STRUCTURE OF CENTIPEDE COMMUNITIES (Myriapoda: Chilopoda) IN OAK-HORNBEAM FORESTS OF THE MALÉ KARPATY MTS AND TRNAVSKÁ PAHORKATINA HILLS (SW SLOVAKIA)

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Abstract

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At 8 sites in the Malé Karpaty Mts and 2 sites in the nearby Trnavská pahorkatina hills the taxocoenoses of centipedes (Chilopoda) were studied in the period of 1999 to 2002. The sites have been covered by 40 to 100 year old oak-hornbeam forests. They are situated at the altitude of 240–350 m a.s.l. The samples have recorded the occurrence of *Cryptops anomalans*, *Henia illyrica*, *Clinopodes flavidus*, *Geophilus flavus*, *Strigamia acuminata*, *S. transsilvanica*, *Schendyla nemorensis*, *Lithobius agilis*, *L. borealis*, *L. dentatus*, *L. erythrocephalus*, *L. forficatus*, *L. lapidicola*, *L. latro*, *L. lucifugus*, *L. melanops*, *L. mutabilis*, *L. muticus*, *L. pelidnus*, *L. piceus*, *L. aeruginosus*, *L. austriacus*, *L. crassipes* and *L. microps*. The highest species richness refers to the site of Lošonský háj grove (17), the lowest diversity was recorded in Vinosady (10). The species diversity index (H') and equitability (e) reached their highest value in the community in Lošonský háj grove. *Strigamia acuminata* had the abundance (12.53 ind.m^{-2}) at the site of Naháč–Katarínka 2. The most abundant taxa have included *Schendyla nemorensis* (at Naháč–Katarínka 1–10.16 ind.m^{-2}, Horný háj grove – 9.6 ind.m^{-2}) and *Lithobius austriacus* (at the site of Naháč–Kukovačník – 8.45 ind.m^{-2}). *Schendyla nemorensis* and *Lithobius muticus* may be classified as eudominant species at all the study sites, their dominance was in average 40%. In all the dendrograms of cluster analyses the community at the site of Vinosady is separated from the other ones on the highest level of dissimilarity. The reason lies in the lowest number of determined species, a unique portion of *Cryptops anomalans*, absence of *Strigamia acuminata* and the lowest number of obtained specimens per 4 years. As for the species identity the centipede communities at the sites Lošonský háj grove and Naháč–Katarínka 1 may be classified as the most similar on the 87% level of similarity. The communities at Fúgelka and Horný háj grove are close to each other (92% similarity) from the quantitative-qualitative point of view. Most of the recorded species occured throughout the year. *Strigamia acuminata* and *Lithobius muticus* were recorded continuously from March to November at most of the study sites. *Schendyla nemorensis*, present at all the sites, was often excluded from the species richness in the summertime samples. The typical centipede community in the oak-hornbeam forests of the Malé Karpaty Mts consists of the species: *Schendyla nemorensis*, *Strigamia acuminata*, *Lithobius agilis*, *L. borealis*, *L. lapidicola*, *L. mutabilis*, *L. muticus*, *L. austriacus*; in more southern drier parts of the Malé Karpaty Mts *Henia illyrica* as well.

Key words: Chilopoda, centipedes, species diversity, equitability, dominance, abundance, Malé Karpaty Mts, Trnavská pahorkatina hills, SW Slovakia

Introduction

Centipedes play a significant role in stabilization of numerous terrestrial ecosystems. In C. Europe the species of the genus *Lithobius* have been well analysed from this point of view. Their ontogeny enables them to react promptly onto changes of environmental conditions. This actually originates in their continual egg lying, development during the whole year being proved by a high number of juveniles sampled at the study sites from March to November, slow ontogeny, late sexual maturation under unsuitable ecological conditions as well as an ability to starve for a long time. In C. Europe their portion in energetic flows approximately equals to 13% of predatory arthropods living in a forest fallen leaf horizon (Albert, 1983). Centipedes may be considered as predatory arthropods with a long lifespan. As K-strategists they play an important role in final interactions of trophic chains amongst organisms of oak-hornbeam forest epigeon. They are typical by low average density of species. According to our results density of the species in the Malé Karpaty Mts in 1999–2002 only rarely exceeded a value of 12 ind.m^{-2}.

The existing data declare that their distribution is determined by soil texture, depth of a leaf litter layer, ability of soil including a leaf litter layer to keep humidity, quantity of wood litter and presence of bigger stones on the soil surface. An influence of soil chemism on centipedes has not been sufficiently known. In fact it has a more significant effect on hypogeous species (Geophilomorpha) than the species active on the surface (Lithobiomorpha) (Dunger, 1983, 1993).

In fact the centipedes of the Malé Karpaty Mts have not been studied in detail yet. The oldest record refers to Attems (1895), who mentioned the species *Geophilus longicornis* var. *austriaca* [= *Geophilus flavus* (D e G e e r, 1778)] from the Kamzík hill (Bratislava, southern part of the Malé Karpaty Mts). Data on *Scutigera coleoptrata* from the southern part of the Malé Karpaty Mts were published by plenty of authors in the first half of the 20th century, the knowledge on distribution of this species in Slovakia have been summarized by Országh (2001). Dobroruka (1966) published records on *Pachymerium tristanicum* [? = *Geophilus flavus* (D e G e e r, 1778)] from Svätý Jur. The species *Strigamia acuminata* (Zbojnícka jaskyňa cave) and *Lithobius forficatus* (Čachtická jaskyňa cave) were captured in caves, respectively in the Malé Karpaty Mts (Országh et al. 1994). The more complex information on centipede diversity in the northern part of the Malé Karpaty Mts have appeared in the paper by Országh (2002). Drdul (1997) analysed changing density of soil macrofauna during the vegetation period in the oak forests rounding the Nuclear Power Station Mochovce, on east from the Malé Karpaty Mts.

Study area

In 1976 the Malé Karpaty Mts were established as a Protected Landscape Area covering a total of 65,504 ha. They are situated in the western part of Slovakia lining from Bratislava towards the town of Nové Mesto nad Váhom on NE at the total length of 100 km. Its maximum broadness (16 km) appears between Lozorno and Sv. Jur near Bratislava, the minimum one (3 km) in the section of Čachtice – Prašník. The altitude ranges from 132 m a.s.l. (near the Danube river) to 768 m a.s.l. (the Záruby Mount). The main range of the mountains grows up to the altitude of 450–650 m a.s.l. the Malokarpatský kras karst is a specific area of these mountains, covering approx. 180 km^2.

The Malé Karpaty Mts belong to the gently warm climatic zone with an mean annual temperature of 7–9 °C. At the altitudes of over 400 m the temperature declines under 8 °C. In average the vegetation period (average daily temperature 10 °C) takes 180 days, at the higher altitudes under 160 days. The annual precipitations (in the Malé Karpaty Mts) reach 650–900 mm, in lowlands they decline onto 600–650 mm.

From the phytogeographic point of view the mountains belong to the area of the West Carpathian flora with dominating forest stands, which have been replaced by vineyards on SE and NW and by bushy pastures, orchards and farmland on N. From the zoogeographic point of view the mountains have been classified into the Subcarpathian district of the deciduous forest province in the Eurosibirian subprovince. The province of steppes of the Pannonian district partially appears rounding the study area. The mountains are inhabited by colinous and submountainous elements, communities of forests, woody steppes and rocky biotopes. Thermophilous species infiltrate from lowlands into the S and SE slopes. The species diversity has been significantly influenced by warm Hungarian lowland.

Study sites

The study sites are located in forest stands (Zlinská et al., 2005, Fig. 1). The sites Cajla (CA); Vinosady (VI); Fúgelka (FU); Lošonec–lom quarry (LL); Lošonský háj grove (LH); Naháč–Kukovačník (NA); Naháč–Katarínka 1, young forest (NK1) and Naháč–Katarínka 2, old forest (NK2) are situated in the zone of oak-hornbeam forests on SE slopes of the Malé Karpaty Mts. The sites Lindava (LI) and Horný háj grove (HH) are located in the boundary zone of the Malé Karpaty Mts and Trnavská pahorkatina hills in the zone of oak and oak-hornbeam forests with diverse degree of anthropogenous impact (deforestation, forest tracks, presence of heavy mechanisms, tractors, etc.). The altitude varies between 240 to 350 m a.s.l. The soils may be considered as acid with pH values of 3.8–5.0. However the sites Lošonec–lom quarry (LL) and Naháč–Katarínka 2, old forest (NK2) have a gently acid reaction, or rather neutral (pH 6.47–6.75). The distance between the first site – Cajla (CA) and the last and most northern one – Naháč–Katarínka 1, young forest (NK1) is 30 km (through the air line). The sites are situated in the zone of oak and oak-hornbeam forests with diverse degree of anthropogenous impact.

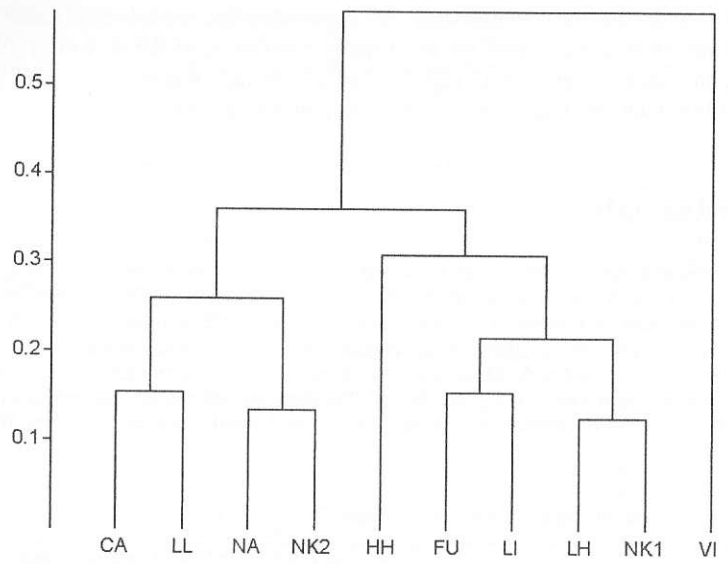


Fig. 1. Hierarchical classification of centipede communities in the forest epigaeon at the study sites according to their species presence/absence similarity (Sørensen's index, complete linkage). Vertical axis = dissimilarity, abbreviations of study sites see text.

Cajla (CA) [Databank of the Slovak Fauna 7669c grid reference number] – 80 to 100 year old oak-hornbeam forest at the altitude of 260–280 m, with S exposition.

Vinosady (VI) [7669d] – 60 to 80 year old oak-hornbeam forest at the altitude of 280 m, with NW exposition.

Fúgelka (FU) [7669b] – 80 to 100 year old oak-hornbeam forest at the altitude of 350 m, with S exposition.

Lindava (LI) [7670a] – 80 to 100 old oak forest in lowland at the altitude of 240 m.

Horný háj grove (HH) [7570b] – 60 to 80 year old oak-hornbeam forest at the altitude of 240 m, with SW exposition.

Lošonec–lom quarry (LL) [7570a] – 80 to 100 year old oak-hornbeam forest at the altitude of 340 m, with SW exposition. The site is regularly impacted by limestone dust imissions close to the quarry.

Lošonský háj grove (LH) [7570b] – 80 to 100 year old oak-hornbeam forest at the altitude of 260 m, with N exposition and with a 15–20 cm deep fallen leaf horizon at many sites. Under the leaf litter the soil has a lumpy texture being humid in a dry year period too.

Naháč–Kukovačník (NA) [7471c] – 40 to 60 year old oak-hornbeam forest at the altitude of 300 m, with NE exposition. The forest is completely surrounded by farmland.

Naháč–Katarínka 1, young forest (NK1) [7471a] – 40 to 60 year old oak-hornbeam forest at the altitude of 340 m, with NW exposition.

Naháč–Katarínka 2, old forest (NK2) [7471a] – 80 to 100 year old oak forest with lindens and maple trees at the altitude of 320 m, with SE exposition.

The map with the study sites and the more detailed pedological and botanical analyses of the study sites as well as the climatic conditions in the period of 1999–2002 are given in the paper Zlinská et al. (2005). The site Naháč–Katarínka 2 (NK2) has been characterized in detail in the paper by Drdulová, Zlatošová (1980).

Material and methods

The centipede sampling refers to the years of 1999–2002 at 9 study sites, at the site Horný háj grove (HH) it has included 3 years (2000–2002). At all the sites the samples were collected in the monthly intervals form March till October, resp. November. The January samples 2000–2002 were excluded from the general evaluation. They served to confirm presence of juveniles and imagines in the winter period. In total the material includes 8,303 centipedes. 6,154 individuals of them have been determined (Table 1). The analyses exclude the damaged specimens. 1,843 juveniles and 306 damaged specimens were not determined. The material is deposed at the Department of Zoology, Faculty of Natural Sciences, Comenius University in Bratislava.

T a b l e 1. Survey of the centipedes (Chilopoda) recorded.

Species	CA	VI	FU	LI	HH	LH	LL	NA	NK 1	NK 2
	a	a	a	a	aa	a	a	a	a	a
Cryptops anomalans N e w p o r t, 1844	0	3	0	0	0	0	0	0	0	0
Henia illyrica (M e i n e r t, 1870)	0	8	0	0	0	0	0	0	0	9
Clinopodes flavidus C. L. K o c h, 1847	3	3	2	5	7	1	0	9	5	3
Geophilus flavus (D e G e e r, 1778)	0	0	26	2	0	4	34	0	0	0
Strigamia acuminata (L e a c h, 1814)	94	0	120	47	22	96	46	165	104	401
Strigamia transsilvanica (V e r h o e f f, 1928)	3	0	2	0	5	4	8	0	2	4
Schendyla nemorensis (C. L. K o c h, 1836)	84	82	90	130	144	151	223	154	325	96
Lithobius agilis C. L. K o c h, 1847	6	0	39	0	17	30	29	40	49	102
Lithobius borealis M e i n e r t, 1868	4	0	8	14	0	8	1	0	3	0
Lithobius dentatus C. L. K o c h, 1844	0	0	0	0	0	0	0	1	0	2
Lithobius erythrocephalus C. L. K o c h, 1847	0	2	3	33	0	12	13	15	6	1
Lithobius forficatus (L i n n a e u s, 1758)	4	0	6	3	2	27	5	7	18	4
Lithobius lapidicola M e i n e r t, 1872	12	1	8	6	0	13	14	4	7	9
Lithobius latro M e i n e r t, 1872	0	9	2	3	0	0	0	4	0	0
Lithobius lucifugus L. K o c h, 1862	2	0	0	0	0	0	0	0	0	0
Lithobius melanops N e w p o r t, 1845	0	0	0	0	0	3	0	4	0	1
Lithobius mutabilis L. K o c h, 1862	10	1	110	25	25	33	51	91	137	72
Lithobius muticus C. L. K o c h, 1847	165	78	121	164	101	114	99	148	246	128
Lithobius pelidnus H a a s e, 1880	1	0	0	0	9	5	1	5	0	0
Lithobius piceus L. K o c h, 1862	0	0	0	0	0	0	0	0	2	0
Lithobius aeruginosus L. K o c h, 1862	0	3	0	0	6	0	0	0	0	0
Lithobius austriacus (V e r h o e f f, 1937)	3	0	0	202	20	36	0	279	150	85
Lithobius crassipes L. K o c h, 1862	3	0	0	28	12	1	0	5	31	2
Lithobius microps M e i n e r t, 1868	0	0	0	0	0	1	1	0	2	0
Lithobius sp. juven.	78	34	214	336	45	155	117	363	286	215
Lithobius sp. damaged	16	9	56	29	23	33	23	47	44	26
Total	488	233	807	1027	438	727	665	1341	1417	1160

Abbreviations of study sites (CA → NK 2) see chapter "Study sites"; a – a total of the specimens recorded in 1999–2002; aa – a total number of the specimens recorded in 2000–2002

For collection of the samples of centipedes as well as mesostigmatid mites (Fenďa, Ciceková, 2005), pseudoscorpiones (Christophoryová, Krumpál, 2005), beetles of Curculionoidea (Holecová at al., 2005) a square method was used. The leaf litter was sieved from a total area of 1 m^2 (16 squares of 25x25 cm). The samples were transported in the textile pockets into the laboratory. The centipedes were extracted in the Moczarski-Winkler's eclectors (Holdhaus, 1910; Balogh, 1958) and have been preserved in 75% ethylalcohol. Generally 285 samples have been obtained (Table 2). Occasionally for a more detailed analysis of diagnostic characters the temporal slides were made in 40 % butyric acid. Five degrees have been used for dominance evaluation: eudominant, dominant, subdominant, recedent, subrecedent (Schwerdtfeger, 1975). Species diversity (diversity of communities) have been calculated according to the Shannon index (Odum, 1971; Spellerberg, Fedor, 2003). All the pairs of diversity values have been compared by the t-test (Poole, 1974). The cluster analysis of the centipede community refers to the NCLAS program (Podani, 1993). The cluster method of complete linkage have been based on Sřrensen's and Wishart's indices.

T a b l e 2. Number of elaborated samples at individual study sites in 1999–2002.

	CA	VI	FU	LI	HH	LH	LL	NA	NK 1	NK 2	Total
1999	7	4	7	8	0	8	7	8	8	8	65
2000	6	6	8	5	4	8	7	8	8	8	68
2001	7	7	8	8	6	4	9	8	8	8	73
2002	8	6	10	9	5	8	8	9	8	8	79
Total	28	23	33	30	15	28	31	33	32	32	285

Abbreviations of study sites (CA → NK 2) see text

The values of species data used in the cluster analysis (Wishart similarity ratio) were transformed with log-trans-formation Y' = log(Y+1), which increase the relative rate of rare species that are mostly good indicators.

Results and discussion

Species diversity, equitability and species diversity test

In the period 1999–2002 the method of leaf litter sieving at 10 sites in the Malé Karpaty Mts led to record 24 centipede species (Table 1) of the families Cryptopidae, Dignathodontidae, Geophilidae, Linotaeniidae, Schendylidae and Lithobiidae. The family of Lithobiidae (17 of the total 24 taxa) may be classified as the most represented. The same fact was published by Stašiov (2002) from the Kremnické vrchy Mts, the Kováčovská dolina valley (15 lithobiid species of the total 27 taxa); by Tajovský (2000) from the Krkonoše Mts, the Czech Republic (in total 15, Lithobiidae 11); by Wytwer (1990) from the Mazovian lowland, Poland (in total 17, Lithobiidae 12); and by Karafiat (1970) from the surroundings of Darmstadt, Germany (in total 15, Lithobiidae 8). In the southern parts of Europe the portion of Lithobiidae appears to be lower; Loksa (1966) presented 13 species (6 of them Lithobiidae) from the Bükk Mts, Hungary; Minelli (1982) recorded 23 species (9 of them Lithobiidae) from northeast Italy, and Zapparoli (1992) 22 taxa (9 of them Lithobiidae) from Central Italy.

Mean number of species per one study site in the Malé Karpaty Mts grows up to 13.7. A higher value (16.75) was declared by Stašiov (2002) in the forest community of

T a b l e 3. Species diversity test (Poole, 1974) and main coenological variables of the centipede communities at the study sites in 1999–2002.

Study site	CA	VI	FU	LI	HH	LH	LL	NA	NK 1	NK 2
CA	*0.000*	383.729	692.378	723.332	814.925	789.531	763.070	619.603	587.312	687.471
VI	2.923**	*0.000*	271.273	277.205	323.290	308.669	382.173	245.378	236.882	263.016
FU	4.849***	6.995***	*0.000*	1192.238	1000.489	1042.413	652.737	1197.151	1148.810	1309.710
LI	4.062***	6.384***	0.979ns	*0.000*	1072.760	1126.817	681.378	1380.397	1339.283	1484.267
HH	2.892**	5.404***	1.973ns	1.093ns	*0.000*	1058.675	774.936	963.152	911.256	1073.229
LH	7.071***	8.715***	3.175**	4.025***	4.661***	*0.000*	748.594	1034.353	980.198	1150.105
LL	2.794**	5.211***	1.503ns	0.746ns	0.187ns	3.914***	*0.000*	581.452	550.880	645.713
NA	5.141***	7.231***	0.073ns	1.136ns	2.168*	3.341**	1.629ns	*0.000*	1968.531	1815.597
NK 1	5.226***	7.298***	0.075ns	1.171ns	2.218*	3.423***	1.656ns	0.000ns	*0.000*	1845.931
NK 2	2.361*	5.103***	3.436***	2.375*	0.963ns	6.343***	1.034ns	3.844***	3.976***	*0.000*
No. sp.	14	10	13	13	12	17	13	15	15	15
MA [ind.m^{-2}]	14.1	8.6	16.3	22.1	24.7	19.3	16.9	28.2	34	28.7
e	0.600	0.567	0.740	0.721	0.697	0.731	0.725	0.702	0.702	0.640
c	0.280	0.360	0.179	0.204	0.242	0.170	0.242	0.186	0.188	0.248
H'	**1.583**	**1.306**	**1.899**	**1.850**	**1.787**	**2.072**	**1.801**	**1.902**	**1.902**	**1.734**

Abbreviations of study sites (CA → NK 2) see text;
t-test values under the diagonal, degrees of freedom above diagonal.
Significance levels: *** = $P < 0.001$; ** = $0.001 < P < 0.01$; * = $0.01 < P < 0.05$; ns = $0.05 < P$ (non-significant);
No. sp. – total number of species; MA [ind.m^{-2}] – mean abundance; e – Pielou's index of equitability;
c – Simpson's index of species dominance; H' – Shannon's index of species diversity

Eu-Fagenion. Wytwer (1990) recorded in average 6 species per site in the forest stand *Tilio-Carpinetum* and 5.33 species in *Potentillo albae-Quercetum*. Moreover there have been published some more data on this matter, e.g. Karafiat (1970) mentioned 9 species per site in a mixed pine-deciduous forest, Loksa (1966) 12.7 in the community of *Ceraso-Quercetum clematidetosum*, Zapparoli (1992) on average 6.4 in an oak forest stand (*Quercetea ilicis*) and 6.16 in a beech community (*Fagetalia sylvaticae*). The comparisons mentioned above emphasise a relatively high species diversity of centipedes in the Malé Karpaty Mts, despite different sampling methods as well as forest communities.

The highest species richness (17) in Malé Karpaty Mts refers to the site of Lošonský háj grove (LH). This is the 80–100 year old oak-hornbeam forest commonly with a 15–20 cm deep leaf litter horizon. The specimens have been represented with a high value of equitability (0.731) and were involved 3 eudominant, 4 dominant and 2 subdominant species with the lowest value of Simpson's index of dominance (0.170) (Tables 3, 4).

T a b l e 4. Mean dominance (%) of the centipede species at the study sites in 1999–2002.

Species	CA	VI	FU	LI	HH	LH	LL	NA	NK 1	NK 2
Cryptops anomalans		1.58								
Henia illyrica		4.21								0.98
Clinopodes flavidus	0.76	1.58	0.37	0.76	1.89	0.18		0.97	0.46	0.33
Geophilus flavus			4.84	0.30		0.74	6.48			
Strigamia acuminata	23.86		22.35	7.12	5.95	17.81	8.76	17.72	9.57	43.63
Strigamia transsilvanica	0.76		0.37		1.35	0.74	1.52		0.18	0.43
Schendyla nemorensis	21.32	43.16	16.76	19.70	38.92	28.01	42.48	16.54	29.90	10.45
Lithobius agilis	1.52		7.62		4.59	5.56	5.52	4.30	4.51	11.01
Lithobius borealis	1.01		1.49	2.12		1.48	0.19		0.28	
Lithobius dentatus								0.11		0.22
Lithobius erythrocephalus		1.05	0.56	5.00		2.23	2.48	1.61	0.55	0.11
Lithobius forficatus	1.01		1.12	0.45	0.54	5.01	0.95	0.75	1.66	0.43
Lithobius lapidicola	3.05	0.53	1.49	0.91		2.41	2.67	0.43	0.64	0.98
Lithobius latro		4.74	0.37	0.45				0.43		
Lithobius lucifugus	0.51									
Lithobius melanops						0.56		0.43		0.11
Lithobius mutabilis	2.54	0.53	20.48	3.79	6.76	6.12	9.71	9.77	12.60	7.83
Lithobius muticus	41.88	41.05	22.53	24.85	27.30	21.15	18.86	15.90	22.63	13.93
Lithobius pelidnus	0.25				2.43	0.93	0.19	0.54		
Lithobius piceus									0.18	
Lithobius aeruginosus		1.58			1.62					
Lithobius austriacus	0.76			30.61	5.40	6.68		29.97	13.80	9.25
Lithobius crassipes	0.76			4.24	3.24	0.18		0.54	2.85	0.22
Lithobius microps						0.18	0.19		0.18	

Abbreviations of study sites (CA → NK 2) see text

On the contrary the maximum value of the dominance index refers to the centipede coenosis at the site of Vinosady (VI) (c = 0.360). The community was represented by 10 species, including two thermophilous centipedes, *Cryptops anomalans* and *Henia illyrica*. Low equitability (0.567) in the species structure at Vinosady (VI) hints at the

fact, that most of the collected specimens (160) belong to 2 eudominant centipedes, *Schendyla nemorensis* and *Lithobius muticus*. *Schendyla nemorensis* (more than 43%) (Table 4) may be classified as the most dominant species in the taxocoenosis.

Apart from the determined species the samples at each site included juveniles and damaged specimens of the genus *Lithobius* (Table 1) excluded from the analyses. Juveniles occurred in the samples throughout the period of observation (March–November) and their abundance varied between 1 and 40, usually with a value of 5 to 15 specimens per sample. An exceptional abundance of 79 juveniles appeared at the site Naháč–Kukovačník (NA) on July 6, 2000.

Generally continual occurrence reflects in egg lying and juvenile ontogeny throughout the year. Regular oscillation in abundance of juveniles throughout the year was not recorded. There were less damaged specimens in the samples. Their abundance varied from 1 to 18, usually 2 to 5 specimens per sample. In the 4-year long research (1999–2002) the juveniles were absent only occasionally, for instance in the sample from November 8, 2002 (site NK1, air temperature 0 to -1 °C). However the sample from November 11, 2000 at the same site (air temperature 4–5 °C) contained 4 juveniles.

The t-test values clearly declare that the sites Cajla (CA) and Vinosady (VI) are the most different from the other (Table 3). The species diversity index (H') hints at high species richness at the sites. The highest diversity (2.072) refers to the community at Lošonský háj grove (LH), on the contrary the lowest value (1.306) appears at Vinosady (VI) with 10 species being recorded by the sieving method. The study site Vinosady is warm, however considerably drier during most of the year.

Dominant species in the centipede communities in the Malé Karpaty Mts

In accordance with the average values of dominance, only *Schendyla nemorensis* and *Lithobius muticus* belonged to the eudominant species at all study sites. Their dominance varied between 10 and 40% (Table 4). Mean abundance of *Schendyla nemorensis* had the values from 3 to 10 ind.m^{-2}, with the maximum of 10.16 ind.m^{-2} at the site of Naháč–Katarínka 1 (NK1) (Table 5). The site has been covered by 40–60 year old oak and hornbeam forest with a suitable soil texture and humidity as well as a rich litter horizon, providing suitable shelters. *Lithobius muticus*, the second dominant species, at all study sites had a dominance 15 to 40%, with an average value of 3 to 8 ind.m^{-2}. The species *Strigamia acuminata* was eudominant at 5 sites (CA, FU, LH, NA, NK2), *Lithobius austriacus* at 3 sites (LI, NA, NK1) and *L. mutabilis* at 2 sites (FU, NK1) only.

Similar data on abundance of centipedes were proved by numerous authors from various areas of Slovakia and other European countries. Stašiov (2002) published, that *L. mutabilis* was the most abundant in the forest community of *Eu-Fagenion*. In *Querceto-Fagetum* resp. *Fagetum quercino-abietinum*, the species *Lithobius forficatus* was the most common one (Stašiov, Maršalek, 1998). Tajovský (2000) presented the subspecies *L. mutabilis sudeticus* as the most frequent and most distributed centipede in the Krkonoše National Park, occurring up to the highest altitudes (over 1500 m a.s.l.). Wytwer (1990) considered *L. mutabilis* as the most abundant species in the forest stands

of *Potentillo albae-Quercetum* and *Tilio-Carpinetum*. In the Bükk Mts (study site Bélkő) Loksa (1966) recorded *Lithobius muticus* as the most common with abundance of 17.6 to 43.2 ind.m^{-2} in summertime. *L. calcaratus* and *Schendyla nemorensis* were the most frequent centipedes in the pine-deciduous forests on wind-flown sands in the surroundings of Darmstadt (Karafiat, 1970). In relation to our fauna there are the interesting Zapparoli's (1992) records of *Strigamia acuminata* in Central Italy in beech forests only. In the Malé Karpaty this species commonly occurred in oak stands at lower altitudes.

Table 5. Mean abundance (ind.1m^{-2}) of the centipede species at the study sites in 1999–2002.

Species	CA	VI	FU	LI	HH	LH	LL	NA	NK 1	NK 2
Cryptops anomalans		0.13								
Henia illyrica		0.35								0.28
Clinopodes flavidus	0.11	0.13	0.06	0.17	0.47	0.04		0.27	0.16	0.09
Geophilus flavus			0.79	0.07		0.14	1.10			
Strigamia acuminata	3.36		3.64	1.57	1.47	3.43	1.48	5.00	3.25	12.53
Strigamia transsilvanica	0.11		0.06		0.33	0.14	0.26		0.06	0.12
Schendyla nemorensis	3.00	3.56	2.73	4.33	9.60	5.39	7.19	4.67	10.16	3.00
Lithobius agilis	0.21		1.18		1.13	1.07	0.93	1.21	1.53	3.18
Lithobius borealis	0.14		0.24	0.47		0.29	0.03		0.09	
Lithobius dentatus								0.03		0.06
Lithobius erythrocephalus		0.09	0.09	1.10		0.43	0.42	0.45	0.19	0.03
Lithobius forficatus	0.14		0.18	0.10	0.13	0.96	0.16	0.21	0.56	0.12
Lithobius lapidicola	0.43	0.43	0.24	0.20		0.46	0.45	0.12	0.22	0.28
Lithobius latro		0.39	0.06	0.10				0.12		
Lithobius lucifugus	0.07									
Lithobius melanops						0.11		0.12		0.03
Lithobius mutabilis	0.36	0.04	3.33	0.83	1.67	1.18	1.64	2.76	4.28	2.25
Lithobius muticus	5.89	3.39	3.67	5.47	6.73	4.07	3.19	4.48	7.69	4.00
Lithobius pelidnus	0.04				0.60	0.18	0.03	0.15		
Lithobius piceus									0.06	
Lithobius aeruginosus		0.13			0.40					
Lithobius austriacus	0.11			6.73	1.33	1.29		8.45	4.69	2.66
Lithobius crassipes	0.11			0.93	0.80	0.04		0.15	0.97	0.06
Lithobius microps						0.04	0.03		0.06	

Abbreviations of study sites (CA → NK 2) see text

The biggest portion of subrecendent species with their dominance under 1% was represented at the sites of NA – 8 species, NK1 – 7 species, NK2 – 9 species (Table 4). Generally regular occurrence of the hygrophilous species *Lithobius agilis* at most of the sites, its eudominant position at NK2, dominant at FU, LH and LL and subdominant at HH, NA and NK1 corresponds with a relatively high degree of humidity in leaf litter during the whole year in central as well as northern part of the Malé Karpaty Mts. A lack of *L. agilis* at the sites Vinosady (VI) and Lindava (LI) indicates a drier and warmer character of oak-hornbeam forests in the southern part of the Malé Karpaty Mts and Trnavská pahorkatina hills.

Seasonal occurrence of centipedes at the study sites in the Malé Karpaty Mts

The months of occurrence of the species at 10 study sites are presented in the Table 6. Most of the determined species were recorded throughout the whole sampling period from March to November 1999–2002. *Lithobius dentatus* and *L. aeruginosus* are the only species, recorded in several specimens in spring months (March, May) and at the beginning of autumn (September). Some of the species were found at different sites in spring and the autumnal months; *Clinopodes flavidus* occurred at the sites Lindava (LI) and Lošonský háj grove (LH) just in April and May and at Fúgelka (FU) in October and November only. The other species, *Strigamia acuminate* and *Lithobius muticus* were confirmed at most of the sites continuously from March to November. *Schendyla nemorensis*, the species occurring at all the study sites, was often absent in the samples from the summer months (June, July, August) (CA absence in June; HH, NA in July; LI, LH in August; NK2 in June–July) . The analyses of the centipede assemblages in the Malé Karpaty Mts in the period of 1999–2002 declare, that most of the recorded species occur throughout the year, even in wintertime, as being proved by the background samples from January 2000–2002 (excluded from the analyses).

Hierarchical classification of the centipede communities (Sørensen's index, complete linkage)

The classification of the ten centipede communities according to their species diversity is shown in the dendrogram (Fig. 1). The dendrogram is split out into the community at Vinosady (VI) and a cluster of the other 9 communities on the similarity level of 42%. The reason of this separated position lies in a low number of species (10), the occurrence of *Cryptops anomalans*, which was not recorded at the other sites and (on the contrary a) the lack of *Strigamia acuminata*, occurring at all the sites except for VI.

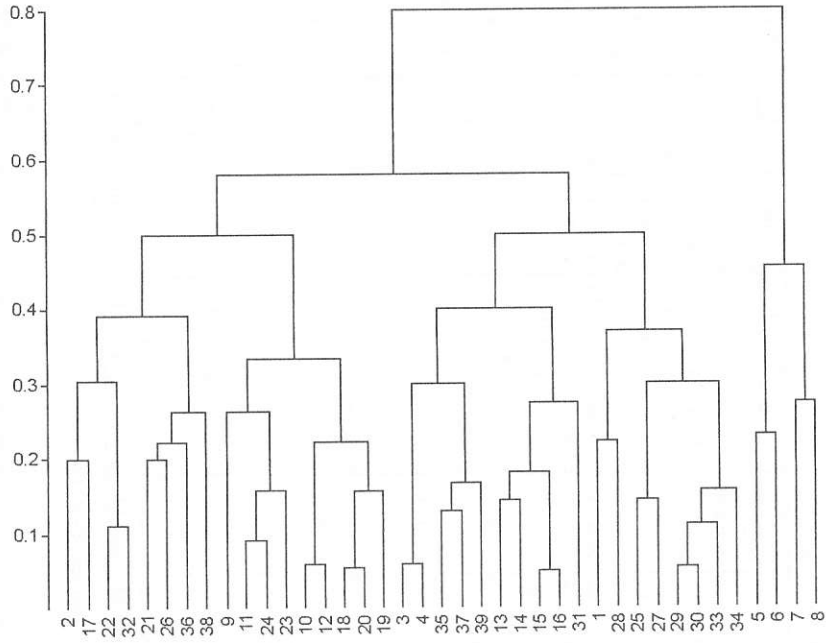
The communities of 9 sites are differentiated on the similarity level of 64% into 2 clusters – CA-LL-NA-NK2 and HH-FU-LI-LH-NK1 determined by a different numbers of mutual species. The first cluster (CA-LL-NA-NK2) has 21 species with seven of them mutual: *Strigamia acuminata*, *Schendyla nemorensis*, *Lithobius agilis*, *L. forficatus*, *L. lapidicola*, *L. mutabilis* and *L. muticus*. The second cluster (HH-FU-LI-LH-NK1) has 20 species and 6 mutual ones: *Clinopodes flavidus*, *Strigamia acuminata*, *Schendyla nemorensis*, *Lithobius forficatus*, *L. mutabilis* and *L. muticus*. *Henia illyrica* and *Lithobius dentatus* appear in the first cluster only, *L. piceus* and *L. aeruginosus* do just in the second cluster. Of the 18 species mutual for both clusters, there are only *Strigamia acuminata*, *Schendyla nemorensis*, *Lithobius forficatus*, *L. mutabilis* and *L. muticus* represented in all 9 centipede communities. On the similarity level of 68% the second cluster is split out with a separate community at the site HH consisting of 12 species. As for the species identity the communities LH and NK1 are the most similar (87%), on the contrary the highest difference appears between the communities at VI and LH-NK1 (46%).

Table 6. Occurrence of centipedes in months at the study sites.

Species	CA	VI	FU	LI	HH	LH	LL	NA	NK 1	NK 2
Cryptops anomalans		6–7,9								
Henia illyrica		4–6,8–9								4–7,10
Clinopodes flavidus	3,8,10	6.8	10–11	4–5	6,8,10	4		4–7,10	3,6–8	4,6,10
Geophilus flavus			3–11	3–4		4,6,9,11	4–11			
Strigamia acuminata	3,5–11		3–11	4–11	5–6,8–11	3–11	4–11	3–11	3–11	3–11
Strigamia transsilvanica	3.7		11		4–6,10–11	4.11	4–5,7–9		7–8	7–8,10–11
Schendyla nemorensis	3–5,7–11	4–9,11	3–10	3–7,9–11	4–6,8–11	3–7,9–11	4–11	3–6,8–11	3–11	3–5,8–11
Lithobius agilis	6,8,10–11		4–11		4–6,8–11	3–11	4,6–11	4–11	3–11	3–11
Lithobius borealis	7		5,7,9	3–8,10–11		5,8–9,11	4		5,8,11	
Lithobius dentatus								5		3.9
Lithobius erythrocephalus		5	4	3–9,11		5,8,11	4,6–8,11	3,5,9–11	4–5,7,11	8
Lithobius forficatus	5–6,9		4,6–7,9	5	5	3–11	5–7,11	4-6,10–11	4–8,11	8-9
Lithobius lapidicola	5,7–11	5	3–7,9	5.1		5–10	5,8–10	3.5	4,6-8	
Lithobius latro		4–9,11	7	10				5		
Lithobius lucifugus	5.7									
Lithobius melanops						7–8		8.9		6
Lithobius mutabilis	3–5,10	4	3–11	4–6,10–11	4–5,8–11	3–11	4–11	4–11	3–11	3–11
Lithobius muticus	3–11	4–6,8	3–8,10–11	4–11	4–11	3–11	4–11	3–11	3–11	3–11
Lithobius pelidnus	10				8–10	4.6	9	3.6		
Lithobius piceus									4.6	
Lithobius aeruginosus		3			9					
Lithobius austriacus	6			3–11	4–6,8–11	3–11		3–11	3–11	3–11
Lithobius crassipes	7			4–5,8–11	5, 8,10–11	11		3.1	3–5,7–11	4.8
Lithobius microps						9	4		7	
Lithobius sp. juven.	4–5,7–11	4–8	3–11	3–11	4–11	4–11	4–11	3–11	3–11	3–11
Lithobius sp. damaged	4–7,9–11	4–7,11	4–7,9–11	4–6,8,10	4–5,7–10	3–6,9,11	4–5,8–9	3–11	3–8,10–11	3–9

Abbreviations of study sites (CA → NK 2) see text; 3 → 11 = March → November

Oscillation in stability of the species structure at the study sites is shown on the Fig. 2. The communities are classified according to all the years of the study (1999–2002). On the similarity level of 20% the dendrogram is split out again into the community at the site VI and the other coenoses. Low species richness at the site VI in each year (1999, 2001 – 6 species; 2000 – 7 species; 2002 – 5 species) seems to be significant enough to establish a separate cluster. The dendrogram declares higher stability of the communities at the sites VI and LI. Their structure changed with a low significance during the 4 years. The communities at the site VI were on the 54 % level of simiarity, at LI this had the value of 82%. The community at VI was more similar in 1999–2000 (more than 75%) than in the period of 2001–2002 (less than 75%).



Order of the sites:
1–4 CA 1999, 2000, 2001, 2002; **5–8 VI** 1999, 2000, 2001, 2002;
9–12 FU 1999, 2000, 2001, 2002; **13–16 LI** 1999, 2000, 2001, 2002;
17–19 HH 2000, 2001, 2002; **20–23 LH** 1999, 2000, 2001, 2002;
24–27 LL 1999, 2000, 2001, 2002; **28–31 NA** 1999, 2000, 2001, 2002;
32–35 NK 1 1999, 2000, 2001, 2002; **36–39 NK 2** 1999, 2000, 2001, 2002.

Fig. 2. Hierarchical classification of centipede communities in the years 1999–2002 at the study sites according to their presence/absence similarity (Sørensen's index, complete linkage). Vertical axis = dissimilarity, abbreviations of study sites see text.

The analyses show even higher value of similarity from the communities at LI – in the period of 1999–2000 app. 85%, later in 2001–2002 95%. The sites CA and FU have couples of years which are differentiated by one splitting only. CA has very similar communities just in the period of 2001–2002 (app. 95%). FU likely in 2000, 2002 (app. 95%). The species structure in the communities at the other sites changed more significantly in the years 1999–2002, they are divided by several splittings.

Hierarchical classification of the centipede communities (Wishart's index, complete linkage)

The centipede communities at the study sites in the Malé Karpaty Mts has split out into the coenosis at the site Vinosady (VI) and the cluster of the other sites on the similarity level of 31 %. The community at VI differs from the others with the lowest species richness (10) as well as total quantity of obtained specimens (233, 190 of them identified) (Table 3). On the similarity level of 57% the 9 communities were classified into a couple of communities FU-HH and the cluster with NA, NK1, NK2, LH, CA, LL and LI communities. In the pair of FU-HH the communities are the most similar (92%) from the qualitative-quantitative point of view. They may be defined by low species richness (FU – 13 species, HH – 12 species). The material from these sites includes 17 determined species, with mutual *Clinopodes flavidus*, *Strigamia acuminata*, *S. transsilvanica*, *Schendyla nemorensis*, *Lithobius agilis*, *L. forficatus*, *L. mutabilis* and *L. muticus*. The communities at NA, NK1, NK2 and LH being situated in the northern part of the Malé Karpaty Mts and with their similarity of 80% belonged to the richest from the qualitative as well as quantitative point of view. During the period of 4 years the sampling obtained almost 2,500 specimens and 20 determined species at these sites (Table 1).

Under the centipede community classification in the period of 1999–2002 (Fig. 4) the community at the site VI has been separated from the other sites on the similarity level of approximately 21% (as in the dendrogram on the Fig. 2). The highest stability (the lowest oscillations in the qualitative and quantitative structures) appears in the coenoses at the site VI (similarity of 68% in 1999–2002), FU (similarity of 75% in 1999–2002), HH (similarity of 78% in 2000–2002). At the site CA the centipede community was stabile only in the years 2000–2002, in 1999 the structure was quite different. The community at NA declared its stability in the period of 1999–2001 however in the last year of studying (2002) the structure significantly changed. The dendrogram (Fig. 4), which explains classification of the communities, takes several variables into account, such as presence or absence of a species and its abundance. The level of stability in the communities during the research period is projected more precisely.

The comparison of the community similarity according to the Sørensen's (Fig. 1) as well as Wishart's indices (Fig. 3) enables us to conclude the separated position of the community at VI and a close position of the communities at CA-LL. The communities at NA, NK1, NK2 and LH correspond with a high value of similarity according to the Wishart's index, however they are divided into the couples of NA-NK2 a LH-NK1 on

the level of 64% similarity according to the Sørensen's index. The level of similarity amongst the communities as well as their stability in the period of 1999–2002 is projected on the Figs 2 and 4 more precisely.

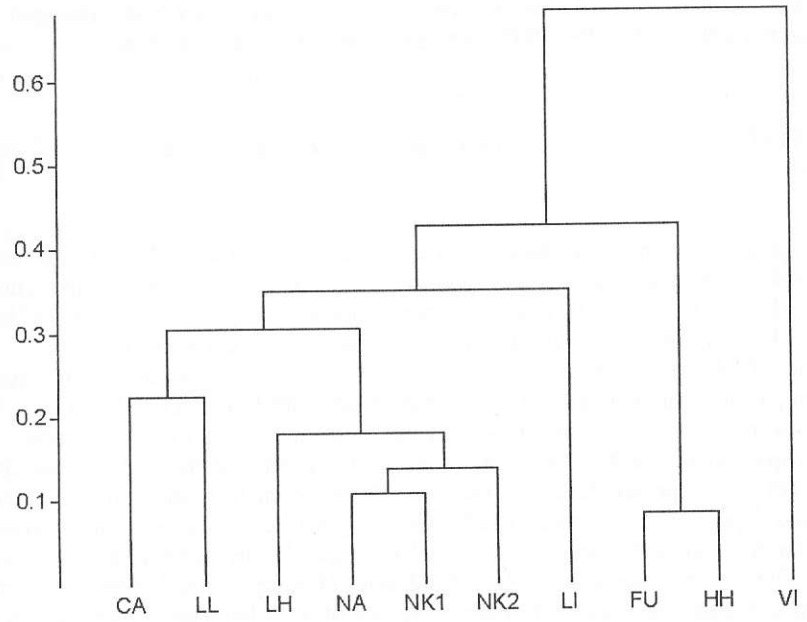


Fig. 3. Hierarchical classification of centipede communities in the forest epigaeon at the study sites according to their abundance similarity (Wishart's index, complete linkage). Vertical axis = dissimilarity, abbreviations of study sites see text.

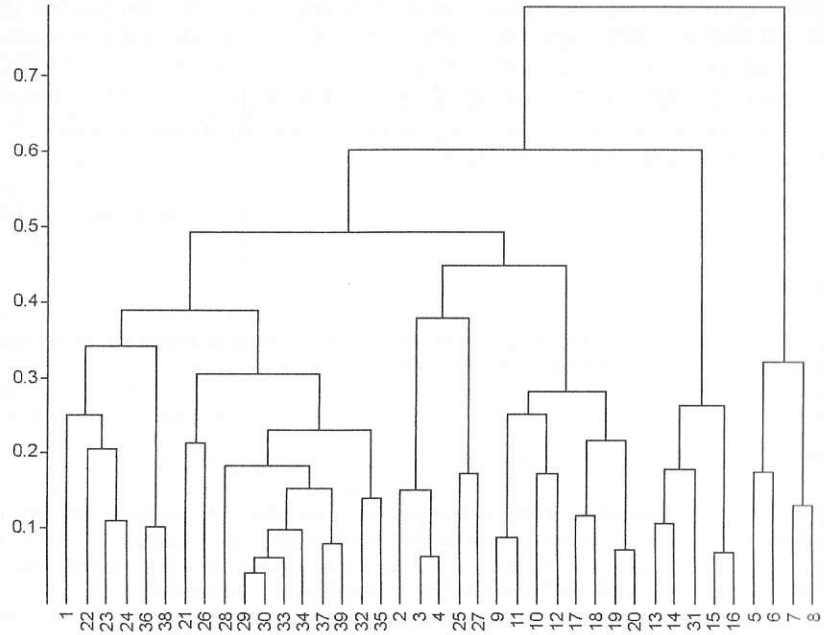
Conclusion

The centipede (Chilopoda) communities in the Malé Karpaty Mts were studied at 9 sites in the period of 1999–2002 and at the site of Horný háj grove in 2000–2002. The communities were sampled in monthly intervals from March to October (resp. November). In total 8,303 specimens were obtained, 6,154 of them were determined. 1,843 juveniles and 306 damaged specimens were excluded from the analyses.

In total 24 species have been determined (Table 1). The widest species spectrum (17) refers to the site Lošonský háj grove. This is the centipede community with high equitability (0.731), 3 eudominant, 4 dominant and 2 subdominant species and with the lowest value of the dominance index (0.170).

On the contrary the highest value of the dominance index refers to the community at Vinosady (0.360), being formed by 10 species including thermophilous *Cryptops anomalans* and *Henia illyrica*. Low equitability (0.567) has been determined by

Schendyla nemorensis and *Lithobius muticus*, which formed the majority (160) of the sampled specimens. The species *Schendyla nemorensis* reached the highest value of dominance (43%).



Order of the sites:
1–4 CA 1999, 2000, 2001, 2002; **5–8 VI** 1999, 2000, 2001, 2002;
9–12 FU 1999, 2000, 2001, 2002; **13–16 LI** 1999, 2000, 2001, 2002;
17–19 HH 2000, 2001, 2002; **20–23 LH** 1999, 2000, 2001, 2002;
24–27 LL 1999, 2000, 2001, 2002; **28–31 NA** 1999, 2000, 2001, 2002;
32–35 NK 1 1999, 2000, 2001, 2002; **36–39 NK 2** 1999, 2000, 2001, 2002

Fig. 4. Hierarchical classification of centipede communities in the years 1999–2002 at the study sites according to their abundance similarity (Wishart's index complete linkage). Vertical axis = dissimilarity, abbreviations of study sites see text.

The t-test declares that the sites of Cajla and Vinosady are the most different from the other sites. The species diversity index hints at high species richness at these sites. The highest value (2.072) appeared in the community from Lošonský háj grove, the lowest one (1.306) at Vinosady with only 10 species obtained by the sieving method.

Schendyla nemorensis and *Lithobius muticus* were eudominant species at all the study sites. The values of their dominance varied between 10 and 40%. The mean abundance of *Schendyla nemorensis* ranged between 3 and 10 ind.m^{-2}, the highest value (10.16 ind.m^{-2}) refers to the site of Naháč–Katarínka 1. Dominance of *Lithobius muticus* reached the values between 15 and 40%, its mean abundance varied from 3 to 8 ind.m^{-2}.

The research in 1999–2002 enables us to conclude that most of the recorded centipedes occur throughout the year including wintertime.

The community similarity dendrograms, based on Sørensen's and Wishart's indices declare separated position of the community at Vinosady and close relation between the communities at CA-LL with similarity level of 85% and 77%. The coenoses NA, NK1, NK2 and LH hint at a high degree of similarity (the Wishart's index dendrogram). The Sørensen's index of similarity has differentiated the couples of NA-NK2 and LH-NK1 on the 64% level of similarity. Oscillation of the stability in qualitative and quantitative structure of centipedes at the study sites is presented by the dendrograms, which classify the communities from the years 1999–2002.

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Országh I., Országhová Z.: **Štruktúra taxocenóz stonožiek** (Myriapoda: Chilopoda) **dubovo-hrabových lesov Malých Karpát a Trnavskej pahorkatiny (JZ Slovensko).**

V období rokov 1999–2002 sme na 8 študijných plochách v Malých Karpatoch a 2 plochách na Trnavskej pahorkatine študovali taxocenózy stonožiek (Chilopoda). Plochy boli pokryté 40 až 100 ročným porastom dubovo-hrabového lesa. Situované boli v nadmorskej výške 240–350 m n.m. Vo vzorkách sme zaznamenali výskyt *Cryptops anomalans, Henia illyrica, Clinopodes flavidus, Geophilus flavus, Strigamia acuminata, S. transsilvanica, Schendyla nemorensis, Lithobius agilis, L. borealis, L. dentatus, L. erythrocephalus, L. forficatus, L. lapidicola, L. latro, L. lucifugus, L. melanops, L. mutabilis, L. muticus, L. pelidnus, L. piceus, L. aeruginosus, L. austriacus, L. crassipes* a *L. microps*. Najvyššia hodnota druhového bohatstva (17) zodpovedá ploche Lošonský háj, najnižšia diverzita (10) bola zistená vo Vinosadoch. Index druhovej rozmanitosti (H') a ekvitabilita (e) dosiahli najvyššiu hodnotu v spoločenstve v Lošonskom háji.*Strigamia acuminata* mal

druhú najvyššiu hodnotu abundancie 12,53 jedincov na m^2 na ploche Naháč–Katarínka 2. K ďalším taxónom s vysokými hodnotami priemernej abundancie patrili *Schendyla nemorensis* na ploche Naháč–Katarínka 1 (10,16 ind.m^{-2}), na ploche Horný háj (9,6 ind.m^{-2}) a *Lithobius austriacus* na ploche Naháč–Kukovačník (8,45 ind.m^{-2}). *Schendyla nemorensis* a *Lithobius muticus* môžeme klasifikovať ako eudominantné druhy na všetkých študijných plochách, ich dominancia dosiahla priemernú hodnotu 40%. Na všetkých dendrogramoch zhlukovej analýzy je spoločenstvo na ploche Vinosady oddelené od ostatných na najvyššej hladine nepodobnosti. Príčinou je najnižší počet determinovaných druhov, unikátne zastúpenie *Cryptops anomalans*, absencia *Strigamia acuminata* a najnižší počet nazbieraných exemplárov za 4 roky. Z hľadiska druhovej identity sú na 87% úrovni najpodobnejšie spoločenstvá stonožiek LH – NK 1. Spoločenstvá dvojice FU – HH sú z hľadiska kvalitatívno-kvantitatívneho zloženia najbližšie až s 92% podobnosťou. Väčšina zistených druhov sa vyskytuje počas celého roka. *Strigamia acuminata* a *Lithobius muticus* boli na väčšine lokalít zistené súvisle od marca do novembra. *Schendyla nemorensis*, druh zastúpený na všetkých lokalitách, často absentoval vo vzorkách z letných mesiacov. Charakteristické spoločenstvo stonožiek dubovo-hrabových lesov Malých Karpát je zložené z druhov *Schendyla nemorensis*, *Strigamia acuminata*, *Lithobius agilis*, *L. borealis*, *L. lapidicola*, *L. mutabilis*, *L. muticus*, *L. austriacus*, v južnejších suchších častiach Malých Karpát tiež *Henia illyrica*.

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MILLIPEDE COMMUNITIES (Diplopoda) OF OAK-HORNBEAM ECOSYSTEMS (THE MALÉ KARPATY MTS, TRNAVSKÁ PAHORKATINA HILLS, SW SLOVAKIA)

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Abstract

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

Millipede communities were studied in ten oak-hornbeam forest localities in the central and northern part of the Malé Karpaty Mts and the Trnavská pahorkatina hills. The research was conducted during the years 1999–2002. Millipedes were sampled using a dry sieve method from the leaf litter within each locality. In total, 3,654 individuals belonging to 18 millipede species were recorded. The records of *Julus curvicornis* are of the highest faunistic importance. It is an endemic species of the West Carpathian region. The westernmost locality of its occurrence was found in the Malé Karpaty Mts. Influence of selected environmental factors on the structure of millipedes communities was discussed.

Key words: Diplopoda, millipedes, Malé Karpaty Mts, Trnavská pahorkatina hills, Slovakia

Introduction

The Malé Karpaty Mts are relatively well-known area of Slovakia concerning the millipede fauna. Data about the millipedes in these mountains were subsequently published by Ortvay (1902), Lang (1933, 1954), Gulička (1955, 1956, 1986), Mišík et al. (1974), Krumpál (1993) and Mock, Janský (2000). Gulička (1986) presented the most comprehensive study with checklist of 30 millipede species from forest communities in the Malé Karpaty Mts Concerning the Trnavská pahorkatina hills, no data about the millipede fauna have been published up to present.

This paper presents the results of the millipede research realized at ten oak-hornbeam forest localities situated in the central and the northern part of the Malé Karpaty Mts and the Trnavská pahorkatina hills.