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SHORT-TERM TRAMPLING EXPERIMENTS IN THE *Juncetum trifidi* K r a j i n a 1933 ASSOCIATION

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Abstract

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The Tatra National Park is the most visited national park in Slovakia. But the high number of visitors causes structural and compositional changes in vegetation around tourist paths, mountain lakes, mountain chalets and hotels. The impacts of trampling on vegetation and soil are perhaps one of the most extensively studied areas in recreation ecology in many countries. In Slovakia, Prof. Ladislav Šomšák with his team, whom Dr. Ferdinand Kubíček has worked like a considerable member, has carried out the pilot research on trampling in the Tatras (Šomšák et al., 1979a, 1981). The team has studied vegetation changes in mountain, subalpine and alpine zones, in the surroundings of paths, mountain chalet, mountain lake and ski resort.
Because observation and detection of changes caused by tourist trampling has ceased, we have carried out an experiment of short-term trampling. The procedure will provide an information on damage of vegetation in response to short-duration trampling. Changes in vegetation cover, vegetation height, bare ground cover, and the cover of individual species can be assessed. The primary objective of this paper is to describe the vegetation response to different levels of trampling. We consider the effect of seasonality to be very important in correlation with trampling. The research presented in this paper records the experimental procedure in the *Juncetum trifidi* K r a j i n a 1933 association. Experimental study sites were established in the most visited paths traverse, near the Kopské sedlo saddleback.
In national parks, the land managers need better information about recreational impacts on the environment to find the optimal balance between natural areas and recreational use. This procedure makes it possible to model the relationship between trampling intensity and vegetation response. The aim of this experiment was to assess the trampling response of the most wide-spread alpine community, the *J. trifidi* K r a j i n a 1933.

Key words: trampling, Tatry Mts, Kopské sedlo saddleback, vegetation changes

Introduction

Trampling may change the species composition and reduce species richness. Resistance and recovery are connected mainly with plant morphological characteristics and grow rate of species (Whinam, Chilcott, 2003). In Slovakia, the pilot research of human trampling was carried out by Prof. Ladislav Šomšák, with colleagues, in the High Tatras. Details of research and results are described in works (Šomšák et al., 1979a, 1981). Dr. Ferdinand Kubíček has worked like a member of the work team.

Trampling effects on vegetation in the Carpathian Mts are described by authors: Šomšák et al. (1979b); Šoltésová (1982a, b); Jurko (1983); Midriak (1989); Barančok (1996a, b, c, d); methods and tools of revitalisation of deteriorated areas by Belčáková (2000). We investigated the effect of timing of short-term trampling influences re-vegetation of the *Juncetum trifidi* association in the Tatra National Park. The association is the most wide-spread alpine community, covers endemic species and like a pioneer community it has a very important function (Kliment, Valachovič, 2007). Moreover, the *J. trifidi* covers the surroundings of the most visited resting place the Kopské sedlo saddleback, the connecting crossway of paths from the High Tatras and the Belianske Tatry Mts. Four trampling experiments were carried out during the summer 2008 to simulate the influence of unofficial trails. The information about the impacts of trampling of various intensities on alpine vegetation (0; 150; 450 passes) was investigated and the impact of the timing of trampling on vegetation. Trampling in the early growing season may have an essential effect on vegetation than trampling carried out later in the season.

Control of recreational impacts on the environment help to find the optimal balance between natural areas and recreational use. The main aim of this experiment was to assess the trampling response, the resistance and the resilience of the *J. trifidi* community.

Study area

Tatra National Park is the oldest national park in Slovakia**,** founded on 1st January 1949. National park is situated in the northern part of Slovakia (Fig. 1). The Tatras are divided in two sub-units – Západné and Východné Tatry Mts. The Východné Tatry Mts have two parts – the High Tatras and the Belianske Tatry Mts (Midriak, 1994). Most parts of the High Tatras and Západné Tatry Mts are formed by magmatic rocks (granodiorite – granite) and metamorphic rocks (gneiss, mica schist, migmatite and others). The Belianske Tatry Mts (Fig. 2) and parts of Západné Tatry Mts (Osobitá, Sivý vrch, Červené hory) are formed by limestone and dolomite (Nemčok et al., 1991). Soils above the timber-line represent Lithosols, Umbric and Rendzic Leptosols, Cambisols and Podzols (Bedrna, Račko, 1999). Experimental study sites were established near the Kopské sedlo saddleback (Fig. 3).

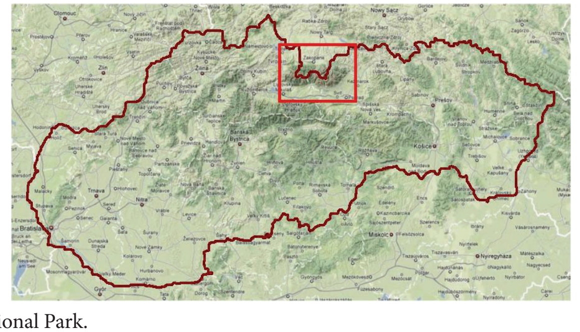

Fig. 1. Tatras National Park.

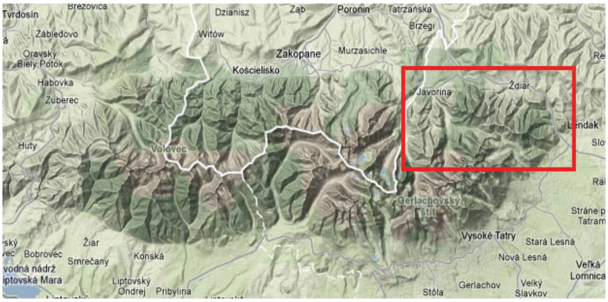

Fig. 2. The Belianske Tatry Mts and part of the High Tatras.

Fig. 3. The Kopské sedlo saddleback.

Generally, the whole study area belongs to the cold region (Landscape Atlas of SR, 2002). The characteristic of climate conditions are based on the data (supplied by the Slovak Hydrometeorologic Institute) from the closest meteorological stations situated in Skalnaté pleso, 1778 a.s.l. (cold mountainous subregion, mean

T a b l e 1. Chosen meteorological data from Tatranská Javorina and Skalnaté pleso.

	Mean temperatures		Sum of precipitations		Snow cover (winter season 2007/2008)		Last day of snow cover occurrence
	January °C	July °C	January (mm)	July (mm)	Height (cm)	Duration (days)	
Tatranská Javorina	-1,69	13,21	84,80	429,80	51	165	18.4.2008
Skalnaté pleso	-2,75	10,47	120,40	311,50	62	182	5.5.2008

temperatures in July from 12°C to 16°C) and Tatranská Javorina, 1007 m a.s.l. (moderately cool subregion, mean temperatures in July less than 10 °C). The development of the weather in 2008 is demonstrated in Table 1 and Fig. 4 and Fig. 5.

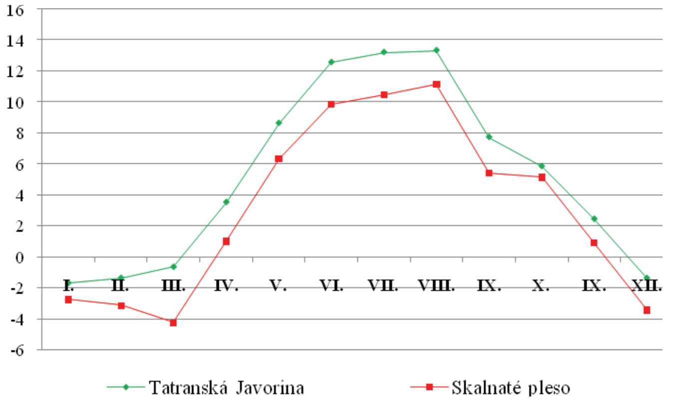

Fig. 4. Average monthly temperature (2008, source SHMÚ).

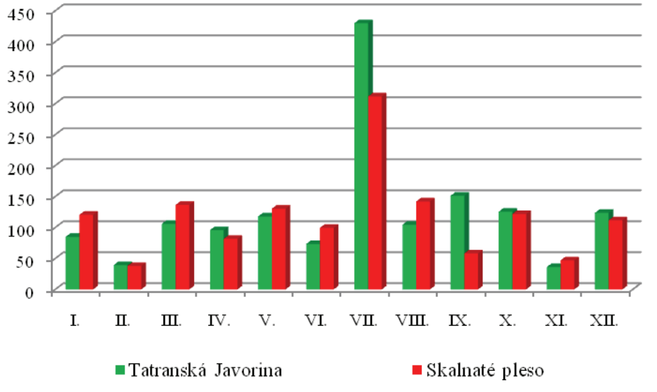

Fig. 5. Monthly sum of precipitation (2008, source SHMÚ).

Methods

Layout of treatment plots

Plot were designed as follows: 0.5 m wide, 0.5 m long and separated by a buffer of at least 0.5 m wide. This width was selected because: (1) it approximates a common width for a footpath, (2) it occupies an intermediate position in the range of widths that have been utilized and (3) it is wide enough to accommodate a quadrant while minimizing edge effects. Each plot should be divided into 25 subplots, and each subplot should be 0.1 m wide and 0.1 m long. Subplots were selected by the botanical grid (Fig. 4). The numbering scheme of subplots is fixed in a horizontal direction from the left side, for example 11, 21, 31, 41, 51; 12, 22, 32, 42, 52; etc.

The configuration of plots is not fixed; they can be arranged in a line or placed irregularly, if this suits the site. Plot locations should be chosen for homogeneity and where they are unlikely to get spurious disturbance.

Experimental plots near the Kopské sedlo saddleback

We established experimental plots near the Kopské sedlo saddleback (1750.2 m a.s.l.) (Fig. 5) on the border between the Belianske and Vysoké Tatry Mts, 1752 m a.s.l., with the association of *Juncetum trifidi* K r a j i n a 1933 (the sketch map – Fig. 7, Table 2).

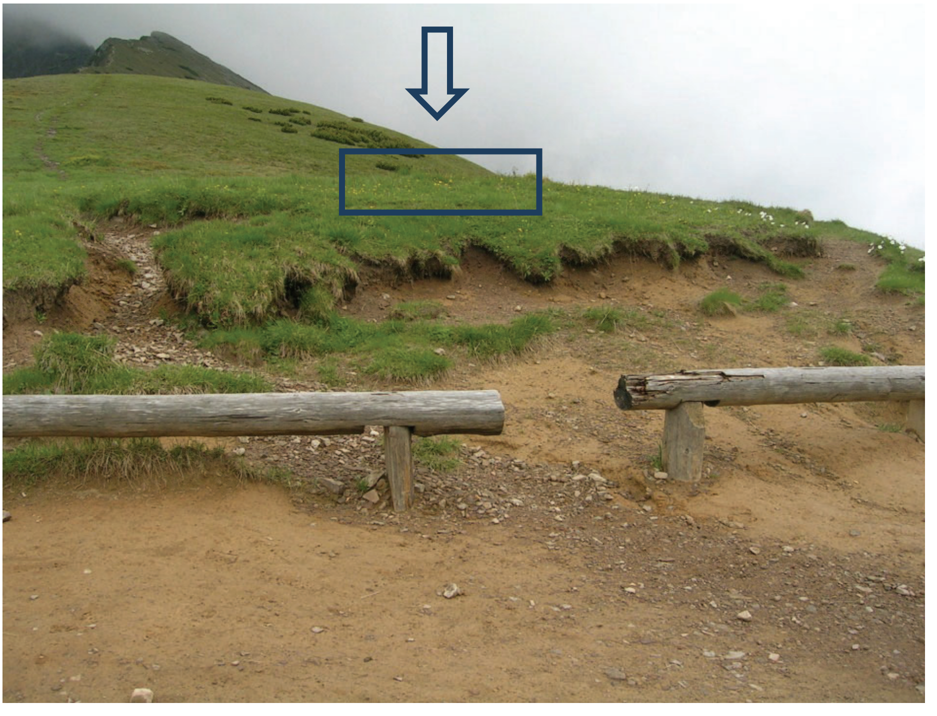

Fig. 6. Permanent plots near the Kopské sedlo saddleback (12th July 2008).

association:	*Juncetum trifidi*
altitude (point 1):	1752 m a.s.l.
geographic position (point 1)	49˚13,751 N, 20˚13,179 E
slope (degree):	22 ˚
aspect:	NNW
distance from the path (point 1):	30,6 m (the Tatranská Javorina village – the Kopské sedlo saddleback)

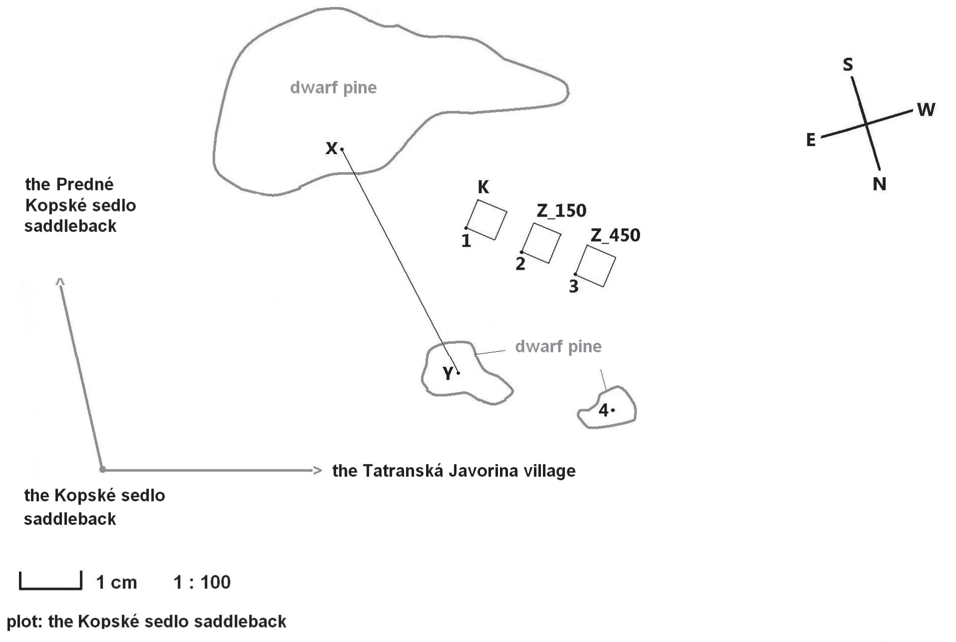

Fig. 7. Sketch map of plot location on the Kopské sedlo saddleback.

X,Y – reference points
1 – left lower corner point of the plot K
2 – left lower corner point of the plot Z_150
3 – left lower corner point of the plot Z_450
4 – dwarf pine
K – control plot, 0 passes
Z_150 – trampled plot, 150 passes
Z_450 – trampled plot, 450 passes

Fig. 8. Legend.

T a b l e 2. Real data for the sketch map of plot location on the Kopské sedlo saddleback.

points	distance [cm]	azimuth [°]
2–1	210	3
2–3	480	44
4–1	284	204
4–3	307	110
5–1	3060	170
6–5	3077	265

Trampling treatment and timing

Each plot should be assigned by the one of three trampling treatments: control (no trampling), 150 passes and 450 passes, where each pass represents one footmark. These treatment intensities were selected because the previous studies in alpine areas had found that these levels can cause damage.

Trampling should occur in the same day for all treatments. Trampling all at once eliminates confounding situations such as trampling occurring partly on rainy and partly on dry days. Treatments should be iteration during the time of the vegetation season (we recommend doing treatments during the time of year when vegetative cover is at least half the growing season or near the maximum remains). Trampling should occur 4 times during the vegetation season, after 21–30 days.

A standard protocol for trampling experiments is suggested by Cole and Bayfield (1993). Preliminary experimentation using this procedure suggests that there is no substantial difference in the responses caused by walkers of different weight or shoe type. Standardizing weight and shoe type is not critical. Authors recommended using walkers of moderate weight (75 ± 10 kg). We used a walker of 60 kg weight.

Parameters to be measured in each subplot are:

1. visual estimates of the top cover perpendicular to the slope angle of each vascular plant species and of mosses and lichens,
2. visual estimates of the top cover perpendicular to the slope angle of bare ground,
3. visual estimates of the top cover perpendicular to the slope angle of litter.

(1) Visual estimates of the coverage (%) of each vascular plant species and of mosses and lichens. Only green photosynthetic material should be included in cover estimates. It is inappropriate to include the cover of surviving stems that had been defoliated by trampling. Cover values are round integral numbers, and if the cover is less than 1% the value 0.5% or 0% can be used, indicating a complete lack of cover.
(2) Visual estimates of the cover (%) of bare ground (ground not covered by live vegetation). Bare ground can be either mineral or soil.
(3) Visual estimates of the cover (%) of litter (including the litter of recently trampled plants).

Resistance and resilience

The main aim of this experiment was to assess the trampling response of each vegetation type, and this response is expressed in terms of two concepts according to Míchal (1994):
(1) resistance (stability) of the ecosystem is its ability to prevent changes during activity of disturbing factors, with the criteria being the range between the "undisturbed state" and the "disturbed state". A smaller range entails higher resistance.
(2) resilience (flexibility) of the ecosystem is its ability to return to the "normal" condition on conclusion of the disturbing factor's influence, with the criteria being the time required to recover from the "disturbed state" to the "undisturbed state".

Results and discussion

Photos of the permanent plots in June, July, August and September 2008

the control plot

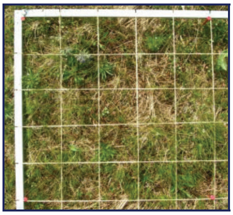

Fig. 9. The plot on 19th June 2008.

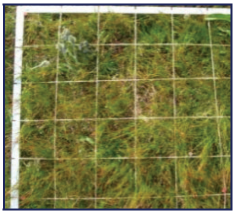

Fig. 10. The plot on 12th July 2008.

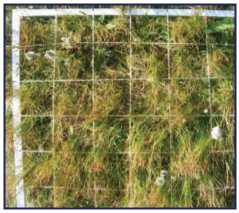

Fig. 11. The plot on 6th August 2008.

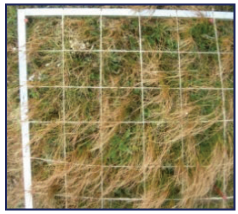

Fig. 12. The plot on 9th September 2008.

150-passed permanent plot

Fig. 13. The plot on 19th June 2008.

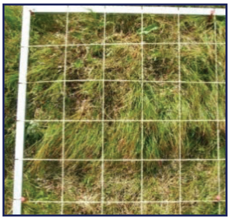

Fig. 14. The plot on 12th July 2008.

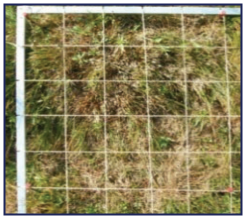

Fig. 15. The plot on 6th August 2008.

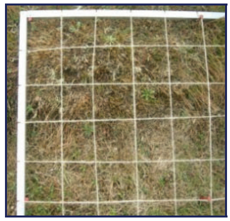

Fig. 16. The plot on 9th September 2008.

450-passed permanent plot

Fig. 17. The plot on 19th June 2008.

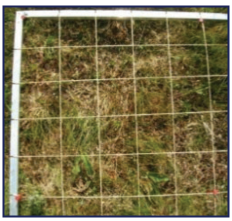

Fig. 18. The plot on 12th July 2008.

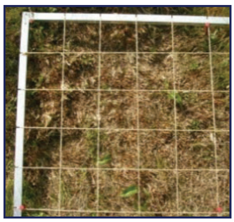

Fig. 19. The plot on 6th August 2008.

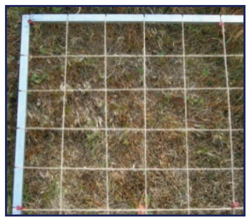

Fig. 20. The plot on 9th September 2008.

Relative cover

Relative cover can be used to characterize the vulnerability of different vegetation types (Cole, Bayfield, 1993). Vulnerability is the ability of a vegetation type to resist being altered by trampling, and this is also referred to as resistance. Relative cover is based on the sum of the coverage of all species, rather than a single estimate of total vegetation cover by Cole and Bayfield (1993). We calculated relative cover for individual species of vascular plats, mosses and lichens. Coverage of individual species changed during the short-term trampling under the impressions of trampling and seasonality. So we evaluated two types of relative cover: (1) relative cover RP – only trampling effect, and (2) relative cover RC – trampling effect with effects of seasonality. This was calculated by using formula:

A. Calculation of relative cover RP:

$$RP = \frac{\text{surviving cover on trampled plots}}{\text{initial cover on trampled plots (always before the next trampling)}} \times 100\%$$

B. Calculation of relative cover RC:

RC = RP x cf

$$\text{where } cf = \frac{\text{initial cover on control plots (always before the next trampling on trampled plots)}}{\text{surviving cover on control plots (always after the next trampling on trampled plots)}}$$

cf – correction factor

Relative cover will be 100% in the absence of any change in cover caused by trampling. Therefore, the extent to which relative cover after trampling deviates from 100% provides a measure of the damage response to trampling. Comparison of the relative cover (Figs 21–24) between 21–30 days provides a measure of the recovery response.

150 passed plot

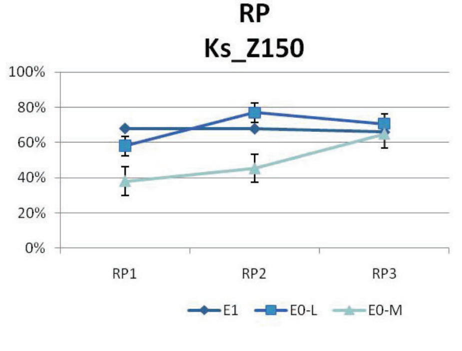

Fig. 21. Relative covers RP of the permanent plot Ks_Z150.

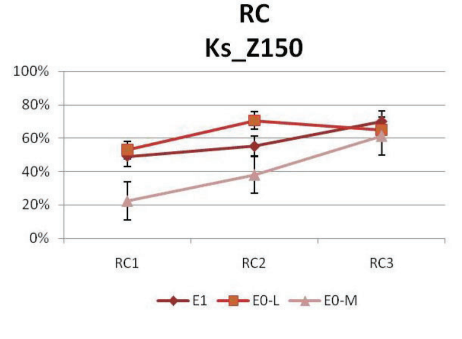

Fig. 22. Relative covers RC of the permanent plot Ks_Z150.

450 passed plot

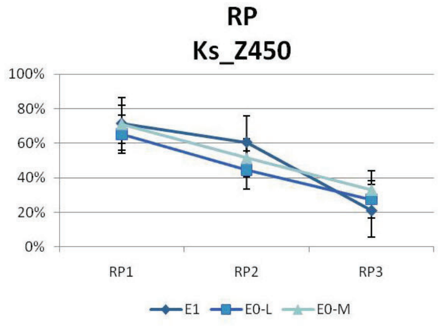

Fig. 23. Relative covers RP of the permanent plot Ks_Z450.

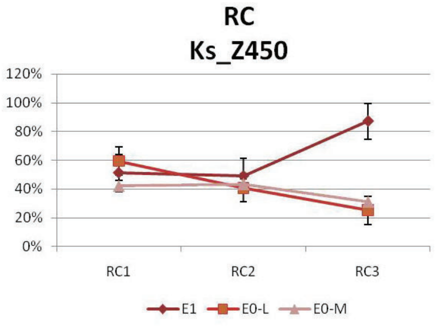

Fig. 24. Relative covers RP of the permanent plot Ks_Z450.

RC – relative cover (only trampling effect)
RP – relative cover (trampling effect with effects of seasonality)
Ks_Z150 – permanent plot 150 passes
Ks_Z450 – permanent plot 450 passes
E1 – herb level
E0_L – lichens level
E0_M – moses level

Fig. 25. Abbrevations (Fig. 21.–Fig. 24.)

Resistance and resilience

We evaluated the resistance of individual species according to changes in relative and absolute cover as follows:

Table 3. Resistance levels of individual species.

Level	Changes of RP,RC	Resistance
1	80–100%	very low
2	60–80%	low
3	40–60%	middle
4	20–40%	high
5	0–20%	very high

The resistance of individual vegetation types is dependent on resistances of individual species. The association of *Juncetum trifidi* has a characteristic average level of resistance of 1.333, and therefore this association has very low to low resistance to trampling. The composition of the association consists of plant species *Juncus trifidus, Campanula alpina, C. tatrae, Hieracium alpinum, Bistorta major, Vaccinium myrtillus, Vaccinium vitis-idaea, Oreochloa disticha, Festuca supina, Agrostis pyrenaica, Huperzia selago;* lichens and bryophytes *Cetraria islandica, C. cucculata, Polytrichum alpinum, P. piliferum, Thamnolia vermicularis, Alectoria ochroleuca, Cladonia squasquamosa, Racomitrium canescens*. The species *Juncus trifidus, Bistorta major, Campanula tatrae, C. alpina, Cetraria islandica* are resistant towards trampling at least. Coverages of these species have decreased with trampling, leaves were ragged, abruptioned; after short time dried up, blowed away and the background has naked. The community consists of hemicryptophytes, transitional forms of hemicyptophyt/geophyte and woody chamaephytes. After each trampling, the coverage of transitional forms of hemicyptophyt/geophyte has decreased, but coverage of woody chamaephytes has markedly increased.

The experiment of short-term trampling points at structural and compositional changes in vegetation. Intensive trampling can cause very negative changes in nature. Visit-rate monitoring is very usefull for the optimal balance between natural areas and recreational use.

Conclusion

The short-term trampling experiments possible to model the relationship between trampling intensity and vegetation response. These experiments were conducted in the *Juncetum trifidi* association, in the border of two mountainous regions the High Tatras and the Belianske Tatry Mts, 4 times during the summer 2008. The *J. trifidi* association is the most wide-spread alpine community, containing endemic species. Dominant plant species are *Juncus trifidus, Vaccinium vitis-idaea, V. myrtillus, Bistorta major, Campanula alpina, Hieracium alpinum*, from lichens and bryophytes *Cetraria islandica, C. cucculata, Polytrichum alpinum, P. piliferum, Thamnolia vermicularis* and *Cladonia squamosa.* From alive plants, transitional forms of geopfyt/hemicryptophyt are at least resistant towards the trampling. Hemicryptophytes have changed only in low decrease. Contra to these forms, the woody chamaephytes like trampling and the coverage has increased best. The coverage of plant species are shown to decrease with increasing trampling. Important is the fact, the coverages of all alive individuals has decreased after 150 passes up to 50% and after 450 passes up to 80%. Besides alive plant individuals, naked soil and dry mass cover the trampled area. The community of *Juncetum trifidi* is characterized by a very low to low resistance to trampling. In the study area, the visiting rate to paths crossing this vegetation type is adequate for bi-directional access. But the area of resting place and surrounding are very load by the number of visitors.

Currently, tourism is one of the largest land uses of the Park, and since this area has an extremely high conservation value, minimizing the amount of disturbance to the environment caused by tourists is of utmost importance for the long-term management of the Park. Experimental trampling studies such as those reported here can be a great help to managers planning recreational usage in this sensitive cultural area.

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