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Revitalising subalpine grasslands: floristic shifts under renewed grazing

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Abstract: The species diversity of the unique flora in the Hrubý Jeseník Mountains is currently threatened due to the absence of traditional grazing, which was historically used as a management practice. This study evaluates changes in floristic composition in areas near the Švýcárna and Ovčárna lodges, where cattle and sheep grazing was reintroduced in 2012 and 2014, respectively, after long-term abandonment. The floristic composition was assessed using permanent plots and analysed statistically. In total, 84 plant species were recorded in the Švýcárna experimental area over 12 years. All experimental plots throughout the study observed an increase in species richness. In the Ovčárna area, a similar trend was detected, particularly in grazed grasslands dominated by *Avenella flexuosa*, *Festuca supina*, and *Ligusticum mutellina*. The reintroduction of grazing in these areas serves not only as a symbolic return to traditional land use but primarily as an effective management tool to suppress ecological succession and maintain or enhance plant species diversity in biologically valuable habitats.

Keywords: nature conservation; biodiversity; livestock; revitalisation; grazing management

Recent research has shown that biodiversity is on the decline, and the loss of biodiversity in European temperate grasslands over the past few decades is considerable (Isselstein 2019). A reduction in biodiversity often results from a decrease in natural habitats, both in the land area they occupy and their variety.

Grazing is considered an effective tool for maintaining grassland biodiversity, as documented by Metera et al. (2010). Isselstein (2005) also highlighted that using livestock to develop and maintain biodiversity in grassland and rangeland systems is a key objective in many regions worldwide. Understanding how grazing contributes to the revitalisation of these ecosystems has profound implications for their sustainable use and efficient conservation, given their unique and global value.

The impact of grazing management on vegetation dynamics has been widely studied in Western

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Europe (e.g., WallisDeVries et al. 1998, Marriott et al. 2002). However, research on livestock grazing in central Europe has concentrated on a small number of case studies, although the use of grazing management has dramatically increased due to socio-economic changes in the rural economy since the 1990s. Consequently, pasture management is a big issue in the prevention of negative changes in many marginal areas (Caredda et al. 2002).

The occurrence of endangered plant species is usually linked to habitats originally affected by grazing, and due to this fact, grazing is renewed in the Czech Republic in the protected areas where it was pursued in the past (e.g. the Giant Mts., the Beskydy Mts.). An example of the successful introduction of renewed grazing of small ruminants for revitalising grasslands is the experimental sheep pasture in the National Nature Reserve Mohelno Serpentine Steppe in the Czech Republic. As Veselý and Řepka (2005) documented, five years after the renewed grazing introduction, plant species diversity was increased on monitored plots. A similar approach with positive results was also applied in the Protected Landscape Area Beskydy and the Protected Landscape Area Bílé Karpaty (Piro and Wolfová 2008).

Concerning the Hrubý Jeseník Mts.'s summits, the grazing management ended there after World War II (Bureš 2013). These areas are primarily occupied by *Avenella flexuosa* (L.) Drejer and *Festuca supina* Schur grasslands at present. The *Calamagrostis villosa* (Chaix) Gmel. and *Vaccinium myrtillus* L. are prevailing on large flanks; ill-drained sites are occupied by stands of *Deschampsia cespitosa* (L.) P. Beauv., and scree habitats are inhabited by *Athyrium distentifolium* Tausch ex Opiz and other tall herbs (Klimeš and Klimešová 1991). Nowadays, the widespread presence of expansive species such as *Vaccinium vitis-idaea* L. and *Vaccinium myrtillus* L. (Klimeš and Klimešová 1991, Zeidler and Banaš 2024), along with non-native species like *Pinus mugo* Turra planted in the second half of 19th century significantly impacts grasslands in various locations. These species form extensive communities, displacing the unique flora of the Hrubý Jeseník Mts.

Therefore, in 2012 and 2014, grazing was experimentally restored also in the Hrubý Jeseník Mts. (the Praděd National Nature Reserve) in the surroundings of Švýcárna and Ovčárna lodges, respectively. Due to their unique flora, these are sites of European importance. The primary aim of reintroducing cattle and sheep grazing was to enhance the non-productive functions of alpine grasslands, such as floristic diversity, landscape formation, and attractiveness for tourism. Understanding the effects of grazing on plant species composition remains necessary. Our research is unique in that no exact research on the effect of renewed grazing on alpine grasslands has been carried out in the monitored area.

Our study aimed to estimate changes in the floristic composition of plant communities at the Švýcárna and Ovčárna sites (located in the Praděd National Nature Reserve), where cattle and sheep grazing were experimentally reintroduced in 2012 and 2014, respectively, after a long period without management.

MATERIAL AND METHODS

Study sites. Our research was conducted in the mountain area near the Švýcárna and Ovčárna lodges in the Hrubý Jeseník Mts. (the Praděd National Nature Reserve; 1 330 m a.s.l.). The location of the study sites in the Czech Republic is shown in Figure 1. The mean annual temperature and precipitation in the study area are 0.9 °C and 1 231 mm, respectively. Predominant soil types are podzols to rankers with an acid soil exchange reaction, typical for the higher altitudes of Hrubý Jeseník Mts. The experimental area is managed by the state-owned enterprise Forests of the Czech Republic. According to the current Forest Management Plan, the grazed land is classified as open land. Following a declaration by the Regional Authority of the Olomouc Region temporarily revoking the land's designation for fulfilling forest functions, grazing was reintroduced using suckler cows (Highland breed) and sheep (Valachian breed) in 2012 at Švýcárna and in 2014 at Ovčárna.

The vegetation surrounding lodges could be characterised as a mosaic of close alpine grasslands, subalpine Vaccinium vegetation, subalpine tall grasslands and subalpine tall-forb vegetation (Chytrý et al. 2010), with the dominant species *Nardus stricta* L. and *Deschampsia cespitosa* (L.) P. Beauv., *Avenella flexuosa* (L.) Drejer, *Bistorta major* S.F. Gray, *Calamagrostis villosa* (Chaix) Gmel., *Festuca supina* Schur and *Luzula sylvatica* (Huds.) Gaudin.

The content of plant-available nutrients (i.e. Ca, Mg, K, P) was determined at the beginning of the trial using the Mehlich III method (Mehlich 1984). From the criterion point of view of the supply of soils under grasslands (Fiala and Krhovjáková 2009), in most cases, the content of calcium, magnesium and phosphorus was evaluated as "low" (< 1 100 mg/kg Ca;

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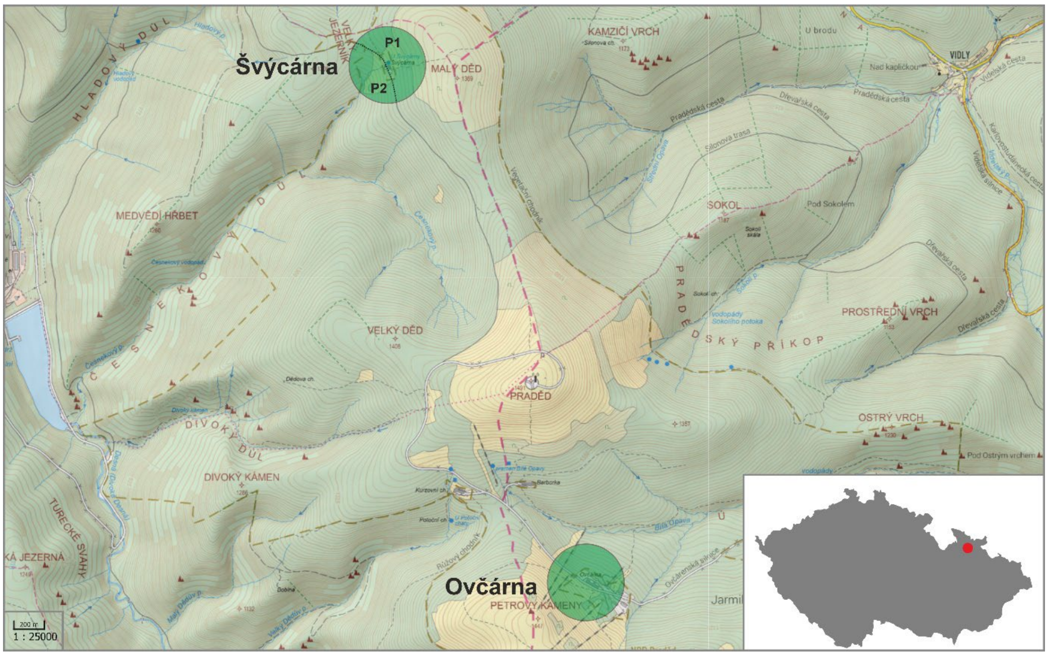

Figure 1. Location of the study sites in the Czech Republic

< 85 mg/kg Mg; < 25 mg/kg P) in all cases. The potassium content ranged from a level we rate as "low" (< 80 mg/kg K) to "acceptable" (81–160 mg/kg). Based on the soil exchange reaction results, which in all cases remained below pH 4.5, the soils at both locations can be classified as extremely acidic.

The rotational grazing system was conducted at both localities, whereas the stocking rate was up to 1 livestock unit (LU) per ha and year. The stocking rate was expressed as the weight of animals per unit area, with one LU being 500 kg of the live weight of an animal. The calculation was performed according to the literature by Hejcman et al. (2002).

The total plot area was 3.6 ha at Švýcárna and 0.85 ha at Ovčárna. The pasture at Švýcárna was divided by a road into two grazing sub-localities (P1 and P2). This division was based on the observation that the floristic composition differed slightly between the sub-localities.

Trial parameters and evaluation of floristic composition. Five permanent plots of 5 × 5 m at each locality were established in 2012 (Švýcárna, GPS 50°06.156'N, 17°12.823'E; P1-A, P1-B, P2-A, P2-B, P2-C) and 2014 (Ovčárna, GPS 50°04.227'N, 17°14.305'E; P-A, P-B, P-C, P-D, P-E) to monitor changes in floristic composition. The main objective of the study was to address nature conservation concerns, so plots in both localities Švýcárna and Ovčárna were arranged to capture the potential floristic variability and diversity as thoroughly as possible. The floristic composition was recorded annually from 2012 (or 2014) to 2024 at the beginning of July, following the establishment of the grazing plots. The projective cover of individual species was visually estimated as a percentage. A few individuals with low coverage were rated with the symbol "+" and solitary species with very low coverage with the symbol "r". Since the estimation was done by eye, there will inevitably be some degree of error in the recording. However, this method is quick to use, and the issues of subjectivity can be reduced if the same observer assesses the coverage consistently throughout the survey. At vegetation plots, edge effects may introduce bias. However, this can be mitigated by using larger, permanent plots situated outside vegetation boundaries. The nomenclature of vascular plants followed Danihelka et al. (2012).

Statistical analysis. The number of species in each plot was plotted, and the effects of the year were analysed using a polynomial regression model in the Statistica program (version 13.2; Tulsa, USA). This was done for each plot separately because the pre-grazing floristic diversity may vary among individual plots, as the plots were arranged to capture the maximum floristic variability in the area. The species covered in different experimental plots and their changes over time were analysed using multivariate analyses in the CANOCO 5 software (ter Braak and Šmilauer 2018). At Švýcárna, two sub-localities, P1 and P2, were analysed separately

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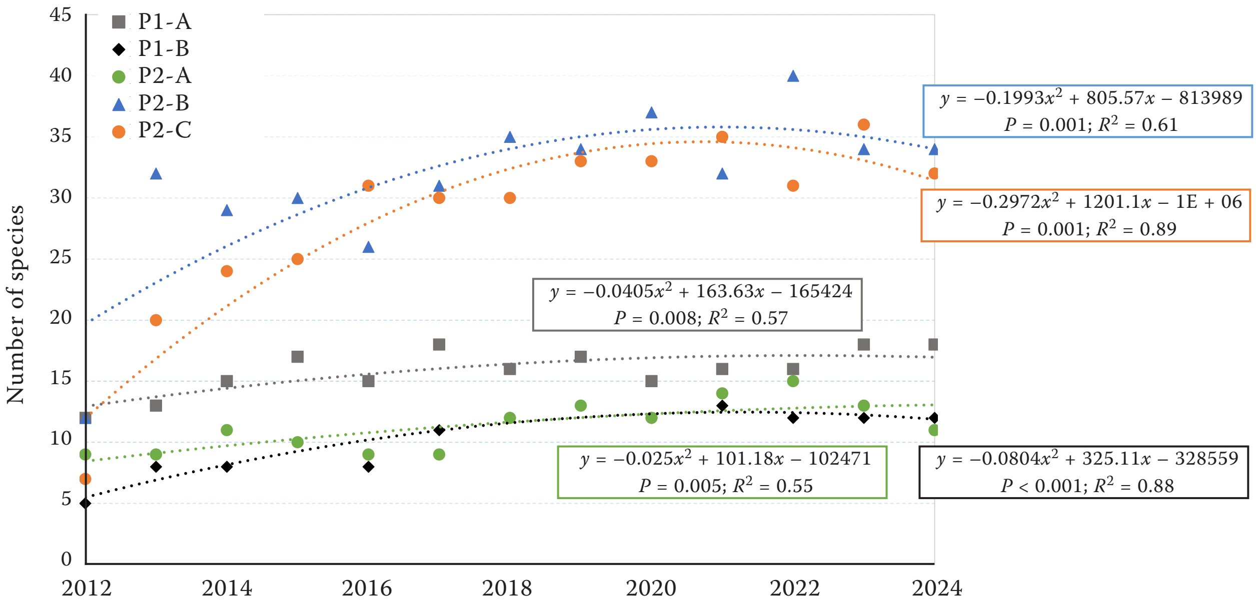

Figure 2. Scatterplot and polynomial regression of the species number together with regression equations, *P*-values and coefficients (R^2) at Švýcárna grazing sub-localities P1-A, B and P2-A, B, C during the two-year interval between 2012–2024. The *P*-value less than 0.05 indicates a statistically significant relationship between the number of species in individual years. The *R*-squared statistic indicates the percentage of variability in the data explained by the fitted model

due to differences in their floristic composition. First, we used detrended correspondence analysis (DCA), detrending by segments. Due to relatively short gradients on the first canonical axes (1.5 and 2.7 SD units for P1 and P2 sub-localities at Švýcárna, respectively, and 2.4 SD for Ovčárna) in the compositional turnover, redundancy analyses (RDA) were used to assess overall variation patterns in the data set. Data were centred by species. For the P2 sub-locality at Švýcárna and Ovčárna, cover values were logarithmically transformed (y + 1). The plots at each locality and the year were used as explanatory variables. The net effect of a particular variable was calculated after excluding the negative effect shared with another variable (which entered the analysis as a covariable). The effects were evaluated using Monte Carlo permutation tests for all canonical axes (999 permutations were used). In this test, the distribution of the test statistics under the null hypothesis was generated by restricted random permutations of environmental data.

RESULTS

Švýcárna locality. Figure 2 shows the changes in the plant species diversity on the experimental plots at Švýcárna from 2012 to 2024. Eighty-four plant species were found in the experimental area over 12 years, with 29 and 75 species recorded at sub-localities P1 and P2, respectively. In all experimental plots, species richness was increased within the study period (Figure 2).

In the multivariate analysis, the effects of both the different plots and the year were found to be highly significant (Table 1). Taken together, these variables explained 81.6% and 51.9% of the total variability

Table 1. The effects of explanatory variables on species composition at sub-localities P1 and P2 at Švýcárna grazing area

Explanatory variable	(%)	*F*-ratio	*P*-value
Sub-locality P1			
All	81.6	51.0	0.001
Plot	64.7	42.1	0.001
Year	72.3	59.9	0.001
Sub-locality P2			
All	51.9	12.6	0.001
Plot	46.8	15.4	0.001
Year	16.5	6.9	0.001

% – percentage of explained variance; *F*-ratio for the test of significance of all canonical axes; *P*-value – corresponding probability value obtained by the Monte Carlo permutation test (999 permutations)

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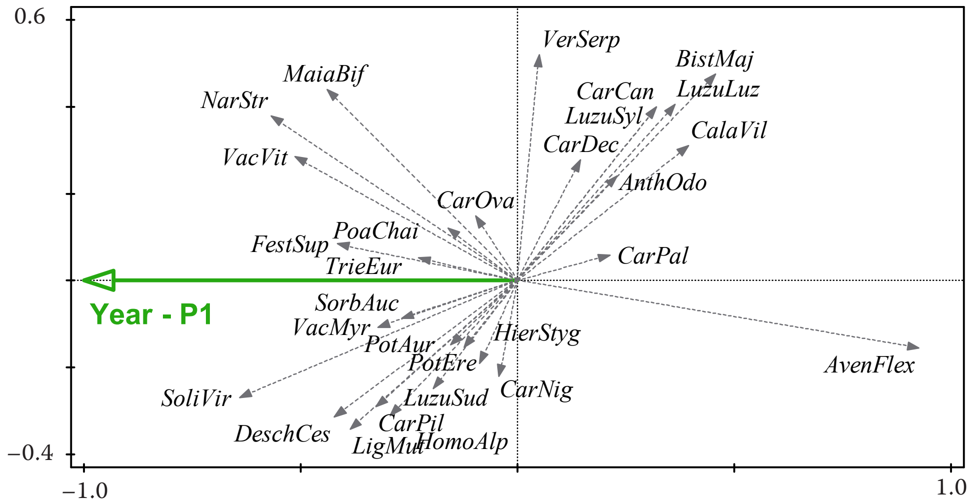

Figure 3. Redundancy analysis (RDA) ordination diagram illustrating the effect of the year on species composition at Švýcárna grazing sub-locality P1. AnthOdo – *Anthoxanthum odoratum* L.; AvenFlex – *Avenella flexuosa* (L.) Drejer; BistMaj – *Bistorta major* S.F. Gray; CalaVil – *Calamagrostis villosa* (Chaix) Gmel.; CarCan – *Carex canescens* L.; CarDec – *Carex decolorans*; CarNig – *Carex nigra* (L.) Reichard; CarOva – *Carex ovalis* Good.; CarPal – *Carex pallescens* L.; CarPil – *Carex pilulifera* L.; DeschCes – *Deschampsia cespitosa* (L.) P. Beauv.; FestSup – *Festuca supina* Schur; HierStyg – *Hieracium stygium* R. Uechtr.; HomoAlp – *Homogyne alpina* Cass.; LigMut – *Ligusticum mutellina* (L.) Crantz; LuzuLuz – *Luzula luzuloides* (Lam.) Dandy et Wilmott; LuzuSud – *Luzula sudetica* (Willd.) Schult.; LuzuSyl – *Luzula sylvatica* (Huds.) Gaudin; MaiaBif – *Maianthemum bifolium* (L.) F.W. Schmidt; NarStr – *Nardus stricta* L.; PoaChai – *Poa chaixii* Vill.; PotAur – *Potentilla aurea* L.; PotEre – *Potentilla erecta* (L.) Hampe.; SoliVir – *Solidago virgaurea* L. subsp. *minuta* (L.) Arcang.; SorbAuc – *Sorbus aucuparia* L.; TrieEur – *Trientalis europaea* L.; VacMyr – *Vaccinium myrtillus* L.; VacVit – *Vaccinium vitis-idaea* L.; VerSerp – *Veronica serpyllifolia* L.

in the studied species data for the sub-localities P1 and P2, respectively. The different plots within the sub-locality explained the majority of the variation.

Changes in plant species occurrence from 2012–2024 at the sub-locality P1 are presented in Figure 3. Table 2 shows the more detailed results of the floristic composition at Švýcárna (P1) in the first and the last year of monitoring. The sub-locality P1 was represented by plots with lower species diversity. Following the reintroduction of grazing, several species that initially accounted for less than 10% cover – such as *Festuca supina* Schur and *Nardus stricta* L. – became more abundant. *Avenella flexuosa* (L.) Drejer was the most abundant species in 2012, with a cover of 50–65%, but its cover declined to only 15% after 12 years of grazing. *Calamagrostis villosa* (Chaix) Gmel. initially occupied 5–10% of the individual plots, but by the end of the monitoring period, its cover had decreased to approximately 1%. *Bistorta major* S.F. Gray was also among the species negatively affected by grazing at sub-locality P1. *Vaccinium myrtillus* L., considered an aggressive species that should be controlled by grazing, showed a negative response in plot P1-B.

Changes in plant species occurrence from 2012–2024 at the sub-locality P2 are presented in Figure 4. Table 3 shows the more detailed results of the floristic composition at Švýcárna (P2) in the first and the last year of monitoring. This sub-locality showed higher species diversity from the very beginning of the experimental period. Species that positively reacted to grazing were typical pasture and meadow plants common in lower altitudes – *Festuca pratensis* Huds. and *Festuca rubra* L. Species *Juncus effusus* L. showed a similar pattern, with initial absence in monitored plots and 25% cover in plot P2-C in 2024. A significant reduction in cover was found in *Avenella flexuosa* (L.) Drejer. This species was dominant in plot P2-A with 50% cover. Grazing reduced its cover to just 3%. *Nardus stricta* L., the dominant grass in P1, nearly disappeared over the years in P2.

Ovčárna locality. Figure 5 illustrates the changes in plant species diversity in experimental plots at Ovčárna during 2014–2024. A total of 89 species were identified at the site. The increasing tendency regarding the total number of species was most evident in plots P-B and P-D.

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Table 2. Floristic composition at Švýcárna (permanent plots P1-A, B) in the first and the last year of the monitoring

	P1-A		P1-B	
	2012	2024	2012	2024
Anthoxanthum odoratum L.	5	+		+
Avenella flexuosa (L.) Drejer	50	15	65	15
Bistorta major S.F. Gray	5	+		+
Calamagrostis villosa (Chaix) Gmel.	10	+	5	+
Carex decolorans	1	+		
Carex canescens L.	2			
Carex nigra (L.) Reichard	3	+		
Carex ovalis Good.				
Carex pallescens L.				
Carex pilulifera L.		3		
Deschampsia cespitosa (L.) P. Beauv.		1		
***Festuca supina* Schur**	8	15	3	15
***Hieracium stygium* R. Uechtr.**		+		
Homogyne alpina Cass.		+		
***Ligusticum mutellina* (L.) Crantz**		+		
Luzula luzuloides (Lam.) Dandy et Wilmott	2			
***Luzula sudetica* (Willd.) Schult.**		+		r
Luzula sylvatica (Huds.) Gaudin	2			
Maianthemum bifolium (L.) F. W. Schmidt				+
Nardus stricta L.	5	25	15	80
Poa chaixii Vill.				
***Potentilla aurea* L.**		+		
Potentilla erecta (L.) Hampe.		3		+
Solidago virgaurea L. subsp. *minuta* (L.) Arcang.		+		+
Sorbus aucuparia L.				
***Trientalis europaea* L.**				
Vaccinium myrtillus L.	5	8	10	3
Vaccinium vitis-idaea L.				+
Veronica serpyllifolia L.				

Species highlighted in bold are species that fall into one of the categories of threat, according to Grulich (2012). Rows without values indicate that the species was present during the study period in a year other than 2012 or 2024

As for the multivariate analysis, the effects of the different plots and the year were highly significant (Table 4). These variables explained 76.6% of the total variability in the studied species data. The majority of the variation was explained by different plots.

Changes in plant species occurrence from 2014 to 2024 at Ovčárna are presented in Figure 6. Table 5 shows the more detailed results of the floristic composition at Ovčárna in the first and the last year of monitoring. *Avenella flexuosa* (L.) Drejer was supported by grazing mainly in plots P-A and P-C. An interesting development was observed also for *Festuca supina* Schur in plot P-D (from 5% to 15%). *Deschampsia cespitosa* (L.) P. Beauv. It was not the abundant species at Ovčárna, but at sites where it was present (P-B, P-E), it increased its cover up to 12% and 25%. A slight increase (to 2%) was observed for *Carex nigra* L. and *C. pilulifera* L., which are less digestible for grazing animals. The grasses *Festuca rubra* L. and *F. pratensis* Huds. were newly introduced to the surveyed areas. Of the threatened species, the more stable occurrence of *Trientalis europaea* L. and *Cerastium fontanum* Baumg. was observed as

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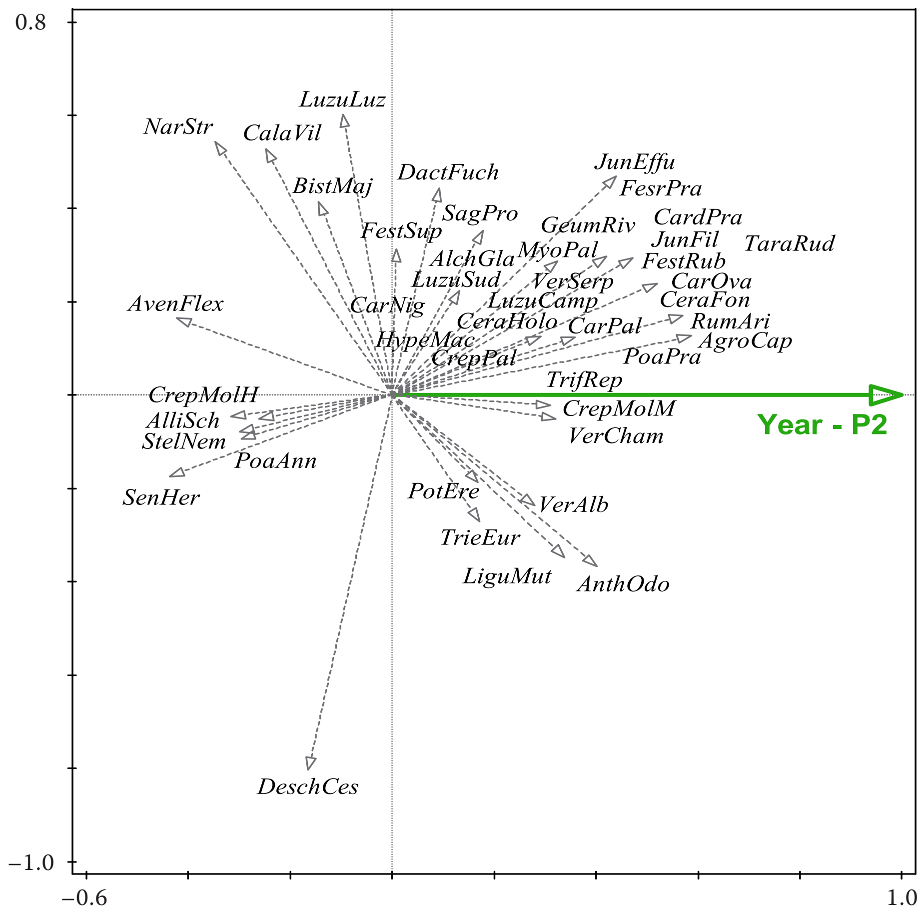

Figure 4. Redundancy analysis (RDA) ordination diagram illustrating the effect of the year on species composition at the sub-locality P2 (minimum species fit into ordination space 6% – 44 out of 75 species are displayed) at Švýcárna grazing area. AgroCap – *Agrostis capillaris* L.; AlchGla – *Alchemilla glabra* Neygenf.; AlliSch – *Allium schoenoprasum* L. subsp. *schoenoprasum*; AnthOdo – *Anthoxanthum odoratum* L.; AvenFlex – *Avenella flexuosa* (L.) Drejer; BistMaj – *Bistorta major* S.F. Gray; CalaVil – *Calamagrostis villosa* (Chaix) Gmel.; CardPra – *Cardamine pratensis* L.; CarNig – *Carex nigra* (L.) Reichard; CarOva – *Carex ovalis* Good.; CarPal – *Carex pallescens* L.; CeraFon – *Cerastium fontanum* Baumg.; CeraHolo – *Cerastium holosteoides* Fr.; CrepMolH – *Crepis mollis* subsp. *hieracioides* (Domin) Domin; CrepMolM – *Crepis mollis* (Jacq.) Asch. subsp. *mollis*; CrepPalu – *Crepis paludosa* (L.) Moench.; DactFuch – *Dactylorhiza fuchsii* (Druce) Soó; DeschCes – *Deschampsia cespitosa* (L.) P. Beauv.; FestPra – *Festuca pratensis* Huds.; FestRub – *Festuca rubra* L.; FestSup – *Festuca supina* Schur; GeumRiv – *Geum rivale* L.; HypeMac – *Hypericum maculatum* Crantz; JunEffu – *Juncus effusus* L.; JunFil – *Juncus filiformis* L.; LiguMut – *Ligusticum mutellina* (L.) Crantz; LuzuCamp – *Luzula campestris* (L.) DC.; LuzuLuz – *Luzula luzuloides* (Lam.) Dandy et Wilmott; LuzuSud – *Luzula sudetica* (Willd.) Schult.; MyoPal – *Myosotis palustris* (L.) Hill. sp. *aggreg.*; NarStr – *Nardus stricta* L.; PoaAnn – *Poa annua* L.; PoaPra – *Poa pratensis* L.; PotEre – *Potentilla erecta* (L.) Hampe.; RumAri – *Rumex arifolius* All.; SagPro – *Sagina procumbens* L.; SenHer – *Senecio hercynicus* Herborg; StelNem – *Stellaria nemorum* L.; TaraRud – *Taraxacum* sect. Ruderalia; TrieEur – *Trientalis europaea* L.; TrifRep – *Trifolium repens* L.; VerAlb – *Veratrum album* L. subsp. *lobelianum* (Bernh.) Melch.; VerCham – *Veronica chamaedrys* L.; VerSerp – *Veronica serpyllifolia* L.

a result of grazing. One species significantly suppressed by grazing was a robust herb, *Senecio hercynicus* Herborg, which has almost disappeared from the sites where it grew before grazing. Similarly, *Calluna vulgaris* (L.) Hull. has completely disappeared, while *Rubus idaeus* L. and *Luzula luzuloides* (Lam.) Dandy et Wilmott have been severely suppressed. In the case of *Rumex arifolius* All., its abundance was low from the beginning, and the cover value of this species remained virtually unchanged.

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Table 3. Floristic composition at Švýcárna (permanent plots P2-A, B, C) in the first and the last year of the monitoring

	P2-A		P2-B		P2-C	
	2012	2024	2012	2024	2012	2024
Agrostis capillaris L.				+		1
Alchemilla glabra Neygenf.				+		+
Alchemilla monticola Opiz				+	1	1
Alchemilla vulgaris L.						
Allium schoenoprasum* L. subsp. *schoenoprasum			3			
Alopecurus pratensis L.				+		
Anthoxanthum odoratum L.		8		+		1
Avenella flexuosa (L.) Drejer	50	3	5	1		
Bistorta major S.F. Gray	5	+		+		
***Botrychium lunaria* (L.) Sw.**						
Calamagrostis villosa (Chaix) Gmel.	15					
***Caltha palustris* L.**						r
Cardamine amara L.						
Cardamine pratensis L.				+		r
Carex echinata Murray						
Carex nigra (L.) Reichard	2	+			5	1
Carex ovalis Good.				+		+
Carex pallescens L.				+		+
Carex pilulifera L.				r		
***Cerastium fontanum* Baumg.**				r		+
Cerastium holosteoides Fr.				+		+
Chaerophyllum hirsutum L.			20	1	35	5
Chrysosplenium alternifolium L.						r
***Crepis mollis* subsp. *hieracioides* (Domin) Domin**						
Crepis mollis* (Jacq.) Asch. subsp. *mollis			r	+		
Crepis paludosa (L.) Moench.				r		+
***Dactylorhiza fuchsii* (Druce) Soó**						
Dactylis glomerata L.			2			
Deschampsia cespitosa (L.) P. Beauv.	3	80	40	30	50	2
Epilobium sp.						
Festuca pratensis Huds.				5		
Festuca rubra L.		+		5		10
***Festuca supina* Schur**	5	1				
Galeopsis bifida Boenn.						
Geranium sylvaticum L.						
Geum rivale L.				r		
Gnaphalium sylvaticum L.						
Hypericum maculatum Crantz						r
Juncus effusus L.						25
Juncus filiformis L.						+
Juncus squarrosus L.						
***Ligusticum mutellina* (L.) Crantz**		8				

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Continued Table 3. Floristic composition at Švýcárna (permanent plots P2-A, B, C) in the first and the last year of the monitoring

	P2-A		P2-B		P2-C	
	2012	2024	2012	2024	2012	2024
Luzula campestris (L.) DC.						+
Luzula luzuloides (Lam.) Dandy et Wilmott	2					
***Luzula sudetica* (Willd.) Schult.**						
Luzula sylvatica (Huds.) Gaudin	5	1	5			
Lysimachia nemorum L.						
Myosotis palustris (L.) Hill. sp. aggreg.				+		3
Nardus stricta L.	5					
***Phleum alpinum* L.**				+		
Phyteuma spicatum L.				r		
Poa annua L.			2	+		
Poa chaixii Vill.		+	5	5	2	
Poa pratensis L.				+		+
Potentilla erecta (L.) Hampe.						
Ranunculus acris L.				+		5
Ranunculus repens L.			3	1		3
Rumex acetosa L.				r		+
Rumex arifolius All.				+		+
Rumex obtusifolius L.						
Sagina procumbens L.						+
Senecio hercynicus Herborg			5		3	
Senecio ovatus (G., M. et Sch.) Willd.						
Stellaria alsine Grimm						+
Stellaria nemorum L.			5		3	+
Taraxacum sect. *Ruderalia*				r		r
***Tephroseris crispa* (Jacq.) Schur**						r
***Trientalis europaea* L.**		+				
Trifolium repens L.				+		
Vaccinium myrtillus L.						
***Veratrum album* L. subsp. *lobelianum* (Bernh.) Melch.**						
Veronica beccabunga L.						
Veronica chamaedrys L.				+		
Veronica serpyllifolia L.				+		+
***Viola biflora* L.**						

Species highlighted in bold are species that fall into one of the categories of threat according to Grulich (2012). Rows without values indicate that the species was present during the study period in a year other than 2012 or 2024

Table 4. The effects of explanatory variables on species composition at Ovčárna grazing area

Explanatory variables	(%)	*F*-ratio	*P*-value
All	76.6	32.0	0.001
Plot	75.8	40.6	0.001
Year	13.3	6.0	0.001

% – percentage of explained variance; *F*-ratio for the test of significance of all canonical axes; *P*-value – corresponding probability value obtained by the Monte Carlo permutation test (999 permutations)

https://doi.org/10.17221/12/2025-PSE

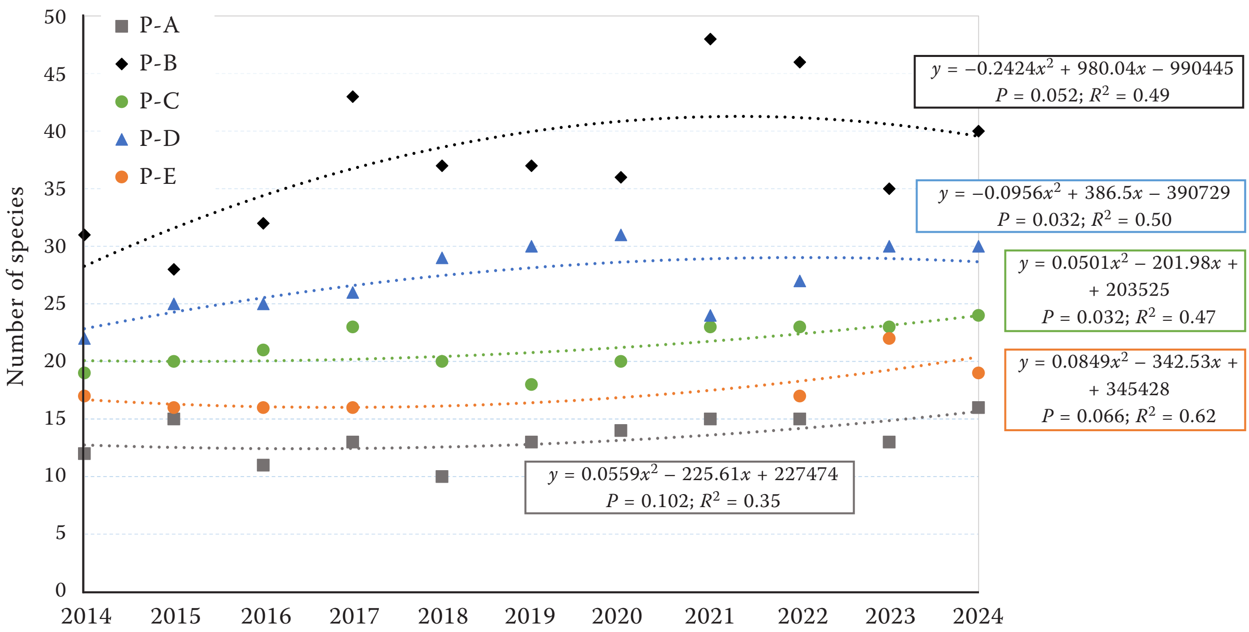

Figure 5. Scatterplot and polynomial regression of the species number together with regression equations, P-values and coefficients (R^2) at Ovčárna grazing plots P-A, B, C, D, E during 2014–2024. The P-value less than 0.05 indicates a statistically significant relationship between the number of species observed in individual years. The R-squared statistic indicates the percentage of variability in the data explained by the fitted model

DISCUSSION

Regarding the literature for our study area, it is evident from numerous floristic data spanning from the late 18th century to the early 20th century (Kolenati 1860) that forestless areas in the Hrubý Jeseník Mountains were more diverse in terms of species and biotope diversity when they were actively managed. Threatened and endangered plants (Grulich 2012) that occurred in the surrounding of Švýcárna lodge in the past (citations in Bureš 2013) were, e.g. *Anemonastrum narcissiflorum* (L.) Holub., *Arabidopsis halleri* (L.) O'Kane et Al-Shehbaz, *Arnica montana* L., *Crepis sibirica* L., *Epilobium anagallidifolium* Lam., *Epilobium nutans* F.W. Schmidt, *Gentiana verna* L., *Pilosella flagellaris* (Willd.) Arv.-Touv., *Pinguicula vulgaris* L., *Pseudorchis albida* (L.) Á. et D. Löve, *Rhinanthus riphaeus* Krock., *Sagina saginoides* (L.) H. Karst., *Trichophorum alpinum* (L.) Pers., *Trifolium spadiceum* L., *Valeriana dioica* L. None of these species were recorded during our research.

According to Bureš (2013), several factors contribute to the decline in species diversity at many locations in the Hrubý Jeseník Mountains, including the cessation of grassland management in areas above the tree line. Many researchers have shown that, almost independently of the vegetation type, cessation of grassland management leads to a successional change and a loss of plant species diversity (Dullinger et al. 2003). At a local scale, vegetation succession facilitates the invasion of shrubs, the dominance of tall growing species from later successional stages and the competitive exclusion of species typical for managed grasslands (Krahulec et al. 2001, Pykälä 2003, Gaisler et al. 2004, Kryszak and Kryszak 2005). All this may be one of the reasons for limiting the spread of endangered species that were originally present in pastures.

Considering these factors, positive changes in floristic composition and plant species diversity can be expected at localities where renewed grazing was introduced after a long period of grassland management cessation. More frequent disturbance creates open areas that provide enough space for the emergence and development of different species during the entire growing season (Lavorel et al. 1994).

So far, ecologists have not established one general, unified theory for successionally induced changes in species composition after the reintroduction of grazing. Possible mechanisms behind changes in species composition could be nutrient cycling. The results of Šimon and Czakó (2014) indicated that the addition of organic matter from various sources (e.g. faeces) affects the soil organic matter and biological activity.

https://doi.org/10.17221/12/2025-PSE

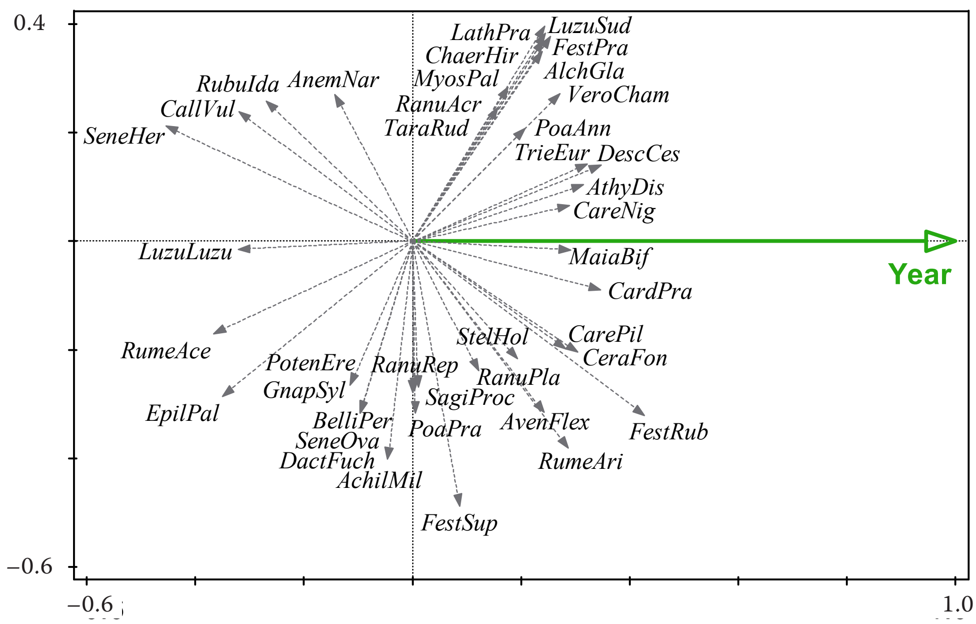

Figure 6. Redundancy analysis (RDA) ordination diagram illustrating the effect of the year on species composition (minimum species fit into ordination space 7% – 40 out of 87 species are displayed) at Ovčárna grazing area. AchilMil – *Achillea millefolium* L.; AlchGla – *Alchemilla glabra* Neygenf.; AnemNar – *Anemonastrum narcissiflorum* (L.) Holub; AthyDis – *Athyrium distentifolium* Tausch ex Opiz; AvenFlex – *Avenella flexuosa* Trin.; BelliPer – *Bellis perennis* L.; CallVul – *Calluna vulgaris* (L.) Hull.; CardPra – *Cardamine pratensis* L.; CareNig – *Carex nigra* (L.) Reichard; CarePil – *Carex pilulifera* L.; CeraFon – *Cerastium fontanum* Baumg.; DactFuch – *Dactylorhiza fuchsii* (Druce) Soó; DescCes – *Deschampsia cespitosa* (L.) P. Beauv.; EpilPal – *Epilobium palustre* L.; FestPra – *Festuca pratensis* Huds.; FestRub – *Festuca rubra* L.; FestSup – *Festuca supina* Schur; GnapSyl – *Gnaphalium sylvaticum* L.; ChaerHir – *Chaerophyllum hirsutum* L.; LathPra – *Lathyrus pratensis* L.; LuzuLuzu – *Luzula luzuloides* (Lam.) Dandy et Wilmott; LuzuSud – *Luzula sudetica* (Willd.) Schult.; MaiaBif – *Maianthemum bifolium* (L.) F. W. Schmidt; MyosPal – *Myosotis palustris* (L.) L.; PoaAnn – *Poa annua* L.; PoaPra – *Poa pratensis* L.; PotenEre – *Potentilla erecta* (L.) Räuschel; RanuAcr – *Ranunculus acris* L.; RanuPla – *Ranunculus platanifolius* L.; RanuRep – *Ranunculus repens* L.; RubuIda – *Rubus idaeus* L.; RumeAce – *Rumex acetosa* L.; RumeAri – *Rumex arifolius* All.; SagiProc – *Sagina procumbens* L.; SeneHer – *Senecio hercynicus* Herborg; SeneOva – *Senecio ovatus* (G., M. et Sch.) Willd.; StelHol – *Stellaria holostea* L.; TaraRud – *Taraxacum* sect. Ruderalia; TrieEur – *Trientalis europaea* L.; VeroCham – *Veronica chamaedrys* L.

Microorganisms, e.g. bacteria, fungi, actinomycetes and microalgae, play a key role in organic matter decomposition, nutrient cycling and other chemical transformations in soil (Murphy et al. 2007). These changes in the soil are also reflected in a change in vegetation over time. The course of succession seems to be unique for each site and year (Kahmen and Poschlod 2004). According to Hejcman et al. (2002), the typical pasture sward does not recreate itself earlier than 40 years after the introduction of renewed grazing. Nevertheless, some positive results can also be found in short-term periods.

The grazing system offers a potentially important conservation management tool, per Dumont and Tallowin (2011). The question remains: what grazing intensity to choose? A non-linear relationship between the species diversity and the management intensity was found by Pötsch et al. (2005). Fuhlendorf et al. (2006) documented that under intensive grazing, only a few resistant species thrived in the sward, as less competitive plant species were excluded. Generally, moderately intense grazing leads to enrichment in species composition in conditions where the competitively dominant plants suffer, but subordinate species face no substantial detrimental effects (Harper 1977). In this case, both competitive and less competitive species may co-exist, which results in species-rich vegetation stands. This is the cornerstone of the intermediate disturbance hypothesis (Huston 1979, Milchunas et al. 1988).

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Table 5. Floristic composition at Ovčárna (permanent plots P-A, B, C, D, E) in the first and the last year of the monitoring

	P-A		P-B		P-C		P-D		P-E	
	2014	2024	2014	2024	2014	2024	2014	2024	2014	2024
Achillea millefolium L.				r						
Agrostis capillaris L.										
Alchemilla glabra Neygenf.				r						
Alchemilla monticola Opiz				r						
***Anemonastrum narcissiflorum* (L.) Holub.**										
Anemone nemorosa L.				r						
Anthoxanthum alpinum Á. Löve & D. Löve		+	+	+		+	+	+		+
Athyrium distentifolium Tausch ex Opiz		+							+	
Avenella flexuosa Trin.	1	10	40	30	3	20	20	20	10	5
Bellis perennis L.										
Bistorta major S.F. Gray	+	+		+	+	1			+	
Calamagrostis villosa (Chaix) Gmel.	1	2			+	1		+		
Calluna vulgaris (L.) Hull.					+					
***Campanula barbata* L.**							1	r		
Cardamine pratensis L.				r				+		
***Carex aterrima* Hoppe**							r			
Carex nigra (L.) Reichard		2								
Carex pallescens L.			r	+			+	+		
Carex pilulifera L.								2		
***Cerastium fontanum* Baumg.**								1		
Cerastium holosteoides subsp. *vulgare* (Hartman) Buttler								+		
Chaerophyllum hirsutum L.			r							
Cruciata glabra (L). Ehrend.										
Dactylis glomerata L.			+	+						
***Dactylorhiza fuchsii* (Druce) Soó**										
Deschampsia cespitosa (L.) P. Beauv.		1		12		+	2	5	1	25
Epilobium angustifolium L.			+							
***Epilobium palustre* L.**			r							
Equisetum sylvaticum L.			r							
Festuca pratensis Huds.				r						
Festuca rubra L.		+				2		3		+
***Festuca supina* Schur**		+	2	1		5	5	15		+
Galium album Mill.			r	r						
Gnaphalium sylvaticum L.										
Hieracium sp.										
***Hieracium stygium* R. Uechtr.**										
Homogyne alpina Cass.			+	+	+	+	+	+	+	+
Hypericum maculatum Crantz			+	r				r	+	+
***Hypochaeris uniflora* Vill.**							+	+		
Lathyrus pratensis L.				+						
Leontodon hispidus L.										
***Ligusticum mutellina* (L.) Crantz**	+	+	10	15	2	+	45	20	10	4

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Continued Table 5. Floristic composition at Ovčárna (permanent plots P-A, B, C, D, E) in the first and the last year of the monitoring

	P-A		P-B		P-C		P-D		P-E	
	2014	2024	2014	2024	2014	2024	2014	2024	2014	2024
Luzula campestris L. (DC).				+						
Luzula luzuloides (Lam.) Dandy et Wilmott	+	+	5	+			+		25	+
***Luzula sudetica* (Willd.) Schult.**										
Luzula sylvatica (Huds.) Gaud	95	75	10	15	5	25	2	5	25	35
Lysimachia nummularia L.										
Maianthemum bifolium (L.) F. W. Schmidt	r		+	+	r	+				
Myosotis palustris (L.) L.				r						
Nardus stricta L.		+	+	1		1	20	3		+
Oxalis acetosella L.					+					
***Phleum alpinum* L.**			r	1						1
Phyteuma spicatum L.								r		
Picea abies (L.) H. Karst										
Poa annua L.				r						
Poa chaixii Vill.			15	3		r	+	3	30	10
Poa pratensis L.										
Polygonatum verticillatum (L.) AII				+		+	+	+		
***Potentilla aurea* L.**			+	+			+	2		+
Potentilla erecta (L.) Räuschel			+	+	r	+	4	+	+	+
Ranunculus acris L.										
Ranunculus platanifolius L.			+	1	r	+			1	r
Ranunculus repens L.			r	1						
Rubus idaeus L.					+					
Rumex acetosa L.			r						+	
Rumex arifolius All.	r	+		+		+		+		+
Sagina procumbens L.										
Senecio hercynicus Herborg			+		r	r	+		10	
Senecio ovatus (G., M. et Sch.) Willd.										
Silene dioica (L.) Clairv.								r		
Silene vulgaris (Moench) Garcke	+				+	2				
Solidago virgaurea L.	+	+	+		r	+			+	+
Sorbus aucuparia L.					r					
Stellaria alsine Grimm										
Stellaria graminea L.				r						
Stellaria holostea L.										
Stellaria nemorum L.			r							
Taraxacum sect. *Ruderalia*				r						
***Thesium alpinum* L.**							r	+		
***Trientalis europaea* L.**	r	+	r	+		+		r	+	+
Trifolium repens L.				r						
Urtica dioica L.										
Vaccinium myrtillus L.	r		+		90	15	+	r		
Vaccinium vitis-idaea L.					5	3				
***Veratrum album* L. subsp. *lobelianum* (Bernh.) Melch.**			+	+	+	+	r	r		
Veronica chamaedrys L.				+						
Veronica serpyllifolia L.				r						
Vicia cracca L.			r							
***Viola lutea* subsp. *sudetica* (Willd.) Nyman**							+	+		

Species highlighted in bold are species that fall into one of the categories of threat according to Grulich (2012). Rows without values indicate that the species was present during the study period in a year other than 2014 or 2024

While our regression analyses demonstrate a consistent increase in species richness over time, causality cannot be conclusively attributed to grazing without a control treatment. Nevertheless, our research is unique because no previous study has specifically examined the effects of renewed grazing on alpine grasslands in the monitored area. Based on our results, medium-intensity grazing near the Švýcárna and Ovčárna lodges can be recommended. Due to their unique flora, these sites are of European conservation importance. It is important to recognise that in large parts of the Hrubý Jeseník Mountains, the most valuable natural heritage is in treeless enclaves. This heritage must be preserved for future generations through appropriate management of these areas.

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