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Biodiversity of soil micro- and macrofauna in oak-hornbeam forest ecosystem on the territory of Bratislava

Comenius University in Bratislava 2012

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Photograph on cover: Devínska Kobyla, southern slope, oak-hornbeam forest (*Querco petraeae-Carpinetum melicetosum uniflorae*) (photo: Milada Holecová).

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Contents

1. Introduction

Milada Holecová

The oak-hornbeam forests in Slovakia used to be the most frequent forest climatic zone formation at lower altitudes. In past, they covered continuous and large areas, especially in plains and lowlands from the altitude of 100 m above sea level, in hilly and submountainous regions up to 600 m above sea level and in all the Inner-Carpathian hollows (Michalko et al. 1986). These forest stands in Slovakia, as well as in other countries of Europe, were under long-term human impact and disturbance. There are just some fragments under considerable anthropogenic pressure in the present agricultural land. Moreover, in the cultural land they represent a refuge for many animal species.

The changes in diversity of animal assemblages in forests and forest fragments may result in a range of consequences linked to changes in trophic webs, loss of some specialists, functional groups and ecosystem engineers (Bengtsson et al. 2000). On the other hand, there is higher probability of occurrence (or higher population density) of the species having abilities to influence the relevant ecosystem in a completely new, "original" way (Krehan, Steyrer 2006).

Forest patches with old trees, namely hollows in built-up area can be important sources and/or refuges of rare and endangered animal species. For this reason it is necessary to pay them attention and try to establish balance between public interests and nature protection.

During four years (1999, 2000, 2005, 2006) we realized a complex coenological research of selected epigeic invertebrate groups (ciliates, naked amoebae, pseudoscorpions, terrestrial isopods, millipedes, bugs, ground beetles, weevils and ants) in oak-hornbeam forests and forest fragments on the territory of the Slovak capital Bratislava. The diversity of soil microfauna and macrofauna was studied at eight study plots along urban – rural gradient. Two study plots represented forest fragments situated directly in an urban built-up area. Six forest stands situated in eastern and southwestern borders of Bratislava represented less fragmented and/or more closed woodland but, to some degree, affected by various human activities (timber harvesting, forest management, coppice culling, synanthropization, tourism).

The aim of our study was to characterize structure and diversity of selected epigeic invertebrate assemblages in oak-hornbeam forests on the territory of Bratislava under different levels of disturbance and located from a build-up town centre to suburban parts.

References

Bengtsson, J., Nilsson, S.G., Franc, A., Menozzi, P., 2000: Biodiversity, disturbances, ecosystem function and management of European forests. Forest Ecology and Management, 132: 39–50.

Krehan, H., Steyrer, G., 2006: Klimaänderung - Schadorganismen bedrohen unsere Wälder. BFW-Praxisinformation, 10: 15–17.

Michalko, J., Berta, J., Magic, D., 1986: Geobotanical map of Czechoslovak Socialist Republic. Slovak Socialist Republic. Text part (in Slovak). VEDA, Bratislava, 168 pp.

2. Ecological characteristics of studied oak-hornbeam forests and forest fragments on the territory of Bratislava

Janka Zlinská, Milada Holecová

The study area

Milada Holecová

Invertebrate assemblages of the mentioned forest stands (*Querco petraeae-Carpinetum*, *Aceri-Carpinetum*, *Primulo veris-Carpinetum*) were analyzed on the territory of Bratislava. All study plots are situated in the southern part of the Malé Karpaty Mts. (Fig. 1). On the territory of Bratislava they are represented by two geomorphological subunits – the Devínske Karpaty Mts. (the southwestern part) and the Pezinské Karpaty Mts. (the eastern part), being predominantly built by crystallinicum. Warts, gneisses, phyllites and amphibolites sporadically occur in the crystallic bed-rock. The southwestern part is also formed by limestones, dolomites and schists. The Devínska Kobyla hill (514 m a.s.l.) in the Devínske Karpaty Mts. is the uppermost situated site on the territory of Bratislava. From the southern part it is bordered by the Devínska brána gate representing a break of the Danube river through the Malé Karpaty Mts. Eastwards the relief of the Devínske Karpaty Mts. decreases and merges into the Bratislavské predhorie foothills with a mean altitude of 250 m a.s.l. The Lamačská brána gate is a significant depression surrounding the Devínske Karpaty Mts. from the north. The Pezinské Karpaty Mts. reaching the northern border of the administrative boundary of Bratislava are situated east of the Lamačská

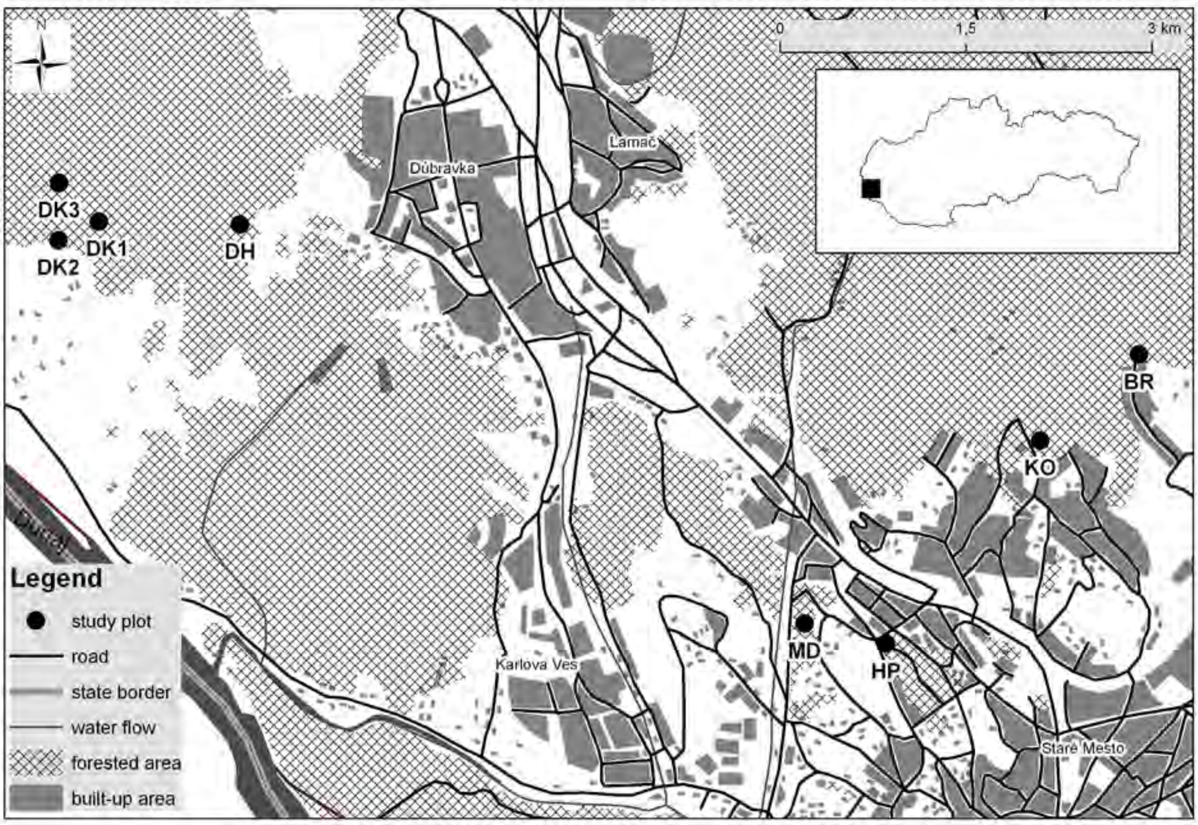


Fig. 1. Study area and position of eight study plots (design: Juraj Holec)

brána gate. We selected eight study plots, which were studied during four vegetation periods (1999, 2000, 2005, 2006) from the zoological point of view.

Horský park (HP), 48°09′36″ N, 17°05′13″ E, GRN (Grid Reference Number of the Databank of the Fauna of Slovakia) 7868a, 212 m a.s.l.
Mlynská dolina (MD), 48°09′39″ N, 17°04′41″ E, GRN 7868a, 190 m a.s.l.
Bratislava – Briežky (BR), 48°10′58″ N, 17°06′40″ E, GRN 7868b, 340 m a.s.l.
Bratislava – Koliba (KO), 48°10′33″ N, 17°06′05″ E, GRN 7868b, 380 m a.s.l.
Devínska Kobyla 1 (DK1), 48°11′05″ N, 16°59′50″ E, GRN 7868a, 340 m a.s.l.
Devínska Kobyla 2 (DK2), 48°10′59″ N, 16°59′35″ E, GRN 7868a, 300 m a.s.l.
Devínska Kobyla 3 (DK3), 48°11′14″ N, 16°59′33″ E, GRN 7868a, 452 m a.s.l.
Dúbravská Hlavica (DH), 48°11′08″ N, 17°00′45″ E, GRN 7868a, 350 m a.s.l.

Four study plots (DK1, DK2, DK3, DH) are situated in the Devínske Karpaty Mts., two of them in the Bratislavské predhorie foothills (HP, MD), and two in the Pezinské Karpaty Mts. (KO, BR).

Climate

Milada Holecová

According to the climatic classification, the area of Malé Karpaty Mts. up to the altitude of 400 m a.s.l. belongs to the moderately warm climatic region. The southern part is classified as a moderately warm and moderately moist climatic district A5 with mild winter, the northern part as a moderately warm and moderately moist hilly district B3 (Holec 1997, Petrovič 1972). The main climatic character of the area refers to a perpendicular position towards dominating NW falling winds on both sides of the mountains.

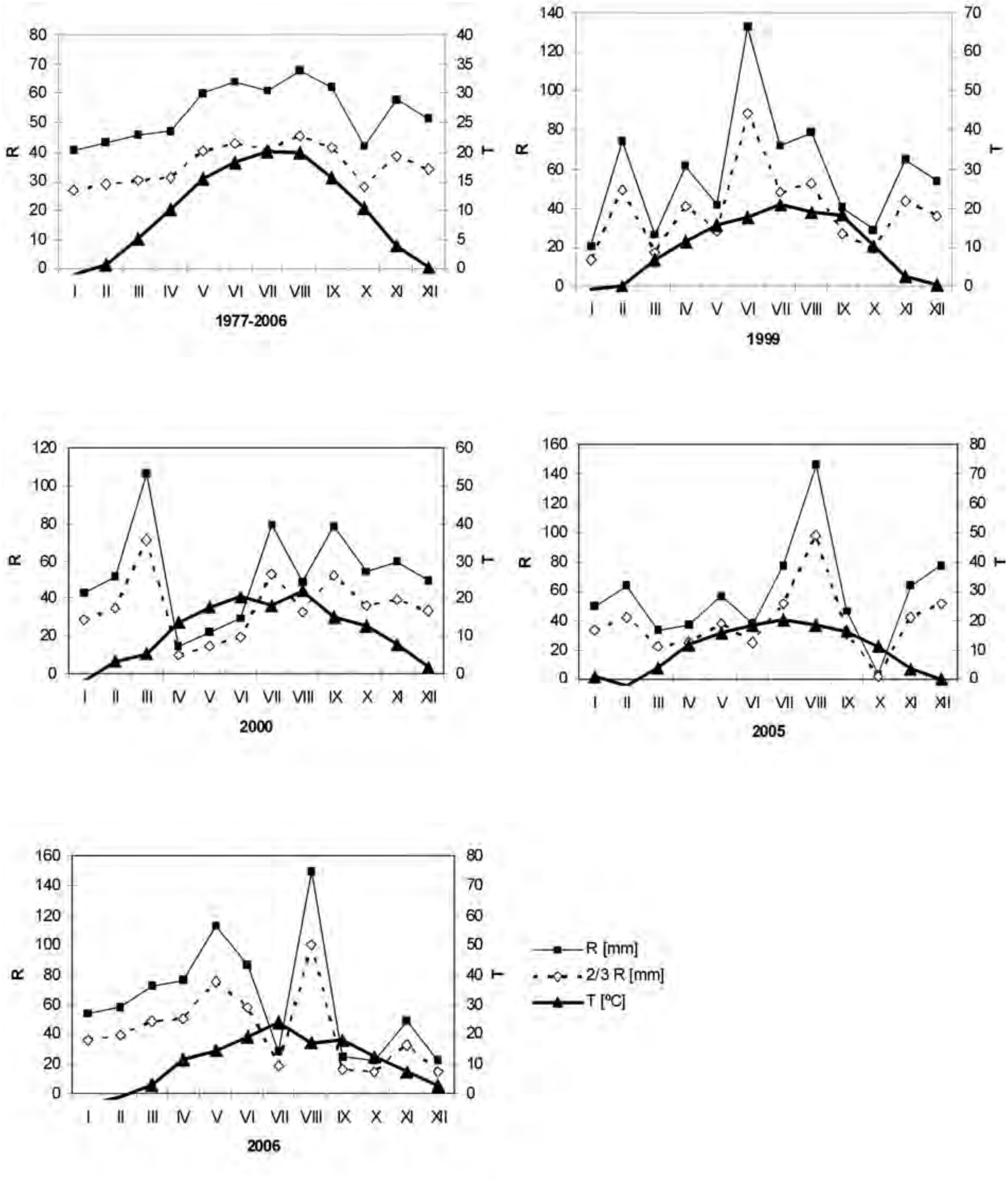
Average annual temperature varies between 9.9–11.3 ºC, in January -3.8–0.8 ºC and in July 18.2–23.9 ºC (Table 1). Average temperatures in vegetation season (April–September) reach 14–15 ºC. Average number of summer days (more than 25 ºC) is 40–60 annually, while there are 30–40 winter days (less than -0.1 ºC) a year (Petrovič 1968, Tarábek 1980).

Long-term average monthly and annual precipitation (1977–2006) from the studied region is given in Table 1. Precipitation of 320 mm refers to the vegetation period (April–September). Snow cover takes 90–100 days annually (Petrovič 1968).

Precipitation is influenced by numerous factors, e.g. altitude. These two variables positively correlate. Monitoring of long-term averages of temperature and precipitation amount appears as important for forest vegetation. However, for research on invertebrates and their dynamics actual average annual temperatures and precipitation amount during sampling have to be taken into account.

Climatic factors represent a complicated complex with interrelationships playing an important role. A better picture is given when temperature and precipitation are in connection. We have constructed climate-diagrams according to the method of Walter (1955) (Figs. 2–6). The heavy line in climate-diagrams represents average monthly temperatures (T) in ºC, the light line precipitation (R) in mm. The dashed line gives 2/3 of the precipitation in mm. The area limited by the heavy line at the top and by the light line at the bottom represents a strong drought which is exceptional in our condition and may occur only during some years. The area limited at the top by the heavy line and at the bottom by the dashed one represents a period of a moderate drought, which occurs more often in southern Slovakia.

According to the meteorological station data, the average annual temperatures in 1999, 2000 and 2006 were significantly higher comparing with the long-term average. Annual precipitation appeared significantly higher in 1999, 2005 and 2006 (Table 1). Therefore the years 1999 and 2005 were warmer and in summertime more humid than averagely. The years 2000 and 2006 were warmer and drier (Figs. 2–6).



Figs. 2–6. Climate-diagrams constructed according to measurements of the meteorological station Bratislava-Koliba (T – temperature, R – rainfall, I–XII – months).

Table 1. Meteorological station Bratislava-Koliba - average monthly and annual air temperature (T) and rainfall (R) in long-term period and in individual years of the research.

1977-2006	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
T [ºC]	-1.1	0.7	5.2	10.1	15.3	18.2	20.2	20	15.5	10.3	4	0.2	9.9
R [mm]	40.5	43.4	45.7	47.0	60.3	64.2	61.1	67.9	62.2	42.0	58.0	51.4	643.6
1999													
T [ºC]	-0.7	-0.1	6.8	11.6	15.8	17.7	20.9	19.1	18.3	10.4	2.7	0.2	10.2
R [mm]	20.7	74.4	26.2	61.9	42	133	71.8	79.3	40.6	29	65.1	54.1	697.8
2000													
T [ºC]	-2	3.4	5.4	13.8	17.7	20.5	18.2	22	15	12.7	7.6	1.6	11.3
R [mm]	43	51.8	107	14.9	22.1	29.5	79.4	48.9	78.2	54.3	59.6	49.9	638.3
2005													
T [ºC]	0.8	-2.3	4	11.4	15.7	18.4	20.2	18.6	16.2	11.2	3.5	0	9.8
R [mm]	49.9	63.4	33.8	37.2	56.5	37.8	77.3	147	46.4	3.2	63.8	77.5	693.4
2006													
T [ºC]	-3.8	-1.2	3	11.7	14.5	19.3	23.9	17.1	17.8	12.6	7.1	2.6	10.4
R [mm]	53.6	58.6	72.9	75.8	113	86.7	28.3	150	24.8	22.2	49.1	22.1	756.6

Soils

Janka Zlinská

The general description, genesis and typology of the soils at eight studied sites of oak-hornbeam and scree forests in Bratislava have similar soil properties to the 10 soil subtypes at 10 sites previously evaluated in the earlier contribution on the evertebrate communities of oak-hornbeam and oak forests in the south-western part of the Malé Karpaty Mts. (Zlinská et al. 2005).

A total of 8 localities with similar oak-hornbeam and scree forests on the southernmost slopes of the Malé Karpaty Mts. in Bratislava were chosen, and description of soil types and basic chemical analysis were carried out. Here, similar forest vegetation and the same soil types developed on the same bedrock of granodiorite, granite, schist and limestone as in the south-western part of the Malé Karpaty Mts. These Bratislava forests have been subjected to intensive anthropogenic activities, and since the 1960's the soils have been very adversely affected by traffic and industrial emissions.

The aims of this subchapter are firstly to identify their soil types and to characterize basic chemical properties of the soils relevant to the occurrence of studied evertebrate groups there, and, secondly, to differentiate soil chemical composition between the Bratislava and south-western Malé Karpaty Mts. sites.

Two forest types consisting of oak-hornbeam forests of the *Querco petraeae-Carpinetum* Soó et Pócs (1931) 1957 association and linden-maple scree forests of the *Tilio-Carpinetum* Klika 1941 association were found at these 8 Bratislava sites. These grow on the three classified soil types of Cambisols, Rendzic Phaeozem and Cutanic Luvisols (formed on loess). These have similar genesis, but different bedrocks, and in one instance a loess layer is blown onto the granite. Soil genesis is determined by warm climate and crystalline (granite, granodiorite, schists) or carbonate (limestone) bedrock. It is also affected by forest stands and water movement along slopes, and physical soil properties here are typified by high levels of aeration due to the large number of rocks, gravel and sand, and the low ratio of silt and clay from the Cambisols and Rendzic Phaeozem. These factors also affect the soil resistance to compaction, and this is particularly noticeable in the shallow sceletic carbonate soils in the Devínska Kobyla 2 site. The resistance here is strengthened by a block of solid bedrock which has risen to the surface, and also by the presence of carbonates which determine coagulation of soil matter. Cambisols in the studied sites numbered 1, 2, 3, 6, 7 and 8 have a higher ratio of silt and clay particles, and these display intermediate resistance, while the Cutanic Luvisols developed from the loess at the Devínska Kobyla 3 site contain the highest silt content and are consequently the least resistant.

The analyzed soils are from 0.8 up to 1.5 m deep, and since they mostly occur on flat or undulated terrain and on moderate slopes, they are not potentially endangered by water erosion. However, Cambisols on the steep south-western slope have an inclination of 45° at the Devínska Kobyla site 2, and with the approximately 650 mm annual precipitation, this combination gives a high risk of water erosion. The results of these conditions are clearly apparent in the accumulated soil layers on the lower parts of this slope.

Although these genetic soil horizons are mostly undisturbed, it is most likely that vineyards existed in site 5 (DK3), so some disturbance is not excluded. In contrast, based on the forest age, the adjacent Devínska Kobyla National Nature Reserve in sites 3, 4 has suffered no interventions for approximately 100 years. This may previously have been managed forest. Forests in sites 7 and 8 in this Bratislava forest park were definitely managed forest, while other forests such as those in sites 1, 2, 6 serve on recreation. The changes in the stands were not accompanied by interventions to the soil profiles, and since timber harvesting without heavy machines was more sparing in the past, these stand changes were due to altered tree composition and also planting of autochthonous and cultural trees.

Bedrocks in 6 of the 8 sites were composed of Haplic Cambisols, with granodiorite in sites 1, 2 and 3 and granite and schist in 6, 7 and 8.

The Cambisols in sites 1, 2 and 3 have very similar chemical properties. Exchangeable pH in the upper part of the humic horizon (Ao) is strongly acidic at 3.07–3.56. The decomposed litter horizon has a pH ranging from the very acidic 3.56 to the acidic 4.79 (Table 2). All of those soils are poorly base saturated and their Ao horizons differ. For example: (1) there was a low Ao horizon content of humus at 2.41% in Devínska Kobyla 1 (site 3), while in Horský park (site 1) it was 9.31% and in Mlynská dolina (site 2) 14.14%, and (2) the highest Ao horizon nitrogen contents were 0.88% in Mlynská dolina (site 2) and 0.72% in Horský park (site 1). Although these are situated in residential areas, they also serve as public forest park, and are overloaded with tourists. Some cultural species have been planted here.

Sites 6, 7 and 8 also have strongly acidic soils with exchangeable pH 2.94–3.12 in the Ao horizon and 3.07–3.65 in the litter horizon. These are weakly base saturated. The extremely low saturation of 13% was found in the Briežky site 8, where strong soil acidity is responsible for the extremely high C:N proportion of 22.18 in the litter horizon and 19.67 in the Ao horizon. The percentage of oxidizable carbon (Cox) is the highest in the Briežky site with 45.17%. This highest amount of organic matter shows that the rate of litter decomposition is slowest due to strong acidity and low base saturation. Relatively high Cox values were also found in litter in the Dúbravská Hlavica site 6 at 20.69% and in Bratislava-Koliba site 7 with 31.03%.

The Rendzic Phaeozem was analyzed in Devínska Kobyla 2, site 4. The exchangeable pH of both litter and the upper part of the humic horizon is neutral here, and this is the only case where the pH of the humic horizon is higher than that of litter. This soil is totally base saturated with a humus content of 6.21% in the Ao humic horizon and appropriate C:N ratios of 9.62 in litter and 8.78 in the humic Ao horizon. The studied portion of the slope is irrigated by flowing water and there is no high evaporation in its northern exposition, so that soil moisture here is the highest of all 8 studied sites.

Cutanic Luvisol formed from loess was recorded only in the locality of Devínska Kobyla 3. Here, loess was blown onto the granite (but it is still on the surface in some places). Exchangeable pH in the humic horizon is acidic at 4.27, due to the bedrock and to water with soil admixture blown from neighbouring slopes where acidic Cambisols formed on the granite. Gathered rocks at the site's edge indicate that it was previously used as a vineyard. The nitrogen content in the humic Ao horizon is the third highest of all studied sites at 0.60%, and this shows synanthropization. This is supported by the C:N ratio of 5.00, which is lower than in natural soils, and here also the soil is well base saturated.

The soil from Briežky site 8 has the worst properties of all analyzed soils, since it is on strongly acidic Haplic Cambisol, with high organic carbon content and a high C:N ratio of 19.67. Both of these are characteristic of strongly acidic soils. The exchangeable base content is critically low, at 40 mval/100 g soil, and the cation exchange capacity is also very low at 10.70 mval/100 g. The saturation value of 13% represents a soil which is poorly base saturated. These properties may be reflected also in edaphon composition by the presence of species which much prefer acidic conditions, rather than those species which prefer alkaline and neutral pH environments.

Although the Haplic Cambisols in sites 3, 6 and 7 are strongly acidic and poorly saturated, there was no increased nitrogen content.

However, there was increased nitrogen content in the humic Ao horizon at 0.6–0.88% in the Haplic Cambisols from the sites 1 and 2, and in the Cutanic Luvisols from the site 5, both related to intensive anthropogenic impact. A moderately increased nitrogen content of 0.4% was also noted in the Rendzic Phaeozem in the site 4.

With regard to geological substrates and soils, it is clear that crystalline bedrocks with Haplic Cambisol prevail in the Bratislava area. All the Cambisols are strongly acidic and poorly saturated with humus content of 2.41–14.14%, so that it is quite safe to assume that this area supports acidophilous, mesophilous evertebrate communities of mesophilous oak-hornbeam and scree forests.

Neutral and base saturated Rendzic Phaeozem has developed on the limestone. It is irrigated by slope water in the lower part of slope and there is less evapotranspiration due to the northern exposition. The site 4 in Devínska Kobyla 2 has retained the most moisture. These sites are occupied by calciphilous, neutrophilous and mesophilous evertebrate communities.

The Cutanic Luvisol developed from loess in site 5 is decalcified with acidic soil reaction, which, however, is well base saturated. It is situated on the non-autochthonous granite bedrock. Acidophilous, neutrophilous and mesophilous evertebrate communities are expected here.

The following differences can be observed when comparing the soils studied in Bratislava with those from the south-western part of the Malé Karpaty Mts. (cf. Zlinská et al. 2005). Rendzic Phaeozems were excluded from comparison, since on three such sites – one in Bratislava and two outside – three different communities occur and there are three different expositions, slopes and level of moisture, thus making comparison impossible. Soils such as Dystric Planosols and Cutanic Luvisols also cannot be compared, because both were found in a single site, however, Cambisols occurred as common soil types in similar expositions and slopes, and therefore these could be compared objectively.

Exchangeable pH in the upper part of the Ao humic horizon in Bratislava Cambisols is 0.2 lower on average, so that Bratislava Cambisols are more acidic than those outside this metropolis. Bratislava Cambisols in the sites 1, 2, 7, 8 contained twice as much acidic mull compared to sites situated outside Bratislava, and their litter registered a minimum of twice the percentage of Cox in their non-composed organic matter. This indicates slower decomposition of organic matter due to higher soil acidity. In addition, the nitrogen content in some Bratislava sites was two or even three times higher than that in managed forests outside Bratislava, such as in the sites 1 and 2.

Finally, increased nitrogen content in Bratislava was also recorded in the Cutanic Luvisol in the site 5, and its value was also moderately increased in the Rendzic Phaeozem in the site 4.

These qualitative changes in soils can have a great impact on evertebrate diversity, and also on the number of coeno-populations.

The names of soil types and subtypes are according to the Morphogenetic Soil Classification System of Slovakia (Šály et al. 2000) and soil analyses were made according to Hraško et al. (1962). The soil samples were taken from litter (Oo) and the upper part (1–5 cm) of humic horizons (Ao, Aoq, Amc) from the same depths as the zoological material. The percentage of oxidizable carbon (Cox) in the litter was analyzed (humification has not occurred yet) and the humus percentage in the surface humic Ao, Aoq and Amc horizon was calculated.

Vegetation

Janka Zlinská

We studied the forest stands in 8 localities differing in their exposition, slope, geological bedrock, soil properties, floristic composition, intensity of anthropization and fragmentation in the city of Bratislava, which is situated on the southernmost foothills of the Malé Karpaty Mts. These forest phytocoenoses are located in the colline zone at altitude ranging from 190 to 452 m a.s.l.

They are classified into the mesophilous oak-hornbeam forests of the *Carpinion betuli* Issler 1931 alliance (sites of Horský park, Devínska Kobyla 1, Devínska Kobyla 3, Dúbravská Hlavica, Bratislava-Koliba and Bratislava-Briežky), which are replaced by the scree forests of the colline zone of the *Tilio platyphylli-Acerion pseudoplatani* Klika 1955 alliance on the steep slopes in the sites of Mlynská dolina, Devínska Kobyla 2.

Most of the analyzed oak-hornbeam forests belong to the Carpathian oak-hornbeam forests of the *Querco petraeae-Carpinetum* Soó et Pócs (1931) 1957 association, which is classified into the separate suballiance of *Carici pilosae-Carpinenion betuli* J. et M. Michalko 1986 (Michalko et al. 1986). Such forests are typical for moderate, southerly, westerly, and easterly oriented slopes with sandy-loamy, from weak to intermediate humous, acidic soils of Haplic Cambisol type formed on the crystalline substrates of granite, granodiorite and schist.

The floristic composition of the natural and semi-natural oak-hornbeam forests is typical by a high abundance of spring geophytes (*Gagea lutea, G. pratensis, Scilla bifolia, Ranunculus ficaria* ssp. *bulbifer, Corydalis cava, C. solida, Galanthus nivalis* and *Allium ursinum*) as well as other species of spring aspect (including *Lathyrus vernus, Convallaria majalis, Hepatica nobilis, Viola reichenbachiana, V. odorata, V. riviniana, Anemone ranunculoides, Isopyrum thalictroides* and *Pulmonaria officinalis*). Many of the spring geophytes are missing in the managed forests. The tree layer is dominated by *Carpinus betulus* and *Quercus dalechampii* with an admixture of *Acer campestre, Tilia cordata* and *Prunus avium*, while *Acer pseudoplatanus* and *A. platanoides* occur rarely. The shrub layer is typical by species such as *Ligustrum vulgare, Crataegus monogyna, C. laevigata, Euonymus europaea, Berberis vulgaris, Ulmus minor, Cornus sanguinea* and *Lonicera xylosteum*. In the herb layer, along with spring geophytes and species of spring aspect, *Carex pilosa, Galium schultesii, G. sylvaticum, Stellaria holostea, Symphytum tuberosum* and *Hedera helix* represent important indicators. Species of the *Fagetalia* order are numerous. These include *Melica uniflora, Galium odoratum, Arum alpinum, Asarum europaeum, Bromus benekenii, Dentaria bulbifera, Euphorbia polychroma, Tanacetum corymbosum, Pulmonaria obscura, Campanula trachelium, Poa nemoralis, Dactylis polygama* and *Melica nutans*. In the oak-hornbeam forests, some nitrophilous species also occur. Here, *Geum urbanum* represents a constant species, and *Mycelis muralis, Geranium robertianum* and *Galeobdolon luteum* are also frequently found. A growing number of nitrophilous species indicates increasing anthropization and forestry activity. These include *Sambucus nigra, Impatiens parviflora, Alliaria petiolata, Viola odorata, Lapsana communis, Rubus caesius, Chelidonium majus, Anthriscus sylvestris, A. cerefolium, Fallopia convolvulus, Galium aparine, Torilis japonica*, and *Heracleum sphondylium*.

If the oak-hornbeam forests growing on the warm slopes of the southernmost part of the Malé Karpaty Mts. are not strongly shaded or if they do not occupy quartzite substrate, some thermophilous species are a natural component of their floristic composition. These include *Melittis melissophyllum, Sorbus torminalis, Euonymus verrucosa, Viburnum lantana, Lathyrus niger, Polygonatum latifolium, Tanacetum corymbosum, Viola alba, Melica uniflora, Cruciata glabra* and *Vincetoxicum hirundinaria*, which are species indicative of *Querco petraeae-Carpinetum melicetosum uniflorae* (Klika ex Futák 1947) Neuhäusl in Moravec et al. 1982 subassociation (Devínska Kobyla 1 and Bratislava-Koliba). In many stands only *Melica uniflora* predominates, while others thermophilous species are absent. These stands are affected by various human activities and increased content of nitrogen. They are not classified into *Querco petraeae-Carpinetum melicetosum uniflorae* subassociation. We treat them as variant with *Melica uniflora* (Horský park site).

The oak-hornbeam forests with a high abundance of *Carex pilosa* and occurrence of characteristic alliance species on non-shaded sites and lacking thermophilous species belong to the typical subassociaton *Querco petraeae-Carpinetum typicum* Neuhäusl et Neuhäuslová 1968 (Dúbravská Hlavica, Bratislava-Briežky).

A rare type of oak-hornbeam forests in the Devínska Kobyla Mts. is represented by Pannonian oak-hornbeam forests of the association *Primulo veris-Carpinetum* Neuhäuslová-Novotná 1964. It is classified into the *Querco robori-Carpinenion* J. et M. Michalko 1986 suballiance, and it is distinguished by the presence of thermophilous species and species occurring in intermittently moist sites, such as *Primula veris, Colchicum autumnale, Viola hirta, Cornus mas, Viola mirabilis, V. alba, Viburnum lantana* and *Buglossoides purpurocaerulea*. Herein, a phytocoenosis type between Carpathian oak-hornbeam forests and thermophilous oak forests is represented. It occurs in this study area on moderate southern loess slopes of the Devínska Kobyla Mts. (site 5, DK3). Although it stands on acidic decalcified Luvisols, it is well base saturated.

On the sites, where moderate slopes are replaced by the steep screes, oak-hornbeam forests are changing into ravine forests of the colline belt of the *Aceri-Carpinetum* Klika

1941 association. These forests are composed partly of oak-hornbeam species, partly those of scree and a high number of nitrophytes, and this study area contains two localities of such forests. The first is located in Mlynská dolina on the warm south-western slope on granodiorite, where the forest grows on strongly acidic poorly base saturated Haplic Cambisols. Here, the humic horizon (Ao) had the highest content of overall nitrogen (0.88%). The second forest was identified on a limestone substrate, where neutral and well base saturated Rendzic Pheozem developed (Devínska Kobyla 2). This stand is on the northern slope, and while it is dominated by *Tilia cordata* with a small number of nitrophytes, it lacks *Quercus dalechampii*.

Since the 1950's, forests in Bratislava and its vicinity have been strongly affected by air pollutants. The effect of acid rains has resulted in a decrease in sensitive lichen species (Lackovičová 1977) and it has also had some impact on the acidity of the upper soil zone (Table 2, Zlinská et al. 2005). This anthropogenic impact is seen in the fragmentation, population density, intensive tourism, application of allochthonous species, forest management and hunting, which have all played important roles in the floristic composition. This impact on our 8 chosen localities is characterized in the following ways:

- 1. Horský park: This is an isolated, fragmented, strongly synanthropized forest park, with a high content of nitrates in the soil, a partly changed tree and shrub layer, a strongly changed herb layer and a highly polluted environment.
- 2. Mlynská dolina: This is an isolated, fragmented, strongly synanthropized forest. It has a high content of nitrates in the soil, with impact from drought and planted allochthonous species in the shrub layer. The herb layer is also very altered. There is highly polluted environment.
- 3. Devínska Kobyla 1: This was an extensively used stand in the past with a moderately synanthropized forest. The floristic composition is close to its natural state in all layers, with a high abundance of nitrophytes. Environmental pollution is clearly apparent here.
- 4. Devínska Kobyla 2: This was also an extensively used stand in the past with a moderately synanthropized forest. Again, the floristic composition is close to its natural state in all layers. Environmental pollution is apparent here.
- 5. Devínska Kobyla 3: This was an extensively used stand in the past with intermediate synanthropized forest. There is increased content of nitrates in the soil and the floristic composition is close to the natural state in all layers. The shrub layer, however, has been eliminated. There is evident environmental pollution.
- 6. Dúbravská Hlavica: This stand was extensively used in the past, with a moderately synanthropized forest. The floristic composition is close to the natural state in all layers. There is actual environmental pollution.
- 7. Koliba: This was a commercially used stand with intermediate synanthropized forest. The soils are acidic and of poor quality. The low cover of the herb layer is most likely an indication of this. There is strongly polluted environment at this location.
- 8. Briežky: This was also a commercially used stand with intermediate synanthropized forest. It has acidic soils of poor quality and a low cover of herb layer. Several series of soil analysis have shown that Briežky has the worst soil conditions of all analyzed soils. There is strongly polluted environment.

The study sites with their phytocoenological relevées

1. The Malé Karpaty Mts., Bratislava-Horský park (HP) is a fragmented remnant of an 80 year-old oak-hornbeam forest of the association *Querco petraeae-Carpinetum* variant with *Melica uniflora*. It is situated in the urban part of Bratislava, 212 m a.s.l., and it stands on the strongly acidic and weakly base saturated Haplic Cambisols Dystric developed on a granodiorite substrate. This forest is a perpetual site for recreational pursuits and it is badly contaminated with domestic animal excrements. Although it is not currently commercially used, as witnessed by the occurrence of all-aged trees, it was most likely used for this purpose in the past. This forest serves as a city park. There were planted also allochthonous trees as *Castanea sativa, Pinus nigra, P. sylvestris*, and *Robinia pseudacacia* (and some others outside the relevé area). Due to synanthropization, *Acer platanoides* and *A. pseudoplatanus* have higher abundances in all layers compared to the natural state. The floristic composition of the herb layer (E_1) is vividly changed. The first 11 species represent those of natural stands, while the remaining 20 are treated as synanthropic (nitrophilous) species. Many natural phytocoenosis species are missing here. The high volumes of cover of *Melica uniflora* (3) and *Hedera helix* (3) are also a result of synanthropization, together with a high content of soil nitrates. The nitrogen content is three times that of natural phytocoenosis (Table 2). This forest is not large, and on all sides it is bordered by built-up areas, so that in most cases there has been no exchange of diaspores and genetic information. Isolation and synanthropization of this forest, together with immissions, have caused retreat of sensitive species of evertebrates. Their species composition and population density may also have decreased due to the absence or poor abundance of some nutrient plants.

Relevé 1

Analyzed area: 400 m^2, exp.: SE, slope: 15°, date: October 10, 2007; June 13, 2008. Age of a stand: 80 years, average height: 22 m, average thickness at chest height: 25 cm, cover: E_3 70%, E_2 40%, E_1 70%, E_0 10%.

E_3: *Quercus dalechampii* 3, *Carpinus betulus* 1, *Prunus avium* +, *Tilia cordata* +, *Fagus sylvatica* r, *Acer platanoides* 2, *Acer campestre* 1, *Fraxinus excelsior* +, *Castanea sativa* +, *Pinus nigra* +, *Pinus sylvestris* +, *Robinia pseudacacia* r

E_2: *Acer platanoides* 3, *Acer campestre* +, *Acer pseudoplatanus* +, *Berberis vulgaris* +, *Crataegus monogyna* +, *Euonymus europaea* 1, *Ligustrum vulgare* +, *Corylus avellana* +, *Sambucus nigra* 1, *Castanea sativa* +, *Rosa canina* agg. +

E_1: *Melica uniflora* 3, *Hedera helix* 3, *Galium odoratum* 1, *Polygonatum odoratum* +, *Quercus dalechampii* +, *Fraxinus excelsior* +, *Prunus avium* +, *Brachypodium sylvaticum* +, *Festuca gigantea* +, *Hieracium sylvaticum* +, *Solidago virgaurea* +, *Rubus caesius* 1, *Geum urbanum* +, *Sambucus nigra* +, *Galium aparine* 2, *Geranium robertianum* 1, *Stachys sylvatica* +, *Heracleum sphondylium* +, *Impatiens parviflora* 2, *Mycelis muralis* 1, *Alliaria petiolata* 1, *Chelidonium majus* 1, *Viola odorata* 1, *Ranunculus ficaria* ssp. *bulbifer* 3, *Corydalis cava* 2, *Corydalis solida* 1, *Anthriscus sylvestris* r, *Sambucus ebulus* 1, *Torilis japonica* +, *Galeopsis pubescens* +, *Acer pseudoplatanus* 2.

2. The Malé Karpaty Mts., Bratislava-Mlynská dolina (MD) is on the SW slope of the Machnáč hill, 190 m a.s.l. It is a fragment of an 80–100 year-old maple-hornbeam scree forest of *Aceri-Carpinetum* association surrounded by road communication and the urban agglomeration. This is a small isolated forest, which is intensively affected by tourism and recreation. It is a neighbourhood with private land in its lower part, and there is plantation of ornamental or useful trees such as *Syringa vulgaris*, *Mahonia aquifolium*, *Robinia pseudacacia*, *Acer negundo* and *Ribes uva-crispa* cv. The forest is not commercially used, as it fulfils protective functions. The composition of the tree and shrub layer resembles natural scree forests of the colline zone, except for the invasive species *Robinia pseudacacia*. Many species in the herb layer are common in an oak-hornbeam forest (the first 13 species). A high abundance of spring ephemerals (*Ranunculus ficaria* ssp. *bulbifer, Galanthus nivalis, Corydalis solida* and *C. cava*), which are typical for scree forests, intermingle with nitrophytes (*Geum urbanum, Galium aparine, Chelidonium majus, Geranium robertianum, Alliaria petiolata, Glechoma hederacea, Impatiens parviflora*, and *Rubus caesius*). The highest content of overall nitrogen in all analyzed soil samples was recorded here at 0.88% in the humic horizon (Ao). The stand is on acidic Haplic Cambisols on granodiorite bedrock. The slope has south-western orientation, and therefore some thermophilous species occur here (*Quercus cerris* and *Polygonatum latifolium*). Some species of herb layer, such as *Sambucus ebulus, Rumex patientia, Taraxacum officinale* agg., *Erigeron annuus* and *Fallopia convolvulus*, indicate ruderalization. Its small area and the adjacent vicinity of communications and settlements is the reason, why the soil is suffering from the drought. These factors, as well as isolation and exhalants, have a devastating effect on species diversity and evertebrate population density, as described in locality 1.

Relevé 2

Analyzed area: 400 m^2, exp.: SW, slope: 45°, date: October 10, 2007; June 13, 2008. Age of a stand: 80–100 years, average height: 25–28 m, average thickness at chest height: 40 cm, cover: E_3 70%, E_2 20%, E_1 100%, E_0 30%.

E_3: *Fraxinus excelsior* 3, *Acer campestre* 2-3, *Robinia pseudacacia* 1, *Carpinus betulus* +, *Ulmus minor* +, *Quercus cerris* +, *Quercus dalechampii* +, *Tilia cordata* +

E_2: *Ligustrum vulgare* 2, *Acer campestre* 2, *Fraxinus excelsior* +, *Euonymus europaea* +, *Tilia cordata* +, *Ulmus minor* +, *Acer platanoides* +, *Crataegus monogyna* +, *Rosa canina* agg. r, *Sambucus nigra* 1, *Robinia pseudacacia* +, *Syringa vulgaris* +, *Acer negundo* r, *Ribes uva-crispa* cv. +, *Mahonia aquifolium* +

E_1: *Melica uniflora* 3, *Hedera helix* 3, *Stellaria holostea* 2, *Polygonatum latifolium* +, *Polygonatum odoratum* +, *Lilium martagon* +, *Carex sylvatica* 1, *C. muricata* L. +, *Brachypodium sylvaticum* +, *Lathyrus vernus* +, *Poa nemoralis* 1, *Dryopteris filix-mas* +, *Arum alpinum* +, *Ranunculus ficaria* ssp. *bulbifer* 2, *Galanthus nivalis* 1, *Corydalis solida* 3, *Corydalis cava* 2, *Viola odorata* 2, *Chaerophyllum temulum* +, *Euonymus europaea* 1, *Fraxinus excelsior* +, *Quercus dalechampii* +, *Acer campestre* 1, *Ulmus minor* +, *Acer platanoides* +, *Crataegus monogyna* 1, *Allium oleraceum* +, *Geum urbanum* 3, *Galium aparine* 2, *Chelidonium majus* 1, *Geranium robertianum* 1, *Alliaria petiolata* 2, *Glechoma hederacea* 1, *Impatiens parviflora* 1, *Rubus caesius* +, *Sambucus ebulus* +, *Erigeron annuus* +, *Rumex patientia* +, *Taraxacum officinale* agg. r, *Fallopia convolvulus* +.

3. The Malé Karpaty Mts., Bratislava-Devínska Kobyla 1 (DK1) is a protected stand in the National Nature Reserve located east of the summit, 340 m a. s. l. It comprises a 60–80 year-old sprout oak-hornbeam forest with a well-developed shrub layer of the *Querco petraeae-Carpinetum melicetosum uniflorae* subassociation. It stands on acidic Haplic Cambisols on granite bedrock. All activities with a negative impact on the biodiversity have been banned since 1964, when this was declared a nature reserve. In the past, and also currently, the forests of the Devínska Kobyla Mts. have served Bratislava inhabitants for recreation purposes (among other things) and their past commercial use was small. This forest remains a very attractive site for tourism and it is visited frequently. It is rich in species characteristic of Carpathian oak-hornbeam forests. Although there is no high nitrogen content in this Ao humic horizon soil, several nitrophytes occur here (Table 2). These include *Galium aparine, Viola odorata, Geranium robertianum, Alliaria petiolata, Chaerophyllum temulum, Geum urbanum* and *Lamiastrum montanum*, and these species document its previous use for pasture. Some impact of surface pollution by emissions and exhalants is also assumed at this site. Several thermophilous species, such as *Sorbus torminalis, Viburnum lantana, Euonymus verrucosa, Melica uniflora, Lathyrus niger, Polygonatum latifolium* and *Tanacetum corymbosum*, indicate a relationship with Pannonian oak-hornbeam forests. Therefore, we classified it into the subassociation of *Querco petraeae-Carpinetum melicetosum uniflorae*. The studied stand is a part of the larger forest complex, and there is no apparent impact of fragmentation on the evertebrate diversity here.

Relevé 3

Analyzed area: 400 m^2, exp.: S, slope: 15°, date: March 21, 2007; July 11, 2008. Age of a stand: 60–80 years, average height: 22 m, average thickness at chest height: 28 cm, cover: E_3 75%, E_2 35%, E_1 70%, E_0 5%.

E_3: *Quercus dalechampii* 4, *Carpinus betulus* 1

E_2: *Lonicera xylosteum* 1, *Ligustrum vulgare* 1, *Fraxinus excelsior* 1, *Acer campestre* 1, *Carpinus betulus* +, *Tilia cordata* +, *Sorbus torminalis* r, *Euonymus verrucosa* r, *Viburnum lantana* r

E_1: *Dactylis polygama* 3, *Melica uniflora* 2, *Galium odoratum* 2, *Poa nemoralis* 1, *Galium schultesii* 1, *Corydalis cava* 2, *Viola reichenbachiana* +, *Gagea lutea* +, *Ranunculus ficaria* ssp. *bulbifer* 2, *Arum alpinum* 1, *Convallaria majalis* +, *Lathyrus niger* +, *Rubus fruticosus* agg. +, *Campanula persicifolia* +, *Polygonatum latifolium* +, *Lathyrus vernus* 1, *Hieracium sylvaticum* +, *Tanacetum corymbosum* r, *Fragaria moschata* +, *Salvia glutinosa* r, *Solidago virgaurea* +, *Prunus avium* +, *Carpinus betulus* +, *Quercus dalechampii* 2, *Acer campestre* r, *Ligustrum vulgare* 1, *Sorbus torminalis* +, *Sorbus aucuparia* r, *Galium aparine* 2, *Viola odorata* 1, *Geranium robertianum* 2, *Alliaria petiolata* +, *Chaerophyllum temulum* +, *Geum urbanum* 1, *Lamiastrum montanum* +.

4. The Malé Karpaty Mts., Bratislava-Devínska Kobyla 2 (DK2) forms a forest on the terrace located over the spring south-east of the summit at 300 m a.s.l. This forest, which belongs to the *Aceri-Carpinetum* association, stands on the Rendzic Phaeozem on calcaric bedrock. The area of phytocoenological relevé is 10 x 40 m, due to the zoological sampling. The location of this research site close to the spring and on the northern exposition causes higher soil moisture compared to the other sites. This research site is also situated within the National Nature Reserve, where all activities are limited. The impact of pollution from immissions and exhalants cannot be excluded even here. Although moderately higher nitrate concentrations were found in the soil (0.41%), nitrophytes rarely occurred here. Exceptions included *Viola odorata, Galium aparine* and *Geum urbanum*. The geological substrate of limestone is indicated by the occurrence of species such as *Carex alba, Buglossoides purpurocaerulea*, and *Melittis melissophyllum*. Thus, *Aceri-Carpinetum* from the Nr. 4 site differs from the *Aceri-Carpinetum* of site Nr. 2. While the Nr. 2 site accommodates abundant nitrophytes and it is “real” scree, there is no scree on the Nr. 4 site, where the soil is not in motion, and with a moderate 10° angle of slope, nitrophytes rarely occur here. Species of Carpathian oak-hornbeam forests prevail, but due to the northern exposition, *Quercus dalechampii* is replaced by *Tilia cordata*. Stands on the Nr. 2 site are on acidic Haplic Cambisols, while those at the Nr. 4 site rest on Rendzic Phaeozem.

Relevé 4

Analyzed area: 400 m^2, exp.: N, slope: 10°, date: March 29, 2007; July 11, 2008. Age of a stand: 40–60 years, average height: 15 m, average thickness at chest height: 12–40 cm, cover: E_3 80%, E_2 15%, E_1 60%.

E_3: *Tilia cordata* 3, *Carpinus betulus* 1, *Acer campestre* 1, *Fagus sylvatica* r, *Robinia pseudacacia* r

E_2: *Corylus avellana* 1, *Acer campestre* +, *Cornus sanguinea* +, *Ligustrum vulgare* 1, *Juglans regia* r

E_1: *Corydalis cava* 3, *Viola riviniana* 1, *Viola odorata* 2, *Viola reichenbachiana* +, *Viola alba* +, *Convallaria majalis* 2, *Ranunculus ficaria* ssp. *bulbifer* 2, *Salvia glutinosa* 1, *Hepatica nobilis* 1, *Hedera helix* 1, *Galium odoratum* +, *Lathyrus vernus* +, *Arum alpinum* +, *Ajuga reptans* +, *Carex alba* 2, *Buglossoides purpurocaerulea* +, *Melittis melissophyllum* r, *Carex brizoides* 1, *Euonymus verrucosa* +, *Acer campestre* +, *Clematis vitalba* +, *Polygonatum multiflorum* +, *Pulmonaria obscura* +, *Sanicula europaea* r, *Fraxinus excelsior* 2, *Prunus avium* +, *Corylus avellana* +, *Viburnum lantana* r, *Geum urbanum* +, *Galium aparine* 2.

5. The Malé Karpaty Mts., Bratislava-Devínska Kobyla 3 (DK3) is a loess terrace with the upper part at altitude of 452 m a.s.l. It is covered by a thermophilous oak-hornbeam forest of the *Primulo veris-Carpinetum* association. In the past, some parts of the forest were most likely used as vineyards as indicated by the rocks being artificially gathered into heaps. Although the bedrock is granite, this is not the soil substrate, because varying thick layers of loess have been blown there and admixed with slope sediments of Cambisol.

This soil is classified as Cutanic Luvisols formed on loess and it is well base saturated. The site is located in the area of the National Nature Reserve, where destructive activities have been banned for the last 50 years. However, since it forms part of a hunting district, some feeders for game occur here, and the forest is affected by tourism. The shrub layer is weakly developed, and the 2% cover indicates anthropogenic impact. The stand in its south-western part passes into thermophilous oak forests of the *Corno-Quercetum pubescentis* association, with species including *Quercus virgiliana, Cornus mas* and *Buglossoides purpurocaerulea*. This forms narrow belts of herb layer typical for Pannonian oak-hornbeam forests. Floristic elements of Pannonian oak-hornbeam forests in the studied stands include *Primula veris, Colchicum autumnale, Viola hirta, Sorbus torminalis*, which indicates its classification in the *Primulo veris-Carpinetum* association.

Relevé 5

Analyzed area: 400 m^2, exp.: S, slope: 2°, date: March 29, 2007; July 11, 2008. Age of a stand: 80 years, average height: 23 m, average thickness at chest height: 28 cm, cover: E_3 80%, E_2 2%, E_1 70%.

E_3: *Quercus dalechampii* 5, *Carpinus betulus* 1, *Acer campestre* +, *Prunus avium* +

E_2: *Ligustrum vulgare* +, *Sorbus torminalis* +, *Acer campestre* +, *Crataegus laevigata* r

E_1: *Primula veris* +, *Colchicum autumnale* r, *Viola hirta* 1, *Viola alba* +, *Carex pilosa* 1, *Melica uniflora* 3, *Dactylis polygama* +, *Polygonatum multiflorum* +, *Convallaria majalis* +, *Viburnum lantana* +, *Hedera helix* +, *Pulmonaria obscura* +, *Corydalis cava* 2, *Ranunculus ficaria* ssp. *bulbifer* 2, *Hepatica nobilis* 1, *Arum alpinum* +, *Symphytum tuberosum* +, *Viola reichenbachiana* +, *Viola odorata* 1, *Galanthus nivalis* +, *Geranium robertianum* +, *Chaerophyllum temulum* +, *Alliaria petiolata* +, *Galium aparine* 2.

6. The Malé Karpaty Mts., Bratislava-Dúbravská Hlavica (DH) is on an eastern exposed slope with a stand of the *Querco petraeae-Carpinetum typicum* association, in the area of "Dúbravská Hlavica" close to the Dúbravka suburb, 350 m a.s.l. It is a typical Carpathian oak-hornbeam forest, relatively well-preserved, with good layer cover, characteristic floristic composition and a rich spring aspect. Despite the vicinity of the town and intensive tourism, nitrophytes are not abundant here. This forest stands on acidic Haplic Cambisols.

Relevé 6

Analyzed area: 400 m^2, exp.: E, slope: 5°, date: March 29, 2007; July 11, 2008. Age of a stand: 80–100 years, average height: 25 m, average thickness at chest height: 35 cm, cover: E_3 80%, E_2 30%, E_1 70%, E_0 5%.

E_3: *Quercus dalechampii* 2, *Carpinus betulus* 2, *Fagus sylvatica* 3, *Fraxinus excelsior* 1, *Acer campestre* r, *Acer platanoides* r, *Tilia cordata* +, *Prunus avium* +

E_2: *Tilia cordata* 1, *Fraxinus excelsior* +, *Lonicera xylosteum* +, *Ulmus minor* r, *Sambucus nigra* +

E_1: *Carex pilosa* 3, *Melica uniflora* 1, *Hedera helix* 2, *Corydalis cava* 3, *Gagea pratensis* +, *Viola reichenbachiana* 1, *Viola odorata* 2, *Viola alba* +, *Viola riviniana* +, *Ranunculus ficaria* ssp. *bulbifer* 3, *Hepatica nobilis* 1, *Allium ursinum* +, *Galanthus nivalis* +, *Galium odoratum* 1, *Fraxinus excelsior* 1, *Acer platanoides* 1, *Anemone ranunculoides* 2, *Pulmonaria officinalis* 1, *Geranium robertianum* 1, *Acer campestre* +, *Poa nemoralis* +, *Rubus fruticosus* agg.+, *Salvia glutinosa* +, *Polygonatum latifolium* +, *Polygonatum multiflorum* +, *Crataegus laevigata* +, *Lonicera xylosteum* +, *Impatiens parviflora* +, *Fallopia convolvulus* +, *Prunus spinosa* r, *Rosa canina* agg. r, *Ligustrum vulgare* r, *Euonymus europaea* r, *Melittis melissophyllum* r, *Lathyrus vernus* 1, *Alliaria petiolata* +, *Torilis japonica* r, *Geum urbanum* 1, *Anthriscus sylvestris* r, *Ajuga reptans* r, *Impatiens parviflora* +, *Carex muricata* r, *Arum alpinum* +, *Lathraea squamaria* r.

7. The Malé Karpaty Mts., Bratislava-Koliba (KO) is a commercially used suburban forest on the slope plateau in the continuous areal with south-western part of the Malé Karpaty Mts. broad-leaved forests at 380 m a.s.l. It belongs to the *Querco petraeae-Carpinetum melicetosum uniflorae* subassociation. The stand originated from the seeds of valuable oaks, and hornbeam was removed as an undesirable tree. It lies on a Haplic Cambisol, which is the most acidic of all analyzed soils with pH 2.94 (Table 2).

The herb layer has only 20–30% cover, and this is most likely because of the low supply of nutrients in the soil. The predominance of *Melica uniflora* grass in the herb layer is not a natural phenomenon, but caused by synanthropization. The low herb layer cover accentuates the absence of nutrient plants, while accumulated litter and soil acidity are considered to be responsible for the decrease in many species of evertebrates and their population density. It is almost certain that acidic rains have also played some role here.

Relevé 7

Analyzed area: 400 m^2, exp.: SW, slope: 1–2°, moderately undulated relief, dates: May 21, 2007; July 11, 2008. Age of a stand: 90–100 years, average height: 27 m, average thickness at chest height: 35–40 cm, cover: E_3 70%, E_2 35%, E_1 20–30%, E_0 1%.

E_3: *Quercus dalechampii* 4, *Carpinus betulus* +, *Tilia cordata* +

E_2: *Tilia cordata* 1, *Carpinus betulus* 1, *Sambucus nigra* 3, *Ulmus minor* r, *Sorbus torminalis* r

E_1: *Melica uniflora* 3, *Viola reichenbachiana* +, *Pulmonaria officinalis* +, *Lathyrus vernus* +, *Symphytum tuberosum* +, *Melica nutans* +, *Quercus dalechampii* +, *Hedera helix* 2, *Polygonatum odoratum* r, *Convallaria majalis* 1, *Galium odoratum* +, *Rubus fruticosus* agg. 1, *Carex pilosa* +, *Lilium martagon* +, *Dactylis polygama* 1, *Poa nemoralis* +, *Cruciata glabra* +, *Vincetoxicum hirundinaria* +, *Mycelis muralis* +, *Prunus avium* +, *Carpinus betulus* +, *Geranium robertianum* +, *Impatiens parviflora* 2, *Galeopsis pubescens* +, *Sambucus nigra* +, *Crataegus monogyna* +, *Fraxinus excelsior* r, *Ranunculus ficaria* ssp. *bulbifer* 1, *Anemone ranunculoides* +, *Ajuga reptans* +.

8. The Malé Karpaty Mts., Bratislava-Briežky (BR) is a managed suburban broad-leaved forest of a moderate slope in the continuous area with the south-western part of the Malé Karpaty Mts. at 340 m a.s.l. It belongs to the *Querco petraeae-Carpinetum typicum* association, and it closely resembles the locality Bratislava-Koliba in structure, floristic composition, ecology, and also management. The oaks originated from seeds here, while the hornbeams regenerated by sprouting. A high abundance of *Acer pseudoplatanus* is obvious in the shrub layer. Strongly acidic Haplic Cambisol also occurs here, with a high C:N disproportion characteristic of strongly acidic soils, with lowest sorption saturation of 13%. This accounts for the lowest nutrient content and the high 19.67% content of acidic humus. These adverse soil properties contribute to the low 30% herb layer cover, and the combination of all these factors is certainly reflected in diminished species diversity and population size of the studied evertebrates.

Relevé 8

Analyzed area: 400 m^2, exp.: SE, slope: 10°, dates: May 21, 2007; July 11, 2008. Age of a stand: 80–100 years, average height: 25 m, average thickness at chest height: 32 cm, cover: E_3 75%, E_2 30%, E_1 30%, E_0 1%.

E_3: *Quercus dalechampii* 4, *Carpinus betulus* 1, *Tilia cordata* +

E_2: *Tilia cordata* 2, *Acer pseudoplatanus* 3, *Acer platanoides* +, *Carpinus betulus* +, *Sambucus nigra* +

E_1: *Carex pilosa* 2, *Melica uniflora* 1, *Stellaria holostea* 1, *Convallaria majalis* 1, *Hedera helix* +, *Viola reichenbachiana* +, *Polygonatum odoratum* +, *Polygonatum latifolium* +, *Lathyrus vernus* +, *Rubus hirtus* agg. +, *Carpinus betulus* +, *Galium odoratum* +, *Dryopteris filix-mas* r, *Dryopteris carthusiana* r, *Geranium robertianum* +, *Crataegus monogyna* +, *Fallopia convolvulus* +, *Lamiastrum montanum* +, *Impatiens parviflora* 3, *Anthriscus sylvestris* +, *Rubus caesius* 2, *Fagus sylvatica* juv. +, *Festuca gigantea* +, *Alliaria petiolata* +, *Galeopsis pubescens* +, *Quercus dalechampii* 1, *Ulmus minor* +, *Tilia cordata* +, *Prunus avium* +, *Acer platanoides* +, *Acer pseudoplatanus* +, *Acer campestre* +, *Sambucus nigra* +.

The nomenclature of vascular plants complies with Ehrendorfer (1973), and phytocoenoses were analyzed according to the Central-European Zürich-Montpellier school (Braun-Blanquet 1964).

Some soil properties and floristic composition of these oak-hornbeam forests and linden-maple scree forests were compared with those in the south-western part of the Malé Karpaty Mts. (Zlinská et al. 2005).

References

Braun-Blanquet, J., 1964: Pflanzensoziologie. Grundzüge der Vegetationskunde. 3 Aufl. Springer Verlag, Wien-New York, 866 pp.

Ehrendorfer, E., 1973: Liste der Gefässpflanzen Mitteleuropas. G. Fischer Verlag, Stuttgart, 320 pp.

Holec, P., 1997: Climate (in Slovak). In: Feráková, V., Kocianová, E. (eds), Vegetation, Geology and Paleontology of Devínska Kobyla. APOP, Bratislava, p. 25.

Hraško, J., Červenka, L., Facek, Z., Komár, J., Pospíšil, F., Sirový, V., 1962: Soil analyses (in Slovak). SVPL, Bratislava, 342 pp.

Lackovičová, A., 1977: Lichens of Malé Karpaty Mts. (in Slovak). Acta Ecol., 6: 1–107.

Michalko, J., Berta, J., Magic, D., 1986: Geobotanical map of Czechoslovak Socialistic Republic. Slovak Socialist Republic. Text part (in Slovak). VEDA, Bratislava, 168 pp.

Petrovič, Š. (ed.), 1968: Climatic and phenological characteristics of Western Slovakia (in Slovak). Hydrometeorologický ústav, Praha, 343 pp.

Petrovič, Š., 1972: Weather and climate (in Slovak). In: Lukniš, M. (ed.), Slovakia 2. Nature. Obzor, Bratislava, p. 203–282.

Šály, R., Bedrna, Z., Bublinec, E., Čurlík, J., Fulajtár, E., Gregor, J., Hanes, J., Juráni, B., Kukla, J., Račko, J., Sobocká, J., Šurina, B., 2000: Morphogenetic soil classification system of Slovakia (in Slovak). VÚPOP in Bratislava, Societas pedologica slovaca, 76 pp.

Tarábek, K., 1980: Map 43. Climatic-geographical types (in Slovak). In: Mazúr, E. (ed.), Atlas of Slovak Socialist Republic. Geografický ústav SAV, Bratislava, p. 64.

Walter, H., 1955: Die Klimagramme als Mittel zur Beurteilung der Klimaverhältnisse für ökologische, vegetationkundliche und landwirtschaftliche Zwecke. Sonderdruck aus Berichten der D. Bot. Gesellschaft, 68: 331–344.
Zlinská, J., Šomšák, L., Holecová, M., 2005: Ecological characteristics of the studied forest communities of an oak-hornbeam tier in SW Slovakia. Ekológia (Bratislava), Vol. 24, Supplement 2/2005: 3–19.

Table 2. The survey of pedological variables at the study sites.

Study site/ horizon	Soil type by WRB06*, sign.	pH/ H_2O	pH/ KCl	% C	% N	C:N	% Cox % humus	SOB	EA	CEC	% BS
								(mval/100 g)			
1. Horský park	Haplic Cambisols KMm[a]										
Oo (Oof+Ooh)-horizon +2–0 cm		5.36	4.79	10.80	1.24	8.71	18.62	31.20	7.40	38.60	81.00
Ao-horizon 0–5 cm		4.31	3.56	5.40	0.72	7.50	9.31	4.80	11.00	15.80	30.00
2. Mlynská dolina	Haplic Cambisols KMm[a]										
Oo (Oof+Ooh)-horizon +2–0 cm		4.36	3.82	9.00	1.08	8.33	15.52	18.40	13.80	32.20	57.00
Ao-horizon 0–5 cm		3.81	3.22	8.20	0.88	9.32	14.14	5.20	14.00	19.20	27.00
3. Devínska Kobyla 1**	Haplic Cambisols KMm[a]										
Oo (Oof+Ooh)-horizon +2–0 cm		4.66	4.00	8.80	0.38	23.16	15.17	23.40	12.30	35.70	66.00
Ao-horizon 0–5 cm		4.12	3.07	1,40	0.29	4.83	2.41	5.00	11.30	16.30	31.00
4. Devínska Kobyla 2**	Rendzic Phaeozem RAm										
Oo (Oof+Ooh)-horizon +2–0 cm		7.32	6.88	10.00	1.04	9.62	17.24	98.20	0.70	98.90	99.00
Amc-horizon 0–5 cm		7.47	7.11	3.60	0.41	8.78	6.21	99.40	0.50	99.90	99.00
5. Devínska Kobyla 3**	Cutanic Luvisols HMm										
Oo (Oof+Ooh)-horizon +2–0 cm		5.64	4.98	7.60	1.08	7.04	13.10	42.00	7.20	49.20	85.00
Aoq-horizon 0–5 cm		5.35	4.27	3.00	0.60	5.00	5.17	14.00	6.40	20.40	69.00
6. Dúbravská Hlavica	Haplic Cambisols KMm[a]										
Oo (Oof+Ooh)-horizon +2–0 cm		4.13	3.65	12.00	0.60	20.00	20.69	22.60	16.70	39.30	58.00
Ao-horizon 0–5 cm		3.90	3.07	2.00	0.21	9.52	3.45	7.80	14.10	21.90	36.00
7. Bratislava-Koliba	Haplic Cambisols KMm[a]										
Oo (Oof+Ooh)-horizon +2–0 cm		3.70	3.07	18.00	1.22	14.75	31.03	17.00	19.40	36.40	47.00
Ao-horizon 0–5 cm		3.65	2.94	4.70	0.39	12.05	8.10	5.80	13.50	19.30	30.00
8. Briežky	Haplic Cambisols KMm[a]										
Oo (Oof+Ooh)-horizon +2–0 cm		3.80	3.28	26.20	1.14	22.98	45.17	19.40	18.70	38.10	51.00
Ao-horizon 0–5 cm		3.73	3.12	5.90	0.30	19.67	10.17	1.40	9.30	10.70	13.00

Explications: [a] acidic, * according to comparison in Šály et al. (2000) and IUSS Working Group WRB. 2006. World reference base for soil resources 2006. World Soil Resources Reports No. 103. FAO, Rome, ** National Nature Reserve, SOB – sum of exchangeable bases, EA – exchangeable acidity, CEC – cation exchangeable capacity, BS – base saturation.

3. Epigeic microfauna

3.1. Active naked amoebae (Amoebozoa: Lobosa, Conosa)

Martin Mrva

Terrestrial habitats are considered to be specific freshwater ecosystems since the active stages of protists always depend on presence of water which has a substantial importance in the species diversity (Bamforth 1973, 1980, Finlay et al. 2000). The leaf litter and mosses provide specific life conditions particularly by an extraordinary high richness of the organic matter in various stages of decomposition processes. That makes these habitats an interesting place for study of the protists diversity.

Naked amoebae include freshwater species with high adaptation ability to invade various soil habitats (Smirnov, Brown 2004), where they play a role of important grazers of bacteria and fungi (Bamforth 1973). In previous studies, a relatively high diversity of ciliates and naked amoebae was recorded in mosses and leaf litter (Mrva 2005b, Tirjaková 2005, Tirjaková et al. 2002).

Modern studies of diversity of naked amoebae focused mainly on water habitats either to freshwater (Smirnov, Goodkov 1996) or sea (Butler, Rogerson 2000). Although the quantity of amoebae in terrestrial habitats has been analyzed (Singh 1946, Bischoff, Anderson 1998, Anderson 2000) and recently Brown, Smirnov (2004) brought results from a study on species of Gymnamoebia in soil, their systematic diversity in various terrestrial habitats remains poorly known. In our territory, mosses and leaf litter have been studied scarcely or marginally by Bartoš (1940, 1947, 1949, 1963), Ertl (1955), Matis et al. (1997), Matis, Mrva (1998). Recently Mrva, Matis (2000) and Mrva (2005a, b) published some further records of species in forest terrestrial habitats.

The samples of leaf litter and mosses were collected monthly in the year 2000 in three sites in oak-hornbeam forests on the territory of Bratislava: Briežky, Devínska Kobyla, Koliba (Table 3).

The sampled material was analyzed according to modification of method used for ciliates (e.g. Foissner 1987, Aescht, Foissner 1995): dry sampled material of moss was flooded with distilled water and incubated 5 days on undirected light and laboratory temperature. The amoebae were directly examined in the suspension pipetted from the flooded sample. Observations were made using the Nikon Labophot microscope with phase contrast optics. Identification of amoebae was performed on the base of morphological criteria according to Page (1988, 1991) and Smirnov, Brown (2004).

Naked amoebae occurred in all the 28 samples examined. Out of the subphylum Lobosa, 19 taxa identified into the species level and more than five taxa identified into the genus level were recorded. Out of the subphylum Conosa, one species identified into the genus level was noted (Table 4). Unidentified heterolobosean amoebae were found at all sites under examination.

Table 3. Studied localities.

Locality	Date of sampling						
Briežky	12.4.2000, 29.4.2000	9.6.2000	25.7.2000	30.8.2000	28.9.2000	26.10.2000	–
Devínska Kobyla	7.4.2000	14.6.2000	26.7.2000	31.8.2000	20.9.2000	–	7.11.2000
Koliba	29.4.2000	–	–	–	–	–	–

The diversity at the study sites varied noticeably from 4 taxa recorded on Koliba, and 9 taxa recorded on Briežky, to 23 taxa noted on Devínska Kobyla locality. The leaf litter with 21 taxa was richer in diversity of naked amoebae than the mosses where 18 species were recorded.

The highest diversity appeared in the family Thecamoebidae (7 species). However, from this family only two species, *Thecamoeba quadrilineata* and *Thecamoeba terricola*, were recorded in all localities. Further species recorded in all studied sites was *Korotnevella stella* from the family Paramoebidae.

Since amoebae were identified on the base of light microscopical observations, the determination depended on the keys based on morphological criteria (Page 1988, 1991, Smirnov, Brown 2004). The results were consulted with works containing descriptions of trophozoites of naked amoebae published before, but also after Page's monographs (Page 1969a, b, 1977, 1983, Smirnov, Goodkov 1994, Smirnov 1999). The classification is based on Smirnov et al. (2011).

In all three studied localities very different species numbers were obtained. It can be related to unequal number of samples under examination, and therefore a low number of recorded species in the Koliba locality could be explained by low number of examined samples. In total, more than 25 taxa of naked amoebae were recorded. This is a relatively high diversity in comparison with published data so far. Earlier authors detected low numbers of species in various terrestrial habitats. Bartoš (1940) identified 6 species of naked amoebae in mosses from Karpaty Mts. (Slovakia), 2 species from mosses near Prague (Czech Republic) (Bartoš 1947), 2 species in Šumava mosses (Czech Republic) (Bartoš 1949), and 2 species of naked amoebae in moss from China (Bartoš 1963). Fantham, Porter (1945) reported 12 species of naked amoebae in various mosses in Canada. Further data came from Ertl (1955) with 2 species from moss of the peat-bog Bór (Slovakia), and from Matis et al. (1997) who recorded 4 species from mosses of Slovenský raj (Slovakia). Later, Matis, Mrva (1998) found 6 species of ameboid protists in mosses in Bratislava (Slovakia). Recently Brown, Smirnov (2004) identified a high diversity of 48 species in grassland soil, and Mrva (2005b) noted 32 taxa of active naked amoebae in mosses of various localities in Malé Karpaty Mts.

Until now the differences between the diversities of gymnamoebae in soil and freshwater habitats remain poorly understood. In general, there are opinions about large overlap and similarity in both environments (Page 1991, Brown, Smirnov 2004, Smirnov, Brown 2004, Mrva 2005a), and the diversity noted in the present study also supports this hypothesis. Similarly like it is known from other works (Page 1977, Mrva 2005a, b), species of the family Thecamoebidae predominated in examined samples of leaf litter and soil. In the present study, 7 species were noted, and this number is congruent with previous records by Mrva (2005a) who found 9 species in mosses of Malé Karpaty Mts. (Western Slovakia). Similarly, other recorded amoebae are known both from soil and freshwater habitats (e.g. Page 1991, Smirnov, Goodkov 1996, Matis et al. 1997), and due to insufficient knowledge it is practically impossible to differentiate species typical for terrestrial and for freshwater habitats.

References

Aescht, E., Foissner, W., 1995: Microfauna. In: Schinner, F., Öhlinger, R., Kandeler, E., Margesin, R. (eds), Methods in soil biology. Springer, Berlin-Heidelberg-New York, p. 316–337.

Anderson, O.R., 2000: Abundance of terrestrial gymnamoebae at a northeastern U. S. site: A four year study, including the El Nino winter. J. Eukaryot. Microbiol., 47: 148–155.

Bamforth, S.S., 1973: Population dynamics of soil and vegetation Protozoa. Amer. Zool., 13: 171–176.

Bamforth, S.S., 1980: Terrestrial Protozoa. J. Protozool., 27: 33–36.
Bartoš, E., 1940: Studien über die moosbewohnenden Rhizopoden der Karpaten. Arch. Protistenkd., 94: 93–160.
Bartoš, E., 1947: The moss-dweling Rhizopoda of the neighbourhood of Prague (in Czech). Sb. Kl. Přír. v Brně, 28: 1–10.
Bartoš, E., 1949: Microscopical fauna of the Šumava-mosses. – I. Mosses from neighbourhood of Lac-Plešné (in Czech). Acta Soc. Zool. Bohemoslov., 13: 10–29.
Bartoš, E., 1963: Die Rhizopoden einiger Moosproben aus China. Acta Soc. Zool. Bohemoslov., 27: 85–96.
Bischoff, P.J., Anderson, O.R., 1998: Abundance and diversity of gymnamoebae at varying soil sites in northeastern U.S.A. Acta Protozool., 37: 17–21.
Brown, S., Smirnov, A.V., 2004: Diversity of gymnamoebae in grassland soil in southern Scotland. Protistology, 3: 191–195.
Butler, H.G., Rogerson, A., 2000: Naked amoebae from benthic sediments in the Clyde Sea Area, Scotland. Ophelia, 53: 37–54.
Ertl, M., 1955: Rhizopoda of the peat-bog Bór (Orava) (in Slovak). Práce II. sekcie SAV, 1, 12: 1–39.
Fantham, H.B., Porter, A., 1945: The microfauna, especially the Protozoa, found in some Canadian Mosses. Proc. Zool. Soc., 115: 97–174.
Finlay, B.J., Black, H.I.J., Brown, S., Clarke, K.J., Esteban, G.F., Hindle, R.M., Olmo, J.L., Rollett, A., Vickerman, K., 2000: Estimating the growth potential of the soil protozoan community. Protist, 151: 69–80.
Foissner, W., 1987: Soil Protozoa: fundamental problems, ecological significance, adaptations in ciliates and testaceans, bioindicators and guide to the literature. Prog. Protistol., 2: 69–212.
Matis, D., Mrva, M., 1998: New amoebae for fauna of Slovakia (in Slovak). Folia faun. Slovaca, 3: 1–8.
Matis, D., Tirjak, J., Tirjaková, E., 1997: Synopsis of amoebae of Slovakia (in Slovak). Folia faun. Slovaca, 2: 1–6.
Mrva, M., 2005a: Diversity of active gymnamoebae (Rhizopoda, Gymnamoebia) in mosses of the Malé Karpaty Mts. (Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 51–58.
Mrva, M., 2005b: Amoebae (Rhizopoda) (in Slovak). In: Majzlan, O. (ed.), Fauna of Devínska Kobyla. APOP, Bratislava. p. 17–19.
Mrva, M., Matis, D., 2000: Rhizopoda in leaf-litter of some localities of oak-hornbeam forests in the Malé Karpaty Mts. (Western Slovakia) (in Slovak). Folia faun. Slovaca, 5: 1–9.
Page, F.C., 1969a: *Hartmannella limax*: the original limax amoeba? Trans. Am. Microsc. Soc., 88: 199–204.
Page, F.C., 1969b: *Platyamoeba stenopodia* n. g., n. sp., a freshwater amoeba. J. Protozool., 16: 437–441.
Page, F.C., 1977: The genus *Thecamoeba* (Protozoa, Gymnamoebia). Species distinctions, locomotive morphology, and protozoan prey. J. nat. Hist., 11: 25–63.
Page, F.C., 1983: Three freshwater species of *Mayorella* (Amoebida) with a cuticle. Arch. Protistenkd., 126: 201–221.
Page, F.C., 1988: A new key to freshwater and soil Gymnamoebae. Freshwater Biological Association, Ambleside, 122 pp.
Page, F.C., 1991: Nackte Rhizopoda. In: Page, F.C., Siemensma, F.J. (eds), Nackte Rhizopoda und Heliozoea. G. Fischer Verlag, Stuttgart-New York, p.1–170.
Singh, B.N., 1946: A method of estimating the numbers of soil Protozoa, especially amoebae, based on their differential feeding on bacteria. Ann. appl. Biol., 33: 112–119.
Smirnov, A.V., 1999: *Korotnevella diskophora* n. sp. (Gymnamoebia, Paramoebidae) – small freshwater amoeba with peculiar scales. Protistology, 1: 30–33.
Smirnov, A.V., Brown, S., 2004: Guide to the methods of study and identification of soil gymnamoebae. Protistology, 3: 148–190.
Smirnov, A.V., Goodkov, A.V., 1994: Freshwater gymnamoebae with a new type of surface structure *Paradermamoeba valamo* and *Paradermamoeba levis* sp. n. (Thecamoebidae), and notes on the diagnosis of the family. Acta Protozool., 33: 109–115.
Smirnov, A.V., Goodkov, A.V., 1996: Systematic diversity of gymnamoebae in the bottom sediments of a freshwater lake in Karelia (Lobosea, Gymnamoebia). Zoosyst. Rossica, 4: 201–203.
Smirnov, A.V., Chao, E., Nassonova, E.S., Cavalier-Smith, T., 2011: A revised classification of naked lobose amoebae (Amoebozoa: Lobosa). Protist, 162: 545–570.
Tirjaková, E., 2005: Ciliates (Ciliophora) (in Slovak). In: Majzlan, O. et al., Fauna of Devínska Kobyla. APOP, Bratislava, p. 20–23.
Tirjaková, E., Mrva, M., Hlúbiková, D., 2002: Ciliophora and Rhizopoda in soil, leaf-litter and mosses of oak-hornbeam forests in the Malé Karpaty Mts. (Western Slovakia). In: Tajovský, K., Balík, V., Pižl, V. (eds), Studies on soil fauna in Central Europe. ISB AS CR, České Budějovice, p. 233–240.

Table 4. Naked amoebae recorded from localities.

Taxon	B	B	DK	DK	K	K
	l	m	l	m	l	m
LOBOSA						
Amoebidae						
Deuteramoeba algonquinensis (Baldock, Rogerson & Berger, 1983) Page, 1987			+			
Deuteramoeba mycophaga (Pussard, Alabouvette, Lemaitre & Pons, 1980) Page, 1988			+	+		
Trichamoeba sinuosa Siemensma & Page, 1986			+			
Hartmannellidae						
Saccamoeba sp.			+			
Saccamoeba limax (Dujardin, 1841) Page, 1974			+	+		
Leptomyxidae						
Rhizamoeba australiensis (Chakraborty & Pussard, 1985) Page, 1988			+	+		
Vermamoebidae						
Vermamoeba vermiformis (Page, 1967) Smirnov & Cavalier-Smith, 2011	+		+	+		
Paramoebidae						
Korotnevella diskophora Smirnov, 1999			+			
Korotnevella stella (Schaeffer, 1926) Goodkov, 1988	+		+	+	+	
Vannellidae						
Vannella spp.			+	+		
Mayorellidae						
Mayorella penardi Page, 1972	+		+	+		
Mayorella vespertilioides Page, 1983			+			
Dermamoebidae						
Dermamoeba sp.		+				
Dermamoeba granifera (Greeff, 1866) Page & Blakey, 1979				+		
Dermamoeba minor (Pussard, Alabouvette & Pons, 1979) Page, 1988			+	+		
Paradermamoeba levis Smirnov & Goodkov, 1994	+		+			
Thecamoebidae						
Sappinia sp.			+	+		
Stenamoeba stenopodia (Page, 1969) Smirnov, Nassonova, Chao & Cavalier-Smith, 2007	+		+	+		
Thecamoeba quadrilineata (Carter, 1856) Lepşi, 1960	+	+	+	+		+
Thecamoeba similis (Greeff, 1891) Lepşi, 1960						+
Thecamoeba sphaeronucleolus (Greeff, 1891) Schaeffer, 1926			+			
Thecamoeba striata (Penard, 1890) Schaeffer, 1926			+	+		
Thecamoeba terricola (Greeff, 1866) Lepşi, 1960		+	+		+	
Acanthamoebidae						
Acanthamoeba spp.	+	+	+	+		
CONOSA						
Filamoebidae						
Flamella sp.				+		
Total	7	4	21	15	2	2

Notes: B – Briežky, DK – Devínska Kobyla, K – Koliba; l – leaf litter, m – moss.

3.2. Ciliates (Alveolata: Ciliophora)

Eva Tirjaková, Peter Vďačný

An increased attention has been recently given to research of terrestrial ciliates in Slovakia. In particular, a comprehensive survey of ciliates living in soil and leaf-litter from several localities in the area of the Malé Karpaty Mts. was conducted. Faunistic and ecological data on terrestrial ciliates were published elsewhere (Tirjaková et al. 2002, Tirjaková 2005, Vďačný et al. 2005, Vďačný, Tirjaková 2007). Diversity and ecology of ciliates living in decaying wood mass, especially from Western Slovakia, were investigated in detail by Bartošová, Tirjaková (2005, 2008), Bartošová et al. (2005, 2007), and Tirjaková, Bartošová (2004). Ciliates from tree-holes in the territory of the Malé Karpaty Mts. were thoroughly inspected by Tirjaková, Vďačný (2005). Tirjaková et al. (2002) and Tirjaková, Mrva (2005) studied ciliates and naked amoebas in leaf litter and soil from the Little Carpathians. In addition, several new and little known ciliate species were described from the surroundings of Bratislava (Tirjaková et al. 2002, Tirjaková, Bartošová 2004, Tirjaková, Vďačný 2004, Vďačný, Tirjaková 2006a, 2006b, 2007, 2009, Vďačný et al. 2006, 2007). However, only two studies on ciliates directly from the region of Bratislava city are available. Specifically, Chrenková, Tirjaková (2000) investigated ciliates living in terrestrial mosses, while Andelová, Tirjaková (2000) examined ciliates in the underlying moss-covered stratum. Based on the moss ciliate communities from Bratislava, Tirjaková, Matis (1982, 1985) also highlighted the possibility of their use for assessing the impact of air pollution.

Samples of leaf-litter and soil (A horizon) were collected from the territory and surroundings of Bratislava in the following localities in year 2000: Briežky (19 samples), Devínska Kobyla 1 (17 samples), Devínska Kobyla 2 (15 samples), and Koliba (17 samples). Altogether, 68 samples were obtained and processed in that year. Apart from this, another 6 samples containing moss, decaying wood mass, leaf litter, and soil were collected from two localities, Mlynská dolina and Horský park, in the town of Bratislava in year 2005.

Samples were collected from an area of about 10 x 10 cm into plastic bags using standard methods. Collected material was cultivated with the non-flooded Petri dish method under laboratory conditions according to the protocol of Foissner (1991). Samples were inspected for ciliates during the first five days after rewetting. Isolated ciliates were identified in vivo under the light microscope Leica DM 1000 following the standard identification keys. The protargol impregnation techniques of Foissner (1991) and Wilbert (1975) were applied to reveal the ciliary pattern.

In total, 112 ciliate taxa were identified at the study area, whereby the highest diversity were recorded in the localities Devínska Kobyla 2 (72 taxa in leaf litter and 14 taxa in soil) and Devínska Kobyla 1 (68 taxa in leaf litter and 14 taxa in soil). At the locality Koliba, 52 taxa were reported from the leaf litter and 11 taxa from soil, while 47 taxa were found in the leaf litter and 11 taxa in the soil in the site Briežky. A distinctly lower number of species was noted directly in the urban area of Bratislava. Specifically, the locality Horský park harboured 10 taxa in the leaf litter and 11 taxa in the soil, while the site Mlynská dolina housed 12 taxa in the leaf litter, 12 taxa in moss, and 15 taxa in the decaying wood mass. In general, the leaf litter samples represented the species richest habitat, while soil (horizon A) samples harboured the lowest number of species (Table 5).

The highest frequencies were recorded in the following species: *Leptopharynx costatus* (91%), *Gonostomum affine* (87%), *Sathrophilus muscorum* (75%), and *Homalogastra setosa*

(44%). The species richest genus was *Colpoda* with 12 taxa, whereby the most frequent species were *C. inflata* (51%), *C. maupasi* (47%), and *C. cucullus* (41%).

The studied area belongs to very valuable ones with respect to the ciliate fauna. Out of the total number of 112 taxa, 13 species were recorded in the territory of Slovakia for the first time according to the Database of Slovak Fauna (Matis et al. 1996). These included *Anteholosticha sigmoidea, Colpoda ecaudata, C. elliotti, Enchelys terricola, Epispathidium terricola, Frontonia solea, F. terricola, Microdiaphanosoma arcuatum, Nivaliella plana, Orthokreyella schiffmanni, Parabryophrya penardi, Spathidium claviforme*, and *Thylakidium typicum*.

The structure of the ciliate community in the studied localities corresponded well with that from soil, leaf litter, and decaying wood mass (e.g., Foissner 1987, Foissner et al. 2002, Tirjaková 2005, Bartošová, Tirjaková 2005, 2008). With respect to the autochthonism of ciliates to terrestrial habitats, Foissner (1987) provided 32 typical terrestrial genera that indicate a long and independent evolution of terrestrial and freshwater fauna. Many representatives of these genera were also observed in our samples.

Most species were recorded in the sites Devínska Kobyla 1 and 2 as well as in the localities Briežky and Koliba. However, species diversities from these localities cannot be compared with those from Mlynská dolina and Horský park because of the different number of samples collected (68 samples in the four former localities vs. 6 samples in the two latter localities). On the other hand, average numbers of species detected per sample are similar between all examined localities. No dependence between forest fragmentation and number of ciliate species was revealed, unlike in other groups investigated in the present study. Microclimatic factors along with food organisms very likely played much more important role with respect to the ciliate diversity, as typical for protists in general.

The species richest genus was *Colpoda* with 12 taxa recorded. Representatives of this genus belong to the r-selective ones. They have specific adaptations to the changing environmental conditions, since they are rapidly able to encyst and excyst, as well as they can quickly reproduce in cysts (Foissner 1987). This was also confirmed by our results from other sites in Bratislava (e.g., Andelová, Tirjaková 2000, Chrenková, Tirjaková 2000) and in the Little Carpathians (e.g. Tirjaková 2005). The genus *Colpoda* is over-represented in terrestrial habitats, in general. For instance, Foissner et al. (2002) reported 17 species of this genus in soils from Namibia, and Bartošová, Tirjaková (2005) recorded 10 species in the decaying wood mass.

Significant differences in the species number were observed between moss, leaf litter and decaying wood mass samples on one hand, and soil (horizon A) samples on the other one. The former three habitats were usually inhabited by a species rich ciliate community, and typically had a similar number of species. By contrast, the soil samples contained a comparatively poor spectrum of taxa whose number usually did not exceed 12 per sample and mostly spanned a range of 4–6. These differences are mainly caused by the food supply, as in leaf litter, decaying wood mass, and mosses there is a permanent and massive degradation of organic material. This results in a massive development of bacteria that represent the essential food base for most terrestrial ciliates. The examined soil samples did not contain root systems, which could form the basis for the development of bacteria and hence also for the ciliate communities. Lower numbers of taxa in the soil horizon A were reported also in other previous works (Foissner 1987, Andelová, Tirjaková 2000, Foissner et al. 2002).

It can be concluded that terrestrial habitats of the surroundings of Bratislava are very valuable because they harbour a comparatively diverse ciliate community. Moreover, out of the 112 recorded species, 13 were noted for the first time in the territory of Slovakia.

References

Andelová, K., Tirjaková, E., 2000: Ciliates (Ciliophora) of the underlying moss-covered stratum on the region of Bratislava city (in Slovak). Folia faunistica Slovaca, 5: 27–36.

Bartošová, P., Tirjaková, E., 2005: Selected ecological characteristics of ciliate communities (Protozoa, Ciliophora) in decaying wood mass in the Malé Karpaty Mountains. Ekológia (Bratislava), 24, Supplement 2/2005: 37–50.

Bartošová, P., Tirjaková, E., 2008: Diversity and ecology of ciliates (Alveolata: Ciliophora) living in the bark and decaying wood mass in Slovakia. Acta Protozool., 47: 173–187.

Bartošová, P., Tirjaková, E., Holecová, M., 2005: The influence of selected factors on the communities of ciliates (Protozoa, Ciliophora) in the decaying wood mass. 8th Central European Workshop on Soil Zoology, České Budějovice, Czech Republic, April 20-22, p. 11.

Bartošová, P., Tirjaková, E., Holecová, M., 2007: The influence of selected factors on the communities of ciliates (Protozoa, Ciliophora) in decaying woody matter. In: Tajovský, K., Schlaghamerský, V., Pižl, V. (eds), Studies on soil fauna in Central Europe, ISB AS CR, České Budějovice, p. 1–5.

Chrenková, Z., Tirjaková, E., 2000: Ciliates (Ciliophora) from the dry mosses of Bratislava (Slovakia) (in Slovak). Folia faunistica Slovaca, 5: 37–48.

Foissner, W., 1987: Soil protozoa: fundamental problems, ecological significance, adaptations in ciliates and testaceans, bioindicators, and guide to the literature. Progr. Protistol., 2: 69–212.

Foissner, W., 1991: Basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa. Eur. J. Protistol., 27: 313–330.

Foissner, W., Agatha, S., Berger, H., 2002: Soil ciliates (Protozoa, Ciliophora) from Namibia (Southwest Africa), with emphasis on two contrasting environments, the Etosha Region and the Namib Desert. Denisia, 5: 1–1063.

Matis, D., Tirjaková, E., Stloukal, E., 1996 : Ciliophora in the Database of Slovak Fauna (in Slovak). Folia faunistica Slovaca, 1: 3–38.

Tirjaková, E., 2005: Ciliates (Ciliophora) (in Slovak). In: Majzlan O. (ed.), Fauna of Devínska Kobyla. APOP, Bratislava, p. 20–23.

Tirjaková, E., Bartošová, P., 2004: First records of ciliates (Protozoa: Ciliophora) in the decaying wood mass in Slovakia (Protozoa: Ciliophora) (in Slovak). Folia faunistica Slovaca, 9: 15–23.

Tirjaková, E., Matis, D., 1982: Utilization of ciliates (Ciliata) from the dry mosses in bioindication of environmental changes (in Slovak). In: Animals as indicator of environmental changes, Bratislava. p. 111–117.

Tirjaková, E., Matis, D., 1985: Ciliates of dry mosses of Bratislava and their utilization for indication of environmental changes (in Slovak). In: Zoocoenoses of urban and suburban areas with emphasis on conditions of Bratislava. Bratislava, p. 7–10.

Tirjaková, E., Mrva, M., 2005: Notes on the ecological characteristics of chosen protozoan groups in leaf litter and mineral layer of soil. In: Tajovský, K., Schlaghamerský, J., Pižl V. (eds), Contributions to soil zoology in Central Europe, ISB AS CR, České Budějovice, p. 187–190.

Tirjaková, E., Vďačný, P., 2004: First records of two species of ciliates: *Holostichides chardezi* Foissner, 1987 and *Australocirrus octonucleatus* Foissner, 1988 (Ciliophora: Hypotrichia) in Slovakia (in Slovak). Folia faunistica Slovaca, 9: 25–30.

Tirjaková, E., Vďačný, P., 2005: Ciliate communities (Protozoa, Ciliophora) in tree-holes and influence of selected environmental factors on their structure. Ekológia (Bratislava), 24, Supplement 2/2005: 20–36.

Tirjaková, E., Mrva, M., Hlúbiková, D., 2002: Ciliophora and Rhizopoda in soil, leaf-litter and mosses of oak-hornbeam forests in the Malé Karpaty Mts. (Western Slovakia). In: Tajovský, K., Balík, V., Pižl, V. (eds), Studies on soil fauna in Central Europe, ISB AS CR, České Budějovice, p. 233–240.

Vďačný, P., Tirjaková, E., 2006a: First records of soil ciliates (Protozoa, Ciliophora) from classes Prostomea, Nassophorea, Spirotrichea, and Colpodea in Slovakia. Biologia, Bratislava, 61: 509–516.

Vďačný, P., Tirjaková, E., 2006b. A new soil hypotrich ciliate (Protozoa, Ciliophora) from Slovakia: *Gonostomum albicarpathicum* nov. spec. Eur. J. Protistol., 42: 91–96.

Vďačný, P., Tirjaková E., 2007: Observations on soil haptorid ciliates (Protozoa, Ciliophora) from Slovakia. Biologia, Bratislava, 62: 720–730.

Vďačný, P., Tirjaková, E., 2009: Soil ciliate biota (Protista, Ciliophora) from forest in Little Carpathian Mts. and White Carpathian Mts. (Central Europe). In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Contributions to soil zoology in Central Europe III, ISB AS CR, České Budějovice, p. 163–166.
Vďačný, P., Hlúbiková, D., Tirjaková, E., 2006: *Spathidium seppelti foissneri* nov. subspec., *Spathidium simplinucleatum* nov. stat., and *Dileptus americanus* Kahl, 1931, one new and two poorly known gymnostome ciliates from soils of Slovakia. Eur. J. Protistol., 42: 175–189.
Vďačný, P., Tirjaková, E., Holecová, M., 2005: Succession in the soil communities of gymnostomate ciliates (Ciliophora: Gymnostomatea). 8th Central European Workshop on Soil Zoology, České Budějovice, Czech Republic, April 20-22, p. 72.
Vďačný P., Tirjaková, E., Holecová, M., 2007: Succession in the soil gymnostomate ciliates (Ciliophora, Gymnostomatea) communities in non-flooded Petri dish cultures. In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Studies on soil fauna in Central Europe, ISB AS CR, České Budějovice, p. 189–193.
Wilbert, N., 1975. Eine verbesserte Technik der Protargolimprägnation für Ciliaten. Mikrokosmos, 64: 171–179.

Table 5. Ciliates recorded at the studied localities.

Taxon	MD			HP		KO		BR		DK1		DK2	
	m	d	l	l	s	l	s	l	s	l	s	l	s
Amphisiella acuta Foissner, 1982						+							
Anteholosticha adami (Foissner, 1982) Berger, 2003					+								
Anteholosticha antecirrata Berger, 2006						+	+	+	+	+		+	+
Anteholosticha multistilata (Kahl, 1928) Berger, 2003												+	
Anteholosticha sigmoidea (Foissner, 1982) Berger, 2003										+			
Apospathidium atypicum (Buitkamp & Wilbert, 1974) Foissner, Agatha & Berger, 2002						+							
Arcuospathidium cooperi Foissner, 1996												+	
Arcuospathidium cultriforme scalpriforme (Kahl, 1930) Foissner, 2003						+							
Arcuospathidium muscorum (Dragesco & Dragesco-Kernéis, 1979) Foissner, 1984												+	
Birojimia muscorum (Kahl, 1932) Berger & Foissner, 1986								+		+		+	
Blepharisma hyalinum Perty, 1849				+		+		+		+		+	
Blepharisma steini Kahl, 1932										+			
Bresslaua vorax Kahl, 1931						+							
Bryometopus pseudochilodon Kahl, 1932	+					+				+		+	
Bryometopus sphagni (Penard, 1922) Kahl, 1932								+		+		+	
Bryophyllum tegularum Kahl, 1931												+	
Caudiholosticha gracilis (Foissner, 1982) Berger, 2006								+		+			+
Caudiholosticha sylvatica (Foissner, 1982) Berger, 2003								+		+		+	
Cinetochilum margaritaceum (Ehrenberg, 1831) Perty, 1849			+				+	+		+		+	+
Circinella filiformis (Foissner, 1982) Foissner, 1994	+											+	
Colpoda aspera Kahl, 1926						+							

Table 5. continued

Taxon	MD			HP		KO		BR		DK1		DK2	
	m	d	l	l	s	l	s	l	s	l	s	l	s
Colpoda cucullus (Müller, 1773) Gmelin, 1790		+			+	+	+	+		+		+	
Colpoda ecaudata (Liebmann, 1936), Foissner, Blatterer, Berger & Kohman, 1991												+	
Colpoda edaphoni Foissner, 1980						+		+		+		+	
Colpoda elliotti Bradbury & Outka, 1967												+	
Colpoda henneguyi Fabre-Domergue, 1889		+						+		+		+	
Colpoda inflata (Stokes, 1884) Kahl, 1931	+	+			+	+	+	+		+	+	+	+
Colpoda lucida Greeff, 1888												+	
Colpoda maupasi Enriques, 1908		+	+			+	+	+	+	+		+	+
Colpoda minima (Alekperov, 1985) Foissner, 1993								+		+			
Colpoda steinii Maupas, 1883		+	+		+	+		+	+	+		+	
Colpoda tripartita Kahl, 1931												+	
Cultellothrix atypica (Wenzel, 1953) Foissner & Xu, 2007	+												
Cyrtohymena candens (Kahl, 1932) Foissner, 1989												+	
Cyrtohymena muscorum (Kahl, 1932) Foissner, 1989						+				+			+
Cyrtolophosis acuta Kahl, 1926					+	+				+		+	
Cyrtolophosis major Kahl, 1926								+					
Cyrtolophosis muscicola Stokes, 1885	+	+				+		+		+			
Dimacrocaryon amphileptoides (Kahl, 1931) Jankowski, 1967						+		+		+		+	
Drepanomonas exigua Penard, 1922						+		+				+	
Drepanomonas pauciciliata Foissner, 1986						+		+					
Drepanomonas revoluta Penard, 1922		+		+		+		+		+		+	+
Drepanomonas sphagni Kahl, 1931													+
Engelmanniella mobilis (Engelmann, 1862) Foissner, 1982	+					+						+	
Enchelyodon armatus (Kahl, 1926) Kahl, 1930										+			
Enchelys terricola Foissner, 1987										+			
Epispathidium amphoriforme (Greeff, 1888) Foissner, 1984										+		+	
Epispathidium terricola Foissner, 1987								+		+		+	
Eschaneustyla terricola Foissner, 1982													
Euplotopsis muscicola (Kahl, 1932) Borror & Hill, 1995						+		+		+		+	
Exocolpoda augustini (Foissner, 1987) Foissner, Agatha & Berger, 2002		+											
Frontonia depressa (Stokes, 1886) Kahl, 1931			+			+		+		+		+	
Frontonia parameciiformis Wenzel, 1953												+	
Frontonia solea Foissner, 1987			+	+						+		+	

Table 5. continued

Taxon	MD			HP		KO		BR		DK1		DK2	
	m	d	l	l	s	l	s	l	s	l	s	l	s
Frontonia terricola Foissner, 1987						+						+	
Furgasonia sp. (cf. *trichocystis*)										+			
Gastrostyla steinii Engelmann, 1862								+		+			
Gonostomum affine (Stein, 1859) Sterki, 1878	+	+	+		+	+	+	+	+	+	+	+	+
Grossglockneria acuta Foissner, 1980						+		+	+		+	+	
Hemisincirra gellerti (Foissner, 1982) Foissner in Berger, 2001						+		+	+	+		+	
Hemisincirra interrupta (Foissner, 1982) Foissner in Berger, 2001						+		+			+	+	
Hemisincirra spp.	+				+								
Hemisincirra vermicularis Hemberger, 1985								+					
Homalogastra setosa Kahl, 1926	+		+	+	+	+				+	+	+	+
Chilodonella uncinata (Ehrenberg, 1838) Strand, 1928	+		+	+						+	+	+	
Chilodontopsis muscorum Kahl, 1931										+			
Kahlilembus attenuatus (Smith, 1897) Foissner, Berger & Kohmann, 1994						+		+		+		+	+
Leptopharynx costatus Mermod, 1914	+	+	+	+	+	+	+	+	+	+	+	+	+
Loxophyllum sp.												+	
Microdiaphanosoma arcuatum (Grandori & Grandori, 1934) Wenzel, 1953						+						+	
Microthorax simulans (Kahl, 1926) Kahl, 1931,										+		+	
Neowallackia franzi (Foissner, 1982) Berger, 2010								+				+	
Nivaliella plana Foissner, 1980								+					
Odontochlamys alpestris Foissner, 1981										+			
Odontochlamys convexa (Kahl, 1931) Blatterer & Foissner, 1992												+	
Odontochlamys gouraudi Certes, 1891				+						+		+	
Orthokreyella schiffmanni Foissner, 1984												+	
Oxytricha granulifera Foissner & Adam, 1983								+		+			
Oxytricha setigera Stokes, 1891						+				+	+	+	
Parabryophrya penardi (Kahl, 1931) Foissner, 1985								+		+		+	
Paracineta lauterborni Sondheim, 1929												+	
Phacodinium metschnicoffi (Certes, 1891) Kahl, 1932				+						+			
Plagiocampa difficilis Foissner, 1981										+		+	
Platyophrya spumacola Kahl, 1927		+			+	+		+		+		+	
Platyophrya vorax Kahl, 1926								+		+		+	
Plesiocaryon elongatum (Schewiakoff, 1892) Foissner, Agatha & Berger, 2002		+				+		+	+	+		+	+
Podophrya libera Perty, 1852						+							

Table 5. continued

Taxon	**MD**			**HP**		**KO**		**BR**		**DK1**		**DK2**	
	m	**d**	**l**	**l**	**s**	**l**	**s**	**l**	**s**	**l**	**s**	**l**	**s**
Protocyclidium muscicola (Kahl, 1931) Foissner, Agatha & Berger, 2002		+				+	+	+	+	+		+	
Protocyclidium terricola (Kahl, 1931) Foissner, Agatha & Berger, 2002						+		+		+	+		
Protospathidium vermiforme Foissner, Agatha & Berger, 2002						+				+			
Pseudocohnilembus putrinus (Kahl, 1928) Foissner & Wilbert, 1981												+	
Pseudoholophrya terricola Berger, Foissner & Adam, 1984						+		+		+		+	
Pseudochilodonopsis mutabilis Foissner, 1981	+		+			+				+		+	
Rimaleptus alpinus (Kahl, 1931) Vďačný & Foissner, 2012						+				+		+	
Sathrophilus muscorum (Kahl, 1931) Corliss, 1960			+	+	+	+	+	+		+	+	+	+
Scyphidia sp.						+							
Spathidium claviforme Kahl, 1930										+			
Spathidium hyalinum Dujardin, 1842						+						+	
Spathidium muscicola Kahl, 1930				+		+		+		+			
Spathidium spathula (Müller, 1773) Moody, 1912						+		+		+		+	
Stammeridium kahli (Wenzel, 1953) Wenzel, 1969									+		+	+	
Sterkiella histriomuscorum (Foissner, Blatterer, Berger & Kohmann, 1991) Foissner, Blatterer, Berger & Kohmann, 1991						+		+		+		+	
Tetrahymena edaphoni Foissner, 1986							+					+	
Tetrahymena rostrata (Kahl, 1926) Corliss, 1952		+				+				+	+	+	
Thylakidium typicum Gellért, 1955										+			
Urosoma acuminata (Stokes, 1887) Bütschli, 1889										+		+	
Urosoma macrostyla (Wrzesniowski, 1866) Berger, 1999							+		+	+	+		
Urosomoida agiliformis Foissner, 1982		+				+		+		+	+	+	
Urosomoida agilis (Engelmann, 1862) Hemberger in Foissner, 1982										+			
Vorticellides astyliformis (Foissner, 1981) Foissner, Blake, Wolf, Breiner & Stoeck, 2009			+			+		+		+		+	
Vorticella infusionum complex										+			
Woodruffia rostrata Kahl, 1931						+							
Total	12	15	12	10	11	52	11	47	11	68	14	72	14

Notes: BR – Briežky, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, HP – Horský park, KO – Koliba, MD – Mlynská dolina; d - decaying wood mass, l – leaf litter, m – moss, s – soil.

4. Epigeic macrofauna

4.1. Pseudoscorpions (Arachnida, Pseudoscorpiones)

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Pseudoscorpions are the fourth largest arachnid order with more than 3380 species described (Harvey 2011). Inhabiting almost all terrestrial habitats, they often play an important ecological role as predators. In Slovakia, only two more intensive researches about pseudoscorpion assemblages from oak-hornbeam forests were carried out. The research by Christophoryová, Krumpál (2005) was performed in four study plots of the Malé Karpaty Mts. and two study plots of the Trnavská pahorkatina hills. A total of 949 specimens belonging to 10 taxa were examined in the course of three years. In all the study plots, 15 selected environmental variables were measured; none of them had a statistically significant influence on the occurrence of pseudoscorpions (Christophoryová, Krumpál 2005). Later, specimens were collected in other six study plots situated in oak-hornbeam forests in Malé Karpaty Mts. (Christophoryová, Krumpál 2007). Altogether 2832 specimens belonging to 11 taxa were collected in the whole study area. The seasonal dynamics of *Neobisium carcinoides* (Hermann, 1804) and *Chthonius boldorii* Beier, 1934 was studied there (Christophoryová, Krumpál 2007).

Only several data on pseudoscorpions inhabiting oak-hornbeam forests were referred in some works from Slovakia. Systematic faunistic and ecological investigation on pseudoscorpions of the Poloniny National Park was carried out by Krumpál, Krumpálová (2003). With regard to deciduous forests, the occurrence of nine pseudoscorpion species was recorded in oak and oak-beech forests. Similar research was performed in 28 localities of the Cerová vrchovina highland in the course of three years (Christophoryová 2009). Five pseudoscorpion species were identified from deciduous forests (oak, hornbeam, beech-hornbeam and oak-beech). Christophoryová, Krumpál (2010) carried out the research of pseudoscorpions in the Nature Reserve Šúr. Seven pseudoscorpion species were found in the Panónsky háj locality (*Quercetum*). Species *Dactylochelifer latreillii* (Leach, 1817), *Chernes hahnii* (C. L. Koch, 1839), *Dendrochernes cyrneus* (L. Koch, 1873) and *Allochernes peregrinus* Lohmander, 1939 were collected using Malaise traps. Christophoryová (2010) recorded species *N. carcinoides* and *Pselaphochernes scorpioides* (Hermann, 1804) in oak hollows. Recently two species were recorded for the first time from Slovakia; *Chthonius hungaricus* Mahnert, 1980 was sifted from fallen wood in an oak forest and found in a sample of leaf litter and soil in an oak-hornbeam-beech forest in the Cerová vrchovina highland (Christophoryová et al. 2011a). One male of *Allochernes powelli* (Kew, 1916) was collected using formaldehyde trap situated in xerotherm oak forest in the Hranovická vrchovina National Nature Reserve (Christophoryová et al. 2011b).

In the Czech Republic, the knowledge about pseudoscorpion assemblages from oak-hornbeam forest is still poorer. Only few faunistic data have been published there. The arthropods of oak-hornbeam forest in the Karlštejnsko region were investigated by Verner (1959), who recorded four species. Ducháč (1988) studied the occurrence of pseudoscorpions in oak forests of České středohoří Mts. He found 15 specimens only, which belonged to three species. Ducháč (1993) found four species in oak hollows; Šťáhlavský (2001) also paid attention to the pseudoscorpions inhabiting tree hollows (also oak and hornbeam).

Life cycles of some British pseudoscorpions occurring in beech, oak and sycamore-ash forests were studied (Gabbutt, Vachon 1965, Gabbutt 1969, Goddard 1976). Wood, Gabbutt (1978) evaluated the phenology and seasonal vertical distribution of *N. carcinoides, C. ischnocheles* (Hermann, 1804) and *Roncus lubricus* L. Koch, 1873 from beech litter in England.

The aims of the present study were (i) to characterize structure and seasonal occurrence of pseudoscorpion assemblages during the two-year investigation, (ii) to compare the pseudoscorpion assemblages of some study plots and (iii) to find out environmental variables that influenced the epigeic pseudoscorpion assemblages.

The investigation of the pseudoscorpion assemblages was performed in eight study plots of the Malé Karpaty Mts. (leg. M. Holecová) – Horský park (HP), Mlynská dolina (MD), Briežky (BR), Koliba (KO), Devínska Kobyla (DK1, DK2, DK3) and Dúbravská Hlavica (DH) during two years. The soil macrofauna was collected by the square method combined with sifting. In approximately 1-month intervals (from April 2005 to January 2006 and from April 2006 to January 2007) the material was collected from the leaf litter and the upper part of soil from 16 squares in each study plot. Each square included 25x25 cm of the area, i.e. altogether an area of 1 m^2 was sifted, representing one sample. The samples were extracted using xereclectors of the Moczarski - Winkler's type. The specimens were preserved in 96% ethyl alcohol and were studied as permanent slide mounts. The specimens were identified using the key of Christophoryová et al. (2011d). The nomenclature for all taxa follows Harvey (2011). The material is deposited in the Comenius University in Bratislava, Slovakia.

Structure of pseudoscorpion assemblages

A total of 1219 pseudoscorpion specimens of ten species, six genera and four families were examined during the two-year research (Table 6). The highest number of species belonged to the family of Chernetidae (four species) and the lowest number to the family of Cheliferidae (one species). At each study site, from three to seven species were recorded (Table 8). The species *Chthonius boldorii* and *Neobisium carcinoides* were common for all study plots, *N. carpaticum* and *Chernes cimicoides* occurred only at the study plot DK3. The species from families of Chthoniidae (42.74%) and Neobisiidae (56.11%) were eudominant and families of Cheliferidae (0.25%) and Chernetidae (0.90%) were subrecedent. The species spectrum was represented by two groups of species – eudominant and euconstant species *Chthonius boldorii, C. fuscimanus* and *N. carcinoides*. The species *N. carpaticum, N. sylvaticum, Dactylochelifer latreillii, Chernes cimicoides, C. similis, Allochernes peregrinus* and *Pselaphochernes scorpioides* were subrecedent with a low constancy (accessoric or accidental) (Table 6).

Seasonal occurrence of pseudoscorpions

Generally, the pseudoscorpions were found in all months of sampling period except January and July 2006 (Table 7). Most specimens occurred in June and October 2005, minimum in September 2005, January and July 2006. Only one species was recorded in September 2005 and July 2006, on the contrary, 7 species were recorded in October 2005 (Table 7). Abundance of pseudoscorpion specimens showed two peaks (Fig. 7). The first peak in June was caused by *C. boldorii* and *N. carcinoides* collected in the sampling year of 2005. The second peak in October was caused by *N. carcinoides*; more than 190 specimens were recorded in 2005 in study plots (Table 7).

More than twice as many specimens were recorded in the first sampling period from April 2005 to January 2006 (873 specimens) comparing to the following year in the same period (346 specimens). The seasonal occurrence of the most abundant species *C. boldorii,*

Table 6. List of pseudoscorpion species and numbers of specimens collected in individual study plots in Malé Karpaty Mts.

Taxon / study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH	n	D(%)	CD	Co(%)	CC
Chthoniidae													
Chthonius (*Ephippiochthonius*) *boldorii* Beier, 1934	60	48	29	47	21	33	57	20	315	25.84	ED	100.00	EC
Chthonius (*E.*) *fuscimanus* Simon, 1900		66	24	28	12	29	24	23	206	16.90	ED	87.50	EC
Neobisiidae													
Neobisium (*Neobisium*) *carcinoides* (Hermann, 1804)	206	99	31	142	30	68	77	12	665	54.55	ED	100.00	EC
Neobisium (*N.*) *carpaticum* Beier, 1935							12		12	0.98	SR	12.50	A
Neobisium (*N.*) *sylvaticum* (C. L. Koch, 1835)	5							2	7	0.57	SR	25.00	A
Cheliferidae													
Dactylochelifer latreillii (Leach, 1817)		2			1				3	0.25	SR	25.00	A
Chernetidae													
Chernes cimicoides (Fabricius, 1793)							1		1	0.08	SR	12.50	A
Chernes similis (Beier, 1932)							2	1	3	0.25	SR	25.00	A
Allochernes peregrinus Lohmander, 1939			1				1	3	5	0.41	SR	37.50	As
Pselaphochernes scorpioides (Hermann, 1804)	1					1			2	0.16	SR	25.00	A

Symbols and abbreviations: n – total number of specimens; D – dominance in %; CD – category of dominance: ED – eudominant, SR – subrecedent; Co – constancy in %; CC – category of constancy: EC – euconstant, As – accessoric, A – accidental. Abbreviations of study plots see in the text.

C. fuscimanus and *N. carcinoides* was studied in the first sampling period (Fig. 8), with regard to the sufficient amount of material. *N. carcinoides* reached the first lower peak of occurrence in late spring (Fig. 8), whereas the maximum number was recorded in October. Subsequently the number of specimens started to decrease (Fig. 8). In comparison to *N. carcinoides* the abundance of the species from the family of Chthoniidae was lower in autumn. *C. boldorii* reached the first peak in June, *C. fuscimanus* even earlier in April. The number of specimens of *C. boldorii* was two times higher in June than in autumn. On the contrary, the number of specimens of *C. fuscimanus* was almost two times lower in April than in autumn (Fig. 8).

Comparison of pseudoscorpion assemblages

Most of the individuals (22%) were found in the study plot HP, 18% of them at the study plots KO and MD; the lowest number was collected at the study plots DK1 and DH (Table 8). The most species were recorded in the study plots DK3 and DH, the lowest in the study plot KO. The mean abundance of pseudoscorpions varied from 3.05 (the study plot DH) to 13.60 ind.m^{-2} (the study plot HP) (Table 8). The highest value of equitability referred to the assemblage of the study plot BR (Table 8). On the contrary, the lowest value of equitability was noticed on assemblage of the study plot HP. It was caused by the occurrence of eudominant species *N. carcinoides* (the highest value of index of dominance was at the study plot HP) (Table 8). The lowest value of species diversity in pseudoscorpion assemblage was recorded at HP. There was a highly significant difference ($P < 0.001$)

Table 7. Seasonal occurrence of pseudoscorpion species in epigeon of oak-hornbeam forests in Malé Karpaty Mts.

Species/ month, year	**IV**		**V**		**VI**		**VII**		**VIII**		**IX**		**X**		**XI**		**XII**		**I**	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2006	2007
C. boldorii	26	15	29	26	66	7	12		32	21		6	33	4	22	1	10	3		2
C. fuscimanus	25	10	6	3	10	8	2		20	19		6	49	16	15	2	8	3		4
N. carcinoides	20	15	30	17	75	29	22		46	33	6	14	192	22	63	14	33	27		7
N. carpaticum													6	2			3	1		
N. sylvaticum	1			1	1					1		2	1							
D. latreillii				1	1													1		
C. cimicoides	1																			
C. similis					2								1							
A. peregrinus	1		1	3																
P. scorpioides													1		1					
Number of specimens	74	40	66	51	155	44	36	0	98	74	6	28	283	44	101	17	54	35	0	13
Number of species	6	3	4	6	6	3	3	0	3	4	1	4	7	4	4	3	4	5	0	3

between the diversity of this assemblage (H' = 0.638) and the other ones (Table 8). On the contrary, the highest value of species diversity was noticed in the assemblages of the study plots DK3 and DH (Table 8).

The family of Chthoniidae was eudominant in all assemblages (Table 9). The lowest value of dominance was noticed in pseudoscorpion assemblage of the study plot HP, because only in this study plot no *C. fuscimanus* specimens were found. The highest value of dominance was recorded in an assemblage of the study plot DH thanks to the highest dominance of *C. fuscimanus* (Table 9). On the contrary, the highest dominance of the family of Neobisiidae was in an assemblage of the study plot HP because of the highest dominance of *N. carcinoides* recorded there. The lowest dominance of *N. carcinoides* was noticed at the study plot DH (Table 9). These two assemblages were also represented with species *N. sylvaticum* (subdominant in the assemblage of DH, recedent in the assemblage of HP). The assemblage of the study plot DK3 was represented besides *N. carcinoides* with dominant species *N. carpaticum* (Table 9). *D. latreillii* from the family of Cheliferidae occurred only in study plots MD and DK1 with dominance category from subrecedent to recedent (Table 9). The most differences between pseudoscorpion assemblages of Malé Karpaty Mts. were recorded in the family of Chernetidae (Table 9). In each of the assemblages of HP, BR

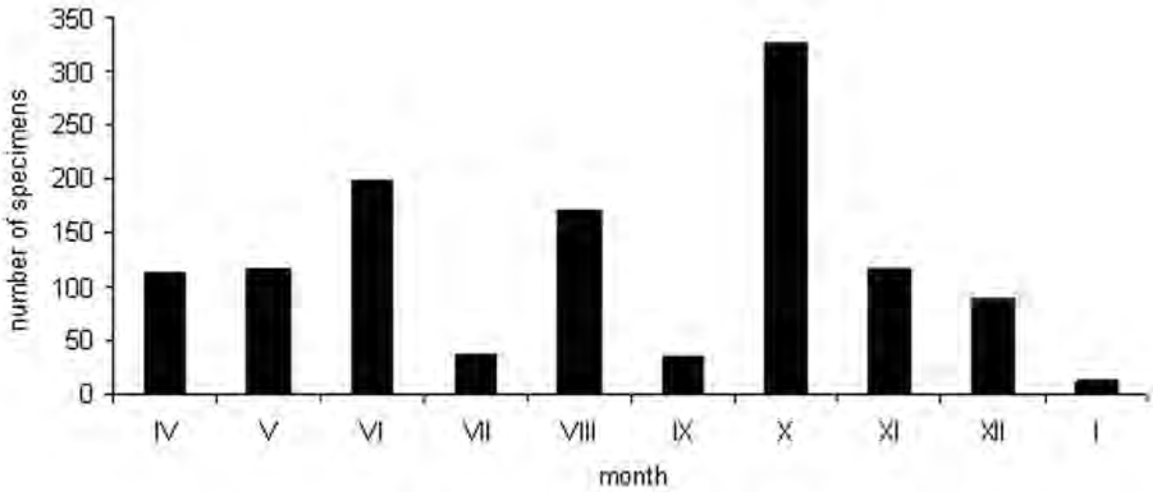

Figure 7. Cumulative numbers of pseudoscorpion specimens recorded in individual months of sampling periods 2005–2007 in Malé Karpaty Mts.

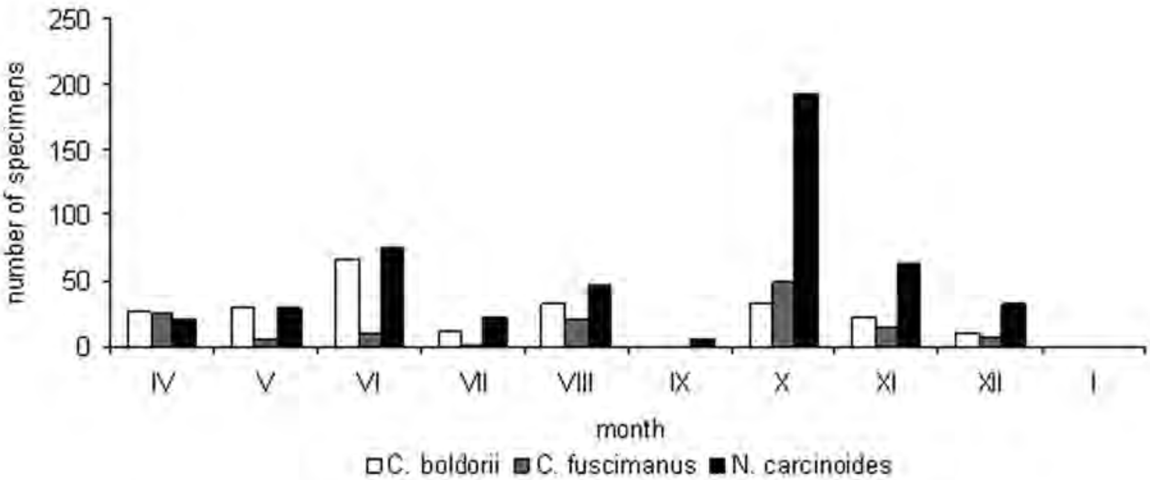

Figure 8. Seasonal occurrence of *C. boldorii, C. fuscimanus* and *N. carcinoides* in Malé Karpaty Mts.

Table 8. Species diversity test and basic coenological characteristics of pseudoscorpion assemblages at study plots of Malé Karpaty Mts.

Study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH
Σ specimens	272	215	85	217	64	131	174	61
Σ species	4	4	4	3	4	4	7	6
MA± SE [ind.m^{-2}]	13.60±20.13	10.75±11.53	4.25±4.98	10.85±20.55	3.20±3.87	6.55±6.67	8.70±11.19	3.05±4.74
e	0.46	0.792	0.825	0.795	0.793	0.764	0.665	0.771
c	0.623	0.356	0.329	0.492	0.363	0.382	0.327	0.292
H'	0.638	1.098	1.144	0.873	1.1	1.059	1.295	1.381
HP		459.542	275.299	487.328	131.212	352.381	360.928	92.956
MD	8.284***		179.195	394.795	93.974	248.63	268.115	75.449
BR	8.047***	0.866 ns		245.476	113.483	211.152	258.648	87.184
KO	3.728***	4.2***	4.432***		122.683	316.336	333.202	89.247
DK1	5.696***	0.024 ns	0.558 ns	2.843**		125.205	166.463	111.933
DK2	6.481***	0.704 ns	1.354 ns	2.936**	0.505 ns		301.409	91.993
DK3	8.761***	2.93**	2.053*	5.736***	2.18*	3.142**		114.218
DH	7.17***	2.884**	2.311*	4.951***	2.455*	3.106**	0.781 ns	

Symbols and abbreviations: Σ specimens – total number of specimens, Σ species – total number of species, MA± SE [ind.m^{-2}] – mean abundance of pseudoscorpions with standard deviation estimate, e – Pielou's index of equitability, c – Simpson's index of dominance, H' – Shannon's index of species diversity. T-test values are under the diagonal and degrees of freedom are above it. Significance levels: *** = P < 0.001; ** = 0.001 < P < 0.01; * = 0.01 < P < 0.05; ns = 0.05 < P (non-significant). Abbreviations of the study plots - see in the text.

and DK2 only one Chernetidae species was presented with the dominance category from subrecedent to recedent. Species *C. cimicoides, C. similis* and *A. peregrinus* were collected in the study plot DK3, the dominance of the family of Chernetidae was subdominant. The highest value of the family of Chernetidae referred to the pseudoscorpion assemblage of DH with subdominant *A. peregrinus* occurring there.

Similarity of the pseudoscorpion fauna in the assemblages of individual study plots

The pseudoscorpion assemblages in forest epigeon of individual study plots were evaluated according to the complete linkage cluster analysis using the Wishart's similarity index (Fig. 9). Based on a qualitative-quantitative similarity, the hierarchical classification divided the pseudoscorpion assemblages into two separate clusters connected on the low level of similarity (Fig. 9). The dividing into these clusters was highly influenced by the presence of eudominant species *N. carcinoides, C. boldorii* and *C. fuscimanus*. The other species appeared in the assemblages randomly (subrecedent category of dominance) and without a distinct influence. The first cluster was characterized with the highest dominance of *N. carcinoides*. The high degree of resemblance within the first cluster was found between assemblages of the study plots KO and HP with the highest dominance of *N. carcinoides* and the lowest dominance of *Chthonius* species (Table 9, Fig. 9). Subsequently, assemblages of the study plots DK3, DK2 and MD were linked with a slightly lower dominance of *N. carcinoides* and in reverse, with successively increasing dominance of *Chthonius* species (assemblage of the study plot MD with the highest dominance of *C. fuscimanus*). The second cluster was characterized with the most decreasing dominance of *N. carcinoides* and increasing dominance of *C. fuscimanus* (the highest dominance of *C.*

Table 9. The dominance (in %) of the pseudoscorpion families and species occurring in the study plots of Malé Karpaty Mts. (Abbreviations of the study plots - see in the text).

Taxon / Study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH
Chthoniidae	22.06	53.02	62.35	34.56	51.56	47.33	46.55	70.49
C. boldorii	22.06	22.33	34.12	21.66	32.81	25.19	32.76	32.79
C. fuscimanus	0.00	30.70	28.24	12.90	18.75	22.14	13.79	37.70
Neobisiidae	77.57	46.05	36.47	65.44	46.88	51.91	51.15	22.95
N. carcinoides	75.74	46.05	36.47	65.44	46.88	51.91	44.25	19.67
N. carpaticum	0.00	0.00	0.00	0.00	0.00	0.00	6.90	0.00
N. sylvaticum	1.84	0.00	0.00	0.00	0.00	0.00	0.00	3.28
Cheliferidae	0.00	0.93	0.00	0.00	1.56	0.00	0.00	0.00
D. latreillii	0.00	0.93	0.00	0.00	1.56	0.00	0.00	0.00
Chernetidae	0.37	0.00	1.18	0.00	0.00	0.76	2.30	6.56
C. cimicoides	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00
C. similis	0.00	0.00	0.00	0.00	0.00	0.00	1.15	1.64
A. peregrinus	0.00	0.00	1.18	0.00	0.00	0.00	0.57	4.92
P. scorpioides	0.37	0.00	0.00	0.00	0.00	0.76	0.00	0.00

fuscimanus and lowest dominance of *N. carcinoides* were recorded in the assemblage of DH).

Relationship between pseudoscorpion assemblages and environmental variables

The selected gradient and categorical environmental variables were measured with the aim to find out those influencing the pseudoscorpion assemblages (Table 10). The redundancy analysis has proved the influence of the forest fragmentation on the assemblages (P value of the Monte Carlo permutation test was lower than 0.05) (Fig. 10). Eigenvalues of the two first canonical axes are λ1 = 0.461 and λ2 = 0.471. The first two canonical axes account for 93.2% of the total variance of the species data and 100% of the species-environment relation. The species *N. carpaticum, C. cimicoides, C. similis* and *A. peregrinus* preferred forests without fragmentation of the study plots DK3 and DH. These species were represented by a low number of individuals. On the contrary, the

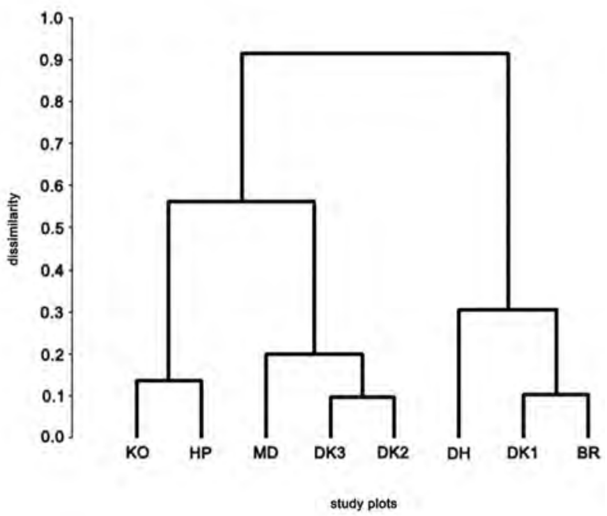

Figure 9. Hierarchical classification of pseudoscorpion assemblages in forest epigeon of individual study plots according to their qualitative-quantitative similarity (Wishart's similarity ratio, complete linkage).

second group was formed by the other species, including the eudominant ones, occurring in fragmented forests (fragmentation from 25% up to 75%). The species *C. boldorii, C. fuscimanus, N. carcinoides, N. sylvaticum* and *D. latreillii* were recorded in the most fragmented forests (Fig. 10).

A total of 1219 pseudoscorpion specimens of ten species were examined during the two-year research in oak-hornbeam forests of the Malé Karpaty Mts. Previous research was performed in 8 study plots of oak-hornbeam forests in Malé Karpaty Mts. and 2 study plots in Trnavská pahorkatina hills (Christophoryová, Krumpál 2005, 2007). Altogether 2832 specimens of 12 taxa (10 of them were present in Malé Karpaty Mts.) were collected during two to four years (Christophoryová, Krumpál 2007). The recorded species in the Malé Karpaty Mts. belonged to the families of Chthoniidae, Neobisiidae and Chernetidae; *D. latreillii* from the family of Cheliferidae was also present, but only in the current research. The species of the family of Chthoniidae and Neobisiidae represented typical epigeic and edaphic species living in the leaf litter and upper part of the soil. On contrary, species from the family of Chernetidae and Cheliferidae occurred more often in different habitat types – in tree hollows, under the bark of trees, in bird nests, manure dumps, decaying wood or compost heaps (Beier 1963, Krumpál, Cyprich 1988, Christophoryová

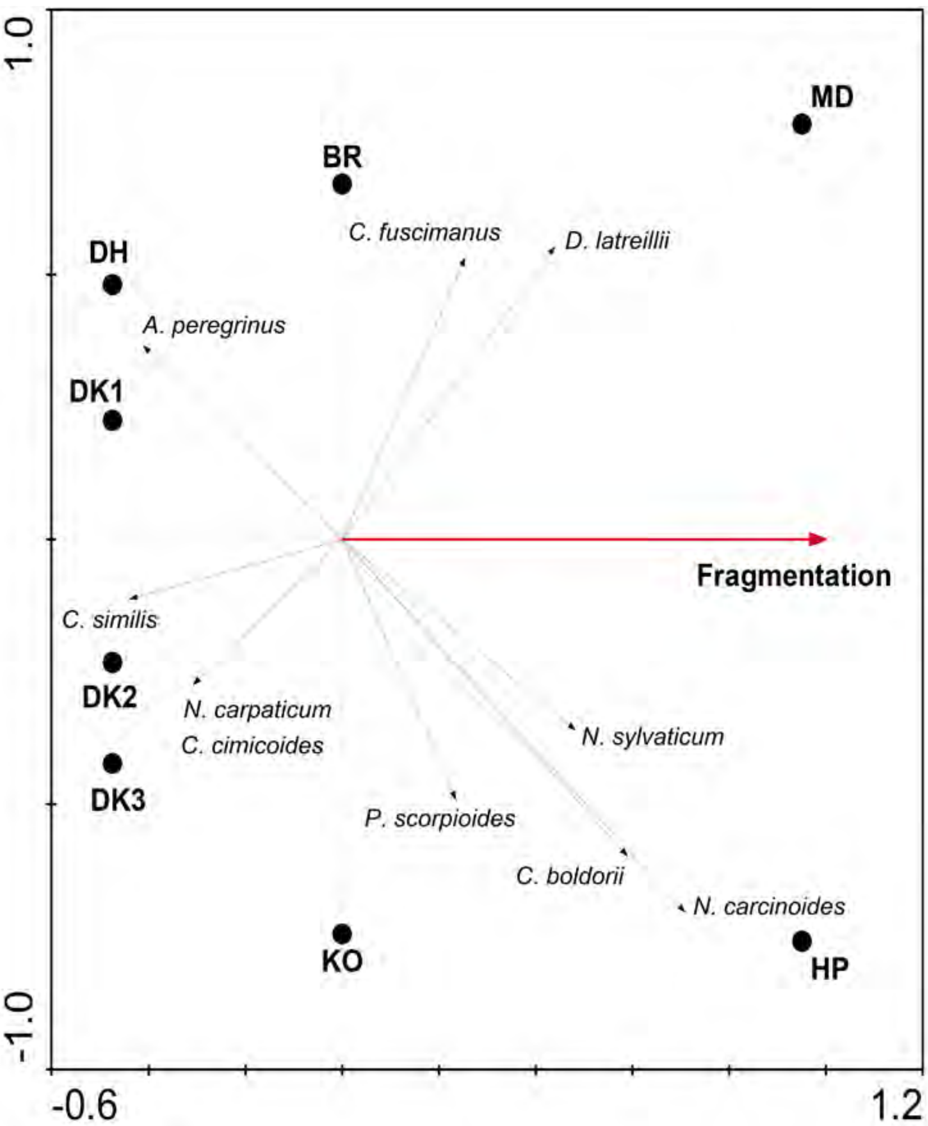

Figure 10. RDA ordination diagram of pseudoscorpion species in the assemblages of individual study plots and environmental factor. Abbreviation of study plots see - in the text.

Table 10. The measured environmental variables at individual study plots of Malé Karpaty Mts. Abbreviations of the study plots see in the text.

Environmental variable/ Study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH
Haplic Cambisols (soil type)	1	1	1	1	1	0	0	1
Rendzic Phaeozem (soil type)	0	0	0	0	0	1	0	0
Cutanic Luvisols (soil type)	0	0	0	0	0	0	1	0
SW exposition of study plot	0	1	1	1	0	0	0	0
S exposition of study plot	0	0	0	0	1	0	1	0
N exposition of study plot	0	0	0	0	0	1	0	0
E exposition of study plot	0	0	0	0	0	0	0	1
SE exposition of study plot	1	0	0	0	0	0	0	0
Slope (in °)	20	45	7	2	15	10	2	5
Age of a forest stand	60 – 80	80 – 100	80 – 100	80 – 100	60 – 80	40 – 60	60 – 80	80 – 100
Cover of E_3 (%)	80	70	75	70	75	80	75	80
Cover of E_2 (%)	40	20	20	35	35	55	20	30
Cover of E_1 (%)	70	100	50	100	70	70	100	70
Forest fragmentation (%)	75	75	25	25	0	0	0	0
pH of litter in H_2O	5.36	4.36	3.8	3.7	4.66	7.32	5.64	4.13
Cox (humus %)	18.62	15.52	45.17	31.03	15.17	17.24	13.1	20.69
Total organic carbon (C %)	10.8	9	26.2	18	8.8	10	7.6	12
Total nitrogen content (N %)	1.24	1.08	1.14	1.22	0.38	1.04	1.08	0.6
C:N	8.71	8.33	22.98	14.75	23.16	9.62	7.04	20
Sum of exchangeable bases	31.2	18.4	19.4	17	23.4	98.2	42	22.6
Exchangeable acidity	9.1	11.5	13.1	12.5	9.5	13.7	1.8	12.8
Cation exchangeable capacity	38.6	32.2	38.1	36.4	98.9	49.2	39.3	36.4
Base saturation (%)	81	57	51	47	66	99	85	58

et al. 2011c). Our research confirmed this result, the families of Chthoniidae and Neobisiidae were eudominant and families of Cheliferidae and Chernetidae were subrecedent.

Five study plots from the Malé Karpaty Mts. were common in the previous (Christophoryová, Krumpál 2005, 2007) and current research. Comparison of the species richness showed that the species *C. boldorii, C. fuscimanus* and *N. carcinoides* occurred in all study plots during the previous and the current research. The species *C. tetrachelatus* was found only during the previous research (Christophoryová, Krumpál 2007). In Central Europe, *C. tetrachelatus* is considered as eurytopic, mainly epigeic species and often most abundant species of the family of Chthoniidae (Beier 1963, Šťáhlavský 2001). In Slovakia, it was one of the most common species of the Chthoniidae family which preferred drier and slightly moist habitats (Krumpál, Kiefer 1981, Krumpál, Krumpálová 2003). In previous research in the Malé Karpaty Mts. the species *C. tetrachelatus* had the lowest value of abundance and dominance from the species of the Chthoniidae family (Christophoryová, Krumpál 2007). According to obtained results, *C. tetrachelatus* might not occur in Slovakia as numerously as it seemed. A possible reason could be the recent distinguishing of a very similar species *C. boldorii* in Slovakia (Christophoryová, Krumpál

2007), which has been eudominant at the study plots of Malé Karpaty Mts. The species *N. carpaticum* occurred in the previous as well as in the current research (Christophoryová, Krumpál 2007). The species mentioned in previous research (Christophoryová, Krumpál 2007) as *Neobisium* sp. was later identified as *N. sylvaticum,* which was found also during the current research. Species *P. scorpioides* from the family of Chernetidae was present in the study plots of oak-hornbeam forests (Christophoryová, Krumpál 2007), in the actual research; three other species from family Chernetidae were collected. One of them, *C. cimicoides,* occurred in subrecedent position in 60–80 years old oak-hornbeam forest. On the contrary, this species was eudominant in 60–80 years old oak-hornbeam forest in Trnavská pahorkatina hills (Christophoryová, Krumpál 2007), where it was collected from the leaf litter with a high content of the decaying wood. This species lives mainly under the bark of trees, in bird nests, formicaries, less often in the leaf litter (Beier 1963, Krumpál, Cyprich 1988, Krištofík et al. 2002, Drogla, Lippold 2004). In Slovakia, *C. cimicoides* was collected in the decaying wood, tree hollow and Malaise traps in the alder forest of the Nature Reserve Šúr (Christophoryová, Krumpál 2010) and one female was found in an oak forest of the Cerová vrchovina highland (Ducháč 1994). The species *A. peregrinus* was recorded in the study plots of hornbeam forests near Bratislava. Until now, only isolated records of *A. peregrinus* were published from Slovakia and also from the Czech Republic (Krumpálová, Krumpál 1993, Ducháč 1995, Christophoryová, Krumpál 2007, 2010). Therefore this species was listed in the Red Data Book of the Czech Republic as vulnerable (Šťáhlavský, Ducháč 2005).

Summarizing the data, the species spectrum of the Malé Karpaty Mts. was represented by two groups of species. The first group included eudominant and euconstant species *C. boldorii, C. fuscimanus* and *N. carcinoides,* which were characteristic for oak-hornbeam forests. The second group was characterized by the species *N. carpaticum, N. sylvaticum, D. latreillii, C. cimicoides, C. similis, A. peregrinus* and *P. scorpioides,* which were not dominant and were only accessoric or accidental. These species completed assemblage structure and formed specified individual assemblages. More or less, they reflected the habitat characteristics, method or time of collecting the material.

The seasonal occurrence of the eudominant species *C. boldorii, C. fuscimanus* and *N. carcinoides* was studied in the first sampling period in oak-hornbeam forests of the Malé Karpaty Mts. The species *N. carcinoides* occurred during the year mainly in the leaf litter, in which its presence was higher than in the soil. Only in the winter months the specimens have migrated into the soil (Goddard 1976, Wood, Gabbutt 1978). The maximum number of *N. carcinoides* specimens was recorded in October, subsequently the number of specimens started to decrease, what was related to vertical migration into the soil, as well as the natural mortality (Christophoryová, Krumpál 2007). In comparison to *N. carcinoides,* the abundance of the species from the family of Chthoniidae was lower in autumn. The *Chthonius* species probably migrated more between the leaf litter and soil and the abundance of their populations was lower in late autumn months.

In previous research, 15 selected environmental variables were measured in study plots of the Malé Karpaty Mts. and Trnavská pahorkatina hills with the aim to find out the ones influencing the assemblages (Christophoryová, Krumpál 2005). Unfortunately, none of the environmental variable had the significant influence on the pseudoscorpion occurrence. In the present study the redundancy analysis has proved the influence of the forest fragmentation on the assemblages. The pseudoscorpion assemblages of three groups of the study plots were compared. The first group included study plots, which were situated in western outskirts of the city and were least exposed to anthropic pressure. The species *N. carpaticum, C. cimicoides, C. similis* and *A. peregrinus*, represented by low specimen number, preferred these oak-hornbeam forests without fragmentation. The fragmentation was higher in the second and third group of the study plots (25 – 75%). The study plots of the second group were situated in eastern outskirt of the city and were anthropically affected (high people visit rate, constant intervention into plantations, mining during the research). The third group was represented by anthropically the most affected study plots situated close to the centre of the city. The lowest value of species diversity was recorded there, simultaneously with the lowest value of equitability because of the occurrence of eudominant species *N. carcinoides* (the highest value of index of dominance). The species *C. boldorii, C. fuscimanus, N. carcinoides, N. sylvaticum* and *D. latreillii* were recorded in the most fragmented forests.

References

Beier, M., 1963: Ordnung Pseudoscorpionidea (Afterskorpione). Bestimmungsbücher zur Bodenfauna Europas. Verlag, Berlin, 313 pp.

Christophoryová, J., 2009: Pseudoscorpions – Pseudoscorpiones (in Slovak). In: Mašán, P., Mihál, I. (eds), Arachnids of Cerová vrchovina hills (Arachnida: Araneae, Pseudoscorpiones, Opiliones, Acari). Štátna ochrana prírody SR Banská Bystrica, Správa CHKO Cerová vrchovina Rimavská Sobota, Ústav zoológie SAV Bratislava, Ústav ekológie lesa SAV Zvolen, p. 125–135.

Christophoryová, J., 2010: Pseudoscorpions (Pseudoscorpiones) under the bark of trees, in tree hollows and nests in Slovakia (in Slovak). Folia Faun. Slov., 15: 1–12. (http://zoology.fns.uniba.sk/ffs/)

Christophoryová, J., Fenďa, P., Krištofík, J., 2011a: *Chthonius hungaricus* and *Larca lata* new to the fauna of Slovakia (Pseudoscorpiones: Chthoniidae, Larcidae). Arachnol. Mitt., 41: 1–6.

Christophoryová, J., Gardini, G., Korenko, S., 2011b: *Allochernes powelli* new to the fauna of Slovakia (Pseudoscorpiones: Chernetidae). Folia Faun. Slov., 16: 67–70. (http://zoology.fns.uniba.sk/ffs/)

Christophoryová, J., Krumpál, M., 2005: Communities of pseudoscorpions (Pseudoscorpiones, Arachnida) in epigeon of oak-hornbeam forests in the Malé Karpaty Mts. and Trnavská pahorkatina hills (SW Slovakia). Ekológia, 24, Supplement 2/2005: 76–86.

Christophoryová, J., Krumpál, M., 2007: Pseudoscorpions (Pseudoscorpiones) from the leaf litter of Malé Karpaty Mts. and Trnavská pahorkatina hills. (in Slovak). Entomofauna carpathica, 19: 27–31.

Christophoryová, J., Krumpál, M., 2010: Pseudoscorpions (Pseudoscorpiones) Šúr Nature Reserve (in Slovak). In: Majzlan, O., Vidlička, Ľ. (eds), Nature of Reserve Šúr. Ústav zoológie SAV, Bratislava, p. 105–114.

Christophoryová, J., Krumpálová, Z., Krištofík, J., Országhová, Z., 2011c: Association of pseudoscorpions with different types of bird nests. Biologia, 66: 669–677.

Christophoryová, J., Šťáhlavský, F., Fedor, P., 2011d: An updated identification key to the pseudoscorpions (Arachnida: Pseudoscorpiones) of the Czech Republic and Slovakia. Zootaxa, 2876: 35–48.

Drogla, R., Lippold, K., 2004: Zur Kenntnis der Pseudoskorpion-Fauna von Ostdeutschland (Arachnida, Pseudoscorpiones). Arachnol. Mitt., 27–28: 1–54.

Ducháč, V., 1988: A contribution to the knowledge of the pseudoscorpions in České středohoří Mts. (in Czech). Fauna. Boh. Septentr., 13: 103–108.

Ducháč, V., 1993: Pseudoscorpions (Pseudoscorpionidea) in tree hollows in Třeboňsko (in Czech). Sbor. Jihoč. Muz. Čes. Bud., Přír. Vědy, 33: 65–69.

Ducháč, V., 1994: Faunistic-bionomic notes to some pseudoscorpion species of Czech and Slovak Republic (in Czech). Fauna. Boh. Septentr., 19: 139–153.

Ducháč, V., 1995: Pseudoscorpionida. In: Rozkošný, R., Vaňhara, J. (eds), Terrestrial Invertebrates of the Pálava Biosphere Reserve of UNESCO, I. Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia, 92, Brno, p. 51–53.

Gabbutt, P.D., 1969: Life-histories of some British pseudoscorpions inhabiting leaf litter. In: Sheals, J.G. (ed), The soil ecosystem, Systematics Association Publication no. 8, London, p. 229–235.

Gabbutt, P.D., Vachon, M., 1965: The external morphology and life history of the pseudoscorpion *Neobisium muscorum*. Proc. Zool. Soc. London, 145: 335–358.

Goddard, S.J., 1976: Population dynamics, distribution patterns and life cycles of *Neobisium muscorum* and *Chthonius orthodactylus* (Pseudoscorpiones: Arachnida). J. Zool. London, 178: 295–304.

Harvey, M.S., 2011: Pseudoscorpions of the World. Version 2.0. Western Australian Museum, Perth. http://www.museum.wa.gov.au/catalogues/pseudoscorpions (accessed 17.12.2011).

Krištofík, J., Šustek, Z., Mašán, P., 2002: Arthropods (Pseudoscorpionida, Acari, Coleoptera, Siphonaptera) in the nests of red-backed shrike (*Lanius collurio*) and lesser grey shrike (*Lanius minor*). Biologia, 57: 603–613.

Krumpál, M., Cyprich, D., 1988: On the occurence of pseudoscorpions (Pseudoscorpiones) in bird nests (Aves) in Slovakia. Zbor. Slov. Nár. Múz., Prír. Vedy, 34: 41–48.

Krumpál, M., Kiefer, M., 1981: A contribution to the knowledge of pseudoscorpions from the family Chthoniidae in ČSSR (Pseudoscorpionidea) (in Slovak). Zprávy Čs. spol. entomol., ČSAV, 17: 127–130.

Krumpál, M., Krumpálová, Z., 2003: Pseudoscorpions – Pseudoscorpiones (in Slovak). In: Mašán, P., Svatoň, J. (eds), Arachnids of the Poloniny National Park (Arachnida: Araneae, Pseudoscorpiones, Opiliones, Acari – Parasitiformes). Štátna ochrana prírody SR Banská Bystrica a Správa Národného parku Poloniny Snina, p. 115–126.

Krumpálová, Z., Krumpál, M., 1993: Funde von für die Slowakei neuen und seltenen Spinnentierarten (Arachnoidea). Arachnol. Mitt., 6: 36–41.

Šťáhlavský, F., 2001: Pseudoscorpions (Arachnida: Pseudoscorpiones) of Prague. Klapalekiana, 37: 73–121.

Šťáhlavský, F., Ducháč, V., 2005: Pseudoscorpiones (in Czech). In: Farkač, J., Král, D., Škorpík, M. (eds), Red list of endangered species of the Czech Republic. Invertebrates. Agentura ochrany přírody a krajiny ČR, Praha, p. 83–84.

Verner, P.H., 1959: Study on arthropods living in soil of oak-hornbeam stands in Karlštejnsko (in Czech). Bohemia centralis, A 1(7): 345–408.

Wood, P.A., Gabbutt, P.D., 1978: Seasonal vertical distribution of pseudoscorpions in beech litter. Bull. Br. Arachnol. Soc. London, 4: 176–183.

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4.2. Terrestrial isopods (Isopoda, Oniscidea)

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Terrestrial isopods belong to those groups of soil macrofauna, which take part in soil-forming processes. They are decomposers of organic matter and thereby they participate in nutrient circulation in nature. Their food mainly consists of plant rests, dead or decomposed. They also play an important role in food web as a source of calcium for insectivorous birds and other animals (Graveland, Vangijzen 1994). Terrestrial isopods are the only one group of crustaceans adapted on terrestrial environment. Countries around Mediterranean Sea are considered to be their cradle, from where they spread across nearly all over the world (Frankenberger 1944). Their biotopes are situated from sea-coasts to high mountains. Central-European species generally need biotopes with lack of light, higher moisture and stable temperature.

Terrestrial isopods are frequently used as biomonitoring model group of soil invertebrates (Paoletti, Hassall 1999), they are studied for their relations to environmental factors (Zimmer et al. 2000, Jabin et al. 2004, Zimmer 2004, Gongalsky et al. 2005). The effect of urbanization on woodlice assemblages is apparent in the abundance patterns of dominant species and the relative distribution of isopod species (Hornung et al. 2004, Vilisics et al. 2007). Besides these studies, the fauna of terrestrial isopods was studied in some cities as Budapest (Korsós et al. 2002), Olomouc (Riedel et al. 2009) and Košice (Palkovičová, Mock 2008).

In the south-western Slovakia, terrestrial isopods were studied several times. Gulička (1960) and Krumpál (1973, 1976) investigated impact of flooding on woodlice in the Svätojurský Šúr. Flasarová (1980, 1986), Flasar, Flasarová (1989) described the fauna of terrestrial isopods of the Malé Karpaty Protected Landscape Area (=PLA) by intensive sampling in more than 50 localities. Other research was targeted mainly on description of communities in oak-hornbeam forests in the area of the Malé Karpaty Mts. and their vicinity (Tuf, Tufová 2005).

Terrestrial isopods were studied in eight forest localities near or in Bratislava city. The short description of localities (for more detailed characteristics see the chapter 2. Ecological characteristics of studied oak-hornbeam forests and forest fragments on the territory of Bratislava).

1. BR- Briežky – forest (*Querco-Carpinetum melicetosum uniflorae*), 80-100 years old, acid subsoil, 340 m a.s.l.)
2. DK1- Devínska Kobyla 1 – National Nature Reserve, forest (*Querco-Carpinetum melicetosum uniflorae*), 60–80 years old, acid subsoil, 340 m a.s.l.
3. DK2- Devínska Kobyla 2 – National Nature Reserve, forest (*Aceri-Carpinetum*), 40–60 years old, in valley, neutral to alkaline subsoil, 300 m a.s.l.
4. DK3- Devínska Kobyla 3 – National Nature Reserve, forest (*Primulo veris-Carpinetum*), 80 years old, acid subsoil, 452 m. a.s.l.
5. KO- Koliba – forest (*Querco-Carpinetum melicetosum uniflorae*), 90–100 years old, acid subsoil, 380 m. a.s.l.
6. MD- Mlynská dolina – forest antropogenized fragment (*Aceri-Carpinetum*), 80–100 years old, acid subsoil, 190 m a.s.l.
7. HP- Horský park – fragmented and antropogenized area (*Querco petraeae-Carpinetum*), 80–years old, acid subsoil, 212 m. a.s.l.
8. DH- Dúbravská Hlavica – forest (*Querco petraeae-Carpinetum typicum*), 80–100 years old, acid subsoil, 350 m a.s.l.

Research was done in the years 1999, 2000, 2005 and 2006. Terrestrial isopods were collected from sites approximately once a month, eight to nine times per year. We started research in 5 localities in 1999, and in 2005 the localities DK3, MD and HP were added. We used only one method – litter sifting. In each locality we sifted a litter from 1 m^2, zoological material was separated using xereclectors and animals were fixed in 75% ethylalcohol. Woodlice were identified by Frankenberger's (1959) monograph and the used classification is after Schmalfuss (2003).

We used Ward's method for cluster analysis of isopod communities in the computer programme JMP (SAS Institute Inc., 1995). Quantitative data were analyzed using the programme CANOCO for Windows 4.5©. With Redundant Analysis (RDA) we evaluated relations among distribution of species and environmental factors. Species data weren't transformed and were centred by species. The model was evaluated using Monte Carlo Permutation test with 499 permutations.

In total, 2209 individuals of terrestrial isopods belonging to 10 species were caught in all 8 localities (Table 11). Communities are formed by 3 to 7 species and the most abundant species were *Protracheoniscus politus* (55%) and *Porcellium collicola* (39%). The period 1999–2000 was richer in isopods than two other years, when there were obtained three times more individuals than in 2005–2006.

DK1: Four species were recorded in this forest locality. *P. politus* was the most abundant species and represented 64% of present isopod community. *Hyloniscus riparius* and *Orthometopon planum* were found only in few specimens.

DK2: The richest community was found in this locality. In general, *P. collicola* predominated, but in 2006 it was missing. *P. politus* was found in every year in relatively stable numbers. *H. riparius* was recorded during whole period, but only in few specimens. Four other species were found irregularly in few individuals.

DK3: We recorded three species in this locality. *P. collicola* predominated, *P. politus* represented 36% of sampled material and *H. riparius* was found only in one individual.

DH: In this locality, a rich isopod community was present. *P. politus* predominated during whole period. *P. collicola* and *Trachelipus ratzeburgi* were abundant, too. Then we found *H. riparius* in few individuals and one specimen of *O. planum*.

KO: In this locality, three species were collected, too. *P. politus* was dominant (77%) and present during whole period of research. Two other species, *P. collicola* and *T. ratzeburgi* were found in low abundances.

BR: Three species were collected in this locality. *P. politus* was present and dominant species (93%) in all years. *P. collicola* was observed only in 2006 and only in one individual. *T. ratzeburgi* was always found in few specimens, except 2005.

MD: A rich isopod community, consisting of five species occuring in low abundances, was sampled in this locality. *P. collicola* was dominant, but present only in 2006. In 2005 we recorded only two species, *P. politus* and *O. planum*, each in one individual. *Trachelipus rathkii* and *Armadillidium vulgare* were found each in one exemplar.

HP: We recorded here a rich isopod community, too. *P. collicola* was predominant during both years. *H. riparius, O. planum, A. vulgare* and *Cylisticus convexus* were sampled in few individuals only in 2005. *T. ratzeburgi* and *T. rathkii* were found in one individual in both years. The isopod *P. politus* was missing.

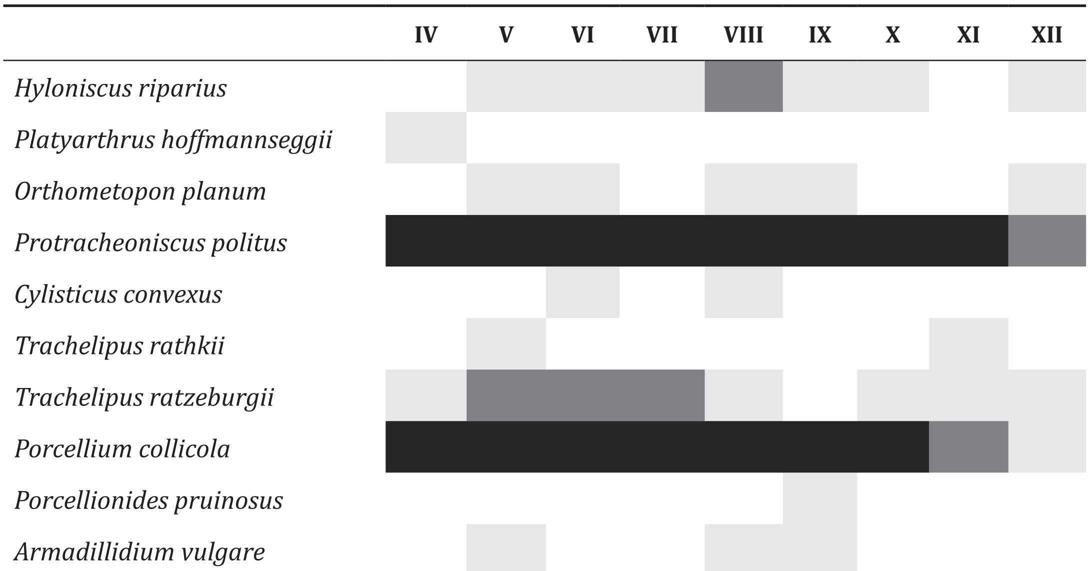
Seasonal distribution of terrestrial isopod species (Table 12) shows *P. politus* and *P. collicola* as the species present in a high density during whole vegetation period. Two other species, *H. riparius* and *T. ratzeburgii*, were present through almost whole period, with the peak in August and May–July, respectively. The other species were recorded occasionally only.

Table 11. Survey of collected material of terrestrial isopods (DK3, MD and HP were sampled for 2 years only).

	BR	DK1	DK2	DK3	KO	MD	HP	DH	together
Family Trichoniscidae									
Hyloniscus riparius (C.L. Koch, 1838)		1	19	1			10	8	39
Family Platyarthridae									
Platyarthrus hoffmannseggii (C.L. Koch, 1838)			1						1
Family Agnaridae									
Orthometopon planum (Budde-Lund, 1885)		5	2			4		1	12
Protracheoniscus politus (C. Koch, 1841)	203	289	144	17	187	1		367	1208
Family Cylisticidae									
Cylisticus convexus (De Geer, 1778)							3		3
Family Trachelipodidae									
Trachelipus rathkii (Brandt, 1833)						1	2		3
Trachelipus ratzeburgii (Brandt, 1833)	14		3		32		1	22	72
Porcellium collicola (Verhoeff, 1907)	1	159	515	29	25	28	83	20	860
Family Porcellionidae									
Porcellionides pruinosus (Brandt, 1833)			1						1
Family Armadillidiidae									
Armadillidium vulgare (Latreille, 1804)						1	9		10
Number of individuals	218	454	685	47	244	35	108	418	2209
Number of species	3	4	7	3	3	5	6	5	10
Shannon's index of diversity	0.12	0.31	0.30	0.32	0.31	0.32	0.37	0.22	

Note: Abbreviation of localities - see in the text.

Table 12. Seasonal distribution of terrestrial isopods (evaluation concerning the whole material).



Notes: Black patch means over 50 ind. collected in relevant month altogether, less dark patch means from 10 to 50 ind., grey means up to 10 ind.

We compared localities according to presence/absence of species and there are results of cluster analysis (Fig. 11). Evidently aside is the urban site HP. Only in this site the common species *P. politus* did not occur at all. Closest are the sites BR and KO, two localities affected by pollutants of chemical factories until 1990. Among other sites, we found no obvious similarities.

The length of gradient in species data was shorter than 1.805, therefore we selected Redundancy Analysis. RDA of isopod assemblages and selected environmental factors (Fig. 12) explains 99.3% of species variability. The model is significant ($F = 23.33$; $p = 0.028$). The first axis explains 60.4% of species variability; the second axis explains 38.7%.

Species *H. riparius, P. pruinosus, P. hoffmannseggi* and *P. collicola* preferred localities with dense shrub layer and low age. *T. rathkii, C. convexus* and *A. vulgare* were present in steeper localities with a high content of nitrogen and *T. ratzeburgii* occupied the localities with high amount of humus in soil.

Until now, for the area of Malé Karpaty there were discovered 30 species (Flasarová 1986, Kuracina, Kabátová 2005). On the territory of Bratislava, we recorded 10 species. Communities of terrestrial isopods are formed by 3 to 7 species. We can consider them as relatively rich, because typical forest woodlice community consists of 3 to 7 species (Farkas et al. 1999). Usually, in urban areas we can find richer communities, composed of about 15 species; it is explained by higher diversity of microhabitats in cities (Riedel et al. 2009). Several researches confirmed that species richness of terrestrial isopods in urban localities is the same or higher than richness in natural, undisturbed localities (Hornung et al., 2007). According Vilisics et al. (2007), there is a mass occurrence of dominant species in natural habitats such as forests.

P. politus was dominant and the most abundant species in the localities BR, DK1, KO and DH. On the other hand, *P. collicola* was dominant and the most abundant in DK2 and DK3, MD and HP. The last two localities are man-influenced forest fragments situated directly in the city of Bratislava. There were found rich communities of isopods, formed of 5 and 6 species. From all the sites, only here we recorded the cosmopolitan species *A. vulgare*, which is associated with man-influenced environments. Other two species, *T. rathkii* and *C. convexus*, were recorded only in this site. These species are cosmopolitan, too. In most cases, new habitats are colonized by species of broad tolerance, mainly by cosmopolitan species (Vilisics et al. 2007). Regarding the number of specimens collected, these two sites have lowest abundance of isopods (together with DK3). Explanation of

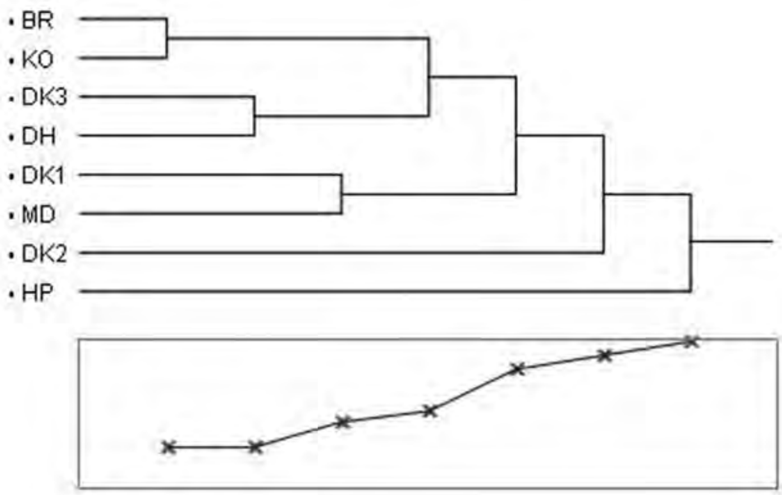


Figure 11. The dissimilarity of communities of terrestrial isopods after their presence at locality. (For abbreviation of localities see in the text)

this phenomenon can be found in an impact of anthropogenic activity. Changes in abundance would influence decomposition process and modify nutrient in the soil (Vilisics et al. 2007). Other reason may be relatively steep slope of these sites.

In RDA analysis, age of forest growth turned out to be the most important environmental factor. Other important factors are cover of shrub layer, pH, content of nitrogen and amount of humus in soil. Soil heterogeneity could vary with phases of the forest cycle, since humus forms change with the age of trees (Salmon et al. 2006). Species *T. rathkii* seems to be fixed to localities with a high amount of humus in soil. Young forest has high cover of E_2 and it causes high abundances of isopods. The highest E_2 is in DK2 (55%), the site with the most species and the highest abundances of them and with a relatively young, 50 years old forest. We recorded here the richest community of terrestrial isopods composed of 7 species. Maximum environmental heterogeneity is in the intermediate succession phase (Salmon et al. 2008), in which this forest appears. Other reason of high diversity may be neutral to alkaline character of soil with pH 7.32. Soil in other sites is acid.

In conclusion, in Bratislava we described relatively rich but typical isopod communities, formed from 3–7 species with predominant *P. politus* and *P. collicola*. These species were present in stable abundances during whole year, while other rare species appeared irregularly according to optimal climatic conditions. There are little differences in composition of communities between natural and anthropogenized sites. According to our analysis , the most important environmental factors impacting structure of assemblages are: age of the forest, shrub layer and pH.

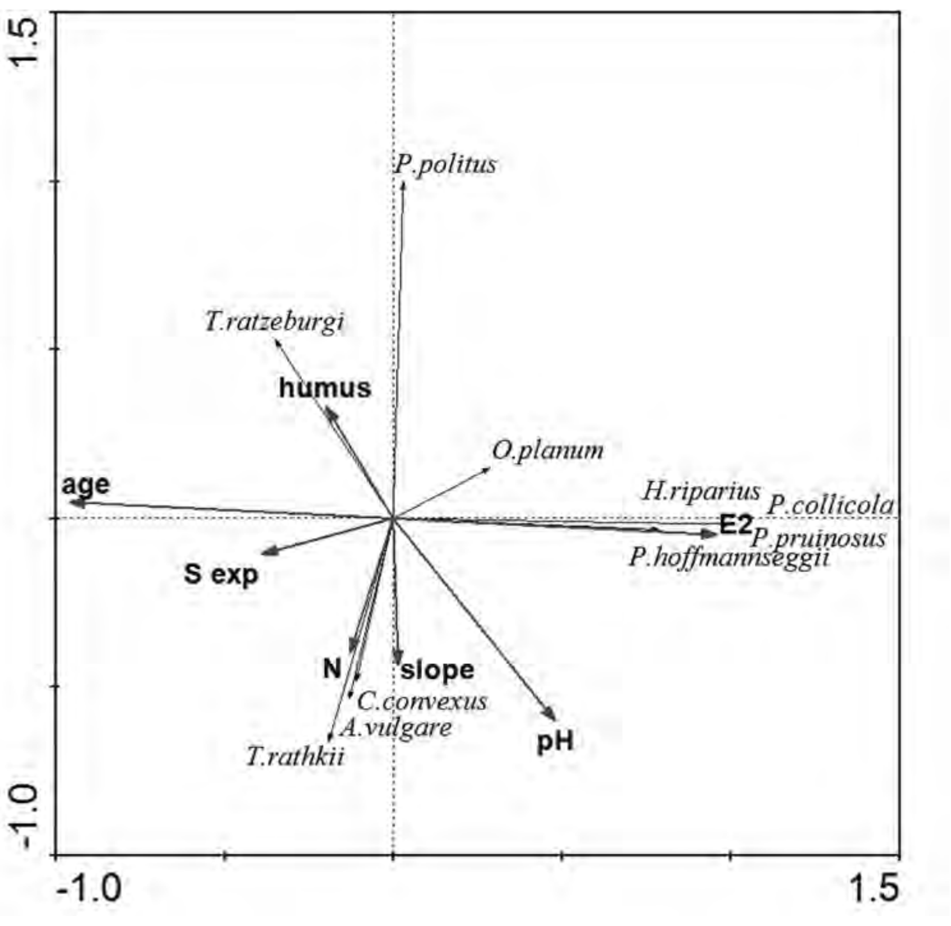


Figure 12. The RDA ordination biplot illustrating distribution of terrestrial isopods in relation to environmental variables. Abbreviations: humus - amount of humus in soil, age - age of wood, E2 - density of shrub layer, S exp - exposition of slope to South, N - amount of nitrogen in soil, slope - steepness of slope, pH - alkalinity of soil.

References

Farkas, S., Hornung, E., Morschhause, T., 1999: Composition of isopod assemblages in different habitat types. In: Tajovský, K., Pižl, V. (eds), Soil Zoology in Central Europe. Proc. of the 5th Central European Workshop on Soil Zoology. Institute of Soil Biology, České Budějovice, p. 37–44.

Flasar, I., Flasarová, M., 1989: Ergänzungen zur Monographie "The Soil Fauna of the Little Carpathians" (Mollusca et Isopoda). Faunistische Abhandlungen, Staatliches Museum für Tierkunde Dresden, 17: 1–18.

Flasarová, M., 1980: *Hyloniscus transsilvanicus* (Verhoeff, 1901) im Gebirge Malé Karpaty in der Westslowakei. Faunistische Abhandlungen, Staatliches Museum für Tierkunde Dresden 7: 273–278.

Flasarová, M., 1986: Isopoda (Asellota, Oniscidea) of the Little Carpathians. In: Nosek, J. (ed.), The Soil Fauna of the Little Carpathians. Ústav experimentálnej biológie a ekológie SAV, Bratislava, p. 183–216.

Frankenberger, Z., 1944: Oniscoidea of Bohemia and Moravia (in Czech). Věstník Král. Čes. Spol. Nauk, tř.mat.-přír., 8: 1–28.

Frankenberger, Z., 1959: Terrestrial Isopods – Oniscoidea (in Czech). Fauna ČSR, volume 14. N ČSAV, Praha, 216 pp.

Graveland, J., Vangijzen, T., 1994: Arthropods and seeds are not sufficient as calcium sources for shell formation and skeletal growth in passerines. Ardea, 82: 299–314.

Gongalsky, K.B., Savin, F.A., Pokarzhevskii, A.D., Filimonova, Z.V., 2005: Spatial distribution of isopods in an oak–beech forest. Eur. J. Soil Biol., 41: 117–122.

Gulička, J., 1960: Impact of changing water regime to soil macrofauna of Svätojurský Šúr (in Slovak). Acta Fac. Rerum Nat. Univ. Comenianae, Zool., 4: 437–486.

Hornung, E., Tóthmérész, B., Magura, T., Vilisics, F., 2007: Changes of isopod assemblages along an urbane-suburbane-rural gradient in Hungary, Eur. J. Soil Biol., 43: 158–165.

Jabin, M., Mohr, D., Kappes, H., Topp, W., 2004: Influence of deadwood on density of soil macro-arthropods in managed oak-beech forest. Forest Ecology and Management, 194: 61–69.

Korkós, Z., Hornung, E., Szlávecz, K., Kontschán, J., 2002: Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. Annls hist.-nat. Mus. nat. Hung., 94: 193–208.

Krumpál, M., 1973: Seasonal dynamics of terrestrial isopod populations (Isopoda, Oniscoidea) in Jurský šúr Nature Reserve (in Slovak). Biológia, Bratislava, 28: 879–884.

Krumpál, M., 1976: Knowledge from biology isopode reproduction in Jurský šúr. Acta Fac. Rerum Nat. Univ. Comenianae, Zool., 20: 63–67.

Kuracina, D., Kabátová, A., 2005: Terrestrial isopods (Crustacea: Isopoda: Oniscoidea) (in Slovak). In: Majzlan, O. et al. (eds), Fauna Devínskej Kobyly. APOP, Bratislava, p. 56-57.

Palkovičová, S., Mock, A., 2008: Epigeic macrofauna (Oniscidea, Diplopoda) of Botanical Garden of P.J. Šafárik University in Košice (in Slovak). Študentská vedecká konferencia, Univerzita Komenského v Bratislave, Bratislava, Zborník príspevkov, 1. zväzok – biologická sekcia: 242–244.

Paoletti, M.G., Hassall, M., 1999: Woodlice (Isopoda: Oniscidea): their potential for assessing sustainability and use as bioindicators. Agriculture, Ecosystems & Environment, 74: 157–165.

Riedel, P., Navrátil, M., Tuf, I.H., Tufová, J., 2009: Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) of the City of Olomouc (Czech Republic). In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Contributions to Soil Zoology in Central Europe, ISB AS CR, České Budějovice, 3, p. 125–132.

Salmon, S., Frizzera, L., Camaret, S., 2008: Linking forest dynamics to richness and assemblage of soil zoological groups and to soil mineralization processes. Forest Ecology and Management, 256: 1612–1623.

Salmon, S., Mantel, J., Frizzera, L., Zanella, A., 2006: Changes in humus forms and soil animal communities in two developmental phases of Norway spruce on an acidic substrate. Forest Ecology and Management, 237: 47–56.

Schmalfuss, H., 2003: World catalog of terrestrial isopods (Isopoda: Oniscidea). Stuttgarter Beiträge zur Naturkunde, Serie A, 654, p. 1–341. (corrected and actualized on the http://www.naturkundemuseum-bw.de/stuttgart/projekte/oniscidea-catalog/)

Tuf, I.H., Tufová, J., 2005: Communities of terrestrial isopods (Crustacea: Isopoda: Oniscidea) in epigeon of oak-hornbeam forests of SW Slovakia. Ekológia (Bratislava), Vol. 24, Supplement 2/2005: 113–123.

Vilisics, F., Elek, Z., Lovei, G., Hornung, E., 2007: Composition of terrestrial isopod assemblages along an urbanisation gradient in Denmark. Pedobiologia, 51: 45–53.

Zimmer, M., 2004: Effects of temperature and precipitation on a flood plain isopod community: a field study. European Journal of Soil Biology, 40: 139–146.

Zimmer, M., Brauckmann, H.J., Broll, G., Topp, W., 2000: Correspondence analytical evaluation of factors that influence soil macro-arthropod distribution in abandoned grassland. Pedobiologia, 44: 695–704.

4.3. Millipedes (Diplopoda)

Slavomír Stašiov

Millipedes are the soil detritivores, which eat decaying leaves and other dead plant matter. These organisms are sensitive to the state and changes of environment. The main factors, influencing the structure of their taxocoenoses, are temperature and humidity of soil (Branquart et al. 1995, Meyer 1999, Gava 2004, and others). Nevertheless, the effect of another factors was ascertained, too (Mattson 1980, Scheu, Poser 1996, Tuf, Ožanová 1999, Stašiov 2002b, Morón-Ríos, Huerta-Lwanga 2006, Smith et al. 2006, and others). The studies on the ecological requirement of the millipedes in oak-hornbeam forest ecosystems were the topics of interests of e.g. Holecová et al. (2005), Rahmani, Mayvan (2003), and Stašiov (2005).

Studied territory of Bratislava is situated in the southern part of the Malé Karpaty Mts. From viewpoint of the millipede fauna, the Malé Karpaty Mts. are considered a relatively well known region of Slovakia. The oldest data about the millipedes in this territory are included in the publications of Ortvay (1902), Lang (1933, 1954), and Gulička (1955, 1956). From among the newer publications, aimed to the research of the millipedes in this region, the data of Mišík et al. (1974), Krumpál (1993), Mock, Janský (2000), Holecová et al. (2005), and Stašiov (2005) seem to be especially relevant. Nevertheless, the most important paper about the millipede fauna of the Malé Karpaty Mts. was published by Gulička (1986). His publication contains a checklist of 30 species of millipedes, recorded in the forest communities of this area. Data about millipedes of Bratislava are given in works of Holecová et al. (2005), Mišík et al. (1974), Mock, Janský (2000), Ortvay (1902), and Stašiov (2005). Up to now, occurrence of common Central-European species was confirmed in this city above all. However, Bratislava is also characterized by penetration of numerous millipede species from Southern and South-Eastern Europe, some species from Alps, and the occurrence of several Carpathian endemics has been documented.

The studies are aimed on the assessment of the influence of 26 environmental factors on the structure of the communities of these organisms. The research was carried out in 8 oak-hornbeam forest stands located on the territory of Bratislava (Devínska Kobyla 1, 2, 3 (DK1, DK2, DK3), Dúbravská Hlavica (DH), Koliba (KO), Bratislava-Briežky (BR), Horský park (HP), Mlynská dolina (MD)). From the viewpoint of phytosociology, this region belongs to the area of West-Carpathian flora with the dominant occurrence of forest stands.

The studied localities differed in altitude, slope, exposure, characteristics of soil, mean age of forest stands, dimensions of trees, species and space structure of forest stands, and degree of human impact. The latter were assessed separately for the litter and the mineral layer of the soil. The detailed ecological characteristics of studied sites (soil, phytosociological and climatic situation) are available in the chapter 2. Ecological characteristics of studied oak-hornbeam forests and forest fragments on the territory of Bratislava.

The studies were carried out in the vegetation periods of 2005–2006. The millipede material was collected from the litter using the sieving method (Stašiov 2005). In each locality, the litter was sampled at approximately one-month intervals from 16 small quadrants with the dimensions of 25 x 25 cm. In this way, 1 m^2 of litter was sampled from each studied site. The millipedes from the sieved samples were separated in the lab using the dry extraction in Moczarski-Winkler's xeroeclectors. The obtained individuals were fixed in 70% ethanol. The studied millipede material is deposited in the author's collection.

Agglomerative clustering was performed for classification of sites and species. Prior to the analysis, data on species abundances were log transformed. Bray-Curtis coefficient and Pearson product-moment correlation coefficient were used as dissimilarity measures for the clustering of sites and species, respectively. Complete linkage algorithm (StatSoft Inc. 2003) was applied as a clustering method. The index of species diversity (H´) and the index of species equitability (E) were calculated according to Odum (1971) using the natural logarithms.

In total, 3138 individuals of millipedes were achieved during the studies. From among them, 3032 were identified at the level of species, whereas the rest 106 undetermined individuals were represented by juveniles or damaged specimens. Sixteen species of millipedes from 7 families and 5 orders were recorded in the studied sites (Table 13). The most species (13) were found in the localities DK2 and DH. These sites represent the best preserved biotopes because they were least exposed to human pressure within the localities compared. The highest density of tree layer, the lowest density of herbal layer and an occurrence of *S. stigmatosum* as well were typical for these localities. The localities KO and BR were characterized by the poorest species spectrum (6 species only were recorded in both of them). Identical exposure, the highest carbon content in litter layer, the highest ratio of carbon to nitrogen (C:N) in mineral layer, the highest content of humus in litter, the highest age and height of forest stand, the highest density of herbal layer, the lowest pH-values of both the mineral and litter layer, the lowest saturation degree and the litter sorption complex were characteristic for these two study plots mentioned above.

C. boleti, L. proximus, H. eremita and *C. rawlinsii* were the most frequent species present in all the localities examined. The rarest were *P. lagurus* (reported in 1 locality only), *S. stigmatosum* and *P. complanatus* (both of them was recorded in 2 localities).

In total, the most abundant species were *C. boleti* (1048 individuals) and *H. eremita* (569 individuals). The lowest abundance was detected in *P. lagurus* (1 individual), *G. tetrasticha* and *M. unilineatum* (7 individuals in each species).

Over the investigation period most of the individuals of millipedes were found in localities with the lowest values of C:N in mineral layer (HP, DK1).

The highest values of the indices of species diversity (H´) and equitability (E) of millipede communities were recorded in DK2. This forest site differed most from the other ones. From among all the sites studied, only this locality had the northern exposure. In addition, this locality was characteristic by the highest pH-value, value of sorption complex and degree of saturation of sorption complex of both soil layers, the highest density of herbal layer, the lowest total acidity values of both soil layers, the lowest mean tree thickness, and the youngest forest stand. In addition, this locality was characterized by lowest total number of collected individuals (263 ex.). The lowest calculated index of species diversity (H´) and equitability (E) of millipede communities were typical for MD. This locality differs from the other ones by highest slope, content of carbon, nitrogen and humus in mineral layer, the lowest value of C:N in litter and the lowest altitude.

The communities formed two main clusters (Fig. 13). The first of them included communities of the localities DK1, DK2, DK3, and DH. The second included communities from the localities KO, BR, HP, and MD. Communitie forming the first cluster were best preserved habitats within the studied localities. These localities were situated in the western border of Bratislava and were least exposed to human pressure. Second cluster included two most similar localities (KO, BR) situated in the eastern border of Bratislava. These localities were markedly influenced by human impact (tourism, thinnings, cutting, pollutants). The other two localities forming the second cluster (HP, MD) were localized

Table 13. Numbers of millipede individuals and some other parameters of millipede communities recorded on studied localities in 2005–2006.

Taxon	DK1	DK2	DK3	DH	KO	BR	HP	MD	∑
Order: Polyxenida									
Family: Polyxenidae									
Polyxenus lagurus (Linnaeus, 1758)				1					1
Order: Glomerida									
Family: Glomeridae									
Glomeris hexasticha Brandt, 1833	100	4	9	162			1	1	277
Glomeris tetrasticha Brandt, 1833	1	4						2	7
Order: Julida									
Family: Julidae									
Cylindroiulus boleti (C. L. Koch, 1847)	232	34	151	45	144	65	89	288	1048
Enantiulus nanus (Latzel, 1884)	46	44	20	7		2			119
Julus curvicornis Verhoeff, 1899	2	27		5			140	1	175
Kryphioiulus occultus (C. L. Koch, 1847)									
Leptoiulus proximus (Nemec, 1896)	20	33	27	8	79	171	57	6	401
Megaphyllum unilineatum (C. L. Koch, 1838)	2	1	3		1				7
Ommatoiulus sabulosus (Linnaeus, 1758)	31	31	42	20	29	31		7	191
Unciger foetidus (C. L. Koch, 1838)	11	10	12	5				1	39
Unciger transsilvanicus (Verhoeff, 1899)	24	2	1	5			2		34
Order: Chordeumatida									
Family: Mastigophorophyllidae									
Haploporatia eremita (Verhoeff, 1909)	1	38	4	19	79	100	210	118	569
Family: Craspedosomatidae									
Craspedosoma rawlinsii Leach, 1815	4	9	1	17	15	74	10	7	137
Order: Polydesmida									
Family: Paradoxosomatidae									
Strongylosoma stigmatosum (Eichwald, 1830)		12		4					16
Family: Polydesmidae									
Polydesmus complanatus (Linnaeus, 1761)				8				3	11
Indet. spp.	36	14	4	13		5	2	32	106
∑ Individuals	510	263	274	319	347	448	511	466	3138
∑ Species	12	13	10	13	6	6	7	10	16
H´	1.57	2.22	1.34	1.68	1.40	1.49	1.38	0.92	
E	0.63	0.87	0.58	0.65	0.78	0.83	0.71	0.40	

Notes: Shannon's index of species diversity (H'), index of species equitability (E), list of studied localities and their acronyms: Devínska Kobyla 1, 2, 3 (DK1, DK2, DK3), Dúbravská Hlavica (DH), Koliba (KO), Bratislava-Briežky (BR), Horský park (HP), Mlynská dolina (MD).

in the centre of Bratislava. They were considerably fragmented and exposed to the highest urbanized impact.

Species formed two main clusters (Fig. 14). The first of them included 8 species (from *P. lagurus* to *C. rawlinsii*) and the second one 7 species (from *G. hexasticha* to *C. boleti*). Whereas species demanding higher humidity of habitat were included into the first cluster, the second one included xeroresistant species or species without special demands for humidity.

The observed area is characterized by the occurrence of species from the South-Eastern Europe (*U. transsilvanicus, S. stigmatosum*), Alps (*H. eremita*), Carpathian endemics (*J. curvicornis*) and the numerous Central-European millipede species (Gulička 1986).

The finding of *J. curvicornis* is significant from the viewpoint of faunistics. Up to now, its westernmost known locality was in Veľká Fatra Mts. (Stašiov 2002a). The finding of this species in Bratislava moves markedly the western limit of its distribution and suggests its possible occurrence even in the Czech Republic, behind western slopes of the Malé Karpaty Mts.

In some localities (DK1, DH, MD), former research realized from 1999 to 2002 (Holecová et al. 2005, Stašiov 2005) uncovered the occurrence of species which were not recorded on these localities within research presented here. In locality DK1, there were recorded *Megaphyllum projectum* (Verhoeff, 1894) and *P. complanatus*; in locality DH, *M. unilineatum* was found, and finally in locality MD *Polyzonium germanicum* Brandt, 1837, *S. stigmatosum* and *Trachysphaera costata* (Waga, 1857) were ascertained by former research. Thereby, the number of millipede species was enriched to 18 in studied localities.

All other recorded species have already been found on the territory of Bratislava by several authors (Ortvay 1902, Mišík et al. 1974, Mock, Janský 2000, Holecová et al.

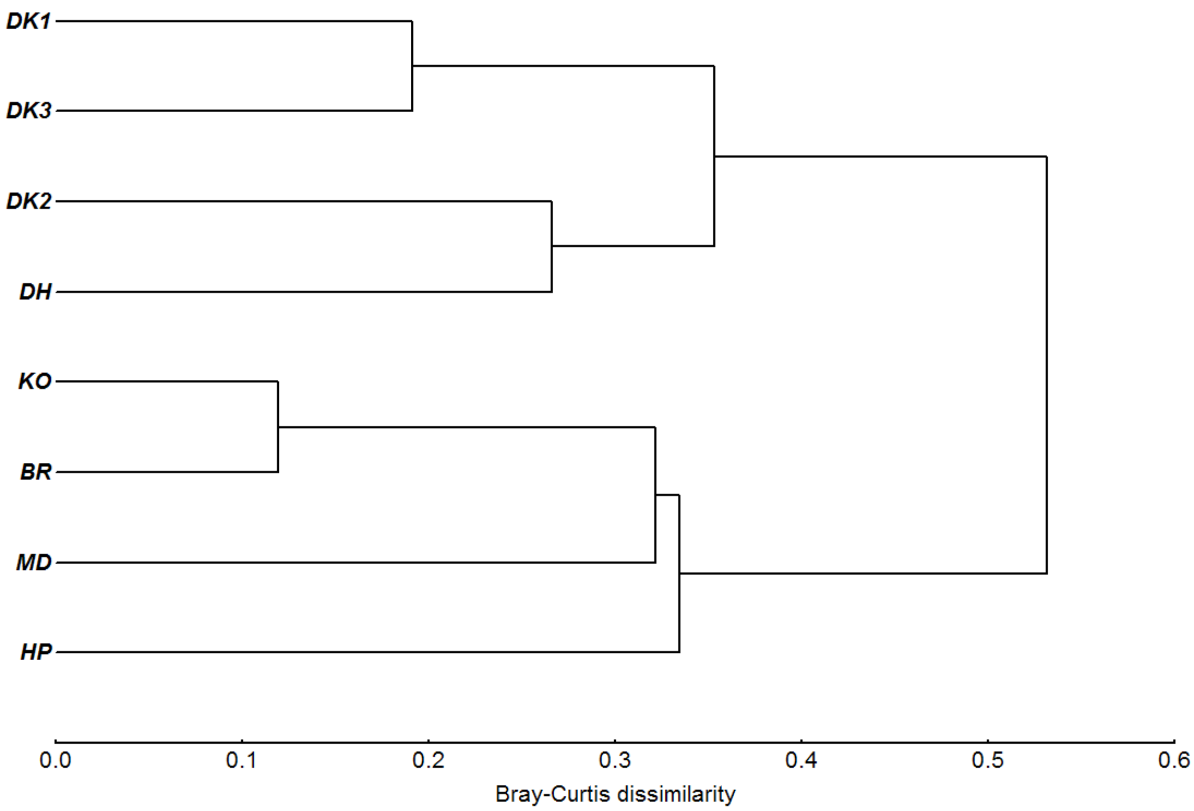


Figure 13. Cluster analysis of the similarity of milipede communities (Devínska Kobyla 1, 2, 3 (DK1, DK2, DK3), Dúbravská Hlavica (DH), Koliba (KO), Bratislava-Briežky (BR), Horský park (HP), Mlynská dolina (MD)).

2005, Stašiov 2005). Besides millipede species listed in this work, on territory of Bratislava were in addition recorded by Ortvay (1902): *Brachydesmus superus* (Latzel, 1884), *Cylindroiulus luridus* (C. L. Koch, 1847), *Julus scandinavius* Latzel, 1884, *Julus terrestris* Linnaeus, 1758, *Ophyiulus pilosus* (Meinert, 1868), *Polydesmus denticulatus* C. L. Koch, 1847, *Polydesmus tatranus* Latzel, 1882 and *Proteroiulus fuscus* (Am Stein, 1857). Mock, Janský (2000) confirmed the occurrence of *Glomeris pustulata* Latreille, 1804 in Bratislava, and Mišík et al. (1974) recorded the occurrence of *Brachyiulus bagnalli* (Curtis, 1845) in this city. Forasmuch as the occurrence of *P. tatranus* in Bratislava and in its surroundings is dubious, until now, 27 species of millipedes are thus known on the territory of Bratislava in total. This species number represents almost one third of Slovak diplopodofauna.

The low abundance and frequency of *P. complantus* recorded in studied localities is questionable as this species is eurytopic and euryvalent, and it is relatively abundant in a wide scale of various habitats. Limitation of *P. complantus* population by interspecific competition (for example by *C. boleti*) is a possible cause of this situation.

Preferring some localities by several millipede species suggests their possible relationship to the specific ecological conditions, typical of the corresponding sites. For instance, the abundant occurrence of *S. stigmatosum* in localities DK2 and DH suggests that this species prefers the sites with higher density of tree layer and with low density of herbal layer. Preferring localities DK1, DK2, DK3, DH by *G. hexasticha, E. nanus, M. unilineatum, U. foetidus* and *U. transsilvanicus* indicates that these species require the well-preserved habitats and avoid sites with marked human impact. On the contrary, species *C. boleti, L. proximus, C. rawlinsii* and especially *H. eremita* are more tolerant to human disturbance. The dominant occurrence of *C. boleti* in the localities DK1 and MD refers to its possible preferring the localities with higher slope, a lower content of carbon and humus in the

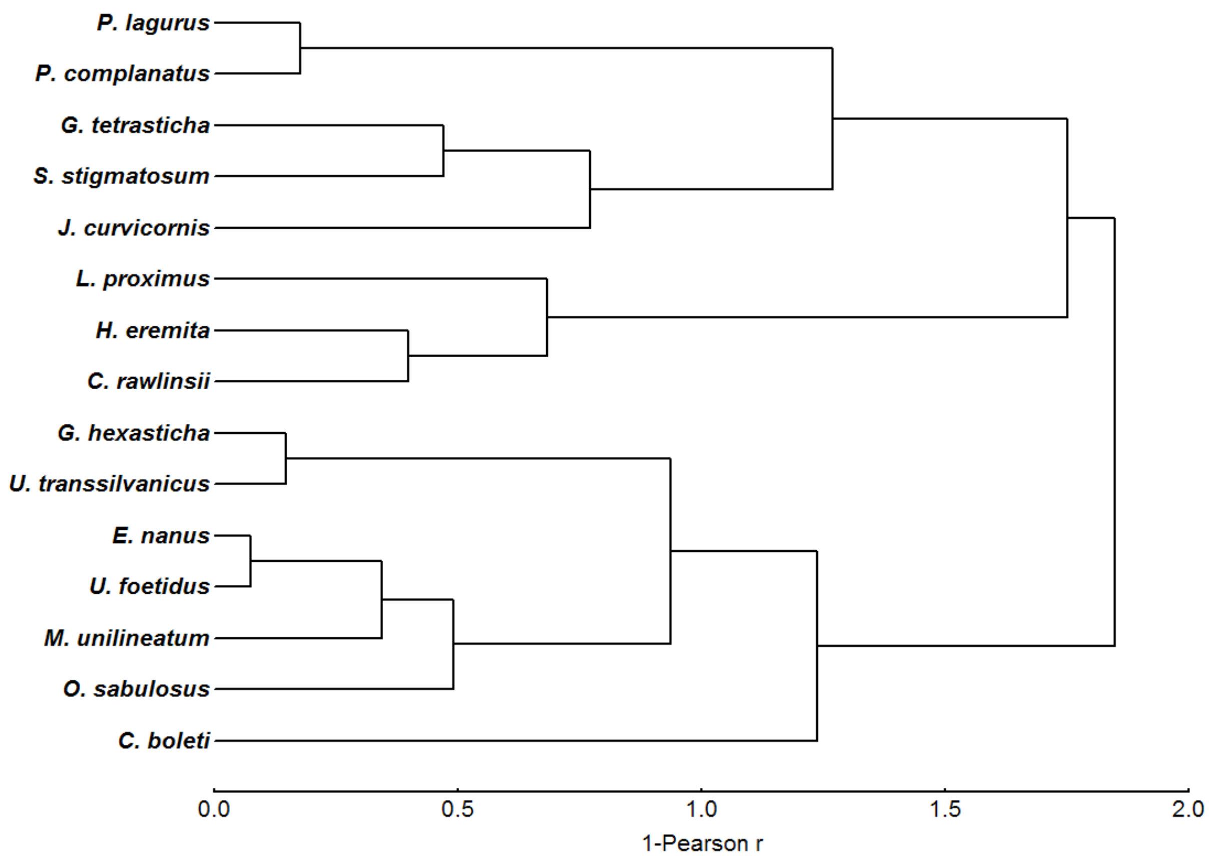


Figure 14. Cluster analysis of the similarity of species.

litter. The abundance of *L. proximus* in Briežky can indicate that this species prefers the soils with a higher content of carbon and humus in the litter, the highest value of C:N in the mineral layer and with lower pH-value of both soil layers. Higher abundance of *U. transsilvanicus* in locality DK1 could suggest that it The abundance of L. proximus in Briežky can indicate that this species prefers the localities with a lower content of carbon, nitrogen and humus in both of the soil layers, the highest value of C:N and total acidity of both soil layers. The marked preference of the locality HP by *H. eremita* could indicate that this species requires habitats with a higher content of nitrogen and with higher pH-value in both soil layers, with a higher amount of organic substances in the mineral soil layer, with a lower value C:N in both soil layers, with low values of the sorption complex of the mineral soil layer, and with lower total acidity of the litter soil layer. Species *C. rawlinsii* preferred locality (BR) with a higher content of carbon in both soil layers and with a higher content of humus in the litter, with a higher value of C:N and with low pH-value of both soil layers, with higher values of both of the sorption complex and degree of saturation of sorption complex of the mineral soil layer.

The influence of some of the above mentioned factors on the structure and biodiversity of soil organisms (including millipedes) was approved by other authors as well. For example, Stašiov (2002b) studied the influence of 34 chosen factors on the structure and dynamics of the millipede communities in the beech forests of the Kremnické vrchy Mts. (Central Slovakia). He demonstrated the significant positive relationship between the content of humus and carbon in the soil and the epigeic activity of *P. germanicum*. Several authors refer to the influence of nitrogen on the distribution of soil organisms. According to the data of Mattson (1980), nitrogen plays a decisive role in the growth of all the organisms. It is considered the limiting factor influencing health, growth, reproduction and survival of many organisms. The influence of the acidity on the soil macrofauna including the millipedes was demonstrated by other authors. For example, Smith et al. (2006) mention that the percentage of the covering by litter, the month of the sampling and the pH-value of the soil are the most important factors, affecting the population density of the four investigated groups of the soil invertebrates (Lumbricidae, Isopoda, Diplopoda, Chilopoda a Formicidae) in the urban parks and gardens of London. Stašiov (2002b) described the negative correlation between the pH-value of litter and the epigeic activity of *P. germanicum, J. curvicornis* and *Mastigona vihorlatica* (Attems, 1899). He also ascertained the positive relationship between the pH-value of soil and the epigeic activity of *P. complanatus*. Other authors, who approved the influence of the soil acidity on the communities of the millipedes, were Scheu, Poser (1996). They analyzed differences between the density, biomass, species composition and vertical distribution of the four groups of soil macrofauna (Diplopoda, Isopoda, Lumbricidae, Chilopoda) at various distances from trees in the beech forests on the limestone geological bedrock in Northern Germany. Their findings demonstrated that the soil at shorter distance from the beech trees had lower pH-value than the soil from the sites, located farther from the trunks. CCA showed that the pH-value of soil was a significant factor, affecting the structure of the millipede communities in the vicinity of the trunks of trees, whereas its importance was less remarkable on the more distant sites.

The research showed that, except for the two main factors (temperature and humidity of environment), whose influence on the millipedes was demonstrated earlier by several authors, this group of invertebrates is also affected by other environmental factors. The results of studies suggest the possible influence of 26 evaluated factors with the specific effect on the corresponding millipede species.

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References

Branquart, É., Kime, R.D., Dufrêne, M., Tavernier, J., 1995: Macroarthropod-habitat relationships in oak forest in South Belgium. 1. Environments and communities. Pedobiologia, Gustav Fischer Verlag, Jena, 39: 243–263.

Gava, R., 2004: Vertical distribution of Diplopoda populations from deciduous forests. Arch. Biol. Sci., Belgrade, 56: 59–64.

Gulička, J., 1955: Two new species of Diplopoda for Czechoslovakia (in Slovak). Biológia, 10: 367–370.

Gulička, J., 1956: Two alpine species of Diplopoda in Slovakia (in Slovak). Acta fac. rer. nat. Univ. Comen., Zoologia, 1: 79–88.

Gulička, J., 1986: Diplopoda of forest communities of the Little Carpathians. In: Nosek, J. (ed.), The soil fauna of the Little Carpathians. Proc. of conference. Bratislava, p. 217–224.

Holecová, M., Krumpál, M., Országh, I., Krumpálová, Z., Stašiov, S., Fedor, P., 2005: Biodiversity of selected invertebrate groups in oak-hornbeam forest ecosystem in SW Slovakia. Ekológia (Bratislava) 24, Supplement 2/2005: 205–222.

Krumpál, M., 1993. Invertebrates (in Slovak). In: Bertová, L. (ed.), Karlova Ves. Homeland monograph. Alfa, Bratislava, p. 57–61.

Lang, J., 1933. A contribution to the knowledge of Czechoslovak diplopods. Věst. Král. spol. nauk, 2: 1–32.

Lang, J., 1954: Millipedes – Diplopoda. Fauna ČSR 2 - Nakladatelství ČSAV, Praha, 187 pp.

Mattson, W.J., 1980: Herbivory in relation to plant nitrogen content. Ann. Rev. Ecol. Syst., 11: 119–161.

Meyer, E., Plankensteiner, U., Grabher, M., Lutz, S., 1999: The effect of fenland drainage on the soil fauna in the Rhine delta (western Austria). In: Tajovský, K., Pižl, V. (eds), Soil Zoology in Central Europe, 5th Central European Workshop on Soil Zoology. ISB BC AS CR, České Budějovice, p. 233–241.

Mišík, M., Gulička, J., Urvichiarová, E., 1974: Devínska Kobyla. Geological conditions, flora and fauna (in Slovak). Obzor, Bratislava, 107 pp.

Mock, A., Janský, V., 2000: Millipedes (Diplopoda) in the collections of the Slovak National Museum in Bratislava (in Slovak). Acta Rer. Natur. Mus. Nat. Slov., Bratislava, 46: 3–10.

Morón-Ríos, A., Huerta-Lwanga, E., 2006: Soil macrofauna of two successional evergreen cloud forest stages from the Cerro Huitepec Nature Reserve, San Cristóbal de las Casas, Chiapas, México. Interciencia, 31: 611–615.

Odum, E.P., 1971: Fundamentals of Ecology, 3rd ed. W. B. Saunders, Philadelphia, 574 pp.

Ortvay, T., 1902: Fauna of Bratislava region and of Bratislava, Trnava, Pezinok, Modra, Svätý Jur cities situated in this region (in Hungarian). Community of Bratislava region, Bratislava, XVI + 648 pp.

Rahmani, R., Mayvan, H.Z., 2003: Diversity and assemblage structure of soil invertebrates in beech, hornbeam and oak-hornbeam forest types. Iranian Journal of Natural Resources, 56: 425–436.

Scheu, S., Poser, G., 1996: The soil macrofauna (Diplopoda, Isopoda, Lumbricidae and Chilopoda) near tree trunks in a beechwood on limestone: indications for stemflow induced changes in community structure. Applied Soil Ecology, 3: 115–125.

Smith, J., Chapman, A., Eggleton, P., 2006: Baseline biodiversity surveys of the soil macrofauna of London's green spaces. Urban ecosystems, 9: 337–349.

Stašiov, S., 2002a: Millipedes (Diplopoda) of Blatnická dolina valley (Veľká Fatra NP, Slovakia) (in Slovak). Matthias Belivs Univ Proc, Banská Bystrica, 2: 123–133.

Stašiov, S., 2002b: Selected groups of epigeic macrofauna (Opilionida, Diplopoda and Chilopoda) as indicators of the status of the top soil layer in submontane beech forest (in Slovak). Scientific Studies. Technical University in Zvolen, Zvolen, 88 pp.

Stašiov, S., 2005: Millipedes communities (Diplopoda) of oak-hornbeam ecosystems (the Malé Karpaty Mts, Trnavská pahorkatina hills, SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 143–151.

Statsoft, Inc., 2003: STATISTICA (data analysis software system), version 6.

Tuf, I.H., Ožanová, J., 1999: Centipedes and millipedes in floodplain forests of various age. In: Tajovský, K., Pižl, V. (eds), Soil Zoology in Central Europe, 5th Central European Workshop on Soil Zoology. ISB BC AS CR, České Budějovice, p. 357–363.

4.4. Bugs (Heteroptera)

Magdaléna Roháčová, Milada Holecová

Mixed oak-hornbeam forests occur naturally in sites, where beech forests can not grow owing to special local climatic conditions (frequent frost period in early spring, basins with temperature inversion) as well as macroclimatic areas with too low precipitations rates. The natural range of oak-hornbeam forests shows clearly a main centre in central-Eastern Europe. Most of the natural oak-hornbeam forests were transformed to very productive agricultural land; nowadays oak-hornbeam forests cover only 15% of its natural range (Barbati, Morchetti 2004).

Indicator species or groups of species are frequently used to assess historical, contemporary and also future human impact on nature. True bugs (Heteroptera) as a guild of suckers can be ranked among species, whose occurrence can reflect certain habitat conditions. Most species are phytophagous and thermo- and heliophilous as well, and occur mainly on plant or tree vegetation; some of them are specialized to certain plant species or family and thus their occurrence can indicate plant species, and vice versa. Predaceous or eventually phyto-zoophagous and necrophagous species represent the minority of this insect order. Some species prefer to live permanently or temporarily in plant litter, moss or in soil and suck on roots, lichens or bryophytes. Presence of true bugs in epigeon corresponds with hibernation also heteropterans seek shelters in detritus, moss or beneath tree barks.

In the southwestern Slovakia, assemblages of Heteroptera in deciduous forests (including oak-hornbeam stands) have been very well explored mainly owing to coenotic studies of O. Štepanovičová and her student followers (Štepanovičová 1973, 1978a,b, 1981, 1985, 1986, 1991, Štepanovičová, Lapková 1984a,b, 1988, Lapková 1986, 1989, 1997, Lapková et al. 1986, Bianchi, Štepanovičová 1998, Bianchi et al. 1999). Some studies were focused only at certain heteropteran taxa (Belavá 1981, Bulánková 1989, 1991, Bulánková, Holecová 1998) or certain protected areas (Országh 1966, Herczek, Halgoš 1991).

Štepanovičová underlined the indicative role of epigeic heteropteran assemblages in conditions of southwestern Slovakia especially in her last studies (Štepanovičová 1994, 1995a, b, 1997, Štepanovičová, Bianchi 1999, 2003, Majzlan, Štepanovičová 1998, Štepanovičová, Degma 1999). Among other heteropterologists, Bianchi (1991) studied epigeic Heteroptera in the vicinity of Bratislava town, Hradil (2005) in detail evaluated assemblages of epigeic Heteroptera in the Malé Karpaty Mts. and Trnavská pahorktina hills and gave comparison of faunistic data on epigeic heteropterans amongst results of several studies. Data on occurrence of some epigeic true bugs in the area of Bratislava were summarized by Stehlík (2002) and Stehlík, Vavřínová 1993, 1995a, b, 1998a, b, 1999).

There are very few comparable data on epigeic Heteroptera assemblages in other Central European countries. Apart from the study of Strawinski (1960) and Rédei, Hufnagel (2003a, b), epigeic heteropterans were mostly dealt as a part of soil insect fauna (Kříštek, Dobšík 1985, Verner 1959).

The aim of present study is to complete information on occurrence of epigeic heteropteran species of oak-hornbeam forests in urban area.

Investigations were performed in 8 study plots in the area of Bratislava city:

1. Complex of the Nature Reserve Devínska Kobyla hill situated on the western city margin, with the best preserved oak-hornbeam forest ecosystem:

DK1 (Devínska Kobyla 1) – 7868a, 340 m a.s.l., 48°11´, 16°59´, a forest of the *Querco-Carpinetum melicetosum uniflorae* subassociation situated eastwards of the hilltop, southern exposition, 15° slope, age 60–80 years, E_3: 75%, E_2: 35%, E_1: 70%.

DK2 (Devínska Kobyla 2) – 7868a, 300 m a.s.l., 48°10´, 16°59´, a forest of the *Aceri-Carpinetum* association situated south-eastwards of the hilltop and in the valley at the spring, northern exposition, 10° slope, age 40–60 years, E_3: 80%, E_2: 15%, E_1: 60%.

DK3 (Devínska Kobyla 3) – 7868a, 452 m a.s.l., 48°11´, 16°59´, submarginal plateau below the hill top, a thermophilous oak stand of the *Primulo veris-Carpinetum* association, southern exposition, 0–2° slope, age 60–80 years, E_3: 80%, E_2: 2%, E_1: 70%.

DH (Dúbravská Hlavica) – 7868a, 350 m a.s.l., 48°11´, 17°00´, a closed forest of the *Querco petraeae-Carpinetum typicum*, eastern exposition, 5° slope, age 80–100 years, E_3: 80%, E_2: 30%, E_1: 70%.

2. Complex of the Koliba hill where oak-hornbeam forest are under considerable human impact (tourist visitors, silvicultural management – timber extraction and coppice culling). Until 1990, the complex was also impacted with chemical pollution of factories situated at the eastern city margin.

KO (Koliba) – 7868b, 380 m a.s.l., 48°10´ N, 17°05´ E, a forest of the *Querco-Carpinetum melicetosum uniflorae* subassociation, south-western exposition, moderately undulated terrain, age 90–100 years, E_3: 70%, E_2: 35%, E_1: 20–30%.

BR (Briežky) – 7868b, 340 m a.s.l., 48°11´ N, 17°06´ E, a forest of the *Querco petraeae-Carpinetum typicum* association, south-western exposition, 5–7° slope, age 80–100 years, E_3: 75%, E_2: 30%, E_1: 30%.

3. Complex of urban oak-hornbeam forests in the city-centre. Localities are impacted to the greatest extent and are fragmented to a great deal:

HP (Horský park) – 7868a, 212 m a.s.l., 48°09´ N, 17°05´ E, a forest of the *Querco petraeae-Carpinetum* association, south-eastern exposition, 10–20° slope, age 80 years, E_3: 70%, E_2: 40%, E_1: 70%.

MD (Mlynská dolina) – 7868a, 190 m a.s.l., 48°09´ N, 17°04´ E, a forest of *Aceri-Carpinetum* association, 45° slope, age 80–100 years, E_3: 70%, E_2: 20%, E_1: 100%.

During the period of 2005–2006, the study plots were investigated from April to the very beginning of January 2007 in approximately 1-month intervals. At each study plot, the material was sampled by sifting of the upper part of soil and leaf litter from $1m^2$ (16 squares of 25 x 25 cm). The sifted material was extracted in xereclectors of the Moczarski-Winkler's type and then conserved in the 75% ethylalcohol. The material was collected by the second author and it is deposited at the Department of Zoology, Faculty of Natural Sciences, Comenius University Bratislava.

Species dominance (in %) is expressed by 5-degree scale according to Tischler (1949) and later modified by Heydemann (1955): ED – eudominant species, D – dominant species, SD – subdominant species, R – recedent species and SR – subrecedent species. Scale of species constancy according to Schwertfeger (1975) that originated from that of Tischler (1949) distinguishes euconstant species (EC), constant (C), accessoric (A) and accidental species (AC).

The cluster analysis based on Wishart's and Sørensen's indices was used for similarity evaluating of heteropteran assemblages. The cluster analysis (clustering method complete linkage) was done in computer program NCLAS (Podani 1993). DCA method (Detrended Correspondence Analysis) in CANOCO software program (ter Braak, Šmilauer 1998) was used for assessing of species and study plots correlations.

Material was identified by the first author and the used nomenclature follows Aukema, Rieger (1996, 2001, 2006) and their consequent amendments.

In total, 185 Heteroptera specimens were collected in eight study plots in 2005–2006. In spite of scanty material, it was species-rich and comprised 34 species of 13 families (Table 14, 15). The family Pentatomidae was the most represented in species number (9 taxa). However, there was an outstanding difference in quantitative representation of families. The rich in species pentatomid family reached only dominant status with 13 specimens (7.03%) contrary to the monospecific and eudominant Cydnidae family (112 specimens, 60.54%).

In the epigeon of oak-hornbeam forest of the Malé Karpaty Mts., Hradil (2005) recorded the Rhyparochromidae family as eudominant (14 species, 32.61%). Within this study, rhyparochromid family reached eudominant value (15.14 %, 7 species) as well. Similar results in terms of family dominance was recorded in study of Štepanovičová (1997) in the soil of the floodplain forest in the vicinity of the Morava river.

Majority of species were phytophagous, only three species were zoophagous (*Nabis* genus and *Orius minutus*); further three species are regarded as phyto- and necrophagous or phytophagous with tendency towards necrophagy (*Pyrrhocoris apterus*, *Ceraleptus gracilicornis* and *C. lividus*).

Representation of individual zoogeographical elements is shown in Fig. 15a, b. Majority of species had Holopalaearctic distribution (Fig. 15a), most of them representing eurytopic species without a strict habitat preference. Holomediterranean and Central Asian (HM(1)+CA) species predominated quantitatively (Fig. 15b) particularly thanks to the cydnid *Legnotus limbosus* with dominance 60.54%. All species of the zoogeographical element HM(1)+CA are thermophilous.

Although species number was similar in individual study plots (5–8), the study plots differed by species presence and their abundance and dominance. (Tab. 16, Fig. 16). Three species that are eurytopic and euryhygric occurred in all of the studied complexes –

Table 14. Survey of the recorded Heteroptera families and their dominance.

Family	Specimen number	Species number	D (%)
Tingidae	1	1	0.54
Miridae	7	3	3.78
Nabidae	6	2	3.24
Anthocoridae	1	1	0.54
Lygaeidae	2	2	1.08
Rhyparochromidae	28	7	15.14
Piesmatidae	2	2	1.08
Pyrrhocoridae	1	1	0.54
Coreidae	5	3	2.70
Cydnidae	112	1	60.54
Scutelleridae	6	1	3.24
Pentatomidae	13	9	7.03
Acanthosomatidae	1	1	0.54
Total	**185**	**34**	**100.00**

Table 15. List of the recorded heteropteran species in individual complexes of the urban oak-hornbeam forest in the territory of Bratislava-city and their ecological characteristics.

Taxon	C 1	C2	C3	Σ	ZgD	Pref	Hb	Vub.
Tingidae								
Campylosteira verna (Fallén, 1826)	1			1	E	GB	st	x
Miridae								
Lygus rugulipennis Poppius, 1911	1	2	2	5	HP	GX	et	e
Orthops (*Orthops*) *basalis* (A. Costa, 1853)	1			1	ES+N	GX	et	e
Agnocoris reclairei (Wagner, 1949)		1		1	HM(1)	GX	et	e
Nabidae								
Nabis (*Nabis*) *p. pseudoferus* Remane, 1949	3			3	WP	GX	et	e
Nabis (*Nabis*) *rugosus* Linnaeus, 1758)	2		1	3	WS	GX	et	e
Anthocoridae								
Orius (*Heterorius*) *minutus* (Linnaeus, 1758)		1		1	E	GX	et	e
Lygaeidae								
Nysius s. senecionis (Schilling, 1829)			1	1	HM(1) +CA	GX	et	e
Kleidocerys r. resedae (Panzer, 1797)	1			1	ES+N	GX	et	e
Rhyparochromidae								
Drymus (*Sylvadrymus*) *b. brunneus* (R. F. Sahlberg, 1848)			1	1	ES	GF	et	h
Eremocoris a. abietis (Linnaeus, 1758)		1		1	HM(1)	GF	st	h
Eremocoris podagricus (Fabricius, 1775)	9	5	4	18	MoM	GF	et	e
Scolopostethus affinis (Schilling, 1829)		1		1	HP	GF	et	e
Graptopeltus lynceus (Fabricius, 1775)		1		1	WP	GX	et	e
Megalonotus chiragra (Fabricius, 1775)	2	3		5	ES	GF	et	e
Emblethis griseus (Wolff, 1802)			1	1	H	GF	et	e
Piesmatidae								
Piesma capitatum (Wolff, 1804)	1			1	ES	GF	et	e
Piesma maculatum (Laporte, 1833)	1			1	HP	GF	et	e
Pyrrhocoridae								
Pyrrhocoris apterus (Linnaeus, 1758)	1			1	H	GX	et	e
Coreidae								
Gonocerus acuteangulatus (Goeze, 1778)	1		1	2	HM(1)+CA	GX	et	e
Ceraleptus gracilicornis (Herrich-Schaeffer, 1835)	1		1	2	HM(1)	GX	st	x
Ceraleptus lividus Stein, 1858		1		1	E	GX	et	e
Cydnidae								
Legnotus limbosus (Geoffroy, 1785)	103		9	112	HM(1)+CA	GB	st	e
Scutelleridae								
Eurygaster maura (Linnaeus, 1758)	2	2	2	6	HP	GX	et	e

Table 15. continue.

Taxon	C 1	C2	C3	Σ	ZgD	Pref	Hb	Vub.
Pentatomidae								
Sciocoris (*Aposciocoris*) *homalonotus* Fieber, 1851	1			1	HM(1)	GB	et	e
Dyroderes umbraculatus (Fabricius, 1775)			1	1	HM	GX	et	h
Aelia acuminata (Linnaeus, 1758)	2		2	4	HP	GX	et	e
Peribalus (Peribalus) s. strictus (Fabricius, 1803)	1			1	PAL	GX	et	e
Dolycoris baccarum (Linnaeus, 1758)	1			1	HP	GX	et	e
Palomena prasina (Linnaeus, 1761)	1		1	2	HP	GX	et	e
Eurydema (*Eurydemma*) *ornata* (Linnaeus, 1758)	1			1	HP+O	GX	et	e
Eurydema (*Eurydemma*) *oleracea* (Linnaeus, 1758)			1	1	HP	GX	et	e
Piezodorus lituratus (Fabricius, 1794)	1			1	WP	GX	et	e
Acanthosomatidae								
Elasmucha g. grisea (Linnaeus, 1758)		1		1	ES	GX	et	e
Total abundance	138	19	28	185				
Species number	22	11	14	34				

Notes: Complex 1 – Complex of the Nature Reserve Devínska Kobyla hill, Complex 2 – Complex of Koliba hill, Complex 3 – Complex of urban oak-hornbeam forests in the city-centre; ZgD – Zoogeographical distribution: E – European species, ES – Eurosiberian species, ES(+N) – Eurosiberian and Nearctic species, H – Holarctic species, HM – Holomediterranean species, HM(1) – Holo- and northern Mediterranean species, HM(1)+CA – Holomediterranean and Central Asian species, HP – Holopalaearctic species, HP+O – Holopalaearctic and Oriental , MoM – montanmediterranean species, PAL – Palaearctic species, WP – Western Palaearctic species; WS - western Euro-Siberian species; Pre – topic preference: GB – geobiont, GF – geophilous species, GX – geoxenous species, H – habitat preference: st – stenotopic species, et – eurytopic species; V – ecological valency: e – euryhygric species, x – xerophilous species, h – hygrophilous species.

geoxenous mirid *Lygus rugulipennis*, scutellerid *Eurygaster maura* and geophilous rhyparochromid *Eremocoris podagricus*.

Most species were recorded within the complex of the Devínska Kobyla NR (22 species and 138 specimens). This complex includes the best preserved oak-hornbeam forests with relative stable nature conditions unlike the remaining oak-hornbeam forest complexes of Koliba hill and forests in city centre (11 species, 19 specimens and 14 species, 28 specimens, respectively) that represent forests influenced by human disturbance.

Comparison of three studied complexes shows an interesting fact. Although it is problematic to compare species and specimen numbers in individual complexes (as complex 1 of the NR Devínska Kobyla hill was investigated in 4 study plots contrary to 2 study plots in complexes 2 and 3), the species number of complex 1 was twice higher then in the complex 2 and 1.6-times higher then in the complex 3. The differences in specimen numbers were more pronounced when specimen number of the complex 1 exceeded more than 7-times that in the complex 2 and nearly 5-times that in the complex 3 (Fig. 16), what was caused mainly by the abundance of the cydnid *Legnotus limbosus*.

Although that species numbers were quite balanced in individual study plots (Table 16, Fig. 16), this quantitative index has a small indicative value, similarly as biodiversity indices have only restricted importance. According to Plachter (1991), higher species diversity within naturally species poor high-moor bogs might just be caused by peat harvesting, or nutrient poor habitats might just be eutrophicated due to human influences, which allows unnatural species to compete successfully and to colonize these habitats. For single study plots, specific guilds were supposed that reflect typical habitat conditions. According to Reck (1995), typical biocoenosis of certain ecological guilds can be expected for different habitat types, which can be related to certain indicator functions of these species. Mainly geobiont and geophilous bug species can be regarded as important keystone species as they need certain favourable habitat condition (mostly humid) contrary to geoxenous species that rather prefer herbage stratum. Within this study, among typical species occurring mostly or exclusively in detritus, leaf litter, under stones, in mosses and lichens, mouldering woods, etc. following species and genera can be ranked: *Campylosteira verna, Drymus brunneus, Emblethis griseus, Eremocoris* spp., *Megalonotus chiragra, Legnotus limbosus, Piesma* spp., *Sciocoris homalonotus, Scolopostethus affinis* and also representants of *Ceraleptus* spp. often stay in plant detritus of their food plants (Stehlík 2002, Stehlík, Vavřínová 1993, 1995a,b, 1998a,b, 1999).

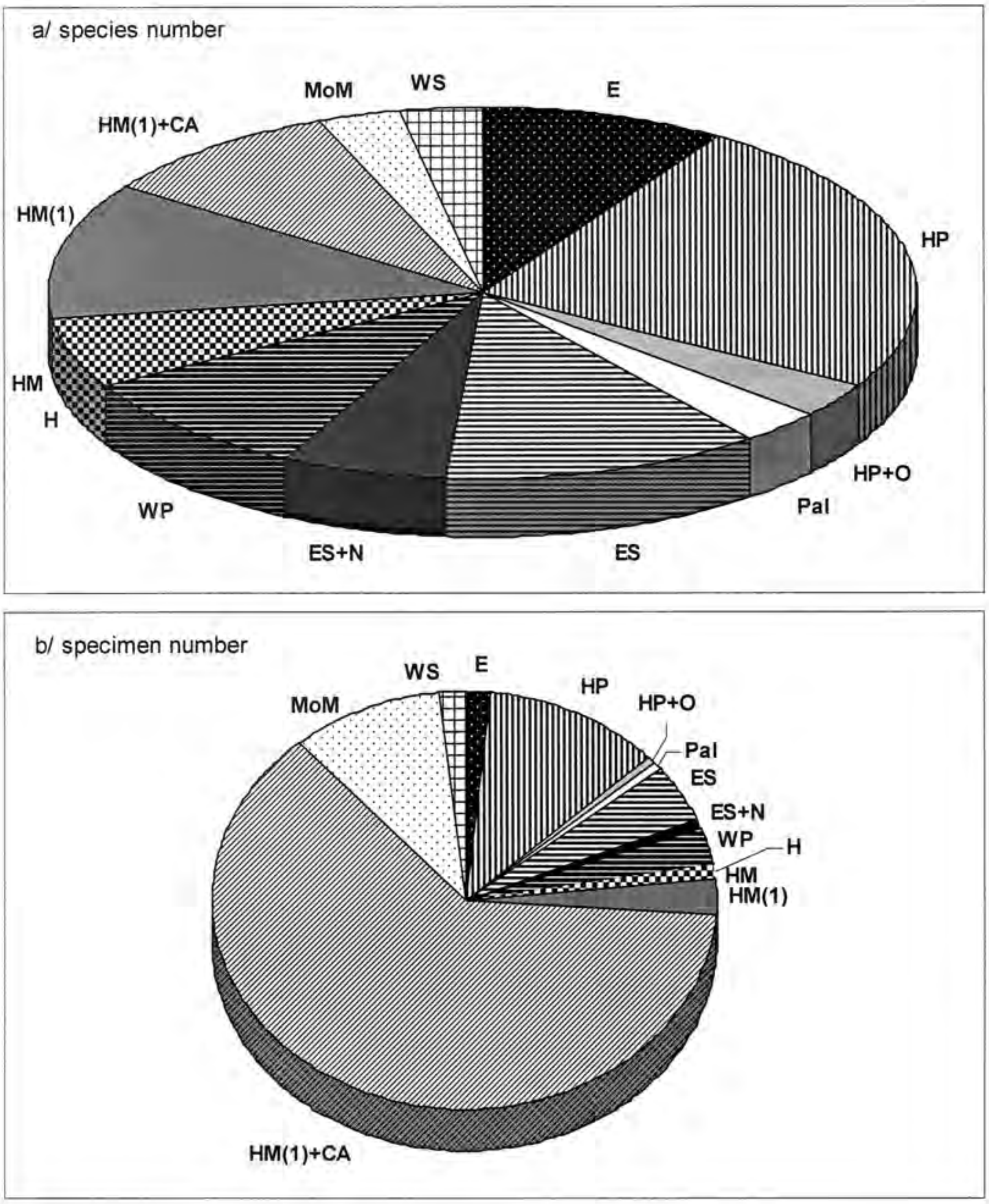

Figure 15. Representation of heteropteran species (a/) and specimens (b/) in zoogeographical elements. For abbreviations see Table 15.

As for total species dominance (Table 16), one species reached eudominant status (*Legnotus limbosus*), *Eremocoris podagricus* was recorded as dominant and *Lygus rugulipennis, Megalonotus chiragra* and *Aelia acuminata* were ranked among subdominant species. The remaining 29 species were recedent and subrecedent (5 and 24 species).

Species abundance of heteropteran assemblage in study plots varied between 1.29–9.28 ex./m^2 with average value 5.44 ex./m^2. Hradil (2005) recorded value range 1.63–4.53 bug ex./m^2 in the epigeon of oak-hornbeam forests in Malé Karpaty Mts. Similar value (4.23 ex./m^2 in 1991–94 and 6.23 ex./m^2 in 1991–96) was published by Štepanovičová from epigeon of the floodplain forests in the vicinity of the Danube river, however, average abundance yielded 8.32 ex./m^2 in 1991–93, respectively 11.8 ex./m^2 in 1993 in the vicinity of the Morava river (Štepanovičová 1997, Majzlan, Štepanovičová 1998, Štepanovičová, Degma 1999). Higher abundance values along the Morava river was characteristic rather for drier floodplain forests. According to Majzlan, Štepanovičová (1998), moist floodplain forest habitats are characteristic by low abundance values, contrary to the drier floodplain forests. Thus, moisture level of forest soils is reflected also in structure of epigeic bug assemblages, especially in their quantitative representation. This conclusion was confirmed also within this study, mainly in case of geophilous and stenophagous eudominant *Legnotus limbosus* species with trophic preference to *Galium molugo* or exceptionally *G. verum* (Stehlík, Vavřínová 1993). According to mentioned authors, it is abundant on *Galium molugo* growths, especially in warm localities in invariably shaded places. *Legnotus limbosus* peaked in abundance in the study plots DK1 and DK3 of the NR Devínska Kobyla complex, except of the moist study plot DK2 situated in the vicinity of forest spring, where it was not recorded. The course of seasonal dynamics of *Legnotus limbosus* abundance in DK1, DK3, DH and MD study plots is illustrated in Fig. 17.

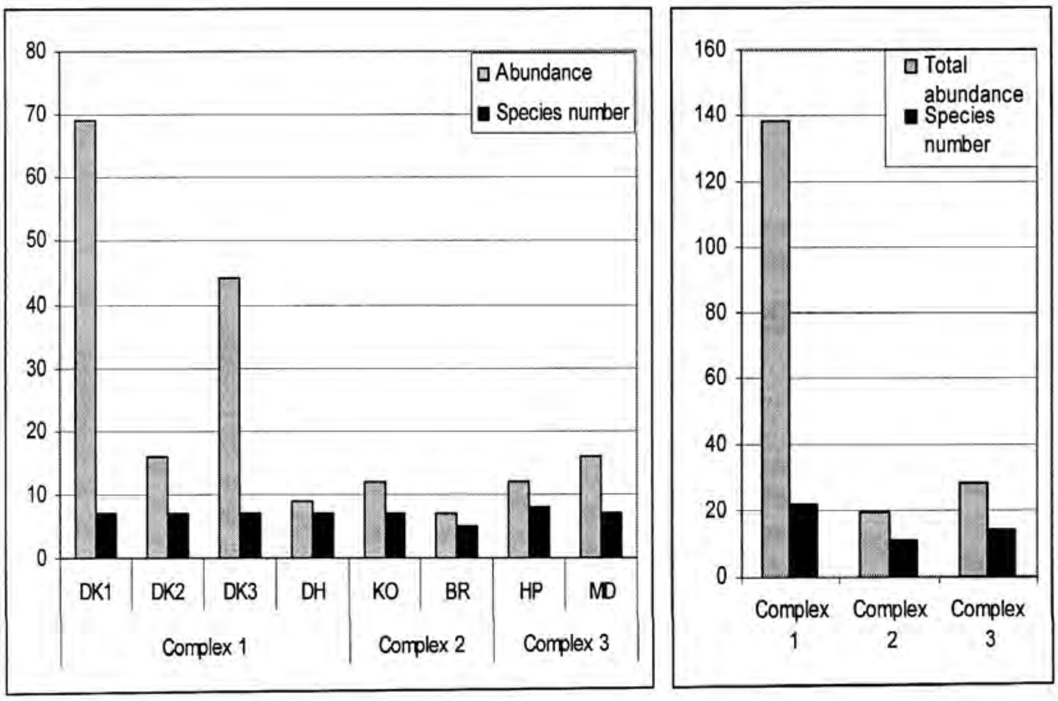

Figure 16. Species and specimen numbers in individual study plots and complexes. Notes: DK1 - Devínska Kobyla hill 1, DK2 - Devínska Kobyla hill 2, DK3 - Devínska Kobyla hill 3, DH – Dúbravská Hlavica, Complex 1 – Complex of the Nature Reserve Devínska Kobyla hill, KO - Koliba, BR – Briežky, Complex 2 - Complex of Koliba hill, HP – Horský park, MD – Mlynská dolina, Complex 3 - Complex of urban oak-hornbeam forests in the city-centre.

Table 16. Dominance (%) of epigeic heteropterans in individual study plots.

Species	DK1	DK2	DK3	DH	C 1	KO	BR	C 2	HP	MD	C 3	TD	C
Campylosteira verna				0.54	**0.54**							**0.54**	12.5
Lygus rugulipennis			0.54		**0.54**	0.54	0.54	**1.08**	0.54	0.54	**1.08**	**2.7**	62.5
Orthops basalis				0.54	**0.54**							**0.54**	12.5
Agnocoris reclairei							0.54	**0.54**				**0.54**	12.5
Nabis p. pseudoferus	0.54	1.08			**1.62**							**1.62**	25
Nabis rugosus	0.54		0.54		**1.08**					0.54	**0.54**	**1.62**	37.5
Orius minutus						0.54		**0.54**				**0.54**	12.5
Nysius s. senecionis									0.54		**0.54**	**0.54**	12.5
Kleidocerys r. resedae				0.54	**0.54**							**0.54**	12.5
Drymus b. brunneus									0.54		**0.54**	**0.54**	12.5
Eremocoris a. abietis							0.54	**0.54**				**0.54**	12.5
Eremocoris podagricus		4.86			**4.86**	2.7		**2.7**	2.16		**2.16**	**9.73**	37.5
Scolopostethus affinis						0.54		**0.54**				**0.54**	12.5
Graptopeltus lynceus							0.54	**0.54**				**0.54**	12.5
Megalonotus chiragra			1.08		**1.08**		1.62	**1.62**				**2.7**	25
Emblethis griseus										0.54	**0.54**	**0.54**	12.5
Piesma capitatum				0.54	**0.54**							**0.54**	12.5
Piesma maculatum				0.54	**0.54**							**0.54**	12.5
Pyrrhocoris apterus		0.54			**0.54**							**0.54**	12.5
Gonocerus acuteangulatus			0.54		**0.54**				0.54		**0.54**	**1.08**	25
Ceraleptus gracilicornis		0.54			**0.54**				0.54		**0.54**	**1.08**	25
Ceraleptus lividus						0.54		**0.54**				**0.54**	12.5
Legnotus limbosus	34.05		20.00	1.62	**55.7**					4.86	**4.86**	**60.54**	50
Eurygaster maura	0.54		0.54		**1.08**	1.08		**1.08**		1.08	**1.08**	**3.24**	50
Sciocoris homalonotus			0.54		**0.54**							**0.54**	12.5
Dyroderes umbraculatus										0.54	**0.54**	**0.54**	12.5
Aelia acuminata		0.54		0.54	**1.08**				1.08		**1.08**	**2.16**	37.5
Peribalus s. strictus		0.54			**0.54**							**0.54**	12.5
Dolycoris baccarum		0.54			**0.54**							**0.54**	12.5
Palomena prasina	0.54				**0.54**					0.54	**0.54**	**1.08**	25
Eurydema ornata	0.54				**0.54**							**0.54**	12.5
Eurydema oleracea									0.54		**0.54**	**0.54**	12.5
Piezodorus lituratus	0.54				**0.54**							**0.54**	12.5
Elasmucha g. grisea						0.54		**0.54**				**0.54**	12.5
Dominance	37.30	8.65	23.78	4.86	**82.14**	6.49	3.78	**10.27**	6.49	8.65	**15.14**		
Number of individuals	69	16	44	9	**138**	12	7	**19**	12	16	**28**	**185**	
Number of species	7	7	7	7	**22**	7	5	**11**	8	7	**14**	**34**	
Average abundance	9.86	2.29	6.29	1.29	**6.27**	1.71	1.40	**1.73**	1.50	2.29	**2.0**	**5.44**	

Notes: DK1 – Devínska Kobyla hill 1, DK2 – Devínska Kobyla hill 2, DK3 – Devínska Kobyla hill 3, DH – Dúbravská Hlavica, C1 – Complex of the Nature Reserve Devínska Kobyla hill, KO – Koliba, BR – Briežky, C2 – Complex of Koliba hill, HP – Horský park, MD – Mlynská dolina, C3 – Complex of urban oak-hornbeam forests in the city-centre, TD – total dominance, C – constancy.

Although data on habitat preference of this species are not uniform, Štepanovičová (1997) characterized it as mesohygrophilous in the conditions of floodplain forests of the Morava and Danube rivers, but its regular occurrence in these habitats indicates floodplain forest habitats that have drier character as a consequence of greater depth of underground water level and absence of inundations. Nor did it occur in Complex 3 of the forests in city centre, contrary to other geophilous seedbug *Drymus brunneus* that is regarded as typical hygrophilous species (Stehlík, Vavřínová 1998b) with marked preference to moister habitats (Štepanovičová 1997) and whose occurrence within this complex indicates its moister character.

Similar conclusions in terms of species number stated Országh (1966) in his study of Nature Reserve Jurský Šúr, when species numbers were approximately by 1/3 richer in drier localities than those in moister habitats.

Stehlík, Vavřínová (1993) mentioned that in conditions of Slovakia the hibernated adults were observed from the second May decade onwards. In the study plot DK1 and DK3, where *Legnotus limbosus* was the most abundant, adults were recorded in epigeon already in the very beginning of April. First nymphs emerged in second decade of July.

Constancy values (Table 16) varied for individual species, when only *Lygus rugulipennis* was recorded as constant species with 62.5% value, while *Legnotus limbosus* and *Eurygaster maura* that reached category of 50% constancy, and *Nabis rugosus, Eremocoris podagricus* and *Aelia acumiata* (37.50%) were among accessoric species. The remaining species were classified as accidental ones.

Similarity of heteropteran assemblages within individual study plots according to Sørensen's and Wishart's indices is illustrated in dendrograms (Figs. 18 and 19).

Hierarchical classification based on qualitative-quantitative dissimilarity (Wishart's similarity ratio, complete linkage, Fig. 18) divided the heteropteran assemblages into 3 separate clusters, that are connected at very low level of similarity. The first cluster represents the assemblages of study plots HP and DK2 joined at 46% similarity. DK2 is a case of locality with the highest humidity and with an absence of the cydnid *Legnotus limbosus*,

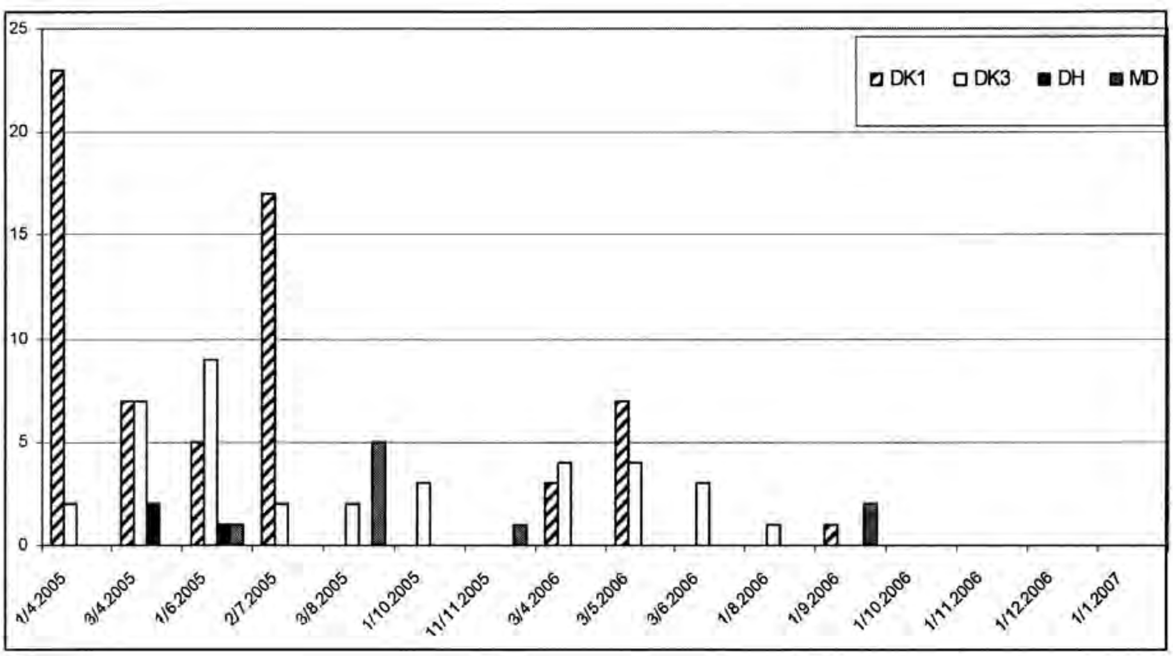

Figure 17. Seasonal dynamics of abundance of *Legnotus limbosus* in respective study plots. Data refers the decade in respective month and year of collection.

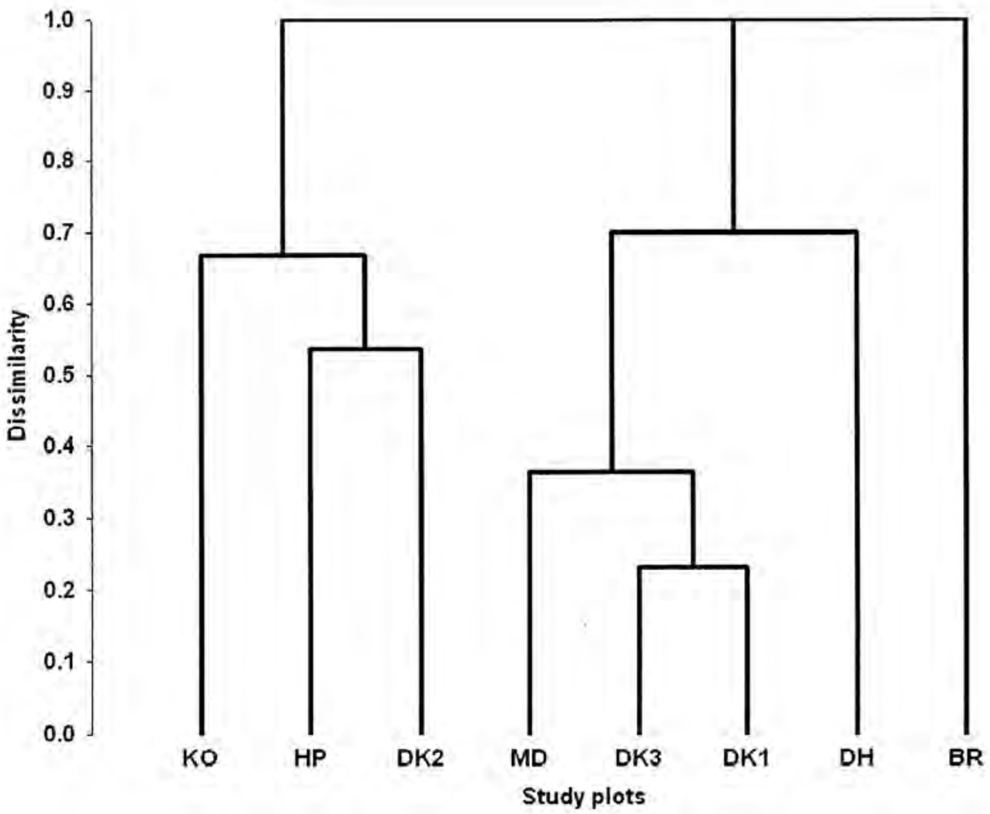

Figure 18. Hierarchical classification of the heteropteran assemblages in individual study plots according to Wishart's similarity ratio (complete linkage). The vertical axis designates dissimilarity. Abbreviations of study plots - see in the text.

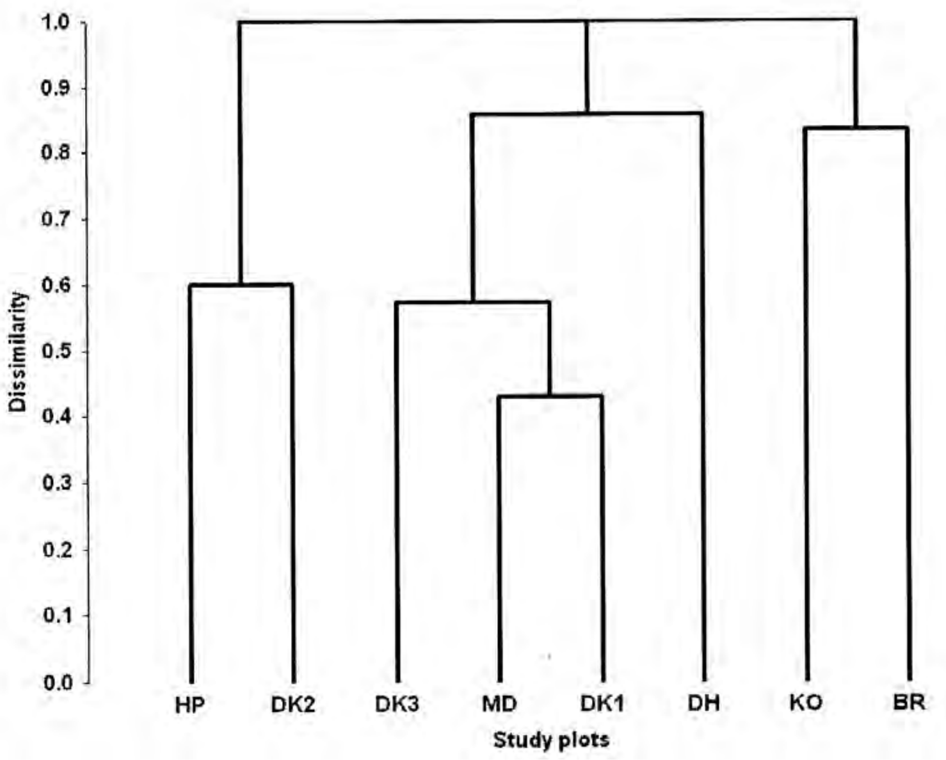

Figure 19. Hierarchical classification of heteropteran assemblages of individual study plots according to Sørensen's index of similarity (complete linkage). Vertical axis reflects dissimilarity. Abbreviations of study plots - see in text.

similarly as it was in the HP and KO study plots that are heavily anthropogenized. Study plot KO is detached at lower level of similarity (33%) to above mentioned study plots. Locality was influenced also with chemical pollution to the end of 1990´s. Within the first cluster, only 16.2% of total abundance were recorded in these poor in species study plots. Most species recorded are euryecious and geoxenous.

The second cluster embodies only the study plots, where the eudominant *Legnotus limbosus* was recorded. It is divided into two branches, where DK1 and DK3 study plots in first branch are connected at the highest level of similarity (78%) and MD is connected to them at 64% of similarity. DK1 and MD are the driest ones with the steep slope similarly as DK3 study plot that represents the locality that dries up to a great extent in summer owing to a different soil type. Assemblages of DK1 and DK3 are joined by the high dominance of *Legnotus limbosus* as majority of specimens were recorded here (89%). DH (second branch, separated line) joined the first branch with assemblages MD, DK1 and DK3 on the 30% of similarity. *Legnotus limbosus* reached in MD subdominant status and in DH only recedent status. DH represents a more humid locality with transition to a beech vegetation tier with recedent occurrence of cydnid *Legnotus limbosus*. This cluster includes presence of more geobionts and geophilous species. It is characteristic with subdominant position of *Legnotus limbosus*.

The third cluster is represented by separate line of BR study plot. Probably owing to a previous chemical pollution, it is study plot that is the poorest in species and specimens with quite different species spectrum.

Dendrogram in Fig. 19 based on Sørensen's index of similarity differentiated also three clusters, but with some slight differences with regard to the species spectra only. Clustering reflects more precisely species spectra according to species demands. There are joined assemblages of HP and DK2 plots at 40% of similarity in the first cluster (study plots with the highest humidity value). Second cluster, that is identical with that one in the dendrogram according to Wishart's index, embodies the driest study plots of MD, DK1 (55% similarity) together with DK3 (42% similarity) in one branch and separate assemblage of DH (15% similarity). DH study plot is situated close to the mentioned group of three plots yet it is more humid and it represents a transition to the beech vegetation tier. Study plots of KO and BR were detached at 18% of similarity in the third cluster. Both of the assemblages are in study plots of the Koliba hill complex. In spite of rich humus layer, oak-hornbeam forests of this complex are under considerable human impact (tourist visitors, silvicultural management – timber extraction and coppice culling). Until 1990, the complex was also impacted with chemical pollution of factories situated at the eastern city margin.

Results of this clustering were confirmed also in biplot of DCA (detrended correspondence analysis). Regarding the long gradient, DCA analysis was used as the most suitable method of ordination method for mutual assessing and comparing of heteropteran assemblages in the epigeon of oak-hornbeam forests in the area of Bratislava city (Fig. 20).

Humidity gradient proved to be as one of the crucial factor of forming heteropteran assemblages, although there are also differences in extent of forest fractionation (75% fragmentation of HP and MD study plots and 25% for KO and BR study plots opposite to other plots with zero value of fragmentation), or e.g. differences in pH value in H_2O (when in acidity gradient the most acid soils were in BR and KO study plots with pH 3.8 and 3.7 opposite to the most alkaline soil of DK2 with 7.32 pH value). Plant associations are not identical in all study plots. Haplic Cambisols was the prevailing soil type while, only DK2 is the study plot with Rendzic Phaeozem and DK3 Cutanic Luvisols. On acid soils, species diversity is relatively low in woodlands (Pfadenhauer 2002), and in general, animals are less dependent on floristic components, but more conditional on structural forms of nature and landscapes (Nagel 1999).

The most humid localities of DK2, HP and KO represent one group of localities in the right-hand of biplot opposite to the study plots with drier character (DK1, DK3 and DH) and more isolated transient MD locality. MD plot on a sheer slope surrounded with area of constructing sites and roads is the smallest forest within this study. BR study plot situated on the axis is a case of the poorest in species plot.

Correlation rate of species recorded towards individual study plots (species score) is expressed with their distance of the respective study plot, where the species was recorded. The more distant from the study plot the species is, the less is its affinity in combination with its abundance recorded. Similarly, species found only in 1 study plots and in low abundance were more distant of the respective study plot. Mostly eurytopic and euryhygric or some hygrophilous species, e.g. *Drymus brunneus* belonging to markedly hy-

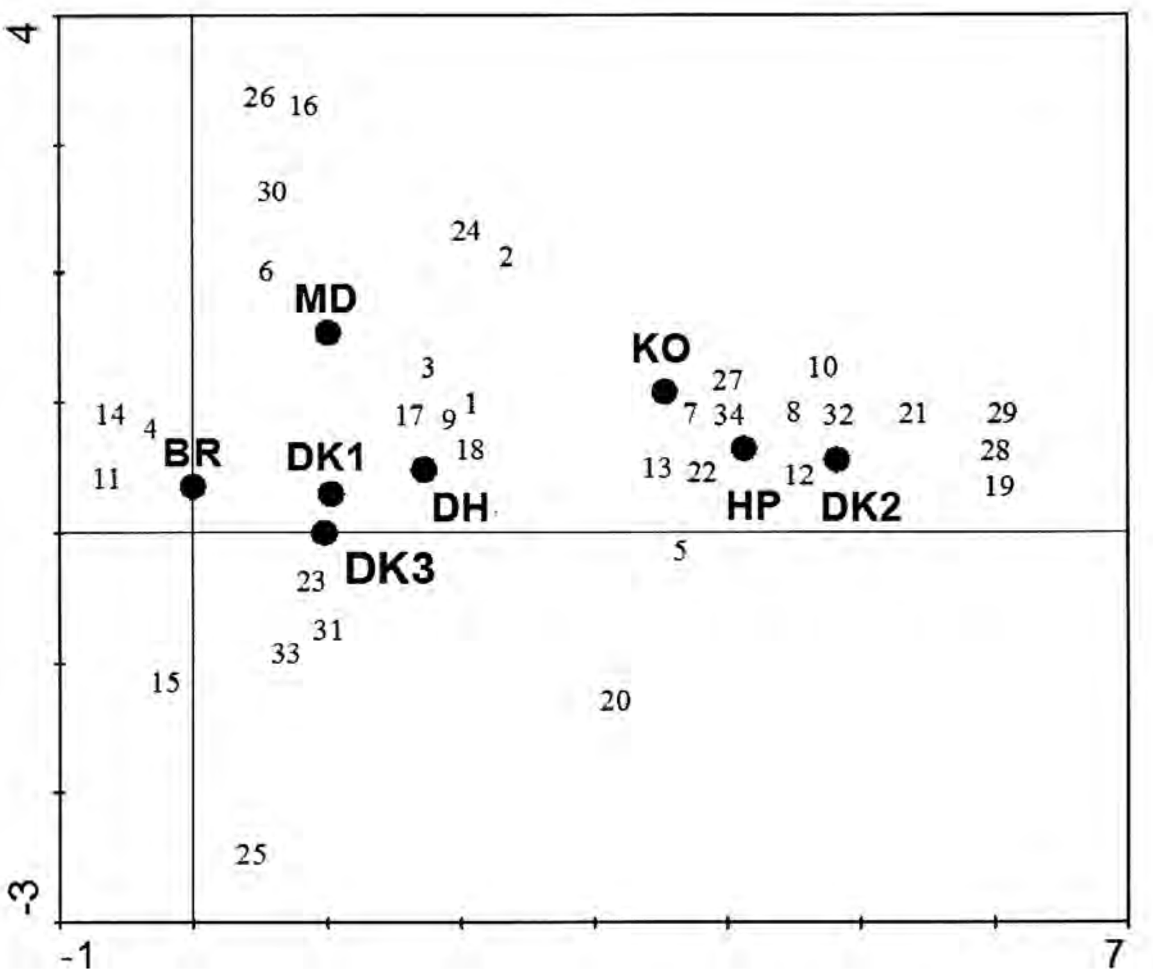

Figure 20. Detrended Correspondence Analysis of heteropteran assemblages in individual study plots. Abbreviations of study plots - see in the text.

Notes: 1-*Campylosteira verna*, 2-*Lygus rugulipennis*, 3-*Orthops basalis*, 4-*Agnocoris reclairei*, 5-*Nabis pseudoferus*, 6-*Nabis rugosus*, 7-*Orius minutus*, 8-*Nysius senecionis*, 9-*Kleidocerys resedae*, 10-*Drymus brunneus*, 11-*Eremocoris abietis*, 12-*Eremocoris podagricus*, 13-*Scolopostethus affinis*, 14-*Graptopeltus lynceus*, 15-*Megalonotus chiragra*, 16-*Emblethis griseus*, 17-*Piesma capitatum*, 18-*Piesma maculatum*, 19-*Pyrrhocoris apterus*, 20-*Gonocerus acuteangulatus*, 21-*Ceraleptus gracilicornis*, 22-*Ceraleptus lividus*, 23-*Legnotus limbosus*, 24-*Eurygaster maura*, 25-*Sciocoris homalonotus*, 26-*Dyroderes umbraculatus*, 27-*Aelia acuminata*, 28-*Peribalus strictus*, 29-*Dolycoris baccarum*, 30-*Palomena prasina*, 31-*Eurydema ornata*, 32-*Eurydema oleracea*, 33-*Piezodorus lituratus*, 34-*Elasmucha grisea*.

grophilous species (Stehlík, Vavřínová 1998b), were concentrated around "the moister" study plots meanwhile except for eurytopic species, more thermophilous or xerophilous species (*Legnotus limbosus, Sciocoris homalonotus, Emblethis griseus*) have connection to group of "drier" study plots. Humidity was also regarded as a limiting factor for species structure in Hradil's study (Hradil 2005) of epigeic heteropterans of the Malé Karpaty Mts. and Trnavská pahorkatina hills.

From the faunistic point of view, occurrence of some species was important. *Dyroderes umbraculatus* is a rare species reaching in Slovakia its northernmost distributional limit in Central Europe (Stehlík, Vavřínová 1993). According to these authors, the species can be found in the undergrowth at the edges of woodland fringing steppe localities or slopes grown with xerothermophilous vegetation. Its occurrence in the MD study plot can be conditioned by great fragmentation of this plot along with the fact, that it is the smallest locality surrounded by constructing sites.

Sciocoris homalonotus is a rare species that can be found in various habitats of Slovakia and Moravia, but in lowland it inhabits meadows adjacent to lowland forest edges or forest clearings and xerothermophilous woodland, in hilly terrain it prefers localities on readily warmed substrate. Its occurrence in DK3 study plot also has probably coincidence with the calcareous soil type here.

Conclusion

The heteropteran assemblages of oak-hornbeam forest epigeon were studied in eight study plots in 2005–2006. Study plots are part of three forest complexes in the area of Bratislava city classified according to their natural conditions. Communities were sampled by sifting method. In total 34 species of 13 families and 185 specimens were recorded. The widest species spectrum (22 species) and occurrence of more geobiont and geophilous species refers to the study plots of the Nature Reserve Devínska Kobyla hill with relatively well preserved forests. Study plots fractionated to a great extent of the central urban forest complex and study plots of the Koliba hill that were influenced by human activities to the greatest extent were the poorest in species (11–14 species). For similarity of species spectra amongst the study plots according to qualitative-quantitative species representation and according to species representation, soil humidity is a factor determining the structure of heteropteran assemblages. Identical conclusion was confirmed also by Detrended Correspondence Analysis. As for abundance, a cydnid *Legnotus limbosus* was eudominant species, however, it occurs only in warm and drier study plots. Occurence of *Dyroderes umbraculatus* and *Sciocoris homalonotus* was outstanding from the faunistic point of view.

References

Aukema, B., Rieger, C. (eds), 1996: Catalogue of the Heteroptera of the Palaearctic Region. Vol. 2. Cimicomorpha. The Nederlands Entomological Society, Amsterdam, 361 pp.

Aukema, B., Rieger, C. (eds), 2001: Catalogue of the Heteroptera of the Palaearctic Region. Vol. 4. Pentatomomorpha I. The Nederlands Entomological Society, Amsterdam, 346 pp.

Aukema, B., Rieger, C. (eds), 2006: Catalogue of the Heteroptera of the Palaearctic Region. Vol. 5. Pentatomomorpha II. The Nederlands Entomological Society, Wageningen, 550 pp.

Barbati, A., Morchetti, M., 2004: Forest types for biodiversity assessment (FTBAs) in Europe: the revised classification scheme. In: Marchetti, M. (ed.), Monitoring and indicators of forest biodiversity in Europe – from ideas to operationality. EFI Proceedings No. 51, p. 105–126.

Belavá, M., 1981: Seasonal dynamics and abundance and biomass of the population of *Palomena prasina* L. (Heteroptera, Pentatomidae) in the herb layer of the Little Carpathian woods. Biológia (Bratislava), 36: 559–603.

Bianchi, Z., 1991: Wanzen (Heteroptera) as Bestandteil des epigäeischen Fauna von Bratislava. Entomol. Nachr. Ber., 35: 206–207.

Bianchi, Z., Štepanovičová, O., 1998: Bugs (Heteroptera) as a part of crown fauna on oaks (in Slovak). Entomofauna carpathica, 10: 97–103.

Bianchi, Z., Štepanovičová, O., Chocholíková A., 1999: Bug assemblages (Heteroptera) in the Borská nížina lowland (in Slovak). Entomofauna carpathica, 11: 117–126.

Bulánková, E., 1989: Population productivity of dominant bug species (Heteroptera) in oak forests (in Slovak). Práce SES pri SAV Bratislava, 8: 15–23.

Bulánková, E., 1991: Structure and function of the community of Nabidae (Heteroptera) in the herb layer of a forest ecosystem. Acta F.R.N. Univ. Comen., Zool., 35: 61–69.

Bulánková, E., Holecová, M., 1998: Structure and dynamics of nabid taxocoenoses (Nabidae, Heteroptera) in the herbage undergrowth of oak-hornbeam forests in Malé Karpaty (in Slovak). Folia faunistica slovaca, 3: 61–68.

Herczek, A., Halgoš, J., 1991: Miridae (Heteroptera) of the Šúr natural reserve near Bratislava. Acta biologica silesiana, 18 (35): 34–40.

Heydemann, B., 1955: Die Frage der topografischen Übereinstimmung des Lebensraumes von Pflanzen- und Tiergesellschaften. Verh. Dtsch. Zool. Ges., Erlangen, 444–452.

Hradil, K., 2005: Bug assemblages in epigeon of oak-hornbeam forests in SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 161–178.

Kříštek, J., Dobšík, B., 1985: Bugs (Heteroptera) in a floodplain forest. Acta sci. Natur. Acad. Sci. Bohemoslov. Brno, 19: 1–55.

Lapková, Z., 1986: Trophic interactions of bugs (Heteroptera) to studied woody plants in Malé Karpaty Mts. (in Slovak). Správy Slov. zool. spol. pri SAV, Bratislava, 12: 158–161.

Lapková, Z., 1989: Arthropodocoenoses in oaks with regard to Heteroptera (in Slovak). Práce SES SAV, Bratislava, 7: 101–104.

Lapková, Z., 1997: Bug communities (Heteroptera) of some characteristic habitats in the area of the Hydroelectric Power Project of the Danube inland delta (in Slovak). Práce SES pri SAV, Bratislava, 4: 189–203.

Lapková, Z., Štepanovičová, O., Krištofová, Ľ., 1986: Bug communities of forest ecosystems in Malé Karpaty Mts. (in Slovak). Práce slov. zool. spol. pri SAV, Bratislava, 12: 154–158.

Majzlan, O., Štepanovičová, O., 1998: Beetle (Coleoptera, Curculionidae) and bug (Heteroptera) taxocoenoses as a part of zooedafon in flood-plain forests (Fraxino-Populetum) of Morava river (Southwestern Slovakia). Quad. Staz. Ecol. Civ. Mus. St. Nat. Ferrara, 11: 89–100.

Nagel, J., 1999: Konzeptionelle Überlegungen zum schrittweisen Aufbau eines waldwachstumskundlichen Simulationssystems für Nordwestdeutschland. Schriften aus der Forstlichen Fakultät der Universität Göttingen. Bd. 128. 122 p.

Országh, I., 1966: Contribution to the knowledge of bug fauna (Heteroptera) in Jurský šúr and adjacent uphills of Malé Karpaty Mts. (in Slovak). Ent. problémy, 6: 37–75.

Pfadenhauer, J., 2000: Landnutzung und Biodiversität – Beispiele aus Mitteleuropa. In: Mallach, N., Siebeck, O. (eds., 2002), Das Ende der Biodiversität? Grundlagen zum Verständnis der Artenvielfalt und Steiner Bedeutung und der Maßnahmen, dem Artensterben entgegen zu wirken. 5. Franz-Ruttner-Symposion. 12.–13. Oktober 2000 in Rosenheim. Laufener Seminarbeiträge 2/02, Bayerische Akademie für Naturschutz und Landschaftspflege (ANL), Laufen/Salzach, Germany, p. 145–159.

Plachter, H., 1991: Naturschutz. Gustav Fischer Verlag, Stuttgart, 462 pp.

Podani, J., 1993: Syn-Tax. Version 5.0. Computer programs for multivariate data analysis in ecology and systematics. User's guide. Scientia Publishing, Budapest, 104 pp.

Reck, H., 1995: Arten- und populationsorientierte Grundlagen für die Planung. Beispiele aus der Flurbereinigung Hettingen auf der Schwäbischen Alb (Baden-Württemberg). In: Riecken, U., Schröder, E. (eds.), Biologische Daten für die Planung. Auswertung, Aufbereitung und Flächenbewertung. Schriftenreihe für Landschaftspflege und Naturschutz, volume 43, Bundesamt für Naturschutz, Bonn-Bad Godesberg, Germany, p. 247–279.

Rédei, D., Hufnagel, L., 2003a: The species composition of true bug assemblages extracted with Berlese funnels. Applied Ecology and Environmental Research, 1: 93–113.

Rédei, D., Hufnagel, L., 2003b: Data to the knowledge on the soil bug fauna of the Hungarian Northern-Mountains (Heteroptera). (Data to the knowledge on the ground-living Heteroptera of Hungary, No 2). (in Hungarian). Folia historico-naturalia Musei Matraensis, 27: 81–89.

Schwerdtfeger, F., 1975: Ökologie der Tiere. Band III – Synökologie. Verlag Paul Parey, Hamburg – Berlin, 451 pp.

Stehlík, J.L., 2002: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Tingidae). Acta Musei Moraviae, Scientiae biologicae (Brno), 87: 151–200.

Stehlík, J.L., Vavřínová, I., 1993: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Pentatomoidea II). Acta Musei Moraviae, Scientiae naturales (Brno), 77: 185–223.

Stehlík, J.L., Vavřínová I., 1995a: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Stenocephalidae, Coreidae, Alydidae, Rhopalidae). Acta Musei Moraviae, Scientiae naturales (Brno), 79: 97–147.

Stehlík, J.L., Vavřínová, I., 1995b: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Piesmatidae, Berytidae). Acta Musei Moraviae, Scientiae naturales (Brno), 79: 149–168.

Stehlík, J.L., Vavřínová, I., 1998a: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Reduviidae, Phymatidae, Nabidae: Prostemmatinae). Acta Musei Moraviae, Scientiae biologicae (Brno), 82: 109–126.

Stehlík, J.L., Vavřínová, I., 1998b: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Lygaeidae II). Acta Musei Moraviae, Scientiae biologicae (Brno), 83: 71–97.

Stehlík, J.L., Vavřínová, I., 1999: Results of the investigations on Hemiptera in Slovakia made by the Moravian Museum (Lygaeidae III). Acta Musei Moraviae, Scientiae biologicae (Brno), 84: 153–201.

Strawinski, K., 1960: Hemiptera – Heteroptera found under stones. Ann. Universitatis Mariae Curie-Skłodowska, Lublin, Sec. C, 15: 1–19.

Štepanovičová, O., 1973: Gesellschaften der Heteropteren im Eichen-Buchenwald in Báb. Acta F.R.N. Univ. Comen., Zool., 22: 45–68.

Štepanovičová, O., 1978a: Quantitative analysis of an association of land bugs (Heteroptera) in crowns of trees and bushes of an oak-hornbeam forest. Biológia (Bratislava), 33: 93–99.

Štepanovičová, O., 1978b: The dynamics of population density of land bugs (Heteroptera) in the crowns of tree and bushes of an oak-hornbeam forest. Biológia (Bratislava), 33: 865–869.

Štepanovičová, O., 1981: Quantitative analysis of the bug community in the herbage undergrowth of deciduous forest (in Slovak). Biológia (Bratislava), 36: 967–972.

Štepanovičová, O., 1985: Struktur der Wanzengemeinschaft in der Krautschicht der Laubwälder. Mitt. Dtsch. Ges. Angew. Entomologie, Kiel, 4: 399–401.

Štepanovičová, O., 1986: A sketsch of entomocoenoses in oak forests with reference to their importance at mass dying of oaks (in Slovak). Správy Slov. zool. spol. pri SAV, Bratislava, 12: 146–149.

Štepanovičová, O., 1991: Formation of taxocoenoses of Heteroptera in plant communities of relatively inaffected ecosystems and those affected by human activities. Acta F.R.N. Univ. Comen., Zool., 35: 31– 51.

Štepanovičová, O., 1994: Heteroptera-Pentatomomorpha of characteristic habitats in Morava floodplain area. Ekológia (Bratislava), Supplement 1: 163–164.

Štepanovičová, O., 1995a: Heteroptera as a part of the floodplain forest epigaeon. In: Gabčíkovo part of the hydroelectric power project. – Environmental impact review. Fac. Nat. Sci. Univ. Comen. Bratislava, Slovakia: 289–296.

Štepanovičová, O., 1995b: Space distribution of selected heteropteran species populations in psamophytous plant communities (in Slovak). Entomofauna carpathica, 7: 110–114.

Štepanovičová, O., 1997: Epigaeic Heteroptera as indicators of moisture relationships of the floodplain forests of the Danube and Morava rivers. Biológia (Bratislava), 52: 243–246.

Štepanovičová, O., Barancová I., 1993: Heteroptera-Pentatomomorpha taxocoenoses of blown sands plant communities of the lowlands of Záhorie. Entomological Problems, 24: 57–68.

Štepanovičová, O., Bianchi, Z., 1999: Wanzen (Heteroptera) im Bereich der Sanddünen an March und Donau. Naturschutz in pannonischen Raum. Sanddünen als Lebensraum. Tagungsberichte 25, Illnitz, p. 41–48.

Štepanovičová, O., Bianchi, Z., 2003: On the fauna of bugs (Heteroptera) of blown sands in the Podunajská nížina lowland (in Slovak). Entomofauna carpathica, 15: 35–40.

Štepanovičová, O., Degma, P., 1999: Effect of some environmental factors on structure of bug taxocoenoses (Heteroptera) in floodplain forest epigaeon of the Danube region. Acta Soc. Zool. Bohem., 63: 225–236.

Štepanovičová, O., Lapková, Z., 1984a: Taxocoenoses of bugs (Heteroptera) of some characteristic habitats in the area of the Danube Hydroelectric Power Project (in Slovak). Práce SES pri SAV, Bratislava, 4: 189–203.

Štepanovičová, O., Lapková, Z., 1984b: Trophic analysis of Heteroptera herbicola and arboricola in beech forests. Abstr. 13/5, XVII. Inter. Congress of Entomology, Hamburg.

Štepanovičová, O., Lapková, Z., 1988: Topic and trophic relationship of the bugs (Heteroptera) community in beech forests in the Small Carpathians. Acta F.R.N., Univ. Comen, Zool. 31: 3–20.

Ter Braak, C.J.F., Šmilauer, P., 1998: CANOCO references manual and user´s guide to Canoco for Windows. Software for cannonical community ordination (version 4). Microcomputer Power (Ithaca, N. Y., USA), 352 pp.

Tischler, W., 1949: Grundzüge der terrestrischen Tierekölogie. Fridrich Vieweg , Braunschweig, 219 pp.

Verner, P.H., 1959: Study on arthropods living in soil of oak-hornbeam forest in environment of Karlštejn. Bohemia centralis, A 1(7): 345–408.

4.5. Ground beetles (Coleoptera: Carabidae)

Zbyšek Šustek

Carabids represent an abundant component of epigeon in almost all terrestrial ecosystems. A minor part of species also lives under bark (genus *Tachyta*, some species of *Dromius*) or, as adults, temporarily inhabit foliage of wooden plants (*Lebia, Calosoma* or some species of Agonini in the tropics) or lives on grasses (*Dromius*). A small part of species is cavernicolous (many species of Trechiini, some species of *Laemosthenus*). Feeding of carabids is very variable. Larvae and adults were originally carnivorous and carnivores is also majority of recent species. But some groups of species become panthophags or even pure phytophags, that are often specialized to plant seeds (granivors), especially those of Daucaceae. The granivory led in the most specialized species to striking morphological adaptations of mandibles (males of *Carterus*) or hypertrophy of head (*Machozetus, Ditomus, Acinopus*). In larvae of *Machozetus*, which are fed by the parents in special larval galleries, it led even to loss of legs. The pantophagy or phytophagy is characteristic for the tribi Harpalini and Zabriini.

Carabids are richly differentiated in relation to their environment. The deciding factors are humidity (there exists a wide scale ranging from strongly hydrophilous species up to expressively xerophilous species), shadowing by tree vegetation (from the stenotopic forest species up to species preferring places without continuous vegetation cover), altitude (from the thermophilous lowland species up to the cryophilous species living at margins of glaciers or in alpine meadows) and soil type (species preferring sandy or clayish soils). A significant factor is soil reaction, which regulates indirectly productivity of populations. In the nitric or basic substrates population sizes of individual species reach multiples of values known from the acid or neutral substrates (Šustek 2009).

An important property of the carabids, which decides about forming of their communities, is ability to fly. Many species completely lost their membranous wings, while populations of other species include brachypterous or macropterous individuals. Many species have obligatorily fully developed wings and fly very well. In general, the species unable to fly are characteristic for more stable forests ecosystems, while the well flying species inhabit unstable riparian habitats and successfully colonize the anthropogenic ecosystems like arable land or greenery in human settlements. However, even the well flying species use to fly only facultatively, during mating period or to escape from the habitats, which have been becoming temporarily unfavourable.

Carabid communities in urban ecosystems were in focus of many authors. In Central Europe the studies were done in Kiel (Topp 1972), Leipzig (Klausnitzer, Richter 1980, Klausnitzer et al. 1980), Warsaw (Czechowski 1980a, 1980b, 1981a, 1981b, 1982), Moscow (Dushenkov 1983) and Brno (Šustek 1979, Šustek, Vašátko 1983a, 1983b), Nitra (Majzlan, Frantzová 1995), Birmigham (Small et al. 2003), Helsinki (Alaruikka et al. 2002, Venn et al. 2003) and Debrecen (Magura et al. 2008), while in West Mediterranean in Madrid (Šustek 2012) and in East Asia in Pyongyang (Šustek 2011). In Bratislava the carabids were studied by Šustek (1984a), but there were published only various more general analyses of community structure or species behaviour (Šustek 1980, 1987, 1999a, 1999b), while list of species found in each locality remained unpublished because of large extent of the tables. A synthesis of many papers on urban fauna and urban ecology in general was recently compiled by Niemelä et al. (2011). The carabid fauna of Devínska Kobyla was studied by Korbel et al. (1997), Majzlan, Baťalík (1997), Majzlan et al. (2005) and Šustek (2004a).

The beetles used for the present study were pitfall-trapped. In each site five traps were installed in a line in distances of 10 m. The traps were exposed from early April 2005 until October/December 2006, inclusively of the whole winter 2005/2006. They were emptied approximately once a month. The collecting was carried out by Milada Holecová. The beetles were identified by the author.

The carabids were characterized by their preference of humidity and shadowing using the two semiquantitative scales (1 – xerophilous to 8 polyhydrophilous; 1 – open landscape species to 4 – species requiring complete shadowing by tree vegetation) proposed by Šustek (2004b). On this base the shadowing and humidity index of community was calculated for each year as arithmetical average of all species weighted by number of each species. The obtained values were used for direct ordination of the communities (Poole 1974). The data on ability of species to fly were taken from Burmeister (1939) and Lindroth (1949). The characteristics of zoogeographic distribution of species and their reproduction cycle and ecological requirements were made by Burmeister (1939), Hůrka (1986), Larsson (1939), Lindroth (1949) and Thiele (1977). The size of individual species was characterized by the average length published for some species by Hůrka (1986) on base of measurement of at least 50 individuals. If this value was not available, the middle value of the minimum and maximum lengths was used. The biomass was calculated as average dry value of at least six specimens weighted after desiccation at 100°C for 24 hours (Šustek 1984a) multiplied by number of individuals. The dominance is characterized by the following scale: > 10% eudominant, 5–10% dominant, 2–5% subdominant, 1–2% recedent, < 1% subrecedent.

The hierarchical classification was made by UPGMA method and the indirect ordination was made by the principle coordinate method. In both cases, the Horn's index reflecting the proportional similarity was used. For the canonical correlation analysis, 12 factors characterizing the individual sites were chosen: altitude, slope and exposition of sites, soil reaction, age, height and thickness of trees, coverage of the layers F_0 – F_3. All characteristics were taken from chapter 2. The Simpson's and Shannon Wiener's indices were used as diversity indices. The calculations were made by the program PAST version 2.17 (Hammer 2012).

Species diversity of carabids in oak-hornbeam forests in Bratislava

In all sites a total of 35 carabid species were recorded. They represent ca. 5.4% of species known to occur in Slovakia. Three species among them (*Abax parallelopipedus, Carabus nemoralis, Carabus coriaceus*) occurred in all one-year samples, one species (*Harpalus atratus*) occurred in 87.5% sites of samples, two species (*Carabus hortensis, Pterostichus oblongopunctatus*) in 75% of samples. These six species were euconstant.

One species (*Carabus glabratus*) occurred in 62.5% of samples, two species (*Carabus convexus, Carabus intricatus*) in 56.5% and four species (*Abax parallelus, Calosoma inquisitor, Carabus ullrichi, Pseudoophonus rufipes*) in 50% of one-year catches. These seven species were constant. All euconstant and constant species represented together 93.2% of all individuals. Other 23 species were accidental or accessoric. Among them 12 were recorded only in one or two one-year catches (Table 17).

Major part of the species (54.3%) were typical forest species requiring or preferring shadowing by tree vegetation, or eurytopic species (14.2%) more or less indifferent to shadowing. They represented 98.9% of all individuals. Only 8 species (*Amara aenea, A. ovata, Calathus fuscipes, Harpalus distinguendus, Harpalus tardus, Harpalus latus, Ophonus azureus, Pseudoophonus rufipes*) were open landscape species, which are xenocenous in forest ecosystems. However, they occurred in the communities only occasionally.

Table 17. List of species, abbreviations of their names (Abb), and their ecological and zoogeographic characteristics.

Species	Abbr	DW [g 10^{-4}]	L [mm]	F	H	S	G	R	T
Abax parallelopipedus (Piller et Mitterpacher, 1783)	Appi	11521	18.6	N	3	4	E	S	C
Abax parallelus (Duftschmidt, 1812)	Apar	5140	15.1	N	3	4	E	A	C
Amara aenea (De Geer, 1774)	Aaen	442	7.5	F	3	1	PP	S	P
Amara ovata (Fabricius, 1792)	Aova	213	9.0	F	3	1	TP	S	P
Amara saphyrea Dejean, 1828	Asap	224	8.8	F	3	1	CB	S	P
Aptinus bombarda (Illiger, 1800)	Abom	879	10.0	N	3	4	CE	A	C
Calathus fuscipes (Goeze, 1777)	Cfus	2256	11.7	B	4	2	WP	A	C
Calosoma inquisitor (Linnaeus, 1758)	Cinq	16412	20.0	F	4	4	WP	S	C
Carabus convexus Fabricius, 1775	Ccnv	11212	17.0	N	4	4	WP	S	C
Carabus coriaceus Linnaeus, 1758	Ccor	65950	36.0	N	5	4	E	A	C
Carabus glabratus Paykull, 1790	Cglb	11215	28.0	N	5	4	E	A	C
Carabus granulatus Linnaeus, 1758	Cgra	11215	19.5	B	4	2	TP	S	C
Carabus hortensis Linnaeus, 1758	Chor	17800	26.0	N	4	4	E	A	C
Carabus intricatus Linnaeus, 1761	Cint	18450	30.0	N	4	4	E	S	C
Carabus nemoralis O. F. Müller, 1764	Cnem	17370	23.5	N	4	4	E	S	C
Carabus scheidleri Panzer, 1799	Csch	21885	27.5	N	5	4	CE	S	C
Carabus ullrichi Germar, 1824	Culr	15132	27.0	N	4	4	CE	S	C
Carabus violaceus Linnaeus, 1758	Cvio	17457	28.5	N	5	4	E	A	C
Cymindis humeralis (Fourcroy, 1785)	Chum	761	9.4	N	3	4	CM	A	C
Cymindis vaporariorum (Linnaeus, 1758)	Cvap	652	8.5	N	2	1	TP	A	C
Harpalus atratus Latreille, 1804	Hatr	1651	11.8	F	4	4	CM	S	O
Harpalus distinguendus (Duftschmidt, 1812)	Hdis	1893	9.7	F	3	1	TP	S	O
Harpalus latus (Linnaeus, 1758)	Hlat	1773	9.3	F	4	1	ES	S	O
Harpalus tardus (Panzer, 1997)	Htar	1893	9.7	F	2	1	PP	A	O
Molops piceus (Panzer, 1793)	Mpic	443	12.0	N	4	4	CE	S	C
Notiophilus rufipes Curtis, 1829	Nruf	239	5.3	F	4	2	E	I	C
Ophonus azureus (Fabricius, 1775)	Oazu	1120	7.8	F	2	1	WP	A	C
Ophonus gammeli (Schaufberger, 1932)	Ogam	1290	11.4	F	2	2	PM	A	C
Panageus bipustulatus (Fabricius, 1775)	Pbip	780	7.6	F	4	1	SM	S	C
Platyderus rufus (Duftschmidt, 1812)	Plrf	520	6.7	N	3	4	PM	A	C
Laemosthenus terricola (Herbst, 1784)	Lter	5412	15.2	N	4	2	WP	A	C
Pseudoophonus rufipes (De Geer, 1774)	Pruf	4995	13.8	F	4	1	WP	A	O
Pterostichus burmeisteri Heer, 1841	Pbur	1546	13.5	N	5	4	CE	S	C
Pterostichus oblongopunctatus (Fabricius, 1775)	Pobl	1941	11.4	N	5	4	ES	S	C
Synuchus vivalis (Illiger, 1798)	Sviv	512	7.4	N	4	2	TP	A	C

Explanations: DW – average dry weight of one individual, L – average body length, F – ability to fly [F –flying, N – non flying, B – brachypterous, occasionaly able to fly], H – preference for humidity, S – preference for shadowing, G – geographic distribution [PP – Panpalaearctic, TP – Transpalaearctic, WP – Westpalaearctic, ES – Eurosiberian, E – European, CE –Central European, CM – Circummediterranean, CB – Carpatho-Balcanic], R – reproduction type [S – spring breeder, A – autumn breeder, P – plastic breeding type], T – trophic relations [C – carnivor, O – omnivor, P – phytophag].

Most of the species have optimum of vertical distribution in lowlands and their occurrence declines toward higher altitudes. Only *Pterostichus burmeisteri, Carabus glabratus* and *Carabus violaceus* have optimum of natural vertical distribution in highlands. *Pterostichus burmeisteri* and *Carabus glabratus* have the lower limit of their vertical distribution at altitudes around 300 m or in the oak-beech vegetation tier (Raušer, Zlatník 1966, Zlatník 1976), while *Carabus violaceus* can penetrate along larger rivers into artificially dried floodplain forests to altitudes of about 100 m.

Composition of individual communities

Only 11 most abundant and constant or euconstant species (*Carabus hortensis* – 27.4%, *Abax parallelopipedus* – 24.2%, *Pterostichus oblongopunctatus* – 16.9%, *Carabus nemoralis* – 8.0%, *Aptinus bombarda* – 3.3%, *Carabus glabratus* – 3.1%, *Harpalus atratus* – 2.9%, *Carabus coriaceus* – 2.6%, *Carabus ullrichi* – 2.3%, *Abax parallelus* – 2.1%, *Carabus convexus* – 1.7%), which represented 94.9% of all individuals, played a determining role at diversification of studied communities. Excepting *Aptinus bombarda* they were present in at least 50% of one-year samples. These species were eudominant simultaneously in several samples, only *Carabus convexus* and *C. ullrichi* were dominant at least in one of the one-year samples.

In Koliba 7 and 15 species were recorded in 2005 and 2006, respectively, in total 15 species occurred here. Subdominant – eudominant were the forest species *Pterostichus oblongopunctatus* (2.6 and 48.8%), *Carabus hortensis* (36.1 and 25.0%), *Carabus glabratus* (23.3 and 9.9%), *Carabus nemoralis* (8.4 and 5.4%) and *Abax parallelopipedus* (5.9% in 2006). The characteristic feature reflecting the altitude was a high dominance of *Carabus glabratus* in both years and presence of *Pterostichus burmeisteri* in 2006.

In Briežky 7 and 14 species were recorded in 2005 and 2006, respectively, in total 14 species occurred here. Subdominant – eudominant were the forest species *Pterostichus oblongopunctatus* (62.4 and 54.9%), *Carabus hortensis* (12.6 and 31.8%), *Carabus glabratus* (23.3 and 9.9%), *Abax parallelopipedus* (17.7 and 7.2%) and *Carabus nemoralis* (3.6% in 2005). The characteristic feature reflecting the altitude and continuity with the higher parts of the Malé Karpaty Mts. was the presence of *Carabus glabratus* in both years, of *Pterostichus burmeisteri* in 2006.

In Devínska Kobyla 1, 20 and 17 species were recorded in 2005 and 2006, respectively, and a total 24 of species was recorded here. Subdominant – eudominant were the forest species *Abax parallelopipedus* (38.2 and 19.6%), *Carabus hortensis* (31.1 and 52.4%), *Carabus convexus* (4.8 and 3.5%), *Carabus ullrichi* (3.6 and 2.6%), *Carabus nemoralis* (5.7 and 3.9%), *Carabus violaceus* (6.8% in 2006), *Calosoma inquisitor* (3.7% in 2005) and *Carabus glabratus* (3.2% in 2006). Reflection of a higher altitude was subdominant to dominant representation of *Carabus violaceus* and *Carabus glabratus*. On the other hand, the warm character of the locality was indicated by occurrence of rare species *Cymindis vaporariorum* and *Cymindis humeralis*.

In Devínska Kobyla 2, 19 and 17 species were found in 2005 and 2006, respectively, in total 22 species occurred here. Subdominant – eudominant were the forest species *Abax parallelopipedus* (47.9 and 34.9%), *Carabus hortensis* (9.2 and 27.9%), *Carabus convexus* (6.3 and 2.6%), *Aptinus bombarda* (5.4 and 19.2%), *Carabus ullrichi* (2.9 and 3.2%), *Carabus nemoralis* (9.2 and 3.3%), *Abax parallelus* (9.4 and 3.7%), *Carabus coriaceus* (2.6% in 2005) and *Carabus glabratus* (2.6% in 2005). The characteristic feature was the high dominance of *Aptinus bombarda*, a species that locally reaches high abundance in forests, especially on basic substrates, and *Ophonus gammeli*, a species of warm, sparse forests.

In Devínska Kobyla 3, 15 species were recorded in each year, in total 19 species occurred here. Subdominant – eudominant species were *Abax parallelopipedus* (24.8 and 27.8%), *Carabus hortensis* (13.6 and 42.3%), *Carabus ullrichi* (2.4 and 2.6%), *Carabus nemoralis* (17.9 and 6.2) and *Carabus coriaceus* (2.4 and 3.8%), *Harpalus atratus* (23.4 and 7.2%), and *Calosoma inquisitor* (2.9% in 2005) as forest species and *Harpalus tardus* (2.4 and 2.6%) as a xenocenous species. The termophilous elements were represented by *Harpalus atratus, Ophonus gammeli* and *Amara saphyrea*.

In Dúbravská Hlavica 18 and 11 species were recorded in 2005 and 2006, respectively, in total 18 species were observed here. Subdominant – eudominant species were *Carabus hortensis* (29.2 and 39.5%), *Abax parallelopipedus* (26.9 and 23.4%), *Pterostichus oblongopunctatus* (9.6 and 17.1%), *Carabus nemoralis* (9.3 and 2.9), *Carabus ullrichi* (5.8 and 5.2%), *Abax parallelus* (4.8 and 2.9%), *Carabus glabratus* (3.2 and 3.8%), *Carabus coriaceus* (2.8% in 2005) and *Aptinus bombarda* (2.2% in 2005). The high elevation was indicated by subdominant representation of *Carabus glabratus* and presence of *Pterostichus burmeisteri*. Presence of the terricolous *Laemosthenus terricola* indicated presence of small mammal burrows. Significant was presence of the stenotopic forest species *Molops piceus*.

In Horský park 9 and 8 species were recorded in 2005 and 2006, respectively, in total 12 species occurred here. Subdominant – eudominant species were *Abax parallelopipedus* (26.3 and 29.3%), *Carabus nemoralis* (26.3 and 25.8%), *Carabus coriaceus* (23.7 and 24.4%), *Harpalus atratus* (2.6 and 7.3%), *Pterostichus oblongopunctatus* (2.4% in 2006), *Abax parallelus* (2.4% in 2006), *Platyderus rufus* (2.6% in 2005) as forest species, *Notiophilus rufipes* (2.6 and 4.9%) as an eurytopic species and *Harpalus tardus* (2.6% in 2005), *Pseudoophonus rufipes* (2.4% in 2006) and *Amara aenea* (2.6% in 2005) as open landscape species. The warm character of the locality was indicated by *Platyderus rufipes, Harpalus atratus* and xenocenous *Harpalus tardus*.

In Mlynská dolina 9 species were recorded each year, in total 12 species occurred here. Subdominant – eudominant species were *Abax parallelopipedus* (29.0 and 34.4%), *Carabus nemoralis* (34.8 and 43.7%), *Carabus coriaceus* (4.4 and 6.2%), *Harpalus atratus* 23.2% in 2005) as forest species, and *Harpalus tardus* (2.6% in 2005), *Pseudoophonus rufipes* (2.4% in 2006), *Amara aenea* (2.6% in 2005) and *Panageus bipustulatus* (2.6% in 2006) as xenocoenous open landscape species.

Classification and ordination of individual communities

According to the proportional similarity (Fig. 21) the communities form three major clusters. The first one includes the communities from Koliba and Briežky. They are characterized by eudominant position of *Pterostichus oblongopunctatus* and *Carabus hortensis* and dominant position of *Abax parallelopipedus* from 1.81 to 17.3%. The communities from Koliba and Briežky form separate subclusters due to a high dominance of *Carabus glabratus* in Koliba.

The second cluster includes the communities from Dúbravská Hlavica and all communities from Devínska Kobyla excepting the community from Devínska Kobyla 3 from 2005. Their common feature is co-occurrence of the eudominant *Abax parallelopipedus* and *Carabus hortensis* and of subdominant *Carabus ullrichi* and *Carabus convexus*. Within this cluster the communities from individual sites form separate subclusters. The communities from Dúbravská Hlavica are characterized by increased dominance of *Pterostichus oblongopunctatus, Abax parallelus* and *Carabus ullrichi*, while those from Devínska Kobyla 2 by increased dominance of *Aptinus bombarda* and *Abax parallelus*. The communities from Devínska Kobyla 1 and 3 from 2006 are characterized by absence or a low dominance of *Abax parallelus*.

The third cluster includes the communities from Horský park, Mlynská dolina and Devínska Kobyla 3 from 2005. Their common feature is eudominance of *Carabus nemoralis*, subdominant to eudominant position of *Carabus coriaceus*, *Harpalus atratus* and *Notiophilus rufipes*.

The principle coordinate analysis basing on Horn's index (Fig. 22) confirms the results of hierarchical classification (Fig. 21) forming three principal clusters, but reflects more finely the relationships between individual one-year catches. The 1st coordinate can be identified with anthropogenic pressure. The most affected sites in Mlynská dolina and Horský park with co-dominance of *Carabus coriaceus, Carabus nemoralis, Abax parallelopipedus* and *Harpalus atratus*, presence of several xenocoenous species, absence of *Carabus hortensis* are placed in the left side. The communities from Devínska Kobyla and Dúbravská Hlavica characterized by co-dominance of *Abax parallelopipedus, Carabus hortensis, Carabus ullrichi* and *Carabus convexus* are in the middle and upper part of ordination space. Within their cluster, the communities with higher dominance of *Aptinus bombarda* are situated in the uppermost part, the community from Devínska Kobyla 3 from 2005 with strongly increased dominance of *Carabus nemoralis* is shifted to left to the communities from Horský park and Mlynská dolina, whereas the communities from Dúbravská Hlavica with increased dominance of *Pterostichus oblongopunctatus* are shifted to the communities from Koliba and Briežky. These communities with co-dominance of *Pterostichus oblongopunctatus, Carabus hortensis* and *Carabus nemoralis* are in the right part of ordination space. Among them, the community from Koliba from 2005 with reduced dominance of *Pterostichus oblongopunctatus* is shifted to the centre, to the communities from Devínska Kobyla and Dúbravská Hlavica.

The canonical correspondence analysis is presented in two diagrams for better lucidity, separately for factors and localities and factors and species (Figs. 23 and 24). There exist two groups of closely associated factors. The first group consists of a high slope, coverage of E_0 layer and presence of *Robinia pseudoacacia,* and freely also coverage of E_1 layer. The most influenced communities from Horský park, Mlynská dolina and, to a certain degree, also Devínska Kobyla 3, in particular from 2005 are associated with

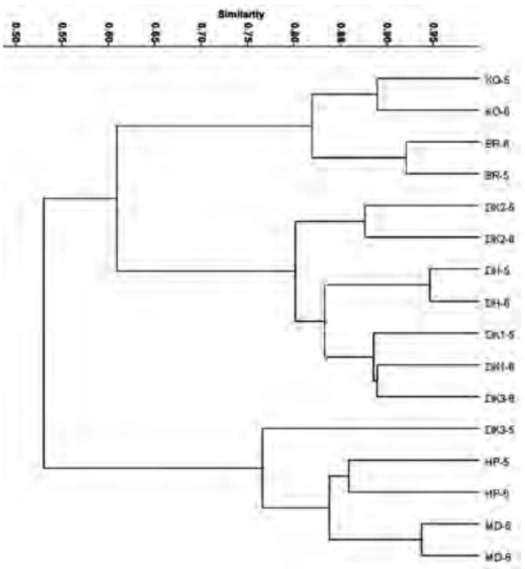

Figure 21. UPGMA classification of 16 Carabid communities from oak-hornbeam forests from Bratislava according to Horn's index.

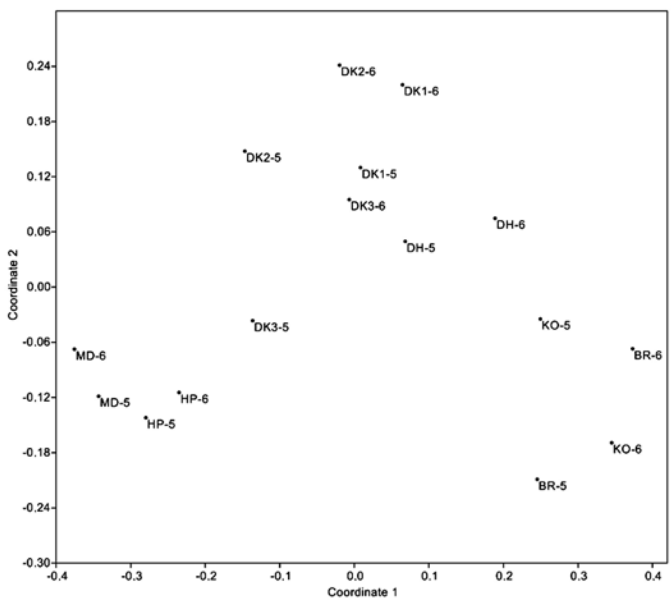

Figure 22. The principle coordinate analysis of 16 Carabid communities from oak-hornbeam forests from Bratislava based on Horn's index.

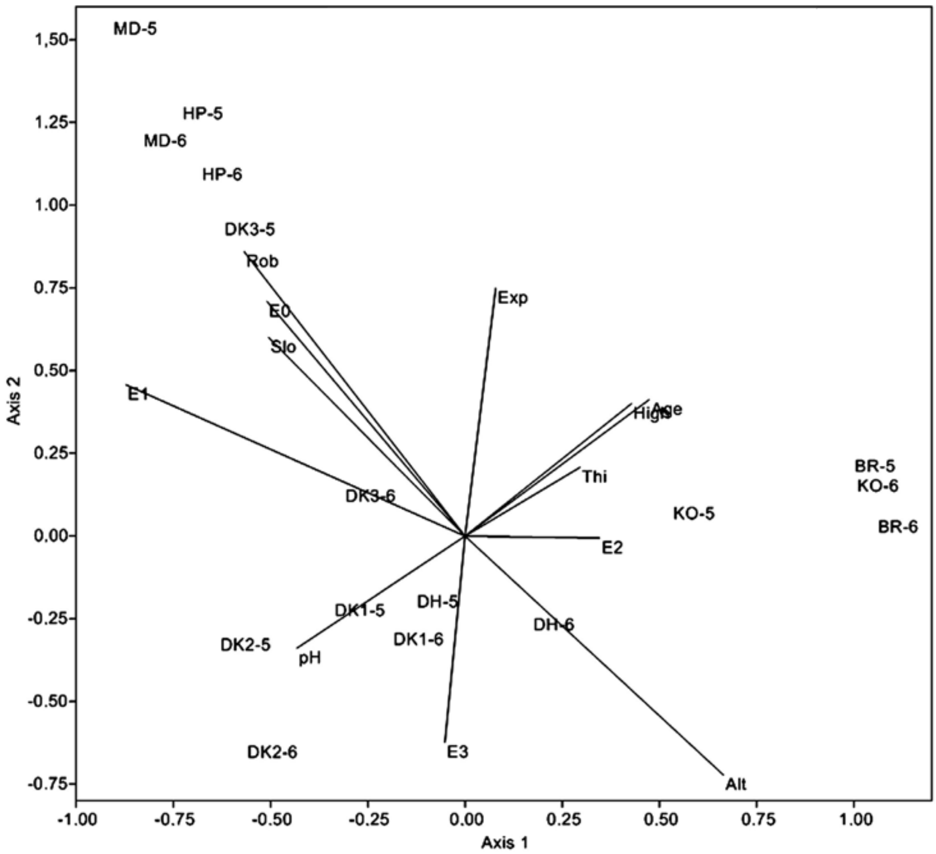

Figure 23. Canonical correspondence analysis – plot of 12 factors and of 16 Carabid communities from oak-hornbeam forests from Bratislava (Exp – exposition, Age – age of the stand, Hei – height of trees, Thi – thickness of trees, Alt – altitude, E0 – E3 – coverage of the layers $E_0 – E_3$, Slo – slope, Rob – presence of *Robinia pseudoacacia* in the stand, abbreviations of samples as in Table 17).

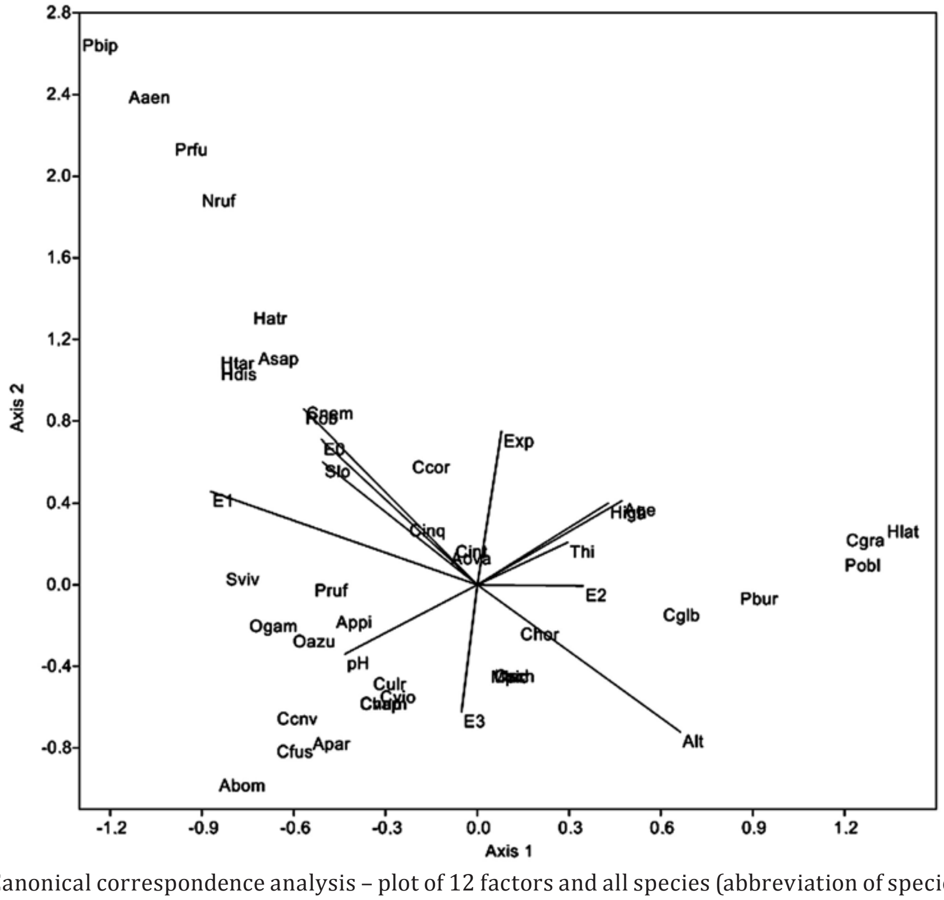

Figure 24. Canonical correspondence analysis – plot of 12 factors and all species (abbreviation of species as in Table 17, abbreviations of factors as in Fig. 23).

these factors. Their common feature is a presence of *Harpalus atratus*, of the heliophious eurytopic *Notiophilus rufipes,* of open landscape species like *Pseudoophonus rufipes* and *Harpalus distinguendus, Harpalus tardus* and *Amara* ssp. Among these factors probably the most significant is presence of *Robinia pseudoacacia*, which gets foliaged later than other trees and enhances the reduced coverage of the E_3 layer, and together with it makes possible increased coverage of lower layers.

The second group of closely related factors includes height and thickness of trees and age of the stand. The communities from Koliba and Briežky are very freely related with this factors.

The altitude is associated with the communities from Koliba and Briežky and to certain degree with communities from Dúbravská Hlavica. A real association of altitude with occurrence of species recorded in these communities exists only in *Carabus glabratus* and *Pterostichus burmeisteri*, which occur here at lower border of their vertical distribution.

The coverage of E_3 layer and soil reaction is associated with the communities from Devínska Kobyla, especially from the site 2, with the limestone substrate, which is reflected in much higher cumulative number of individuals and biomass (Table 18, Fig. 26).

Temporal changes in community structure

In spite of only two-year sampling period, there are two minor features common either for the samples from 2005 or 2006. In 2005 by occurrence of *Calosoma inquisitor* was characterized for the sites in western part of Bratislava, while in the eastern part (Koliba and Briežky) this species occurred in 2006. In some samples hygrophilous *Carabus granulatus* appeared in 2006.

Relationship of species to the shadowing and humidity

In the ordination diagram (Fig. 25), two clusters of communities arise. A compact cluster in the right upper corner includes the communities from Koliba and Briežky. Their index of humidity preference ranges from 4.40 to 4.63, while that for shadowing 3.91–4.0.

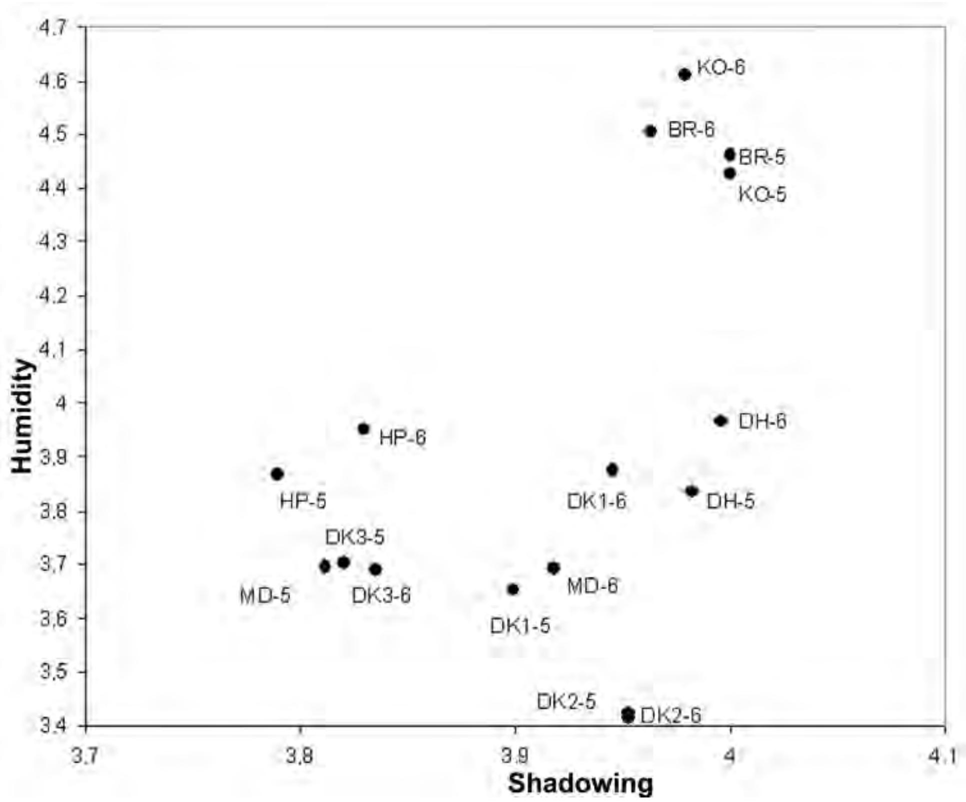

Figure 25. Direct ordination of the communities according to preference for shadowing (abscissa) and humidity (ordinate).

Thus these communities are mesohygrophilous, almost with an absence of the open landscape species.

The second cluster forms a strip along the shadowing gradient. Its left part includes communities from Horský park, Devínska Kobyla 3 and Mlynská dolina from 2005 with a slightly increased portion of the open landscape species (range 3.78–3.83), while in the right part of the gradient (range 3.9–4.0) includes communities from Devínska Kobyla 1 and 2, Dúbravská Hlavica and Mlynská dolina from 2006.

Productivity of the communities

Cumulative number of individuals and biomass were positively correlated in all localities. It was caused by a high representation of largest species (Fig. 26). There were considerable differences between individual sites. But only in the case of Horský park the obviously lower number of individuals and biomass can be interpreted as a consequence of anthropogenic pressure on the locality. In other cases, the differences represented between-year fluctuation with a strong increase in 2006. Only in Devínska Kobyla 3 the cumulative number of individuals slightly declined, while the cumulative biomass increased. It was caused by simultaneous decline of number of individuals of *Harpalus atratus* (from 48 to 14) and of *Carabus nemoralis* (from 37 to 12). There was not found a clear difference in these two parameters between communities on acid or neutral substrates on one hand and basic substrates on other hand, which are known from many other localities (Šustek 2009).

The Shannon-Wiener's index (Table 18, Fig. 27) ranges from 1.15 to 2.06 (Dúbravská Hlavica in 2006). The lowest values were in both years in Briežky (1.15 and 1.18) due to extremely high dominance of *Pterostichus oblongopunctatus* and Mlynská dolina (1.55 and 1.37) due to a low number of species and high dominance of *Carabus nemoralis* and *Abax parallelopipedus*. The highest values were in Devínska Kobyla 3 in 2006 (balanced representation of eudominant *Abax parallelopipedus, Carabus hortensis, Carabus nemoralis* and *Harpalus atratus*) and Dúbravská Hlavica in 2005 (balanced representation of eudominant *Abax parallelopipedus, Carabus hortensis, Carabus nemoralis, Carabus ullrichi* and *Pterostichus oblongopunctatus*).

In all localities, excepting Briežky, the diversity and equitability declined in 2006. This decline was caused by a strong increase in number of individuals of three species *Abax parallelopipedus, Carabus hortensis* and *Pterostichus oblongopunctatus* and by stagnation of number of individuals of most other species (Table 18, Fig. 26). On the contrary, in Briežky the simultaneous increase of *Carabus hortensis* and *Pterostichus oblongopunctatus* led to more balanced representation of species and to a moderate increase of diversity index.

The equitability was closely correlated with the diversity index with exception of community from Koliba from 2005 and from Horský park from both years (in all cases, a low number of species was equally distributed over low number of individuals, Table 18).

Zoogeographic structure of Carabid communities

Within the material studied, nine aerographic types of species (in decreasing order of their approximate size: Panpalaearctic, Transpalaearctic, Westpalaearctic. Eurosiberian, European, Central European, Circummediterranean, Pontomediterranean and Carpatho-Balcanic) were distinguished (Table 17, Figs. 28 and 29).

Qualitatively the largest portion consisted of the European species represented by the typical forest species *Abax parallelopipedus, A. parallelus, Carabus nemoralis, C. hortensis, C. glabratus, C. violaceus, C. intricatus* and *C. coriaceus*. It ranged from 33% in Devínska Kobyla 3 in 2006 to about 86% on Koliba in 2005 and Briežky in 2005. They were fol-

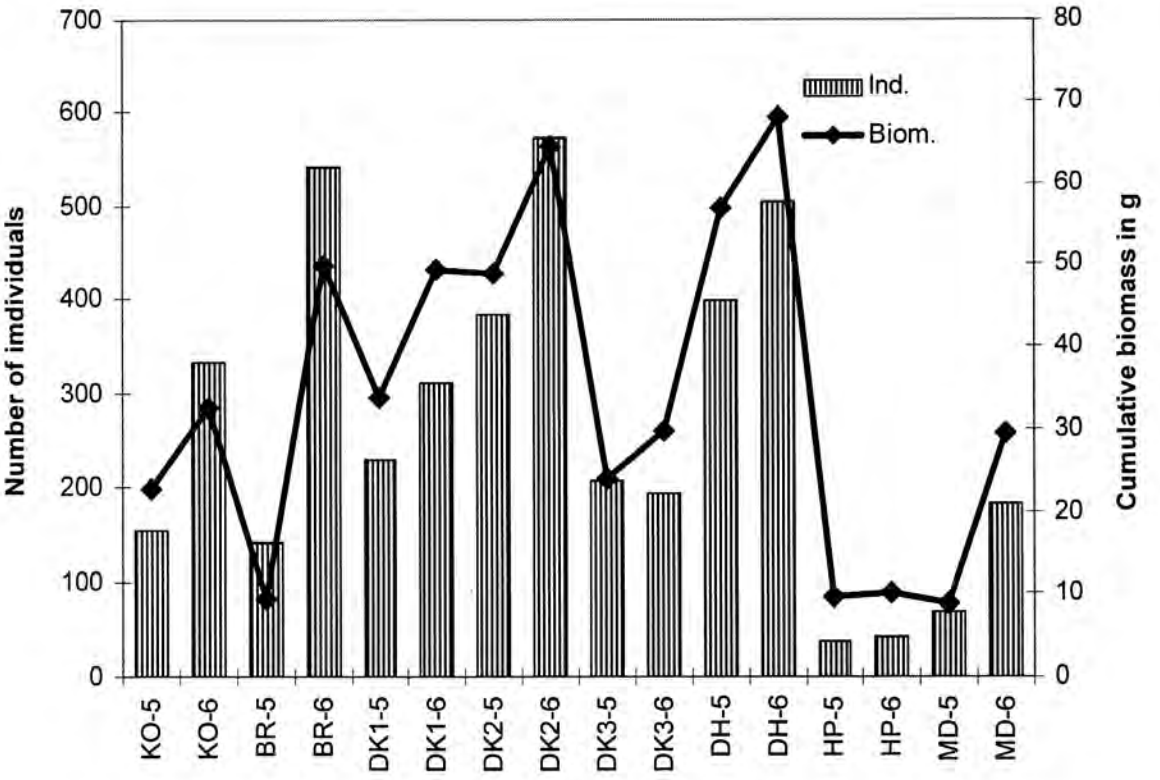

Figure 26. Cumulative number of individuals and biomass of 16 one-year samples of carabids in oak-hornbeam forests in Bratislava.

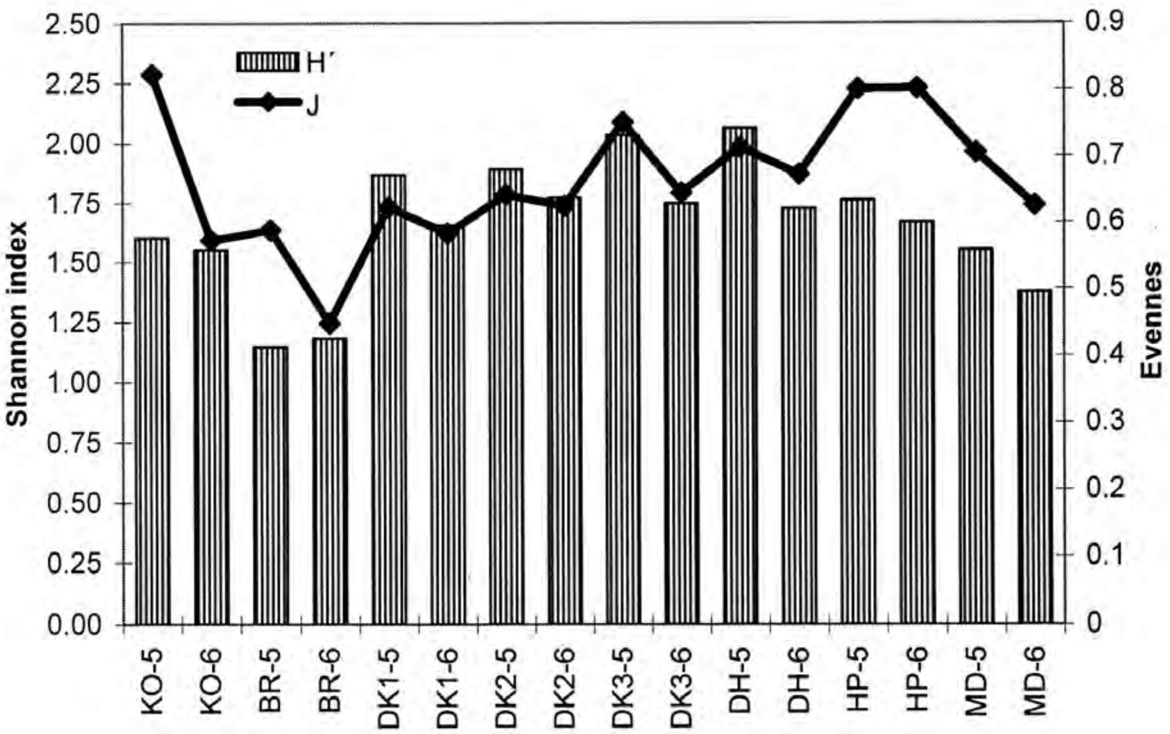

Figure 27. Diversity index (H') and equitability (J) of 16 one-year samples of carabids in oak-hornbeam forests in Bratislava.

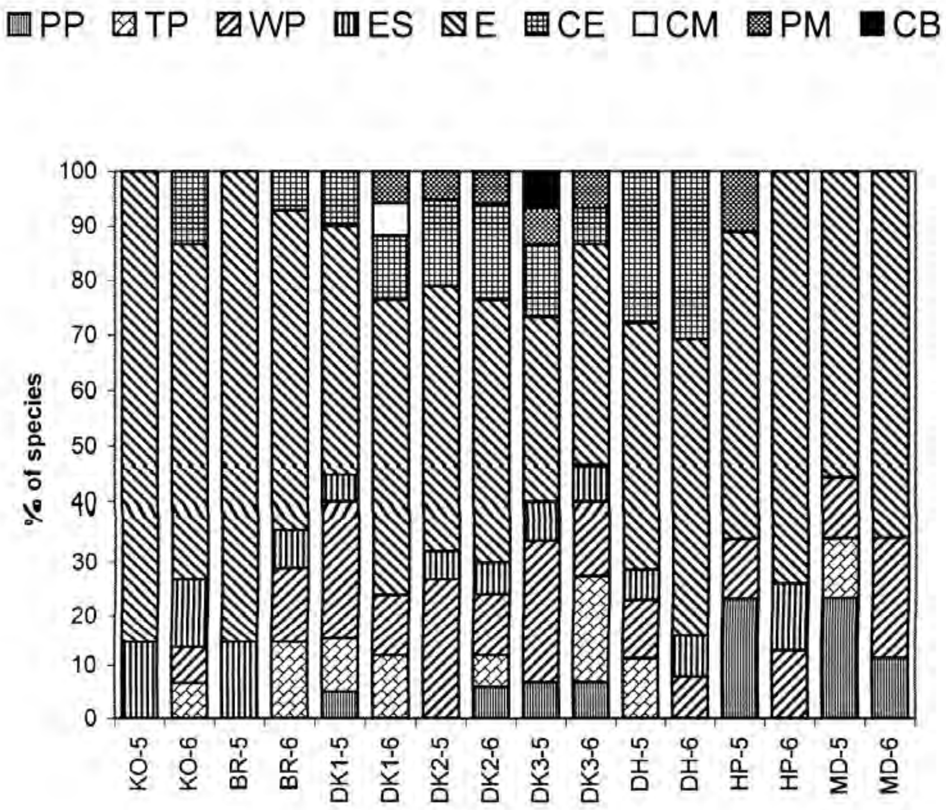

Figure 28. Qualitative representation of species with different distributional ranges (PP – Panpalaearctic, TP – Transpalaearctic, WP – West Palaearctic, ES – Eurosiberian, E – European, CE – Central European, CM – Circummediterranean, PM – Pontomediterranean, CB – Carpatho-Balcanic).

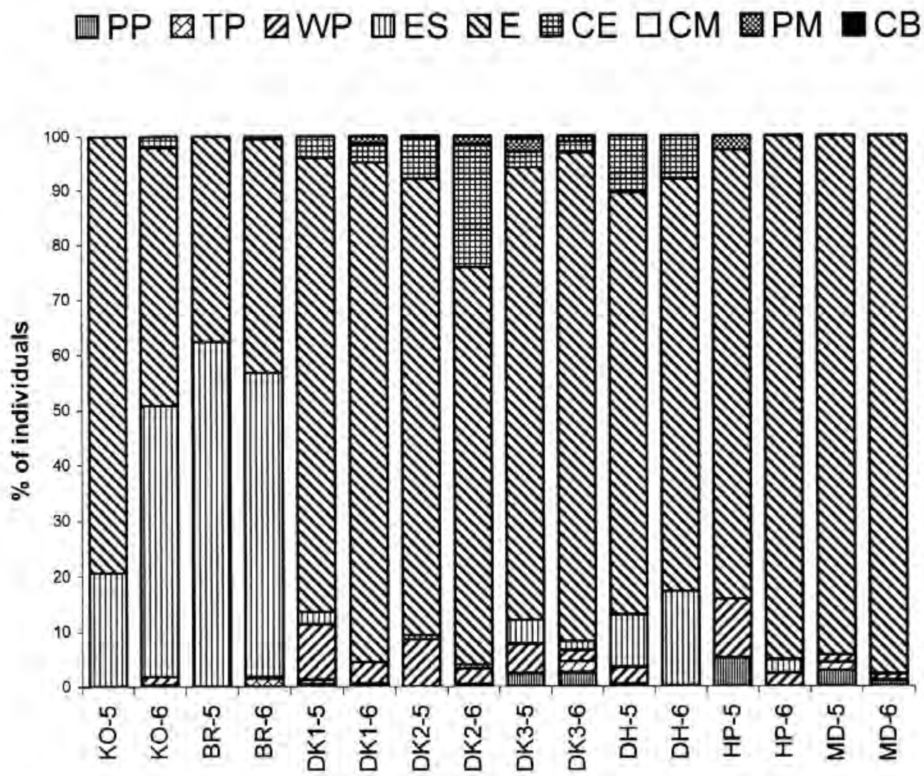

Figure 29. Quantitative representation of species with different distributional ranges (PP – Panpalaearctic, TP – Transpalaearctic, WP – West Palaearctic, ES – Eurosiberian, E – European, CE – Central European, CM – Circummediterranean, PM – Pontomediterranean, CB – Carpatho-Balcanic).

lowed alternatively the Eurosiberian (*Pterostichus oblongopunctatus* in Briežky in 2005, Horský park and Mlynská dolina in 2005), Westpalaearctic (*Carabus convexus* and *Calosoma inquisitor* in Devínska Kobyla 1 and 3 in 2005), Transpalaearctic (*Carabus granulatus* and *Cymindis vaporrariorum* in Devínska Kobyla 3 in 2006) and Central European species (*Carabus ullrichi* and *C. scheidleri* in Dúbravská Hlavica).

From the quantitative point of view, the aerographic structure was much simpler. In most localities the European species highly predominated, ranging from 37 to 97% of individuals. Only in Koliba in 2006 and Briežky in both years they had approximately a balanced representation with Eurosiberian *Pterostichus oblongopunctatus* represented by 49–62% of individuals. In Dúbravská Hlavica the European species were followed by a balanced representation of the Eurosiberian (*Pterostichus oblongopunctatus*: 9–17%) and Central European species (*Carabus ullrichi* and *C. scheidleri*: together 7.9–10.5%), while in Devínska Kobyla 1 and 2 and Horský park in 2005 there was a balanced representation of Westpalaearctic species (*Carabus convexus* and *Calosoma inquisitor*: together 8.5–10.5%). In Devínska Kobyla 2 in 2006 the Central European species (*Carabus ullrichi* and *Aptinus bombarda*) represented 23% of individuals. Species of other distribution types mostly did not exceed 10% of individuals.

Absence of Holarctic species and a low quantitative representation of the Panpalaearctic and Transpalaearctic species on one hand and predominance of the European, Central European species accompanied by some Westsiberian or Westpalaearctic forest species indicates a high degree of naturalness of the studied communities.

The size of distribution area of a species is positively correlated with its dispersal power and increased adaptability and tolerance. Thus the species of larger areas are characteristic for azonal and less stable ecosystem or disturbed ecosystem, inclusively of the urban ones. On the contrary, the species with smaller areas tend to be stenotopic and characteristic for more stable natural ecosystems. The absence of the Holarctic and low representation of the Palaeartic and Transpalaeartic species and predominance of the Eurosiberian, Westpalaearctic, European and Central European species on one hand and presence of some Pontomediterranean or Carpatho-Balcanic species on other hand can be taken as a feature of a high degree of naturalness of the studied sites.

Representation of flying and non-flying species

Ability to fly is essential factor of dispersal power of the carabids. The flying species are characteristic first of all for riparian and floodplain ecosystems, as well as secondarily for the arable land, urban habitats and other anthropogenic ecosystems. In these ecosystems only the flying can survive due to frequent disturbances and necessity to abandon the momentary unfavourable sites and to search other places offering temporarily more favourable conditions. On the contrary, the apterous or brachypterous species are characteristic for the stable ecosystems, especially for the forests. Thus the mutual proportion of the flying and non-flying species can characterize the state and naturalness of the ecosystems.

Qualitatively, the non-flying species predominated in all sites on the city margin, ranging here from 53% (Devínska Kobyla 3 in 2005) to 100% (Dúbravská Hlavica in 2006) (Fig. 30). In the localities in city interior, the portion of non-flying species was much lower, ranging from 33% in Mlynská dolina in 2005 to 62% in Horský park in 2006.

Quantitatively, the portion of non-flying species was much higher in all localities (Fig. 31). On the city margin it ranged mostly in narrow limits of 87 to 100%, excepting Devínska Kobyla 3 in 2005, where they reached only 67%. In both localities in city interior their representation decreased to 68–86%. The lower quantitative portion of non-flying species in Devínska Kobyla 3 and Horský park and Mlynská dolina are caused by increased

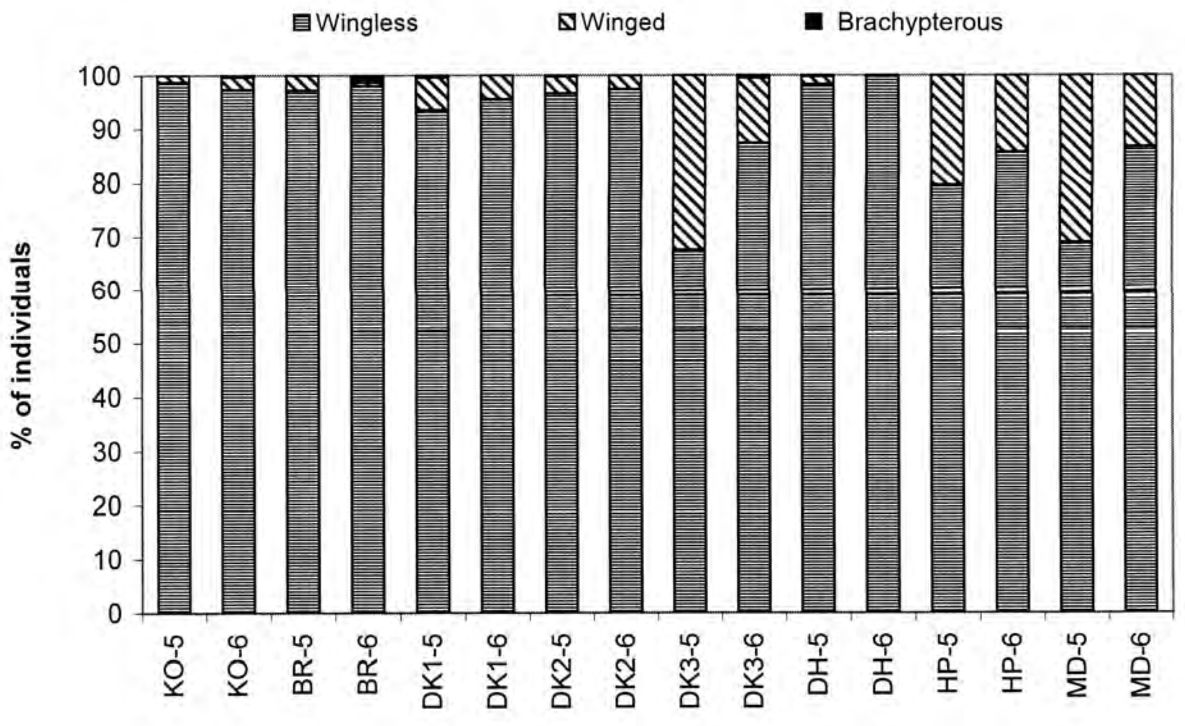

Figure 30. Qualitative representation of wingless, winged and brachypterous species.

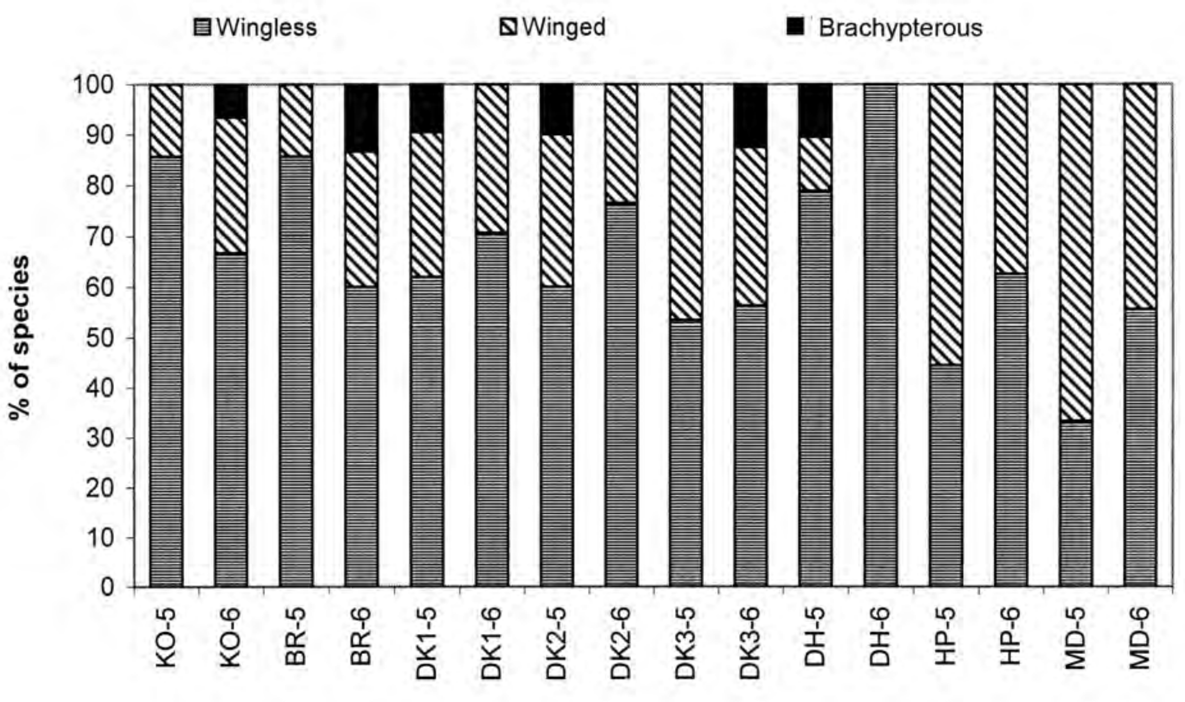

Figure 31. Quantitative representation of wingless, winged and brachypterous species.

representation of the flying forest species *Harpalus atratus*, and in both localities in city interior by occasional occurrence of different open landscape species of the genera *Amara, Pseudoophonus* and *Harpalus*. Their representation indicates certain degree anthropogenic influencing and fragmentation of these localities, but these species do not form a constituent part of the community.

Representation of reproduction types

The division of carabids into two basic reproduction types makes possible, to certain degree, to reduce overlap of similar ecological niches and competition for food in similarly sized species hunting similar prey. In the studied communities representation of the spring and autumn breeding species was qualitatively balanced or the autumn breeders prevailed representing even 2/3 of species (Fig. 32). Quantitatively, however, the spring breeding species mostly prevailed, but with wide between year fluctuations in each lo-

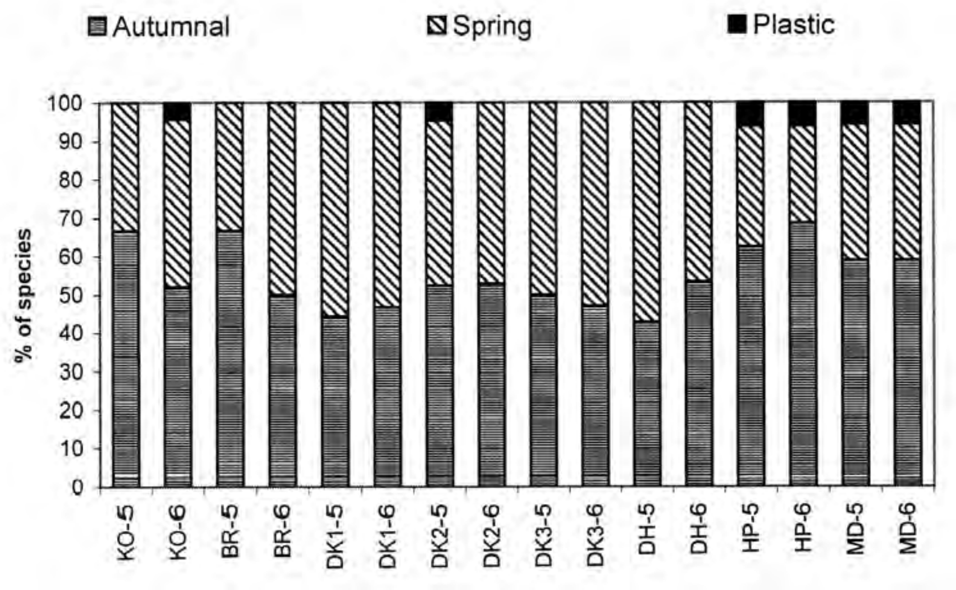

Figure 32. Qualitative representation of species with autumnal, spring and plastic reproduction type.

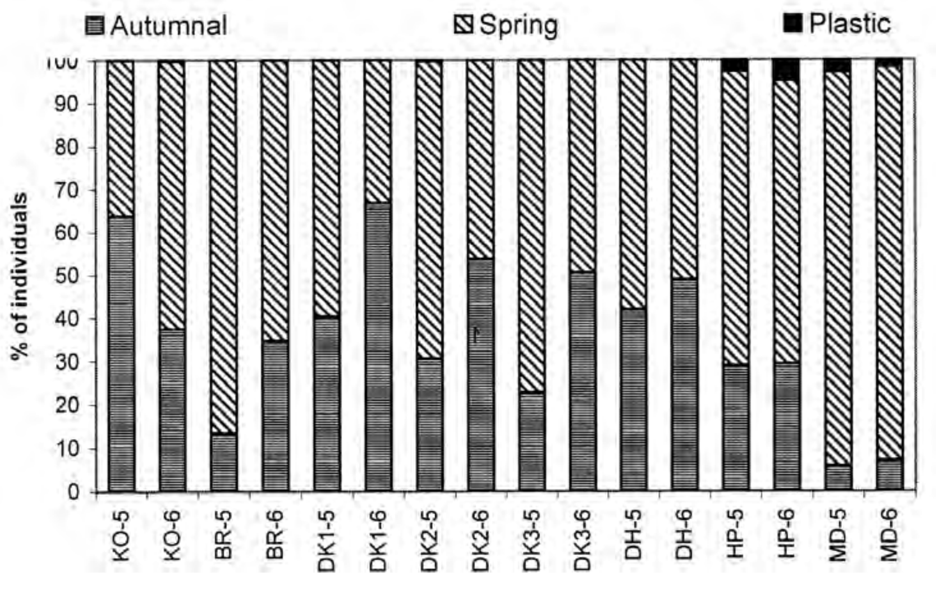

Figure 33. Quantitative representation of species with autumnal, spring and plastic reproduction type.

cality (Fig. 33). As a stable tendency, the prevailing of spring breeders could be taken only in both localities in city centre. It was, however, caused by absence of the abundant autumn breeding *Carabus hortensis* in these localities. The strong fluctuations of *Carabus hortensis* and *Harpalus atratus* also were the main causes of large differences between individual localities and years.

Representation of trophic groups

In all sites the carnivorous species formed the major part of species spectrum, ranging from 55 to 100% of species. The omnivors represent 10–32% of species and the phytophags 5–11% of species (Fig. 34). Quantitatively, the predominance of the carnivors

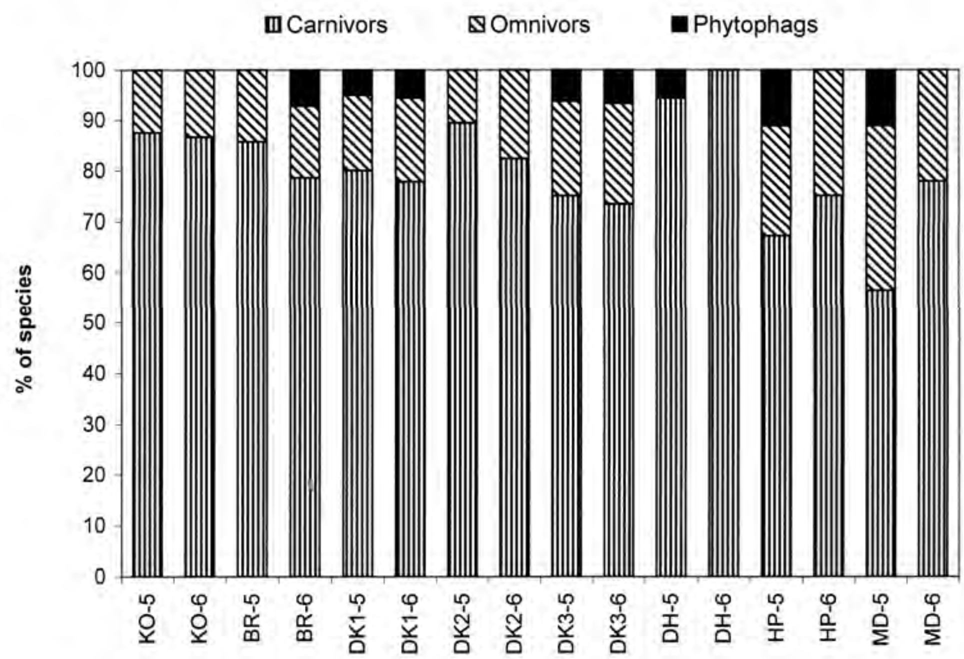

Figure 34. Qualitative representation of carnivorous, omnivorous and phytophagous species.

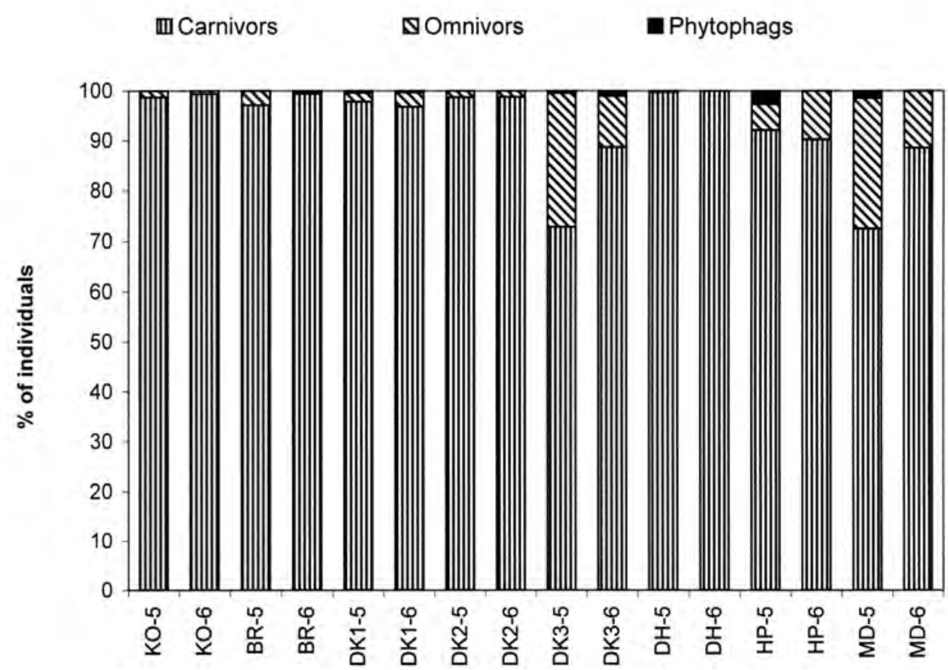

Figure 35. Quantitative representation of carnivorous, omnivorous and phytophagous species.

is still higher, 72–100%, while the cumulative portion of omnivors and phytophags is small (Fig. 35). There is an obvious increase in portion of the omnivorous and phytophagous species of Horský park and Mlynská dolina in two localities in the city centre. This is, however, not caused by some advantage of this food preference in the city interior, but with its high correlation with the ability to fly and preference for open landscape (Table 17).

Body size distribution

Body size distribution in the guild of carnivorous carabids has a high bioindicative value in two directions. First the large body size can be taken as a feature of K-strategy characteristic for stable natural habitats, while their absence indicates disturbed habitats. Even in the natural carabid communities in regularly inundated floodplain forests the largest species have a length of maximum 23 mm, whereas in the mesohygrophilous forests the maximum length reaches almost always at least 32 mm (most species of the genus *Carabus*) and frequently even 40 mm (*Carabus coriaceus*). Second, the continuity of this distribution from the smallest carabid species to the largest one (in Central Europe from 2 to 40 mm) indicates their role in predation of minor arthropods. The largest carabids can represent competitors of the smallest insectivors of the genus *Sorex*.

The body size in all localities ranges from the average size of individuals of 5 mm to 35 mm (Figs. 36–39). Thus there are missing the smallest species of the genus *Trechus*, which are characteristic for natural forest communities in higher elevations (*Trechus pulchellus, T. pillisensis, T. latus*), but at the same time there are missing several small species (*Bembidion lampros, Trechus quadristriatus*), which indicates disintegration of the canopy. The widest scale of body size was observed in Koliba in 2005, Devínska Kobyla 2 in 2006 and in both localities in city centre. In other localities the smallest recorded species had the average body length of 8 mm. As to the continuity of the distribution, the largest continuity was observed in all localities in Devínska Kobyla and in Dúbravská Hlavica, especially in 2006. The lowest discontinuity was observed in Briežky in 2005, when much lower number of species and individuals was caught (Table 18), and according to expectation , in Horský park and Mlynská dolina (Fig. 39). However, even in these sites the largest species, *Carabus coriaceus*, was always present.

All studied communities reflect the very specific environmental situation of Bratislava. It incorporated into its territory many islands of natural or seminatural forest habitats, and to a considerable degree preserved them. The built-up area is horse-shoe-shaped. Owing to it the massive of the Malé Karpaty Mts. penetrates close to the very centre of the city. In the western part of Bratislava, the forests islands form an almost continuous strip reaching from Devínska Kobyla up to the residential settlements westernly of the Castle of Bratislava. These forest islands preserved or, by turn of 19th and 20th century, restored carabid communities of considerably natural character (Šustek 1984a). They have qualitatively a very similar composition as communities in analogous conditions in free landscape in warm lowlands of Central Europe (Šustek 1976, 1983, 1984b).

Each of the studied communities was poorer in number of species than the number of species recorded by Korbel et al. (1997), Majzlan, Baťalík (1997) and Majzlan et al. (2005) in Devínska Kobyla. But these authors pooled collections from different habitats with different species composition. However, the approximate sequence of the dominant species presented by Majzlan, Baťalík (1997) was similar. There was not also recorded *Calosoma sycophanta* (Linnaeus, 1758) found in more places in the investigated area by Jendek et al. (2009). The communities from Devínska Kobyla were not penetrated by species inhabiting the steppe part of this locality (Majzlan, Baťalík, 1997, Šustek 2004a).

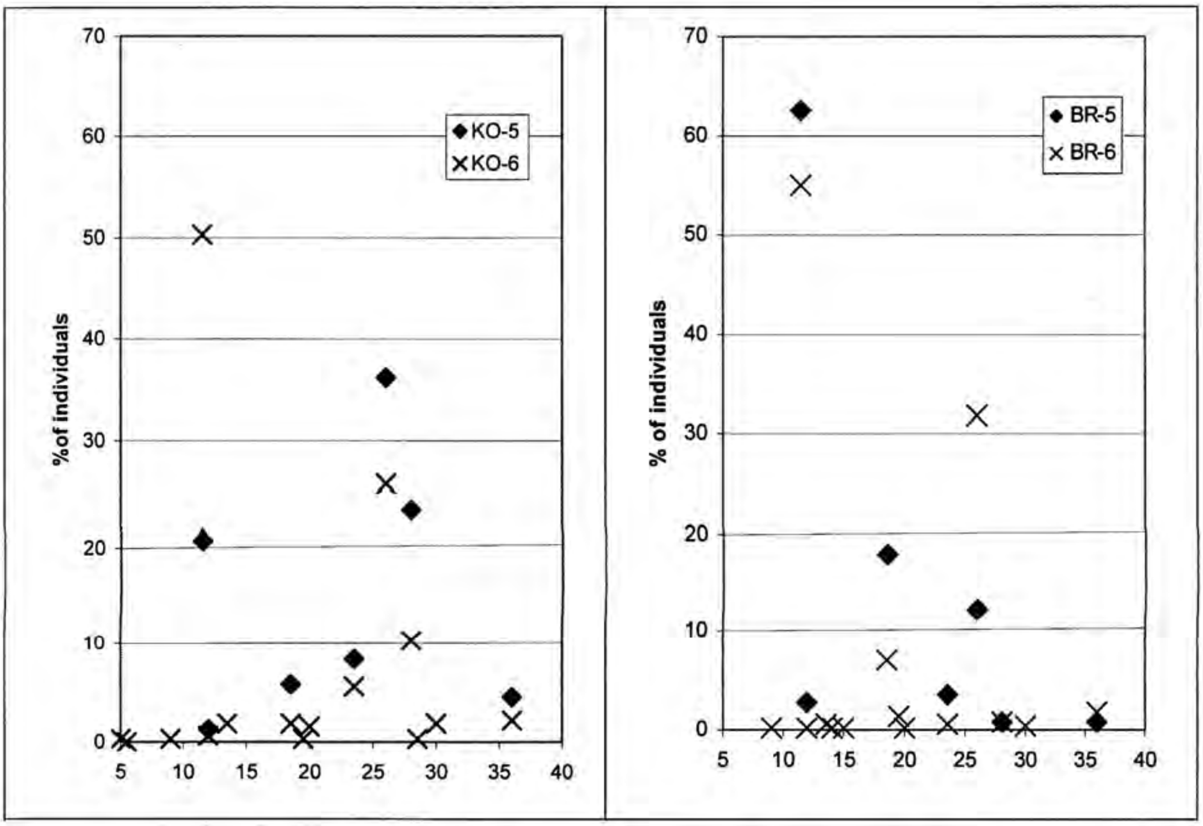

Figure 36. Body size distribution of carabids in Koliba and Briežky in 2005 and 2006 (abscissa body length in mm).

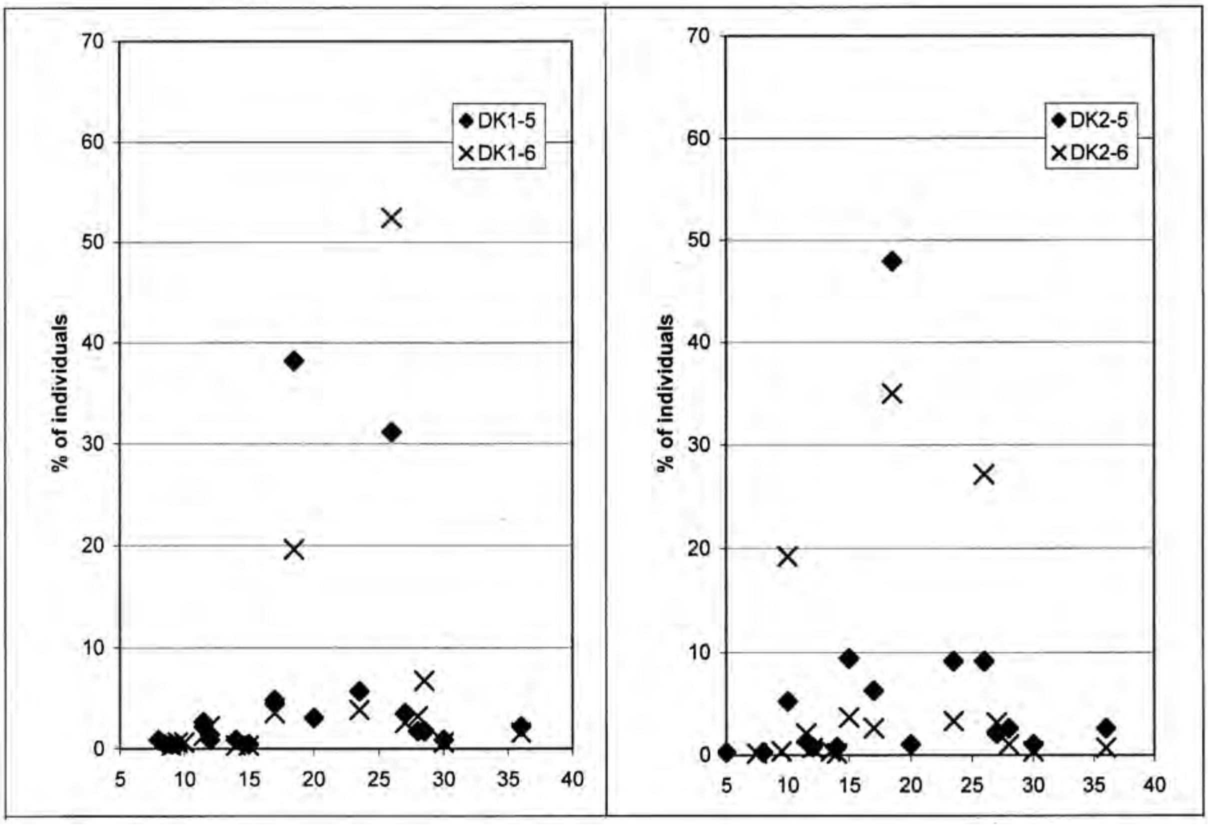

Figure 37. Body size distribution of carabids in Devínska Kobyla 1 and 2 in 2005 and 2006 (abscissa body length in mm).

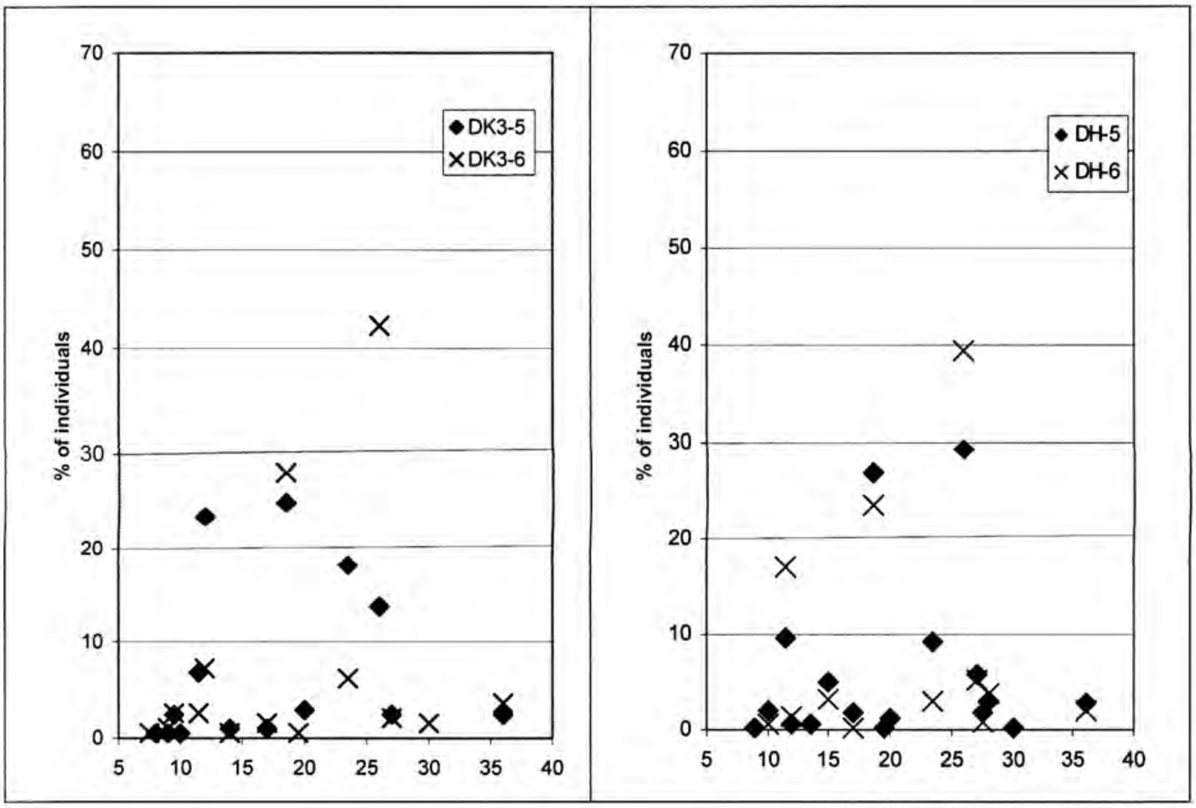

Figure 38. Body size distribution of carabids in Devínska Kobyla 3 and Dúbravská Hlavica in 2005 and 2006 (abscissa body length in mm).

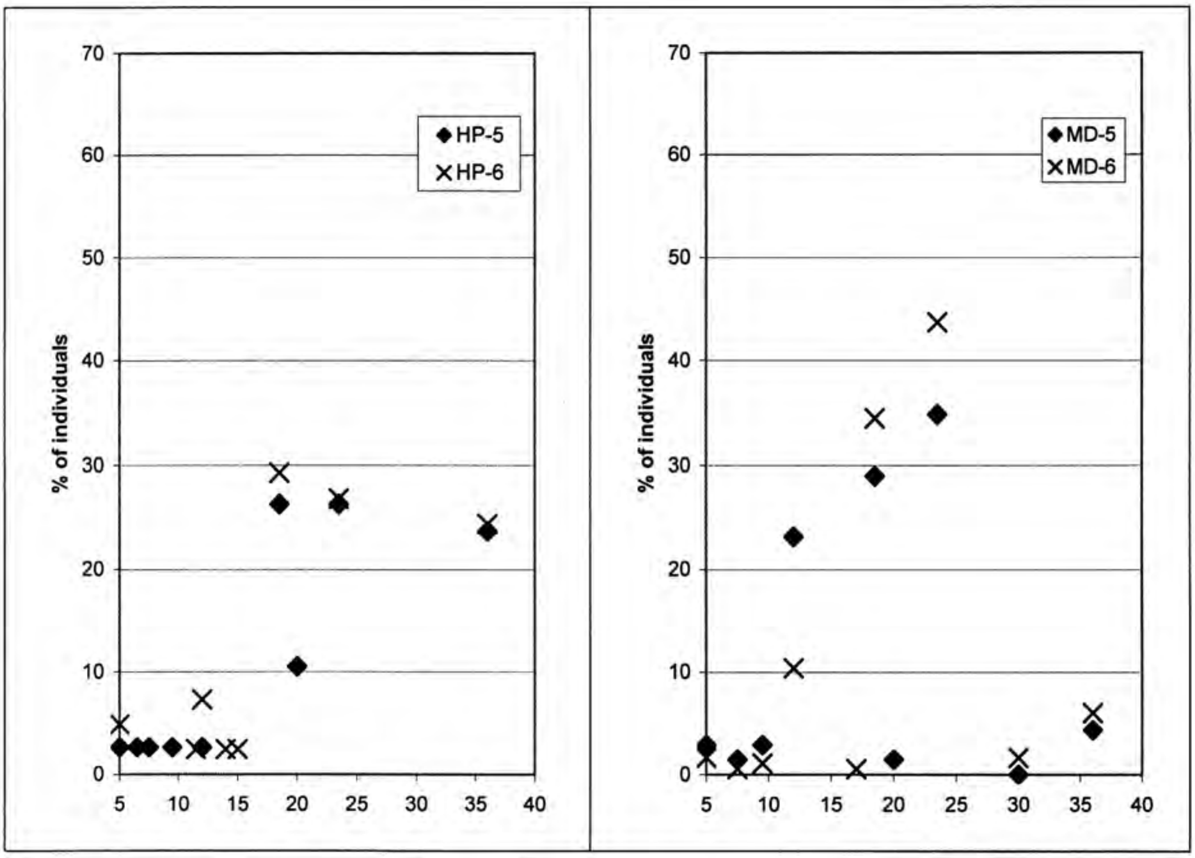

Figure 39. Body size distribution of carabids in Horský park and Mlynská dolina in 2005 and 2006 (abscissa body length in mm).

The community composition reflected position of the localities at the border zone between the beech-oak and oak-beech vegetation tier (Zlatník 1976) by occurrence of *Pterostichus burmeisteri* in some sites situated at altitudes above ca. 300 m or in zone of the oak-beech vegetation tier where this species has lower limit of its vertical distribution (Šustek 2000) and by occurrence of *Carabus glabratus* in all localities with exception of Devínska Kobyla 3, Horský park, or of *Carabus violaceus* in Koliba and Devínska Kobyla 1. On other hand, in Mlynská dolina, as the lowest locality, the thermophilous species *Platyderus rufus* occurred. This species is known to occur sporadically in more warm forests at low altitudes. These species reflect the difference of 0.4 °C in average annual temperature between the meteorological stations in Mlynská dolina (10.8 °C) and Koliba (10.4 °C) (Horecká, Tekušová 2011).

Further characteristic thermophilous elements of the communities from Devínska Kobyla were the Pontomediterranean species *Ophonus gammeli* and Carpatho-Balcanic *Amara saphyrea*. Occurrence of the first one was not published in zoocoenologic studies carried out in forests in Slovakia, while the former one is known to occur in sparse forests and coppices in lowlands in West Slovakia (Šustek 1984a, Hůrka 1996).

A remarkable element in majority of studied communities was *Carabus intricatus* found in all localities, except for Horský park. This species never occurs abundantly in natural forests, but has an remarkable ability to overcome vertical obstacles (Šustek 1999b) and is the only *Carabus* species in Central Europe penetrating even in the densely built-up parts of cities. Its absence in Horský park was also observed in early 1980-s, but was found in Kalvária.

Unlike other cities (Alaruikka et al. 2002, Czechowski 1980a, 1980b, 1981a, 1981b, 1982, Klausnitzer, Richter 1980, Klausnitzer et al. 1980, Magura et al. 2008, Šustek 2011, 2012, Šustek, Vašátko 1983a, 1983b, Topp 1972, Venn et al. 2003) and the proper centre of Bratislava (Šustek 1984a, 1987), and absence of large species in the studied localities there was not observed, only in Horský park and Mlynská dolina their number (but not dominance) was reduced.

The increase in abundance of *Carabus hortensis* and *Pterostichus oblongopunctatus* and to a limited degree also of *Abax parallelopipedus* in 2006 was observed in all sites, where these species occurred (Table 18). It obviously represented consequence of a globally acting factor. The most probable cause was the relatively dry year 2004 (precipitation sum in Bratislava - airport 536 mm) and a slow increase of annual precipitation in next years (549.2 mm in 2005, 581.5 mm in 2006, 597.9 mm in 2007). Similar one-year delay of reaction of carabid communities on extreme drought and later restoration community parameters was observed also in High Tatra in 2007–2011 (Šustek, Vido 2012). These changes show that observed differences between the communities (Table 18) have just a temporary character.

Absence of the otherwise very frequent species *Carabus hortensis* in the communities from Horský park and Mlynská dolina was observed also in early 1980-s in two sites in Horský park and one site in Kalvária (Šustek 1984a). This fact is surprising because this species is very frequent in the near Sitina forest and adjacent areas of the zoological garden or the Slovak Academy of Sciences. In the alluvium of Vydrica, directly below the study site “Mlynská dolina” it was frequently recorded in early 1980-s (Šustek 1984a). So there exists a chance for its reimmigration. In addition, this species relatively easily passes over the smooth vertical obstacles.

The zoogeographic structure was in the focus of structure of carabid communities in urban ecosystems only in Brno, Bratislava, Pyongyang and Madrid (Šustek 1980, 1984a, 2011 and 2012). In these cases proportion of species with large distribution areas considerably increased toward the most influenced sites in the city centres, whereas the species with small areas disappeared in the suburban zones. This phenomenon was not observed in the studied localities, where the species with middle sized distribution areas strongly predominated, and was similar to the more or less natural communities in free landscape.

Other general tendencies of structural changes in carabid communities known from other cities, namely an increase of absolute and relative representation of panthophagous or phytophagous species or of the s.c. generalists (Niemelä et al. 2011) toward city centre, decrease of representation or absence of wingless species, increase of proportion of open landscape species and autumnal breeders were observed in a moderate extent only in Horský park and Mlynská dolina. This extent corresponded to the state found in Horský park or in similar habitats in Sitina and Kalvária in 1981 and 1982 (Šustek 1984a).

All these facts give evidence, that the communities from Koliba, Briežky, Devínska Kobyla and Dúbravská Hlavica preserve a considerably high degree of naturalness. Their penetration by the xenoucoenous species did not exceed the degree known even from natural reserves of forests ecosystem in lowlands (Šustek 1976, 1983).

Conclusions

1. The studied communities from Devínska Kobyla, Dúbravská Hlavica, Koliba and Briežky were in individual years slightly poorer in species than analogous communities in free landscape, but they were not penetrated by xenocoenous species indicating an anthropogenetic disturbance and they preserved a highly natural character.
2. Structure of the studied communities reflected the ca. 200-m difference in altitude (in vegetation tiers) by sporadic descending of species having optimum of vertical distribution at higher altitudes.
3. The communities from Horský park and Mlynská dolina were poorer in number of species and in number of individuals than other studied communities. They preserved only a part of species corresponding to the natural state of such ecosystems, but were penetrated by several xenocoenous species due to their isolation of recreation or horticultural pressure.
4. All communities, irrespectively of their position or disturbance were subjected to strong between-year fluctuations in representation of individuals species. These fluctuations, however, showed common features in the whole studied area. It was disappearance of *Calosoma inquisitor* in 2006, a strong increase of abundance of *Carabus hortensis* and *Pterostichus oblongopunctatus* in 2006. These fluctuations are probably connected with low annual precipitation in 2004 and its increase in next years.
5. From the view of carabids, the studied sites represent valuable ecosystems deserving protection.

References

Alaruikka, D., Kotze, D.J., Matveinen, K., Niemelä, J., 2002: Carabid beetle and spider assemblages along a forested urban-rural gradient in southern Finland. Journal of Insect Conservation, 6: 195–206.

Burmeister, F, 1939: Biologie, Ökologie und Verbreitung der europäischen Käfer auf systematischer Grundlage. I. Band; Adephaga I, Familiengruppe: Caraboidea. Hans Goecke Verlag, Krefeld, 307 pp.

Czechowski, W.,1980a: Influence of the manner of managing park areas and their situation on the formation of the communities of carabid beetles (Coleoptera, Carabidae). Fragmenta faunistica, 25: 199–219.

Czechowski, W., 1980b: Carabids (Coleoptera, Carabidae) of the Wistula escarpments in Warszaw. Fragmenta faunistica, 25: 293–316.

Czechowski, W. 1981a: Carabids (Carabidae, Coleoptera) of Warszaw and Mazowia. Memorabilia zoologica, 34: 119–144.

Czechowski, W., 1981b: Influence of environment urbanisation on seasonal dynamics of carabids (Coleoptera, Carabidae) (in Polish). Przegłąd zoologiczny, 26: 68–74.

Czechowski, W., 1982: Occurrence of carabids (Coleoptera, Carabidae) in the urban greenery of Warsaw according to the land utilization and cultivation. Memorabilia zoologica, 39: 1–108

Dushenkov, V.M., 1983: On carabid fauna of Moscow (in Russian). Fauna i ekologija pochvennykh bespozvonochnykh. Moskva, p. 111–112.

Hammer, Ø., 2012: PAST: Paleontological Statistics, Version 2,16 Reference manual, Natural history museum, University of Oslo, Oslo, 227 pp.

Horecká, V., Tekušová, M., 2011: Changes in air temperature in Bratislava and in its surroundings (in Slovak). In: Středová, H., Rožnovský, J., Litschmann, T. (eds), Mikroklima a mezoklima krajinných struktur a antropogenních prostředí. Skalní mlýn, 2. – 4.2., ISBN 978-80-86690-87-2.

Hůrka, K., 1996: Carabidae of the Czech and Slovak Republic. Kabourek, Zlín, 565 pp.

Jendek, E., Štrba, M., Kautman, V., Hergovits, R., Rychlík, I., 2009: Monitoring of selected endangered and protected beetles (Coleoptera) in territory of Bratislava – a basis to discussion about specific protection of insects in Slovakia (in Slovak). Folia faunistica Slovaca, 14: 17–29.

Klausnitzer, B., Richter, K., 1980: Qualitative und quantitative Aspekte der Carabidenfauna der Stadt Leipzig. Wissenschaftliche Zeitschrift der Universität Leipzig, Mathematisch-naturwissenschaftliche Reihe, 29: 567–573.

Klausnitzer, B., Richter, K., Köberlein, C., Köberlein, F., 1980: Faunistische Untersuchungen der Bodenarthropodes zweier Leipziger Stadparks unter besonderer Berücksichtigung der Carabiden und Staphyliniden. Wissenschaftliche Zeitschrift der Universität Leipzig, Mathematisch-naturwissenschaftliche Reihe, 29: 583–597.

Korbel, L., Rychlík, I., Majzlan, O., 1997: Epigaeic beetles (Coleoptera) of the Devínska Kobyla hill (the Malé Karpaty mountains, SW Slovakia). Biologia, Bratislava, 52: 263–272.

Larsson, S.G., 1939: Entwicklungstypen und Entwicklungszeiten der dänischen Carabidae. Entomol. Medd., 20: 277–560.

Lindroth, C.H., 1949: Die Fennoskandischen Carabidae I. Spezieller Teil, Wettergren & Kerbers Förlag, Göteborg, 710 pp.

Magura, A., Tóthmérész, B. Molnár, T., 2008: A species-level comparison of occurrence patterns in carabids along an urbanisation gradient. Landscape and Urban Planning, 86: 134–140.

Majzlan, O., Baťalík, P., 1997: Taxocoenoses of carabids (Coleoptera, Carabidae) as a part of epigeon of the Devínska Kobyla National Nature Reserve (in Slovak). Folia faunistica Slovaca, 2: 57–60.

Majzlan, O., Frantzová, E., 1995: Structure and dynamics of Carabids (Coleoptera, Carabidae) in epigeon of the Nitra town interior (in Slovak). Rosalia, 10: 107–118.

Majzlan, O., Rychlík, I., Korbel, L., 2005: Beetles (Coleoptera) (in Slovak). In Majzlan, O. (ed.), Fauna Devínskej Kobyly, Asociácia priemyslu a ochrany prírody (edícia APOP), Bratislava, p. 87–117.

Niemelä, J., Breuste, J.H., Guntenspergen, G., McIntyre, N.E., Elmqvist, T.J.P., 2011: Urban Ecology Patterns, Processes and Applications. Oxford University Press, Oxford, 388 pp.

Poole, R.W., 1974: An introduction to quantitative ecology. McGraw-Hill, New York, 532 pp.

Raušer, J., Zlatník, A., 1966: Biogeography I. National atlas of Czechoslovakia, folio 21, offprint (in Czech).

Small, E., Sadler, J.P., Telfer, M., 2003: Carabid beetle assemblages on urban derelict sites in Birmingham, UK. Journal of Insect Conservation, 6: 233–246.

Šustek, Z., 1976: Role of carabids and staphylinids in forest geobiocoenoses (thesis, in Czech). Vysoká škola zemědělská, Fakulta lesnická, Brno, 64 pp.

Šustek, Z., 1979: Geoecology of the parks of Brno city: a case study of carabids and staphylinids in the Lužánky park (in Czech). Zprávy Geografického ústavu ČSAV Brno, 16: 156–174.

Šustek, Z., 1980: Some connections of geographic distribution of carabids (Col. Carabidae) and their ability to colonize urbanized landscape ecosystems (in Czech). Zprávy Geografického ústavu ČSAV Brno, 18: 30–40.

Šustek, Z., 1983: The comparison of the Carabidae and Staphylinidae (Ins., Col.) in the selected geobiocenoses of Pavlovské kopce hills during the years 1971–1981. Biológia, 38: 105–115.

Šustek, Z., 1984a: Bioindication ability of carabids and staphylinids (Coleoptera, Carabidae et Staphylinidae) of big central European cities (PhD thesis, in Slovak). Institute of Experimental Biology and Ecology of the Centre of Biological and Ecological Sciences of the Slovak Academy of Sciences, Bratislava, 366 pp.

Šustek, Z., 1984b: Carabidae and Staphylinidae of two forest reservations and their reactions on surrounding human activity. Biológia (Bratislava), 39: 137–162.

Šustek, Z., 1987: Changes in body size structure of Carabid communities (Coleoptera, Carabidae) along an urbanisation gradient. Biológia (Bratislava), 42: 145–156.
Šustek, Z., 1999a: Light attraction of carabid beetles and their survival in the city centre. Biologia (Bratislava), 54: 539–551.
Šustek, Z., 1999b: A curious case of wall climbing in *Carabus intricatus*: do the carabids orient by odour trails? Entomofauna carpathica, 11: 58–62.
Šustek, Z., 2000: Carabid communities (Coleoptera, Carabidae) and their use as supplementary characteristics of geobiocoenologic units: problems and state of knowledge (in Slovak). In: Štykar, J., Čermák, P. (eds), Geobiocenologická typizace krajiny a její aplikace. Geobiocenologické spisy, 5, Brno, p. 18–30.
Šustek, Z., 2004a: Carabid communities (Col. Carabidae) in degradation stages of pubescent oak forests (Corni-Querceta deg.) in oak vegetation tier. In: Polehla, P. (ed.), Hodnocení stavu a vývoje lesních geobiocenóz. Sborník příspěvků z mezinárodní konference 15.-16. 10. 2004 v Brně. Geobiocenologické spisy, Brno, 9: 203–209.
Šustek, Z., 2004b: Characteristics of humidity requirements and relations to vegetation cover of selected Central-European carabids (Col., Carabidae). In: Polehla, P. (ed.), Hodnocení stavu a vývoje lesních geobiocenóz. Sborník příspěvků z mezinárodní konference 15.-16. 10. 2004 v Brně. Geobiocenologické spisy, Brno, 9: 210–214.
Šustek, Z., 2009: Changes of secondary productivity of carabid communities (Insecta, Coleoptera) in natural forest ecosystems in relation to geological substrate and vertical zonality. Oltenia, Studii şi comunicări, Ştiinţele Naturii. Muzeul Olteniei Craiova, 25: 83–90.
Šustek, Z., 2011: Changes in carabid communities along the urbanization gradient in Pyongyang (North Korea). Oltenia, Studii şi comunicări, Ştiinţele Naturii. Muzeul Olteniei Craiova, 27: 87–96.
Šustek, Z., 2012: Changes in carabid communities (Insecta, Coleoptera) along urbanization gradient in Madrid (Spain). Oltenia, Studii şi comunicări, Ştiinţele Naturii. Muzeul Olteniei Craiova, 28: 73–92.
Šustek, Z., Vašátko, J., 1983a: Model groups of invertebrates in a big city (in Czech). Živa, 31: 142–145.
Šustek, Z., Vašátko, J., 1983b: Coleoptera and Mollusca (Gastropoda) of the Brno agglomeration (in Czech). In: Bína, J., Folk, Č. (eds), Geoekologie brněnské aglomerace. Studia Geographica, 83: 116–123.
Šustek, Z., Vido, J., 2012: Drought as one of major factors influencing succession of carabid communities in the forests, damaged by the wind catastrophe in High Tatra in 2004. 20th International Poster Day Transport of Water, Chemicals and Energy in the System Soil-Crop Canopy-Atmosphere, Bratislava.
Thiele, H.U., 1977: Carabid beetles in their environments. Springer-Verlag, Berlin-Heidelberg-New York, 369 pp.
Topp, W., 1972: Die Besiedlung eines Stadtparks durch Käfer. Pedobiologia, 12: 336–346.
Venn, S.J., Kotze, D.J., Niemelä, J., 2003: Urbanization effects on carabid diversity in boreal forests. European Journal of Entomology, 100: 73–80.
Zlatník, A., 1976: Survey of groups of geobiocoens of original forest and shrub communities in Czechoslovakia (preliminary communication) (in Czech). Zprávy Geografického ústavu ČSAV v Brně, 13: 53–64.

Table 18. Survey of species in individuals localities and years, their percentage on the whole material, presence (P) and average number of individuals per one year catch (A).

Species	Locality and year																%	P	A
	KO	KO	BR	BR	DK1	DK1	DKI2	DK2	DK3	DK3	DH	DH	HP	HP	MD	MD			
	2005	2006	2005	2006	2006	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006			
Abax parallelopipedus	9	6	25	38	87	61	183	200	51	54	107	118	10	12	20	63	24.31	100.00	65.25
Abax parallelus				1	1	1	36	21			19	15		1			2.21	50.00	5.94
Amara aenea													1		1		0.05	12.50	0.13
Amara ovata				1	1	1				2	1						0.14	31.25	0.38
Amara saphyrea									1								0.02	6.25	0.06
Aptinus bombarda						2	20	110	1		8	3					3.35	37.50	9.00
Calathus fuscipes					1		1										0.05	12.50	0.13
Calosoma inquisitor		5		1	7		4		6		5		4		1		0.77	50.00	2.06
Carabus convexus					11	11	24	15	2	3	7	1				1	1.75	56.25	4.69
Carabus coriaceus	7	7	1	10	5	5	10	4	5	7	11	10	9	10	3	11	2.68	100.00	7.19
Carabus glabratus	36	33	1	4	4	10	10	6			12	19					3.14	62.50	8.44
Carabus granulatus		1		7						1	1						0.23	25.00	0.63
Carabus hortensis	56	83	17	172	71	163	35	155	28	82	116	199					27.40	75.00	73.56
Carabus intricatus		6		2	2	2	4	2		3	1					3	0.58	56.25	1.56
Carabus nemoralis	13	18	5	3	13	12	35	19	37	12	37	15	10	11	24	80	8.01	100.00	21.50
Carabus scheidleri											7	4					0.26	12.50	0.69
Carabus ullrichi					8	8	8	18	5	4	23	26					2.33	50.00	6.25
Carabus violaceus		1			4	21											0.61	18.75	1.63
Cymindis humeralis						1											0.02	6.25	0.06
Cymindis vaporariorum					1												0.02	6.25	0.06
Harpalus atratus	2	1	4	1	1	7	2	4	48	14			1	3	16	19	2.86	87.50	7.69

Table 18. continue

Species	Locality and year																%	P	A
	KO	KO	BR	BR	DK1	DK1	DKI2	DK2	DK3	DK3	DH	DH	HP	HP	MD	MD			
	2005	2006	2005	2006	2006	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006			
Harpalus distinguendus						1									1		0.05	12.50	0.13
Harpalus latus		1															0.02	6.25	0.06
Harpalus tardus					1			2	5	5			1		1	2	0.40	43.75	1.06
Molops piceus		1			1		1				2	7					0.28	31.25	0.75
Notiophilus rufipes		1					1						1	2	2	3	0.23	37.50	0.63
Ophonus azureus					2		1		1								0.09	18.75	0.25
Ophonus gammeli						4	1	8	5	2							0.47	31.25	1.25
Panageus bipustulatus																1	0.02	6.25	0.06
Platyderus rufus													1				0.02	6.25	0.06
Laemosthenus terricola											1	1					0.05	12.50	0.13
Pseudoophonus rufipes				1	2	1	3	1	2	1				1			0.28	50.00	0.75
Pterostichus burmeisteri		6		3				2			2						0.30	25.00	0.81
Pterostichus oblongopunctatus	32	162	88	297	5		3	4	9	3	38	86		1			16.95	75.00	45.50
Synuchus vivalis								1		1							0.05	12.50	0.13
Number of species	7	15	7	14	20	17	19	17	15	15	18	13	9	8	9	9			
Number of individuals	155	332	141	541	228	311	382	572	206	194	398	504	38	41	69	183			
Dominance concentration	0.76	0.68	0.56	0.59	0.75	0.68	0.74	0.76	0.83	0.73	0.82	0.75	0.79	0.77	0.74	0.68			
Shannon-Wiener H´	1.60	1.55	1.15	1.18	1.87	1.65	1.89	1.77	2.03	1.75	2.06	1.73	1.76	1.67	1.55	1.37			
Equitability	0.82	0.57	0.59	0.45	0.62	0.58	0.64	0.62	0.75	0.64	0.71	0.67	0.80	0.80	0.71	0.63			

Explanations: KO – Koliba, BR – Briežky, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DK3 – Devínska Kobyla 3, DH – Dúbravská Hlavica, HP – Horský park, MD – Mlynská dolina.

4.5. Weevils (Coleoptera: Curculionoidea)

Milada Holecová

Weevils belong to predominant beetle groups in the ecosystem of deciduous forests in Europe (Funke 1971, Grimm 1976, Schauermann 1973, 1976, Nielsen 1978a, b, c, Holecová 1991b, 1992, Dajoz 2000, etc.). Geobiont species associated with forest floor and leaf litter are important phyllophages, mycophages but also decomposers of dead and decaying wood. They have an influence on soil and vegetation, both directly and indirectly (Wallwork 1976, Speight 1989, Dajoz 2000). Due to their low mobility and inability to take flight they often live in isolated populations. They are sensitive indicators of negative human impact, e.g. forest fragmentation, clear cutting, pollution, disturbance, changes of soil moisture and vegetation (Holecová 1986, Holecová, Sukupová 2002, Zach et al. 1999, Beránek 2008).

Soil beetles in forests of the oak-hornbeam vegetation tier in various parts of Slovakia were studied by Drdul (1973, 1977, 1997), Kožíšek, Drdul (1991), Majzlan (1986, 1991). Majzlan, Hošták (1996), Holecová (1991a, 1995), Holecová, Sukupová (2000, 2002), Holecová et al. (2002, 2005c) were focused on epigeic weevils.

Our research originated in the project being concentrated on animal communities in oak-hornbeam forests in SW Slovakia. Several studies of various groups of soil microfauna (ciliates, naked amoebae, water bears) and arthropods (beetles, ants, spiders, pseudoscorpions, soil mites, terrestrial isopods, centipedes. millipedes, earwigs, bugs) in this territory (Malé Karpaty Mts., SW Slovakia) have been already published (Bartošová, Tirjaková 2005, Bartošová et al. 2007, Christophoryová, Krumpál 2005, Degma et al. 2005, Fenďa, Ciceková 2005, Holecová et al. 2005 a, b, c, Hradil 2005, Krumpálová 2005, Mrva 2005, Országh 2005, Országh, Országhová 2005, Stašiov 2005, Tirjaková, Vďačný 2005, Tuf, Tufová 2005, Vďačný et al. 2007, etc.).

The present study gives results of the 4-year investigation (1999, 2000, 2005 and 2006) on weevil assemblages (Coleoptera, Curculionoidea) in epigeon of oak-hornbeam forests on the territory of Bratislava.

The aims of our study are to:

- characterize structure, dynamics and temporal occurrence of weevil communities;
- analyze representation of topic, trophic and ecological-bionomic groups;
- find out biotic, abiotic and anthropic factors with an influence on epigeic weevil assemblages;
- compare biodiversity of weevil fauna in study plots situated directly in an urban agglomeration and in suburban areas as well.

The investigation refers to 8 study plots (40 to 100 years of their age) in the urban and suburban area of the Bratislava city (Malé Karpaty Mts., SW Slovakia). All the study plots were affected to a certain degree by human activities.

Horský park (HP), 48°09′36″ N, 17°05′13″ E, GRN (Grid Reference Number of the Databank of the Fauna of Slovakia) 7868a, 212 m a.s.l.: a 60–70 year-old forest of the ass. *Querco petraeae-Carpinetum*, situated in the urban part of Bratislava, oriented onto SE. *Quercus dalechampii, Carpinus betulus* and *Acer platanoides* predominate in the tree layer.

Mlynská dolina (MD), 48°09′39″ N, 17°04′41″ E, GRN 7868a, 190 m a.s.l.: an 80–100 year-old forest fragment (ass. *Aceri-Carpinetum*) surrounded by the road communication and urban agglomeration. Besides of *Fraxinus excelsior* and *Acer campestre* the tree stratum consists of *Robinia pseudoacacia, Carpinus betulus, Ulmus campestre, Quercus cerris, Q. dalechampii, Tilia cordata*.

Bratislava – Briežky (BR), 48°10′58″ N, 17°06′40″ E, GRN 7868b, 380 m a.s.l.: an 80–100 year-old forest of the subass. *Querco petraeae-Carpinetum typicum* oriented to the SW. *Quercus dalechampii, Carpinus betulus* and *Tilia cordata* predominate in the tree layer.

Bratislava – Koliba (KO), 48°10′33″ N, 17°06′05″ E, GRN 7868b, 380 m a.s.l.: a 90–100 year-old forest belonging to the subass. *Querco-Carpinetum melicetosum uniflorae* oriented to the SW. *Quercus dalechampii* and *Carpinus betulus* predominate in the tree layer. This forest stand was strongly affected by human activities (tourist visitors, forest clearing, coppice culling).

Devínska Kobyla 1 (DK1), 48°11′05″ N, 16°59′50″ E, GRN 7868a, 340 m a.s.l.: a 60–80 year-old forest belonging to the subassociation *Querco-Carpinetum melicetosum uniflorae* oriented to the S. *Quercus dalechampii* and *Carpinus betulus* predominate in the tree layer.

Devínska Kobyla 2 (DK2), 48°10′59″ N, 16°59′35″ E, GRN 7867a, 300 m a.s.l: a 40–60 year-old forest of the ass. *Aceri-Carpinetum* oriented to the N. *Tilia cordata, Carpinus betulus, Acer campestre, Fagus sylvatica* and *Robinia pseudoacacia* predominate in the tree layer. A small stream rises on this study plot.

Devínska Kobyla 3 (DK3), 48°11′14″ N, 16°59′33″ E, GRN 7868a, 452 m a.s.l.: a 60–80 year-old forest (ass. *Primulo veris-Carpinetum*) oriented to S. *Quercus virgiliana, Q. dalechampii, Carpinus betulus, Acer campestre, Cerasus avium* predominate in the tree layer.

Dúbravská Hlavica (DH), 48°11′08″ N, 17°00′45″ E, GRN 7868a, 350 m a.s.l.: an 80–100 year-old forest of the *Querco petraeae-Carpinetum typicum* association oriented to the E. *Fagus sylvatica, Quercus dalechampii, Carpinus betulus* and *Tilia cordata* predominate in the tree layer.

All study plots are situated in the southern part of Malé Karpaty Mts. Managed oak-hornbeam forests cover the study area. According to the Geobotanic Map of Slovakia (Michalko et al. 1986) Carpathian mesophilous oak-hornbeam woods (*Carpinion betuli* Issler 1931 em. Mayer 1937) (the study plots HP, MD, BR, KO, DK1, DK2, DH) and submediterranean xerothermophilous woods (*Quercion pubescentis-petrae* Br.-Bl. 1931) (DK3) should be considered as typical natural vegetation in this territory. Soil types are represented by Haplic Cambisols (HP, MD, BR, KO, DK1, DH), Rendzic Phaeozem (DK2) and Cutanic Luvisols (DK3). The map, pedological and phytocoenological characteristics of the investigated area are given in detail in the chapter 2.

The soil macrofauna was collected by the square method combined with sifting. In each study site, in about 1-month intervals from April to November (in 2006–2007 to December and January). In KO, BR, DK1, DK2, DH the soil macrofauna was collected during four years (1999, 2000, 2005, 2006 and January 2007), in DK3, HP, MD the material was captured in 2005, 2006 and January 2007. The examined material was collected from the leaf litter and upper part of soil from 16 squares. Each square comprised 25x25 cm, i.e. altogether an area of 1 m^2 was sifted, representing one sample. The samples were extracted using xereclectors of the Moczarski - Winkler's type. The material is deposited at the Department of Zoology, Comenius University in Bratislava. In total, 189 quantitative samples were used for statistical analysis.

The species dominance is characterized by the scale proposed by Tischler (1949) and completed by Heydemann (1955): ED - eudominant, D - dominant, SD - subdominant, R - recedent, SR - subrecedent. The species constancy was expressed by categories according to Tischler (1949) and Schwerdtfeger (1975): EC - euconstant, C - constant, AS - accessoric and A - accidental. The indices of Shannon-Wiener (H'), Pielou (e) and Simpson (c) were used as the alpha diversity indices (Odum 1977, Spellerberg, Fedor 2003). All the couples of Shannon-Wiener's diversity indices were compared with a t-test, to see if they are significantly different (Poole 1974).

The trophic groups of weevil adults were established according to Brown, Hyman (1986). We distinguished four basic groups: S1 - monophages, S2 - narrow oligophages, S3 - wider oligophages, and G - polyphages (S1 – S3 - specialists and G - generalists). Other ecological characteristics of weevil adults (habitat preference, humidity preference, topic groups, bionomic groups, relationship between weevil imagoes and subsoil) are given according to Koch (1992). The cluster analysis of weevil communities (geobiont and geophilous species associated directly with forest floor) was done using the computer program NCLAS (Podani 1993). The clustering method complete linkage in combination with Wishart's similarity ratio was used (Wishart 1969).

The weevil communities were analyzed according to the indirect gradient analysis (PCA), effects of environmental variables on weevil community composition were studied using the canonical correspondence analysis (CCA) ordination technique by CANOCO software program (ter Braak, Šmilauer 1998).

The input data matrices used in hierarchical classification (dendrogram) and ordination methods (PCA a CCA) were based on geobiont and geophilous species associated directly with the epigeon. The geoxenes occurring often accidentally in the forest floor were excluded from analyses.

Gradient variables: pedological and chemical characteristics of leaf litter such as total organic carbon (7.6–26.2%); total nitrogen content (0.38–1.24%); sum of exchange bases (Ca2+, Mg2+, Na+, K+) (17–98.2 mval/100g); exchangeable acidity (1.8–13.7 mval/100g); pH of litter in H_2O (3.7–7.32); humus content (13.1–45.17%); base saturation (51–99%); age of a forest stand (40–100 years); cover of E_3: (70–80%); cover of E_2 (20–55%); cover of E_1 (50–100%); forest fragmentation (0–75%); slope (2–45°).

Categorial variables: exposition of study plots (E, N, S, SW); soil types (Haplic Cambisols, Cutanic Luvisols, Redzic Phaeozem) (Table 19).

Nomenclature of weevils was assumed according to Alonso-Zarazaga, Lyal (1999).

Community structure

A total of 1509 individuals of 70 species, 42 genera and 4 families (Anthribidae, Rhynchitidae, Apionidae, Curculionidae) were examined at eight study plots (Table 20).

In the study sites, from 14 to 35 species were recorded. The mean abundance of weevils varied from 3.06 (the study plot HP) to 22.69 ind.m^{-2} (the study plot DK2) (Table 21).

Geobionts *Acalles echinatus, A. fallax* and *Barypeithes chevrolati* occurred as eudominants, geobionts *A. camelus, Brachysomus echinatus, Ruteria hypocrita*, geophiles *Ceutorhynchus pallidactylus, Otiorhynchus raucus,* geoxenes *Trichopterapion holosericeum, C. typhae* as subdominants. Dominant species were not present in the analyzed material.

The characteristic species spectrum is represented by three groups of species:

1. highly dominant species (eudominant, dominant, subdominant) with a high constancy (euconstant or constant) – saproxylic geobionts *Acalles camelus, A. echinatus, A. fallax, Ruteria hypocrita*, phyllophagous geobionts *Barypeithes chevrolati, Brachysomus echinatus*, geophiles *Ceutorhynchus pallidactylus, Otiorhynchus raucus* and geoxenous species *C. typhae* (a wider oligophage on Brassicaceae), *Trichopterapion holosericeum* (an arboricolus species associated with hornbeams but often aestivating in forest soil);
2. euconstant or constant, non-dominant species –saproxylic geobionts *Acallocrates colonnellii, Trachodes hispidus* and geoxenous species *Ceutorhynchus scrobicollis* (a herbicole associated with *Alliaria petiolata*), *C. erysimi* (a wider oligophage on Brassicaceae), *Bradybatus kellneri, Coeliodes trifasciatus, Curculio glandium, Phyllobius argentatus* (arboricolous species associated with tree canopy);

Table 19. Categorial and gradient environmental variables examined in canonical correspondence analysis.

Variables/Study plots	HP	MD	BR	KO	DK1	DK2	DK3	DH
Soil type								
Haplic Cambisols	1	1	1	1	1	0	0	1
Rendzic Phaeozem	0	0	0	0	0	1	0	0
Cutanic Luvisols	0	0	0	0	0	0	1	0
Exposition								
SW	0	1	1	1	0	0	0	0
S	0	0	0	0	1	0	1	0
N	0	0	0	0	0	1	0	0
E	0	0	0	0	0	0	0	1
SE	1	0	0	0	0	0	0	0
Slope	20°	45°	7°	2°	15°	10°	2°	5°
Age of a forest	2	3	3	3	2	1	2	3
E_3 (%)	80	70	75	70	75	80	75	80
E_2 (%)	40	20	20	35	35	55	20	30
E_1 (%)	70	100	50	100	70	70	100	70
Fragmentation (%)	75	75	25	25	0	0	0	0
Pedological characteristics								
pH in H_2O	5.36	4.36	3.8	3.7	4.66	7.32	5.64	4.13
Cox (%)	18.62	15.52	45.17	31.03	15.17	17.24	13.1	20.69
C (%)	10.80	9.00	26.20	18.00	8.80	10.00	7.60	12.00
N (%)	1.24	1.08	1.14	1.22	0.38	1.04	1.08	0.6
C:N	8.71	8.33	22.98	14.75	23.16	9.62	7.04	20
SOB	31.20	18.40	19.40	17.00	23.40	98.20	42.00	22.60
EA	9.10	11.50	13.10	12.50	9.50	13.70	1.80	12.80
CEC	38.60	32.20	38.10	36.40	98.90	49.20	39.30	36.40
BS (%)	81.00	57.00	51.00	47.00	66.00	99.00	85.00	58.00

Explanatory notes.
Age of a forest: 1 (40–60 years), 2 (60–80 years), 3 (80–100 years); E_3 – canopy density, E_2 – shrub stratum density, E_1 – herbage undergrowth density; Cox(%) – humus content, C(%) – total organic carbon, N(%) – total nitrogen content, C:N – carbon – nitrogen ratio, SOB – sum of exchangeable bases, EA exchangeable acidity, CEC – cation exchangeable capacity, BS – base saturation.

3. differential species – a saproxylic geobiont *Kyklioacalles suturatus*, phyllophagous geobionts *Barypeithes albinae, Brachysomus dispar, B. hirtus, B. setiger*, and *Coeliodes transverseoalbofasciatus, Curculio venosus, C. propinquus* (arboricolous species associated with oaks, but aestivating in leaf litter).

The above review shows that the first two groups of characteristic species spectrum have wider ecological amplitude. The third group is represented by stenovalent species reaching often only a low dominance and constancy, but associated exclusively or namely with forests of the oak-hornbeam vegetation tier.

Seasonal occurrence and dynamics

Abundance of weevils in soil showed 2 peaks: vernal (April, May – the 1st half of June) and serotinal to autumnal (September – October). The spring peaks were determined by typical geobionts of the *Barypeithes, Brachysomus, Acalles* genera. The peaks in serotinal and autumnal were defined by some xylodetriticoles such as the species of *Acalles, Ruteria* genera and *Trachodes hispidus*. Seasonal dynamics in species richness corresponds with abundance dynamics as well. The peak appeared in vernal aspect (April – June) with species richness of 10, resp. 13 geobionts (in May and June) and 4 (in April), resp. 2 geophiles (in May and June). The second peak in species richness hints at autumnal aspect with a frequent occurrence of saproxylic geobionts (*Acalles* spp., *Ruteria hypocrita, Trachodes hispidus*), geophiles (*Otiorhynchus raucus*). However, a rapid increase of number of geoxenous species (Fig. 40) is significant as well. The first group is formed by geoxenes, which migrate into the forest ecosystem from the nearby open habitats in the period of mild or strong drought and later to hibernate. Geoxenous species from the upper forest strata create the second group, which includes particularly arboricolous species, often aestivating in forest soil (e.g. the genera of *Coeliodes* and *Curculio* from oaks, *Trichopterapion holosericeum* from hornbeams, *Furcipus rectirostris* from wild cherries, etc.). The Table 22 presents the seasonal occurrence of the species.

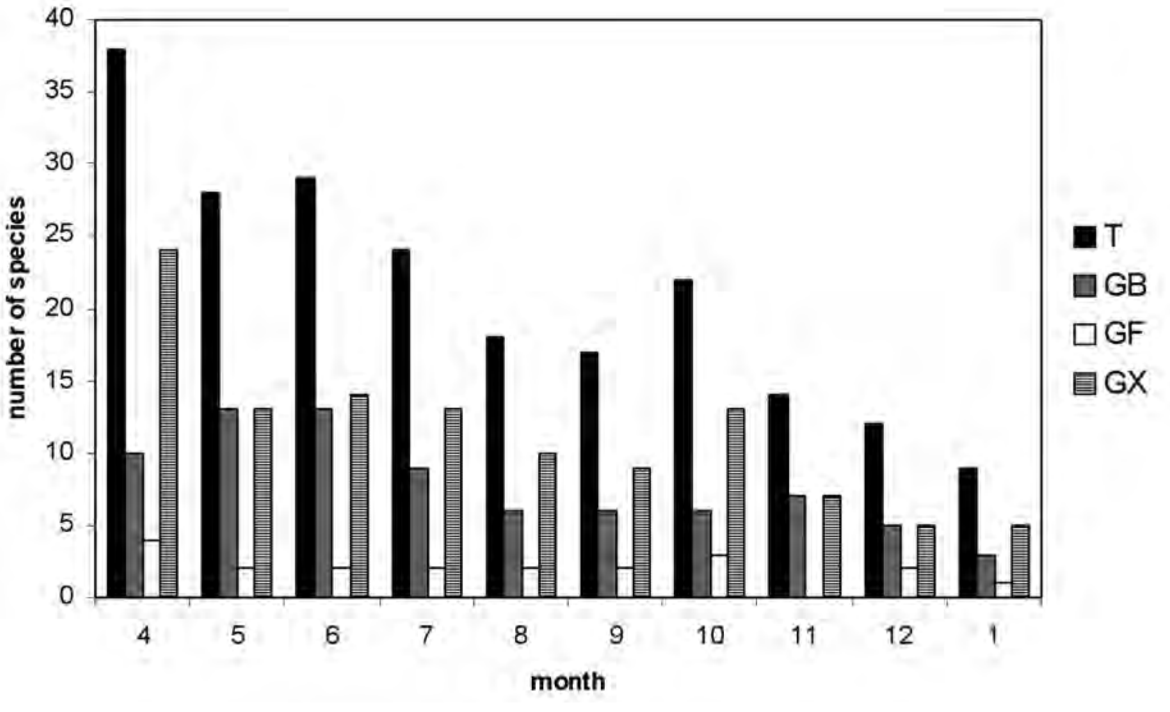

Figure 40. Cumulative numbers of weevil species recorded in individual months of the field study (1999, 2000, 2005, 2006). Explanations: T – total number of weevil species, G – geobionts, GF – geophiles, GX – geoxenes.

Table 20. List of weevil species and numbers of individuals found in the epigeon of oak-hornbeam forests on the territory of Bratislava during 1999–2006.

Family, species / study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH	total	DO(%)	CD	CO(%)	CC	Geo	Top	Tro	Bio	Hab	Hum
Anthribidae																			
Tropideres albirostris (Herbst, 1783)							1		1	0.07	SR	12.50	A	GB	T	G	XF	ST	HY
Rhynchitidae																			
Deporaus betulae (Linnaeus, 1758)			1						1	0.07	SR	12.50	A	GX	A	G	FF	EU	XE
Apionidae																			
Ceratapion gibbirostre Gyllenhal, 1813					2				2	0.13	SR	12.50	A	GX	A	S3	FF	EU	EH
Eutrichapion viciae (Paykull, 1800)	1			1					2	0.13	SR	25.00	AS	GX	H	S3	FF	EU	EH
Ischnopterapion loti (Kirby, 1808)						1			1	0.07	SR	12.50	A	GX	H	S1	FF	EU	XE
Oxystoma craccae (Linnaeus, 1767)	1								1	0.07	SR	12.50	A	GX	H	S2	FF	EU	EH
Kalcapion semivittatum (Gyllenhal, 1833)				1					1	0.07	SR	12.50	A	GX	H	S1	FF	ST	XE
Protapion fulvipes (Foucroy, 1785)	3		3	4	1	2			13	0.86	SR	62.50	C	GX	H	S2	FF	UB	EH
Protapion trifolii (Linnaeus, 1768)		1							1	0.07	SR	12.50	A	GX	H	S3	FF	EU	XE
Trichopterapion holosericeum Gyllenhal, 1833				24		12	1	7	44	2.92	SD	50.00	C	GX	A	S1	FF	ST	EH
Curculionidae																			
Acalles camelus (Fabricius, 1792)			5	1	5	7		34	52	3.45	SD	62.50	C	GB	T	G	XF	ST	HY
Acalles echinatus (Germar, 1824)	23	19	2	30	17	242	12	9	354	23.46	ED	100.00	EC	GB	T	G	XF	ST	HY
Acalles fallax Boheman, 1844			2	3	12	110	1	125	253	16.77	ED	75.00	EC	GB	T	G	XF	ST	HY
Acallocrates colonnellii Bahr, 2003		2		5	5	1	4	1	18	1.19	SR	75.00	EC	GB	T	S3	XF	ST	HY
Anthonomus pomorum (Linnaeus, 1758)				1					1	0.07	SR	12.50	A	GX	A	S2	FF	ST	EH
Archarius pyrrhoceras (Marsham, 1802)								1	1	0.07	SR	12.50	A	GX	A	S2	FF	EU	EH
Bagous argillaceus Gyllenhall, 1836						1			1	0.07	SR	12.50	A	GX	H	?	FF	ST	HY
Barypeithes albinae Formanek, 1903							1		1	0.07	SR	12.50	A	GB	T	?	FF	ST	HY

Table 20. continue.

Family, species / study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH	total	DO(%)	CD	CO(%)	CC	Geo	Top	Tro	Bio	Hab	Hum
Barypeithes chevrolati (Boheman, 1843)	2	10	38	32	32	150	21	15	300	19.88	ED	100.00	EC	GB	T	?	FF	ST	HY
Barypeithes pellucidus (Boheman, 1843)	2	3		4					9	0.60	SR	37.50	AS	GB	T	G	FF	EU	HY
Brachysomus dispar Penecke, 1910					1				1	0.07	SR	12.50	A	GB	T	?	FF	ST	XE
Brachysomus echinatus (Bonsdorff, 1785)	4	1			2	25	3		35	2.32	SD	62.50	C	GB	T	G	FF	EU	EH
Brachysomus hirtus (Boheman, 1845)					1				1	0.07	SR	12.50	A	GB	T	?	FF	ST	XE
Brachysomus setiger (Gyllenhal, 1840)						2			2	0.13	SR	12.50	A	GB	T	G	FF	ST	XE
Bradybatus fallax Gerstaecker, 1860								2	2	0.13	SR	12.50	A	GX	A	S2	FF	ST	EH
Bradybatus kellneri Bach, 1854	1				1	1		4	7	0.46	SR	50.00	C	GX	A	S2	FF	ST	EH
Ceutorhynchus alliariae Brisout de Barneville, 1860					11				11	0.73	SR	12.50	A	GX	H	S1	FF	ST	HY
Ceutorhynchus erysimi (Fabricius, 1787)	3	1	4	4	1		1	1	15	0.99	SR	87.50	EC	GX	H	S3	FF	UB	EH
Ceutorhynchus nigritulus Schultze, 1787					1	1			2	0.13	SR	25.00	AS	GX	H	S2	FF	ST	XE
Ceutorhynchus obstrictus (Marsham, 1802)			4	4				1	9	0.60	SR	37.50	AS	GX	H	S3	FF	UB	EH
Ceutorhynchus pallidactylus (Marsham, 1802)			5	13	8	6	1	5	38	2.52	SD	75.00	EC	GF	H	S3	FF	UB	EH
Ceutorhynchus scrobicollis (Neresheimer et Wagner, 1924)				1	17	4	2	3	27	1.79	R	62.50	C	GX	H	S1	FF	ST	HY
Ceutorhynchus typhae (Herbst, 1795)		1	7	8	2	7	1	4	30	1.99	SD	87.50	EC	GX	H	S3	FF	UB	EH
Coeliodes transverseoalbofasciatus (Goeze, 1777)					3				3	0.20	SR	12.50	A	GX	A	S2	FF	ST	XE
Coeliodes trifasciatus Bach, 1854	1		2	1	1			1	6	0.40	SR	62.50	C	GX	A	S2	FF	ST	XE
Curculio glandium Marsham, 1802	1		4	1			3		9	0.60	SR	50.00	C	GX	A	S2	FF	EU	EH
Curculio propinquus (Desbrochers, 1868)					1				1	0.07	SR	12.50	A	GX	A	S1	FF	ST	XE
Curculio venosus (Gravenhorst, 1807)				2	1			1	4	0.27	SR	37.50	AS	GX	A	S2	FF	EU	EH
Cycloderes pilosus (Fabricius, 1792)								1	1	0.07	SR	12.50	A	GB	TH	G	FF	ST	XE
Dorytomus longimanus (Forster, 1771)	1								1	0.07	SR	12.50	A	GX	A	S2	FF	ST	HY

Table 20. continue.

Family, species / study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH	total	DO(%)	CD	CO(%)	CC	Geo	Top	Tro	Bio	Hab	Hum
Eusomus ovulum Germar, 1824					3				3	0.20	SR	12.50	A	GX	H	G	FF	EU	XE
Furcipus rectirostris (Linnaeus, 1758)					3		1		4	0.27	SR	25.00	AS	GX	A	S2	FF	ST	HY
Hypera postica (Gyllenhal, 1813)				1		1			2	0.13	SR	25.00	AS	GX	H	S3	FF	EU	EH
Hypera rumicis (Linnaeus, 1758)		1							1	0.07	SR	12.50	A	GX	H	S2	FF	EU	HY
Kyklioacalles suturatus (Dieckmann, 1983)					4				4	0.27	SR	12.50	A	GB	T	G	XF	ST	HY
Leiosoma cribrum (Gyllenhal, 1834)						2			2	0.13	SR	12.50	A	GF	H	S2	FF	ST	HY
Lignyodes uniformis Desbrochers, 1894					1			1	2	0.13	SR	25.00	AS	GX	A	S1	FF	ST	EU
Magdalis flavicornis (Linnaeus, 1758)				1					1	0.07	SR	12.50	A	GX	A	S2	FF	ST	XE
Orchestes fagi (Linnaeus, 1758)			1					2	3	0.20	SR	25.00	AS	GX	A	S1	FF	ST	EH
Otiorhynchus raucus (Fabricius, 1777)	1	8		4	7	50	1	2	73	4.84	SD	87.50	EC	GF	T	G	FF	EU	EH
Otiorhynchus rugosostriatus (Goeze, 1777)	1								1	0.07	SR	12.50	A	GF	T	G	FF	ST	XE
Phyllobius argentatus (Linnaeus, 1758)			1	6	2	1		5	15	0.99	R	62.50	C	GX	A	G	FF	EU	EH
Phyllobius oblongus (Linnaeus, 1758)					2				2	0.13	SR	12.50	A	GX	A	G	FF	EU	EH
Polydrusus cervinus (Linnaeus, 1758)			1						1	0.07	SR	12.50	A	GX	A	G	FF	EU	EH
Polydrusus marginatus Stephens, 1831				1	1				2	0.13	SR	25.00	AS	GX	A	G	FF	EU	XE
Polydrusus tereticollis (De Geer, 1775)								1	1	0.07	SR	12.50	A	GX	A	G	FF	EU	EH
Rhinoncus bruchoides (Herbst, 1784)						1			1	0.07	SR	12.50	A	GX	H	S2	FF	ST	XE
Ruteria hypocrita (Boheman, 1837)	2	4	10	8	4	15		12	55	3.64	SD	87.50	EC	GB	T	G	XF	ST	HY
Sciaphilus asperatus (Bonsdorff, 1785)		1							1	0.07	SR	12.50	A	GF	H	G	FF	EU	HY
Simo variegatus (Boheman, 1843)		1				7			8	0.53	SR	25.00	AS	GX	A	G	FF	EU	XE
Sitona macularius (Marsham, 1802)			5	6	4	4	1	1	21	1.39	R	75.00	EC	GX	H	S3	FF	EU	XE
Sitona suturalis Stephens, 1831					1	3		1	5	0.33	SR	37.50	AS	GX	H	S1	FF	EU	EH

Table 20. continue.

Family, species / study plot	HP	MD	BR	KO	DK1	DK2	DK3	DH	total	DO(%)	CD	CO(%)	CC	Geo	Top	Tro	Bio	Hab	Hum
Stenocarus ruficornis (Stephens, 1831)						1			1	0.07	SR	12.50	A	GX	H	S2	FF	ST	XE
Stereonychus fraxini (De Geer, 1775)		1							1	0.07	SR	12.50	A	GX	A	S2	FF	ST	HY
Stomodes gyrosicollis (Boheman, 1843)								2	2	0.13	SR	12.50	A	GB	T	S3	FF	ST	XE
Trachodes hispidus (Linnaeus, 1758)			3	6	7	1	4	7	28	1.86	R	75.00	EC	GB	T	G	XF	EU	EH
Trachyphloeus bifoveolatus (Beck, 1817)					1				1	0.07	SR	12.50	A	GB	T	G	FF	EU	XE
Trachyphloeus scabriculus (Linnaeus, 1771)					1				1	0.07	SR	12.50	A	GB	T	G	FF	EU	XE
Tychius meliloti Stephens, 1831	1			1					2	0.13	SR	25.00	AS	GX	H	S2	FF	ST	XE
Tychius picirostris (Fabricius, 1787)	1		1	1					3	0.20	SR	37.50	AS	GX	H	S2	FF	EU	EH
Total	49	54	99	175	166	658	59	249	1509	100.00									

Symbols and abbreviations: % – dominance; CD – category of dominance: ED – eudominant, D – dominant, SD – subdominant, R – recedent, SR – subrecedent; Co – constancy in %; CC – category of constancy: EC – euconstant, C – constant, As – accessoric, A – accidental; Geo – interaction of weevils to subsoil: GB – geobiont, GF – geophilous, GX – geoxenous; Top – topic group: T – terricolous, TH – terriherbicolous, H – herbicolous, HA – herbiarboricolous; A – arboricolous; Tro – trophic group: S1 – monophages, S2 – narrow oligophages, S3 – wider oligophages, G – generalists (polyphages); Bio - bionomical group of imagoes: XF – xylophagous (wood-eating), FF – phyllophagous (leaf-eating); Hab – habitat preference: ST – stenotopic, EU – eurytopic, UB – ubiquitous; Hum – humidity preference: HY – hygrophilous, XE – xerophilous, EH – euryhygric. Abbreviation of study plots: HP – Horský park, MD – Mlynská dolina, BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DK3 – Devínska Kobyla 3, DH – Dúbravská Hlavica.

Ecological requirements of the weevil assemblages

According to the relationship between the weevil adults and subsoil, the curculionids were classified into three groups: geobionts living permanently in leaf litter, geophilous species living in other forest strata but occurring regularly in soil and geoxenous species occurring in leaf litter only accidentally. The geoxenous species predominated qualitatively (by species number), but the geobionts predominated quantitatively (by number of individuals) (Fig. 41).

With regard to habitat preference, the weevil beetles were classified into four groups: terricoles (16 spp.) living in the leaf litter; terriherbicoles (4 spp.) associated with the litter and herbage undergrowth; herbicoles preferring the herbage stratum (25 spp.) and arboricoles associated with woody plants (25 spp.). In total, the terricoles predominated by number of species and individuals (Fig. 42). The terricoles and arboricoles predominated quantitatively in the spring aspect. The herbicoles occurred more numerously during both the summer and autumnal aspects (e.g. the herbicolous species *Ceutorhynchus pallidactylus, C. erysimi, C.typhae* aestivated here, other species were possibly searching for their hibernation place or occurred accidentally in the forest epigeon).

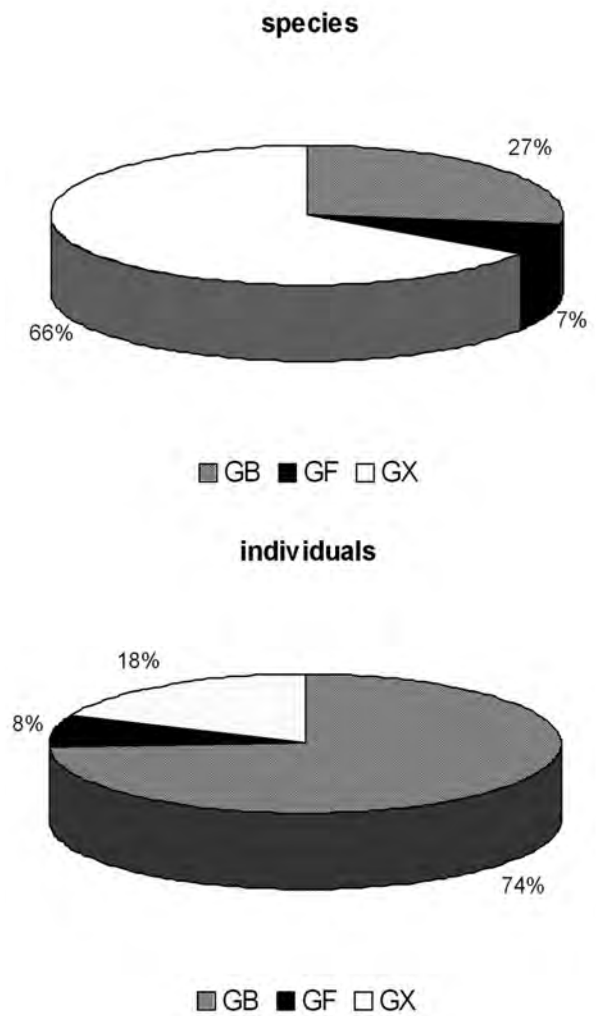

Figure 41. Percentages of weevil groups according to their relationship to subsoil. Explanations: GB – geobionts, GF – geophiles, GX – geoxenes.

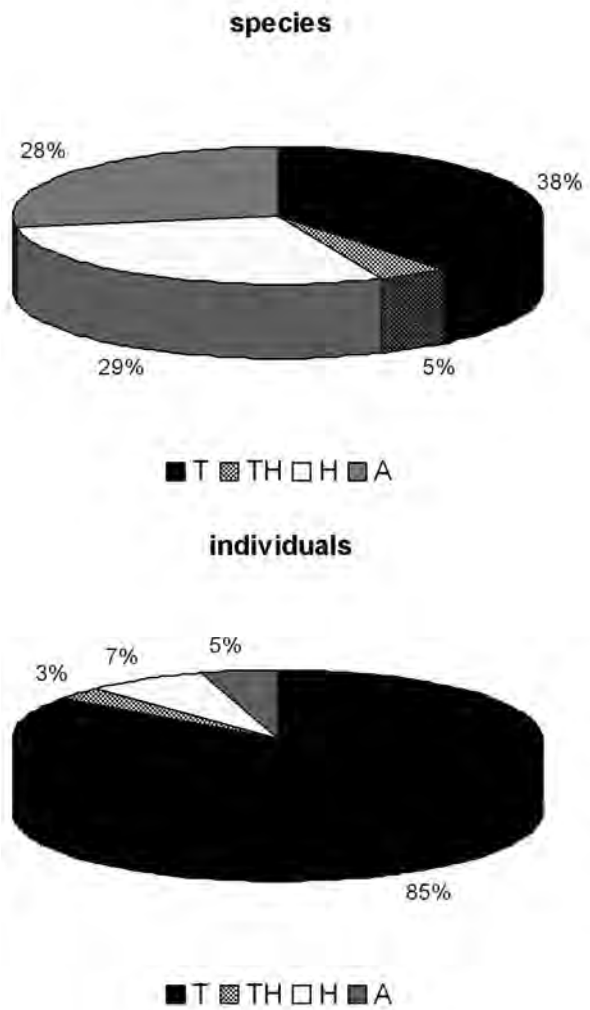

Figure 42. Percentages of weevil topic groups. Explanations: T – terricoles, TH – terriherbicoles, H – herbicoles, A – arboricoles.

Considering the trophic requirements of weevil adults, four groups were distinguished: monophages (S1) associated with one plant species (9 spp.); narrow oligophages (S2) associated with one plant genus (22 spp.); wider oligophages (S3) living on more genera from one plant family or relative families (11 spp.), unknown trophics (4 spp.), and polyphages or generalists (G) (24 spp.). Trophic specialists (S1-S3) predominated by number of species but generalists by number of individuals (Fig. 43).

Two bionomical groups of weevil adults are distinguishable in the examined material: phyllophages (leaf-eating curculionids) (62 spp.) and xylophages (wood-eating, namely saproxylic weevils) (8 spp.). In spite of the fact that phyllophages predominated by number of species, quantitative proportion of phyllophages and xylophages is balanced (Fig. 44).

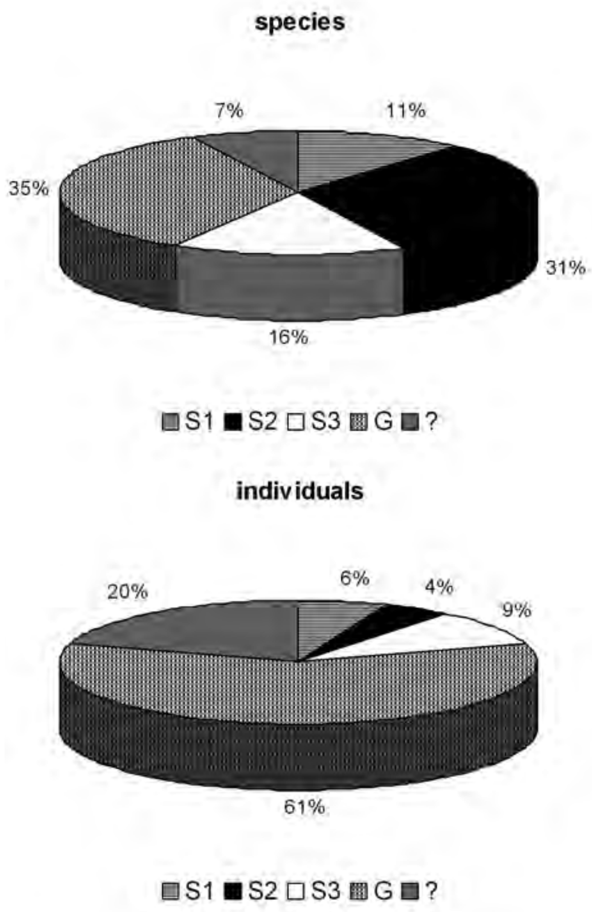

Figure 43. Percentages of weevil trophic groups. Explanations: S1 – monophages, S2 – narrow oligophages, S3 – wider oligophages, G – generalists, ? – unknown.

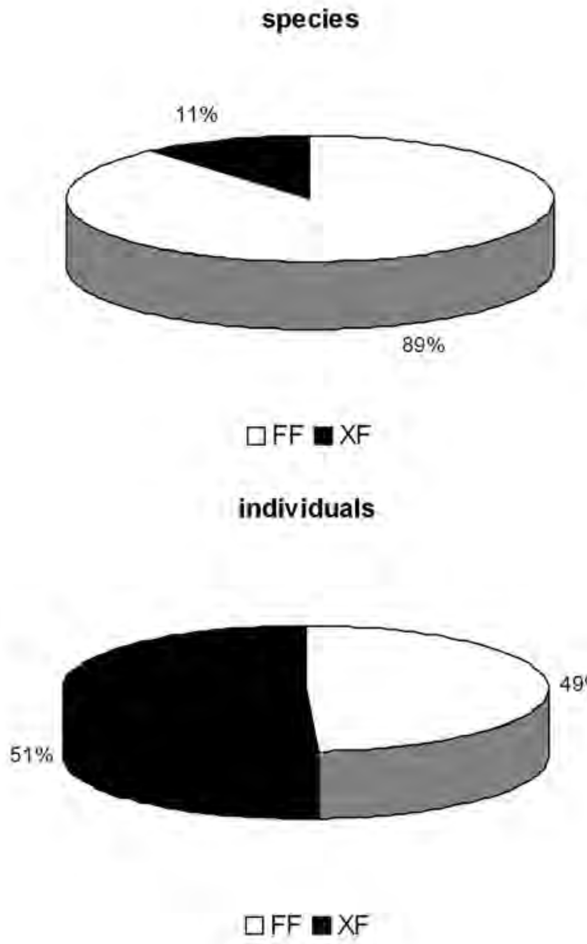

Figure 44. Percentages of weevil bionomic groups. Explanations: XF – xylophages (wood-eating), FF – phyllophages (leaf-eating).

The weevil adults differ in their habitat preference. Stenotopic species predominated both by number of species and individuals (Fig. 45).

With regard to humidity preference hygrophilous species predominate quantitatively (by number of individuals) (Fig. 46). However, amongst the relevant stands there are significant differences in a qualitative-quantitative structure of the species according to their humidity preferences. The lowest quantity of the hygrophilous species appeared in the fragment forest in urban area of Bratislava (HP) and in the stands influenced by cutting (BR, KO) (61, 58, resp. 48% of total specimen numbers).

Comparison of weevil assemblages

Hierarchical classification

Being based on qualitative-quantitative similarity (Wishart similarity ratio, complete linkage), the hierarchical classification divided the weevil taxocoenoses into two separate clusters (Fig. 47).

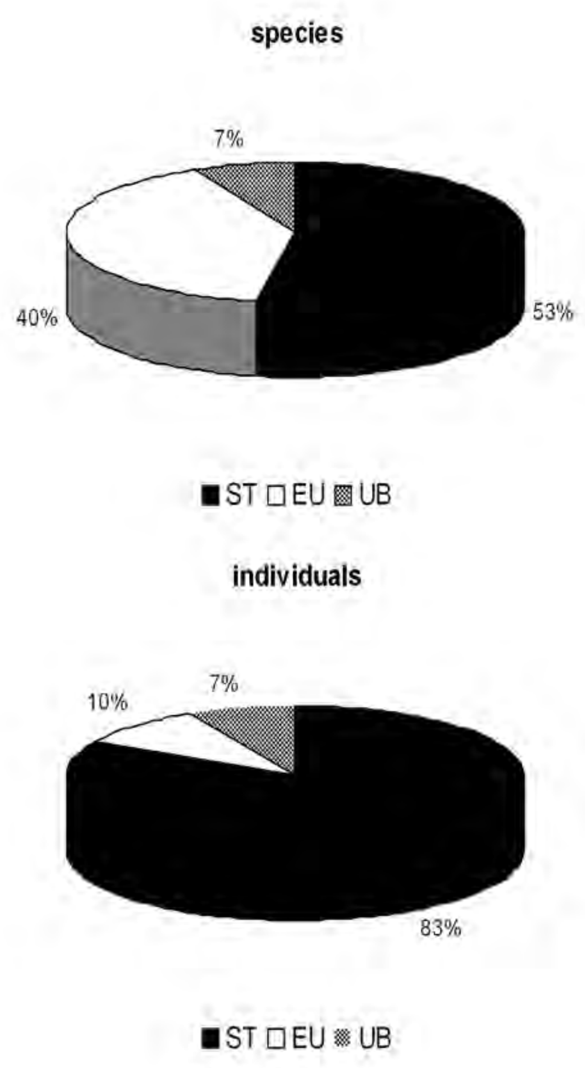

Figure 45. Percentages of weevil groups according to their habitat preference.
Explanations: ST – stenotopic, EU – eurytopic, UB – ubiquitous.

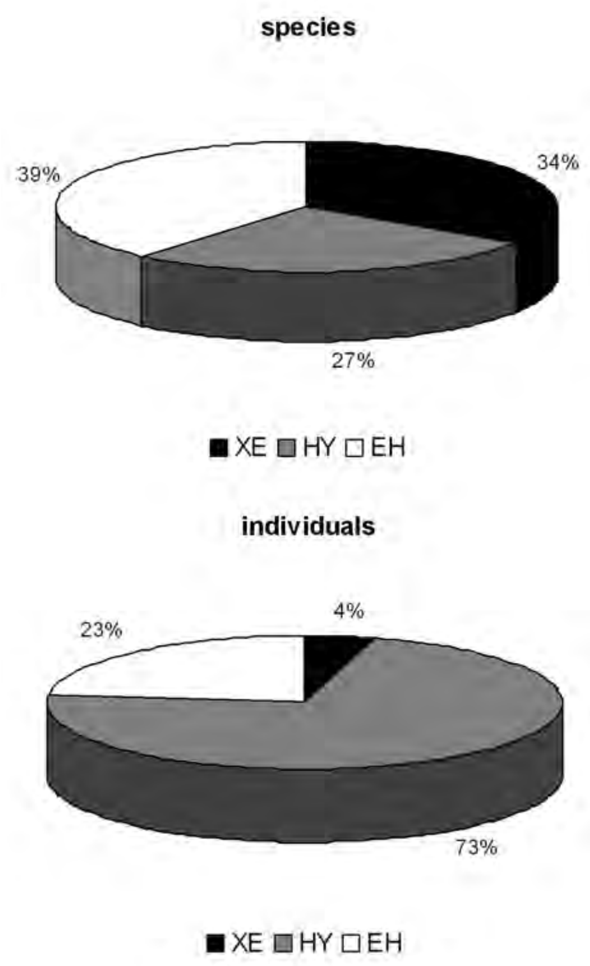

Figure 46. Percentages of weevil groups according to their moisture preference.
Explanations: HY – hygrophilous, XE – xerophilous, EH – euryhygric.

The first cluster is built up of the coenoses DH and DK2 communicating with the second one on the low level of their similarity. The study sites DH and DK2 represent closed forest stands with significant canopy (80%) and lower density of undergrowth (70%) with sufficient amount of decaying wood. The above mentioned study sites are more humid due to their exposition (N, E), density of shrub stratum (55.30%) and the presence of small stream (DK2). There is no significant difference between diversities of the compared assemblages ($P>0.05$, Table 22). Both weevil communities exhibit the lower diversity, equitability but higher mean abundance (DK2: H'=1.909, e=0.579, MA_total=22.69 ind.m^{-2}, MA_GB=19.07 ind.m^{-2}, DH: H'=1.996, e=0.606, MA_total=8.59 ind.m^{-2}, MA_GB=7.10 ind.m^{-2}). For detail information see Table 20. The communities are typical by quantitative dominance of xylophagous geobionts, particularly *Acalles fallax, A. echinatus, A. camelus, Ruteria hypocrita* as well. *Barypeithes chevrolati* is the only phyllophagous geobiont mutual for both the compared coenoses (Table 20, Fig. 48).

The second cluster with its 2 divisions (1. KO+DK3+DK1+BR, 2. MD+HP) includes the other assemblages. The first division contains the communities from the sites situated in the suburban areas of Bratislava representing light and drier forests with less significant canopy (70–75%) and different density of the herbage stratum (50–100%). The assemblage from DK1 was the most diversified (35 spp., H'=2.962, e=0.833), but the dominance was concentrated onto small number of species (c=0.079). There is significant difference between the compared assemblages of the 1st division ($P<0.05$) except for DK3 and BR assemblages ($P>0.05$) (Table 21). In such light and drier forests the communities are typical by quantitative dominance of phyllophagous geobionts, especially *Barypeithes chevrolati* (Table 20). The second division may be determined by the communities associated with forest fragments at the sites HP and MD being situated in the urban part of Bratislava. The compared coenoses are less abundant and diversified (HP: 17 spp., MA_total=3.06 ind.m^{-2}, MA_GB=2.06 ind.m^{-2}, H'=2.087, e=0.737, MD: 13 spp., MA_total=3.38 ind.m^{-2}, MA_GB=2.44 ind.m^{-2}, H'=2.029, e=0.769), but exhibit higher number of codominant species (c=0.244, resp. 0.193). There is no significant difference ($P>0.05$) in diversity between HP ad MD assemblages (Table 21).

Principal component analysis (PCA)

Indirect gradient analysis (PCA) confirms the isolation of weevil communities at the study sites DK2 and DH (Fig. 49). Eigenvalues of the two first axes are $\lambda_1 = 0.828$ and $\lambda_2 = 0.154$. The first canonical axes account for 98.2% of the total variance of the species data.

The scatter of species forms three groups (Fig. 50). The first group contains the saproxylic weevils *Acalles camelus, A. fallax, Ruteria hypocrita* and *Trachodes hispidus* associated with shady, more humid forest habitats of various vegetation tiers (the upper right quadrant and central part of the upper left quadrant of the ordination diagram).

The second group (the lower left and right quadrant of the diagram) is formed by saproxylic and phyllophagous species living in drier and light forest habitats, forest ecotons, shrub formations and some of them also in open habitats (*Brachysomus echinatus, B. hirtus, B. dispar, B. setiger, Leiosoma cribrum, Otiorhynchus raucus, Acalles echinatus, Otiorhynchus rugosostriatus, Trachyphloeus bifoveolatus, T. scabriculus, Barypeithes albinae, B. chevrolati, B. pellucidus, Tropideres albirostris, Acallocrates colonnellii, Kyklioacalles suturatus, Sciaphilus asperatus*).

The third group contains two xerothermophilous species associated with non-forest habitats (*Stomodes gyrosicollis* and *Cycloderes pilosus*).

Ceutorhynchus pallidactylus is the ubiquitous, euryhygric species living in open habitats, forests with lower canopy as well as shady and more humid forest stands.

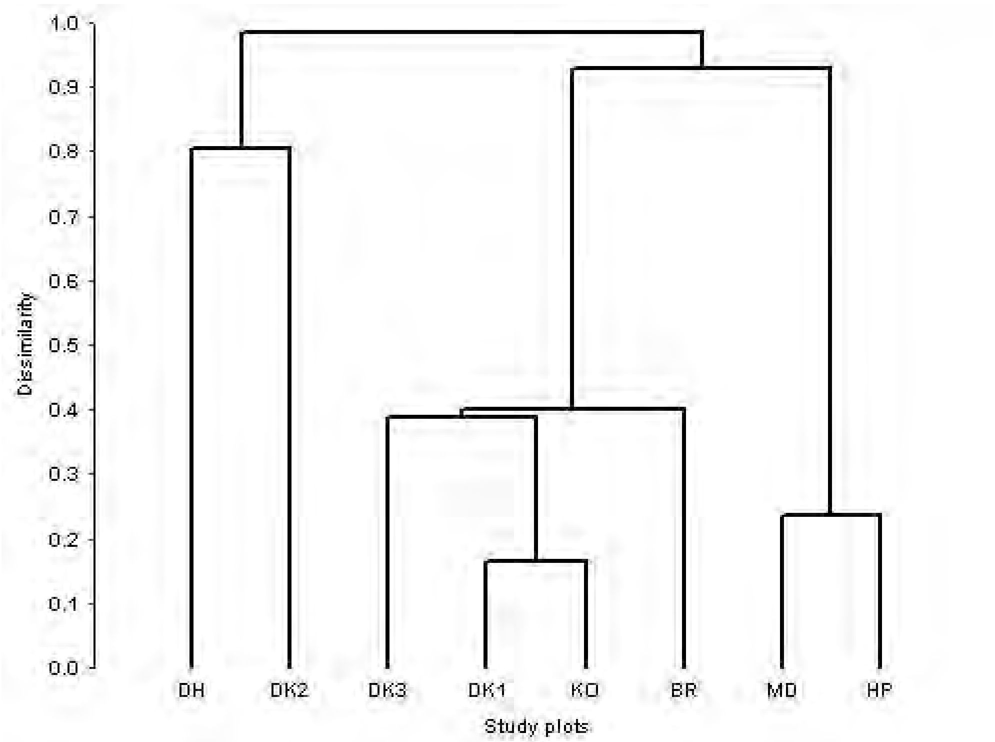

Figure 47. Hierarchical classification of weevil assemblages based on species associated with forest floor (geobiots and geophiles) according to their qualitative–quantitative similarity (Wishart's similarity ratio, complete linkage).

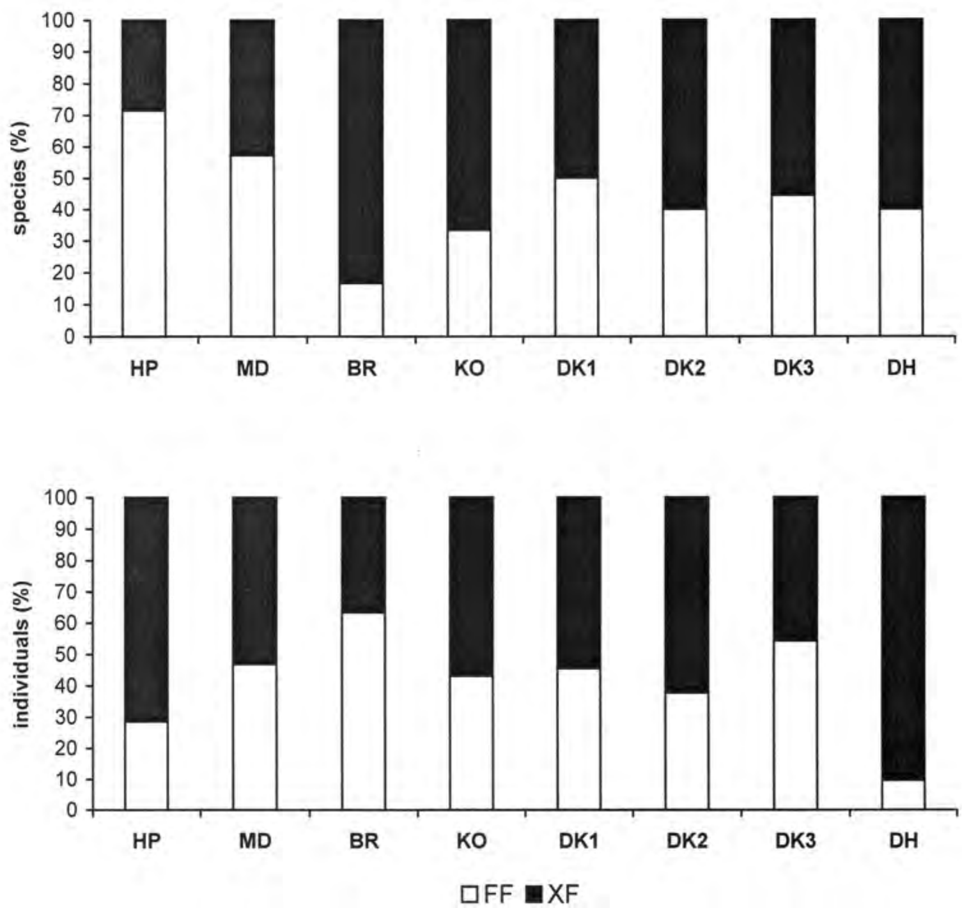

Figure 48. Qualitative and quantitative proportion of bionomic groups within geobiont species.
Explanations: XF – xylophagous (wood-eating), FF – phyllophagous (leaf-eating).

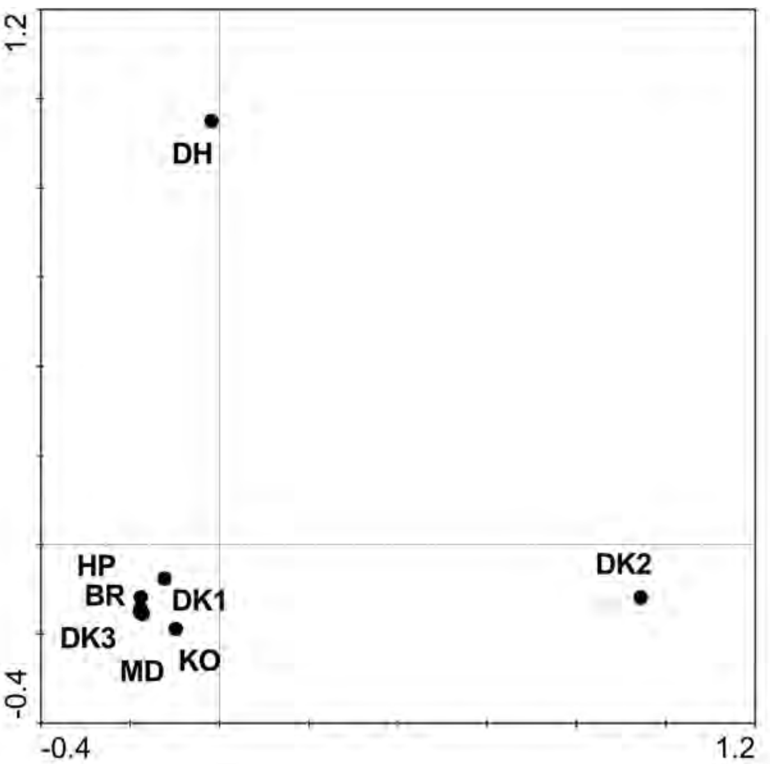

Figure 49. PCA ordination diagram of weevil assemblages in eight study sites on the territory of Bratislava.
Notes: HP – Horský park, MD – Mlynská dolina, BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DK3 – Devínska Kobyla 3, DH – Dúbravská Hlavica.

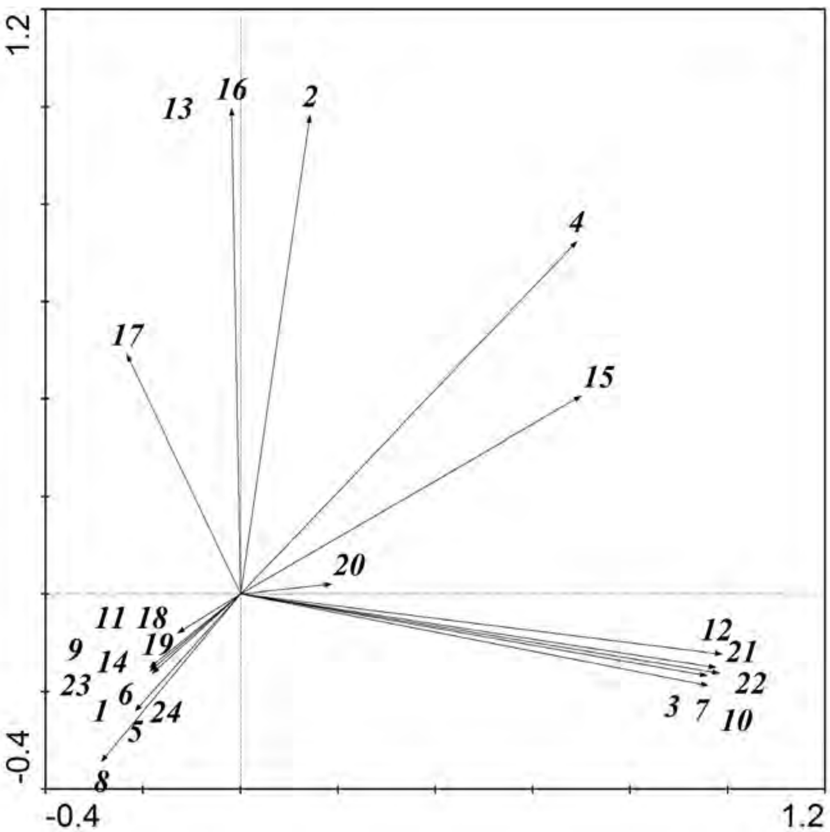

Figure 50. PCA ordination diagram of weevil species asociates with forest floor (geobionts and geophiles).
Symbols: 1 – *Tropideres albirostris*, 2 – *Acalles camelus*, 3 – *Acalles echinatus*, 4 – *Acalles fallax*, 5 – *Acallocrates colonnellii*, 6 – *Barypeithes albinae*, 7 – *Barypeithes chevrolati*, 8 – *Barypeithes pellucidus*, 9 – *Brachysomus dispar*, 10 – *Brachysomus echinatus*, 11 – *Brachysomus hirtus*, 12 – *Brachysomus setiger*, 13 – *Cycloderes pilosus*, 14 – *Kykliacalles suturatus*, 15 – *Ruteria hypocrita*, 16 - *Stomodes gyrosicollis*, 17 - *Trachodes hispidus*, 18 – *Trachyphloeus bifoveolatus*, 19 – *Trachyphloeus scabriculus*, 20 – *Ceutorhynchus pallidactylus*, 21 - *Leiosoma cribrum*, 22 – *Otiorhynchus raucus*, 23 – *Otiorhynchus rugosostriatus*, 24 – *Sciaphilus asperatus*.

Relationship between weevil assemblages and environmental variables

Twenty-four weevil species associated with the forest floor (geobionts and geophiles) were selected for the canonical correspondence analysis. The cover of shrub stratum, northern exposition and soil type (Rendzic Phaeozem) from amongst 15 gradient and 8 categorial variables were significant and explanatory in the analysis (P value of the Monte Carlo permutation test was lower than 0.05). The result of CCA is shown in Fig. 51. Eigenvalues of the two first canonical axes are $\lambda_1 = 0.424$ and $\lambda_2 = 0.406$. The first two canonical axes account for 35.5% of the total variance of the species data and 82.7% of species - environment relation. Sum of all eigenvalues is 2.428, sum of all canonical eigenvalues is 1.041.

Direct and significant influence of canopy architecture was observed also at epigeic spiders (Krumpálová 2005), bugs (Hradil 2005) and ants (Holecová et al. 2005) in Carpathian oak-hornbeam forests.

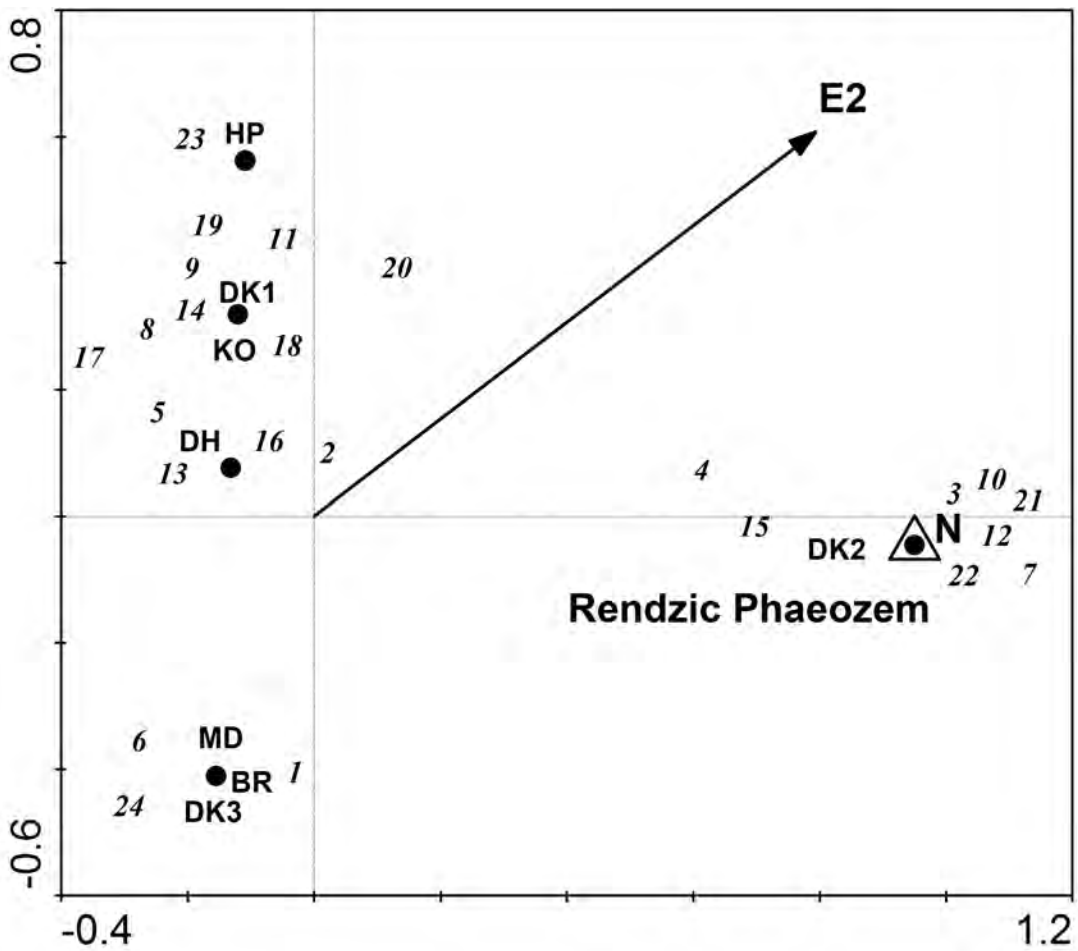

Figure 51. CCA ordination diagram of weevil geobiont and geophilous species, study plots and environmental factors. Notes: E_2 – shrub stratum, N – north exposition. Symbols: 1 – *Tropideres albirostris*, 2 – *Acalles camelus*, 3 – *Acalles echinatus*, 4 – *Acalles fallax*, 5 – *Acallocrates colonnellii*, 6 – *Barypeithes albinae*, 7 – *Barypeithes chevrolati*, 8 – *Barypeithes pellucidus*, 9 – *Brachysomus dispar*, 10 – *Brachysomus echinatus*, 11 – *Brachysomus hirtus*, 12 – *Brachysomus setiger*, 13 – *Cycloderes pilosus*, 14 – *Kykliacalles suturatus*, 15 – *Ruteria hypocrita*, 16 – *Stomodes gyrosicollis*, 17 – *Trachodes hispidus*, 18 – *Trachyphloeus bifoveolatus*, 19 – *Trachyphloeus scabriculus*, 20 – *Ceutorhynchus pallidactylus*, 21 – *Leiosoma cribrum*, 22 – *Otiorhynchus raucus*, 23 – *Otiorhynchus rugosostriatus*, 24 – *Sciaphilus asperatus*. Abbreviation of study plots: HP – Horský park, MD – Mlynská dolina, BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DK3 – Devínska Kobyla 3, DH – Dúbravská Hlavica.

Table 21. Species diversity test and basic coenological characteristics of weevil assemblages at study plots in 1999–2006.

Study plot	**HP**	**MD**	**BR**	**KO**	**DK1**	**DK2**	**DK3**	**DH**
∑spp	17	14	19	29	35	25	17	27
∑GB spp.	5	6	6	8	13	9	8	9
∑GF spp.	2	2	1	2	2	3	2	2
∑GX spp.	10	6	12	18	20	15	7	16
MA_total	3.06	3.38	3.67	6.25	5.93	22.69	3.69	8.59
MA_GB	2.06	2.44	2.22	3.18	3.29	19.07	2.94	7.10
MA_GF	0.13	0.56	0.19	0.61	0.54	2.00	0.13	0.24
MA_GX	0.88	0.38	1.26	2.46	2.11	1.62	0.63	1.24
e	0.737	0.769	0.784	0.807	0.833	0.579	0.764	0.606
c	0.244	0.193	0.179	0.099	0.079	0.224	0.186	0.281
H’	**2.087**	**2.029**	**2.308**	**2.716**	**2.962**	**1.909**	**2.165**	**1.996**
HP		93.167	87.668	67.132	68.172	55.21	97.971	75.362
MD	0.238ns		121.733	89.918	91.878	66.302	112.991	106.991
BR	0.956ns	1.457ns		187.559	190.731	132.623	125.295	229.235
KO	2.955**	4.062***	2.774**		340.008	309.314	93.92	423.992
DK1	4.095**	5.482***	4.41***	2.089*		286.646	95.822	413.622
DK2	0.882ns	0.771ns	3.04**	8.445***	10.798***		71.02	379.47
DK3	0.311ns	0.634ns	0.722ns	3.125**	4.495***	1.568ns		110.336
DH	0.419ns	0.189ns	2.001*	5.644***	7.48***6	0.793ns	0.922ns	

Symbols and abbreviations: Σ spp. – total number of species, Σ GB spp. – total number of geobiont species, Σ GF spp. – total number of geophilous species, Σ GX spp. – total number of geoxenous species, MA_total [ind.m^{-2}] – mean abundance of weevils, MA_GB [ind.m^{-2}] – mean abundance of geobionts, MA_GF [ind.m^{-2}] – mean abundance of geophilous species, MA_GX [ind.m^{-2}] – mean abundance of geoxenes, H’ – Shannon’s index of species diversity, e – Pielou’s index of equitability, c – Simpson’s index of dominance. T-test values are under the diagonal and degrees of freedom are above it.
Significance levels: *** = $P < 0.001$; ** = $0.001 < P < 0.01$; * = $0.01 < P < 0.05$; ns = $0.05 < P$ (non-significant).
Abbreviations of the study plots: HP – Horský park, MD – Mlynská dolina, BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DK3 – Devínska Kobyla 3, DH – Dúbravská Hlavica.

Table 22. Seasonal occurrence of individual weevil species in epigeon of studied oak-hornbeam forests.

Family, species / month of occurrence	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**I**
Anthribidae										
Tropideres albirostris (Herbst, 1783)				+						
Rhynchitidae										
Deporaus betulae (Linnaeus, 1758)		+								
Apionidae										
Ceratapion gibbirostre Gyllenhal, 1813							+			
Eutrichapion viciae (Paykull, 1800)	+						+			
Ischnopterapion loti (Kirby, 1808)	+									
Oxystoma craccae (Linnaeus, 1767)	+									
Kalcapion semivittatum (Gyllenhal, 1833)										+
Protapion fulvipes (Foucroy, 1785)	+					+	+	+	+	+
Protapion trifolii (Linnaeus, 1768)								+		
Trichopterapion holosericeum Gyllenhal, 1833	+		+	+	+			+		
Curculionidae										
Acalles camelus (Fabricius, 1792)	+	+	+	+	+	+	+	+	+	
Acalles echinatus (Germar, 1824)	+	+	+	+	+	+	+	+	+	+
Acalles fallax Boheman, 1844	+	+	+	+	+	+	+	+	+	+
Acallocrates colonnellii Bahr, 2003	+		+	+	+	+	+	+	+	+
Anthonomus pomorum (Linnaeus, 1758)		+								
Archarius pyrrhoceras (Marsham, 1802)	+									
Bagous argillaceus Gyllenhall, 1836			+							
Barypeithes albinae Formanek, 1903			+							
Barypeithes chevrolati (Boheman, 1843)	+	+	+	+						
Barypeithes pellucidus (Boheman, 1843)	+	+	+	+						
Brachysomus dispar Penecke, 1910			+							
Brachysomus echinatus (Bonsdorff, 1785)	+	+	+							
Brachysomus hirtus (Boheman, 1845)			+							
Brachysomus setiger (Gyllenhal, 1840)		+								
Bradybatus fallax Gerstaecker, 1860	+									
Bradybatus kellneri Bach, 1854	+		+	+		+	+			
Ceutorhynchus alliariae Brisout de Barneville, 1860	+	+	+		+					
Ceutorhynchus erysimi (Fabricius, 1787)		+	+	+	+	+	+	+	+	
Ceutorhynchus nigritulus Schultze, 1787				+			+			
Ceutorhynchus obstrictus (Marsham, 1802)				+	+		+			
Ceutorhynchus pallidactylus (Marsham, 1802)	+	+	+	+	+	+	+		+	
Ceutorhynchus scrobicollis (Neresheimer et Wagner, 1924)	+	+	+	+	+	+	+	+		+
Ceutorhynchus typhae (Herbst, 1795)	+		+	+	+	+	+	+	+	

Table 22. continue

Family, species / month of occurrence	IV	V	VI	VII	VIII	IX	X	XI	XII	I
Coeliodes transverseoalbofasciatus (Goeze, 1777)				+						
Coeliodes trifasciatus Bach, 1854	+	+	+	+	+		+			+
Curculio glandium Marsham, 1802	+		+							
Curculio propinquus (Desbrochers, 1868)			+							
Curculio venosus (Gravenhorst, 1807)	+	+								
Cycloderes pilosus (Fabricius, 1792)		+								
Dorytomus longimanus (Forster, 1771)		+								
Eusomus ovulum Germar, 1824		+								
Furcipus rectirostris (Linnaeus, 1758)	+									
Hypera postica (Gyllenhal, 1813)	+								+	
Hypera rumicis (Linnaeus, 1758)						+				
Kyklioacalles suturatus (Dieckmann, 1983)	+		+					+		
Leiosoma cribrum (Gyllenhal, 1834)	+						+			
Lignyodes uniformis Desbrochers, 1894	+							+		
Magdalis flavicornis (Linnaeus, 1758)			+							
Orchestes fagi (Linnaeus, 1758)					+	+				
Otiorhynchus raucus (Fabricius, 1777)	+	+	+	+	+	+	+		+	
Otiorhynchus rugosostriatus (Goeze, 1777)	+									
Phyllobius argentatus (Linnaeus, 1758)		+	+							
Phyllobius oblongus (Linnaeus, 1758)	+									
Polydrusus cervinus (Linnaeus, 1758)	+									
Polydrusus marginatus Stephens, 1831		+	+							
Polydrusus tereticollis (De Geer, 1775)	+									
Rhinoncus bruchoides (Herbst, 1784)	+									
Ruteria hypocrita (Boheman, 1837)	+	+	+	+	+	+	+	+	+	
Sciaphilus asperatus (Bonsdorff, 1785)										+
Simo variegatus (Boheman, 1843)	+	+	+	+						
Sitona macularius (Marsham, 1802)	+			+	+	+	+		+	
Sitona suturalis Stephens, 1831	+			+						
Stenocarus ruficornis (Stephens, 1831)				+						
Stereonychus fraxini (De Geer, 1775)					+					
Stomodes gyrosicollis (Boheman, 1843)		+								
Trachodes hispidus (Linnaeus, 1758)	+	+	+	+	+	+	+	+		
Trachyphloeus bifoveolatus (Beck, 1817)		+								
Trachyphloeus scabriculus (Linnaeus, 1771)		+								
Tychius meliloti Stephens, 1831							+			+
Tychius picirostris (Fabricius, 1787)		+				+	+			

Human impact

All study stands represent managed and in some way human-impacted forests. The most serious anthropogenous impact appears in a stand fragmentation (a lack of originally continuous forest habitat and its contact with nearby open landscape) and cutting.

Although the stand fragmentation did not declare any significant and explainable impact within a complex analysis of the weevil communities (Fig. 51), the separate evaluation of all the sites hints at increased proportion of herbicoles in the fragmented forest complex. Assemblages of epigeic weevils from the study sites situated in the urban environment (HP, MD) are significantly poorer in comparison with curculionid communities of suburban study sites (Table 21).

Epigeic weevil assemblages are probably sensitive to mechanical disturbance of habitats, particulate, chemical pollution and also to forest cutting. Vast majority of typical weevil geobionts are apterous or brachypterous. They have low mobility and are not able to survive unfavourable conditions (Holecová 1986). On the contrary, the woodlands affected by imissions are to a higher extent attacked by leaf-feeding insects (Bulánková 1990, Bulánková, Holecová 1998, 2000, Cicák et al. 1999, Kulfan et al. 2002, 2004, etc.). Only a few species (in general mostly known as "pests") can thrive in areas with pollution impacts. Such the gradations often lead into an abundance increase of their natural predators and parasitoids. Bulánková, Holecová (1998, 2000) hinted at considerably higher abundance of Nabidae predators in the forest habitat polluted by calcareous dust in the comparison with the background without pollution impact.

The effects of air pollutants on insects have been reviewed by several authors (Alstaed et al. 1982 and Dopcherty et al. 1997, etc.). It is evident that any polluted area has its own special features (pollutants and other anthropogenic impacts, abiotic conditions, flora, fauna, etc.). Also, differences in response of particular insect species to pollution are apparent. The factors act in many combinations and interferences (Cicák et al. 1999, Führer 1985, Kulfan 1988, Kulfan et al. 2002, 2004, Zelinková et al. 2004).

References

Alonso-Zarazaga, M.A., Lyal, CH.H.C., 1999: A world catalogue of families and genera of Curculionoidea (Insecta: Coleoptera). (Excepting Scolytidae and Platypodidae). Entomopraxis, S.C.P, Barcelona, 315 pp.

Alstaed, D.N., Edmunds G.F., Weinstein, L.H., 1982: Effects of air pollutants on insect populations. Ann. Rev. Ent., 27: 369–384.

Bartošová, P., Tirjaková, E., 2005: Selected ecological characteristics of ciliate communities (Protozoa, Ciliophora) in decaying wood mass in the Malé Karpaty Mountains. Ekológia (Bratislava), 24, Supplement 2/2005: 37–50.

Bartošová, P., Tirjaková, P., Holecová, M., 2007: The influence of selected factors on the communities of ciliates (Protozoa, Ciliophora) in decaying woody mater. In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Contribitions to Soil Zoology in Central Europe, Vol. 2. ISB AS CR, České Budějovice, p. 1–5.

Beránek, J., 2008: The response of weevil communities (Coleoptera: Curculionoidea) to the altitudinal zones of beech stands. J. For. Sci., 54: 262–272.

Brown, V.K., Hyman, P.S., 1986: Succesional communities of plants and phytophagous Coleoptera. Journal of Ecology, 74: 963–975.

Bulánková, E., 1990: Effects of immissions from cement works on the structure of the community of Nabidae (Heteroptera). Acta F.R.N. Univ. Comen. – Zoologia, 33: 61–69.

Bulánková, E., Holecová, M., 1988: Structure of nabid taxocoenoses (Nabidae, Heteroptera) in the herb undergrowth of oak-hornbeam forests in the Malé Karpaty Mts (in Slovak). Folia faunistica Slovaca, 3: 51–68.

Bulánková, E., Holecová, M., 2000: Species representation of nabid bugs (Heteroptera, Nabidae) in leaf bearing crowns of oak-hornbeam forests in Malé Karpaty Mts (in Slovak). Folia faunistica Slovaca, 5: 99–107.

Christophoryová, J., Krumpál, M., 2005: Communities of pseudoscorpions (Pseudoscorpiones, Arachnida) in epigeon of oak-hornbeam forests in the Malé Karpaty Mts and Trnavská pahorkatina hills (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 76–86.

Cicák, A., Mihál, I., Kulfan, J., Šušlík, V., Zach, P., Krištín, A., 1999: Health state of forest tree species and selected groups of fungi and animals in surroundings of a magnesium factory (central Slovakia). Ekológia (Bratislava), 18: 211–222.

Dajoz, R., 2000: Insects and forests. The role and diversity of insects in the forest environment. Tec & Doc. Londres - Paris - New York, 668 pp.

Degma, P., Šimurka, M., Gulánová, S., 2005: Community structure and ecological macrodistribution of moss-dwelling water bears (Tardigrada) in Central European oak-hornbeam forests (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 59–75.

Dopcherty, M., Salt, D.T., Holopainen, J.K., 1997: The impact of climatic change and pollution on forest pests. In: Watt, A.D., Stork, N.E., Hunter, M.D. (eds), Forest and insects. Chapman & Hall, London, p. 229–247.

Drdul, J., 1973: Coleoptera im Boden des Eichen-Hainbucheswalds in Báb bei Nitra. Acta F. R. N. Univ. Comen – Zoologia, 18: 129–145.

Drdul, J., 1977: Beetles in soil of an oak-hornbeam forest in the Malé Karpaty Mts (in Slovak). Západné Slovensko, 4: 90–99.

Drdul, J., 1997: To the knowledge of leaf litter macrofauna in xerothermic oak forests in surroundings of the atomic power station near the Mochovce village (in Slovak). Acta Fac. Paed. Univ. Tyrnaviensis, Ser. B., 1: 27–39.

Fenďa, P., Ciceková, J., 2005: Soil mites (Acari, Mesostigmata) of oak forests in the Malé Karpaty Mts. (W Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 102–112.

Funke, M., 1971: Food and energy turnover of leaf-eating insects and their influence on primary production. Ecological Studies, 2: 81–93.

Führer, E., 1985: Air pollution and the incidence of forest insect problems. Z. angew. Ent., 99: 371–377.

Grimm, R., 1976: Der Energieumsatz phytophager Insekten im Buchenwald. I. Untersuchungen an Populationen der Rüsselkäfer (Curculionidae) *Rhynchaenus fagi* L., *Strophosomus* (Schönherr) und *Otiorhynchus singularis* L. Oecologia (Berlin), 11: 187–262.

Heydemann, B., 1955: Die Frage der topographischen Übereinstimmung des Lebensraumes von Pflanzen- und Tiergesellschaften. Verh. dtsch. Zool. Ges., Erlangen: 444–452.

Holecová, M., 1986: Influence of forest harvesting on phytophagous insect communities (in Slovak). Acta F.R.N.Univ. Comen. – Formatio et Protectio Naturae, 12: 31–47.

Holecová, M., 1991a: Curculionidae (Coleoptera) of the State nature reserve Sitno and Protected area Holík (in Slovak). Ochrana prírody, 11: 258–274.

Holecová, M., 1991b: Structure of weevil communities (Coleoptera, Curculionidae) of deciduous trees in forest and non-forest ecosystems. Acta F. R. N. Univ. Comen., Zoologia, 34: 45–70.

Holecová, M., 1992: Seasonal dynamics of weevil (Coleoptera, Curculionidae) communities in leaf bearing crowns of trees in forest ecosystems. Acta Zool. Univ. Comen., 36: 3–23.

Holecová, M., 1995: Weevils (Coleoptera, Curculionidae) of the Nature reservation Príboj (Central Slovakia) (in Slovak). Naturae tutela, 3: 157–170.

Holecová, M., Sukupová, J., 2000: Weevils (Coleoptera, Curculionoidea: Attelabidae, Apionidae, Curculionidae) of the Nature reserve Lošonecký háj (SW Slovakia). Folia faunistica Slovaca, 5: 123–134.

Holecová, M., Sukupová, J., 2002: Weevils (Coleoptera, Curculionoidea) as a part of the oak-hornbeam forest epigaeon. In: Tajovský, K., Balík, V., Pižl, V. (eds), Studies on Soil Fauna in Central Europe. Proceedings of 6th Central European Workshop on Soil Zoology, ISB AS CR, České Budějovice, p. 59–67.

Holecová, M., Zach, P., Kardošová, J., 2002: Epigaeic weevils (Coleoptera, Curculionoidea) of oak-hornbeam forests in a vicinity of Bratislava (SW Slovakia) (in Slovak). Folia faunistica Slovaca, 7: 39–48.

Holecová M., Krumpál M., Országh I., Krumpálová Z., Stašiov, S., Fedor P., 2005a: Biodiversity of selected invertebrate groups in oak-hornbeam forest ecosystem in SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 205–222.

Holecová, M., Lukáš, J., Haviar, M., Harakaľová, E., 2005b: Ants (Hymenoptera, Formicidae) as an important part of the epigeic fauna in Carpathian oak-hornbeam forests. In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Contribution to Soil Zoology in Central Europe I. ISB AS CR, České Budějovice, p. 31–35.

Holecová M., Némethová D., Kúdela, M. 2005c: Structure and function of weevil assemblages (Coleoptera, Curculionoidea) in epigeon of oak-hornbeam forests in SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 179–204.

Hradil, K., 2005: Bug assemblages in epigaeon of oak-hornbeam forests in SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 161–178.

Koch, K., 1992: Die Käfer Mitteleuropas. Ökologie. Band 3. Krefeld, Goecke und Evers, 389 pp.

Kožíšek, T., Drdul, J., 1991: Beetle communities in soil of chosen localities of the Zobor hill (in Slovak). Zobor (Nitra), 2: 133–140.

Krumpálová, Z., 2005: Epigeic spiders (Araneae) of the ecosystems of the oak-hornbeam forests in the Malé Karpaty Mts (Slovakia) and their ecological categorisation. Ekológia (Bratislava), 24, Supplement 2/2005: 87–101.

KULFAN, J., 1988: Caterpillars on three species of deciduous trees affected by immissions from cement work (in Slovak). Lesnictví, 34: 537–546.
KULFAN, J., ZACH, P., ŠUŠLÍK, V., ANDERSON, J., 2002: Is abundance of the moth Bucculatrix ulmella affected by immissions? Ekológia (Bratislava), 21, Supplement 2/2002: 143–151.
KULFAN, J., ZACH, P., SUJOVÁ, K., 2004: Moth larvae (Lepidoptera) on oak and hornbeam trees in surroundings of the magnesite plant Lubeník. Entomofauna carpathica, 16: 24–28.
MAJZLAN, O., 1986: Beetle communities in soil of meadow and forest ecotops in intravilan of the Bratislava town (in Slovak). Acta F.R.N.Univ.Comen. – Formatio et Protectio Naturae, 12: 49–64.
MAJZLAN, O., 1991: Geobiont beetles (Coleoptera) of an oak forest near the Obyce village (in Slovak). Rosalia, Nitra, 7: 185–193.
MAJZLAN, O., HOŠTÁK, P., 1996: Bioindication importance of Oniscoidea and Curculionidae in soil of an oak forest in the National nature reserve Dubník near the Sereď town (in Slovak). Ochrana prírody, Banská Bystrica, 14: 83–87.
MICHALKO, J., BERTA, J., MAGIC, D., 1986: Geobotanic Map of Czechoslovakia, Slovak part (in Slovak). Veda, Bratislava, 168 pp + 12 maps.
MRVA, M., 2005: Diversity of active gymnamoebae (Rhizopoda, Gymnamoebia) in mosses of the Malé Karpaty Mts (Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 51–58.
NIELSEN, B.O., 1978a: Above ground food resources and herbivory in a beech forest ecosystem, Oikos, 31: 273–279.
NIELSEN, B.O., 1978b: Aspects of the population ecology and energetics of some beech leaf-feeding insects. Natura Jutl., 20: 259–272.
NIELSEN, B.O., 1978c: Food resource partition in the beech leaf-feeding guild. Ecol. Ent., 3: 193–201.
ODUM, E.P., 1977: The basis of ecology. Academia, Praha, 987 pp.
ORSZÁGH, I., 2005: Phenology of *Chelidurella acanthopygia* (Dermaptera: Forficulidae) nymphal instars in oak-hornbeam forests of the Malé Karpaty Mts and Trnavská pahorkatina hills (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 152–160.
ORSZÁGH, I., ORSZÁGHOVÁ, Z., 2005: Structure of centipede communities (Antennata: Chilopoda) in oak-hornbeam forests of the Malé Karpaty Mts and Trnavská pahorkatina hills (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 152–160.
PODANI, J., 1993: Syn-tax. Version 5.0. Computer programs for Multivariate Data Analysis in Ecology and Systematics. User's guide. Scientia Publishing, Budapest, 104 pp.
POOLE, R.W., 1974: An introduction to quantitative ecology. McGraw-Hill, New York, 532 pp.
SCHAUERMANN, J., 1973: Zur Energieumsatz phytophager Insekten in Buchenwald. II. Die produktionsbiologische Stellung der Rüsselkäfer (Curculionidae) mit rhizophagen Larvenstadien. Oecologia (Berlin), 13: 313–350.
SCHAUERMANN, J., 1976: Zur Abundanz- und Biomassendynamik der Tiere in Buchenwäldern des Solling. Verhdl. Ges. Ökol. Göttingen: 113–127.
SCHWERDTFEGER, F., 1975: Ökologie der Tiere. Band III – Synökologie. Verlag Paul Parey, Hamburg – Berlin, 451 pp.
SPEIGHT, M.C.D., 1989: Saproxylic invertebrates and their conservation. Council of Europe: Publications and Documents Division, Strassbourg, 81 pp.
SPELLERBERG, I.F., FEDOR, P.J., 2003: A tribute to Claude Shannon (1916-2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon-Wiener" Index. Global Ecology and Biogeography, 12: 177–179.
STAŠIOV, S., 2005: Millipede communities (Diplopoda) of oak-hornbeam ecosystems (the Malé Karpaty Mts, Trnavská pahorkatina hills (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 20–36.
TER BRAAK, C.J.F., ŠMILAUER, P., 1998: CANOCO References Manual and User's: Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power (Ithaca, NY, USA), 352 pp.
TIRJAKOVÁ, E., VĎAČNÝ, P., 2005: Ciliate communities (Protozoa, Ciliophora) in tree-holes and influence of selected environmental factors on their structure. Ekológia (Bratislava), 24, Supplement 2/2005: 20–36.
TISCHLER, W., 1949: Grundzüge der terrestrischen Tierökologie. Friedrich Vieweg, Braunschweig, 219 pp.
TUF, I.H., TUFOVÁ, J., 2005: Communities of terrestrial isopods (Crustacea: Isopoda: Oniscidea) in epigeon of oak-hornbeam forests of SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 113–123.
VĎAČNÝ P., TIRJAKOVÁ, E., HOLECOVÁ, M., 2007: Succession in the soil gymnostomate ciliates (Ciliophora, Gymnostomatea) communities in non-flooded Petri dish cultures. In: TAJOVSKÝ, K., SCHLAGHAMERSKÝ, J., PIŽL, V. (eds), Studies on soil fauna in Central Europe, ISB AS CR, České Budějovice, p. 189–193.
WALLWORK, J.A., 1976: The distribution and diversity of soil fauna. Academic Press, London, 355 pp.
WISHART, D., 1969: An algorithm for hierarchical classifications. Biometrics, 22: 165–170.
ZACH, P., HOLECOVÁ, M., SIITONEN, J., RAUH, J, MARTIKAINEN, P., KÖBLER, M., SAMPSON, B., 1999: Natural and managed forests: composition and diversity of weevil assemblages (Coleoptera, Curculionoidea: Attelabidae, Curculionidae). Acta Zool. Univ. Comenianae, 43: 85–97.
ZELINKOVÁ, D., KULFAN, J., ZACH, P., 2004: Coccinellid beetles (Coleoptera: Coccinellidae) on beech trees affected by immissions from an aluminium plant. Entomofauna carpathica, 16: 71–73.

4.5. Ants (Hymenoptera: Formicidae)

Milada Holecová

Ants are an outstanding group in the structure and function of a community because they have important influence on soil, vegetation, and other faunal groups both directly and indirectly. All ant species are polyphagous with emphasis on the animal component of their diet. Due to predation, longevity and total biomass, ants are important components of all natural, seminatural and supplementary communities.

In Central Europe, qualitative and quantitative data on the myrmecofauna in forest habitats of the oak-hornbeam vegetation tier can be found only in few papers. In Poland, ants of linden-oak-hornbeam habitats in the Białowieska Forest (Podlasie) were studied by Karpiński (1956), those in the Augustowska Forest (the Masurian Lakeland) by Krzysztofiak (1985), while the Mazovian Lowland was studied by Pisarski (1981), who examined, among others, the myrmecofauna of a linden-oak-hornbeam grove on the outskirts of Warsaw and of an out-town as a comparative habitat. Czechowski, Pisarski (1990) examined ant assemblages in linden-oak-hornbeam (*Tilio-Carpinetum*) and thermophilous oak forests (*Potentillo albae-Quercetum*) on the Mazovian Lowland, their species composition and structure being defined on the basis of nest density stated by means of square searching method (10 m^{-2} and 100 m^{-2}). Althogether 20 ant species have been reported from Polish forests of *Tilio-Carpinetum* and *Potentillo albae-Quercetum* associations. Diversity and structure of ant assemblages in forest habitats in South Hungarian Plain near Szeged were surveyed by Alvarado, Gallé (1999). The authors compared species richness of ants in autochthonous oak, poplar and juniper forests and introduced ones as black locust, pine, *Eleagnus angustifolia,* and hybrid poplar. It was found that forest ant species in the introduced and degraded forests are replaced by grassland ant species. The saproxylic communities of ants were studied in lying oak trunks in hardwood floodplain forests in southern Moravia (Czech Republic) by Schlaghamerský (1999, 2000, 2001). In Slovakia, there are only several faunistical papers concerning the ant fauna of oak-hornbeam forests in the surroundings of Nitra, Bratislava, the Zoborské vrchy hills, Tribeč Mts., Štiavnické vrchy hills and the Boky Nature Reserve near Zvolen (Ambros et al. 1998, Drdulová 1991, Kožíšek 1984, 1985a, 1985b, 1986, Randuška 1995).

It is difficult to compare the results from Slovakia as well as from other countries of Central Europe due to differences in methodology, study intensity as well as the lack of detailed quantitative data.

In the present study the structure and dynamics of epigeic ant assemblages were investigated in the forest ecosystem of the oak-hornbeam vegetation tier. The research has been done in five forest stands of the age from 40 to 100 years situated in suburban parts of Bratislava (the southern part of the Protected Landscape Area Malé Karpaty Mts., SW Slovakia). The soil macrofauna was collected in 2005 and 2006 by the sifting method. The ant assemblages were compared on the basis of the species presence/absence similarity, abundance similarity, diversity and equitability. A special attention was paid to some microclimatic factors and human activities (forest clearing, coppice culling, synanthropization, tourism).

Five study plots were selected in suburban parts of Bratislava.

Devínska Kobyla 1 (DK1), 48°11′05″ N, 16°59′50″ E, GRN 7868a, 340 m a.s.l.: a 60–80 year-old forest belonging to the subassociation *Querco-Carpinetum melicetosum uniflorae* oriented to the S. *Quercus dalechampii* and *Carpinus betulus* predominate in the tree layer.

Devínska Kobyla 2 (DK2), 48°10′59″ N, 16°59′35″ E, GRN 7867a, 300 m a.s.l: a 40–60 year-old forest of the ass. *Aceri-Carpinetum* oriented to the N. *Tilia cordata, Carpinus betulus, Acer campestre, Fagus sylvatica* and *Robinia pseudoacacia* predominate in the tree layer. A small stream rises on this study plot.

Dúbravská Hlavica (DH), 48°11′08″ N, 17°00′45″ E, GRN 7868a, 350 m a.s.l.: an 80–100 year-old forest of the *Querco petraeae-Carpinetum typicum* association oriented to the E. *Fagus sylvatica, Quercus dalechampii, Carpinus betulus* and *Tilia cordata* predominate in the tree layer.

Bratislava – Briežky (BR), 48°10′58″ N, 17°06′40″ E, GRN 7868b, 380 m a.s.l.: an 80–100 year-old forest of the subass. *Querco petraeae-Carpinetum typicum* oriented to the SW. *Quercus dalechampii, Carpinus betulus* and *Tilia cordata* predominate in the tree layer.

Bratislava – Koliba (KO), 48°10′33″ N, 17°06′05″ E, GRN 7868b, 380 m a.s.l.: a 90–100 year-old forest belonging to the subass. *Querco-Carpinetum melicetosum uniflorae* oriented to the SW. *Quercus dalechampii* and *Carpinus betulus* predominate in the tree layer.

The study plots BR and KO were strongly influenced by human activities (tourist visitors, forest clearing, coppice culling). Until 1990, they were also impacted with chemical pollution of factories situated at the eastern city margin.

All study plots are situated in the southern part of the Malé Karpaty Mts. Soil types are represented by Haplic Cambisols (BR, KO, DK1, DH) with strongly acidic pH of an Oo horizon (3.70–4.66), A-horizon (3.65–4.12) and Rendzic Phaeozem (DK2) with neutral pH of both the Oo and A horizon (7.32 and 7.47). The studied portion of the slope in DK2 is irrigated by flowing water and there is no high evaporation in its northern exposition, so that soil moisture here is the highest of all 5 studied sites. The map, pedological and phytocoenological characteristics of the investigated area are given in detail in the chapter 2.

The soil macrofauna was collected by the square method combined with sifting. In each study plot, at about 1-month invervals from April to October, the material was collected from the leaf litter and the upper part of soil from 16 squares. Each square comprised 25x25 cm, i.e. altogether an area of 1 m^2 was sifted, representing one sample. The samples were extracted using xereclectors of the Moczarski-Winkler's type. The material is deposited at the Department of Zoology, Comenius University in Bratislava.

The species dominance is characterized by the scale proposed by Tischler (1949) and completed by Heydemann (1955): ED - eudominant, D - dominant, SD - subdominant, R - recedent, SR - subrecedent.

The indices of Shannon-Wiener (H'), Pielou (e) and Simpson (c) were used as the alpha diversity indices (Odum 1977, Spellerberg, Fedor 2003). All the couples of Shannon-Wiener's diversity indices were compared with a t-test, to see if they are significantly different (Poole 1974).

The clustering method complete linkage in combination with Soerensen's index and Wishart's similarity ratio was used (Podani 1993, Schwerdtfeger 1975, Wishart 1969). The ant communities were analyzed according to the indirect gradient analysis (PCA), effects of environmental variables on ant community composition were studied using the canonical correspondence analysis (CCA) ordination technique by CANOCO software program (ter Braak, Šmilauer 1998).

Ants were identified according to Czechowski et al. (2002) and Seifert (2007). The characteristics of zoogeographic distribution of ant species and their ecological groups were made by Czechowski et al. (2002). The functional groups are distinguished according to Andersen (2000).

A total of 10497 ant specimens belonging to 3 subfamilies, 10 genera and 23 species were collected (Table 23). All identified ant species were already recorded in SW Slovakia and represented more than 21% of the ant fauna known from Slovakia (Bezděčka 1996, Werner, Wiezik 2007). On individual study plots from 10 to 14 species were obtained. The mean abundance of ants varied from 105.92 to 192.54 ind.m^{-2} of the soil surface. Differences in the mean abundance of ants between individual study plots were not statistically significant [Univariate ANOVA: F = 1.048, P = 0.390] (Table 24, Fig. 52).

Temnothorax crassispinus, Stenamma debile, T. unifasciatus and *Myrmecina graminicola* predominated at all study plots. *Temnothorax crassispinus* was an ecological eudominant and represented 72.33% of all collected ants. This skiophilous (shade-loving) ant species is characteristic of native, mainly deciduous forests (Stitz 1939, Bezděčka 1995, Alvarado, Gallé 1999, Czechowski et al. 2002). *Stenamma debile, Temnothorax unifasciatus* are forest species, but *Myrmecina graminicola* prefers light deciduous forests, gardens, forest steppes and non-woodland habitats (e.g. limestone rocks and screes, rocky and grassy steppes) (Pisarski 1975, Bezděčka 1995, Czechowski et al. 2002).

The abundance dynamics of ants exhibited two peaks in the forest epigeon. The first maximum was observed in the spring aspect (May), the second one in the later summer aspect (August) (Fig. 53).

The complete linkage clustering based on the presence/absence similarity (Sörensen's index) confirmed the difference between ant assemblages living in the shady and more humid forest stand (DK2) and the drier lighter study plots (DK1, DH, KO, BR). The hygrophilous species *Myrmica scabrinodis* and three forest species (*Aphaenogaster subterranea, Camponotus aethiops, C. ligniperda*) occurred exclusively on the study plot with a

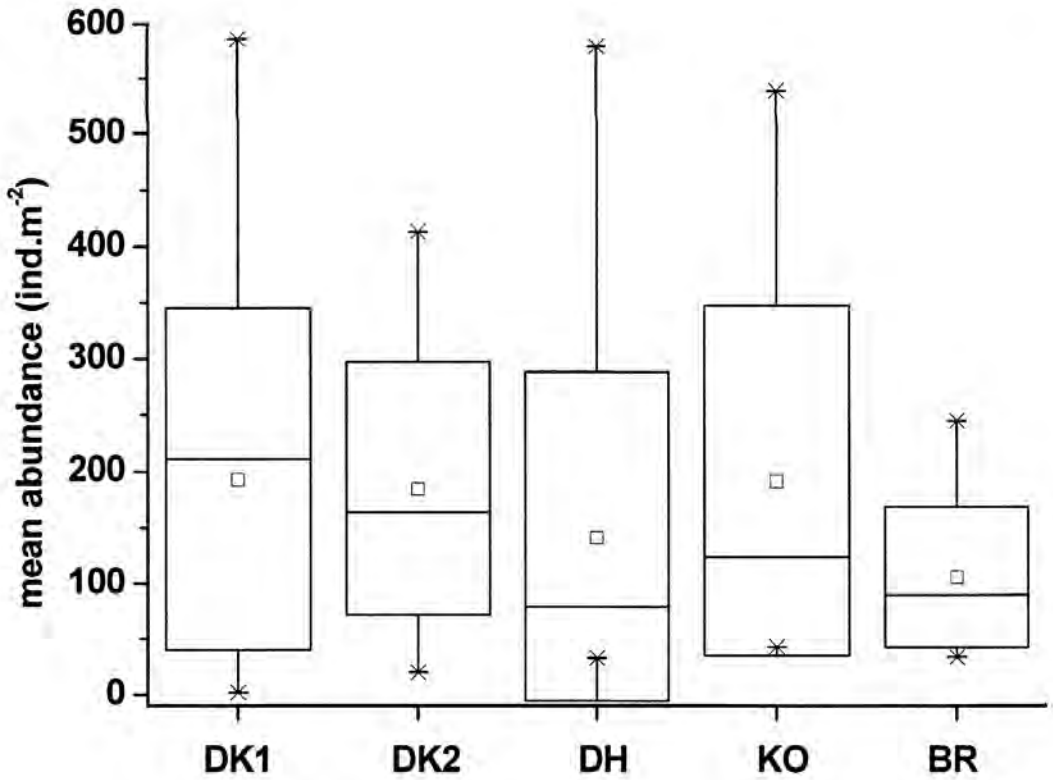

Figure 52. Mean abundance of ant assemblages in the epigeon of individual study plots.
Explications: mean (□), median (line inside of box), whole box (standard deviation), abscissa (range) and x (the 1st and 99th percentile). Abbreviation of study plots: BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DH – Dúbravská Hlavica.

Table 23. General survey of ant species found in epigeon of suburban oak-hornbeam forests on the territory of Bratislava city.

taxon\study plot	DK1	DK2	DH	KO	BR	∑	%	CD	ZG	EE	FS
Ponerinae											
Ponera coarctata (Latreille, 1802)	1	1	2			4	0.04	SR	MD	S	CS
Myrmicinae											
Aphaenogaster subterranea (Latreille, 1802)		7				7	0.07	SR	MD	O	CS
Temnothorax affinis (Mayr, 1855)		35	24	95		154	1.47	R	EC	S	CC
Temnothorax interruptus (Schenck, 1852)					53	53	0.50	SR	E	S	CC
Temnothorax crassispinuss (Karavajev, 1926)	2042	1600	1361	1648	942	7593	72.33	ED	EC	O	CC
Temnothorax unifasciatus (Latreille, 1798)	95	234	135	232	57	753	7.17	D	EC	O	CC
Myrmecina graminicola (Latreille, 1802)	82	166	55	5	1	309	2.94	SD	AP	O	CC
Myrmica rubra (Linnaeus, 1758)				1		1	0.01	SR	NP	E	Op
Myrmica ruginodis (Nylander, 1846)	32		7	17	2	58	0.55	SR	NP	P	Op
Myrmica sabuleti (Meinert, 1860)			3			3	0.03	SR	ES	O	Op
Myrmica scabrinodis (Nylander, 1846)		18				18	0.17	SR	ES	P	Op
Stenamma debile (Förster, 1850)	176	290	190	327	147	1130	10.76	ED	EC	O	CC
Tetramorium cf. *caespitum*			28	24	24	76	0.72	SR	SP	P	Op
Formicinae											
Camponotus aethiops (Latreille, 1798)		1				1	0.01	SR	MD	S	SC
Camponotus ligniperda (Latreille, 1802)		2				2	0.02	SR	E	O	SC
Formica gagates Latreille, 1798	11		1			12	0.11	SR	MD	O	Op
Formica pratensis (Retzios, 1783)			1			1	0.01	SR	SP	P	CC
Formica rufa (Linnaeus, 1758)				1		1	0.01	SR	NP	O	CC
Lasius alienus (Foerster, 1850)	13	34	11	75	15	148	1.41	R	SP	O	CC
Lasius brunneus (Latreille, 1798)	48	10	16	55	28	157	1.50	R	EC	O	CC
Lasius emarginatus (Olivier, 1791)	2		2	1		5	0.05	SR	SE	O	CC
Lasius fuliginosus (Latreille, 1798)	1			7		8	0.08	SR	AP	O	CC
Lasius niger (Linnaeus, 1758)		1			2	3	0.03	SR	NP	P	CC
Total number of individuals	2503	2399	1836	2488	1271	10497					

Explanations: % – dominance; CD – category of dominance according to Tischer (1949) and Heydemann (1955): ED – eudominant, D – dominant, SD – subdominant, R – recedent, SR – subrecedent; ZG – zoogeographic elements according to Czechowski et al. (2002): NP – North-Palaearctic, AP – Amphipalaearctic, E – European, ES – Eurosibearian, EC – Eurocaucasian, SE – South-Europaean, SP – South-Palaearctic, MD – Mediterranean; EE – ecological elements according to Czechowski et al. (2002): P – polytopic, O – oligotopic, S – stenotopic; functional groups (sensu Andersen 2000): CS – cryptic species, CC – cold climate specialist, Op – opportunistic species, SC - subordinate Camponotini.

small forest stream (DK2). The forest stand in Devínska Kobyla 2 distinguished significantly by its pedological characteristics (Rendzic Phaeozem with neutral or slightly alkalic pH on the limestone bedrock), northern exposition and soil moisture. The formicocoenoses of Devínska Kobyla 1 and Dúbravská Hlavica were the most similar (10 common species) due to a close vicinity of both compared study plots (Fig. 54, Table 23).

The hierarchical classification according to the abundance similarity (Wishart's similarity ratio, complete linkage) indicated the high similarity level of four studied ant assemblages (DK1, DK2, DH, KO) due to the predominance of *Temnothorax crassispinus*. The formicocoenosis in Briežky is connected on the lower similarity level because this ant community is quantitatively poorer (Fig. 53). Occurrence of the xerophilous species *Temnothorax interruptus* was confirmed exclusively here (Table 23).

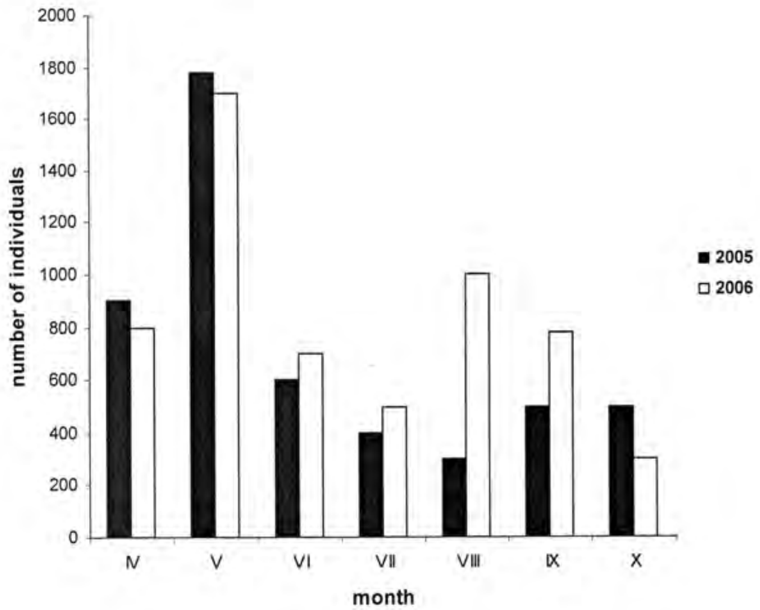

Figure 53. Cumulative abundance dynamics of ants in the ecosystem of Carpathian oak-hornbeam forests.

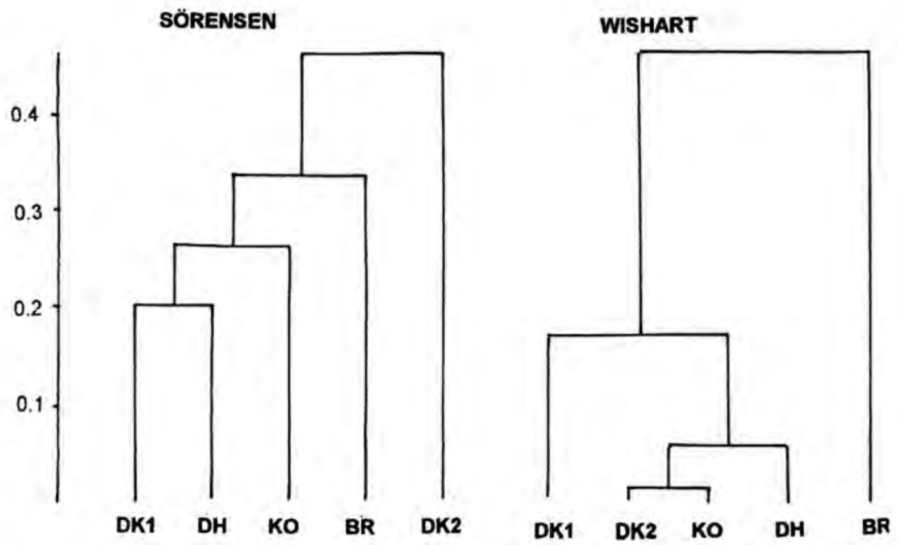

Figure 54. Hierarchical classification of ant assemblages in the forest epigeon of individual study plots according to their presence/absence similarity (Sörensen's index, complete linkage) and their abundance similarity (Wishart's index, complete linkage). (Vertical axis designates dissimilarity).
Abbreviation of study plots: BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DH – Dúbravská Hlavica.

According to results of the principal component analysis, we suppose that not only “the openness of a forest stand to sun rays” but also humidity and shade are important environmental abiotic factors affecting the qualitative and quantitative structure of individual formicocoenoses (Fig. 55). Eigenvalues of the two first axes are $\lambda_1 = 0.409$ and $\lambda_2 = 0.266$. The first two canonical axes account for 67.5% of the total variance of the species data. The forest clearing caused decreasing of species richness, but on the other hand increasing of abundance of some ant species characteristic of open habitats, forest steppes and light forests (*Temnothorax affinis,. T. unifasciatus, Stenamma debile, Lasius alienus, L. brunneus, Tetramorium* cf. *caespitum* etc.). The scatter diagram forms two groups of species. The first group contains species mainly associated with shady and more humid forest stands (the central part of the lower left quadrant of the diagram): *Ponera coarctata, Aphaenogaster subterranea, Myrmica scabrinodis, Temnothorax crassispinus, Camponotus aethiops, C. ligniperda*, but also *Myrmecina graminicola,* a species preferring lighter forest stands and half shady habitats. The second group (the upper left and both right quadrants of the diagrams) is formed: (1) by species associated with lighter deciduous forests and polytopic forest species (*Formica gagates, Myrmica ruginodis, Lasius brunneus, Lasius fuliginosus, Formica rufa, Temnothorax affinis, Stenamma debile, Temnothorax unifasciatus*); (2) by species living in drier deciduous forests and dry grasslands (*Lasius niger, Myrmica rubra, Formica pratensis, Lasius alienus, L. emarginatus, Myrmica sabuleti*) and (3) by species preferring open dry grasslands (*Temnothorax interruptus, Tetramorium* cf. *caespitum*).

The selected gradient and categorical environmental variables were measured with the aim to find out those influencing the ant assemblages (see Table 19 in the chapter 4.6). The results of the canonical correspondence analysis has proved the significant influence of the canopy density (E_3) on the ant assemblages (P=0.03, F=1.554, Monte Carlo permutation test) (not illustrated). Eigenvalues of the two first canonical axes are $\lambda_1 = 0.461$ and

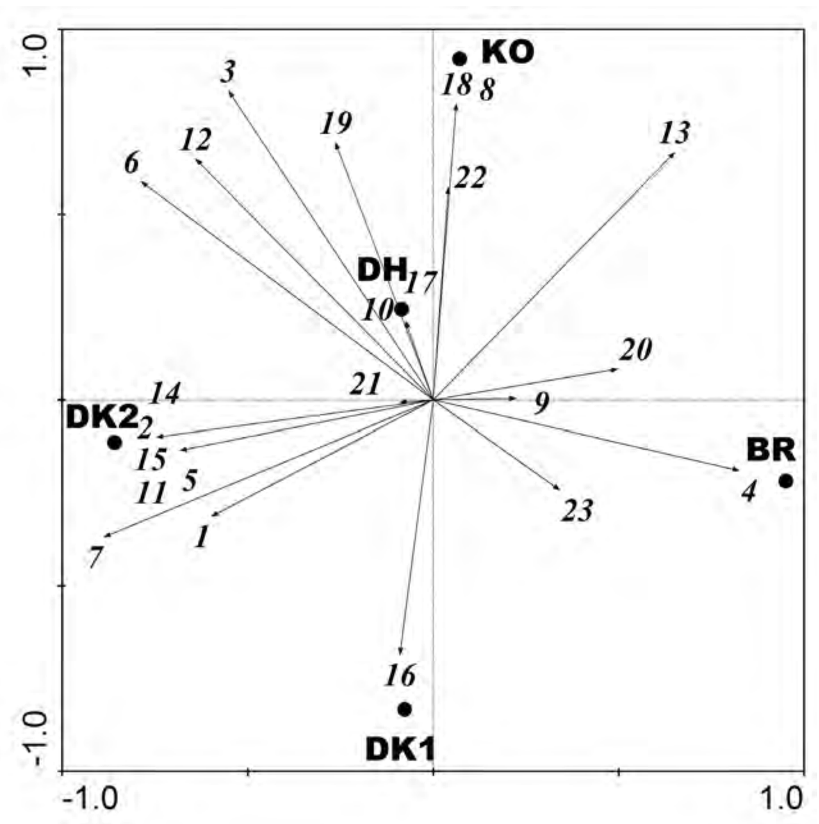

Figure 55. Principal component analysis of ant assemblages in the forest epigeon of individual study plots.
Symbols: 1 - *Ponera coarctata*, 2 - *Aphaenogaster subterranea*, 3 - *Temnothorax affinis*, 4 - *Temnothorax interruptus*, 5 - *Temnothorax crassispinus*, 6 - *Temnothorax unifasciatus*, 7 - *Myrmecina graminicola*, 8 - *Myrmica rubra*, 9 - *Myrmica ruginodis*, 10 - *Myrmica sabuleti*, 11 - *Myrmica scabrinodis*, 12 - *Stenamma debile*, 13 - *Tetramorium caespitum*, 14 - *Camponotus aethiops*, 15 - *Camponotus ligniperda*, 16 - *Formica gagates*, 17 - *Formica pratensis*, 18 - *Formica rufa*, 19 - *Lasius alienus*, 20 - *Lasius brunneus*, 21 - *Lasius emarginatus*, 22 - *Lasius fuliginosus*, 23 - *Lasius niger*.
Abbreviation of study plots: BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DH – Dúbravská Hlavica.

λ_2 = 0.471. The first two canonical axes account for 93.2% of the total variance of the species data and 100% of the species-environment relation.

Euro-Caucasian (22%), Mediterranean (17%) and North-Palaearctic species (17%) were the most frequent in the studied oak-hornbeam forests. South-Palaearctic, Amphipalaearctic, European, Euro-Siberian, South-European species were represented less numerously (Fig. 56).

Three ecological groups of ants were represented in the examined material: polytopic, oligotopic and stenotopic species. Oligotopic species significantly predominated at all study sites. Higher proportion of stenotops was observed in DK2 (the shady, more humid forest stand of the northern exposition). On the other hand, the proportion of polytopic species was higher in the study site BR affected by forest clearing, coppice culling, tourism and synanthropization (Fig. 57).

Four from seven known functional groups of ants were present in studied suburban forests on the territory of Bratislava (Fig. 58). All study plots are characterized by predominance of cold climate specialists (64–80% of species). Four functional groups (cold climate specialists, cryptic species, opportunists and subordinate Camponotini) occurred in forest stands localized in the area of Devínska Kobyla hill (DK1, DK2 and DH) , where the anthropic pressure and disturbance were lower. Only two functional groups (Cold Cli-

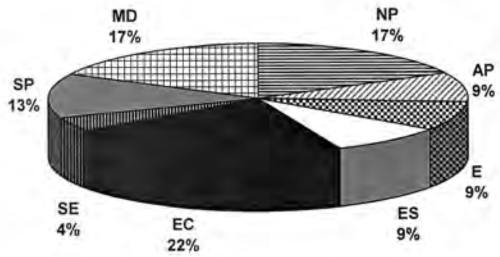

Figure 56. Qualitative representation of zoogeographical elements according to Czechowski et al. (2002): NP – North-Transpalaearctic, AP – Amphipalaearctic, E – European, ES – Euro-Siberian, EC – Euro-Caucasian, SE – South-Europaean, SP – South-Palaearctic, MD – Mediterranean.

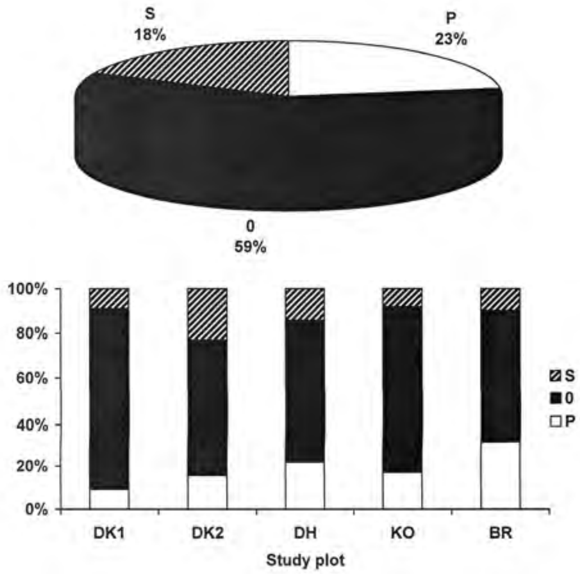

Figure 57. Qualitative representation of ecological elements according to Czechowski et al. (2002): P – polytopic, O – oligotopic, S – stenotopic. Abbreviation of study plots: BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DH – Dúbravská Hlavica.

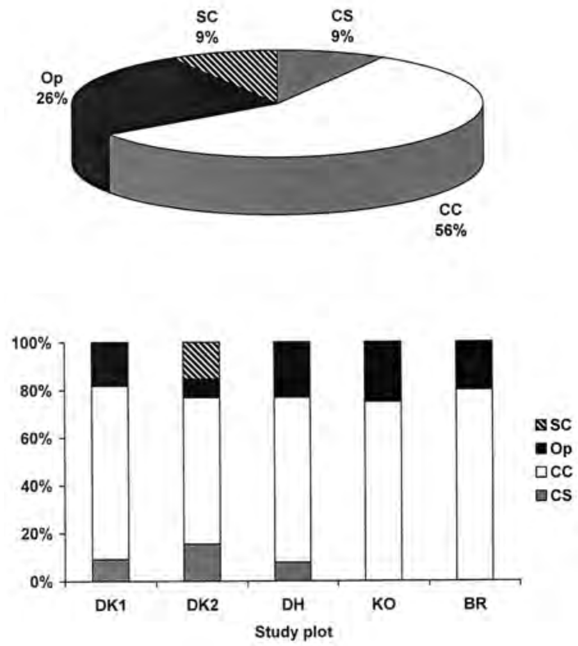

Figure 58. Qualitative representation of functional groups sensu Andersen (2000): CS – cryptic species, CC – cold climate specialists, Op – opportunistic species, SC – subordinate Camponotini. Abbreviation of study plots: BR – Briežky, KO – Koliba, DK1 – Devínska Kobyla 1, DK2 – Devínska Kobyla 2, DH – Dúbravská Hlavica.

Table 24. Species diversity test and basic coenological characteristics of ant assemblages on individual study plots in 2005–2006.

study plot	DK1	DK2	DH	KO	BR
Σ spp.	11	13	14	13	10
MA [ind.m^{-2}]	192.54	184.54	141.23	191.38	105.92
e	0.327	0.449	0.379	0.465	0.426
c	0.674	0.474	0.567	0.468	0.567
H'	**0.784**	**1.152**	**1.001**	**1.193**	**0.981**
DK1		4896.74	3906.416	4984.615	2620.75
DK2	10.528***		3741.697	4886.957	2487.123
DH	5.5***	3.897***		3809.663	2819.006
KO	11.615***	1.195ns	4.927***		2530.548
BR	4.59***	4.06***	0.443ns	5.006***	

Explanations: Σ spp. – total number of species, MA [ind.m^{-2}] – mean abundance, H' – Shannon's index of species diversity, e – Pielou's index of equitability, c – Simpson's index of dominance. T-test values are under the diagonal, and degrees of freedom are above it. Significance levels: *** = P < 0.001; ** = 0.001 < P < 0.01; * = 0.01 < P < 0.05; ns – 0,05 < P (non-significant).

mate specialists and opportunists) were recorded at forest sites with higher disturbance (KO and BR).

Conclusion

The structure and dynamics of ant assemblages were studied in five suburban forests of the oak-hornbeam vegetation tier on the territory of Bratislava city (the Malé Karpaty Mts., SW Slovakia). Each site was affected, to some degree, by various human activities (timber harvesting, coppice culling, thinnings, tourist visitors, synantropization, etc.). Ants were sampled by sifting method. In total 23 species belonging to 10 genera, 3 subfamilies and 10497 individuals were recorded. The number of species found at particular sites ranged from 10 to 14. The mean abundance of ants varied from 105.92 to 192.54 ind. m^{-2} of the soil surface. *Temnothorax crassispinus, Stenamma debile, Temnothorax unifasciatus* and *Myrmecina graminicola* predominated at all study sites. Canopy density from amongst 15 gradient and 6 categorial variables analyzed had direct and significant influence on the structure of epigeic ant assemblages.

The study plots are a part of two forest complexes. The Nature Reserve Devínska Kobyla hill (Devínska Kobyla 1, Devínska Kobyla 2, Dúbravská Hlavica) with relatively well preserved forests and study plots of the Koliba hill (Koliba, Briežky) where more strongly affected by anthropic impact. There were observed no significant differences in species number and mean abundance of ant assemblages between compared forest complexes. On the other hand, the diversity of ant functional groups was lower at study sites with stronger disturbance (Cryptic Species and Subordinate Camponotini were not found).

Several records of ant species, namely those of *Ponera coarctata, Aphaenogaster subterranea, Temnothorax affinis* and *Stenamma debile*, are of faunistic interest.

References

Alvarado, M., Gallé, L., 1999: Diversity and structure of ant assemblages in forest habitats in the South Hungarian Plain. In: Tajovský, K., Pižl, V. (eds), Soil Zoology in Central Europe. ISB AS CR, České Budějovice, p. 1–6.

Ambros, M., Rychlík, I., Gálová, J., 1998: Notes on ant fauna (Hymenoptera: Formicoidea) of the Zoborské vrchy hills (in Slovak). Rosalia, 13: 121–128.

Andersen, A.N., 2000: Global ecology of rainforest ants. Functional groups in relation to environmental stress and disturbance. In: Agosti, D., Majer, J., Alonso, L.E., Schultz, T.R. (eds), Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Institution Press, Washington, D.C., p. 25–34.

Bezděčka, P., 1995: Hymenoptera: Formicoidea. In: Rozkošný, R., Vaňhara, J. (eds), Terrestrial Invetebrates of the Pálava Biophere Reserve of UNESCO, II. Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia, 93, p. 323–329

Bezděčka, P., 1996: Ants of Slovakia (Hymenoptera: Formicidae) (in Slovak). Entomofauna carpathica, 8: 108–114.

Czechowski, W., Czechowska, W., Radchenko, A., 2002: The Ants of Poland. Museum and Institute of Zoology PAS, Warszawa, 200 pp.

Czechowski, W., Pisarski, B., 1990: Ants (Hymenoptera, Formicoidea) of linden-oak-hornbeam forests and thermophilous oak forests of the Mazovian Lowland. I. Nest density. Fragm. faun., Warszawa, 34: 133–141.

Drdulová, A., 1991: A contribution to the knowledge of ants (Hymenoptera, Formicoidea) of the Zobor hill (in Slovak). Zobor, 2: 95–102.

Heydeman, B., 1955: Die Frage der topographischen Übereinstimmung des Lebensraumes von Pflanzen und Tiergesellschaften. Vehr. dtsch. Zool. Ges. Erlangen: 444–452.

Karpiński, J.J., 1956: Ants in the biocoenosis of the Białowież National Park (in Polish). Rocz. Nauk. leśn., Warszawa, 14: 201–221.

Kožíšek, T., 1984: Notes on occurrence of ants in the area of the Tribeč hills (in Slovak). Rosalia, 1: 59-62.

Kožíšek, T., 1985a: Distribution of ants (Formicoidea) in meadow and forest habitats of the town residential area of Bratislava (in Slovak). In: Zborník referátov z konferencie Zoocenózy urbánnych a suburbánnych celkov so zvláštnym akcentom na podmienky Bratislavy, p. 118–122.

Kožíšek, T., 1985b: Ants (Formicidae) of chosen habitats in the Protected Landscape Area Ponitrie (Tribeč hills, Vtáčnik Mts.) (in Slovak). Rosalia, 2: 241–246.

Kožíšek, T., 1986: Ants of selected habitats in the Protected Landscape Area Štiavnické vrchy hills (in Slovak). In: Zborník I., XXI. TOP Počúvadlo, p. 149–155.

Krzysztofiak, L., 1985: Distribution and nest density of ants in the Augustowska Forest (the Masurian Lakeland) (in Polish). Fragm. faun., Warszawa, 29: 137–149.

Odum, E.P., 1977: The basis of ecology. Academia, Praha, 987 pp.

Pisarski, B., 1975: Ants – Formicoidea (in Polish). Katalog fauny Polski, 26, 1. PWN, Warszawa, 84 pp.

Pisarski, B., 1981: Ants (Formicidae, Hymenoptera) (in Polish). In: Zoocenologiczne podstawa kształtowania środowiska przyrodniczego osiedla mieszkaniowego Białołęka Dworska w Warszawie. 1. Skład gatunkowy i struktura fauny terenu projektowanego osiedla mieszkaniowego. Fragm. faun., Warszawa, 26: 341–354.

Podani, J., 1993: SYN-TAX - pc. Computer Programs for Multivariate Data Analysis in Ecology and Systematics. User's guide, Socientia Publishing, Budapest, 104 pp.

Poole, R.W., 1974: An Introduction to Quantitative Ecology. McGraw-Hill, New York, 532 pp.

Randuška, P., 1995: Ants of the State Nature Reserve Boky (in Slovak). Entomofauna carpathica, 7: 20–26.

Seifert, B., 2007: Die Ameisen Mittel- und Nordeuropas. Lutra Verlags- und Vertriebsgesselschaft, Görlitz/Tauer, 368 pp.

Schwerdtfeger, F., 1975: Ökologie der Tiere. Band III – Synökologie. Verlag Paul Parey, Hamburg – Berlin, 451 pp.

Schlaghamerský, J., 1999: The impact of flooding on saproxylic beetles and ants in South Moravian floodplain forests. In: Tajovský, K., Pižl, V. (eds), Soil Zoology in Central Europe. ISB AS CR, České Budějovice, p. 277–287.

Schlaghamerský, J., 2000: The saproxylic beetles (Coleoptera) and ants (Formicidae) of Central European hardwood floodplain forests. Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia, 103: 1–168.

Schlaghamerský, J., 2001: Dead wood and diversity of arthropods on example of the South Moravian hard floodplain forest. In: Tlející dřevo 2001. Sborník referátů MZLU Brno, p. 29–34.

Spellerberg, I.F., Fedor, P.J., 2003: A tribute to Claude Shannon (1916-2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon-Wiener" Index. Global Ecology and Biogeography, 12: 177–179.

Stitz, H., 1939: Die Tierwelt Deutschlands und der angrenzenden Meeresteile nach ihren Merkmalen und ihrer Lebensweise. 37. Teil. Hautflügler oder Hymenoptera I: Ameisen oder Formicidae. Gustav Fischer Verlag, Jena, 428 pp.

Ter Braak, C.J.F., Šmilauer, P., 1998: CANOCO References Manual and User's: Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power (Ithaca, NY, USA), 352 pp.

Tischler, W., 1949: Grunzüge der terrestrischen Tierökologie. Friedrich Vieweg, Braunschweig, 219 pp.

Werner, P., Wiezik, M., 2007: Vespoidea: Formicidae (in English and Czech). In: Bogush, P., Straka, J., Kment, P. (eds), Annotated checklist of the Aculeata (Hymenoptera) of the Czech Republic and Slovakia. Acta Entomologica Musei Nationalis Pragae, Supplementum 11, p. 133–164.

Wishart, D., 1969: An algorithm for hierarchical classifications. Biometrics, 22: 165–170.

5. Faunal richness of selected invertebrate groups in epigeon of oak-hornbeam forests on the territory of Bratislava

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The monograph summarizes analyses of four-year long coenological research (1999, 2000, 2005, 2006) on epigeic micro- and macrofauna in a forest ecosystem of the oak-hornbeam vegetation tier on the territory of the Bratislava city. The studied forest stands, 40–100 years of age, are situated in the orographic unit of the Malé Karpaty Mts., and may be classified into three vegetation types: *Querco petraeae-Carpinetum*, *Aceri-Carpinetum*, *Primulo veris-Carpinetum*.

The diversity of soil microfauna and macrofauna was studied at three forest complexes along an urban – rural gradient:

1. Complex of the Nature Reserve Devínska Kobyla hill situated on the western city margin, with the best preserved oak-hornbeam forest ecosystem (study plots Devínska Kobyla 1, Devínska Kobyla 2, Devínska Kobyla 3, and Dúbravská Hlavica);
2. Complex of the Koliba hill, where oak-hornbeam forests are under considerable human impact (tourist visitors, silvicultural management – timber extraction and coppice culling). To 1990, the complex was also impacted with chemical pollution of factories situated at the eastern city margin (study plots Koliba and Briežky);
3. Complex of urban oak-hornbeam forests in the city centre. Localities are impacted to the greatest extent and are fragmented to a great deal (study plots Mlynská dolina and Horský park).

In most European countries, invertebrates in such a forest type have not yet been intensively studied as a whole. Relevant papers dealing with fauna of oak-hornbeam forests are usually focused on pests (e.g. Patočka et al. 1999), or are limited by partial taxocoenoses of certain invertebrates (for example, naked amoebae: Mrva, Matis 2000, Mrva 2003, 2005b; ciliates: Tirjaková 2002, Tirjaková et al. 2002, Tirjaková, Mrva 2005, Bartošová et al. 2007, Vďačný, Tirjaková 2007, Vďačný et al. 2007, Bartošová, Tirjaková 2008; pseudoscorpions: Gabbutt, Vachon 1965, Gabbutt 1969, Goddard 1976, Wood, Gabbutt 1978, Ducháč 1988, 1993, Šťáhlavský 2001, Christophoryová 2009, Christophoryová, Krumpál 2007, 2010; terrestrial isopods: Gulička 1960, Krumpál 1973, 1976, Flasarová 1980, 1986, Flasar, Flasarová 1989; centipedes: Wytwer 1990, Tajovský 2001; millipedes: Gulička 1986, Branquart et al. 1995, Korsós 1997, David et al. 1999, Rahmani, Mayvan 2003; bugs: Štepanovičová, Kovačovský 1971, Bianchi 1991, Bakonyi et al. 2002, Rédei, Hufnagel 2003a, b; beetles: Korbel 1966, 1973, Korbel et al. 1997, Drdul 1973, Czechowski 1989, Majzlan 1986, 1991, Majzlan, Hošták 1996, Majzlan et al. 2000, Holecová, Sukupová 2002, Holecová et al. 2002, Šustek 2004; ants: Karpiński 1956, Pisarski 1981, Kožíšek 1984, 1985a, 1985b, 1986, Krzysztofiak 1985, Czechowski, Pisarski 1990, Drdulová 1991, Randuška 1995, Ambros et al. 1998, Alvarado, Gallé 1999, partially Schlaghamerský 1999, 2000, 2001, etc.).

Results of coenological research on invertebrate macrofauna associated with epigeon and on microfauna associated with the leaf litter and the upper part of soil, mosses, dead wood (in various decay degrees) and dendrotelmae of oak-hornbeam forests from the central and northern part of the Malé Karpaty Mts. and the nearby Trnavská pahorkatina hills were published in Ekológia (Bratislava), 24, Supplement 2/2005 (ciliates: Tirjaková, Vďačný 2005, Bartošová, Tirjaková 2005; naked amoebae: Mrva 2005a; water bears: Degma et al. 2005; pseudoscorpions: Christophoryová, Krumpál 2005; spiders: Krumpálová 2005; mesostigmatid mites: Fenďa, Ciceková 2005; terrestrial isopods: Tuf, Tufová 2005; centipedes: Országh, Országhová 2005; millipedes: Stašiov 2005; earwigs: Országh 2005; bugs: Hradil 2005; weevils: Holecová et al. 2005a).

General and complex view on arthropod fauna in Central European oak-hornbeam forests has been included just in few papers (e.g. Balogh, Loksa 1948, Verner 1959, Loksa 1966, 1968, Nosek 1968, Holecová et al. 2005b).

To study epigeic and soil macrofauna we applied two collecting methods - sieving the leaf litter and the upper part of soil as well as the formaldehyde ground traps. The microfauna was studied from samples of the leaf litter and separately the upper part of soil, mosses, and wood by direct analyses of sampled material that was cultivated using modifications of the non-flooded Petri-dish method. All materials were collected in regular monthly intervals in the same study plots and periods.

General characterization of oak-hornbeam invertebrate assemblages and their faunal richness on the territory of Bratislava seems to be very disputable due to the rich material of various systematic groups and their different life strategies, often from many types of microhabitats. However, this chapter will project a certain synthesis.

In total we determined 25739 invertebrate specimens (except for protists) belonging to 358 taxa (349 identified to the species level and 9 only to the genus level) from three phyla (Rhizopoda, Ciliophora, Arthropoda). Generally, the study presents a detailed ecological analysis of nine systematic groups (naked amoebae, ciliates, pseudoscorpions, terrestrial isopods, millipedes, bugs, ground beetles, weevils, ants) being provided by the authors of individual chapters. Centipedes (23 species, 1859 individuals, I. Országh det.) and earwigs (1 species, 828 individuals, M. Holecová det.) are included just in the review of taxa in the studied oak-hornbeam forests on the territory of Bratislava, even though they were not coenologically assessed. In this part, we summarize the obtained data. Moreover, an environmental impact on the studied animals was taken into account.

Naked amoebae were studied from leaf litter and mosses in three forest sites (Briežky, Koliba and Devínska Kobyla). The diversity at the investigated localities varied noticeably from 4 taxa recorded at Koliba and 9 taxa found at Briežky to 23 taxa noted at Devínska Kobyla. The leaf litter with 21 taxa was richer in diversity of naked amoebae than the mosses where 18 species were recorded. The highest diversity appeared in the family Thecamoebidae (7 species). However, from this family only two species, *Thecamoeba quadrilineata* and *T. terricola*, were recorded at all localities. Another species observed in all studied sites was *Korotnevella stella* from the family Paramoebidae, previously known mainly from aquatic habitats. In total, 25 taxa of naked amoebae were recorded. Until now, the differences between the diversities of gymnamoebae in soil and freshwater habitats remain poorly understood. In general, there are opinions about large overlap and similarity in both environments. Due to the insufficient knowledge it is practically impossible to differentiate species typical for terrestrial and for freshwater habitats.

In total, 112 ciliate taxa were identified in the study area, whereby the highest diversity was recorded in the localities Devínska Kobyla 2 (72 taxa in leaf litter and 14 taxa in soil) and Devínska Kobyla 1 (68 taxa in leaf litter and 14 taxa in soil). At the locality Koliba, 52 taxa were reported from the leaf litter and 11 taxa from soil, while 47 taxa were found in the leaf litter and 11 taxa in soil in the site Briežky. However, a distinctly lower number of species was noted directly in the urban area of Bratislava. Specifically, the locality Horský park harboured 10 taxa in the leaf litter and 11 taxa in soil, while the site

Mlynská dolina housed 12 taxa in the leaf litter, 12 taxa in moss, and 15 taxa in the decaying wood mass. In general, the leaf litter samples represented the species richest habitat, while soil (horizon A) samples harboured the lowest number of species. Average numbers of species detected per sample are similar between all examined localities. No dependence between forest fragmentation and number of ciliate species was revealed, unlike in other groups investigated in the present study. Microclimatic factors along with food organisms very likely played much more important role with respect to the ciliate diversity, as typical for protists in general. Moreover, out of the 112 recorded species, 13 were noted for the first time in the territory of Slovakia - *Anteholosticha sigmoidea, Colpoda ecaudata, C. elliotti, Enchelys terricola, Epispathidium terricola, Frontonia solea, F. terricola, Microdiaphanosoma arcuatum, Nivaliella plana, Orthokreyella schiffmanni, Parabryophrya penardi, Spathidium claviforme*, and *Thylakidium typicum*.

A total of ten species of pseudoscorpions were examined during the two-year research. The families Chthoniidae and Neobisiidae were eudominant, while the families Cheliferidae and Chernetidae were subrecedent. The species spectrum was represented by two species groups, eudominant and euconstant, *Chthonius boldorii, C. fuscimanus* and *Neobisium carcinoides*, which are characteristic for oak-hornbeam forests. On the contrary, *N. carpaticum, N. sylvaticum, Dactylochelifer latreillii, Chernes cimicoides, C. similis, Allochernes peregrinus* and *Pselaphochernes scorpioides* achieved lower dominance and low constancy. Depending on the collecting methods or time period of obtaining the material, the subrecedent species helped to differentiate the studied habitats from each other. The redundancy analysis proved the influence of the forest fragmentation on the assemblages. The species *N. carpaticum, C. cimicoides, C. similis* and *A. peregrinus* preferred assemblages of forests without fragmentation, whereas *C. boldorii, C. fuscimanus, N. carcinoides, N. sylvaticum* and *D. latreillii* were recorded in the most fragmented forests. The species *Allochernes peregrinus* was noted at the study plots of hornbeam forests nearby Bratislava. Until present only isolated records of *A. peregrinus* were announced from Slovakia and also from the other Central European countries. Therefore, this species was listed in the Red Data Book of the Czech Republic as vulnerable.

Ten species of terrestrial isopods were recorded in the studied suburban and urban forest sites. We noticed relatively rich but typical isopod communities, formed from 3 to 7 species with predominant *Protracheoniscus politus* and *Porcellium collicola*. These species were present at stable abundances during whole year and other rare species appeared irregularly according to optimal climatic conditions. There are little differences in composition of communities between natural and anthropogenized sites. The most important environmental factors impacting structure of assemblages are the age of the forest, shrub layer and pH. Species *Hyloniscus riparius, Porcellionides pruinosus, Platyarthrus hoffmannseggii* and *Porcellium collicola* preferred localities with dense shrub layer and low age. *Trachelipus rathkii, Cylisticus convexus* and *Armadillidium vulgare* were present at steeper localities with high content of nitrogen and *Trachelipus ratzeburgii* occupied localities with high amount of humus in soil.

Sixteen millipede species were recorded in the studied forest sites. The most species (13) were found in the locality Devínska Kobyla 2 and Dúbravská Hlavica belonging to the forest complex of the Nature Reserve Devínska Kobyla hill situated at the south-western city margin. These localities were presented by most well-preserve biotopes and they are the least exposed to human pressure within the compared localities. The poorest were the localities Koliba and Briežky (only 6 species were ascertained on each of them). The research showed that, except for the two main factors (temperature and humidity of environment), this group of invertebrates is also affected by some other environmental factors. The record of *Julus curvicornis* is considered the most interesting from the viewpoint of faunistics. This species is considered West-Carpathian endemic and Bratislava is the westernmost locality on which it has ever been recorded.

Epigeic heteropteran assemblages were studied at eight study plots within three different oak-hornbeam forest complexes in the territory of the Bratislava city. Totally, 34 species were recorded in material of 185 individuals sampled by sifting method. The complex of well preserved stands of the Nature Reserve Devínska Kobyla hill was the richest both in the species and the specimen numbers (22 species and 138 specimens). On the contrary, the poorest species richness and abundance was noted at the oak-hornbeam stands of the Koliba hill complex (11 species and 19 specimens) and at the complex of urban oak-hornbeam forests in the city centre (14 species, 28 specimens). Both localities are human-disturbed to the greatest extent. The geobiont cydnid species *Legnotus limbosus* was recorded as eudominant and it occurred most frequently and abundantly only in the Devínska Kobyla hill. When comparing species spectra of individual study plots, humidity level was found to be a limiting factor for forming heteropteran assemblages. Occurrence of pentatomids *Dyroderes umbraculatus* and *Sciocoris homalonotus* are remarkable from the faunistic point of view.

Thirty-five ground beetle species were recorded in the examined forest stands on the territory of Bratislava. Major part of the species (54.3%) were typical forest inhabitants requiring or preferring shadowing by tree vegetation. There were also some eurytopic species (14.2%), which are more or less indifferent to shadowing. Members of both groups accounted for 98.9% of all individuals. Only eight species (*Amara aenea, A. ovata, Calathus fuscipes, Harpalus distinguendus, H. tardus, H. latus, Ophonus azureus, Pseudoophonus rufipes*) typically live in open landscape, and are thus considered to be xenocenous in forest ecosystems. They occurred in the examined assemblages only occasionally. The communities from Devínska Kobyla, Dúbravská Hlavica, Koliba, and Briežky were slightly poorer in number of species than those from free landscape. The former four localities were not penetrated by xenocoenous species, indicating that they have preserved a natural character. The communities from Horský park and Mlynská dolina were poorer in number of species and individuals than other studied coenoses. These two localities represent urban forest fragments whose ground beetle assemblages were penetrated by several xenocoenous species, what was very likely caused by the isolation, recreation activities, and/or horticultural pressure. All communities, irrespectively of their position or disturbance, were subjected to strong between-year fluctuations in representation of individuals species. Among the carabids, only occurrence of the rare species *Cymindis vaporariorum* in Devínska Kobyla 1 and of *Ophonus gammeli* in all three sites of Devínska Kobyla are remarkable from faunistic and ecosozologic point of view. They were not recorded there by Majzlan et al. (2005).

The weevils were studied with regard to their community structure, species richness, temporal occurrence and ecological requirements of individual species. Seventy species classified into 42 genera and 4 families were recorded. The number of species found at the particular sites ranged from 14 to 35 species. The mean abundance of weevils varied from 3.06 to 22.69 ind.m^{-2}. Geobionts *Acalles echinatus, A. fallax, A. camelus, Barypeithes chevrolati, Brachysomus echinatus, Ruteria hypocrita*, geophilous species *Ceutorhynchus pallidactylus, Otiorhynchus raucus* and geoxenes *Ceutorhynchus typhae* and *Trichopterapion holosericeum* predominated in the material from the oak-hornbeam forest epigeon. The canopy architecture, humidity of forest floor associated with N exposition and soil type (Rendzic Phaeozem) had a direct and significant influence on the structure of epigeic weevil assemblages. The forest fragmentation and cutting caused the weevil abundance and faunal richness to decrease in the forest floor of island woods situated in the urban part of Bratislava. Several records of weevil species, namely those of *Kalcapion semivittatum, Bagous argillaceus, Barypeithes albinae, Curculio propinquus, Kyklioacalles suturatus, Otiorhynchus rugosostriatus*, are of faunistic interest.

Among other beetle families, occurrence of two rove beetles – *Staphylinus chloropterus* (Panzer 1796) and *Ocypus mus* (Brullé, 1832) is remarkable from faunistic and ecosozological point of view. *Staphylinus chloropterus* is a thermophilous species occurring in southern parts of Europe (Herman 2001) and having the northern border of its distribution in Central Europe. Everywhere is considered as rare (Zanetti, Tagliapietra 2004, Majzlan 2010). Within the studied localities it was found in pitfall traps in the study sites Dúbravská Hlavica (5 ex. 26.5.2006), Briežky (3 ex. 25.5.2006) and Devínska Kobyla 2 (1 ex. 30.8.2005). In Devínska Kobyla it was not found by Majzlan et al. (2005). Its occurrence confirms the great value of the studied localities for preservation of biodiversity and continuity of its occurrence in the wider area of Bratislava (Šustek 1984).

Ocypus mus is a thermophilous species which started to spread to north in early 1970-s (Šustek 1992). In warm forests of Slovakia it rapidly occupied a dominant position in staphylinid communities. It was found in all studied localities, but it was especially abundant in pitfall traps at the study site Devínska Kobyla 3 (114 individuals). Its occurrence confirms its stabilized position in ecosystems occupied about 30–40 years ago.

The structure and dynamics of ant assemblages were studied at five suburban forests of the oak-hornbeam vegetation tier on the territory of the Bratislava city. In total, 23 ant species belonging to 10 genera, and 3 subfamilies were recorded. The number of species found in particular sites ranged from 10 to 14. The mean abundance of ants varied from 105.92 to 192.54 ind. m^{-2} of the soil surface. *Temnothorax crassispinus, Stenamma debile, Temnothorax unifasciatus* and *Myrmecina graminicola* predominated in all study plots. Among all variables analyzed only canopy density was revealed as significantly influencing the structure of epigeic ant assemblages. The study plots are a part of two forest complexes. The Nature Reserve Devínska Kobyla hill (Devínska Kobyla 1, Devínska Kobyla 2, Dúbravská Hlavica) with relatively well preserved forests and the study plots of the Koliba hill (Koliba, Briežky), which are more strongly affected by anthropic impact. There were observed no significant differences in species number and mean abundance of ant assemblages between the compared forest complexes. On the other hand, the diversity of ant functional groups was lower at study sites with stronger disturbance, as cryptic species and subordinate Camponotini were not found there. Several records of ant species, namely those of *Ponera coarctata, Aphaenogaster subterranea, Temnothorax affinis* and *Stenamma debile*, are of faunistic interest.

Conclusions

- Results of our investigation confirmed the fact that the urban forest islands in a built-up city area are characterized by significantly lower richness of epigeic invertebrate fauna in comparison with the suburban more closed forest complexes.
- Each animal community specifically responds to anthropogenic pressure.
- Of the analyzed gradient and categorial variables, just forest fragmentation, canopy density, coverness of shrub stratum, humidity associated with N exposition of a forest stand, and to a lesser extent humus content, age of forest, nitrogen content and slope gradient appeared as significantly influencing the studied arthropod communities associated with forest floor.
- Suburban forest complexes can become refuges for rare invertebrate species and it is therefore necessary to protect them.

References

ALVARADO, M., GALLÉ, L., 1999: Diversity and structure of ant assemblages in forest habitats in the South Hungarian Plain. In: TAJOVSKÝ, K., PIŽL, V. (eds), Soil Zoology in Central Europe. ISB AS CR, České Budějovice, p. 1–6.

AMBROS, M., RYCHLÍK, I., GÁLOVÁ, J., 1998: Notes on ant fauna (Hymenoptera: Formicoidea) of the Zoborské vrchy hills (in Slovak). Rosalia, 13: 121–128.

BAKONYI, G., CSÖLLE, C., FABÓK, V., FÖLLESSY, M., HUFNAGEL, L., KONDOROSY, E., RÉDEI, D., TÖLGYESNÉ-NELL, T., VARGA, I., VÁSÁRHELYI, T., 2002: The Heteroptera Fauna of the Fertö-Hanság National Park. Hungarian Natural History Museum, Budapest: 325–350.

BALOGH, J., LOKSA, I., 1948: Arthropod coenosis of the litter stratum of an oak forest. Arch. Biol. Hung., Ser. 2, 18: 264–279.

BARTOŠOVÁ, P., TIRJAKOVÁ, E., 2005: Selected ecological characteristics of ciliate communities (Protozoa, Ciliophora) in decaying wood mass in Malé Karpaty Mountains. Ekológia (Bratislava), 24, Supplement 2/2005: 37–50.

BARTOŠOVÁ, P., TIRJAKOVÁ, E., 2008: Diversity and ecology of ciliates (Alveolata: Ciliophora) living in the bark and decaying wood mass in Slovakia. Acta Protozool., 47: 173–187.

BARTOŠOVÁ, P., TIRJAKOVÁ, E., HOLECOVÁ, M., 2007: The influence of selected factors on the communities of ciliates (Protozoa, Ciliophora) in decaying woody matter. In: TAJOVSKÝ, K., SCHLAGHAMERSKÝ, V., PIŽL, V. (eds), Studies on soil fauna in Central Europe, ISB AS CR, České Budějovice, p. 1–5.

BIANCHI, Z., 1991: Wanzen (Heteroptera) als Bestandteil des epigäischen Fauna von Bratislava. Entomol. Nachr. Ber., 35: 206–207.

BRANQUART, É., KIME, R.D., DUFRÊME, M., TAVERNIER, J., 1995: Macroarthropod – habitat relationships in oak forest in South Belgium. 1. Environments and communities. Pedobiologia, 39: 243–263.

CHRISTOPHORYOVÁ, J., 2009: Pseudoscorpions – Pseudoscorpiones (in Slovak). In: MAŠÁN, P., MIHÁL, I. (eds), Arachnids of Cerová vrchovina hills (Arachnida: Araneae, Pseudoscorpiones, Opiliones, Acari). Štátna ochrana prírody SR Banská Bystrica, Správa CHKO Cerová vrchovina Rimavská Sobota, Ústav zoológie SAV Bratislava, Ústav ekológie lesa SAV Zvolen, p. 125–135.

CHRISTOPHORYOVÁ, J., KRUMPÁL, M., 2005: Communities of pseudoscorpions (Pseudoscorpiones, Arachnida) in epigeon of oak-hornbeam forests in the Malé Karpaty Mts. and Trnavská pahorkatina hills. Ekológia (Bratislava), 24, Supplement 2/2005: 76–86.

CHRISTOPHORYOVÁ, J., KRUMPÁL, M., 2007: Pseudoscorpions (Pseudoscorpiones) from the leaf litter of Malé Karpaty Mts. and Trnavská pahorkatina hills (in Slovak). Entomofauna carpathica, 19: 27–31.

CHRISTOPHORYOVÁ, J., KRUMPÁL, M., 2010: Pseudoscorpions (Pseudoscorpiones) of Šúr Nature Reserve (in Slovak). In: Majzlan, O., Vidlička, Ľ. (eds), Nature of Reserve Šúr. Ústav zoológie SAV, Bratislava, p. 105–114.

CZECHOWSKI, W., 1989: Carabidae (Coleoptera) of linden-oak-hornbeam and thermophilous oak forests of the Mazovian Lowland. Fragm. Faun., Warszawa, 32: 95–155.

CZECHOWSKI, W., PISARSKI, B., 1990: Ants (Hymenoptera, Formicoidea) of linden-oak-hornbeam forests and thermophilous oak forests of the Mazovian Lowland. I. Nest density. Fragm. faun., Warszawa, 34: 133–141.

DAVID, J.F., DEVERNAY, S., LOUCOUGARAY, G., LE FLOCH, E., 1999: Belowground biodiversity in a Mediterranean landscape: relationships between saprophagous macroarthropod communities and vegetation structure. Biodiversity and Conservation, 8: 753–767.

DEGMA, P., ŠIMURKA, M., GULÁNOVÁ, S., 2005: Community structure and ecological macrodistribution of moss-dwelling water bears (Tardigrada) in Central European oak-hornbeam forests (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 59–75.

DRDUL, J., 1973: Coleoptera im Boden des Eichen-Hainbuchenwalds in Báb bei Nitra. Acta F.R.N. Univ. Comen. – Zoologia, 18: 129–145.

DRDULOVÁ, A., 1991: A contribution to the knowledge of ants (Hymenoptera, Formicoidea) of the Zobor hill (in Slovak). Zobor, 2: 95–102.

DUCHÁČ, V., 1988: A contribution to the knowledge of the pseudoscorpions in České středohoří Mts. (in Czech). Fauna. Boh. Septentr., 13: 103–108.

DUCHÁČ, V., 1993: Pseudoscorpions (Pseudoscorpionidea) in tree hollows in Třeboňsko (in Czech). Sbor. Jihoč. Muz. Čes. Bud., Přír. Vědy, 33: 65–69.

FENĎA, P., CICEKOVÁ, J., 2005: Soil mites (Acari, Mesostigmata) of oak forests in Malé Karpaty Mts. (W Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 102–112.

FLASAR, I., FLASAROVÁ, M., 1989: Ergänzungen zur Monographie „The Soil Fauna of the Little Carpathians" (Mollusca et Isopoda). Faunistische Abhandlungen, Staatliches Museum für Tierkunde Dresden, 17: 1–18.

FLASAROVÁ, M., 1980: *Hyloniscus transsilvanicus* (Verhoeff, 1901) im Gebirge Malé Karpaty in der West-Slowakei. Faunistische Abhandlungen, Staatliches Museum für Tierkunde Dresden, 7: 273–278.

Flasarová, M., 1986: Isopoda (Asellota, Oniscidea) of the Little Carpathians. In: Nosek, J. (ed.), The Soil Fauna of the Little Carpathians. Slovak Academy of Sciences, Bratislava, p. 183–216.
Gabbutt, P.D., 1969: Life-histories of some British pseudoscorpions inhabiting leaf litter. In: Sheals, J.G. (ed.), The soil ecosystem, Systematics Association Publication no. 8, London, p. 229–235.
Gabbutt, P.D., Vachon, M., 1965: The external morphology and life history of the pseudoscorpion *Neobisium muscorum*. Proc. Zool. Soc. London, 145: 335–358.
Goddard, S.J., 1976: Population dynamics, distribution patterns and life cycles of *Neobisium muscorum* and *Chthonius orthodactylus* (Pseudoscorpiones: Arachnida). J. Zool. London, 178: 295–304.
Gulička, J., 1960: Impact of changing water regime to soil macrofauna of Svätojurský Šúr (in Slovak). Acta F.R.N. Univ. Comen. – Zoologia, 4: 437–486.
Gulička, J., 1986: Diplopoda of the forest communities of the Little Carpathians. In: Nosek, J. (ed.), The soil fauna of the Little Carpathians. Slovak Academy of Sciences, Institute of Experimental Biology and Ecology of the Centre for Biological Sciences, Bratislava, p. 217–224.
Herman, L.H., 2001: Catalog of the Staphylinidae (Insecta: Coleoptera), 1758 to the end of the second millenium. Bulletin of the American Museum of Natural History, 265: 1–4218.
Holecová, M., Sukupová, J., 2002: Weevils (Coleoptera, Curculionoidea) as a part of the oak-hornbeam forest epigaeon. In: Tajovský, K., Balík, V., Pižl, V (eds), Studies on Soil Fauna in Central Europe, ISB AS CR, České Budějovice, p. 59–67.
Holecová, M., Zach, P., Kardošová, J., 2002: Epigaeic weevils (Coleoptera, Curculionoidea) of oak-hornbeam forests in a vicinity of Bratislava (SW Slovakia) (in Slovak). Folia faunistica Slovaca, 7: 39–48.
Holecová, M., Némethová, D., Kúdela, M., 2005a: Structure and function of weevil assemblages (Coleoptera, Curculionoidea) in epigeon of oak-hornbeam forests in SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 179–204.
Holecová, M., Krumpál, M., Országh, I., Krumpálová, Z., Stašiov, S., Fedor, P., 2005b: Biodiversity of selected invertebrate groups in oak-hornbeam forest ecosystem in SW Slovakia. Ekológia (Bratislava) 24, Supplement 2/2005: 205–222.
Hradil, K., 2005: Bug assemblages in epigeon of oak-hornbeam forests in SW Slovakia. Ekológia (Bratislava), 24, Suplement 2/2005: 161–178.
Karpiński, J.J., 1956: Ants in the biocoenosis of the Białowież National Park (in Polish). Rocz. Nauk. leśn., Warszawa, 14: 201–221.
Korbel, L., 1966: Zur Erkenntnis des bionomischen Gruppen der Coleoptera im Boden des gemischen Karpatenwaldes. Acta F.R.N. Univ. Comen. – Zoologia, 13: 141–149.
Korbel, L., 1973: Käfer – Coleoptera des Eichen-Hainbuchenwalds bei Báb. Acta F.R.N. Univ. Comen. – Zoologia, 18: 91–127.
Korbel, L., Rychlík, I., Majzlan, O., 1997: Epigaeic beetles (Coleoptera) of the Devínska Kobyla hill (the Malé Karpaty mountains, SW Slovakia). Biologia, Bratislava, 52: 263–272.
Korsós, Z., 1997: The millipede fauna of the Dráva region, southern Hungary (Diplopoda). Ent. scand. Suppl., 51: 219–224.
Kožíšek, T., 1984: Notes on occurrence of ants in the area of the Tribeč hills (in Slovak). Rosalia, 1: 59–62.
Kožíšek, T., 1985a: Distribution of ants (Formicoidea) in meadow and forest habitats of the town residential area of Bratislava (in Slovak). In: Zborník referátov z konferencie Zoocenózy urbánnych a suburbánnych celkov so zvláštnym akcentom na podmienky Bratislavy, p. 118–122.
Kožíšek, T., 1985b: Ants (Formicidae) of chosen habitats in the Protected Landscape Area Ponitrie (Tribeč hills, Vtáčnik Mts.) (in Slovak). Rosalia, 2: 241–246.
Kožíšek, T., 1986: Ants of selected habitats in the Protected Landscape Area Štiavnické vrchy hills (in Slovak). In: Zborník I., XXI. TOP Počúvadlo, p. 149–155.
Krumpál, M., 1973: Seasonal dynamics of terrestrial isopod populations (Isopoda, Oniscoidea) in Jurský šúr Nature Reserve (in Slovak). Biológia (Bratislava), 28: 879–884.
Krumpál, M., 1976: Knowledge from biology isopode reproduction in Jurský šúr. Acta F.R.N. Univ. Comen. – Zoologia, 20: 63–67.
Krumpálová, Z., 2005: Epigeic spiders (Araneae) in ecosystems of oak-hornbeam forests in Malé Karpaty Mts. (Slovakia) and their ecological categorization. Ekológia (Bratislava), 24, Supplement 2/2005: 87–101.
Krzysztofiak, L., 1985: Distribution and nest density of ants in the Augustowska Forest (the Masurian Lakeland) (in Polish). Fragm. faun., Warszawa, 29: 137–149.
Loksa, I., 1966: Die bodenzoozönologischen Verhältnisse der Flaumeichen-Buschwälder Südostmitteleuropas. Akadémiai Kiadó, Budapest, 437 pp.
Loksa, I., 1968: Quantitative Makrofauna-Untersuchungen in den Waldböden des Bükkgebirges (Ungarn). Ann. Univ. Scient. Budapestinensis de Rolando Eötvös nominatae, sect. Biol., 9-10: 265–289.

Majzlan, O., 1986: Beetle communities in soil of meadow and forest ecotops in intravilan of the Bratislava town (in Slovak). Acta F.R.N. Univ. Comen. – Formatio et Protectio Naturae, 12: 49–64.
Majzlan, O., 1991: Geobiont beetles (Coleoptera) of an oak forest near the Obyce village (in Slovak). Rosalia, Nitra, 7: 185–193.
Majzlan, O., 2010: Beetle fauna (Coleoptera) in the Nature Reserve Suché doly (National park Muránska planina) (in Slovak). Naturae Tutela, 14: 15–27.
Majzlan, O., Hošták, P., 1996: Bioindication importance of Oniscoidea and Curculionidae in soil of an oak forest in the National Nature Reserve Dubník near the Sereď town (in Slovak). Ochrana prírody, Banská Bystrica, 14: 83–87.
Majzlan, O., Rychlík, I., Korbel, L., 2005: Beetles (Coleoptera) (in Slovak). In Majzlan, O. (ed.), Fauna Devínskej Kobyly, Asociácia priemyslu a ochrany prírody (edícia APOP), Bratislava, p. 87–117.
Majzlan, O., Štepanovičová, O., Fedor, P.J., 2000: Chosen Insect Groups (Coleoptera, Heteroptera, Blattodea, Ensifera et Caelifera) in National Nature Reserve Čachtický hradný vrch (Protected Landscape Area Malé Karpaty) (in Slovak). Folia faunistica Slovaca, 5: 135–150.
Mrva, M., 2003: Diversity of active gymnamoebae (Rhizopoda, Gymnamoebia) in dendrotelmae of oak-hornbeam forests in Malé Karpaty Mts. (Western Slovakia). Protistology, 3: 121–125.
Mrva, M., 2005a: Diversity of active gymnamoebae (Rhizopoda, Gymnamoebia) in mosses of the Malé Karpaty Mts. (Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 51–58.
Mrva, M., 2005b: Amoebae (Rhizopoda) (in Slovak). In: Majzlan, O. (ed.), Fauna of Devínska Kobyla. APOP, Bratislava. p. 17–19.
Mrva, M., Matis, D., 2000: Rhizopoda in leaf litter of some localities of oak-hornbeam forests in Malé Karpaty Mts. (Western Slovakia) (in Slovak). Folia faunistica Slovaca, 5: 1–9.
Nosek, J. (ed.), 1986: The soil fauna of the Little Carpathians. Results of Research program MAB, Slovak Academy of Sciences, Institute of Experimental Biology and Ecology of the Centre for Biological Sciences, Bratislava, 340 pp.
Országh, I., 2005: Phenology of *Chelidurella acanthopygia* (Dermaptera: Forficulidae) nymphal instar in oak-hornbeam forests of the Malé Karpaty Mts and Trnavská pahorkatina hills (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 152–160.
Országh, I., Országhová, Z., 2005: Structure of centipede communities (Antennata: Chilopoda) in oak-hornbeam forests of Malé Karpaty Mts. and Trnavská pahorkatina hills (SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 124–142.
Patočka, J, Krištín, A., Kulfan, J., Zach, P. (eds.), 1999: Die Eichenschädlinge und ihre Feinde. Institut für Waldökologie der Slowakischen Akademie der Wissenschaften, Zvolen, 396 pp.
Pisarski, B., 1981: Ants (Formicidae, Hymenoptera) (in Polish). In: Zoocenologiczne podstawa kształtowania środowiska przyrodniczego osiedla mieszkaniowego Białołęka Dworska w Warszawie. 1. Skład gatunkowy i struktura fauny terenu projektowanego osiedla mieszkaniowego. Fragm. faun., Warszawa, 26: 341–354.
Rahmani, R., Mayvan, H.Z., 2003: Diversity and assemblage structure of soil invertebrates in beech, hornbeam and oak-hornbeam forest types. Iranian Journal of Natural Resources, 56: 425–436.
Randuška, P., 1995: Ants of the State Nature Reserve Boky (in Slovak). Entomofauna carpathica, 7: 20–26.
Rédei, D., Hufnagel, L., 2003a: The species composition of true bug assemblages extracted with Berlese funnels (Data to the knowledge on the ground-living Heteroptera of Hungary, No 1). Applied Ecology and Environmental Research, 1: 93–113.
Rédei, D., Hufnagel, L., 2003b: Data to the knowledge on the soil bug fauna of the Hungarian Northern-Mountains (Heteroptera) (Data to the knowledge on the ground-living Heteroptera of Hungary, No 2) (in Hungarian). Folia historico-naturalia Musei Matraensis, 27: 81–89.
Schlaghamerský, J., 1999: The impact of flooding on saproxylic beetles and ants in South Moravian floodplain forests. In: Tajovský, K., Pižl, V. (eds.), Soil Zoology in Central Europe. ISB AS CR, České Budějovice, p. 277–287.
Schlaghamerský, J., 2000: The saproxylic beetles (Coleoptera) and ants (Formicidae) of Central European hardwood floodplain forests. Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia, 103: 1–168.
Schlaghamerský, J., 2001: Dead wood and diversity of arthropods on example of the South Moravian hard floodplain forest. In: Tlející dřevo 2001. Sborník referátů MZLU Brno, p. 29–34.
Stašiov, S., 2005: Millipede communities (Diplopoda) of oak-hornbeam ecosystems (Malé Karpaty Mts., Trnavská pahorkatina hills, SW Slovakia). Ekológia (Bratislava), 24, Supplement 2/2005: 143–151.
Šťáhlavský, F., 2001: Pseudoscorpions (Arachnida: Pseudoscorpiones) of Prague. Klapalekiana, 37: 73–121.
Štepanovičová, O., Kovačovský, P., 1971: A qualitative-quantitative analysis of hibernating Heteroptera interrelations (in Slovak). Biológia (Bratislava), 26: 115–123.
Šustek, Z., 1984: Bioindication ability of carabids and staphylinids (Coleoptera, Carabidae et Staphylinidae) of big central European cities (PhD thesis, in Slovak). Institute of Experimental Biology and Ecology of the Centre of Biological and Ecological Sciences of the Slovak Academy of Sciences, Bratislava, 366 pp.

Šustek, Z., 1992: Expansion and ecology of *Ocypus mus* (Brullé, 1832), (Coleoptera, Staphylinidae) in Slovakia and Moravia. Biológia (Bratislava), 47: 129–132.

Šustek, Z., 2004: Carabid communities (Col. Carabidae) in degradation stages of pubescent oak forests (*Corni-Querceta* deg.) in oak vegetation tier. In: Polehla P. (ed.), Hodnocení stavu a vývoje lesních geobiocenóz. Sborník příspěvků z mezinárodní konference 15.-16. 10. 2004 v Brně. Geobiocenologické spisy, Brno, 9: 203–209.

Tajovský, K., 2001: Present state of the investigation of millipedes, centipedes and terrestrial isopods in the Podyjí National Park (in Czech). Thayensia (Znojmo), 4: 161–167.

Tirjaková, E., 2002: Occurrence of Suctoria (Protozoa: Ciliophora) in soil and forest litter of Malé Karpaty Mts. (Slovakia) (in Slovak). Folia faunistica Slovaca, 7: 1–4.

Tirjaková, E., Mrva, M., 2005: Notes on the ecological characteristics of chosen protozoan groups in leaf-litter and mineral layer of soil. In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Contributions to soil zoology in Central Europe, ISB AS CR, České Budějovice, p. 187–190.

Tirjaková, E., Mrva, M., Hlúbiková, D., 2002: Ciliophora and Rhizopoda in soil, leaf-litter and mosses of oak-hornbeam forests in the Malé Karpaty Mts. (Western Slovakia). In: Tajovský, K., Schlaghamerský, J, Pižl, V. (eds), Studies on Soil Fauna in Central Europe, ISB AS CR, České Budějovice, p. 233–240.

Tirjaková, E., Vďačný, P., 2005: Ciliate communities (Protozoa, Ciliophora) in tree-holes and influence of selected environmental factors on their structure. Ekológia (Bratislava), 24, Supplement 2/2005: 20–36.

Tirjaková, E., Mrva, M., Hlúbiková, D., 2002: Ciliophora and Rhizopoda in soil, leaf-litter and mosses of oak-hornbeam forests in the Malé Karpaty Mts. (Western Slovakia). In: Tajovský, K., Schlaghamerský, J, Pižl, V. (eds), Studies on Soil Fauna in Central Europe, ISB AS CR, České Budějovice, p. 233–240.

Tuf, I. H., Tufová, J., 2005: Communities of terrestrial isopods (Crustacea: Isopoda: Oniscidea) in epigeon of oak-hornbeam forests of SW Slovakia. Ekológia (Bratislava), 24, Supplement 2/2005: 113–123.

Vďačný, P., Tirjaková, E., 2007: Observations on soil haptorid ciliates (Protozoa, Ciliophora) from Slovakia. Biologia, Bratislava, 62: 720–730.

Vďačný P., Tirjaková, E., Holecová, M., 2007: Succession in the soil gymnostomate ciliates (Ciliophora, Gymnostomatea) communities in non-flooded Petri dish cultures. In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds), Studies on soil fauna in Central Europe, ISB AS CR, České Budějovice, p. 189–193.

Verner, P.H., 1959: Study on arthropods living in soil of an oak-hornbeam forest in the surroundings of Karštejn (in Czech). Boh. Centr. A, 1 (7): 345–408.

Wood, P.A., Gabbutt, P.D., 1978: Seasonal vertical distribution of pseudoscorpions in beech litter. Bull. Br. Arachnol. Soc. London, 4: 176–183.

Wytwer, J., 1990: Chilopoda of linden-oak-hornbeam (*Tilio-Carpinetum*) and thermophilous oak forests (*Potentillo albae-Quercetum*) of the Mazovian Lowland. Fragmenta Faunistica, 34: 73–94.

Zanetti, A., Tagliapietra, A., 2004: Studi sulle taxocenosi a Staphylininae in boschi di latifoglie italiani (Coleoptera, Staphylinidae). Studi Trentini di Sci. Nat., Acta Biol., 81: 207–231.

APPENDIX 1.

Review of taxa found in studied oak-hornbeam forests on the territory of Bratislava in 1999–2006.

Phylum: RHIZOPODA
Class: LOBOSA
Family: Amoebidae
Deuteramoeba algonquinensis (Baldock, Rogerson & Berger, 1983) Page, 1987
Deuteramoeba mycophaga (Pussard, Alabouvette, Lemaitre & Pons, 1980) Page, 1988
Trichamoeba sinuosa Siemensma & Page, 1986
Family: Hartmannellidae
Saccamoeba sp.
Saccamoeba limax (Dujardin, 1841) Page, 1974
Family: Leptomyxidae
Rhizamoeba australiensis (Chakraborty & Pussard, 1985) Page, 1988
Family: Vermamoebidae
Vermamoeba vermiformis (Page, 1967) Smirnov & Cavalier-Smith, 2011
Family: Paramoebidae
Korotnevella diskophora Smirnov, 1999
Korotnevella stella (Schaeffer, 1926) Goodkov, 1988
Family: Vannellidae
Vannella spp.
Family: Mayorellidae
Mayorella penardi Page, 1972
Mayorella vespertilioides Page, 1983
Family: Dermamoebidae
Dermamoeba sp.
Dermamoeba granifera (Greeff, 1866) Page & Blakey, 1979
Dermamoeba minor (Pussard, Alabouvette & Pons, 1979) Page, 1988
Paradermamoeba levis Smirnov & Goodkov, 1994
Family: Thecamoebidae
Sappinia sp.
Stenamoeba stenopodia (Page, 1969) Smirnov, Nassonova, Chao & Cavalier-Smith, 2007
Thecamoeba quadrilineata (Carter, 1856) Lepşi, 1960
Thecamoeba similis (Greeff, 1891) Lepşi, 1960
Thecamoeba sphaeronucleolus (Greeff, 1891) Schaeffer, 1926
Thecamoeba striata (Penard, 1890) Schaeffer, 1926
Thecamoeba terricola (Greeff, 1866) Lepşi, 1960
Family: Acanthamoebidae
Acanthamoeba spp.
Class: CONOSA
Family: Filamoebidae
Flamella sp.

Phylum: CILIOPHORA
Class: HETEROTRICHEA
Order: HETEROTRICHIDA
Family: Blepharismidae
Blepharisma hyalinum Perty, 1849
Blepharisma steini Kahl, 1932
Class: SPIROTRICHEA
Subclass: PHACODINIIDIA
Order: PHACODINIIDA
Family: Phacodiniidae
Phacodinium metschnicoffi (Certes, 1891) Kahl, 1932
Subclass: HYPOTRICHIA
Order: EUPLOTIDA
Family: Euplotidae
Euplotopsis muscicola (Kahl, 1932) Borror & Hill, 1995
Order: SPORADOTRICHIDA
Family: Amphisiellidae
Amphisiella acuta Foissner, 1982
Circinella filiformis (Foissner, 1982) Foissner, 1994
Family: Gonostomatidae
Gonostomum affine (Stein, 1859) Sterki, 1878
Family: Kahliellidae
Engelmanniella mobilis (Engelmann, 1862) Foissner, 1982
Neowallackia franzi (Foissner, 1982) Berger, 2010
Family: Oxytrichidae
Cyrtohymena candens (Kahl, 1932) Foissner, 1989
Cyrtohymena muscorum (Kahl, 1932) Foissner, 1989
Gastrostyla steinii Engelmann, 1862
Oxytricha granulifera Foissner & Adam, 1983
Oxytricha setigera Stokes, 1891
Sterkiella histriomuscorum (Foissner, Blatterer, Berger & Kohmann, 1991) Foissner, Blatterer, Berger & Kohmann, 1991
Urosoma acuminata (Stokes, 1887) Bütschli, 1889
Urosoma macrostyla (Wrzesniowski, 1866) Berger, 1999
Urosomoida agiliformis Foissner, 1982
Urosomoida agilis (Engelmann, 1862) Hemberger in Foissner, 1982
Family: Trachelostylidae
Hemisincirra gellerti (Foissner, 1982) Foissner in Berger, 2001
Hemisincirra interrupta (Foissner, 1982) Foissner in Berger, 2001
Hemisincirra spp.
Hemisincirra vermicularis Hemberger, 1985
Order: UROSTYLIDA
Family: Epiclintidae
Eschaneustyla terricola Foissner, 1982
Family: Urostylidae
Anteholosticha adami (Foissner, 1982) Berger, 2003
Anteholosticha antecirrata Berger, 2006
Anteholosticha multistilata (Kahl, 1928) Berger, 2003
Anteholosticha sigmoidea (Foissner, 1982) Berger, 2003
Birojimia muscorum (Kahl, 1932) Berger & Foissner, 1986
Caudiholosticha gracilis (Foissner, 1982) Berger, 2006
Caudiholosticha sylvatica (Foissner, 1982) Berger, 2003
Class: LITOSTOMATEA
Subclass: RHYNCHOSTOMATIA
Order: DILEPTIDA

Family: Dimacrocaryonidae
Dimacrocaryon amphileptoides (Kahl, 1931) Jankowski, 1967
Rimaleptus alpinus (Kahl, 1931) Vďačný & Foissner, 2012
Subclass: HAPTORIA
Order: HAPTORIDA
Family: Enchelyodonidae
Enchelyodon armatus (Kahl, 1926) Kahl, 1930
Order: PLEUROSTOMATIDA
Family: Litonotidae
Loxophyllum sp.
Order: PSEUDOHOLOPHRYIDA
Family: Pseudoholophryidae
Pseudoholophrya terricola Berger, Foissner & Adam, 1984
Order: SPATHIDIIDA
Family: Arcuospathidiidae
Arcuospathidium cooperi Foissner, 1996
Arcuospathidium cultriforme scalpriforme (Kahl, 1930) Foissner, 2003
Arcuospathidium muscorum (Dragesco & Dragesco-Kernéis, 1979) Foissner, 1984
Cultellothrix atypica (Wenzel, 1953) Foissner & Xu, 2007
Family: Bryophyllidae
Bryophyllum tegularum Kahl, 1931
Family: Enchelyidae
Enchelys terricola Foissner, 1987
Family: Protospathidiidae
Protospathidium vermiforme Foissner, Agatha & Berger, 2002
Family: Spathidiidae
Apospathidium atypicum (Buitkamp & Wilbert, 1974) Foissner, Agatha & Berger, 2002
Epispathidium amphoriforme (Greeff, 1888) Foissner, 1984
Epispathidium terricola Foissner, 1987
Spathidium claviforme Kahl, 1930
Spathidium hyalinum Dujardin, 1842
Spathidium muscicola Kahl, 1930
Spathidium spathula (Müller, 1773) Moody, 1912
Class: PHYLLOPHARYNGEA
Subclass: PHYLLOPHARYNGIA
Order: CHLAMYDODONTIDA
Family: Chilodonellidae
Chilodonella uncinata (Ehrenberg, 1838) Strand, 1928
Odontochlamys alpestris Foissner, 1981
Odontochlamys convexa (Kahl, 1931) Blatterer & Foissner, 1992
Odontochlamys gouraudi Certes, 1891
Pseudochilodonopsis mutabilis Foissner, 1981
Subclass: SUCTORIA
Order: EXOGENIDA
Family: Paracinetidae
Paracineta lauterborni Sondheim, 1929
Family: Podophryidae
Podophrya libera Perty, 1852
Class: NASSOPHOREA
Order: MICROTHORACIDA
Family: Microthoracidae
Drepanomonas exigua Penard, 1922
Drepanomonas pauciciliata Foissner, 1986
Drepanomonas revoluta Penard, 1922
Drepanomonas sphagni Kahl, 1931
Leptopharynx costatus Mermod, 1914
Microthorax simulans (Kahl, 1926) Kahl, 1931
Stammeridium kahli (Wenzel, 1953) Wenzel, 1969
Order: NASSULIDA
Family: Furgasoniidae
Furgasonia sp. (cf. *trichocystis*)
Order: SYNHYMENIIDA
Family: Scaphiodontidae
Chilodontopsis muscorum Kahl, 1931
Class: PROSTOMATEA
Order: PRORODONTIDA
Family: Plagiocampidae
Plagiocampa difficilis Foissner, 1981
Class: OLIGOHYMENOPHOREA
Subclass: PENICULIA
Order: PENICULIDA
Family: Frontoniidae
Frontonia depressa (Stokes, 1886) Kahl, 1931
Frontonia parameciiformis Wenzel, 1953
Frontonia solea Foissner, 1987
Frontonia terricola Foissner, 1987
Subclass: SCUTICOCILIATIA
Order: PHILASTERIDA
Family: Cinetochilidae
Cinetochilum margaritaceum (Ehrenberg, 1831) Perty, 1849
Sathrophilus muscorum (Kahl, 1931) Corliss, 1960
Family: Cohnilembidae
Kahlilembus attenuatus (Smith, 1897) Foissner, Berger & Kohmann, 1994
Family: Pseudocohnilembidae
Pseudocohnilembus putrinus (Kahl, 1928) Foissner & Wilbert, 1981
Family: Uronematidae
Homalogastra setosa Kahl, 1926
Order: PLEURONEMATIDA
Family: Cyclidiidae
Protocyclidium muscicola (Kahl, 1931) Foissner, Agatha & Berger, 2002
Protocyclidium terricola (Kahl, 1931) Foissner, Agatha & Berger, 2002
Subclass: HYMENOSTOMATIA
Order: HYMENOSTOMATIDA
Family: Tetrahymenidae
Tetrahymena edaphoni Foissner, 1986
Tetrahymena rostrata (Kahl, 1926) Corliss, 1952
Subclass: PERITRICHIA
Order: Sessilida
Family: Scyphidiidae
Scyphidia sp.
Family: Vorticellidae
Vorticellides astyliformis (Foissner, 1981) Foissner, Blake, Wolf, Breiner & Stoeck, 2009
Woodruffia rostrata Kahl, 1931
Class: COLPODEA

Order: COLPODIDA
Family: Bryophryidae
Parabryophrya penardi (Kahl, 1931) Foissner, 1985
Family: Colpodidae
Bresslaua vorax Kahl, 1931
Colpoda aspera Kahl, 1926
Colpoda cucullus (Müller, 1773) Gmelin, 1790
Colpoda ecaudata (Liebmann, 1936), Foissner, Blatterer, Berger & Kohman, 1991
Colpoda elliotti Bradbury & Outka, 1967
Colpoda henneguyi Fabre-Domergue, 1889
Colpoda inflata (Stokes, 1884) Kahl, 1931
Colpoda lucida Greeff, 1888
Colpoda maupasi Enriques, 1908
Colpoda minima (Alekperov, 1985) Foissner, 1993
Colpoda steinii Maupas, 1883
Colpoda tripartita Kahl, 1931
Exocolpoda augustini (Foissner, 1987) Foissner, Agatha & Berger, 2002
Family: Grossglockneriidae
Grossglockneria acuta Foissner, 1980
Nivaliella plana Foissner, 1980
Order: BURSARIOMORPHIDA
Family: Bryometopidae
Bryometopus pseudochilodon Kahl, 1932
Bryometopus sphagni (Penard, 1922) Kahl, 1932
Thylakidium typicum Gellért, 1955
Order: CYRTOLOPHOSIDIDA
Family: Cyrtolophosididae
Cyrtolophosis acuta Kahl, 1926
Cyrtolophosis major Kahl, 1926
Cyrtolophosis muscicola Stokes, 1885
Plesiocaryon elongatum (Schewiakoff, 1892) Foissner, Agatha & Berger, 2002
Family: Kreyellidae
Microdiaphanosoma arcuatum (Grandori & Grandori, 1934) Wenzel, 1953
Orthokreyella schiffmanni Foissner, 1984
Order: PLATYOPHRYIDA
Family: Platyophryidae
Platyophrya spumacola Kahl, 1927
Platyophrya vorax Kahl, 1926
Family: Woodruffiidae
Woodruffia rostrata Kahl, 1931

PHYLUM: ARTHROPODA
Subphylum: CHELICERATA
Order: PSEUDOSCORPIONES
Family: Chthoniidae
Chthonius (Ephippiochthonius) boldorii Beier, 1934
Chthonius (E.) fuscimanus Simon, 1900
Family: Neobisiidae
Neobisium (Neobisium) carcinoides (Hermann, 1804)
Neobisium (N.) carpaticum Beier, 1935
Neobisium (N.) sylvaticum (C.L. Koch, 1835)
Family: Cheliferidae
Dactylochelifer latreillii (Leach, 1817)
Family : Chernetidae
Chernes cimicoides (Fabricius, 1793)
Chernes similis (Beier, 1932)
Allochernes peregrinus Lohmander, 1939
Pselaphochernes scorpioides (Hermann, 1804)
Subphyllum: BRANCHIATA
Order: ISOPODA
Suborder: ONISCIDEA
Family: Trichoniscidae
Hyloniscus riparius (C.L. Koch, 1838)
Family: Platyarthridae
Platyarthrus hoffmannseggii (C.L. Koch, 1838)
Family Agnaridae
Orthometopon planum (Budde-Lund, 1885)
Protracheoniscus politus (C.L. Koch, 1841)
Family: Cylisticidae
Cylisticus convexus (De Geer, 1778)
Family: Trachelipodidae
Trachelipus rathkii (Brandt, 1833)
Trachelipus ratzeburgii (Brandt, 1833)
Porcellium collicola (Verhoeff, 1907)
Family: Porcellionidae
Porcellionides pruinosus (Brandt, 1833)
Family: Armadillidiidae
Armadillidium vulgare (Latreille, 1804)
Subphylum: MYRIAPODA
Class: CHILOPODA
Order: SCOLOPENDROMORPHA
Family: Cryptopidae
Cryptops anomalans Newport, 1844
Cryptops parisi Broelemann, 1920
Order: GEOPHILOMORPHA
Family: Dignathodontidae
Henia illyrica (Meinert, 1870)
Family: Geophilidae
Clinopodes flavidus C.L. Koch, 1847
Geophilus flavus (De Geer, 1778)
Geophilus linearis C.L. Koch, 1835
Family: Linotaeniidae
Strigamia acuminata (Leach, 1814)
Family: Schendylidae
Schendyla nemorensis (C.L. Koch, 1836)
Order: LITHOBIOMORPHA
Family: Lithobiidae
Lithobius agilis C.L.Koch, 1847
Lithobius dentatus C.L.Koch, 1844
Lithobius erythrocephalus C.L.Koch, 1847
Lithobius forficatus (Linnaeus, 1758)
Lithobius lapidicola Meinert, 1872
Lithobius macilentus L. Koch, 1862
Lithobius melanops Newport, 1845
Lithobius mutabilis L. Koch, 1862
Lithobius muticus C.L. Koch, 1847
Lithobius pelidnus Haase, 1880
Lithobius piceus L. Koch, 1862
Lithobius tricuspis Meinert, 1872
Lithobius aeruginosus L. Koch, 1862
Lithobius austriacus (Verhoeff, 1937)
Lithobius crassipes L. Koch, 1862
Class: DIPLOPODA
Order: POLYXENIDA

Family: Polyxenidae
Polyxenus lagurus (Linnaeus, 1758)
Order: GLOMERIDA
Family: Glomeridae
Glomeris hexasticha Brandt, 1833
Glomeris tetrasticha Brandt, 1833
Order: JULIDA
Family: Iulidae
Cylindroiulus boleti (C. L. Koch, 1847)
Enantiulus nanus (Latzel, 1884)
Julus curvicornis Verhoeff, 1899
Kryphioiulus occultus (C. L. Koch, 1847)
Leptoiulus proximus (Nemec, 1896)
Megaphyllum unilineatum (C. L. Koch, 1838)
Ommatoiulus sabulosus (Linnaeus, 1758)
Unciger foetidus (C. L. Koch, 1838)
Unciger transsilvanicus (Verhoeff, 1899)
Order: CHORDEUMATIDA
Family: Mastigophorophyllidae
Haploporatia eremita (Verhoeff, 1909)
Family: Craspedosomatidae
Craspedosoma rawlinsii Leach, 1815
Order: POLYDESMIDA
Family: Paradoxosomatidae
Strongylosoma stigmatosum (Eichwald, 1830)
Family: Polydesmidae
Polydesmus complanatus (Linnaeus, 1761)
Subphyllum: HEXAPODA
Class: INSECTA
Order: DERMAPTERA
Family: Forficulidae
Chelidurella acanthopygia (Géné, 1832)
Order: HETEROPTERA
Family: Tingidae
Campylosteira verna (Fallén, 1826)
Family: Miridae
Lygus rugulipennis Poppius, 1911
Orthops (Orthops) basalis (A. Costa, 1853)
Agnocoris reclairei (Wagner, 1949)
Family: Nabidae
Nabis (Nabis) p. pseudoferus Remane, 1949
Nabis (Nabis) rugosus Linnaeus, 1758)
Family: Anthocoridae
Orius (Heterorius) minutus (Linnaeus, 1758)
Family: Lygaeidae
Nysius s. senecionis (Schilling, 1829)
Kleidocerys r. resedae (Panzer, 1797)
Family: Rhyparochromidae
Drymus (Sylvadrymus) b. brunneus (R. F. Sahlberg, 1848)
Eremocoris a. abietis (Linnaeus, 1758)
Eremocoris podagricus (Fabricius, 1775)
Scolopostethus affinis (Schilling, 1829)
Graptopeltus lynceus (Fabricius, 1775)
Megalonotus chiragra (Fabricius, 1775)
Emblethis griseus (Wolff, 1802)
Family: Piesmatidae
Piesma capitatum (Wolff, 1804)
Piesma maculatum (Laporte, 1833)
Family: Pyrrhocoridae
Pyrrhocoris apterus (Linnaeus, 1758)
Family: Coreidae
Gonocerus acuteangulatus (Goeze, 1778)
Ceraleptus gracilicornis (Herrich-Schaeffer, 1835)
Ceraleptus lividus Stein, 1858
Family: Cydnidae
Legnotus limbosus (Geoffroy, 1785)
Family: Scutelleridae
Eurygaster maura (Linnaeus, 1758)
Family: Pentatomidae
Sciocoris (Aposciocoris) homalonotus Fieber, 1851
Dyroderes umbraculatus (Fabricius, 1775)
Aelia acuminata (Linnaeus, 1758)
Peribalus s. strictus (Fabricius, 1803)
Dolycoris baccarum (Linnaeus, 1758)
Palomena prasina (Linnaeus, 1761)
Eurydema (Eurydemma) ornata (Linnaeus, 1758)
Eurydema (Eurydemma) oleracea (Linnaeus, 1758)
Piezodorus lituratus (Fabricius, 1794)
Family: Acanthosomatidae
Elasmucha g. grisea (Linnaeus, 1758)
Order: COLEOPTERA
Family: Carabidae
Abax parallelopipedus (Piller et Mitterpacher, 1783)
Abax parallelus (Duftschmidt, 1812)
Amara aenea (De Geer, 1774)
Amara ovata (Fabricius, 1792)
Amara saphyrea Dejean, 1828
Aptinus bombarda (Illiger, 1800)
Calathus fuscipes (Goeze, 1777)
Calosoma inquisitor (Linnaeus, 1758)
Carabus convexus Fabricius, 1775
Carabus coriaceus Linnaeus, 1758
Carabus glabratus Paykull, 1790
Carabus granulatus Linnaeus, 1758
Carabus hortensis Linnaeus, 1758
Carabus intricatus Linnaeus, 1761
Carabus nemoralis O. F. Müller, 1764
Carabus scheidleri Panzer, 1799
Carabus ullrichi Germar, 1824
Carabus violaceus Linnaeus, 1758
Cymindis humeralis (Fourcroy, 1785)
Cymindis vaporariorum (Linnaeus, 1758)
Harpalus atratus Latreille, 1804
Harpalus distinguendus (Duftschmidt, 1812)
Harpalus latus (Linnaeus, 1758)
Harpalus tardus (Panzer, 1997)
Molops piceus (Panzer, 1793)
Notiophilus rufipes Curtis, 1829
Ophonus azureus (Fabricius, 1775)
Ophonus gammeli (Schaufberger, 1932)
Panageus bipustulatus (Fabricius, 1775)
Platyderus rufus (Duftschmidt, 1812)
Laemosthenus terricola (Herbst, 1784)
Pseudoophonus rufipes (De Geer, 1774)
Pterostichus burmeisteri Heer, 1841
Pterostichus oblongopunctatus (Fabricius, 1775)
Synuchus vivalis (Illiger, 1798)
Suprafamily: Curculionoidea

Family: Anthribidae
Tropideres albirostris (Herbst, 1783)
Family: Rhynchitidae
Deporaus betulae (Linnaeus, 1758)
Family: Apionidae
Ceratapion gibbirostre Gyllenhal, 1813
Eutrichapion viciae (Paykull, 1800)
Ischnopterapion loti (Kirby, 1808)
Oxystoma craccae (Linnaeus, 1767)
Kalcapion semivittatum (Gyllenhal, 1833)
Protapion fulvipes (Foucroy, 1785)
Protapion trifolii (Linnaeus, 1768)
Trichopterapion holosericeum Gyllenhal, 1833
Family: Curculionidae
Acalles camelus (Fabricius, 1792)
Acalles echinatus (Germar, 1824)
Acalles fallax Boheman, 1844
Acallocrates colonnellii Bahr, 2003
Anthonomus pomorum (Linnaeus, 1758)
Archarius pyrrhoceras (Marsham, 1802)
Bagous argillaceus Gyllenhall, 1836
Barypeithes albinae Formanek, 1903
Barypeithes chevrolati (Boheman, 1843)
Barypeithes pellucidus (Boheman, 1843)
Brachysomus dispar Penecke, 1910
Brachysomus echinatus (Bonsdorff, 1785)
Brachysomus hirtus (Boheman, 1845)
Brachysomus setiger (Gyllenhal, 1840)
Bradybatus fallax Gerstaecker, 1860
Bradybatus kellneri Bach, 1854
Ceutorhynchus alliariae Brisout de Barneville, 1860
Ceutorhynchus erysimi (Fabricius, 1787)
Ceutorhynchus nigritulus Schultze, 1787
Ceutorhynchus obstrictus (Marsham, 1802)
Ceutorhynchus pallidactylus (Marsham, 1802)
Ceutorhynchus scrobicollis (Neresheimer et Wagner, 1924)
Ceutorhynchus typhae (Herbst, 1795)
Coeliodes transverseoalbofasciatus (Goeze, 1777)
Coeliodes trifasciatus Bach, 1854
Curculio glandium Marsham, 1802
Curculio propinquus (Desbrochers, 1868)
Curculio venosus (Gravenhorst, 1807)
Cycloderes pilosus (Fabricius, 1792)
Dorytomus longimanus (Forster, 1771)
Eusomus ovulum Germar, 1824
Furcipus rectirostris (Linnaeus, 1758)
Hypera postica (Gyllenhal, 1813)
Hypera rumicis (Linnaeus, 1758)
Kyklioacalles suturatus (Dieckmann, 1983)
Leiosoma cribrum (Gyllenhal, 1834)
Lignyodes uniformis Desbrochers, 1894
Magdalis flavicornis (Linnaeus, 1758)
Orchestes fagi (Linnaeus, 1758)
Otiorhynchus raucus (Fabricius, 1777)
Otiorhynchus rugosostriatus (Goeze, 1777)
Phyllobius argentatus (Linnaeus, 1758)
Phyllobius oblongus (Linnaeus, 1758)
Polydrusus cervinus (Linnaeus, 1758)
Polydrusus marginatus Stephens, 1831
Polydrusus tereticollis (De Geer, 1775)
Rhinoncus bruchoides (Herbst, 1784)
Ruteria hypocrita (Boheman, 1837)
Sciaphilus asperatus (Bonsdorff, 1785)
Simo variegatus (Boheman, 1843)
Sitona macularius (Marsham, 1802)
Sitona suturalis Stephens, 1831
Stenocarus ruficornis (Stephens, 1831)
Stereonychus fraxini (De Geer, 1775)
Stomodes gyrosicollis (Boheman, 1843)
Trachodes hispidus (Linnaeus, 1758)
Trachyphloeus bifoveolatus (Beck, 1817)
Trachyphloeus scabriculus (Linnaeus, 1771)
Tychius meliloti Stephens, 1831
Tychius picirostris (Fabricius, 1787)
Order: HYMENOPTERA
Family: Formicidae
Subfamily: Ponerinae
Ponera coarctata (Latreille, 1802)
Subfamily: Myrmicinae
Aphaenogaster subterranea (Latreille, 1802)
Leptothorax affinis (Mayr, 1855)
Leptothorax interruptus (Schenck, 1852)
Leptothorax crassispinus Karawajew, 1926
Leptothorax unifasciatus (Latreille, 1798)
Myrmecina graminicola (Latreille, 1802)
Myrmica rubra (Linnaeus, 1758)
Myrmica ruginodis (Nylander, 1846)
Myrmica sabuleti (Meinert, 1860)
Myrmica scabrinodis (Nylander, 1846)
Stenamma westwoodi (Westwood, 1840)
Tetramorium cf. caespitum
Subfamily: Formicinae
Camponotus aethiops (Latreille, 1798)
Camponotus ligniperda (Latreille, 1802)
Formica gagates (Latreille, 1798)
Formica pratensis (Retzios, 1783)
Formica rufa (Linnaeus, 1758)
Lasius alienus (Foerster, 1850)
Lasius brunneus (Latreille, 1798)
Lasius emarginatus (Olivier, 1791)
Lasius fuliginosus (Latreille, 1798)
Lasius niger (Linnaeus, 1758)

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