

Successional pathways following fire disturbance in the National Park Slovenský raj, Slovakia

M. SABOVČÍK¹ and Š. BRYNDZOVÁ²

¹Institute of High Mountain Biology, Tatranská Javorina 7, SK-059 56 Slovak Republic; ²The Administration of the National Park Slovak Paradise, Letecká 3, SK-052 01 Spišská Nová Ves, Slovak Republic

Abstract. The study presents the results of vegetation investigation carried out in 2008-2009, in the term of successional pathways after fire disturbance in the locality Koč in the National Park Slovak Paradise (Slovenský raj), where 20 ha of the forest fell down by fire in July 2007. The study is mainly focused to damaged forest ecosystem on four monitoring sites established in 2008, having different typological classification and different stage of destruction. In conclusion, according to the results and findings are evaluated rare and endangered species recorded in this area.

Key words: fire, succession, relevé, *Geranium bohemicum*

Introduction

Fire as an ecological factor influenced ecosystems ever before. Being man assistant, fire is of great value, but it may be destructive and can easily remove the current overstory vegetation (Fischer 1992). Fire impact to biota may be of positive or negative aspect either. Positive fire impact is, for example, vegetation refreshing, creating new coenosis, distribution or soil seeds bank improvement, such as is the case of Czech Crane's-bill (*Geranium bohemicum*), which is growing in the affected area Koč in the National Park Slovak Paradise (868m a.s.l., 48° 55.491' ; 20° 19.900'). On the other hand, disruption of the dynamic equilibrium, erosion, disturbance of photosynthesis and economic losses may be consequences. Impact of the fire depends on many factors. Distinctively destructive fire impact is recorded in the areas with great relief dynamics, shallow soil layer, or if lack of fire resistant plants. These features characterize also Koč hill, which border Sokol National Nature Reserve and the area is closed for tourists. This site fell down by fire on July 22, 2007, the fire was caused probably by lightning and 20 ha of the forest was completely burnt.

Mapping and monitoring of relevant plant communities and species was the main activity in the Koč area affected by the fire in September 2009. During this period took place field investigations and relevés were taken. However, it is rare to evaluate the vegetation succession after intensive dis-

turbance in Slovakia, such examples are the studies on understory and overstory vegetation succession after forest fires in the Záhorská nížina lowland (Novotný 1998) and in the Slovak Paradise National Park (Bevilaqua 2000; Holécy *et al.* 2004; Jančová 1993, 2006). Šoltés *et al.* (2010) studied early successional pathways after fire disturbance in the Tatra Mts, where 230 hectares of forest ecosystem were completely burnt. Since similar data are lacking, we have decided to fill this knowledge gap.

Material and Methods

The object of investigation is the location Koč, in the National Park Slovak Paradise. This area was hit by fire on July 22, 2007, 20ha was completely burnt. Location border the National Nature Reserve Sokol. Next year after the fire, a significant plant Czech Crane's-bill (*Geranium bohemicum*), was recorded on this territory, the plant is the main object of investigation and indicates recovery of vegetation by fire affected area. Some relevés indicating previous state have been consulting from the reports stored in the NP Slovak Paradise (Leskovjanská 2009).

All the relevés were taken following standard procedures of the Zürich-Montpellier School (Braun-Blanquet 1964; Westhoff and van den Maarel 1978), using the 7-degree Braun-Blanquet's sampling scale. While for scientific names the nomenclature follows Marhold (1998), for plant determination the flora of Dostál and Červenka (1991, 1992) were used. Pictures were taken by camera Lumix GF1.

Results

Situation in 2008

One year after fire, the forest on the Koč is dead, distinct evidence of erosion is visible on the hill top. The single living plant the Czech Crane's-bill (*Geranium bohemicum*) is found on the location (Leskovjanská 2009).

Site 1/2008

This area is placed at the foot of the west facing slope close to the valley near the dam Blazloch. These fire place arose in July 2007. The site corners are marked on the trees: 1-beech, 2-spruce, 3-beech, 4-beech. On this area is a bigger rocky cliff. The area is less affected by the fire, some of the trees have burned root system. The plants age is estimated at 120, 60 or 20 years respectively. All

the woods in the shrub level are dead. From the typological point of view, the area is ranked as *Abieto-Fagetum* (AF) and *Fagetum dealpinum* (Fde). Relevé, see Table 1 (Leskovjanská 2009).

Site 2/2008

The area is located near the ridge. Nearly all the pines and larches are charred and dead. There are windthrows on the area and the tree branches are charred. Weathered rocks cover soil surface. From typological point of view, the area is ranked as *Pinetum dealpinum* (Pide). Relevé see Table 2 (Leskovjanská 2009).

Site 3/2008

The area is located on the summit area of Koč near the Sokol border area. Czech Crane's-bill (*Geranium bohemicum*) is abundant at the area of 30 x 10 meters. Relevé see Table 3 (Leskovjanská 2009).

Site 4/2008

Exclusively trees are present in site 4 - beech, fir, spruce and maple (Leskovjanská 2009). Date: September 11, 2008, NW aspect, 45°, 20 x 20m; cover E₃ 70%, E₁ 15%, E₀ 20%, list of woods: *Fagus sylvatica* (intact, scorched), *Abies alba* (scorched), *Picea abies* (intact, scorched), *Acer pseudoplatanus* (scorched).

Situation in 2009

The destruction is nearly covered by vegetation, seedlings are grazed by animals, *Geranium bohemicum* is declining in the area, the plant is overgrown by others, competitively more efficient species.

Site 1/2009

The area started to overgrown also in the moss layer. While all the pines are dead on this site, five larches survived. Relevé see Table 5.

Site 2/2009

The herb layer and the moss layer became to develop in the pinewood on crumbled limestone. Relevé see Table 6.

Site 3/2009

The cover of the Czech Crane's-bill (*Geranium bohemicum*) decreased in 2008 to 3%, mainly sterile plants are present. The plants have been replaced by competitively stronger species - wood spurge (*Tithymalus amygdaloides*), stinging nettle (*Urtica dioica*), small reed (*Calamagrostis varia*), rosebay willowherb (*Epilobium angustifolium*). Relevé see Table 7.

Site 4/2009

On September 9, 2009, all the relevant plants were faded away. Date: September 9, 2009, NW aspect, 45°, 20 x 20m; cover E₃ 15%, E₂ 0%, E₁ 65% E₀ 20%, list of woods: *Fagus sylvatica* (intact, scorched), *Abies alba* (scorched), *Acer pseudoplatanus* (intact, scorched), *Larix decidua* (intact, scorched).

Discussion

Increasing altitude is connected with the increasing rainfall, reducing the risk of fires. The first and second level of forest vegetation having low rainfall

Relevé 1a

Date:	September 11, 2008,
Aspect	W
Inclination:	40°
Area:	20 x 20m,
Cover E ₃ :	70%
Cover E ₂ :	0.1%
Cover E ₁ :	1%
Typological classification:	AF-Fde

E₃ List of species not recorded

E₂ *Daphne mezereum*

E₁

Mercurialis perennis, *Pimpinella major*, *Fagus sylvatica*, *Viola* sp., *Lamium purpureum*, *Lathyrus vernus*, *Acer pseudoplatanus*, *Abies alba*, *Frangula alnus*, *Oxalis acetosella*, *Tithymalus amygdaloides*, *Carex alba*, *Geranium robertianum*, *Dryopteris filix-mas*, *Urtica dioica*, *Coronilla varia*, *Prenanthes purpurea*, *Maiathemum bifolium*, *Anuncus sylvestris*, *Valeriana tripteris*, *Campanula rapunculoides*

Table 1. Relevé, site 1/2008 by (Source: Leskovjanská 2009).

Relevé 2a

Date:	September 11, 2008,
Aspect	NW
Inclination:	30°
Area:	20 x 20m,
Cover E ₃ :	10%
Cover E ₂ :	10%
Cover E ₁ :	15%
Cover E ₀ :	20%
Typological classification:	Pide

E₃ List of species not recorded

E₂ List of species not recorded

E₁

Epilobium angustifolium 2, *Cardaminopsis arenosa* 1, *Pimpinella major* +, *Pinus silvestris* +, *Viola* sp. +, *Acer pseudoplatanus* +, *Festuca tatrae* +, *Genista pilosa* +, *Rubus saxatilis* +, *Tithymalus cyparissias* +, *Geranium robertianum* +, *Cirsium arvense* +, *Urtica dioica* +, *Coronilla varia* +, *Larix decidua* +, *Senecio vulgaris* +, *Veronica chamaedrys* +, *Vicia tenuifolia* +, *Salix caprea* +, *Epilobium montanum* +, *Lembotropis nigricans* +, *Solidago virgaurea* +, *Campanula rapunculoides* +

E₀ List of species not recorded

Table 2. Relevé, site 2/2008 (Source: Leskovjanská 2009).

Relevé 3a

Date:	September 11, 2008,
Aspect	NW
Inclination:	1°
Area:	5 x 5m,
Cover E ₁ :	90%
Cover E ₀ :	1%
Typological classification:	Pide

E₁

Geranium bohemicum 3, *Galium schultesii* 2, *Medicago lupulina* 2, *Vicia tenuifolia* 2, *Epilobium angustifolium* 2, *Poa striata* 1, *Calamagrostis varia* 1, *Mycelis muralis* 1, *Tithymalus amygdaloides* 1, *Fagus sylvatica* +, *Trifolium pratense* +, *Viola* sp. +, *Gentiana asclepiadea* +, *Lathyrus niger* +, *Fragaria vesca* +, *Calamintha clinopodium* +, *Acer pseudoplatanus* +, *Digitalis grandiflora* +, *Carex alba* +, *Rubus caesius* +, *Geranium robertianum* +, *Cirsium vulgare* +, *Taraxacum officinale* +, *Coronilla varia* +, *Senecio vulgaris* +, *Veronica chamaedrys* +, *Lembotropis nigricans* +

Table 3. Relevé, site 3/2008 (Source: Leskovjanská 2009).

Relevé 1b	
Date:	September 9, 2009,
Aspect:	W,
Inclination:	40°
Area:	20 x 20m,
Cover E ₃	5%,
Cover E ₁	20%.
Cover E ₀	30%,
Typological classification: AF-Fde	
E ₃ List of species not recorded	
E ₁ <i>Epilobium angustifolium</i> 2, <i>Taraxacum officinale</i> 1, <i>Calamagrostis varia</i> +, <i>Poa stiriaca</i> +, <i>Carex digitata</i> +, <i>Campanula carpatica</i> +, <i>Vicia tenuifolia</i> +, <i>Pimpinella major</i> +, <i>Pinus sylvestris</i> +, <i>Viola</i> sp. +, <i>Fragaria vesca</i> +, <i>Genista pilosa</i> +, <i>Rubus saxatilis</i> +, <i>Asperula tinctoria</i> +, <i>Euphorbia cyparissias</i> +, <i>Geranium robertianum</i> +, <i>Cirsium arvense</i> +, <i>Tussilago farfara</i> +, <i>Urtica dioica</i> +, <i>Coronilla varia</i> +, <i>Rhamnus cathartica</i> r, <i>Arabis hirsuta</i> r, <i>Deschampsia caespitosa</i> r, <i>Fagus sylvatica</i> r, <i>Knautia arvensis</i> r, <i>Lembotropis nigricans</i> +, <i>Campanula rapunculoides</i> +, <i>Cardaminopsis arenosa</i> +, <i>Larix decidua</i> +, <i>Populus tremula</i> +, <i>Salix caprea</i> +, <i>Acer pseudoplatanus</i> +,	
E ₀ List of species not recorded	

Table 5. Relevé, site 1/2009 (leg. authors).

Relevé 2b	
Date:	September 9, 2009,
Aspect:	NW
Inclination:	25°
Area:	20 x 20m
Cover E ₃	10%
Cover E ₂	15%
Cover E ₁	65%
Cover E ₀	20%
Typological classification: Pide	
E ₃ List of species not recorded	
E ₂ List of species not recorded	
E ₁ <i>Epilobium angustifolium</i> 3, <i>Vicia sylvatica</i> 2, <i>Tithymalus amygdaloides</i> 2, <i>Geranium robertianum</i> 2, <i>Calamagrostis varia</i> 1, <i>Carex alba</i> 1, <i>Taraxacum officinale</i> 1, <i>Mycelis muralis</i> 1, <i>Epilobium montanum</i> 1, <i>Vicia tenuifolia</i> 1, <i>Arabis hirsuta</i> +, <i>Sambucus nigra</i> +, <i>Pimpinella major</i> +, <i>Campanula rapunculoides</i> +, <i>Verbascum thapsiforme</i> +, <i>Viola</i> sp. +, <i>Gentiana asclepiadea</i> +, <i>Fragaria vesca</i> +, <i>Hieracium murorum</i> +, <i>Chelidonium majus</i> +, <i>Galium schultesii</i> +, <i>Poa</i> sp. +, <i>Poa stiriaca</i> +, <i>Rubus idaeus</i> +, <i>Digitalis grandiflora</i> +, <i>Carex digitata</i> +, <i>Cirsium erisithales</i> +, <i>Cirsium vulgare</i> +, <i>Cirsium arvense</i> +, <i>Tussilago farfara</i> +, <i>Urtica dioica</i> +, <i>Coronilla varia</i> +, <i>Sedum maximum</i> +, <i>Silene vulgaris</i> +, <i>Prenanthes purpurea</i> +, <i>Populus tremula</i> +, <i>Maianthemum bifolium</i> +, <i>Valeriana tripteris</i> +, <i>Salix caprea</i> +, <i>Lembotropis nigricans</i> +, <i>Campanula carpatica</i> +, <i>Cardamine impatiens</i> +, <i>Cardaminopsis arenosa</i> +.	
E ₀ List of species not recorded	

Table 6. Relevé, site 2/2009 (leg. authors).

are therefore more susceptible to the fire, rich grass cover and shrub layer in addition make the fire easier. In the Slovak Paradise, the fifth vegetation level is dominated. So it might seem that it is relatively fire resistant, the reality is different. Bedrock consisting of limestone is covered in shallow redzinas with typical dealpine plant communities, these plant communities are highly flammable. Annual bulk precipitation and climatic conditions are influenced by

Relevé 3b	
Date:	September 11, 2009,
Aspect:	NW
Inclination:	1°
Area:	5 x 5m
Cover E ₁	95%
Cover E ₀	5%
Typological classification: Pide	
E ₁ <i>Calamagrostis varia</i> 3, <i>Epilobium angustifolium</i> 3, <i>Tithymalus amygdaloides</i> 3, <i>Urtica dioica</i> 3, <i>Vicia tenuifolia</i> 1, <i>Galium schultesii</i> 1, <i>Medicago lupulina</i> 1, <i>Geranium bohemicum</i> 1, <i>Fagus sylvatica</i> +, <i>Trifolium pratense</i> +, <i>Gentiana asclepiadea</i> +, <i>Lathyrus niger</i> +, <i>Fragaria vesca</i> +, <i>Calamintha clinopodium</i> +, <i>Acer pseudoplatanus</i> +, <i>Digitalis grandiflora</i> +, <i>Carex alba</i> +, <i>Poa stiriaca</i> +, <i>Rubus caesius</i> +, <i>Geranium robertianum</i> +, <i>Cirsium vulgare</i> +, <i>Taraxacum officinale</i> +, <i>Coronilla varia</i> +, <i>Senecio vulgaris</i> +, <i>Mycelis muralis</i> +, <i>Veronica chamaedrys</i> +, <i>Lembotropis nigricans</i> +.	
E ₀ List of species not recorded	

Table 7. Relevé, site 3/2009 (leg. authors).

the close Tatra Mts, the NP Slovak Paradise is in the rain shadow of this mountain ridge.

During the thirty years of the fire monitoring in the NP Slovak Paradise there were 392 landscape fires, out of them 133 were forest fires (Vida *et al.* 2008). The fire in the Koč area was most likely caused by lightning. The consequence of soil destruction is bedrock denudation. The slope and terrain configuration made difficult to put out the resulting fire. Result of fire in this area has been disastrous for the natural environment. It can take very long time after a disturbance for a forest to return to its original structure (Kuuluvainen and Rouvinen 2000, Flachbart 2001). Heavily burnt areas are colonized by plants disseminated by airborne diaspores (Šoltés *et al.* 2010), less burnt localities are settled by plants surviving by root system, so the cover in initial stages of succession is minimal. More over, the opportunity to enroot in such extreme dry conditions is minimal.

The study revealed that succession runs significantly slower all over on disturbed sites than on less burnt habitats where is charred only top soil layer. So, the restoration of forest ecosystems represent different stages of succession and should be under investigation for many years.

A year after fire disaster, a rare plant Czech Crane's-bill (*Geranium bohemicum*) has been discovered here (Leskovjanská *et al.* 2009), the plant is similar to Herb Robert (*Geranium robertianum*). The fire is not essential for this antracofil plant, it grows on ashe of old fire places or charcoal piles also, if environment temperature reaches at least 35° C. The seeds in soil seedbank have been activated by the fire, during three years the plants were replaced by another, more competitive species. Now, the seeds will be waiting in the soil another tens years for any fire or heat.

Acknowledgements

The author appreciate translation by Ján Graban and constructive suggestions from Rudolf Šoltés, Institute of High Mountain Biology, University of Žilina.

References

- Bevilaqua, D. 2000: Požiare v Národnom parku Slovenský raj. *Enviromagazín*, **2(5)**: 10-11.
- Braun-Blanquet, J. 1964. Pflanzensozologie. Grundzüge der Vegetationskunde. Ed. 3. Springer-Verlag, Wien, New York.
- Dostál, J. and Červenka, M. 1991: Veľký kľúč na určovanie vyšších rastlín I. SPN, Bratislava.
- Dostál, J. and Červenka, M. 1992: Veľký kľúč na určovanie vyšších rastlín II. SPN, Bratislava.
- Fischer, A. 1992: Long term vegetation development in Bavarian Mountain Forest ecosystems following natural destruction. *Vegetatio*, **103**: 93-104.
- Flachbart, V. 2001: Prečo znova horelo v Národnom parku Slovenský raj? *Les*, **57**: 22.
- Holécy, J., Tuček, J., Škvarenina, J. and Mindáš, J. 2004: Výskyt lesných požiarov v Národnom parku Slovenský raj, výsledky štatistickej analýzy. In *Zborník referátov k 40. výročiu ochrany prírody v Národnom parku Slovenský raj* (ed. F. Divok), pp. 76-85. Zvolen.
- Jančová, M. 1993: Prírodná obnova lesného spoločenstva požiarom poškodenej časti ŠPR "Kyseľ" v národnom parku Slovenský raj 1994. *Zborník referátov zo seminára v Záhorskej Bystrici 6. - 8. apríl 1993*, 73-79.
- Jančová, M. 2006: Prírodná obnova lesa na plochách poškodených požiarom na príklade Národnej prírodnej rezervácie Kyseľ Technická univerzita vo Zvolene, Zvolen.
- Kuuluvainen, T. and Rouvinen, S. 2000: Post-fire understorey regeneration in boreal *Pinus sylvestris* forest sites with different fire histories. *J. Veg. Sci.*, **11**: 801-812.
- Leskovjanská, A. (ed.) 2009: Záverečná správa za rok 2009. Rezervačná kniha NPR Sokol. Odborné údaje. Depon. in Správa NP Slovenský raj.
- Leskovjanská, A., Dražil, T. and Bryndzová, Š. 2009: Vzácnny výskyt pakosta českého (*Geranium bohemicum*) Torner in L. v Národnom parku Slovenský raj. *Chránené územia Slovenska*, **77**: 17-19.
- Marhold, K. 1998: Ferns and flowering plants. In *Checklist of non-vascular and vascular plants of Slovakia* (eds. K. Marhold and F. Hindák), pp. 333-687. Veda, Bratislava.
- Vida, T., Škvarenina, J. and Holécy, J. 2008: Meteorologické podmienky, vývoj, frekvencia a príčiny vzniku krajinných požiarov na území Národného parku Slovenský raj. v období 1976-2005. In *Bioklimatologické aspekty hodnocení procesů v krajině, Mikulov 9. - 11.9.2008* (eds. J. Rožnovský and T. Litschmann), CD-ROM. ISBN 978-80-86690-55-1. Online: <http://www.cbks.cz/sbornik08b/Vida.pdf> (retrieved 10.4.2010).
- Šoltés R., Školek, J., Homolová, Z. and Kyselová, Z. 2010: Early successional pathways in The Tatra Mountains (Slovakia) forest ecosystems following natural disturbances. *Biologia*, **65(6)**: 958-964.
- Westhoff, V. and van den Maarel, E. 1978: The Braun-Blanquet approach. In *Classification of plant communities* (ed. R.H. Whittaker), pp. 289-399. W Junk, The Hague.

Received 5 July 2010; accepted 3 September 2010.