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The influence of stand density on the structure of centipede (Chilopoda) and millipede (Diplopoda) communities in the submountain beech forest

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Abstract

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The paper deals with the effect of stand density on the community composition of centipede (Chilopoda) and millipede (Diplopoda) communities. The study was conducted in Kováčovská dolina valley (Kremnické vrchy Mts, Central Slovakia) in 1997 and 1998 by pitfall trapping. In total, 17 species of centipedes from 4 families and 7 species of millipedes from 6 families were recorded. The intensity of previous thinning influenced the species structure of both studied communities. Species richness increased with increasing intensity of past thinning, especially for centipede communities. The effect of stand density was apparent for all but eurythopic species, namely: *Lithobius forficatus*, *Lithobius mutabilis* (Chilopoda) and *Unciger foetidus*, *Polydesmus complanatus* (Diplopoda).

Key words

beech forest, centipedes, Chilopoda, Diplopoda, Kováčovská dolina valley, Kremnické vrchy Mts, millipedes, stand density, Slovakia

Introduction

Centipedes and millipedes belong to the soil invertebrates, which respond quickly to environmental changes. Temperature and humidity of soil are considered the main abiotic factors influencing the structure of millipede communities (Branquart et al., 1995; Meyer et al., 1999; Gava, 2004). Besides that, the character of their communities is markedly influenced by vegetation. For example, the species structure of communities of both these groups is markedly influenced by stand density, which determine microclimate, the amount and quality of leaf litter and other environmental variables related to centipede and millipede distribution.

The impact of vegetation on community structure of Myriapoda was studied by Bokor (1993), Dangerfield (1992), David et al. (1999), Korsós (1997), Madari et al. (1996a, 1996b), Meyer and Singer (1997), Rahmani and Mayvan (2003), Stašiov and Maršalek (1998), Stašiov et al. (2012b), Tuf and Ožanová (1998), etc.

The work brings results of two-year research, dealing with the influence of stand density on the structure of centipede and millipede communities in the submountain beech forest.

Material and methods

The research was carried out on 4 research plots (marked as S1 to S4) situated in the Kováčovská dolina valley (Kremnické vrchy Mts) (48°38′ N, 19°4′ E). The altitude of experimental sites is 450–475 m a.s.l. All experimental sites were placed on the same slope with 30% gradient and western exposure. The soil on the experimental sites is a loamy-clay cambisol with the depth of 51–70 cm.

The forest stand consists of *Fagus sylvatica* (62% dominance), *Abies alba* (22%), *Quercus dalechampii* (7%), *Carpinus betulus* (6%) and *Tilia cordata* (3%). Its age is on average 90 years.

The stand density was modified on the experimental sites S1 (0.3 – heavy thinning), S2 (0.5 – moderate thinning) and S3 (0.7 – light thinning) in February, 1989. The last stationary (S4) remained without changes.

The research was carried out in 1997 and 1998 by pitfall trapping. The invertebrates were trapped on each of the experimental sites in 5 pitfall traps, placed on a contour line in a 5 m distance. 0.7l cylindrical jars with an upper diameter of 7.5 cm and a depth of 14 cm were used for this purpose. They were filled with 10% formaldehyde to one-third of their volume.

In both years of the investigations, the traps were exposed from April, 4 to October, 31. The trapped invertebrates were collected at 30-day intervals. The obtained samples were stored in 70% ethyl alcohol and are deposited at the author's workplace.

The Shannon-Weaver index of species diversity (*H'*) using the natural logarithm was used to compare the diversity of centipede and millipede communities on individual plots (Shannon, 1948). The evenness of communities (*E*) was calculated using the Shannon-Weaver index (Begon et al., 1990).

The species similarity of experimental sites was evaluated by means of hierarchical clustering. The cluster analysis was conducted using STATISTICA for Windows 5.1. (StatSoft, Inc., 1999) with Euclidean distance and Ward´s clustering algorithm.

An ordination analysis was used to gain more insight to species composition of sites. Principal coordinate analysis (PCoA) with Bray-Curtis dissimilarity was applied to square-root transformed species data. PCoA was performed in R language (R Development Core Team, 2011).

Results and discussion

In total, 970 individuals of centipedes and 675 individuals of millipedes were obtained. The occurrence of 17 species of centipedes from 4 families and 7 species of millipedes from 6 families was recorded on the studied area (Table 1).

The ascertained species structure of both studied communities of Myriapoda responds to the condition of environment in the submountain beech forests. The high species diversity, especially in centipedes, reflects a relatively low disturbance of the studied area.

The high species richness of centipede communities was also discovered by the other authors. For example, Poser (1988) found 10 centipede species in the beech forests near Göttingen in the North Germany. Stašiov et al. (2012a) revealed the occurrence of 12 centipede species in an enclave of the beech forest in Boky National Nature Reserve (Slovakia). Leśniewska (2000) discovered 19 centipede species at one beech forest site. Leśniewska (1997) found as many as 21 centipede species in the beech forests located in the Buki nad Jeziorem Lutomskim National Nature Reserve (Poland).

The high species richness of centipede communities in beech forests results from the fact that the beech forests offer very favourable habitats for several species. The most species rich in centipede communities can be found in this type of forest stands. Almost one third of all centipede species in Slovakia (42 species) can be found in the beech forests (monocultures or mixed forests).

Diplopodocoenoses of the beech forests are mostly species-poor. Altogether 43 millipede species were found in the beech forests of Slovakia. Communities of these stands are formed by euryvalent species and species of submontane and montane forests. However, some millipede species occurring in the beech forests are not strictly bounded to over-story composition but rather to other environmental conditions and therefore they occur also in other forest stand as well as in open habitats.

Most of the recorded species belong to the native European fauna with a relatively frequent occurrence in Slovakia. They are wide-spread in various forest habitats from lowlands to mountains. Nevertheless, the records of *J. curvicornis* (Diplopoda) are considered especially important. A Carpathian-endemic *J. curvicornis* is hither-to known only from Slovakia and Hungary (Bükk Mts), although its occurrence is also supposed in the Polish part of the High Tatras Mts. In Slovakia, this species is frequent especially in deciduous and coniferous forests with higher altitudes.

In addition to the list of myriapod species presented above, the occurrence of the following further species is known on the same experimental sites from the previous investigations: *Geophilus insculptus* Attems, 1895, *Lithobius borealis* Meinert, 1868 (Stašiov, 1998), *Schendyla nemorensis* (C. L. Koch, 1836), *Clinopodes linearis* (C. L. Koch, 1835), *Lithobius burzenlandicus* Verhoeff, 1931, *Lithobius crassipes* L. Koch, 1862, *Lithobius curtipes* C. L. Koch, 1847, *Lithobius microps* Meinert, 1868, *Lithobius muticus* C. L. Koch, 1847 (Stašiov, 2002) and millipedes *Polyxenus lagurus* (Linnaeus, 1758), *Craspedosoma rawlinsi* Leach, 1814 (Diplopoda) (Stašiov, 1998, 2002). In total, the occurrence of 26 species of centipedes and 9 species of millipedes has been known from Kováčovská dolina valley so far.

The intensity of previous thinning influenced especially the species richness of the studied communities on the observed sites. Species richness increased with increasing intensity of past thinning, especially for centipede communities (Table 1). The elevated species richness was probably caused by the occurrence of species that are able to tolerate more open habitats such as centipedes *S. crassipes*, *L. aeruginosus*, *L. dentatus* and *L. erythrocephalus*. On the other hand, sensitive forest

Table 1. The total epigeic activity of the species found out in 1997–1998 and diversity measures of centipede and millipede communities (*H´* – Shannon index, *E* – evenness)

Family / Species	Experimental site				∑
	S1	S2	S3	S4	
Geophilidae					
Geophilus flavus (De Geer. 1778)	1	1		1	3
Dignathodontidae					
Strigamia acuminata (Leach. 1814)	2		3	3	8
Strigamia crassipes (C. L. Koch. 1835)	1		1		2
Cryptopidae					
Cryptops parisi Brolemann. 1920	1		1	1	3
Lithobiidae					
Lithobius aeruginosus L. Koch. 1862	1				1
Lithobius agilis C. L. Koch. 1847	8				8
Lithobius austriacus (Verhoeff. 1937)		1			1
Lithobius dentatus C. L. Koch. 1844		1	1		2
Lithobius erythrocephalus C. L. Koch. 1847	1		1		2
Lithobius forficatus (Linnaeus. 1758)	44	124	77	111	356
Lithobius lapidicola Meinert. 1872	1	6		4	11
Lithobius macilentus L. Koch. 1862		2			2
Lithobius melanops Newport. 1845	2				2
Lithobius mutabilis L. Koch. 1862	117	160	101	118	496
Lithobius salicis Verhoeff. 1925	1	1			2
Lithobius tenebrosus Meinert. 1872			1		1
Lithobius tricuspis Meinert. 1872		1			1
Lithobius spp. juvenils	26	17	11	10	64
Lithobius spp. damaged	3		1	1	5
Glomeridae					
Glomeris hexasticha Brandt. 1833	44	40	45	33	162
Polyzoniidae					
Polyzonium germanicum Brandt. 1837			2		2
Julidae					
Julus curvicornis Verhoeff. 1899	29	34	41	41	145
Unciger foetidus (C. L. Koch. 1838)	35	8	37	6	86
Mastigophorophyllidae					
Mastigona bosniensis (Verhoeff. 1897)	5	10	9	13	27
Paradoxosomatidae					
Strongylosoma stigmatosum (Eichwald. 1830)	1			1	2
Polydesmidae					
Polydesmus complanatus (Linnaeus. 1761)	59	38	106	38	241
∑ centipede ex.	209	314	198	249	970
∑ centipede spp.	12	9	8	6	17
H´ – centipede communities	1.06	0.90	0.90	0.87	
E – centipede communities	0.43	0.41	0.43	0.49	
∑ millipede ex.	173	130	240	132	675
∑ millipede spp.	6	5	6	6	7
H´ – millipede communities	1.47	1.44	1.43	1.47	
E – millipede communities	0.82	0.89	0.80	0.82	

species may temporary disappear from the sites with lower stand density. The species richness of millipede communities was more or less similar across all stands.

The influence of stand density on the occurrence of saprophagous macroarthropoda (including millipedes) was ascertained by David et al. (1999) on 27 localities near Mas de Cazarils in southern France. They found that the species diversity was the highest on open stands. Both the frequency and the total biomass of saprophagous macroarthropoda were lower on dense stands.

Species richness and Shannon index of species diversity of both groups increased with increasing intensity of past thinning (Table 1). Different pattern was found for evenness where the highest values for centipedes and millipedes were reached at the reference stand S4 and moderate thinning stand S2, respectively.

The similarity of experimental sites was evaluated by cluster analysis using the data on the total epigeic activity of individual species during the entire period of investigations. The results did not demonstrate a significant influence of stand density on the species structure of both investigated communities. Nevertheless, we supposed that the eurythopic species (*L. forficatus, L. mutabilis, P. complanatus* and *U. foetidus*) markedly influenced the results of cluster analysis by their high epigeic activity on all the experimental sites compared (Table 1). Considering this fact, the data of all the eurythopic species were excluded from the further analysis.

The following cluster analysis separates stationary S1 from the others as the most different in terms of the community structure (Fig. 1). The other 3 experimental sites form a separate cluster. The experimental sites S2 and S4 are the most similar, while the stationary S3 is grouped with them as less similar.

The separation of the site S1 from the other experimental sites is apparently due to the different environmental conditions. While the site S1 has the lowest stand density and tree crown canopy, it is the only site where the compact understorey of a new generation of trees develops underneath the main tree layer. In all probability, this thick understorey influenced the microclimatic characteristics of the soil surface layers.

The different environmental conditions on the site S1 in comparison with S2–S4 can also be caused by the ecotone effect, which was the most marked on S1. This site is characterised by the highest difference between the stand density of its forest and the stand density of a forest that encloses it. Bokor (1993) also adverted on the influence of an ecotone effect on centipede communities in her work. This author studied the epigeic mac-

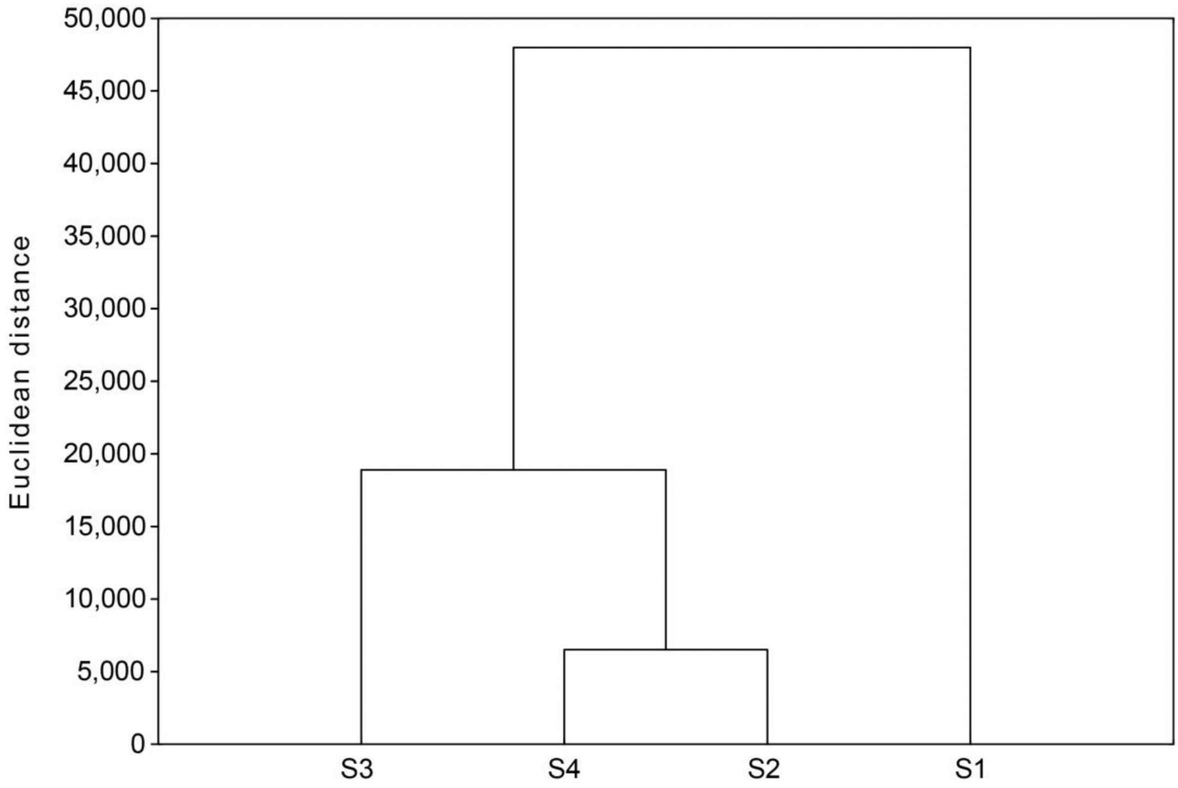

Fig. 1. Community similarity of experimental sites as revealed by the hierarchical cluster analysis using Ward´s method and Euclidean distances.

rofauna in the beech forests of Bükk Mts (Hungary). She found that the frequency of centipedes was twice higher on ecotone sites than on forest sites.

Tuf and Ožanová (1998) demonstrated the influence of ecotone on the epigeic activity of millipedes in chosen localities in Litovské Pomoraví Protected Landscape Area. Using the cluster analysis, they showed a close correlation between the character of habitat and the structure of millipede communities. They found that millipedes had the highest epigeic activity on an ecotone between a floodplain forest and an arable land.

PCoA, like cluster analysis, revealed that stands S2 and S4 were the most similar in term of the total epigeic activity of individual species during the entire period of investigations (Fig. 2). Centipedes *L. forficatus*, *L. lapidicola*, *L. mutabilis* and millipede *M. Bosniensis* were typical for these stands (Fig. 1, Table 1). Millipede *P. complanatus* and centipede *L. agilis* dominated at S3 and S1 stands, respectively.

Summary

Based on the obtained results we can conclude that the changed density of a mature forest in the submountain beech forests by previous thinning may significantly influence the structure of studied communities of epigeic macrofauna only when a very intensive thinning is used and the stand density is reduced to 0.3 or less. The stand density did not influence all the studied species alike. We must therefore analyse the influence of this factor on the structure and the dynamics of individual populations of epigeic fauna separately. The aspiration to generalize the relation of this group to the stand den-

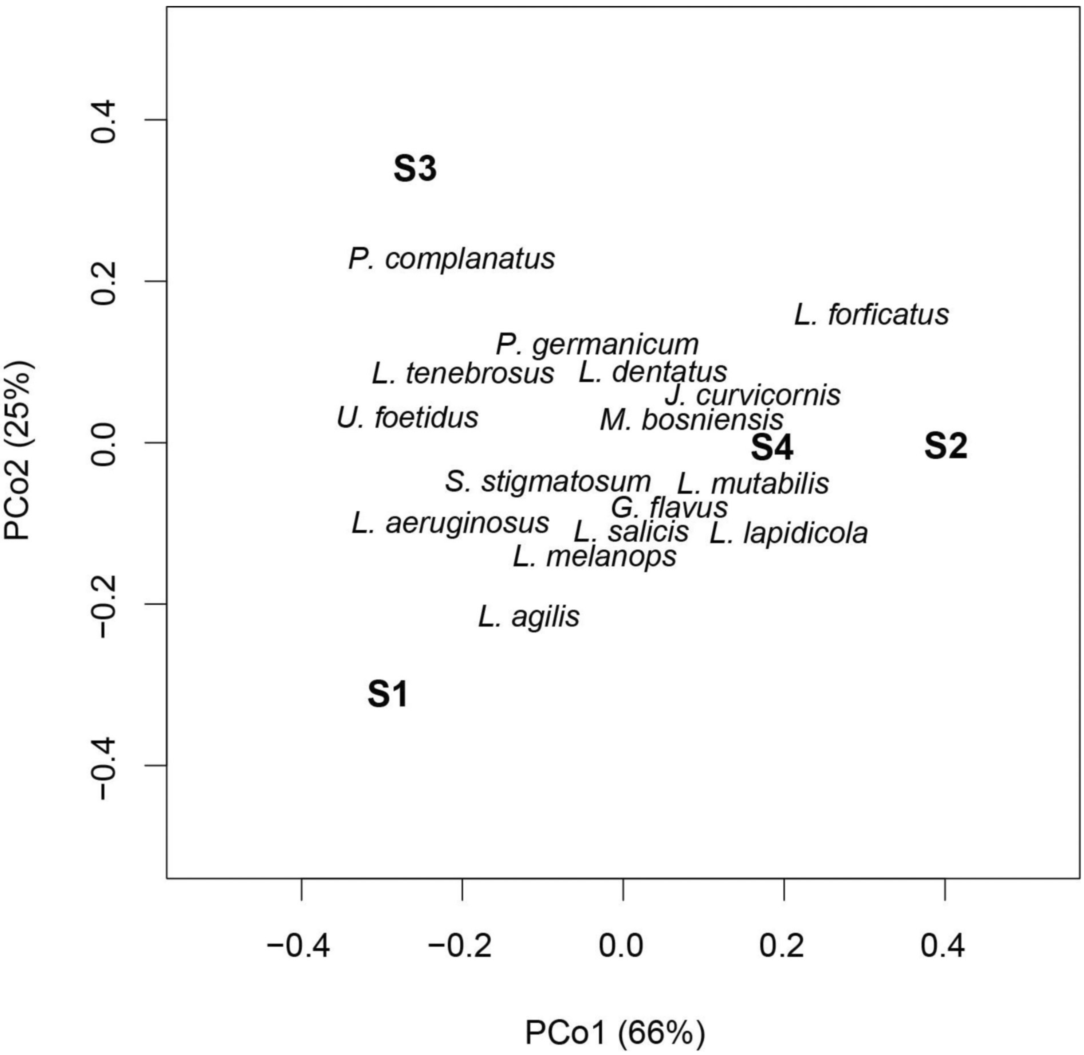

Fig. 2. Results of PCoA on square-root transformed species data. Variation explained by particular axis is given in parentheses. Ordination plot is scaled symmetrically. Only species with higher ordination scores are displayed.

sity is defective in terms of using these invertebrates in biomonitoring of environment.

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