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The subterranean fauna of a biodiversity hotspot region - Portugal: an overview and its conservation

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Abstract:

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An overview of the obligate hypogean fauna in Portugal (including Azores and Madeira archipelagos) is provided, with a list of obligated cave-dwelling species and subspecies, and a general perspective about its conservation. All the available literature on subterranean Biology of Portugal since the first written record in 1870 until today has been revised. A total of 43 troglobiont and 67 stygobiont species and subspecies from 12 orders have been described so far in these areas, included in the so-called Mediterranean hotspot of biodiversity. The subterranean fauna in Portugal has been considered moderately poor with some endemic relicts and it remains to be demonstrated if this fact is still true after investing in standard surveys in cave environments. The major problems related to the conservation of cave fauna are discussed, but it is clear that the protection of this specialized fauna implies an adequate management of surface habitats.

Keywords: Biospeleology, hypogean fauna, patterns of diversity, conservation, caves, karst, lava tubes, Portugal, Azores, Madeira

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INTRODUCTION

Extensive biological studies have been made in the main karst areas around the world, namely in the eastern United States of America and in the region from the Pyrenees to Slovenia and the Dinaric karst (Culver et al., 2000; Culver & Pipan, 2009).

Information about subterranean fauna in mainland Portugal is sparse and scattered along many publications mostly from the middle of the 20th century. The main thrust in the subterranean biology was given by the survey of caves made by Barros Machado during the 1940s, and by the prospection of well-dwelling crustaceans in the north of the country by researchers of the former Instituto de Zoologia "Dr. Augusto Nobre" from Porto University (Gama & Afonso, 1994). In addition, endogean habitats have been subject of considerable coleopterological exploration in the last decade by Serrano & Aguiar (see 2008a, 2008b and works cited therein).

Particularly in the Azores, the 1990's were a very productive decade with several biospeological expeditions to study the volcanic cave fauna covering most of the nine islands (e.g., Oromí et al., 1990; Oromí & Borges, 1991; Borges, 1993; Borges & Oromí, 1994; Borges et al., 2004, 2007, 2008) and the discovery of at least 19 new obligate hypogean taxa. In the last years an intensive survey of cave fauna has been carried out in all the islands in search of ground-beetle fauna (Amorim, 2005). In Madeira archipelago, the studies of the volcanic cave fauna received also a particular attention in the last years with an exhaustive biodiversity study of lava tubes (Nunes, 2005).

Caves harbor a very specialized fauna and are unique evolutionary laboratories for the study of adaptation and natural selection (Howarth, 1983; Culver & Pipan, 2009). Subterranean habitats (SH) are characterized by abiotic factors crucial to their biocoenoses, being the most limiting ones the absence of light, the low amount of food resources and the high levels of humidity (Culver & Pipan, 2009). Several ecological classifications have been proposed to categorize the subterranean fauna based on morpho-physiological adaptations (Sket, 2008). In the present paper, we use the term troglobiont or obligate hypogean species for the species that display

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troglobiomorphisms (*sensu* Christiansen 2005), such as integument depigmentation, absence or reduced ocular structures and exclusive presence in the SH. The word stygobiont is used for obligate hypogean aquatic animals.

The same adaptations that make the obligate hypogean fauna able to successfully colonize the subterranean environment also decrease their fitness of survival in case of sudden changes in their habitat, especially those related to human activities (Sket, 1999). Likewise, reduction of habitat areas as a result, for instance, of limestone quarries will lead to their extinction. In fact, caves, as islands, are isolated entities and as a consequence, they lack the "rescue effect": only "source" species can be maintained in ecological and evolutionary time (Rosenzweig, 1995). In the Azores, Borges et al. (2008) concluded that there is an urgent need to set rank priorities for conservation, since the resources are not enough to protect all caves in the region.

Several types of subterranean habitats are known in mainland Portugal, but until today the subject of biological studies have been mostly the caves and the freshwater aquifers. The biodiversity in karst and non-karst areas, as well as in the so called "milieu souterrain superficiel" (MSS) (Juberthie et al., 1980a, 1980b) (or mesovoid shallow substratum *sensu* Culver, 2001) and in the anchialine caves still remain to be unraveled.

According to Bellés (1987) the terrestrial obligate hypogean fauna in mainland Portugal is included in two subterranean biogeographic districts: the Lusitanic which covers most of Portugal, and the Baetic which mainly extends through Spanish Andalusia but also includes the Portuguese Algarve to the west. Some considerations about the biogeography of hypothetical troglobionts in the north of Portugal were made by Jeannel, relating them to the Galaico-Cantabrian area (Jeannel, 1941). The terrestrial subterranean fauna of the Portuguese archipelagos belongs to the biogeographic area called Macaronesia. Taking into consideration that mainland Portugal and the archipelagos of the Azores and Madeira are included in the so-called Mediterranean Hotspot of Biodiversity, there is some urgency to know in detail the real diversity of subterranean organisms in order to improve their conservation management (Myers et al., 2000). The main goals of this work are: i) to list for the first time all the species and subspecies of obligate hypogean fauna of Portugal, including the archipelagos of Madeira and Azores; ii) to discuss the conservation vulnerabilities of this specialized fauna in the studied regions.

MATERIAL AND METHODS

Region of study

Portugal is the southwesternmost country of Europe, located in the western part of the Iberian Peninsula and including two volcanic archipelagos (Madeira and Azores). The Portuguese territory has a total area of 92,090 km² and borders with Spain to the north and east, and to the south and west with the Atlantic Ocean, where the two archipelagos are located (Figure 1).

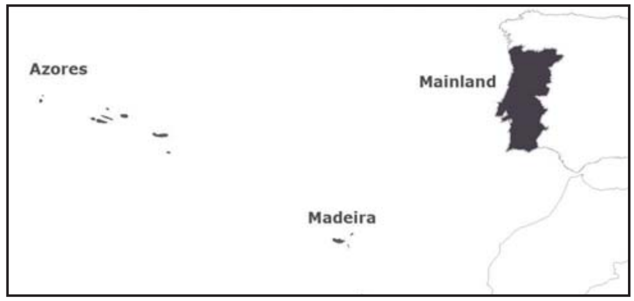

Fig. 1. Location of Portugal, mainland and archipelagos.

Since the archipelagos are of volcanic origin and have almost no carbonate rocks, all karst areas are found in the mainland (Figure 2). Several caves are included in ten protected areas of different status, such as parks, protected landscapes and classified sites. Anyway, all caves are public domain according to the Article 84 of the Portuguese Constitution [1. Belong to the public domain: c) the natural underground cavities].

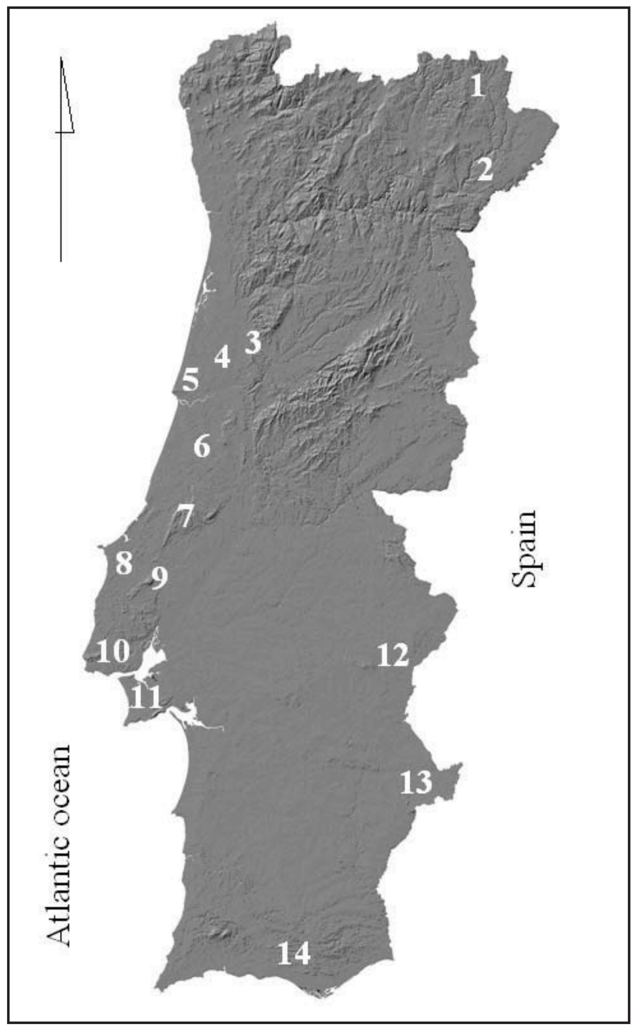

Fig. 2. Major karst areas of Portugal. 1 – Dine; 2 – Vimioso; 3 – Cantanhede; 4 – Mealhada; 5 – Boa Viagem; 6 – Sicó-Condeixa e Alvaiázere; 7 – Estremenho; 8 – Cesaredas; 9 – Montejunto; 10 – Península de Lisboa; 11 – Arrábida; 12 – Estremoz-Cano; 13 – Adiça-Ficalho; 14 – Algarve.

The most important karst areas are Jurassic limestones and dolomites: Estremenho (Serra d'Aire e Candeeiros), Arrábida, Sicó-Condeixa-Alvaiázere, Montejunto, and Algarve; but there are also caves present in Cambrian limestones and marbles in Estremoz and Adiça in the Alentejo, and in Vimioso on the northeast region (Brilha et al. 2005). Caves are found from the sea level in Arrábida, Boa Viagem and Algarve up to the higher karst point at 667 m in Serra do Montejunto (Machado & Machado, 1948). The air temperature of caves ranges from 11 °C to 21 °C (pers. obs.).

In the archipelagos of Azores and Madeira the terrain is mainly volcanic, with the exception of thin layers of limestone of coastal reef origin in Madeira, Ilhéu da Cal and Azores, Santa Maria (Ávila et al., 2008). The volcanic origin of the archipelagos implies that subterranean habitats are rather different than those in mainland karst areas, but also inhabited by an adapted and highly endemic fauna, especially in the Azores (Oromí et al., 1990; Borges, 1993; Borges & Oromí, 1994; Nunes, 2005). The abundant caves on these islands are mostly lava tubes and volcanic pits (Oromí et al., 1990; Nunes, 2005; Pereira et al., in press) but the particular MSS of volcanic areas has also provided obligate hypogean species (Borges, 1993), though much is still to be done concerning the sampling of this environment.

Data

The entire bibliography on Portuguese hypogean biology has been revised (not including references to Chiroptera). Among the different degrees of adaptation to subterranean life that can be found, for the present paper, we only consider as obligate hypogean fauna (also called troglobiont) those species with exclusive presence in subterranean habitats, which clearly show at least one of the following characters: integument depigmentation, absence or at least clear reduction of eyes, slender and long body and appendages, and wings absent or rudimentary (for insects).

In Portuguese the term cave has different names according to their morphology and regionalism: 'lapa, cova, fojo, furna, gruta or lorga' for small horizontal caves, 'algar, algarve, algarão or algueirão' for vertical caves and 'gruta' or 'furna' for horizontal caves.

RESULTS

A total of 110 species and subspecies from 12 orders have been listed here as obligate hypogean fauna living in caves, MSS and groundwaters of Portugal. Among them, 43 are troglobionts and 67 are stygobionts.

The majority of the obligate hypogean fauna is very often restricted to one or few caves. In the mainland, the species are usually endemic to one karst massif or part of it, and in the archipelagos most of the species are single island endemisms (SIEs) (Borges et al., 2008).

Most of the stygobionts were found in wells in non-karst areas with the exception of Syncarida, obtained by the Karaman-Chappuis method (Camacho, 2003a; 2003b) and the Amphipoda from Madeira archipelago collected with the Bou-Rouch biophreatical pump (Stock & Abreu, 1992; Stock, 1992).

The subterranean species of Portugal are listed below, by taxonomic group, for mainland and islands, with their localities. For the Azores, the list of species with a detailed 500x500 grid distribution is available in the Azorean Biodiversity Portal (http://www.azoresbioportal.angra.uac.pt) (Borges et al., 2005; in press).

Oligochaeta (1)

Mainland (1)

Tubificidae. *Rhyacodrilus lindbergi* Hrabe, 1963 – Estremenho: Gruta das Alcobertas, Rio Maior, also recorded in caves in France (Giani et al., 2001).

Palpigradi (1)

Islands (1)

Eukoeneniidae. *Eukoenenia madeirae* Strinati & Condé, 1995 – Madeira: Gruta de Cavalum I and II, Machico (Nunes, 2005).

Pseudoscorpiones (5)

Mainland (2)

Neobisiidae. *Roncocreagris blothroides* (Beier, 1962) (=*Microcreagris blothroides* Beier, 1962) – Sicó: Cova da Moura, Condeixa (Zaragoza, 2007). *Roncocreagris cavernicola* (Vachon, 1946) (=*Microcreagris cavernicola* Vachon, 1946) – Sicó: Algar Sul das Corujeiras, Algar da Lapa, Ansião, Pombal (Zaragoza, 2007).

Islands (3)

Chthoniidae. *Paraliochthonius cavalensis* Zaragoza, 2004 – Madeira: Gruta do Cavalum III, Machico (Zaragoza et al., 2004; Nunes, 2005).

Syarinidae. *Pseudoblothrus oromii* Mahnert, 1990 – Azores, São Jorge: Gruta da Beira (Pereira et al., in press).

Pseudoblothrus vulcanus Mahnert, 1990 – Azores, Terceira: Gruta das Agulhas, Gruta do Coelho, Gruta da Malha, Gruta dos Principiantes, and Pico: Furna da Baliza, Furna Frei Matias, Furna Nova I (Pereira et al., in press).

Opiliones (1)

Mainland (1)

Sironidae. *Iberosiro dyctilus* Bivort & Giribet, 2004 – Montejunto: Algarve da Terra da Rolha, Cadaval (Bivort & Giribet, 2004).

Araneae (8)

Mainland (4)

Leptonetidae. *Teloleptoneta synthetica* (Machado, 1951) – Arrábida: Cova do médico, Sesimbra; Adiça: Cova da Adiça, Moura; and Algarve: Algueirão do Garrafão, Algarinhos, Loulé; Algueirão dos Mouros, Moncarapacho; Abismo Novo, Moncarapacho, Olhão; Algarinhos de Benafim, Alte (Ribera, pers. com.; Ribera, 1988).

Dysderidae. *Harpactea stalitoides* Ribera, 1993 – Algarve: Algarão menor do Paulino, Algarão dos mouros, Gruta do Vale Telheiro, Loulé and Gruta da Senhora, Moncarapacho (Reboleira, pers. obs.; Ribera, 1993).

Symphytognathidae. *Anapistula ataecina* Cardoso & Scharff, 2009 – Arrábida: Gruta do Fumo, Lapa da Furada, Gruta da Utopia, Sesimbra (Cardoso & Scharff, 2009).

Nesticidae. *Nesticus lusitanicus* Fage, 1931 – Estremenho: this species is in the entire massif and is observed from areas near the caves entrance to a depth of 150 meters (Reboleira, 2007).

Islands (4)

Theridiidae. *Rugathodes pico* (Merrett & Ashmole, 1989) – Azores, Pico: Gruta das Canárias, Furna dos Montanheiros, Gruta da Agostinha, Gruta do Henrique Maciel, Gruta do Mistério da Silveira I, Gruta do Soldão; and Faial: Furna Ruim (Pereira et al., in press).

Linyphiidae. *Turinyphia cavernicola* Wunderlich, 2005 – Azores, Terceira: Algar do Carvão (Borges & Wunderlich, 2008) and Gruta da Malha (Pereira et al., in press). *Centromerus anoculus* Wunderlich, 1995 – Madeira: Gruta dos Cardais, São Vicente (Wunderlich, 1995). *Centromerus sexoculatus* Wunderlich, 1992 – Madeira: Furnas de Cavalum, Machico (Wunderlich, 1992).

Chilopoda (2)

Mainland (1)

Lithobidae. *Lithobius dimorphus* Machado, 1946 – Algarve: Algarão do Barrocal do Esguicho, Loulé, Algarão menor do Paulino, Cerro da Cabeça Gorda (Machado, 1946).

Islands (1)

Lithobidae. *Lithobius obscurus azoreae* Eason & Ashmole, 1992 – Azores, Faial, Pico, Graciosa, Terceira: in many caves (Pereira et al., in press).

Syncarida (8)

Mainland (8)

Parabathynellidae. *Iberobathynella barcelensis* (Noodt & Galhano, 1969) – Gravel bank in Cávado River, Barcelos. *Iberobatynella cavadoensis* (Noodt and Galhano, 1969) – Gravel bank in Cávado River, Barcelos, also recorded in Spain (Camacho, 2003 a). *Iberobatynella gracilipes* (Braga, 1960b) – Gravel bank in Idanha-a-Nova. *Iberobatynella lusitanica* (Braga, 1949) – Gravel bank in Leça da Palmeira. *Iberobatynella pedroi* Camacho, 2003 – Gravel bank on the River Mondego in Coimbra (Camacho, 2003a). *Iberobatynella serbani* Camacho, 2003 – Gravel bank on the Lima River, in Ponte de Lima (Camacho, 2003a). *Iberobatynella valbonensis* (Galhano, 1970) – Gravel bank in Gondomar, also recorded in Spain (Camacho, 2003a). *Hexabathynella minuta* Noodt & Galhano, 1969 – Gravel bank in Zebreiros, Douro River (Camacho, 2003b).

Amphipoda (11)

Mainland (6)

Bogidiellidae. *Bogidiella helenai* Mateus & Maciel, 1967 – In brackish water, Foz do Douro (Mateus & Mateus, 1978; Notenboom, 1990) .

Niphargidae. *Haploginglymus bragai* Mateus & Mateus 1958 – Leça da Palmeira, also in Spain (Mateus & Mateus, 1978; Notenboom, 1990).

Melitidae. *Pseudoniphargus callaicus* Notenboom, 1987 – North Atlantic coast of Portugal, also recorded in the Northwest of Spain (Notenboom, 1990). *Pseudoniphargus longispinum* Stock, 1980 – Mainland Portugal (Notenboom, 1990). *Pseudoniphargus mateusorum* Stock, 1980 – Arrábida: Fojo dos Morcegos, Sesimbra (Notenboom, 1990).

Hadziidae. *Metahadzia tavaresi* (Mateus & Mateus, 1972) – Algarve (Notenboom, 1990).

Islands (5)

Melitidae. *Pseudoniphargus brevipedunculatus* Stock, 1990 – Azores, Faial (Sánchez, 1990). *Pseudoniphargus litoralis* Stock & Abreu, 1992 – Madeira: São Roque spring, Machico (Stock & Abreu, 1992). *Pseudoniphargus macrurus* Stock & Abreu, 1992 – Madeira: south of Porto Moniz, Ribeira Brava and Ribeira da Janela (phreatic pump in gravel) (Stock & Abreu, 1992). *Pseudoniphargus portosancti* Stock & Abreu, 1992 – Madeira, Porto Santo: spring of Tanque and fountain of Baião (Stock & Abreu, 1992).

Ingolfiellidae. *Ingolfiella ungiculata* Stock, 1992 – Lugar de Baixo, anchialine pool, Madeira (Stock, 1992).

Isopoda (55)

Mainland (54)

Asellidae. *Bragasellus conimbricensis* (Braga, 1946) – Coimbra. *Bragasellus frontellum* (Braga, 1964) – Ponte da Barca, Vila do Conde, Minho (Afonso, 1987b). *Bragasellus incurvatus* Afonso, 1984 –Figueira de Castelo Rodrigo and Pinhel, Beira-Alta (Afonso, 1984b). *Bragasellus pauloae* (Braga, 1958) – Idanha-a-Nova. *Bragasellus seabrai* (Braga, 1943) – Leça da Palmeira, Matosinhos. *Proasellus arthrodilus* (Braga, 1945) – Sicó: Gruta de Legacão, Ansião (Afonso,1983). *Proasellus assaforensis* Afonso, 1988 – Península de Lisboa: Gruta da Assafora, Sintra (Afonso,1983). *Proasellus exiguus* Afonso, 1983 – Viseu, Serra da Lapa. *Proasellus lusitanicus* (Frade, 1938) – Estremenho: dark pit of Alviela, Alcanena, Gruta da Contenda, Gruta do Mindinho and Gruta dos Moinhos Velhos, Mira d'Aire (Afonso, 1983; Magniez, 1966). *Proasellus mateusorum* Afonso, 1982 – Vendas Novas, Évora (Afonso, 1982c). *Proasellus rectangulatus* Afonso, 1982 – Montemor-o-Novo, Alentejo (Afonso, 1982a). *Proasellus rectus* Afonso, 1982 – Horta dos Moinhos, Évora (Afonso, 1982b). *Proasellus spinipes* Afonso, 1979 – Estremenho: Algar do Ladoeiro, Porto de Mós (Afonso, 1979). *Proasellus nobrei* Braga, 1942 – Foz do Douro (Braga, 1942b). *Psammasellus capitatus* Braga, 1968 – Alluvial phreatic in Douro River, Entre-os-Rios. *Stenasellus galhanoae* Braga, 1962 – Algarve: Tavira, São Brás de Alportel, Lagos, Tavira (Braga, 1962; Magniez, 1999). *Stenasellus virei nobrei* Braga, 1942 – Dark pit in Foz do Douro and Freixo de Numão, Guarda (Braga, 1942b; Magniez, 1999). *Synasellus albicastrensis* Braga, 1960 – Castelo Branco, Beira-Baixa. *Synasellus barcelensis* Noodt & Galhano, 1969 – Cávado river (Noodt & Galhano, 1969). *Synasellus bragai* Afonso, 1987 – Minho, São Pedro da Torre (Afonso, 1987a). *Synasellus brigantinus* Braga, 1959 –

Bragança (Afonso, 1992). *Synasellus capitatus* (Braga, 1968) – Porto. *Synasellus exiguus* Braga, 1944 – Douro River, Vila da Parede (Braga, 1944). *Synasellus dissimilis* Afonso, 1987 – Serzedelo, Amêdos (Afonso, 1987b). *Synasellus favaiensis* Eiras, 1974 – Douro River (Eiras, 1974). *Synasellus flaviensis* Afonso, 1996. *Synasellus fragilis* (Braga, 1946) – Valbom, Porto. *Synasellus henrii* Afonso, 1987 – Póvoa do Lanhoso (Afonso, 1987b). *Synasellus insignis* Afonso, 1984 – Aguda, Miramar (Afonso, 1984a). *Synasellus intermedius* Afonso, 1985 – Vila Franca das Naves, Douro (Afonso, 1985). *Synasellus lafonensis* Braga, 1959 – Vouga River, São Pedro do Sul (Afonso, 1992). *Synasellus longicauda* Braga, 1959 – Meda, Beira-Alta (Braga, 1959). *Synasellus longicornis* Afonso, 1978 – Sabugal (Afonso, 1978). *Synasellus mariae* (Braga, 1942) – Leça da Palmeira, Minho (Braga, 1942a; Afonso, 1992). *Synasellus mateusi* Braga, 1954 – Vila Real, Trás-os-Montes (Afonso, 1992). *Synasellus meirelesi* Braga, 1959 – Idanha-a-Nova, Beira-Baixa (Braga, 1959). *Synasellus minutus* Braga, 1959 – Curia, Coimbra. *Synasellus nobrei* Braga, 1967 – Entre-os-Rios, Douro (Braga, 1967). *Synasellus pireslimai* Braga, 1959 – Vouga River, Gouveia, Beira-Alta (Afonso, 1992). *Synasellus pombalensis* Afonso, 1987 – Serra de Sicó, Pombal (Afonso, 1987b). *Synasellus robusticornis* Afonso, 1987 – Estradinha, Santa Comba Dão (Afonso, 1987b). *Synasellus serranus* Braga, 1967 – Serra d'Arga, Viana do Castelo (Braga, 1967). *Synasellus tirsensis* Afonso, 1987 – Vila das Aves, Vizela River (Afonso, 1987b). *Synasellus transmontanus* Braga, 1954 – Bragança (Afonso, 1992). *Synasellus valpacensis* Afonso, 1996 – Valpaço (Afonso, 1996). *Synasellus vidaguensis* Afonso, 1996 – Douro River (Afonso, 1996). *Synasellus vilacondensis* Afonso, 1987 – Vila do Conde (Afonso, 1987).

Porcellionidae. *Porcellio cavernicolus* Vandel, 1945 – Sicó: Gruta dos Alqueves, Coimbra, Algar da Lapa, Ansião (Vandel, 1945).

Trichoniscidae. *Trichoniscoides broteroi* Vandel, 1945 – Sicó: Gruta dos Alqueves, Coimbra (Vandel, 1945). *Trichoniscoides subterraneus* Vandel, 1945 – Estremenho: Gruta Alta do Cabeço-dos-Mosqueteiros, Fátima (Vandel, 1945). *Trichoniscoides meridionalis* Vandel, 1945 – Estremenho: Lapa da Chã de Cima, Gruta das Alcobertas, Rio Maior (Vandel, 1945). *Trichoniscoides ouremensis* Vandel, 1945 – Estremenho: Lapa Salgada, Fátima (Vandel, 1945). *Trichoniscoides machadoi subterraneus* Vandel, 1945 – Algarve: Loulé.

Armadillidiidae (Vandel, 1945). *Troglarmadillidium machadoi* Vandel, 1945 – Algarve: Algarão Menor do Paulino, Abismo Novo, Loulé, Moncarapacho (Vandel, 1945).

Islands (1)

Trichoniscidae. *Trichoniscus bassoti* Vandel, 1960 – Madeira: Furnas de Cavalum, also found in the Canary Islands (Dalens, 1984; Oromí, 1992).

Collembola (1)

Mainland (1)

Onychiuridae. *Onychiurus confugiens* Gama, 1962 – Estremenho: Gruta das Alcobertas, Rio Maior, Algar do Pena, Alcanena, Gruta das Ventas do Diabo, Mira d'Aire (Gama, 1962).

Homoptera (2)

Islands (2)

Cixidae. *Cixius azopicavus* Hoch, 1991 – Azores, Pico: in many caves (Pereira et al., in press). *Cixius cavazoricus* Hoch, 1991 – Azores, Faial: Gruta das Anelares, Gruta do Cabeço do Canto (Hoch, 1991).

Coleoptera (15)

Mainland (4)

Carabidae. *Trechus gamae* Reboleira & Serrano, 2009 – Estremenho: Algar de Marradinhas II, Algar de Gralhas VII, Algar do Pena, Alcanena, Algar do Ladoeiro, Algar da Arroteia, Porto de Mós (Reboleira et al., 2009). *Trechus lunai* Reboleira & Serrano, 2009 – Estremenho: Gruta do Almonda, Torres Novas, Gruta da Contenda, Mira d'Aire (Reboleira et al., 2009). *Trechus machadoi* Jeannel, 1941 – Estremenho: Gruta de Alcobertas, Rio Maior (Jeannel, 1941).

Leiodidae. *Speonemadus angusticollis* (Kraatz, 1870) – Algarve: very abundant in caves along the Algarve (Reboleira pers. obs.) (Jeannel, 1941).

Islands (11)

Carabidae. *Trechus isabelae* Borges & Serrano, 2007 – Azores, São Jorge: Algar do Morro Pelado (=Montoso) (Borges et al. 2007). *Trechus jorgensis* Oromí & Borges, 1991 – Azores, São Jorge: Algar das Bocas do Fogo (Oromí & Borges, 1991). *Trechus montanheirorum* Oromí & Borges, 1991 – Azores, Pico: Gruta dos Vimes, Furna dos Montanheiros, Furna Frei Matias (Oromí & Borges, 1991). *Trechus oromii* Borges, Serrano & Amorim, 2004 – Azores, Faial: Gruta do Parque do Capelo (Borges et al., 2004). *Trechus pereirai* Borges, Serrano & Amorim, 2004 – Azores, Pico: Gruta da Ribeira do Fundo; Gruta das Cabras II (Borges et al., 2004). *Trechus picoensis* Machado, 1988 – Azores, Pico: in several caves (Borges et al., 2007). *Trechus terceiranus* Machado, 1988 – Azores, Terceira: in several caves (Borges et al., 2007). *Thalassophilus azoricus* Oromí & Borges, 1991 – Azores, São Miguel: Gruta da Água de Pau (Oromí & Borges, 1991). *Thalassophilus coecus* Jeannel, 1938 – Madeira: MSS of laurisilva forest (Oromí & Borges, 1991). *Thalassophilus pieperi* Erber, 1990 – Madeira: Furnas de Cavalum and Gruta de Landeiros, Machico, Gruta dos Cardais, São Vicente (Erber,1990; Nunes, 2005).

Staphylinidae. *Medon vicentensis* Serrano, 1993 – Madeira: Gruta dos Cardais, São Vicente (Serrano, 1993).

DISCUSSION

Patterns of diversity

In order to analyze subterranean biodiversity in Portugal we must make a distinction between troglobiont (Figure 6, Table 1) and stygobiont (Table 2) fauna, and among the three main biogeographic parts: mainland Portugal, Azores and Madeira. These regions present different lithogeny, species origin, ancestors, biogeographical patterns, distribution and faunal composition.

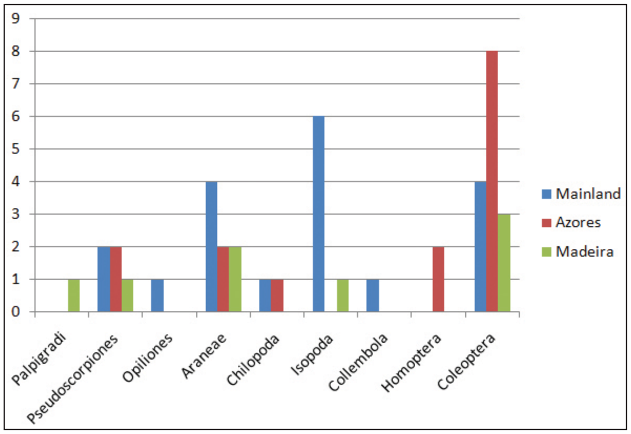

Fig. 6. Number of troglobiont species by taxonomic groups in the mainland and the two archipelagos. Mainland in blue, Azores in red and Madeira in green.

Table 1. Number of troglobiont species and subspecies in Portugal.

Taxa	Mainland	Azores	Madeira	Total
Palpigradi	0	0	1	1
Pseudoscorpiones	2	2	1	5
Opiliones	1	0	0	1
Araneae	4	2	2	8
Chilopoda	1	1	0	2
Isopoda	7	0	1	8
Collembola	1	0	0	1
Homoptera	0	2	0	2
Coleoptera	4	8	3	15
Total	20	15	8	43

Table 2. Number of stygobiont species and subspecies in Portugal.

Taxa	Mainland	Azores	Madeira	Total
Oligochaeta	1	0	0	1
Syncarida	8	0	0	8
Amphipoda	6	1	4	11
Isopoda	47	0	0	47
Total	62	1	4	67

Troglobionts of mainland Portugal

Fig.3

All terrestrial obligate hypogean species known from mainland Portugal are endemic to one massif, or to subunits of each karst areas, with the exception of the beetle Speonemadus angusticollis that is also present in subterranean spaces of the centre and south of the Iberian Peninsula (Salgado et al., 2008), and the spider Teloleptoneta synthetica that is found in caves in Arrábida, Alentejo and Algarve.

All Pseudoscorpiones, Opiliones, Isopoda, Collembola and three Araneae are eyeless and display a high degree of troglobiomorphism in opposition to Coleoptera, that are not eyeless but microphtalmous, and do not display a high degree of troglobiomorphism.

Some troglobionts from karst areas have been considered by their authors as relicts, such as Teloleptoneta synthetica, Harpactea stalitoides and Troglarmadillidium machadoi, attesting to their antiquity in the continental Portugal.

Fig. 3. Troglobionts of mainland Portugal. a) *Harpactea stalitoides* Ribera, 1993; b) *Nesticus lusitanicus* Fage, 1931; c) *Porcellio cavernicolous* Vandel, 1946; d) *Roncocreagris blothroides* (Beier), 1962 and e) *Trechus gamae* Reboleira & Serrano, 2009. (Photos: S. Reboleira and P. Oromí)

An interesting example is the typical allopatric speciation by geographic isolation in the subterranean habitat of the genus Trechus Clairville, 1806 in the Estremenho karst massif, where each geological subunit of this massif has its own cave-dwelling species (Reboleira et al., 2009).

Troglobionts of the Azores

Fig.4

The ground-beetle *Thalassophilus azoricus*, the spider *Turinyphia cavernicola* and the two pseudoscorpion species of *Pseudoblothrus* are highly interesting because no congeneric epigean species are known in the archipelago, thus they may be considered as regional relicts. Most notably *Pseudoblothrus oromii* and *Thalassophilus azoricus* are known from a single cave each, in São Jorge and São Miguel respectively. In both cases the land above the caves is highly modified due to intensive pastures.

All the Azorean hypogean *Trechus* species are single island endemics (Borges et al., 2007) and, except in Terceira and São Miguel islands, there are no known epigean species. It could be assumed that they are local relicts, though very recent extinctions due to massive deforestations might also explain this apparent relict condition. These species and particularly the epigean ones are among the rarest Azorean endemic arthropods, since they occur on only one island and in very specific habitats, underneath terrains formerly occupied by native woodlands and now transformed into pastureland.

The Azorean lava tubes frequently have abundant roots hanging inside, allowing the presence of troglobiont planthoppers. One of the most intriguing biogeographical puzzles in the Azorean subterranean

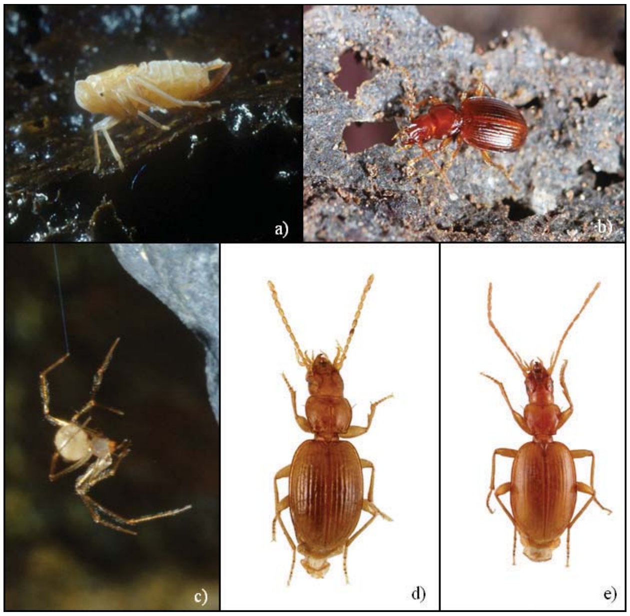

Fig. 4. Troglobionts of Azores. a) *Cixius cavazoricus* Hoch, 1991; b) *Trechus terceiranus* Machado, 1988; c) *Rugathodes pico* (Merrett & Ashmole, 1989); d) *Trechus jorgensis* Oromí & Borges, 1991 and e) *Trechus picoensis* Machado, 1988. (Photos: P. Oromí and E. Mendonça).

fauna is the register of the same nominal species in two or even more islands; these taxonomical enigmas can be solved after molecular analysis of the populations from different islands.

Troglobionts of Madeira

Fig. 5

Most of the few Madeiran obligate hypogean species belong to genera with epigean species, which are rather probably their close relatives. All Madeiran troglobionts belong to genera also present in other Macaronesian archipelagos, being represented also by obligate hypogean species such as the pseudoscorpion *Paraliochthonius* and the coleopterans *Thalassophilus* and *Medon* all of them still having reduced eyes. *Thalassophilus coecus* was described based on a male found under a stone in the humid laurel forest; due to its ocular regression, it has been considered in the present work as a true subterranean species. The spiders *Centromerus anoculus*, described after a male, and C. *sexoculatus*, described after a female, have been recently collected, both species and both sexes, in the caves Furnas de Cavalum and are probably the same species, in which case *C. anoculus* would be a junior synonym of *C. sexoculatus* (Ribera, pers. com.). No obligate hypogean species have been found in the MSS, probably due to the absence of studies in such habitat.

Stygobionts

The stygobiont species so far known from mainland Portugal (Table 2) belong to Oligochaeta, Amphipoda and Isopoda. Several species of Copepoda have also been recorded in subterranean aquifers (Lescher-Moutoué, 1981), but none of these species are considered as stygobionts.

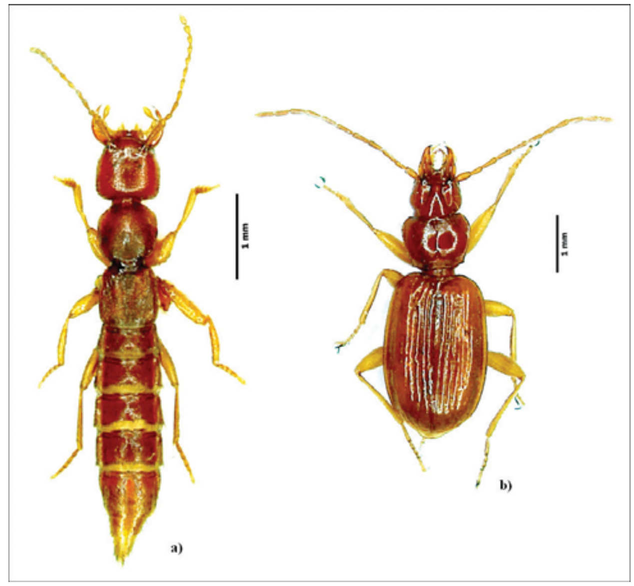

Fig. 5. Troglobionts of Madeira. a) *Medon vicentensis* Serrano, 1993 and b) *Thalassophilus pieperi* Erber, 1990. (Photos: E. Mendonça).

The order Isopoda is the most diversified group among stygobionts, being represented by: 5 species of the Iberian endemic genus *Bragasellus* Henry & Magniez, 1968; 9 of the perimediterranean genus *Proasellus* Dudich, 1925; one of the endemic monospecific genus *Psammasellus* Braga, 1968; 30 of *Synasellus* Braga, 1944 and one species and subspecies of *Stenasellus* Dollfus, 1987.

Concerning the amphipods, the genus *Haploginglymus* Mateus & Mateus, 1958 is strictly endemic to the Iberian Peninsula, being the most widely distributed stygobiont amphipod (Notenboom, 1990). A curious fact is the absence in Portugal of some Iberian genera of stygobionts, such as *Salentinella* Ruffo, 1947 frequently found together with *Haploginglymus* and *Niphargus* Schiödte, 1849.

The genus *Pseudoniphargus* Chevreux, 1901 has a disjunct distribution in the Iberian Peninsula with three ranges: northern Spain, southern Spain, and Lusitanic (Notenboom 1990). Their origin in subterranean waters is probably related to a common thalassostygobiont ancestor from the Atlantic and West Mediterranean coasts (Bréhier & Jaume, 2009). This may explain the presence of *Pseudoniphargus* near the coast in mainland Portugal and in the Macaronesian archipelagos, where it is the major representative of the insular stygofauna known so far.

Around 90% of the stygobionts in mainland Portugal are known from non-karst areas of the northern regions. This high percentage may not reflect the real biodiversity but the result of a great prospective effort by the researchers of the Instituto de Zoologia “Dr. Augusto Nobre” of Porto University, during the second half of the 20th century, in those areas.

Conservation

The main problem on obligate hypogean life conservation is chiefly derived from human pollution produced on the surface, which quickly percolates the superficial layers of limestone, contaminating the

Table 3. Major threats to conservation and protection in karst areas of Portugal. Legend: Troglobionts interest is based in the proportional number of species by karst area. P, Pollution; Q, Quarries; I, Industry; A, Agriculture; H, Human utilization; T, Touristic caves; V, cave visits; D, degraded, S, Radical modification of surface substratum; CS, Classified Site; PL, Protected Landscape; N2000, Natura 2009;*, part of it.

Karst area	Province	Troglobionts	Major problems	Protection
Dine	Trás-os-Montes	Low	V	Park
Vimioso	Trás-os-Montes	Low	D	None
Cantanhede	Beira-Litoral	Medium	P, A, I, D	None
Mealhada	Beira-Litoral	Medium	P, A, I, D	None
Boa Viagem	Beira-Litoral	Low	Q, P, A	N2000
Sicó	Beira-Litoral	High	Q, P, I, A, H, T, V, D	N2000*
Estremenho	Estremadura and Ribatejo	High	Q, P, I, A, H, T, V, D	Park*, Ramsar*
Cesaredas	Estremadura	High	P, A, D	None
Montejunto	Estremadura	High	Q, P, A, V	PL*, N2000
Lisboa	Estremadura	High	P, S, I, V,S	None
Arrábida	Estremadura	High	Q, P, A, V, D	Park, CS
Estremoz-Cano	Alto Alentejo	Low	Q, P, A, D	None
Adiça-Ficalho	Baixo Alentejo	Low	A, P	None
Algarve	Algarve	High	Q, P, A, H, V, D	None

subterranean habitats (Watson et al., 1997).

On the other hand, another problem, related to the direct destruction of the subterranean habitat, arises from the economic value of the karst itself (Table 3). Agriculture, industry, freshwater supply, limestone extraction and massive tourism are the most important activities in Portuguese karst areas. In several natural parks, like Serra de Aire e Candeeiros and Arrábida, caves and landscapes are being destroyed by quarrying, which also damages the surface layer inducing deep changes in the way that water, nutrients and pollutants reach the deep parts of the massifs.

Extreme pollution is produced by several industries that are pouring industrial sewage directly into cave systems, as in the case of Gruta de Colaride (Cacém, Lisboa), and by the lack of pervasive treatment of domestic sewage, as it happens in Gruta do Soprador do Carvalho (Sicó). This is a source of outbreaks of microbial infections resulting in public health problems, as it happens in Mira d'Aire (Estremenho).

The soil use on the surface and the hydrologic disturbance may also disrupt obligate hypogean populations. This can also have a natural cause, such as fires that induce deep changes in the vegetation cover, changing the acidification of infiltrating water. Modifications in water pH may induce deep changes on living subterranean communities, especially on the stygobiont communities (Watson et al., 1997).

For example, in Gruta de Alvide (Cascais, Lisboa), where no troglobiont species have been found so far, the superficial vegetation has been totally replaced by buildings, inducing changes of water and nutrient flow in the deep karst.

Another issue threat to the obligate hypogean biodiversity is the mass speleological tourism, which induces deep changes on morphological cave structure, on water chemistry and movement, composition and temperature of air masses, and promotes the introduction of artificial light and exotic species, besides the vandalism present in caves both open or not to public visit (Reboleira, 2007).

The ecological protection in karst areas is clearly inefficient. There is increase of use of pesticides and fertilizers in agriculture, the continued proliferation of quarries and the change in vegetation cover. There is no specific legislation and no effective control on the visits of most cavities, with the exception of Algar do Pena (Estremenho), there is no concerted concern for the conservation of subterranean biodiversity, even in caves protected by law like Gruta do Zambujal (Arrábida), Gruta da Assafora (Sintra) and Gruta do Almonda (Estremenho).

In the Azores the main problem on the conservation of subterranean fauna is related to the destruction of native forest for pasture development, which causes clay filling of underground spaces and a limitation of lava-tubes available for the obligate hypogean fauna. This can easily lead to the extinction of locally endemic populations often limited to a single cave, with the corresponding loss of this biological endemic heritage. Troglobiont planthoppers populations, which depend on the presence of tree roots for survival inside the caves, are especially affected. Currently the 267 caves known in the Azores (Pereira et al. in press) are being evaluated for their conservation value (see Borges et al., 2008). A working group (GESPEA) was created by the Azores Government Decree nr. 149/98 of 25th July to study this diversified natural, cultural, scientific and aesthetic heritage, which must be preserved with special measures. Since then four caves were classified as Regional Natural Monuments (Algar do Carvão in Terceira, Furna do Enxofre in Graciosa, Gruta das Torres in Pico, Gruta do Carvão in São Miguel) and have special regulations concerning their use as show caves.

Based on the work of GESPEA, all the Azorean caves are now classified in four levels of priority (A, B, C, D), the level A including 30 caves in six islands that will be subject to special conservation actions. The

importance of these caves is based on their biological diversity and geological value, a show cave index and an integrity index (see also Gabriel et al. 2008 for an application example with bryophytes).

In the island of Madeira only 13 caves are known, the largest cave (Gruta de São Vicente) was drastically changed and rebuilt in the 1990's to be transformed in a show cave with the financial support of EC through the Regional Government, with very important changes that eliminated the specialized cave fauna. Gruta dos Cardais, also in São Vicente, is now used for storing animals and junk, and Grutas de Cavalum in Machico is full of litter due to uncontrolled visits.

CONCLUDING REMARKS

The troglobiont and stygobiont species listed represent a small proportion of the overall rich fauna of the studied regions. In general, all species are local endemisms. In addition, most of the species occur in single locations or there is a high degree of isolation between different populations. Apparently, the vast majority of troglobionts and stygobionts fulfill the IUCN criteria for endangered species. For instance, in the United States of America, 50% of the national species listed as vulnerable or imperiled, as defined by Nature Conservancy, are cave obligated species (Culver et al., 2000).

It is therefore fundamental to carry out more field work, discovering new caves and describing new species that remain to be found, updating the distribution of species, assessing the abundance of species and evaluating their conservation status according to the latest IUCN criteria (IUCN Standards and Petitions Subcommittee, 2010).

Cave fauna can also be viewed as a unique biological laboratory where evolutionary and ecological processes can be studied.

In conclusion, additional efforts should be undertaken in order to:

a) improve the cave and MSS biodiversity knowledge;

b) determine what triggers the evolution of species-rich genera (e.g. *Trechus* beetles). This will help in the identification of evolutionary significant units for conservation;

c) investigate the effects of exotic species that are spreading in cave entrances and may be putative threats to the cave obligate species also occurring near entrances (e.g. in Azores);

d) collaborate on the conservation management of surface habitats, putting together high quality distribution data of cave species with information on surface land-uses through GIS projects and propose according conservation management measures;

e) select crucial areas to the conservation of Portuguese obligate cave fauna. The restricted distribution of most species would imply that most caves are unique and largely irreplaceable. A multiple-criteria index incorporating diversity- and rarity-based indices could help in selecting priorities;

f) provide ecotoxicological information on the sensitiveness of subterranean species to several anthropogenic pollutants, contributing to estimate their impacts on these particular ecosystems.

The preservation of the biodiversity of the subterranean environment is critical if the 2010 Biodiversity Target – Convention of Biological Diversity, United Nations Environmental Program (CBD, 2007) is to be met, which will require a serious and prompt commitment from land management agents and politicians. This is already occurring in the Azores, but similar efforts are absent in mainland Portugal and Madeira.

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APPENDIX

Table 1. Troglobionts of mainland Portugal

Order	Family	Species	Karst area
Pseudoescorpiones	Neobisiidae	*Roncocreagris blothroides* (Beier), 1962	Sicó
		Roncocreagris cavernicola (Vachon), 1946	Sicó
Araneae	Dysderidae	*Harpactea stalitoides* Ribera, 1993	Algarve
Opiliones	Sironidae	*Iberosiro dyctilus* Bivort & Giribet, 2007	Montejunto
	Leptonetidae	*Teloleptoneta synthetica* (Machado, 1951)	Arrábida, Adiça, Algarve
	Nesticidae	*Nesticus lusitanicus* Fage, 1931	Estremenho
	Symphytognathidae	*Anapistula ataecina* Cardoso & Scharff, 2009	Arrábida
Lithobiomorpha	Lithobidae	*Lithobius dimorphus* Machado, 1946	Algarve
Isopoda	Porcelionidae	*Porcellio cavernicolous* Vandel, 1945	Sicó
	Trichoniscidae	*Trichoniscoides broteroi* Vandel, 1945	Sicó
		Trichoniscoides subterraneus Vandel, 1945	Estremenho
		Trichoniscoides meridionalis Vandel, 1945	Estremenho
		Trichoniscoides ouremensis Vandel, 1945	Estremenho
		Trichoniscoides machadoi subterraneus Vandel, 1945	Algarve
	Armadillidiidae	*Troglarmadillidium machadoi* Vandel, 1945	Algarve
Entomobryomorpha	Onychiuridae	*Onychiurus confugiens* Gama, 1962	Estremenho
Coleoptera	Carabidae	*Trechus machadoi* Jeannel, 1942	Estremenho
		Trechus gamae Reboleira & Serrano, 2009	Estremenho
		Trechus lunai Reboleira & Serrano, 2009	Estremenho
	Leiodidae	*Speonemadus angusticollis* (Kraatz, 1870)	Algarve

Table 2. Stygobionts of mainland Portugal

Order	Family	Species	Area
Tubificida	Tubificidae	*Rhyacodrilus lindbergi* Hrabe, 1962	Estremenho, France
Syncarida	Parabathynellidae	*Hexabathynella minuta* (Noodt & Galhano, 1969)	Douro
		Iberobathynella lusitanica (Braga, 1949)	Leça da Palmeira
		Iberobathynella barcelensis (Noodt & Galhano, 1969)	Barcelos
		Iberobathynella valbonensis (Galhano, 1970)	Gondomar, Spain
		Iberobathynella gracilipes (Braga, 1960)	Idanha-a-Nova
		Iberobathynella cavadoensis (Noodt & Galhano, 1969)	Cávado, Spain
		Iberobathynella serbani Camacho, 2003	Ponte de Lima
		Iberobathynella pedroi Camacho, 2003	Mondego, Coimbra
Amphipoda	Melitidae	*Pseudoniphargus mateusorum* Stock, 1980	Arrábida
		Pseudoniphargus longispinum Stock, 1980	Portugal
		Pseudoniphargus callaicus Notenboom, 1987	North Atlantic and Spain
	Niphargidae	*Haploginglymus bragai* Mateus & Mateus 1958	Leça da Palmeira, Spain
	Hadziidae	*Metahadzia tavaresi* (Mateus & Mateus, 1972)	Algarve
	Bogidiellidae	*Bogidiella helenae* Mateus & Maciel, 1967	Foz do Douro
Isopoda	Asellidae	*Bragasellus seabrai* (Braga, 1943)	Matosinhos
		Bragasellus conimbricensis (Braga, 1946)	Coimbra
		Bragasellus frontellum (Braga, 1964)	Minho
		Bragasellus incurvatus Afonso, 1984	Douro
		Bragasellus pauloae (Braga, 1958)	Idanha-a-Nova
		Proasellus arthrodilus (Braga, 1945)	Sicó
		Proasellus assaforensis Afonso, 1988	Sintra
		Proasellus exiguus Afonso, 1983	Viseu
		Proasellus lusitanicus (Frade, 1938)	Estremenho
		Proasellus mateusorum Afonso, 1982	Vendas Novas
		Proasellus nobrei Braga, 1942	Foz do Douro
		Proasellus rectus Afonso, 1982	Évora
		Proasellus rectangulatus Afonso, 1982	Montemor-o-Novo
		Proasellus spinipes Afonso, 1979	Estremenho
		Psammasellus capitatus Braga, 1968	Douro
		Synasellus albicastrensis Braga, 1960	Castelo Branco
		Synasellus barcelensis Noodt & Galhano, 1969	Cávado
		Synasellus bragai Afonso, 1987	Minho
		Synasellus brigantinus Braga, 1959	Bragança
		Synasellus capitatus (Braga, 1968)	Porto
		Synasellus dissimilis Afonso, 1987	Serzedelo
		Synasellus exiguus Braga, 1944	Douro
		Synaselus favaiensis Eiras, 1974	Douro
		Synasellus flaviensis Afonso, 1996	Minho
		Synasellus fragilis (Braga, 1946)	Gondomar
		Synasellus henrii Afonso, 1987	Póvoa de Lanhoso
		Synasellus insignis Afonso, 1984	Vila Nova de Gaia
		Synasellus intermedius Afonso, 1985	Douro
		Synasellus lafonensis Braga, 1959	Vouga
		Synasellus longicauda (Braga, 1959)	Douro
		Synasellus longicornis Afonso, 1978	Interior
		Synasellus mariae (Braga, 1942)	Leça da Palmeira
		Synasellus mateusi Braga, 1954	Chaves
		Synasellus meirelesi Braga, 1959	Algarve
		Synasellus minutus Braga, 1959	Curia
		Synasellus nobrei Braga, 1967	Douro
		Synasellus pireslimai Braga, 1959	Vouga

(Table 2, continued)

Order	Family	Species	Area
Isopoda	Asellidae	*Synasellus pombalensis* Afonso, 1987	Pombal
		Synasellus robusticornis Afonso, 1987	Santa Comba Dão
		Synasellus serranus Braga, 1967	Viana do Castelo
		Synasellus tirsensis Afonso, 1987	Rio Varziela
		Synasellus transmontanus Braga, 1954	Bragança
		Synasellus valpacensis Afonso, 1996	Valpaço
		Synasellus vidaguensis Afonso, 1996	Vidago
		Synasellus vilacondensis Afonso, 1987	Vila do Conde
		Stenasellus galhanoae Braga, 1962	Algarve
		Stenasellus virei nobrei Braga, 1942	Douro, Guarda

Table 3. Troglobionts of Madeira Archipelago

Order	Family	Species	Islands
Palpigradi	Eukoeneniidae	*Eukoenenia madeirae* Strinati & Condé, 1995	Madeira
Pseudoscorpiones	Chthoniidae	*Paraliochthonius cavalensis* Zaragoza, 2004	Madeira
Araneae	Linyphiidae	*Centromerus sexoculatus* Wunderlich, 1992	Madeira
		Centromerus anoculus Wunderlich, 1995	Madeira
Isopoda	Trichoniscidae	*Trichoniscus bassoti* Vandel, 1960	Madeira
Coleoptera	Carabidae	*Thalassophilus pieperi* Erber, 1990	Madeira
		Thalassophilus coecus Jeannel, 1938	Madeira
	Staphylinidae	*Medon vicentensis* Serrano, 1993	Madeira

Table 4. Stygobionts of Madeira Archipelago

Order	Family	Species	Islands
Amphipoda	Melitidae	*Pseudoniphargus portosancti* Stock & Abreu, 1992	Porto Santo
		Pseudoniphargus macrurus Stock & Abreu, 1992	Madeira
		Pseudoniphargus litoralis Stock & Abreu, 1992	Madeira
	Ingolfiellidae	*Ingolfiella ungiculata* Stock, 1992	Madeira

Table 5. Troglobionts of Azores Archipelago

Order	Family	Species	Islands
Pseudoescorpiones	Syarinidae	*Pseudoblothrus vulcanus* Mahnert, 1990	Terceira
		Pseudoblothrus oromii Mahnert, 1990	São Jorge
Araneae	Theridiidae	*Rugathodes pico* (Merrett & Ashmole, 1989)	Pico, Faial
	Linyphiidae	*Turinyphia cavernicola* Wunderlich, 2005	Terceira
Lithobiomorpha	Lithobidae	*Lithobius obscurus azoreae* Eason & Ashmole, 1992	Faial, Pico, Graciosa, Terceira
Homoptera	Cixidae	*Cixius azopicavus* Hoch, 1991	Pico
		Cixius cavazoricus Hoch, 1991	Faial
Coleoptera	Carabidae	*Thalassophilus azoricus* Oromí & Borges, 1991	S. Miguel
		Trechus terceiranus Machado, 1988	Terceira
		Trechus picoensis Machado, 1988	Pico
		Trechus pereirai Borges, Serrano & Amorim, 2004	Pico
		Trechus montanheirorum Oromí & Borges, 1991	Pico
		Trechus jorgensis Oromí & Borges, 1991	S. Jorge
		Trechus oromii Borges, Serrano & Amorim, 2004	Faial
		Trechus isabelae Borges & Serrano, 2007	S. Jorge

Table 6. Stygobiont of Azores

Order	Family	Species	Islands
Amphipoda	Melitidae	*Pseudoniphargus brevipedunculatus* Stock, 1990	Faial