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*Author-formatted, not peer-reviewed document posted on 19/04/2021*

DOI: <https://doi.org/10.3897/arphapreprints.e67563>

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# **Cave-adapted beetles from continental Portugal**

 **Ana Sofia P. S. Reboleira,**  **Rita Eusébio**

# Cave-adapted beetles from continental Portugal

Ana Sofia P. S. Reboleira<sup>‡,§</sup>, Rita P. Eusébio<sup>‡</sup>

<sup>‡</sup> Centre for Ecology, Evolution and Environmental Changes (cE3c), and Departamento de Biologia Animal, Faculdade de Ciências, University of Lisbon, Lisboa, Portugal

<sup>§</sup> Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

| Centre for Ecology, Evolution and Environmental Changes (cE3c), Faculdade de Ciências, University of Lisbon, Lisbon, Portugal

Corresponding author: Ana Sofia P. S. Reboleira ([sreboleira@snm.ku.dk](mailto:sreboleira@snm.ku.dk))

## Abstract

## Background

The cave biodiversity of continental Portugal faces tremendous conservation challenges, mostly linked to their direct destruction and contamination infiltrating from surface. Beetles are the most diverse insects and one of the most diverse arthropod groups in caves of Portugal.

## New information

We present the IUCN Red List profiles for the cave-adapted beetles from continental Portugal, all endemic to their respective geological units and massifs. Ground beetles (Carabidae) are the most diverse family of cave-adapted beetles in continental Portugal, followed by rove beetles (Staphylinidae). Beetles in caves of Portugal are mostly terrestrial and only one species is known to have evolved to live in groundwater. *Trechus* is the most diverse genus with four species, followed by *Domene* with three species, and by *Speonemadus* and *Iberoporus*, both with one cave-adapted species. The aim of this contribution is to assess all endemic cave-adapted species of beetles from continental Portugal and to support their specific protection, to promote an adequate management of surface habitats and the establishment of priority areas for conservation.

This document can be used in spatial planning and territory management in karst, based on the current scientific knowledge.

## Keywords

Coleoptera, Subterranean habitats, Iberian Peninsula, Conservation, Rocky habitats, Trogllobiont, Stygobiont

## Introduction

Cave fauna has relatively low specific richness, but high conservation value for the global biodiversity of our planet (Mammola et al. 2019). Subterranean species have unique traits that emerged as a result of isolation and convergent adaptation towards the underground life (Mammola et al. 2020).

Among subterranean fauna, the beetles - insects of the order Coleoptera - stand out, as a group that presents the greatest animal specific richness worldwide (Didham et al. 2020). Of the 211 recognized families of Coleoptera (Bouchard et al. 2011), around 10 have cave-adapted species, of which about 92% belong to the family Carabidae (mostly Trechinae) and Leiodidae (mostly Cholevinae) (Deharveng and Bedos 2018).

Portugal is located in the western part of the Iberian Peninsula, has more than 2000 caves identified, and is considered a hotspot of subterranean biodiversity (Reboleira et al. 2011b). More than 58 terrestrial and 64 aquatic subterranean-obligate species are described to date (Reboleira et al. 2013a, Reboleira and Enghoff 2018, Ribera and Reboleira 2019). Beetles are the thirdmost diverse order of terrestrial cave-adapted species in continental Portugal, preceded by pseudoscorpions (13 species) and terrestrial isopods (12 species) (Reboleira et al. 2015, Zaragoza and Reboleira 2018).

The first beetle species collected in caves of Portugal was identified as *Trechus fulvus* Dejean, 1831, captured by M.L.W. Schaufuss, the caves then explored remain unknown (Putzeys 1870). The first cave-adapted beetle of Portugal, *Trechus machadoi* Jeannel, 1941, was found more than a century later, and described based on two specimens collected by the pioneer of Portuguese cave biology, António de Barros Machado (Jeannel 1941). Since this, almost seven decades have passed until the description of further cave-adapted beetles in continental Portugal, also belonging to the genus *Trechus* Clairville, 1806 (Reboleira et al. 2009, Reboleira et al. 2010). The first Staphylinidae beetle was described in 2010 from a karst cave, belonging to the genus *Domene* Fauvel, 1873 (Reboleira et al. 2011a), followed more recently by the description of two more species of the same genus from non-karst caves (Serrano et al. 2015, Magrini and Carotti 2019). Despite the high richness of Leiodidae in the neighbouring Spain (Salgado et al. 2008), only one cave-adapted leiodid is known from Portugal (Reboleira et al. 2017).

All cave-adapted beetle species from continental Portugal are endemic and exhibit an extremely reduced distribution area. These unique species face major conservation threats, and lack of adequate specific management (Reboleira et al. 2011b). Here, we present the IUCN Red List profiles for the nine species of cave-adapted beetles from continental Portugal.

## Material and Methods

Caves of continental Portugal have been intensively sampled over the last 15 years. Sampling was performed by direct searching and baited pitfall traps, both in caves and in the mesovoid shallow substratum (scree slopes). Most of this sampling was performed under the framework of MSc's and PhD studies (Reboleira 2007, Reboleira 2012, Eusébio 2020), and all specimens were collected under legal permits of the Instituto de Conservação da Natureza e das Florestas. Specimens were sorted and identified to species level using dissection and microscopy support, and compared with collection specimens and the appropriate bibliography.

Extent of occurrence (EOO) and area of occupancy (AOO) were calculated, and the maps were created in the open source software QGIS 3.14.16, with the natural protected areas of Portugal layer (ICNF 2020).

Threats were observed *in situ* in the field, and complemented with appropriate literature surveys. Threats, conservation actions, research needed, and the type of habitat classifications were assigned based on the IUCN Red List database.

## Species Conservation Profiles

### Iberoporus pluto Ribera & Reboleira, 2019

#### Species information

##### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Dytiscidae

##### Taxonomic notes

*Iberoporus pluto* is the biggest and widest of all the subterranean species of its genus (Ribera and Reboleira 2019).

##### Region for assessment:

- Europe

##### Figure(s) or Photo(s):

Fig. 1

## Reviewers

Reviewers

## Editor

Editor

## Geographic range

### Biogeographic realm:

- Palearctic

### Countries:

- Portugal

### Map of records (Google Earth):

Suppl. material 1

**Basis of EOO and AOO:** Known habitat extent

### Basis (narrative)

The extent of occurrence (EOO) is 15 km<sup>2</sup> and the area of occupancy (AOO) is 4 km<sup>2</sup>.

**Min Elevation/Depth (m):** 218

### Range description

*Iberoporus pluto* is a groundwater-adapted beetle known from a stream in a single cave located in northeastern Sicó karst area. The cave stream where it was found flows in a subterranean system of approximately 15 km of horizontal implementation (Ribera and Reboleira 2019).

## Extent of occurrence

**EOO (km<sup>2</sup>):** 15

**Trend:** Decline (observed)

**Justification for trend**

A decline in EOO is inferred due to the degradation of the cave by anthropogenic impact as Soprador do Carvalho Cave, which is subject to recreational visitation and direct trampling on the subterranean stream.

**Causes ceased?:** No

**Causes understood?:** Yes

**Causes reversible?:** Yes

**Extreme fluctuations?:** Unknown

**Area of occupancy**

**AOO (km<sup>2</sup>):** 4

**Trend:** Decline (projected)

**Justification for trend**

No decline in AOO has been observed but it is inferred due to the decline and vulnerability of the habitat.

**Causes ceased?:** No

**Causes understood?:** Yes

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

**Locations**

**Number of locations:** 1

**Justification for number of locations**

*Iberoporus pluto* occurs in a single cave, Soprador do Carvalho, in the Sicó karst area in central Portugal and it is under moderate disturbance (Ribera and Reboleira 2019).

**Trend:** Stable

**Justification for trend**

This cave is the only known location in the historical range, as several caves in the same karst massif nearby have been sampled and this species has never been found elsewhere. Therefore the current trend in number of locations is stable.

**Extreme fluctuations?:** Unknown

## **Population**

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

## **Population Information (Narrative)**

Only one specimen (female) of this species is known from a single location in central Portugal.

## **Subpopulations**

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

**Severe fragmentation?:** Unknown

## **Habitat**

**System:** Freshwater

**Habitat specialist:** Yes

### **Habitat (narrative)**

The specimen was collected in the bottom of a clay pool connected to a subterranean stream (Ribera and Reboleira 2019).

**Trend in extent, area or quality?:** Decline (observed)

### **Justification for trend**

Soprador do Carvalho Cave is located in the vicinity of a village, agricultural fields and a quarry (NEC 2020, Neves et al. 2005). It is also affected by turistic activities as tourists visit the cave and step over the habitat (Ribera and Reboleira 2019).

**Habitat importance:** Major Importance

## Habitats:

- 5.1. Wetlands (inland) - Permanent Rivers/Streams/Creeks (includes waterfalls)
- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

## Ecology

**Size:** 2.8 mm

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

The genus *Iberoporus* Castro & Delgado, 2001 is endemic to the Iberian Peninsula and exclusively stygobiont (Castro and Delgado 2001, Ribera 2003, Ribera and Reboleira 2019, Ribera et al. 2002). *Iberoporus pluto* has extreme troglomorphic traits (anophthalmy and depigmentation), and unusually elongated legs not adapted for swimming (Ribera and Reboleira 2019).

## Threats

**Threat type:** Ongoing

### Threats:

- 1.1. Residential & commercial development - Housing & urban areas
- 3.2. Energy production & mining - Mining & quarrying
- 6.1. Human intrusions & disturbance - Recreational activities
- 9.1.2. Pollution - Domestic & urban waste water - Run-off

### Justification for threats

The cave is explored for tourism and visitors step over the habitat where the species was found (Ribera and Reboleira 2019). Other threats include the proximity to a quarry located at 1.4 km from the cave entrance. It also distances 67 m from the closest houses, and is surrounded by agricultural lands. The subterranean stream flows below habitational areas and run-off of urban wastewater directly to the stream is observable (Reboleira et al. 2011b).

## Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 2.3. Land/water management - Habitat & natural process restoration
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

**Justification for conservation actions**

Measures should be taken to prevent infiltration of wastewaters from the village into the cave stream. The nearby quarry has been reportedly in the national media to be the source of the infiltration of small particles of quarry dust that have been deposited all over the gallery of Algarinho Cave by flood events. This type of slurry is known to impact perniciously groundwater quality (Piccini et al. 2019) and Algarinho Cave is part of the "Dueça Speleological System", therefore hydrologically connected to Soprador do Carvalho Cave.

**Other**

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

**Justification for research needed**

Further investigation is needed about the distribution, ecology and life cycle of the species. Developing a management plan for this species is crucial. This plan will aid the conservation of the cave-adapted species of the Sicó karst area.

**Trechus machadoi Jeannel, 1941****Species information****Taxonomy**

Kingdom	Phylum	Class	Order	Family
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Animalia	Arthropoda	Insecta	Coleoptera	Carabidae
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### Taxonomic notes

This species is part of the “*T. fulvus*-group” species complex and is recognizable by the shape of the aedeagus.

### Region for assessment:

- Europe

### Figure(s) or Photo(s):

Fig. 2

### Reviewers

Reviewers

### Editor

Editor

### Geographic range

#### Biogeographic realm:

- Palearctic

#### Countries:

- Portugal

#### Map of records (Google Earth):

Suppl. material 1

**Basis of EOO and AOO:** Known habitat extent

#### Basis (narrative)

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both 0.004 km<sup>2</sup>.

**Min Elevation/Depth (m):** 389

**Max Elevation/Depth (m):** 400

## Range description

*Trechus machadoi* is a troglobiont beetle known only in the Alcobertas Cave and in a continuous mesovoid shallow substratum (MSS) located in the Serra dos Candeeiros subunit of the Estremenho karst massif, central Portugal (Eusébio 2020, Reboleira 2007, Reboleira 2012, Reboleira et al. 2009). The cave extends horizontally for approximately 210 m (Reboleira 2007, Reboleira 2012, Reboleira et al. 2009), and the MSS area distances 80 m from the type locality (Eusébio 2020).

## Extent of occurrence

EOO (km<sup>2</sup>): 0.004

Trend: Decline (observed)

### Justification for trend

Despite intensive sampling in the type locality (cave), no specimens have been found in there since the species description. Only recent sampling in the MSS contiguous to the cave retrieved specimens.

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

## Area of occupancy

AOO (km<sup>2</sup>): 0.004

Trend: Decline (observed)

### Justification for trend

AOO decline has been inferred due to the vulnerability of the habitat.

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

## Locations

**Number of locations:** 2

#### **Justification for number of locations**

*Trechus machadoi* is known only from the Alcobertas Cave and from the adjacent MSS, located approximately 80 m from each other. Its distribution is likely to be confined to the subterranean habitats of the Serra dos Candeeiros subunit (Reboleira et al. 2009). This population is under intense disturbance.

**Trend:** Stable

#### **Justification for trend**

Alcobertas is the only known location in the historical range, therefore the current trend in number of locations is stable.

**Extreme fluctuations?:** Unknown

### **Population**

**Number of individuals:** Unknown

**Trend:** Unknown

#### **Justification for trend**

The type locality was monitored for six months in 2009 but no specimens were sampled or observed, most likely due to the human impact to this cave described below (Reboleira 2007).

**Causes ceased?:** No

**Causes understood?:** Yes

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

#### **Population Information (Narrative)**

So far, only one population is known from the Alcobertas Cave, which is also dispersed in the contiguous mesovoid shallow substrate at 0.5 m depth in scree slopes (Reboleira 2007, Reboleira et al. 2009, Reboleira et al. 2010).

### **Subpopulations**

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

## Habitat

**System:** Terrestrial

**Habitat specialist:** Yes

### Habitat (narrative)

The Alcobertas Cave was subject of a megalomaniac anthropogenic intervention in the beginning of the 70s of the last century, with the intention to transform it to receive mass tourism. During that process, a second entry was opened near the end of the gallery, this induced strong changes in the climatology of the cave (Reboleira 2007). Many explosions inside the cave originated large accumulations of powdery residues that can still be observed nowadays, which associated with the air fluxes between the two entrances may have displaced *Trechus machadoi* population to other parts of the subterranean network (Reboleira et al. 2009). The Alcobertas Cave is currently used for tourism by a local association. Recently, *Trechus machadoi* was collected during winter at 50 cm deep in the mesovoid shallow substrate (MSS) in scree slopes close to the type locality (Eusébio 2020, Eusébio et al. in press). These scree slopes are classified as western Mediterranean and thermophile deposits, and protected by Natura 2000 network (Eusébio et al. in press).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### Habitats:

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves
- 7.2. Caves and Subterranean Habitats (non-aquatic) - Other Subterranean Habitats

## Ecology

**Size:** 4.85 mm (lectotype)

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

*Trechus machadoi* is a troglolobiont species with reduced eyes and body depigmentation. It lives exclusively in subterranean habitats, it is known only from a single cave and recently was found in scree slopes habitats in the Serra dos Candeeiros subunit of the Estremenho karst massif in central Portugal (Eusébio 2020, Reboleira 2007, Reboleira et al. 2009).

## Threats

**Threat type:** Ongoing

**Threats:**

- 1.1. Residential & commercial development - Housing & urban areas
- 3.2. Energy production & mining - Mining & quarrying
- 3.3. Energy production & mining - Renewable energy
- 6.1. Human intrusions & disturbance - Recreational activities

**Justification for threats**

Since the 70's this cave has been intensively explored for touristic activities. During that period a second entrance has been opened, drastically changing the environment (Reboleira 2007, Reboleira et al. 2009). The scree slope where it was recently found is disturbed by herds of goats that graze the area (Eusébio 2020, Eusébio et al. in press). Both localities are located 640 m from a field of energy windmills, 1 km from a quarry, 850 m from agricultural lands and 690 m from the nearest village.

**Conservation**

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

**Justification for conservation actions**

The habitats are protected under the EU "Rede Natura 2000" (Directive 1992, ICNB 2000) but the species lacks formal protection framework. The monitorization of the population trends and extent of distribution in the underground in the nearby areas is crucial to understand the species' abundance patterns and life cycle. Improvements are needed to reduce the impacts of the quarry and windmills on the habitat.

**Other**

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan

- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

### Justification for research needed

Further investigation is needed about the population size, extent of distribution, ecology and life cycle. It is urgent to develop a management plan for this species, which will consequently improve the conservation of further cave-adapted species of Serra dos Candeeiros subunit of the Estremenho massif.

## Trechus gamae Ribeira & Reboleira, 2009

### Species information

#### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Carabidae

#### Taxonomic notes

This species is part of the "*T. fulvus*-group" species complex and is recognizable by the shape of the aedeagus.

#### Region for assessment:

- Europe

#### Figure(s) or Photo(s):

Fig. 3

### Reviewers

Reviewers

### Editor

Editor

### Geographic range

#### Biogeographic realm:

- Palearctic

**Countries:**

- Portugal

**Map of records (Google Earth):**

Suppl. material 1

**Basis of EOO and AOO:** Known habitat extent

**Basis (narrative)**

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both of 63.8 km<sup>2</sup>.

**Min Elevation/Depth (m):** 250

**Max Elevation/Depth (m):** 485

**Range description**

*Trechus gamae* is a troglobiont beetle known from five caves and from the mesovoid shallow substrate (scree slopes), all located in the Santo António plateau, the central subunit of the Estremenho karst massif (Eusébio 2020, Eusébio et al. in press, Reboleira 2007, Reboleira 2012, Reboleira and Ortuño 2011, Reboleira et al. 2009).

**Extent of occurrence**

**EOO (km<sup>2</sup>):** 63.8

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

**Area of occupancy**

**AOO (km<sup>2</sup>):** 63.8

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

## Locations

**Number of locations:** 6

### Justification for number of locations

*Trechus gamae* was found in five caves: Algar de Marradinhas II, Algar das Gralhas VII, Algar do Pena, Algar da Arroteia and Algar do Ladoeiro, all located in the Santo António plateau, the central subunit of the Estremenho karst massif (Reboleira 2007, Reboleira and Ortuño 2011, Reboleira et al. 2009). Recently, a single specimen was found in the mesovoid shallow substrate at 0.5 m depth in scree slopes of Fórnea, which is also located in the Santo António plateau, showing that this species may also disperse through more superficial subterranean habitats (Eusébio 2020). The species is geographically isolated within the subterranean network of the Estremenho's massif subunit Santo António plateau (Eusébio 2020, Reboleira 2007, Reboleira 2012, Reboleira and Ortuño 2011, Reboleira et al. 2009, Reboleira et al. 2010).

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

## Population

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

### Population Information (Narrative)

Among the six known localities with populations of *T. gamae*, Algar das Gralhas VII Cave had the largest population, followed by Algar do Pena Cave, Algar das Marradinhas Cave and Algar da Arroteia Cave (Reboleira 2007, Reboleira and Ortuño 2011). Algar do Ladoeiro Cave and the mesovoid shallow substrate in scree slopes in Fórnea (contiguous to Algar da Arroteia Cave) had the smallest populations (Reboleira et al. 2009; Eusébio et al. in press). All the known populations are within the Santo António Plateau in the Estremenho karst massif, central Portugal.

## Subpopulations

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

## Habitat

**System:** Terrestrial

**Habitat specialist:** Yes

### Habitat (narrative)

*Trechus gamae* was found in the deepest parts of the caves, from 50 to 95 m deep, all with high humidity levels (>98%), and temperatures ranging from 13.5°C (in Algar do Pena) to 17°C (in Algar de Marradinhas II) (Reboleira 2007, Reboleira 2012, Reboleira and Ortuño 2011, Reboleira et al. 2009). The caves where the species was found are located at an altitude ranging from 250 to 485 m asl (Reboleira and Ortuño 2011). More recently, a single specimen was collected in MSS traps in scree slopes in Fórnea, which is located between the Algar da Arroteia and the Algar do Ladoeiro caves. The MSS specimen was collected in the winter, in a pitfall trap placed at 50 cm deep into the scree slope (Eusébio et al. in press).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### Habitats:

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves
- 7.2. Caves and Subterranean Habitats (non-aquatic) - Other Subterranean Habitats

## Ecology

**Size:** 4.83–5.38 mm (males), 3.94–5.44 mm (females)

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

*Trechus gamae* was the only cave-adapted beetle collected in the caves and MSS of the Santo António Plateau, and it shows a strict subterranean lifestyle (Eusébio et al. in press, Reboleira 2007, Reboleira 2012, Reboleira and Ortuño 2011, Reboleira et al. 2009, Reboleira et al. 2010). Both adults and larvae were found in the sampled caves, and some

seasonal abundance variation was recorded, being more abundant in spring and summer (Reboleira and Ortuño 2011).

## Threats

**Threat type:** Ongoing

**Threats:**

- 1.1. Residential & commercial development - Housing & urban areas
- 3.2. Energy production & mining - Mining & quarrying
- 6.1. Human intrusions & disturbance - Recreational activities
- 9.1.2. Pollution - Domestic & urban waste water - Run-off

### Justification for threats

The distribution area of the species is all covered by the Natural Park of Serras d'Aire e Candeeiros. However intense quarry activity is currently ongoing in the surrounding areas of the known localities. Algar do Pena is located 300 m from a quarry and Algar das Gralhas VII 168 m from the same quarry. Algar do Ladoeiro's entrance is 840 m from the closest urbanisation, Algar das Marradinhas II is located 1.5 km from the nearest village and Algar da Arroiteia is located 112 m from the closest house and 1.3 km from a quarry. Algar do Pena Cave hosts a laboratory and is open for visit upon previous booking. Fórnea is located 595 m from the closest house and 1.9 km from a quarry. The distribution area faces severe groundwater contamination (Reboleira et al. 2013b), due to the generalized lack of proper wastewater treatment (Reboleira et al. 2011b).

## Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

### Justification for conservation actions

Although the habitat is protected under legislation by the "Rede Natura 2000" (Directive 1992, ICNB 2000), the species is not. Population trends need to be monitored in order to better understand the species' abundance patterns and life cycle. Measures should be taken to prevent infiltration of wastewaters from the nearby town into the soil and underground habitats and to minimize the negative effects of the quarry in the habitat.

## Other

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

### Justification for research needed

Additional investigation about the population size, extent of distribution, ecology and life cycle is required. The development of a management plan that will improve the conservation of this cave-adapted species in the Santo António plateau subunit of the Estremenho karst massif is fundamental to ensure its conservation and protection.

## Trechus lunai Ribeira & Reboleira, 2009

### Species information

#### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Carabidae

#### Taxonomic notes

This species is part of the "*T. fulvus*-group" species complex and is recognizable by the shape of the aedeagus.

**Region for assessment:**

- Europe

**Figure(s) or Photo(s):**

Fig. 4

## Reviewers

Reviewers

## Editor

Editor

## Geographic range

### Biogeographic realm:

- Palearctic

### Countries:

- Portugal

### Map of records (Google Earth):

Suppl. material 1

### Basis of EOO and AOO: Known habitat extent

### Basis (narrative)

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both of 2.4 km<sup>2</sup>.

**Min Elevation/Depth (m):** 95

**Max Elevation/Depth (m):** 307

### Range description

*Trechus lunai* is a troglobiont Carabidae known from three horizontal caves located in Serra de Aire/São Mamede plateau (Reboleira et al. 2009).

### Extent of occurrence

**EOO (km<sup>2</sup>):** 2.4

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

### **Area of occupancy**

**AOO (km2):** 2.4

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

### **Locations**

**Number of locations:** 3

#### **Justification for number of locations**

*Trechus lunai* was found in three caves of the Serra de Aire/São Mamede plateau subunits. The southernmost distribution is the Almonda Cave, but this species is also known from the Contenda and Moinhos Velhos Cave system (Reboleira et al. 2009).

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

### **Population**

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

#### **Population Information (Narrative)**

Three populations are known exclusively from the Serra d'Aire/São Mamede plateau subunit of the Estremenho karst massif (Reboleira et al. 2009).

## Subpopulations

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

## Habitat

**System:** Terrestrial

**Habitat specialist:** Yes

### Habitat (narrative)

*Trechus lunai* only occurs in the deepest parts of the caves, from 50 to 80 m deep. The three caves have high humidity levels and average temperature of 18°C (Reboleira et al. 2009, Reboleira et al. 2015). In Moinhos Velhos Cave, the species was found in a subterranean stream that has high input of a sewage from surface and is located below the village of Mira d'Aire in the connection between the Gruta de Mira d'Aire Show Cave and the Pena spring. Moinhos Velhos is contiguous to Contenda Cave and are hydrologically connected (Reboleira et al. 2009). The other locality is Almonda Cave, which distances 8.4 km in a straight line from the Moinhos Velhos-Contenda cave system. Almonda Cave, also known as “Olho do Moinho da Fonte”, is the largest cave of Portugal with more than 10 km of horizontal development mapped (Thomas 1991).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### Habitats:

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

## Ecology

**Size:** 3.55–4.73 mm

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

*Trechus lunai* was the only troglóbiont species captured in these caves. All known localities are caves that flood seasonally (Reboleira et al. 2009).

## Threats

**Threat type:** Ongoing

**Threats:**

- 1.1. Residential & commercial development - Housing & urban areas
- 1.2. Residential & commercial development - Commercial & industrial areas
- 2.3. Agriculture & aquaculture - Livestock farming & ranching
- 9.1.2. Pollution - Domestic & urban waste water - Run-off

**Justification for threats**

Almonda Cave is located 50 m from a factory that conducts the subterranean river into the building for industrial use of the water, and at 420 m from the village centre. The surrounding village is also heavily populated by agricultural fields. Contenda and Moinhos Velhos caves are heavily contaminated, as their subterranean network extends below the village of Mira d'Aire. The entrance of Moinhos Velhos Cave is located in the village center and it has been explored for tourism since the 1960's with several complementary touristic infrastructures built (Crispim et al. 2014).

## Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

**Justification for conservation actions**

The Contenda and Moinhos-Velhos caves develop below the village of Mira d'Aire and infiltration of sewage is observed in the underground. Therefore an effort to improve sewage treatment is necessary in order to prevent wastewater run-off into subterranean galleries and groundwaters. Almonda Cave is classified as Property of Public Interest (IIP) since 1993 and protected due to archaeological heritage (Hoffmann et al. 2013). The archaeological arguments for cave protection are clearly inappropriate for cave-adapted fauna conservation, so it is urgent to set specific measures to be applied in order to ensure its protection.

## Other

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

**Justification for research needed**

Information about the population size, extent of distribution, ecology and life cycle of this species is scarce, therefore further investigation is required. It is also necessary to develop a management plan that will improve the conservation of the species in the Serra de Aire/S. Mamede plateau subunits of the Estremenho karst massif.

## Trechus tatai Reboleira & Ortuño, 2010

### Species information

#### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Carabidae

#### Taxonomic notes

This species is part of the “*T. fulvus*-group” species complex alongside the Portuguese species of the group: *T. machadoi*, *T. gamae* and *T. lunai*. It is recognizable by the shape of the aedeagus and has a slim body, rudimentary wings, reduced eyes (microphthalmia) and depigmentation this species is classified as of most troglomorphic ground-beetle known from Portugal (Reboleira et al. 2010).

**Region for assessment:**

- Europe

**Figure(s) or Photo(s):**

Fig. 5

## Reviewers

Reviewers

## Editor

Editor

## Geographic range

### Biogeographic realm:

- Palearctic

### Countries:

- Portugal

### Map of records (Google Earth):

Suppl. material 1

### Basis of EOO and AOO: Known habitat extent

### Basis (narrative)

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both of 0.00008 km<sup>2</sup>.

Min Elevation/Depth (m): 380

### Range description

*Trechus tatai* is a cave-adapted hygrophilous Carabidae known only from one small cave located in Serra do Montejunto (Reboleira et al. 2010).

### Extent of occurrence

EOO (km<sup>2</sup>): 0.00008

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

**Extreme fluctuations?:** Unknown

## **Area of occupancy**

**AOO (km<sup>2</sup>):** 0.00008

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

## **Locations**

**Number of locations:** 1

### **Justification for number of locations**

*Trechus tatai* only occurs in one cave, Algar do Javali, located in Serra do Montejunto. This species exhibits geographic isolation (Reboleira et al. 2010).

**Trend:** Stable

### **Justification for trend**

Algar do Javali is the only known location for this species, therefore trend in number of locations is stable.

**Extreme fluctuations?:** Unknown

## **Population**

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

## Population Information (Narrative)

Only one population is known from Algar do Javali Cave in Montejunto karst massif in Portugal.

## Subpopulations

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

## Habitat

**System:** Terrestrial

**Habitat specialist:** Yes

### Habitat (narrative)

*Trechus tatai* was only collected in the deep oligotrophic areas of the cave. It was never found in areas with high organic material content (bat guano accumulation zones). The cave is 10 m deep and extends for 80 m. Temperatures in the deepest zone of the cave ranged from 14.2 °C in winter to 15 °C in summer (Reboleira et al. 2010).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### Habitats:

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

## Ecology

**Size:** 5.2–5.9 mm (males), 4.8–6 mm (females)

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

*Trechus tatai* is the most troglomorphic Carabidae beetle from continental Portugal. Other caves of the area were sampled but *T. tatai* was never collected elsewhere. The seasonal activity pattern of the beetle was studied during one year in the deepest zone of the cave and specimens were collected during winter, autumn and spring (Reboleira et al. 2010). The absence of *T. tatai* during summer is most likely caused by the low humidity in the

cave during this season. It is very likely that during summer this species escapes from the cave into the MSS in search of smaller gaps that retain humidity (Reboleira et al. 2010).

## Threats

**Threat type:** Ongoing

**Threats:**

- 1.1. Residential & commercial development - Housing & urban areas
- 2.2. Agriculture & aquaculture - Wood & pulp plantations
- 3.2. Energy production & mining - Mining & quarrying
- 4. Transportation & service corridors

### Justification for threats

Algar do Javali Cave is located 1.6 km from a quarry and 2.9 km from the closest village. The cave entrance is located 50 m from a road and surrounded by Eucalyptus intensive plantation at surface.

## Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

### Justification for conservation actions

Although this cave is protected under legislation by the “Rede Natura 2000” (Directive 1992, ICNB 2000), the species is not. This species is rare, a single cave endemics, and it is considered the most troglomorphic carabid beetle of Portugal, therefore, a conservation plan for this cave area is crucial to ensure its environmental sustainability.

## Other

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends

- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

### Justification for research needed

Some crucial steps necessary for the protection of the species are the development of a management plan for the conservation of this cave-adapted species in Serra do Montejunto and the promotion further studies regarding population size, extent of distribution, ecology, and life cycle.

## Speonemadus algarvensis Reboleira, Fresneda & Salgado, 2017

### Species information

#### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Leiodidae

#### Taxonomic notes

This species is part of the "*Speonemadus escalerae*-group" and is recognizable by the equal/subequal length of the 2<sup>nd</sup>, 4<sup>th</sup>, 5<sup>th</sup> and 7<sup>th</sup> antennomeres and a slightly transverse and hexagonal pronotum (Reboleira et al. 2017).

#### Region for assessment:

- Europe

### Reviewers

Reviewers

### Editor

Editor

### Geographic range

#### Biogeographic realm:

- Palearctic

**Countries:**

- Portugal

**Map of records (Google Earth):**

Suppl. material 1

**Basis of EOO and AOO:** Known habitat extent

**Basis (narrative)**

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are unknown. The three caves are located along a 48 km straight line, with Algarão do Remexido Cave distancing 23 km from Vale Telheiro, and Vale Telheiro Cave distancing 25 km from Senhora Cave.

**Min Elevation/Depth (m):** 72

**Max Elevation/Depth (m):** 269

**Range description**

*Speonemadus algarvensis* was collected in three caves in the southernmost province of Portugal in the Algarve, being most likely endemic to the central and eastern parts of the Algarve karst massif, a region also known as Barrocal Algarvio (Reboleira et al. 2017).

**Extent of occurrence**

**EOO (km<sup>2</sup>):** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

**Area of occupancy**

**AOO (km<sup>2</sup>):** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

## Locations

**Number of locations:** 3

### Justification for number of locations

*Speonemadus algarvensis* is known from three caves (Vale Telheiro, Algarão do Remexido and Senhora) in the Algarve karst massif (Reboleira et al. 2017).

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

## Population

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

### Population Information (Narrative)

There are three populations known from Portugal, all from caves in the Algarve karst massif. The largest number of individuals was collected in Vale Telheiro Cave, followed by Senhora Cave and Algarão do Remexido Cave (Reboleira et al. 2017).

## Subpopulations

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

**Severe fragmentation?:** Unknown

## Habitat

**System:** Terrestrial

**Habitat specialist:** Yes

### **Habitat (narrative)**

Specimens were collected in three caves, 15 to 30 m deep, with high humidity levels and average temperatures of 17.8°C (Vale Telheiro Cave), 18.8°C (Senhora Cave) and 19.3°C (Algarão do Remexido Cave). This species is endemic to the Algarve karst massif (Reboleira et al. 2017).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### **Habitats:**

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

### **Ecology**

**Size:** 4–4.9 mm

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### **Ecology and traits (narrative)**

*Speonemadus algarvensis* occurs exclusively in the Algarve, Portugal and does not exhibit the typical troglomorphisms found in other cave-adapted species like evident eye reduction, severe depigmentation and extreme body and appendages elongation although it has only been collected in caves and never at surface. This species was found to carry ectoparasitic fungus of the order Laboulbeniales (*Stichomyces conosomatis* Thaxt., 1901) attached to the cuticle, and foresic acari (Reboleira et al. 2017).

### **Threats**

**Threat type:** Ongoing

### **Threats:**

- 1.1. Residential & commercial development - Housing & urban areas
- 1.2. Residential & commercial development - Commercial & industrial areas
- 2.3. Agriculture & aquaculture - Livestock farming & ranching
- 9.1.2. Pollution - Domestic & urban waste water - Run-off

### **Justification for threats**

Algarão do Remexido is located under agricultural lands, 370 m from the closest house and 1.7 km from the closest village. Vale Telheiro is located 290 m from the closest house

and 745 m from the closest urbanisation. Senhora Cave is located 168 m from the closest house and 900 m from an industrial complex.

## Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

### Justification for conservation actions

Although the habitat is protected under legislation by the “Rede Natura 2000” (Directive 1992, ICNB 2000), the species is not. Population trends need to be monitored in order to better understand the species' abundance patterns and life cycle. Measures should be taken to prevent infiltration of wastewaters, and to ensure conservation of natural landscape and vegetal communities at surface, vital to maintain nutrient inflow to the subterranean ecosystem.

## Other

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

### Justification for research needed

The development of a management plan for the conservation of this cave-adapted species in the Algarve karst massif and the encouragement of more studies regarding population size, extent of distribution, ecology and life cycle are essential measures for the protection of the species.

# Domene lusitanica Reboleira & Oromí, 2011

## Species information

### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae

### Taxonomic notes

Individuals display several troglomorphisms such as microphthalmia, lack of wings and body elongation (Reboleira et al. 2011a).

### Region for assessment:

- Europe

### Figure(s) or Photo(s):

Fig. 6

## Reviewers

Reviewers

## Editor

Editor

## Geographic range

### Biogeographic realm:

- Palearctic

### Countries:

- Portugal

### Map of records (Google Earth):

Suppl. material 1

Basis of EOO and AOO: Known habitat extent

**Basis (narrative)**

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both of 0.0426 km<sup>2</sup>.

**Range description**

*Domene lusitanica* was found in a single cave located in the Sicó karstic massif (Reboleira et al. 2011a).

**Extent of occurrence**

EOO (km<sup>2</sup>): 0.0426

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

**Area of occupancy**

AOO (km<sup>2</sup>): 0.0426

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

**Locations**

Number of locations: 1

**Justification for number of locations**

*Domene lusitanica* was collected in Cerâmica Cave, located in the Sicó karst area in central Portugal (Reboleira et al. 2011a). This cave extends for 355 m (Nóbrega et al. 1984).

Trend: Unknown

**Extreme fluctuations?:** Unknown

## **Population**

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

### **Population Information (Narrative)**

This species is known from a single population in central Portugal (Reboleira et al. 2011a).

## **Subpopulations**

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

**Severe fragmentation?:** Unknown

## **Habitat**

**System:** Terrestrial

**Habitat specialist:** Yes

### **Habitat (narrative)**

Specimens were exclusively collected in the deepest zones of the cave (10 m deep), in high humidity levels and with average temperatures of 16.4°C (Reboleira et al. 2011a).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### **Habitats:**

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

## **Ecology**

**Size:** 9–9.48 mm

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

*Domene lusitanica* is a predator troglobiont rove beetle, with reduced eyes, apterous, depigmented and elongated body and appendages (Reboleira et al. 2011a). It is only known from one cave in the Sicó karst area and is a rare species, as the type locality and several other caves nearby have been monitored for more than a decade and only 8 specimens have been observed so far: 7 collected in 2010 (type material) and 1 collected in December 2019. It shares habitats with other single cave endemic species, the troglobiont pseudoscorpion *Roncocreagris borgesii* Zaragoza & Reboleira, 2013, and several other cave-adapted species: the pseudoscorpions *Occidenchthonius vachoni* Zaragoza & Reboleira, 2018 and *Roncocreagris blothroides* Beier, 1962; the millipede *Scutogona minor* Enghoff & Reboleira, 2013; and the woodlice *Trichoniscoides sicoensis* Reboleira & Taiti, 2015, *Miktoniscus longispina* Reboleira & Taiti, 2015, *Porcellio cavernicolus* Vandel, 1946 (Enghoff and Reboleira 2013, Reboleira et al. 2013c, Reboleira et al. 2015).

### Threats

**Threat type:** Ongoing

**Threats:**

- 1.1. Residential & commercial development - Housing & urban areas
- 2.3. Agriculture & aquaculture - Livestock farming & ranching
- 3.2. Energy production & mining - Mining & quarrying

### Justification for threats

Cerâmica Cave is located 550 m from an animal farm, 3.5 km from the nearest village and 3.6 km from a quarry. It is surrounded by agricultural lands and *Eucalyptus* plantations.

### Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness
- 5.1.3. Law & policy - Legislation - Sub-national level

**Justification for conservation actions**

The habitat is located in an “Rede Natura 2000” area (Directive 1992, ICNB 2000). Population trends need to be monitored in order to better understand the species' abundance patterns and life cycle. Measures should be taken to prevent infiltration of agricultural lands and livestock farms and to prevent the pernicious effects of the quarry activity on the surrounding habitats.

**Other**

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology
- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

**Justification for research needed**

In order to build a sustainable conservation plan for the species in the Sicó karst area more information about population size, extent of distribution, ecology and life cycle is needed. The threats also need to be addressed and minimized if possible in order to improve the habitat quality.

**Domene viriatoi Serrano & Boieiro, 2015****Species information****Taxonomy**

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae

**Taxonomic notes**

This species displays body, leg and antennae elongation, microphthalmia and lack of wings (Serrano et al. 2015).

**Region for assessment:**

- Europe

## Reviewers

Reviewers

## Editor

Editor

## Geographic range

### Biogeographic realm:

- Palearctic

### Countries:

- Portugal

### Map of records (Google Earth):

Suppl. material 1

### Basis of EOO and AOO: Known habitat extent

### Basis (narrative)

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both unknown.

### Range description

*Domene viriatoi* was collected in two galleries of the Buraco da Moura Cave, located in the Serra da Estrela Mountain foothills (Serrano et al. 2015).

## Extent of occurrence

EOO (km<sup>2</sup>): Unknown

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

## Area of occupancy

AOO (km<sup>2</sup>): Unknown

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

## Locations

Number of locations: 1

### Justification for number of locations

*Domene viriatoi* was collected from the Buraco da Moura Cave in the border of the Estrela Mountain chain (Serrano et al. 2015).

Trend: Unknown

Extreme fluctuations?: Unknown

## Population

Number of individuals: Unknown

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

### Population Information (Narrative)

This species is known from a single population in the Estrela Mountain chain, the highest mountain of continental Portugal (Serrano et al. 2015).

## Subpopulations

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

**Severe fragmentation?:** Unknown

## Habitat

**System:** Terrestrial

**Habitat specialist:** Yes

### Habitat (narrative)

The cave forms in granitic rock, and extends for 150 m of underground galleries (Serrano et al. 2015).

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### Habitats:

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

## Ecology

**Size:** 6.9–8.2 mm (males), 6.3–8.8 mm (females)

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

*Domene viriatoi* is included in the subgenus *Lathromene*, together with the other two portuguese species of cave-adapted *Domene*: *D. lusitanica* and *D. darinkae*. Both adults and larvae of this species were observed foraging for preys in bat guano on the cave substrate (Serrano et al. 2015).

## Threats

**Threat type:** Ongoing

### Threats:

- 1.1. Residential & commercial development - Housing & urban areas
- 6.1. Human intrusions & disturbance - Recreational activities
- 7.2. Natural system modifications - Dams & water management/use

- 9.1.2. Pollution - Domestic & urban waste water - Run-off

### **Justification for threats**

The cave entrance is located 127 m from the closest house, 530 m from a hydroelectric power station and 1.2 km from the closest village and is under anthropogenic disturbance due to tourism.

### **Conservation**

**Conservation action type:** In Place

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 5.1.3. Law & policy - Legislation - Sub-national level

**Conservation action type:** Needed

**Conservation actions:**

- 2.1. Land/water management - Site/area management
- 4. Education & awareness

### **Justification for conservation actions**

Buraco da Moura Cave was classified as a “National Important Underground Shelter for Bats” therefore a decrease in human disturbance is expected (Serrano et al. 2015). However, concrete monitoring plans for this species are required in order to understand its ecology and distribution.

Although the habitat is protected under legislation by the “Rede Natura 2000” (Directive 1992, ICNB 2000), the species is not. Population trends need to be monitored in order to better understand the species' abundance patterns and life cycle. Measures should be taken to prevent infiltration of wastewaters from the nearby town into the soil and underground habitats and to minimize the effects of the hydroelectric power station on the surrounding habitats.

### **Other**

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology

- 2.1. Conservation Planning - Species Action/Recovery Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

### Justification for research needed

A sustainable conservation plan for the species is only possible if more information about population size, extent of distribution, ecology and life cycle is collected.

## Domene darinkae Magrini & Carotti 2019

### Species information

#### Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae

#### Region for assessment:

- Europe

### Reviewers

Reviewers

### Editor

Editor

### Geographic range

#### Biogeographic realm:

- Palearctic

#### Countries:

- Portugal

#### Map of records (Google Earth):

Suppl. material 1

Basis of EOO and AOO: Known habitat extent

**Basis (narrative)**

The extent of occurrence (EOO) and the maximum estimated area of occupancy (AOO) are both unknown.

**Range description**

*Domene darinkae* is a cave-adapted rove beetle known from an abandoned mine in northern Portugal (Magrini and Carotti 2019).

**Extent of occurrence**

EOO (km<sup>2</sup>): Unknown

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

**Area of occupancy**

AOO (km<sup>2</sup>): Unknown

Trend: Unknown

Causes ceased?: Unknown

Causes understood?: Unknown

Causes reversible?: Unknown

Extreme fluctuations?: Unknown

**Locations**

Number of locations: 1

**Justification for number of locations**

*Domene darinkae* is known from a single horizontal artificial cave, Santa Isabel mine, located in the Marão Mountain chain in North Portugal (Magrini and Carotti 2019).

Trend: Unknown

**Extreme fluctuations?:** Unknown

## **Population**

**Number of individuals:** Unknown

**Trend:** Unknown

**Causes ceased?:** Unknown

**Causes understood?:** Unknown

**Causes reversible?:** Unknown

**Extreme fluctuations?:** Unknown

### **Population Information (Narrative)**

Only one specimen of this species is known from a single location in northern Portugal (Magrini and Carotti 2019).

## **Subpopulations**

**Trend:** Unknown

**Extreme fluctuations?:** Unknown

**Severe fragmentation?:** Unknown

## **Habitat**

**System:** Terrestrial

**Habitat specialist:** Yes

### **Habitat (narrative)**

The only known specimen was collected in the rocky debris along the main tunnel of the Santa Isabel mine (Magrini and Carotti 2019). The geological matrix of this mine is quartzites with iron.

**Trend in extent, area or quality?:** Unknown

**Habitat importance:** Major Importance

### **Habitats:**

- 7.1. Caves and Subterranean Habitats (non-aquatic) - Caves

## Ecology

**Size:** 6.93 mm (male holotype)

**Generation length (yr):** 1

**Dependency of single sp?:** Unknown

### Ecology and traits (narrative)

This species exhibits troglomorphisms like depigmentation, elongation of body and antennae, and accentuated microphthalmia (Magrini and Carotti 2019).

## Threats

**Threat type:** Past

**Threats:**

- 6.3. Human intrusions & disturbance - Work & other activities
- 7.3. Natural system modifications - Other ecosystem modifications

## Conservation

**Conservation action type:** Needed

**Conservation actions:**

- 1.1. Land/water protection - Site/area protection
- 1.2. Land/water protection - Resource & habitat protection
- 2.1. Land/water management - Site/area management
- 4. Education & awareness

### Justification for conservation actions

Undisturbed areas in the surface of the mine need to be defined and established

## Other

**Use type:** International

**Ecosystem service type:** Very important

**Research needed:**

- 1.2. Research - Population size, distribution & trends
- 1.3. Research - Life history & ecology

- 2.2. Conservation Planning - Area-based Management Plan
- 3.1. Monitoring - Population trends
- 3.4. Monitoring - Habitat trends

### Justification for research needed

Further information about population size, extent of distribution, ecology and life cycle is needed to better protect the species and the habitat. The mine where the species was found is an anthropogenic construction that clearly intercepted the natural habitat of the species that should be the deep fissures and the mesovoid shallow substrate of the area. Therefore, it urges to sample these habitats in the area to understand the distribution of this species and to define new conservation priorities.

## Discussion

2021 is the International Year of Caves and Karst (<http://iyck2021.org>), an event organized by the International Union of Speleology to promote the awareness for the importance of caves and their habitats. Under this framework, a global initiative created the International Cave Animal of the Year (<http://iyck2021.org/index.php/cave-animal-of-the-year>) devoted to cave beetles. Within this initiative, different countries selected their own endemic species as flag for advocating the conservation of subterranean ecosystems. Here we offer information about the distribution Suppl. material 1, habitat, species ecology, current threats and conservation measures for the nine cave-adapted beetles of continental Portugal. This information is essential to raise the awareness about the threats faced by subterranean ecosystems and to establish conservation measures needed specific for each country.

Beetles are the most diverse insects of caves of Portugal (Reboleira et al. 2011a, Reboleira et al. 2017, Borges et al. 2019). Cave-adapted beetles from continental Portugal are highly endemic with a very reduced extent of occurrence (EOO) and area of occupancy (AOO). This occurs because they are all endemic from their correspondent karst massif unit or collected in artificial mines in granite or quartzite rock. Four of the known species are endemic to single caves, while the other five species can be found in more than one cave. The use of molecular methods may shed further light on the evolutionary relationships and species delimitation, especially for the genus *Trechus*, which shows a radiation in contiguous areas of karst massifs in central Portugal (Reboleira et al. 2010).

Most of the cave-adapted species of beetles are extremely rare, appearing only once or twice per decade of constant sampling. For example, *Iberoporus pluto*, the only groundwater-adapted (stygobiont) beetle from Portugal was described based on a female specimen and no further specimens have been found in a cave that was constantly monitored for more than a decade. Its habitat, the Soprador do Carvalho Cave is under serious anthropogenic threats, such as groundwater contamination and touristic pressure (Ribera and Reboleira 2019).

Some of the major threats that cave-adapted species face are habitat destruction due to the intensive quarrying activity that occurs nearby the majority of the localities and the severe groundwater contamination caused by the lack of proper wastewater treatment in most villages of the central Portugal karst massifs. Some of these threats have been identified previously by Reboleira et al. 2011b, but no specific conservation measures have been taken hitherto. The infiltration of contaminants and fertilizers originated by agricultural practices and industry at surface, also pose major threats to the integrity of subterranean organisms (Castaño-Sánchez et al. 2020). Therefore, it is urgent to generate ecotoxicological data on the sensitivity of cave-adapted beetles to understand if the pernicious impacts that have been already evaluated for some endemic groundwater-adapted species in Portugal (Reboleira et al. 2013b), are also impacting the terrestrial cave species.

In order to create protection strategies for cave-adapted species in continental Portugal, it is necessary to improve our knowledge about their population size, extent of distribution, ecology and life cycle. We hope this contribution may help to support decision making on territory planning and to establish conservation measures for these highly endemic species. These will act as umbrella species for the conservation of other cave-adapted species that share the same subterranean habitats.

## Acknowledgements

This work was supported by a research grant (15471) from the VILLUM FONDEN, and by Portuguese National Funds through Fundação para a Ciência e a Tecnologia (FCT) within the cE3c Unit funding UIDB/00329/2020.

## References

- Borges P, Lamelas-Lopez L, Amorim I, Danielczak A, Boieiro M, Rego C, Wallon S, Nunes R, Cardoso P, Hochkirch A (2019) Species conservation profiles of cave-dwelling arthropods from Azores, Portugal. *Biodiversity Data Journal* 7: e32530. <https://doi.org/10.3897/bdj.7.e32530>
- Bouchard P, Bousquet Y, Davies AE, Alonso-Zarazaga MA, Lawrence JF, Lyal CH, Newton AF, Reid CA, Schmitt M, Slipiński SA, Smith AB (2011) Family-group names in Coleoptera (Insecta). *ZooKeys* 88: 1-972. <https://doi.org/10.3897/zookeys.88.807>
- Castaño-Sánchez A, Hose GC, Reboleira AS (2020) Ecotoxicological effects of anthropogenic stressors in subterranean organisms: A review. *Chemosphere* 244 <https://doi.org/10.1016/j.chemosphere.2019.125422>
- Castro A, Delgado JA (2001) *Iberoporus cermenius*, a new genus and species of subterranean water beetle (Coleoptera: Dytiscidae) from Spain. *Aquatic Insects* 23 (1): 33-43. <https://doi.org/10.1076/aqin.23.1.33.4931>
- Crispim JA, Constantino R, Duarte J (2014) Espeleomergulho nas Grutas de Mira de Aire: importância para o conhecimento da rede espeleológica, a captação de água

- subterrânea e a divulgação das grutas turísticas. Cuevatur 2014, Iberoamérica Subterrânea 373-379.
- Deharveng L, Bedos A (2018) Diversity of terrestrial invertebrates in Subterranean Habitats. In: Moldovan O, Kováč L, Halse S (Eds) Cave ecology. Ecological studies (analysis and synthesis). 235. Springer, Cham. [https://doi.org/10.1007/978-3-319-98852-8\\_7](https://doi.org/10.1007/978-3-319-98852-8_7)
  - Didham RK, Barbero F, Collins CM, Forister ML, Hassall C, Leather SR, Packer L, Saunders ME, Stewart AJA (2020) Spotlight on insects: trends, threats and conservation challenges. *Insect Conservation and Diversity* 13 (2): 99-102. <https://doi.org/10.1111/icad.12409>
  - Directive H (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Union* 206: 7-50.
  - Enghoff H, Reboleira AS (2013) A new cave-dwelling millipede of the genus *Scutogona* from central Portugal (Diplopoda, Chordeumatida, Chamaesomatidae). *Zootaxa* 3736 (2). <https://doi.org/10.11646/zootaxa.3736.2.5>
  - Eusébio RP (2020) Terrestrial subsurface biodiversity in central Portugal. University of Copenhagen, Master Thesis, 50 pp.
  - Eusébio RP, Enghoff H, Solodovnikov A, Michelsen A, Barranco P, Salgado JM, Sendra A, Reboleira AS (in press) Temporal and spatial dynamics of arthropod groups in terrestrial subsurface habitats in central Portugal. *Zoology*.
  - Hoffmann DL, Pike AW, Wainer K, Zilhão J (2013) New U-series results for the speleogenesis and the Palaeolithic archaeology of the Almonda karstic system (Torres Novas, Portugal). *Quaternary International* 294: 168-182. <https://doi.org/10.1016/j.quaint.2012.05.027>
  - ICNB (2000) Grutas não exploradas pelo turismo. Plano sectorial da Rede Natura 2000: Habitats Naturais (8130). URL: <http://www2.icnf.pt/portal/pn/biodiversidade/rn2000/resource/doc/rn-plan-set/hab/hab-8310/view>
  - ICNF (2020) Rede Nacional de Áreas Protegidas (RNAP). <https://sig.icnf.pt/portal/home/item.html?id=02b7a03f8fbd4dada77f5f3e5f91f186>. Accessed on: 2021-4-05.
  - Jeannel R (1941) Premières explorations des grottes du Portugal par M.A. de B. Machado. *Coléoptères. Anais da Faculdade de Ciências do Porto* 26 (2): 5-15.
  - Magrini P, Carotti G (2019) Una nuova specie appartenente al genere *Domene* Fauvel, 1873 (subg. *Lathromene* Koch, 1938) del Portogallo (Coleoptera, Staphylinidae, Paederinae). *Giornale Italiano di Entomologia* 15 (64): 495-502.
  - Mammola S, Cardoso P, Culver DC, Deharveng L, Ferreira RL, Fišer C, Galassi DP, Griebler C, Halse S, Humphreys WF, Isaia M, Malard F, Martínez A, Moldovan OT, Niemiller ML, Pavlek M, Reboleira AS, Souza-Silva M, Teeling EC, Wynne JJ, Zagamajster M (2019) Scientists' warning on the conservation of subterranean ecosystems. *BioScience* 69 (8): 641-650. <https://doi.org/10.1093/biosci/biz064>
  - Mammola S, Amorim IR, Bichuette ME, Borges PV, Cheeptham N, Cooper SJ, Culver DC, Deharveng L, Eme D, Ferreira RL, Fišer C, Fišer Ž, Fong DW, Griebler C, Jeffery WR, Kowalko J, Jugovic J, Lilley TM, Malard F, Manenti R, Martínez A, Meierhofer MB, Northup DE, Pellegrini TG, Protas M, Niemiller M, Reboleira AS, Pipan T, Venarsky MP, Wynne JJ, Zagamajster M, Cardoso P (2020) Fundamental research questions in subterranean biology. *Biological Reviews* 95 (6): 1855-1872. <https://doi.org/10.1111/brv.12642>

- NEC (2020) <https://www.nec-espeleo.org/grutas/varzeadueca.htm>
- Neves J, Soares M, Redinha N, Medeiros S, Cunha L (2005) Dueça speleological cave system. In: Hellenic Speleological Society (Ed.) 14th International Congress of Speleology.
- Nóbrega A, Carvalho F, Alte da Veiga F, Soares M, Neves J, Pupo Correia J (1984) Gruta da Cerâmica. Espeleo Divulgação 4: 1314. URL: <http://revistas.ua.pt/index.php/espeleo/article/view/2854/2680>
- Piccini L, Di Lorenzo T, Costagliola P, Galassi DMP (2019) Marble Slurry's impact on groundwater: The case study of the Apuan Alps karst aquifers. Water 11 (12). <https://doi.org/10.3390/w11122462>
- Putzeys J (1870) Trechorum oculatorum Monographia. Entomologische Zeitschrift 31: 7-48.
- Reboleira AS (2007) Os coleópteros (Insecta, Coleoptera) cavernícolas do maciço calcário Estremenho: uma aproximação à sua biodiversidade. Universidade de Aveiro, Master Thesis, 74 pp. URL: <http://hdl.handle.net/10773/721>
- Reboleira AS, Gonçalves FJ, Serrano AR (2009) Two new species of cave dwelling *Trechus* Clairville, 1806 of the *fulvus* group (Coleoptera, Carabidae, Trechinae) from Portugal. Deutsche Entomologische Zeitschrift 56 (1): 101-107. <https://doi.org/10.1002/mmnd.200900009>
- Reboleira AS, Ortuno VM, Goncalves F, Oromi P (2010) A hypogean new species of *Trechus* Clairville, 1806 (Coleoptera, Carabidae) from Portugal and considerations about the *T. fulvus* species group. Zootaxa 2689 (1): 15-26. <https://doi.org/10.5281/zenodo.199484>
- Reboleira AS, Ortuño VM (2011) Description of the larva and female genitalia of *Trechus gamae* with data on its ecology. Bulletin of Insectology 64 (1): 43-52.
- Reboleira AS, Gonçalves F, Oromí P (2011a) On the Iberian endemic subgenus *Lathromene* Koch (Coleoptera: Staphylinidae: Paederinae): description of the first hypogean *Domene* Fauvel, 1872 from Portugal. Zootaxa 2780: 48-56. <https://doi.org/10.11646/zootaxa.2780.1.5>
- Reboleira AS, Borges P, Gonçalves F, Serrano A, Oromí P (2011b) The subterranean fauna of a biodiversity hotspot region - Portugal: an overview and its conservation. International Journal of Speleology 40 (1): 23-37. <https://doi.org/10.5038/1827-806X.40.1.4>
- Reboleira AS (2012) Biodiversity and conservation of subterranean fauna of Portuguese karst. Universidade de Aveiro, PhD Thesis, 333 pp. URL: <http://hdl.handle.net/10773/1086>
- Reboleira AS, Gonçalves F, Oromí P (2013a) Literature survey, bibliographic analysis and a taxonomic catalogue of subterranean fauna from Portugal. Subterranean Biology 10: 51-60. <https://doi.org/10.3897/subtbiol.10.4025>
- Reboleira AS, Abrantes N, Oromí P, Gonçalves F (2013b) Acute toxicity of copper sulfate and potassium dichromate on stygobiont *Proasellus*: General aspects of groundwater ecotoxicology and future perspectives. Water, Air, & Soil Pollution 224 (5). <https://doi.org/10.1007/s11270-013-1550-0>
- Reboleira AS, Zaragoza JA, Gonçalves F, Oromí P (2013c) On hypogean *Roncocreagris* (Arachnida: Pseudoscorpiones: Neobisiidae) from Portugal, with descriptions of three new species. Zootaxa 3670 (2). <https://doi.org/10.11646/zootaxa.3670.2.11>

- Reboleira AS, Gonçalves F, Oromí P, Taiti S (2015) The cavernicolous Oniscidea (Crustacea: Isopoda) of Portugal. *European Journal of Taxonomy* 161: 1-61. <https://doi.org/10.5852/ejt.2015.161>
- Reboleira AS, Fresnada J, Salgado JM (2017) A new species of *Speonemadus* from Portugal, with the revision of the *escalerai*-group (Coleoptera, Leiodidae). *European Journal of Taxonomy* 261: 1-23. <https://doi.org/10.5852/ejt.2017.261>
- Reboleira AS, Enghoff H (2018) First continental troglobiont *Cylindroiulus* millipede (Diplopoda, Julida, Julidae). *ZooKeys* (795)93. <https://doi.org/10.3897/zookeys.795.27619>
- Ribera I, Aguilera P, Hernando C, Millán A (2002) Los coleópteros acuáticos de la península Ibérica. *Quercus* 201: 38-42.
- Ribera I (2003) Are Iberian endemics Iberian? A case-study using water beetles of family Dytiscidae (Coleoptera). *Graellsia* 59 (2-3): 475-502. <https://doi.org/10.3989/graellsia.2003.v59.i2-3.261>
- Ribera I, Reboleira AS (2019) The first stygobiont species of Coleoptera from Portugal, with a molecular phylogeny of the *Siettita* group of genera (Dytiscidae, Hydroporinae, Hydroporini, Sietitiina). *ZooKeys* 813: 21. <https://doi.org/10.3897/zookeys.813.29765>
- Salgado JM, Blas M, Fresnada J (2008) Fauna Ibérica. Coleoptera, Cholevidae. 31. MNCN, CSIC, *Madrid*.
- Serrano AR, Conde J, Antunes S, Aguiar CA, Boieiro M (2015) A new species of *Domene* Fauvel, 1873 (Coleoptera: Staphylinidae: Paederinae) from a granitic cavity in Serra da Estrela (Portugal). *Zootaxa* 3974 (3): 401-412. <https://doi.org/10.11646/zootaxa.3974.3.7>
- Thomas C (1991) Gruta da nascente d'ALMONDA. SIFON Bulletin interne des commissions plongée souterraine de l'île de France 12: 8.
- Zaragoza JA, Reboleira AS (2018) Five new hypogean *Occidenchthonius* (Pseudoscorpiones, Chthoniidae) from Portugal. *Journal of Arachnology* 46 (1): 81-103. <https://doi.org/10.1636/JoA-S-17-031.1>



Figure 1.

*Iberoporus pluto* Ribera & Reboleira, 2019. Soprador do Carvalho Cave, Penela, Coimbra district, Portugal. Scale bar: 1 mm.



Figure 2.

*Trechus machadoi* Jeannel, 1941. Alcobertas Cave, Rio Maior, Portugal. Lectotype deposited at the Natural History Museum of Paris.



Figure 3.

*Trechus gamae* Reboleira & Serrano, 2009. Algar do Pena Cave, Estremenho karst massif, Portugal.



Figure 4.

*Trechus lunai* Reboleira & Serrano, 2009. Almonda Cave, Estremenho karst massif, Portugal.



Figure 5.

*Trechus tatai* Reboleira & Ortuño, 2010, Algar do Javali Cave, Montejunto karst massif, Portugal.



Figure 6.

*Domene lusitanica* Reboleira & Oromí, 2011, from Cerâmica Cave in Sicó karst area, central Portugal.

## Supplementary material

### Suppl. material 1: Distribution of cave-adapted beetle in continental Portugal

**Authors:** A.S.P.S. Reboleira, R.P. Eusébio

**Data type:** Species distribution map

**Brief description:**

1: *Trechus machadoi* (blue circle); 2: *T. gamae* (yellow circle); 3: *T. lunai* (pink circle); 4: *T. tatai* (red circle); 5: *Iberoporus pluto* (blue star); 6: *Domene lusitanica* (yellow diamond); 7: *D. viriatoi* (pink diamond); 8: *D. darinkae* (blue diamond); and 9: *Speonemadus algarvensis* (pink triangle). (A) Detail of northern distribution, (B) Detail of central distribution, and (C) Detail of southern distribution. In green are protected areas.

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