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BIOLOGICAL DIVERSITY OF MYRIAPOD COMMUNITIES (DIPLOPODA, CHILOPODA) ON THE MADARA PLATEAU, NORTH-EASTERN BULGARIA

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Abstract: *The assessment of the biodiversity of natural complexes has a significant practical application and can be used as a sample for the analysis of the role of environment in the spread and bio-geographic distribution of species, the models of faunogenesis and the establishment of the specific biota. The aim of this research is to study the α- and β-diversity of millipede and centipede communities in the various habitats along the Madara Plateau, North-eastern Bulgaria. The material for the analysis was collected through pitfall traps, arranged in lines of ten on eleven sampling plots, which have been reported on a monthly basis in the period June 2012 - February 2015. A total of 3415 myriapods have been collected – 2776 millipedes of 12 species and 639 centipedes of 16 species. The millipede communities feature higher diversity in species and a comparatively higher degree of equality compared to those of the centipede communities. The forest habitats along the Madara Plateau are characterized with high diversity of millipede communities, while the open areas are the preferred habitat of Chilopoda.*

Keywords: *α-diversity, β-diversity, biodiversity, Diplopoda, Chilopoda.*

Introduction: Nowadays the preservation of biodiversity is one of the main environmental issues. It has already gained global significance as its reduction leads to destabilization of the biota, violation of the integrity of the biosphere and the conditions for the existence and sustainable development of mankind.

All activities in terms of biodiversity preservation should be based on reliable inventarization of the taxons which has not been completed as of yet. Large-scale international programmes (Planetary Biodiversity Inventory Program, Encyclopaedia of Life, Catalogue of Life, Tree of Life) are trying to fill in the lack of information on various taxons, however, a big number of groups of invertebrates still remain poorly studied and documented.

The assessment of the biodiversity of natural complexes has a significant practical importance as it allows for the genetic potential of the species to be controlled and preserved, it gives an idea of the condition of the eco-systems in a specific region and serves as the basis for the development of strategies for the management of the protected areas.

The aim of this research is to study the α- and β-diversity of subphylum Myriapoda (Diplopoda, Chilopoda) in the various habitats in a region in North-eastern Bulgaria, which has been comparatively poorly studied – the Madara Plateau.

Materials and methods:

Region of research: The study was conducted in the region of the Madara Plateau, situated in North-eastern Bulgaria, in the southern part of the East Danubian Plain. Together with the Krivnensko Plateau, situated east of the Madara Plateau, they comprise the Royak Plateau, which is part of the protected area Provadiisko-Royaksko Plateau. The climate is moderate-continental characterized with comparatively cold winters and warm summers. The soil is carbonate, typical and leached chernozems, while the higher parts are defined by grey forest soil.

The Madara Plateau is situated in the eastern part of the Moesian forest vegetation area, lowland-foothill and foothill midmountain belt of oak forests (0-600 m a.s.l).

The specific natural conditions of the Madara Plateau contribute to the development of rich and varied vegetation. There are over 95 woody shrub ecosystems in it (Donchev & Karakashev, 2012). The vegetation cover is characterized by a predominance of xerophilous and thermophilic elements that are prevalent in almost all parts of the plateau. They are represented mainly by ecosystems of *Carpinus orientalis* Mill., *Quercus pubescens* Willd., *Quercus cerris* Linnaeus, 1753, *Quercus frainetto* Ten., *Syringa vulgaris* L., and *Paliurus spina-christi* Mill., among others.

The mesophilic and mesothermal elements are more sparsely distributed. Their main representatives are *Carpinus betulus* Linnaeus, 1753, *Quercus robur* Linnaeus, 1753, *Tilia tomentosa* Moench, *Ulmus campestris* Mill., etc.

Sampling plots: The study was conducted on 11 sampling plots, located in the north-western part of the Madara Plateau, situated 12 km East of the town of Shumen, North-east Bulgaria (Fig. 1). The plots reflect the main ecosystems and include the major forest and open-space habitats on the Plateau. The altitude they were located at varies between 300 m and 450 m. The sampling plots differ in terms of the type and composition of plant formations in them:

MP1- coniferous forest of *Pinus nigra* of artificial origin; **MP2-**open meadow covered with wheat and steppe grass and sporadic shrubs; **MP3-** deciduous forest comprised of *Carpinus orientalis* shoots; **MP4-**open meadow with herbaceous vegetation and single shrubs and trees; **MP5-** deciduous-coniferous forest dominated by *Pinus sylvestris* and *P. nigra* with single members of *Tilia platyphyllos*, *Carpinus betulus*, *Quercus cerris* and *Betula pendula*, of artificial origin; **MP6-** deciduous forest composed of *Q. cerris*, *C. betulus*, *Acer campestre* with single members of *T. platyphyllos* and *Fagus sylvatica*; **MP7-** coniferous forest composed of *P. nigra* (70%) and *P. sylvestris* (30%) of artificial origin; **MP8-**deciduous forest of *C. orientalis* (100%) shoots; **MP9-**deciduous forest dominated by *C. orientalis* (80%) and *C. betulus* (20%) shoots; **MP10-** deciduous forest of *C. orientalis* (100%) shoots and **MP11-**deciduous forest composed of *T. platyphyllos* (60%), *Fraxinus ornus* (10%), *A. campestre* (10%), *Q. cerris* (10%) and *C. betulus* (10%) shoots.

Collection of material: The material was collected through pitfall traps, 10 in each sampling plot, arranged in a straight line at a distance of 10 m from one another. The catch from the traps has been reported on a monthly basis in the period June 2012- February 2015.

The variety of species was estimated using the index of Shannon-Weaver (H') and the degree of equality using the index of Berger-Parker *(d)*. β-diversity was determined through comparison between the myriapod communities collected from the different sampling plots using the quotient of similarity Czekanowski-Dice-Sørensen (Q_s) as well as using cluster analysis of the data on the quality content of myriapod fauna in the various habitats.

Fig. 1. Map of the area of research (in Google Earth format) and the distribution of the habitats under study

Results and discussion: The total of 3415 myriapods have been gathered in the period of research – 2776 millipedes and 639 centipedes. Up to the present moment the faunistic database of the myriapod fauna on the Madara Plateau includes a total of 28 species – 12 species of class Diplopoda, of 4 orders – Glomerida, Polydesmida, Chordeumatida and Julida and 16 species of the class Chilopoda of the orders Scutigeromorpha, Lithobiomorpha, Scolopendromorpha and Geophilomorpha (Kaczmarek, 1970; Doichinov & Bachvarova, 2014; Krasteva et al., 2015).

The comparison of the two analysed classes of Myriapoda shows considerable differences in their diversity of species. Shannon-Weaver's index (H') for the millipede community (1,93) is higher compared to the one of the centipede community (1,30) (Table 1 A, B).

Table 1 A, B

α-diversity of the millipede (A) and centipede (B) communities on the Madara Plateau

A. Diplopoda

Species	Number of individuals	pi	ln pi	H'	d
Glomeris balcanica	**31**	0.011167147	-4.494779117	-0.050193859	**3.478696742**
Glomeris hexasticha	**798**	0.287463977	-1.246657724	-0.358369187	
Polydesmus complanatus	**489**	0.176152738	-1.736403832	-0.305872289	
Polydesmus renschi	**19**	0.00684438	-4.984327342	-0.034114632	
Anamastigona bilselii	**13**	0.004682997	-5.363816964	-0.025118739	
Leptoiulus trilineatus	**270**	0.097262248	-2.330344363	-0.226654531	
Cylindroiulus boleti	**351**	0.126440922	-2.067980098	-0.261477311	
Megaphyllum bosniense	**365**	0.13148415	-2.028868968	-0.266764111	
Megaphyllum lictor	**73**	0.02629683	-3.63830688	-0.095675937	
Megaphyllum transsylvanicum	**336**	0.121037464	-2.111655162	-0.255589386	
Megaphyllum unilineatum	**1**	0.000360231	-7.928766322	-0.002856184	
Pachyiulus hungaricus	**30**	0.010806916	-4.52756894	-0.048929059	
Total:	**2776**	**1**		**1.931615226**	

B. Chilopoda

Species	Number of individuals	pi	ln pi	H'	d
Scutigera coleoptrata	**1**	0.001564945	-6.459904454	-0.010109397	**1.558536585**
Lithobius forficatus	**6**	0.009389671	-4.668144985	-0.043832347	
Lithobius lucifugus	**4**	0.006259781	-5.073610093	-0.031759688	
Lithobius mutabilis	**62**	0.097026604	-2.332770069	-0.226340758	
Lithobius muticus	**33**	0.051643192	-2.963396893	-0.153039276	
Lithobius nigripalpis	**72**	0.112676056	-2.183238335	-0.245998686	
Lithobius crassipes	**1**	0.001564945	-6.459904454	-0.010109397	
Lithobius microps	**1**	0.001564945	-6.459904454	-0.010109397	
Pleurolithobius patriarchalis	**410**	0.641627543	-0.443747295	-0.284720486	
Scolopendra cingulata	The species is not registered in the current study				
Cryptops anomalans	**31**	0.048513302	-3.02591725	-0.146797237	
Himantarium gabrielis	**1**	0.001564945	-6.459904454	-0.010109397	
Clinopodes flavidus	**6**	0.009389671	-4.668144985	-0.043832347	
Stenotaenia linearis	**2**	0.00312989	-5.766757274	-0.018049319	
Henia illyrica	**2**	0.00312989	-5.766757274	-0.018049319	
Strigamia crassipes	**7**	0.010954617	-4.513994305	-0.049449077	
Total:	**639**	**1**		**1.302306126**	

The millipede community is represented by species with comparatively high numbers. It is only the species *Megaphyllum unilineatum* and *Anamastigona bilselii*, registered with 1 and 13 individuals respectively, that feature low numbers. All other species, especially: *Glomeris hexasticha, Polydesmus complanatus, Leptoiulus trilineatus, Cylindroiulus boleti, Megaphyllum bosniense, Megaphyllum lictor,* and *Megaphyllum transsylvanicum* have high and comparatively similar numbers which attributes high degree of equality to the community and high values of the index of Berger-Parker *(d)* – 3,478 (Table 1 A).

The bigger part of the species comprising the centipede community feature very low (from 1 to 10 individuals) or average numbers (between 30 and 70 individuals). Only the species *Pleurolithobius patriarchalis* has high numbers – 410 registered individuals which makes it the dominant species in the community. This considerable difference in the numbers of the species comprising the centipede community on the Madara Plateau attributes to the community a low degree of equality and small values of the index of Berger-Parker *(d)* – 1,558 (Table 1B).

α-diversity of the myriapod communities in the analysed habitats on the Madara Plateau is very different. The highest diversity of species (H'=1,748) and comparatively high degree of equality (*d*=2,876) are characteristic of the millipede community in the pine forest (MP7). In general, all forest habitats on the Madara Plateau are characterized with big α-diversity of the millipede communities where the index of Shannon-Weaver and the degree of equality are the highest (Table 2). The lime forest (MP11) and the open spaces (MP2 and MP4), which feature more xeric conditions, which are unfavourable to the development of the millipedes, particularly in the hot and arid summer months, are characterized with low biodiversity.

Table 2

α-diversity of the millipede communities in the analysed habitats on the Madara Plateau

Sampling plot	Diversity index (H')	Equality index *(d)*
MP1– Coniferous forest	0.966073	1.39
MP2– Open meadow	1.433655	2.666667
MP3– Deciduous hornbeam forest	1.287368	1.808824
MP4– Meadow with steppe grass and scrubs	0.917194	1.346809
MP5– Mixed coniferous forest	1.316851	1.643777
MP6– Mixed deciduous forest	1.418084	2.548077
MP7– Pine forest	1.748316	2.876289
MP8– Deciduous hornbeam forest	1.088859	2
MP9– Deciduous hornbeam forest	1.516192	2.363636
MP10– Deciduous hornbeam forest	1.445034	3.058824
MP11– Lime forest	0.911658	1.894737

In general, the centipede communities in all analysed habitats are characterized with lower diversity of species and lower degree of equality compared to those of the millipedes (Table 3). As open areas are the preferred type of habitat for the centipedes, the analysed crest meadows (MP2 and MP4) feature the highest index of diversity (H'=1,494 and 1,308 respectively) and degree of equality (*d*=2,666 and 1,747). In contrast, the centipede communities in the forest habitats are characterized with low values of the index of Shannon-Weaver – 0,311 for the mixed deciduous forest (MP6); 0,693 for the lime forest (MP11) and 0,850 for the coniferous forest (MP1). Due to the high number of the species *Pleurolithobius patriarchalis*, which is dominant in almost all sampling plots, the values of the index of equality of Berger-Parker are low.

Table 3

α –diversity of the centipede communities in the sampling plots on the Madara Plateau

Sampling plot	Index of diversity (H')	Index of equality *(d)*
MP1– Coniferous forest	**0.850771**	**1.333333**
MP2– Open meadow	**1.494175**	**2.666667**
MP3– Deciduous hornbeam forest	**1.071018**	**1.7**
MP4– Meadow with steppe grass and shrubs	**1.308964**	**1.747253**
MP5– Mixed coniferous forest	**1.099627**	**1.602151**
MP6– Mixed deciduous forest	**0.311435**	**1.067164**
MP7– Pine forest	**1.275851**	**1.680556**
MP8– Deciduous hornbeam forest	**0.950271**	**1.666667**
MP9– Deciduous hornbeam forest		
MP10– Deciduous hornbeam forest		
MP11– Lime forest	**0.693147**	**2**

The comparative analysis of the myriapod fauna in the analysed sampling plots shows that in the area of research, in terms of species composition, there are no fully identical habitats as the distribution of species on the one hand is determined by the potential species' carrying capacity of each habitat, the feeding grounds and the living conditions which they offer, while on the other hand, it reflects the specific biological abilities of the species to adapt and reproduce (Trojan, 1994). The level of similarity in the composition of millipede communities on the Madara Plateau varies widely. Sørensen's gradient is lowest between the lime forest (MP11) and the coniferous forest (MP1) – 0,44 but it reaches almost maximum values when comparing the deciduous hornbeam forests (MP6 and MP3 – 0,92 and MP6 and MP10 – 0,91) (Table 4).

Table 4

Values of the gradient of Czekanowski-Dice-Sörensen (Qs) for the millipede communities in the analysed habitats on the Madara Plateau.

Sampling plot	MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8	MP9	MP10	MP11
MP1	1										
MP2	**0.91**	1									
MP3	0.77	0.83	1								
MP4	0.63	0.53	0.71	1							
MP5	0.63	0.53	0.71	**0.9**	1						
MP6	0.67	0.73	**0.92**	0.75	0.75	1					
MP7	0.63	0.53	0.71	**0.9**	**0.9**	0.75	1				
MP8	0.6	0.67	0.73	0.57	0.57	0.8	0.57	1			
MP9	0.5	0.55	0.77	0.75	0.75	0.83	0.75	0.8	1		
MP10	0.55	0.6	0.83	0.67	0.67	**0.91**	0.67	0.67	0.73	1	
MP11	**0.44**	0.5	0.6	0.46	0.46	0.67	0.46	0.86	0.67	0.75	1

The highest quotient of similarity is registered between the millipede communities in the coniferous and mixed coniferous-deciduous forests with the open habitats on the plateau. Sørensen's quotient is 0,91 for the coniferous forest of *P. nigra* (MP1) and the open crest meadow (MP2), where 5 out of the total of 11 registered species are common for both sampling plots. The quotient shows such high values (0,90) when comparing the mixed coniferous-deciduous forest MP5, dominated by *P. sylvestris* and *P. nigra* to the coniferous forest MP7, as well as these two to the open crest meadow MP4. These are the sampling plots characterized with highest abundance of species. This high degree of similarity between habitats which greatly differ in their flora component and food base is probably due to the nearly identical environmental conditions they offer. This fact coincides with the research carried by Kime et al. (1992) in Belgium which proved that the distribution of soil organisms depends most of all on the climatic and edaphic environmental factors – soil structure, its water and mineral content, the type of humus and temperature. The habitats mentioned above are characterized with more xeric conditions and very poor trophic base mostly due to the absence of typical deciduous forest leaf litter. They offer a very harsh living environment during the hot and arid summer months and are inhabited mostly by evritopic and polytopic species which adapt to these living conditions thanks to various devices – ability to fold and bury themselves in the leaves and the soil, waterproof body coverings, a special type of respiratory apparatus, and the ability to move to adjoining territories, among others. These species belong to the "bulldozer" ecomorphological type according to the classification offered by Hopkin & Read (1992) and Gruner et al. (1993), which allows them to penetrate very hard soils freely and to migrate to a considerable depth. Most of these species have cuticle structures heavily coated with calcium and magnesium carbonate which prevents the body from the evaporation of water. The results fully correspond to the data collected from the research on the myriapod fauna on the Madara Plateau where the highest quotient of similarity of millipede communities is also shown by the habitats which offer the most xeric conditions (Bachvarova et al., 2015).

The comparison of deciduous forest habitats also registers high degree of similarity in the species composition of the millipede communities. The similarity quotient of Czekanowski-Dice-Sörensen fluctuates from 0,73 between sampling plots MP10 and MP9 and reaches 0,83 for MP9 and MP6.

The lowest similarity is registered between the millipede communities inhabiting deciduous forest habitats and the coniferous forests and the open crest meadows (Table 4).

The millipede fauna in the analysed area features comparatively high quotient of similarity in the separate sampling plots. It is divided into three main groups, two of which are formed by the more xeric habitats – the open crest meadows and the coniferous forests, and the third one is formed by the habitats dominated by *Carpinus orientalis* (Fig. 2).

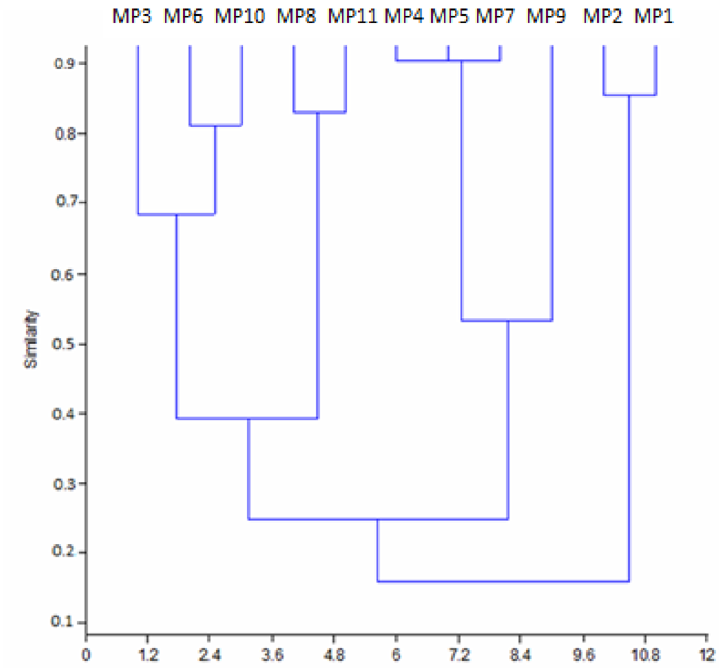

Fig. 2. Dendogram of the similarity in composition of the species in the millipede communities in the analysed habitats on the Madara Plateau.

The group of the open crest meadow (MP4) and the mixed deciduous-coniferous forest (MP5) and the pine forest (MP7) stand out with the highest quotient of similarity (90%). The deciduous forest of *C. orientalis* (MP9) joins this group. This weird similarity between unusual habitats is most likely due to the fact that these sampling plots feature a very steep gradient (10^0) and are characterized with very poor, rocky and heavily leached soils with low water retention properties, making them the most xeric habitats of the deciduous forests. Sampling plot MP2, located in the second open meadow and the pine forest composed of *P. nigra* (MP1) form the other group of xeric habitats with a quotient of similarity of 83%. In the group of the deciduous forests there are two tandems with a comparatively equal quotient of similarity of around 82-83% that are formed. The first tandem is comprised of sampling plots MP6 and MP10, and the second one of MP8 and MP11 featuring Sørensen's quotient of 0,91 and 0,86 respectively.

These three groups correlate at a very low quotient of similarity (17%) which is an indication of the very high specialization of the millipedes to the composition of plant formations and the ecological conditions of the habitat.

In general, the centipede fauna in the analysed area shows a very low quotient of similarity compared to that of the millipedes. The values of the quotient of Sørensen move within very wide range – from 0,17 of the lime forest (MP11) and the mixed deciduous-coniferous forest (MP5) to very high values (0,89) obtained at the comparison of the mixed deciduous-coniferous forest – MP5 and the coniferous forest of *P.sylvestris* and *P. nigra* – MP7 (Table 5).

Comparing 4 of the sampling plots – MP9 to MP1, MP9 to MP2, MP11 to MP9, and then all sampling plots to MP10 there are no common species that are found, whereby the quotient of Sørensen equals 0,00. Generally, the species composition of the centipede community in the lime forest (MP11) shows the lowest degree of similarity when compared to all other habitats (Table 5).

Table 5

Values of the quotient of Czekanowski-Dice-Sörensen (Qs)
for the centipede communities in the analysed habitats on the Madara Plateau.

площадка	MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8	MP9	MP10	MP11
MP1	1										
MP2	**0.8**	1									
MP3	0.67	0.67	1								
MP4	0.57	0.57	0.62	1							
MP5	0.53	0.53	0.57	0.63	1						
MP6	0.4	0.6	0.44	0.57	0.53	1					
MP7	0.46	0.46	0.5	0.59	**0.89**	0.62	1				
MP8	0.25	0.25	0.29	0.33	0.46	0.75	0.55	1			
MP9	0	0	0.4	0.2	0.18	0.33	0.22	0.5	1		
MP10	0	0	0	0	0	0	0	0	0	1	
MP11	0.57	0.29	0	0.18	0.17	0.29	0.2	0.4	0	0	1

The centipede communities in the analysed area are divided into two main groups at a quotient of similarity 46% (Fig. 3).

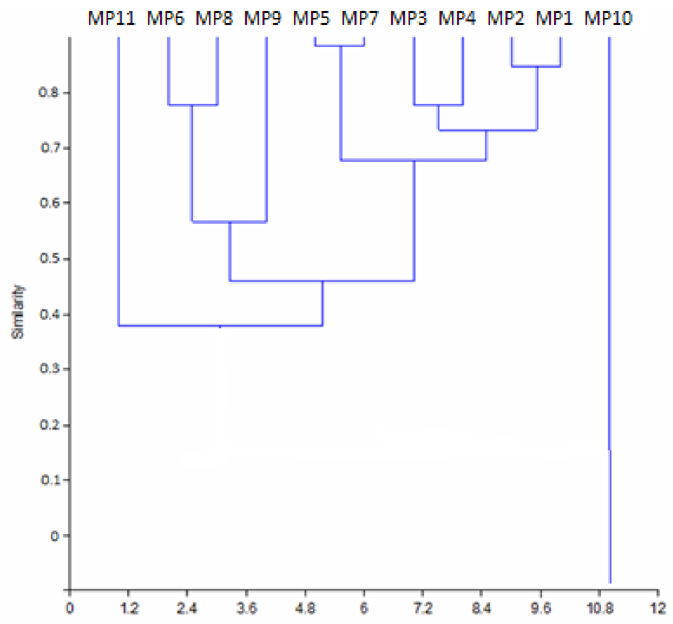

Fig. 3. Dendogram of the similarity in composition of the species in the centipede communities in the analysed habitats on the Madara Plateau.

They strongly resemble the clusters of the millipede communities – the first one of them is formed by the deciduous forests, while the other, which is much richer, by the more xeric habitats. Once again, the two sampling plots: MP5 – the mixed deciduous-coniferous forest and MP7 – the coniferous forest of *P. sylvestris* and *P. nigra*, show the highest degree of correlation (90%). The second group of the xerophilic habitats – the open meadow (MP2) and the coniferous forest dominated by *P. nigra* (MP1) is formed at a quotient of similarity of 85%, while the open crest meadow – MP4 and the hornbeam forest – MP3 form the third domain at a quotient of similarity of 78%.

The group of the deciduous forests is formed by the hornbeam habitats of sampling plots MP6 and MP8 which correlate at 78%, and at correlation of 57% sampling plot MP9 joins them. The lime forest (MP11) is with the lowest quotients of similarity and a degree of correlation 38%.

In general, the myriapod fauna on the Madara Plateau is characterized with a comparatively poor species composition – 28 registered species of myriapods in all analysed habitats. In comparison, only in the reserve Bukaka, located in Natural Park Shumen Plateau, there have been registered 29 species (Bachvarova, 2011). Most probably this is as a result of the strong human presence and active agricultural activity on the Madara Plateau. The biggest diversity of species of both classes of Myriapoda in the region of Shumen is registered in the suburban area of park Kyoshkovete with 17 species of Diplopoda and 20 species of Chilopoda (Bachvarova, 2011), a fact which to a considerable degree confirms the trend of increase in the diversity of species in conditions of weak anthropogenic pressure as ascertained by some scholars

(Vepsäläinen & Wuorenrinne, 1978; Trojan, 1981; Schaefer, 1982; Kuznetzova, 1994).

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