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MILLIPEDES (DIPLOPODA) FROM CAVES OF PORTUGAL

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Abstract: Millipedes play an important role in the decomposition of organic matter in the subterranean environment. Despite the existence of several cave-adapted species of millipedes in adjacent geographic areas, their study has been largely ignored in Portugal. Over the last decade, intense fieldwork in caves of the mainland and the island of Madeira has provided new data about the distribution and diversity of millipedes. A review of millipedes from caves of Portugal is presented, listing fourteen species belonging to eight families, among which six species are considered troglobionts. The distribution of millipedes in caves of Portugal is discussed and compared with the troglobiont biodiversity in the overall Iberian Peninsula and the Macaronesian archipelagos.

Introduction

Millipedes play an important role in the decomposition of organic matter, and several species around the world have adapted to subterranean life, being found from cave entrances to almost 2000 meters depth (Culver and Shear, 2012; Golovatch and Kime, 2009; Sendra and Reboleira, 2012). Although the millipede faunas of many European countries are relatively well studied, this is not true of Portugal. Thus, only 44 millipede species are listed from the Portuguese mainland in Fauna Europaea, compared to 178 species from the Spanish mainland, 264 species from the French mainland, and 440 species from the Italian mainland (Enghoff and Kime, 2009). The primitive status of knowledge of Portuguese mainland millipedes stands in contrast to the well-documented diversity of millipede fauna in the Atlantic archipelagos of Madeira and Azores (Enghoff, 1982, 1983a,b, 1992; 2010; Enghoff and Borges, 2005).

What is true of millipedes in general, is true of Portuguese cave millipedes. Knowledge about terrestrial invertebrates from caves of Portugal has increased significantly in recent years, but troglobiont millipedes from Portugal were unknown until last year (Reboleira et al., 2013a). In mainland Portugal, the presence of millipedes in caves was first documented by Barros Machado, but despite several species having been recorded from caves, no troglobiont species had been discovered (Machado, 1946; Reboleira et al., 2011a; Reboleira et al., 2013a).

Intense fieldwork in recent years in caves of mainland Portugal and on Madeira Island is synthetized here, listing new species for Portugal and new distribution data for millipedes in caves.

Material and Methods

Specimens were collected in caves of Portugal from 1989 to 2013, mainly in karst caves of mainland Portugal and in the lava tubes of Madeira (Fig. 1). Identification of species was made using the collection of the Zoological Museum of University of Copenhagen and the pertinent literature.

All specimens from mainland Portugal were collected by A.S.P.S. Reboleira, while collectors of Madeiran specimens are identified in the text. Material is deposited in the following collections: Zoological Museum of University of Copenhagen, Department of Animal Biology, University of La Laguna, Spain and in the collection of Sofia Reboleira, Portugal.

Species were classified according to their degree of dependence on the subterranean environment, following the Schiner-Racovitza system and using the same criteria as Reboleira et al. (2011a): *epigean species* are those whose occurrence in caves is accidental; *troglophiles* are species with affinities to the subterranean environment but lacking troglomorphisms; *troglobionts* are species that exhibit a combination of depigmentation and eye lack or reduction, in the families that normally have them, and which are found only in the subterranean environment.

Results

A total of fourteen species, belonging to eight families, were identified. Troglobionts are represented by six species, five from karst caves in mainland and one from lava tubes in Madeira (Table 1).

Most of the studied caves lack troglobiont millipedes; only three massifs have yielded troglobionts so far: Sicó and Estremoz-Cano, with one new species of Chordeumatida each in families Chamaesomatidae and Opisthocheiridae, respectively, and the Algarve, with two species of Julida in family Blaniulidae and one of Polydesmida in family Paradoxosomatidae (Table 1). In the Portuguese Atlantic archipelagos, only one troglobiont species of Julida, family Julidae, has been recorded so far, in caves of Madeira.

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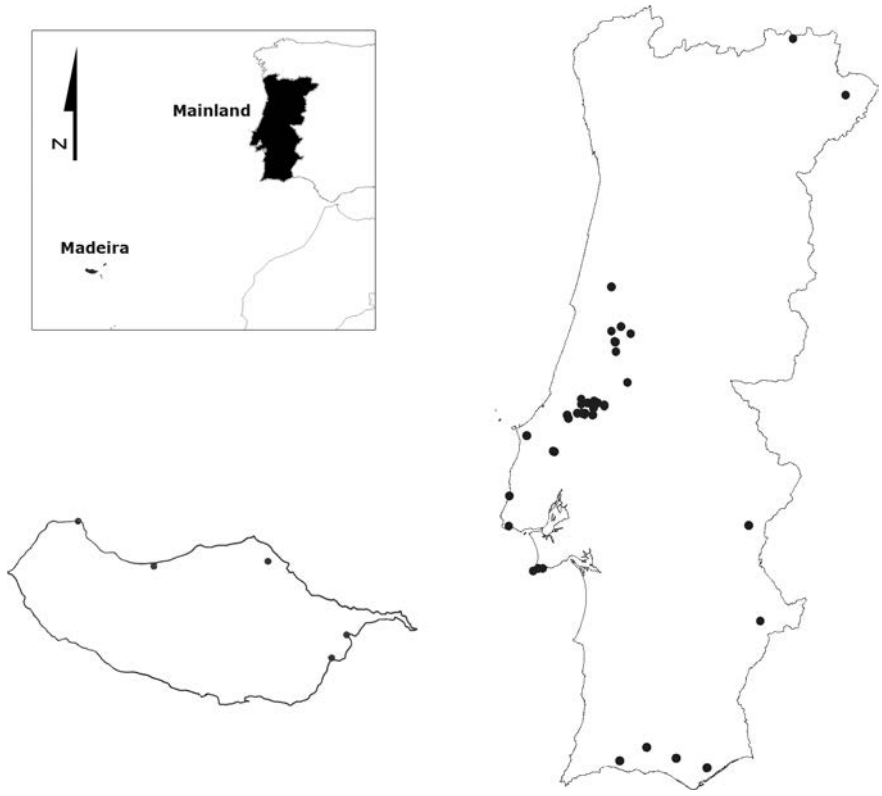

Figure 1. Locations of sampled caves in Portugal.

Table 1. Millipedes from caves of Portugal.

Family/Species	Life Style	Distribution in Caves
Haplobainosomatidae		
Haplobainosoma lusitanum	Troglophile	Sicó, Estremenho, and Montejunto massifs
Chamaesomatidae		
Scutogona n. sp.	Troglobiont	Sicó massif
Opisthocheiridae		
Gen. indet. sp. indet.	Troglobiont	Estremoz-Cano massif
Dorypetalidae		
Lusitanipus alternans	Epigean	Outil-Cantanhede and Sicó massifs
Blaniulidae		
Acipes bifilum	Troglobiont	Eastern Algarve massif
Acipes machadoi	Troglobiont	Central Algarve massif
Blaniulus guttulatus	Epigean	Madeira
Julidae		
Cylindroiulus sp. 1	Epigean	Estremenho massif
Cylindroiulus sp. 2	Troglobiont	Madeira
Choneiulus palmatus	Epigean	Madeira
Nopoiulus kochii	Epigean	Madeira
Polydesmidae		
Polydesmus coriaceus coriaceus	Troglophile	Outil-Cantanhede and Sicó massifs and Madeira
Paradoxosomatidae		
Oxidus gracilis	Epigean	Outil-Cantanhede massif and Madeira
Boreviulisoma barrocalense	Troglobiont	Algarve

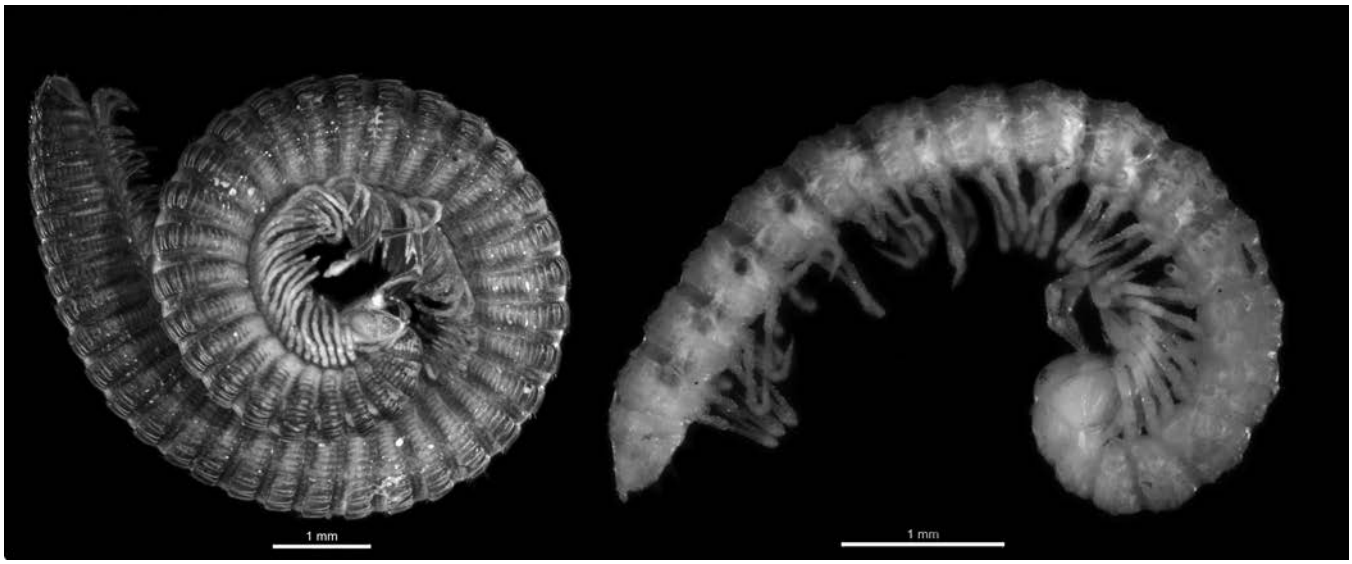

Figure 2. Millipede species of caves in Portugal, the surface species *Lusitanipus alternans* at left and the troglobiont species *Boreviulisoma barrocalense* at right.

LIST OF PORTUGUESE CAVE MILLIPEDES

Class Diplopoda
Order Chordeumatida
Family Haplobainosomatidae
Haplobainosoma lusitanum Verhoeff, 1900

Studied material: Portugal, Estremenho massif: Gruta da Contenda, 27 January 2007, 1 ♀; Algar do Ladoeiro, 6 January 2007, 1 ♂, 2 ♀; 6 February 2007, 1 ♂, 3 ♀; Sicó massif: Gruta da Cerâmica, 29 August 2009, 1 ♀; Montejunto massif: Algar do Javali, 1 ♂, 2 ♀, 4 juv; 24 December 2009, 3 ♂, 4 ♀.

Remarks: Epigean species, often found near cave entrances of central Portugal. Also present in the Azores (Terceira, Pico, Faial, São Miguel, and Santa Maria) (BDBA, 2013).

Family Chamaesomatidae
***Scutogona* sp.**

Localities: Portugal, Sicó massif, Gruta da Arrifana, 13 January 2013, 3 ♂, 7 ♀, 1 juvenile; Gruta da Senhora da Estrela, 11 June 2009, 1 ♂, 1 ♀; same data but 11 June 2009, 1 ♀.

Remarks: Troglobiont, blind and depigmented, found in two caves of Sicó massif.

Family Opisthocheiridae
gen. indet. sp. indet.

Locality: Portugal, Estremoz-Cano massif: Gruta de Santo António, 10 October 2008 1 ♂; 22 May 2009, 3 ♀; 4 September 2009, 2 ♂, 2 ♀.

Remarks: Troglobiont, blind and depigmented, only found in one cave of the Alentejo. The allocation of this species to the family Opisthocheiridae is tentative (J.-P. Mauriès, 2013).

Order Callipodida
Family Dorypetalidae
***Lusitanipus (Silvestria) alternans* (Verhoeff, 1893)**
Lysiopetalum alternans Verhoeff, 1893
Silvestria alternans: Verhoeff, 1895
Lusitanipus alternans: Mauriès, 1978: 575

Studied material: Portugal, Sicó massif: Penela, Gruta do Soprador do Carvalho, 30 August 2009, 2 ♂, 15 ♀; Condeixa, Gruta da Arrifana, 12 January 2013, 1 juv; Algar das Corujeiras, 10 July 2011, 1 ♂. Outil-Cantanhede massif: Portunhos, Gruta d'el Rey, 12 December 2008, 1 ♀ and 1 ♂; 8 October 2008, 2 ♀ and 4 ♂; 19 May 2009, 3 ♂ and 3 ♀.

Previous records: Portugal, Coimbra, Serra da Estrela and Buçaco, no date available (Machado, 1946); Arcozela das Maias, Viseu district, 28 March 1993, in oak wood (D.T. Bilton unpublished, D. Kime pers. com.).

Remarks: Troglophile species, found in caves of Sicó and Cantanhede-Outil massifs.

Order Julida
Family Blaniulidae
***Acipes bifilum* Enghoff and Reboleira, 2013**

Studied material: Algarve massif, Moncarapacho, Gruta da Senhora, 29 December 2012, 1 ♂.

Remarks: Troglobiont, only known from type locality in the Algarve massif.

***Acipes machadoi* Enghoff and Reboleira, 2013**

Studied material: Portugal, Algarve massif, Gruta do Vale Telheiro, 30 June 2011, 1 ♂ and 1 juv.

Remarks: Troglobiont, only known from type locality in the Algarve massif.

***Blaniulus guttulatus* (Fabricius, 1798)**

Studied material: Madeira, Machico, Furnas do Cavalum, 8 May 1989, Lange leg., 1 ♀; same locality, 13 September 1988 and 16 September 1988, Erber leg. São Vicente, Gruta do Cardal, 25 September 1990, Erber and Pieper leg., many ♂ and ♀.

Remarks: Epigean species.

Family Julidae

***Cylindroiulus* sp. 1**

Locality: Portugal, Estremenho massif, Rio Maior, Gruta das Alcobertas, MSS (mesovoid shallow substratum), 26 March 2009, 1 ♀.

Remarks: Epigean species, identification to species level was not possible, due to the lack of male specimens.

***Cylindroiulus* sp. 2**

Locality: Portugal, Madeira, Machico, Landeiros lava tube, 18 September 2002, E. Nunes leg., 1 ♂, 28 August 2002, 2 ♀. São Vicente, Gruta do Cardal, 25 September 1990, Erber and Pieper leg., 2 ♂ and several ♀. Furnas do Cavalum, 13 September 1988, Pieper leg., 1 ♀.

Remarks: Troglobiont species.

***Choneiulus palmatus* (Nemec, 1895)**

Locality: Madeira, Furnas do Cavalum, Machico, 12 September 1989, H. Pieper leg., 1 juv.

Remarks: Epigean species.

***Nopoiulus kochii* (Gervais, 1847)**

Locality: Madeira, São Vicente, Gruta do Cardal, 25 September 1990, Erber and Pieper leg., 2 ♀ juv.

Remarks: Epigean species.

Order Polydesmida

Family Polydesmidae

***Polydemus coriaceus coriaceus* Porat, 1870**

Syn. *Polydesmus gallicus* Latzel, 1894: Bull. Soc. Amis Sci. Natur. Rouen, 1883(2)19: 269.

Studied material: Outil-Cantanhede massif: Gruta d'el Rey, Portunhos, Cantanhede, S. Reboleira leg., 12 November 2008, 1 ♂, 8 October 2009; 14 January 2008, 1 ♀. Sicó massif: Gruta da Cerâmica, 27 December 2010, 1 ♀. Madeira island, Gruta de São Vicente, 5 January 1996, D. Erber leg., 3 ♂; Furnas do Cavalum, 13 September 1989, H. Pieper leg., 1 ♂; same locality, 16 September 1988, several specimens, Erber leg.

Family Paradoxosomatidae

***Oxidus gracilis* (C.L. Koch, 1847)**

Locality: Portugal, Outil-Cantanhede massif: Cantanhede, Portunhos, Gruta d'el Rey, S. Reboleira leg. (SR-200), 19 May 2009, 2 ♂, 1 ♀. Portugal, Madeira, Machico, Furnas do Cavalum, 08.05.1989, Lange leg., 3 ♂ and 1 ♀; 16 September 1988, Erber leg., several specimens.

Remarks: Introduced species, colonizes superficial caves and cave entrances. Found also in Azores, all islands except in São Jorge (BDBA, 2013).

***Boreviulisoma barrocalense* Reboleira and Enghoff, 2013**

Locality: Portugal, Algarve massif, Loulé, Gruta do Vale Telheiro, 24 May 2009, S. Reboleira leg., 1 ♀; 13 March 2009, 1 ♂, 1 ♀; 30 June 2011.

Remarks: Troglobiont, only known from type locality in the Algarve massif.

Discussion and Final Remarks

The majority of the collected millipede species in caves of mainland Portugal occur in the most superficial parts of the caves, where they play an important role in the decomposition of organic matter that comes from the surface. This is the case of the troglophile *Haplobaionosoma lusitanum*, widely distributed in caves of central Portugal, including Estremenho, Sicó, and Montejunto massifs. Also, *Polydesmus coriaceus coriaceus* has cave populations, especially where bat colonies are present and consequently large amounts of guano are available.

The known distribution of troglobiont species of millipedes in mainland Portugal is, for now, confined to three massifs (Fig. 3): Sicó, Estremoz-Cano, and Algarve, the latter being the richest, with three troglobiont species of millipedes.

The two troglobiont species *Acipes machadoi* and *Boreviulisoma barrocalense* inhabit the same cave, Vale Telheiro, coincidentally the richest cave in troglobiont species of Portugal (Enghoff and Reboleira, 2013; Reboleira and Enghoff, 2013).

Among all the central karst areas, which include the largest and higher extension of karst in Portugal, only one troglobiont species, *Scutogona* sp., was found, in several caves of the Sicó massif.

Mainland Portugal has been separated into two main biospeleological areas, the Lusitanian district in central Portugal and the Baetic district in the south; the latter includes the Algarve and extends through the Spanish Andalusia (Bellés, 1987; Reboleira et al., 2011a). The pattern of troglobiont richness for millipedes in the south of Portugal matches the patterns for troglomorphic species in other arthropod groups that inhabit caves and is influenced by biogeographical factors of the Iberian Peninsula (Reboleira et al., 2010a, 2010b, 2010c, 2011b, 2012a, 2012b, 2013a, 2013b).

Within the Iberian Peninsula overall, the richest areas in cave millipedes are located in the north and eastern areas, where several species, mainly in the order Julida, are known, namely the generaa *Mesoiulus* in the Cantabrian and Vasque mountains, *Blaniulus* (= *Typhloblaniulus*) in the Pyrenees, and *Syniulus* (= *Paratyphloiulus*) in Catalonia. Another rich area for troglobiont millipedes is located in the south of the Iberian Peninsula, including the Spanish Andalusia and the Portuguese Algarve, represented by troglobiont species of julids of the genera *Acipes*, *Dolichoiulus,* and *Euzkadiulus* (= *Iberoiulus*) (Bellés, 1987; Enghoff and Reboleira, 2013). Chordeumatidans are also a

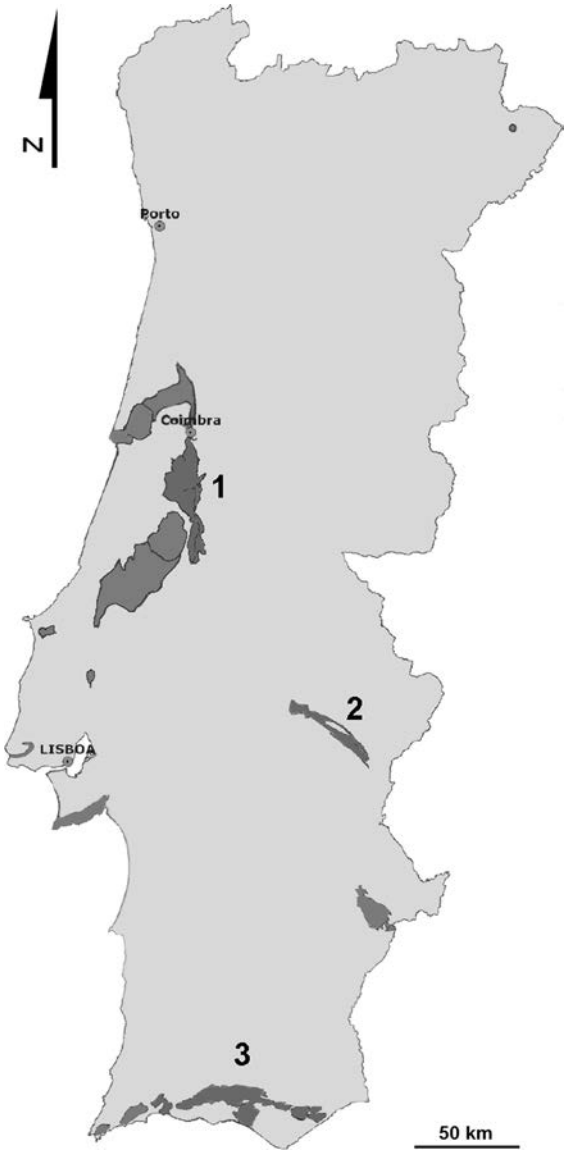

Figure 3. The karst massifs of Portugal with troglobiont species of millipedes: 1 - Sicó, 2- Estremoz-Cano, and 3 - Algarve.

diverse group in the caves in the Iberian Peninsula, represented by thirteen genera, mainly distributed in northeastern Spain (Mauriès, 1975; Mauriès and Vicente, 1977a, 1977b; Vicente, 1980, 1981; Vicente and Mauriès, 1980; Bellés, 1987; Mauriès, 2012, 2013) and now with two troglobiont species in the western part of the Iberian Peninsula. Another interesting millipede order, so far with no troglobiont representatives in Portugal, is the Glomerida, which is represented by seven troglobiont species in continental Spain, mostly distributed in the north, with the exception of *Glomeris albida* Mauriès and Vicente, 1977, known from one cave in Andalusia (Mauriès and Vicente, 1977a; Bellés, 1987), and one species on Tenerife (Golovatch and Enghoff, 2003). True troglobiont Polydesmida are only described from Cantabria, the relict *Cantabrodesmus lorioli* Mauriès, 1971, and recently from southern Portugal, *Boreviulisoma barrocalense* (Mauriès, 1971; Reboleira and Enghoff, 2013).

A troglobiont new species of *Cylindroiulus* is recorded in Madeira, where several species of epigean millipedes are frequently found in caves. The Azores lack troglobiont millipedes (Reboleira et al. 2011a), whereas in the Canary Islands, eight species of troglobiont millipedes are known, four on Tenerife, three on Gran Canaria, and one on El Hierro (Enghoff, 2002, 2012; Golovatch and Enghoff, 2003).

This suggests that, although the knowledge of the Portuguese cave millipede fauna increased with this work, sampling in caves has been mostly neglected. Complete sampling of the richness of millipedes in the subterranean ecosystems of Portugal requires a consistent sampling effort.

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