

## Vegetation of the selected Slovakian ski pistes

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*Abstract:* In this study, the floristic composition of ski piste grasslands was compared between the plots treated and untreated by the artificial snow. Research was accomplished in the four ski centers of Central Slovakia (Inner Western Carpathians; temperate zone) located under 1000 m a.s.l. To identify floristic diversity, the Shannon-Wiener's diversity index and Pielou's evenness index was calculated from the vegetation relevés. Results showed occurrence of the varied vegetation mosaic (comprising four to five vegetation units - alliances), both on the treated and untreated plots. Floristic composition of studied plots contained species typical for: i.) mesic hay meadows, ii.) mesic pastures and disturbed perennial grasslands, iii.) mesic montane meadows, iv.) grasslands of deforested sites of montane belts, and v.) oligotrophic grasslands. Species diversity between treated and untreated plots was significantly different in one of four ski centers, while species evenness was significantly different in two of four assessed ski centers. Mixture of species is result of the past and present management activities. Studied ski pistes were based on the mesic hay meadows, pastures and perennial grasslands that were originally natural mesic forests. Operation of the ski pistes on the existing grasslands and meadows can finally save these plant communities against the succession and degradation as in the studied sites. Fundamental differences in the species composition between the plots treated and untreated by the artificial snow was not observed.

*Key Words:* floristic composition, meadow, grassland, ski resort, artificial snow, piste

### INTRODUCTION

Growing popularity of winter tourism leads to development of European mountainous regions (Rixen et al. 2011, Mikloš et al. 2018). More and more popular winter sports increase public demand for the smooth ski pistes with perfect snow conditions. Regardless of climate change, new ski pistes are created and snowed by the artificial snow even at the higher elevations of Alps and Carpathians. Creation of new ski pistes usually includes deforestation, removal of topsoil and vegetation layer and building infrastructure (roads, ski lifts, engineering networks) (Freppaz et al. 2013). In the fragile mountainous ecosystems these activities may lead to geo-hazards such as massive soil erosion or landslides with consequences of the ecosystem's degradation. Many studies identified decline in biodiversity and changes of plant communities (Burt and Rice 2009, Roux-Fouillet et al. 2011). Mentioned studies were conducted in the higher elevations of Alps, mostly above the 1000 m a.s.l., in the Alpine habitats or in the deforested areas.

Compared to previous studies, in the presented work ski pistes under 1000 m a.s.l., based on the existing grasslands and meadows, were analyzed. The vegetation of four ski pistes in four ski centers was studied to achieve the following aims:

- to identify and compare floristic composition and diversity on the representative parts of ski pistes where the snowmaking is used and not used.
- to identify plant species of the disturbed parts of ski piste where the topsoil and vegetation layer was damaged.

### MATERIAL AND METHODS

The investigations were carried out in the four ski centers of Central Slovakia (Inner Western Carpathians). Study sites are described in the Table 1.

In the summer 2016, 8 relevés (quadrant size 1 m<sup>2</sup>) and 2 relevés (quadrant size 25 m<sup>2</sup>) in each of four ski centers were made according to methods of Zurich-Montpellier school (Braun-Blanquet 1964) using the new Braun-Blanquet 9-membered ordinal cover abundance scale (Westhoff et van der Maarel 1978). Each pair of 4 relevés (1 m<sup>2</sup>) was made according to the GLORIA field manual (2015) on the geomorphologically most similar sites with same soil, humidity and management conditions. 4 relevés were under the influence of the artificial snow, while remaining 4 relevés were not. Each 4 relevés were located within the 25 m<sup>2</sup> relevé where the list of species was made. For phytosociological survey were selected most representative parts of ski pistes. Vegetation types were defined on the basis of locally characteristic species. Identified vegetation alliances are briefly described in Hegedúšová et Škodová (2014). Calculation of the Shannon-Wiener's diversity index (H') and Pielou's evenness index (J) was done in the JUICE software.

*Table 1 Description of the study sites. \* according to Miklós (2002), Gömöröyová et al. (2013), Hrvol' et al. (2009), Mikloš et al. (2017), Mind'áš and Škvarenina (1994), Šatala et al. (2017), Střelcová et al. (2006), Vilček et al. (2016)*

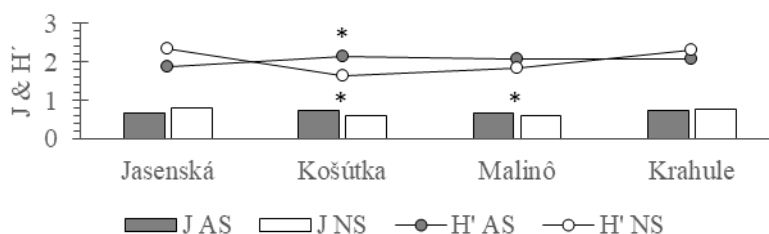
Ski center	Krahule	Malinô	Košútka	Jasenská
Region	Pohronie	Liptov	Podpoľanie	Turiec
Mountain	Kremnické vrchy	Veľká Fatra	Veporské vrchy	Veľká Fatra
Ski piste elevation (m a.s.l.)	895 – 1 060	545 – 1 209	510 – 720	540 – 640
Relevé elevation (m a.s.l.)	990	950	670	590
Grassland management	Mowing Grazing	Mowing	Mowing Grazing	Mowing
Aspect (°)	225	45	360	360
Slope (°)	10	20	10	10
Longitude	185650.90	191535.39	193216.33	190036.73
Latitude	484343.52	490307.98	483323.99	490031.63
Climatic region *	Cool	Cool	Moderately warm	Cool
Annual precipitation totals (mm) *	1000 – 1200	900 – 1000	800 – 900	700 – 800
Mean January air temperature (°C) *	-5 – -6	-5 – -6	-5 – -6	-4 – -5
Mean July air temperature (°C) *	12 – 14	14 – 16	16 – 18	14 – 16
Geological base *	Andesites	Limestones	Tonalites	Sandstones
Soil type *	Cambisols	Cambisols	Cambisols	Rendzic Leptosols
Potential natural vegetation (forest) *	Beech/Fir-beech	Spruce-pine	Beech/Fir-beech	Beech/Fir-beech

## RESULTS

In all four study sites, the vegetation was mosaic (comprising of four to five vegetation units - alliances), both on the treated and untreated plots, were identified. Floristic composition of relevés contained species typical for: i.) mesic hay meadows (*Arrhenatherion elatioris* Luquet 1926), ii.) mesic pastures and disturbed perennial grasslands (*Cynosurion cristati* Tüxen 1947), iii.) mesic montane meadows (*Polygono bistortae-Trisetion flavescens* Br.-Bl. et Tüxen ex Marschall 1947), iv.) grasslands of deforested sites of montane belts (*Nardo strictae-Agrostion tenuis* Sillinger 1933), and v.) oligotrophic grasslands distributed from the lowland areas to the montane belt in Central Europe (*Violion caninae* Schwickerath 1944). On the parts of ski pistes where the vegetation and soil was disturbed because of deforestation, infrastructure creation or machine grading, the high occurrence of the ruderal plant species (*Sambucus ebulus*, *Calamagrostis epigejos*, *Cirsium arvense*, *Solidago Canadensis*, *Tanacetum vulgare* etc.) or pioneer tree species (*Betula pendula*, *Salix caprea*, *Populus tremula*) was identified. On the snowed parts of studied ski pistes the higher occurrence of the dry hay meadow species was detected (*Leontodon hispidus*, *Euphrasia rostkoviana*, *Thymus pulegioides*, *Cruciata glabra* etc.). In the Košútka ski center, every season mulched seedlings of *Betula pendula* on the graded part of ski piste (sandy-skeletal soil) resulted in the high frequency of occurrence and coverage. The parts of ski piste with natural snow had optimal conditions and higher frequency of occurrence tall broadleaf grasses (*Dactylis glomerata*, *Phleum pratense*, *Alopecurus pratensis*) and herbs (*Taraxacum* sect. *Ruderalia*, *Aegopodium podagraria*, *Anthriscus sylvestris* etc.).

Species diversity between treated and untreated plots (by the artificial snow) was significantly different in Košútka ski center (p-value:  $9.7 \times 10^{-3}$ ), while species evenness was significantly different in Košútka (p-value: 0.031) and Malinô ski center (p-value: 0.024).

Figure 1 Mean species evenness and species diversity on the plots treated by the artificial snow and on the untreated plots with natural snow. \* indicate significant difference between treated and untreated plots at the 95.0% confidence level (unpaired t test).



Legend: J – Pielou's evenness index, H' – Shannon-Wiener's index, AS – artificial snow, NS – natural snow

## DISCUSSION

In the presented study, the substantial changes in species composition on the plots treated by the artificial snow were not observed, except for disturbed parts of slope (Rixen et al. 2003), probably because the ski pistes were based on the existing grasslands and meadows (vegetation management remained unchanged – mowing, grazing). Snowed parts of studied ski pistes are in operation every season, while parts with natural snow are open for skiers irregularly (shortage of natural snow). Occurrence of tall and broadleaf grasses and herbs on the edge or adjacent parts of ski pistes with natural snow is probably a result of lower intensity of the ski slope operation. Lower intensity can protect the vegetation (defoliation) and soil layer (protect the nutrient-rich topsoil layer against erosion) against damage (Rixen et al. 2003). On the contrary, higher intensity of winter management (grooming, skiing) on the snowed parts of ski slopes can favor species of nutrient-poor, dry meadows (Pohl et al. 2009). On the studied ski pistes, the species of dry hay meadows were more frequent on the snowed, disturbed parts. Higher occurrence of woody plants (seedlings) on the snowed ski pistes was not observed by the other studies. On Swiss ski pistes, the woody plants are reduced because of mechanical damage (Rixen et al. 2003). The significant changes in species diversity were not observed compared to other authors (Rixen et al. 2003, Allegrezza et al. 2017), probably because the original vegetation was saved during the ski center construction and because the milder environmental condition (Allegrezza et al. 2017).

## CONCLUSION

On the ski pistes where vegetation and soil layer is not disturbed during its creation, the mosaic of original plant communities occurs. High frequency of occurrence on these slopes has grass and herbs species of mesic meadows and grasslands. Floristic composition and species diversity on the snowed parts and parts of ski slopes with natural snow is not particularly different. Floristic composition differs mainly on the disturbed parts of slopes where the trees and shrubs were removed, the piste was graded or the ski center infrastructure was built. The disturbed sites are colonized by the ruderal and pioneer species. The pioneer tree species can occupy ski slopes where the vegetation and topsoil layer was removed (ski piste grading) and bare sandy-skeletal soil occurs. Mulching the seedlings only stimulate their spreading. Grasslands and meadows of ski pistes must be mowed or grazed because the high vegetation is unacceptable for the ski piste operation. In general, the original and species-rich plant communities are damaged on some parts of studied ski pistes but on the other parts are maintained by the proper management and thus, saved against the succession.

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