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IMPACT OF TOURISM UPON STRUCTURE AND DIVERSITY OF COLLEMBOLA ASSEMBLAGES (HEXAPODA) – A CASE STUDY OF THE GOMBASECKÁ CAVE, SLOVAK KARST (SLOVAKIA)

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T. Barciová, Ľ. Kováč, D. Miklisová: Impact of tourism upon structure and diversity of Collembola assemblages (Hexapoda) – a case study of the Gombasecká Cave, Slovak Karst (Slovakia)

Abstract: In 1998 – 2000 and 2006 – 2007 investigations were carried out in the Gombasecká Cave (Slovak Karst, Slovakia) to assess potential impact of tourism upon the communities of terrestrial Arthropoda with special reference to Collembola. Pitfall trapping with different fixation liquids and extraction of baits and organic debris (rotten wood) were used as basic collecting methods. Five sites were selected for detail study in different distance from the tourist path. In total, 52 Collembola were registered during the study in the Gombasecká Cave, rather low species number (27) was detected in its internal parts that is likely linked with oligotrophic conditions and low impact of tourism. Four species were troglobiotic, *Arrhopalites aggtelekiensis*, *Deuteraphorura schoenviszkyi, Deuteraphorura cf. kratochvili* and *Pseudosinella aggtelekiensis*, all representing Western Carpathian endemics. They populated preferably the deeper cave parts with exception of *P. aggtelekiensis* that occurred also at both entrance sites. Eutroglophiles *Arrhopalites pygmaeus*, *Arrhopalites caecus* and *Folsomia candida* dominanted in the cave. Collembolan assemblages of the entrance sites differed from those situated in greater distances from the cave entrance. Within adjacent reference localities not open to public, Stará Brzotínska and Nová Brzotínska caves, 22 and 21 collembolan species were recorded, respectively. Three obligate cave species were registered in both caves, *A. aggtelekiensis, D. schoenviszkyi* and *D.* cf. *kratochvili*;. eutroglophiles *Plutomurus carpaticus, Folsomia candida and Arrhopalites pygmaeus* were the most abundant. The study revealed a great level of similarity of Collembola between tourist and reference caves investigated. However, *Plutomurus carpaticus*, abundant and frequent in the Brzotínska Cave system, was absent in the Gombasecká Cave. In contrary, troglobiotic *Pseudosinella aggtelekiensis*, rather frequent in the Gombasecká Cave was totally absent in the Brzotínska Cave system. In the studied show cave we observed no clear negative effect of tourism upon Collembola communities close to the tourist path.

Key words: Collembola, tourist cave, Slovak Karst, Gombasecká Cave, troglobiotic species, cave fauna

INTRODUCTION

In addition to the natural corrosion processes in caves, the combined effect of an increase in CO_2 concentration and temperature variations induced by visitors can directly affect the intensity of wall corrosion processes (Mulec and Kosi, 2009; Pulido and Bosch et al., 1997). New openings for tourist purposes may modify air circulation and change the microclimate sufficiently to cause the disappearance of the fauna (Juberthie, 2000).

One of the characteristics of the natural cave environment is low nutrient input (Simon et al., 2007) that is changed with the introduction of light energy in tourist caves. Such drastic changes to the cave ecosystem directly and indirectly influence cave fauna. Higher nutrient input in cave environments enables newcomers to be more competitive than the originally present troglomorphic organisms. Consequently obligate cave-dwelling organisms are threatened and may become extinct (Pipan, 2005). The intensive tourism in caves may cause disappearance of some species and the entry of invasive ones (Gunn, 2004).

In the present paper we focused on Collembola communities of the Gombasecká Cave, a tourist cave open to public, in 1995 enrolled on the UNESCO's World Heritage List. The neighbouring Stará and Nová Brzotínska caves, devoid of direct human impact, were selected as reference sites. Literature data on cave invertebrates of the caves under study are very scarce. Paclt (1957) recorded a single Collembola species in the Gombasecká Cave. Later, Mock et al. (2002a) discovered a blind adult female of millipede belonging to the genus *Typhloiulus* in the cave. It is belonging to the northernmost caves in Europe inhabited by obligate cave-dwelling millipedes and documenting close relationship between cave fauna of the Slovak Karst and the Balkan Peninsula. The Stará Brzotínska Cave is an important site from the point of view of speleobiology. It represents type locality of cavernicolous carabid *Duvalius hungaricus brzotinensis* Janák, 1987 and troglobiotic pseudoscorpion *Neobisium slovacum* Gulička, 1977.

Within the present study we aimed: (1) to analyse diversity and community structure of Collembola in a show cave, (2) to compare Collembola diversity of the show cave with nearby reference caves devoid of human influence, and (3) to evaluate impact of tourism upon subterranean fauna of the tourist cave studied.

MATERIAL AND METHODS

The Gombasecká Cave (Fig. 1) is situated in the Slovak Karst geo-morphological unit, south-eastern Slovakia. The cave entrance (48°33' N, 20°27' E) is situated on western slope of the Silická Plateau above spring of the Čierny potok Brook at altitude of 250 m a. s. l. Total length of the cave is 1.525 m (Bella et al., 2007). It was discovered in 1951 through the narrow spaces of the karstic spring. It is open to public as a show cave since 1955 after construction of a short artificial entrance passage (Bella, 2003). Yearly visitation by tourists is rather low, i. e. around 10 000 visitors (Nudziková and Gaál, 2010). It is a characteristic oligotrophic cave with low amounts of available organic matter derived from animals and/or plants (Gnaspini and Trajano, 2000). Due to protection of unique speleothems, the cave gate is not provided with free entrance for bats. The bat guano is missing in the cave due to absence of bats. Only few exemplars of *Rhinolophus hipposideros* occur sporadically in spring or autumn in the entrance passage (Bernadovič, 2000). During our investigations we observed excrements of dormouse (*Glis glis*) that were very scarce in several parts of the cave. The active underground stream present may potentially mediate transport of organic matter or even living animals into the cave. However, its known ponors are located on the Silická Plateau more than 5 km in the air distance. Thus, this potential food enrichment for the cave invertebrates is less probable. Remnants of rotten wood are present in negligible amounts. Investigations of arthropods in the Gombasecká Cave cave were carried out at the following periods: 21. 5. 1998 – 8. 7. 1998, 22. 10. 1999 – 1. 12. 2000, 18. 5. 2006 – 25. 10. 2006, 25. 10. 2006 – 1. 5. 2007 and 5. 10. 2007 – 6. 10. 2007. Following sampling sites (Fig. 1A) were selected: 1/ entrance

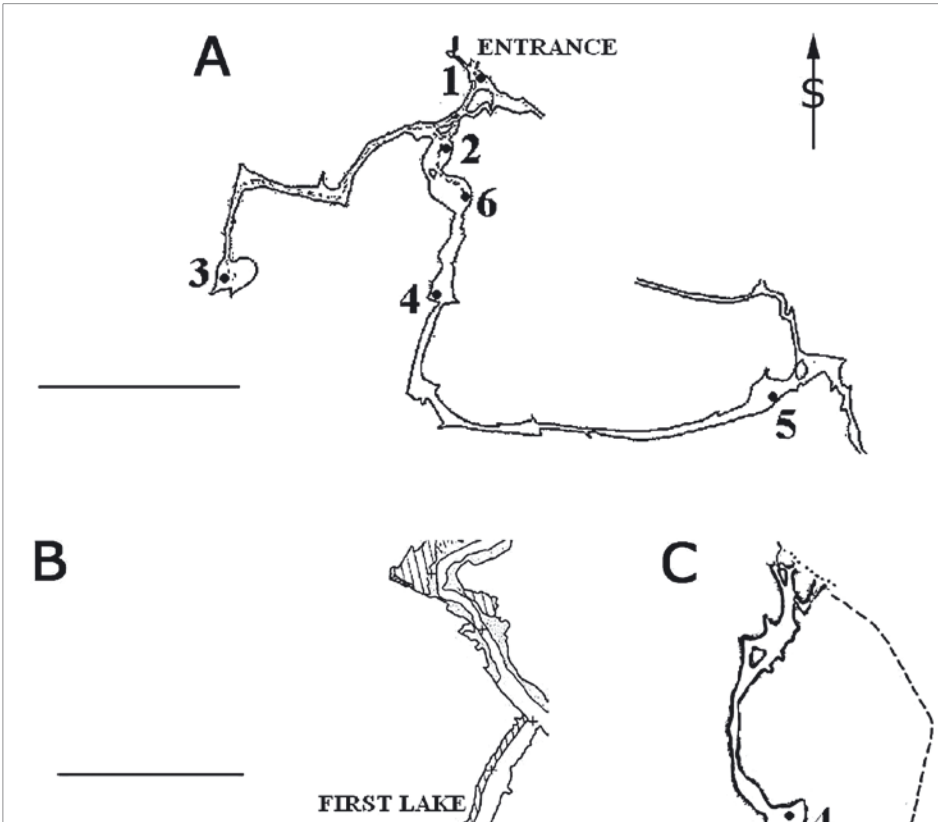

Fig. 1. Situation maps of caves with location of the study sites: A – Gombasecká Cave, B – Nová Brzotínska Cave, C – Stará Brzotínska Cave (for site numbers see text, scales: A – 100 m, B – 20 m, C – 20 m)

passage, 2/ Herényi´s Hall, 3/ Marble Hall, 4/ Clay Passage – fore part, 5/ Clay Passage – Hall of Quills and 6/ Rozložník´s Hall. Sites 1, 2, 3 and 6 were placed in close distance (5 – 10 m) from the tourist path. In addition, samples of the soil and moss growing on the rocks in front of cave (maple beechwood, *Acereto-Fagetum*) were taken (site 0). The air temperature (°C) measured at sites in October 2006 and May 2007 was as follows: 1/ 9.7 and 9.7; 2/ 9.4 and 9.5; 3/ 9.3 and 9.3; 4/ 9. 1 and 9.3 and 5/ 9.6 and 9.4, respectively.

The reference sites, the Nová and Stará Brzotínska caves are located on eastern slope of the Plešivecká Plateau (48°36' N, 20°28' E), roughly 6 km in air distance from the Gombasecká Cave . The Nová Brzotínska Cave (NBC) is a large spring cave with total length of 800 m (Fig. 1B), the entrance (270 m a. s. l.) situated 130 meters northerly from the Stará Brzotínska Cave. The cave is distinguished by the year-round active underground hydrologic flow. The Stará Brzotínska Cave (SBC) is 120 m long with entrance 258 m a. s. l. (Bella et al., 2007). It represents a temporal tributary of the previous cave with marked hydrological activity only during higher level of underground water (Fig. 1C). Thus, both caves are involved in the same hydrological system. As to the amount of organic material Brzotínska Cave system have very similar conditions with the Gombasecká Cave. Since small and narrow entrance the Stará Brzotínska Cave is practically not affected by human intervention. It serves as hibernating site for small number of bats (Hapl et al., 2002). Bat guano is spread on the bottom in low amount and small patches between sites 3 and 4, and close to the site 1, as well (see below). The Nová Brzotínska Cave is not open to public, due to heavy underground stream it serves as an important regional source of drinking water. During our observations small amount of organic material (leaf litter and excrements of marten) was deposited in the artificially constructed entrance passage of the cave. In both reference caves the arthropods were sampled during 15. 5. 1998 – 8. 7. 1998. Three sampling sites in NBC and four sites in SBC were selected for the study (Fig. 1B, C). For comparison, samples from the organic soil profile (leaf litter and humus) and moss growing on rocks (maple beechwood – *Acereto-Fagetum*) were taken in front of the Stará Brzotínska Cave (site 0).

Three fundamental collecting methods were used to survey terrestrial arthropods: 1) pitfall trapping with three different fixation liquids (96% ethyl-alcohol; mixture of ethylene-glycol and beer (1 : 1); 4% formaldehyde), 2) extraction of organic material (exposed baits, rotten wood) in a high-gradient apparatus, and 3) hand collecting of subterranean fauna on baits, organic debris (rotten wood), sediments and speleothems. In NBC and SBC pitfall traps (96% ethyl-alcohol as a fixation liquid) and baits (wooden sawdust with cardboard) were used. Extracted material of Arthropoda was sorted in binocular stereomicroscope, Collembola were taxonomically identified using keys of Bretfeld (1999) and Pomorski (1998), and other important literature (e. g. Christiansen et al., 1990; Vargovitsh, 2009). Qualitative cluster analysis (Sörensen´s index, Group Average method) was performed using PC-ORD package (McCune, 1987) to assess the similarity between Collembola communities studied.

RESULTS

Gombasecká Cave

In 2006 – 2007 Collembola, Diptera and Acari had highest activity in the pitfall traps in the Gombasecká Cave. Collembola were dominant arthropod group with the highest average numbers of specimens (Fig. 2), they showed highest activity at site 3 (83.1 ind. trap^{-1}). Diptera (larvae and adults) dominated at sites close to the cave entrance

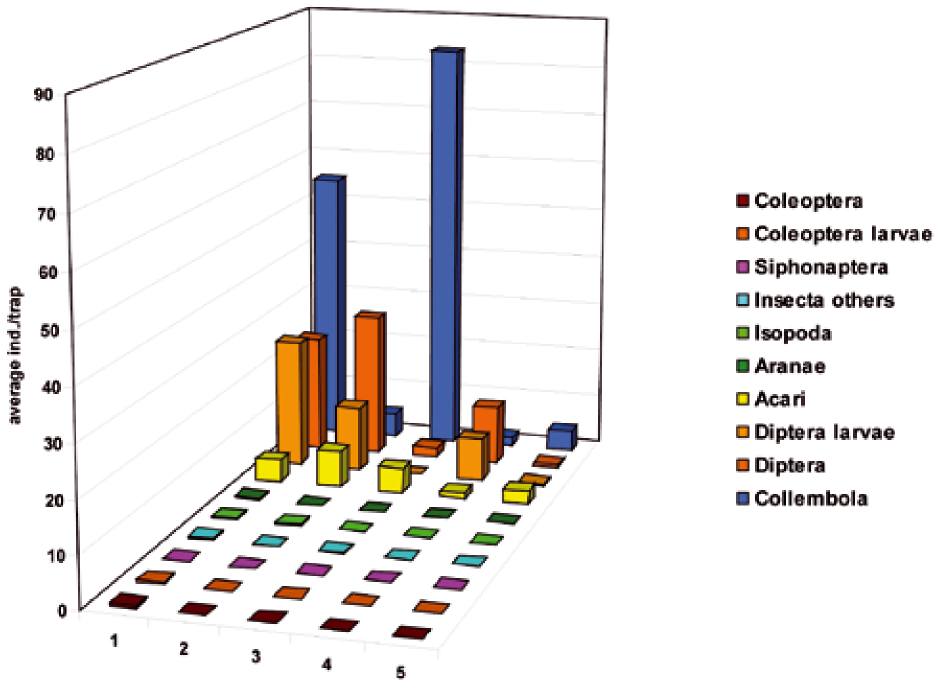

Fig. 2. Average numbers of arthropod groups in pitfall traps in the Gombasecká Cave at sites during 2006 – 2007 (for site numbers see text)

(sites 1 and 2) with average activity of 48.8 and 41.6 ind. trap^{-1}, respectively. Acari had highest activity at site 2 (7.4 ind. trap^{-1}). The other taxa (Aranae, Coleoptera, Coleoptera, Isopoda, Siphonaptera) detected in the cave represented minor part of the arthropod communities.

A total of 52 Collembola species were identified in the Gombasecká Cave, external (reference) site included (Tab. 1 and 2). Among them 18 species were restricted to cave, 25 species were associated with the soil in front of the cave and 9 were common to both habitats. During May 2006 – October 2007 totally 1,735 specimens were caught by pitfall traps (Tab. 1). During 1998 – 2007 2,622 individuals were extracted from the cave organic materials collected (Tab. 2). Many species preferred habitats situated close to the cave entrance (sites 1 and 2). However, Collembola species richness was found to be rather high at site 3 that is rather distant from the entrance. Four troglobiotic species occurred in the cave: *Pseudosinella aggtelekiensis* collected by pitfall traps, *Deuteraphorura* cf. *kratochvili* collected by extraction of organic debris, and *Arrhopalites aggtelekiensis* and *Deuteraphorura schoenviszkyi* collected by both methods. With exception of *Pseudosinella aggtelekiensis* all other troglobiotic Collembola were restricted to deeper sites (3 – 5). The eutroglophiles *Arrhopalites pygmaeus*, *Arrhopalites caecus* and *Folsomia candida* represented dominant species of the Gombasecká Cave not recorded outside the cave. Qualitative cluster analysis of Collembola collected by pitfall trapping and by extraction of organic material in 2006 – 2007 divided communities at sites into two basic branches (Fig. 3). The most similar were two sites located in entrance parts of the cave, the other were clustered together involving communities from the sites situated in greater distances from the cave entrance (>100 m).

Table 1. Average activity of Collembola in pitfall traps (average numbers per trap) at sites in the Gombasecká Cave in 2006 – 2007 (● – troglobiont, o – eutroglophile; for site numbers see text)

Species	**1**	**2**	**3**	**4**	**5**
Arhopalites ulehlovae	0.07				
● *Arrhopalites aggtelekiensis*				0.76	2.66
Arrhopalites bifidus			3.31		
o *Arrhopalites caecus*	1.6	1.25	50.6	2.88	0.83
o *Arrhopalites pygmaeus*	2.33	1.5	16.7	0.25	0.33
o *Ceratophysella bengtssoni*	0.13	0.13			
● *Deuteraphorura schoenviszkyi*			0.15		
o *Folsomia candida*	0.07	1.38			2.5
Folsomia manolachei	0.07				
o *Heteromurus nitidus*	17	3.13	0.08		
Hypogastrura purpurescens	1.53				
Hypogastrura sp. juv.	0.07				
o *Megalothorax minimus*	0.13				
o *Oncopodura crassicornis*	0.13				
Parisotoma notabilis			24.8		
o *Protaphorura armata*	0.2	0.13			
●*Pseudosinella aggtelekiensis*	0.25	0.25			1.67
Pseudosinella alba		0.13			
Tomocerus minor	0.13				
Species number	14	8	6	3	5

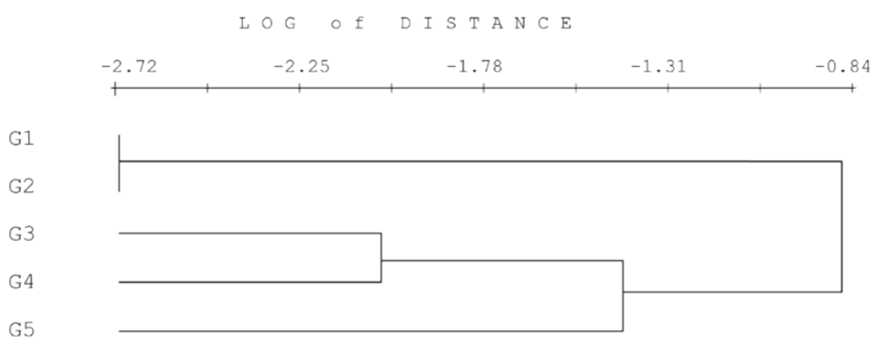

Fig. 3. Qualitative cluster analysis (Sörensen index, Group Average method) of Collembola communities at sites in the Gombasecká Cave in 2006 – 2007 (for site numbers see text)

Brzotínska Cave system

In total, 28 Collembola species were collected in NBC and SBC, 15 species occurred inside the caves and 9 ones represented typical soil forms limited by their occurrence to external site (Tab. 3). Eight species were restricted to deeper internal parts of the cave system. Three troglobionts were detected, *Arrhopalites aggtelekiensis*, *Deuteraphorura schoenviszkyi* and *Deuteraphorura* cf. *kratochvili*, the last one only being frequent. *D. schoenviszkyi* was collected by extraction of bait deposited at the deepest site of SBC (site 4). Among eutroglophiles *Arrhopalites pygmaeus*, *Plutomurus carpaticus* and *Protaphorura armata* were frequent underground. Four species were found in both cave and external site, of them *Folsomia candida* and *Parisotoma notabilis* being frequent.

Table 2. List of Collembola species and their numbers in different microhabitats at the surroundings (0) and inside (1 – 6) the Gombasecká Cave in 1998 – 2000 and 2006 – 2007 (B – bait, G – bat guano, M – moss on rocks, S – soil/sediment, W – rotten wood; for site numbers see text)

	0		**1**		**2**	**3**		**4**		**5**			**6**
Species	**S**	**M**	**W**	**B**	**B**	**W**	**B**	**W**	**B**	**W**	**G**	**B**	**B**
● *Arrhopalites aggtelekiensis*						2		1					
o *Arrhopalites caecus*						13	3	4	4	32		13	
o *Arrhopalites pygmaeus*						2			1				
o *Ceratophysella bengtssoni*				2									
Desoria propinqua	2												
Desoria tigrina	103		22										
● *Deuteraphorura cf. kratochvili*											1		
● *Deuteraphorura schoenviszkyi*						3		41					
Deuteraphorura silesiaca	66												
Deutonura albella	2												
Entomobryidae juv.	3	4											
○ *Folsomia candida*				2		81		626	16	35		27	1
Folsomia fimetaria	14									61		23	
Folsomia kerni	3												
Folsomia manolachei	21												
Folsomia penicula	354												
Friesea albida	2												
Friesea truncata	2												
Heteraphorura variotuberculata	5	1											
o *Heteromurus nitidus*				7	8		1						
Hymenaphorura sp. juv.	1												
Hypogastrura purpurescens				8									
Isotomiella minor	23												
Isotomurus fucicolus		16											
Kalaphorura carpenteri	119												
Lepidocyrtus lanuginosus	10												
Lepidocyrtus lignorum	75	36	1						1				
o *Megalothorax minimus*				30		8		82					
Mesaphorura sylvatica										11			
Mesaphorura tenuisensillata						28							
Micranurida granulata		1											
o *Oncopodura crassicornis*			1										
Onychiuroides pseudogranulosus	1												
‘’Onychiurus‘‘ sp. juv.	1							1					
Parisotoma notabilis	119	9				185	14						
o *Plutomurus carpaticus*	7												
Pogonognathellus flavescens	17	11											
Proisotoma sp. juv.	1	17											
o *Protaphorura armata*	2												
Protaphorura cancellata	20												
Protaphorura sp. juv.	9												
Pseudosinella horaki	13												
Sminthurinus aureus	1												
Spatulosminthurus flaviceps	1												

Table 2. Continued

	0		1		2	3		4		5			6
Species	**S**	**M**	**W**	**B**	**B**	**W**	**B**	**W**	**B**	**W**	**G**	**B**	**B**
Tetrodontophora bielanensis	8												
Tomocerus minor	11	33											
Tomocerus minutus	56												
Willemia scandinavica								17					
Species number	35		8		1	9		10		5			1

Table 3. List of Collembola species and their numbers in the Nová and Stará Brzotínska Caves in 1998 (B – bait, E – decomposed excrement, M – moss on rocks, Pt – pitfall trap, S – soil/sediment, W – rotten wood, ● – troglobiont, o – eutroglophile; for site numbers see text)

	Nová Brzotínska j.					**Stará Brzotínska j.**										
	1	**2**		**3**		**0**		**1**	**2**		**3**					**4**
Species	**E**	**B**	**Pt**	**B**	**Pt**	**S**	**M**	**Pt**	**B**	**Pt**	**W**	**T**	**B**	**Pt**	**S**	**B**
● *Arrhopalites aggtelekiensis*					4									21		
○ *Arrhopalites bifidus*														21		
○ *Arrhopalites pygmaeus*	1	3	9	3	26			7			1		79	110	1	1
○ *Ceratophysella bengtssoni*	3	87														
Desoria propinqua						55										
Desoria tigrina						68										
● *Deuteraphorura* cf. *kratochvili*	12			6	1								2		1	
● *Deuteraphorura schoenviszkyi*																15
Deuteraphorura silesiaca						1										
Deutonura albella			3			9										
Deutonura phlegraea			1													
Entomobryidae juv.						1										
○ *Folsomia candida*	11	27	1	38		12		2			88				2	
Hypogastrura purpurescens		1														
Lepidocyrtus lignorum						55	1	7								
○ *Megalothorax minimus*								1			3					
Mesaphorura italica												1				
○ *Oncopodura crassicornis*														1		
Parisotoma notabilis	2	1	1			32					1	1				
Plutomurus carpaticus	2	9	51					66		3			18	25		5
Proisotoma sp. juv.						41										
○ *Protaphorura armata*	9	3	16					4	3		1	5			11	28
Protaphorura pannonica	1															
Protaphorura sp. juv.						1										
Pseudachorutes dubius						1										
Superodontella sp.						1										
Tomocerus minor						1										
Willemia scandinavica	8	17						1			2	2				
Species number	**9**	**8**	**7**	**3**	**3**	**14**	**1**	**7**	**1**	**1**	**6**	**4**	**3**	**5**	**4**	**4**

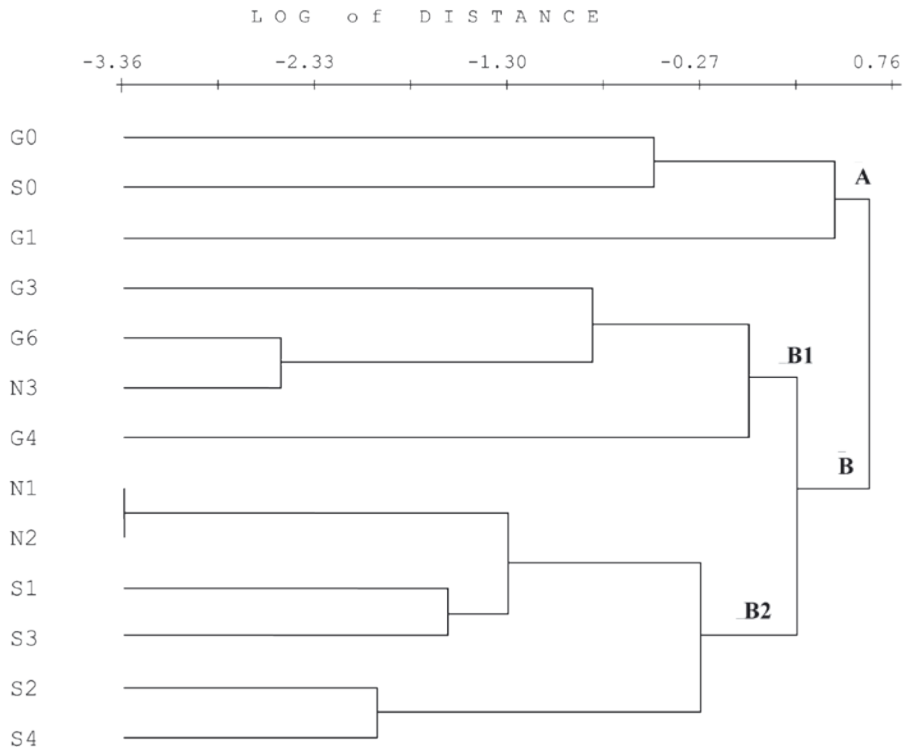

Fig. 4. Qualitative cluster analysis (Sörensen´s index, Group Average method) of Collembola communities at sites in the Gombasecká Cave (G0-6) and in the Nová and Stará Brzotínska caves – (N1-3; S0-S4) in 1998

Comparison of Collembola communities of cave and external sites

The cluster analysis was used for qualitative comparison of Collembola between cave sites (Gombasecká Cave and Brzotínska Cave system) and external sites situated in front of caves (Fig. 4). The analysis separated Collembola into two clusters (A, B). Cluster A consists of communities inhabited soil and moss in front of the caves (G0, S0) and that of the entrance passage of the Gombasecká Cave (G1). Within the cluster B two distinct sub-clusters are recognized, sub-cluster B1 involving predominantly sites of the Gombasecká Cave (G3, G4, G6), whereas communities of SBC and NBC were grouped in the sub-cluster B2.

DISCUSSION

In spite of rather intensive sampling the species number of Collembola (27) detected in internal parts of the Gombasecká Cave was similar to caves of the same karstic unit, Silická Plateau (Slovak Karst), not open to public. Our investigations in the Brzotínska Cave system revealed 15 species associated with the cave environment. For further examples from the territory of the Silická Plateau, 15 species were found in the Čertova Diera Cave near the Domica (Kováč, 2000), 24 species in the Ardovská Cave (Kováč, 1998) and 33 species recorded in the Majkova Cave (Papáč et al., 2006). It is clear, indeed, that species number of a given faunal group recorded is depending on sampling intensity, collecting methods used and the character of the cave under study. Generally, lower species Collembola diversity reflects undisturbed and well balanced conditions in hypogean ecosystems of these caves (Kováč, 1998a). In the contrary, the Domica Cave with 40 species detected during similar investigation (Kováč, 1998b) is apparently a different case. Here the higher Collembola diversity is most probably related to: (1) active transport of aboveground organic matter and epigeic fauna by water from adjacent ponors into the cave, (2) presence of larger accumulations of bat guano, and (3) human impact. There is markedly higher number of visitors during the year in the Domica Cave compared to the Gombasecká Cave, i. e. around 27 000 and 10 000, respectively (Nudziková and Gaál, 2010). We may conclude that rather low overall number of Collembola species dwelling the Gombasecká Cave is likely linked with oligotrophic conditions and low impact of tourism.

Collembola community was more diverse in front of the caves, where sufficient amount of the organic matter (leaf litter, humus) is concentrated. Higher accumulations of organic material (leaf litter, humus) may occur in the entrance passages of the caves. If a suitable microclimate (higher humidity), such spaces serve as important ecotones with larger variety of troglophilous species, the Majkova Cave being the case (Papáč et al., 2006). In the present study several species were observed to be abundant as soil dwellers and also as cave inhabitants. Several surface-soil dwellers were found in entrance parts of the caves, i. e. *Desoria tigrina* and *Lepidocyrtus lignorum* in the Gombasecká Cave, and *Deutonura albella* and *Lepidocyrtus lignorum* in the Brzotínske caves. Some of them even penetrated into deeper parts, i. e. *Folsomia fimetaria* (Gombasecká Cave) and *Parisotoma notabilis* (Gombasecká and Brzotínske caves). Their passive transport by hypogean water streams or by small mammals is also probable.

Qualitative cluster analysis divided communities of the Gombasecká Cave into two basic groups: (1) those of sites located nearby the cave entrance, and (2) those of the sites more distant from the entrance and the tourist path. The analysis showed a clear difference between Collembola communities inhabiting the cave entrance and communities from deeper cave parts. The cluster analysis of communities of both Gombasecká and Brzotínska Cave system showed clear difference between aboveground and cave sites. The present study revealed a great level of similarity of Collembola between caves investigated. Nevertheless, several important differences were found. For example eutroglophile *Plutomurus carpaticus*, abundant and frequent in the Brzotínska Cave system, absented in the Gombasecká Cave. And on the other hand, troglobiotic *Pseudosinella aggtelekiensis*, rather frequent in the Gombasecká Cave was totally absent in SBC and NBC. Based on the present data we may only hypothesize that *Neobisum slovacum* selectively preys upon the *P. aggtelekiensis* since this collembolan species is absent in caves inhabited by the pseudoscorpion, e. g. Šingliarova Cave, Slovak Karst (Kováč et al., 2010).

Several eutroglophilous Collembola species frequently occurred in the caves investigated. Eutroglophile is essentially an epigean species with ability to maintain a permanent subterranean population (Sket, 2008). *Arrhopalites bifidus*, inhabitant of both Gombasecká Cave and Brzotínska Cave system, is frequently distributed in Europe, except of Scandinavia. It has been known to inhabit numerous caves in Slovakia, e. g. in the Majkova and Drienovská caves in the Slovak Karst (Papáč et al., 2006; Kováč, unpubl.). *Heteromurus nitidus* was associated with entrance parts of the Gombasecká Cave. It is characterized by wide ecological valence and considered as synanthropic species (Gruia, 1998; Sterzyńska, 1990). The presence of relatively abundant population of *H. nitidus* around the tourist path in the Domica Cave was explained as a consequence of the human impact (Kováč, 2000). However, the species is mainly associated with caves rich in bat colonies with larger guano accumulations, irrespective of the tourist activity. It is the case of the Domica and Drienovská caves in the Slovak Karst, the latter one not open to public (Kováč et al. 2005 and unpubl.; Lukáň et al., 2004). In addition, the species is associated with warmer caves as in case of the Biokovo Mts. (Croatia) where it preferred localities situated in lower altitudes (Lukić and Deharveng, 2008). Both in the Domica and the Gombasecká Cave several sites were defined to be commonly inhabited by eutroglophilous *H. nitidus* and troglobiotic *Pseudosinella aggtelekiensis*. Since the latter is likely more specialized in food selection, it seems that both species do not compete for the same trophic sources. Similarly as two previous eutroglophilous species, *Plutomurus carpaticus* is often inhabitant of the Western Carpathian caves. Lukáň et al. (2004) reported its frequent occurrence in the Jasovská Cave (Slovak Karst) that serves as a tourist cave. We observed it to be frequent in the Brzotínska Cave system that is not used by tourists. *Folsomia candida* is a ripicolous species inhabiting flood debris (Skarżyński, 2001) and often inhabitant. of European caves. It was frequent in both caves systems under study.

Troglobionts, as highly adapted forms, have usually small distribution ranges. All troglobiotic collembolans recorded during the study are Western Carpathian endemic species. *Deuteraphorura* cf. *kratochvili*, *D. schoenviszkyi* and *Pseudosinella aggtelekiensis* are restricted in the distribution to caves of the Slovak Karst, whereas *Arrhopalites aggtelekiensis* has broader range. It is dwelling caves of the plateau-karst regions (Slovak Karst, Muránska Plateau, Slovak Paradise) and several smaller geographically and geologically associated karstic regions. Presence of endemic and highly adapted cave species is of great importance for the cave protection since they are unique, rare and highly vulnerable (Juberthie, 2000). Such species serve as reliable indicators of undisturbed cave environment. They were detected in the Gombasecká Cave preferably at sites distant from the tourist path (4 and 5), but also closer to the path (site 3). *Pseudosinella aggtelekiensis* was even relatively abundant near the entrance (sites 1 and 2). This indicates undisturbed and stable conditions in the cave and little impact of the tourism on Collembola assemblages. This is supported by occurrence of subterranean carabid beetle *Duvalius hungaricus sziliczensis* (Csiki, 1912) collected by pitfall traps. Its population was very sparsely distributed at every site under study with higher activity at the most distant one (5) and in some extent also at the cave entrance (site 1). During individual visits of the cave we collected other important cave adapted taxa by visual searching. Palpigrade *Eukoenenia spelaea* (Peyerimhoff, 1902), small arachnid of the order Palpigradi, have been found in three specimens in distant sites (4, 5) and also in one specimen at site 3 close to the tourist path. The palpigrades have been considered to be rare, probably often overlooked during speleobiological investigations due to their minute size. We collected an individual of the same species very near the tourist path in a distance up to 1 m in the Domica Cave, Slovak Karst (Kováč, unpubl.) and in the Važecká Cave, northern Slovakia (Mock et al., 2002b). On the other hand, in the Gombasecká Cave a single female of troglobiotic millipede *Typhloiulus* sp. was collected at the most distant site only (Mock et al. 2002a). Whether it is the consequence of negative impact of tourism upon this rare taxon remains just a question.

The terrestrial arthropods are likely not so vulnerable to human impact than those aquatic since water is the main agent of transport of chemical pollution (Juberthie, 2000). The topic apparently deserves more attention especially in caves with high tourist attendance. The higher number of exotic (trogloxene) taxa detected in some frequently visited caves used longer time for tourist purposes indicates a possible linkage that requires further investigation (Kováč, 1998; Greenslade, 2002).

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