and contain one of the highest number of vascular plant species at small scales in Europe. In 2012, we recorded 100 vascular plant species in the area of 25 m^2. Within the study area, eight plant communities or vegetation types (characterised by specific species combination and species dominance) were ordered into the alliances *Arrhenatherion elatioris*, *Violion caninae*, *Nardo strictae-Agrostion tenuis*, *Polygono bistortae-Trisetion flavescentis*. All types of recorded vegetation represent transitional and successional stages. After 13–17 years the vegetation studied on permanent monitoring plots 5 × 5 m showed some changes. Meadows which have been regularly managed since 1990 have relatively stable species composition and species diversity. Abandoned plots experienced decrease in the total number of species and the emergence of expansive grasses like *Calamagrostis varia* (mesic and subxerophilic sites), *Brachypodium pinnatum* (wetter, mesic and subxerophilic sites) and *Calamagrostis arundinaceae* (mesic oligotrophic and acidic sites). In areas where cutting of trees, restoration or irregular mowing of meadows took place the number of species slightly increased. On the present, the plots are still threatened by expansion of *Calamagrostis arundinacea* species.

Keywords

diversity, grassland, phytosociology, Slovenský raj

Introduction

Semi-natural grasslands belong to the plant communities with the highest species diversity, especially in a small scale (Kull and Zobel, 1991; Klimeš, 2001, Wilson et al., 2012). Meadow and pasture communities occupying only 5% of the area of the National park Slovenský raj are the result of the traditional land-use in the past. Kopanecké lúky (meadows) ranks among the most valuable and most integrated complex of meadows in NP Slovenský raj. These communities represent the richest grasslands in Central Europe. In 2000, seventy-five vascular plants were recorded per 1 m^2 and 109 per 25 m^2, respectively (Šeffer et al., 2010). Many authors Smieškova (1970), Dzubinová (1984), Pitoniak (1978), later Dražil et. al. (1998) studied flora and vegetation of Kopanecké lúky. This paper introduces phytosociological characteristics of grassland communities in the area and the description of their changes on the 11 monitoring plots after 13–17 years. The study area is situated in the south-western part of the NP Slovenský raj in the cadaster of Vernár, district Poprad. The altitude of the aforesaid area ranges from 900 to 1,186 m asl.

Material and methods

Fifty five relevés from 55 monitoring plots (MP) recorded during the growing seasons 2012–2014 were used for the phytosociological description of the area. Between 1996 and 1999 relevés from 11 MPs and one relevé from 2000 (old relevés) (Dražil, 2004) were recorded in order to compare the species composition. Between 2012 and 2013 relevés were again recorded in 11 MPs. Some MPs are documented by more than one relevé in the old or new set of relevés. Nomenclature of vascular plants follows Marhold et al. (1998). Names of syntaxa follow Hegedüšová Vantarová et al. (2014). All relevés have been recorded according to the principles of the Zürich-Montpellier school (Braun-Blanquet, 1964) using the new Braun-Blanqet 9-degree cover scale (Barkman et al., 1964). Mosses and lichens were not determined. The size of each plot was 5 × 5 m. Relevés were stored in a database program Turboveg (Hennekens and Schaminée, 2001) and imported into the program Juice (Tichý, 2002). As the gradient length in DCA analysis was short (2.961 and 2.375 for the first two axes), the PCA (principal component analysis) which is included in the program Canoco 4.5 (Ter Braak, Šmilauer, 2002) was applied. Divisive polythetic classification Twinspan (Hill, 1979) in program Juice (Tichý, 2002) was used for the numerical classification of relevés. Pseudospecies cut levels were set to 0, 5, 15, 25. Diagnostic or differential taxa were determined according to fidelity and for its calculation the phi coefficient and standardization of the number of relevés in the synoptic column were carried out. The statistical significance of fidelity was tested by Fisher exact test ($p < 0.01$) (Chytrý et. al., 2002). Species with phi > 0.30 were considered as diagnostic. Species with a cover > 30% in relevés were considered to be dominant and species with a frequency > 90% in column were considered to be constant. Apart from diagnostic species, constant species were also decisive for differentiation of communities due to relative small dataset. Shannon diversity index and the mean unweighted values of Ellenberg`s ecological indices (Ellenberg et al., 1992) for nutrients, soil reaction, light, temperature, continentality and moisture were calculated for individual relevés in the program Juice (Tichý, 2002). They entered the analysis as supplementary data. To test the correlation of mean values of Ellenberg´s ecological indices (EIIs) calculated for grassland communities with 1. and 2. PCA axis „Modified randomized test with species indicator values" was used (Zelený and Schaffers, 2012).

Results and discussion

Phytosociological characteristics of grassland communities

Typical plant communities or vegetation types of the studied area in various stages of transition or succession were documented by phytocoenological relevés. The historically developed secondary meadow communities are influenced by the dominance of expansive species (*Arrhenatherum elatius*, *Brachypodium pinnatum*, *Calamagrostis arundinacea*, *C. varia*). Also Norway spruce (*Picea abies*) has a high contribution to the overgrowing of meadows. Irregular and poorly managed parts of the grassland complex Kopanecké lúky

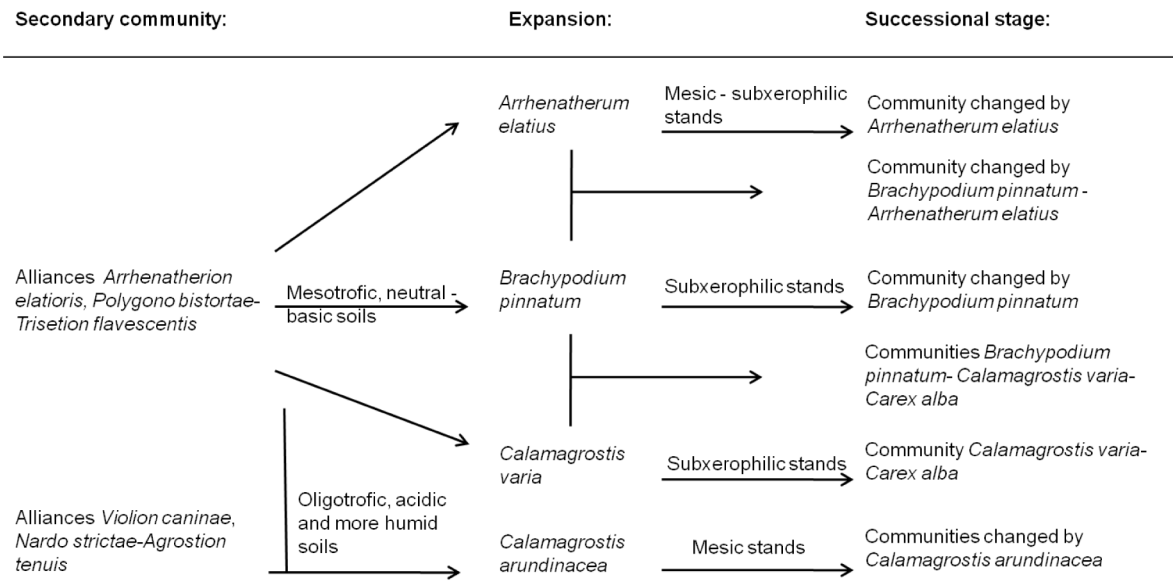

Fig. 1. Successional scheme of the most widespread communities in complex of Kopanecké lúky (authors: Vadel and Dražil, 2014).

are most affected by succession (Fig. 1). Therefore, it was not possible to classify some relevés exactly to syntaxa so we characterized them only as vegetation types.

55 relevés representing grassland communities were divided into 8 groups using a classification program Twinspan (Hill, 1979). In PCA analysis environmental factors as supplementary data were derived from mean values of Ellenberg`s ecological indices (EIIs). The first ordination axis explains 17.3% and the second axis 13.2% of the variability of species data. According to "Modified randomized test with species indicator values" (Zelený and Schaffers, 2012), EIIs for moisture, soil reaction and nutrients had a significant correlations with the first two PCA axes ($p < 0.05$). Moisture had positive correlation, but soil reaction had negative correlation with both PCA axes. Nutrients show negative correlation with 1.PCA axis and positive with 2.PCA axis (Fig. 2).

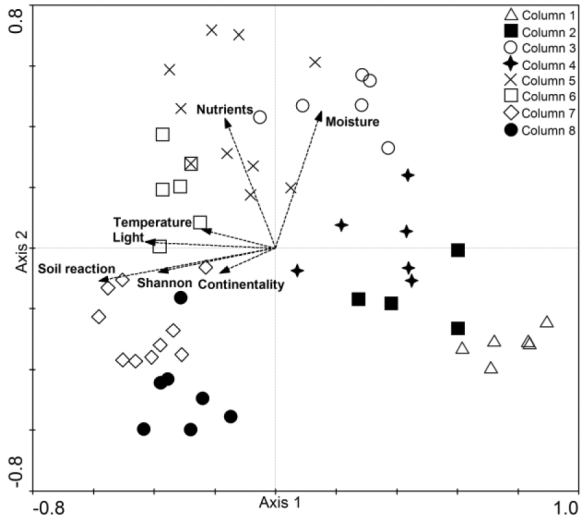

Fig. 2. Ordination graph of principal components analysis (PCA) shows the position of 55 relevés from 55 monitoring plots classified to 8 groups.

The first group of relevés (Table 1) represents transitional stages of communities of the alliance *Nardo strictae-Agrostion tenuis.* These mesic and oligotrophic grasslands are represented by acidophilous diagnostic species as *Avenella flexuosa*, *Nardus stricta*, *Soldanella hungarica, Trommsdorfia uniflora*. Constant species are *Pyrethrum clusii*, *Carlina acaulis* and *Luzula luzuloides*. Two relevés show affinity to the association *Viola sudeticae-Agrostietum capillaris*. The original vegetation is changed by expansion of grass species *Calamagrostis arundinacea* which is dominant and diagnostic for this group. It is the consequence of inadequate management in the particular part of the area. These secondary communities were developed after deforestation of fir-beech and spruce forests (Ujházy and Kliment, 2007). Some relevés contain subalpine elements, such as *Pulsatilla scherfelii, Trientalis europaea, Homogyne alpina, Veratrum album* subsp. *lobelianum*.

Dominant *Calamagrostis arundinacea* affects vegetation in the second group of relevés as well (Table 1). These communities have successional character of alliance *Violion caninae,* which are typical of mixture of species of meadow and mat-grass communities (Kliment and Ujházy, 2014). Diagnostic species are *Hieracium lachenalii*, *Vaccinium myrtillus*, *V. vitis-idaea.* Species *Agrostis capillaris, Avenella flexuosa, Veronica chamaedrys, Fragaria vesca, Campanula patula, Jacea phrygia, Lotus corniculatus, Luzula luzuloides, Hypericum maculatum, Pimpinella saxifraga, Ranunculus polyanthemos, Cruciata glabra* etc. are constant. Several of these species are typical of the *Polygono bistortae-Trisetion flavescentis* and *Arrhenatherion elatioris* alliances. In comparison with the previous group, these communities are species-richer and *Nardus stricta* occurs only with low abundance in one relevé.

Grasslands formed by species *Agrostis capillaris*, *Arrhentherum elatius* and *Festuca rubra* with lower species diversity on more humid and deeper soils are documented in the third column of Table 1. The group is differentiated by species *Deschampsia cespitosa, Poa humilis, Achillea distans,* which have higher fidelity index. Characteristic species composition is complemented by constant species, such as *Crepis mollis, Cardaminopsis halleri, Stellaria graminea, Acetosa pratensis, Festuca rubra, Ranunculus acris, Hypericum maculatum, Trifolium pratense* etc. Swards can be characterised as successional stages of the most widespread grassland association in Slovenský raj – *Antoxantho odorati-Agrostietum tenuis* (Pitoniak, 1978), with close relation to the communities of the *Polygono bistortae-Trisetion flavescentis* alliance. *Deschampsia cespitosa* species occurs on sites of association *Antoxantho odorati-Agrostietum tenuis* at higher altitudes (Uhliarová et al., 2014).

The fourth column of Table 1 documents species-rich communities despite being influenced by *Calamagrostis arundinacea*. Species *Cerastium holosteoides, Prunella vulgaris, Viola canina* and *Avenella flexuosa* differentiate the group. Constant species of grasses are represented by *Briza media, Festuca rubra, F. ovina*. Species *Agrostis capillaris* has the frequency of 83%. Species *Cardaminopsis halleri, Trifolium repens* and *T. pratense, Alchemilla* sp. div. are typical of lower herb layer. These swards having characteristic species *Luzula luzuloides, Ranunculus polyanthemos* and *Thymus pulegioides* occur on nutrient-poorer soil. This group represents successional stages of communities of alliance *Polygono bistortae-Trisetion flavescentis*. According to species composition and ecological conditions, some relevés probably represent a successional stage of association *Crepido*

Table 1. Synoptic table containing only diagnostic species (with fidelity over 30, in gray fields), constant species and species with frequency over 65%

Group number	1	2	3	4	5	6	7	8
Number of relevés	6	4	6	6	10	6	10	7
Alliance/Species	Frequency (%)							
Alliance *Nardo strictae-Agrostion tenuis*								
Nardus stricta	100 75.1	25 ---	. ---	17 ---	10 ---	. ---	10 ---	. ---
Soldanella hungarica	50 68.3	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Trommsdorfia uniflora	100 62	50 ---	33 ---	33 ---	. ---	. ---	. ---	. ---
Hieracium murorum	50 51	. ---	. ---	. ---	. ---	. ---	. ---	29 ---
Gymnadenia conopsea	100 49.7	50 ---	17 ---	17 ---	10 ---	17 ---	40 ---	43 ---
Alliance *Violion caninae*								
Hieracium lachenalii	17 ---	75 75.4	. ---	. ---	. ---	. ---	. ---	. ---
Vaccinium vitis-idaea	100 62	100 62	. ---	17 ---	. ---	. ---	. ---	. ---
Vaccinium myrtillus	67 44.5	75 52.4	. ---	17 ---	. ---	. ---	. ---	. ---
***Antoxantho odorati-Agrostietum tenuis* – successional stages**								
Deschampsia cespitosa	. ---	25 ---	100 59.2	17 ---	20 ---	50 ---	20 ---	. ---
Poa humilis	---	25 ---	83 53.3	17 ---	20 ---	17 ---	10 ---	. ---
Achillea distans	33 ---	. ---	67 51.4	17 ---	. ---	. ---	. ---	14 ---
Alliance *Polygono bistortae-Trisetion flavescentis* – successional stages								
Cerastium holosteoides	. ---	. ---	. ---	83 53.6	40 ---	33 ---	30 ---	. ---
Viola canina	17 ---	25 ---	33 ---	100 53.2	40 ---	33 ---	20 ---	. ---
Calamagrostis arundinacea	100 44.3	100 ---	17 ---	100 44.3	10 ---	. ---	10 ---	. ---
Avenella flexuosa	100 42.5	100 ---	33 ---	100 42.5	10 ---	. ---	10 ---	. ---
Prunella vulgaris	. ---	25 ---	. ---	100 43.1	20 ---	100 43.1	60 ---	43 ---
Poo-Trisetetum flavescentis								
Trisetum flavescens	. ---	. ---	. ---	17 ---	80 60.9	33 ---	. ---	14 ---
Crepis biennis	. ---	. ---	. ---	. ---	30 52.2	. ---	. ---	. ---
Myosotis nemorosa	. ---	. ---	. ---	. ---	30 52.2	. ---	. ---	. ---
Avenula pubescens	17 ---	. ---	17 ---	. ---	90 52.1	67 ---	20 ---	14 ---
Trollius altissimus	17 ---	. ---	. ---	. ---	50 45.1	17 ---	10 ---	. ---
Taraxacum sp.	. ---	. ---	50 ---	. ---	80 42.5	33 ---	40 ---	29 ---
Carex pallescens	. ---	. ---	17 ---	50 ---	70 37.4	50 ---	10 ---	14 ---
Primula elatior	. ---	. ---	17 ---	33 ---	80 35.3	50 ---	60 ---	43 ---
Rhinanthus serotinus	50 ---	50 ---	17 ---	83 ---	100 31.5	83 ---	60 ---	29 ---
***Arrhenatherion elatioris* - successional stages**								
Colymbada scabiosa	. ---	. ---	. ---	17 ---	10 ---	100 52.4	90 44.4	57 ---
Carum carvi	. ---	. ---	33 ---	. ---	50 ---	83 47.8	50 ---	. ---
Arrhenatherum elatius	33 ---	. ---	50 ---	17 ---	60 ---	100 47	40 ---	14 ---
Alliance *Polygono bistortae-Trisetion flavescentis* – warm type of community								
Carex ornithopoda	. ---	. ---	. ---	. ---	. ---	. ---	40 60.7	. ---
Carex panicea	. ---	. ---	. ---	. ---	30 ---	33 ---	90 57.5	43 ---
Plantago major	. ---	. ---	. ---	. ---	. ---	. ---	30 52.2	. ---
Arenaria serpyllifolia	. ---	. ---	. ---	. ---	. ---	. ---	30 52.2	. ---
Sanguisorba minor	. ---	25 ---	. ---	. ---	. ---	83 ---	100 51.5	71 ---
Carex alba	. ---	50 ---	. ---	. ---	. ---	17 ---	90 51.5	71 ---
Carex caryophyllea	17 ---	25 ---	. ---	17 ---	50 ---	33 ---	100 50.9	43 ---
Festuca pallens	. ---	. ---	. ---	. ---	. ---	. ---	40 42.4	29 ---
Viola hirta	. ---	. ---	. ---	17 ---	. ---	. ---	40 41.4	14 ---
Galium mollugo	17 ---	. ---	67 ---	33 ---	20 ---	67 ---	100 40.3	71 ---
Trifolium montanum	17 ---	25 ---	. ---	50 ---	60 ---	50 ---	100 39.0	86 ---
Plantago media	. ---	. ---	. ---	67 ---	50 ---	100 ---	100 38.9	71 ---
Clinopodium vulgare	. ---	25 ---	. ---	83 ---	20 ---	50 ---	80 34.8	29 ---
Festuca pratensis	. ---	. ---	33 ---	50 ---	80 ---	100 ---	100 34.6	71 ---
Polygonatum verticillatum	33 ---	50 ---	. ---	50 ---	. ---	33 ---	80 34.5	43 ---
Plantago lanceolata	17 ---	. ---	50 ---	17 ---	50 ---	100 ---	90 33.6	43 ---
Dianthus carthusianorum	33 ---	75 ---	. ---	83 ---	50 ---	67 ---	100 30.0	86 ---
***Calamagrostis varia* – (*Sesleria albicans*) – vegetation type**								
Aquilegia vulgaris	. ---	. ---	. ---	33 ---	. ---	17 ---	20 ---	71 53.3
Arabis hirsuta	17 ---	. ---	. ---	. ---	10 ---	17 ---	50 ---	71 47.5
Galium pumilum	17 ---	. ---	. ---	17 ---	. ---	17 ---	50 ---	71 46.1
Acinos alpinus	. ---	. ---	. ---	. ---	. ---	17 ---	90 58.3	86 54.5
Calamagrostis varia	. ---	. ---	. ---	. ---	10 ---	17 ---	90 53.5	100 62
Carduus glaucinus	. ---	. ---	. ---	. ---	. ---	. ---	70 45	100 72.8
Constant and other species								
Anthyllis vulneraria	17 ---	50 ---	. ---	83 ---	30 ---	100 ---	90 ---	86 ---
Potentilla heptaphylla	. ---	. ---	. ---	. ---	40 ---	67 ---	20 ---	29 ---

Table 1. Synoptic table containing only diagnostic species (with fidelity over 30, in gray fields), constant species and species with frequency over 65% – continued

Group number	1	2	3	4	5	6	7	8
Number of relevés	6	4	6	6	10	6	10	7
Alliance/Species	Frequency (%)							
Constant and other species								
Campanula glomerata	.	50	.	83	.	33	70	57
Linum catharticum	17	.	.	17	50	83	80	86
Brachypodium pinnatum	.	25	.	17	80	100	60	86
Poa chaixii	50	75	83	83	30	.	10	.
Lilium bulbiferum	.	.	.	17	.	67	40	57
Sesleria albicans	.	.	.	.	.	.	20	29
Phyteuma orbiculare	17	50	17	83	70	33	90	100
Cirsium arvense	.	75	50	.	.	50	.	.
Thymus pulegioides	67	75	17	100	80	100	100	86
Jacea phrygia	50	100	83	100	100	83	90	100
Helianthemum	17	25	.	50	40	83	70	43
Leontodon hispidus	33	75	17	67	60	100	90	86
Heracleum sphondylium	17	50	50	67	40	33	30	29
Cruciata glabra	83	100	100	100	100	100	90	100
Fragaria vesca	17	100	33	83	20	67	80	71
Cardaminopsis halleri	83	75	100	100	100	100	100	100
Ajuga reptans	.	50	.	67	10	33	60	29
Carlina acaulis	100	100	.	100	60	17	90	100
Festuca rubra	67	75	100	100	100	100	70	57
Veronica chamaedrys	67	100	100	100	100	100	70	71
Stellaria graminea	67	75	100	67	90	33	40	29
Alchemilla sp.	50	75	83	100	100	100	90	29
Dactylis glomerata	.	75	100	67	90	83	90	29
Ranunculus polyanthemos	83	100	83	100	100	83	100	71
Leucanthemum vulgare	50	75	33	83	80	83	100	86
Rumex acetosa	50	75	100	100	100	50	80	14
Campanula patula	33	100	83	100	70	67	30	14
Hypericum maculatum	67	100	100	83	80	83	60	29
Campanula persicifolia	50	75	67	100	20	83	70	86
Colchicum autumnale	.	25	67	17	90	100	100	100
Trifolium pratense	17	75	100	100	100	83	70	43
Lotus corniculatus	83	100	83	83	100	100	100	100
Trifolium flexuosum	33	50	50	67	60	67	50	14
Luzula luzuloides	100	100	67	100	40	50	60	14
Trifolium repens	33	75	83	100	80	83	100	43
Ranunculus acris	17	25	100	83	80	83	50	43
Lathyrus pratensis	.	25	50	50	80	100	90	71
Anthoxanthum odoratum	83	50	17	83	60	100	90	57
Pimpinella major	67	50	100	100	90	83	80	71
Vicia cracca	.	25	50	33	90	67	90	71
Pyrethrum clusii	100	100	83	100	80	67	100	86
Crepis mollis	17	75	100	50	100	67	90	43
Briza media	50	50	33	100	90	100	100	100
Achillea millefolium agg.	17	75	33	83	90	100	100	86
Festuca ovina	83	100	67	100	80	67	80	71
Astrantia major	50	.	17	67	70	33	40	29
Potentilla aurea	83	75	33	50	50	67	50	14
Vicia sepium	.	.	67	50	50	33	.	.
Luzula multiflora	50	25	33	50	50	67	30	43
Crepis conyzifolia	33	50	.	67	60	17	40	14
Leontodon hispidus	50	50	33	67	80	100	100	57
Potentilla erecta	50	75	83	33	80	50	30	29
Agrostis capillaris	83	100	100	83	90	100	80	29
Polygala amara	83	.	.	33	60	33	70	71

Gray highlight – the occurrence of diagnostic species with fidelity (coefficient phi Φ) over 30 in particular type of phytocoenoses (local validity). Probability of non-random occurrence was evaluated by Fisher's exact test, $p > 0.01$. The size of each column was standardized to 12.5% of the size of the dataset.

mollis-Agrostietum capillaris. It belongs to species-rich communities of mountain meadows. In one relevé from 2013 seventy-three species were recorded. Such community occurs in colder and more humid places of submontane and montane zones (700–1,200 m asl) in the Slovenský raj, Nízke Tatry, Poľana, Muránska planina Mts. (Hegedüšová Vantarová, 2014). Ružičková (2004) regards association as a Carpathian vikariant of the *Cardaminopsio halleri-Agrostietum* Moravec 1965 which has been described in the Šumava Mts. as an replacement community of acidophilous beech forests. The change of land-use caused the change of species composition and decline of species of mesophilous meadows. Species of poor habitats appear increasingly and succession continues in the communities of alliance *Nardo strictae-Agrostion tenuis* (Hegedüšová Vantarová, 2014).

Mesophilous grasslands on moister and nutrients-rich soils belong to the *Poo-Trisetetum flavescentis* association (Table 1, column 5). Phytocoenoses are characterized by diagnostic species *Trisetum flavescens*, *Avenula pubescens*, *Myosotis nemorosa, Crepis biennis, Trollius altissimus, Carex pallescens, Taraxacum* sp. Species *Trisetum flavescens* and *Festuca rubra* are dominant grasses and *Briza media, Agrostis capillaris, Dactylis glomerata* are constant grasses. *Trollius altissimus* and *Myosotis nemorosa* occur in moister stands. Lower herb layer consists of *Trifolium pratense, Lotus corniculatus* and *Cruciata glabra* species. In the lower swards *Rhinanthus serotinus* prevails, during spring *Primula elatior* prevails among the flowering individuals. Species such as *Crepis mollis* and *Cardaminopsis halleri* of the *Polygono bistotrae-Trisetion flavescentis* alliance have high constancy. Community forms transitional successional stages. In comparison with the *Anthoxantho odorati-Agrostietum tenuis* it occurs on deeper soils with higher content of available nutrients (Uhliarová et al., 2014).

Successional stages of mesic communities of the *Arrhenatherion elatioris* alliance with the dominance of *Arrhenatherum elatius* and *Brachypodium pinnatum* are documented in the sixth synoptic column of Table 1. The composition of grasses is complemented by *Briza media*, *Festuca pratensis, F. rubra, Anthoxanthum odoratum* and *Agrostis capillaris* species. This group is characterised by the following diagnostic species: *Colymbada scabiosa, Carum carvi, Prunella vulgaris* and *Arrhenatherum elatius*. Lower herb layer is formed by *Alchemilla* sp. div, *Cardaminopsis halleri, Thymus pulegioides, Lotus corniculatus, Cruciata glabra, Leontodon hispidus* and *Veronica chamaedrys*. *Colchicum autumnale* flowers during late summer. The communities are relatively rich in species; the number of species in relevés varied from 52 to 74.

The seventh group of relevés (Table 1) includes species-rich phytocoenoses with subxerophilic character that represent warm type of communities of the *Polygono bistortae-Trisetion flavescentis*. Thermophilous taxa of the *Festuco-Brometea* class bound to the mesotrophic soil derived from calcareous bedrock such as *Carduus glaucinus*, *Carex caryophyllea*, *Colymbada scabiosa*, *Dianthus carthusianorum*, *Plantago media*, *Sanguisorba minor*, *Trifolium montanum* are characteristic for this group. Physiognomy is mostly affected by grass species *Calamagrostis varia* and *Carex alba,* on some plots accompanied by *Brachypodium pinnatum* and *Agrostis capillaris*, less frequently also by *Briza media* and *Festuca pratensis* species. *Sesleria albicans* was recorded on dolomite substrate in plots located around the top of the hill Javorina which is the highest point of the studied area (1,186 m asl). The species of the *Arrhenatherion elatioris* alliance are frequent, e.g. *Leucanthemum vulgare, Trifolium repens, Colchicum autumnale* and *Leontodon hispidus*. In spring *Crocus discolor* and *Primula elatior* species dominate among the flowering individuals. According to the species composition, the group is closely related to the association *Campanulo glomeratae-Geranietum sylvatici.* Swards are influenced by *Calamagrostis varia* and *Brachypodium pinnatum* species to lesser extent. They occur on warmer south-facing slopes with lower and open vegetation. In the MP 10, an extraordinary species-richness was recorded in 2000 (Dražil, 2004) and 2012 with 109 and 100 vascular plant species, respectively.

Relevés in the eighth synoptic column of Table 1 were classified as a vegetation type composed of calcareous grasses *Calamagrostis varia – Sesleria albicans* that follows previous group along a succession gradient. *Calamagrostis varia* as expansive and dominant species indicates successional trend. These unmanaged communities were documented on the southern slopes with favourable thermic conditions and subxerophilous character. Relevés with *Sesleria albicans* were documented on dolomite substrate under the hill Javorina. Thermophilous species are typical of these warm slopes, e.g. *Carduus glaucinus, Aquilegia vulgaris, Galium pumilum, Arabis hirsuta*. Lower herb layer is formed by *Acinos alpinus, Cruciata glabra, Lotus corniculatus, Cardaminopsis halleri*, etc. Smiešková (1970) mentioned a similar example from Kopanecké lúky where *Festuca rubra*, *Carex alba*, *Calamagrostis varia* occur but *Brachypodium pinnatum* has only low abundance. She describes such community as calcareous and more xerophilous occupying small area on a south-facing slope. Soil was characterized as shallow, calcareous rendzic leptosols with higher content of the skeleton. Along a temperature gradient, this vegetation type is the most xerophilous in the study area. In the relevés, thermophilous species of the class *Festuco-Brometea* were recorded (*Arabis hirsuta*, *Festuca pallens*, *Leontodon incanus*, *Colymbada scabiosa*, *Erysimum witmannii*, *Bupleurum falcatum*, *Carduus glaucinus*).

According to the plant communities and vegetation types occurring in transitional and successional stages of development, a direction of succession in the area is indicated where expansive grasses assume dominance throughout time. Smiešková (1970) described stands of phytocoenoses as homogeneous because they had been managed regularly. The current physiognomy of the stands in the meadows of Kopanecké lúky is more heterogeneous and mosaic depending on the frequency of mowing and the length of abandonment in particular parts.

Comparison of monitoring plots (MP)

On 11 monitoring plots relevés were recorded during the years 1996–1999 and one relevé from the MP 10 in 2000. Some relevés have been repeatedly made during this period. Differences in species composition on MP are influenced by the used method and by intensity of management. During the years 1996–2013 these monitoring plots were managed differently. Meadows were restored, mowed on a regular basis or sporadically, or abandoned. It was reflected in the dynamics of plant communities on monitoring plots.

The difference in mean values of Ellenberg`s ecological indices (EII) calculated for new (2012–2013) and old relevés (1996–2000) indicates the changes of particular environmental factors (Table 2). The changes of EII could not be tested by t-test because of very small sample size.

Re-sampling of relevés on monitoring plots (MP) has shown that the trend in the development of phytocoenoses is dependent on their management. Meadows which have been regularly managed since 1990 have relatively stable species composition, species diversity and moderate increase of heliophilic species (MP 1, 2, 10). For MP 1 (column 5, Table 1) is characteristic the dominant occurrence of species *Trisetum flavescens* whose abundance has varied in the past 17 years (Table 3). *Luzula luzuloides* disappeared while during the period 1996–1999 its cover ranged from 3 to 2m; on the other hand, the abundance of *Agrostis capillaris* species increased. The dominant grass *Brachypodium pinnatum* occurring on MP 2 (column 5) is complemented by species *Agrostis capillaris* and *Festuca rubra*. The cover of *Luzula luzuloides* and *Cardaminopsis halleri* species decreased considerably (Table 3). *Dactylis glomerata* and *Trifolium repens* occurred with higher cover in 2013. The extremely species-rich plot MP 10 (column 7, Table 1) is remarkable by very high number of species per 25 m^2 ranged from 93 to 109. New relevés do not contain significant dominant species; therefore, Shanonn diversity index (2012: 4.29; 2013: 4.21) and value of evenness (2012: 0.93; 2013: 0.92) are high (Table 2). Abundance of the expansive grass *Brachypodium pinnatum* decreased from cover value 4 to 2b. This condition results from regular mowing since 1999 and restoration of some parts of meadows which keeps this plot in a favourable condition. MP 4 (column 7) is not mown every year, but on the other side, it is grazed by wild animals just like the abandoned MP 15 (column 7). Such moderate disturbance keeps these plots relatively stable. Community with subxerophilic character on MP 4 is mowed sporadically, every 2nd–3rd year. In the new relevés, the cover of *Brachypodium pinnatum* as a dominant species increased, but *Carex alba*, *C. panicea* and *Calamagrostis varia* species decreased considerably. MP 15 is the highest plot of the area. In new relevés abundance of *Agrostis capillaris* and *Festuca pratensis* species increased. This plot is species-rich; in 2013 eighty-five species were recorded but only 74 species in 1998, although Shannon diversity index was higher.

Abandoned plots recorded a decrease in the number of species and the emergence of expansive grasses which are dominant in the communities (MP 8, 14, 16). Mainly MP 14 (column 7, Table 1) is changed by expansion of *Calamagrostis varia* which replaced the dominant species *Agrostis capillaris*. The contact zone of the plot is affected by natural regeneration of *Picea abies* having the maximum height of 2 meters. Shannon diversity index decreased from values 4.25 or 4.26 to 3.86 in 2012 (Table 2). Ninety-three or ninety-five species occurred on 25 m^2 in 1998 and 1999, but only 76 in 2012. The absence of management indicates an increase in the abundance of *Carlina acaulis* species. In 2012 many rare species were not confirmed at all, e.g. *Ophioglossum vulgatum, Listera ovata, Lilium bulbiferum, Gymnadenia conopsea, Coeloglossum viride*. On the unmowed plot MP 16 (column 8) with the dominant species *Calamagrostis varia*, the diversity decreased moderately. The abundance of *Carex alba* species decreased from value 3 (1998) to 2a (2013) (Table 3). The unmanaged MP 8 with wetter soil is affected by expansion of *Brachypodium pinnatum*. *Dactylis glomerata* acted as subdominant species in new relevé whereas in old relevés it had only low abundance (Table 3). Decrease of species diversity is the result of abandonment of the plot throughout the years.

In the areas where cutting of trees, restoration of grassland (especially in the years 2003–2006) or sporadic mowing of meadows took place the number of species increased slightly (MP 5, 13, 11 – oligotrophic stands), although plots are still threatened by expansion of grass *Calamagrostis arundinacea* which displaces competitively weaker and more heliophilic species. Halada et al. (2010) argued that this grass reacts on restoration of grassland rather weakly. MP 5 (column 4) was abandoned, then mown irregularly about every 3rd–5th year, last time in 2011. In comparison with the old relevés *Luzula luzuloides, Hypercium maculatum* and *Fragaria vecsa* species have higher abundance. New relevés contain 68 species, which is on 8 or 9 more than in the old relevés (Table 2). Relevés have lower values

Table 2. The Shannon-Wiener index of diversity and values of ecological factors calculated according to Ellenberg et al. (1992) for old and new phytocoenological relevés

Characteristic	Index*		Light		Temperature		Continentality		Moisture		Soil reaction		Nutrients		Number of species	
Relevés	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New
**Mp1	3.58	3.58	7.08	7.11	4.43	4.5	3.81	3.8	5.04	5.22	5.96	6.06	3.87	4.18	64.5	68
Mp2	3.49	3.62	7.06	7.15	4.56	4.51	3.8	3.79	4.74	4.77	5.99	5.84	3.67	3.72	68	63.5
Mp4	3.53	3.79	7.04	7.12	4.82	5.07	3.9	3.91	4.62	4.53	6.62	7.01	3.32	3.47	67.5	68
Mp5	3.36	3.66	6.94	6.74	4.66	4.84	3.64	3.74	4.78	4.92	5.83	5.79	3.88	4.09	59.5	68
Mp8	3.45	3.28	7.04	7.02	4.94	4.97	3.76	3.85	5.16	5.28	6.71	6.51	4.32	4.59	61.5	57
Mp10	4.08	4.25	7.07	7.13	4.88	4.81	3.89	3.8	4.69	4.69	6.48	6.48	3.68	3.65	98.6	97.5
Mp11	2.8	3.15	6.64	6.95	4.27	4.32	3.88	3.72	4.77	4.72	5.07	5.17	2.87	3.12	34	45.5
Mp13	3.39	3.76	6.61	7	4.67	4.7	3.7	3.84	4.83	4.73	5.5	5.76	3.83	3.52	63	74
Mp14	4.25	3.86	7.07	7.18	4.75	4.81	3.76	3.88	4.51	4.6	6.37	6.49	3.43	3.77	94	76
Mp15	3.99	3.95	7.07	6.97	4.46	4.66	3.83	3.8	4.58	4.66	6.35	6.27	3.42	3.44	74	82.5
Mp16	3.71	3.47	6.94	6.91	5.03	5.01	3.92	3.89	4.4	4.31	7.16	7.06	3.41	3.39	72	65

*Shannon-Wiener index, ** Monitoring plot.

Table 3. Changes of abundance of plant species during the years 1996–2013 (highlighted are significant differences)

Monitoring plot	1				2					4			5				8			10					11			13				14			15			16		
Year	1996	1999	2012	2013	1996	1997	1998	1999	2012	2013	1996	2012	2013	1996	1997	2012	2013	1996	1996	2012	1996	1997	2000	2012	2013	1996	2012	2013	1997	1999	2012	2013	1998	1999	2012	1998	2012	2013	1998	2012	2013
Species	Abundance																																							
Trisetum flavescens	**3**	**a**	**a**	**4**	1	1	1	+	.	+	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Avenula pubescens	**a**	**1**	**3**	**a**	a	a	1	+	1	a	.	+	+	.	.	.	.	**1**	**m**	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Agrostis capillaris	+	**a**	**b**	**3**	a	3	a	a	b	m	.	.	.	a	3	a	a	1	1	1	1	b	a	b	a	.	**m**	+	**a**	**3**	**1**	.	**3**	**3**	**1**	**m**	**3**	**3**	.	.	.
Dactylis glomerata	**1**	**1**	**a**	**a**	.	+	.	.	.	**a**	+	+	m	1	a	1	b	**a**	**a**	**3**	1	a	1	1	a	.	.	.	.	.	**1**	**a**	1	1	1	.	.	+	.	.	.
Crepis mollis	.	+	+	**a**	.	.	+	.	+	+	+	+	.	.	.	+	**1**	.	+	1	.	.	m	+	+	.	**1**	+	.	.	**1**	+	+	.	1	1	+	+	.	.	.
Arrhenatherum elatius	.	.	+	**a**	.	.	.	.	.	**m**	.	**1**	**m**	.	.	.	.	.	.	**a**	.	.	.	.	.	.	.	.	.	.	.	.	**1**	.	.	.	.	.	.	.	.
Gladiolus imbricatus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	m	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium repens	.	.	.	**a**	.	.	+	+	+	**a**	.	+	**m**	+	.	1	m	.	.	.	.	+	a	+	m	.	.	.	+	.	1	m	.	+	1	.	+	+	.	.	.
Myosotis nemorosa	.	.	+	**r**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium holosteoides	.	.	+	**r**	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	+	1	r	+	.	.	.	.	.	.	.	+	+	+	+	.	1	+	.	.	.
Pimpinella major	.	.	**1**	+	.	.	+	.	+	+	.	+	+	+	1	1	1	a	1	a	+	+	**1**	**a**	**a**	.	+	**1**	+	1	1	+	+	+	.	1	1	1	+	+	**a**
Crepis biennis	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium flexuosum	.	.	.	**a**	.	.	.	.	+	**m**	.	.	**m**	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	**a**	.	.	.	.	.	+	.	.	.	.	.	.
Anthyllis vulneraria	**1**	+	.	.	+	+	.	+	.	.	+	+	+	.	.	+	.	+	.	.	1	b	1	1	b	+	.	.	.	+	1	+	1	1	1	1	1	+	1	a	1
Polygala vulgaris	+	+	.	.	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Luzula luzuloides	**3**	**m**	+	.	**a**	**3**	**a**	**m**	**a**	+	+	.	.	**a**	**a**	**b**	**3**	.	.	+	**1**	**a**	**1**	+	.	**1**	**b**	**m**	b	a	b	a	.	.	**1**	+	a	+	.	.	.
Cardaminopsis halleri	1	m	1	+	**a**	**3**	**b**	**m**	**1**	+	1	+	+	**a**	**3**	**1**	**m**	.	+	+	+	**a**	**b**	**1**	+	+	+	+	a	m	1	m	+	+	1	1	1	+	+	+	m
Orchis ustulata	.	.	.	.	.	.	.	.	**r**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**r**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dactylorhiza sambucina	.	.	.	.	.	.	.	.	**r**	**r**	**r**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clinopodium vulgare	.	.	.	.	.	.	.	.	+	+	.	.	.	+	1	1	+	.	.	.	.	.	.	**1**	+	.	.	.	.	.	**1**	+	.	.	+	.	+	+	.	**1**	+
Ranunculus acris	1	+	a	+	.	.	.	.	+	+	+	+	+	+	a	.	+	+	1	+	+	.	r	+	+	.	.	.	+	.	.	+	+	+	.	1	1	+	.	+	.
Gymnadenia conopsea	**r**	+	+	.	+	**r**	+	+	.	.	+	+	r	.	.	.	.	.	+	.	.	.	+	+	.	1	r	+	.	r	+	.	+	+	.	+	.	.	+	.	.
Coeloglossum viride	.	.	.	.	**r**	**r**	**r**	.	.	.	**r**	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	+	.	.	.	+	+	.	+	.	.	.	.	.
Avenella flexuosa	.	.	.	.	+	**1**	+	.	.	.	.	.	.	+	**1**	+	**a**	.	.	.	.	.	.	.	.	.	**a**	**b**	**3**	**1**	+	**a**	**b**	+	.	.	.	+	.	.	.	.
Listera ovata	.	.	.	.	**r**	.	+	.	.	.	+	+	+	.	.	.	.	.	.	.	+	+	**r**	.	.	.	.	.	.	+	.	.	+	**r**	.	.	.	.	+	.	+
Carex ornithopoda	.	.	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	+	1	1	1	.	.	.	.	.	.	.	.	1	1	+	+	.	+	**1**	.	.
Gentianella lutescens	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	**1**	+	.	**1**	.	.	.	.	.
Taraxacum sp.	1	1	+	+	**1**	+	+	+	.	.	+	.	.	.	.	.	.	**1**	**1**	.	+	a	m	+	+	.	.	.	.	.	.	.	+	1	+	+	.	.	+	.	.
Brachypodium pinnatum	1	+	.	m	4	4	4	3	3	3	**a**	**a**	**3**	.	.	.	.	4	4	4	**3**	**3**	**4**	+	**b**	.	.	.	.	.	.	.	+	+	.	.	.	.	+	**1**	**b**
Carex alba	.	.	.	.	.	.	+	.	.	.	**3**	**a**	**m**	.	.	.	.	.	.	+	**1**	**a**	**m**	**b**	**b**	.	.	.	.	.	.	.	**1**	**a**	**b**	m	b	a	**3**	**a**	**b**
Carex panicea	.	.	.	+	.	.	.	.	.	.	**3**	+	+	.	.	.	.	.	+	.	1	3	m	a	+	.	.	.	.	.	.	.	.	.	+	+	+	m	.	.	.
Potentilla erecta	a	m	b	m	1	b	m	m	1	m	**+**	**a**	**a**	+	+	m	+	1	+	1	+	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.

Table 3. Changes of abundance of plant species during the years 1996–2013 (highlighted are significant differences) – continued

Monitoring plot	1				2							4			5				8			10					11			13				14			15		16		
Year	1996	1999	2012	2013	1996	1997	1998	1999	2012	2013		1996	2012	2013	1996	1997	2012	2013	1996	1996	2012	1996	1997	2000	2012	2013	1996	2012	2013	1997	1999	2012	2013	1998	1999	2012	1998	2012	2013	1998	2012	2013
Species	Abundance																																								
Campanula glomerata	.	.	.	.	.	.	.	.	.	.		.	1	+	.	.	+	+	.	.	.	+	+	1	1	+	.	.	.	.	.	r	+	+	+	.	.	.	1	1	1
Erysimum witmannii	.	.	.	.	.	.	.	.	.	.		.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Galium boreale	.	.	.	.	.	.	.	.	.	.		.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salvia verticillata	.	.	.	.	.	.	.	.	.	.		.	+	1	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex flacca	.	.	+	.	.	.	.	.	.	.		.	+	+	.	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pimpinella saxifraga	1	m	b	m	1	a	a	m	a	m		.	+	m	1	1	+	1	.	+	.	+	+	a	a	+	+	1	+	1	1	1	1	+	+	1	m	1	+	+	.	.
Viola hirta	.	.	.	.	.	.	.	.	.	.		.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Origanum vulgare	.	.	.	.	.	.	.	.	.	.		.	+	+	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Potentilla heptaphylla	.	.	.	.	.	.	.	.	.	.		.	.	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bupleurum falcatum	.	.	.	.	.	.	.	.	.	.		.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trollius altissimus	a	a	a	a	.	.	.	.	.	.		+	.	.	.	.	+	.	a	1	a	.	.	r	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Gentiana cruciata	.	.	.	.	.	.	.	.	.	.		r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Salvia pratensis	.	.	.	.	.	.	.	.	.	.		+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca pallens	.	.	.	.	.	+	.	.	.	.		1	+	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	+	.	.	1	1	.	.	.	.	a	+
Knautia maxima	r	.	.	.	.	.	.	.	.	.		+	.	.	.	.	.	r	.	+	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	+	.	.	.	.
Cardaminopsis arenosa	.	.	.	.	.	.	.	.	.	.		+	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.
Hypericum maculatum	1	+	1	+	+	+	+	+	+	+		.	+	.	1	1	b	3	+	+	+	+	+	+	1	+	.	.	.	+	+	b	a	+	1	.	.	.	1	.	.	.
Fragaria vesca	.	.	.	.	.	.	.	.	.	.		+	+	m	+	+	b	3	.	.	.	+	1	1	1	m	.	.	.	+	+	1	.	m	m	1	.	+	+	+	+	+
Festuca rubra	4	3	3	3	3	b	3	a	b	b		.	.	.	+	.	a	a	.	.	.	.	.	m	a	m	.	1	+	+	.	1	a	m	1	1	1	1	.	+	.	.
Pyrethrum clusii	1	.	+	.	a	a	a	1	1	b		+	a	m	a	a	1	+	.	.	1	+	+	1	+	1	1	1	1	1	+	+	1	1	1	+	+	+	+	+	+	+
Campanula persicifolia	.	.	.	.	.	.	.	.	.	.		+	.	+	+	+	1	a	.	+	.	+	1	m	.	+	+	+	+	1	+	m	+	+	.	.	.	.	1	1	m
Angelica sylvestris	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex pallescens	+	+	1	+	+	a	+	+	1	m		.	.	.	.	.	+	+	.	.	1	.	1	+	+	+	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.
Heracleum sphondylium	.	.	.	.	+	+	r	+	.	+		.	.	.	.	.	1	+	+	1	1	+	+	+	+	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.
Briza media	+	1	1	m	1	1	1	+	1	+		1	1	m	.	.	.	a	1	1	.	1	a	m	1	b	.	1	m	+	+	1	a	m	1	1	1	a	+	+	+	.
Convallaria majalis	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	.	+	1	.	.	.	.	.	.	.	+	+	+
Rubus idaeus	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rosa canina agg.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Asarum europaeum	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	+	+	+
Viola riviniana	.	.	.	.	.	.	.	+	.	.		.	.	+	.	.	m	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Mercurialis perennis	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	+	r	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	+	r	.
Polygonatum verticillatum	.	.	.	.	.	.	.	.	.	.		.	.	+	.	.	+	+	.	.	.	.	+	r	+	+	.	+	+	.	.	+	+	.	r	1	+	r	+	+	+	+
Festuca pratensis	1	m	.	+	+	.	.	.	+	+		.	.	+	.	.	1	a	+	1	+	1	1	m	b	b	.	.	.	.	.	+	.	1	1	1	1	b	b	.	.	.
Galium mollugo	.	.	.	.	.	.	.	.	.	.		.	+	+	.	.	1	+	+	1	+	+	.	+	+	1	.	.	.	.	.	1	+	+	+	3	.	1	m	+	a	m
Lotus corniculatus	3	m	b	+	3	b	3	m	b	m		1	a	m	1	a	m	.	a	+	1	1	3	m	b	m	1	1	m	a	1	1	+	m	m	1	1	+	+	+	1	m
Rhinanthus serotinus	1	m	a	a	a	1	3	3	1	3		a	1	m	+	+	.	.	1	+	.	.	+	+	b	m	.	1	b	1	+	+	m	.	.	.	.	+	.	.	.	.
Trifolium montanum	1	+	1	.	3	3	a	m	a	b		a	a	m	+	+	.	.	.	.	+	1	a	m	1	m	.	.	.	.	.	+	a	1	m	1	m	1	m	+	+	.
Digitalis grandiflora	.	.	.	.	.	.	.	.	.	.		.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	a	b
Trifolium badium	.	.	.	.	.	.	.	.	.	.		.	.	.	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa pratensis	.	+	.	.	+	.	.	+	.	.		.	.	.	+	1	.	.	a	1	.	.	.	1	.	.	.	.	.	.	+	.	.	.	1	.	.	.	+	.	.	.
Deschampsia cespitosa	.	+	.	.	.	.	.	.	.	.		.	.	.	.	.	+	.	+	+	a	.	.	.	.	+	.	.	.	.	.	+	.	.	+	.	.	1	a	.	.	.
Chaerophyllum aromaticum	.	.	.	+	.	.	.	.	.	.		.	.	.	.	.	.	+	.	+	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acetosa pratensis	1	1	1	+	+	+	+	+	+	+		.	.	.	+	1	+	1	.	.	+	+	1	1	+	1	.	.	.	+	+	1	+	+	+	+	+	+	+	+	.	.	.
Roegneria canina	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Geranium pratense	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ajuga reptans	.	.	.	.	.	.	.	+	+	+		.	.	+	+	1	+	+	.	.	+	+	+	1	1	+	.	.	.	+	.	+	.	+	+	.	.	.	+	.	.	.
Crepis praemorsa	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	+	.	.	.	+	.	.	.	+	+	.	+	.	.	.	1	.	.	.	+	.	.	.	.	.	.
Vicia sylvatica	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Cirsium erisithales	.	.	.	.	.	.	.	.	.	.		+	.	.	1	1	+	+	.	.	r	.	r	.	.	.	.	.	.	.	.	+	+	+	+	+	.	.	+	+	+	1	1
Jacea phrygia	1	1	b	a	1	1	1	1	1	1		1	1	1	1	a	1	1	1	1	.	1	+	1	a	a	.	.	+	+	1	1	a	1	a	1	1	1	1	1	1	1
Ranunculus auricomus	+	+	+	.	.	.	.	.	.	.		.	.	.	+	.	+	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phyteuma orbiculare	1	1	+	r	1	b	1	1	+	+		1	+	+	+	+	1	+	+	+	.	1	a	b	a	+	.	+	+	1	+	.	+	m	m	1	1	+	+	+	1	+
Trifolium pratense	1	+	a	1	+	1	+	+	1	+		+	.	+	+	1	1	m	+	+	.	1	+	m	a	m	.	.	.	+	+	.	+	m	1	1	1	+	.	+	+	+
Plantago lanceolata	+	+	+	.	.	.	.	.	.	.		+	+	.	.	.	.	.	+	+	.	+	+	m	1	1	.	.	.	.	.	.	.	m	m	+	1	a	a	.	.	.
Tragopogon orientalis	1	1	1	+	+	1	+	+	+	+		+	.	+	.	.	.	.	1	+	.	1	+	1	+	1	.	.	.	.	.	.	.	1	+	.	1	+	m	+	.	.
Potentilla inclinata	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Colymbada scabiosa	.	.	.	.	.	.	.	.	.	.		a	b	b	.	.	.	.	.	.	.	+	+	+	+	a	.	.	.	.	.	.	.	+	1	a	+	.	+	+	+	+
Thymus pulegioides	1	+	+	+	1	+	+	+	+	+		+	1	m	1	+	1	+	+	.	.	+	b	a	1	+	.	1	+	1	+	+	m	m	m	1	m	m	b	1	+	m

Table 3. Changes of abundance of plant species during the years 1996–2013 (highlighted are significant differences) – continued

Monitoring plot	1				2						4			5				8			10					11			13				14			15			16		
Year	1996	1999	2012	2013	1996	1997	1998	1999	2012	2013	1996	2012	2013	1996	1997	2012	2013	1996	1996	2012	1996	1997	2000	2012	2013	1996	2012	2013	1997	1999	2012	2013	1998	1999	2012	1998	2012	2013	1998	2012	2013
Species	Abundance																																								
Festuca ovina	. . . **m**	. 1 . 1 . a									1 1 .			+ + 1 m				. . .			**1 3 3 a +**					**1 3 a**			1 a 1 m				**m m** .			a b m			+ . +		
Bromus erectus	. . . .	. . . . .									. . .			. . . .				. . .			**. . . + +**					. . .			. . . .				. . .			. . .			. . .		
Tussilago farfara	. . . +	. . . . .									. . .			. . . .				+ + 1			**. . . + +**					. . .			. . . .				. . .			. . .			. . .		
Euphrasia rostkoviana	. . . .	. . . . .									. . .			. . . .				. . .			**+ + 1 . .**					. . .			. . . .				**+ 1 . m . .**			. . .			. . .		
Aquilegia vulgaris	. . . .	. . . . .									. . .			**+ + . .**				+ . .			**+ . + . .**					. . .			**. . + +**				**+ + .**			+ . +			. . .		
Scabiosa lucida	. . . .	. . . + . .									+ + +			**+ + . .**				+ . .			**+ 1 1 . .**					. + .			. . . .				+ + +			+ + 1			. + .		
Pilosella cymosa	. . . .	. . . . .									. . .			. . . .				. . .			**. + + . .**					. + .			. . . .				. . .			. . .			. . .		
Ophioglossum vulgatum	. . . .	. . . . .									1 + +			. . . .				. . .			**+ . + . .**					. . .			. . . .				**1 1 .**			. . r			**+ . .**		
Hieracium murorum	. . . .	. . . . .									. . .			. . . .				. . .			**. + r . .**					**1 . .**			**+ + . .**				. . .			. . .			**. + +**		
Trommsdorfia maculata	. . . .	. . . . .									. . .			. . . .				. . .			**1** + . .					. . .			. . . .				. . .			. . .			. . .		
Antennaria dioica	. . . .	. . . . .									. . .			. . . .				. . .			**. + r . .**					**+ . .**			. . . .				**1** + .			r . .			. . .		
Carlina acaulis	+ . . +	1 a 1 1 a 1									1 1 1			1 1 1 1				+ + 1			1 1 1 + +					**+ 1 3**			a 1 a b				**+ 1 a**			+ a 1			+ + 1		
Nardus stricta	. . . .	. + . . + .									. . .			. . . .				. . .			. . . . .					**. 1 a**			. . . .				**1** + .			. . .			. . .		
Trientalis europaea	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					**. m m**			. . . .				. . .			. . .			. . .		
Crepis conyzifolia	+ + + +	+ + + 1 1 a									. . .			. . . .				**. . +**			+ + . + +					**. a +**			+ 1 1 +				+ + 1			**+ . .**			. . .		
Leontodon hispidus ssp. *danubialis*	. 1 1 1	. . 1 m + .									**. + 1**			. . . .				. . .			. . m 1 1					**. 1 1**			**. . 1 +**				1 m a			**1 . .**			1 + 1		
Leontodon hispidus ssp. *hispidus*	1 m a +	a b m 1 a 1									1 + 1			+ + + .				. + .			a 3 a a 1					**. 1 1**			+ . 1 1				1 m a			m 1 +			+ . 1		
Veronica chamaedrys	1 + 1 m	+ 1 1 1 + +									**+ . .**			a a 1 m				1 1 1			+ 1 1 + +					**. + m**			+ + 1 +				1 1 1			+ + +			+ + m		
Gymnadenia densiflora	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					**. r r**			. . . .				. . .			. . .			. . .		
Dianthus carthusianorum	+ . . .	1 + + + + +									+ + +			. . . .				. . .			1 1 1 1 +					**. + +**			+ + + +				+ + +			1 1 m			1 + m		
Ranunculus polyanthemos	1 + + +	1 a + 1 + +									1 + +			1 1 1 +				. . .			1 1 1 1 1					**. + +**			1 1 1 +				1 m 1			1 + +			+ + +		
Potentilla aurea	+ . . .	+ + 1 + + +									. . .			. + . .				. . .			+ + 1 + +					**. 1 m**			+ + . +				**1 1 .**			m + m			. . .		
Anthoxanthum odoratum	1 + 1 m	a a m + 1 a									**+ . .**			1 + + +				. . .			**1 1 m a b**					**. . a**			**+ + + a**				1 1 +			r + +			. . .		
Astrantia major	. 1 1 a	+ + + + + +									. . .			. + 1 1				+ 1 a			+ + + + +					**+ . .**			1 + 1 1				**+ + .**			+ + +			+ 1 1		
Homogyne alpina	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					**+ . .**			. . . .				. . .			. . .			. . .		
Gentiana asclepiadea	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					+ . .			. . . .				. . .			. . .			. . .		
Vaccinium myrtillus	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					**b a m**			**1 m a b**				. . .			. . .			. . .		
Poa chaixii	. . . .	. . . . .									. . .			a 3 b b				. . .			. . . . .					. . .			**+ + 1 3**				. . .			. . .			. . .		
Helianthemum grandiflorum ssp.. *obscurum*	a . . m	a b m m b m									. . .			1 1 1 m				. . .			+					. . .			**+ 1 a a**				**a a 1**			. . .			**. + +**		
Stellaria graminea	+ + 1 +	+ + + + . +									. . .			. 1 + .				+ . +			+ 1 + + +					. . +			**. . 1 +**				**+ + .**			m + .			. . .		
Populus tremula	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					. . .			**. . + +**				. . .			. . .			. . .		
Picea abies	. . . .	r + r . + r									r + .			. . . .				. . .			. . . . .					. . .			**. . + +**				. r +			**. + +**			. . .		
Botrychium lunaria	+ . . .	+ + + + r .									. . .			**+ + . .**				. . .			. . . . .					+ 1 +			**. . + +**				+ + r			+ r +			. . .		
Lilium bulbiferum	. . . .	. . . . .									. . .			. . . .				. . .			+ + + + r					. . .			**. . r +**				**+ + .**			+ . .			r r +		
Prunella vulgaris	. . . .	. . . . .									. . .			. 1 . +				+ + +			1 1 m a m					. . .			**. . + +**				m 1 +			+ + +			. . .		
Epilobium collinum	. . . .	. . . . .									. . .			. . . +				. . .			. . . . .					. . .			**. . + +**				. . .			. . .			. . .		
Laserpitium latifolium	. . . .	. . . . .									. . .			. . + .				. . .			. . . . .					. . .			**. . + +**				. . .			. . .			+ + +		
Trommsdorfia uniflora	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					a + b			**a . + .**				. . .			. . .			. . .		
Soldanella hungarica	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					1 . +			**+ + . .**				. . .			. . .			. . .		
Galium pumilum	. . . .	. . . . .									+ . +			. . . .				. . .			. . + . +					. . +			**+ + . .**				**+ + .**			1 . m			1 . +		
Viola reichenbachiana	. . . .	. . . . .									. . .			. + . .				+ . .			. . . . .					. . .			**+ 1 . .**				. . .			. . .			. + .		
Primula elatior	a m a +	+ + + + + +									**+ . .**			+ + + +				+ 1 1			+ + + 1 +					. . .			**1 + . .**				**+ + .**			1 . .			+ . +		
Aconitum firmum	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					. . .			**r + . .**				. . .			. . .			. . .		
Calamagrostis varia	+ . . .	1 + + + 1 .									**3 3 m**			. . . .				. . .			**+ 1 1 1 a**					. . .			. . . .				**1 a 3**			**1 b m**			**3 4 4**		
Thalictrum aquilegiifolium	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					. . .			. . . .				**. . r**			**+ . .**			. . .		
Euphrasia rostkoviana ssp. *montana*	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					. . .			. . . .				**. . +**			**. a +**			. . .		
Campanula patula	+ + . +	+ + + + + +									. . .			1 1 1 m				. + +			. . . . +					. . .			+ 1 + m				**. . +**			. . .			. . .		
Carum carvi	1 + + +	1 . + . + +									. . .			. . . .				+ 1 +			1 + b 1 +					. + .			. . + .				**. . 1**			. . .			. . .		
Crocus discolor	. + + +	. 1 + 1 + .									. . .			. + . .				. . .			. + + + .					. . .			. . . .				**+ + .**			**+ . .**			. . .		
Thesium alpinum	. . . .	+ r + + + +									. . .			+ . + .				. . .			+ + + 1 +					. . .			+ . + +				**+ + .**			**+ . .**			**. + +**		
Polygala amara	. . . +	. + . . . +									**. . +**			. . . .				. . .			+ + r + +					. . .			. . . . +				**+ + .**			+ + +			**+ . .**		
Pilosella bauhinii	. . . .	+									. . .			. . . .				. . .			1 1 m + +					. . .			. . . . .				**+ + .**			. . +			+ + .		
Danthonia decumbens	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					. . .			. . . . .				**+ + .**			. . .			. . .		
Festuca tatrae	. . . .	. . . . .									. . .			. . . .				. . .			. . . . .					. . .			. . . . .				1 . .			**m a b**			**+ . .**		

Table 3. Changes of abundance of plant species during the years 1996–2013 (highlighted are significant differences) – continued

Monitoring plot	1				2							4			5				8			10					11			13				14			15			16		
Year	1996	1999	2012	2013	1996	1997	1998	1999	2012	2013		1996	2012	2013	1996	1997	2012	2013	1996	1996	2012	1996	1997	2000	2012	2013	1996	2012	2013	1997	1999	2012	2013	1998	1999	2012	1998	2012	2013	1998	2012	2013
Species	Abundance																																									
Alchemilla sp.	3	m	b	b	1	a	m	m	1	1		.	.	1	a	a	1	a	b	1	1	1	a	a	a	a	.	1	+	**.**	**.**	**1**	**1**	a	m	a	**3**	**a**	**1**	.	.	.
Acinos alpinus	.	.	.	.	.	.	.	.	.	.		+	+	m	.	.	.	.	.	.	.	+	1	+	1	m	.	.	.	.	.	.	.	+	+	+	**+**	**1**	**b**	m	1	+
Sesleria albicans	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**a**	**a**	.	.	.
Arabis hirsuta	.	.	.	.	.	.	.	.	.	.		+	r	+	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	.	+	.	.	**.**	**+**	**+**	+	+	+
Calamagrostis arundinacea	.	.	.	.	.	.	.	.	.	.		.	.	.	4	4	3	3	.	.	.	.	.	.	.	.	3	3	3	4	4	4	b	.	.	.	**.**	**1**	**+**	.	.	.
Viola lutea ssp. *sudetica*	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**r**	**r**	.	.	.
Vicia cracca	+	m	+	+	+	1	+	+	+	+		+	+	+	+	+	+	+	1	+	1	1	1	b	1	+	.	.	.	+	+	+	+	.	.	.	**.**	**1**	**+**	+	+	.
Acer pseudoplatanus	.	.	.	.	r	r	r	.	.	.		.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**r**	**r**	.	.	.
Lathyrus pratensis	+	1	1	+	1	+	+	+	+	+		.	.	.	+	1	1	m	a	a	1	1	+	m	+	+	.	.	.	+	.	1	+	.	+	+	**.**	**1**	**+**	1	+	+
Parnassia palustris	.	1	+	+	.	.	.	.	.	.		.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**+**	**+**	.	.	.
Koeleria pyramidata	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**a**	**m**	.	.	.
Larix decidua	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	**.**	**r**	**r**	.	.	.
Viola rupestris	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	**+**	**.**	**.**	+	.	.
Carduus glaucinus	.	.	.	.	.	.	+	.	.	.		1	1	a	.	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.	.	+	+	+	+	.	+	**1**	**1**	**a**
Phyteuma spicatum	.	+	.	.	+	.	.	+	.	.		.	+	.	.	.	.	r	**1**	**+**	**.**	+	.	.	+	+	+	+	.	+	+	.	+	.	.	.	**.**	**1**	.	+	.	**.**	**+**	+
Knautia arvensis	.	.	.	r	.	+	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	+	**.**	**+**	**1**
Erysimum odoratum	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**.**	+
Orobanche reticulata	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**.**	**r**	**r**
Anacamptis pyramidalis	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**+**	**.**	+
Hieracium bifidum	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**+**	**.**	**.**
Carex caryophyllea	1	+	+	.	1	+	1	m	1	a		+	.	+	.	.	.	.	.	.	.	1	b	a	a	+	.	.	.	.	.	.	.	m	1	1	1	.	+	**1**	**.**	**.**
Viola collina	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	**+**	**.**	**.**

of Ellenberg`s ecological indices for light, soil reaction, temperature as well as Shannon diversity index, because soil is moderately acidic and the spreading of more termophilic and heliophilic species in the lower layer is inhibited by the expansion of *Calamagrostis arundinacea* species. The oligotrophic sward on MP 13 (column 4) is influenced by the dominance of *Calamagrostis arundinacea* as well although its abundance decreased in 2013. The abundance of *Poa chaixii* increased and along with *Calamagrostis arundinacea* species it forms physiognomy of community (Table 3). Shannon diversity index is higher in new relevés (Table 2). The above mentioned plot is mown irregularly about every 3rd–5th year, last time in July 2011. The species-poorer MP 11 (column 1) with oligotrophic character contains a higher number of acidophilous species. In new relevés dominate species *Avenella flexuosa, Calamagrostis arundinacea*, *Carlina acaulis* and *Pulsatilla scherfelii*. In comparison with 1996, species diversity has increased, which may be the result of grassland restoration and irregular mowing in this part of meadows. Relevé in 1996 had lower EII for light. All relevés have low EII for soil reaction, light, temperature and Shannon diversity index (Table 2), which is associated with the occurrence of typical psychrophilous mountain and acidophilous species (e.g. *Trientalis europaea, Nardus stricta, Potentilla aurea*).

Some plots where Dražil (2004) recorded relevés during the years 1996–1999 have been already overgrown by a closed spruce forest with almost no undergrowth. Kopanecké lúky is a remarkable site from the point of view of species diversity resulting from the traditional land-use in the past. Nowadays, in the past formed communities are in various stages of secondary succession, which is reflected by changed character resulting from the expansion of competing grasses and their lower syntaxonomical representativeness. Further development of the meadows is dependent on appropriate management which is crucial for the preservation of their biodiversity.

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