

A REVIEW OF THE DISTRIBUTION OF CAVE COLLEMBOLA (HEXAPODA) IN THE WESTERN CARPATHIANS

by

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I - INTRODUCTION

The Western Carpathians represent the northwestern part of the Carpathian mountain arch. Karstic areas occur in Poland, Slovakia and Hungary (Fig. 1) and involve basically three types of karst: plateau, articulated and alpine (JAKÁL, 1982). Based on their geographical location, richness of their cave faunas and especially on the occurrence of troglobitic species, the Western Carpathians are not considered to lie within the zone of maximum of underground endemism (JUBERTHIE and DECU, 1994). Moreover, the distribution of Collembola in Western Carpathian caves is still poorly known.

Since STACH's paper (1929) on the peculiar Collembola from Baradla Cave in Hungary, many studies have been dedicated to cave representatives of this group in the Western Carpathians. Collembola were intensively explored in course of biospeleological research in the Aggtelek Karst and Bükk Mountains (DUDICH, 1932; BAJOMI, 1968, 1969; LOKSA, 1959a, 1959b, 1961, 1962, 1967, 1969). KOWALSKI (1955), STACH (1954, 1959) and WEINER (1990) published important data on cave species from the Polish Tatra Mountains. Data on cave Collembola from Slovakia mostly come from single investigations (NOSEK, 1962, 1963a, 1963b, 1964, 1967, 1975a, 1975b; PACLT, 1957a, 1957b, 1972; RUSEK, 1961) including some recent contributions on the topic (KOVÁC, 1992, 1998; KOVÁC and MOCK, 1999; KOVÁC *et al.*, 1997, 1999).

The aims of this paper are (1) to review the occurrence of particular collembolan species in the Western Carpathians that are known exclusively from caves, and (2) to analyse distributional patterns of troglobitic Collembola in this region.

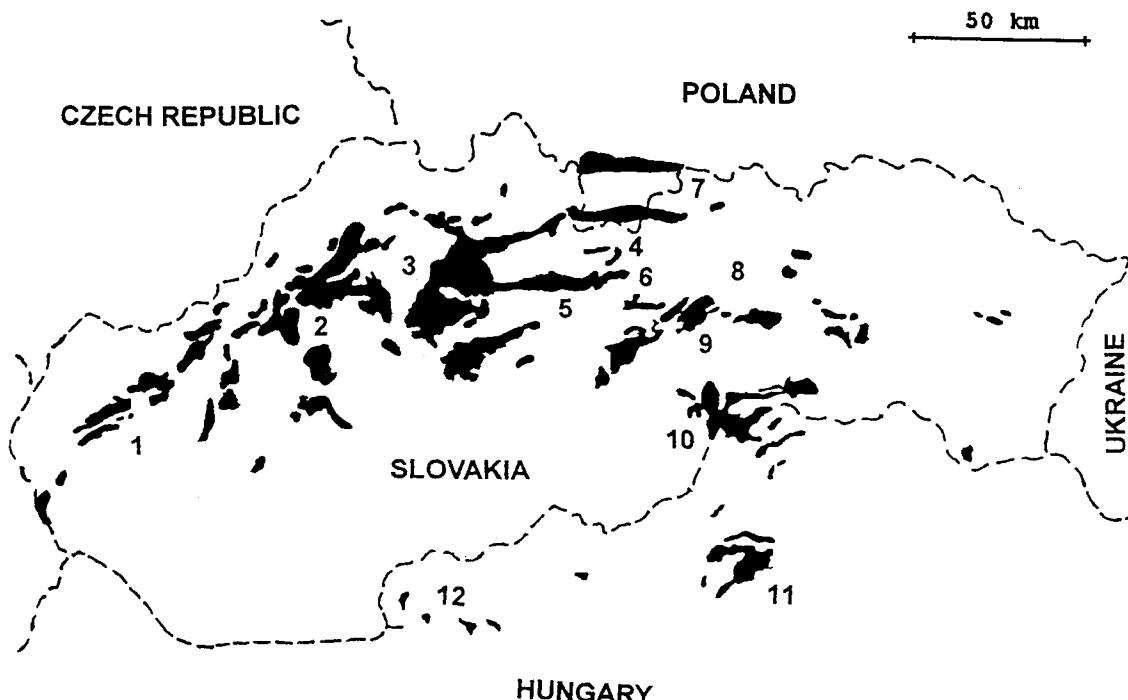


Fig. 1 - Karstic areas of Western Carpathians (for numbers see tabl. 1).

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II - CLASSIFICATION OF TROGLOBITIC SPECIES

Morphological adaptations may be used to classify particular species as troglobites, such as enlarged body size, anophthalmia, reduction of body pigment, elongation of antennae and legs, elongation of foot complex, etc. (DEHARVENG and THIBAUD, 1989; THIBAUD and DEHARVENG, 1994) CHRISTIANSEN (1992) stressed the fact that troglobiomorphy is not universal among cave organisms. It is, for example, absent in communities of guano piles, an environment rich in energy. Another and more accurate way to distinguish troglobitic species is to study biological and ecophysiological adaptations of the species (THIBAUD, 1994). However, we still lack such information for many cave habitats. Thus, troglobiomorphic characters served in this analysis as a provisional tool to recognise troglobites.

III - TROGLOBITIC COLLEMBOLA IN THE WESTERN CARPATHIANS

The distributional analysis of Collembola in the Western Carpathian caves is based on published data and also on some important unpublished records. At first, troglophilous species, present also in above-ground habitats, were discarded from the total list. Explored orographic regions with caves and abysses are given in Tabl. 1. Potentially troglobitic forms (28 in total), in this region known exclusively from underground spaces, are listed in Tabl. 2. In sorting species according to distributional area, it was necessary to eliminate species for which there was only a single record as there was too little information to predict their overall distribution.

Tabl. 1 - Orographic regions and caves/abyss with occurrence of cave Collembola (H. Hungary, S = Slovakia, P = Poland) (see map fig. 2).

| | |
|---------------------------------|----------------------------------|
| 1. Little Carpathians | 8. Hornádska Basin |
| a/ Plavecké Podhradie Cave (S) | Dreveník - Ice Cave (S) |
| b/ Rostún Cave (S) | 9. Slovak Paradise |
| c/ Driny Cave (S) | a/ Certova Cave (S) |
| 2. Strázovské Mts. | b/ Dobsinská Ice Cave (S) |
| Dúpna diera Cave (S) | c/ Duca cave (S) |
| 3. Veľká Fatra Mts. | d/ Koniarova Cave (S) |
| Harmanecká Cave (S) | e/ Klastorná Cave (S) |
| 4. Tatra Mts. | f/ Medvedia Cave (S) |
| a/ Magurska Cave (P) | g/ Na Skale Cave (S) |
| b/ Cave in valley Kalatówka (P) | h/ Psie Diery Cave (S) |
| c/ Mylna Cave (P) | i/ Ruzová Cave (S) |
| d/ Czarna cave (P) | j/ Stratenská Cave (S) |
| e/ Kamienne Mleko Cave (P) | k/ Vicia Cave (S) |
| f/ Szczelina Cave (P) | l/ Vojenská Cave (S) |
| g/ Zimna Cave (P) | 10. Slovak-Agtelek Karst |
| h/ Groby Cave (P) | a/ Jasovská cave (S) |
| i/ Dzuira cave (P) | b/ Ardovská Cave (S) |
| j/ Dziura Wyzna Cave (P) | c/ Domica Cave (S) |
| k/ Belianska Cave (S) | d/ Baradla Cave (H) |
| l/ Kresanica Abyss (S) | e/ Szabadság Cave (H) |
| 5. Low Tatra Mts. | f/ Meteor Cave (H) |
| a/ Demänovská Ice Cave (S) | g/ Kifli Abyss (H) |
| b/ Demänovská Slobody Cave (S) | h/ Öz Abyss (H) |
| c/ Demänovská Mieru Cave (S) | i/ Hideglyuk Abyss (H) |
| d/ Pustá Cave (S) | 11. Bükk Mts. |
| e/ Vel'ká Stanisovská Cave (S) | a/ István Cave (H) |
| 6. Kozie Chrbty Mts. | b/ Forrás Cave (H) |
| Vazecká Cave (S) | c/ Szamenta Cave (H) |
| 7. Pieniny Mts. | 12. Cserhát Mts. Naszály Plateau |
| Aksamitka Cave (S) | Nászép Cave (H) |

The following unpublished records were included in the distribution analysis.

Mesogastrura ojcoviensis (Stach, 1919)

Slovak-Agtelek Karst, Drienovská Cave, decomposing wood, 12. 2. 1997, A. Mock leg.

Protaphorura janosik (Weiner, 1990)

Hornádska Basin, Dreveník (Travertine Hill), L'adová (Ice) Cave, pitfall trap, 15. 11. 1996 30. 3. 1997, L. Kováč leg.

Slovak-Agtelek Karst, Hacavská Cave, pitfall trap, 24. 5. 23. 6. 1996, L' Kovác leg.

Pseudosinella agtelekiensis (Stach, 1929)

Slovak-Agtelek Karst, Hacavská Cave, 27. 6. 1987, V. Kosel leg. pitfall trap, 24. 5. 23. 6. 1996, L' Kovác leg.

Pseudosinella thibaudi Stomp, 1977

Little Carpathian Mts, Zbojnícka Cave, pitfall trap, 28. 5. 20. 11. 1997, V. Kosel leg.

Bonetogastrura Thibaud, 1974 is a special case of relic genus with rare and limited occurrence (DEHARVENG and THIBAUD, 1989). All other genera of the species listed (Tabl. 2) have hemiedaphic species, i. e. their occurrence is not restricted to the underground environment.

Fourteen of the analysed forms were potentially troglobites. Partial troglobiomorphy has been documented in pigmented *Bonetogastrura cavicola* (Börner, 1901), *Mesogastrura ojcoviensis* (Stach, 1919), *Arrhopalites bifidus* (Stach, 1945), *A. pygmaeus* (Wankel, 1860) and *A. slovacicus* (Nosek, 1975). Pigmented eyes in these species indicate that these forms are not strictly adapted to cave life. In *B. cavicola* a tendency for body depigmentation and elongation of the unguis is apparent. This species together with *A. pygmaeus* are considered as glacial relicts, in which colonisation of underground spaces and the emergence of troglobiomorphic adaptations began during the Pleistocene. (STACH 1959, THIBAUD 1980).

Protaphorura janosik Weiner, 1990, *Deuteraphorura* cf. *finetaria* (L.) (auct.) (STACH, 1934), *Arrhopalites hungaricus* Loksa, 1967 and *A. intermedius* Loksa, 1969 are completely depigmented, but lack other typical troglobiomorphic characters, such as elongation of extremities and foot complex. An exception is *P. janosik* with its large body size (3.5 - 4.2 mm) which contrasts with the size (1.2 - 1.4 mm) of the closely related *Protaphorura tricampata* (Gisin, 1956).

Forms strictly limited to underground habitats include *Pseudosinella agtelekiensis* (Stach, 1929), *Pseudosinella paclti* Rusek, 1961, *Arrhopalites agtelekiensis* Stach, 1929 and *A. buekkensis* Loksa, 1969 showing a high degree of troglobiomorphy. These forms are characteristic troglobites of the Western Carpathians belonging to European cavernicolous fauna, that is generally considered as relic of ancient (Tertiary) fauna (VANDEL, 1965).

IV - ZOOGEOGRAPHICAL ANALYSIS

Cavernicolous Collembola may be grouped according to the size of their geographical range. Species whose distributions extend beyond the Western Carpathians are: *Bonetogastrura cavicola*, *Mesogastrura ojcoviensis*, *Arrhopalites pygmaeus* and *A. bifidus*. They are distributed in caves throughout Europe, except Scandinavia. In the Western Carpathians they are known only from caves. *B. cavicola* and *A. pygmaeus* rarely also inhabit above-ground habitats and therefore they are considered as regional troglobites, while *M. ojcoviensis* is generally classified as euedaphic, nidicolous and guanophilous species (CHRISTIAN, 1987).

Protaphorura janosik is an endemic species with a distribution restricted to the Western Carpathians, where it inhabits caves of many orographic regions (see Table. 2 and above text). A closely related form is known from Westphalia in Germany (WEINER 1990). This form together with *P. janosik* was considered before as the same species, *Onychiurus armatus* var. *multituberculatus* Stach, 1934.

A third group consists of endemic species with smaller distributional areas.

Pseudosinella paclti mainly occurs in central mountains of the Western Carpathians. Plateau karst (Slovak Paradise, Slovak-Agtelek Karst, Bükk Mts.) is inhabited by *Arrhopalites agtelekiensis* and *A. buekkensis*. Occurrence of *Pseudosinella agtelekiensis*, *Arrhopalites hungaricus* and *A. slovacicus* is limited to the Slovak-Agtelek Karst. More detailed distributional pattern of undescribed *Deuteraphorura* sp. (see above text and Table. 2) is not clear, but it apparently belongs to the Western Carpathian endemics with smaller area.

Pseudosinella thibaudi Stomp, 1977 with, 2 + 2 pigmented eyes represents an interesting case of a troglobilophilous species with rare occurrence. The Little Carpathian Mts. are one only two areas where this species has been detected (described from a cave in Franconian Jura in Germany). It is probable, as with most species of the *Pseudosinella vandeli* group, that this species actually has a broader, circumalpine, distribution (STOMP, 1986).

One of the main reasons for perceived "endemism" or "rareness" of the species mentioned here may be the scarce knowledge of their taxonomy and autecology (CHRISTIAN, 1998). There are still unexplored karstic areas in the Western Carpathians and we have no information on other types of caves other than karstic. "Milieu Souterrain Superficiel" has not yet been investigated in this region.

Species with more developed troglobiomorphic characters are in the Western Carpathians distributed especially in plateau karst: Slovak Paradise, Slovak-Agtelek Karst and Bükk Mts. (Fig. 1, Table. 2). These areas were not covered by glaciers during the last (Würm) glaciation (Fig. 2). *Pseudosinella paclti* interestingly occurs in places that in the past contacted directly with glaciers. The effect of glaciation was demonstrated by SKALSKI (1994), who noted that in caves in Poland no Tertiary relic species survived to Pleistocene

glaciations. On the other hand, VORNATSCHER (1979) stressed that several terrestrial arthropods could survive to glaciations in great karstic underground systems but it is not known whether this also applies to Western Carpathian Collembola and further exploration is needed.

KOSEL (1998) analysed the distribution of cavernicolous fauna in karstic areas of Slovakia and northern Hungary. He considered the Slovak-Agtelek Karst as an evolutive center of the cave fauna of this region. The same seems also to be true for Collembola as this is the area in the Western Carpathians where three forms with clear troglobiomorphic characters occur together (Fig. 2).

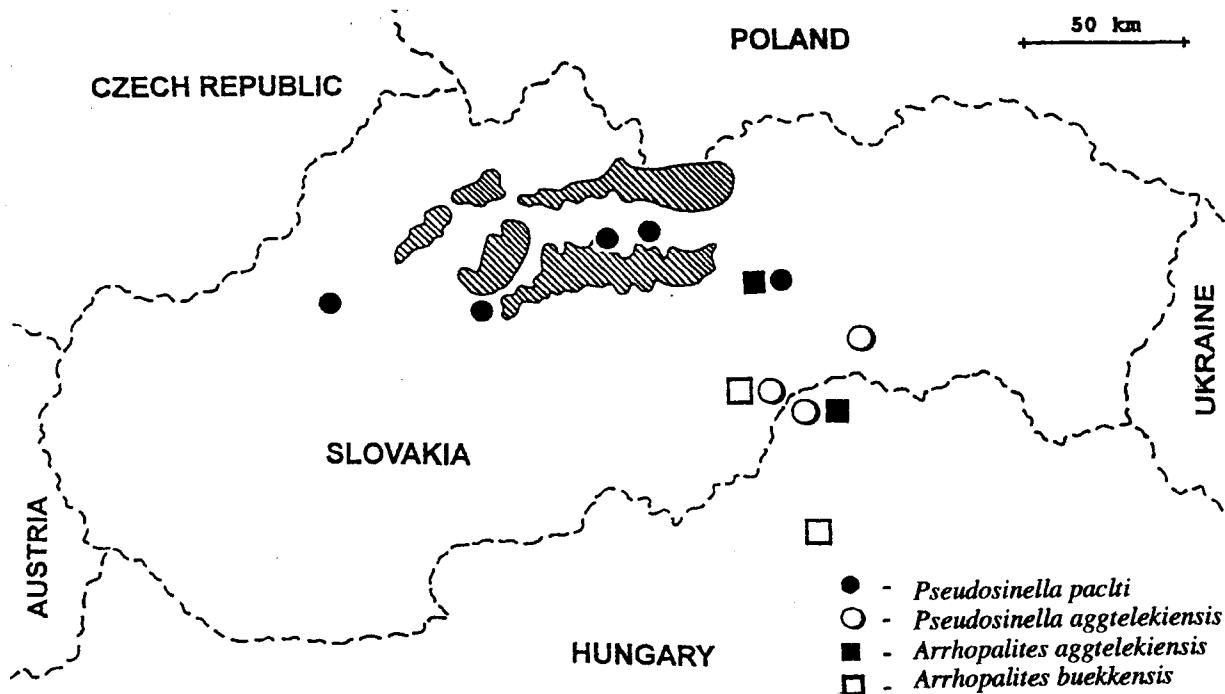


Fig. 2 - Distribution of endemic troglobitic Collembola in the Western Carpathians (striped areas indicate extent of permanent ice and snow during Würm period) 1-10 = Legend in Table 1.

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ABSTRACT

The distribution of cave Collembola from the Western Carpathians is reviewed, using published data and important new unpublished records. Species present both in caves and above-ground habitats were excluded from this geographical analysis. Due to doubtful taxonomic status and/or scarce knowledge of their distribution and ecology, only 13 of 28 species analysed may be considered as troglobites. According to the presence of troglobiomorphic characters and their occurrence in underground habitats of particular karstic areas these species show different degrees of adaptations to caves.

Among the studied species, *Pseudosinella agttelekiensis* (Stach, 1929), *P. paceti* Rusek, 1961, *Arrhopalites agttelekiensis* Stach, 1929 and *A. bukkensis* Loksa, 1969, the most probably represent preglacial forms of cavernicolous fauna, in which troglobitic adaptations emerged during the Tertiary. Three of them dwell caves in the Slovak-Agtelek Karst and this supports the hypothesis that the area served as a centre of evolution of troglobitic Collembola in the Western Carpathians.

RÉSUMÉ

La répartition des Collemboles souterrains des Carpates Occidentales est passée en revue en utilisant les données publiées et de nombreuses informations non publiées. Les espèces présentes à la fois dans les grottes et les habitats de surface sont exclues de cette analyse biogéographique. Compte tenu du statut taxonomique douteux et/ou des connaissances sur l'écologie et la répartition de certaines espèces, seulement 13 des 28 espèces analysées peuvent être considérées comme troglobies. Ces espèces montrent différents degrés d'adaptations en milieu souterrain.

Des espèces, *Pseudosinella agttelekiensis* (Stach, 1929), *Pseudosinella paceti* Rusek, 1961, *Arrhopalites agttelekiensis* Stach, 1929 and *Arrhopalites bukkensis* Loksa, 1969, représentent probablement des formes cavernicoles antérieures aux glaciations quaternaires, chez lesquelles les adaptations morphologiques liées à la vie souterraine se mettent en place au tertiaire. Trois de ces dernières espèces peuplent les grottes du Slovak-Agtelek Karst et ceci est un argument pour le considérer comme le centre d'évolution des Collemboles souterrains des Carpates Occidentales.

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Table 2: List of cave Collembola of the Western Carpathian caves (* - troglobitic species, for distribution see Table 1 and Fig. 1)

| Species | Distribution | References |
|--|---|--|
| <i>Hypogastrura crassaegranulata carpatica</i> Nosek, 1962 | 1a, b | Nosek (1962, 1963b) |
| <i>Hypogastrura crassaegranulata dobsinensis</i> (Stach, 1949) | 9b | Stach (1949), Nosek (1967), Kováč et al. (1999) |
| * <i>Bonetogastera caricola</i> (Börner, 1901) | 8, 10f-i, 11b | Loksa (1962), Bajomi (1968, 1969), Kováč (1992) |
| * <i>Mesogastrura ojcoviensis</i> (Stach, 1919) | 1a | Nosek (1962, 1963b) |
| <i>Mesogastrura anthrohungarica</i> Loksa, 1959 | 12 | Loksa (1959b) |
| * <i>Neanura dudichi</i> Loksa, 1967 | 10h | Loksa (1967), Bajomi (1968) |
| <i>Hymenaphorura pseudosibirica</i> (Stach, 1954) | 10d | Stach (1954) |
| * <i>Protaphorura janosik</i> Weiner, 1990 | 1b, 4a-f, k-l, 5a, 7, 9b-d, f, h, j-k | Stach (1954, 1959), Kowalski (1955), Pacłt (1957b), Nosek (1963b, 1964, 1967), Weiner (1990), Kováč & Mock (1999), Kováč et al. (1999) |
| <i>Protaphorura kadicci</i> (Loksa, 1967) | 10h-i | Loksa (1967), Bajomi (1968) |
| <i>Protaphorura troglophila</i> (Nosek, 1975) | 10c | Nosek (1975a) |
| * <i>Deuteraphorura cf. fumaria</i> (L.) (auct.) (Stach, 1934) | 7, 9a, c, e-h, j, l, 10b 10f-g | Kováč (1998), Kováč & Mock (1999), Kováč et al. (1999) |
| <i>Onychiurus schoenvisztyi</i> Loksa, 1967 | 5a | Loksa (1967), Bajomi (1968, 1969) |
| <i>Onychiurus kratochvíli</i> Nosek, 1963 | 12 | Nosek (1963a, 1967) |
| <i>Onychiurus microchaetus</i> Loksa, 1959 | 1a | Nosek (1959b) |
| <i>Sternaphorura japygiformis</i> Absolon, 1900 | 10e-f | Nosek (1962, 1963b) |
| <i>Folsomia antarctica</i> Loksa, 1959 | 10b, d-e | Loksa (1959a), Bajomi (1969) |
| * <i>Pseudosinella agetelekensis</i> (Stach, 1929) | 1a | Stach (1929), Dudich (1932), Loksa (1961), Kováč (1998) |
| <i>Pseudosinella binoculata</i> Kseneman, 1935 | 2, 3, 5a-e, 6, | Nosek (1962, 1963b - as P. ksenemani Gisin, 1944) |
| * <i>Pseudosinella paceti</i> Rusek, 1961 | 9 d-f, i 1 | Pacłt (1957a, 1957b, 1972), Rusek (1961), Nosek (1967), Kováč et al. (1999) (see text) |
| <i>Pseudosinella thibaudi</i> Stomp, 1977 | 9e | Loksa (1961) |
| <i>Oncopodura egerszögensis</i> Loksa, 1961 | 9a, f-h, j-k, 10d 9i, 10e, 11a-b | Stach (1929, 1945), Dudich (1932), Nosek & Paoletti (1984), Kováč et al. (1999) |
| * <i>Arrhopalites agetelekensis</i> Stach, 1929 | 10b, 11c 10g-j | Loksa (1961, 1962), Kováč et al. (1999) |
| * <i>Arrhopalites bifidus</i> Stach, 1945 | 10f | Loksa (1969), Kováč (1998) |
| * <i>Arrhopalites bukensis</i> Loksa, 1969 | 10f | Loksa (1967), Bajomi (1968) |
| * <i>Arrhopalites hungaricus</i> Loksa, 1967 | 10f | Loksa (1969), Bajomi (1969) |
| * <i>Arrhopalites intermedius</i> Loksa, 1969 | 1c, 2, 4a, g-k, 5b, 6, 7, 9c, e-f, h, l, 10b, d-e, 12 | Dudich (1932), Stach (1945, 1959), Kowalski (1955), Pacłt (1957a, 1957b, 1972), Loksa (1959b, 1961), Kováč (1998), Kováč & Mock (1999), Kováč et al. (1999) |
| * <i>Arrhopalites slovacus</i> Nosek, 1975 | 10c | Nosek (1975a, 1975b), Kováč et al. (1997) |