

## Effects of elevational gradient on leaf and stomatal morphology of Caucasian alder (*Alnus subcordata*) in the Hyrcanian forest, Iran

Mohammad Reza Akbarian<sup>1</sup>, Masoud Tabari<sup>2</sup>, Moslem Akbarinia<sup>1</sup>, Mehrdad Zarafshar<sup>1</sup>, Jorge A. Meave<sup>2</sup>, Hamed Yousefzadeh<sup>1</sup>, Ali Sattarian<sup>3</sup>

<sup>1</sup>Department of Forestry, Natural Resources Faculty, Tarbiat Modares University, Noor, Mazandaran, Iran

<sup>2</sup>Departamento de Ecología y Recursos Naturales, Facultad de Ciencias, Universidad Nacional Autónoma de México, México 04510, D.F., Mexico

<sup>3</sup>Department of Forestry, Gonbad Kavous University, Golestan, Iran

### Abstract

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*Alnus subcordata* C.A.Mey (Betulaceae) is a commercial, fast growing species that is widely distributed in the Hyrcanian forest of northern Iran. In this study, the effect of altitude on the whole leaf and stomatal morphology of this species was analyzed. In eastern Mazandaran province, ten sites were selected along an elevational gradient. The altitudinal separation between sites was 100 m. At each site, leaves from six individual trees were collected for determination of leaf traits. Correlation analyses showed a significant, positive relationship of tooth number with altitude, whereas leaf blade and petiole length were significantly but inversely related to this factor. Similarly, stomatal length decreased with the increasing altitude. A principal component analysis (PCA) was performed to identify those traits causing the main differentiation between sites. Leaf width and length, together with petiole length, were best correlated with PC1 scores, whereas stomatal traits were best correlated with PC2 scores. The large plasticity of the studied leaf traits of *A. subcordata* was confirmed through a plasticity analysis ( $PI = 0.56$ ). The trait displaying the lowest plasticity was leaf base shape ( $PI = 0.2$ ). A high plasticity in leaf traits subjected to environmental fluctuations was also observed, especially for apex length, leaf length, petiole length, tooth number and size of stomata. These findings may explain the broad elevational distribution of *A. subcordata* in the Hyrcanian forest. It is concluded that leaf base shape is a valuable trait for the taxonomy in the genus *Alnus*.

### Key words

*Alnus*, leaf traits, PCA, plasticity, stomata

### Introduction

The Hyrcanian forest (northern Iran) is one of the most ancient and unique forest communities of the world: about 80 tree and 50 shrub species occur in its less than two million hectares (MOHAJER, 2007). *Parrotia persica*, *Populus caspica*, *Pterocarya fraxinifolia*, *Quercus castaneifolia*, *Alnus glutinosa* and *A. subcordata* are

well-known representatives of the unique flora that thrives in this forest. *Alnus subcordata* (Caucasian alder) is one of the commercial and fast growing species that is currently exploited in the Hyrcanian forest. In addition to a substantial timber production, alder is important because of its ability to fix nitrogen into the soil. For this reason, alder is utilised as an auxiliary species for reforestation, especially for providing adequate growing

\*Corresponding author's address: Tarbiat Modares University, Noor, Mazandran, Iran, Box 14155-4838; tel: +98-122-6253103 +98-122-6253101; fax: +98-122-6253499; e-mail: Mtabari@modares.ac.ir

conditions for beech saplings (*Fagus orientalis*), and for soil improvement (TALESHI et al., 2009). Alder displays a very broad ecological range, as it occurs across many elevational floors from the coastal plain at sea level to an altitude of around 2,000 m. Its wide elevational range suggests that this species is finely adapted to a large variety of ecological conditions.

As altitude changes in mountain systems, ecological, edaphic and climatic conditions such as temperature, rainfall, solar radiation vary considerably (KORNER, 2007), and trees often show a range of responses to them, particularly by modifying their morphological and physiological attributes (TURESSON, 1992; VELÁZQUEZ-ROSAS et al., 2002). Such changes may be achieved in two ways: plasticity or genetic changes (BRUSCHI et al., 2003; HOVENDEN and VANDER SCHOOR, 2006).

Along an elevational gradient both leaf morphology and foliar shapes can vary noticeably (HOVENDEN and VANDER SCHOOR, 2006). For example, a large variation in leaf traits of *Nothofagus* trees such leaf size, thickness and total leaf area associated with elevation (HOVENDEN and VANDER SCHOOR, 2004). Similarly, large variations in leaf characteristics of *Parrotia persica* were observed along an elevational gradient of the Hyrcanian forests (YOUSEFZADEH et al., 2010). Interestingly, leaf morphology and ecological gradient are sometimes poorly correlated (KOVACIC and NIKOLIC, 2005). The study of plant responses to environmental changes along elevational gradients is particularly relevant in the case of those species like *A. subcordata* that have very broad ecological amplitudes, as it may shed light on the prevailing mechanisms of species coexistence and unique responses of species to the environment (QIANG et al., 2003; HOLLAND and RICHARDSON, 2009; ROYER et al., 2006). Accordingly, the aim of this study was to examine the variability of leaf traits in *A. subcordata* along the broad elevational gradient through which it occurs, focusing on general leaf and stomatal morphology.

## Material and methods

The study was conducted in the eastern portion of the Hyrcanian forest (Mazandran province, Iran). Ten sites were systematically selected along the established transect to represent the altitudinal variation. The elevational difference between adjacent sites was 100 m (Table 1, Fig. 1). In October 2009, we selected six individual mature trees per each site. Several terminal leaves were collected from the outer light exposed part of the crown of each tree and then mixed in order to sample five leaves randomly. Only leaves lacking signs of abnormal growth, mechanical damage, or pathogen or insect infestation were used. The parameters measured included seven macro-morphological traits: lamina length (LL), lamina width (LW), lamina width at the first decile of leaf length from the base (LW 0.1), lamina width at

the ninth decile of leaf length from the base (LW 0.9), petiole length (PL), apex length (AL), number of teeth (counted in a 2 cm section of the leaf margin) (Fig. 2). In addition, we calculated four ratios: leaf length/leaf width (LL/LW), leaf length/petiole length (LL/LP), leaf base shape character (LW 0.1/LW) and leaf apex shape character (LW 0.9/LW). These ratios, which represent independent shape variables, have been used extensively in leaf morphometrics analyses. Stomatal characteristics were determined on two leaves per each tree. The leaf was boiled for 15–20 minutes. Very thick epiderm layers from leaf were sampled by cutter. Stomatal characteristics were studied on 10 stomata per each leaf by light microscopy. Finally, the following variables related to leaf stomata were measured: stomata length (SL), stomata width (SW), stomata area (SA), and stomata density (SD).

Table 1. Geographical location and elevation of the sampling sites of leaves of *Alnus subcordata* in the Hyrcanian forest (northern Iran)

Site	Elevation [meter]	Longitude	Latitude
1	250	54°16'22" E	36°45'07" N
2	350	53°26'53" E	36°41'24" N
3	450	54°23'06" E	36°44'44" N
4	550	53°36'50" E	36°40'50" N
5	650	54°16'28" E	36°44'29" N
6	750	53°36'43" E	36°40'21" N
7	850	54°22'60" E	36°47'30" N
8	950	53°36'45" E	36°40'07" N
9	1,050	54°23'35" E	36°47'04" N
10	1,150	54°36'49" E	36°39'56" N

Variation in leaf parameters was examined using principal component analysis (PCA). Generally, PCA helps to describe the total variation in a sample in a few dimensions (RHOLF, 1971). Eigenvectors were calculated to assess the contribution of each variable to site separation related to leaf traits (ZARAFSHAR et al., 2010).

Total within-population plasticity (PI) was calculated for each trait using the smallest and the greatest mean values, as follows:

$$PI = 1 - (x/X)$$

where  $x$  is the smallest value and  $X$  is the largest value measured for any given leaf trait (ASHTON et al., 1998; BRUSCHI et al., 2003).

## Results

Table 2 summarises the results of PCA, including the eigenvalues, the proportion of the total variance explained

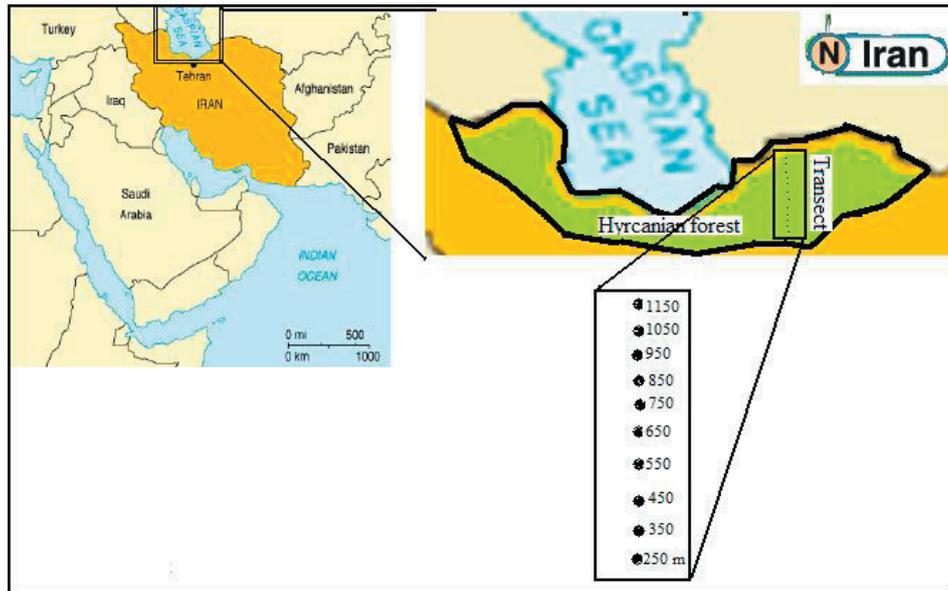


Fig. 1. Location of the sampling sites in the Hyrcanian forest (northern Iran).

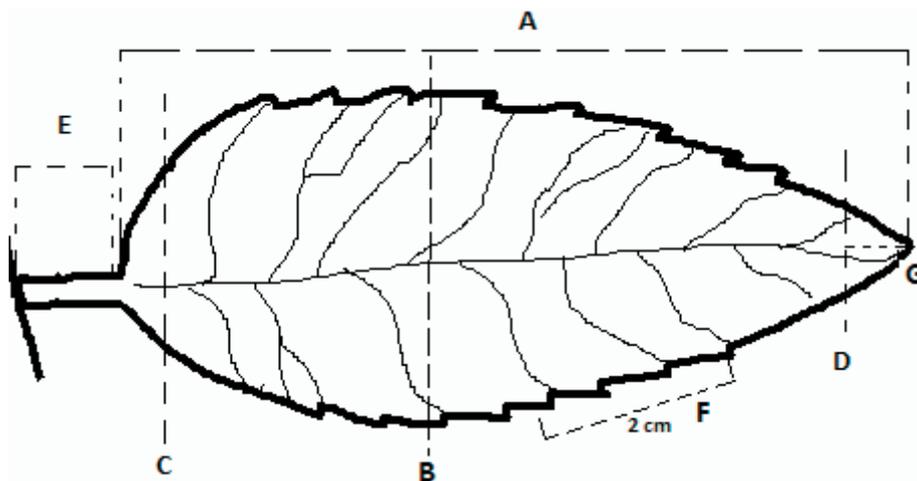


Fig. 2. Macro-morphological leaf traits used as input for the principal component analysis. A: lamina length (LL); B: lamina width (LW); C: lamina width at the first decile of leaf length (LW 0.1); D: lamina width at the ninth decile of leaf length (LW 0.9); E: petiole length (PL); F: number of teeth (counted in a 2 cm section of the leaf margin) (NT); G: apex length (AL).

by each component, and the cumulative proportion of this variance explained by the first components. The first four principal components accounted for 78% of the total variance of all traits, whereas the other components explained a small percentage of total variation (22%). Together, PC1 and PC2 accounted for 55% of the total variance (31% and 24.0%, respectively), indicating a high degree of correlation among the analysed parameters. The individual percentages of explained variance for PC3 and PC4 were 15% and 8%, respectively. Leaf size parameters such as lamina length, lamina width, lamina width at the ninth length decile, and petiole length were positively correlated with PC1, while

stomatal length was negatively related to this component's scores. Leaf shape parameters were not significantly correlated with PC1. In turn, PC2 was positively related to all stomata parameters but stomata density. Lamina width at the first decile, leaf apex shape and leaf shape parameters showed strong correlations with PC3. PC4 was significantly, negatively related with tooth number and traits reflecting leaf base shape. Results of the correlation analyses between leaf traits and ecological (elevation) and geographical (longitude, latitude) factors are presented in Table 3. Tooth number was significantly and positively related to elevation, whereas lamina length and petiole length showed significant,

negative correlations with this factor. This analysis showed that elevation is not the only factor capable of causing significant variation in leaf traits, as stomatal length was significantly and negatively related to latitude. The dissection of the shared variance components (elevation, tree, and error) based on the axes derived from the PCA showed that PC1 accounted for 49% of

total variance related to elevation, for 19% of variance related to within-site tree diversity, and for 33% of total variance related to errors such as within-canopy leaf variability. In the second and third axis less than 20% of the total variance related to altitude was accounted for (Table 4).

Table 2. Correlation coefficients between leaf traits and four principal components analysis and proportion of variability by the first four components

		Factor 1	Factor 2	Factor 3	Factor 4
Leaf traits	LL [cm]	<b>0.33</b>	0.29	0.04	0.07
	LW [cm]	<b>0.35</b>	0.22	0.23	0.00
	LW 0.1 [cm]	0.10	-0.33	<b>0.57</b>	0.12
	LW 0.9 [cm]	<b>0.34</b>	0.22	0.25	-0.15
	PL [cm]	<b>0.35</b>	0.24	-0.01	-0.10
	NT	-0.10	-0.22	-0.09	<b>-0.54</b>
	AL [cm]	0.21	0.20	-0.25	-0.28
Leaf shape	LL/LW	-0.05	0.16	<b>-0.39</b>	-0.16
	LW 0.1/ LW	-0.07	0.00	0.07	<b>-0.68</b>
	LW 0.9/ LW	-0.17	-0.23	<b>0.42</b>	0.07
	LL/PL	-0.22	-0.07	0.03	0.07
Stomata trait	SL	<b>-0.33</b>	<b>0.29</b>	0.12	-0.05
	SW	<b>-0.24</b>	<b>0.37</b>	0.14	-0.05
	SA	<b>-0.29</b>	<b>0.36</b>	0.14	-0.06
	SD	0.14	-0.28	0.23	-0.20
Variance	Eigen value	4.89	3.82	2.42	1.28
	Explained variance	30.58	23.90	15.17	8.05
	Cumulative variance [%]	30.58	54.48	69.66	77.71

Bold values indicate high contribution of the trait in the explained variance.

Table 3. Correlation between biometrical traits with ecological factors of 10 sites

		Altitude	Latitude	Longitude
Leaf traits	LL [cm]	-0.32*	0.19	-0.15
	LW [cm]	-0.22	0.18	-0.18
	LW 0.1 [cm]	-0.06	0.12	-0.002
	LW 0.9 [cm]	-0.17	0.14	-0.16
	PL [cm]	-0.29*	0.16	-0.09
	NT	0.35**	-0.04	0.04
	AW [cm]	-0.06	-0.02	-0.07
Leaf shape	LL/LW	-0.01	-0.02	0.12
	LW 0.1/ LW	-0.1	-0.14	-0.01
	LW 0.9/ LW	-0.14	-0.08	0.08
	LL/PL	0.09	-0.06	0.06
Stomata trait	SL	0.15	-0.28**	0.12
	SW	-0.04	-0.04	-0.12
	SA	-0.04	-0.17	-0.01
	SD	0.12	0.13	-0.01

\*Selected Spearman R values significant at  $p < 0.005$ . \*\*Selected Spearman R values significant at  $p < 0.001$ .

Table 4. Partitioning of variation by hierarchical component in all leaf traits

Axes	Variance [%]		
	Elevation	Tree	Error
Axes 1 [PCA1]	48.58	18.69	32.73
Axes 2 [PCA2]	17.26	46.84	35.90
Axes 3 [PCA3]	19.09	29.01	51.89
Axes 4 [PCA4]	8.91	70.81	20.28
Axes 5 [PCA5]	7.10	27.51	56.30

The plasticity values calculated for the studied leaf traits were generally high (mean PI = 0.56). The largest plasticity corresponded to apex length (PI = 1) and petiole length (PI = 0.8), while the minimum was observed for leaf base shape (PI = 0.2). Along the elevational gradient, the studied stomata parameters displayed low plasticity value (Fig. 3).

## Discussion

Environmental heterogeneity is a major cause of variation in leaf morphology (GEESKE et al., 1994; VELÁZQUEZ-ROSAS et al., 2002; MCPHERSON et al., 2004), and the effects of altitude on leaf morphology and physiology are important for a plant development. In this study, clear changes in leaf morphology were associated with

elevational gradient in the Hyrcanian forest in Iran, as seen by the large proportion (approximately 49%) of total variance of leaf morphology that was explained by the altitudinal component of the environment.

Our results are in line with other's findings in various environments, such as significant reductions of lamina length with altitude (VELÁZQUEZ-ROSAS et al., 2002; HOVENDEN and VANDER SCHOOR, 2004). We also confirmed the tendency for leaves to bear a larger number of teeth at higher altitudes, reported earlier by ROYER and WILF (2006). They suggested that a larger number of teeth along the border of the lamina provide protection for the leaf against high wind speeds and help ensure a better access to water for the plant. Similarly, our results confirm the long-held idea that tooth number is negatively associated with mean annual temperature (GREENWOOD et al., 2004; ROYER et al., 2005; TRAISSER et al., 2005), an environmental factor that decreases with increasing elevation. Indeed, for a plant growing in a high elevation environment, having more teeth may represent a general adaptive advantage, albeit complex to dissect, as this trait has also been suggested to be mechanism resulting in increased photosynthesis, evaporation, respiration within the primary tooth in the growing season (BAKER-BROSH and PEET, 1997; ROYER and WILF, 2006). Considering the close association between leaf morphology and environmental factors (BRUSCHI et al., 2003), *A. subcordata* displays multiple changes that confirm the response of this species to the elevational gradient, but the different traits sometimes display opposite behaviours. For example, there was a negative correlation between altitude and both petiole length and lamina length, while tooth number responded positively

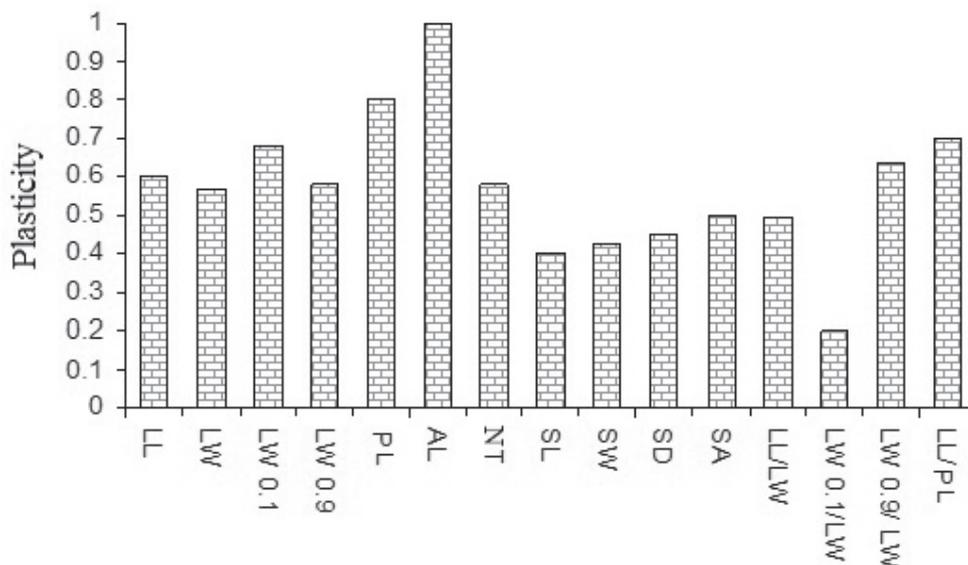


Fig. 3. Comparison of the plasticity calculated for the 15 analysed leaf traits. LL, lamina length; LW, lamina width; LW 0.1, lamina width at the first decile of leaf length; LW 0.9, lamina width at the ninth decile of leaf length; PL, petiole length; AL, apex length; NT, number of teeth; SL, stomata length; SW, stomata width; SD, stomata density; SA, stomata area.

to the increasing altitude. Interestingly, in *A. subcordata* leaf shape parameters remained unaffected by the increasing elevation (as shown by the low plasticity value – approximately 0.2 – for the leaf base shape), in contrast to findings of other authors (HOVENDEN and VANDER SCHOOR, 2004). Leaf base shape has often been used as an identifying character in the taxonomy of *Alnus* (SABETI, 1965). Since our results show that this trait is little affected by the complex changes of environmental factors associated with elevational gradient, we conclude that it may be extensively utilised by botanists for the diagnosis of several species within the genus. Conversely, stomatal traits tended to be positively associated with altitude, for example stomatal length. Although stomatal morphology is mainly affected by leaf developmental stage (ČAŇOVÁ et al., 2008) and leaf development is initially driven by gene expression (LI et al., 2010), we found some evidences for *A. subcordata* being forced to undergo altitudinal changes in stomatal traits, perhaps as a need to adapt to decreasing CO<sub>2</sub> concentrations, decreased temperature and modified light conditions in higher sites (QIENG et al., 2003). This possibility is also confirmed by the strong correlation between stomatal size traits and PC2.

We concluded that the phenotypic variation of *A. subcordata* leaves, especially that of lamina and petiole lengths, number of teeth and stomatal size, represent an integrative adaptive response to altitude-related varying environmental conditions.

Considering the large leaf variability displayed by the broadly distributed *A. subcordata* in the Hyrcanian forest, the potential diagnostic value of some traits for the taxonomy of the genus became evident.

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## Vplyv výškového gradientu na morfológiu listov a prieduchov *Alnus subcordata* v hyrkánskych lesoch Iránu

### Súhrn

*Alnus subcordata* C.A.Mey (Betulaceae) je komerčnou rýchlorastúcou drevinou so značným prirodzeným rozšírením v oblasti hyrkánskych lesov v severnom Iráne. V tejto štúdií sme skúmali vplyv nadmorskej výšky na celkovú morfológiu listov a prieduchov tejto dreviny. Vo východnej provincii Mazandaran sme pozdĺž výškového gradientu vybrali desať výskumných plôch s výškovým rozdielom 100 m medzi jednotlivými plochami. Na každej ploche bolo vyselektovaných 6 dospelých stromov, z ktorých sa odoberali listy na určenie listových parametrov. Bola zistená významná pozitívna korelácia medzi počtom listových zubov a nadmorskou výškou, zatiaľ čo veľkosť listovej čepele a dĺžka listovej stopky negatívne korelovali s týmto faktorom. Podobne sa aj dĺžka prieduchov skracovala so stúpajúcou nadmorskou výškou. Za účelom identifikácie faktorov zodpovedných za diferenciáciu medzi výskumnými plochami bola uskutočnená analýza základných komponentov. Šírka a dĺžka listovej čepele spolu s dĺžkou listovej stopky najlepšie korelovali s hodnotami prvého základného komponentu, zatiaľ čo parametre prieduchov najlepšie korelovali s hodnotami druhého základného komponentu. Hodnotením plasticity sa zistila vysoká priemerná hodnota pre listové parametre ( $PI = 0,56$ ). Najnižšia plasticita bola zaznamenaná pre tvar listovej bázy ( $PI = 0,20$ ). Vysoká plasticita listových parametrov vystavených environmentálnym fluktuáciám bola pozorovaná pre dĺžku listového vrcholu, dĺžku listovej čepele, dĺžku listovej stopky, počet listových zubov a veľkosť prieduchov. Tieto zistenia môžu vysvetľovať rozsiahle výškové rozšírenie *A. subcordata* v hyrkánskych lesoch. Zo štúdie vyvodzujeme, že tvar listovej bázy je užitočným znakom pre taxonomické účely v rode *Alnus*.

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## Climate response to forest management in beech stands

Milan Barna<sup>1</sup>, Branislav Schieber<sup>2</sup>

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen,  
Slovak Republic,

<sup>1</sup>E-mail: barna@savzv.sk, <sup>2</sup>E-mail: schieber@savzv.sk

### Abstract

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This work summarises the climatic data assembled in five submountain beech forest stands with different cutting patterns. The highest mean monthly air temperature values in March–July were obtained on a plot with 20-year-old beech thicket (T); in August–October on a stand after light shelterwood cuts (L) and in November–February in a closed stand (C – control). On the contrary, in the summer months June–July the C manifested the lowest temperature values, while in the winter (October–February) the temperature was the lowest on the open area (OA). The maximum one-hour (12-min averages were recorded) temperature increased with decreasing stand density of parent trees. The highest temperature value making 33.3 °C was measured in T, in OA reaching at the same time 32.9 °C, while on the C only 28.9 °C. The highest mean daily temperature showed a similar trend. Maximum soil temperature at a depth of 5 cm on the C occurred from the end of July to the beginning of September. The same hold for this variable on T but with the values lower by about 0.5 °C. The soil temperature at 20 cm had the peak not sooner than in the first ten-day period of September. During the whole period, the difference between the rainfall on OA and the throughfall in the C was statistically significant ( $P \leq 0.05$ ). The highest monthly air humidity was always found on the OA, or on the T without parent stand (with variation from 72% in April to 95% in November). The lowest mean air humidity was observed in the densest adult stands: in March–October on plot L and in November–February (after the leaf fall) on the control.

### Key words

air and soil temperature, humidity, shelterwood cut, stand density, throughfall

### Introduction

Beech forest stands belong to the stand types considerably influencing the site microclimate. Due to diverse architecture of forest ecosystems, solar radiation displays diverse distribution patterns inside the ecosystems (REITMAYER et al., 2002; ZRAK and JALOVIAK, 2009) which is also reflected in vertical microclimate heterogeneity (STŘELCOVÁ et al., 2003). The gradient of natural solar radiation serves a major role in growth of regeneration, as well as in forming plant communities in these ecosystems. Temperature resulting from the radiation affects most of the biological processes requiring a specific temperature range to function, with intensity much influenced namely by the temperature.

Therefore, temperature is an essential external controlling factor significantly affecting e.g. phenophase timing in beech regeneration (SCHIEBER, 2006; JAZBEC et al., 2007; BARNA et al., 2009) and in herb synusia (SCHIEBER, 2007). In this context, such a phenomenon as late spring frosts represents a limiting factor for development of leaves and shoots and so also for the whole growth process in the given year (DITMAR et al., 2005). The harmful effect may to some extent depend on the site microclimate. The microclimatic diversity in a given ecosystem controls also the biodiversity in this ecosystem (DE FREITAS and ENRIGHT, 1995; GLONČÁK, 2009). Temperature and humidity have been suggested by ZLATNÍK (1976) as the main characteristics for the species-specific classification of forest environment in

terms of so called vegetation tiers. In process of transformation of precipitation water has a key role interception – trapping rainfall and snow by crowns of trees and shrubs and by the ground vegetation. The interception is commonly expressed as the negative difference between the throughfall and rainfall on the open area. Interception in forest stands is mostly determined by the species composition, canopy density, stocking density and stand age. The leaf area structure is the background of high variability in water penetration through tree crowns. The total precipitation amount trapped by the tree crowns displays a wide range, reaching up to 60% (MRÁČEK and KREČMER, 1975). The largest precipitation amounts are trapped by dense, multiple shaded spruce and beech forest stands (TUŽINSKÝ, 1999, 2000; JOST et al., 2004).

It is evident that microclimate in forest stands is much influenced by the stand species composition, age, but especially by the stocking and canopy density. The effect concerns primarily the light supply into lower stand stories, air and soil temperature and uptake, distribution and evaporation of water – that means the water cycle comprising also runoff. These processes, however are complicated and interconnected, and as such, not always easy to explain. The aim of this paper is to quantitatively express selected climatic variables (air temperature and humidity, soil temperature, rainfall) in beech ecosystems with diverse structure resulted after regeneration cutting interventions.

## Material and methods

The research ran in a 110-year-old beech forest stand in the Kremnické vrchy Mts (48°38' N and 19°04' E). The stand is situated at 470–490 m a.s.l. The study area belongs to the moderately warm region, moderately warm and humid hilly sub-region (LAPIN et al., 2002). The long-term (1951–1980) mean annual air temperature is about 6.8 °C with a mean of 17 °C in the warmest month (July) and –4 °C in the coldest month (January). The long-term mean annual precipitation is 780 mm. About 55% of the annual rainfall falls from April to September (STŘELEČEK, 1992). The prevailing soil type is Andosolic cambisol with a high skeleton content (20–60%; KUKLA, 2002).

Detailed research on influence of stand density on temperature and humidity in the stand was carried out over one year (from 1 March 2008 to 28 February 2009), in five beech forest stands differing in stand density – modelled by different regeneration cutting methods. The open area – OA, representing a clearing after clear cut; thicket (T) aged 20 years formed by natural regeneration after removal of parent shelter by cuts performed in 1989 and 2004; stand subjected to heavy shelterwood cuts (H) in 1989 and 2004 with stocking degree ( $G/G_{\max}$ ) of 0.3 (stand density 86 stems

$\text{ha}^{-1}$ , and with natural regeneration of more than 77,000 individuals  $\text{ha}^{-1}$ ); stand after light shelterwood cuts (L) – stocking degree 0.5, 174 stems  $\text{ha}^{-1}$ , 35,000 ind.  $\text{ha}^{-1}$ ; control – no cuts (C) – stocking degree 1.0, 613 stems  $\text{ha}^{-1}$ , 25,000 ind.  $\text{ha}^{-1}$  (BARNÁ, 2008). Before the cuts, the dominant woody plant was beech (65–90%), associated species were fir, hornbeam and oak. The cutting was primarily focused on the admixed species, dying and ill trees and trees of a very low quality.

One-hour continual measurements of air temperature and humidity we carried out with using a digital data-logger (equipped with a temperature and humidity sensor EMS 33, Brno) placed at 2 m above the ground. The one-hour average values were determined as the average values from five point data (12-min interval). The fixed-time soil temperature at depth of 5 and 20 cm was measured with bent mercury soil thermometers and recorded always in the same time (9:00 a.m.). The throughfall amount was measured by the rain gauges installed with uniform spacing across the plot. There was measured only precipitation fallen in form of rain, so the evaluation concerns only the period March–November 2008.

## Results and discussion

### Air temperature

Table 1 illustrates that the mean values of monthly air temperature in March–July were the highest on the plot covered with thicket without parent stand (plot T), in August–October on the plot with partially (light) opened parent stand (L), and in November–February on the open plot. The lowest monthly values were recorded in October–February on the open area (OA), in March–May and August–September on the plot with parent stand opened with heavy cut (H), and in summer in June and July on the control plot (C). As for temperature extremes, the absolute 60 min minimum (–16.0 °C) was recorded in January on the OA situated close to beech natural regeneration. The value of this variable increased with stand density up to the plot with complete closed stand (C, –15.3 °C). The observation of the lowest temperature values on forest clearings has also been confirmed with the lowest mean daily (24-h) value recorded on the open area –12.1 °C, compared to the corresponding value in closed stand (C) –11.7 °C. The maximum one-hour temperature showed the opposite trend: increasing with decreasing stand density. The highest value of 33.3 °C was measured in the stand with natural regenerated beech thicket aged 20 years (T), in the OA reached 32.9 °C, in the C 28.9 °C. The highest mean daily temperature showed the similar course: in the thicket reaching 22.1 °C, in OA 22.6 °C, and in control plot only 22.5 °C (Fig. 1).

Table 1. Average monthly air temperature (°C, March 2008–February 2009) on beech plots with different regeneration cutting intensity (plots: OA and T – without parent stand, H – (stand density 86 stems ha<sup>-1</sup>), L – (174 stems ha<sup>-1</sup>), C – (613 stems ha<sup>-1</sup>))

	Open area (OA)	Thicket (T)	Heavy cut (H)	Light cut (L)	Control plot (C)
March	3.16	<b>3.40</b>	<u>3.14</u>	3.40	3.38
April	9.36	<b>9.89</b>	<u>9.28</u>	9.65	9.55
May	14.14	<b>14.64</b>	<u>13.83</u>	14.22	13.85
June	17.39	<b>17.58</b>	16.95	17.36	<u>16.89</u>
July	17.73	<b>17.83</b>	17.42	17.80	<u>17.42</u>
August	17.66	17.85	<u>17.49</u>	<b>17.91</b>	17.61
September	12.41	12.59	<u>12.41</u>	<b>12.70</b>	12.59
October	<u>9.16</u>	9.30	9.17	<b>9.42</b>	9.41
November	<u>4.57</u>	4.68	4.68	4.85	<b>4.92</b>
December	<u>0.55</u>	0.57	0.78	0.90	<b>0.99</b>
January	<u>-4.09</u>	-3.96	-3.98	-3.75	<b>-3.69</b>
February	<u>-1.33</u>	-1.06	-1.27	-1.05	<b>-1.02</b>

max; min

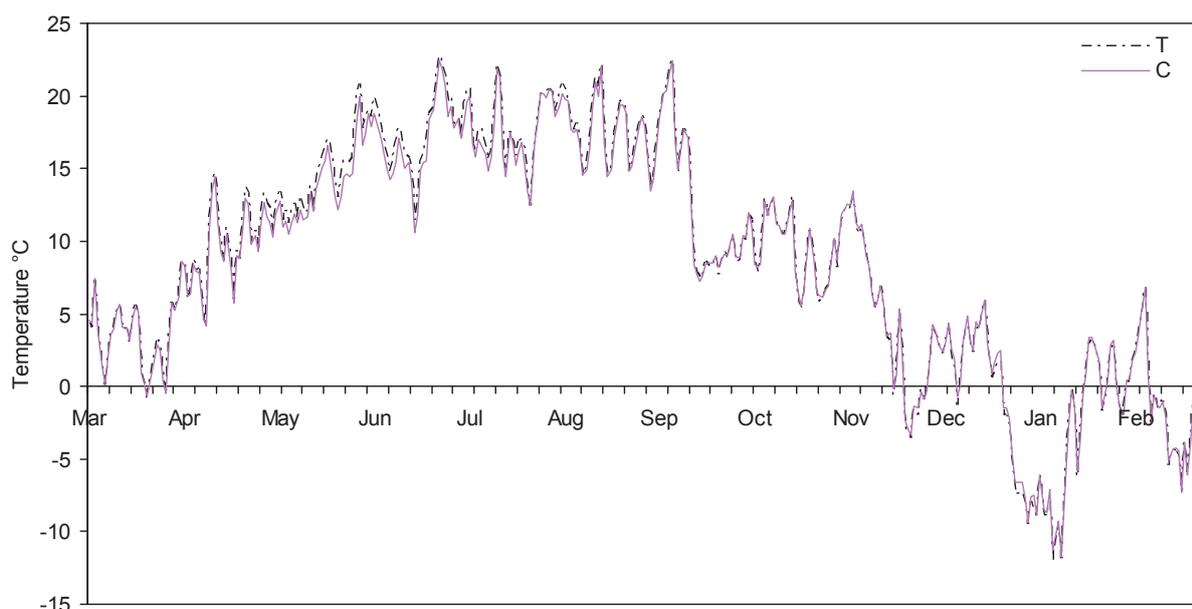


Fig. 1. Course of mean daily (24-h) temperatures (1 March 2008–28 February 2009) in a 110-year-old beech stand (C) and 20-year-old beech thicket (T) in the Kremnické vrchy Mts (470 m a.s.l.). Scaling on x-axis represent 7-day periods.

Figure 1 illustrates the course of the mean daily temperature values over 12 months in a closed beech stand aged 110 years (C), and in 20-year-old thicket (T). The variance of temperature was the smallest in May, the largest in September–February. The figure shows an evident raise in the mean 24-h temperature value from the end of the first April 10-day period, and, on the other hand a conspicuous decrease in the second 10-day period of September with a decrease in 24-h mean temperature by almost 15 °C within a single week. In the winter

(December–February), there were alternating noticeably warm periods with the mean daily temperature exceeding 5 °C and relative cold periods with daily means even under -10 °C. Comparing the values between the stands C and T, there is no distinct difference in the temperature course. Slight differences are discernible since the first April days to the first September days – with higher values in the thicket. Then, there is practically no difference until the mid-October when the temperature becomes higher in the closed adult stand.

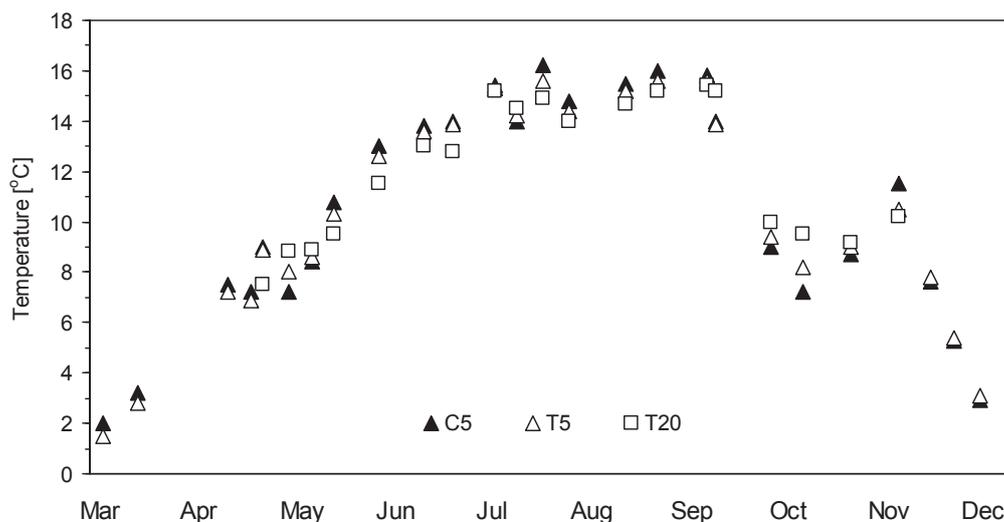


Fig. 2. Fixed-time soil temperature (9:00 a.m.) in March–November 2008 at soil depth of 5 cm and 20 cm on control plot with 110-year-old stand (C) and on plot with 20-year-old thicket (T).

### Soil temperature

Figure 2 shows that the soil temperature at a depth of 5 cm reached minimum values ranging 1.5–2.0 °C at the beginning of March. On the other hand, the maximum at the same depth was observed on the control plot (110-year-old stand) in the mid-July and at the beginning of the third ten-day period of August, reaching the values of 16.2 °C, and 16.0 °C, respectively. On the plot with thicket (20-year-old stand) were maximum values at 5 cm soil depth observed on the same dates as on the control, but lower by about 0.5 °C. The soil temperature at 20 cm reached the peak only in the first ten-day period of September, with a value of 15.4 °C. In this period when the mean daily air temperature exceeded the long term average values by about 5 °C, the soil temperature at 20 cm was higher than at 5 cm by more than 1 °C. In a 10-day period from the mid-September, the soil temperature values in the two depths decreased by about 5 °C. Then followed a relative stable period – until

the end of the first ten-day period of November, with comparatively small fluctuations in soil temperature and fixed-time values at depths of 5 and 20 cm oscillating about 8.5 °C and 9.5 °C, respectively. An exception was the first five-day period of November with a short term temperature increase at both depths by almost 2 °C, at 5 cm exceeding 11.5 °C. This phenomenon was connected with above-normal warm weather with daily air temperature values reaching 10–13 °C (Fig. 1) which means ca. +6 °C compared to the long term normal. Since the mid-November, there followed a distinct decrease again, with the fixed-time values towards the end of November fallen down to 3.0 °C.

### Throughfall

The throughfall is rainfall or snow water not intercepted by tree crowns and fallen through gaps in vegetation onto the ground. Figure 3 illustrates how the stand

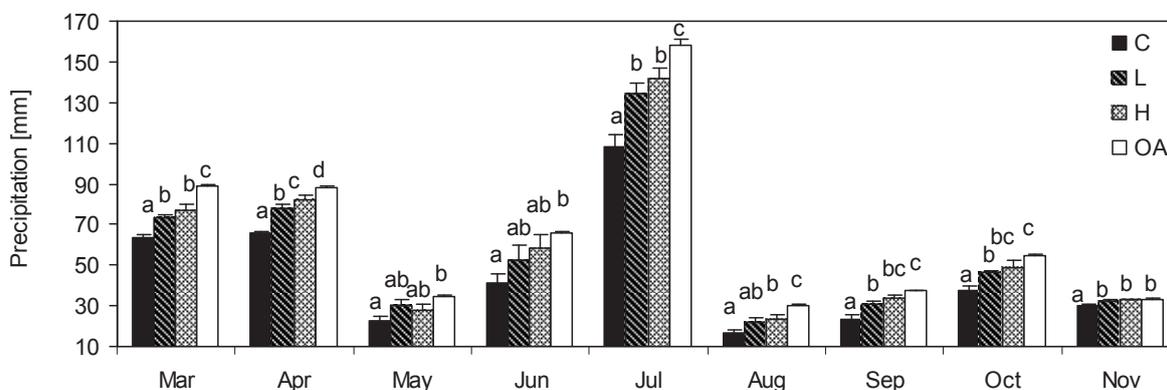


Fig. 3. Monthly rainfall totals on selected plots (C, control; L, light cut; H, heavy cut; OA, open area). Different letters indicate statistically significant differences between the means; Duncan's test applied ( $P \leq 0.05$ ).

density affects the throughfall. The difference in throughfall between the open area (OA) and the closed adult stand (C) was statistically significant ( $P \leq 0.05$ ) over the whole study period. In the spring and summer months when the monthly precipitation totals were above 60 mm, there were found also significant differences in comparison with the two other plots (L and H). The differences between the stands were reduced to minimum in November after the leaf fall. The difference between throughfall in the stand L with stocking degree 0.5 (50% of basal area of the parent stand according to table values), and the rainfall on OA (stocking degree 0.0) was not statistically significant; the difference with the C (stocking degree 1.0) was significant (Fig. 3, November). In each month, the throughfall values increased from C to OA, only in May was observed an insignificant drop in H compared to L – due to inhomogeneous canopy and various sized gaps in stands H and L, created after the cutting.

Figure 4 presents percentage values of throughfall obtained in individual forest stands compared to

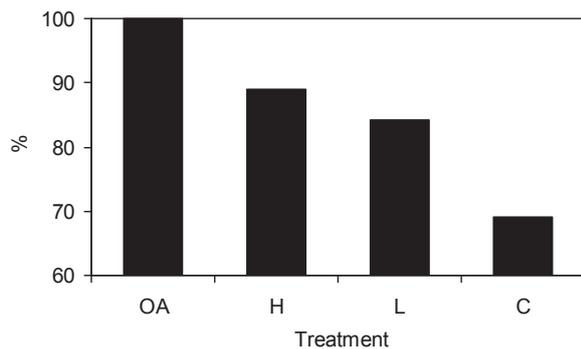


Fig. 4. Percentages of throughfall on individual forested plots compared to the open area (OA, open area; H, heavy cut; L, light cut; C, control).

the open plot over the study period. The throughfall total in the closed stand (C) was 409 mm, representing 69% of the total amount fallen on the open area, in the other stands the throughfall values were 84% (L), and 89% (H).

### Humidity

The highest mean monthly air humidity was always on plots OA and T, that means on the clearing and the plot without parent stand (Fig. 5). The variable displayed seasonal variations, with minimum in April (72%), and maximum in November (95%). On the other hand, the lowest mean monthly air humidity values were obtained in the densest stands: in March–October on plot L (on average 78%), later (November–February) after the leaf fall on plot C (on average 90%, Fig. 5). Minimum 60 min humidity decreased with decreasing stand density, the lowest value, however, was observed in April in the stand treated by light cut (L) – 8%, and the highest minimum humidity was found on the open area – 9%. Similar was the case of the 24-hour mean humidity: L – 46%, OA – 50%.

### Discussion

The results manifest that the diverse stand density considerably affected the selected stand climate variables. The highest mean monthly temperature values in the vegetation period (April–September) were mostly observed on the plot with thicket (T), or in the stand with the stocking degree of 0.5 (L). Outside the vegetation period (October–March), the highest mean monthly temperature values were measured on the plot treated with heavy cut (H), or on the control plot (C), in the cold half of year, on the other hand, on the plot OA

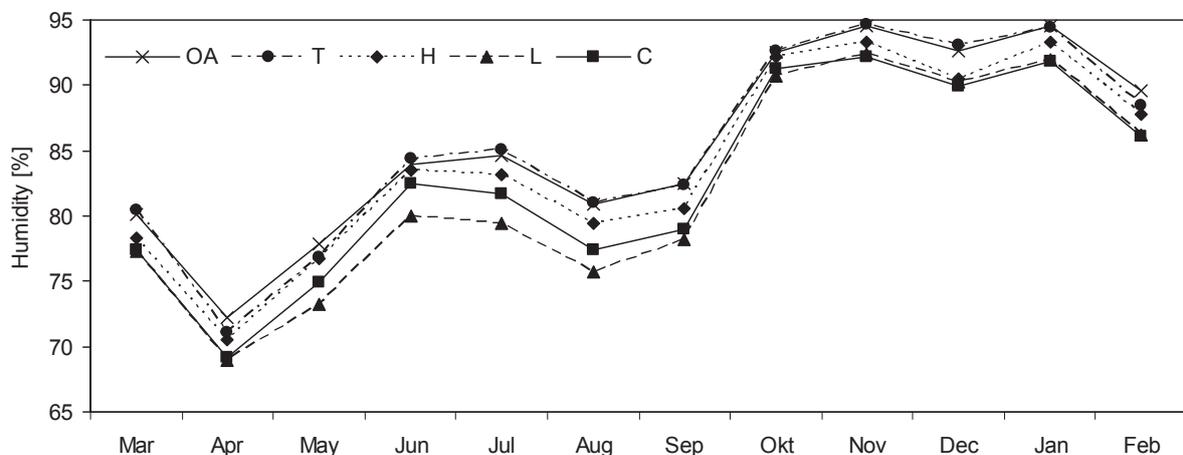


Fig. 5. Mean monthly air humidity in stands subjected to different regeneration cuts (OA, open area; T, thicket; H, heavy cut; L, light cut; C, control).

without forest cover. Also occurrence of air temperature extremes depended on the stand structure. The absolute minimum of one-hour temperature as well as the lowest mean daily temperature were recorded on plot OA, on the other hand, on the control plot reached these variables their maxima. On the contrary, the absolute one-hour maximum and the highest mean daily temperature showed an opposite course: their values were the highest in the stand with natural regeneration consisting of beech thicket aged 20 years (T), or on OA; while reaching the lowest values on the C. Open plots or plots with much released canopy in forest environment manifest wider amplitudes of air temperature compared to adult closed stand. Such a stand, thanks to its structure, has a damping effect on positive as well as negative temperature extremes – which is in accordance also with our results. STRĚLEC (1991) obtained by analysing the impact of harvest-regeneration cuts on temperature in ground layer in submountain beech stands on the same plots after the first regeneration cut in 1989 a significant shift in the daily course of air temperature between the clear cut plot and the control plot without intervention. The daily air temperature extremes (min, max) were noticeably lower compared to the clearing. Similar results were obtained by POTTER et al. (2001). MORECROFT et al. (1998) report, that differences in air temperature between clearing and forest stand were more distinct in summer than in winter. RITTER et al. (2005) measured in a beech stand with clearings the highest values of mean or maximum daily temperature in the centre of a clearing. The values in the centre were by 5–10 °C higher than in other parts of the clearing.

Fixed-time temperature values at the soil depth of 5 cm in March–September were higher on the plot with adult stand than on the plot grown with thicket. In autumn, there was observed a reverse trend. By comparing soil temperature values between the depths of 5 cm and 20 cm within the same plot, it was revealed that in March–September was the soil temperature higher at 5 cm, while in September–December at 20 cm. Deeper soil layers warm more slowly in the spring and summer, on the other hand, the heat loss in autumn is less abrupt compared to the surface. PETŘÍK (1988) comparing the measurements between the primeval forests Badín and Dobroč reports the differences between open area and forest stand making up to 5.1 °C in case of maximum, 2.5 °C in case of minimum and 5.1 °C in case of the range. HOLST et al. (2004) have found that soil temperature in beech stands with varied density, growing on slopes varying in exposition is affected equally by the stand density and slope exposition, especially in the growing season. JANÍK (2005, 2009) reports light conditions and soil temperature varying with varying stand density. The author observed that the soil temperature at 5 and 20 cm had significant influence on the herb layer production.

Also the rainfall amounts measured on the individual plots have confirmed that the rainfall distribution to the ground stand layer depends on the stand structure. The most distinct difference in the precipitation totals over the period March–December was found between the precipitation on the open area (OA) and throughfall in the completely closed adult stand (C) in which the interception value was above 30%. The values on the other plots ranged from 11 to 16% compared to OA. GREGOR (1991) obtained in the same forest stands in the Kremnické vrchy Mts one year after the cutting intervention (1989) the following interception values: 9% at stocking degree 0.3; 19% at 0.5; 29% at 0.7; and even 34% at 0.9. DUBOVÁ (2001a, b) reports that the summary interception in the same stands analysed 5 and 10 years after the cutting intervention manifested the most evident changes on plots with stocking degree 0.5 and 0.7. This was probably caused by the largest increment in crown volume and leaf area in these stands. The data provided by KANTOR (1984) inform that the mean interception value in 120-year-old beech stand with 1.0 stocking degree was only about 8% – thanks to presence of abundant horizontal precipitation. In May–October periods 2005–2008 interception was 6–16% of the total atmospheric precipitation (25-year-old beech stand). TUŽINSKÝ (2004) obtained for adult beech stands situated at lower altitudes a mean interception value ranging between 21–27%, while the value at higher altitudes was 9–27% representing on average 18% of the total fallen on the open ground. These data show that the rather high variability of interception values in beech stands is, apart from the just discussed factors, affected by the leaf area architecture and by the phenophase. The overall water balance in beech stands is also influenced by stem flow. Some authors (TUŽINSKÝ, 2004; KANTOR and ŠACH, 2008) suggest that the stem flow values may attain or even exceed 10% of the total amount fallen on open area.

Interesting is the fact that the lowest mean monthly air humidity was in the densest adult beech stands. BUBLINEC (1990) writes about more evaporation and drying in the stands with dominant beech (*Querceto-Fagetum*) than in the stands with dominant oak (*Fageto-Quercetum*). The primary cause is permanent air ventilation in stands with prevailing beech and simple architecture without shrub storey, on the other hand, very well developed in natural oak forest stands.

The climate change expected in the near future implies more frequent occurrence of vegetation periods with low rainfall totals and with temperature extremes. This will entail changes in bioclimatic environment required for occurrence of individual woody plants: primarily gradual retreat of spruce and expansion of beech in the 4-th and 5-th forest vegetation tiers (ŠKVARENINA et al., 2004). More frequent and longer lasting soil water cycles with limited accessible soil water reserves may exert adverse effects on the moisture control, health

condition and production in beech trees, especially in lower situated forest vegetation tiers (3<sup>rd</sup> f.v.t.) with dominant oak (TUŽINSKÝ, 2004). The danger associated with the soil water regimen in beech stands is present also in case of excessive and longer lasting soil wetting; most often when soil defrosts in winter – when the beech trees may have impaired stabilising performance of their root systems and be prone to mechanical damage by extreme winds (KODRÍK, 1996).

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## Vplyv hospodárenia na klímu v bukových porastoch

### Súhrn

V príspevku sú kvantifikované vybrané klimatické faktory (teplota a vlhkosť vzduchu, teplota pôdy, podkorunové zrážky) v bukových porastoch s diferencovanou štruktúrou (holina – OA, mladina – T, dospelý porast so zakmenením 0,3 – H, 0,5 – L, 1,0 – C), ktoré vznikli po ťažbovo-obnovných zásahoch rôznej sily. Najvyššie priemerné mesačné teploty vzduchu za mesiace marec–júl boli na ploche s 20 ročnou bukovou mladinou (T), v období august–október v poraste s čiastočne preriedeným materským porastom (L) a v zimnom období (november–február) v zapojenom dospelom bukovom poraste (C). Naopak v letných mesiacoch jún–júl v tomto poraste (C) boli najnižšie teploty, v zimnom období (október–február) to bolo na otvorenej ploche (OA). Maximálna hodinová teplota bola tým vyššia, čím redší bol materský porast. Najvyššia hodnota 33,3 °C bola nameraná v mladine (T), na otvorenej ploche dosahovala 32,9 °C, kým na kontrole len 28,9 °C. Najvyššia priemerná denná teplota mala tú istú tendenciu. Maximálne teploty pôdy v hĺbke 5 cm boli na kontrolnej ploche (C) koncom júla až začiatkom septembra. Na ploche T boli maximálne hodnoty v hĺbke 5 cm pozorované v tých istých termínoch ako na C, ale približne o 0,5 °C nižšie. V hĺbke 20 cm teplota kulminovala až v prvej septembrovej dekáde s hodnotou 15,4 °C. V tomto období, kedy boli priemerné denné teploty vzduchu vyššie asi o 5 °C oproti dlhodobému priemeru (1951–1980), dosahovala teplota pôdy v hĺbke 20 cm vyššie hodnoty v porovnaní s hĺbkou 5 cm a rozdiel predstavoval viac ako 1 °C. V podkorunových zrážkach, medzi úplne zapojeným dospelým porastom (C) a zrážkach na voľnej ploche (OA), bol zistený štatistický významný rozdiel ( $P \leq 0,05$ ) počas celého obdobia. V novembri, po opade listov, boli zistené najmenšie rozdiely v zrážkach medzi porastmi. V zapojenom poraste (C) predstavoval úhrn 409 mm, čo tvorilo 69,2% z úhrnu na voľnej ploche. Najvyššia priemerná mesačná vlhkosť vzduchu bola vždy na plochách OA a T, tzn. na holine, resp. na ploche bez materského porastu. Jej hodnota sa menila počas roka,

najnižšie hodnoty dosahovala v apríli (72%), najvyššie v novembri (95%). Na druhej strane najnižšia priemerná vlhkosť bola v najhustejších porastoch: v období marec – október na ploche L, v neskoršom období (november – február) po opade listov – na ploche C. Minimálna hodinová vlhkosť klesala s hustotou porastu, ale najnižšia bola zistená v apríli v poraste po miernej ťažbe (plocha L) – 8% a najvyššia minimálna hodinová vlhkosť bola na voľnej ploche – 9%. Podobne to bolo aj s najnižšou priemernou dennou vlhkosťou: L – 46%, OA – 50%.

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## Comparative study of leaf litter decomposition of exotic and native species in an ecotop of the hornbeam-oak forest near Báb village, SW Slovakia

Andrej Halabuk, Katarína Gerháťová

Institute of Landscape Ecology of the Slovak Academy of Sciences, Branch Nitra, Akademická 2, 949 01 Nitra, Slovak Republic,  
E-mail: andrej.halabuk@savba.sk

### Abstract

HALABUK, A., GERHÁTOVÁ, K. 2011. Comparative study of leaf litter decomposition of exotic and native species in an ecotop of the hornbeam-oak forest near Báb village, SW Slovakia. *Folia oecol.*, 38: 17–27.

We present here a comparative study of leaf litter decomposition in some exotic and native species in a hornbeam-oak forest ecosystem. We focused on the exotic invasive species *Robinia pseudoacacia*, *Ailanthus altissima*, *Impatiens parviflora* and on the expansive native species *Alliaria petiolata*. These species were compared to the native co-occurring species *Acer campestre* and *Mercurialis perennis*. In addition, we studied also cellulose decomposition and site microclimate. We used the litter-bag method on five experimental plots within the managed part of hornbeam-oak forest near Báb, SW Slovakia. The plots were located in closed forest, on forest edge and in a clearing. The course of litter decomposition was fitted with the 1-phase and 2-phase negative exponential decay model for each species. The most conspicuous loss in litter weight was detected in case of the species *Impatiens parviflora* species (26% of mass remaining), followed by *Alliaria petiolata* (29% of mass remaining) and *Mercurialis perennis* (29% of mass remaining). In woody species, the biggest loss of litter was detected in *Ailanthus altissima* (45% of mass remaining), followed by *Acer campestre* (63% of mass remaining) and *Robinia pseudoacacia* (70% of mass remaining). Cellulose decomposition varied significantly in different habitats, with the highest rate in the closed forest. The pattern of herbaceous species was similar. However, this effect of the habitat was not evident in case of woody species.

### Key words

Báb village, decomposition, leaf litter, hornbeam-oak forest, invasive species

### Introduction

Invasive species influence ecosystem processes in a complex way. According to many examples in literature, an invasive species alters processes and subsequent species composition and biodiversity in the ecosystem (LEVINE and D'ANTONIO, 1999; LEVINE et al., 2003; VI-TOUSEK, 1990).

When the species composition has been changed there is a high probability that the subsequent soil-plant interactions and carbon and nutrient cycles will chan-

ge, too. These consequences may, in turn, have an impact on the invasive susceptibility of ecosystems and the invasiveness of species (EHRENFELD, 2003). Invasive and expansive species have a potential to change many components of the carbon and nitrogen cycles of an ecosystem. EHRENFELD (2003) has summarized, that invasive plant species frequently increase phytomass production, net primary production, nitrogen availability, alter nitrogen fixation rates and produce litter with higher decomposition rates than the co-occurring native species.

Leaf litter decomposition plays an important role in carbon and nitrogen cycling in ecosystems, being a main source of nutrients and organic matter for plants and soil organisms. Leaf litter decomposition is affected by both biotic and abiotic factors: temperature, moisture, litter chemistry, soil nutrient supply and decomposer community structure. Due to the large number of factors controlling the leaf litter decomposition, comprehensive study of impact of invasive species on leaf litter decomposition rate is difficult to pursue. The importance of specific factors and their interactions are often studied in order to find the relative effect of each particular factor. Furthermore, specific habitat conditions can affect microbial activity and leaf litter decomposition significantly (ŠIMONVIČOVÁ, 1995; LANCUCH and ŠIMONVIČOVÁ, 2008). Comparative studies of invasive species and co-occurring native species in field conditions can provide valuable information on this topic.

Disturbed ecosystems are examples exhibiting obvious invasions of exotic and expansive plant species. Clear-cut areas and forest openings with high nutrient availability in soil are very sensitive to invaders. The invaders are mostly very effective in nitrogen using. Under conditions of forest opening they can invade extremely (ELIÁŠ, 2000). Even though it is probable that exotic plant invasions may alter soil and ecosystem properties, it is not always the case (EHRENFELD and SCOTT, 2001). In addition, environmental conditions much varying on a gradient from clear-cut to closed forest gradient may result in a very variable decomposition rate (DIDHAM, 1998). Therefore, there is still a need for case studies on different invasive plant species in various types of habitats.

In our contribution, we compare the decomposition rates of selected exotic species with relevant native species. We select *Robinia pseudoacacia* and *Ailanthus altissima* from the exotic expansive woody species and *Impatiens parviflora* and *Alliaria petiolata* from expansive herbaceous species. Although *Alliaria petiolata* is not an exotic species, it is considered as native expansive species. *Acer campestre* and *Mercurialis perennis* were selected as native co-occurring species for comparative analysis. There are many studies on ecology of these invasive species in Slovakia; to our knowledge, however, there has not been performed yet a study of litter decomposition rates in these species in Slovakia.

## Material and methods

### Study site

The research site is located in the SW Slovakia (48°18'09''; 17°53'27'') in the Báb forest situated in a warm and dry region, with the mean annual temperature of 9.3 °C and precipitation total of 580 mm (TUŽINSKÝ, 2004). The parent material is calcareous loess, the for-

med soils are Albi-Haplic Luvisols with 2.6–3.3% organic matter content and C/N ratio of 13.9 in the 0–10 cm horizon (SOMBATHOVÁ and ZAUJEC, 2001; GONET et al., 2008). The geobiocoenosis belongs to the Fageto-Quercetum group of forest type (KUBIČEK and BRECHTL, 1970), with prevailing oaks – *Quercus robur*, *Q. petraea*, *Q. cerris* with admixture of *Carpinus betulus* and *Acer campestre* in the tree layer of phytocoenosis. The herbaceous layer is dominated by *Mellica uniflora*, *Dactylis glomerata*, *Carex pilosa*, *Asperula odorata*, *Hedera helix*, *Pulmonaria officinalis* and *Geum urbanum*. Since 1966, a part of the Báb forest is protected. In this part has been prohibited forest management. In the adjacent area, 4 clear cuttings were applied at the end of the year 2006. The clear-cut areas were consecutively massively occupied by *Ailanthus altissima*, *Robinia pseudoacacia* and *Alliaria petiolata* species.

### Litter bag experiment

For determination of leaf litter decomposition, we used the standard litter bag method (see HARMON et al., 1999). Leaf litter was collected in late summer when senescence was evident. In case of tree species, the litter was collected from branches immediately before shading of leaves in October 2008. The collected material was air dried in the laboratory for 14 days and filled in bags in amounts of 3–5 g. The initial leaf moisture content was estimated with subsamples set aside from litter samples and dried at 75 °C. Our litterbags were 16 cm × 12 cm in size, made of nylon mesh (1 mm mesh size), with three sides double-stitched with nylon thread, and provided with small plastic tags with identification numbers. We established five plots on a gradient from clear-cut area

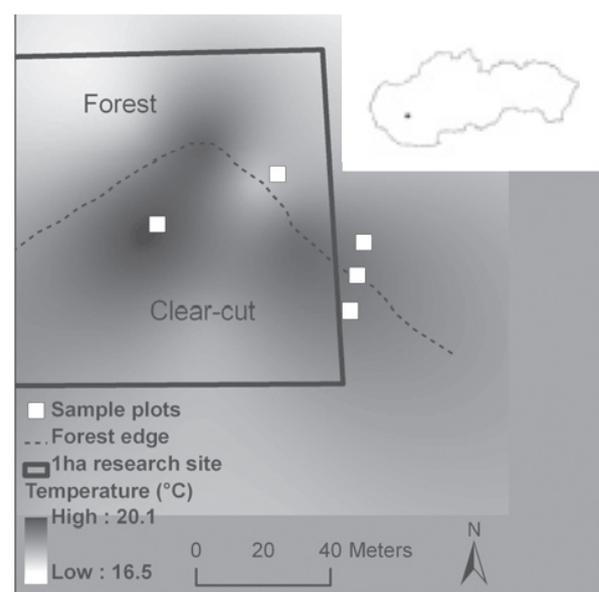


Fig. 1. Location of 5 sampling plots and spatial variation of mean near-ground temperature during the vegetation season 2009.

to closed forest (Fig. 1). The litter bags were placed randomly on particular plots, directly on the ground under the recent litter. The number of litterbags of individual species on particular plot varied from 30 to 50. Altogether we used 500 litterbags in the field. Together 4–6 samples of every species were taken in field in each sampling period. The sampling dates for herbaceous litter were: 4 September 2008, 17 October 2008, 14 November 2008, 19 December 2008, 27 January 2009, 19 March 2009 and 24 July 2009; for woody species: 17 October 2008, 19 December 2008, 27 January 2009, 19 March 2009, 24 July 2009 and 25 September 2009. The species determination was made according to DOSTÁL and ČERVENKA (1991) and the nomenclature follows that of MARHOLD and HINDÁK (1998).

The standard cellulose decomposition experiment was made with the aid of cellulose filter paper inserted in the litter bags (ŠKOLEK, 1980). The litter bags with cellulose filter paper were placed under the leaf litter (ca 1 cm in the topsoil) and exposed for 2 months in the field in spring 2009. Five replicates were used on each plot, together 25 litter bags. Then the litterbags were transported in the laboratory, cleaned of adhering waste (soil, mosses, rock fragments, etc.), oven dried at 75 °C until a stable weight (usually ca. 48 hours), and weighed to determine the dry weight. Two-way ANOVA (STATSOFT, INC., 2010) was used in order to reveal significant differences for testing differences in litter decomposition rate among different species across the study site. Herbaceous and tree species were analysed separately. The annual profile of decomposition was analyzed by 1-phase and 2-phase negative exponential decay model (OLSON, 1963; LINDSAY and FRENCH, 2004). The K decomposition constant, half-lives and 90% decay life and R coefficient of determination of the fitted model were obtained by means of GraphPad Prism software (GRAPHPAD SOFTWARE, 2009).

The near-ground (30 cm) air temperature was monitored in clear cut area and closed forest canopy with HOBO Pro temperature loggers (ONSET Computers, USA) at 30 min intervals. There was analysed the period from 4 September 2008 to 21 September 2009. Volumetric soil moisture was monitored in 30 min interval with Virrib sensors (AMET, ČR) based on phase transmittance method at 10, 30 and 70 cm depth in clear-cut area and closed forest.

## Results

The decomposition rate leaf litter in herbaceous species varied substantially both among herb species and in time (Fig. 2). The biggest differences in weight of herb species litter are visible before the winter, after exposition in the field one month (1<sup>st</sup> sampling date) where all mean differences in litter weight were even statistically significant ( $p < 0.05$ ). Later, after 100 days in the field,

differences in weight of herb species litter continuously decreased (Fig. 3), mainly in case of *Alliaria petiolata* and *Mercurialis perennis*, where also the inverse pattern occurred on 4<sup>th</sup> and 5<sup>th</sup> sampling date. After 324 days of exposure in the field, conspicuous loss of litter weight was detected in case of *Impatiens parviflora* species (74%), followed by *Alliaria petiolata* (71%) and *Mercurialis perennis* species (71%). However, only the mean difference in litter weight loss between *Impatiens parviflora* and *Mercurialis perennis* species was statistically significant. Mean differences in litter loss of all studied species and their statistical significance for every sampling date are presented in Table 1.

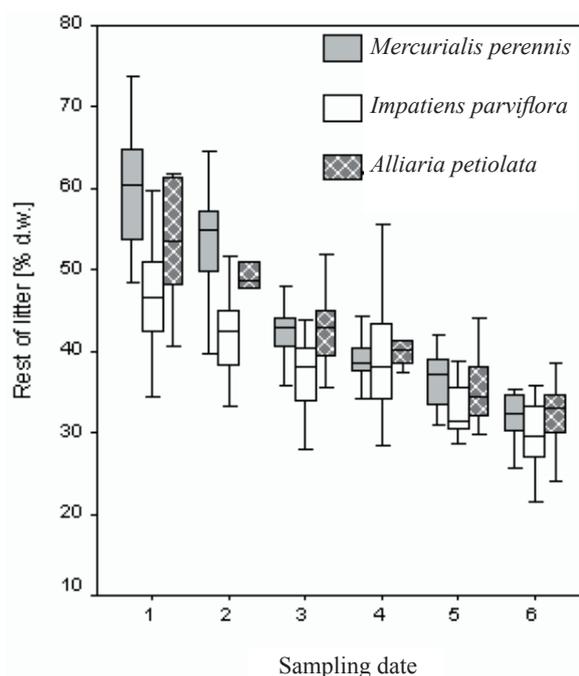


Fig. 2. Leaf litter weight loss from 4. 9. 2008 to 6 sampling dates (1: 17. 10. 2008, 2: 14. 11. 2008, 3: 19. 12. 2008, 4: 27. 1. 2009, 5: 19. 3. 2009, 6: 24. 7. 2009).

In case of woody species, the litter loss differences were statistically significant during the whole monitoring period. The differences slightly increased during the time period in the field. Especially, the low decomposition of *Robinia pseudoacacia* litter in the later period is noticeable (Fig. 4). After 344 days of exposure in the field, the great loss of litter was detected in case of *Ailanthus altissima* species (55%), followed by *Acer campestre* (37%) and *Robinia pseudoacacia* species (30%).

The values of regression coefficients show the two-phase exponential decay model as better explaining the litter decomposition in all the plant species than the one-phase exponential model (Table 2). However, the results of the one-phase exponential decay model allow standard comparison with other published results. The first phase of litter decomposition (50% of

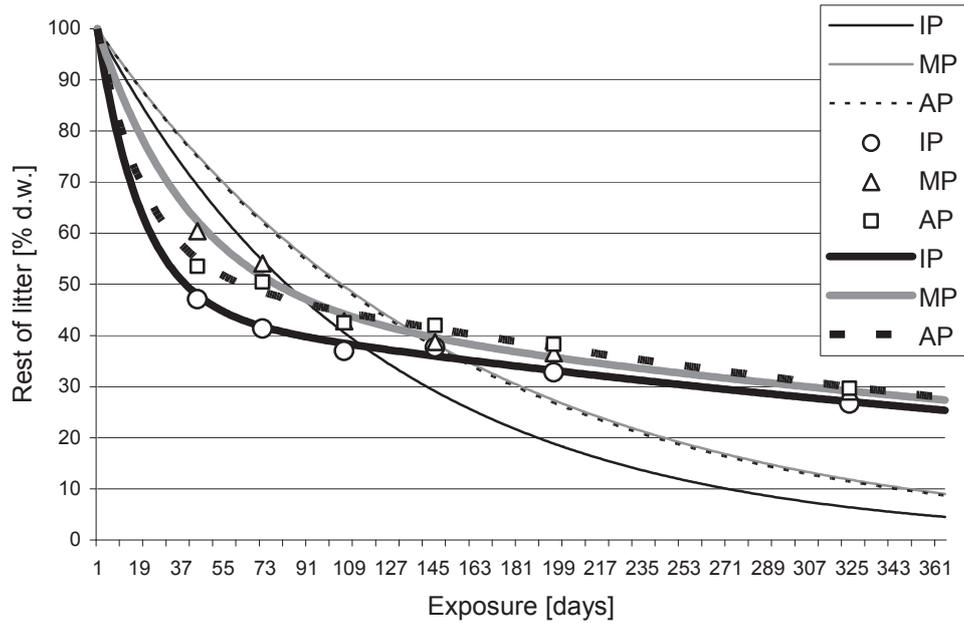


Fig. 3. Course of decomposition of leaf litter fitted by 1-phase (thin line) and 2-phase (bold line) decay models (IP, *Impatiens parviflora*; MP, *Mercurialis perennis*; AP, *Alliaria petiolata*).

Table 1. Mean differences in rate of litter decomposition and their statistical significance (IP, *Impatiens parviflora*; MP, *Mercurialis perennis*; AP, *Alliaria petiolata*; AC, *Acer campestre*; AA, *Ailanthus altissima*; RP, *Robinia pseudoacacia*)

Sampling date	Species A	Species B	Rest of litter [%]	Sig.	Sampling date	Species C	Species D	Rest of litter [%]	Sig.		
17. 10. 2008	IP	MP	13.29(*)	.00	14. 11. 2008	AC	AA	12.33(*)	.00		
	MP	AP	6.86(*)	.02			RP	.98	.34		
		AP	-6.43(*)	.05			AA	AC	-12.33(*)	.00	
	AP	IP	-6.86(*)	.02			RP	AC	-11.34(*)	.00	
		MP	6.43(*)	.05			AA	AA	11.34(*)	.00	
19. 12. 2008	IP	MP	12.70(*)	.00		27. 1. 2009	AC	AA	16.17(*)	.00	
	MP	AP	3.60	.19				RP	1.54	.22	
		AP	9.09(*)	.00				AA	AC	-16.17(*)	.00
	AP	IP	-3.60	.19				RP	AC	-14.63(*)	.00
		MP	9.09(*)	.00				AA	AA	14.63(*)	.00
27. 1. 2009	IP	MP	5.80(*)	.00	19. 3. 2009		AC	AA	17.92(*)	.00	
	MP	AP	.32	.85				RP	3.48	.19	
		AP	-5.80(*)	.00				AA	AC	-17.92(*)	.00
	AP	IP	-5.49(*)	.00				RP	AC	-14.43(*)	.00
		MP	5.49(*)	.00				AA	AA	14.43(*)	.00
27. 1. 2009	IP	MP	-4.7	.83		19. 3. 2009	AC	AA	17.92(*)	.00	
	MP	AP	-3.26	.17				RP	3.48	.19	
		AP	4.7	.83				AA	AC	-17.92(*)	.00
	AP	IP	-2.79	.28				RP	AC	-14.43(*)	.00
		MP	2.79	.28				AA	AA	14.43(*)	.00

Table 1. Continued

Sampling date	Species A	Species B	Rest of litter [%]	Sig.	Sampling date	Species C	Species D	Rest of litter [%]	Sig.	
19. 3. 2009	IP	MP	3.76	.16	24. 7. 2009	AC	AA	14.35(*)	.00	
		AP	-1.76	.53			RP	AA	-10.65(*)	.00
	MP	IP	-3.76	.16			AA	AC	-14.35(*)	.00
		AP	-5.53	.06			RP	AC	-25.01(*)	.00
	AP	IP	1.76	.53			AA	AA	25.01(*)	.00
24. 7. 2009	IP	MP	3.54(*)	.05	25. 9. 2009	AC	AA	15.73(*)	.00	
		AP	.75	.68			RP	AC	-8.33(*)	.00
	MP	IP	-3.54(*)	.05			AA	AC	-15.73(*)	.00
		AP	-2.79	.08			RP	AC	-24.07(*)	.00
	AP	IP	-.75	.68			AA	AA	24.07(*)	.00
		MP	2.79	.08						

\*The mean difference is significant at the .05 level.

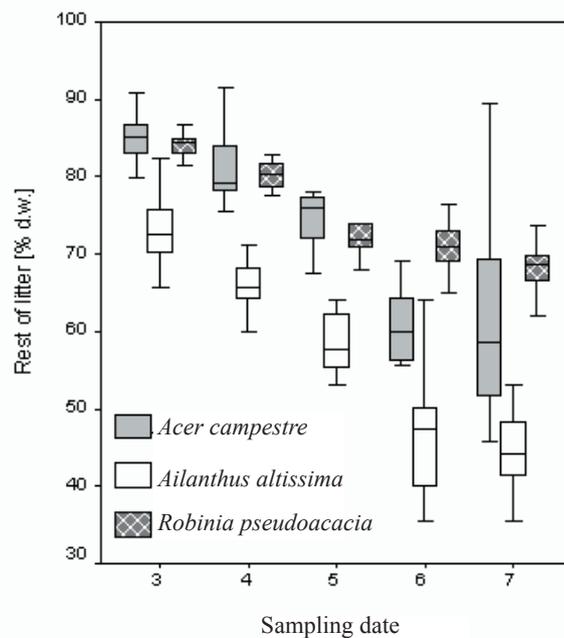


Fig. 4. Leaf litter loss from 17. 10. 2008 to 5 sampling dates (3: 19. 12. 2008, 4: 27. 1. 2009, 5: 19. 3. 2009, 6: 24. 7. 2009, 7: 25. 9. 2009).

weight) was found the fastest in *Impatiens parviflora* species, followed by *Alliaria petiolata* and *Mercurialis perennis*. The substantial decrease of decomposition is evident in winter season; however, in later periods the decay profile is very similar for all species (Fig. 5).

The rate of cellulose decomposition varied significantly among the habitats, with the maximum in the closed forest (Fig. 6). This pattern was to extent similar to the decomposition pattern in herbaceous species litter (Fig. 7). However, the results of ANOVA proved

the habitat effect to be significant only for the species *Mercurialis perennis* and *Impatiens parviflora*. This habitat effect was not observable in woody species (Fig. 8). However, the evident considerable variability in these values may be caused by many factors of habitat affecting the decomposition rate of litter. Varying site microclimate was detected throughout the forest clear-cut area to closed forest gradient (Fig. 1, Fig. 9). The mean difference in values of near-ground air temperature recorded in clear-cut area and in closed

Table 2. Results of 1-phase and 2-phase exponential decay models (IP, *Impatiens parviflora*; P, *Mercurialis Perennis*; AP, *Alliaria petiolata*; AC, *Acer campestre*; AA, *Ailanthus altissima*; RP, *Robinia pseudoacacia*)

Model	Parameter	AC	AA	RP	IP	MP	AP
1-phase	K [years]	0.71	1.24	0.61	3.09	2.41	2.44
	R square	0.88	0.73	0.61	0.63	0.79	0.66
	Half-lives [days]	335	188	391	82	105	103
	95% decay time [years]	4.2	2.4	4.9	0.97	1.25	1.23
	90% decay time [years]	3.3	1.8	3.8	0.74	0.96	0.94
2-phase	KFast [years]	47.3	34.47	20.78	19.24	9.17	18.49
	KSlow [years]	0.49	0.6	0.23	0.58	0.56	0.66
	R square	0.984	0.9928	0.966	0.997	0.996	0.995
	Half-lives [days]	544	256	1098	38	77	63
	95% decay time [years]	5.87	4.5	11.97	3.80	4.06	3.61
	90% decay time [years]	4.47	3.35	9.01	2.60	2.81	2.56

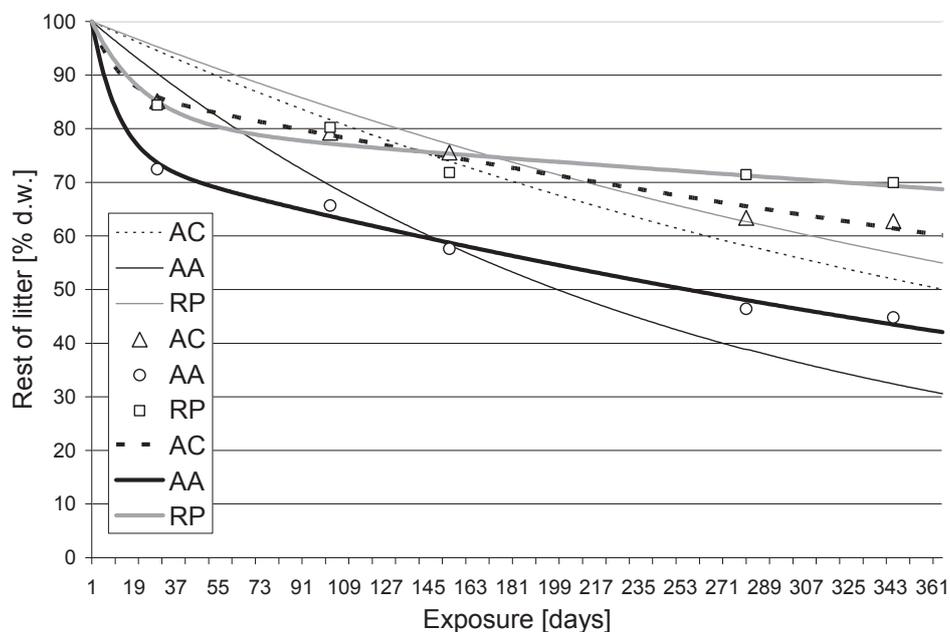


Fig. 5. Course of decomposition of tree leaves litter fitted by 1-phase (thin line) and 2-phase (bold line) decay model (AC, *Acer campestre*; AA, *Ailanthus altissima*; RP, *Robinia pseudoacacia*).

forest during the period from 4 September 2008 to 21 September 2009 made 0.36 °C. However, the mean daily temperature difference (7.00 a.m.–18.00 p.m.) made 2.76 °C. In daily profile, the greatest differences were identified between 13.00 and 14.00 p.m. Similarly, the values of mean difference of relative air humidity recorded during the period from 22 April 2009 to 21 September 2009 in clear-cut area and closed forest made 12% and the mean daily difference 2.3% (Fig. 10). The soil moisture value in the clear-cut area was permanently higher compared to the soil moisture in the closed forest (HALABUK, 2010). The biggest differences in soil moisture values recorded in the clear-cut area and closed

forest were detected mainly at a depth of 70 cm. In top-soil, where cellulose decomposition was measured, the moisture differences were not such conspicuous, probably due to the higher input of precipitation water and due to dew formation.

## Discussion

It is obvious that decomposition rate of herbaceous litter is faster than that of tree leaf litter (MAYER, 2008). Decomposition of plant litter is strongly affected by plant litter quality. The rate of microbial decomposition of

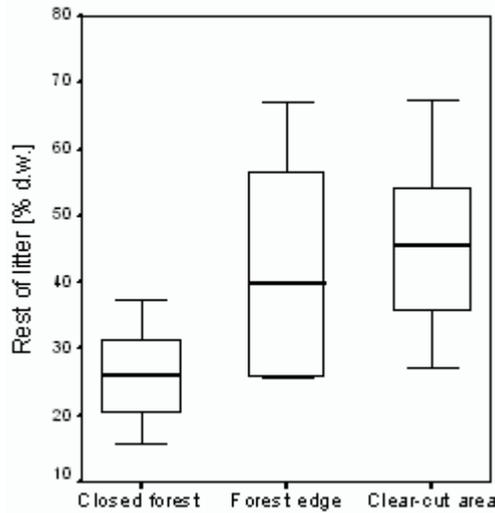


Fig. 6. Habitat effect on rate of cellulose decomposition.

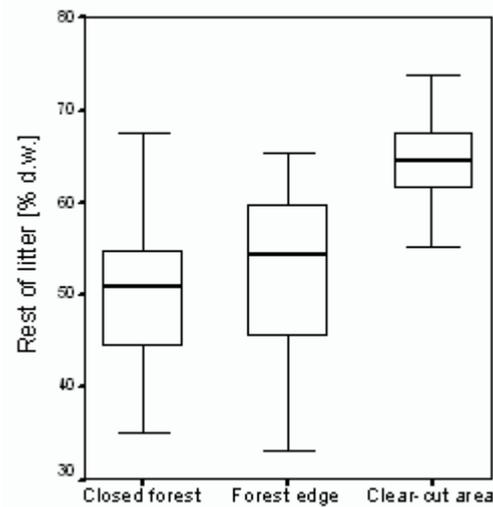


Fig. 7. Habitat effect on rate of litter decomposition of herbaceous species in the 1<sup>st</sup> stage of decomposition.

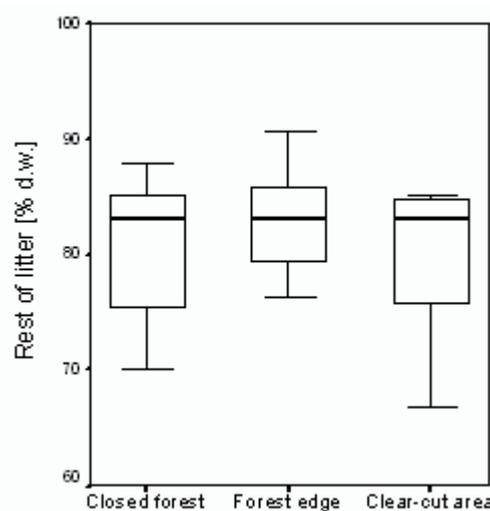


Fig. 8. Habitat effect on rate of litter decomposition of woody species in the 1<sup>st</sup> stage of decomposition.

plant litter is usually highly positively correlated with increasing N concentration and negatively correlated with increasing C/N ratios in this litter, probably reflecting differences in its structural and secondary compounds, such as lignin and phenols (TUMA, 2002). This variable chemistry of litter during decomposition results in a two stage decay profile exhibiting evidently faster decomposition of labile compounds at the beginning of exposure in the field. That is why the two-phase decomposition model usually better explains decomposition within a shorter period (LINDSAY, 2004); and allows, in such a way, better comparison of results of decomposition of different species litter (DIDHAM, 1998). However, better long-term prediction of litter decomposition pattern requires longer exposition of samples in the field (e.g. during the next winter), which

in turn would need more litter of herbaceous species in the bags. On the other hand, regarding the studied effect of invasive plant species on mineral cycling during decomposition, the short term decomposition, with the major part of biomass decomposed is important. Invasive species considered having higher leaf N content and lower C/N ratios, usually decompose faster (EHRENFELD, 2003; ASHTON, 2005; LINDSAY, 2004). The fast decomposition rate of rich-in-nutrients leaves of *Ailanthus altissima* (CASTRO-DIEZ, 2009), *Robinia pseudoacacia* (TATENO et al., 2007), *Alliaria petiolata* (RODGERS, 2008) and *Impatiens parviflora* species (VANDERHOEVEN et al., 2007) has been documented; although their decomposition differences have never been compared in the same environmental conditions. Our results showed that the litter decomposition of invasive

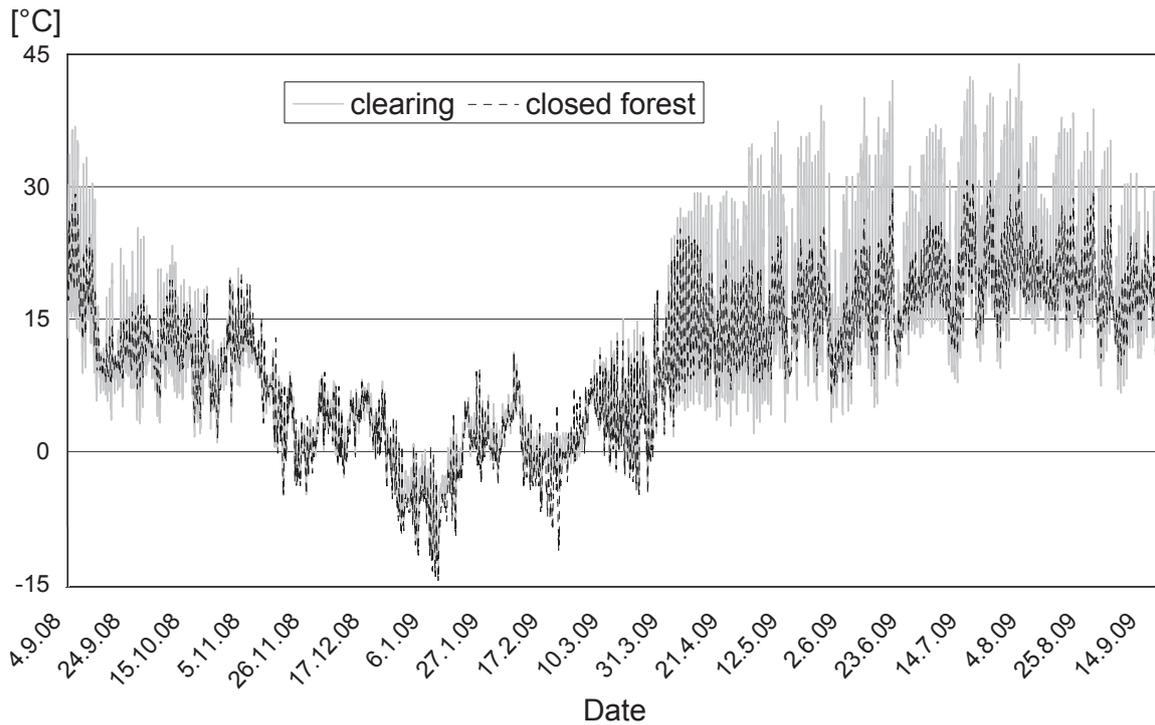


Fig. 9. Course of near-ground (30 cm) temperature in closed forest and clearing during the research period.

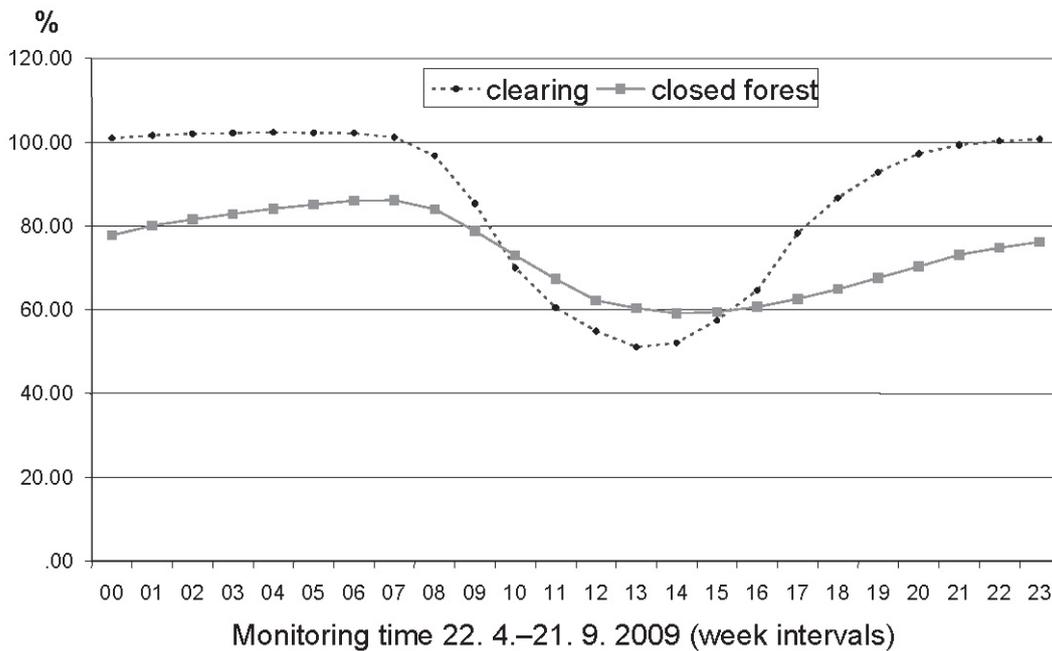


Fig. 10. Course of mean daily relative air humidity in closed forest and clearing.

species was faster compared to the indigenous species, with exception of *Robinia pseudoacacia* leaf litter. This was a surprise as *Robinia pseudoacacia* is a nitrogen fixing species with high N content and low C/N ratio in leaves. This possible explanation is high lignin content in locust leaves increasing their resistance against most

decomposing organisms – as it has been also documented by CastroDIES (2009).

Despite the well documented fact that the leaf litter quality of plant species is a main driver of differences in rate of its decomposition (FUNK, 2005; STANDISH et al., 2004), the habitat (site) effect should also be considered in or-

der to identify additional factors possibly affecting the decomposition. Furthermore, canopy of invasive tree species may create a specific environment facilitating decomposition of plant litter irrespective of its quality (ASHTON, 2005), providing, in such a way, positive feedback for expansion of this species.

Variable soil moisture and temperature across a disturbed forest could affect plant decomposition (TEŠAŘOVÁ, 1993). Logging of forest stands is accompanied by extensive organic matter decomposition and humus mineralization, since conspicuous changes in microclimate on clear-cut areas create more favourable conditions for the activity of soil micro-organisms (ZÁHORA, 1996; TŮMA, 1998). However, TŮMA (2002) ascertained only positive effect of temperature on decomposition rate. Negative correlation between soil moisture and microbial decomposition rate may reflect possible slower heating of waterlogged soils on clear-cut areas (TŮMA, 1999). In our study, there was a consistent effect of plant species leaf litter across the site, since in the two-way ANOVA, there was no significant interaction between the site effect and the effect of plant species leaf litter. However, we did not register a higher decomposition rates in clear-cut area. Furthermore, herbaceous species litter and cellulose tests proved higher decomposition in the closed forest compared to clear-cut area. We documented that clear-cut area was wetter and warmer than the closed forest, however these differences vary in dependence of the season. BUBLINEC (1975) stated that the greatest decomposition rates were evident at the beginning of vegetation season and they substantially decreased in August. The author also pointed to the soil moisture as possible cause of temporal dynamics of decomposition. The greatest differences in microclimate between closed forest and clear-cut area, however, were ascertained in summer, being low in autumn and early spring.

In a well designed multifactor experiment by MAYER (2008), the author documented that decomposition rate is more affected by litter moisture than soil temperature, which can explain the higher decomposition loss of plant litter under forest canopies. In fact, higher near-ground air humidity in a closed forest during day time (Fig. 10) may contribute to surface wetness in the litter horizon. Furthermore, litter decomposition in old forest stands is also influenced by communities of decomposers adapted to consuming the large stocks of leaf litter (MAYER, 2008). The specific differences in composition of soil micro-organisms and lower microbial activity in Báb clear-cut area compared to the adjacent closed forest may refer to this fact (ĎUGOVÁ, 2008). We also need to note that by using mesh litter bags in our study we excluded a well known effect of macrodetritivores on decomposition rate (MAYER, 2008), which may underestimate the faster decomposition of plant litter in well structured forest. However, in the near future, massive expansion of invasive species across the clear-cut area

may change this pattern, as these species are able to change the microclimate (STANDISH, 2004) and community of decomposers at the site (HOLLY, 2009). The issue requires several years of additional experiments.

We can summarise that, except *Robinia pseudoacacia*, leaves of exotic and native invasive and expansive species were decomposing faster, mainly in the first stage – decomposition of the most valuable litter parts with high nitrogen content. This pattern was the same across the closed forest, forest edge and clearing. Although the clearing was wetter and warmer on average, decomposition rates of cellulose and of herbaceous litter were higher in the closed forest.

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## Porovnanie dekompozície listovej fytohmoty vybraných introdukovaných a pôvodných druhov v dubovohrabovom lese pri obci Báb, juhozápadné Slovensko

### Súhrn

V predkladanom článku prezentujeme údaje o rýchlosti dekompozície vybraných introdukovaných a pôvodných druhov zistených v rôznych mikrostanovištných podmienkach: na rúbanisku, lesnom okraji a v zapojenom lese. Pomocou metódy vreciek sme po dobu 324 (byliny), resp. 344 (dreviny) dní exponovali listy týchto druhov: *Ailanthus altissima*, *Robinia pseudoacacia*, *Acer campestre*, *Impatiens parviflora*, *Alliaria petiolata* a *Mercurialis perennis*. Rýchlosť dekompozície v období 1 roka bola charakterizovaná prostredníctvom 2-fázového negatívne exponenciálneho modelu. Najrýchlejšie sa rozkladá nadzemná fytohmota druhu *Impatiens parviflora* (ostalo 26% fytohmoty), pomalšie sa rozkladali druhy *Alliaria petiolata* a *Mercurialis perennis* (obidva druhy so zostatkom 29% fytohmoty). V prípade drevín bol zdokumentovaný najväčší úbytok listov *Ailanthus altissima* (ostalo 45% fytohmoty), pomalšie sa rozkladali listy druhov *Acer campestre* (63% zvyšok) a *Robinia pseudoacacia* (70% zvyšok fytohmoty). Dekompozícia celulózy významne závisela od vlastností mikrostanovišťa, pričom najväčšia bola v zapojenom lesnom poraste. Podobne prebiehala aj dekompozícia bylín, zatiaľ čo v prípade drevín nebol zaznamenaný vplyv mikrostanovištných rozdielov na priebeh dekompozície. Listy inváznych rastlín (okrem druhu *Robinia pseudoacacia*) podliehajú rýchlejšiemu rozkladu (najmä v prvej fáze, kedy je spotrebovaný materiál s vysokým obsahom dusíka), čo môže v prípade ich expanzie podstatne zlepšiť najmä dusíkový režim stanovišťa a následne zvýšiť zastúpenie nitrofilných druhov rastlín.

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## The limits of the vegetative period, defined based on daily mean temperature: a comparison of various approaches

Petr Hora<sup>1</sup>, Petr Štěpánek<sup>2</sup>

Czech Hydrometeorological Institute, Kroftova 43, 616 67 Brno, Czech Republic,

<sup>1</sup>E-mail: petr.hora@chmi.cz, <sup>2</sup>E-mail: petr.stepanek@chmi.cz

### Abstract

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The vegetative period can be defined by using daily mean temperature values. In Czech and Slovak climatological praxis, temperatures of 5 °C, 10 °C and 15 °C are used to limit different parts of the vegetative period. This article analyses and compares two basic methods for the estimation of the beginning and end date of the vegetative period: a method of consecutive days and a method operating with temperature sums. The first method works only with the number of days with a temperature above the given limit; the second examines the particular temperature values. These two methods (or three – because the first method has two variants, 6 or 5 consecutive days) were tested on a so-called technical series for 268 climatological stations of the Czech Republic and assembled during the period of 1961–2007. Also, long-term averages instead of data from particular years were utilized for analysis. ProClimDB software, which is also available in a freeware version, has been developed for all the calculations.

### Key words

air temperature, period with prevailing temperatures, phenology, vegetative period

### Introduction

The vegetative period is a basic concept used in many research fields, such as ecology, agriculture, climatology, etc. SOBÍŠEK (1993) defines it very simply as the period in which plants have optimal conditions for growth. In this context, air temperature and precipitation are the most important climatological variables. Because each plant has its own ecological demands, the vegetative period varies among individual species. The best estimation of the vegetative period is done by observing specific plants in nature. This subject of study is the research field referred to as phenology. It deals not only with the course of significant periodical repetitive life activity of plants and animals, but also investigates their dependence on manifestations such as environmental conditions, especially weather and climate (SOBÍŠEK, 1993). The practical output of this research field, in both the Czech Republic and Slovakia, was a simplified definition of the vegetative period, based

on air temperature. From this, the Czech and Slovak climatological praxis applies the terms “great vegetative period”, limited by reaching and then dropping to a daily mean temperature of 5 °C and “small (main) vegetative period”, limited by reaching and then dropping to 10 °C. “Vegetative summer” is another term that is used which refers to the start and end dates of daily mean temperatures of 15 °C. It should be noted here that researchers often avoid using the abovementioned terms and, e.g. the great vegetative period limited by the dates mentioned above is called the period with prevailing temperatures above 5 °C. The given definitions of the vegetative period (also applied in this general context on vegetative summer) are quite clear, but the problem is applying them in practice. Daily mean temperatures rarely continuously increase in spring and decrease in autumn. The more frequent case is that air temperature reaches the limit given in the definition of the vegetative period for one day, but again drops below this limit in subsequent days. The limit may only

be permanently exceeded (in the part of the year when temperatures generally rise) a very long time after the first occurrence in the year.

In the past, the delimitations of the abovementioned characteristic periods were carried out by means of dates of monthly mean air temperatures (VESECKÝ, 1961). Values were taken at the middle of a month (15<sup>th</sup> day). For the calculation, between these dates, air temperature constantly rose or fell. In this way, the annual course of air temperature was smoothed and, except in certain cases (e.g. mean monthly temperature of above 5 °C in March and below 5 °C in April), the estimation of the beginning and end date was not at all complicated. The estimation during the warmest or coldest months of a year is more problematic. When the values are assigned to the 15<sup>th</sup> day of the month, it results in the temperatures of the other days of the warmest months being underestimated and the temperatures of the other days of the coldest months being overestimated. This discrepancy leads to systematic errors in setting limits for the vegetative period. The general problem in using the monthly mean temperatures is overly-strong simplification that may result in establishing the start of the vegetative period on a day in which the air temperature was lower (or higher) than the limit required by the definition.

In literature, we often see the results of statistical processing being given without the proper description of (or reference to) the methodology. The evaluation of periods with prevailing temperatures in *Agroklimatické podmienky ČSSR* (KURPELOVÁ et al., 1975) is an example of this.

The development of computing technologies in recent years has enabled the application of more complicated methods that work straight with daily values for identifying the limits of the vegetative period.

## Material and methods

In this work, we analyse and compare two basic methods that work with daily mean temperatures to estimate the beginning and end date of the vegetative period in individual years. As mentioned above, such methods (working with daily data) could only be widely applied in recent years with the development of computers. Thanks to fast computers, it is possible to invent very sophisticated methods that fit well with processes taking place in nature. This works only as long as the vegetative period (i.e. the period in which vegetation develops) is set based on the limit value of air temperature.

We will discuss two methods in this work, one of which has two versions (modifications), so three final results will be given.

We will call the first method the method of consecutive days. This method was used e.g. in the CECILIA research project (EC 6<sup>th</sup> Framework Programme) (POK-

LADNÍKOVÁ et al., 2008). The beginning of the period commences with the first interval of at least 6 days with a daily mean temperature above the defined level. The end of the period comes with the first interval of 6 days with a daily mean temperature below the defined level. The important rule is that the beginning of the period must be in the first half of the year and the end of the period in the second half of the year. This method can be easily applied on computers but it does have some problems. In the case of a warm weather episode, the beginning of the period can occur in the early days of year (February, March), only to be followed by a drop in temperatures to low values that can last for a very long time. In praxis, this problem can be reduced if the first two months of the year are omitted from processing (the beginning of the period can start in March, at the earliest). However, this approach is rather controversial because an earlier start of the vegetative period in some years and locations cannot be considered wrong. The early end of the period in cases when temperatures temporarily drop below the limit is a similar problem. In the CECILIA project, this methodology was used only for delimitation of the great vegetative period. POKLADNÍKOVÁ et al. (2008) uses this method for determining the limits of the small vegetative period, as well. The condition of 6 consecutive days, however, seems too strong. While air temperatures around 5 °C usually occur in the parts of the year with steep temperature gradients (in the annual cycle), temperatures of 10 °C for stations with higher elevations or 15 °C generally occur in areas without such distinct gradients. For these higher limits, air temperature usually fluctuates, thereby decreasing the frequency of occurrences above the limit value. The length of the small vegetative period and vegetative summer is shorter than the great vegetative period. This fact might suggest delimiting the beginning and end of the vegetative period by only using 5 or even less consecutive days. Another problem is dating of the beginning till the end of June and the end after the beginning of July. This does not influence limits for periods with 5 °C and more, but in the case of 10 °C for stations with higher elevations and for 15 °C in general, it may not be until July that the first occurrence of 6 consecutive days occurs. In this work, it has not been our intention to shift the “middle of the year”, but, alongside 6 consecutive days, we also investigated how the results would change if only 5 consecutive days were applied (this is the second variation of the first method).

The second method discussed in this article was used e.g. in the *Climate atlas of Czechia* (TOLASZ, 2007). This method, referred to as the “sums of temperatures method” is more sophisticated than the previous one. It not only uses the days with the given temperatures, but also particular values of the temperature. The first step is the calculation of the temperature sums in the warm and cold periods (the periods with temperatures above or below the given value). The beginning of the vegetative

period is decided based on the fact that the sum of temperature differences from a given limit during cold waves is smaller than the sum calculated during warm waves from the beginning of the period. The end of the period is also estimated in a similar manner (when the sum of temperature differences from a given limit during cold waves prevails over those of warm waves). With this method, it is possible for the beginning of the period to be determined by an interval of just one day with temperature above a particular level.

Those two methods (or three – because of the two variants of the first method) were tested on a so-called technical series for 268 climatological stations in the Czech Republic in the period of 1961–2007. By a technical series, we mean a quality-controlled homogenized series with filled gaps. Details about the technical series can be found in ŠTĚPÁNEK et al. (2011), quality control and homogenization is described e.g. in ŠTĚPÁNEK et al. (2009).

The last point will discuss the long-term average of daily mean temperature as a means for simpler definition of the average beginning and end date of the vegetative period at individual stations.

This work extends the findings from previous work dealing the issue through data gained from a smaller sample of stations (HORA, 2009).

## Results

### Period with prevailing temperatures above 5 °C – beginning date

The sums of temperatures method (hereinafter referred to as TS) and the method of 6 consecutive days (CD6) give the same results (beginning date) in 49% of cases. This number is valid for all the stations in the Czech Republic; for individual areas, the same results varied from 30 to 72% within the period studied, 1961–2007. For all the stations, in 29% of cases, an earlier beginning date was estimated with the method of temperature sums as compared to the method of 6 consecutive days, a later date was estimated in the remaining 22%. The largest absolute difference between these two methods was 95 days (method TS delayed after method CD6), as opposed to, TS outrunning CD6 by 53 days, at the most. The mean absolute difference was 11 days.

Differences between the CD6 and CD5 (5 consecutive days) methods are driven by certain rules. First, CD6 cannot estimate the beginning date earlier than CD5. Second, in there were more cases with CD6 in which vegetative periods were not identified due to 6 consecutive days with the temperature above the given limit not occurring in the particular year. Nonetheless, this rule was manifested mainly for defining limits of the period with prevailing temperatures of 10 and 15 °C; in the case of the great vegetative period, this has never

happened. The same results for CD6 and CD5 were obtained in 78% of the cases for 5 °C. For individual stations, it varied from 57 to 94% of cases. For all stations, CD6 have results delayed compared to CD5 in 22% of cases. The maximum difference between the two methods was 106 days; the mean absolute difference was 5 days.

Because of the difference between CD6 and CD5, comparison results of TS with CD5 are not the same as TS with CD6. CD5 method coincides with the TS method in 48% of cases (for all stations); it varies from 19 to 66% for individual stations. The TS method shows earlier results compared to CD5 in 19% of cases, while delayed results in 33% of cases. The maximal differences between TS and CD5 are the same as for the TS and CD6 comparison: 95 days for later date applying TS and 53 days for earlier date applying TS. The mean absolute difference was 11 days.

Figure 1 shows different results for the individual methods on concrete dates, in this case, for the station Protivanov in the year 2007. The graph shows the values of the daily mean temperature from the 60<sup>th</sup> day of the year (1<sup>st</sup> March) till the 109<sup>th</sup> day (19<sup>th</sup> April). Bars relative to 5 °C are used to simplify the explanation (warmer or colder days are easily identified). The first three consecutive days in the year with an air temperature of 5 °C or more had already been recorded on 9<sup>th</sup> January. 5 consecutive days were recorded on 12<sup>th</sup> March (CD5 method). The first 6 consecutive days were recorded on 9<sup>th</sup> April (CD6). The method of temperature sums (TS) estimated the beginning of the period in a different way, as 25<sup>th</sup> March. This method, as explained above, works with temperature values of individual days and compares cold and warm waves (with regard to a limit value). In the case we are using for illustrative purposes, the 25<sup>th</sup> of March to 8<sup>th</sup> of April is an important period. Since the sum of positive deviations from the limit value of 5 °C is higher than the sum of negative deviations from the same limit (i.e. average temperature for the given period is equal or higher than 5 °C), this period is regarded as part of the vegetation period. Warm waves also occurred before the 25<sup>th</sup> March, but those warm waves were followed by “stronger” cold waves.

In previous paragraphs, we described the frequencies and the sizes of differences for individual methods and for individual years. For the average beginning dates of the great vegetative period (in the period 1961–2007), the differences are smaller. Differences for average beginning dates, a limit temperature of 5 °C, individual stations and the TS and CD6 methods are shown in Fig. 2. The maximal difference is 17 days delay, or 2 days earlier beginning date for TS compared to CD6 method. Figure 2 and those that follow depict values according to the altitude of a station in order to determine whether we can speak about results being dependent on altitude. For the limit value of 5 °C, such dependence is not evident. The average difference of the beginning

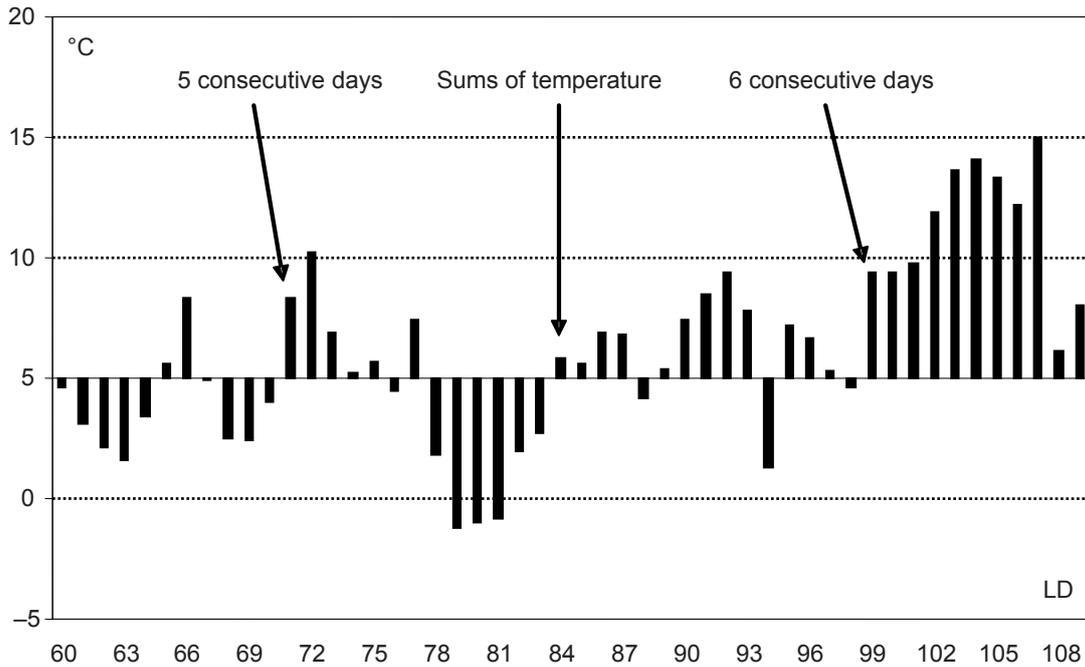


Fig. 1. Daily mean temperature in Protivanov in 2007 from March 1<sup>st</sup> to April 19<sup>th</sup> with marked delimitation of beginning date applying various methods.

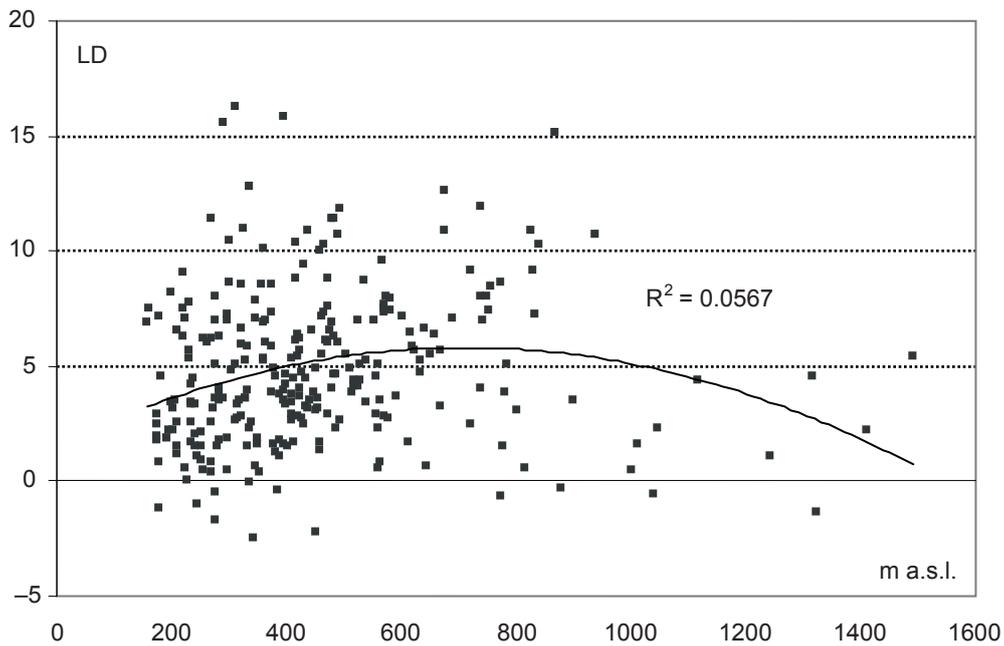


Fig. 2. Beginning of the period with prevailing temperatures 5 °C – differences between sums of temperatures and 6 consecutive days methods, polynom of 2<sup>nd</sup> degree.

date between TS and CD6 method for all stations was a 5-day delay of TS method. Compared to CD6, the CD5 method gives an earlier beginning date as well, by 5 days, but for individual station it varies from 1 to 12 days. The TS method, when compared to CD5, results in all stations having an average delay of 10 days.

#### Period with prevailing temperatures above 5 °C – end date

The results of the TS and CD6 method coincide in the end date timing for 5 °C in 50% of cases; from 28 to 72% for individual stations. In 38% of cases, earlier

date of end is given by TS method, in 12% cases by CD6 method. The largest absolute difference between the two methods was 103 days of delay of TS after CD6 method; on the contrary, an earlier end date using TS, as opposed to the CD6 method, was at most, 54 days. The mean absolute difference was 6 days.

The results of the CD6 and CD5 methods coincide in 83% of cases. The rest (17%) belong to later end of period in CD6. For individual stations, the same results agree in 72 to 96% of cases. The maximal difference is 108 days – delay of CD6 method after CD5, the mean absolute difference is 3 days.

The TS method coincides with CD5 in 51% of cases; from 34 to 68% of cases for individual stations. In 29% of cases earlier end date is given by TS method, while in 20% of cases by CD5 method. The maximal difference between the methods was 108 days of delay and a 40-day earlier end date with TS. The mean absolute difference was 7 days.

For average end dates of the great vegetative period (in the period 1961–2007), the differences in the results when using the various methods are smaller than in the case with the beginning date. The differences in results for TS and CD6 are shown in Fig. 3. With this, we can start to consider that the results do depend on the altitude. For stations with lower altitudes, the TS and CD6 methods give a difference of 4 days (both earlier and delayed date) for individual stations. For stations with higher altitudes, the end date estimated by TS is later than that given with using the CD6 method, by a maximum of 11 days. In an average of all stations, the difference between the two methods is zero. The CD6 method is delayed after CD5 for individual stations

from 1 to 9 days; by 3 days in an average of all stations. Then in an average of all stations, the TS method is delayed by 3 days when compared to CD5.

### Length and other characteristics of period with prevailing temperatures above 5 °C

The various beginning and end dates given by the methods is reflected in the various lengths of vegetative periods. In an average of all stations, the great vegetative period given by the TS method is shorter by 5 days compared to those given when using the CD6 method and by 7 days compared to those given when using CD5. For individual stations large variability is seen in the results for individual stations: in stations with lower altitudes, a shorter period is prevalent when the TS method is employed, by up to 18 days. For colder stations, this difference changes, and in an extreme example, the length of the vegetative period estimated by TS was longer by 8 days compared to CD6.

We showed earlier that different methods often give different results. In regard to average results for the period 1961–2007, discrepancies are somewhat suppressed. This was valid for the delimitation of the beginning and end date of the vegetative period. The question is whether it is also valid for other characteristics, like the sum of temperatures over a period, precipitation total, etc. We will not be discussing such characteristics in this article but we do need to make a few comments related to this. The influence of the period length on some of the characteristics is straightforward: a longer period given by one of the methods also means that the sums of temperature or precipitation sums will

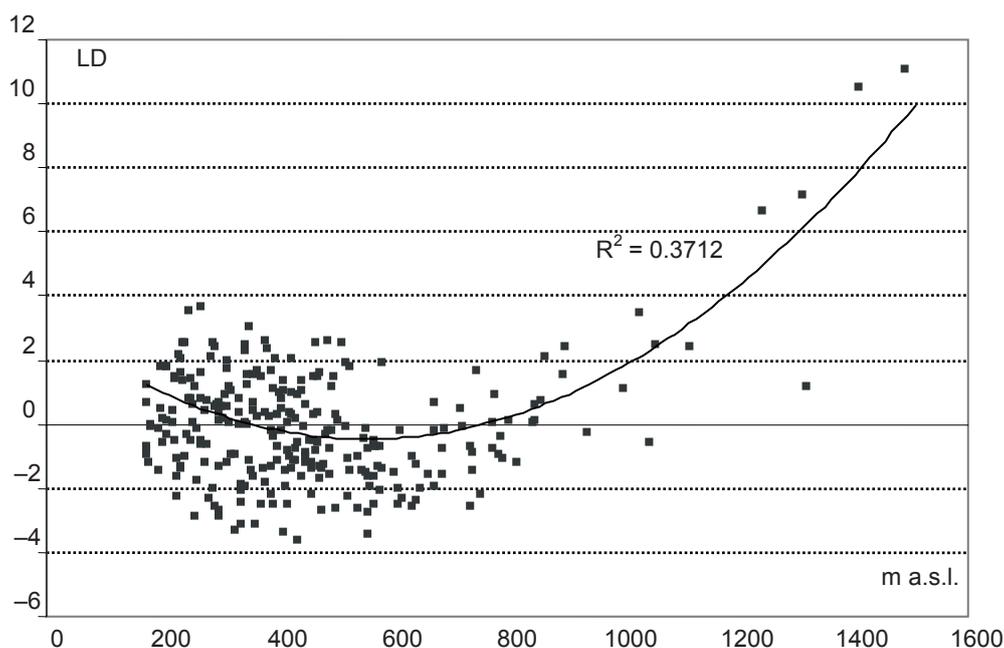


Fig. 3. End of the period with prevailing temperatures 5 °C – differences between sums of temperatures and 6 consecutive days methods, polynomial of 2<sup>nd</sup> degree.

increase. But average temperatures, for instance, can behave in another way: the average temperature is supposed to be lower over longer periods – since the methods differ in those parts of a year with cold days. It is a more complicated case when the TS method gives the same results for the length of a vegetative period as the CD6 (or CD5) method. In the case of different dates for the beginning and end of the period, then it always holds true that the temperature sums according to the TS method are bigger than the temperature sums for the period estimated by CD6 (or CD5). The explanation for this is that the TS method (method of temperature sums) does not exclude any warm wave and omit colder waves, while the CD method does not work with temperature values themselves, it just estimates the period with a temperature over or below a limit value. Into such a period, the CD method then simply also includes the cold waves and omits the warm waves.

#### Period with prevailing temperatures above 10 °C

The consecutive days (CD) method was used within the CECILIA project only for the delimitation of the great vegetative period. For its application to the small vegetative period or the vegetative summer (i.e. higher limit values), the usage of this method without any deep analysis is questionable. The problem with higher limits is that, with more and more years, it is not possible to find a given number of consecutive days. In regard to periods with prevailing temperatures above 10 °C, while it was not possible to delimit the vegetative period using the CD6 method in 74 out of all 12,596 cases (15 stations out of all 268 stations), with CD5, it was not

possible in only 34 cases (9 stations). The TS method does not put any limitation constraints on the number of days (just one day is sufficient) and, in this case, the small vegetative period was able to be estimated in all cases.

Very shortly, we will mention the percentage of cases in which the methods give the same results. For the timing of the beginning date of the small vegetative period, the results coincide in 57% of the cases for TS and CD6 and in 56% for TS and CD5. CD6 and CD5 coincide in 82% of cases. Dependence on altitude is evident in the results (see Fig. 4). In the average results for stations up to 900 m a.s.l. in the period 1961–2007, the TS method gives a 3-day earlier beginning date to a 9-day later date compared to CD6. For the coldest stations, the TS method shows noticeably later dates than the CD6 method. The explanation is simple: colder years are not included in the CD6 calculation, since the given number of consecutive days was not reached. The results of CD6 are delayed by 0 to 8 days after those of CD5.

Similar results are obtained for dating the end date of a period with prevailing temperatures above 10 °C. The TS method coincides with CD6 in 54% of cases and with CD5 in 55% of cases. CD6 and CD5 coincide in 81% of cases. For average results in lower altitudes, TS and CD6 results are similar (maximal difference is 4 days, for both earlier and later days). For higher altitudes, TS method again delays the end date compared to CD6 method (see Fig. 5). CD6 results show delays of 0 to 13 days (more on stations with higher altitudes) compared to those of CD5.

The length of the small vegetative period is usually shorter by a few days for TS than for CD6 and for

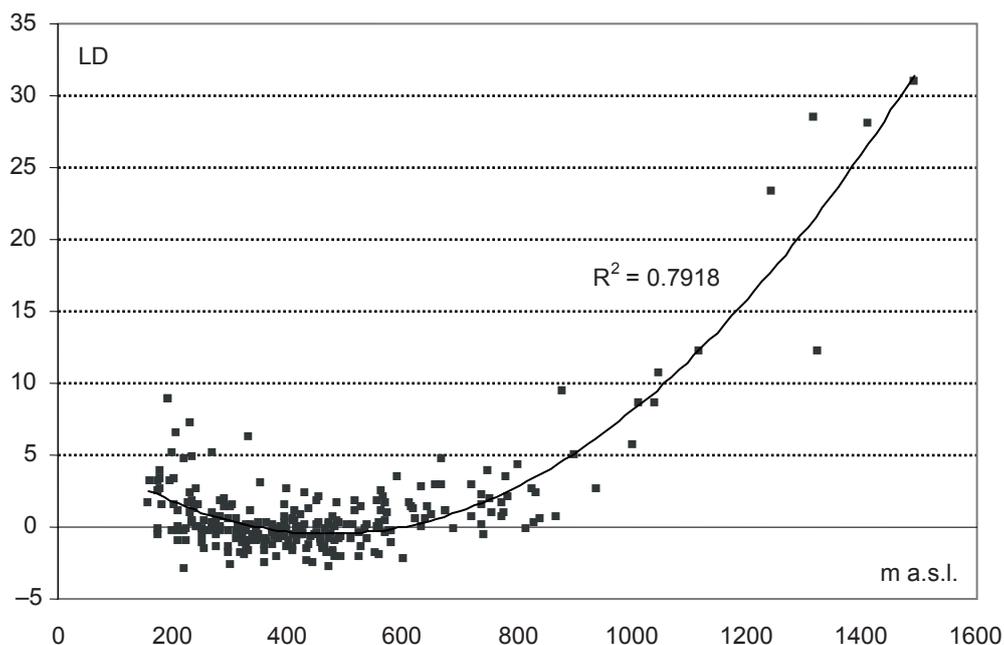


Fig. 4. Beginning of the period with prevailing temperatures 10 °C – differences between sums of temperatures and 6 consecutive days methods, polynomial of 2<sup>nd</sup> degree.

stations with lower elevations. For higher altitudes, it was the opposite. It is needed to make a remark to these results that in case that the period was not estimated by the method, its length was set to zero.

### Period with prevailing temperatures above 15 °C

In the estimation of the vegetative summer, the CD methods face considerable difficulties. For stations with higher elevations, the cases in which a number of 5 or 6 consecutive days is not found is very high: 1,844 cases (15% of all cases) for CD6 and 1,074 cases for CD5. Vegetation summer was able to be established for only 32 stations in all the years between 1961 and 2007 in the case of CD6 method. In the case of CD5 it was 105 stations (out of 268 stations). With the TS methods (where one day with air temperature of 15 °C or more is sufficient), there was only one case in the entire period of 1961–2007 when it was not possible to estimate vegetation summer.

The same beginning date is found with both the TS and CD6 methods in 37% of the cases, with TS and CD5 in 36% of the cases, and with CD6 and CD5 in 75% of the cases. For average results for the period 1961–2007, in comparison to CD6, TS shows delayed beginning dates of the vegetative summer: from 0 days for lower stations and up to 40 days for mountainous stations (see Fig. 6). CD6 method results are also delayed in comparison to those of CD5, but here it is caused by a higher number of cases in which it was not possible to estimate the vegetative summer.

For the end date estimation, TS coincides with CD6 in 31% of the cases, TS and CD5 in 29% of the

cases and CD6 and CD5 in 75% of the cases. For average results, in comparison to CD6, TS is delayed up to 24 days for mountainous stations, but for some lowland stations, TS is up to 3 days earlier (see Fig. 7).

In comparison to CD6, TS methods results give the length of vegetative summer shorter by several days for lowland stations. With increasing altitude, this quickly changes, and TS estimates a longer vegetative summer than CD6 for most of the stations (thanks to the fact that the length of the vegetative summer is often zero).

### Utilization of long-term averages for the calculation

The last point discussed in this article is the testing of the utilization of long-term averages (1961–2007), i.e. daily normals, for vegetative period dating. In such data, air temperature rises and drops relatively smoothly within a year, and so therefore, the difference in results of various methods should not be as noticeable. This presumption proved true in 85% of the cases in a comparison of the TS method with the CD6 method. In the rest, the maximum difference was 13 days.

If we compare the differences between the individual years and results obtained from long-term averages (daily normals) within the individual methods, we find quite big differences. Generally, the TS method shows smaller differences than CD6 or CD5. Differences in results are least for setting the limits for the period with prevailing temperatures above 5 °C, larger for 10 °C and the largest for 15 °C. For example, with the TS method, temperatures above 5 °C and the beginning date, the maximum difference is 12 days earlier and 6 days later for the daily normals method compared to individual years.

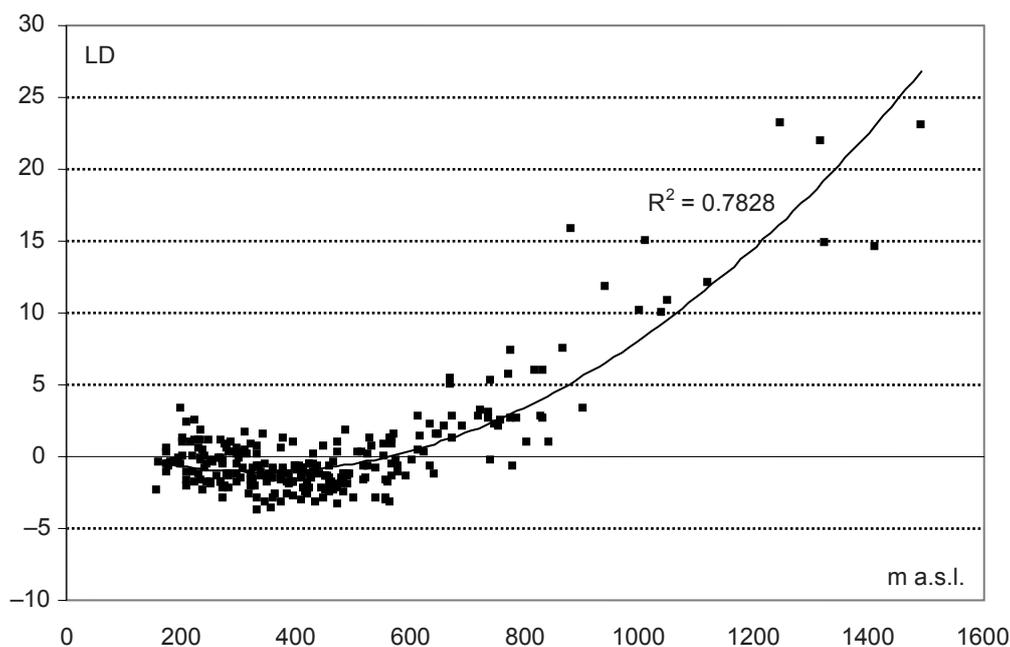


Fig. 5. End of the period with prevailing temperatures 10 °C – differences between sums of temperatures and 6 consecutive days methods, polynomial of 2<sup>nd</sup> degree.

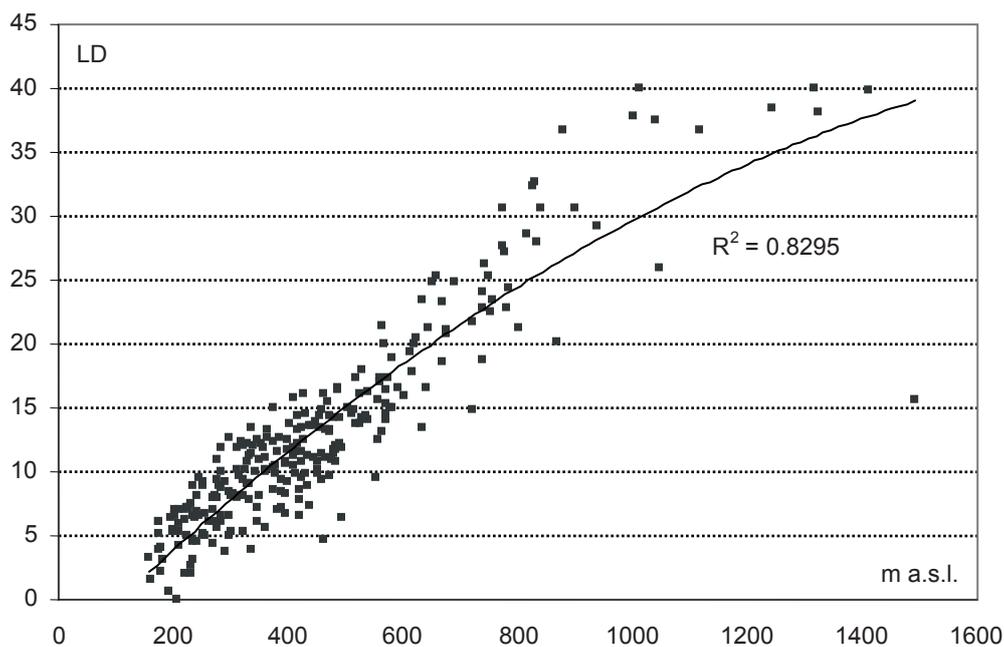


Fig. 6. Beginning of the period with prevailing temperatures 15 °C – differences between sums of temperatures and 6 consecutive days methods, polynomial of 2<sup>nd</sup> degree.

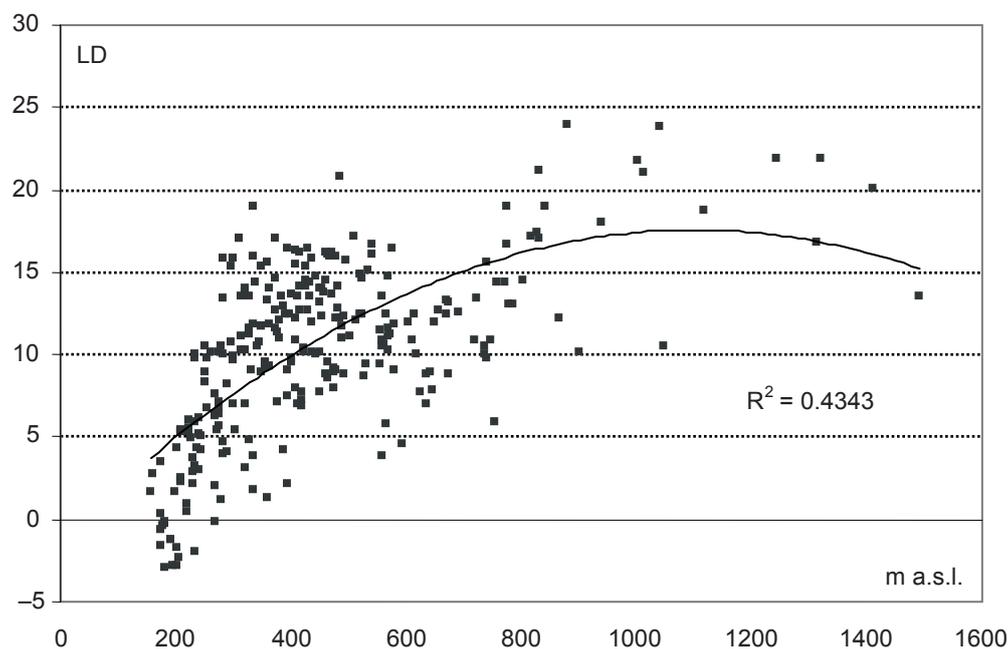


Fig. 7. End of the period with prevailing temperatures 15 °C – differences between sums of temperatures and 6 consecutive days methods, polynomial of 2<sup>nd</sup> degree.

## Conclusions

In this work, our aim was to test various methods of dating the vegetative period: a method using temperature sums (TS) and a method using consecutive days (CD6

or CD5). The differences in results obtained by these various methods for various limit values (periods with prevailing temperatures of 5, 10 and 15 °C) were studied on a large dataset of 268 technical series created for the Czech Republic. The percentage in which the results

were the same is about 50%, but in individual cases, the differences can be quite huge. The problem with the CD methods is that they may give the start date of a vegetative period in winter after a short thaw; on the contrary, in cases when temperatures fluctuate around 5 °C, the estimate for the beginning date can be very late. Similar problems are faced for the estimation of the end date of the vegetative period. Unlike the TS method, the CD method has another methodological problem and this is the utilization of a “half year”, which is set to the end of June. It would be possible to set it to late July, but the fact is that the warmest days of a year can occur in a longer time span. The CD method was unable to estimate the vegetative period in some years (because of 6 or 5 successive days being a condition), while with the use of the TS method, small vegetative periods and even the vegetative summer were found to be longer than 100 days.

Utilization of daily normals (long-term averages) for delimitation of the vegetative period lead to different results compared to calculations for individual years. Thus, such simplification should be only applied with caution.

All the calculations for such a huge dataset were obtained through the use of ProClimDB software (ŠTĚPÁNEK, 2008), which is available on the Internet.

### Acknowledgement

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## Vymezení vegetačního období podle průměrných denních teplot vzduchu

### Súhrn

K vymezení vegetačního období se často využívá zjednodušeného přístupu pracujícího s průměrnými denními teplotami vzduchu. Velké vegetační období, malé vegetační období a vegetační léto je vymezeno pomocí teplot vzduchu 5, 10 a 15 °C. Samotné vymezení jednotlivých období je ale s ohledem na časté kolísání teploty vzduchu velkým problémem. Předkládaný příspěvek analyzuje a srovnává dvě různé metody určení nástupu a konce

vegetačních období. První z nich je metoda sousedících dnů, kdy se za začátek období bere výskyt prvních n-dní následujících za sebou s teplotou vzduchu rovnou a vyšší teplotě hledaného období. Většinou se pracuje s 5 či 6 dny. Konec období se vyhledá podobně při výskytu n-dní s teplotou nižší než je teplota vymezující hledané období. Druhý přístup je velmi odlišný. Metoda teplotních sum pracuje s konkrétními hodnotami teploty vzduchu a srovnává teplé a chladné vlny (dny s teplotou nad a pod hraniční hodnotou) mezi sebou. Tato druhá metoda se může právem označit jako vynikající metoda sloužící k vymezení období s převládajícími teplotami.

Na datovém materiálu 268 stanic České republiky za období 1961–2007 byly porovnány výsledky jednotlivých metod. Bylo zjištěno, že metoda 6, respektive 5 sousedících dnů a metoda teplotních sum dávají stejné výsledky zhruba v 50 % případů (u teplot 15 °C to bylo méně). Extrémní rozdíly dosahovaly až 100 dní. V dlouhodobých průměrech se rozdíly zmenší, ale jen výjimečně jsou nulové.

Rovněž byla otestována možnost vyhledávání vegetačních období pomocí dlouhodobých hodnot teploty vzduchu. I zde bylo prokázáno, že tento přístup neposkytuje kompatibilní výsledky s přístupem pracujícím s daty jednotlivých let.

Cílem článku bylo, vedle přehledného popisu jednotlivých metod vymezení vegetačních období, ukázat, že různé způsoby hledání téhož mohou a dávají různé výsledky. Tuto skutečnost je nutno respektovat v jakémkoli vědeckém bádání a nedopouštět se případných omylů srovnáváním nesrovnatelného.

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## Response of walking spruce bark beetles *Ips typographus* to host odours

Rastislav Jakuš, Miroslav Blaženec

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen,  
Slovak Republic, E-mail: jakus@savzv.sk

### Abstract

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A two-choice walking bioassay olfactometer was used to assess the response of walking *Ips typographus* (L.) towards the odours from logs of Norway spruce (*Picea abies* [L.] Karst.) subjected to various treatments. The odour coming from fresh log from standing, unstressed trunk was unattractive or slightly repellent to males over clean air in bioassay. The same odour was neutral or slightly attractive to females. Storing of a log for one month led to increased attractiveness to both sexes. The odour from log after bark beetle breeding was slightly more attractive to both sexes over clean air, excepting very low level of source contact in males. Results on overall attraction are more unclear for females. The level of source contact was the main difference between the males and females. The females manifested higher levels of source contact than males.

### Key words

*Ips typographus*, Norway spruce, primary attraction

### Introduction

Two general theories were used to explain the host searching strategies in bark beetles. Pioneer beetles are either attracted to find susceptible hosts in response to olfactory stimuli from stressed trees (primary attraction), or they land on trees at random and select the tree to attack in response to gustatory stimuli (RUDINSKY, 1962; WOOD, 1982; GRIES et al., 1989; BYERS, 1996). Both ways of host location can be seen as subsequent steps after habitat (stand) selection, a behaviour which is likely a balance of positive input from host (conifer) kairomone and negative input from non-host (angiosperm broad-leaves) volatiles, NHV (ZHANG and SCHLYTER, 2004). FÜHRER et al. (1997) demonstrated that attacks of *I. typographus* occur on vigorously growing trees suffering seriously from a sudden stress. In endemic conditions, *I. typographus* utilises downed trees (JAKUŠ, 1995). According to RAFFA et al. (2008), the tree-killing bark beetle species display flexible host-selection strategies. When the populations are low, avoiding healthy trees is adaptive. Vigorous trees pose a risk to beetles because of their superior defence. Physiologically compromised trees pose less risk, but are sparsely distributed in space,

ephemeral in time, and nutritionally suboptimal. In the first stage of the outbreak in mountainous conditions (incipient epidemic population), *I. typographus* utilises predominantly wind thrown trees – mostly on fresh forest edges (spot initialisation), like in endemic conditions. Once populations increase, the discriminating behaviour becomes less adaptive because of the greater likelihood of recruiting enough beetles to overcome healthy trees. Once beetles have successfully killed a tree, because of low tree resistance and/or high beetle population, they may rapidly switch to the closest trees (ANDERBRANT et al., 1988). Such trees may likely become foci of aggregation and could be killed regardless of their resistance level. Originally vigorous trees provide a largely vacant resource, and in general they are the most suitable nutritionally for the beetles – because of their thick phloem. The beetles are more likely to attack trees adjacent to the already initialized spots (JAKUŠ et al., 2003).

In Norway spruce (*Picea abies* [L.] Karst.), it appears that disturbances of the water balance or storing of cut log per se bring about the emanation of volatile substances to which *I. typographus* (L.) shows olfactory responses (MERKER, 1956). Most of the European entomologists state that these materials are not known

(RUDINSKY, 1962). Mathematical simulations showed that in random search, maintenance of the population required a flight capacity, population size, and host tree abundance which are unlikely to occur at sub-outbreak levels in nature (GRIES et al., 1989). The aim of this study is to test the response of *I. typographus* to various host odours in a laboratory bioassay.

## Material and methods

### Plant material

Five logs were cut from middle parts of trunks of two Norway spruce trees from Romefåsen in southern Sweden. The trees were dominant ones in an about 50-year-old commercial spruce plantation. The diameter at breast height was about 20 cm. The trunk was sawn into logs 20 cm high. Each log was packed into a polyethylene bag. Both ends of the logs were sealed with paraffin. The logs had diameter about 15 cm. The first pair of logs was cut one month before the experiment (May) and stored at +4 °C. The first log (Nr. 1) had an undamaged surface, while the second one (Nr. 2) was cut with a knife. About 10 strips about 1 cm wide and 10 cm long were peeled from the bark surface to allow free release of volatiles. The second pair of logs was tested immediately after the cutting (June). Log Nr. 3 was used as undamaged and log Nr. 4. as cut in the similar way as the stored logs (Nr. 2). The log Nr. 5 was a log after bark beetle breeding, coming from the continuous bark beetle culture.

### Animals

The beetles were provided from a continuous laboratory culture on natural material in Alnarp as described earlier (ANDERBRANT et al., 1985 and SCHLYTER and ANDERBRANT, 1993). For bioassays, the beetles were collected every 12 hours and stored immediately at 98% relative humidity, +4 °C, in plastic cups with pieces of towel paper, exposed in a flight chamber (SCHLYTER and LÖFQUIST, 1986) for periods of 48 hours. Then they were sex-separated (SCHLYTER and CEDERHOLM, 1981). Five groups of males and five groups of females were used in the experiment. Each group consisted of 15 beetles.

### Bioassay

The results reported here concern the use of a two-choice walking bioassay olfactometer in June. The two-choice walking bioassay olfactometer was made by adaptation of an open area walking bioassay olfactometer. Earlier pilot studies with an open area walking bioassay olfactometer (BYERS and WOOD, 1981) could not be considered as valid because of low male response to the attractants (SCHLYTER et al., 1995). This bioassay is modified for an open area walking bioassay olfactometer (SCHLYTER

et al., 1995). It includes a two-choice platform (Fig. 1), two glass stimulus containers, plastic tubes and glass joints. The new two-choice platform was made of 5 mm bright and 3 cm high plastic walls. In order to achieve uniform light conditions, it was covered by transparent plastic plate covered by white paper. Each glass stimulus containers had a volume of 3 l. The experiments were performed in an environmental chamber at 22–23 °C. The air used in treatment and control, was drawn from an environmental chamber into a charcoal filter, through stimulus containers, through plastic tubes and was exhausted in glass tubes at bioassay. The balance of flows in treatment and control was controlled by flowmeters. The wind speed was about 1 m s<sup>-1</sup>. The approximately laminar flow of the pure air was due to charcoal filtering of reduced-pressure compressed air let into baffle with spaced 2 mm holes. The complete two choices platform and plastic tubes were washed in 96% ethanol before each series of tests. Glass stimulus containers were washed in ethanol and heated to 150 °C. Paper parts were replaced. A mix of synthetic pheromone components, MB & cV at ratio 150 : 1 were used as a neat solution evaporating from 50 µl Microcaps ® (Inner Ø 0.80 mm). The release rate (g min<sup>-1</sup>) was estimated based on the retreat of meniscus over time (1.7 × 10<sup>-6</sup>).

### Test procedure

One hour before the experiment, the beetles were placed in an experimental chamber in plastic Petri dishes with wet filtering paper. In the test, the beetles were released in groups in centre of the area opposite to the odour source (Fig. 1). Then, the platform was covered with a plastic cover. The duration of test was 10 minutes. The beetles leaving the platform at the part belonging to treatment or control were collected and counted. At the end of the test, the beetles in different parts of the apparatus were counted. The beetles reaching the line of the middle wall were scored as responding. The contact of beetles with the odour source was considered as source contact. When all the groups were tested, the bioassay was washed. Then all the groups of separate sexes were joined together and tested on clean bioassays.

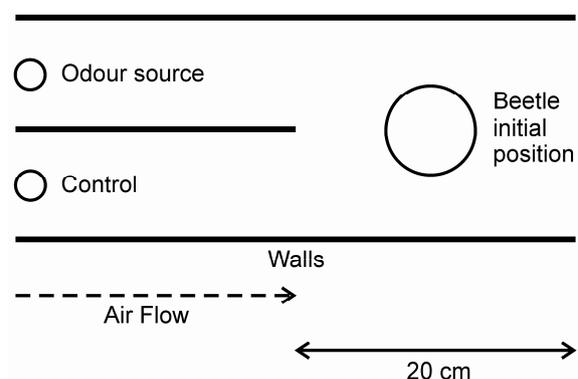


Fig. 1. Two-choices platform.

## Statistics

The following indices were used to quantify the response: The percentage of responding beetles preferring the treatment (% T), calculated as  $\% T = (T/(T+C)) \times 100$ , where T = number of beetles responding to treatment and C = number of beetles responding to control. The percent of beetles contacted the odour source (% SC) calculated as  $\% SC = (TSC/(TO + CO)) \times 100$ , where TSC = source contact at treatment, TO = number of beetles leaving platform at treatment part, CO = number of beetles leaving platform at control part.

Statistical analysis of these indices was done by a parametric test (ANOVA) and Duncan's multiple range test of arcsin  $p^{0.5}$  transformed data (SPSS/PC procedure ONEWAY).

In order to compare the treatment and control at separate runs of tests, the following indexes were calculated:  $\% T$ ,  $\% C = (C/(T+C)) \times 100$ ,  $\% SC$ ,  $\% SC - C = SC = (CSc/(TO + CO)) \times 100$ , where CSc = source contact at control. These indices were tested by paired t-test of arcsin  $p^{0.5}$  transformed data (SPSS/PC procedure t-test).

## Results

The results are shown in Figs 2, 3, 4, 5. The males responded more significantly to stored and damaged log with or without pheromone than to the control (Fig. 2).

The stored and damaged log without pheromone showed a slightly higher attraction than stored and damaged log with pheromone (Figs 2, 3). The lowest response was to the fresh log. The difference between the damaged stored log and the fresh log was statistically significant. The response to the fresh undamaged log was slightly lower than to a blank. The response and the percentage of source contact were lower in the fresh undamaged log than in the fresh damaged log. The percentage of source contact to the fresh damaged log was slightly higher than to the pheromone, to the stored damaged log with pheromone and to the stored log. A log after breeding (old) showed higher response than the fresh log. The percentage of source contact was the lowest at the log after breeding.

The females were significantly more attracted by stored and damaged logs with or without the pheromone than by the blank (Figs 4, 5). The stored and damaged log with the pheromone showed slightly higher attraction than the stored and damaged log without the pheromone. In the case of source contact, the pheromone alone was slightly less attractive than the stored log without or with pheromone. The females responded significantly less to the fresh log than to the control (pairs treatment and control; Fig. 4). The lowest response was in case of the fresh damaged log. The difference between the stored and damaged logs and the damaged fresh log was statistically significant. The response in case of the fresh damaged log was slightly lower than to the blank (clear air in both parts of platform). The response and

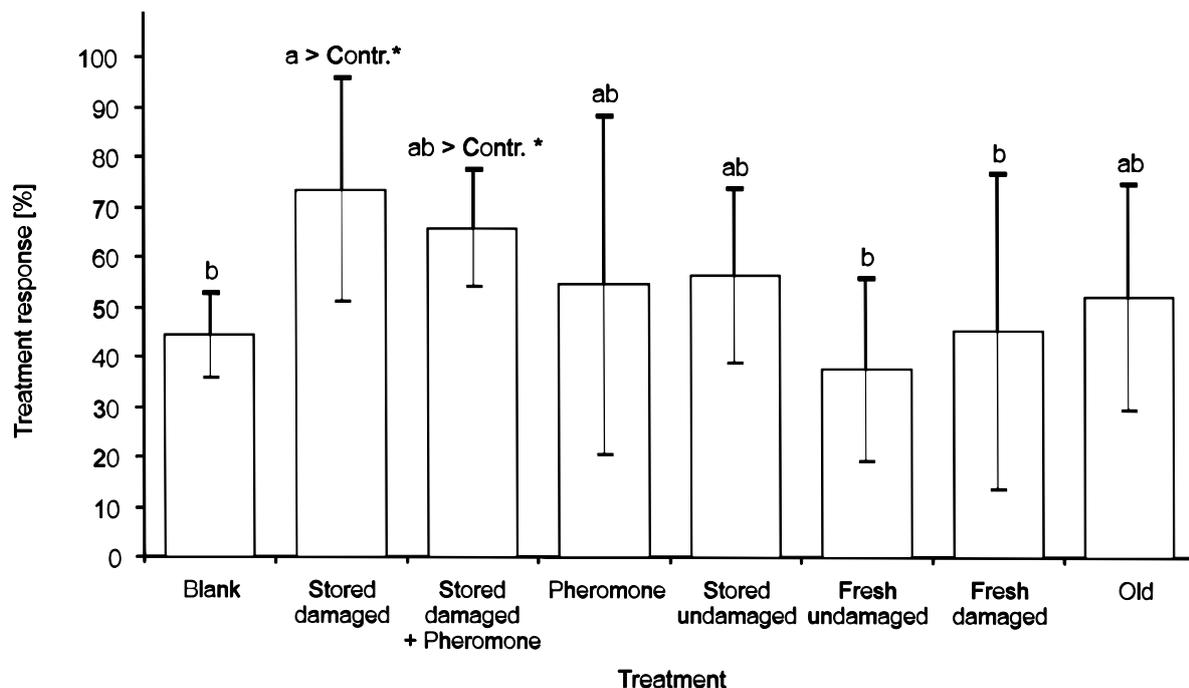


Fig. 2. Response of males to logs. Bars (+ standard error) with the same letters are not different by Duncan's multiple range test. ">Contr.\*" denotes pairs treatment and control statistically different by t-test at  $P = 0.05$ .

the percentage of source contact were lower at the fresh damaged log than the fresh undamaged log. The log after breeding (old) showed higher attractiveness than

the fresh damaged log and lower attractiveness than the fresh undamaged log.

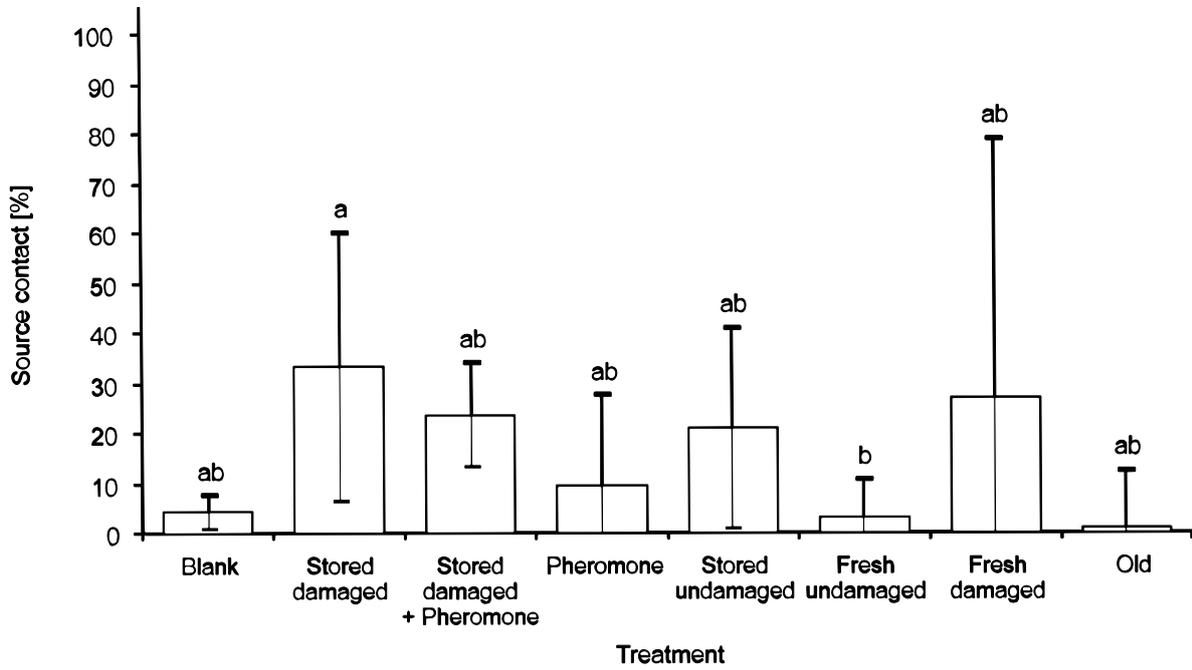


Fig. 3. Percentage of source contact of males to logs. Bars (+ standard error) with the same letters are not different by Duncan's multiple range test.

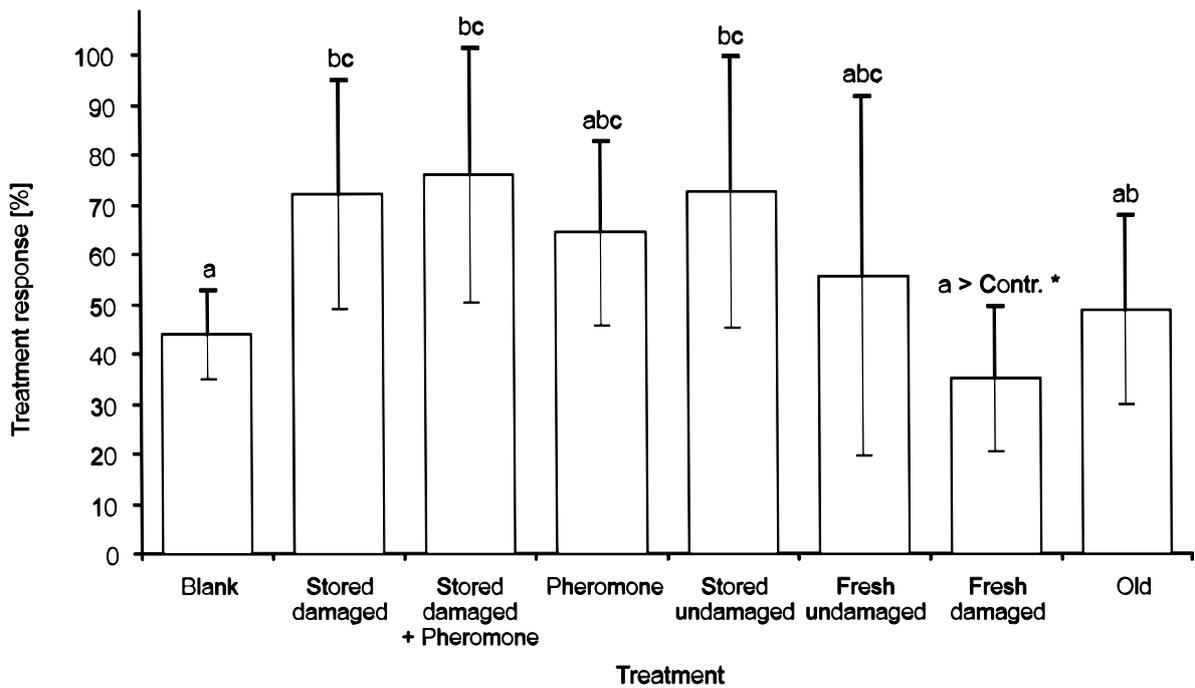


Fig. 4. Response of females to logs. Bars (+ standard error) with the same letters are not different by Duncan's multiple range test. "a > Contr. \*" denotes pairs treatment and control statistically different by t-test at P = 0.05.

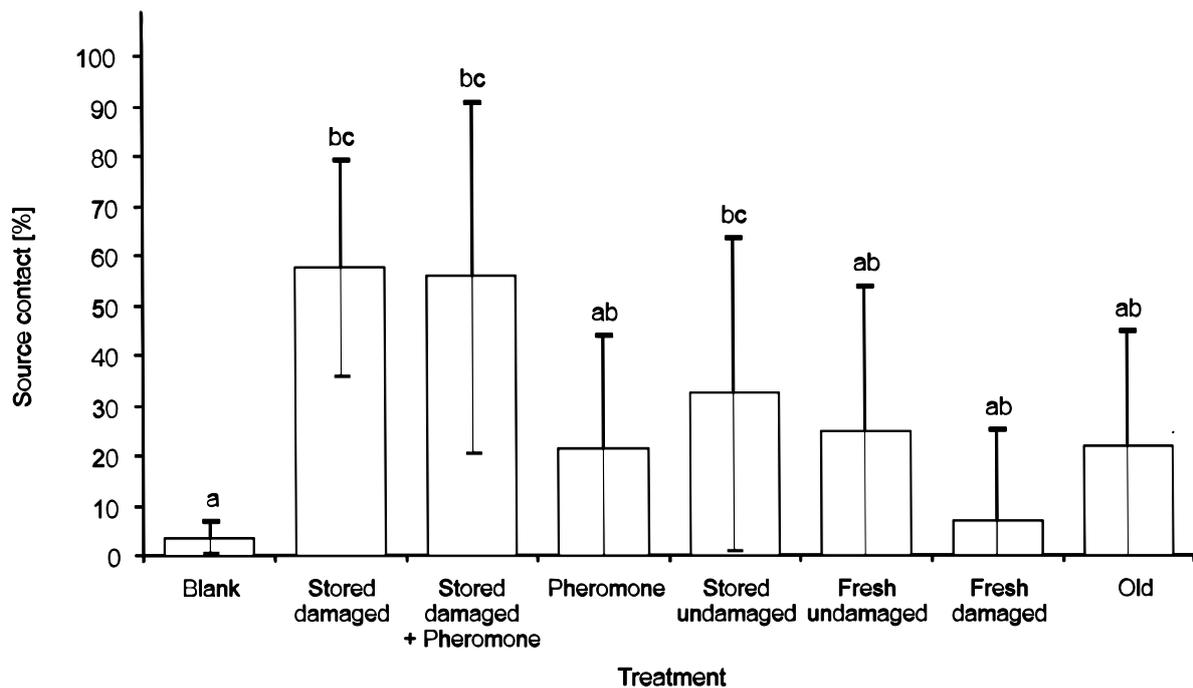


Fig. 5. Percentage of source contact of females to logs. Bars (+ standard error) with the same letters are not different by Duncan's multiple range test.

## Discussion

The results show, that the odour coming from a standing, unstressed trunk (fresh log) was unattractive or slightly repellent to males in the bioassay. The same odour was neutral or slightly attractive to females. Mechanical damage to standing, unstressed trunk (damaged fresh log) led to a slight increase of attraction in males and to repellence in females. Storing of log for one month increased attractiveness for both sexes. The damaged stored log was slightly more attractive than the undamaged to both sexes. The stored log simulates a trap tree or a downed tree.

According to MERKER (1956), healthy turgid trees are low attractive or repellent to *I. typographus*. GOSSENAUER-MAROHN (1988) showed that the odour from a fresh cut log is not statistically significantly attractive to walking *I. typographus* in bioassay. Our results are in agreement with both of these authors. The avoidance of healthy conifers by bark beetles is also shown by FÜHRER et al. (1997) and RAFFA et al. (2008).

Damaging of relatively fresh spruce logs led to increased number of bark beetle attacks (JOHANN, 1986a). At our bioassay, damaging of the fresh log caused a slight increase of attraction to males. The observed repellence to females is not in disagreement with the JOHANN's findings (1986a).

Cut spruce trunks are attacked by bark beetles after 6–8 weeks. This traditional forestry knowledge is the background for the method of trap trees (JOHANN,

1986a). The odour from the stored log was attractive to both sexes in our bioassay. Damage to the stored log led to a slight increase of attraction to both sexes. JOHANN (1986a) showed that damage to a stored log led to decreased number of bark beetle attacks. This disagreement with our results may be explained by possible different timing of experiments.

The odour from the log after bark beetle breeding was slightly attractive to both sexes, with very low level of source contact of males. This positive response may be explained either by habitat preference of bark beetles or by trace of pheromone remains. The odour from the old log was more attractive than the clear air.

A synthetic pheromone alone is several times more attractive than spruce logs in field conditions (BAKKE, 1977). Several authors (BAKKE 1970, 1977; RUDINSKY et al., 1971; ŠVIHRA, 1972) showed several times higher levels of *I. typographus* attraction to bark-beetle-invaded logs than to logs alone in field conditions. Much higher attraction than pheromone or than spruce log separately was achieved with the combination of fresh logs or logging debris with a synthetic pheromone (AUSTRARA et al., 1986; JOHANN 1986a, 1986b). The relative disagreement of results from our bioassay with the results from field experiments could be explained by the differences in the odour situation between the bioassay and a field conditions. In case of bioassay, the atmosphere and the control were a clean air. The atmosphere of spruce forest contains monoterpenes in considerable concentrations (STEINBRECHER et al., 1990).

The catches of *I. typographus* are the highest in pheromone traps placed in clearcut areas in spruce forests logged in the previous winter and gradually drop with the time after the felling. Agricultural areas manifested the lowest catches (BAKKE 1985; SANDERS 1987). These findings are in agreement with our results. In case of a pheromone trap situated on a clear-cut in spruce forest logged the previous winter, flying beetles are probably exposed to an odour similar to the odour coming from a stored log combined with pheromone odour in a bioassay. The response of a flying bark beetle to a pheromone trap in agricultural land is similar to the response to an odour coming from a pheromone source in a bioassay. The concentration of primary attractants in suitable spruce forest air is probably much higher than the concentration of secondary pheromones. *I. typographus* probably needs primary attractants mainly for habitat selection and attraction of pioneer beetles. Therefore, the mixture of primary and secondary attractants and avoidance of NHV (ZHANG and SCHLYTER, 2004) leads to colonization of a particular host substrate. The pheromone alone provides beetles with confusing information.

The catches of *I. typographus* are relatively low in old clear-cuts (BAKKE, 1985) or in pheromone traps near to old dry spruce log (JOHANN, 1986b). Our results from testing the odour of the old log formerly colonised by bark beetles correspond with the previous results. A slightly higher response of males to odour coming from the old log may be explained as the habitat selection.

The level of the source contact was the main difference between the males and females. The females displayed higher level of source contact than males. Males are a pioneering sex, they need to find a suitable site for a nuptial chamber. A male needs semiochemicals for broader orientation. A female needs to find a gallery to enter. The higher level of female source contact perhaps suggests that the females are orienting towards short-range chemical signals released by males at the entrance holes (PAYTNER et al., 1990). The response of males to the damaged stored log was slightly higher than to the damaged stored log with pheromone. On the other hand, the response of females to the damaged stored log was slightly lower than to the damaged stored log with pheromone. This difference could be explained by the difference in behaviour of pioneer males and females searching for galleries with males.

## Conclusions

The odour coming from a fresh log was unattractive or slightly repellent to males over a clear air in the bioassay. Storing of the log for one month led to increased attractiveness for both sexes. The odour from a log after bark beetle breeding was slightly attractive to both sexes over clear air. The level of source contact was the

main difference between the males and females. The females had higher level of source contact than males.

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## **Reakcia lezúceho lykožrúta smrekového *Ips typographus* (L.) na vône šíriace sa od hostiteľa**

### **Súhrn**

Pomocou dvojcestného rozhodovacieho olfaktometra sme skúmali reakciu lezúceho lykožrúta smrekového *Ips typographus* (L.) na vône z rôzne pripravených a upravených sekcií kmeňa smreka (*Picea abies* [L.] Karst.). Vôňa čerstvej sekcie zo zdravého smreka bola neatraktívna, alebo až mierne repelentná pre samcov. Tá istá vôňa bola neutrálna, alebo mierne atraktívna pre samičky. Vôňa zo sekcie kmeňa, skladovanej jeden mesiac, bola atraktívna pre obe pohlavia. Vôňa z kmeňa po skončení vývoja lykožrúta smrekového bola atraktívnejšia ako čistý vzduch. Výsledky pre samičky boli menej jasné. Hlavným rozdielom medzi samcami a samičkami bol výrazne väčší kontakt samičiek so zdrojom vône.

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## Use of anti-attractants in specific conditions of protected areas

Rastislav Jakuš<sup>1</sup>, Miroslav Blaženec<sup>1</sup>, Oldřich Vojtěch<sup>2</sup>

<sup>1</sup>Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,  
E-mail: jakus@savzv.sk

<sup>2</sup>National Park Šumava, Sušická 399, 341 92 Kašperské Hory, Czech Republic

### Abstract

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Tests for protection of spruce forest stands against spruce bark beetle (*Ips typographus*) by using anti-attractants were performed in specific conditions of protected areas in which standard sanitary cutting is not allowed. The experiments have shown that application of anti-attractants in a no-cutting zone can significantly reduce bark beetle attacks on the standing trees. In case when the trees at stand edges are not damaged by wind, there is possible to reduce the tree mortality by up to 73%, even in case of large bark beetle populations and even in living green trees growing immediately next to trees attacked by spruce bark beetle. On the other hand, anti-attractants are ineffective at stand edge segments either damaged by freshly wind-thrown or broken trees or wedged with wind-thrown areas, as it was shown in semi-application tests in the NP Šumava.

### Key words

anti-attractants, *Ips typographus*, Norway spruce

### Introduction

Protection of spruce stands edges against attacks of spruce bark beetle *Ips typographus* L. (Coleoptera: Scolytidae) is a serious problem in managed forests. Beside cutting and sanitation of infested trees, barriers of pheromone traps can considerably reduce tree mortality in such areas (JAKUŠ, 1998). JAKUŠ and DUDOVÁ (1999), JAKUŠ et al. (2003) and SCHIEBE et al. (2011) demonstrated a significant reduction of bark beetle attacks after applying one dose of a complex blend of NHV (non-host volatiles) and verbenone on protected trees in combination with pheromone trap barrier (push and pull system). Bark beetle outbreaks represent a serious problem in protected areas where only limited interventions are allowed, and, in many cases, tree mortality requires to be reduced without sanitary cutting (JAKUŠ et al., 2009).

Practical application of new methods for bark beetle control based on anti-attractants has been pioneered in N. America, mostly for pine bark beetles of the genus *Dendroctonus*. SALOM et al. (1998) and CLARKE et al. (1999) elaborated a reliable anti-attractant (verbenone)

based technique for the protection of standing pine trees against the southern pine beetle (*Dendroctonus frontalis* Zimm., Coleoptera, Scolytidae) in conditions of North America. This technique includes protections of forest stands without sanitary cutting.

The aim of this paper is to show the results of an experiment and semi application tests for spruce forest edges protection by applying anti-attractants in specific conditions of protected areas, where standard sanitary cutting is not allowed.

### Material and methods

#### 1. Experiment – lokality Žerucha

(the Tatra National Park, Slovakia)

We established five pairs of experimental plots in the Tatra National Park (TANAP), the locality “Žerucha” (GPS 49°09′02″ N, 19°53′29″ E) at altitudes ranging from 1,100 to 1,200 m above the sea level (a.s.l.) in early spring 2008. The plots were situated at stand edges created by a wind storm in November 2004.

The downed trees were removed. The sanitary cutting of standing trees was not allowed. There was a large source of migrating bark beetles from the neighbouring spruce stands where neither sanitary cutting nor removing of the downed trees was allowed. Each pair of experimental plots consisting of a treated and a control segment (zone). The two segments were separated with a non-evaluated strip, min 10 m in wide. Each segment comprised 10 dominant or codominant spruce trees in the first line and 10 trees of the same status in the second tree line from the stand edge (Fig. 1). Experimental stands were 70–100 years old and forest edges were oriented to the south-east. The trees attacked one year earlier had not been removed. The experimental plots were established in an area affected by a bark beetle outbreak in the no-management zone of the National Park. The whole forest edge was protected with a barrier of pheromone traps (JAKUŠ, 1998). Three coupled pheromone traps ECOTRAP (Fytofarm, Ltd.) were used in one position. The distance between the positions was approximately 20 m. Pheromone dispensers IT ECOLURE Extra (Fytofarm, Ltd.) containing primary attractants were used.

In the treated zones, the stems of dominant or codominant trees at the active stand edge (together 20, see above) were provided with dispensers of anti-attractants IT-REP (Fytofarm, Ltd.) (Fig. 1). The IT-REP is a wick dispenser (VARKONDA, 1996) with a combination of NHV; racemic trans-conophthorin (tC), GLV (1-hexanol) and bark C8 alcohols (1-octen-3-ol, 1-octanol), and the old-host bark compound (S)-(–)-verbenone (Vn). The estimated dispenser performance was 8 weeks. Each treated tree had two dispensers attached to the trunk at the shadow side, one at 2 m and the other at 6 m above the ground. The dispensers had been installed before the bark beetles attacked the stand edge. After the end of the growing period, all dispensers were removed from the tree stems.

The experiment was evaluated by comparing the bark-beetle-caused tree mortality between the treated and control zones of experimental plots (JAKUŠ et al. 2003, SCHIEBE et al., 2011). For statistical evaluation, assumptions for use of parametric statistics were tested (Shapiro-Wilk test and Levene test; Underwood 2001). The data that did not comply with the assumptions were processed with the nonparametric Kruskal-Wallis test followed by Mann-Whitney U test. All statistical calculations were done using the Statistica 5.5 software.

## 2. Semi application tests

(NP Šumava, the Czech Republic)

In 2008 we tested anti-attractants in two localities situated in the National Park Šumava (Czech Republic). It was not possible to establish control (untreated) plots in these localities.

### a) Description of experimental localities:

- Locality “Prameny Vltavy” (springs of the Vltava river, GPS 48°58′29″ N, 13°33′34″ E): 400 treated trees at a south-facing mature spruce forest edge created by a windstorm (Kyril) and partially by sanitary cuttings at altitudes ranging from 1,200 to 1,260 m asl. The locality is situated on a mountain plateau. Most of forest edges are adjacent to the windblown area. Bark beetles colonized the wind blown spruces in the previous year. In 2008 bark beetles started to attack the standing trees. In all accessible areas, barrier of pheromone traps was installed. The distance between the traps was approximately 20 m. There were used pheromone traps of a “Theysohn” type.
- Locality “Kalamitní svážnice” (a calamity skidding road, 48°47′18″ N, 13°49′31″ E): 350 treated trees at a west-south-facing mature spruce forest edge resulted from sanitary cuttings in previ-

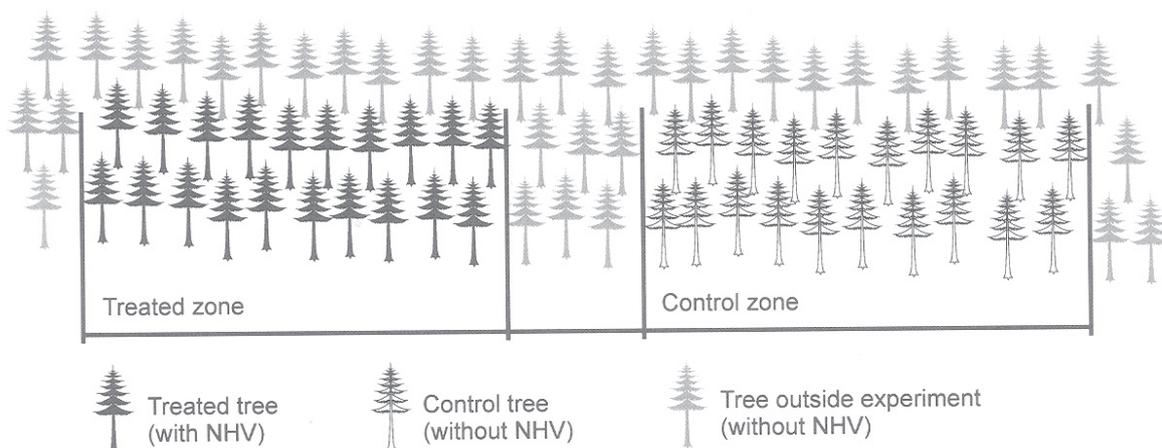


Fig. 1. Experimental design for testing of anti-attractants.

ous years, at altitudes ranging from 1,050 to 1,120 m a.s.l. The locality is situated on a north-facing slope close by a gale disaster area at a distance of 100 m. Bark beetles colonized wind blown spruce trees in the previous year. In 2008, bark beetles started a massive attack to standing trees.

b) Methods of application

Dispensers with anti-attractants were installed in the same way as in the locality Žerucha. Unlike in the test in the locality “Žerucha”, there were treated the entire stand edges. Considering the results of the preceding experiments, the line (zone) of treated trees avoided freshly windthrown and broken trees (Fig. 2). The treatment of trees situated immediately by the windthrown and broken trees had no protective effect against attacks of spruce bark beetle.

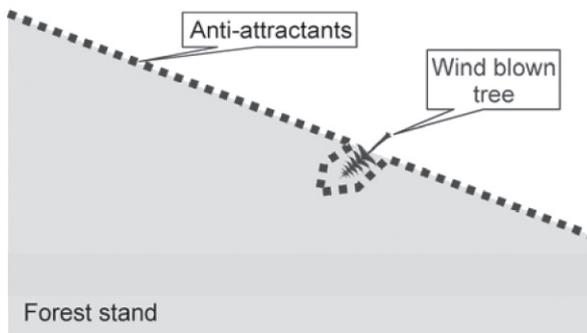


Fig. 2. Treatment of forest stand edge with anti-attractants (semi-application tests).

In some cases, the edge of forest stand was not regular, and the treatment would have required applying much more dispensers with anti-attractants. In these cases, we only treated compact stand parts without promontories (Fig. 3).

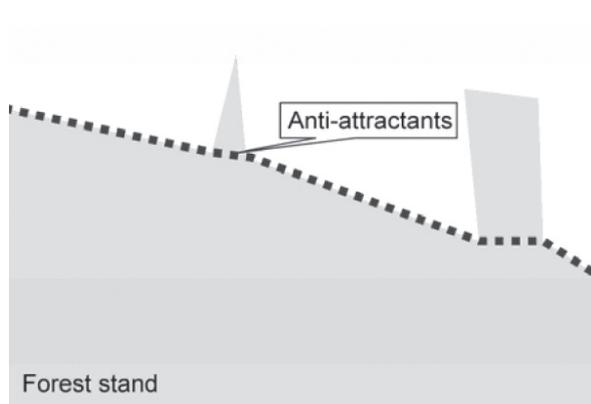


Fig. 3. Treatment of irregular forest stand edge with anti-attractants (semi-application tests).

Where it was possible, pheromone trap barriers were installed near the treated stand edges.

c) Methods used for detailed evaluation

Primary units for field observations were one-tree-narrow sections of the stand border perpendicular to the stand edge. The first and the second tree from the stand edge were treated with anti-attractants. The basic units were monitored for insect attack and for penetration of the attack inside the stand.

Results

1. Experiment – locality Žerucha

The bark beetle attack on the stand edges in the zones treated with anti-attractants was significantly reduced by up to 73% comparing to the control (Fig. 4). Population size of the spruce bark beetle as well as the history of its swarming in the locality “Žerucha” are characterised with data representing the average numbers of individuals collected from pheromone traps in the studied localities (Fig. 5).

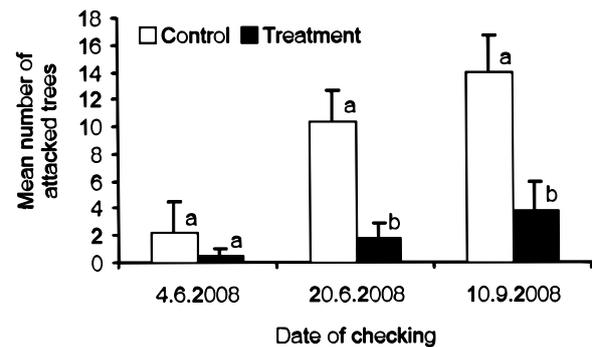


Fig. 4. Results (means and SEs) of experiment in locality “Žerucha”. Bars with the same letter are not different according to the Mann-Whitney U-test.

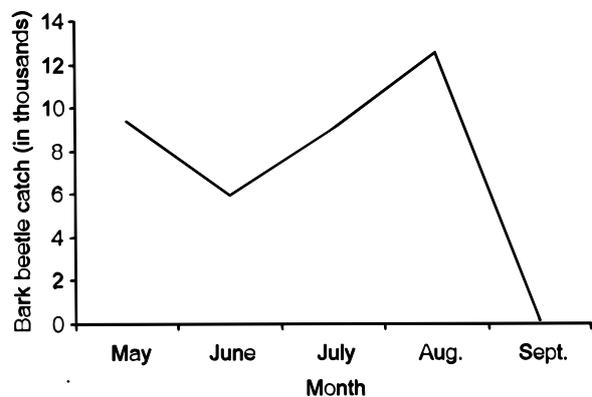


Fig. 5. Average trap catch of pheromone traps (142 traps) in the locality “Žerucha” (experiment).

## 2. Semi application tests

### a) Description – general

- i) Spruce bark beetle has neither attacked the treated trees nor crossed the defence line (barrier) at the stand edge distant more than 5 m from areas with attractive windthrown or broken trees.
- ii) Bark beetle has exceeded the defence line and penetrated 20 m inside the stand edge in areas:
  - directly adjacent to the windthrown area. In these areas, the windthrown trees (their crowns) did not cross forest edge or penetrate inside the stand (Fig. 6).
  - in areas around individual windthrown trees (their crowns), where their crowns crossed forest edge and penetrated inside the stand.
- iii) Spruce bark beetle attack has penetrated across the barrier up to several tens meters inward the stand in these cases:
  - windthrown trees from a calamity area were wedged into the protected stand edge. The trees have been attacked since 2007.
  - the stand edge was impaired by attractive windthrown or broken trees up to several tens meters inwards the stand.

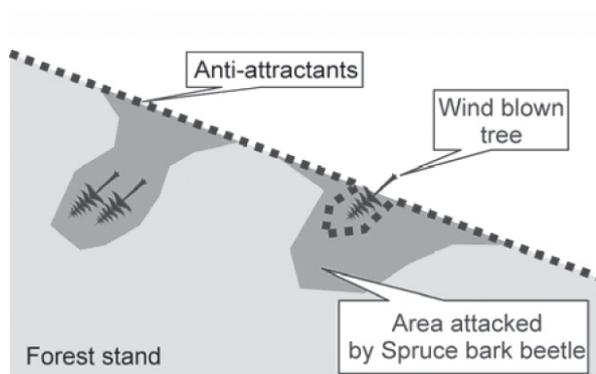


Fig. 6. Bark beetle attack at the forest stand edge with freshly wind thrown and broken trees treated with anti-attractants (semi-application tests).

### b) Description – according to localities

#### i) Locality: Prameny Vltavy

Bark beetle has exceeded the defence barrier with anti-attractants in an area adjacent to a windthrow. In the lower part (by the road), the invasion reached to a 50 m distance from the stand edge, in the central, it was 15 m. In the upper quarter of the locality, the treated stand edge has not been exceeded.

#### ii) Locality: Kalamitní svážnice

Spruce bark beetle has crossed the barrier with anti-attractants and invaded the stand up to 50 m inwards close to attractive windthrown or broken trees (Fig. 6).

### c) Analysis of the bark beetle attack

Figures 7 and 8 present the results of analysis of in-

vasion on stand edges treated with anti-attractants in spring 2008. There were monitored invasions up to the end of July 2008 – period of effective performance of the dispensers. The figures inform about percents of non-attacked stand edge, percents of stand edge with attacked treated trees in the first or in the second tree line and percents of treated line exceeded by the beetles inside the stand.

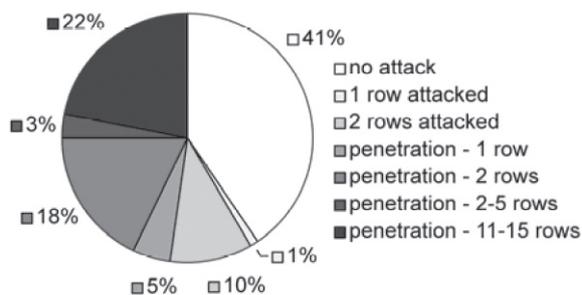


Fig. 7. Result of semi-application tests in locality "Prameny Vltavy".

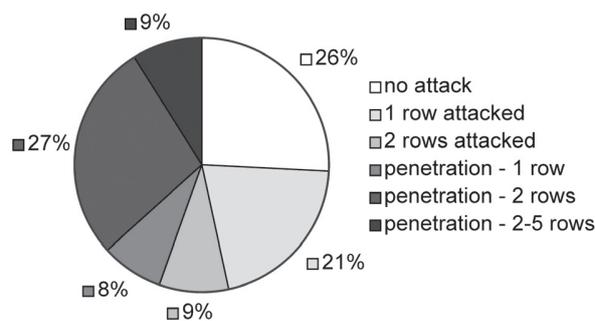


Fig. 8. Result of semi-application tests in locality "Kalamitní svážnice".

### d) Population size in the localities

Population size of the spruce bark beetle as well as history of its swarming in the NP Šumava are characterised with data representing average numbers of individuals collected from 5 randomly selected traps placed across the studied localities (Fig. 9).

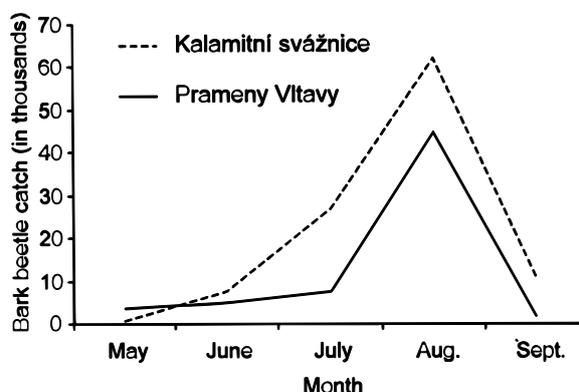


Fig. 9. Average trap catch in 5 randomly selected pheromone traps in the studied localities in NP Šumava (semi-application tests).

## Discussion

The experiment in the locality “Žerucha” has shown that application of anti-attractants in a no-cutting zone can significantly reduce bark beetle attacks on the standing trees. In case when the trees at stand edges are not damaged by wind, there is possible to reduce the tree mortality by up to 73% even in case of large bark beetle populations and even in living green trees growing immediately next to trees attacked by spruce bark beetle in previous year. These results are comparable to the results of experiments in the managed forests (JAKUŠ and DUDOVÁ, 1999; JAKUŠ et al., 2003 and SCHIEBE et al., 2011). No total protection of the treated forest edges could be attained. However, no conventional method, except possibly massive insecticide applications, gives a total protection.

On the other hand, anti-attractants are ineffective at stand edge segments either damaged by freshly windthrown or broken trees or wedged with windthrown areas, as it was shown in semi-application tests in the NP Šumava. The semi-applied tests in the NP Šumava lack the data allowing us to hypothesize about development of situation in case without application of anti-attractants. The effect was only possible to estimate based on the size of the area inside the stand invaded by bark beetles through the protective barrier. The important factor influencing tree mortality was very high populations of bark beetles emerging from neighbouring or near situated wind blown trees. The bark beetle population in experiments localities in NP Šumava was much higher than in locality “Žerucha”.

According to experience obtained during field experiments, the most suitable timing for installation of dispensers is before spring swarming of bark beetles. The effect of the method is the strongest during the spring swarming (JAKUŠ and DUDOVÁ, 1999). Installation in summer can cause problems. In this period, active attack trees can be just present at active stand edges. If such trees were neither cut and sanitized nor removed, the efficacy of the stand edge protection would not be guaranteed any longer. Some attacked trees could be not identified in time of anti-attractant application. Installation of anti-attractant dispensers on such trees could also cause inefficiency of forest edge protection.

## Conclusions

Application of anti-attractants in localities with non-destructive management cannot give 100% protection against bark beetle attacks. Anti-attractants are ineffective at stand edge segments with either freshly windthrown or broken trees or wedged with windthrow areas. On the other hand, in case when the trees at stand edges are not damaged by wind, there is possible to re-

duce the tree mortality by up to 73% even in case of large bark beetle population and even in living green trees growing immediately next to trees attacked by spruce bark beetle.

## Acknowledgement

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## **Aplikácia anti-atraktantov v špecifických podmienkach chránených území**

### **Súhrn**

V roku 2008 sme v bezťažbových zónach chránených území uskutočnili testy a poloprevádzkové pokusy aplikácií anti-atraktantov na ochranu okrajov smrekových porastov pred náletom lykožrúta smrekového (*Ips typographus*). Pokusy ukázali, že pomocou anti-atraktantov je možné znížiť nálet na porastové steny v bezťažbových zónach až o 73 % v porovnaní s plochami bez aplikácie anti-atraktantov. Aplikácie boli účinné aj v prípade veľmi veľkej populácie lykožrúta smrekového a aj v prípadoch, keď ošetrované stromy susedili so stromami obsadenými v predošlom roku. Na druhej strane, anti-atraktanty nefungujú v prípadoch, keď sa čerstvé vývraty alebo zlomy nachádzajú priamo v ošetrovanej porastovej stene.

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## Successful overwintering of Lepidoptera larvae and eggs on spruce trees uprooted by the wind

Ján Kulfan<sup>1</sup>, Peter Zach<sup>2</sup>

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,  
<sup>1</sup>E-mail: kulfan@savzv.sk, <sup>2</sup>E-mail: zach@savzv.sk

### Abstract

KULFAN, J., ZACH, P. 2011. Successful overwintering of Lepidoptera larvae and eggs on spruce trees uprooted by the wind. *Folia oecol.*, 38: 52–56.

Windstorm on November 19, 2004 seriously affected Norway spruce (*Picea abies*) forests in Tatra Mountains, Northern Slovakia. We studied as to whether moth larvae and eggs overwintered successfully on branches of uprooted spruce trees. Also, we evaluated differences in assemblage structure of overwintering developmental stages of moths between the upper and middle crown area of wind-felled spruce trees. In May 2005, we sampled branches from a total of 12 wind-felled trees in Tichá dolina valley in the altitudes between 1,020 and 1,050 m. From each tree, a total of 30 branches were collected from both its upper and middle crown area. In addition, a total of 400 cones were sampled from the wind-felled trees. Moth larvae or hatched adults were obtained from branches or cones through photoelectors in the laboratory. Larvae of one species developing in cones (*Cydia strobilella*), 3 species of bud-borers (*Argyresthia glabratella*, *A. amiantella*, *A. bergiella*), 7 needle spinning species (*Batrachedra pinicolella*, *Chionodes electella*, *Syndemis musculana*, *Dichelia histrionana*, *Pseudohermenias abietana*, *Epinotia tedella*, *E. nanana*), one free living species (*Thera variata*) and one species feeding on lichens or algae (fam. Psychidae – Naryciinae, not identified) were recorded. The moth *Zeiraphera griseana* was the only species overwintering in the egg stage. Branches of uprooted spruce trees hosted all moth species common on living standing spruce trees in other mountain valleys of Tatra Mountains. Specimens of needle-spinning species overwintering in the larval stage were collected in significantly greater numbers on the upper crown than on the middle crown branches of the individual wind-felled trees ( $p < 0.05$ , Wilcoxon matched pairs test). In bud-borers, such significant differences were not found. The numbers of moth specimens belonging to the rest feeding groups were low. Successful development of all moth species overwintering on uprooted trees in the larval stage (13 species) was highly likely. Most larvae of *Z. griseana* emerging from eggs in spring, possibly, died because of the lack of opening buds and young needles on most fallen trees which were drying out gradually.

### Key words

Lepidoptera, Norway spruce, middle crown, overwintering, *Picea abies*, upper crown, uprooted trees, wind disturbance

### Introduction

Wind disturbances are frequently affecting spruce forests in Europe (SKUHRAVÝ, 2002). Windstorms influence insect populations in these forests in different way (cf. BOUGET and DUELLI, 2004). The insects dwelling in tree crowns may be affected directly by the strong

wind currents (usually short lasting) and indirectly by modified abiotic and biotic conditions following windstorms. Uprooted spruce trees provide plant-eating insects with food, the quality of which is greatly changed. Drought-stressed Norway spruce becomes a better-matching food source for some insect species (MATTSON and HAACK, 1987; BJÖRKMAN and LARSSON, 1999) but

severe and prolonged drought can become debilitating to phytophagous insects (MATTSON and HAACK, 1987). Often, windstorms damage European spruce forests out of growing season (SKUHRAVÝ, 2002) and affect overwintering insects on spruce trees. Over that period of time, the insects are passive or almost passive. On spruce trees uprooted in autumn, the insects accelerate their activity several months later (in the spring).

Main objectives of this study were to find out as to whether:

1. The moth larvae and eggs on branches of Norway spruce (*Picea abies*) trees uprooted by the strong wind on November 19, 2004 overwinter and complete their development successfully
2. The wind-felled spruce trees host larvae of all moth species mostly occurring on living standing spruce trees
3. The assemblages of overwintering developmental stages of moths in the upper crown area differ from the assemblages on the middle crown area of the uprooted spruce trees.

## Material and methods

In May 2005, branches were sampled from a total of 12 spruce trees uprooted by the wind in November 2004 in the bottom of the Tichá dolina valley, Tatra Mountains, northern Slovakia, at 1,020–1,050 m a.s.l. (49°10'27.39" N, 19°55'3.29" E). From each sample tree, a total of 30 branches were collected from the upper crown area (top section of a tree, 5 m long), and a total of 30 branches were collected from the middle crown area (middle section of a tree, 7–12 m apart from the top). Sample branches were 0.5 m long each. Only the branches not touching the ground were collected from tree crowns. The sample trees were 60–80 years old and 25–30 m high. In addition, a total of 400 cones were sampled from the wind-felled spruce trees. The sample branches and cones were placed in photoelectors in the laboratory. Moth larvae or hatched adults of moth species were collected from the electors regularly. Material examined consisted of a total of 92 moth specimens obtained from the upper and a total of 69 moth specimens gathered from the middle crown area, and a total of 135 moth specimens collected from spruce cones.

Moth larvae overwintering on branches of living standing trees aged 60–80 years were monitored in the bottom of Tichá dolina valley in the altitude of some 1,030 m. In April or May (depending on weather), a total of 10 terminal parts of branches, 1 m long each, were sampled from the lower parts of spruce crowns, in this particular case 2–3 m above the ground. Moth larvae or emerged adults were obtained using electors. A total of 18, 19 and 7 moth specimens were collected in 1998, 1999 and 2000.

The spruce forests in Tichá dolina valley are the habitats of Community interest – NATURA 2000 No. 9410: Acidophilous *Picea* forests of the montane to alpine levels (Vaccinio-Piceetea). However, they were managed in the past.

## Results and discussion

In total, 13 moth species overwintering as larvae or eggs were recorded on branches of the uprooted spruce trees (Table 1). Most of them overwinter in the larval stage – as larvae or prepupae; only a single species *Zeiraphera griseana* overwinters in the egg stage. Number of specimens differed greatly among the individual sample trees (Fig. 1). According to behaviour and food requirements of particular species moth larvae were classified into four feeding guilds: (1) needle-spinning species, (2) bud-borers, (3) free-living species feeding on needles and (4) species feeding on lichens or algae (Table 1). Abundance of all species was low (latency period – no outbreak). The average density of moths (larvae or adults), expressed as the number of specimens on 100 branches (0.5 m long each), was the following: needle-spinning larvae – 6.9 specimens in the upper crown area against 5.6 specimens in the middle crown area; bud-borers – 18.3 specimens in the upper crown area against 12.8 specimens in the middle crown area; free-living larvae feeding on needles – 0.8 specimens in the middle crown area; species feeding on lichens or algae – 0.3 specimens in the upper crown area. The larvae of *Argyresthia* spp. overwintering in buds were predominant (Fig. 2).

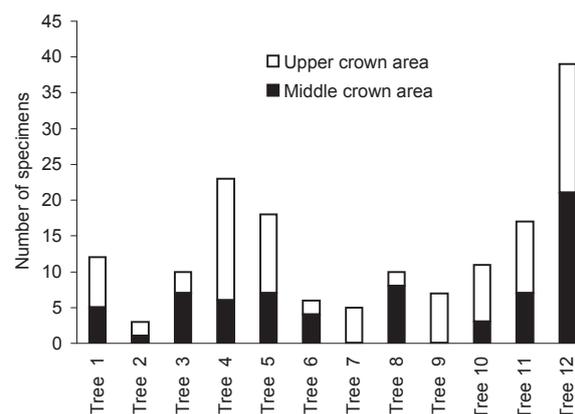


Fig. 1. Number of moth specimens recorded on sample branches in two crown areas of wind-uprooted Norway spruce trees (n = 12) in Tichá dolina valley, Tatra Mountains, in 2005.

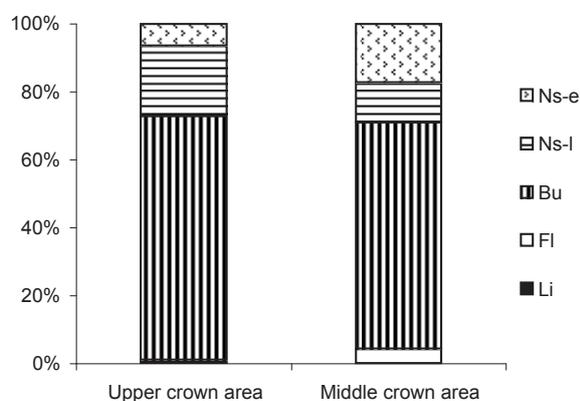
Needle-spinning overwintering larvae were significantly more in the upper crown than on the middle crown area of the individual uprooted trees (Wilcoxon matched pairs test, N = 12, Z = 2.03, p < 0.05). In

Table 1. Dominance (in %) of moth taxa recorded in two crown areas of wind-uprooted Norway spruce trees in Tichá dolina valley, Tatra Mountains, in 2005

Guild	Taxon	Upper crown area	Middle crown area	Upper + middle area
Li	Naryciinae sp.	1.1		0.6
Bu	<i>Argyresthia glabratella</i> (Zeller, 1847)	16.3	13.0	14.9
Bu	<i>Argyresthia amiantella</i> (Zeller, 1847)	41.3	30.4	36.6
Bu	<i>Argyresthia bergiella</i> (Ratzeburg, 1840)	14.1	23.2	18.0
Ns-l	<i>Batrachedra pinicolella</i> (Zeller, 1839)	2.2		1.2
Ns-l	<i>Chionodes electella</i> (Zeller, 1839)	4.3	2.9	3.7
Ns-l	<i>Syndemis musculana</i> (Hübner, 1799)	1.1		0.6
Ns-l	<i>Dichelia histrionana</i> (Frölich, 1828)	2.2		1.2
Ns-l	<i>Pseudohermenias abietana</i> (Fabricius, 1787)	5.4	1.4	3.7
Ns-l	<i>Epinotia tedella</i> (Clerck, 1759)		1.4	0.6
Ns-l	<i>Epinotia nanana</i> (Treitschke, 1835)	5.4	5.8	5.6
Ns-e	<i>Zeiraphera griseana</i> (Hübner, 1799)	6.5	17.4	11.2
Fl	<i>Thera variata</i> (Denis & Schiffermüller, 1775)		4.3	1.9
Total		100	100	100

Larval guilds: Li, species feeding on lichens or algae; Bu, bud-borers; Ns-l, needle-spinning species overwintering as larvae; Ns-e, needle-spinning species overwintering in the egg stage; Fl, free-living species feeding on needles.

bud-borers, such significant differences were not found (Wilcoxon test,  $N = 12$ ,  $p > 0.05$ ). The numbers of specimens belonging to the rest feeding groups were too low to test for statistical significance.



Larval guilds: Ns-e, needle-spinning species overwintering in egg stage; Ns-l, needle-spinning species overwintering in larval stage; Bu, bud-borers; Fl, free-living species feeding on needles; Li, species feeding on lichens or algae

Fig. 2. Proportion of moth guilds overwintering as larvae or eggs on branches of uprooted spruce trees in Tichá dolina valley, Tatra Mountains, in 2005.

All moth specimens collected from spruce cones belonged to a single species, *Cydia strobilella* (Linnaeus, 1758).

The larvae obtained from the branches of living standing trees in 1998, 1999 and 2000 were represented by a total of 6 species (Table 2). Their abundance was

low (latency). All these species were also found to be developing on the branches of spruce trees uprooted in May 2005.

Table 2. Dominance (in %) of moth taxa recorded on branches of living spruce trees in Tichá dolina valley, Tatra Mountains, before windstorm in November 2004 (data from 1998, 1999, 2000)

Guild	Taxon	Year		
		1998	1999	2000
Li	Naryciinae sp.		15.8	
Bu	<i>Argyresthia glabratella</i> (Zeller, 1847)	11.1	42.1	14.3
Bu	<i>Argyresthia amiantella</i> (Zeller, 1847)	16.7	5.3	14.3
Ns-l	<i>Chionodes electella</i> (Zeller, 1839)	16.7		28.6
Ns-l	<i>Epinotia nanana</i> (Treitschke, 1835)	22.2	31.6	14.3
Fl	<i>Thera variata</i> (Denis & Schiffermüller, 1775)	33.3	5.3	28.6
Total		100	100	100

Larval guilds: Li, species feeding on lichens or algae; Bu, bud-borers; Ns-l, needle-spinning species overwintering in larval stage; Fl, free-living species feeding on needles.

Branches of the uprooted spruce trees hosted all moth species which are common in other mountain valleys of Tatra Mountains, e.g. in Skalnatá dolina and Velická dolina valley (KULFAN and ZACH, 2004, 2005).

Larvae (or prepupae) of 13 moth species (*C. strobilella* and the species listed in Table 1 except for *Z. griseana*) overwintered on uprooted trees successfully. As the branches of uprooted trees are slowly drying out in nature, successful development of those larvae is likely. The larvae of *Z. griseana* emerge from eggs in spring and feed in opening buds, young needles and shoots (KALINA et al., 1985). This is why they are able to survive only on branches of living spruce trees. On trees uprooted by the wind they can only survive if the roots of these trees are covered with soil. All the wind-felled spruce trees in Tichá dolina valley were dying, producing no shoots in the spring. As a result, most larvae of *Z. griseana* dwelling on these trees, possibly, died. In contrast, overwintering needle-spinning larvae feeding on old needles could complete their development the following spring (Fig. 2).

Although the direct effect of wind (in November 2004) on the moth larvae was likely it was not documented. Endophagous larvae living in cones and buds (bud-borers) were well protected against the wind; some needle-spinning, and especially free-living larvae might be blown by the wind or injured by sharp needles of fast moving branches. Free living larvae are most sensitive to such events, as they overwinter unprotected, roosting on green twigs, stretched along a needle (DVOŘÁČKOVÁ and KULFAN, 2009). Also, some larvae might be knocked from branches during the wind-felling. Some parts of crowns of uprooted trees were touching the ground. The larval mortality in these tree parts might be higher than that in the other parts of tree crowns.

The data obtained did not enable to quantify the proportion of larvae surviving the windstorm and successfully overwintering on the fallen trees. On the uprooted trees the number of overwintering needle-spinning, and especially free living larvae, was low compared to the number of the bud-borers (compare Ns-I and FI against Bu, Fig. 2). In standing living trees in the Tichá dolina valley (this study), Skalnatá dolina valley (KULFAN and ZACH, 2004) and Velická dolina valley (KULFAN and ZACH, 2005), the proportion of needle-spinning and free living larvae in larval assemblages was higher. Thus, the impact of windstorm on unprotected or partly protected moth larvae overwintering on spruce branches might be much greater than that on well protected moth larvae living in buds (requires further study).

## Acknowledgement

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## Úspešné prezimovanie húseníc a vajíčok motýľov (Lepidoptera) na smrekoch vyvrátených víchricou

### Súhrn

Víchrice z 19. novembra 2004 vážne poškodila smrekové lesy Tatier. Vyvrátené smrekové lesy postupne odumierali. Študovali sme, 1) či húsenice a vajíčka motýľov úspešne prezimujú na konároch smrekov vyvrátených touto

vichricou a či húsenice môžu na nich dokončiť svoj vývin; 2) či na vyvrátených smrekoch sú prítomné húsenice obvykle sa vyskytujúce na živých stojacich stromoch; 3) či sa spoločenstvá zimujúcich vývinových štádií motýľov na vyvrátených smrekoch v hornej časti koruny odlišujú od spoločenstiev v strednej časti koruny. V máji r. 2005 sme odobrali konáre z 12 vyvrátených dospelých smrekov v Tichej doline (1 020–1 050 m n. m.). Z každého stromu sme odrezali 30 polmetrových konárov z hornej a 30 polmetrových konárov zo strednej časti koruny. Okrem toho sme z konárov odobrali 400 šišíek. Konáre aj šišky sme umiestnili do fotoeklektorov v laboratóriu. Húsenice alebo imága vyliahnuté vo fotoeklektoroch sme z nich pravidelne odoberali. Takýmto spôsobom sme zistili prítomnosť húseníc jedného druhu vyvíjajúceho sa v šiškách (*Cydia strobilella*) a na vzorkových konároch 3 druhy žijúce v púčikoch (*Argyresthia glabratella*, *A. amiantella*, *A. bergiella*), 7 druhov spriadajúcich ihlice (*Batrachedra pinicolella*, *Chionodes electella*, *Syndemis musculana*, *Dichelia histrionana*, *Pseudohermenias abietana*, *Epinotia tedella*, *E. nanana*), jeden voľne žijúci druh živiaci sa ihlicami (*Thera variata*) a jeden druh živiaci sa lišajníkmi a riasami (bližšie neurčený, čeľaď Psychidae, podčeľaď Naryciinae). Motýle zimujúce v štádiu vajíčok reprezentoval na vzorkových konároch jediný druh – *Zeiraphera griseana*. Na vyvrátených smrekoch sme zistili všetky druhy motýľov, ktoré sa v jarnom období často vyskytujú aj na žijúcich stojacich smrekoch. Druhy spriadajúce ihlice zimujúce v larválnom štádiu boli prítomné vo väčšom počte jedincov na vzorkových vyvrátených stromoch v hornej časti korún v porovnaní so strednou časťou ( $p < 0,05$ , Wilcoxonov test). Pri húseniciach žijúcich v púčikoch sme takýto rozdiel nezistili. Počet jedincov ostatných potravných skupín bol nízky a neumožňoval štatistické porovnanie. Na vyvrátených stromoch s vysokou pravdepodobnosťou úspešne dokončili svoj vývin druhy zimujúce na konároch smrekov v larválnom štádiu (13 druhov). Naproti tomu väčšina lariev *Z. griseana*, ktoré sa vyliahli z vajíčok na jar, pravdepodobne zahynula pre nedostatok potravy na postupne usychajúcich vyvrátených smrekoch. Húsenice tohto druhu sa živia pletivami v otvárajúcich sa púčikoch, mladými ihlicami a výhonkami.

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## Seasonal dynamics of geobiont arthropods in mountainous spruce forests with a special emphasis on beetles (Coleoptera)

Oto Majzlan<sup>1</sup>, Peter J. Fedor<sup>2</sup>

<sup>1</sup>Department of Biology, Faculty of Education, Comenius University, 8 Bratislava, Slovak Republic, E-mail: oto.majzlan@fedu.uniba.sk

<sup>2</sup>Department of Ecosozology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovak Republic, E-mail: fedor@fns.uniba.sk

### Abstract

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Eclosion phenology of beetles (Coleoptera) was studied using soil photoelectors (POT) at 3 study sites along the Tichá dolina valley, the Vysoké Tatry Mts (Slovakia). In the vegetation period 2008 (144 days), the average abundance of arthropods reached the value of 2,763 ex. m<sup>-2</sup>. Arthropods were represented by 24 orders, including dominant Diptera (30.0%), Hymenoptera (11.5%) and Araneae (11.7%). The community of Coleoptera (7.6%) included 145 species of 29 families and culminated in June at all the study sites, varying between 181 and 1,016 ex. m<sup>-2</sup>. The main goal of the project was to analyse changes in seasonal dynamics of geobiont arthropods, particularly beetles (Coleoptera).

### Key words

beetles, macrofauna, phenology, soil ecology, the Tatra Mts

### Introduction

Research on geobiont (soil-dwelling) arthropods always brings a challenge to analyse and understand the whole soil complex and even ecosystem. An analysis of their dynamics, structure and diversity may mean an important potential for bioindication studies aimed to identify interactions among the species and their environmental conditions. This is undisputedly emphasized if the system is impacted by various types (natural, anthropogenic) of disturbances.

A soil photoelector method (POT) is usually applied to observe eclosion phenology in various geobiont insects. There were published numerous papers on this matter in Slovakia (e.g. MAJZLAN and FEDOR, 2005, 2009). In the Austrian Alps the trap was applied to monitor the area of 0.5 m<sup>2</sup> (TROGER et al., 1994).

One of the scientific schools dealing with geobiont arthropod dynamics has been established by FUNKE (1997). Consequentially, plenty of papers have been published, e.g. DURMEK et al. (1993).

### Study sites

The whole study area, situated along the Tichá dolina valley (DFS grid square 6885 b), the Vysoké Tatry Mts, included the 3 following sites:

- o Site A: coordinates: 49°08' N, 19°53' E, altitude: 965 m a.s.l., Alnetum incanae carpathicum – wetland with *Alnus incana*, *Salix* sp., *Betula pendula*, *Caltha palustris*, located by the Belá creek just under a forest road in the locality of Podbanské (Fig. 1).
- o Site B: coordinates: 49°09' N, 19°55' E, altitude: 1,001 m a.s.l., Lariceto-Piceetum on podzolic cambisol, sparse forest stand of *Picea abies* with a cover density of 60%, surrounded by fallen Norway spruces and European larches (standing : fallen trees 60 : 40 at the area of 300 × 300 m), mouth of the Tichá dolina valley close to an arboriculture (Fig. 2).
- o Site C: coordinates: 49°10' N, 19°55' E, altitude: 1,086 m a.s.l., Lariceto-Piceetum on podzolic cambisol, just in the valley centre in a totally disturbed area (standing : fallen trees 10 : 90 at the site of 300 × 300 m) (Fig. 3).



Fig. 1. The POT traps at the site A, a wetland with *Sorbus*, *Betula*, *Alnus* trees, with a Malaise trap in background.



Fig. 2. 3 POT traps at the site B (Larici-Piceetum).



Fig. 3. The POT and Malaise traps at the site C with a high degree of damaged stands.

## Material and methods

A soil photoeclector (POT) records eclosion abundance and other dynamic activities of insects over a certain soil area. Arthropods are captured in a collecting jar with

monoethylenglycol as a conservation medium. In the past, picric acid was used (MAJZLAN and FEDOR, 2005).

Three soil photoeclector traps (POT) were installed at each study site situated along the Tichá dolina valley, for a period of 144 days (May 9, 2008 – September 29, 2008). Each non-stationary trap, covering an area of  $0.125 \text{ m}^2$  ( $3 = 0.375 \text{ m}^2$ ), was moved onto another area once a month, and the material was sampled at 1-week intervals. The research was accompanied by exposition of Malaise traps, managed once a week.

Some of the captured taxa were identified by: P. Průdek – Latridiidae and Cryptophagidae, T. Jászay – Staphylinidae, O. Šauša – Elateridae, E. Jendek – Buprestidae.

## Results and discussion

### Arthropoda

Abundance of arthropods reached the values of 2,062 ex.  $\text{m}^{-2}$  (site A), 3,453 ex.  $\text{m}^{-2}$  (site B), 2,773 ex.  $\text{m}^{-2}$  (site C), with an average of 2,763 ex.  $\text{m}^{-2}$  for the whole study area (Table 1). In the period of 144 days the daily values were recorded as 14 ex.  $\text{m}^{-2}$  (site A), 24 ex.  $\text{m}^{-2}$  (site B), 19 ex.  $\text{m}^{-2}$  (site C). In 2007 analysing dynamics of arthropods in the area impacted by wind calamity and fire as well as intensive management we observed a significantly lower value of 1,661 ex.  $\text{m}^{-2}$  (MAJZLAN and FEDOR, 2009).

Diversity of soil macrofauna appears identical for both years.

Dipterans, especially those of Nematocera, may be generally classified as dominant in the whole study area (in total: A 800, B 1,054, C 1,514 ex.  $\text{m}^{-2}$ , in daily values: A 5.5, B 7.3 and C 10.5 ex.  $\text{m}^{-2}$ ) (Table 2). Comparing Diptera in our older research in 2007 (STRAKA and MAJZLAN, 2009), the daily abundance ranged between 0.7 (at the site damaged by wind and fire) and 4.0 (reference site).

Analysing dynamics of arthropods, their abundance reach its culmination point in June (838 ex.  $\text{m}^{-2}$  in average) for the whole study area (Table 2). At the site A with no impact the values continuously increase from May to June when they decline gradually (Fig. 4).

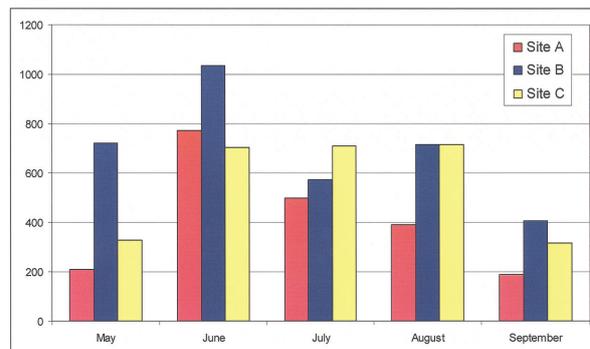


Fig. 4. Abundance dynamics of the arthropods sampled in 2008.

## Coleoptera

The total abundance of beetles for the whole period (144 days) varied between 181 and 1,016 ex. m<sup>-2</sup>, with the daily values of 1.2 (A), 7.0 (B) and 3.0 (C) ex./days/m<sup>2</sup>. For the sites A and C, the values correspond with our previous analyses in the area impacted by the wind calamity and fire in 2007. The higher abundance at the site B refers to eclosion of *Cryphalus piceae* (300 ex. m<sup>-2</sup>).

In 2007, an average abundance of beetles per 1 m<sup>2</sup> ranged between 0.9 ex./days at the site impacted by the wind calamity and 3.2 ex. day<sup>-1</sup> at the reference site (MAJZLAN and FEDOR, 2009).

The beetle species diversity (richness: A 44, B 78, C 75) appears similar at the sites B and C, in accordance with their similar ecological conditions (Lariceto-Piceetum) and with 29 species occurring at both sites. There are only 10 species occurring at all 3 study sites.

### Site A

At the site A, a wetland with more dynamic upper soil horizon, the beetles are predominantly represented by predacious Staphylinidae and phytophagous Curculionidae (Table 3). The analyses declare the lowest abundance (290.6 ex. m<sup>-2</sup>), but the highest values obtained by applying Malaise traps with massive eclosion of *Byturus tomentosus* in May (1,000 ex. per week).

### Site B

The community may be determined by the dominant (28.8%) *Cryphalus piceae* (Scolytidae), eclosing in the 20<sup>th</sup> week between May 9–19, and subdominant representatives of Curculionidae and Staphylinidae (Table 3). At the site B, the abundance reached the highest values (997.3 ex. m<sup>-2</sup>) within the whole study area, supported particularly by 6 species of Scolytidae (*Cryphalus piceae*, *Hylastes ater*, *Hylastes cunicularius*, *Ips typographus*, *Pityogenes chalcographus* and *Xyloterus lineatus*). Even 4 years after the calamity, eclosion of Scolytidae and their invasion to the nearby stands is evident, when 626.6 specimens were eclosed per 1 m<sup>2</sup> in the period of 144 days. This quantity was predominantly due to *Ips typographus* (29.3 ex. m<sup>-2</sup>) and *Pityogenes chalcographus* (90.6 ex. m<sup>-2</sup>).

### Site C

Dominated by Chrysomelidae, Curculionidae and Scolytidae, the beetle abundance reached the value of 474.6 ex. m<sup>-2</sup>, with a special portion of Scolytidae (72 ex. m<sup>-2</sup>), including *Ips typographus* (56 ex. m<sup>-2</sup>). Consequentially, the results declare that in the deforested area 4 years after the calamity, the populations of Scolytidae have been significantly declined (Table 3).

## Acknowledgement

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Table 3. Survey of beetles sampled at 3 study sites (month/specimens) in 2008

Taxone	Site A	Site B	Site C
<b>Carabidae</b>			
<i>Cychrus caraboides</i> (Linnaeus, 1758)			8/1
<i>Carabus linnaei</i> Panzer, 1810			8/1
<i>Pterostichus aterrimus</i> (Herbst, 1784)	6/1		
<b>Ptiliidae</b>			
<i>Acrotrichis intermedia</i> (Gillmeister, 1845)		6/1,7/2	
<i>Pteryx suturalis</i> (Heer, 1841)	7/2	8/1	
<b>Staphylinidae</b>			
<i>Acidota crenata</i> (Fabricius, 1792)			8/1
<i>Alevonota egregia</i> (Rye, 1876)			5/1
<i>Alevonota rufotestacea</i> (Kraatz, 1856)		6/1	
<i>Amischa analis</i> (Gravenhorst, 1802)	8/1		6/2,7/2
<i>Amphichroum canaliculatum</i> (Erichson, 1840)		6/1	6/3
<i>Anotylus tetracarinated</i> (Block, 1799)	7/12		8/1
<i>Anthophagus alpestris</i> Heer, 1839		6/5,8/2	8/4
<i>Anthophagus bicornis</i> (Block, 1799)			8/1
<i>Anthophagus omalinus arrowi</i> Koch, 1933		8/1	
<i>Atheta fungi</i> (Gravenhorst, 1806)		6/1	
<i>Atheta fungivora</i> (Thomson, 1867)			5/1
<i>Atheta episcopalis</i> Bernhauer, 1910	9/1		
<i>Atheta pilicornis</i> (Thomson, 1852)		6/1	
<i>Atheta procera</i> (Kraatz, 1856)		6/2	6/1
<i>Eusphalerum limbatum</i> (Erichson, 1840)		5/2,6/1	
<i>Eusphalerum luteum</i> (Marsham, 1802)		5/1	
<i>Eusphalerum rectangulum</i> (Fauvel, 1869)	6/1	6/6,7/1,9/1	
<i>Liogluta wuesthoffi</i> (Benick, 1938)	7/1	8/1	9/1
<i>Lordithon exoletus</i> (Erichson, 1839)		9/1	
<i>Omalium caesum</i> Gravenhorst, 1806		6/1	
<i>Othius angustus</i> Stephens, 1833			8/1
<i>Philonthus decorus</i> (Gravenhorst, 1802)			9/1
<i>Phloeoporus corticalis</i> (Gravenhorst, 1802)			7/1
<i>Phloeoporus scribae</i> (Eppelsheim, 1884)			7/2
<i>Placusa depressa</i> Mäklin, 1845		7/1	6/1,7/1
<i>Placusa tachyporoides</i> (Waltl, 1839)		8/1	
<i>Proteinus brachypterus</i> (Fabricius, 1792)		8/3,9/1	9/1
<i>Quedius paradisianus</i> (Heer, 1839)			9/1
<i>Rugilus rufipes</i> Germar, 1836	6/1		
<i>Tachinus laticollis</i> Gravenhorst, 1802	6/2		
<i>Tachinus signatus</i> (Gravenhorst, 1802)	5/1		
<i>Tachyporus chrysomelinus</i> (Linnaeus, 1758)			7/1
<i>Xantholinus laevigatus</i> Jacobsen, 1847			5/1
<b>Pselaphidae</b>			
<i>Trimium brevicorne</i> (Reichenbach, 1813)			8/1
<i>Bibloporus bicolor</i> (Denny, 1825)			6/1

Table 3. Continued

Taxone	Site A	Site B	Site C
<b>Helodidae</b>			
<i>Elodes elongata</i> Tournier, 1868	6/1		
<b>Scarabaeidae</b>			
<i>Aphodius abdominalis</i> Bonelli, 1812			7/1
<b>Byrrhidae</b>			
<i>Byrrhus glabratus</i> Heer, 1841		6/1	5/1,6/1,7/2
<b>Elateridae</b>			
<i>Agriotes obscurus</i> (Linnaeus, 1758)			7/1
<i>Ampedus aethiops</i> (Lacordaire, 1835)	5/1	6/3	6/2
<i>Ampedus balteatus</i> (Linnaeus, 1758)	6/1		
<i>Ampedus nigrinus</i> (Herbst, 1784)	5/5	5/1,6/2,7/1	5/1,6/1,7/2
<i>Ampedus sanguineus</i> (Linnaeus, 1758)			6/1
<i>Anostirus castaneus</i> Linnaeus, 1758	6/1		
<i>Athous subfuscus</i> (Müller, 1767)		5/2,6/8	5/2,6/11
<i>Ctenicera cuprea</i> (Fabricius, 1781)		6/1	
<i>Hemicrepidius niger</i> (Linnaeus, 1758)	6/1	7/2	
<i>Hypnoidus riparius</i> (Fabricius, 1792)			6/1
<i>Liotrichus affinis</i> (Paykull, 1800)	5/5	6/1	
<i>Melanotus castanipes</i> (Paykull, 1800)	6/1		
<i>Prosternon tessellatum</i> (Linnaeus, 1758)			8/1
<b>Lycidae</b>			
<i>Pyropterus nigrojuber</i> (De Geer, 1774)		7/3	
<b>Cantharidae</b>			
<i>Absidia pilosa</i> (Paykull, 1798)		6/1	
<i>Absidia rufotestacea</i> (Letzner, 1845)		6/1,7/1	7/1
<i>Cantharis obscura</i> Linnaeus, 1758	6/2		6/1
<i>Cantharis pagana</i> Rosenhauer, 1846		6/1	
<i>Cratosilis denticollis</i> (Schummel, 1844)			7/1
<i>Malthodes minimus</i> (Linnaeus, 1758)			7/1
<i>Malthodes hexacanthus</i> Kiesenwetter, 1852		7/2	
<i>Malthodes pumilus</i> (Brébisson, 1835)		7/2	
<i>Rhagonycha nigripes</i> Redtenbacher, 1842		7/1	
<b>Anobiidae</b>			
<i>Ernobius angusticollis</i> (Ratzeburg, 1847)		5/1	
<b>Cleridae</b>			
<i>Thanasimus femoralis</i> (Zetterstedt, 1828)			6/1,8/1
<b>Nitidulidae</b>			
<i>Meligethes aeneus</i> (Fabricius, 1775)		5/1,9/1	
<i>Epuraea pygmaea</i> (Gyllenhal, 1808)	7/1	6/1	6/1
<i>Epuraea boreella</i> (Zetterstedt, 1828)		5/1	
<i>Epuraea marseuli</i> Reitter, 1827		9/1	
<i>Epuraea binotata</i> Reitter, 1827		6/1	
<i>Epuraea rufomarginata</i> (Stephens, 1830)			8/1
<b>Rhizophagidae</b>			
<i>Rhizophagus dispar</i> (Paykull, 1800)			6/1,8/1

Table 3. Continued

Taxone	Site A	Site B	Site C
<b>Silvanidae</b>			
<i>Dendrophagus crenatus</i> (Paykull, 1799)	6/1		
<b>Cucujidae</b>			
<i>Leptophloeus alternans</i> (Erichson, 1845)		8/1	
<b>Cryptophagidae</b>			
<i>Atomaria umbrina</i> (Gyllenhal, 1827)	6/1		
<i>Atomaria nigripennis</i> (Kugelann, 1792)	6/1	7/1	
<b>Byturidae</b>			
<i>Byturus tomentosus</i> (De Geer, 1774)			
<b>Coccinellidae</b>			
<i>Coccinella septempunctata</i> (Linnaeus, 1758)			7/3
<i>Aphidecta oblitterata</i> (Linnaeus, 1758)		8/1	
<b>Corylophidae</b>			
<i>Corylophus casssidoides</i> (Marsham, 1802)		6/1	
<i>Orthoperus atomus</i> (Gyllenhal, 1808)	6/1	6/1,7/1	
<b>Latridiidae</b>			
<i>Aridius nodifer</i> (Westwood, 1839)	8/2,9/1		
<i>Corticaria longicornis</i> (Herbst, 1793)		7/1	5/1,8/1
<i>Corticaria obscura</i> Brisout, 1863		7/1	
<i>Corticaria rubripes</i> Mannerheim, 1844		7/1	6/1
<i>Corticarina minuta</i> (Fabricius, 1792)	6/1,7/1	6/2,7/2	6/1
<i>Corticarina parvula</i> Mannerheim, 1844			6/1
<i>Cortinicara gibbosa</i> (Herbst, 1793)			6/1,7/4,8/1
<i>Enicmus fungicola</i> Thomson, 1868		7/1	
<i>Stephostethus angusticollis</i> (Gyllenhal, 1827)		8/1	
<b>Melandryidae</b>			
<i>Xylita laevigata</i> (Hellenius, 1786)	6/1		
<b>Oedemeridae</b>			
<i>Oedemera virescens</i> (Linnaeus, 1767)	7/1		
<b>Tenebrionidae</b>			
<i>Corticeus suberis</i> (Lucas, 1846)		7/1	
<b>Cerambycidae</b>			
<i>Isarthron castaneus</i> (Linnaeus, 1758)		6/1	6/1
<i>Monochamus sutor</i> (Linnaeus, 1758)			6/1,7/1 8/1
<b>Chrysomelidae</b>			
<i>Altica oleracea</i> (Linnaeus, 1758)	5/2,6/4	6/2	
<i>Batophila rubi</i> (Paykull, 1790)	5/1,6/3		
<i>Galeruca tanacetii</i> (Linnaeus, 1758)			8/1
<i>Chaetocnema hortensis</i> (Geoffroy, 1785)			6/1
<i>Chrysolina cuprina</i> (Duftschmid, 1825)			9/4
<i>Chrysolina rufa</i> Duftschmid, 1825			6/2
<i>Chrysolina varians</i> (Schaller, 1783)		6/1	5/1 6/11 7/3 8/3
<i>Longitarsus luridus</i> (Scopoli, 1763)		6/1,7/1	6/1
<i>Longitarsus suturellus</i> (Duftschmid, 1825)	9/1		5/4,6/8,7/2,8/1
<i>Luperus viridipennis</i> (Germar, 1824)		7/1	

Table 3. Continued

Taxone	Site A	Site B	Site C
<b>Chrysomelidae</b>			
<i>Minota carpathica</i> Heikertinger, 1911			5/1,6/2
<i>Mniophila muscorum</i> (Koch, 1831)		5/1	
<i>Oreina intricata</i> (Germar, 1824)			5/1
<i>Phyllotreta nigripes</i> (Fabricius, 1775)		9/1	6/5,7/3
<i>Phyllotreta nigripes</i> (Fabricius, 1775)	5/1		
<i>Phyllotreta vittula</i> (Redtenbacher, 1849)			8/1
<b>Anthribidae</b>			
<i>Brachytarsus nebulosus</i> (Forster, 1771)			9/1
<b>Curculionidae</b>			
<i>Anthonomus rubi</i> (Herbst, 1758)	7/1		
<i>Curculio pellitus</i> (Boheman, 1843)	9/1		
<i>Donus oxalidis</i> (Herbst, 1795)			7/1,8/1
<i>Hyllobius abietis</i> (Linnaeus, 1758)	6/3	5/3,6/3,7/2	6/2,7/2
<i>Magdalis punctulata</i> (Mulsant et Rey, 1859)			6/1
<i>Otiorhynchus equestris</i> (Richter, 1821)			6/1
<i>Otiorhynchus multipunctatus</i> (Fabricius, 1792)		6/1	
<i>Otiorhynchus niger</i> (Fabricius, 1775)		5/3,6/23,7/8,8/2	6/1,7/1
<i>Otiorhynchus lepidopterus</i> (Fabricius, 1794)		6/1	
<i>Phyllobius alpinus</i> Stierlin, 1859	6/3		
<i>Phyllobius arborator</i> (Herbst, 1797)		7/3	
<i>Polydrusus amoenus</i> (Germar, 1824)		7/1	
<i>Polydrusus pallidus</i> Gyllenhal, 1834	6/1	6/2,7/1	7/1
<i>Polydrusus impar</i> Des Gozis, 1882		7/2,8/7,9/4	7/1,8/3
<i>Rhamphus pulicarius</i> (Herbst, 1795)	6/2,8/2		
<i>Rhyncolus ater</i> (Linnaeus, 1758)		7/1	
<i>Rutidosoma fallax</i> (Otto, 1897)			6/1
<i>Sitona sulcifrons</i> (Thunberg, 1798)		9/1	
<i>Trachodes hispidus</i> (Linnaeus, 1758)	7/1		
<b>Scolytidae</b>			
<i>Ips typographus</i> (Linnaeus, 1758)	6/1	7/1,8/3	
<i>Crypturgus pusillus</i> (Gyllenhal, 1813)	6/1		
<i>Dryocoetes autographus</i> (Ratzeburg, 1867)		6/2	6/2,8/1
<i>Hylurgops glabratus</i> (Zetterstedt, 1828)		7/1	6/2
<i>Cryphalus piceae</i> (Ratzeburg, 1837)		5/110,6/5,7/4,8/3	
<i>Hylurgops palliatus</i> (Gyllenhal, 1813)	6/5,8/1	6/1	6/4,
<i>Pityogenes chalcographus</i> (Linnaeus, 1761)	5/1,6/2,7/4,8/2	5/11,6/24,7/3,8/1,9/1	5/5,6/13
<i>Hylastes ater</i> (Paykull, 1800)		6/5	
<i>Hylastes cunicularius</i> Erichson, 1836		5/7,6/7	
<i>Polygraphus poligraphus</i> (Linnaeus, 1758)			8/3
<i>Xyloterus lineatus</i> (Olivier, 1795)		5/20,6/2	

Table 2. Abundance of arthropods in the period May–September 2008

Arthropoda	Month (site, abundance per 1 m <sup>2</sup> )
Diplopoda	5.(A 5, B 5), 7.(A 4, B 4, C 5), 8.(A 5, B 4)
Chilopoda	7.(A 4), 8.(C 4)
Acarina	5.(A 29), 6.(B 16), 7(A 29, C 13)
Araneae	5.(A 53, B 8, C 4), 6.(A 99, B 53, C 40), 7.(A 43, B 27, C 5), 8.(A 56, B 29, C 53), 9.(A 32, B 13, C 27)
Opiliones	6.(C 8), 7.(B 5, C 4), 9.(B 4)
Collembola	5.(A 16, B 53, C 72), 6.(A 99, B 53, C 40), 7.(A 8, B 75, C 45) 8.(A 48, B 107), 9.(A 27, B 155, C 69)
Plecoptera	5.(A 11, C 4), 6.(A 40, B 21), 7.(A 24, B 53, C 13), 8.(A 4, B 8, C 5), 9.(B 11, C 4)
Isopoda	6.(A 4), 8.(A 4), 9.(A 4)
Pseudoscorpiones	8.(B 4), 9.(B 5)
Dermaptera	7.(A 4)
Blattodea	6.(C 5), 8.(B 4, C 4)
Heteroptera	5.(A 4, C 4), 6.(C 57), 7.(C 43), 8.(A 4, B 8, C 13), 9.(A 4, C 11)
Caelifera	6.(C 4), 7.(C 11), 8.(C 21), 9(C 8)
Aphidoidea	5.(A 4, B 40, C 27), 6.(B 72, C 13), 8.(B 13), 9(C 5)
Auchenorrhyncha	5.(A 4, C 4), 6.(A 5, B 5, C 11), 7.(A 165, B 45, C 19), 8.(A 64, B 91, C 69), 9.(A 5, B 13, C 13)
Psocoptera	7.(C 4), 8.(B 5, C 4), 9.(A 4, B 27)
Thysanoptera	5.(A 4, B 4, C 24), 6.(A 8, B 43, C 45), 7.(A 5, B 67, C 35), 8.(A 13, B 109, C 72), 9.(A 4, B 8, C 4)
Hymenoptera	5.(A 11, B 32, C 4), 6.(A 99, B 171, C 240), 7.(A 40, B 75, C 43), 8.(A 61, B 56, C 203), 9.(A 8, B 91, C 45)
Coleoptera	5.(A 19, B 430, C 56), 6.(A 113, B 379, C 258), 7.(A 15, B 117, C 75), 8.(A 21, B 59, C 64), 9.(A 13, B 31)
Neuroptera	7.(C 4), 8.(B 8), 9.(B 4)
Raphidioptera	7.(C 4)
Mecoptera	7.(C 4)
Lepidoptera	6.(A 11, B 8, C 13), 7.(B 5, C 21), 8.(A 4, C 16), 9.(C 5)
Trichoptera	7.(B 4)
Diptera	5.(A 56, B 208, C 216), 6.(A 376, B 432, C 792), 7.(A 155, B 128, C 275), 8.(A 117, B 227, C 114), 9.(A 96, B 59, C 117)
Larvae div.	5.(C 5), 6.(A 5), 9.(A 4, C 8)

Table 1. Abundance (specimens per 1 m<sup>2</sup>) of arthropods in the study area in 2008

	May	June	July	August	September	In total
Site A	210	774	499	391	188	2,062
Site B	722	1037	572	716	406	3,453
Site C	328	703	709	717	316	2,773

# Sezónna dynamika pôdnych článkonožcov so zameraním na chrobáky (Coleoptera)

## Súhrn

Dynamiku abundancie pôdnych článkonožcov je možné sledovať metódou pôdnych fotoeklektorov. Na troch študijných plochách v profile Tichej doliny vo Vysokých Tatrách sme takýto výskum uskutočnili v roku 2008. Počas vegetačnej sezóny (144) dní sme získali bohatý študijný materiál článkonožcov a najmä hmyzu, ktorý sa liahne z pôdy. Priemerná abundancia počas sledovaného obdobia bola 2,763 ex. m<sup>-2</sup>. V spoločenstve článkonožcov (zástupcovia 24 radov) dominovali Diptera 30,0 %, Hymenoptera 11,5 % a Araneae 11,7 %. Chrobáky (Coleoptera) dosiahli najvyššiu hodnotu dominancie 7,6 % v mesiaci jún.

Abundancia chrobákov s 145 druhmi (29 čeľadí) sa pohybovala v hodnotách 181 a 1,016 ex. m<sup>-2</sup>. Priemerná hodnota fenológie (liahnutia a aktivity) imág chrobákov má hodnotu 3,7 ex. Druh *Cryphalus piceae* dosiahol najvyššiu hodnotu abundancie 300 ex. m<sup>-2</sup> na ploche B.

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## Climate and treeline dynamics in the Ukrainian Carpathians Mts

Vazira Martazinova<sup>1</sup>, Olena Ivanova<sup>1</sup>, Oleksandra Shandra<sup>1</sup>

<sup>1</sup>Ukrainian Hydrometeorological Institute of the Ukrainian Academy of Science, 37 Nauki Av, Kyiv, Ukraine 03028, E-mail: alya.shandra@gmail.com

### Abstract

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In this paper we examine climate change and treeline dynamics of the Ukrainian Carpathians Mts during the 20<sup>th</sup> century. Changes in atmospheric circulation responsible for higher summer and winter temperatures are examined. Comparison of treeline positions in 1930s and 2000 reveals a decrease of area above the treeline and a general rise of treeline elevation, mostly in places where the treeline is formed by coniferous species. However, at locations with predominantly deciduous species there is little or no change. The magnitude of change is spatially heterogeneous. We consider warmer temperatures, among other relevant factors, to have impacted the observed treeline changes.

### Key words

climate change, coniferous species, deciduous species, treeline dynamics, Ukrainian Carpathians Mts

### Introduction

On a global scale, climate determines vegetation zonation, including montane vertical vegetation belts. Climate warming has been observed to raise the world's temperature by  $0.6 \pm 0.2$  °C in the 20<sup>th</sup> century. Atmospheric circulation is an important agent in determining global and regional climates, as well as causing extreme weather events. Temporal assessment of the variability of large-scale atmospheric circulation and its weather types for climate change analysis is a traditional task of synoptic climatology and is studied by different methods: statistical methods, classification of synoptic patterns, by Empirical Orthogonal Functions, by method of analogs, cluster analysis, Canonical Correlation Analysis, and Principal Component Analysis.

Climate change, associated with rising temperatures, has been reported to raise the treeline elevation in many places of the world; moreover, paleoclimatic investigations indicate a higher treeline position in previous warm epochs. At local scales, however, the modern treeline in Europe is influenced by other factors, both natural and anthropogenic; the latter include grazing, tourism and logging, which also change on a temporal basis (GEH-

RIG-FASEL et al., 2007). Climatic, edaphic, wind, and anthropogenic treeline types are discriminated by various researchers in the Ukrainian Carpathians. The treeline of the Ukrainian Carpathians is mainly coniferous (main species – spruce *Picea abies*), but at some parts it is formed by beech (*Fagus sylvatica*). Its average altitude is 1,200–1,300 m, lowering to 1,000 m in regions with intense grazing and close proximity to settlements. The altitude rises from west to east, indicating an influence of continentality, and thus higher summer temperatures. Overall, the position of the modern treeline is a result of a sum of relevant factors. Evaluation of changes in treeline position provides insight on how the coupled human-induced and natural processes impact the environment.

### Material and methods

Mean monthly fields of Sea Level Pressure (SLP) and geopotential fields over the North Hemisphere archive from the World Data Center, Obninsk Russia (1961–2000) and database of the Climate Research and Long-Range Weather Forecast Department, Ukrainian

Hydrometeorological Institute (1990–2005) were used (both  $5 \times 5^\circ$  regular grid) for analysis of the large-scale atmospheric circulation. Historical data was taken from (LAMB, 1961). Change to the large-scale atmospheric circulation is studied from decade to decade during the 20<sup>th</sup> century.

Objective classification of synoptic processes in this research was made on the basis of method of analogs (MARTAZINOVA, 2005). Etalons of SLP fields were chosen. An etalon for each class of synoptic situations is a SLP field selected among others which has the greatest similarity with all the other fields in its class. SLP etalons of the most probable class characterize the pattern of atmospheric circulation which formed predominant weather conditions for each month of the 20<sup>th</sup> century.

For assessment of treeline dynamics of the Ukrainian Carpathians ( $47^\circ 40' - 49^\circ 32' \text{ N}$ ,  $22^\circ 40' - 24^\circ 50' \text{ E}$ ) WIG historical maps issued by the Polish Military Institute circa 1930 (1 : 100,000) and renewed Czech maps based on the Third Military Survey of the Austro-Hungarian Monarchy issued circa 1925 (1 : 75,000) were compared with Landsat ETM images (2000–2002) and contemporary topographic maps (1 : 100,000; 2006) in ArcInfo software produced by ESRI. A Digital Elevation Model was produced based on contour heights digitized from 1 : 200,000 topographic maps. There were selected 71 mountain ridges, based on visual analysis of satellite images and maps. Two vector layers were created by manually delineating the forest-free area above the treeline – the first, “historical” one from Polish and, where their coverage was insufficient, Austrian maps ( $S_1$ ), and the second, “contemporary” one from the Landsat images ( $S_2$ ). The difference  $\Delta S = S_1 - S_2$  was calculated. To compare spatially the measure of treeline dynamics, a treeline advance coefficient  $k$  was introduced:  $k = \Delta S / L$ , where  $L$  is the length of each mountain ridge (measured based on the highest points within the  $S_1$  polygons). Thus,  $k$  represents the amount of meadow area decrease per kilometer. The average treeline altitude for each mountain ridge was calculated based on DEM values. Based on a geobotanic map (GOLUBETS, 1968) and satellite vegetation spectral features, one of four categories (coniferous, deciduous, mixed – mainly coniferous, mixed – mainly deciduous) was assigned to each ridge based on the prevailing tree species at the treeline.

## Results and discussion

### Transformation of atmospheric circulation in the Atlantic-European sector during the recent decades

Changes in the global climate over the last century have been spatially and temporally heterogeneous. Three periods can be distinguished in the global temperature regime: two periods of warming (end of 19 century – 1940

and end of 1970's – end of 1990's) are separated with a period of relative temperature stability (1940–1970's) (*WMO statement on the status of the global climate in 1995*, 1996). It has been shown (MARTAZINOVA and SVERDLIK, 1998) that this periodicity can be explained by changes in the large-scale atmospheric circulation. In this article we will examine changes to the atmospheric circulation over the Atlantic-European sector during the last period of global warming.

Over the North hemisphere, the maximum warming since the end of the 1970s took place in continental areas between  $40^\circ \text{ N}$  and  $70^\circ \text{ N}$  in winter and spring. The winter planetary atmospheric circulation of the North hemisphere in the middle layer of the troposphere in the latitudinal sector  $40^\circ$  and  $70^\circ \text{ N}$  is a three-vortex system consisting of three ridges (North Atlantic, Siberian and Canadian maximums of pressure). Three vortex minimums of pressure are placed between them (European, Aleutian, and Icelandic). In winter weather of the Ukrainian Carpathians, an important role is played by the state of the European minimum and Siberian maximums of pressure. In this paper prevailing pressure fields are shown for winter and summer of the three decades of the period 1974–2005 (Fig. 1).

The area of high pressure was predominating in winter over the Ukrainian Carpathians during 1974–1983; however, cyclones also well developed in the area of Icelandic minimum and in Eastern Europe, causing cool and snowy winters in Ukraine. The summer of 1974–1983 was characterized by less intensive SLP gradients with moderately warm weather. In winter of the subsequent decades (1986–1995 and 1996–2005), the high pressure moved eastward and occupied almost all Europe including Ukraine. Such a position of high pressure creates anomalously warm winters with little or no snow. From the East, the contraction of Siberian maximum significantly reduces the opportunity for cold air to inflow to the East Europe and Ukraine.

In following decades in summer high pressure is intensified over Central Europe creating mainly hot and dry weather in Europe, including its eastern part. High temporal stability is another distinctive feature of the most probable SLP field during the recent decade that sometimes resulted in heat waves and droughty conditions in Europe.

It is widely recognized that atmospheric circulation greatly influences the climatic regime of any given territory. The role of atmospheric circulation for the climatic regime of the Ukrainian Carpathians is exemplified in Fig. 2.

The monthly average temperature of the Rahiv weather station (431 m a.s.l., see Fig. 3) during the period of 1974–1983 in January was fairly temperate, which is explained by the combination of well-developed cyclones and area of high pressure. However, in July the etalon situation caused meridional air-mass transport over the Ukrainian Carpathians, which resulted in cooler than

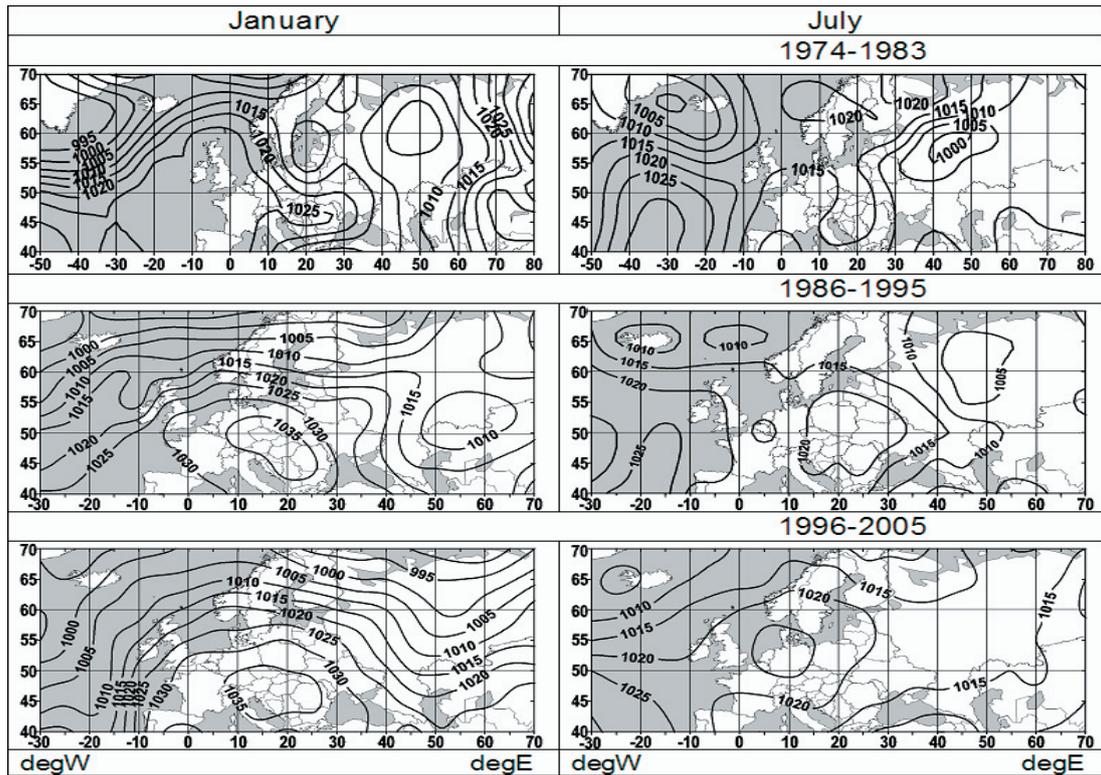


Fig. 1. Etalon SLP fields in the Atlantic-European sector in winter and summer, 1974–1983, 1985–1995, 1996–2005.

average monthly temperature. In the period of 1986–1995 the dominating field of high air pressure resulted in a general rise of monthly average air temperature both in January and July, on the other hand, short-termed but anomalously cold non-etalon atmospheric processes (not represented in Fig. 1) caused years with below-average monthly temperature both in January and July. The above-average temperature of July is especially significant for trees growing at the treeline, since their growing season is confined to the warmest months of the year.

#### Comparison of treeline positions (1930s to 2000)

During the study period, the total meadow area above the treeline decreased by 15,380.8 ha, which is 24% of the initial area  $S_j$ ; and, consequently, the treeline position has been shifted to a higher elevation. The largest meadow area decrease was observed on ridges with coniferous species at the treeline (42%,  $k = 305.3$ ). On the contrary, ridges with deciduous forest experienced a small increase in meadow area, and therefore a rise in treeline position (–6%,  $k = -18.1$ ). Ridges with mainly coniferous forests have experienced decrease of meadow area, but less than in the 1<sup>st</sup> group (24%,  $k = 178.7$ ), while the rate of meadow decrease on

ridges with mainly deciduous species was quite low (32%,  $k = 69.8$ ) (Table 1).

The high  $\Delta S/S_j$  and relatively low  $k$  value in the last group of Table 1 is caused by complete afforestation of small, low-elevated ridges (mainly located in the Beskid area), which constitute a significant part of the overall number of ridges of this category. The treeline advance coefficient represents the magnitude of treeline position change more adequately than  $\Delta S/S_j$  on a spatial scale.

Overall, the treeline dynamics in the Ukrainian Carpathians demonstrates regional peculiarities (Fig. 3). The largest treeline advance coefficients belong to the Gorgan, Chornogora, and Marmarosh area, followed by minimal positive values in the Beskids and negative values in the Polonina region. The changes in average treeline height for these regions are described in Table 2. As seen from the table, the changes in treeline altitude are proportional to treeline advance coefficients. The Beskid region comprises low-elevated mountains proximate to settlements. It is probable that human disturbance has impeded further treeline advance at these locations. The Gorgans, remote high elevated mountains with limited human access, have experienced the most significant treeline rise. On the contrary, the treeline of the Poloniny mountain ridge, located in the beech forest zone, was lowered during the study period. Treeline altitude

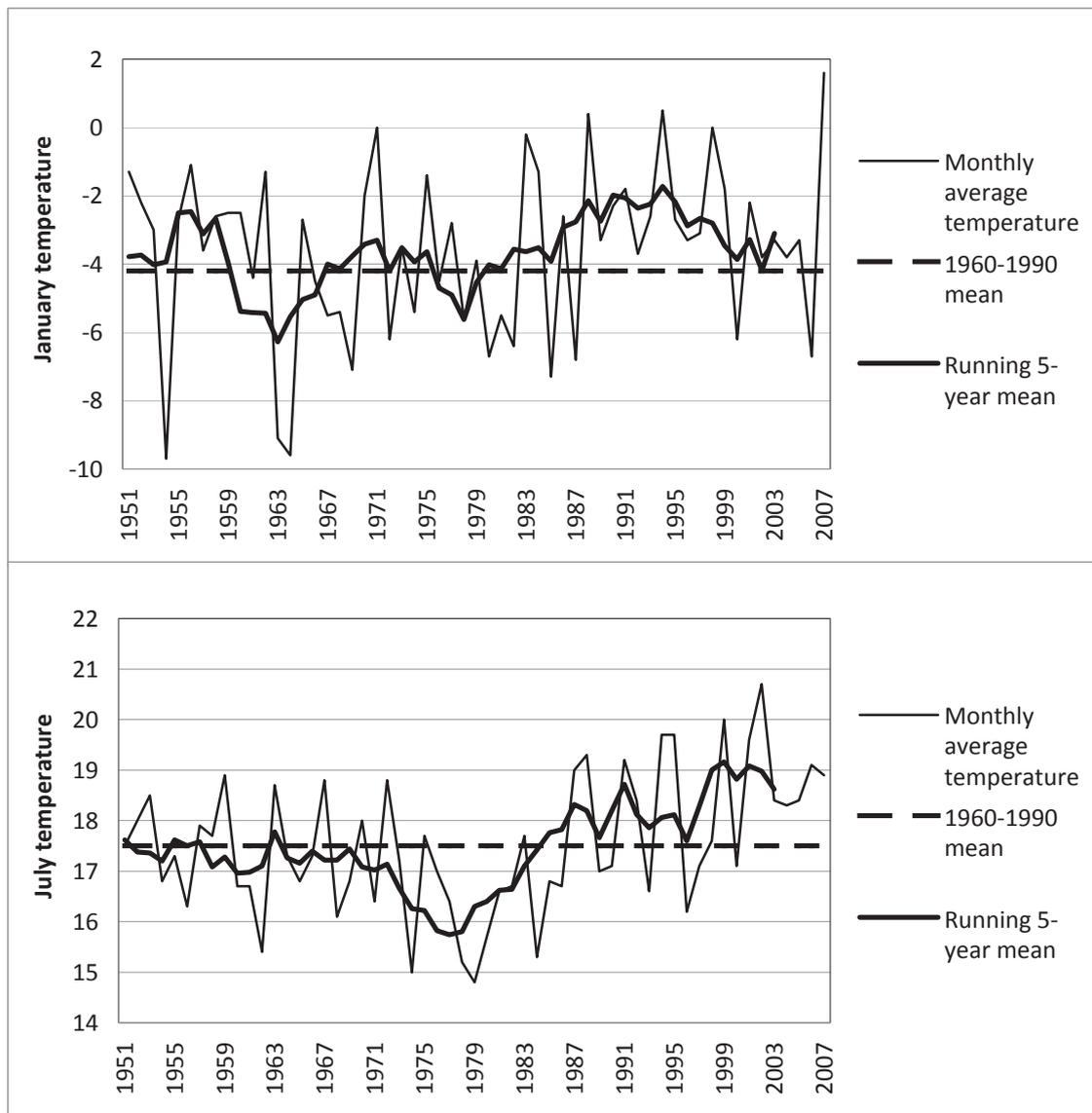


Fig. 2. Monthly average and running 5-year mean of January and July temperature at Rahiv weather station (431 m a.s.l.).

of the Chornogora and Marmarosh, the highest-elevated mountain ridges of the Ukrainian Carpathians, has risen but to a somewhat smaller extent than on the Gorgans.

At some locations, such as the Svidovets ridge from the Polonina system, the treeline on the northern slopes is constituted by coniferous trees, while on the southern slopes it is formed by beech (Fig. 4). At this location, the treeline of coniferous species demonstrated a noticeable rise in altitude while the beech treeline was stable or lowered. The influence of human presence and grazing is represented by sheds (as located on a 1 : 100,000 topographic map), which are most probably shepherd's huts. Though grazing intensiveness has generally fallen in the last decades, at some locations the presence of sheds has impeded treeline rise.

A general trend in the Carpathians forest dynamics of the last decades is a gradual replacement of

coniferous forests by mixed forests (MIHAI et al., 2007; personal communication). However, in this study, colonization by coniferous species was observed at some locations above the beech treeline. Given that the beech treeline in the Ukrainian Carpathians is considered by many researchers to be of secondary origin, this could indicate an ongoing process of restoration of the montane vegetation zones. With regard to the observed high rates of treeline advance in coniferous species, it must be stated that at the treeline in the Ukrainian Carpathians, coniferous tree species experienced better conditions for expansion. In general, the rate of treeline rise was positively correlated with altitude, which reflects more difficult access to elevated mountaintops and thus better conditions for tree establishment.

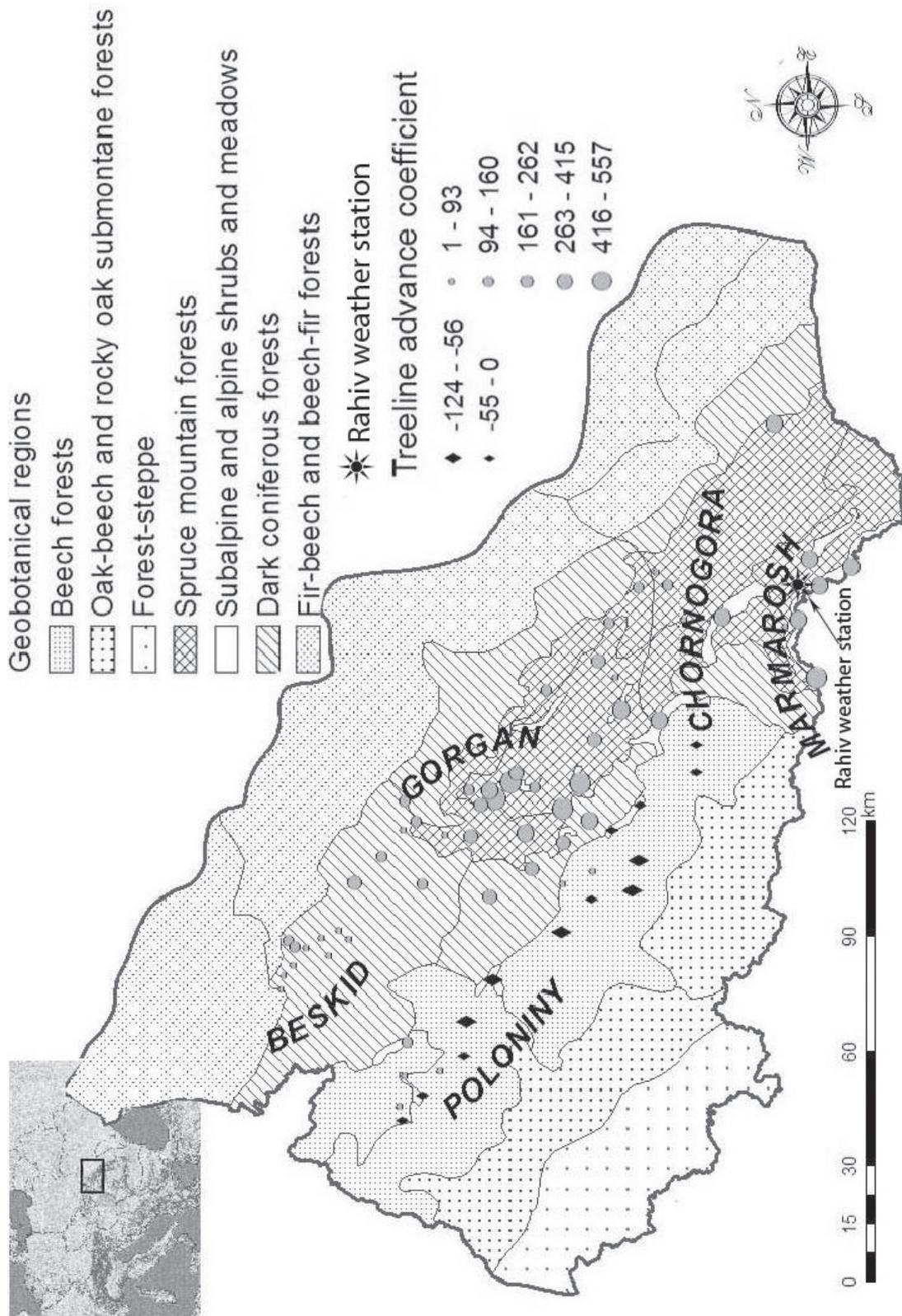


Fig. 3. Spatial distribution of tree line advance coefficients over geobotanical regions.

Table 1. Changes in mountain meadow area during the study period

Categories of mountain ridges	$S_1$ [ha]	$S_2$ [ha]	$\Delta S$ [ha]	$\Delta S/S_1$ [%]	$k$
All categories	62,971.4	47,590.6	15,380.8	24	147.8
1. Coniferous forest	20,575.9	12,017.3	8,558.6	42	305.3
2. Deciduous forest	11,103.4	11,736.7	-633.3	-6	-18.1
3. Mixed forest – mainly coniferous	30,150.4	23,057.9	7,092.5	24	78.7
4. Mixed forest – mainly deciduous	1,141.3	778.7	362.5	32	69.8

$S_1$ , meadow area on historical map;  $S_2$ , meadow area on modern map;  $\Delta S = S_1 - S_2$ ;  $k$  – coefficient of treeline advance. Area is shown in hectares.

Table 2. Changes in average treeline elevation

Region	Average $h_1$ [m]	Average $h_2$ [m]	$\Delta h$ [m]
Beskid	1,105	1,096	9
Gorgan	1,393	1,347	46
Poloniny	1,169	1,183	-14
Chornogora	1,370	1,345	25
Marmarosh	1,448	1,413	35
All	1,306	1,293	13

$h_1, h_2$ , average treeline elevation on historic maps and satellite images respectively;  $\Delta h = h_1 - h_2$ .

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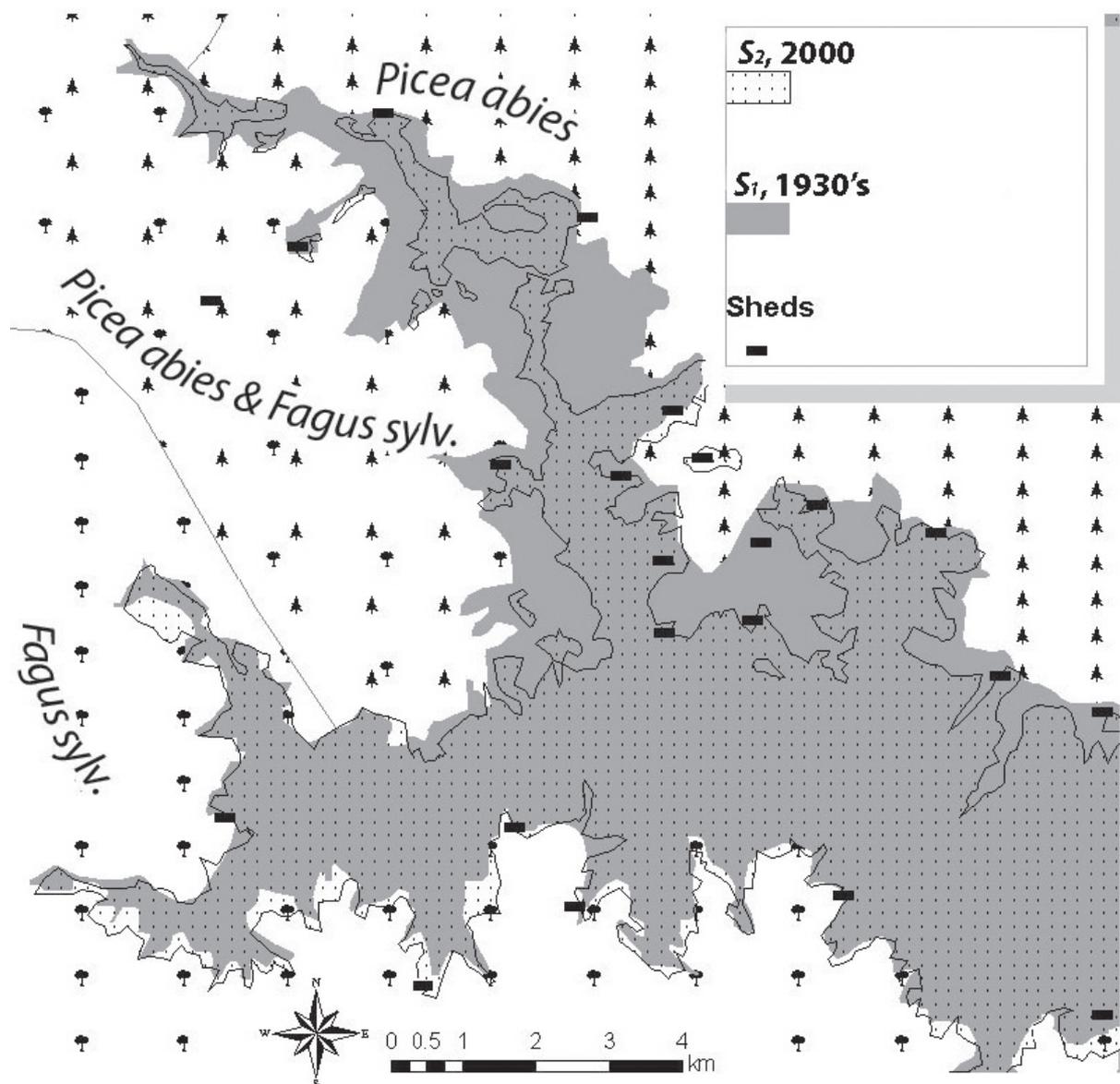


Fig. 4. Changes in treeline position on Svidovets mountain ridge. Geobotanic zones are from GOLUBETS, 1968.

## Klíma a dynamika hornej hranice lesa v Ukrajinských Karpatoch

### Súhrn

Práca sa zaoberá zmenami klímy a dynamikou hornej hranice lesa v Ukrajinských Karpatoch v priebehu 20. storočia. Predmetom výskumu boli zmeny atmosférickej cirkulácie zodpovedné za nárast letných aj zimných teplôt. Porovnanie medzi hornou hranicou lesa v rokoch 1930 a 2000 ukázalo, že územie nad touto hranicou sa zmenšilo najmä v oblastiach, kde túto hranicu tvoria ihličnaté dreviny. Na druhej strane, v oblastiach s listnatými drevinami boli tieto zmeny menšie alebo žiadne. Veľkosť posunu vykazuje značnú priestorovú variabilitu. Názor autorov práce je, že príčinou posunu hornej hranice lesa bol, okrem iných faktorov, nárast teploty.

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## Population dynamics of spruce bark beetle in a nature reserve in relation to stand edges conditions

Pavel Mezei<sup>1</sup>, Rastislav Jakuš<sup>1</sup>, Miroslav Blaženec<sup>1</sup>, Slávka Belánová<sup>2</sup>, Ján Šmídt<sup>3</sup>

<sup>1</sup>Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,  
E-mail: mezei@savzv.sk, jakus@savzv.sk, blazenec@savzv.sk

<sup>2</sup>National Park Muránska planina, J. Kráľa 12, 050 01 Revúca, Slovak Republic

<sup>3</sup>Revúcka Lehota 106, 049 18 Lubeník, Slovak Republic

### Abstract

MEZEI, P., JAKUŠ, R., BLAŽENEC, M., BELÁNOVÁ, S., ŠMÍDT, J. 2011. Population dynamics of spruce bark beetle in a nature reserve in relation to stand edges conditions. *Folia oecol.*, 38: 73–79.

Over the period 2006–2009 spruce bark beetle (*Ips typographus* [L.]) population was monitored after two windstorm events in a nature reserve in Slovak Ore Mountains. The monitoring was carried out with pheromone traps in three different forest edges: 1) edge of wind-felled trees area, 2) disturbed stand edge and 3) undisturbed stand edge. The one-way ANOVA confirmed statistically significant differences among stand edges in each year and a post-hoc test was applied. In first two years after the primary disturbance the most attractive for spruce bark beetle was the edge of wind-felled trees area. After two years from the primary disturbance the most attractive became the disturbed stand edge. The undisturbed stand edge showed a similar attractivity for spruce bark beetles almost over the whole monitoring period.

### Key words

nature reserve, pheromone trap, population dynamics, spruce bark beetle

### Introduction

Spruce bark beetle (*Ips typographus* [L.]) is an integral part of spruce ecosystems. As a pioneer it colonizes dying trees and thus starts wood decomposition (WERMELINGER, 2004) and it can be also considered as a natural tool for spruce forests restoration (JONÁŠOVÁ and PRACH, 2004). In an outbreak conditions, however, the spruce bark beetle can cause considerable damage to production forests. In November 2004, Slovakia was hit by heavy windstorm and this event was followed by bark beetle outbreaks in several mountain units. One of the tool for bark beetle management are pheromone traps, which represents a tool for monitoring the beetle's populations as well as for reducing its abundance.

The windstorm in November 2004 hit also the Nature Reserve NR Fabova hoľa where the volume of wind fallen trees was about 7,600 m<sup>3</sup>. Another storm

in August 2007, left another 7,600 m<sup>3</sup> of felled trees. The area attacked in August 2007 was about 1.5 km far from the area attacked in November 2004. In both cases, the age of the forest stands was about 150 years. These events were followed by a gradation of bark beetles population in subsequent years. All the wind felled trees were retained in the nature reserve. In area, which was hit by the 2004 storm, barriers of pheromone traps were deployed and in the surroundings of the nature reserve sanitation felling was carried out.

The volume of wind felled trees in 2004 in the forest stands from which our data have been assembled was about 2,100 m<sup>3</sup> and the area of wind-throw was about 4.3 ha. Another 1,500 m<sup>3</sup> covering 2.9 ha were in the adjacent stand.

As the reserve was attacked by wind in November 2004, we considered the year 2005 as the first year of the development of bark beetle population. In this and

in the following year (2006), the insects attacked primarily the fallen trees. In summer 2006, they started attack on the surrounding standing trees, but the main attack to standing trees began in 2007 with a volume of about 390 m<sup>3</sup> in the studied stands, and 750 m<sup>3</sup> in the adjacent stand. The windstorm event in 2007 left another 400 m<sup>3</sup> of wood in study stands.

In 2008, another 1,400 m<sup>3</sup> of standing trees were attacked in the study stands, and 850 m<sup>3</sup> in the adjacent stand, in 2009 these amounts increased by 1,200 m<sup>3</sup> and 300 m<sup>3</sup>, respectively.

In summary, the amount of attacked wood in our study area was 3,000 m<sup>3</sup> and in the adjacent stand 1,900 m<sup>3</sup>.

The aims of this study was to define the dynamics of development of spruce bark beetle's (*Ips typographus*) population and its inter-annual dynamics based on the catches in pheromone-baited traps in years 2006–2009 according to the trap position: on the edge of the wind felled area, in a new-formed stand edge (disturbed stand edge) and in an intact stand edge (used at the same time as the control plot).

## Material and methods

### Study area

The NR Fabova hoľa is situated in the ridge part of the mountain massive Fabova hoľa in the Veporské vrchy Mts belonging to the Slovenské rudohorie Mts (summit of Fabova hoľa: N 48°46.346', E 19°53.149') at 1,100 to 1,439 m a.s.l. The reserve has an area of 260 ha, more than 250 ha are covered with forests.

The bedrock material is crystalline complex of rocks, the climate is cold, mountainous, with average temperature in July 10–12 °C (ANONYMUS, 2009). The forest communities, belonging to the 6<sup>th</sup> and 7<sup>th</sup> forest vegetation tier, are: Fagetum abietino-piceosum, Ace-reto-Piceetum and Sorbeto Piceetum. The NR Fabova hoľa is a part of the National Park Muránska planina, mountain plateau.

### Methods used in monitoring

Monitoring of the bark beetles was carried out in the NR Fabova hoľa in forest stands attacked by the wind storm in 2004. The wind attacked area was situated on a W-oriented slope at 1,250–1,350 m a.s.l., with an area of about 4.3 ha, and with 2,100 m<sup>3</sup> of windthrown wood.

For monitoring of spruce bark beetle Ecotrap pheromone traps were used over the whole study period (2006–2009), in 2006 Theysohn pheromone traps were also used. The traps were arranged in a barrier (JAKUŠ, 1998a) on circumference of the oval-shaped wind felled area.

The Ecotrap traps were provided with selective sieves – to prevent trapping larger insect species. Pheromone lures of two types: IT Ecolure Extra (Fytofarm Ltd.) in years 2006–2008 and Pheroprax A (BASF) in year 2009 were used. These two pheromone lures can be considered as comparable (ZÁHRADNÍK and GERÁKOVÁ, 2010). The arrangement of pheromone traps, application of pheromone lures as well as bark beetles sampling followed the Slovak standard STN 48 2711 (ANONYMUS, 1997) according which the distance to the nearest healthy spruce tree was at least 10 m and the active surface of the traps was placed from 1.5 to 2 m above the ground.

### Data processing

The data for further processing were selected from the traps situated in the barrier in such a way that they can be clearly classify into one of the following category:

1. Edge of wind-felled trees area – it was the lower part of the barrier of pheromone traps placed around the wind-felled area. The traps were arranged on the boundary between the disturbed area and a young, artificially established spruce stand, not yet with closed canopy, aged of about 15 years. The traps were situated on a west-facing slope.
2. Disturbed stand edge, that means a new-formed stand edge above the wind felled trees area, i.e. the upper part of the trap barrier. In this place, the wind felled area came together with the adjacent closed canopy forest stands. These traps were also situated on a west-facing slope.
3. Undisturbed stand edge, i.e. stand edge undisturbed by wind. These traps were placed lowest, at a 400 m distance from the wind-felled area. The traps were situated on a slope facing S or SW. These traps served also as a control plot.

The catches of bark beetles were evaluated statistically, using the STATISTICA software. Annual catches of spruce bark beetle were evaluated. The catches were compared with one-way analysis of variance. Then a post hoc test (Fischer LSD test) was applied to compare the annual mean values per a trap according to the trap position. The traps were arranged in numbers as we can see in Table 1. The numbers of traps of different categories were different in most of the years, because of the terrain accessibility, damage by game and snow and in some years lures for six-spined spruce bark beetle (*Pityogenes chalcographus*) were also used.

Table 1. Numbers of pheromone traps used in our study

Stand edge type	2006	2007	2008	2009
Edge of wind-felled area	6	10	8	8
Disturbed stand edge	11	9	10	12
Undisturbed stand edge	11	11	9	12

## Results

The data on annual catch of spruce bark beetles were processed by one-way analysis of variance. The results have been summarised in Table 2. The differences between catches in pheromone traps were found statistically significant in each year. The dependence of catches according to trap position was tested with Fischer LSD test separately for each year (Fig. 1). The LSD test was calculated for each year separately. In 2006, the disturbed stand edge differed from the undisturbed edge as well as from the edge of wind-felled trees. In 2007, the catches in the disturbed stand edge and in the edge of wind-felled trees area were already the same. In the following years (2008 and 2009), there were conspicuous differences between the three different forest edges.

Table 2. Results of one-way analysis of variance in annual catches of spruce bark beetles in pheromone traps in years 2006–2009

Year	F	p
2006	6.5091	0.005301
2007	10.6198	0.000396
2008	42.7076	0.000000
2009	8.5276	0.001222

Statistically significant at  $p < 0.05$ .

Over the whole monitoring period, an increasing trend in number of caught spruce bark beetle was observed in the disturbed stand edge.

The same trend was observed at the edge of wind-felled trees until 2008, in 2009 it was followed by the first drop in numbers of spruce bark beetles caught.

The disturbed stand edge trapped more individuals than the undisturbed one in the third year after the primary disturbance.

In 2009, the highest mean catches were obtained in the undisturbed stand edge. In our opinion, this was caused by tree felling and skidding near the pheromone trap barrier, which was placed alongside the undisturbed forest edge. This fact has been confirmed also when we modelled the population curve of spruce bark beetle population in year 2009 based on mean catches of bark beetles after each control of pheromone traps (Fig. 2).

Figure 2 clearly illustrates that during the first swarming period the mean catches of bark beetles in the undisturbed stand edge were only halves of the catches in the disturbed stand edge. In the summer swarming, however, the mean catches in the undisturbed stand edge were much higher compared to the disturbed stand edge, namely in the period when the mentioned tree felling and skidding was carried out nearby (so the beetles were not “attracted” by the stand edge primarily but by the freshly logged trees near the stand edge).

## Discussion

The main purpose of the pheromone trap barrier installed in the NR Fabova hoľa was to eliminate the possible impacts of bark beetle outbreak on forest stands in the neighbourhood of the reserve. Based on the results obtained during the monitoring we can discuss two phenomena: we can assess the development of spruce bark beetle population and compare the attractiveness of different stand edges.

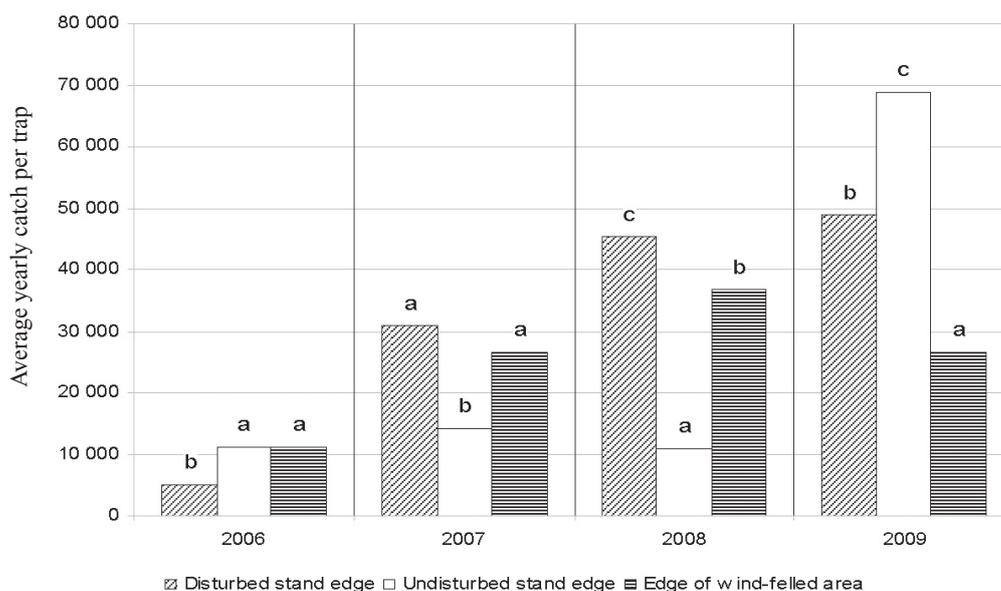


Fig. 1. Mean annual catches of spruce bark beetle per trap in years 2006–2009 and the result of Fischer LSD test.

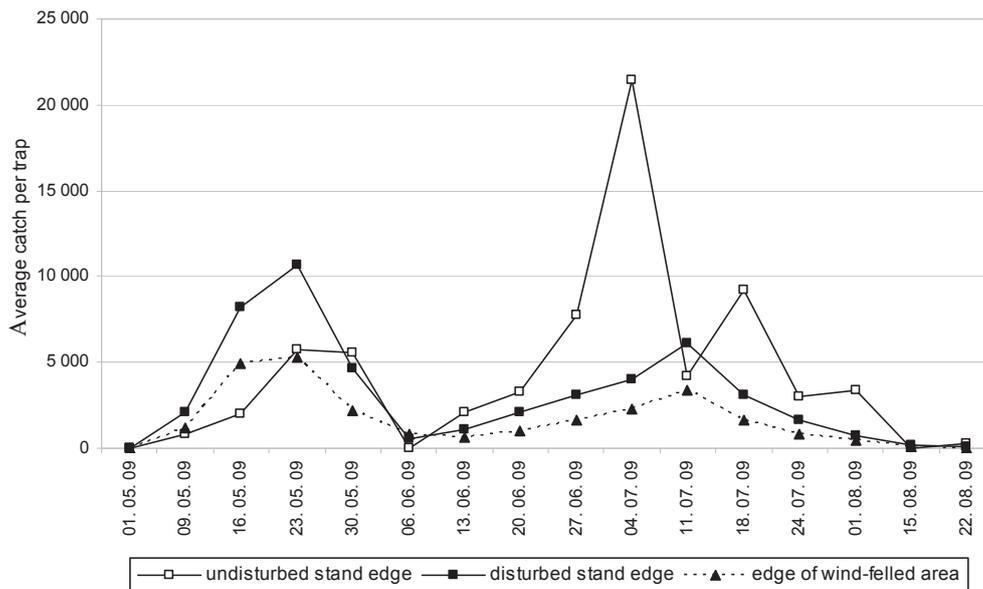


Fig. 2. Development of spruce bark beetle population in the NR Fabova hoľa in 2009 according to trap position.

### Population dynamics of spruce bark beetle

A monitoring of bark beetles similar to our, was performed by ZACH et al. (2009) in the National Nature Reserve Tichá dolina valley in the High Tatras National Park. The wind disturbance in the High Tatras Mts took place in the same year as the disturbance on the Fabova hoľa (2004). Fabova hoľa, however, was disturbed by wind again in 2007. The research in Tichá dolina was running with non-baited traps placed directly in stands with three different structures (heavy influenced, influenced and non-influenced); our results, on the other hand, were obtained in forest edges differing in structure, with baited pheromone traps arranged in barriers. The catches in Tichá dolina showed culmination in the third year after the disturbance (2007) followed by decreases in bark beetle catches in all the three stand types. On the other hand, the catches in Fabova hoľa culminated in 2008 – but only at the edge of wind-felled trees area. In the disturbed stand edge, a small increase in bark beetle catches was recorded even in 2009, five years after the primary disturbance. The question arises, however, to what extent can be compared spruce bark beetle catches in case of use of baited and non-baited pheromone traps. For example NIEMEYER (1985) caught in non-baited traps from 3.7% to 27.9% of the amount of bark beetles caught in baited traps. The baited traps were placed only 1 m far from the non-baited ones. Another think to mention is that pheromone traps themselves can act as attractants for bark beetles. Stressed trees release primary attractants while the traps may be sources of secondary (Pheroprax) or even together primary and secondary attractants (IT-Ecolure) (JAKUŠ, 1998a). In such a way, there can be a synergic effect at-

tracting more individuals of bark beetles into the barrier than either the stand wall or pheromone traps alone.

Catches of spruce bark beetle in Fabova hoľa did not differ from the catches in Tichá dolina only in time of their culmination. In Tichá dolina the most massive invasion was recorded just in 2006 but the catches in Fabova hoľa culminated one year later (2007). In Tichá dolina the catches of spruce bark beetles in partly influenced forest were conspicuously higher compared to the strongly influenced one. The differences between the edge of wind-felled trees area and the disturbed stand edge in Fabova hoľa were not such conspicuous. These differences, however, as mentioned above, could result from different monitoring methods of bark beetle (traps installed at stand edges and use of pheromone lures in case of Fabova hoľa).

### Attractiveness of stand edge

As it has been just mentioned above, the first year of the spruce bark beetle population development in Fabova hoľa can be dated in 2005 in which monitoring with pheromone traps was not performed yet. But in the first two years, bark beetle individuals were invading the lying trees (documented with the data about the attacked wood volume), in the summer 2006, they started invading neighbouring forest stands. This was caused by the fact that an area covered with fallen trees and lacking standing ones provides favourable conditions for some bark beetle species in the first and the second year after the disturbance, while partially influenced (disturbed) area provides, thanks certain specific conditions, favourable substrate for longer time (ZACH et al., 2009).

Considerable change took place in 2007 that means in the third year after the disturbance, with the highest number of spruce bark beetles trapped in the disturbed stand edge (Fig. 1). This could be caused by the fact that broken wind-thrown trees are attacked by bark beetles in the first year after the disturbance, while wind-thrown trees still keeping contact with soil are attacked in the second year (JAKUŠ, 1998b). Jakuš, on an endemic population of spruce bark beetle in the Poľana Mts observed, that damaged trees having good contact with the soil are colonised in the second year only in their upper parts, while their lower parts are invaded in the third year only. It means that in the first two years, bark beetles have sufficient feeding substrate on fallen trees, and that they attacked the disturbed wall only after they have colonised all this substrate. Another important factor influencing the colonisation of trees by spruce bark beetles is insolation, which effect is increasing in time elapsed from wind disturbance (JAKUŠ, 1998a, 1998b). Tree stems around area with wind-felled trees are stressed by enhanced solar irradiation, and the trees become more prone to attack from bark beetles. After die-back of all the trees in the closest neighbourhood of the area with wind-felled trees, further trees in the disturbed stand wall become suffer form insolation. This is the mechanism which underlies the highest attractiveness of disturbed stand edges for bark beetles over time.

SCHROEDER and LINDELÖV (2002) report examples from Sweden in forest stands from which wind-thrown wood has not been removed. In these stands, most trees were dying in the 2<sup>nd</sup> and the 3<sup>rd</sup> year after the disturbance; on the other hand, practically no dieback was observed in the 1<sup>st</sup> year. The major part of dying trees was at stand edges, in years 1997 and 1998 representing 20 times more trees per one hectare in comparison with the stand interior. The observation of ZACH et al. (2009), and SCHROEDER and LINDELÖV (2002) are consistent with our observations to which one or two years after the disturbance, the most attractive forest edges for bark beetles became the disturbed stand edge.

The number of bark beetles catches to pheromone traps situated on the border of wind-felled trees area in Fabova hoľa culminated in the fourth year after the primary disturbance; while the numbers of bark beetles caught in severely influenced stands in Tichá dolina showed maxima already in the third year. This difference may have resulted from the fact that Fabova hoľa suffered an additional wind storm in 2007, resulting in additional cca 400 m<sup>3</sup> of trees suitable for bark beetle development. In the third year after the disturbance culminated also the bark beetle outbreak in the Alps (WERMELINGER et al., 2002). A study carried out in the Nature Reserve Osaby in Sweden conducted after one wind-throw event in year 2005 (KOMONEN et al., 2010) showed that 10% of fallen trees were colonised in the first years after the disturbance and 64% of such trees

were colonised in the second year after the disturbance. WERMELINGER (2004) reports that the gradation of spruce bark beetle in low elevations or in wind-throws with broken trees, the peak of abundance of spruce bark beetle reaches in the second summer after the disturbance, in mountain conditions or areas with uprooted trees, in the third year after the disturbance. WERMELINGER (2004) also notes, that bark beetle outbreak in ordinary conditions lasts between 3–6 years. The data concerning the bark beetle outbreak in the High Tatras Mts in years 1993–1998 from data of the attacked wood amount document a population drop in 1996–1997, that means about four years after the outbreak (GRODZKI et al., 2006). Similar data present SCHROEDER and LINDELÖV (2002) from Gruvskogen and Hochharz, where high tree mortality occurred even in the third year, and from Banwald Napf where it was still present in the fifth year after the disturbance. SCHROEDER (2001) lists in his analysis about 16 different localities with non-removed wind-thrown trees, and in five of them the tree die-back lasted longer than 3 years. High catches of bark beetles in pheromone traps in Fabova hoľa indicate the same course of the outbreak. Fabova hoľa is situated in cold mountainous climate where according to BOUGET and DUELLI (2004) tree die-back associated with spruce bark beetle is slower, but the outbreak itself takes more time. Moreover, another wind storm in 2007 has resulted in additional substrate suitable for bark beetle development.

In 2006, at the beginning of the monitoring, the catches in the undisturbed stand edge were similar to the catches in the edge of wind-felled trees. This was probably caused by the fact that the undisturbed stand wall could trap beetles migrating into the wind-thrown area. The catches in undisturbed stand edge were very similar over the whole period, so we suggest that the attractiveness of this stand edge for spruce bark beetle remained unchanged over the whole monitoring period. The 7-fold catch increase in the undisturbed stand edge in 2009 compared to 2008, may be due to wood felling and skidding in stands adjacent to the reserve and in the proximity of pheromone traps. Fresh logs and fresh felling residues are a source of primary attractants. Together with secondary attractants (pheromone lures in traps), they can attract higher amount of bark beetles, as reported e.g. by AUSTARA et al. (1986).

### **Influence of trap barriers on bark beetle population**

There are some records from the past when the use of pheromone trap barrier succeeded in drop in population of spruce bark beetles in outbreak conditions (JAKUŠ, 1998a; SCHLYTER et al., 2001). On the other hand, there have also been reported cases when application of pheromone traps had no influence on bark beetle population (WESLIEN, 1992). DIMITRI et al. (1992) suggest that a massive catch of bark beetles can limit their increase

in their population to some extent, but the primary factors governing the population dynamics are still weather conditions and food accessibility. The catch numbers for bark beetles trapped in pheromone traps can serve as an indicator for assessment of the developmental trend for the bark beetle population in the following year (FACCOLI and STERGULC, 2006). In case of Fabova hoľa it is evident that in spite of use of the pheromone traps, the catches of spruce bark beetles increased year after year but on the other hand, it is possible that the gradation rate of spruce bark beetles may have been slightly reduced thanks to these traps.

An experiment carried out by DUELLI et al. (1997) showed, that one third of the local bark beetle population can be trapped in pheromone traps, and the other two thirds migrating to more remote localities. WESLIEN and LINDELOW (1989) imply that about 80% of individuals caught belong to migrating ones; a similar figure (70%) was also given by NEMEC et al. (1993). WICHMANN and RAVN (2001) found out, that new spruce bark beetle infestations were formed mostly at 500 m distance from old attacked trees; that means that individuals leaving attacked trees on Fabova hoľa could migrate across the reserve and in its close neighbourhood. This may have been also the case of the border of area with wind-felled trees, showing high catch numbers even quite long after the primary disturbance. Another factor, probably affecting raising numbers of spruce bark beetle catches later, was a second wind storm; so the lower-situated traps – at the edge of the wind-throw area trapped the migrating individuals. This could result also in the fact, that the catches in 2006 in the undisturbed stand edge and in the edge of wind-felled trees area were very similar – because the lower situated undisturbed edge could trap also spruce bark beetle individuals flying to the one-year-old plot covered with wind-thrown trees.

## Conclusions

1. The attractiveness of stand edges for spruce bark beetle is changing according to time elapsed from the primary disturbance.
2. In the first two years after the disturbance the most attractive are wind-felled trees offering the most suitable substrate for spruce bark beetle development.
3. When bark beetles deplete their substrate of wind-thrown trees, the most attractive is becoming the disturbed stand edge close to the windblown trees.
4. The catches of spruce bark beetles in pheromone traps can be considerably influenced by migration.

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## Populačná dynamika lykožrúta smrekového v prírodnej rezervácii v závislosti od stavu porastových okrajov

### Súhrn

Populačná dynamika lykožrúta smrekového (*Ips typographus*) bola sledovaná v období rokov 2006 až 2009 v Prírodnej rezervácii Fabova hoľa v troch rôznych porastových okrajoch: v narušenej porastovej stene, nenarušenej porastovej stene a na okraji vývratiska. Monitoring bol robený pomocou feromónových lapačov na území prírodnej rezervácie. Údaje o odchytených lykožrútoch sme podrobili jednofaktorovej analýze variancie. Následne sme porovnali priemerné celoročné hodnoty odchytovej lykožrútoch na jeden lapač podľa pozície lapača post hoc testom (Fischerov LSD test). Rozdiely medzi odchytmami do feromónových lapačov boli v každom roku štatisticky významné.

Atraktivita porastových stien sa pre lykožrúta smrekového menila v závislosti od času od prvotnej disturbance. Prvé dva roky po disturbance bol najviac atraktívny okraj ležiacej hmoty, ktorá ponúkala najvhodnejší substrát pre vývoj lykožrúta smrekového. Aj naďalej však v nej stúpala počet odchytených lykožrútoch, keďže prírodná rezervácia bola zasiahnutá vetrovým polomom ešte raz, čím pribudol vhodný substrát pre vývoj lykožrútoch. Po ukončení vývoja lykožrútoch na ležiacej hmote sa najatraktívnejšími stali vetrom narušené porastové okraje v blízkosti ležiacej hmoty. Nenarušená porastová stena si zachovala približne rovnakú atraktivitu pre lykožrúta smrekového takmer počas celého obdobia monitoringu.

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## Occurrence of fungi of the genus *Nectria* s.l. (Ascomycota, Hypocreales, Bionectriaceae, Nectriaceae) in Slovakia

Ivan Mihál

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic, E-mail: mihal@savzv.sk

### Abstract

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In this work we present the recent data on occurrence of 22 fungal species belonging to the *Nectria* genus s.l. – of families Bionectriaceae and Nectriaceae, the occurrence of which in Slovakia was recorded in our survey and/or which were already recorded and published by other authors in the past. For each individual species, we describe its ecological features and its significance in terms of phytopathology. Sporadic occurrence has been found for the species *Cosmospora coccinea*, *C. purtonii*, *Hydropisphaeria peziza*, *Nectria berolinensis*, *Nectriopsis violacea*, *Neonectria ditissima*, *N. fuckeliana*, *N. punicea*. The first records in Slovakia hold for the species *Nectria coryli*, *Neonectria radicola*, *Monographella nivalis*, *Paranectria oropensis*, *Pronectria pertusariicola*, *Pseudonectria rousseliana* and *Sphaerostibella aureonitens*. *Nectria tuberculariformis*, *Nectriopsis indigena* and *Pronectria tinctoria* can also be considered as very rare and, related to the record date, also threatened of even extinct from the Slovak mycoflora.

### Key words

Ascomycota, Bionectriaceae, Nectriaceae, *Nectria* s.l., Slovakia

### Introduction

The fungi belonging to the genus *Nectria* s.l., belong by taxonomy to the families Bionectriaceae Samuels & Rossman and Nectriaceae Tul. & C. Tul., order Hypocreales and class Ascomycota. BOOTH (1959), ROSSMAN (1996) and ROSSMAN et al. (1999) report more than 200 fungal species belonging to the genus *Nectria* s.l. recorded up to now. These taxa are typical pyrenomycetous fungi associated with herbs and woody plants as saprophytes, saproparasites and parasites. The genus *Nectria* also involves important vascular parasites – primarily on forest woody plants. These parasites damage bark of their hosts with necrosis of tracheomycotic type. The occurrence of species of the *Nectria* genus in Slovakia, their trophic demands and role related to the plant pathology have been described e.g. by MIHÁL (2002a), MIHÁL et al. (2000, 2007, 2009a, b), SUROVEC (1990), ZÚBRIK et al. (1999).

In this contribution we present data on the current occurrence and distribution of fungi belonging to the

genus *Nectria* s.l. across Slovakia. Paralelly we describe certain ecological features of these species and inform about their importance for plant pathology related to necrosis on forest woody plants. From Slovakia, there have been published occurrence records for fungi of the genus *Nectria* by e.g. CÍČÁK and MIHÁL (2002), KUNCA (1996), KUTHAN et al. (1999), LIZOŇ (1977), MIHÁL (2002a), MIHÁL et al. (2000, 2007, 2009a, b), MORAVEC (1960), SVRČEK (1959, 1987).

### Material and methods

Our records were made in surveys running during 1990–2010 in localities selected in several geomorphological units in Slovakia. Each survey took several years. The occurrence identified in Slovakia by other authors in the past have been obtained from the literature and other databases.

The material was acquired in the field by the method *in vivo* in form of fruiting bodies (sporocarps)

in the sexual stage (teleomorphs) sampled from wood substrate (bark of living and dead broadleaved and coniferous trees, denuded and rotting wood, stump cut surface), as well as from other substrates (plant leaves, fungi belonging to Aphyllophorales s.l., Pyrenomycetes, Lichenes). Several species were indentified *in vitro* in the laboratory – by cultivation on substrates as well as by analysing sequences obtained from clones cultivated from nrDNA templates. DNA templates were extracted from soil samples. From the templates, there were amplified fragments of nuclear ribosomal acid – with using polymerase chain reaction – PCR at presence of primers specific for fungi (GRYNDLER et al., 2004). More details about the method can be found in BUČINOVÁ (2008).

All the sampled species were identified in the laboratory, with the aid of identification keys assembled by BRAYFORD et al. (2004), BREITENBACH and KRÄNZLIN (1986), BUTIN (1995), ČERVENKA et al. (1972), MOSER (1963), ROSSMAN et al. (1999), SAMUELS (1976), as well as by comparing with the reference collection of the author. As far as not specified otherwise, all the identifications (data not published) have been made by the author of this paper.

The herbarium items for most species have been deposited by the author in the Institute of Forest Ecology SAS in Zvolen, except the species *Monographella nivalis*, *Nectria tuberculariformis*, *Nectriopsis indigens*, *N. violacea*, *Neonectria radicolica* and *Pronectria tincta*. The scientific names and author's abbreviations for the individual taxa were received from ROSSMAN et al. (1999), ŠKUBLA (2003), or from the database CABI BIOSCIENCE (2010).

## Results and discussion

The following list contains 22 species belonging to the *Nectria* species s.l., from the families Bionectriaceae – genera: *Hydropisphaeria* Dumort., *Nectriopsis* Maire, *Paranectria* Sacc., *Pronectria* Clem., *Sphaerostibella* (Henn.) Saac. & D. Sacc. and Nectriaceae – genera: *Cosmospora* Rabenh., *Monographella* Petr., *Nectria* (Fr.) Fr., *Neonectria* Wollenw., *Pseudonectria* Seaver, the occurrence of which was recorded during our study of Slovak mycoflora or recorded and published formerly by other authors. Parallel, each taxon has been labelled with the hitherto recognised synonyms for the reproductive phase (teleomorphs) as well as growth phase (anamorphs) – according to ROSSMAN et al. (1999) and according to the database CABI BIOSCIENCE (2010).

In case of certain generally distributed species with abundant published and unpublished records, these data are given in a short form (numbers of the records in individual localities and geomorphological units – to save the place).

## Bionectriaceae

### *Hydropisphaeria peziza* (Tode: Fr.) Dumort.

[syn.: teleomorpha – *Sphaeria peziza* Tode, *Dialonectria peziza* (Tode) Cooke, *Nectria peziza* (Tode) Fr., *Neuronectria peziza* (Tode) Munk, *Nectria aurea* (Grev.) Cooke, anamorpha – *Acremonium* sp.]

Published data: the Záhorská nížina lowland – Kopčany, Sirková voda (Zadný diel), September 1975 (LIZOŇ, 1977 in ŠKUBLA, 2003).

Unpublished data: the Chvojnická pahorkatina hills – Zámčisko, 25 June 2008, the Javorie hills – Michalková, 27 July 2008, the Kremnické vrchy Mts – Kováčovská dolina, 8 July 2008, the Muránska planina mountain plateau – Šarkanica, 20 October 2001, the Revúcka vrchovina hills – Lubeník, 28 October 2005, Revúca – (extra) and intravilan, 1 December 2001.

A rare species, growing in decaying wood of broadleaved and coniferous woody plants. Apart from beech bark and wood, we recorded the species also on bark of *Sambucus nigra* L. KEIZER (1998) reports the occurrence of *H. peziza* also in decaying fruiting bodies of the fungus *Polyporus squamosus* (Huds.) Fr.

### *Nectriopsis indigens* (Arnold) Diederich et Schroers

[syn.: teleomorpha – *Secoliga indigens* Arnold, *Nectria indigens* (Arnold) Rehm, *Gyalecta indigens* (Arnold) H. Olivier, anamorpha – *Acremonium* sp., *Gliocladium* sp., *Verticillium* sp.]

Published data: the Západné Tatry Mts, Vrch Baranec hill, September 1966 (VĚZDA, 1970 in ŠKUBLA, 2003).

In Slovakia an isolated, old record – suggesting that *N. indigens* is either a very rare or omitted in surveys. The literature classifies the species of the genus *Nectriopsis* into the group of mycotrophic and lichenicolous parasitic fungi (ČERVENKA et al., 1972; VĚZDA, 1970).

### *Nectriopsis violacea* (Fr.) Maire

[syn.: teleomorpha – *Sphaeria violacea* Fr., *Nectria violacea* (Fr.) Fr., *Hypomyces violaceus* (Fr.) Tul., *Pekiella violacea* (Fr.) Sacc., *Byssonectria violacea* (Fr.) Seaver, *Hyphonectria violacea* (Fr.) Petch, anamorpha – *Acremonium fungicola* (Sacc.) Samuels]

Published data: the Šarišská vrchovina hills – Sedlice – Stará smola, 31 October 2004, (lgt. et det. P. KEŠELÁK), the Vysoké Tatry Mts – Podbánske, 12 October 2008, (lgt. et det. P. KEŠELÁK in *Nectriopsis violacea*, (J.C. Schmidt) Maire (1911) rážovka fialová, DATABASE, 2010).

An interesting species with violet-coloured subiculum parasitizing on fruiting bodies of *Fuligo septica* (L.) Wiggers is not possible to confuse with similar fungi. In Slovakia, there exists only one record of this species occurrence – in two localities recorded by P. KEŠELÁK (published on the web). The occurrence of the species *Fuligo septica* in Slovak forests is very frequent, locally

massive, so the scarce occurrence of *Nectriopsis violacea* is surprising.

***Paranectria oropensis* (Ces.) D. Hawksw. & Piroz.**

[syn.: teleomorpha – *Sphaeria oropensis* Ces. in Rabenh., *Ciliomyces oropensis* (Ces.) Höhn., *Nectria lichenicola* P. Crouan & H. Crouan., *Pleonectria lichenicola* (P. Crouan & H. Crouan) Sacc., *Pleonectria appendiculata* Vouaux, anamorpha – unknown]

Unpublished data: the Muránska planina mountain plateau – Poludnica, 15 November 2007 (lgt. D. Blanár).

A very rare and interesting species, whose little fruiting bodies were found growing on thalluses of non-identified lichen (Lichenes). This occurrence can be considered as the first record of *P. oropensis* in Slovakia. In Europe, the species *P. oropensis* has hitherto been recorded in Austria, France, Ireland, Italia and Scotland on thalluses of the lichens *Cladonia* sp., *Lecidea ente-roleuca* Fr. and *Parmeliella atlantica* Degel. (ROSSMAN et al., 1999).

***Pronectria pertusariicola* Lowen**

[syn.: teleomorpha – *Pronectria pertusariicola* Lowen, anamorpha – unknown]

Unpublished data: the Zvolenská kotlina basin – Borová hora, 15 November 1997 (lgt. S. Glejdura).

A very rare species, found growing in remnants of broadleaved wood burnt in the Arboretum Borová hora Zvolen. This is the first record from Slovakia. The species has been given the name according to its host – the lichen *Pertusaria pertusa* (Weigel) Tuck in the type locality for *P. pertusariicola* reported in the literature from Sweden (ROSSMAN et al., 1999). Additional records are from France and Spain. Our record of *P. pertusariicola* from the former burnt space may suggest wider ecological demands of this lichenicolous and probably also carbonicolous fungi.

***Pronectria tinctoria* (Fuckel) Lowen**

[syn.: teleomorpha – *Cryptodiscus tinctorius* Fuckel, *Calonectria tinctoria* (Fuckel) Rehm, *Nectriella tinctoria* (Fuckel) R. Sant., *Nectriella coccinea* Fuckel, *Nectriella fuckelii* Sacc., anamorpha – unknown]

Published data: the Spišská Magura Mts, Vojňany (Spišská Belá), July 1963 (VĚZDA, 1970 in ŠKUBLA, 2003), the record was published as *Nectriella coccinea*.

The literature (ROSSMAN et al., 1999) provides the records of this species also from Switzerland, Finland and Russia – on thalluses of the lichens *Anaptychia ciliaris* (L.) Körb. ex A. Massal, *Evernia prunastri* (L.) Ach. and *Physcia stellaris* (L.) Nyl. The dating of this only record in Slovakia allows us to judge about its very rare occurrence or omitting in inventories. It is also possible that in Slovakia is the species extinct.

***Sphaerostibella aureonitens* (Tul. & C. Tul.) Seifert, Samuels & W. Gams**

[syn.: teleomorpha – *Hypomyces aureonitens* Tul. & C. Tul., *Nectriopsis aureonitens* (Tul. & C. Tul.) O. Kuntze, *Hyphonectria aureonitens* (Tul. & C. Tul.) Petch, *Nectria mycetophila* Peck, *Dialonectria sulphurea* Ellis & Calk., *Cucurbitaria sulphurea* (Ellis & Calk.) O. Kuntze, anamorpha – *Gliocladium penicillioides* Corda]

Published data: the Kremnické vrchy Mts – Kováčovská dolina valley, September 1990, 1992, 2001, (MIHÁL, 2002b in ŠKUBLA, 2003).

From the past more frequently reported as *Nectriopsis aureonitens* (genus *Nectriopsis*, family Bionectriaceae). At present, recognised by ROSSMAN et al. (1999) as *Sphaerostibella aureonitens* (family Hypocreaceae). This rare species can be identified based on small, gold-coloured fruiting bodies growing as saproparasites on fruiting bodies of fungi from the order Polyporales s.l. Hitherto, there has been published one single record of *S. aureonitens* from Slovakia – on fruiting bodies of *Stereum rugosum* (Pers.) Fr. in a fir-beech forest in Central Slovakia.

**Nectriaceae**

***Cosmospora coccinea* Rabenh.**

[syn.: teleomorpha – *Nectria cosmariospora* Ces. et De Not., *Dialonectria cosmariospora* (Ces. et De Not.) Z. Moravec, anamorpha – *Verticillium olivaceum* W. Gams]

Published data: In total 10 localities in 9 geomorphological units across Slovakia (ŠKUBLA, 2003).

Unpublished data: the Kremnické vrchy Mts – Badínsky prales, 24 September 2008, the Muránska planina mountain plateau – Malá Stožka, 19 September 1999, Poludnica, 30 April 2009, the Poľana Mts – Kozí chrbát, 1 July 2009, the Štiavnické vrchy Mts – Jalná, 22 April 2004.

An interesting species, rather frequent as mycotrophic saproparasite on older fruiting bodies of the lignicolous *Inonotus nodulosus* (Fr.) P. Karst. in beech forest stands.

***Cosmospora episphaeria* (Tode: Fr.) Rossman et Samuels**

[syn.: teleomorpha – *Sphaeria episphaeria* Tode, *Dialonectria episphaeria* (Tode) Cooke, *Nectria episphaeria* (Tode) Fr., *Nectria sanguinea* (Sibth.) ss. auct. brit., anamorpha – *Fusarium aquaeductuum* (Radlk. et Rabenh.) Lagerh. var. *medium* Wollenw.]

Published data: In total 19 localities in 13 geomorphological units in Slovakia (ŠKUBLA, 2003).

Unpublished data: the Kremnické vrchy Mts – Kováčovská dolina valley, 4 May 2007, Štagiar, 16 September 2005, the Muránska planina mountain plateau – Javorníkova dolina valley, 28 April 2009, Muráň, 11 May 2009, Poludnica, 30 April 2009, Závadka nad Hronom,

22 April 2009, the Revúcka vrchovina hills – Jelšavská Teplica, 6 May 2009, Licince, 29 February 2008, Revúca, 28 February 2008, the Slovenský kras Karst – Hucín, 20 March 2009, the Stolické vrchy Mts – Muránska Zdychava, 17 January 2009.

The species occurs, likewise the species *Cosmospora coccinea*, as a mycotrophic saproparasite on vital as well as dead fungal fruiting bodies, especially pyrenomycetous fungi: *Diatrype disciformis* (Hoffm.) Fr., *D. stigma* (Hoffm.) Fr., *Eutypella quaternata* (Pers.) Rappaz, *Hypoxyton fragiforme* (Pers.) J. Kickx f., *H. multi-forme* (Fr.) Fr. or *Valsa ambiens* (Pers.) Fr. This species is the most frequent among the mycotrophic species belonging to the genus *Nectria* s.l.

#### ***Cosmospora purtonii* (Grev.) Rossman & Samuels**

[syn.: teleomorpha – *Sphaeria purtonii* Grev., *Nectria purtonii* (Grev.) Berk., *Nectria appianata* Fuckel, anamorpha – *Fusarium aquaeductuum* (Radlk. et Rabenh.) Lagerh.p.p.]

Published data: the Kremnické vrchy Mts – Kováčovská dolina valley, September 1990, June 1998, the Malé Karpaty Mts – Smolenice, July 1998, Havrania skala, November 1998, the Poľana Mts – Kozí chrbát, June 1998 (ŠKUBLA, 2003).

Unpublished data: the Muránska planina mountain plateau – Cigánka, 15 June 2007, the Revúcka vrchovina hills – Mokrú Lúka, 11 March 2009, the Slovenský kras Karst – Hucín, 20 March 2009, the Stolické vrchy Mts – Stolica, 13 August 2009.

An interesting fungus, growing as a mycotrophic saproparasite – likewise the two preceding species. We have recorded from the species *Diatrype disciformis*, *Eutypella quaternata* and *Hypoxyton fragiforme*. The occurrence of *C. purtonii* from fruiting bodies of the species *Diatrype stigma* has been reported by ROSSMAN et al. (1999). This species is less frequent than the two species discussed above.

#### ***Monographella nivalis* (Schaffnit.) E. Müll.**

[syn.: teleomorpha – *Calonectria nivalis* Schaffnit., *Micronectriella nivalis* (Schaffnit.) C. Booth., *Calonectria graminicola* F. Stevens non (Berk. et Broome) Wollenw., *Melioliphila graminicola* (F. Stevens) Speg., anamorpha – *Fusarium nivale* (Fr.) Sorauer, *Fusarium nivale* f. *graminicola* W. C. Snyder et H. N. Hansen, *Gerlachia nivalis* (Ces. ex Sacc.) W. Gams et E. Müll.]  
Published data: The only one record in Slovakia (lgt. Adamčík et al., in 1998) published in ŠKUBLA (2003), details on the site are lacking.

In the literature, the species is known mostly as *Calonectria graminicola* or *Melioliphila graminicola*. ROSSMAN et al. (1999) report this species according to MÜLLER (1977) under the name *Monographella nivalis*. The *Melioliphila* and *Calonectria* were described by SPEGAZZINI (1924 in ROSSMAN et al., 1999) as fungi parasitizing on plant-associated fungi.

#### ***Nectria berolinensis* (Sacc.) Cooke**

[syn.: teleomorpha – *Pleonectria berolinensis* Sacc., *Thyronectria berolinensis* (Sacc.) Seaver, *Nectria ribis* Niessl., *Thyronectria ribis* (Rabenh.) Z. Moravec, *Nectria fenestrata* Berk. et M. A. Curtis, *Pleonectria fenestrata* (Berk. et M. A. Curtis) Berl. et Voglino, anamorpha – *Tubercularia berolinensis* (Wollenw.) Rossman]

Unpublished data: the Revúcka vrchovina hills – Revúca (intravilan), 6 April 2008, Sirk (intravilan), 2 November 2004, the Zvolenská kotlina basin – Zvolen (extravilan), 8 November 2002.

A rare species, in Slovakia growing as a saproparasite on *Ribes* sp. (ČERVENKA et al., 1972). The summarised work of ŠKUBLA (2003) do not contain a record on *N. berolinensis* occurrence in Slovakia, in spite of the fact that this saproparasite on stems and branches of currants in our gardens is much more distributed but escaping our observations.

#### ***Nectria cinnabarina* (Tode: Fr.) Fr.**

[syn.: teleomorpha – *Sphaeria cinnabarina* Tode, *Nectria cinnabarina* (Tode) Fr., anamorpha – *Tubercularia vulgaris* Tode: Fr.]

Published data: In total 71 localities in 30 geomorphological units in Slovakia (ŠKUBLA, 2003).

Unpublished data: the Revúcka vrchovina hills – Licince, 20 March 2009, Revúca (intravilan), 9 April 2009, Revúcka Lehota, 3 September 2009, the Slánske vrchy Mts – Dargov, 28 April 2003, the Stolické vrchy Mts – Muránska Zdychava, 28 October 2009, the Štiavnické vrchy Mts – Jalná, 12 November 2003, Žiar nad Hronom, 31 March 2004, the Veporské vrchy Mts – Fabova hoľa, 24 April 2009, the Zvolenská kotlina basin – Zvolen (intravilan), 7 October 2008.

A generally known and distributed species growing as a saproparasite and saprophyte on a variety of wooden and herbal substrates. We have recorded the species *N. cinnabarina* on *Abies alba* Mill., *Acer platanoides* L., *A. pseudoplatanus* L., *Aesculus hippocastanum* L., *Armeniaca vulgaris* Lam., *Betula pendula* Roth, *Carpinus betulus* L., *Cerasus avium* (L.) Moench, *Clematis vitalba* L., *Corylus avellana* L., *Daphne arbuscula* Čelak., *Fagus sylvatica* L., *Frangula alnus* Mill., *Fraxinus excelsior* L., *Grossularia* sp., *Juglans regia* L., *Laburnum anagyroides* Medik., *Malus domestica* Borkh., *Picea abies* (L.) P. Karst., *Pinus sylvestris* L., *Quercus* sp., *Rhamnus* sp., *Ribes alpinum* L., *Robinia pseudoacacia* L., *Rubus* sp., *Salix fragilis* L., *Sambucus nigra* L., *Sorbus aucuparia* L., *Swida sanguinea* (L.) Opiz, *Tilia* sp., *Vitis vinifera* L., *Wisteria* sp. and even on rotting leaves from a rosette of an ananas – *Ananas comosus* (L.) Merr. (Zvolen – intravilan, 7 October 2008, lgt. et det. I. Mihál).

#### ***Nectria coryli* Fuckel**

[syn.: teleomorpha – *Chilonectria coryli* (Fuckel)

Ellis & Everh., *Creonectria coryli* (Fuckel) Seaver, *Colosphaeria acervata* P. Karst., *Nectria coryli* f. *salicis* Rehm, anamorph – *Tubercularia* sp.?)

Published data: the Starohorské vrchy Mts – Zamrlô valley, May 1998 (MIHÁL, 2002a in ŠKUBLA, 2003).

The species was hitherto recorded only in one locality, and there are also lacking data on its bionomy. We identified fruiting bodies of this rare species on bark of a cut beech stem in a fir-beech stand on an exposed slope in the mountain valley Zamrlô in the Starohorské vrchy Mts. BREITENBACH and KRÄNZLIN (1986) and MOSER (1963) describe this species as rarely occurring in spring on bark of broadleaved woody plants as e.g. *Corylus* sp., *Populus* sp., *Salix* sp.

### ***Nectria tuberculariformis* (Rehm ex Sacc.)**

#### **G. Winter**

[syn.: teleomorpha – *Hypocrea tuberculariformis* Rehm, *Hypocreopsis tuberculariformis* Rehm ex Sacc., *Creonectria tuberculariformis* (Rehm ex Sacc.) Seaver, *Nectria carneorosea* Rehm, anamorph – unknown]

Published data: the Belianske Tatry Mts – Tatranská Kotlina, a slope of the Bujačí vrch Mt., August 1956 (SVRČEK, 1959; KUBIČKA, 1964 in ŠKUBLA, 2003).

In Slovakia, there was recorded only one locality with this species, moreover, long ago. We can suppose either its extinction or extremely rare occurrence – escaping identification.

### ***Neonectria coccinea* (Pers.: Fr.)**

#### **Rossmann et Samuels**

[syn.: teleomorpha – *Sphaeria coccinea* Pers., *Nectria coccinea* (Pers.) Fr., anamorph – *Cylindrocarpon candidum* (Link.) Wollenw.]

Published data: In total 24 localities in 12 geomorphological units in Slovakia (ŠKUBLA, 2003).

Unpublished data: the Bukovské vrchy Mts Havešová, 16 September 2005, the Cerová vrchovina hills – Tachty, 25 July 2006, the Kremnické vrchy Mts – Badínsky prales, 15 October 2008, the Muránska planina mountain plateau – Poludnica, 26 October 2001, the Poľana Mts – Kozí chrbát, 1 July 2009, the Nitrianska pahorkatina hills – Chynoranský luh, 20 September 1998 (lgt. G. Juhásová), the Revúcka vrchovina Mts. – Lubeník, 7 June 1995, the Slánske vrchy Mts – Dargov, 28 April 2003, the Stolické vrchy Mts – Kohút, 9 October 2009, the Štiavnické vrchy Mts – Žiar nad Hronom, 26 June 2003, the Veľká Fatra Mts – Dedošova dolina valley, 18 August 2008, the Veporské vrchy Mts – Vrch Dobroč hill, 3 October 2002.

A common species, in Slovakia growing on broadleaved woody plants as a saproparasite or parasite. In broadleaved forest stands, the fungus is a frequent causal agent of necrotic bark disease of tracheomycotic type. Apart from beech bark, we observed this species on *Acer pseudoplatanus* L., *Fraxinus excelsior* L. and *Sambucus nigra* L.

### ***Neonectria ditissima* (Tul. & C. Tul.)**

#### **Samuels & Rossman**

[syn.: teleomorpha – *Nectria ditissima* var. *arctica* Wollenw., *Nectria ditissima* var. *major* Wollenw., *Nectria major* (Wollenw.) J. Moravec, anamorph – *Fusarium willkommii* Lindau, *Cylindrocarpon willkommii* (Lindau) Wollenw.]

Published data: the Cerová vrchovina hills – Fenek, June 1995, the Kremnické vrchy Mts – Kováčovská dolina valley, September 1990, June 1997 (det. G. Juhásová), the Malé Karpaty Mts – Bratislava, Rača, September 1977 (LIZOŇ, 1977 in ŠKUBLA, 2003), the Veporské vrchy Mts – Dobročský prales, September 1998 (det. G. Juhásová), (according to LIZOŇ, 1977; MIHÁL, 1997, 2002a in ŠKUBLA, 2003).

Unpublished data: the Nitrianska pahorkatina hills – Chynoranský luh, 20 September 1998 (lgt. et det. G. Juhásová), the Revúcka vrchovina Mts – Revúca (intravilan), 2 January 2009.

A species relative to and difficult to distinguish from *Neonectria galligena*, therefore, we can hypothesize about its much more frequent occurrence. It grows as a saproparasite or parasite on broadleaved woody plants. In broadleaved forest stands, the fungus is a frequent cause of necrotic beech bark disease of tracheomycotic type. Apart from beech, the species was also observed growing on *Malus domestica* Borkh. and *Quercus* sp.

### ***Neonectria fuckeliana* (C. Booth) Castl. & Rossman**

[syn.: teleomorpha – *Sphaeria cucurbitula* Tode, *Nectria cucurbitula* (Tode) Fr., *Scolecconectria cucurbitula* (Tode) C. Booth, *Nectria cylindrospora* Sollm., *Ophionectria cylindrospora* (Sollm.) Berl. et Voglino, *Nectria fuckeliana* C. Booth, anamorph – *Cylindrocarpon cylindroides* Wollenw., *Cylindrocarpon cylindroides* var. *tenue* Wollenw., *Zythiostroma pinastri* (P. Karst.) Höhn. ex Weese]

Published data: the Belianske Tatry Mts – Tatranská Kotlina, Dolina Siedmich prameňov valley, May 1961, the Bukovské vrchy Mts – Stučica, September 1999, the Nízke Beskydy Mts – Udava, October 1989, the Oravské Beskydy Mts – Babia hora, September 2000, the Veporské vrchy Mts – Vrch Dobroč hill, September 1996, the Štiavnické vrchy Mts – Sitno, April 2000 (SVRČEK, 1987; KUTHAN et al., 1999; KUNCA, 1996; MIHÁL, 2002a in ŠKUBLA, 2003).

Unpublished data: the Muránska planina mountain plateau – Veľká Stožka, 22 February 2008, the Revúcka vrchovina Mts – Muránska Dlhá Lúka, 31 December 2000, the Stolické vrchy Mts – Kohút, 13 June 2008, the Poľana Mts – Výbohovo, 20 May 2010.

An interesting species, preferring substrate of coniferous woody plants. It is a surprise that the species has hitherto been identified in a few localities only. In Slovakia was saproparasitic and parasitic occurrence of *N. fuckeliana* identified only on *Abies alba* Mill., *Picea abies* (L.) P. Karst. and *Pinus sylvestris* L. The fungus

often causes necrotic bark disease of tracheomycotic type on conifers, in Slovakia primarily on spruce.

***Neonectria galligena* (Bres.) Rossman et Samuels**

[syn.: teleomorpha – *Nectria galligena* Bres. ex Strasser, anamorpha – *Fusarium mali* Allesch., *Cylindrocarpon mali* (Allesch.) Wollenw., *Cylindrocarpon heteronema* Berk et Broome]

Published data: In total 40 localities in 22 geomorphological units in Slovakia (ŠKUBLA, 2003).

Unpublished data: the Muránska planina mountain plateau – valley of the Rimava river, 24 June 2003, Muránska Huta, 31 December 2008, the Nitrianska pahorkatina hills – Chynoranský luh, 20 September 1998 (lgt. et det. G. Juhásová), the Revúcka vrchovina Mts – Revúca (intravilan), 13 June 2008, the Stolické vrchy Mts – Muránska Zdychava, 9 October 2008.

The species is in Slovakia common and wide-spread – growing as a saproparasite and parasite on bark of broadleaved woody plants. Parasitizing in beech forest stands, it is the causal agent of necrotic beech bark disease of tracheomycotic type. Apart from beech, *N. galligena* was also found growing on *Malus domestica* Borkh. and *Quercus* sp.

***Neonectria punicea* (J. C. Schmidt)**

**Castl. & Rossman**

[syn.: teleomorpha – *Sphaeria punicea* Kunze et J. C. Schmidt, *Nectria punicea* (Kuntze et J. C. Schmidt) Fr., anamorpha – *Cylindrocarpon album* (Sacc.) Wollenw.]  
Published data: the Bukovské vrchy Mts – Nová Sedlica, September 1998, the Kremnické vrchy Mts – Turová, Štagiar-Zábučie, March 2001 (MIHÁL, 2002a in ŠKUBLA, 2003).

Unpublished data: the Javorie hills – Michalková, 27 July 2008, the Revúcka vrchovina Mts – Hodošov les, 18 September 2007, Revúca (intravilan), 17 November 2008, the Stolické vrchy Mts – Muránska Zdychava, 16 November 2008, the Zvolenská kotlina basin – Borová Hora, 4 October 1997.

A less known and rather rare species growing on broadleaved woody plants. Several of our records have been taken from cut surfaces on old beech stumps. Apart from beech, *N. punicea* was also identified on bark of *Laburnum anagyroides* Medik.

***Neonectria radicola* (Gerlach & L. Nilsson)**

**Mantiri & Samuels**

[syn.: teleomorpha – *Nectria radicola* Gerlach & L. Nilsson, anamorpha – *Cylindrocarpon destructans* (Zins.) Scholten]

Published data: the Kremnické vrchy Mts – Kováčovská dolina valley, 30 May 2005 (lgt. et det. K. Bučínová, in MIHÁL et al., 2009a).

This species is parasitizing on roots of broadleaved woody plants – primarily beech and oak. It frequently occurs in its vegetative form *Cylindrocarpon de-*

*structans*. The fungus can cause considerable damage to plants in forest nurseries. The presence of this species in the locality Kováčovská dolina valley in the Kremnické vrchy Mts was identified by *in vitro* cultivation from soil samples, by sequencing clones from nrDNA templates (BUČINOVÁ, 2008; GRYNGLER et al., 2004). The literature does not contain an earlier record of this species in Slovakia, except MIHÁL et al. (2009a).

***Pseudonectria rousseliana* (Mont.) Wollenw.**

[syn.: teleomorpha – *Nectria rousseliana* Mont., *Stigmaea rousseliana* (Mont.) Fuckel, *Nectriella rousseliana* (Mont.) Sacc., *Notarisiella rousseliana* (Mont.) Sacc. in Clem. & Shear, *Nectria rousseliana* Mont. var. *viridis* Berk. & Broome, anamorpha – *Sesquicillium buxi* (Link: Fr.) W.Gams., *Volutella buxi* (DC.: Fr.) Berk.]

Unpublished data: the Revúcka vrchovina Mts – Jelšava (extravilan), 19 April 2009, Revúca (extra- and intravilan), 10 January 2009 (lgt. D. Blanár).

A very rare species – with occurrence hitherto recorded only on leaves and rotting branches of *Buxus sempervirens* L. ROSSMAN et al. (1999) report occurrence of *P. rousseliana* in the North America and France as a type locality for Europe. We recorded a large amount of *P. rousseliana* fruting bodies on adaxial leaf sides of *Buxus sempervirens*. The occurrence of this species in the Revúcka vrchovina Mts represents the first record in Slovakia.

The species *Nectria cinnabarina*, *Neonectria coccinea*, *N. galligena* and *Cosmospora episphaeria* are common across Slovakia, and their occurrence can be very abundant in presence of suitable substrate and favourable conditions. Less frequent is the occurrence of the species *Cosmospora coccinea*, *C. purtonii*, *Hydropisphaeria peziza*, *Neonectria ditissima*, *N. fuckeliana* and *N. punicea*. The species *Nectria berolinensis* and *Nectriopsis violacea* can be classified as rare. A special group consists of the species recorded in Slovakia only one or two times. The first records in the Slovak mycoflora can be considered the very rare *Nectria coryli*, *Neonectria radicola*, *Monographella nivalis*, *Paranectria oropensis*, *Pronectria pertusariicola*, *Pseudonectria rousseliana* and *Sphaerostibella aureonitens*. The *Nectria tuberculariformis*, *Nectriopsis indigena* and *Pronectria tinctoria* can also be classified as very rare and, in context of their occurrence period, endangered or extinct. Their actual occurrence in the Slovak mycoflora needs to confirm with additional records.

At the same time, several species of the genus *Nectria* s.l. are important parasites on forest woody plants. As vascular parasites, these fungi cause serious damage, locally even epiphytoses. An example is the epiphytosis of necrotic beech bark disease in Slovakia (CÍČAK and MIHÁL, 2002). The first symptoms of necrotic disease of forest woody plants are: crown reduction due to branches broken in the necrotised parts and drying out. The

most frequent symptoms are: necrotic wounds on tree stems and branches – from small and un conspicuous up to so called break necroses severely distorting the stems and branches. Very frequent are breaks in necrotised parts – due to considerably lowered wood strength.

The primary common entrance spots for spreading infections by these parasites into the conductive pathways in trees are: bark injuries caused by beetles and forest game, tree felling, leaf scarfs, lenticels, frost cracks and sunburnt cracks. The fungi of the *Nectria* genus penetrate these wounds with germinating hyphae of ascospores, conidia and mycelium hyphae. The spreading of the parasite is promoted by several abiotic (wind, water) and especially biotic vectors (insects, birds, forest game, man).

Several authors (LEONTOVYČ and GÁPER, 1997; PARKER, 1976; PERRIN, 1984) consider as the most dangerous parasites on forest woody plants, especially on European beech (*Fagus sylvatica* L.), the species *Neonectria coccinea*, *N. ditissima* and *N. galligena* – initiating beech bark necrotic disease with typical tracheomycotic symptoms. For example, LEONTOVYČ and GÁPER (1997) characterise the species *N. ditissima* and *N. galligena* as the most important pathogenic fungi in young beech forest stands. PERRIN and GARBAGE (1984) and SUROVEC (1992) report occurrence of *N. ditissima* mostly on beech trees in earlier growth phases (natural seeding, young growth), and pinpoint the negative effects of this fungus mainly on beech branches. SUROVEC (1990) accents the fact that the primary cause of epiphytoses-related dieback of young beech forest stands is deposition of airborne pollutants, persistent water deficit in soils, and frequent damage caused by frosts and hail. In coniferous forests, primarily spruce, the species *Neonectria fockeliana* manifests parasitic activities.

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# Príspevok k výskytu húb rodu *Nectria* s.l. (Ascomycota, Hypocreales, Bionectriaceae, Nectriaceae) na Slovensku

## Súhrn

V príspevku uvádzame aktuálne údaje o výskyte 22 druhov húb, prináležiacich k širšiemu okruhu druhov rodu *Nectria* s.l. z čeľadi Bionectriaceae a Nectriaceae, ktorých výskyt sme zistili na Slovensku, resp. ktorých výskyt bol už v minulosti zaznamenaný a publikovaný inými autormi z územia Slovenska. Opisujeme aj niektoré ekologické charakteristiky druhov a uvádzame ich fytopatologický význam. Sporadický výskyt bol zistený u druhov *Cosmospora coccinea*, *C. purtonii*, *Hydropisphaeria peziza*, *Nectria berlinensis*, *Nectriopsis violacea*, *Neonectria ditissima*, *N. fuckeliana*, *N. punicea*. Ako prvonálezy pre Slovensko uvádzame druhy *Nectria coryli*, *Neonectria radicolica*, *Monographella nivalis*, *Paranectria oropensis*, *Pronectria pertusariicola*, *Pseudonectria rousseliana* a *Sphaerostibella aureonitens*. Druhy *Nectria tuberculariformis*, *Nectriopsis indigens* a *Pronectria tinctoria* taktiež považujeme za veľmi vzácne huby a vzhľadom na ich dávnu dobu nálezu dokonca za huby ohrozené, príp. už vymiznuté z našej mykoflóry. U druhov z rodov *Nectria* a *Neonectria*, ktoré sú najvýznamnejšie z lesoochránarskeho hľadiska, sa plodničky najčastejšie vyskytovali na kôre listnatých drevín, najviac na *Fagus sylvatica*, menej na *Acer pseudoplatanus*, *Carpinus betulus* a vzácne aj na ihličnatých drevinách. Druh *Neonectria fuckeliana* sa vyskytoval len na ihličnatých drevinách (*Abies alba*, *Picea abies* a *Pinus sylvestris*). Zaujímavé sú druhy *Cosmospora episphaeria* a *C. purtonii*, ktoré boli zbierané ako mykotrofni saproparaziti na starých plodniciach lignikolných pyrenomycétov *Diatrype disciformis*, *D. stigma*, *Eutypella quaternata*, *Hypoxylon fragiforme*, *H. multiforme* a *Valsa ambiens*. Viaceré druhy rodu *Nectria* sú zároveň významnými parazitmi lesných drevín, na ktorých ako vaskulárni paraziti spôsobujú veľké škody, miestami až epifytácie. Za najnebezpečnejších parazitov listnatých drevín, a zvlášť buka lesného (*Fagus sylvatica*), sa považujú druhy *Neonectria coccinea*, *N. ditissima* a *N. galligena*, ktoré vyvolávajú nekrotické ochorenie kôry buka s typickými tracheomykóznymi príznakmi.

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## Harvestmen (Arachnida, Opiliones) in disturbed forest ecosystems of the Low and High Tatras Mts

Ivan Mihál<sup>1</sup>, Boris Astaloš<sup>2</sup>

<sup>1</sup>Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,  
E-mail: mihal@savzv.sk

<sup>2</sup>Slovak National Museum in Martin, Malá Hora 2, 036 80 Martin, Slovak Republic,  
E-mail: boris.astalos@SNM.sk

### Abstract

MIHÁL, I., ASTALOŠ, B. 2011. Harvestmen (Arachnida, Opiliones) in disturbed forest ecosystems of the Low and High Tatras Mts. *Folia oecol.*, 38: 89–95.

The work presents a summary of harvestmen findings from area of the Low and High Tatras Mts. Total 17 harvestmen species were recorded in the 11 studied localities. This amount represents almost 51.5% of the total species diversity of harvestmen fauna in Slovakia. There were recorded thermophilous species such as *Dicranolasma scabrum* and *Egaenus convexus*, a typically mountainous species *Ischyropsalis manicata* and a Carpathian endemite *Paranemastoma kochi*. Discussed is use of the species spectrum of harvestmen in the Low and High Tatras Mts in bio-monitoring of structural changes in forest ecosystems affected by the extensive wind disturbance in year 2004 causing damage to both mountain ranges.

### Key words

faunistics, harvestmen, High Tatra Mts, Low Tatra Mts, Opiliones, Slovakia

### Introduction

Opiliones in area of Central Slovakia have been studied to various extents in various geomorphological areas. Certain areas have been surveyed thoroughly; about others there exist only scarce, old dated information. Several records have not been published yet. It is a paradox that also the fairly large mountain range of the Low Tatras Mts belongs to areas in which research on harvestmen was considered only of marginal importance.

The literature concerning harvestmen of the Low Tatras Mts contains incomplete data from the past, recorded by several collectors and summarised by KRATOCHVÍL (1934). The most recent partial data about harvestmen diversity in the Low Tatras Mts can be found in MIHÁL and MAŠÁN (2006), STAŠIOV (1999, 2004), STAŠIOV and SNOPOKOVÁ (2002) and STAŠIOV et al. (2003). The mentioned works, however, have summarized only 6 harvestmen species – a very low number in context of the large size of the Low Tatras Mts, a wide variety of

habitats and opportunities for on-harvestmen-oriented research. On the other hand, there exist 129 spider species documented from this geographic area (BENOVA and SVATOŇ, 2009).

We are considering this number of documented spider species also as a insufficient, because from Slovakia on the present is documented more than 927 spider species (GAJDOŠ et al., 1999).

It is necessary to notice that research on Opiliones in the neighbouring geomorphological units was performed more thoroughly and brought more results. Opiliones in the High Tatras Mts were studied by MIHÁL et al. (2010a), in the Popradská kotlina basin by MIHÁL and MAŠÁN (2006), in the Podtatranská kotlina basin by KRATOCHVÍL (1934) and STAŠIOV (2004), in the Kozie chrbty Mts ASTALOŠ et al. (2004) and MIHÁL et al. (2010b), in the Slovenský raj National Park by KOŠEL (1984) and STAŠIOV (2004), on the Muránska planina mountain plateau by MIHÁL (2005), in the Veporské vrchy Mts by STAŠIOV (2004), in the Horehronské podolie river valley by MIHÁL and GAJDOŠ (2010), in the

Starohorské vrchy Mts by MIHÁL and KORENKO (2010) and in the Veľká Fatra Mts by ASTALOŠ (2002) and by JARAB and KUBOVČÍK (2002).

This work summarises the hitherto reported harvestmen findings from the Low Tatras Mts, with the aim to enhance the number of harvestmen occurrence records in this area. The work represents also harvestmen diversity known from the High Tatras Mts. Discussed is possibility of using harvestmen in the High and Low Tatras Mts in biomonitoring of structural changes in forest ecosystems occurring in both mountain ranges after the serious wind and snow disaster in 2004.

## Material and methods

Harvestmen (Opiliones) in various localities in the Low Tatras Mts were sampled at irregular intervals in field trips made during the growing seasons 2009 and 2010. Further data on harvestmen occurrence in this area were obtained from works published by several authors (KRATOCHVÍL, 1934; MIHÁL and MAŠÁN, 2006; STAŠIOV, 1999, 2004; STAŠIOV and SNOPKOVÁ, 2002; STAŠIOV et al., 2003).

Material was sampled by hand searching from soil surface, under stones, lying wood, stumps and ground vegetation and also by extraction (sieving) from leaf litter and by catching in soil pitfall formaline traps. The major part of the material collected in years 2009 and 2010 was identified by the authors of this work, following the identification keys assembled by MARTENS (1978) and ŠILHAVÝ (1956, 1971), as well as by comparing with material from the deposit of the first author. The majority of the sampled material has been conserved in 70% ethanol and stored in the collection of the first author of this paper in the IFE SAS Zvolen.

## Description of localities

We studied harvestmen occurrence at 11 localities situated on northern and southern slopes of the Low Tatras Mts. The brief description of selected localities is following. Abbreviations used in the description are: L1–L11, locality; CA, cadastral area; DFS, quadrangle code in the Databank of Fauna in Slovakia; ALT, altitude; EXP, exposition; H, type of habitat; sampling person: leg., ?; no record/record was not at disposal.

**L1 – Iľanovská dolina Valley**, CA: Iľanovo, DFS: 6983, ALT: 680, EXP: NE, H: forest spring area in Norway spruce-fir forest stand, leg. B. Astaloš, I. Mihál

**L2 – Poludnica**, CA: Iľanovo, DFS: 6983, ALT: 1,300–1,500, EXP: ?, H: Norway spruce forest stands, leg. P. Fend'a, A. Šestáková

**L3 – Rohačka**, CA: Iľanovo, DFS: 6983, ALT: 800–825, EXP: E, H: secondary grazing pastures, leg. A. Šestáková

**L4 – Suchá dolina Valley**, CA: Závažná Poruba, DFS: 6983, ALT: 700, EXP: N, H: forest spring area in Norway spruce forest stands, leg. B. Astaloš, A. Krajča, I. Mihál

**L5 – Ždiarska dolina Valley**, CA: Liptovská Teplička, DFS: 7086, ALT: 680–1,220, EXP: ?, H: mountain pastures and Norway spruce forest stands, leg. P. Fend'a, P. Gajdoš

**L6 – Snežná jama Hole**, CA: Liptovská Štiavnica, DFS: 7082, ALT: 1,359, EXP: ?, H: dysphotic zone 9 meters from entrance of the cave, leg. S. Stašiov

**L7 – Ďumbier**, CA: Liptovský Ján, DFS: 7083, ALT: ?, EXP: ?, H: ?, leg. S. Hrabě, V. Šilhavý

**L8 – NNR Ďumbier**, CA: Bystrá, DFS: 7083, ALT: 1750, EXP: E, H: alpine meadows, leg. P. Bitušík, P. Novikmec

**L9 – Mýtňanská jaskyňa Cave**, CA: Mýto pod Ďumbierom, DFS: 7184, ALT: ?, EXP: ?, H: cave and entrance of cave, leg. V. Franc

**L10 – Pod Čertovicou**, CA: Jarabá, DFS: 7084, ALT: 1200, EXP: ?, H: Norway spruce forest stands, leg. J. Kleinert, S. Stašiov

**L11 – NNR Príboj**, CA: Slovenská Lupča, DFS: 7281, ALT: 350–490, EXP: SW, H: oak-hornbeam forest stands, leg. E. Snopková, S. Stašiov.

## Results and discussion

Summarising the data obtained in our sampling as well as the data from literature, we can declare that in the Low Tatras Mts occur together 17 harvestmen species belonging to 5 families.

The list below gives the identified species. In the list, the following abbreviations are used: F, female; M, male; subad., subadult; juv., juvenile.

### Palpatores Thorell, 1879

#### Nemastomatidae Simon, 1879

##### 1. *Nemastoma lugubre* (Müller, 1776)

Published data: **L11** – 1M, 3F, 19 October 1999, 2M, 3F, 5 May 2000, 2M, 2F, 5 June 2000, 2M, 2F, 5 July 2000 (STAŠIOV and SNOPKOVÁ, 2002)

Unpublished data: **L5** – 1F, 22 May 2009, 1M, 1F, 19 June 2009, 1M, 25 July 2009, 2M, 2F, 23 August 2009, 4M, 3F, 23 October 2009

##### 2. *Paranemastoma kochi* (Nowicki, 1870)

Unpublished data: **L1** – 1M, 1F, 22 October 2010

##### 3. *Mitostoma chrysomelas* (Hermann, 1804)

Unpublished data: **L5** – 1M, 23 October 2009

### Dicranolasmatidae Simon, 1879

##### 4. *Dicranolasma scabrum* (Herbst, 1799)

Published data: **L11** – 1F, 5 June 2000, 1M, 5 October 2000 (STAŠIOV and SNOPKOVÁ, 2002)

### Trogulidae Sundevall, 1833

##### 5. *Trogulus nepaeformis* (Scopoli, 1763)

Published data: **L11** – 1M, 2F, 2 May 1999, 1F, 2

- September 1999, 1F, 1 October 1999, 1M, 4F, 5 May 2000, 3F, 5 June 2000, 1M, 7F, 5 July 2000, 1M, 5 August 2000, 1M, 1F, 5 September 2000, 2F, 5 November 2000 (STAŠIOV and SNOPOKOVÁ, 2002)  
 Unpublished data: **L5** – 1M, 1F, 22 May 2009, 1M, 25 July 2009, 1M, 1F, 23 August 2009, 2F, 2M, 1 subad., 25 September 2009, 23 October 2009, 1 subad., 21 June 2010
6. *Trogulus tricarinatus* (Linnaeus, 1767)  
 Unpublished data: **L5** – 1F, 19 June 2009, 1M, 25 July 2009, 1F, 25 September 2009, 4M, 2F, 23 October 2009, 1M, 21 June 2010
- Ischyropsalididae** Simon, 1879
7. *Ischyropsalis manicata* L. Koch, 1865  
 Published data: **L6** – 1F, 17 August 2002 (STAŠIOV et al., 2003), **L10** – 4M, 2F, from July to September 1987 (STAŠIOV, 1999)
- Phalangiidae** Simon, 1879
8. *Phalangium opilio* Linnaeus, 1761  
 Unpublished data: **L5** – 2M, 6F, 14 subad., 25 July 2009, 8M, 8F, 23 August 2009, 7M, 23F, 25 September 2009, 9M, 3F, 23 October 2009
9. *Platybunus bucephalus* (C. L. Koch, 1835)  
 Published data: **L7** – ?M, ?F, ? subad., ? juv., 1934 (KRATOCHVÍL, 1934), **L11** – 2F, 5 May 2000 (STAŠIOV and SNOPOKOVÁ, 2002)  
 Unpublished data: **L2** – 1M, 23 June 2010, **L4** – 1M, 23 June 2010, **L5** – 2 juv., 9 August 2003, 1 juv., 19 June 2009, 1M, 23 August 2009, 20 juv., 21 June 2010
10. *Rilaena triangularis* (Herbst, 1799)  
 Unpublished data: **L5** – 1F, 3 subad., 5 juv., 19 June 2009, 2M, 3F, 28 subad., 14 juv., 25 July 2009
11. *Lophopilio palpinalis* (Herbst, 1799)  
 Unpublished data: **L5** – 7 subad., 17 juv., 22 May 2009, 7M, 6F, 6 juv., 19 June 2009, 2F, 3 juv., 25 July 2009
12. *Egaenus convexus* (C. L. Koch, 1835)  
 Published data: **L11** – 1M, 1F, 2 May 1999, 4M, 5F, 5 June 2000 (STAŠIOV and SNOPOKOVÁ, 2002)
13. *Oligolophus tridens* (C. L. Koch, 1836)  
 Unpublished data: **L4** – 1 subad., 23 June 2010, **L5** – 16 subad., 14 juv., 19 June 2009, 1M, 1F, 4 subad., 25 July 2009, 2M, 6F, 25 September 2009, 9M, 16F, 23 October 2009
14. *Lacinius ephippiatus* (C. L. Koch, 1835)  
 Unpublished data: **L3** – 1M, 22 June 2010, **L5** – 6 subad., 1 juv., 19 June 2009, 4M, 4F, 25 July 2009, 13M, 5F, 2 subad., 23 August 2009, 5M, 1F, 25 September 2009, 1M, 1 subad., 21 June 2010
15. *Mitopus morio* (Fabricius, 1799)  
 Published data: **L7** – ?M, ?F, ? subad., ? juv., 1934 (KRATOCHVÍL, 1934), **L8** – ?M, ?F, ? subad., ? juv., 24 October 2001 (STAŠIOV, 2004)  
 Unpublished data: **L2** – 2 subad., 23 June 2010, **L5** – 1M, 2 subad., 25 July 2009, 13M, 6F, 23 August 2009

16. *Gyas titanus* Simon, 1879  
 Published data: **L9** – ?M, ?F, ? subad., ? juv., 30 January 1999 (STAŠIOV, 2004)
17. *Leiobunum* aff. *rupestre* (Herbst, 1799)  
 Published data: **L5** – 1 juv., 9 August 2003 (MIHÁL and MAŠÁN, 2006)  
 Unpublished data: **L3** – 1 juv., 22 June 2010.

The mentioned 17 harvestmen species from the Low Tatras Mts represent 51.5% of the total diversity of harvestmen species hitherto identified in Slovakia (S = 33, according to BEZDĚČKA, 2009; STAŠIOV, 2004). The highest species numbers were identified in localities No. 5 (Ždiarska dolina Valley, Liptovská Teplička = 12 species) and No. 11 (NNR Príboj, Slovenská Ľupča = 5 species). The highest occurrence frequency has been documented by the species *Platybunus bucephalus* (identified in 5 localities) and *Mitopus morio* (identified in 4 localities).

From this species spectrum it is necessary to notice especially *Ischyropsalis manicata* and *Paranemastoma kochi* which are the typical mountainous species and their occurrence in the Low Tatras is expected and their distribution in this area is more extended. Moreover, *P. kochi* is considered as a Carpathian endemic species (STAŠIOV, 2004). On south-facing foothills of the Low Tatras Mts were also recorded two thermophilous, originally Euromediterranean and Pontic species *Dicranolasma scabrum* and *Egaenus convexus*, occurring in the locality NNR Príboj in optimum conditions of an open oak-hornbeam forest stand situated on a SW-facing slope (STAŠIOV and SNOPOKOVÁ, 2002). Occurrence of these species, having in the Carpathians the northernmost part of their distribution area is not a genuine surprise in the Low Tatras Mts, as their occurrence in Slovakia has been reported from even more northward situated localities such as the Malá Fatra Mts, the Ondavská vrchovina Mts and the Bukovské vrchy Mts (STAŠIOV, 2004).

In conditions of submountainous and mountainous forest and non-forest habitats of the Low Tatras Mts can be expected in the future occurrence of more harvestmen species such as *Siro carpaticus* Rafalski, 1956, *Opilio parietinus* (De Geer, 1778), *Platybunus pallidus* Šilhavý, 1938, *Zacheus crista* (Brullé, 1832), *Astrobus laevipes* (Canestrini, 1872), *Leiobunum rotundum* (Latreille, 1798), *Nelima semproni* Szalay, 1951.

Tables 1 and 2 summarise the hitherto obtained knowledge of the species composition of harvestmen in the Low and High Tatras Mts. These are the two highest mountain ranges in Slovakia, manifesting many common features concerning their geology, geomorphology, climate, soil, structure of flora, fauna and structure of forest habitats. Remarkable similarity between these two mountain units is reflected also in their opiliofauna spectrum, consisting mostly of the same species. Three species listed in Table 2 as hitherto recorded only in the High Tatras Mts (*Opilio parietinus*, *Platybunus*

*pallidus*, *Leiobunum rotundum*) without doubt occur also in the Low Tatras Mts and are waiting for confirmation by the next research. On the other hand, the occurrence of thermophilous species *Dicranolasma scabrum* and *Egaenus convexus*, hitherto recorded in the Low Tatras Mts only (Table 1), on southern foothills of the High Tatras Mts is dubious, as these harvestmen species are thermophilous, preferring warmer habitats situated at lower altitudes. Occurrence of *E. convexus* in the submountainous zone of the High Tatras Mts has been reported by ŠILHAVÝ (1974), other authors, however, (MIHÁL et al., 2010a, STAŠIOV, 2004) speculate that the finding is dubious, requiring confirmation with another finding *in situ* in the future. Moreover, as a dubious finding from the past has been reported a non-verified record of occurrence of the species *Nelima aurantiaca* (Roewer, 1923) = *Amilenus aurantiacus* (Simon, 1881) in the locality Ďumbier in the Low Tatras Mts. To prove the occurrence of this species so long later would be an interesting fact, as the above-mentioned record was not considered as dubious even by KRATOCHVÍL (1934) and MARTENS (1969). According to the latest opinions, *Nelima aurantiaca* was determined erroneously as *Gyas titanus*, as juvenile individuals of the both species exhibit similar identification features.

Extensive, even catastrophic wind disturbance in the Low and High Tatras Mts in 2004 affected especially

complexes of submountainous and mountainous spruce forests. The harvestmen species spectres on the affected plots in these two mountain units are almost identical and seem as an appropriate invertebrate group meeting the needs of biomonitoring of structural changes in such disturbed forest ecosystems. As for the role of harvestmen of Tatras as a bioindicator invertebrate group, they can be sorted according their ecotrophic and ecotopic demands in three basis bioindicator groups specified in Tables 1 and 2: typical forest with closed canopy, ecotone or variously disturbed forest, and open habitat without connected forest cover. For these three habitat groups are listed dominant and accompanying harvestmen species typical for the given habitat, which means occurring at the highest abundance at all developmental phases or occurring in more than one habitat as accompanying species.

For mountain forests or submountain waterlogged spruce stands are typical: *Paranemastoma kochi*, *Mitostoma chrysomelas*, *Ischyropsalis manicata*, *Platybunus pallidus*, *Gyas titanus* and others. These species indicate undisturbed site conditions of climax mountain spruce stands in both Low and High Tatra Mts (MIHÁL et al., 2010a; STAŠIOV, 2004; ŠILHAVÝ, 1956).

On the other hand, the harvestmen group typical for forest communities also involves species diffusing frequently towards forest edges or clear cuts, for example:

Table 1. Harvestmen (Opiliones) of the Low Tatra Mountains and their preference for particular habitats

Species	Forest	Ecotone	Open habitat
<i>Nemastoma lugubre</i> (Müller, 1776)	●	●	
<i>Paranemastoma kochi</i> (Nowicki, 1870)	●		
<i>Mitostoma chrysomelas</i> (Hermann, 1804)	●	○	
<i>Dicranolasma scabrum</i> (Herbst, 1799)	●	○	
<i>Ischyropsalis manicata</i> L. Koch, 1865	●		
<i>Trogulus tricarinatus</i> (Linnaeus, 1767)	●	●	
<i>Trogulus nepaeformis</i> (Scopoli, 1763)	●	●	
<i>Phalangium opilio</i> Linnaeus, 1761		○	●
<i>Platybunus bucephalus</i> (C. L. Koch, 1835)	●	●	○
<i>Rilaena triangularis</i> (Herbst, 1799)	○	●	●
<i>Lophopilio palpinalis</i> (Herbst, 1799)	●	○	
<i>Egaenus convexus</i> (C. L. Koch, 1835)	○	●	●
<i>Oligolophus tridens</i> (C. L. Koch, 1836)	●	●	○
<i>Lacinius ephippiatus</i> (C. L. Koch, 1835)	●	○	○
<i>Mitopus morio</i> (Fabricius, 1799)	○	●	●
<i>Gyas titanus</i> Simon, 1879	●		
<i>Leiobunum</i> aff. <i>rupestre</i> (Herbst, 1799)		●	●

Forest – closed canopy forests, virgin forests, monocultures, forest spring stands.

Ecotone – forest edges, hedgerows, open canopy forests.

Open habitat – mountains meadows, clear cuts, burnt areas after fire, human settlements.

● a dominant species.

○ an incidental species.

Table 2. Harvestmen (Opiliones) of the High Tatra Mountains and their preference for particular habitats (according to MIHÁL et al., 2010a)

Species	Forest	Ecotone	Open habitat
<i>Nemastoma lugubre</i> (Müller, 1776)	●	●	
<i>Paranemastoma kochi</i> (Nowicki, 1870)	●		
<i>Mitostoma chrysomelas</i> (Hermann, 1804)	●	○	
<i>Trogulus tricarinatus</i> (Linnaeus, 1767)	●	●	
<i>Trogulus nepaeformis</i> (Scopoli, 1763)	●	●	
<i>Ischyropsalis manicata</i> L. Koch, 1865	●		
<i>Phalangium opilio</i> Linnaeus, 1761		○	●
<i>Opilio parietinus</i> (De Geer, 1778) *		○	●
<i>Platybunus bucephalus</i> (C. L. Koch, 1835)	●	●	○
<i>Platybunus pallidus</i> Šilhavý, 1938	●		
<i>Rilaena triangularis</i> (Herbst, 1799)	○	●	●
<i>Lophopilio palpinalis</i> (Herbst, 1799)	●	○	
<i>Oligolophus tridens</i> (C. L. Koch, 1836)	●	●	○
<i>Lacinius ephippiatus</i> (C. L. Koch, 1835)	●	○	○
<i>Mitopus morio</i> (Fabricius, 1799)	○	●	●
<i>Gyas titanus</i> Simon, 1879	●		
<i>Leiobunum rotundum</i> (Latreille, 1798)	○	●	●
<i>Leiobunum</i> aff. <i>rupestre</i> (Herbst, 1799)		●	●

Forest – closed canopy forests, virgin forests, monocultures, forest spring stands.

Ecotone – forest edges, hedgerows, open canopy forests.

Open habitat – mountains meadows, clear cuts, burnt areas after fire, human settlements.

● a dominant species.

○ an incidental species.

\* a synanthropic species, frequent in ecotones and open habitats.

*Nemastoma lugubre*, *Trogulus nepaeformis*, *T. tricarinatus*, *Platybunus bucephalus*, *Oligolophus tridens*, *Mitopus morio*. According to observation by MIHÁL (1997), MIHÁL et al. (2010a) and STAŠIOV (2001) in submountain forest ecosystems, these harvestmen can occur even massively in different ecotonal assemblages and easily respond to abrupt changes to the forest environment (clear cuts, regeneration cuts). The harvestmen are fairly mobile Arachnida, and as such, they belong to the food opportunists with possible seasonal massive occurrence, thus representing a permanent component of soil zoo-edaphon in almost all ecotonal assemblages in which they can occur with typical forest species and the species associated with open habitats.

On the other hand, ecotonal assemblages may enter the species typical for sun-heated habitats, forest meadows, clear cuts, borders of agricultural land and even for human settlements: *Phalangium opilio*, *Opilio parietinus*, *Rilaena triangularis*, *Egaenus convexus*, *Mitopus morio*, *Leiobunum rotundum*, *L. aff. rupestre*. These and some other species indicate open, well illuminated and mostly warmer biotopes of all types (often also the human settlements), which has been confirmed

also by KROMP and STEINBERGER (1992), MIHÁL (1997), STAŠIOV et al. (2010).

The knowledge of the bioindicator value of harvestmen as well as their species richness in the given habitat is, in case of abrupt structural changes, an efficient tool for fast recognition of sorting or concentration of the animals in certain groups. These groups next colonise only the parts of the habitat that meet their food and habitat demands. Today, this fact seems of interest for bio-monitoring of post-calamity changes in the forest and non-forest ecosystems in the Low and High Tatra Mts.

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## **Kosce (Arachnida, Opiliones) v kalamitných lesných ekosystémoch Nízkych a Vysokých Tatier**

### **Súhrn**

Práca podáva súhrn doposiaľ známych nálezov koscov z Nízkych Tatier, čím chce prispieť k obohateniu chudobných faunistických záznamov o výskyte koscov na tomto území. V práci sa zároveň prezentuje aj druhová diverzita koscov Vysokých Tatier, pričom sa diskutuje o možnostiach využitia koscov Nízkych a Vysokých Tatier pri biomonitoringu štrukturálnych zmien v lesných ekosystémoch, ktoré v oboch pohoriach nastali po vetrovej a snehovej kalamite z roku 2004. Po sumarizácii výsledkov našich zberov koscov, ako aj údajov z literatúry, možno konštatovať, že doposiaľ je z územia Nízkych Tatier známych celkovo 17 druhov koscov, patriacich do 5 čeladi, čo tvorí 51,5 % z celkovej druhovej diverzity koscov doposiaľ determinovaných z územia Slovenska. Zistil sa výskyt typicky horského druhu *Ischyropsalis manicata* ako aj karpatského endemita *Paranemastoma kochi*. Na južných predhorách Nízkych Tatier boli zaznamenané teplomilné euromediterránne a pontické druhy *Dicranolasma scabrum* a *Egaenus convexus*. V tabuľkách 1 a 2 uvádzame doposiaľ známe druhové zloženie koscov Nízkych a Vysokých Tatier, nakoľko ide o naše najvyššie pohoria, s množstvom spoločných znakov. Výraznú podobnosť oboch blízkych pohorí potvrdzuje aj zloženie ich opiliofauny, kde je prevažná väčšina spoločných druhov. V oboch pohoriach možno v budúcnosti očakávať výskyt ďalších druhov koscov, napr. druhy *Siro carpaticus*, *Opilio parietinus*, *Platybunus pallidus*, *Zacheus crista*, *Astrobonus laevipes*, *Leiobunum rotundum*, *Nelima semproni* a iné.

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## Microclimatic specificity of a Mediterranean oak woodland (montado) in context of global change

Jorge Nunes<sup>1</sup>, José Andrade<sup>2</sup>, Francisco Abreu<sup>4</sup>, Luis Gazarini<sup>3</sup>, Manuel Madeira<sup>4</sup>

<sup>1</sup>ICAAM- Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Universidade de Évora, Apartado 94, 7002-554 Évora, Portugal, E-mail: jdnunes@uevora.pt

<sup>2</sup>ICAAM/Departamento de Geociências, Universidade de Évora, Apartado 94, 7002-554 Évora, Portugal, E-mail: zalex@uevora.pt

<sup>3</sup>ICAAM/Departamento de Biologia, Universidade de Évora, Apartado 94, 7002-554 Évora, Portugal, E-mail: gazarini@uevora.pt

<sup>4</sup>Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal, E-mail: fgabreu@isa.utl.pt; mavmadeira@isa.utl.pt

### Abstract

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The effects of oak trees on microclimatic parameters in *Quercus rotundifolia* Lam. woodland in Alentejo, Southern Portugal, are reported. The results show that oak trees create a marked differentiation in the grass matrix between open and tree-canopied habitats. Compared to open areas, oak canopy cover is associated with lower soil moisture content, lower soil temperature and lower photosynthetically active radiation (PAR). Soil temperature values outside the canopy shelter are generally higher than under the canopy, even two-fold during the winter. The decrease in soil water content is more rapid in areas not affected by tree canopy, but the recharge is earlier faster. PAR intercepted by tree canopy exceeds 60%, affecting dramatically production in herbs. Different climatic conditions at presence of trees, associated with higher variability in chemistry environment under the canopy, if combined with the IPCC forecasts for the Mediterranean region, pose new challenges in management of the montado areas.

### Key words

montado, *Quercus rotundifolia*, PAR, soil water content, soil temperature

### Introduction

Mediterranean-type evergreen oak woodlands consisting of *Quercus rotundifolia* Lam. (holm oak) and *Quercus suber* L. (cork oak) trees cover ample areas in Southern Portugal where they occupy 862.4 10<sup>3</sup> ha (D.G. F., 2006) – representing about 28% of the region. Anthropogenic activities have shaped these oak woodlands into savannah-type ecosystems or landscapes with scattered trees within a continuous grass matrix, in an agroforestry system called montado (DAVID et al., 2004). The primary aim of this system is feeding livestock and cork extraction. The net effect of trees on grass production can be negative, neutral or positive,

changing with tree age, size and density (SCHOLLES and ARCHER, 1997).

Isolated individuals may alter chemical, physical and biological soil properties through their impact on energy and nutrient fluxes (GALLARDO et al., 2000). In fact, soil organic matter quantity and quality are affected positively by the tree presence (ESCUADERO et al., 1985; ROVIRA and VALLEJO, 2007). Nitrogen mineralization rate and microbial biomass-N were observed higher in soils under tree canopy than in open areas (GALLARDO et al., 2000; GALLARDO, 2003), together with higher contents of organic C, N, base cations and values of cation exchange capacity (ZINKE, 1962; BARTH, 1980; RYAN and MCGARITY, 1983). The soil under tree

canopy also exhibited more developed soil profiles and improved water regime (KOECHLIN et al., 1986). ZINKE (1962) pointed out that individual trees have an influence proportional to their crown area projected onto the soil surface.

The interactions between the trees and the understorey environment may have an important role in the management of these systems in a multiple use perspective. Although the study of these interactions is of utmost importance, some uncertainty subsists in Southern Portugal regarding the role of trees in context of microclimatic and soil characteristics, especially soil water content, chemical characteristics and nutrient availability. The considerable economic and ecological importance of the montado silvopastoral multi-purpose systems and the considerable concern about their long-term sustainability has raised the relevance of studying their functioning, and their influence on nutrient cycling in a way facilitating recognition of management practices affecting the long-term sustainability of these ecosystems.

## Material and methods

The study was carried out in Southern Portugal at the Centro de Estudos e Experimentação da Mitra (CEEM), experimental campus of the University of Évora (38°32' N, 8°01' W, 243 m), during 2001–2002. The local climate is of the Mediterranean-type (Csa according to Köppen), characterized by wet-winter and dry-summer pattern. The mean annual rainfall is 665 mm, most of which falls from autumn to early spring (90%), in less than 75 days of rain per year (INMG, 1991). The mean annual air temperature is about 15.4 °C, ranging from 8.6 °C in January to 23.1 °C in August. The relative air humidity is about 70%. The dry period lasts up to 5 months.

The landscape is gently undulating. The slope at the study site has an inclination from 3 to 8%. The geological substratum consists of granites and gneisses (CARVALHOSA et al., 1969). The prevailing soils are Eutric Leptosols developed on gneiss (WRBSR, 2006), with a maximum soil depth of about 1 m. The soil texture is sandy to sandy loamy.

The vegetation consists of open pastures with scattered trees of *Q. suber* L and *Q. rotundifolia* Lam. The tree density ranges from 35–45 trees ha<sup>-1</sup> with an average canopy cover of 21% (DAVID, 2006). Major forbs include *Rumex bucephalophorus* L., *Silene gallica* L., *Ornithopus compressus* L., *Ornithopus pinnatus* (Miller) Druce, *Geranium purpureum* Vill., *Tolpis barbata* (L.) Gaertner, *Tuberaria guttata* L. Fourr. Common annual grass species are *Vulpia bromoides* (L.) S.F. Gray, *Bromus rigidum* Gaudin, *Hordeum murinum* L. and *Briza maxima* L. The herbaceous layer has been invaded by shrubs, mainly *Cistus salvifolius* L.

Microclimatic parameters (photosynthetically active radiation, soil temperature and soil moisture) were monitored under tree canopies and outside their influence. Photosynthetically active radiation (PAR) was recorded by PAR sensors, placed at 0.30 m above the soil surface, at the upper limit of herbaceous layer. Average hourly soil temperature under tree canopy was recorded continuously, using copper-constantan thermocouples Delta-t placed on soil organic surface layers, between surface organic horizon and mineral profile (0 cm), and at 2.5 cm, 5 cm, 10 cm, 15 cm and 20 cm. In the open area, average hourly soil temperature was also recorded continuously with thermocouples placed at 2.5 cm, 5 cm, 10 cm, 15 cm and 20 cm. Soil moisture was monitored with 20 ThetaProbe sensors (ML2x, Delta-T Devices, Cambridge, UK). The sensors are designed to measure volumetric soil water content ( $\theta_v$ ) using a simplified standing wave measurement to determine the impedance of a sensing rod array (MILLER and GASKIN, n.d.). Ten sensors were installed in soil under an isolated *Q. rotundifolia* tree (crown radius was 7.2 m) for use in precipitation interception studies, and ten sensors were installed outside the crown projection. In both cases, half of the sensors were installed at 0.06 m depth, and the other half at 0.25 m depth. Soil volumetric water content was averaged and stored at half-hourly intervals. All sensors were connected to a DL2<sub>c</sub> data-logger (Delta-T Devices, Cambridge, UK).

## Results and discussion

The amount of solar radiation reaching the soil under tree canopy depends on multiple factors; the season, cloud cover, tree height, and density of tree cover. *Quercus rotundifolia* is an evergreen oak, therefore, the interception of solar radiation in this species does not display such a marked seasonality as in deciduous trees – there are only slight variations, around 5%, all year around.

The global solar radiation (G) and photosynthetically active radiation (PAR) during most of the daytime was higher in open areas than in areas influenced by tree canopy (Figs 1 and 2). The G and PAR interception by the tree and shrub layers attained 95% and 85%. The pattern of radiation decrease is in accordance with patterns recognised by other authors (BELSKY et al., 1993) in savanna formations.

Soil temperature values observed during December 2001 and March 2002 at soil depth of 2.5 cm and 10 cm were always higher in the areas outside canopy influence (Figs 3–6). However, the differences in soil temperature found between these areas and at those canopy-influenced were still more accentuated during the summer months. A similar pattern was found by RORISON (1991), who compared north and south slopes, and by BELSKY et al. (1993) in his studies with *Acacia*

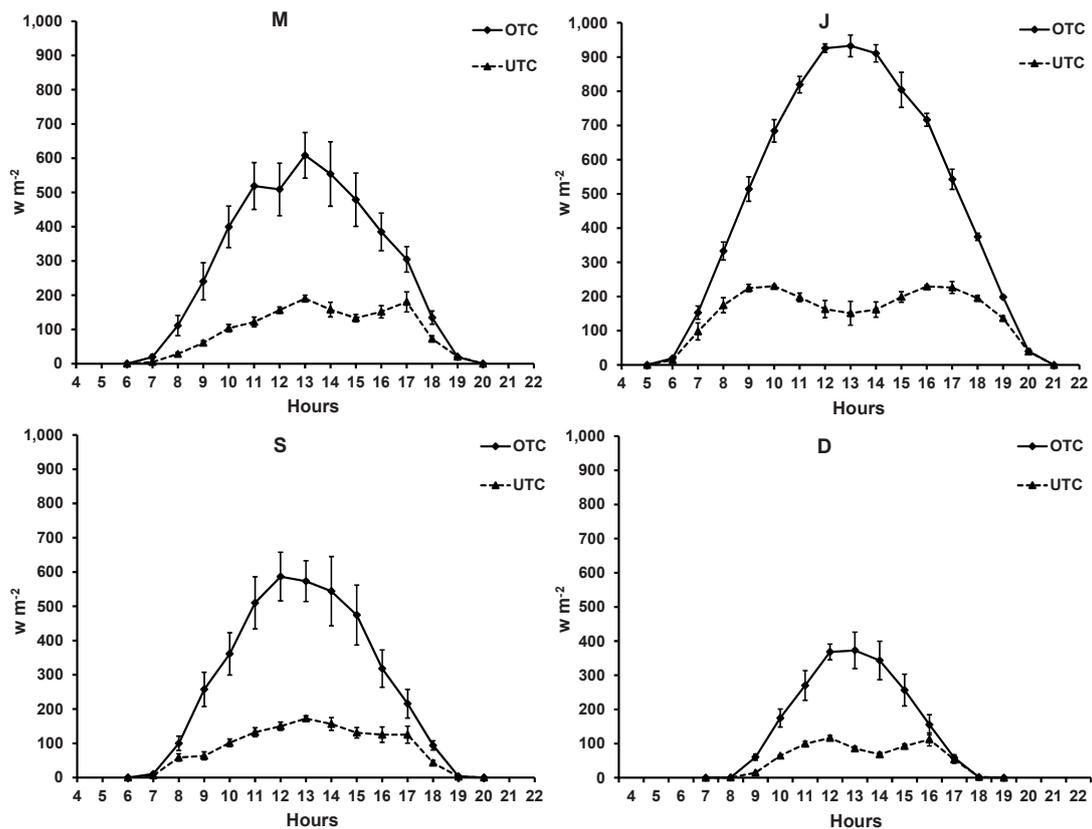


Fig. 1. Average time course of solar global radiation ( $G$ ,  $w m^{-2}$ ), under tree canopy (UTC) and outside tree canopy (OTC), during March, June, September and December 2002.

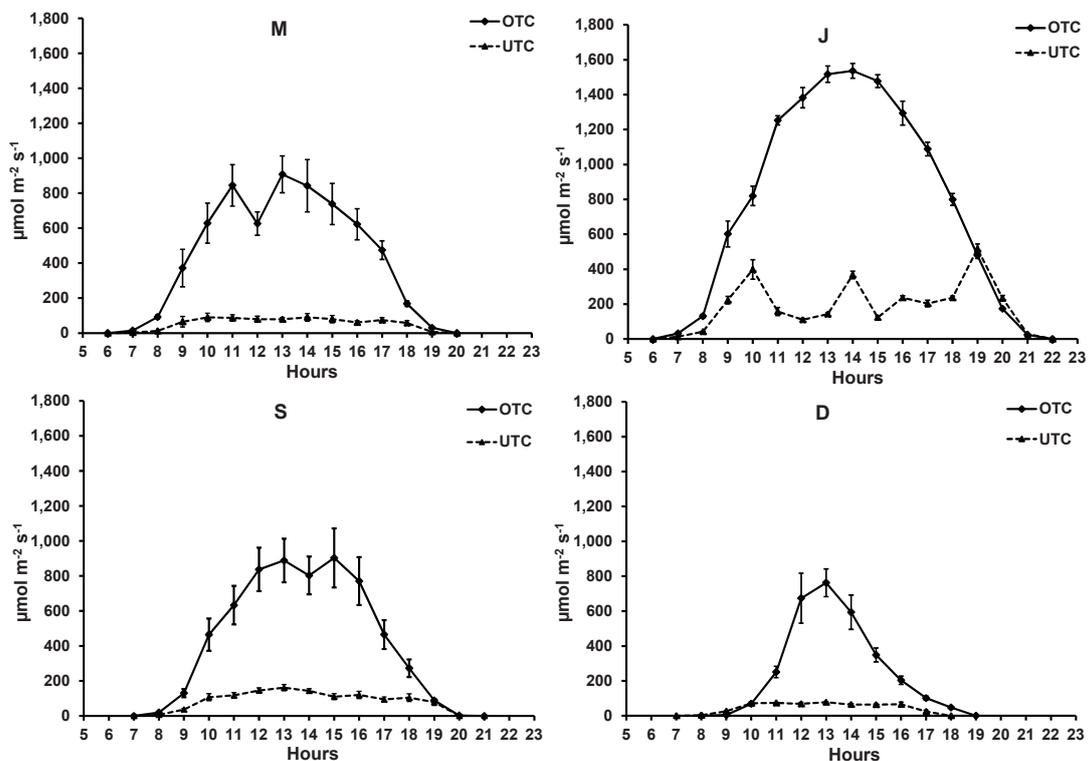


Fig. 2. Average time course of photosynthetically active radiation (PAR,  $\mu mol m^{-2} s^{-1}$ ), under tree canopy (UTC) and outside tree canopy (OTC), during March, June, September and December 2002.

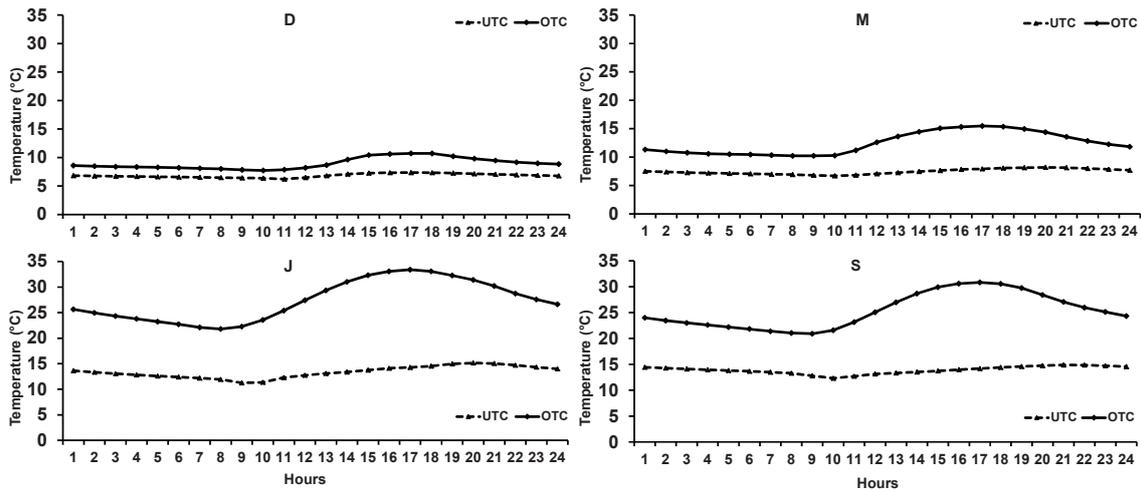


Fig. 3. Average time course of soil temperature ( $^{\circ}\text{C}$ ) at 2.5 cm depth, under tree canopy (UTC) and outside tree canopy (OTC), during December 2001 and March, June and September 2002.

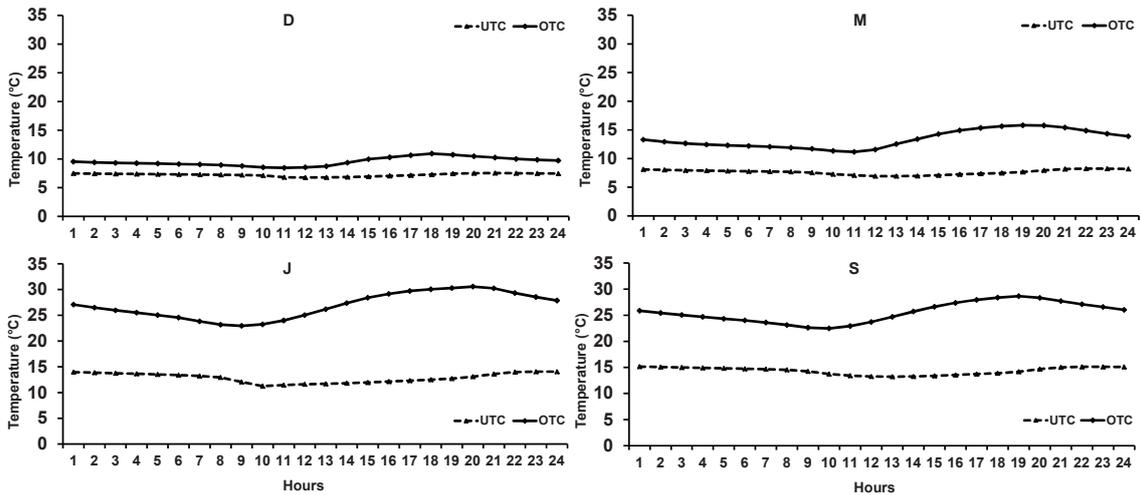


Fig. 4. Average time course of soil temperature ( $^{\circ}\text{C}$ ) at 10 cm depth, under tree canopy (UTC) and outside tree canopy (OTC), during December 2001 and March, June and September 2002.

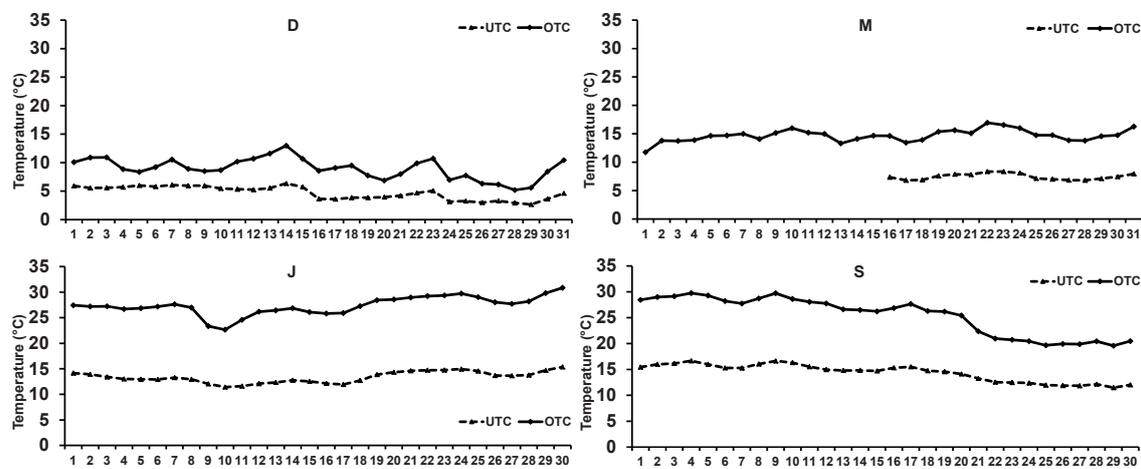


Fig. 5. Average daily course of soil temperature ( $^{\circ}\text{C}$ ) at 2.5 cm depth, under tree canopy (UTC) and outside tree canopy (OTC), during December 2001 and March, June and September 2002.

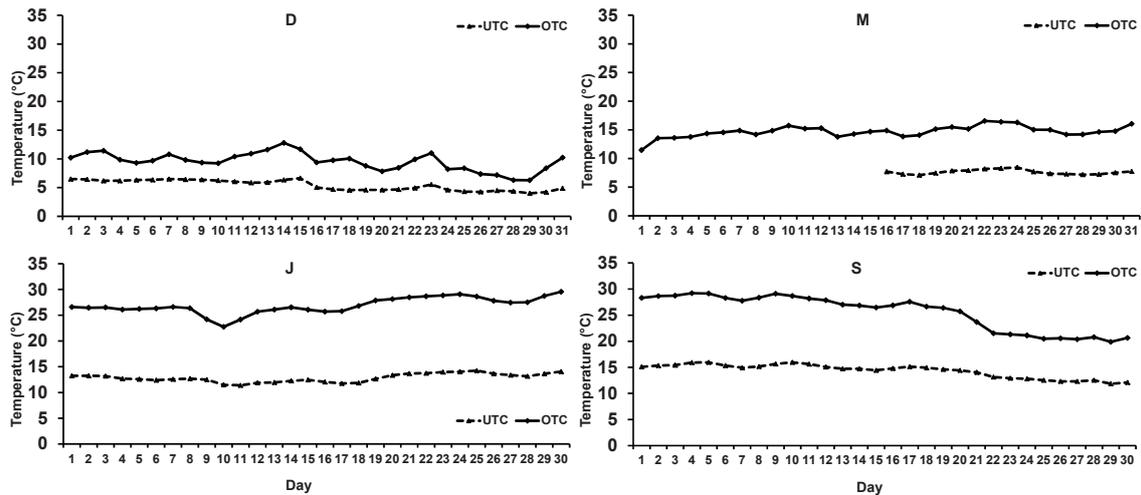


Fig. 6. Average daily course of soil temperature ( $^{\circ}\text{C}$ ) at 10 cm depth, under tree canopy (UTC) and outside tree canopy (OTC), during December 2001 and March, June and September 2002.

*tortilis* and *Adansonia digitata*. HAWORTH and MCPHERSON (1995) in grasslands of semi-arid areas (South-Eastern Arizona, U.S.A) with *Quercus emoryi* trees, and Pereira et al. (2007) in a pasture land (Northeast of Portugal) with isolated ash trees (*Fraxinus angustifolia* Vahl), observed patterns similar to the present study in the summer period, with soil temperatures lower below tree canopy than in open area. Conversely, in the winter period, they observed just opposite patterns – with higher temperatures under tree canopy. This is in contradiction with our results, and may be explained by physiology (evergreen tree) and conformation of *Quercus rotundifolia* canopy. The crown of Holm oak has a homo-genizing effect on soil temperature, since the values of soil temperature in canopy-influenced areas show less marked variations, both in time and daily course (Figs 3–6).

The pattern of soil moisture variation during the dry period was similar for both areas, although the highest values were always obtained for open areas (Figs 7 and 8). The minimum moisture content observed in

the topsoil during the summer was of the same order of magnitude in both areas. This indicates that the tree cover did not affect the minimum water content in soil, but only the rate of moisture loss, even during spring and early summer. In canopy-influenced areas, moisture content at 25 cm depth was generally higher than at the soil surface. The values of soil moisture at this depth did not reflect the occurrence of precipitation events as dramatically as the surface.

As the result of the first rains after the summer drought, the soil wetting rate at the two habitats was very similar, nevertheless, somewhat higher in open areas. After soil wetting by continuous autumn rains, both areas had the same soil water content on surface by the end of November to early December (Fig. 8). However, at 25 cm depth, soil water content at the end of this period, was higher in open areas than under the oak canopy. Nevertheless, there were found no statistically significant differences in soil moisture values between the canopy-influenced and open areas, for all the measured periods.

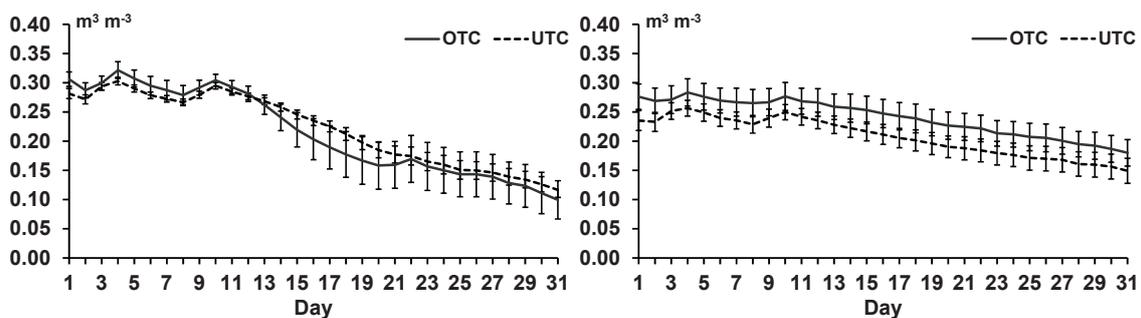


Fig. 7. Average soil water contents under canopy of *Q. rotundifolia* tree (UTC) and outside tree canopy (OTC) at 6 cm (Left) and 25 cm (Right), in May 2002.

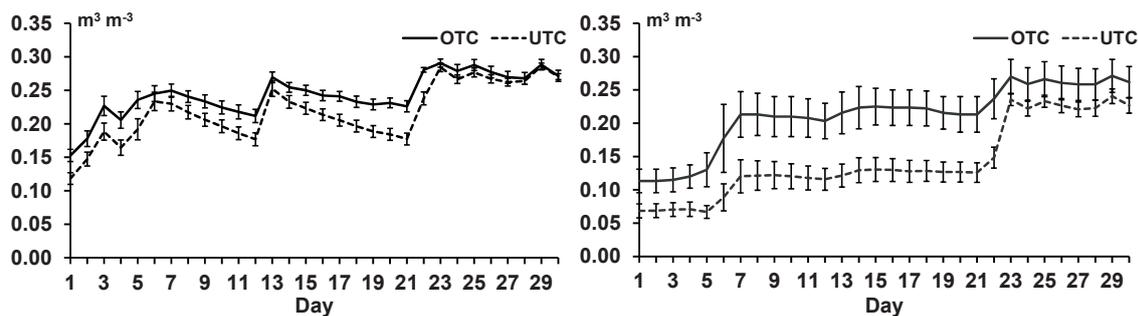


Fig. 8. Average soil water contents under canopy of *Q. rotundifolia* tree (UTC) and outside tree canopy (OTC) at 6 cm (Left) and 25 cm (Right), in November 2002.

Our results are in accord neither with those obtained for the same species in Spain (JOFFRE and RAMBAL, 1988, 1993), nor with those obtained for other species in similar savanna systems (BELSKY, 1994; BELSKY et al., 1989, 1993; JACKSON et al., 1990), as we observed higher moisture content more frequently in open areas than in canopy-influenced ones. Nevertheless, BELSKY and AMUNDSON (1998) report that water content in soil under canopy shelter may be both higher and lower than in unsheltered soil. The pattern found in this study can follow from the fact that trees determine an interception loss of around 27% of the gross rainfall per unit of effective cover (DAVID, 2006). The tree canopy cover ensures higher values of soil water content in dry periods, extending periods of water availability for plants.

In these agroforestry systems, Holm oak trees, more or less isolated, catch precipitation particles and redeploy them across the pasture in throughfall and stemflow. At the same time, they influence the microclimatic conditions, physical and chemical characteristics of soil and the rates of biogeochemical processes in the areas under the action of the trees. As a result of these changes, the production of pastures exhibits qualitative and quantitative differences between the two habitat types (CUBERA et al., 2009), with carbon and nitrogen production / accumulation higher in the canopy-influenced areas (NUNES et al., 2007).

Given the scenarios of high variability in the precipitation and temperature patterns referred to the regions of Mediterranean climate (MIRANDA et al., 2002; IPCC, 2007), the performance of this mosaic ecosystem may be strongly changed. The differentiation between areas with and without tree canopy in soil carbon and nitrogen cycles, and in herb production will probably be exacerbated, questioning the sustainability of the montado ecosystem. The animal support capacity may decrease, and tree susceptibility to diseases may increase.

## Conclusions

The canopy of *Quercus rotundifolia* trees causes dramatic changes to the microclimatic environment be-

neath: concerning namely photosynthetically active solar radiation, global solar radiation, soil temperature and soil moisture of the first layer. This differentiation is reflected in differences in herb production, nitrogen mineralization and carbon storage between under-canopy and without-canopy areas. The expected climate change for Mediterranean region may seriously disturb the present equilibrium of the montado ecosystem – by sharpening the differences between canopy-sheltered and open areas, putting in question the sustainability of this ecosystem.

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# Význam mikroklimaticky špecifických systémov montado v agrolesníctve v kontexte globálnych klimatických zmien

## Súhrn

Práca sa zaoberá vplyvom duba *Quercus rotundifolia* Lam. na mikroklimu lesnatej krajiny v oblasti Alentejo v južnom Portugalsku. Výsledky ukazujú, že duby spôsobujú výraznú diferenciáciu trávnej matrice medzi otvorenými biotopmi a biotopmi clonenými korunami stromov. V porovnaní s neclonenými plochami, plochy pod clonou dubového zápoja vykazujú nižší obsah pôdnej vlhkosti, nižšiu teplotu pôdy a nižšiu fotosynteticky aktívnu radiáciu (PAR). Teplota pôdy mimo clony je vo všeobecnosti vyššia ako teplota pôdy pod clonou, v zime dokonca dvojnásobne. Pokles obsahu pôdnej vody je výraznejší na plochách mimo clony, na druhej strane, dopĺňanie prebieha skôr a je rýchlejšie. Podiel fotosynteticky aktívnej radiácie zachytenej stromami je vyšší ako 60 %, čo má výrazný vplyv na produkciu bylinnej vrstvy. Odlišné klimatické podmienky v prítomnosti stromov spojené s vyššou chemickou variabilitou prostredia pod korunovou clonou spolu s predpoveďami IPCC pre oblasť Stredomoria nastoľujú nové úlohy v obhospodarovaní oblastí montado.

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## Bird communities in the natural spruce-beech forests in the Veľká Fatra Mts, Western Carpathians

Miroslav Saniga

Institute of Forest Ecology of the Slovak Academy of Sciences, Research Station, SK-976 02 Staré Hory,  
Slovak Republic, E-mail: uelsav@bb.sanet.sk

### Abstract

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The qualitative-quantitative composition of bird communities in the natural spruce-beech forests in the Veľká Fatra mountains (Slovakia) was studied during the spring season (April–June) in 2008–2010, using the strip transect method on three study plots. The bird assemblage of the investigated spruce-beech forests comprised 49 bird species at a density of 58.4 ind. per 10 ha. Bird community in the natural spruce-beech forest Skalná alpa was the richest (49 species at a density of 62.5 ind./10 ha). At the locality Suchý vrch were found 48 species at a density of 57.8 ind./10 ha, on the study plot Čierny kameň were identified 45 species at a density of 55.4 ind./10 ha.

### Key words

beech, bird community, natural forest, spruce, Veľká Fatra Mts, Western Carpathians

### Introduction

At present, forest biocoenoses are more and more stressed by air pollution, acid rain, and global warming, the long-term effect of which results in changes to the species composition and to the structure of the vegetation components, thus having a secondary impact on animals, too.

It is therefore of fundamental importance to determine in detail the structure of all animal assemblages (including bird communities) in primeval and relatively undamaged forest ecosystems – in order to be able, in the future, to compare the structure of these communities in damaged biocoenoses with those in the natural forests. Primeval forests represent the unique ecosystems and are identified as areas of high nature conservation value from the landscape ecology aspect.

Problems of the relationship between bird communities and the vegetation cover have been studied by many authors (e.g. FERRY, 1960; SHORT, 1979; KOČIAN, 1981; WIENS, 1981; VERNER and LARSON, 1989; KRISTÍN, 1990, 1991, 1993; SANIGA, 1995; KROPIL, 1996a, b; ADAMÍK et al., 2003; KORŇAN, 2004).

In the spruce vegetation tier of the Veľká Fatra Mts, fragments of non-affected primeval forests have

been conserved at some less accessible sites up to now. I focused my attention on the bird communities of these fragments during the years 2008–2010. The Veľká Fatra Mts has already been the subject of a number of ornithological studies (e.g. TOPERCER, 1989; SANIGA, 1994a, b, 1995). The aims of this study are as follows:

1. Analysis of the qualitative-quantitative structure of the breeding bird communities
2. Analysis of the population abundance, dominance and species diversity
3. New data supplementing the previous bird censuses in this area.

### Material and methods

Bird communities were investigated over the spring seasons (from the beginning of April to late June) 2008–2010. Bird censuses were carried out using the strip transect method (VERNER, 1985). A singing male, pair of birds, family, feeding bird, and a bird defending nest area were considered as a pair (2 individuals) during the spring season. One bird seen or heard was considered as one individual in this period (BLONDEL et al., 1970).

Lengths of transects are as follows: locality Suchý vrch (1,000 m), Skalná alpa (1,200 m), and Čierny kameň (1,000 m). A total of 30 field checks were made (10 evening investigations).

Birds were generally counted twice per day (early in the morning from 03.00 to 09.00 CET and later in the evening from 17.00 to 20.00 CET). All checks were made under satisfactory weather conditions. Species with nocturnal activity (order Strigiformes, species *Caprimulgus europaeus* L.) were observed during night. Individuals outside the survey belt were also recorded, yet without the quantitative indices („x“ in Table 2).

The results obtained were used for calculating the following population characteristics: density (D); relative abundance (A %), SHANNON-WEAVER'S (1949) equation was used for calculating the diversity index (H'); and index of equitability (E) was calculated according to SHELDON (1969).

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Breeding status was determined by direct evidence found on or near the study sites (nests, fledglings, feeding birds) or data from previous observations in the same habitats.

I concentrated on the bird communities in the primeval spruce-beech forests (altitude ranging from 1,100 to 1,300 m a.s.l.) in the Veľká Fatra Mts (E = 18°50'–19°18'; N = 48°47'–49°19'). The main habitat features of three census sites are given in Table 1. The geobiocoenology nomenclature of the groups of forest types is used according to RANDUŠKA et al. (1986). The characteristics of the study plots are given according to the Forest management plans made in the years 1998 and 2008 by Lesoprojekt.

Table 1. Features of the examined localities

Locality	Group of forest types	Tree composition	
Suchý vrch (Veľká Fatra Mts)	Fageto-Aceretum	<i>Picea abies</i>	5%
	140-year-old	<i>Fagus sylvatica</i>	95%
Skalná alpa (Veľká Fatra Mts)	Fageto-Aceretum 200-year-old	<i>Fagus sylvatica</i>	60%
		<i>Picea abies</i>	25%
		<i>Acer pseudoplatanus</i>	10%
		<i>Abies alba</i>	5%
Čierny kameň (Veľká Fatra Mts)	Fageto-Aceretum 150-year-old	<i>Fagus sylvatica</i>	90%
		<i>Acer pseudoplatanus</i>	5%
		<i>Picea abies</i>	5%

Table 2. The density (D – ind./10 ha), relative abundance (A%), diversity index (H'), and equitability index (E) for bird communities in natural spruce-beech forests in the Veľká Fatra Mts, Slovakia in 2008–2010 (x – occurrence outside the strip belt)

Locality Species	Suchý vrch		Skalná alpa		Čierny kameň		Total	
	D	A	D	A	D	A	D	A
<i>Parus montanus</i> Bald.	1.2	2.1	1.2	1.9	1.0	1.8	1.2	2.0
<i>Regulus regulus</i> (L.)	1.1	1.9	1.1	1.8	1.1	2.0	1.1	1.9
<i>Fringilla coelebs</i> L.	9.0	15.6	12.4	19.8	10.0	18.1	10.5	18.0
<i>Erithacus rubecula</i> (L.)	5.0	8.6	6.0	9.6	5.2	9.4	5.4	9.2
<i>Turdus torquatus</i> L.	3.0	5.2	3.8	6.1	4.0	7.2	3.6	6.2
<i>Prunella modularis</i> L.	3.0	5.2	3.2	5.1	2.8	5.0	3.0	5.1
<i>Troglodytes troglodytes</i> (L.)	3.0	5.2	3.0	4.8	2.8	5.0	2.9	5.0
<i>Certhia familiaris</i> L.	2.6	4.5	2.8	4.5	2.8	5.0	2.7	4.6
<i>Ficedula albicollis</i> (Temm.)	2.6	4.5	2.8	4.5	2.8	5.0	2.7	4.6
<i>Sitta europaea</i> L.	2.4	4.2	2.6	4.2	2.2	4.0	2.4	4.1
<i>Phylloscopus collybita</i> (Viell.)	2.0	3.5	2.0	3.2	1.8	3.2	1.9	3.2
<i>Phylloscopus trochilus</i> (L.)	2.0	3.5	1.8	2.9	1.6	2.9	1.8	3.1
<i>Phylloscopus sibilatrix</i> (Bechst.)	2.0	3.5	1.8	2.9	1.6	2.9	1.8	3.1
<i>Phoenicurus phoenicurus</i> (L.)	2.0	3.5	1.8	2.9	1.4	2.5	1.7	2.9
<i>Sylvia atricapilla</i> (L.)	1.6	2.8	1.8	2.9	1.4	2.5	1.6	2.7

Table 2. Continued

Locality Species	Suchý vrch		Skalná alpa		Čierny kameň		Total	
	D	A	D	A	D	A	D	A
<i>Turdus philomelos</i> Brehm	1.6	2.8	1.8	2.9	1.4	2.5	1.6	2.7
<i>Pyrrhula pyrrhula</i> (L.)	1.4	2.4	1.4	2.2	1.2	2.2	1.3	2.2
<i>Turdus viscivorus</i> L.	1.4	2.4	1.4	2.2	1.2	2.2	1.3	2.2
<i>Turdus merula</i> L.	1.4	2.4	1.4	2.2	1.2	2.2	1.3	2.2
<i>Tetrastes bonasia</i> (L.)	1.1	1.9	1.1	1.8	1.1	2.0	1.1	1.9
<i>Dendrocopos leucotos</i> (Bechst.)	1.0	1.7	0.8	1.3	0.8	1.5	0.9	1.5
<i>Dendrocopos major</i> (L.)	1.0	1.7	0.8	1.3	0.8	1.5	0.9	1.5
<i>Parus ater</i> L.	1.0	1.7	0.8	1.3	0.8	1.5	0.9	1.5
<i>Parus cristatus</i> L.	0.8	1.4	0.6	1.0	0.4	0.7	0.6	1.0
<i>Columba palumbus</i> L.	0.6	1.0	0.5	0.8	0.4	0.7	0.5	0.9
<i>Glaucidium passerinum</i> (L.)	0.5	0.8	0.5	0.8	0.5	0.9	0.5	0.9
<i>Loxia curvirostra</i> L.	0.4	0.6	0.4	0.5	0.4	0.7	0.4	0.7
<i>Parus palustris</i> L.	0.4	0.6	0.4	0.5	0.4	0.7	0.4	0.7
<i>Parus caeruleus</i> L.	0.4	0.6	0.4	0.5	0.4	0.7	0.4	0.7
<i>Aegithalos caudatus</i> (L.)	0.4	0.6	0.4	0.5	0.4	0.7	0.4	0.7
<i>Muscicapa striata</i> (Pall.)	0.4	0.6	0.4	0.5	0.4	0.7	0.4	0.7
<i>Regulus ignicapillus</i> (Temm.)	0.2	0.4	0.1	0.2	0.2	0.4	0.2	0.3
<i>Carduelis spinus</i> (L.)	0.2	0.4	0.2	0.2	0.1	0.2	0.2	0.3
<i>Scolopax rusticola</i> L.	0.2	0.4	0.1	0.2	0.1	0.2	0.1	0.2
<i>Picoides tridactylus</i> (L.)	0.2	0.4	0.1	0.2	0.1	0.2	0.1	0.2
<i>Dryocopus martius</i> (L.)	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2
<i>Nucifraga caryocatactes</i> (L.)	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2
<i>Anthus trivialis</i> (L.)	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2
<i>Aegolius funereus</i> (L.)	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2
<i>Coccothraustes coccothraustes</i> (L.)	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2
<i>Tetrao urogallus</i> L.	0.1	0.2	0.1	0.2			0.03	0.1
<i>Cuculus canorus</i> L.	0.1	0.2	0.1	0.2			0.03	0.1
<i>Sylvia curruca</i> (L.)			0.1	0.2	0.1	0.2	0.03	0.1
<i>Accipiter nisus</i> (L.)	x		x		x		x	
<i>Garrulus glandarius</i> (L.)	x		x		x		x	
<i>Accipiter gentilis</i> (L.)	x		x				x	
<i>Strix uralensis</i> Pall.	x		x		x		x	
<i>Strix aluco</i> L.	x		x		x		x	
<i>Caprimulgus europaeus</i> L.	x		x				x	
Total	57.8	100.0	62.5	100.0	55.4	100.0	58.4	100.0
Total species	48		49		45		49	
Diversity index (H')	4.00		4.10		3.78		4.20	
Equitability index (E)	0.75		0.77		0.72		0.78	

## Results

During the spring season, 49 species at a total density of 58.4 ind./10 ha formed the bird community in the natural spruce-beech forests. *Fringilla coelebs* L. (18.0%) was eudominant, with *Erithacus rubecula* (L.) (9.2%),

*Turdus torquatus* L. (6.2%), and *Prunella modularis* (L.) (5.1%) being dominant. The diversity index H' was 4.20 and the value of the equitability index E was 0.78.

In total, 46 species were considered to nest in the primeval spruce-beech forests. Individual as of

*Accipiter nisus* (L.), *Sylvia curruca* (L.), and *Coccothraustes coccothraustes* (L.) were observed several times in this type of habitat, but breeding was not apparent.

The highest species richness was found in the bird assemblage of the spruce-beech forest Fageto-Aceretum at the locality Skalná alpa (49 species at a total density 62.5 ind./10 ha). *Fringilla coelebs* L. (19.8%) was eudominant, with *Erithacus rubecula* (L.) (9.6%), *Turdus torquatus* L. (6.1), and *Prunella modularis* (L.) (5.1%) being dominant.

Bird community of the natural spruce-beech forest of the group of forest types Fageto-Aceretum at the locality Suchý vrch formed 48 species at a total density of 57.8 ind./10 ha. *Fringilla coelebs* L. (15.6%) was eudominant, with *Erithacus rubecula* (L.) (8.6%), *Turdus torquatus* L. (5.2%), *Prunella modularis* (L.) (8.5%), and *Troglodytes troglodytes* (L.) (5.2%) being dominant.

Forty-five species at a total density of 55.4 ind./10 ha formed the bird community in the natural spruce-beech forest of the group of forest types Fageto-Aceretum at the locality Čierny kameň. *Fringilla coelebs* L. (18.1%) was eudominant, with *Erithacus rubecula* (L.) (9.4%), and *Turdus torquatus* L. (7.2%) being dominant.

Based on the results obtained by dividing bird species into guilds and from the results of previous studies carried out in the natural spruce-beech forests in the Veľká Fatra Mts, it may be concluded that bird species of the understudied vegetation tiers displayed their optimum vertical occurrence patterns. The species structure and relative abundance of the bird assemblage showed a high temporal stability.

Bird communities on the study plots situated in the natural spruce-beech-fir forests of the Veľká Fatra Mts did not differ a great deal in the number of species. Differences among the compared bird communities have been discovered both in the species composition in respect to their dominance and in the number of individuals in the populations.

## Discussion

KLÍMA (1959) used the strip transect method in studying the bird community of the primeval spruce-beech-fir forests of the nature reserve Boubín, within altitude from 922 to 1,100 m a.s.l. and recorded altogether 40 bird populations with a total density of 290.3 ind./10 ha. Populations of species *Fringilla coelebs* L., *Phylloscopus sibilatrix* (Bechst.), *Certhia familiaris* L., *Parus ater* L., *Regulus regulus* (L.), and *Troglodytes troglodytes* (L.) exhibited dominant occurrence in this bird community.

In the mountain area of the West Tatras, KOCIAN (1981) found 31 bird species from which 13 were breeders.

In the spruce-beech-fir biocoenoses of the Bavarian forest (altitude 900–1,200 m a.s.l.) SCHERZINGER (1985) ascertained a bird community consisting of 31 species with a total density of 34 ind./10 ha. Individuals of the species *Fringilla coelebs* L., *Regulus regulus* (L.), *Phylloscopus sibilatrix* (Bechst.), *Regulus ignicapillus* (Temm.), *Erithacus rubecula* (L.), and *Certhia familiaris* L. occurred with a dominance higher than 5.1%.

MOSIMANN et al. (1987), studying a bird community in fir-beech biocoenoses at altitudes ranging from 900–1,300 m a.s.l. in Switzerland, recorded 49 populations of birds with the most frequent *Fringilla coelebs* L., *Parus ater* L., *Regulus ignicapillus* (Temm.), *Turdus philomelos* Brehm and *Erithacus rubecula* (L.).

ADAMÍK et al. (2003), who investigated a bird assemblage of an old-growth beech-fir forest in the Šrámková National Nature Reserve in the Malá Fatra Mts, recorded 23 bird species.

CELUCH and KROPIL (2004) found out 37 bird species with an abundance of 63.3 breeding pairs per 10 ha in a primeval fir-beech forest in the Latiborská hoľa National Nature Reserve (National Park Nízke Tatry). The diversity index  $H'$  was 4.03 and the value of the equitability index  $E$  was 0.82, which are the values very similar to my results. The high density of *Fringilla coelebs* L., *Erithacus rubecula* (L.), *Troglodytes troglodytes* (L.), *Parus ater* L. and *Regulus regulus* was typical for that study plot, which was in accordance also with the Veľká Fatra Mts. Higher density of the bird species in comparison with this study resulted from using different census method – combined version of the mapping method.

KORŇAN (2004) studied a breeding bird assemblage of a primeval beech-fir forest in the Šrámková National Nature Reserve (the Malá Fatra Mts), using an improved version of the mapping method. He found 57 bird species (52 breeders). Among these, 48 species reached a mean density of 58.17 breeding pairs per 10 ha. The Shannon diversity index ( $H'$ ) varied between 4.10–4.36 bites. The evenness index ( $J'$ ) reached values between 0.78–0.82. In summary, seven bird species were characterized as dominant: *Fringilla coelebs* L., *Erithacus rubecula* (L.), *Sylvia atricapilla* (L.), *Parus ater* L., *Phylloscopus collybita* (Viell.), *Regulus regulus* (L.), and *Prunella modularis* L. Dominance of the most abundant species, Shannon diversity and evenness indices are very similar to the results from the Veľká Fatra Mts, even though this study was carried out by the mapping method.

Comparing the results of the present paper with the data mentioned above, it is obvious that there exists similarity in the species composition of the compared bird communities. The differences are distinct in the density of the compared communities and in the substitution of the dominant species. Such differences may result both from the distinctions in the character of the forest biocoenoses (composition of the tree species, vertical

stratification of the vegetation), and from the different years when investigations were carried out.

By comparing the data of this study with the investigations carried out on these study plots in years 1989–91 (SANIGA, 1994a, b; SANIGA, 1995), there have not been found significant differences in the qualitative-quantitative structure of the bird communities. Altogether 59 bird species populations formed a bird community of the spruce-beech-fir forest biocoenoses at a density 60.2 ind./10 ha in the years 1989–91, which are values very similar to these from the years 2008–2010 (49 species with abundance 58.4 ind./10 ha). This shows that the bird communities in the fragments of original forests, relatively unspoiled by human activities, are very stable in comparison to the managed forests.

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## **Vtáčie spoločenstvá v prírodných smrekovo-bukových lesoch vo Veľkej Fatre, Západné Karpaty**

### **Súhrn**

V prírodných smrekových lesoch vo Veľkej Fatre (Slovensko) boli skúmané kvalitatívno-quantitatívne zloženie vtáčích spoločenstiev v hniezdom období (apríl–jún) v rokoch 2008–2010. Na troch výskumných plochách sa vyšetřovali vtáčie spoločenstvá použitím pásovej transektovej metódy. Vtáčia zložka všetkých troch skúmaných lokalít pozostávala zo 49 druhov s priemernou hustotou 58,4 jedincov na 10 ha. *Fringilla coelebs* L. (18,0%) bol eudominantný. *Erithacus rubecula* (L.) (9,2%) a *Turdus torquatus* L. (6,2%) a *Prunella modularis* (L.) (5,1%) boli prítomné dominantne. Index druhovej diverzity tohto vtáčieho spoločenstva mal hodnotu 4,20 a index druhovej vyrovnanosti 0,78. Najrozmanitejšie vtáčie spoločenstvo bolo zistené v prírodnom bukovom lese skupiny lesných typov Fageto-Aceretum na lokalite Skalná alpa (49 druhov s denzitou 62,5 jedincov na 10 ha). Na lokalite Suchý vrch pozostávalo vtáčie spoločenstvo prírodného bukového lesa skupiny lesných typov Fageto-Aceretum zo 48 druhov s hustotou 57,8 jedincov na 10 ha. Druhovo i početne najchudobnejšie vtáčie spoločenstvo prírodného bukového lesa bolo zistené na lokalite Čierny kameň v skupine lesných typov Fageto-Aceretum (45 druhov s denzitou 55,4 jedincov na 10 ha). Pri porovnaní výsledkov výskumu vtáčích spoločenstiev z týchto výskumných plôch uskutočnených v rokoch 1989-91 s údajmi prezentovanými v tejto práci neboli zistené rozdiely v ich kvalitatívno-quantitatívnej štruktúre. Tento fakt svedčí o tom, že vtáčie spoločenstvá vo fragmentoch pralesov, ktoré sú minimálne atakované ľudskou činnosťou, sú veľmi stabilné v porovnaní so spoločenstvami vtákov v hospodárskych lesoch.

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## Why the capercaillie population (*Tetrao urogallus* L.) in mountain forests in the Central Slovakia decline?

Miroslav Saniga

Institute of Forest Ecology of the Slovak Academy of Sciences, Research Station,  
SK-976 02 Staré Hory, Slovak Republic, E-mail: uelsav@bb.sanet.sk

### Abstract

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From 1981–2010, population dynamics of the capercaillie *Tetrao urogallus* L. was studied on forty-three leks in the Western Carpathians (Slovakia). Nest and chick losses were also studied. Altogether, 94 nests with clutches, 124 hens with chicks in June and 132 in the period between 1<sup>st</sup> August and 15<sup>th</sup> September were checked. Results demonstrate a marked decrease (>50%) in numbers of cocks and hens on twelve monitored leks (28%) and a slight decrease (<50%) on ten display grounds (24%). During the study period, capercaillie cocks became extinct on eleven (25%) leks and in their surroundings. More or less constant numbers were found on only eight leks (19%) and a slight increase occurred on only 2 leks (4%). The mean number of juveniles per a hen was 1.9 over the whole study. The average number of chicks accompanying a hen significantly decreased during the study period. Female chicks were consistently outnumbering male chicks. Predation appeared to be of major importance in limiting numbers of capercaillie chicks. Out of 94 capercaillie clutches 59 (63%) were destroyed. Predaceous pressure on chicks was high in spite of the fact that with progressing breeding season, the food offer for predators was continually increasing.

### Key words

capercaillie, population dynamics, Slovakia, Western Carpathians

### Introduction

Capercaillie (*Tetrao urogallus* Linnaeus, 1758) is a large ground-nesting grouse species with precocial chicks inhabiting, in small isolated populations, also Central-European mixed spruce-beech-fir and mountain spruce forests in the Western Carpathians (KLAUS et al., 1986; SANIGA, 1996a, 1996b, 1996c). These forests have been undergoing radical changes from a natural regime to a managed system, especially in the course of the last century. Continuous multi-aged forests have been transformed to patchworks of even-aged stands.

In the recent years, more attention has been directed towards the effects of forest habitat changes on faunal diversity and performance of wildlife populations (e.g. HELLE, 1985; VÄISÄNEN et al., 1986; LINDÉN, 1989; STORAAS et al., 1999). In terms of landscape ecology,

this large-scale change in forest management is expected to have profound effects on spatial patterns and range use of wildlife species, especially those having home ranges and cruising radii within the critical area interval (ROLSTAD and WEGGE, 1989a). Capercaillie belongs to this area-sensitive category, inhabiting old forests most of the year, and having seasonal ranges between 10 and 1,000 hectares in size (WEGGE and LARSEN, 1987).

In recent few decades, populations throughout most of western Europe have declined markedly (e.g. NOVÁKOVÁ and ŠTASTNÝ, 1982; KLAUS et al., 1986; KLAUS and BERGMANN, 1994; SANIGA, 1999). A decline in capercaillie populations has also been observed during the last 20–30 years in Fennoscandia and Russia (e.g. RAJALA and LINDÉN, 1984; ROLSTAD and WEGGE 1989a).

This paper reports on the findings of a thirty-year capercaillie population study in the mountain forests

of Central Slovakia (West Carpathians). This study is aimed at:

1. Examining population dynamics of the capercaillie on leks and their surroundings
2. Chick losses during the summer in this forest-dwelling tetraonid
3. Evaluation of the sex ratio in the chicks
4. Evaluation of the relationship between nest and chick losses and predaceous factors
5. Explore reasons for the persistent downward trend in numbers that was documented over the study period.

## Material and methods

The field work was conducted in the mountains of Central Slovakia (Veľká Fatra Mts, Malá Fatra Mts, Kremnické vrchy Mts, Starohorské vrchy Mts, and Nízke Tatry Mts, 18°50'–19°10' E; 48°47'–49°19' N) from 1981–2010.

The topography rises from 600 m a.s.l. to 1,530 m a.s.l. The climate is moderately continental with a mean temperature of the warmest month (July) of 14.5 °C and minus 5.5 °C for the coldest (January). Yearly mean precipitation is 1,000–1,400 mm, and the ground is usually covered with snow from mid-November to late March or April (depending on the sea-level and exposure).

In the area under study, mixed forest biocoenoses consisting of the spruce-beech-fir vegetation tier dominate (90%) (*Picea abies* (L.), *Abies alba* Mill., *Fagus sylvatica* L., *Acer pseudoplatanus* L.). Coniferous forests of the spruce vegetation tier constitute around 10% of the study area (*Picea abies* (L.) dominated, sprinkled with *Acer pseudoplatanus* L., *Fagus sylvatica* L., and *Sorbus aucuparia* L.).

Capercaillies are difficult to count at most times of year, but it is practicable to count the number of cocks displaying on leks in spring (KLAUS et al., 1986). Accuracy of quantitative investigations depends on the exact timing of the census. In the initial phase of display activity (late March), cocks do not visit leks regularly. The period between 20<sup>th</sup> April and 10<sup>th</sup> May is most suitable for surveys of the capercaillie in Central Europe (SANIGA, 1998a). In this period, hens also visit the leks regularly.

In 1981–2010, a total of forty-three leks were monitored during the spring display season. The study was largely carried out by observing birds from the vicinity of the leks, so that they were left not disturbed. Observation sites were usually occupied in the evening before the arrival of the males and were usually abandoned when the morning display ended. Capercaillies were counted at least twice during the spring display season on the lek. The leks were censused especially during the period between 20<sup>th</sup> April to 10<sup>th</sup> May (peak

of lekking activity). A possible bias in the material is that data from some leks were not obtained during this peak period. The numbers of hens present on the leks are considered underestimated in comparison to cocks, as hens are much less conspicuous on the leks. Altogether 652 evening and 1,088 morning observations were carried out on the forty-three leks during the spring display season.

## Results and discussion

### Spring density in natural forests

Spring density of the capercaillie during 1989–1991 in natural forests varied between 0.5 ind./100 ha (in dwarfed pine stands), 1.4–1.9 ind./100 ha (forests of the spruce vegetation tier), and 2.0–2.7 ind./100 ha (forests of the spruce-beech-fir vegetation tier). In the period 1999–2001, there was found a dramatic decline in the spring density in the natural forests: 0.1 ind./100 ha (in dwarfed pine stands), 0.7–1.1 ind./100 ha (forests of the spruce vegetation tier), and 0.9–1.3 ind./100 ha (forests of the spruce-beech-fir vegetation tier). The density estimate for dwarfed pine stands was affected by a methodological bias due to the proportionately shorter length of transect. In contrast to the situation in Fennoscandia and Russia, long-term population studies of capercaillie based on censuses of leks during the display season are scarce in Central Europe (MÜLLER, 1974). In Norway, WEGGE (1983) found out a density around 2.5 ind./100 ha. RAJALA (1974) found the capercaillie density to be 5.98 ind./100 ha in central Finland. According to KLAUS et al. (1986), this density is the upper limit for optimal habitats.

### Population dynamics on leks

Results demonstrate a marked decrease (>50%) in numbers of cocks and hens on twelve monitored leks (28%) and a slight decrease (<50%) on ten display grounds (24%). During the study period, capercaillie cocks became extinct on eleven (25%) leks and in their surroundings. Comparable numbers were found on only eight leks (19%) and a slight increase occurred on only two leks (4%). The average number of birds per lek was 6.3 cocks and 6.0 hens when the monitoring started in 1981. It declined to 1.5 cocks ( $r = 0.83$ ,  $p = 0.001$ ,  $y = -0.189x + 20.588$ ) and 1.5 hens ( $r = 0.67$ ,  $p = 0.001$ ,  $y = -0.142x + 15.823$ ) per lek in 2010 (Table 1). Findings of this study concerning the numbers of cocks and hens visiting the leks during the display season agree roughly with KOIVISTO and PIKOLA (1961), who monitored 185 leks in Finland. They found 2.3–5.2 cocks and 2.8–3.9 hens per lek.

Table 1. Presence of capercaillies on examined 43 leks during spring display season (West Carpathians, Slovakia, 1981–2010)

Year	Checked leks	Individuals		Average per lek	
		Males	Females	Males	Females
1981	4	25	24	6.3	6
1982	4	24	27	6	4.3
1983	7	31	27	4.4	3.9
1984	7	31	28	4.4	4
1985	7	23	29	3.3	2.7
1986	6	24	17	4	2.8
1987	8	18	19	2.3	2.4
1988	8	27	17	3.4	2.1
1989	13	40	28	3.1	2.2
1990	23	74	43	3.2	1.9
1991	23	78	52	3.4	2.3
1992	21	68	52	3.2	2.5
1993	23	67	62	2.9	2.7
1994	17	53	55	3.1	3.2
1995	25	71	61	2.8	2.4
1996	22	50	46	2.3	2.1
1997	22	41	46	1.9	2.1
1998	10	21	27	2.1	2.7
1999	10	19	25	1.9	2.5
2000	9	16	22	1.8	2.4
2001	10	17	26	1.7	2.6
2002	62	118	104	1.9	1.7
2003	72	116	128	1.6	1.8
2004	69	124	119	1.8	1.7
2005	79	137	110	1.8	1.4
2006	73	124	108	1.7	1.5
2007	66	112	93	1.7	1.4
2008	73	110	116	1.5	1.6
2009	74	111	108	1.5	1.4
2010	56	84	82	1.5	1.5
Altogether	903	1,854	1,701	2.1	1.9

Surrounding habitats are expected to influence lek population size in the capercaillie (LARSEN and WEGGE, 1984). Forest stands over 80 years old with suitable age and spatial structure covered 20–90% of the area within 1 km of the checked lek centres. On four leks surrounded by forest with only 20–30% old growth, 1–2 cocks displayed. On the contrary, on six leks with 80–90% old growth 5–12 cocks displayed (Table 2). Comparing the number of cocks on forty-three leks with the proportion of old-growth forest (>80 years old forest with suitable spatial structure) within 1 km radius of a lek, a statistically highly significant correlation between the amount of old-growth forest and the number of cocks attending a lek was found (Pearson correlation coefficient

$r = 0.725$ ,  $p < 0.01$ ). This supports WEGGE and ROLSTAD's (1986) findings that leks surrounded by a high proportion of old-growth forest supported more males than leks in fragmented areas. On nine out of eleven leks where capercaillies disappeared completely during the study period the surrounding habitat changed drastically. Presence of old-growth forests with suitable spatial structure within 1 km radius of a lek declined to less than 20%.

When old natural forests are fragmented by clearcuts, the landscape lose qualities which are very important to this tetraonid. Transformation of the forest landscape from old-growth forests to clearcuts and younger stands augments the number of small rodents.

Table 2. Relationship between the amount of old forests (over 80 years old) within a 1 km radius of the lek centres and the maximum number of cocks attending a lek (West Carpathians, Slovakia, 1981–2010,  $r = 0.025$ ,  $p < 0.01$ )

Old forest %	Number of cocks								Sum leks
	1	2	3	4	5	6	8	12	
21–30	3	1							4
31–40	2	2	1						5
41–50	2	2	1						5
51–60			3	1					4
61–70			3	2					5
71–80			4	8	1	1			14
81–90					1	3	1	1	6
Sum leks	7	5	12	11	2	4	1	1	43

This presumably favours higher densities of generalist predators (especially marten and fox), which prey on capercaillie eggs and chicks (ROLSTAD and WEGGE, 1989b). Furthermore, the fragmentation of continuous forest habitat and its replacement with young stands unsuitable for capercaillie disrupts the social organization of capercaillie populations, particularly the formation of lek communities (KLAUS and BERGMANN, 1994).

#### Chick losses during summer

Between 1<sup>st</sup> August and 15<sup>th</sup> September, 81 out of 132 recorded capercaillie hens led chicks (Table 3). The mean number of juveniles per hen was 1.9 over the whole study. The average number of chicks accompanying a hen significantly decreased during the study period ( $r = 0.77$ ,  $p = 0.0003$ ,  $y = -0.409x + 41.155$ ).

Predaceous pressure on chicks was high in spite of the fact that, as breeding season progressed, food offer for predators was continually increasing. Mean clutch size in capercaillie was 6.8 eggs ( $n = 94$ ). In nests which were not destroyed or abandoned ( $n = 37$ ), on average 5.7 chicks hatched. Hen led on average only 2.4 chicks ( $n = 124$ ) in June and only 1.9 chicks ( $n = 132$ ) in the period between 1<sup>st</sup> August and 15<sup>th</sup> September.

Nest losses in capercaillie depend on many factors as habitat type, vegetation cover, timing of the egg-laying, egg colour, nest localization, or weather conditions (MÜLLER, 1984). Predaceous pressure on capercaillie chick losses is modified by regional differences, but also depends on season and other factors (KLAUS et al., 1986). An uncamouflaged nest is detected and robbed by corvid birds (raven, jay) with a high probability. On the contrary, mammalian predators use much olfactory cues, thus nest camouflage does not play a significant role (KLAUS et al., 1986).

#### Sex ratio in the chicks

Of all broods observed in the mountains of Central Slovakia in the period between 1<sup>st</sup> August and 15<sup>th</sup> Septem-

ber, 96 were counted with confidence. Chick numbers varied between two and six. Broods of three were encountered most frequently, making up more than 1/3 of all broods seen. The mean brood size was 2.2. Broods were significantly larger in the beginning of the study period than in later years (Table 3).

Only 53 broods totalling 171 chicks were sexed with confidence. They consisted of 69 males and 102 females. Female chicks were consistently outnumbering male chicks. The deviation from 1:1 ratio was in each case significant at ten-percent probability or smaller when tested by  $\chi^2$  using YATE'S correction ( $\chi^2 = 12.41$ ,  $p < 0.001$ ). The sex ratio was clearly related to the size of the brood. In thirteen 2-chick broods, seven consisted solely of females, in five there was one of each sex and one consisted solely of males. In both cases, the deviation from the 1:1 ratio was statistically significant. The difference seemed to even out as broods become larger, but the pattern was inconsistent. Table 4 illustrates the predominance of female chicks and how the sex ratio is related to the size of brood. There was a remarkable increase in the proportion of chick females when brood size decreased from three to two. When comparing the sex composition between successively larger broods, there were no statistical difference between sizes three, four, five, and six, whereas the difference between two and three was significant at ten percent probability ( $t = 2, 25$ ,  $p < 0.10$ , 31 df, one-tailed t-test). Brood sizes one and two had significantly fewer males than did any other brood size.

#### Predators influencing the capercaillie populations

Predation appears to be the major factor in limiting the numbers of birds, including capercaillie. Out of 75 capercaillie clutches 49 (65%) were destroyed. Main mammalian egg predators of the capercaillie were found stone marten (*Martes martes* (L.)), pine marten (*Martes foina* (Erxl.)), mustelids (*Mustela* sp.), and red fox (*Vulpes vulpes* L.) (altogether 18%), wild boar (*Sus scrofa* L.) (6%), and brown bear (*Ursus arctos* L.) (4%).

Table 3. Observations of capercaillie hens with chicks between 1st August and 15<sup>th</sup> September (West Carpathians, Slovakia, 1983–2010, n = 132)

Year	Number of chicks					Total	Average per hen
	0	2	3	4	5		
1983			1	1	1	3	4
1984		1		1		3	4
1986			1	2	1	4	4
1987		1	1		1	3	3.3
1989			2	3		5	3.6
1990		2	2	2		6	2.7
1991	2	3	3			8	1.9
1992	3		2	2		7	2
1993	2	1	2			5	1.6
1994			1	1		2	3.5
1995	3		2	2		7	2
1996	3		2	2		7	2
1997	4	2	2	1		9	1.6
1998	3		1	2		6	1.8
1999	4		1	2		7	1.6
2000	2	3	2			7	1.7
2001	3		2	2		7	2
2002	1	2				3	1.9
2003	3		1			4	1.6
2004	2	2				4	1.6
2005	2	2				4	1.9
2006	3			1		4	2
2007	3		1	1		5	2
2008	2	1	1			4	1.9
2009	3		1			4	1.2
2010	3		1			4	0.8
Total	51	20	32	25	3	132	1.9

Table 4. Composition of capercaillie broods sampled between 1<sup>st</sup> August and 15<sup>th</sup> September (West Carpathians, Slovakia, 1983–2010, n = 53)

Proportion Size	n				%	%
		Males	Females	M/F	Males	Females
2	13	0.54	1.46	0.37	26.9	73.1
3	20	1.2	1.8	0.67	40	60
4	16	1.75	2.25	0.78	43.7	56.3
5	3	2.33	2.67	0.88	46.7	53.3
6	1	3	3	1	50	50
Altogether	53	1.3	1.92	0.68	40.4	59.6

According to KLAUS (1984), proportion of wild boar on capercaillie nest loss can locally reach 30%. Main avian egg predators were corvid birds, particularly jay (*Garrulus glandarius* (L.)) and raven (*Corvus corax* L.) (altogether 18%).

In the years with very cold weather during May (heavy snowfall), nests were destroyed by snow cover and abandoned (21%). Four clutches (8%) were found abandoned, their hens probably having been predated by goshawk (*Accipiter gentilis* (L.)), golden eagle (*Aquila*

*chrysaetos* (L.), and ural owl (*Strix uralensis* Pall.), or by some of the mammalian predators – lynx (*Lynx lynx* L.) The damage agent was not known in 12 destroyed and abandoned nests (25%).

Predaceous pressure on capercaillie nests decreased significantly during the incubation period (74% nest losses during the first half of May, n = 49; 54% in the second half of May, n = 35). Decreased nest losses during the incubation period were expected, as on the timing of the capercaillie egg-laying, there does not breed any bird species, except birds of prey and owls. The capercaillie nests quite early in the spring, prior to the onset of breeding of most sedentary and migratory birds. Thus the predaceous pressure on this forest-dwelling grouse is much higher in the first half of May than later – when 53–59 bird species breed in forest habitats inhabited by these tetraonids (SANIGA, 1994, 1995a, 1995b). A second factor is that nests placed on the ground at the beginning of May may be too exposed to predators, until the vegetation has adequately developed (FULLER, 1995). Thus the predaceous pressure on early breeding birds is expected to be much higher than in later stages of the breeding season.

### Fences, wires and disturbances

Out of 23 perished adult capercaillies, collision with fences was a common cause of death to 11 (48%) capercaillies. Fences used in mature forests, where browsing by deer is preventing the growth and development of natural regeneration, presents a considerable hazard to the capercaillie, especially when a fence runs through a forest. Two capercaillies were found to be killed on cables of the ski-lifts.

Enthusiastic gamekeepers and birdwatchers anxious to view a lek were harmful to displaying capercaillies. Similarly, forest management during the display season caused continued disturbance and had a deleterious effect on lekking capercaillies. Tourism is a significant limiting factor in most capercaillie habitats in Central Europe (KLAUS and BERGMANN, 1994).

### Conclusions

Several factors have contributed to the recent dramatic decline in capercaillie population in the mountains of the Western Carpathians. Habitat deterioration has probably played a main role. The correlation between the amount of old forest and the number of cocks attending a lek has been significant. The presence of older trees has appeared to be important for capercaillie in Western Carpathians, as elsewhere. Other factors have also contributed to the rapid decline. The recent decline in numbers has also been associated with an increase in rainfall and snowfall in early June. The number of rain- and snow-days in this crucial period, when most

of the chicks hatch, has been inversely associated with capercaillie breeding success. Deteriorating climatic conditions for capercaillie could override any improvements in habitat quality (MOSS and PICOZZI, 1994). Predation has appeared to be the major factor in limiting the numbers of capercaillie populations. Fences have also been an important cause of capercaillie mortality. Continued disturbance caused by gamekeepers, enthusiastic birdwatchers and forest managers also had a deleterious effect on lekking capercaillies. The future of capercaillie populations in the Western Carpathians will depend on the way in which the forest resources will be used, and also on the effects of air pollution on forest health, ground vegetation and the abundance of insects available to chicks during the first weeks of their life (PORKERT, 1991). Habitat improvement via forest management practices should be the most successful way to save the species.

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## Prečo klesá populácia tetraova hlucháňa (*Tetrao urogallus* L.) v horských lesoch stredného Slovenska?

### Súhrn

V rokoch 1981–2010 bola skúmaná populačná dynamika tetraova hlucháňa (*Tetrao urogallus* L.) na štyridsiatich troch tokaniskách v Západných Karpatoch (Slovensko).

Sledované boli tiež straty na znáškach a mláďatách tohto tetrovovitého vtáčieho druhu. V júni sa sledovalo 124 samíc s kuriatkami a v časovom intervale od počiatku augusta do polovice septembra bolo monitorovaných 132 sliepok. Výsledky demonštrujú značný pokles (>50 %) v počte kohútov a sliepok na dvanástich monitorovaných tokaniskách (28 %) a mierny úbytok (<50 %) na desiatich miestach tokania (24 %). Počas skúmaného obdobia sa kohúty tetraova hlucháňa vytratil z jedenástich tokanísk (25 %). Viac-menej stabilné počty tetrovov hlucháňov boli zaznamenané na ôsmich miestach tokania (19 %). Mierny nárast v populácii tejto lesnej kury bol zistený iba na dvoch tokaniskách (4 %). Počas celého obdobia výskumu pripadalo na jednu samicu v priemere 1,9 mláďat v časovom intervale od začiatku augusta do polovice decembra. Počet mláďat vodených sliepkou signifikantne klesal počas skúmaného obdobia. Medzi mláďatami samičie pohlavie prevyšovalo samčie. Predácia bola limitujúcim faktorom ovplyvňujúcim prežívanie hluchánčiat. Z 94 hluchánich znášok 59 (63 %) bolo zničených predátormi. Predačný tlak bol najvyšší na počiatku inkubačnej doby, kedy v životnom prostredí tetraova hlucháňa hniezdi minimum vtáčích druhov, čo spôsobuje maximálnu orientáciu predátorov na tento vtáči druh. K dramatickému znižovaniu početnosti tetraova hlucháňa v pohoriach Západných Karpát prispieva viacero negatívnych faktorov pôsobiacich v súčinnosti (drastické lesohospodárske zásahy do životného prostredia, turistické aktivity, masový a živelný časovopriestorovo nelimitovaný zber lesných plodov, nevhodné klimatické pomery v čase inkubácie a liahnutia mláďat).

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## The impact of ungulate game on natural regeneration in a fir-beech national nature reserve, Western Carpathians

Andrea Šuleková<sup>1</sup>, Milan Kodrík<sup>2</sup>

<sup>1</sup>University Forest Enterprise of the Technical University in Zvolen

<sup>2</sup>Technical University in Zvolen, Faculty of Forestry, T. G. Masaryka 20, 960 53 Zvolen, Slovak Republic,  
E-mail: kodrik@vsld.tuzvo.sk

### Abstract

ŠULEKOVÁ, A., KODRÍK, M. 2011. The impact of ungulate game on natural regeneration in a fir-beech national nature reserve, Western Carpathians. *Folia oecol.*, 38: 118–125.

The objective of this work was to assess the impact of ungulates on the natural regeneration of woods in a model area within the National Nature Reserve (NNR) of Mláčik – by comparing marked specimens within a pair of research areas. Damage to the naturally regenerating woods was analyzed, the impact of damage to height growth, the impact of game species on the development of the number of trees and their species represented within the growth. The measurements began in the autumn 2007, then they were repeated twice a year (spring, when damage caused by ungulates during the winter was surveyed, and in the autumn – for the damage caused during the summer). The saplings found in the NNR Mláčik are: ash, beech, sycamore, elm, fir, and Wild Service Tree. Scattered are aspen, birch and willow. Ash, fir, maple and elm suffer the most damage due to gnawing. As the regeneration of fir saplings occurs only sporadically, this species may be considered the most endangered tree within the reservation. After two years of protection, significant differences were found in the number of fir trees between the open areas in comparison to the enclosed areas. From the degree of damage and significantly reduced numbers one, can ascertain its high attractiveness to the game. Overall, beech is the least damaged species by game, with only a marginal difference recorded between the plots (fenced and unfenced).

### Key words

beech-fir mountains, game damages, natural regeneration, nature reserve, ungulate game

### Introduction

A natural part of forest ecosystems is wild game, which consume not only herbal components of the ecosystem, but also tree species. The degree of their damage depends on the frequency of game, which is regulated by predators in the wild, or by man in commercial forests. In natural conditions of a balanced and normally functioning ecosystem, in general, the proportion of vegetable games' food does not exceed 5% of the annual biomass production (MÜLLER, 1992).

Among the numerous influences that determine endangerment to forest species by game, the most significant are the growing stage, the development stage

and predisposition of individual tree species to damage by game in accordance with the forest altitudinal vegetation zones (KONŮPKA and HELL, 2004). The consequences of damage to tree species by game depend on several factors. The most important among them are: the tree species, its age, position in the forest and the season. The main causes of damage are: high frequency of game, food supply and disturbance to games' biorhythm – which causes increased activity (BLAŠKO, 2009). Damage caused by game can be controlled and influenced by phytotechnical preventative measures – mechanical, chemical or biotechnological (HLAVÁČ, 2002). Long-term and stable regulation of game frequency requires the most up to date knowledge on

wild game, which is not in evidence in many cases. Regulation of game frequency and the concept of game management is often determined only by shooting large numbers for sought after trophies (TRISL, 1998).

An intense browsing of tree species by game leads in many areas to substantial interference with the artificial and natural forest regeneration. Regeneration is delayed, tree species decline in increment and quality, which ultimately increases their mortality. As a result of selective browsing by game, there are visible changes in species composition. Actually, tree species with a higher nutritional attraction are often excluded from full regeneration. The consequences of this impact are visible both at the economic and environmental level – restriction of natural adaptation processes, predisposition to other damage (e.g. drought) and reduction of species diversity (ČERMÁK and MRKVA, 2007).

## Material and methods

The Mláčik National Nature Reserve (NNR) lies in the southern part of Kremnické vrchy Mts, 6 km north of the village of Železná Breznica (district of Zvolen). The protected area is located within the range of altitude 690 to 960 m a.s.l., mainly on south-westerly exposed slopes with an inclination of 10–20% (in the centre of the area), 40–45% (in the eastern part), 50–65% (in the western part). The surface of the Reserve is 147.20 hectares. According to the current organisation of forest management, a part of the NNR territory belongs to the district of Forests of the Slovak Republic, State Enterprise; OLZ (Forest Enterprise) Žarnovica, LS (Forest District) Ihráč. Another part of the territory belongs to the district of VŠLP TU vo Zvolene (University Forest Enterprise of the Technical University in Zvolen), LS (Forest District) Budča.

According to Professor Zlatník, the forests of the NNR Mláčik are classified into two forest altitudinal vegetation zones: fir-beech and beech. Overall, 6 forest type groups are represented (fir-beech – AF, beech – Fp, typical beech – Ft, lime-beech – Ftil, maple-beech – Fac, ash-maple – FrAc).

Mainly the European beech (*Fagus sylvatica* L.) and the silver fir (*Abies alba* Mill.), occasionally found with the Norway spruce (*Picea abies* L. Karst.), the wych elm (*Ulmus glabra* Huds.) and the sycamore maple (*Acer pseudoplatanus* L.) occur in the tree layer. The shrub layer has not been usually developed.

The impact of ungulate game on natural regeneration in the NNR Mláčik was observed through a network of permanent monitoring plots. Ten paired plots (10 fenced and 10 unfenced) have been constructed in the reserve's territory. Research is carried out on a surface of the reserve within the area of the VŠLP district, which is approximately half the total surface of

the reserve. The demarked plots are square-shaped; the fences are made of wooden panels, 2 metres high. The size of the fence is 6 × 6 m, while inside the fenced plot only the surface of 5 × 5 m is evaluated. From the inside of the fenced plot, a 0.5 m wide strip was omitted, in order to avoid edge effects – the potential impact of game through the lath inhibitions. The unfenced plots were established near the fenced ones, with an area of 5 × 5 m, they are demarked with wooden pins. Additional information by ŠULEKOVÁ and KODRÍK (2009).

The research began in autumn of 2007, when an entry inventory was made. The tree species not exceeding the height of 200 cm were identified in the plots. The species composition and frequency was registered, their height was measured and damage evaluated. The measurements were taken twice a year.

## Results

The measurements in the NNR Mláčik were carried out from autumn 2007 until spring 2010. During this three-year period, information on the state of regeneration in the reserve area, namely the species composition and their frequency, was obtained. It was found which tree species are the most attractive and least attractive to game. Further examination dealt with the effects of damage relating to height growth of trees species and their overall development.

### Species composition

There were 12 tree species overall in regeneration in the paired plots in the NNR Mláčik during the first measurement in autumn 2007. An inventory of the species, including their abbreviations can be found in the following summary:

**Trees** – European ash – EA (*Fraxinus excelsior* L.), European beech – EB (*Fagus sylvatica* L.), sycamore maple – SM (*Acer pseudoplatanus* L.), Norway maple – NM (*Acer platanoides* L.), wych elm – WE (*Ulmus glabra* Huds.), silver fir – SF (*Abies alba* Mill.), European mountain ash – EM (*Sorbus aucuparia* L.), common aspen – CA (*Populus tremula* L.), European birch – EB (*Betula pendula* Roth.); **shrubs** – goat willow – GW (*Salix caprea* L.), common hazel – CH (*Corylus avellana* L.), rose – RO (*Rosa* sp.).

The most represented tree species in the plots was the European ash. It was followed by the European beech and sycamore maple. These three species together accounted for almost 90% of all the individual trees under examination. The Norwegian maple, the silver fir, the wych elm and the European mountain ash were less represented. The common aspen and the European birch occurred sporadically. Among shrubs, the goat willow, the common hazel and rose were found in the plots but

their presence was minimal. In the next evaluation only the tree component was taken into account.

The most represented species in the fenced plots are the European ash (49%), the European beech (26%) and the sycamore maple (13%). They are followed by the Norwegian maple (5%), the wych elm (2%), the European mountain ash (2%) and the silver fir (2%). The common aspen and the European birch are found here with a representation of less than 1%. In the unfenced part, the most represented species were the European ash (50%), the European beech (27%) and the sycamore maple (14%). They were followed by the Norwegian maple (4%), the silver fir (2%) and the wych elm (2%). The European mountain ash and the European birch were represented by less than one percent.

### Changes in frequency of tree species

During the research, a gradual reduction in the frequency of the European ash was discovered. This tree species regenerates abundantly in the reserve area, but during growth it is severely injured and gradually dies. The mortality occurs fairly equally in both the unfenced and fenced plots. In the fenced plots, this condition is mainly caused due to damage from the period prior to the establishment of research plots. The European beech, as the main basic tree species in the forest, is the least injured of all species in the reserve. The decline in the frequency of the European beech in the fenced and unfenced plots is comparable. The fact that this species was not significantly damaged even in previous periods suggests that reduction of the European beech also in unprotected areas was caused by natural mortality rather than the influence of game. The maples, which are commonly found with the European ash are damaged

comparably to the European ash and they also gradually die. If they are found in combination with other tree species, mainly with the European beech, they are damaged to a lesser extent. The silver fir, despite its relatively rich regeneration in the reserve, occurred rarely in the research plots. Although the number of marked specimens was too small for an objective evaluation of the frequency change, from the given state one can ascertain its attractiveness for the game in this area. As well as the silver fir, the wych elm was found in the plots only sporadically. Therefore, its evaluation will be only informative. Despite intense damage, the frequency of this species was not reduced.

Several specimens, especially among the species of the European ash and sycamore maple, despite still being registered, gradually die due to intense damage. This means that the decline in the frequency of these species will be subsequently higher than reported in Figs 1, 2.

### Tree species injuries

The most injured tree species in the NNR Mláčik are the silver fir and valuable broadleaves – the sycamore maple, the Norwegian maple, the European ash and the wych elm.

Most of the European ash has been totally destroyed, by repetitive multiannual browsing of all shoots, leaving only a small trunk with a number of dwarf shoots. Throughout the whole reserve, quite numerous and heavily browsed areas are created. The specimens have thickened trunks with multiple branches at the top, with almost no height growth. They gradually die. When testing the degree of damage with reference to the height, statistically a very significant difference

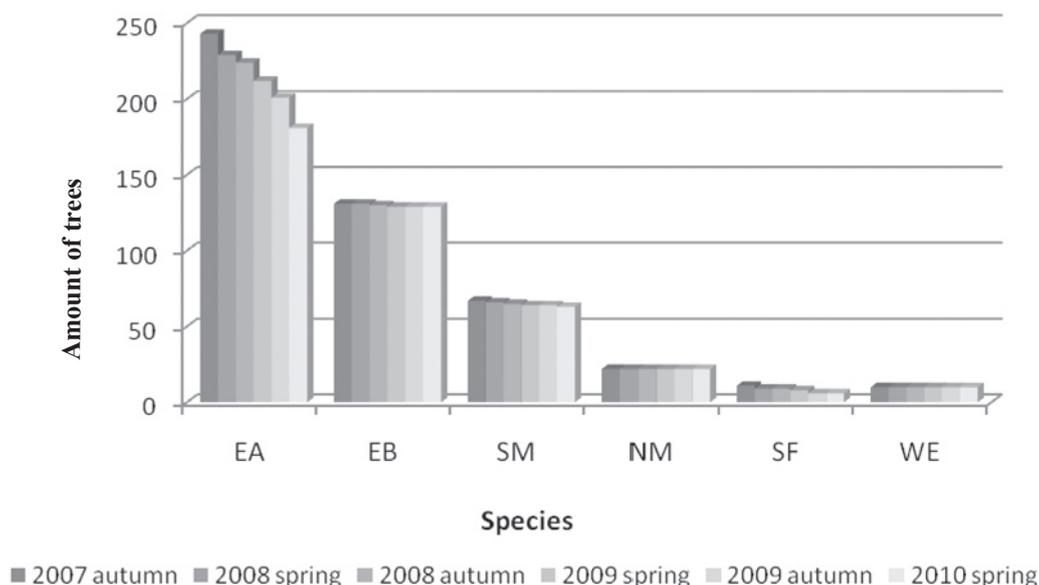


Fig 1. Trend of absolute frequencies of unfenced plots for the period 2007–2010.

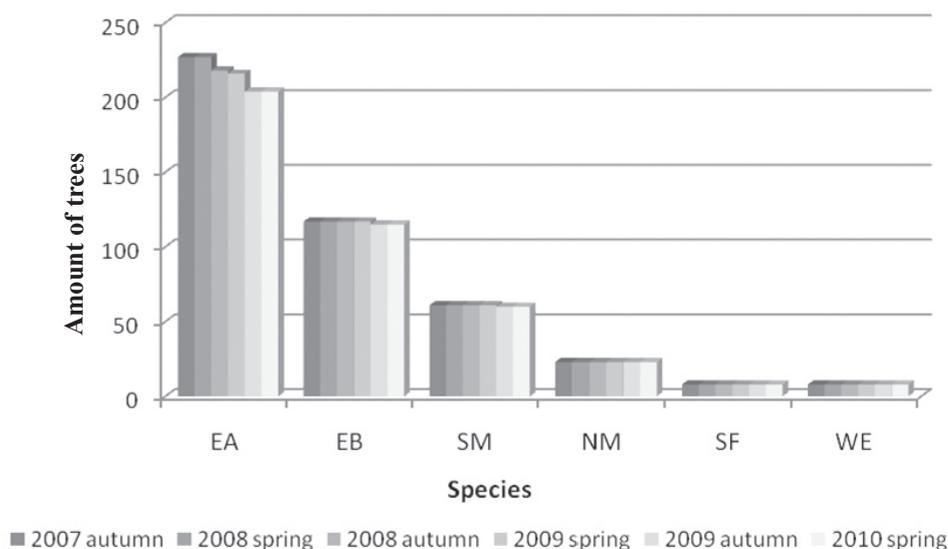


Fig 2. Trend of absolute frequencies of fenced plots for the period 2007–2010.

between the damage in different height classes was confirmed. It was proved that the higher the specimens were, the more damaged they were.

The European beech is the least damaged of all the evaluated species. In the years 2007 and 2008, only very slight damage was discovered: 95% of specimens had a maintained top shoot. In the spring of 2009, damage to even this species increased. We noted browsing of the terminal shoot in the case of 25% of specimens. Despite the fact that several specimens of this species were injured during the winter, it can be concluded that the European beech regenerates in this area without problems.

When comparing the degree of damage between the sycamore maple and the Norwegian maple, a significant difference was confirmed. In a summary evaluation of the damage degree, more damage to the sycamore maple was recorded. The reason is the height of the assessed species. The Norwegian maple occurred only in the 1<sup>st</sup> and 2<sup>nd</sup> height class (up to 50 cm), the sycamore maple in the 1<sup>st</sup>–5<sup>th</sup> height class (over 130 cm). In the case of the sycamore maple, testing the degree of damage with relation to the height class, confirmed a statistically significant difference. Similarly, damage to the European ash grew with increasing height. When damage to both species in the individual height classes was compared, it was very similar.

There is a noticeable decline in the silver fir, raising concerns about the quality of forests in the future. From evaluating the degree of its damage, even though only a small group of specimens was assessed, a high preference for the silver fir in game was obvious. The damage occurs mainly during the winter months. In spring 2009, only 9% of specimens did not have damaged terminal shoots.

The wych elm belongs among the most intensely injured tree species in the area. Although only a small group was evaluated, it was observed that the wych elm is one of the species with a very good regenerative capacity. After only a one-year isolation period from the impact of game, all the observed specimens replaced their terminal shoots.

#### Mean height of tree species

The evaluation included the average increment in the height of the European beech, the sycamore maple, the Norwegian maple, the European ash, the silver fir and the wych elm. The average height increments of the individual species over a three-year period, and the difference in the mean height increment between the fenced and unfenced plots are shown in Fig. 3. At the beginning of the research, the species in both the protected and unprotected areas displayed a comparable height. Gradually, a more significant growth of the tree species is visible in the fenced plots.

After a two year observation period, the mean heights were differentiated with reference to the fencing and tree species. The sycamore maple, the Norwegian maple and the silver fir in areas freely accessible to the game achieved no height growth over the evaluated period. Compared to the baseline state, a height reduction was even reported, despite the fact that in the case of the Norwegian maple and the silver fir, the mean height was less than 30 cm, i.e. outside the zone of games' greatest impact. In the fenced plots there was an increase of 21.0% in the Norwegian maple, 27.2% in the sycamore maple and 36.6% in the silver fir.

A big difference between the fenced and unfenced plots was found in the case of the wych elm. Its height

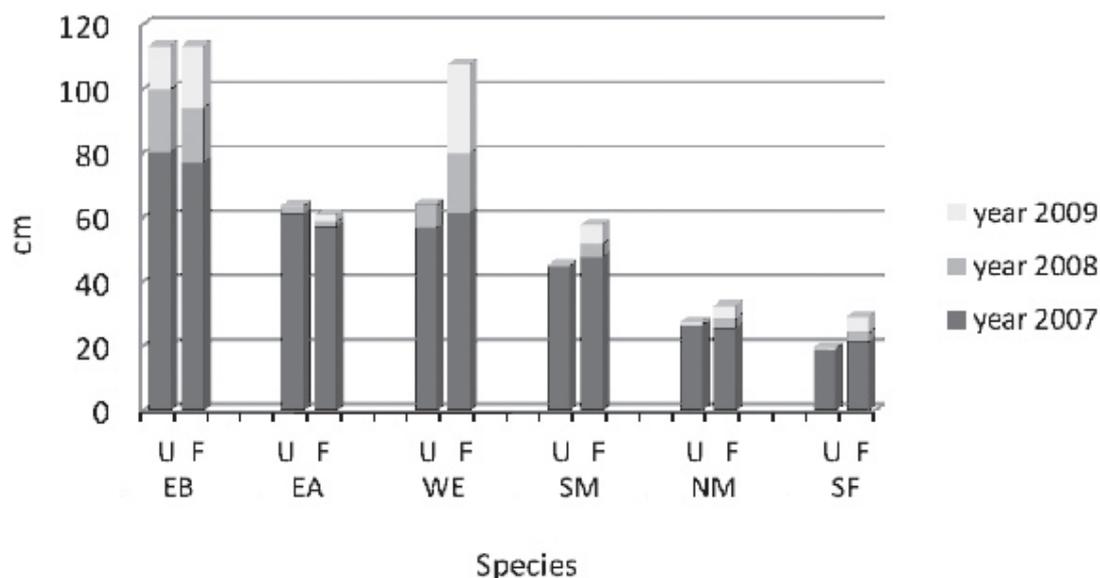


Fig. 3. Changes in the average height of individual tree species over three years (U, unfenced plots; F, fenced plots).

increment was 6-times higher on the protected plots. In the unfenced plots, the height increment was 13.2% over a two-year period, in the fenced plots up to 74.8% of the original height.

In contrast, the growth of the European beech in the paired plots is balanced. Because of a lesser attractiveness in the given area, game influences its development very little. In the fenced plots, the increase in the mean height was 47.1%, on the unfenced ones 41.3%.

The European ash also grows equally in the plots, but for an opposite reason – even protected specimens were in previous periods, damaged to such an extent that their development has significantly reduced. The unprotected specimens are less harmed, because on heavily damaged specimens there is nothing for game to eat. The height increment of the European ash over the two year period was 4.1% in the unfenced plots, 6.5% on the fenced ones.

In all species on the unfenced plots, a lower height increment was found during the second year of evaluation. The reason is a higher degree of damage during the winter of 2008/2009. Even the referred species sycamore maple, the Norwegian maple, the silver fir and the European ash, which in the final evaluation showed no (or minimal) height increment, during the first year gained in height, however, during the second year their height decreased. In the fenced plots, the development was to the contrary.

### Discussion and conclusions

The objective of this research was to assess the impact of game on the natural regeneration within the National Nature Reserve Mláčik. By comparing the status of na-

tural regeneration in areas where game has free access with plots where its access was excluded, the impact of game was reliably distinguished from other influences.

According to FINĐO (1985a), the growth of tree species accessible to game largely depends on the attractiveness of the given species to game. According to the author, valuable broadleaves can be considered as having grown out of the reach of game at a height of between 2.0 to 2.3 m. In the constructed plots, trees of over 2.0 m did not occur at all. All the specimens had a height accessible to game. From these findings it can be concluded that in the case of species very attractive to game, the damage increases with height, as game 'does not allow' the trees to grow out of its reach. In the case of the highest specimens, the damage accumulates over years.

According to our research, the findings of some authors (PAULENKA, 1986; AMMER 1996; ČERMÁK, 1998) believing that damage of tree species decreases intensely with their increasing representation, were not confirmed. In the NNR Mláčik, the European ash is the most harmed species despite having the highest representation in the regeneration. Abundant regeneration of this species was observed in the reserve during an inspection, focusing particularly on the forest type group Abieto-Fagetum, where its damage is the greatest. When testing the degree of damage with reference to the height, statistically a very significant difference between the damage in different height classes was confirmed.

PFEFFER (1961) states that if a tree repeatedly loses its terminal shoot, it grows in width and often dies. FINĐO and ŽILINEC (1993) also describe the same process. They affirm that when tree species are damaged, various morphological changes occur, such as deformations of the

trunk, or the formation of branched axes. The research confirmed this claim in the European ash. Heavily injured European ashes had a thickened trunk with multiple branches in the highest areas. These damaged tree species, even in the fenced plots, were merely surviving and had no height increment. Ultimately, many of them have died, or in the near future will dry out. In some cases, an affected specimen replaced the terminal shoot in the bottom part of the trunk (usually amounting to about 20 cm from the ground). The replaced terminal was characterized by very intense growth. The reason was a well developed root system. The upper parts of such injured specimens do not put forth shoots, but gradually die. ČASNOCHA (1968) in his work describes various consequences of damage to different species. For example, lime, according to his claims, after intense damage enters into a bush form. In contrast, the sycamore maple, the Norwegian maple or the European ash put forth the terminal shoot from a lower bud after browsing, and for a few years the initial severe injury to the tree cannot be located. According to our research, we can only confirm his claim that the European ash replaces its terminal shoot. Conversely, the development of lime and maple was different. Lime, even after severe damage, regenerated very well, as confirmed by KESSL (1957). He included it among the species with the easiest regeneration. The observation of the specimens has only been over a three year period so far, therefore, subsequent development may differ slightly. A high degree of damage was also recorded on the wych elm, the sycamore maple and the Norwegian maple. The wych elm turned out to be a species with a very good regenerative capacity, even though the research on this species was conducted only on a small group. Similarly, KESSL (1957) ranked the wych elm among the species with the easiest regeneration. According to our research, it belongs among the intensely damaged species. However, after one-year period of isolation from the influence of game, all the observed specimens replaced their terminal shoot. At the end of the observation period, the value of the degree of damage to this species was 1, despite the fact that the wych elm is the second most damaged tree species after the European ash.

FINĐO et al. (1993), from their research in Poľana indicate that a statistically significant loss of height occurred in unfenced areas in the sycamore maple, the European ash, the goat willow and the wych elm. He did not record a statistically significant impact in the height of the silver fir, which he explains by its low mean height. According to our results, height growth was most influenced in the sycamore maple, the Norwegian maple and the silver fir. In the unfenced plots, these species achieved no increment over a two-year period. The height even decreased compared to the baseline state. The silver fir is highly damaged even though all the specimens are small. Their mean height is even lower than FINĐO (1993) stated in his work. Inside the fenced

plots, they grow very gradually. A big difference between the fenced and unfenced plots is also found in the wych elm. In the fenced plots, the height increment was 6 times bigger than in the unfenced plots. The growth of the European beech in the paired plots is balanced. Its development in this area is affected very little by game. The European ash had also a balanced height increment in the plots. However, as protected specimens were also previously significantly injured, their development was reduced. In all the species in the unfenced areas, a lower height increment was found in the second evaluated period. The reason is a higher degree of damage during the winter of 2008/2009. In the fenced plots, the height increment was bigger during the second evaluated year.

The least damaged of all species was the European beech. Despite the fact that several specimens of this species were injured during the winter, it can be concluded that the European beech regenerates in this area without problems. Similarly, the European beech is also reported as the least damaged tree species by FINĐO (1985b), FINĐO and ŽILINEC (1993); GAŠPARÍK (2001); KAŠTIER (2002); ČERMÁK and MRKVA (2003).

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## Vplyv raticovej zveri na prirodzenú obnovu jedľovo-bukových porastov v národnej prírodnej rezervácii, Západné Karpaty

### Súhrn

Cieľom práce bolo na modelovom území v národnej prírodnej rezervácii Mláčik zistiť vplyv raticovej zveri na stav prirodzenej obnovy porovnávaním označených jedincov na párových výskumných plochách. Analyzovalo sa

poškodenie prirodzene sa obnovujúcich drevín, vplyv poškodenia na výškový rast, vplyv zveri na vývoj početnosti drevín a ich druhové zastúpenie v poraste.

S meraním sa začalo na jeseň roku 2007, následne sa vykonávalo dvakrát do roka (na jar, kedy sa zisťovali škody zverou spôsobené v zimnom období a na jeseň, škody spôsobené v lete). V NPR Mláčik sa v zmladení nachádzajú jaseň, buk, javor horský, brest, jedľa, jarabina. Ojedinele osika, breza, vŕba. Odhryzom sú najviac poškodzované jaseň, jedľa, brest a javory. Za najviac ohrozenú drevinu v rezervácii možno považovať jedľu, ktorá sa v zmladení vyskytuje len sporadicky. Pri porovnaní zmladenia po dvoch rokoch ochrany sa zistil významný rozdiel v početnosti jedle v oplôtkoch a na voľnej ploche. Zo stupňa poškodenia a značnej miery redukcie vidieť jej vysokú obľúbenosť pre zver. Buk je v danej lokalite zverou poškodzovaný najmenej zo všetkých drevín.

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## Land use influence on micro-aggregates

Erika Tobiašová

Slovak Agricultural University in Nitra, Tr. A. Hlinku 2, 949 01 Nitra, Slovak Republic,  
E-mail: erika.tobiasova@uniag.sk

### Abstract

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There were assessed differences in micro-aggregate composition depending on soil organic matter and soil texture in different ecosystems (forest, meadow and urban ecosystems and in agro-ecosystems on various plots) on Eutric Fluvisols and Haplic Chernozems. Micro-aggregate formation is influenced mainly by soil texture, but in agro-ecosystems, the quantity and quality of soil organic matter play an important role. The content of total organic carbon and its labile fraction positively influence creation of micro-aggregates larger than 0.01 mm. In relation to the quality of soil organic matter, creation of micro-aggregates is influenced mainly by the stabilised humus substances. In this research, the effect of humic acids was positive in case of smaller aggregates, but in case of their bound with the larger fraction of 0.25 mm their degradation occurred, thus the soil organic matter was less stabilised. Conversely, content of fulvic acids was mostly in negative correlation with the individual micro-aggregate fractions, but in case of micro-aggregates to 0.001 mm it was the positive correlation, because with increasing formation of aggressive humus substances, clay content is increasing, as well. Soil organic matter plays an important role especially in the creation of larger aggregates.

### Key words

ecosystems, Eutric Fluvisols, Haplic Chernozems, micro-aggregates, soil organic matter, soil texture

### Introduction

In the recent years, soil structure is considered important in assessing of carbon sequestration and turnover (SIX et al., 2004). Many studies (SIX et al., 1998; MARTENS, 2000; HERNANZ et al., 2002; ZAUJEC and ŠIMANSKÝ, 2006, 2008) have confirmed that the aggregates have an important role in the stabilization of organic matter within aggregates by inhibiting the oxidation of carbon. Organic carbon in micro-aggregates is more protected physically, therefore a higher content of biochemical recalcitrant fraction leads to more stable micro-aggregates and lower intensity of decay inside the aggregates (JASTROW, 1996). Organo-mineral particles and some microbial polysaccharides may also participate in micro-aggregate creation (ANGERS, 1998). Organo-mineral parti-

cles and micro-aggregates are likely to expand the period of resistance of organic carbon against degradation by micro-organisms through chemical complexation or improve physical protection (POWERS and SCHLESINGER, 2002). Different fractions of organic matter participate in creation and stabilization of soil aggregates in different ways (ROBERSON et al., 1991). In the permanent state of the micro-aggregates (0.053–0.250 mm), degraded aromatic humus substances in conjunction with polyvalent metal ions participate in bindings with clay particles (TISDALL and OADES, 1982). The stabilization of micro-aggregates (<0.25 mm), is participated significantly also by the iron and aluminium hydroxides (BARRY et al., 1998). The aim of this work was to assess differences in micro-aggregate composition in different ecosystems, depending on soil organic matter and soil texture.

## Material and methods

The study areas are located in the Danubian Lowland consisting of a plain and a hilly part. Localities on Eutric Fluvisols (FAO, 1998) (agro-ecosystem, forest ecosystem, meadow ecosystem) are situated in the plain part of the lowland, all ecosystems on Haplic Chernozems (FAO, 1998) and urban ecosystem on Eutric Fluvisols in the hilly part of the lowland. Geological substrates of the Danubian lowland are neogene clays, sands and gravels, in most areas covered with loess and loess loam. Fluvial sediments are along the Váh and Nitra rivers. The plain part of the Danubian lowland is mostly an alluvial plain. The hilly part is covered by loess and loess loam. In some places, neogene rafts of clays, sands and gravels appear. Sites on Haplic Chernozems are located on a slight slope facing SW (forest and meadow ecosystems, agro-ecosystem) and NE (urban ecosystem).

Samples were taken in the spring down to the depth of 0.3 m in 3 replications in the following ecosystems: forest (CH-FO, FL-FO), meadow (CH-ME, FL-ME), an urban ecosystem (CH-UR, FL-UR), an agro-ecosystem (CH-AG, FL-AG), and from four different plots (CH 01-04, FL 01-04), with different crop composition. From the physical properties, there were determined: the texture composition – by pipette method (FIALA et al., 1999), micro-aggregate composition – by Kačinský method (HRAŠKO et al., 1962). Soil for determination of micro-aggregate fractions was sieved (<2 mm) and dispersed with water. After 24 h, samples were shaking 2 h and sieved (<0.25mm). Then the procedure is the same with the determination of texture composition, and time periods for pipetation are different. From the chemical properties, there were determined: organic carbon – by Tyurin method (GRIŠINA and ORLOV, 1981), labile carbon (LOGIN et al., 1987) and fractional composition of humus substances by PONOMAREVA and PLOTNIKOVA (1975).

The obtained results were analyzed with using the statistical software Statgraphic Plus. In addition to the basic descriptive statistical indicators, multi-factorial analysis of variance (ANOVA) was used for evaluation the relevance of various factors on the observed parameters. Differences between the variants were assessed with the Tukey test at a significance level  $P < 0.05$ . Correlation analysis was used for exploring mutual dependences. Minimum significant correlation coefficient was determined at significance levels  $P < 0.05$  and  $P < 0.01$ .

## Results and discussion

Shares of micro-aggregate fractions in different ecosystems differed, with the highest content of the fraction 0.01–0.05 mm (Fig. 1). Micro-aggregate stability

of this fraction was significantly influenced by the content of the total organic carbon ( $P < 0.01$ ,  $r = 0.674$ ), labile carbon ( $P < 0.05$ ,  $r = 0.631$ ), amounts of extracted humic acids ( $P < 0.05$ ,  $r = 0.582$ ) and fulvic acids ( $P < 0.05$ ,  $r = -0.542$ ), with the strongest effect of fulvic acids bound with  $\text{Ca}^{2+}$ .

Content of total organic carbon was in a negative linear dependence with the smaller fractions of micro-aggregates <0.01 mm (Table 1). The higher total organic carbon content, the lower amount of micro-aggregates <0.01 mm was. Labile carbon was also in negative correlation with the smaller micro-aggregates. This points to the fact that the smaller micro-aggregates, the less organic matter they consist and in the smallest fraction of the smallest micro-aggregates, organic matter almost is not present. This is too small fraction, in which dominating binding agents are oxides. According to OADES et al. (1989) the aggregating effect of oxides is mainly at the micro-aggregate level.

According to ŠIMANSKÝ and ZAUJEC (2009) lower contents of labile carbon are just in more intensively cultivated soils.

If there is little organic carbon in soil, the function of binding agents takes over polyvalent metals and silicate clays (MBAGWU, 1989). The portions of smaller micro-aggregates were influenced by the amount of free fulvic acids and fulvic acids bound with mobile  $\text{R}_2\text{O}_3$  and  $\text{Ca}^{2+}$ . In the case of fraction 0.01–0.05 mm, there was a positive correlation, but in case of the smaller micro-aggregates <0.001 mm it was a negative correlation. This shows the effect of calcium on colloid coagulation, occurring mainly in smaller particles, and in the case of bivalent calcium and trivalent iron causing irreversible coagulation (KUTÍLEK, 1978; ROTH and PAVAN, 1991; BALDOCK et al., 1994). In general, pressure changes result in creation of micro-aggregates (<0.002 mm), but in the case of particles <0.01 mm calcium reduces the effect of the cohesion forces between the particles (REHÁK and JANSKÝ, 2000). Higher share of free fulvic acids and fulvic acids bound with mobile  $\text{R}_2\text{O}_3$  resulted in smaller share of the smallest fractions of micro-aggregates (Table 1). In case of larger micro-aggregates 0.01–0.05 mm, correlation is positive, because into the bindings with mineral portion enter all molecules of fulvic acids, which are also stabilized by calcium. On the surface of particles, they form coatings, which act as cement.

TISDALL and OADES (1982) describe this as a permanent state, in which in binding participate degraded aromatic humus substances in conjunction with the polyvalent metal ions, which are strongly bound to the clay particles to produce micro-aggregates (0.053–0.250 mm).

Since fulvic acids are less stable than humic acids, they are more oxidized and the binding is less stable, as well. In contrast, the content of humic acids was in positive correlation with the amount of micro-aggregate

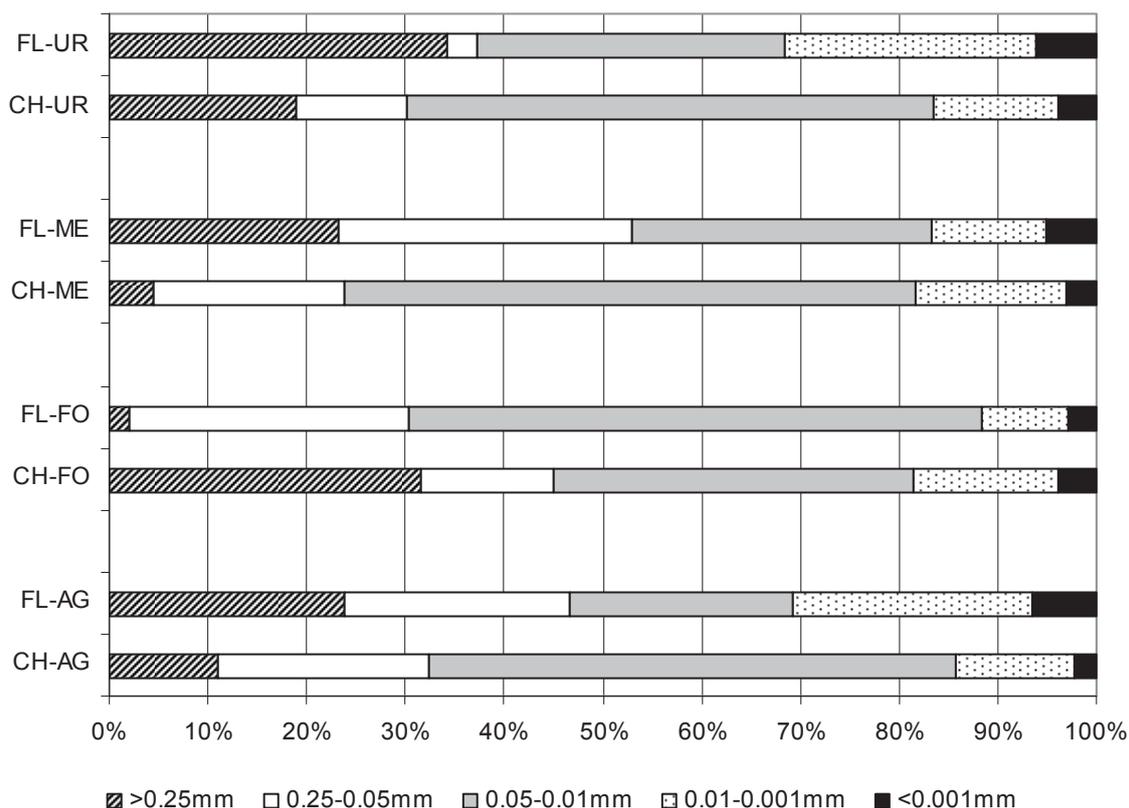


Fig 1. Shares of micro-aggregate fractions in different ecosystems on Eutric Fluvisols and Haplic Chernozems. FL, Eutric Fluvisols; CH, Haplic Chernozems; UR, urban ecosystem; ME, meadow ecosystem; FO, forest ecosystem; AG, agro-ecosystem.

fractions 0.01–0.05 mm. So it seems that the most stable fraction of micro-aggregates is just fraction 0.01–0.05 mm binded with humic acids.

Conversely, in case of larger fraction >0.25 mm, dependence between the content of this fraction and humic acid content was negative. In this case, humic acids are a mediator of binding between mineral particles, but they are more exposed to oxidation. This leads to their degradation, causing aggregate disintegration. This means that the greater share of larger aggregates, the lower share of humic acids, because they decompose and the organic matter is less stabilized. The strongest bindings are formed at the creation of humus substances (PICCOLO and MBAGWU, 1990; REHÁK and JANSKÝ, 2000), and gradually they get weaker. The largest fraction of aggregates was in negative correlation with the fraction of humic acids bound to the mineral component and stable  $R_2O_3$ , which is also in accordance with the theory that the most stabilized components are in case when higher portion of larger micro-aggregates are more degraded.

Micro-aggregate stability is given by the shares of granularity fractions. Micro-aggregate creation was influenced mainly by clay and silt (Table 1). According to REHÁK and JANSKÝ (2000), fractions of sand and silt make micro-aggregate creation impossible.

All fractions of micro-aggregates are not affected equally (Table 1). Content of coarse silt (0.01–0.05 mm) negatively correlated with the smallest micro-aggregates <0.001 mm. The fraction of fine and medium silt (0.001–0.01mm) was in turn in a positive correlation primarily with smaller fractions of micro-aggregates <0.01 mm.

Shares of micro-aggregate fractions in each ecosystem (Fig. 1) considerably fluctuated. The highest content of the micro-aggregate fraction (0.01–0.05 mm) was in the forest ecosystem (47.21%), followed by the meadow ecosystem (43.94%), urban ecosystem (42.32 %) and agro-ecosystem with the lowest content (38.04%). The content of this fraction is significantly affected by the total organic carbon, as well as its labile form. The highest shares were just in the forest ecosystem, the richest one in organic matter. Content of this micro-aggregate fraction was in a positive exponential dependence with the content of fulvic acids, having also the highest average portion in the forest ecosystem, in particular the fraction of fulvic acids bound with stable  $R_2O_3$ . Their extractability was the highest in the forest ecosystem (9.81%). The values in the meadow and the urban ecosystem were lower by about 19% and 26%, respectively, in the agro-ecosystem even by about 54%. Soil in the forest ecosystem of the same soil types

Table 1. Tendency of dependences between micro-aggregates, macro-aggregates and selected factors

	Linear	r	Logarithmic	r	Power-law	r	Exponential	r
TOC and MI <0.01 mm	$y = -0.0015x + 47.786$	0.559+	$y = -24.274\ln(x) + 258.45$	0.558+	$y = 185.016x^{-0.9398}$	0.486	$y = 52.911e^{-6E-05x}$	0.485
TOC and MI 0.001–0.01 mm	$y = -0.0012x + 38.663$	0.555+	$y = -19.876\ln(x) + 211.14$	0.554+	$y = 145.104x^{-0.9386}$	0.485	$y = 41.91e^{-6E-05x}$	0.483
TOC and MI 0.01–0.05 mm	$y = 0.0025x - 4.9607$	0.674++	$y = 40.576\ln(x) - 356.2$	0.660+	$y = 0.0008x^{1.102}$	0.664++	$y = 10.894e^{7E-05x}$	0.681++
C <sub>L</sub> and MI <0.001 mm	$y = -0.0012x + 7.5036$	0.540+	$y = -3.489\ln(x) + 31.422$	0.578+	$y = 851.71x^{-0.7036}$	0.599+	$y = 7.0125e^{-0.0003x}$	0.579+
C <sub>L</sub> and MI <0.01–0.05 mm	$y = 0.0071x + 21.755$	0.631+	$y = 20.9\ln(x) - 121.89$	0.689++	$y = 0.3973x^{0.5857}$	0.715++	$y = 22.237e^{0.0002x}$	0.656+
HA3 and MA >0.25 mm	$y = -2.6741x + 47.884$	0.656+	$y = -32.703\ln(x) + 96.197$	0.654+	$y = 20379x^{-3.0411}$	0.788++	$y = 233.99e^{-0.251x}$	0.802++
Σ HA and MA >0.25 mm	$y = -1.1663x + 52.133$	0.545+	$y = -37.477\ln(x) + 144.06$	0.577+	$y = 37385x^{-2.3413}$	0.468	$y = 118.4e^{-0.0724x}$	0.438
Σ HA and MI 0.01–0.05 mm	$y = 1.7849x - 11.267$	0.582+	$y = 54.675\ln(x) - 142.94$	0.590+	$y = 0.3509x^{1.3936}$	0.557+	$y = 9.9875e^{0.0458x}$	0.553+
FA1 and MI <0.01 mm	$y = -2.3877x + 38.624$	0.553+	$y = -15.56\ln(x) + 51.104$	0.573+	$y = 72.613x^{-0.6979}$	0.579+	$y = 41.545e^{-0.1073x}$	0.559+
FA1 and MI 0.001–0.01 mm	$y = -1.9682x + 31.238$	0.552+	$y = -12.466\ln(x) + 40.83$	0.557+	$y = 56.513x^{-0.6876}$	0.569+	$y = 33.234e^{-0.1083x}$	0.563+
FA2 and MI 0.01–0.05 mm	$y = -2.5284x + 52.124$	0.795++	$y = -8.7833\ln(x) + 48.797$	0.750++	$y = 47.281x^{-0.2418}$	0.765++	$y = 52.568e^{-0.0728x}$	0.848++
FA2 and MI <0.001 mm	$y = 0.3568x + 2.6637$	0.564+	$y = 1.1578\ln(x) + 3.2076$	0.497	$y = 2.9704x^{0.1992}$	0.439	$y = 2.8028e^{0.0535x}$	0.434
Σ FA and MI 0.01–0.05 mm	$y = -1.7579x + 79.956$	0.542+	$y = -37.385\ln(x) + 156.02$	0.538+	$y = 960.93x^{-1.0486}$	0.559+	$y = 115.37e^{-0.0499x}$	0.571+
CY and MI <0.001 mm	$y = 0.2336x - 3.8256$	0.606+	$y = 8.1249\ln(x) - 24.366$	0.563+	$y = 0.0151x^{1.5513}$	0.552+	$y = 0.7727e^{0.0441x}$	0.588+
MFS and MI <0.001 mm	$y = 0.3414x - 1.5672$	0.628+	$y = 5.2651\ln(x) - 10.426$	0.566+	$y = 0.1881x^{1.0541}$	0.581+	$y = 1.144e^{0.0665x}$	0.629+
CS and MI <0.001 mm	$y = -0.2299x + 12.517$	0.698++	$y = -8.1164\ln(x) + 33.059$	0.734++	$y = 883.53x^{-1.554}$	0.721++	$y = 16.989e^{-0.0435x}$	0.678++
MFS and MI <0.01 mm	$y = 1.16x + 1.1506$	0.601+	$y = 20.079\ln(x) - 35.059$	0.607+	$y = 1.1719x^{0.9944}$	0.676++	$y = 7.124e^{0.0568x}$	0.662++
CS and MI 0.01–0.05 mm	$y = 0.9295x + 7.4234$	0.561+	$y = 31.771\ln(x) - 71.925$	0.571+	$y = 1.9245x^{0.8403}$	0.560+	$y = 15.598e^{0.0248x}$	0.554+
CY and MI 0.05–0.25 mm	$y = -0.8633x + 50.025$	0.600+	$y = -33.352\ln(x) + 137.65$	0.619+	$y = 32.866x^{-2.1465}$	0.684++	$y = 121.32e^{-0.0567x}$	0.676++
MFS and MI 0.05–0.25 mm	$y = -1.2239x + 41.027$	0.604+	$y = -21.955\ln(x) + 81.381$	0.632+	$y = 519.17x^{-1.2243}$	0.605+	$y = 55.885e^{-0.0695x}$	0.589+
CY and MA >0.25 mm	$y = 0.8069x - 9.8274$	0.595+	$y = 30.447\ln(x) - 89.169$	0.599+	$y = 0.0034x^{2.3648}$	0.604+	$y = 1.9234e^{0.0588x}$	0.554+
CS and MA >0.25 mm	$y = -0.5258x + 39.566$	0.751++	$y = -18.213\ln(x) + 84.335$	0.702++	$y = 1.9967x^{-1.3582}$	0.679++	$y = 70.905e^{-0.0392x}$	0.727++

MI, micro-aggregates; MA, macro-aggregates; TOC, total organic carbon; C<sub>L</sub>, labile carbon; HA3, humic acids binded with the mineral component of soil and stable R<sub>2</sub>O<sub>3</sub>; FA1, fulvic acids free and bound with mobile R<sub>2</sub>O<sub>3</sub>; FA2, fulvic acids bound with Ca<sup>2+</sup>; Σ HA, sum of humic acids; Σ FA, sum of fulvic acids; CY, clay (<0.01 mm); MFS, medium and fine silt (0.001–0.01 mm); CS, coarse silt (0.01–0.05 mm).

is considered as the soil of the highest quality, because its properties are nearly equal to the natural undisturbed territory, in which physical, chemical and biological properties are in equilibrium (DORAN and PARKIN, 1994). But forest soils are characterized by the highest content of fulvic acids in humus. Ratio of  $C_{HA} : C_{FA}$  showed that humus quality decreased from the agro-ecosystem (1.46), meadow ecosystem (1.28), urban ecosystem, (1.23) down to the forest ecosystem (1.17).

In case of ecosystems, shares of micro-aggregates depended on the shares of clay fraction <0.001 mm, being the highest in the agro-ecosystem (19.48%) and urban ecosystem (19.53%) and lower in the meadow (15.08%) and forest ecosystem (14.36%). More marked than the effect of organic matter on shares of micro-aggregate fractions was the influence of clay content – which is in accordance with the theory that the micro-aggregates are less affected by management system than the macro-aggregates (SIX and JASTROW, 2002). There is also a secondary effect – regulating the quantity and quality of soil organic matter in soil.

The reason is a higher intensity of mineralization in macro-aggregates than micro-aggregates (ELLIOTT, 1986).

Even in the case of plots in each agro-ecosystem (Fig. 2), differences in distribution of micro-aggregate fractions were observed. Differences were more

marked in Eutric Fluvisols than in Haplic Chernozems. In the agro-ecosystem in Haplic Chernozems, the plots CH-01 and CH-04 exhibited the lowest portion of micro-aggregate fraction <0.01 mm, while only on these plots was recorded positive carbon balance during the 6-year period. In the other two, the balance was found negative. GARTZIA-BENGOETXEA et al. (2009) report that concentration of organic carbon was not increasing with enlarging aggregates in a forest ecosystem; however, this was found true for agricultural soils by TISDALL and OADES (1982).

In the case of permanent cultivated soils, however, the importance of soil organic matter is indisputable, even in the case of micro-aggregate creation – as the reduction of organic matter in soil results in distortions of micro-aggregates. OADES (1984) reports, that decomposition of particular organic matter is associated with releasing of metabolism products. Macro-aggregates become more stable and micro-aggregates form inside the first.

In case of Eutric Fluvisols, formation of smaller micro-aggregates <0.001 mm was limited by content of sand fraction.

It follows that under natural conditions, the micro-aggregate dynamics is more influenced by natural factors, such as soil texture; but in case of cultivated soils, soil organic matter is the governing factor affecting

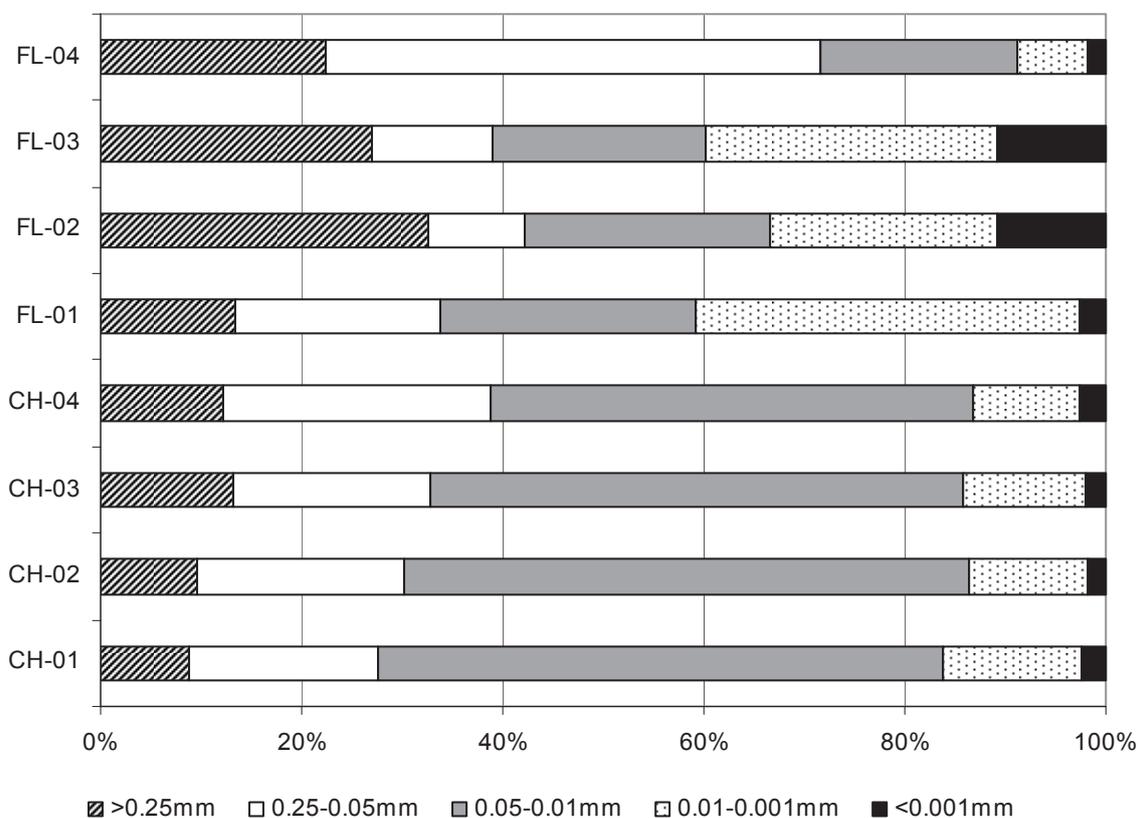


Fig. 2. Shares of micro-aggregate fractions in different plots of agro-ecosystems on Eutric Fluvisols and Haplic Chernozems. FL, Eutric Fluvisols; CH, Haplic Chernozems; 01–04, plots in agro-ecosystems.

the micro-aggregate formation. Since the micro-aggregates are the key element in macro-aggregate creating, it is essential to monitor inputs of organic matter in the soil, especially in intensively cultivated soils.

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## Vplyv využívania pôdy na mikroagregáty

### Súhrn

V rôznych ekosystémoch (lesný, lúčny, urbánny ekosystém a v agroekosystéme aj na rôznych honoch) na černozei a fluvizemi boli posudzované rozdiely v zastúpení mikroagregátov v závislosti od pôdnej organickej hmoty a pôdnej textúry. Tvorba mikroagregátov je ovplyvňovaná predovšetkým pôdnou textúrou, ale v agroekosystémoch zohráva dôležitú úlohu aj množstvo a kvalita pôdnej organickej hmoty. Obsahy celkového organického uhlíka a jeho labilnej frakcie vplyvajú pozitívne na tvorbu mikroagregátov väčších ako 0,01 mm. Vo vzťahu ku kvalite pôdnej organickej hmoty ovplyvňujú tvorbu mikroagregátov predovšetkým stabilizované humusové látky. Vplyv humínových kyselín bol pozitívny v prípade menších agregátov, pričom v prípade ich väzby s väčšou frakciou nad 0,25 mm dochádzalo k ich odbúraniu, teda stabilizácia pôdnej organickej hmoty bola nižšia. Naopak obsah fulvokyselín bol prevažne v negatívnej korelácii s jednotlivými frakciami mikroagregátov, ale v prípade mikroagregátov do 0,001 mm v pozitívnej, pretože pri zvýšenej tvorbe agresívnych humusových látok sa zvyšuje obsah ílu. Pôdna organická hmota zohráva dôležitú úlohu predovšetkým pri tvorbe väčších agregátov.

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## Erratum

In the article by Zarafshar, M., Akbarinia, M., Bruschi, P., Hosseiny, S.M., Yousefzadeh, H., Taieby, M., Sattarian, A., titled Phenotypic variation in chestnut (*Castanea sativa* Mill.) natural populations in Hyrcanian forest (north of Iran), revealed by leaf morphometrics (*Folia oecol.*, 37: 113–121), one of the authors' names was spelled incorrectly. Sieid Mohsen Hosseiny should have been spelled Seyed Mohsen Hosseini.

The publisher apologises for any confusion caused.

## Instructions for authors

**Folia oecologica** is a journal devoted to publishing original scientific papers from the fields of ecology of forest ecosystems, communities and populations of plants, fungi and animals associated with forest environment and also the ecology of woody plants growing in both forest and non-forest environment, human settlements included.

The journal also publishes short communications, methodological and survey papers in the area, book reviews, personalia and information about scientific events. The manuscripts are submitted to reviewers for evaluation of their significance.

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EIBERLE, K., NIGG, H. 1984. Zur Ermittlung und Beurteilung der Verbissbelastung. *Forstwiss. Cbl.*, 103: 97–110.

*Book*

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CIBEREJ, J., KOVÁČ, G., BILÁ, A. 1999. Faktory ovplyvňujúce početný stav kamzíka vrchovského v TANAP-e [Factors influencing game populations in chamois (*Rupicapra rupicapra* L.) in the High Tatra National Park]. In KOREŇ, M. (ed.). *Päťdesiat rokov starostlivosti o lesy TANAP-u. Zborník referátov z konferencie*. Poprad: Marmota Press, p. 111–116.

*Dissertation*

CHROMOVÁ, L. 2002. *Pôdne a vegetačné zmeny lesných spoločenstiev okolia obce Brusno (Veporské vrchy)* [Changes in soils and vegetation of forest communities of the Brusno village (the Veporské Mts.)]. PhD thesis. Bratislava: Comenius University, Faculty of Natural Sciences. 122 p.

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