COMPARISON OF THE WORLDWIDE CAVE COLLEMBOLA AT THE GENERIC LEVEL[1]

Gabriela Castaño-Meneses[2,3] and José G. Palacios-Vargas[2]

ABSTRACT: We present a comparison at the generic level of the cave Collembola fauna recorded around the world. Using the biogeographical provinces proposed by Christiansen and Bellinger (1995), we analyzed the similarity among regions according to the Collembola genera inhabiting caves. The European region is separated from the remaining biogeographical regions, and one of the main groups includes the Asia Pacific region, North America, and the Arctic and Subarctic regions. This can be related to the differences in the distribution of the genera, and the wide distribution of some of them in the world. Some provinces share the same Collembola in spite of their great geographic distances, perhaps resulting from their geological origin or from the different collecting efforts in each region.

KEY WORDS: Diversity, cave, distribution, springtails, troglobites

Caves represent a very peculiar environment, drawing the attention of many different kinds of research, including archaeology, biology, hydrology, geology and ethnology, and cultural aspects including legends and myths (Barr and Holsinger, 1985; Christman and Culver, 2001; Hapka and Rouvinez, 1997; Jennings, 1985; Steel, 1997). Caves are very important to ecosystem functioning in the areas where they are present (Emmett and Telfer, 1994; Gibert and Deharveng, 2002).

Springtails occupy different biotopes in caves, such as in guano, soil and detritus. Since their populations can be abundant, they have an important role in decomposition and energy flow in subterranean trophic webs. As some caves are very poor in nutrients, the role of these animals is very important as prey of several groups such as spiders, mites and insects.

Worldwide, several hundred species of springtails have been reported from caves and 278 of these are considered troglomorphic (Thibaud and Deharveng, 1994). In Mexico, 122 species have been recorded from caves (Christiansen and Reddell, 1986; Palacios-Vargas, 1989; 1997), which makes this, in the Neotropical region, the country with the best information about cavernicolous Collembola.

Springtails are a very useful model for biogeographic studies (Christiansen and Culver, 1987; Cassagnau, 1990; Christiansen and Bellinger, 1994). The analysis of the geographic distribution of the Collembola, using the ancient systems of division of biogeographic regions, that include Neartic, Paleartic, Afrotropic, Indomalayan, Australasian, Neotropicical, Oceania and Antarctic regions, does

[1] Received on January 28, 2011. Accepted on March 13, 2011.

[2] Unidad Multidisciplinaria de Docencia e Investigación, Facultad de Ciencias, Campus Juriquilla, Universidad Nacional Autónoma de México. Juriquilla, Querétaro, 76230, México. E-mail: gcm@hp.fciencia.unam.mx

[3] Ecologia y Sistemática de Microartrópodos, Departamento de Ecologia y Recursos Naturales, Facultad de Ciencias, Universidad Nacional Autônoma de México, 04510, México, D. F. E-mail: troglolaphysa@hotmail.com

Mailed on July 30, 2012

not contribute to an understanding of their actual distribution, nor does it explain some of the great differences that exist between relatively close areas (Christiansen, 1982).

That is why we consider it important to use the new system proposed by Christiansen and Bellinger (1995; Culik and Zeppelini, 2003). Although this division might seem excessive, in the future it will prove to be useful for Collembola and, perhaps, also for other groups of arthropods that are so diverse and abundant in soil and caves.

The main purpose of this contribution is to present a general revision of the cave Collembola distribution at the generic level around the world, mainly those considered troglomorphic, and to compare this with the 37 different biogeographic provinces proposed by Christiansen and Bellinger (1995), and discover their biogeographic relationships and how close they are.

METHODS

We have elaborated a list of cave Collembola genera with information taken from the web page of Janssens (Bellinger et al., 1996-2011), since it is in agreement with the proposal of Christiansen and Bellinger (1995) for the biogeographic regions and provinces.

To compare the similarity of Collembola genera among regions, we performed a cluster analysis, using the method of average amalgamation of non-couplet means or UPGMA and dissimilarity percentage (Van Ooyen, 2001). The analysis was performed using the software Statistica ver 6.0 (StatSoft, 1999).

RESULTS

According to Bellinger, et al. (1996-2011), there are 769 genera of Collembola in the world, and 72 of them, representing about 9% of the total, have been recorded from caves. Only nine genera of Collembola are considered exclusively cavernicolous: *Gulgastrura, Ongulogastrura, Ongulonychiurus, Gnathofolsomia, Bessoniella, Cyphoderopsis, Disarrhopalites, Troglospinotheca,* and *Troglobius*. That means that nearly 13% of the Collembola genera that have inhabitants in caves are exclusive to that environment. The genus *Gisinea* had been recorded only from Belgian caves, but the species *G. tiliae* was described from soils of southern Siberia (Babenko, 1998).

The families Onychiuridae and Hypogastruridae presented the highest number of genera in caves, with sixteen and twelve, respectively, followed by Entomobryidae with nine genera (Fig. 1).

The genus with the most troglomorphic species (119) is *Pseudosinella,* representing about 38% of the total species of the genus (313 spp.). This genus has a cosmopolitan distribution.

With the cluster analysis, we obtained a dendrogram which compares 37 different biogeographic provinces according to the level of similarity at the generic level (Fig. 2).

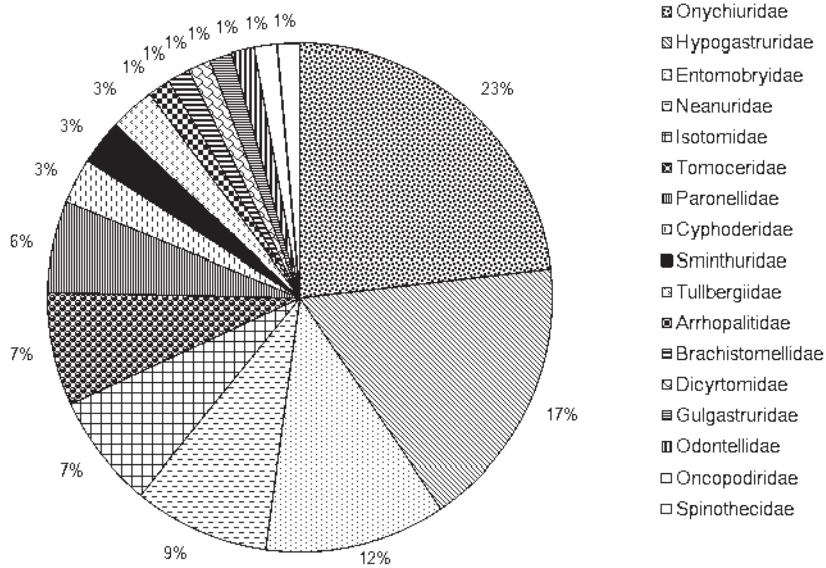

Fig. 1. Percentage of genera in families of Collembola with cavernicolous species

The dendrogram shows two main groups. The smaller group includes the regions where there are more records of cave Collembola fauna, like Europe (2a), Pacific North American (8) and Mediterranean (5). In this group, the geographical proximity and water current connections explain an extreme similarity among the faunas of western Europe, Mediterranean and the Macaronesian regions. On the other hand, the region of Northern North America, Southern North America and Pacific North America are related to the Caribbean mainland region, according to their similarity of Collembola genera.

The biggest group is divided into two parts, with large areas having few records of cave Collembola, like Juan Fernández (30), Northeast African Highlands (11), Antarctic and Subantarctic (37) and Patagonian (36) regions in one group, and the other group including mainly the regions of South America, Australia and Asia.

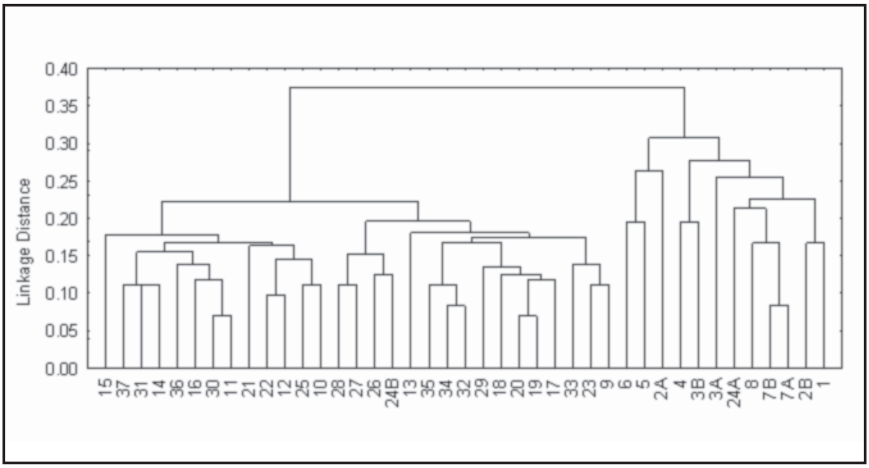

Fig. 2 Dendrogram for comparison of the cave Collembola from the 37 biogeographical provinces. 1, Arctic and Sub-arctic; 2a, Europe; 2b, Asia; 3a, Sino-Japanese; 3b, Himalayan; 4, West and Central Asia; 5, Mediterranean; 6, Macaronesian; 7a, North of North American; 7b, South of North American; 8, Pacific North American; 9, African Indian Desert; 10, Sudanese Park Steppe; 11, North East African Highland; 12, West African Rain Forest; 13, Steppe of the African East; 14, South African; 15, Madagascar; 16, Ascencion and St. Helena; 17, Indian; 18, Continental South East Asia; 19, Malaysian; 20, Hawaiian; 21, New Caledonia, 22, Melanesia and Micronesia; 23, Polynesia; 24a West Caribbean; 24b East Caribbean; 25, Venezuela and Guiana; 26, Amazon; 27, South of Brazil; 28, Andean; 29, Pampas; 30, Juan Fernandez; 31, Cape; 32, North and East Australia; 33, South West Australia; 34, Central Australia; 35, New Zealand; 36, Patagonian; 37, Antarctic and Subantarctic (according with Christiansen and Bellinger, 1995).

After this preliminary analysis of the biogeographic distribution, we realized that there are several endemic genera in some provinces. Nevertheless, most of the genera have a wide distribution. Many important regions have not been studied and, thus, are lacking any information about the cave Collembola. Several provinces even lack karstic areas where caves can develop. The Palearctic Region is the best studied and has the highest number of cave genera (32), and the second region is the Neotropical, with 22 genera.

This can be due to two factors. First, by the differences in the actual distribution of the cave genera, or second, to the fact that many genera are widely distributed in the world, and some regions share fauna and therefore appear not so different, in spite of the great geographic distances because they have not been well studied enough to find endemic genera.

DISCUSSION

Among a total of 769 genera worldwide, only 72 have cave species. These genera include more than 1,500 species recorded from different environments, and 278 of them have been considered true troglomorphic species (Thibaud and Deharveng, 1994). This number is about 3.4 % of the total species of Collembola in the world (8,171 according to Bellinger et al., 1996-2011).

There are 17 families of springtails with troglomorphic species (from a total of 34), representing 50% of the known families in the world (Bellinger et al., 1996-2011). Genera *Gulgastrura, Ongulogastrura, Ongulonychiurus, Gnathofolsomia, Bessoniella, Cyphoderopsis, Disarrhopalites, Troglospinotheca* and *Troglobius* are exclusively troglobitic, with only one or two species each. The distribution of those species is mainly European, with the exception of *Gulgastrura* which has been recorded only in Korea, corresponding to the Himalayan biogeographic region, and *Troglospinotheca* which is Patagonian and *Troglobius,* distributed in the Amazon, southern Brazil and Madagascar.

In a previous analysis, Palacios-Vargas (2002) found a very different distribution of the genera, and in that study the Europe region (2a, according to Christiansen and Bellinger, 1995) shows a clear isolation from the remaining biogeographical regions, probably as a result of differential collecting effort. Nevertheless, Europe is the best known region as far as cave Collembola fauna (55 genera) and endemic species, but recently there has been development in other areas, and the difference between Europe and the other regions is less today than formerly. The Pacific North American region (8) includes 49 genera of Collembola, the Mediterranean includes 46 (region 5), followed by the Sino-Japanese area (3a), with 42.

The increase in number of records of the distribution of Collembola in caves around the world gives more clear information in order to determine the relationships between their faunas. There are some genera, like *Arrhopalites,* that have been studied recently, and their known distribution has increased, which can explain the relationship between North America and the Asian region (Zeppelini and Christiansen, 2003; Park and Kang, 2007), but this genus also has many edaphic species.

Some answers about actual distribution of cave Collembola should be found in the different geological histories of the geographic provinces. We believe that there is still much study to be done, and despite the close proximity of some of the geographic regions, we believe the cave faunas are far more different from what has been described to date.

ACKNOWLEDGEMENTS

The authors appreciate the support for this project from PAPIIT (UNAM) grant IN238003.

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