CHANGES IN THE DIVERSITY OF DRY CALCAREOUS GRASSLANDS AFTER ABANDONMENT OF TRADITIONAL MANAGEMENT IN DEVÍNSKA KOBÝLA NATIONAL NATURE RESERVE (SOUTHWESTERN SLOVAKIA, CENTRAL EUROPE)

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Abstract

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This study is focused on the evaluation of the values of the diversity indices of semi-natural dry calcareous grasslands of the *Festuco-Brometea* class in the area of Devínska Kobyla National Nature Reserve 50 years after abandonment of traditional management (grazing and mowing). The values of the species richness, the Shannon–Wiener index of diversity, the Simpson index, and Pielou's measure of species evenness in the communities in the old and recent data, and the values of the environmental variables based on the Ellenberg indicator values of species were analyzed. For most of these analyses, we used Kruskal–Wallis in R 3.5.1. Compared to the past, we have recorded a significant lower values of the species richness, biodiversity, and species evenness in some communities. In some communities, no significant changes were recorded. Only in one community—*Poo badensis-Festucetum pallentis*, the higher values of Shannon–Wiener index was recorded compared to the past. The analysis of the Ellenberg indicator values revealed a statistically significant higher Ellenberg indicator values for moisture and nutrients and lower values for light in more recent period compared to the old period. The recorded results could be caused by the changes in the management after the year 1965, after abandonment of grazing and the gradual overgrowing by woody species took place in the area. The frequency of occurrence of some woody species (e.g., *Populus alba*, *P. nigra*, and *Robinia pseudoacacia*) in some communities increased compared to the past.

Key words: Devínska Kobyla Mts, *Festuco-Brometea*, succession, vegetation biodiversity conservation.

Introduction

Semi-natural dry calcareous grasslands (*Festuco-Brometea* class) have spread in Central Europe after forest clearing and consecutive traditional land use such as grazing and mowing (Poschlod, WallisDeVries, 2002; Chytrý, 2007). These specific habitats cannot exist without the repeated removal of biomass by grazing, mowing, burning, or by other ways and control of species not adapted to such disturbance regimes. Formation of dry grasslands is influenced by these disturbances and stress caused by extreme habitat conditions (low content of nutrients, low humidity, and high temperature), which allows the existence of many adapted species indirectly by limiting the growth of competitively stronger species (Kubíková, 1999; Münzbergová, 2001; Chytrý, 2007). Because of disturbance regime and long history of development, dry calcareous grasslands belong to the most species-rich types of vegetation ever (Willems, 1983; During, Willems, 1984; Bobbink et al., 1987; Poschlod, WallisDeVries, 2002; Chytrý, 2007; Schrautzer et al., 2009). They also harbor a large number of endangered species (Wolkinger, Plank, 1981; Pipenbaher et al., 2013).

The abandonment of traditional forms of land use such as grazing and mowing over the last decades has brought an increasing concern about the consequences of the resulting expansion of shrubs and trees on species-rich dry calcareous grasslands (Dzwonko, Loster, 1998; Hansson, Fogelfors, 2000; Willems, 2001; Bába, 2003; Alard et al., 2005; Köhler et al., 2005; Dostálek, Frantík, 2008; Schrautzer et al., 2009; Jacquemyn et al., 2010; Ruprecht et al., 2010; Török, Szitár, 2010; Tälle et al., 2018). Some studies have shown that the abandonment of traditional land use had negative impact on the species richness, diversity, and area of dry grasslands in Central Europe (Poschlod, WallisDeVries, 2002; Galvánek, Lepš, 2008; Schrautzer et al., 2009; Hegedüšová, Senko, 2011; Pipenbaher et al., 2013), and in the last few years, more attention is being devoted to conservation management (Poschlod et al., 1998; Barbaro et al., 2001; Münzbergová, 2001; Willems, 2001; Kahmen et al., 2002; Riecken et al., 2002; WallisDeVries et al., 2002; Bába, 2004; Masé, 2005; Bornkamm, 2006; Stadler et al., 2007; Dostálek, Frantík, 2008; Peter et al., 2009; Kuzemko et al., 2016). The importance of conservation management and maintenance of traditional ways of farming is visible not only in the case of grasslands but also in the case of various other types of habitats (Mojšes, Petrovič, 2013; Špulerová et al., 2016) and other scientists have also devoted their research to changes in various types of vegetation (Palaj, Kollár, 2018).

Devínska Kobyla Mt. (southern part of Male Karpaty Mts., Slovakia, Central Europe) is a unique area with specific environmental conditions. Dry grasslands at Devínska Kobyla Mt. have formed due to agricultural activity and deforestation of the area (Kaleta, 1965; Hajdúk, 1986). Grazing by goats and sheep and mowing were the main factors that influenced the development and the maintenance of the species-rich dry grassland communities at the area. During the mid-20th century, the traditional land use such as grazing, mowing, and burning was ceased. The gradual expansion of shrubs and trees took place in the area (Hegedüšová, Senko, 2011).

Dry grasslands in Devínska Kobyla were studied by Domin (1931); Kaleta (1965); Michalko (1977); Hajdúk (1986); Baláz (1994); Hajdúk (1997); Maliníková (2003), Miškovic,

Dúbravcová (2004a;b); Zlínka (2004); Senko et al. (2008) and Hegedúšová, Valachovič (2015). Hegedúšová and Senko (2011) reported changes in species composition of dry grasslands in Devínska Kobyla Mt., but they did not pay attention to changes in diversity indices and environmental conditions. Our study overcomes this gap and also bring new results from survey performed in the last years and help in the management of protected area. The aim of this study is to assess the values of the diversity indices in reference (1964) and recent (2012–2018) phytosociological data. Hypothesis: we expected that the values of the species richness, Shannon–Wiener index of diversity, Simpson index, and Pielou's measure of species evenness in vegetation would be lower in comparison to the past, because of previously mentioned abandonment of traditional management of the area.

Material and methods

Study area

Devínska Kobyla National Nature Reserve is located on the southwestern and western slopes of the Devínska Kobyla Mt., which is the southernmost part of the Little Carpathians Mts. (Slovakia, Central Europe). The entire massif of Devínska Kobyla is part of the Malé Karpaty Protected Landscape Area. In 1964, the Devínska Kobyla State Nature Reserve was established to protect thermo-xerophilous habitats covering the area of 27.97 ha. Later, in 1986, it was enlarged to its current area of 101.12 ha. On the basis of later legal regulations, the reserve was included in the list of national nature reserves under the currently valid name Devínska Kobyla National Nature Reserve (Feráková, Kocianová, 1997).

There is an unusual variety of environmental phenomena concentrated on the area of Devínska Kobyla. It is unique because of its geographical position, history, extraordinary environmental conditions such as topography and climate, and mainly because of its thermophilous grassland- and forest-steppe flora and vegetation (Feráková, Kocianová, 1997; Hegedúšová, Valachovič, 2015).

The study area belongs to the warm climatic region, and it is one of the warmest and driest parts of Slovakia. It has an average 50 summer days per year or more, with a daily maximum temperature of 25 °C and higher. The average duration of sunshine is one of the longest in Slovakia (in the vegetation period, it is 60% = 1,600 h) (Feráková, Jarolímek, 2011).

The most common soil types in the Devínska Kobyla NNR are Cambisols (Calcaric) and Rendzic Leptosol, on deluvium of carbonate–silicate weathered rock. On a smaller area, especially in the territories with the local names Sandberg and Merice, occur soil types Haplic Regosol (Calcaric) on neogene sand and sandstones, while on weathered limestones and dolomites dominate Rendzic Leptosol and Lithic Leptosol. Rarity in the territory of Devínska Kobyla NNR is the occurrence of 1 ha of soils formed on the loess, namely Cutanic Luvisols and Haplic Chernozem, as well as several cubic meters of Rendzic Leptosol on the weathered Tertiary calcareous conglomerates (Feráková, Jarolímek, 2011).

The Devínska Kobyla NNR is also known by the near proximity of a well-known paleontological site Sandberg. It is the old sandpit, where remnants of rocks of the Tertiary Sea, Miocene marine, and nonmarine sediments are situated. The horizontally deposited layers of the Tertiary sea with the estimated age of 14–16 million years can be found here. Fossils of the sea fauna were conserved in Sandberg (Feráková, Kocianová, 1997; Hyžný et al., 2012).

Data source

We have analyzed 153 phytosociological relevés of dry grassland communities of *Festuco-Brometea* class, which includes the dry grassland vegetation of the Eurosiberian steppes and warm regions in the temperate zone of Europe. These plant communities are dominated by grasses and have high proportion of dicotyledonous perennial herbs. They usually grow on nutrient poor calcareous soils and developed secondary on areas of former forests (Chytrý, 2007). We used the relevés of four associations from the *Festuco-Brometea* class: *Poo badensis-Festucetum pallentis*, *Festuco pallentis-Caricetum humilis*, *Festuco valesiacae-Stipetum capillatae*, and *Polygalo majoris-Brachypodietum pinnati*; grasslands of these four associations cover most of the area of Devínska Kobyla NNR. The *Poo badensis-*

Festucetum pallentis association includes open dry grassland communities growing on shallow dry soils on the steep slopes. The stands of the *Festuco pallentis*-*Caricetum humilis* association usually grow on shallow to moderately deep soils, and the *Festuco valesiacae*-*Stipetum capillatae* occurs on deeper soils. Among the four analyzed associations, the stands of the *Polygalo majoris*-*Brachypodietum pinnati* association grow on the relatively deepest soils (Chytrý, 2007; Hegedúšová-Vantarová, Škodová, 2014).

The data were sampled during two time periods with the time span of ~50 years. Data (40 relevés) sampled in 1964 (Kaleta, 1965) are used as reference data (Fig. 1). Recent data (113 relevés) were sampled in 2012–2018 (Miškovic, 2018) (Fig. 2). The number of recorded relevés in the studied vegetation types was as follows: *Poo badensis*-*Festucetum pallentis*—8 old relevés and 36 recent relevés, *Festuco pallentis*-*Caricetum humilis*—8 old relevés and 22 recent relevés, *Festuco valesiacae*-*Stipetum capillatae*—12 old relevés and 6 recent relevés, and *Polygalo majoris*-*Brachypodietum pinnati*—12 old relevés and 49 recent relevés.

The recent plot sizes corresponded to old plot sizes (Kaleta, 1965) and the plot size of 25 m² was used. We tried to sample some relevés in 2012–2018 at the same localities as old relevés. This could be done in the case of ~20 relevés, but we were not able to do this in the case of all relevés because of the absence of permanent plots in historical research. Since Devínska Kobyla is a relatively small area, the possibility of mistakes was low. Because of the missing permanent plots, we did more new relevés, which made the research more precise and this could also eliminated mistakes. The same process of plot selection as used in old time period was used to obtain comparable dataset. The relevés were sampled according to the actual occurrence and distribution of the communities with the intention to record all types of dry grasslands and cover entire area of reserve. The phytosociological research in both time periods was performed according to the methodology of the Zürich-Montpellier school (Braun-Blanquet, 1964). In 1964, the old Braun-Blanquet cover-abundance scale was used. In 2000–2018, the modified Braun-Blanquet cover-abundance scale was used, extended by categories 2m (cover 1–5%, abundance high), 2a (cover 5–12.5%), and 2b (cover 12.5–25%) values (Barkman et al., 1964).

Fig. 1. Distribution of recorded relevés in the study area in 1964.

Fig. 2. Distribution of recorded relevés in the study area in the years 2012–2018.

Relevés were imported into a TURBOVEG database (Hennekens, Schaminée, 2001) and analyzed in the program JUICE (Tichý, 2002). Bryophytes, lichens, and taxa of vascular plants determined only to the genus level were excluded from the analysis. Taxa that occurred in more than one layer were merged. Some taxonomically problematic species were merged to higher or more broadly defined taxa: *Achillea millefolium* agg. (*A. collina* Becker ex Rchb., *A. millefolium* L., *A. pannonica* Scheele, and *A. setacea* Waldst. et Kit.), *Arenaria serpyllifolia* agg. (*A. leptoclados* (Rchb.) Guss. and *A. serpyllifolia* L.), *Erophila verna* agg. (*E. spathulata* Láng and *E. verna* (L.) Chevall), *Erysimum diffusum* agg. (*E. andrzejkowskianum* Besser and *E. diffusum* Ehrh.), *Galium mollugo* agg. (*G. album* Mill. and *G. mollugo* L.), *Lotus corniculatus* agg. (*L. borbasii* Ujhelyi, *L. corniculatus* L. and *L. tenuis* Waldst. et Kit. ex Willd.), and *Poa pratensis* agg. (*P. angustifolia* L. and *P. pratensis* L.). Because different cover-abundance scales have been used in old and recent relevés, the values 2m, 2a, and 2b in both datasets were converted to value 2.

Phytosociological relevés were analyzed by numerical classification (cluster analysis) in the program SYN-TAX 2000 (Podani, 2001). Data were not transformed. The Group average method in combination with Ružička's coefficient proved to be the most effective linkage method and distance measure and the results obtained by them corresponded to our field experience. Clusters were assigned to associations by diagnostic species (Jarolímek, Šibík, 2008; Hegedúšová-Vantarová, Škodová, 2014) and by electronic expert system for identification of syntaxa of grassland vegetation (Janišová, 2007).

The species richness (number of species), the Shannon–Wiener index of diversity [H'] (Hill, 1973), the Simpson index (Hill, 1973), and the Pielou's measure of species evenness [$J = H'/\ln(S)$, where H' is the Shannon diversity index and S is the number of taxa per relevé] were calculated for each relevé in the program JUICE. Subsequently, the number of species and the values of indices were calculated for each association, both for reference and recent time periods. The normality of data distribution was tested by Shapiro–Wilk test. As the data were not normally distributed, the Kruskal–Wallis analysis in R 3.5.1 (R Core Team, 2018) was applied to test the differences in these values between the periods in each association and also in whole dataset.

As an explanatory variable to show possible changes in vegetation ecological characteristics, the Ellenberg indicator values for light, temperature, continentality, moisture, soil reaction, and nutrients (Ellenberg et al., 1992) based on species presence were calculated, using the program JUICE. We analyzed the Ellenberg indicator values in total old and recent datasets (all associations together) using the Kruskal–Wallis analysis in R 3.5.1 (R Core Team, 2018), because by testing the Ellenberg indicator values between the two time periods and associations differences were found not significant.

Nomenclature

The nomenclature of taxa follows Marhold (1998), and the nomenclature of syntaxa follows Hegedúšová-Vantarová, Škodová (2014).

Results

The hypothesis was confirmed in the case of some associations (Table 1). The Kruskal–Wallis analysis revealed a statistically significant lower values of the median of species richness in recent relevés from the association *Festuco pallentis*-*Caricetum humilis* ($p = 0.0002$, level of significance $\alpha = 0.05$, $\chi^2 = 13.77$) and from the association *Polygalo majoris*-*Brachypodietum pinnati* ($p = 0.0002$, $\alpha = 0.05$, $\chi^2 = 13.44$) compared to old relevés (Table 2 and Fig. 3).

The values of the median of Shannon–Wiener index of diversity were significantly lower over time in the association *Polygalo majoris*-*Brachypodietum pinnati* ($p = 0.001$, $\alpha = 0.05$, $\chi^2 = 11.10$) (Table 2 and Fig. 4).

The median values of Simpson index were significantly lower in the association *Polygalo majoris*-*Brachypodietum pinnati* ($p = 0.0001$, $\alpha = 0.05$, $\chi^2 = 14.68$) (Table 2 and Fig. 5).

The median values of Pielou's measure of species evenness were significantly lower in the associations *Poo badensis*-*Festucetum pallentis* ($p = 0.0039$, $\alpha = 0.05$, $\chi^2 = 8.35$) and *Polygalo majoris*-*Brachypodietum pinnati* ($p = 0.0047$, $\alpha = 0.05$, $\chi^2 = 7.98$) (Table 2 and Fig. 6).

T a b l e 1. Summarization of significancy of the results of analysis of differences in the biodiversity in the associations between the old and recent data.

	<i>Poo badensis-Festucetum pallentis</i>	<i>Festuco pallentis-Caricetum humilis</i>	<i>Festuco valesiacae-Stipetum capillatae</i>	<i>Polygalo majoris-Brachypodietum pinnati</i>
Species richness	No significant difference	Significantly lower	No significant difference	Significantly lower
Shannon–Wiener index of diversity	Significantly higher	No significant difference	No significant difference	Significantly lower
Simpson index	No significant difference	No significant difference	No significant difference	Significantly lower
Pielou’s measure of species evenness	Significantly lower	No significant difference	No significant difference	Significantly lower

T a b l e 2. Results of Kruskal–Wallis analysis testing differences in the species richness and diversity indices in the communities between the old and recent data.

Association	χ^2	p Value	Significancy
Species richness			
<i>Poo badensis-Festucetum pallentis</i>	0.81	0.37	NO
<i>Festuco pallentis-Caricetum humilis</i>	13.77	0.0002	YES
<i>Festuco valesiacae-Stipetum capillatae</i>	0.05	0.82	NO
<i>Polygalo majoris-Brachypodietum pinnati</i>	13.44	0.0002	YES
Shannon–Wiener index of diversity [<i>H'</i>]			
<i>Poo badensis-Festucetum pallentis</i>	7.38	0.01	YES
<i>Festuco pallentis-Caricetum humilis</i>	1.01	0.32	NO
<i>Festuco valesiacae-Stipetum capillatae</i>	0.001	0.98	NO
<i>Polygalo majoris-Brachypodietum pinnati</i>	11.10	0.001	YES
Simpson index			
<i>Poo badensis-Festucetum pallentis</i>	0.03	0.87	NO
<i>Festuco pallentis-Caricetum humilis</i>	0.70	0.40	NO
<i>Festuco valesiacae-Stipetum capillatae</i>	0.08	0.78	NO
<i>Polygalo majoris-Brachypodietum pinnati</i>	14.68	0.0001	YES
Pielou’s measure of species evenness			
<i>Poo badensis-Festucetum pallentis</i>	8.35	0.004	YES
<i>Festuco pallentis-Caricetum humilis</i>	0.04	0.83	NO
<i>Festuco valesiacae-Stipetum capillatae</i>	0.01	0.99	NO
<i>Polygalo majoris-Brachypodietum pinnati</i>	7.98	0.005	YES

The median values of Shannon–Wiener index of diversity were higher in the association *Poo badensis-Festucetum pallentis* ($p = 0.01$, $\alpha = 0.05$, $\chi^2 = 7.38$) (Table 2 and Fig. 4).

The differences in values in the median of species richness and indices in other associations were not statistically significant (Tables 1, 2).

By Kruskal–Wallis analysis of differences in Ellenberg indicator values between old and recent relevés of the studied associations, no statistically significant results were obtained

Fig. 3. The species richness of the old and recent relevés of studied vegetation types of Devínska Kobyla. Notes: - □ median; 0 25 75%; I min-max; o outliers; a b - significant difference; a a - not significant difference; 1 - *Poo badensis-Festucetum pallentis*, reference relevés—1964 (Kaleta, 1965); 2 - *Poo badensis-Festucetum pallentis*, recent relevés—2000–2018 (Miškovic, 2018); 3 - *Festuco pallentis-Caricetum humilis*, reference relevés—1964 (Kaleta, 1965); 4 - *Festuco pallentis-Caricetum humilis*, recent relevés—2000–2018 (Miškovic, 2018); 5 - *Festuco valesiacae-Stipetum capillatae*, reference relevés—1964 (Kaleta, 1965); 6 - *Festuco valesiacae-Stipetum capillatae*, recent relevés—2000–2018 (Miškovic, 2018); 7 - *Polygalo majoris-Brachypodietum pinnati*, reference relevés—1964 (Kaleta, 1965); 8 - *Polygalo majoris-Brachypodietum pinnati*, recent relevés—2000–2018 (Miškovic, 2018).

Fig. 4. The Shannon-Wiener index of diversity [H'] for the old and recent relevés of studied vegetation types of Devínska Kobyla. Explanation corresponds to those in Figure 3.

Fig. 5. The Simpson index for the old and recent relevés of studied vegetation types of Devínska Kobyla. Explanation corresponds to those in Figure 3.

Fig. 6. The Pielou's measure of species evenness for the old and recent relevés of studied vegetation types of Devínska Kobyla. Explanation corresponds to those in Figure 3.

(Table 3). The analysis of the Ellenberg indicator values in total dry grassland vegetation by Kruskal–Wallis analysis revealed a statistically significant lower Ellenberg values for light in recent period compared to the past ($p = 0.004$, $\alpha = 0.05$, $\chi^2 = 8.5$) (Table 3 and Fig. 7a). There was no significant difference in Ellenberg indicator values for temperature (Fig. 7b), conti-

mentality (Fig. 7c). The analysis revealed a significant higher Ellenberg indicator values for moisture ($p = 0.01$, $\alpha = 0.05$, $\chi^2 = 6.2$) (Table 3 and Fig. 7d). There was no significant difference in Ellenberg indicator values for soil reaction (Fig. 7e) between past and recent period. There were a significant higher Ellenberg indicator values for nutrients ($p = 0.0001$, $\alpha = 0.05$,

T a b l e 3. Results of Kruskal–Wallis analysis testing differences in the Ellenberg indicator values between the old and recent data.

	χ^2	p Value	Significancy
Light	8.45	0.004	YES
Temperature	0.99	0.32	NO
Continentality	1.49	0.22	NO
Moisture	6.2	0.01	YES
Soil reaction	1.59	0.21	NO
Nutrients	15.8	0.0001	YES

Fig. 7. The Ellenberg indicator values for light (a), temperature (b), continentality (c), moisture (d), soil reaction (e), and nutrients (f) for the reference (year 1964) and recent (years 2000–2018) relevés.
Notes: 1 - reference relevés (1964); 2 - recent relevés (2000–2018); a b -significant difference; a a -not significant difference; - median; 0 25 75%; I min-max; o outliers.

T a b l e 4. Frequency of occurrence and cover range of woody species in recent relevés (2000–2018), which were not recorded in the past (1964).

	<i>Pb-Fp</i>	<i>Pm-Bp</i>
<i>Cornus mas</i>	–	10 ¹
<i>Fraxinus ornus</i>	–	6 ⁺²
<i>Pinus sylvestris</i>	6 ⁺	–
<i>Populus alba</i>	11 ²⁻³	–
<i>Populus nigra</i>	11 ⁺²	–
<i>Robinia pseudoacacia</i>	3 ²	–
<i>Swida sanguinea</i>	8 ¹⁻²	4 ⁺
<i>Ulmus minor</i>	–	4 ⁺

Notes: The numbers given in the table are frequency values of a species for a particular vegetation type; their upper indices represent the cover range of species. *Pb-Fp*—*Poo badensis-Festucetum pallentis* and *Pm-Bp*—*Polygalo majoris-Brachypodietum pinnati*.

$\chi^2=15.8$) in recent period compared to the past (Table 3 and Fig. 7f).

As an explanatory feature we present the table with the values of frequency of occurrence and cover range of woody species in recent relevés (2000–2018), which were not recorded in the past (1964) (Table 4). The numbers given in the table are frequency values of a species for a particular vegetation type and their upper indices represent the cover range of species. The frequency of occurrence of some woody species increased in associations *Poo badensis-Festucetum pallentis* and *Polygalo majoris-Brachypodietum pinnati* (Table 4).

Discussion

The majority of significant results of analyses revealed the lower values of species richness, diversity, and evenness in studied dry grassland communities of Devínska Kobyla in recent period compared to the past (Tables 1,d 2 and Figs 3–6). This decline of values of diversity indices is probably caused mainly by the abandonment of traditional land use (grazing and mowing) in the area after 1965, because the disturbances caused by grazing and mowing are necessary for the maintenance of the species richness and diversity of dry grasslands (Kubíková, 1999; Münzbergová, 2001; Chytrý, 2007; Galvánek, Lepš, 2008).

The significant higher values in recent period were recorded only in the case of Shannon–Wiener in one association—*Poo badensis-Festucetum pallentis* (Table 2 and Fig. 4). Hegedúšová, Senko (2011) in study from Devínska Kobyla found out that species richness in this association declined over time, which is in the contrast with our result of increase in Shannon–Wiener index. Hegedúšová, Senko (2011) recorded the increase of species richness in the other association—*Festuco valesiacae-Stipetum capillatae*. Authors consider *Festuco valesiacae-Stipetum capillatae* the least endangered by successional changes.

We did not record significant differences of any diversity index in the association *Festuco valesiacae-Stipetum capillatae* between old and recent data. The possible reason can be that the association is species rich and grows on relatively steeper soils, where succession is slower than in deeper soils, where grows the association *Polygalo majoris-Brachypodietum pinnati*, which showed decrease of all diversity indices.

The explanation of the higher diversity index in the association *Poo badensis-Festucetum pallentis* in recent period can be that this association occurs on rocks with the shallowest soils, where significant changes in management did not occur. There were no grazing or

mowing in the rocky shallow soil in the past. That could be the reason why this association is less endangered by successional changes after abandonment of traditional management than other analyzed associations, which grow on sites with deeper soil, where management changes occurred. On the other hand, it is still a fact that some changes occurred also in the association *Poo badensis-Festucetum pallentis*, for example, overgrowing by woody species (Table 4).

Fig. 8. Overgrowing by woody species in the stands of the association *Poo badensis-Festucetum pallentis* at Sandberg, Devínska Kobyla (Author of photo: Ján Miškovic).

Although no significant differences of the Ellenberg indicator values between old and recent period were found for some of the environmental variables, the Ellenberg indicator values for nutrients and moisture were significantly higher in recent period (Fig. 7). This result could have connection with overgrowing by woody species and increased accumulation of died biomass after abandonment and its increased decomposition, and thus enrichments of soils by nutrients. Similar results were achieved by Ruprecht et al. (2010), and the accumulation of biomass is a consequence of abandonment of grasslands. After the abandonment of the traditional management, the gradual overgrowing by woody species took place in the Devínska Kobyla (Hegedúšová, Senko, 2011). The frequency of occurrence of some woody species was higher in the recent relevés from the associations *Poo badensis-Festucetum pallentis* and *Polygalo majoris-Brachypodietum pinnati* (Table 4). The overgrowing by species such as *Populus alba*, *P. nigra*, and invasive species *Robinia pseudoacacia* in the stands of the *Poo badensis-Festucetum pallentis* association in Devínska Kobyla is also evident in the photography from the studied area (Fig. 8). The stands of *Poo badensis-Festucetum pallentis* are open (average total cover of species in relevé is 40%) because of extreme environmental conditions (shallow dry soils and steep slopes) of places where the stands grow. The open vegetation is more prone to introduction of new species such as *Populus alba* and *P. nigra*. The stands of the association *Polygalo majoris-Brachypodietum pinnati*, on the other hand, grow on deeper soils. From a long-term perspective, these conditions fit to some woody species. Also other authors found the overgrowing by woody species as one of the main sign of degradation of dry grasslands (Dostálek, Frantík, 2008; Schrautzer et al., 2009; Hegedúšová, Senko, 2011) or habitat alteration (Smit, 2004).

Our study confirmed the trend of decline in biodiversity of species-rich dry calcareous grasslands after abandonment of traditional management during recent decades shown in other studies from Central Europe (Galvnek, Lepš, 2008; Schrautzer et al., 2009; Hegedššov, Senko, 2011; Pipenbaher et al., 2013). From numerous studies, it is clear that the dry calcareous grasslands should receive attention in regard to conservation management (WallisDeVries, 1999; Barbaro et al., 2001; Mšnzbegov, 2001; Willems, 2001; Kahmen et al., 2002; Riecken et al., 2002; WallisDeVries et al., 2002; Baba, 2004; Mas, 2005; Bornkamm, 2006; Stadler et al., 2007; Dostlek, Frantk, 2008; Peter et al., 2009; Hegedššov, Senko 2011; Kuzemko et al., 2016). Our study showed similar conclusions as these studies. As the diversity of dry grasslands in the Devnska Kobyla NNR decreased after the grazing cessation, restoring the grazing should be the part of the conservation management in the area. Grazing is recognized as one of the most natural methods of management of dry grasslands (Hadar et al., 1999; Peter et al., 2009; Hegedššov, Senko, 2011).

In the last few years, the traditional management has begun to be partly restored in Devnska Kobyla NNR. The biomass of *Robinia pseudoacacia* L. has been being removed from the year 2016, and the goat grazing was reintroduced in 2017 again. In the recent years, the goats have been grazed also on the steep slopes, where they promote heightened erosion with potentially negative impact on the dry grassland communities. The best possible way is to combine goat and sheep co-grazing on the moderate slopes with removal of the biomass of woody species on the steep slopes. Also other authors (Barbaro et al., 2001; Hegedššov, Senko, 2011; Bojkovski et al., 2014) found the combination of shrub clearing and grazing as one of the best ways of conservation management of dry grasslands.

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