

THE BRISTLE MILLIPEDES (DIPLOPODA, PENICILLATA, POLYXENIDA) OF THE IBERIAN PENINSULA, BALEARIC AND CANARY ISLANDS WITH NEW RECORDS AND DATA ON THEIR DISTRIBUTION

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ABSTRACT

Polyxenida, commonly known as bristly or pincushion millipedes, is a small order of millipedes, usually found in dead wood, under bark on dead logs and living trees and scrubs, in soil, leaf litter and under rocks. Given their small size and elusive nature, they have been frequently overlooked, and available information of most species is very limited. Their distribution and diversity in most regions of the Iberian Peninsula, the Balearic Islands and the Canary Islands are still largely unknown. Here we compile both published and new records for Polyxenida species in these three geographical areas. We also present pictures of living specimens of several species. In the studied regions there are representatives of three families, 5 genera and at least 10 species. In the family Synxenidae, only one species, *Phryssonotus platycephalus* (Lucas, 1846), occurs on in the Iberian Peninsula and the Balearic Islands. The Polyxenidae is more diverse: *Polyxenus lagurus* (Linnaeus, 1758) is widespread in the Iberian Peninsula and the Balearic Islands, where there could be yet another species of *Polyxenus* Latreille, 1804; in the Canary Islands there is a possibly introduced widespread species, *P. fasciculatus* Say, 1821, and one endemic, *P. oromii* Nguyen Duy-Jacquemin, 1996; the genus *Macroxenus* Brolemann, 1917 is represented by *M. rubromarginatus* (Lucas, 1846) in the Iberian Peninsula and *M. enghoffi* Nguyen Duy-Jacquemin, 1996, probably another endemic species, in the Canary Islands. Finally, in the family Lophoproctidae we find *Lophoproctus jeanneli* (Brolemann, 1910) both on the Iberian Peninsula and the Balearic Islands; *L. lucidus* (Chalande, 1888), reported here for the first time from the Iberian Peninsula and El Hierro Island; *L. pagesi* Condé, 1981, endemic to caves in Mallorca, with a closely related form, *L. cf. pagesi* also from caves in Portugal; *Lophoproctinus inferus inferus* (Silvestri, 1903), with a few records from Mallorca, and *L. i. maurus* Marquet & Condé, 1950, known from the Canary Islands. Our new records, as well as those from the citizen science initiative iNaturalist, notably expand the known distribution ranges of several Polyxenida species in the Iberian Peninsula. Many species show very fragmented distribution patterns, with isolated records in different geographical areas. Further study including more intensive sampling and molecular data will help to understand the true nature of such patterns.

Keywords. Bristly millipedes, new records, Iberian Peninsula, Balearic Islands, Canary Islands, Polyxenidae, Lophoproctidae, Synxenidae.

RESUMEN

Los polixénidos (Diplopoda, Penicillata, Polyxenida) de la península Ibérica, Baleares y Canarias con nuevos registros y datos sobre su distribución

Polyxenida es un orden pequeño de milpiés que usualmente se encuentran en el suelo, madera muerta, bajo cortezas de troncos muertos o de árboles y arbustos vivos, en hojarasca y debajo de rocas. Dado su pequeño tamaño y su naturaleza elusiva, se han estudiado poco, de modo que el conocimiento sobre la distribución, diversidad, biología e historia natural de las especies ibéricas, baleares y canarias es muy limitado. En este trabajo recopilamos todos los registros publicados y proporcionamos nuevas citas para las áreas mencionadas. También incluimos fotos en vivo de varias especies ibéricas previamente no fotografiadas. En las regiones de estudio se encuentran representantes de 3 familias, 5 géneros y al menos 10 especies. La familia Synxenidae incluye un solo representante, *Phryssonotus platycephalus* (Lucas, 1846), en la península Ibérica y en las islas Baleares. La diversidad es más alta para Polyxenidae, con una especie de amplia distribución, *Polyxenus lagurus* (Linnaeus, 1758), en Iberia y también Baleares, en donde podría haber otra especie del género no descrita; en las Canarias está presente otra especie de amplia distribución, *P. fasciculatus* Say, 1821, y el endemismo *P. oromii* Nguyen Duy-Jacquemin, 1996; el género *Macroxenus* Brolemann, 1917 está representado por *M. rubromarginatus* (Lucas, 1846) en Iberia, y *M. enghoffi* Nguyen Duy-Jacquemin, 1996, posiblemente endémica de las Canarias.

Finalmente, en la familia Lophoproctidae, *Lophoproctus jeanneli* (Brolemann, 1910) se encuentra tanto en la península como en Baleares; *L. lucidus* (Chalande, 1888) es registrado por primera vez en la península ibérica y en la isla del Hierro; *L. pagesi* Condè, 1981 es endémico de cuevas de Mallorca, con una forma relacionada en cuevas de Portugal, *L. cf. pagesi*; *Lophoproctinus inferus inferus* (Silvestri, 1903) está presente con unos pocos registros en Mallorca y *L. i. maurus* Marquet & Condè, 1950 se encuentra en las Canarias. Nuestros nuevos registros junto con registros procedentes de iniciativas de ciencia ciudadana (iNaturalist), expanden notablemente el área de distribución conocida de varias especies de Polyxenida en la península Ibérica. Muchas de estas especies presentan patrones de distribución fragmentados, con registros aislados en diferentes áreas geográficas. Un estudio más intenso incluyendo muestreo exhaustivo y datos moleculares ayudará a entender mejor la naturaleza real de estos patrones de distribución.

Palabras clave. Polixénidos, nuevos registros, península ibérica, islas Baleares, islas Canarias, Polyxenidae, Lophoproctidae, Synxenidae

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Introduction

The order Polyxenida, commonly known as bristly or pincushion millipedes, includes tiny millipedes with a body length of usually less than 5 mm, characterised by an uncalcified cuticle and especially by the presence of tufts of trichomes on both the head and body segments (Nguyen Duy-Jacquemin & Geoffroy, 2003) (Fig. 1). With little over 150 extant and a few fossil species preserved in Cretaceous amber, Polyxenida is one of the smallest orders among the Diplopoda (Edgecombe, 2015; Short, 2015a). Its phylogenetic placement makes it the sister lineage to Chilognatha, a sub-class that includes all other extant millipede order (Benavides *et al.*, 2023). They are known as bark-dwelling millipedes (Hopkin & Read, 1992), as they are often found under the bark of dead wood or of living trees and scrubs, but they also live in soil and leaf litter, under stones, in rock crevices, in ant nests, bird nests, epiphytic plants and even in caves (Donisthorpe, 1927; Condè, 1981; Ishii & Yamaoka, 1982; Miquel *et al.*, 2000; Tajovský *et al.*, 2001; Stoev & Lapeva-Gjonova, 2005; Alexander, 2006; Cardoso *et al.* 2008; Whitaker & Ruckdeschel, 2010).

Given the often elusive nature of these animals and their small size, they are frequently overlooked. The first report of this group in the Iberian Peninsula was by Silvestri (1923), who cited *Phryssonotus platycephalus* (Lucas, 1846) from two localities in Girona and Tarragona. *Polyxenus lagurus* (Linnaeus, 1758) was not recorded until 1946, when Machado published the first Polyxenida records from northern Portugal (Machado, 1946). The first Iberian Lophoproctidae, a population of *Lophoproctus jeanneli* (Brolemann, 1910) from Barcelona, was mentioned by Condè (1954a). In the Balearic Islands, the first records were those of Condè (1954a), who reported three species

of Polyxenidae and Lophoproctidae from Mallorca. In the Canary Islands, Polyxenida was thoroughly revised by Nguyen Duy-Jacquemin (1996), providing the first records of the order for the archipelago. Currently, the three recognized families of the order are present in the Iberian Peninsula, the Balearic Islands and the Canary Islands (Melic, 2015), including one species of the family Synxenidae, five species of Polyxenidae and three species (one with two subspecies) of Lophoproctidae (Kime & Enghoff, 2011).

Our knowledge of the basic biology and general distribution of most species is still incomplete and largely unknown. For instance, in the Atlas of European Millipedes (Kime & Enghoff, 2011), the occurrence of Polyxenida is indicated in only 18 of the nearly 300 50 × 50 km² UTM squares on the Iberian Peninsula and the Balearic Islands, most of them along the Mediterranean coast and the Pyrenees. Here we give an overview of the known distribution of the Iberian, Balearic, and Canarian Polyxenida, and present new distribution data for five species: *Polyxenus lagurus*, *P. fasciculatus* Say, 1821, *Lophoproctus jeanneli*, *L. lucidus* (Chalande, 1888) and *Phryssonotus platycephalus*, extending their known distribution to new areas in the studied regions.

Material and methods

We compiled all published records of Polyxenida in the Iberian Peninsula, the Balearic Islands and the Canary Islands, and reviewed material newly collected in these geographic regions. Specimens were found by actively searching under stones, bark of dead trees and scrubs, logs, in the soil and in leaf litter, during several years of fieldwork from 2013 to 2018. Some specimens were collected and preserved in absolute

ethanol for further identification under a microscope. This material is currently under study and will be deposited eventually at the Arthropoda collection at the Museo Nacional de Ciencias Naturales (MNCN).

We examined the specimens mounted in glycerine as temporary microscope preparations with a SWIFT SW350T compound microscope, and unmounted specimens with a Leica MZ16A stereo microscope, equipped with a Leica DFC550 camera used for photographing the specimens. Measurements and picture processing was done with LAS v4.3 software. Identifications were based on original descriptions and on published redescriptions and illustrations (e.g., Silvestri, 1923; Condè, 1968, 1989; Nguyen Duy-Jacquemin, 1976, 1993; Vadell, 2010; Short, 2015b).

Maps were created in R using the packages ggplot2 (ver. 3.4.0, see <https://ggplot2.tidyverse.org/>; Kahle & Wickham, 2013), rnaturalearthdata (ver. 0.1.0, see <https://cran.r-project.org/package=rnaturalearthdata>; South & South, 2016) and gridExtra (ver. 2.3, see <https://cran.r-project.org/web/packages/gridExtra/index.html>).

We also searched records from the citizen science project iNaturalist (<https://www.inaturalist.org/>; accessed on January 14, 2023).

Results

Considering published and new data, the diversity of Polyxenida in the Iberian Peninsula comprises a total of six species, including three Lophoproctidae (*Lophoproctus jeanneli*, *Lophoproctus* cf. *pagesi* Condè, 1981, and *L. lucidus*, the last mentioned reported here for the first time in the region), two Polyxenidae [*Polyxenus lagurus* and *Macroxenus rubromarginatus* (Lucas, 1846)] and one Synxenidae (*Phryssonotus platycephalus*) (Figs 2–4).

The Balearic Islands harbours populations of at least five species, one Synxenidae (*Phryssonotus platycephalus*), three Lophoproctidae [*Lophoproctus pagesi*, *L. jeanneli* and *Lophoproctinus inferus inferus* (Silvestri, 1903)] and one Polyxenidae (*Polyxenus lagurus*), although there could be at least one more species of *Polyxenus* Latreille, 1804 (see Condè, 1954a) (Figs 2–4).

In the Canary Islands there are two species of Lophoproctidae (*Lophoproctus lucidus*, reported here for the first time in the region, and *Lophoproctinus inferus maurus* Marquet & Condè, 1950) and three Polyxenidae (*Polyxenus fasciculatus*, *P. oromii* Nguyen Duy-Jacquemin, 1996 and *Macroxenus enghoffi* Nguyen Duy-Jacquemin, 1996) (Figs 3–4).

We found 55 records correctly identified as Polyxenida in iNaturalist, 53 from the Iberian Peninsula and two from Tenerife, Canary Islands (Fig. 5). Among the Iberian records, seven of them corresponded to Lophoproctidae and were tentatively identified as *Lophoproctus* Pocock, 1895. Identification

at species level with the available pictures is not possible. However, two of them were tentatively, and likely wrongly, identified as *Lophoproctus coecus* Pocock, 1895, with no obvious justification (these specimens appear now as *Lophoproctus*). 39 samples were tentatively identified as *Polyxenus*, 13 of them as *Polyxenus lagurus*. The two records from Tenerife were identified as *Polyxenus fasciculatus*. Based on the available photographs, these specimens can be identified with certainty only to family level, either Lophoproctidae or Polyxenidae.

CHECKLIST OF THE IBERIAN, BALEARIC, AND CANARIAN POLYXENIDA

Family Synxenidae Silvestri, 1923

Phryssonotus platycephalus (Lucas, 1846) (Figs 1F, 2)

Polyxenus platycephalus Lucas, 1846: 283.

Synxenus platycephalus (Lucas): Silvestri, 1923: 9.

Koubanus platycephalus (Lucas): Attems, 1928: 198.

Phryssonotus platycephalus (Lucas): Condè, 1954b: 496.

GENERAL DISTRIBUTION. The species was originally described based on material from Kouba, Algeria (Lucas, 1846). It has been found at sparse, isolated points in the western Mediterranean, including Sicily, the Balearic Islands, and the Iberian Peninsula (Silvestri, 1923; Müller *et al.*, 2007; Vadell, 2010; Jiménez-Valverde *et al.*, 2015).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. **Iberian Peninsula.** **Spain:** **Girona:** Lloret de Mar (Silvestri, 1923); Tarragona: montem “Montsià” ad Ulldecona (Silvestri, 1923); **Alicante:** Sierra de Aitana (Jiménez-Valverde *et al.*, 2015). **Balearic Islands:** Spain: Illes Balears: **Ibiza** (without further locality) (Müller *et al.*, 2007); Illes Balears: **Cabrera:** Cabrera Gran, zona Monument als Francesos (Vadell, 2010).

NEW RECORDS. **Iberian Peninsula.** **Spain:** **Castellón:** Benicasim, Desierto de las Palmas, 40°04'17"N 0°01'01"E, forest of *Pinus halepensis*, 19/II/2017, P. Rodríguez-Flores, E. Recuero, D. Osca leg. (n = 1); **Girona:** Lloret de Mar: Ermita de Santa Cristina, 41°41'21"N 2°48'54"E, mixed forest of *Pinus halepensis* and *Quercus ilex*, 21/IX/2017 (n = 3) and 19/XII/2017 (n = 1), P. Rodríguez-Flores, E. Recuero leg.; **Girona:** Aprox. 2 Km N Blanes, 41°42'08"N 2°47'14"E, forest of *Pinus pinea* with *Quercus suber*, 15/IX/2017, E. Recuero, M. García París leg. (n = 10); **Girona:** Blanes: Castell de Sant Joan, 41°40'43"N 2°47'59"E, forest of *Pinus halepensis* with *Quercus ilex*, 4/III/2018, E. Recuero, P. Rodríguez-Flores leg. (n = 3).

COMMENTS. Given the habitats occupied by the species and its wide but disjunct distribution, additional populations are likely to be found in more places.

Family Polyxenidae Lucas, 1840

Polyxenus lagurus (Linnaeus, 1758) (Figs. 1H, 2)

Scolopendra lagura Linnaeus, 1758: 637.

Iulus lagurus (Linnaeus): De Geer, 1778: 572.

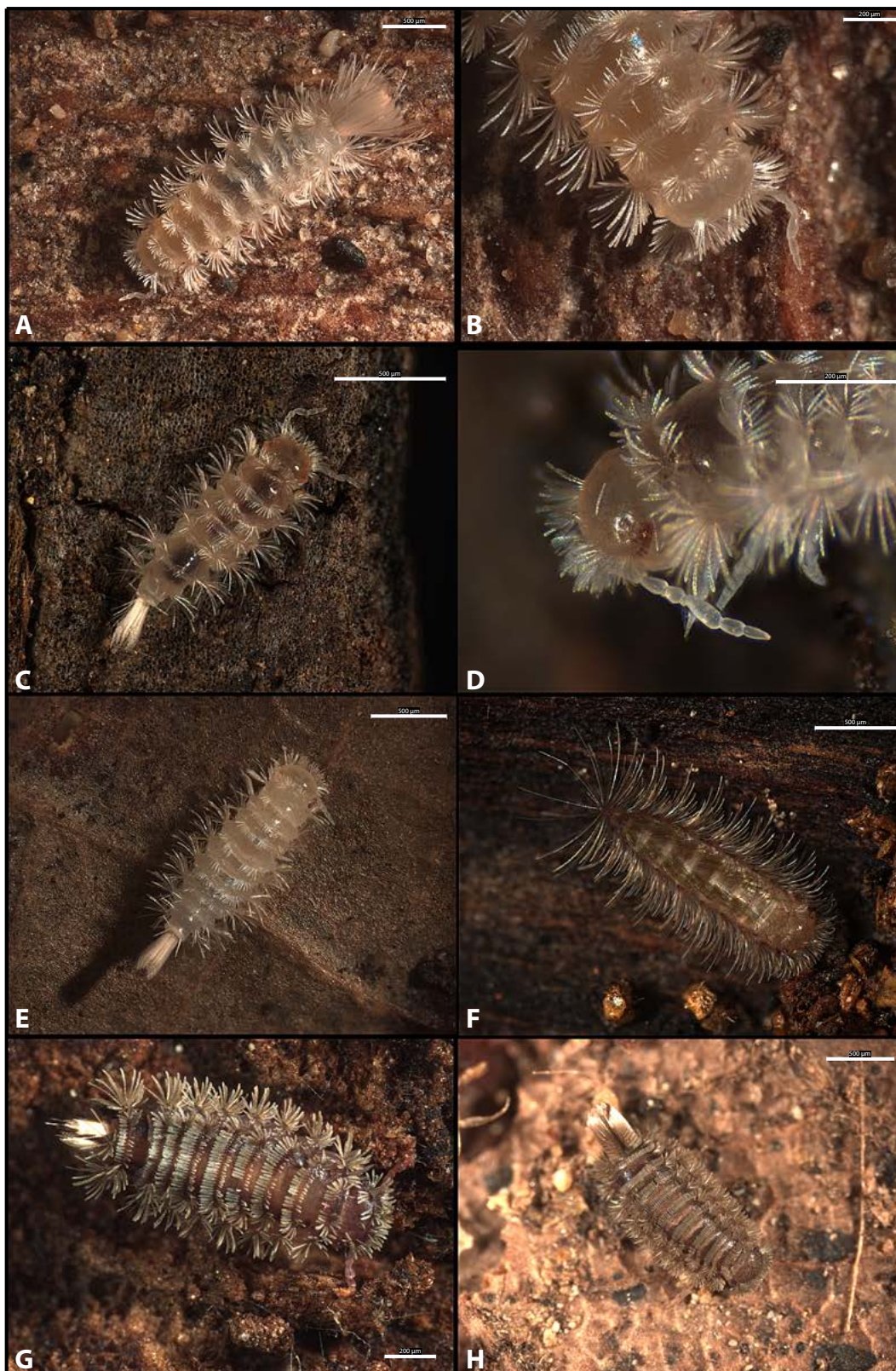


Fig. 1.— Living specimens of some species of Polyxenida occurring in the Iberian Peninsula, the Balearic Islands and the Canary Islands. A-B: *Lophoproctus jeanneli*, Girona, Lloret de Mar. C-E: *Lophoproctus lucidus*, C-D: Girona, Blanes, Cala St. Françesc, E: Albacete, Munera. F: *Phryssonotus platycephalus*, Girona, Blanes. G: *Polyxenus fasciculatus*, Tenerife, Mirador del Torreón. H: *Polyxenus lagurus*, Girona, Lloret de Mar. Pictures by PCRFB.

Fig. 1.— Ejemplares vivos de algunas especies de Polyxenida presentes en la península ibérica, Baleares y Canarias. A-B: *Lophoproctus jeanneli*, Girona, Lloret de Mar. C-E: *Lophoproctus lucidus*, C-D: Girona, Blanes, Cala St. Françesc, E: Albacete, Munera. F: *Phryssonotus platycephalus*, Girona, Blanes. G: *Polyxenus fasciculatus*, Tenerife, Mirador del Torreón. H: *Polyxenus lagurus*, Girona, Lloret de Mar. Fotografías por PCRFB.

Iulus penicillatus De Geer, 1778: 572.
Pollyxenus [sic] *lagurus* (Linnaeus): Latreille, 1804: 81.
Polyxenus lagurus (Linnaeus): Latzel, 1884: 74.
Polyxenus germanicus Verhoeff, 1941: 263.

GENERAL DISTRIBUTION. *Polyxenus lagurus* shows the largest distribution range among Polyxenida species, being reported across the Western Palaearctic, from the British Islands in the west to the Caucasus in the east, and Scandinavia in the north and North Africa in the south (Brolemann, 1930; Condé, 1961; Kime & Enghoff, 2011; Short *et al.*, 2020), with presence also in Israel (Condé & Nguyen Duy-Jacquemin, 1970, but see Short, 2020). It has been recorded from the Azores Archipelago (Brolemann, 1896; Condé, 1961), where it was probably introduced by human activity, as also seems to be the case in North America, where it is widely distributed (Condé, 1996; Hoffman, 1999) and in Australia (Short & Vahtera, 2017).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS, AND/OR CANARY ISLANDS.

PUBLISHED DATA. **Iberian Peninsula. Portugal:** Porto: Porto (Machado, 1946); Portugal: Porto: Recarei (Machado, 1946); Braga: Joane (Machado, 1946); Braga: Mata da Albergaria (Parque Nacional da Peneda-Geres) (Cardoso *et al.*, 2008); **Spain:** Guipúzcoa: “Mte. Alzo bei Tolosa” (likely Monte Ollagón, between Tolosa and Altzo) (Attems, 1952); Girona: without locality data (Nguyen Duy-Jacquemin, 1976); Barcelona: Parc Natural de Sant Llorenç del Munt i l’Obac (Miquel *et al.*, 2000); Asturias: Mieres: Área recreativa de El Cantu, (Torralba Burrial & Outomuro, 2007); Granada: Sierra Nevada, pico Veleta (Schubart, 1959; Gilgado *et al.*, 2015); Granada: Sierra Nevada, Pradollano (Schubart, 1959); Granada: Sierra Nevada, Loma de Monachil (Schubart, 1959). **Balearic Islands.** Spain: Illes Balears: Mallorca: Llucmajor, Cabo Blanco (Enghoff & Vicente, 2000); Illes Balears: Ibiza: La Joya (Sammler *et al.*, 2006); Illes Balears: Ibiza: Club Cala Llenya (Sammler *et al.*, 2006).

NEW RECORDS. **Iberian Peninsula. Spain:** Madrid: El Pardo, 40°28'55"N 3°44'45"W, forest of *Quercus ilex*, 13/II/2013 (n=3) and 24/IV/2013 (n=1), E. Recuero leg.; Madrid: Horcajo de la Sierra, 41°03'44"N 3°35'18"W, 11/IV/2018, E. K. López-Estrada, M. García-París leg. (n = 3); Pontevedra: Catoira, 42°40'09"N 8°42'58"W, in leaf litter sample, 8/I/2017, R. González leg. (n = 2); Alicante: Denia: La Xara, 38°49'20"N 0°03'51"E, in soil sample, Mediterranean scrub on limestone karst, 18/II/2017, P. Rodríguez-Flores, E. Recuero leg. (n = 1); Girona: Lloret de Mar: Playa de Santa Cristina, 41°41'21"N 2°48'54"E, in leaf litter samples from mixed forest of *Pinus halepensis* and *Quercus ilex*, 20/X/2017, P. Rodríguez-Flores, E. Recuero leg. (n = 3); Cáceres: Aprox. 2.5 Km SE Torres de Santa María, 39°14'32"N 6°05'13"W, in forest fragment of *Quercus ilex*, 24/II/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 7); Álava: Laguardia, 42°32'25"N 2°33'59"W, open scrubland among cultivated fields, 5/XII/2018, E. K. López-Estrada, M. García-París leg. (n = 2); **Balearic Islands.** Spain: Illes Balears: Menorca: Aprox. 3 Km S Fornells, 40°01'38"N 4°06'53"E, open forest of *Pinus halepensis*, 3/IV/2017, P. Rodríguez-Flores, E. Recuero, M. García-París, P. Mas leg. (n = 1); Illes Balears:

Mallorca: Cala Murta, 39°57'02.0"N 3°12'02.1"E, under rocks in forest of *Pinus halepensis* on limestone karst, 1/IV/2018, P. Rodríguez-Flores, E. Recuero, M. García-París, P. Mas leg. (n = 1).

COMMENTS. Kime & Enghoff (2011) provide 8 records in the Iberian Peninsula and two in the Balearic Islands; for some of them we could not find precise localities, but they are indicative of the presence of the species in the Pyrenees and the Ebro Valley. This species is not reported from the Canary Islands. The species is reported for the first time from the island of Menorca and from central Iberia, where it is probably widespread. The taxonomic identity of Iberian and Balearic population needs additional study. Preliminary data suggest that they could represent a species morphologically close but different to *P. lagurus* (Short *et al.*, 2020). However, pending further molecular studies, we prefer to stick with the traditional use of the name *P. lagurus* for these populations.

Polyxenus fasciculatus Say, 1821 (Figs 1G, 3)

Polyxenus fasciculatus Say, 1821: 108.

GENERAL DISTRIBUTION. Widely distributed in central and southeastern United States, with presence in several Atlantic islands: Bermuda, Madeira, and the Canary Islands (Nguyen Duy-Jacquemin, 1996; Hoffman, 1999).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. **Canary Islands.** Spain: Las Palmas: Gran Canaria: W of Artenara, 1200 m (Nguyen Duy-Jacquemin, 1996); Las Palmas: Gran Canaria: Cruz de Tejada, 1500 m (Nguyen Duy-Jacquemin, 1996); Las Palmas: Gran Canaria: Vega de Acusa (Nguyen Duy-Jacquemin, 1996); Las Palmas: Gran Canaria: Valle de Agaete (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Montaña de la Hoya (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Los Carboneros (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Vueltas Taganana (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Agua Garcia et Las Mercedes (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Sieste Cañadas (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Gomera: Barranco de Nuestra Señora de Guadalupe (Nguyen Duy-Jacquemin, 1996); Santa Cruz: El Hierro: Montaña de las Cuevas (Nguyen Duy-Jacquemin, 1996); Santa Cruz: El Hierro: El Fayal, c. 4 km SSW Mirador de Jinama (Nguyen Duy-Jacquemin, 1996).

NEW RECORDS. **Canary Islands.** Spain: Santa Cruz: Tenerife: Mirador del Torreón, aprox. 1 km NW El Tanque, 28°21'42"N 16°47'30"W, in a grove of *Eucalyptus* and scrub of *Erica*, 11/I/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 4); Santa Cruz: Tenerife: Tacoronte: Agua García, 28°27'23"N 16°24'06"W, in an old plantation of *Pinus radiata* with *Erica* scrub, 14/I/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 1).

COMMENTS. The species has been suggested as probably introduced in the Canary Islands (Arndt *et al.*, 2008), but there are no studies on the dispersion routes for the species.

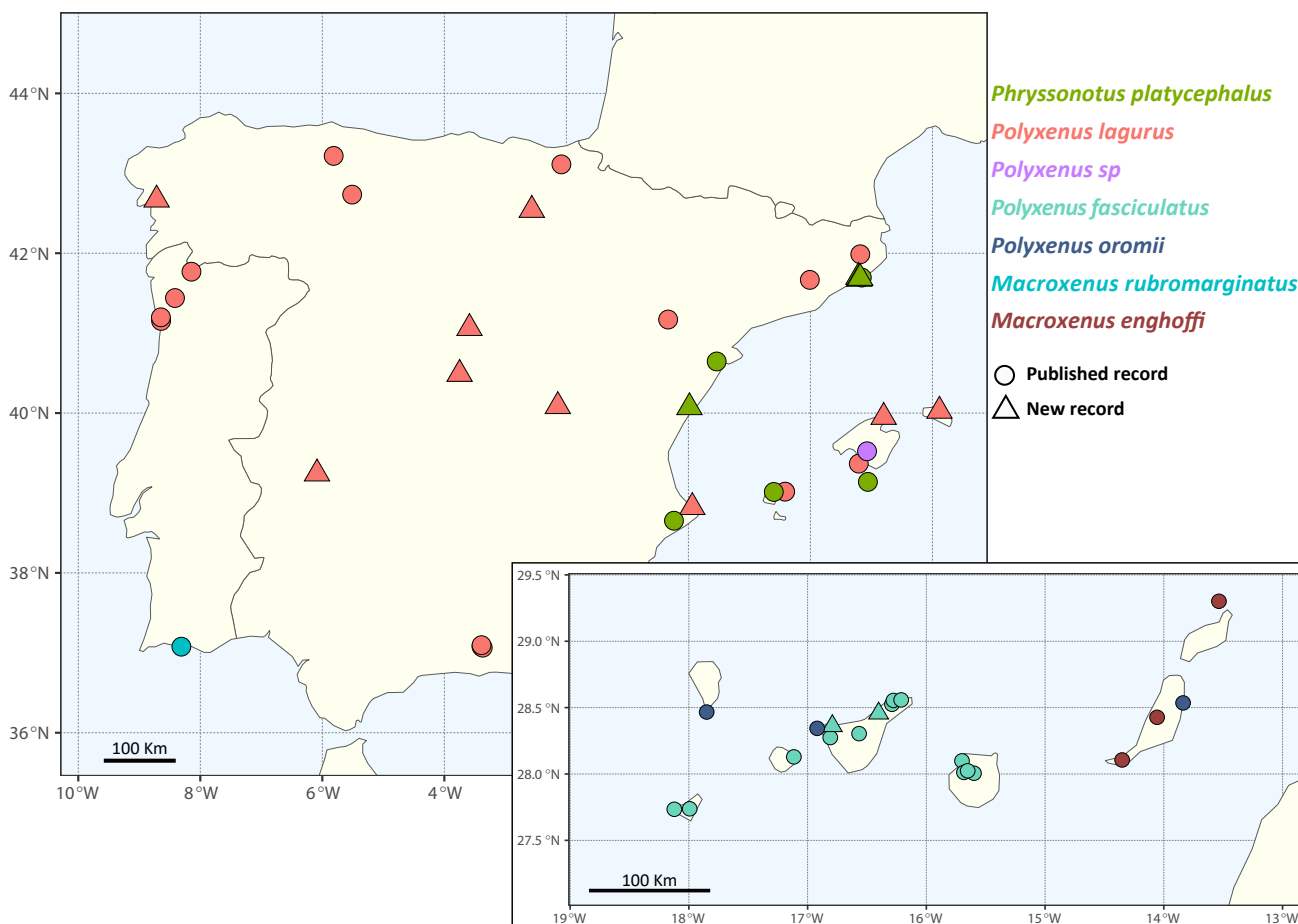


Fig. 2.— Map showing published and unpublished records of *Phryssonotus platycephalus*, *Polyxenus lagurus*, *Polyxenus sp.*, and *Macroxenus rubrimarginatus* in the Iberian Peninsula, Balearic and Canary Islands.

Fig. 2.— Mapa que muestra los registros publicados e inéditos de *Phryssonotus platycephalus*, *Polyxenus lagurus*, *Polyxenus sp.* y *Macroxenus rubrimarginatus* en la península ibérica, Islas Baleares y Canarias.

Polyxenus oromii Nguyen Duy-Jacquemin, 1996 (Fig. 3)
Polyxenus oromii Nguyen Duy-Jacquemin, 1996: 116.

GENERAL DISTRIBUTION. An endemic species known only from the Canary Islands (La Palma, Tenerife and Fuerteventura) (Nguyen Duy-Jacquemin, 1996).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. **Canary Islands.** Spain: Santa Cruz: La Palma: Teneguia (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Punta del Teno (Nguyen Duy-Jacquemin, 1996); Las Palmas: Fuerteventura: Puerto Lajas (Nguyen Duy-Jacquemin, 1996).

COMMENTS. The species has been found only in littoral rocky habitats (Nguyen Duy-Jacquemin, 1996).

Polyxenus sp. (Fig. 2)

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. **Balearic Islands.** Spain: Illes Balears: Mallorca: Randa, route menant au monastère de N. S. de Cura (Condè, 1954a).

COMMENT. This record corresponds to a female with antennal characters as in *P. lapidicola* Silvestri, 1903 and trichomes as in *P. lagurus* (Condè, 1954a). This morphologically peculiar specimen could be indicative of the presence of further species of the genus *Polyxenus* in the Balearic Islands.

Macroxenus enghoffi Nguyen Duy-Jacquemin, 1996 (Fig. 3)
Macroxenus enghoffi Nguyen Duy-Jacquemin, 1996: 117.

GENERAL DISTRIBUTION. Known with certainty only from a few localities in the eastern Canary Islands, it could also be present in Cape Verde (Nguyen Duy-Jacquemin, 1996).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. **Canary Islands.** Spain: Las Palmas: Fuerteventura: Cumbre Jandia (Nguyen Duy-Jacquemin, 1996); Las Palmas: Fuerteventura: Betancuria (Nguyen Duy-Jacquemin, 2009); Las Palmas: Montaña Clara (Macías *et al.*, 2003).

COMMENTS. One immature specimen from Santo Antão Island, Cape Verde, was identified as *affinis* to this

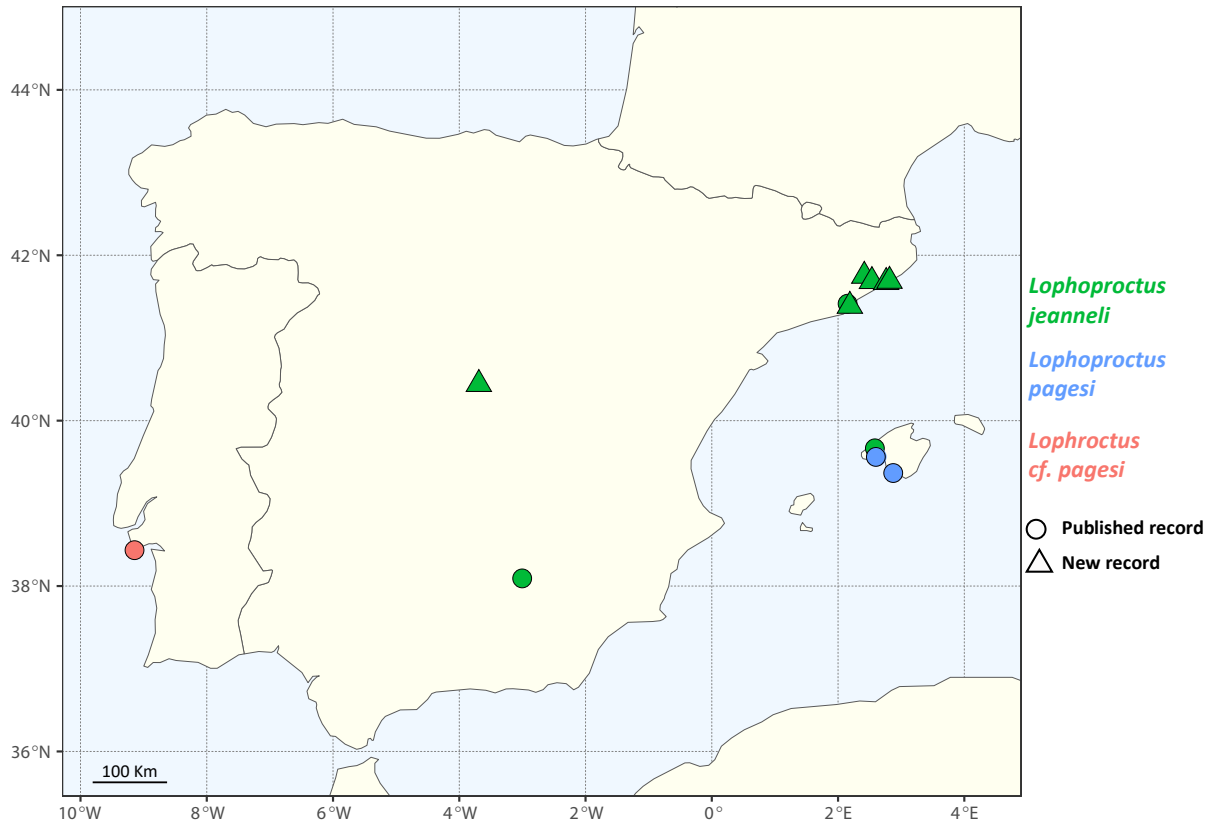


Fig. 3.— Map showing published and unpublished records of *Lophoproctus jeanneli*, *Lophoproctus pagesi*, *Lophoproctus cf. pagesi*, *Polyxenus fasciculatus*, *Polyxenus oromii*, and *Macroxenus enghoffi* in the Iberian Peninsula and Balearic Islands.

Fig. 3.— Mapa que muestra registros publicados y no publicados de *Lophoproctus jeanneli*, *Lophoproctus pagesi*, *Lophoproctus cf. pagesi*, *Polyxenus fasciculatus*, *Polyxenus oromii* y *Macroxenus enghoffi* en la península ibérica y Baleares.

species, but it could represent an additional species (Nguyen Duy-Jacquemin, 1996).

Macroxenus rubromarginatus (Lucas, 1846) (Fig. 2)

Polyxenus rubromarginatus Lucas, 1846: 283.

Macroxenus rubromarginatus (Lucas): Brolemann, 1917: 114.

GENERAL DISTRIBUTION. Very few records exist for this species, sparsely distributed in Algeria, Morocco, Malta, and southern Portugal (Lucas, 1846; Brolemann, 1917; Condè, 1954c; Nguyen Duy-Jacquemin, 2009).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS, AND/OR CANARY ISLANDS

PUBLISHED DATA. **Iberian Peninsula. Portugal:** Faro: Albufeira: Praia de Lourenço (Nguyen Duy-Jacquemin, 2009).

COMMENTS. The distribution pattern could suggest a still largely unknown real distribution of this species or, alternatively, events of long-distance, perhaps anthropogenic, dispersal.

Family **Lophoproctidae** Silvestri, 1897

Lophoproctinus inferus (Silvestri, 1903) (Fig. 4)

Lophoproctus inferus Silvestri, 1903: 5.

Lophoproctinus inferus (Silvestri): Silvestri, 1948: 217.

Lophoproctinus inferus maurus Marquet & Condè, 1950: 124.

GENERAL DISTRIBUTION. Originally described from Portici, in the Gulf of Naples (Italy) (Silvestri, 1903), it has also been recorded from southern Corsica (France) and Mallorca (Spain) (Condè, 1953, 1954a). A second subspecies, *L. inferus maurus* was described from Algeria and is also recorded from Tunisia, Morocco and the Canary Islands (Spain) (Marquet & Condè, 1950; Condè, 1954c; Nguyen Duy-Jacquemin, 1996; Kime & Enghoff, 2011).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. **Balearic Islands. Spain:** Illes Balears: Mallorca: Son Servera, km 11.1 of the road to Capdepera (Condè, 1954a); Illes Balears: Mallorca: Between Son Servera and Porto Cristo (Condè, 1954a); Illes Balears: Mallorca: Porto-Cristo, road to Cueva del Drach (Condè, 1954a); Illes Balears: Mallorca: Porto Colom (Condè, 1954a). **Canary Islands. Spain:** Las Palmas: Fuerteventura: Jandia: Barranco del Ciervo, Morro de Cavedero N of Morro Jable (Nguyen Duy-Jacquemin, 1996); Las Palmas: Gran Canaria: Roque Bentayga, SW slope (Nguyen Duy-Jacquemin, 1996); Santa Cruz: Tenerife: Barranco de Las Cuevas, Teno Alto (Nguyen Duy-Jacquemin, 1996); Santa Cruz: El Hierro: El Justo Cave (Kime & Enghoff, 2011).

Lophoproctus jeanneli (Brolemann, 1910) (Figs 1A-B, 3)

Polyxenus lucidus var. *jeanneli* Brolemann, 1910: 341.

Lophoproctus jeanneli (Brolemann): Condè, 1953: 34.

Lophoproctus litoralis Verhoeff, 1952: 148.

GENERAL DISTRIBUTION. Described from a cave in southeastern France (Brolemann, 1910), *L. jeanneli* has also been recorded from scattered points in the Iberian Peninsula, the Mediterranean islands of Mallorca, Corsica, Capri and Malta, and from Lebanon (revised in Short, 2015b). The record from Israel by Condè & Nguyen Duy-Jacquemin (1970) likely corresponds to *L. israelensis* Short, 2020 (Short, 2020).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS AND/OR CANARY ISLANDS

PUBLISHED DATA. Iberian Peninsula. Spain: Barcelona: Parc Municipal de Barcelone (with no further detail) (Condè, 1954a); Jaén: Villacarrillo: Cueva de la Morciguilla (Golovatch & Mauriès, 2013). **Balearic Islands. Spain:** Illes Balears: Mallorca: Esporlas (Condè, 1954a).

NEW RECORDS. Iberian Peninsula. Spain: Girona: Lloret de Mar: Ermita de Santa Cristina, 41°41'21"N 2°48'54"E, mixed forest of *Pinus halepensis* and

Quercus ilex, 20/IX/2017 (n = 4), 20/X/2017 (n = 3), 19/XII/2017 (n = 10) and 05/V/2018 (n = 3), P. Rodríguez-Flores, E. Recuero leg.; Girona: Blanes, 41°40'27"N 2°45'44"E, in meadow surrounded by cultivated fields, 14/XI/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 3); Barcelona: Fogàs de Monclús: La Costa de Montseny, 41°45'00"N 2°24'55"E, in oak forest, 18/I/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 1); Barcelona: Barcelona: Parque de la Ciudadela, 41°23'13"N 2°11'13"E, in garden with abundant leaf litter, 15/IX/2018, E. Recuero leg. (n = 2); Barcelona: Sant Celoni: Boscos del Montnegre, 41°41'09"N 2°32'11"E, in *Quercus suber* forest, 16/II/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 7); Madrid: Madrid: Museo Nacional de Ciencias Naturales, 40°26'29"N 3°41'24"W, in small garden with *Quercus ilex*, 11/XII/2018, P. Rodríguez-Flores, E. Recuero leg. (n = 5).

COMMENTS. The distribution of this species in the Iberian Peninsula is highly disjunct, with presence in three geographically distant and ecologically diverse regions. This could be due to a lack of sampling in the intervening areas, long-distance dispersal or range fragmentation of a formerly wider distribution range.

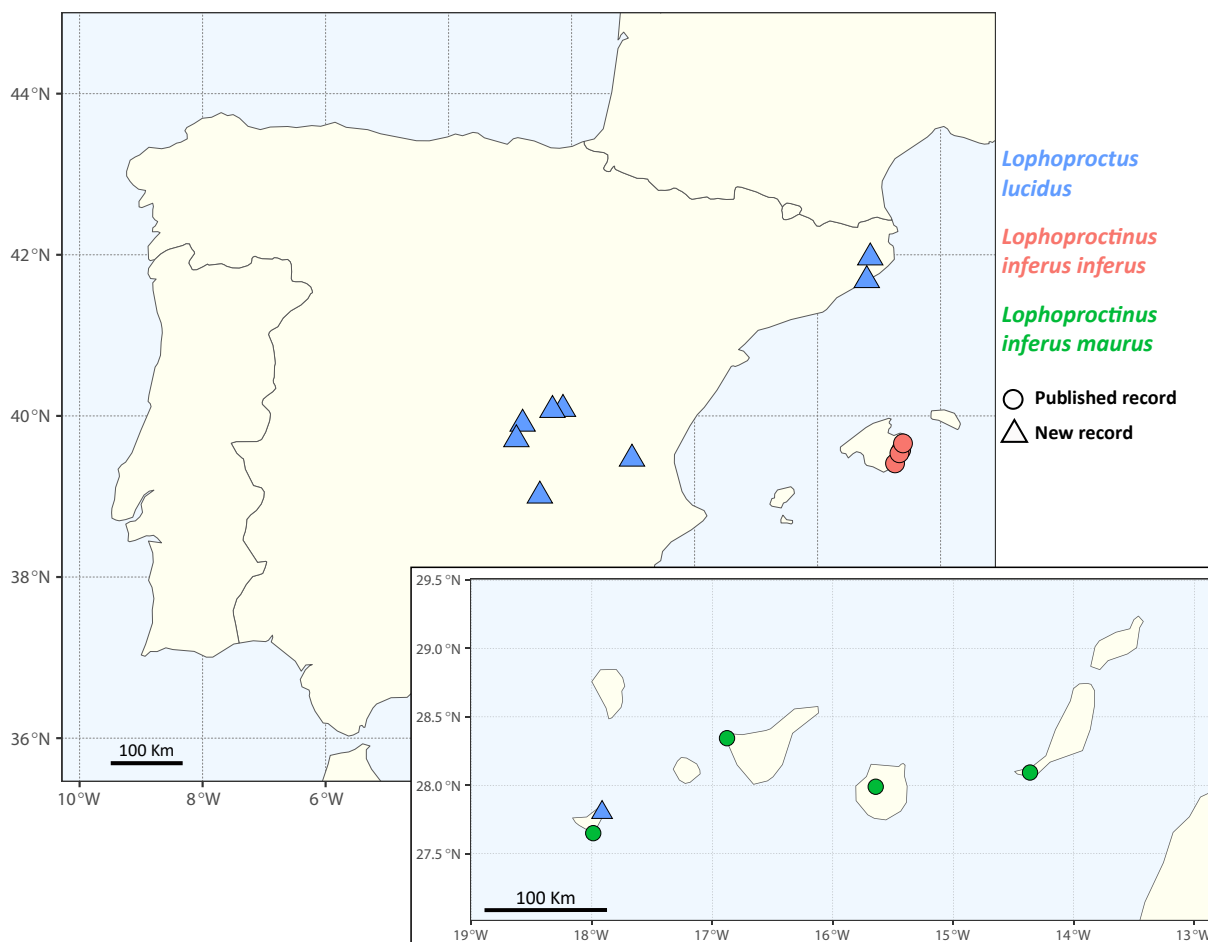


Fig. 4.— Map showing published and unpublished records of *Lophoproctinus inferus inferus*, *Lophoproctinus inferus maurus* and *Lophoproctus lucidus* in the Iberian Peninsula, Balearic, and Canary Islands.

Fig. 4.— Mapa que muestra los registros publicados y no publicados de *Lophoproctinus inferus inferus*, *Lophoproctinus inferus maurus* y *Lophoproctus lucidus* en la península ibérica, Baleares y Canarias.

Lophoproctus lucidus (Chalande, 1888) (Figs 1C-D, 4)

Pollyxenus lucidus Chalande, 1888: 99.

Lophoproctus lucidus (Chalande): Silvestri, 1894: 196.

GENERAL DISTRIBUTION. *Lophoproctus lucidus* was described from the Pyrénées-Orientales Department in southern France (Chalande, 1888), and has been recorded from several localities in southeastern France, as well as from isolated points in Morocco, Algeria and Tunisia (revised in Short, 2015b). It is reported here for the first time from the Iberian Peninsula and the Canary Islands.

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS, AND/OR CANARY ISLANDS

NEW RECORDS. **Iberian Peninsula. Spain:** **Girona:** Blanes: Cala de Sant Francesc, 41°40'42" N 2°48'04"E, in pine-oak forest with *Pinus halepensis*, *Quercus suber* and *Q. ilex*, 9/XII/2017 (n=2), 10/III/2018 (n=4), 3/VII/2018 (n=5), P. Rodríguez-Flores, E. Recuero leg.; **Girona:** Blanes, Ermita de Santa Barbara, 41°40'58"N 2°48'01"E, in dense forest of *Quercus suber* and *Pinus halepensis*, 8/XI/2017, P. Rodríguez-Flores leg. (n=2); **Girona:** La Creueta, 41°57'54"N 2°51'9"E, in forest of *Pinus pinaster*, 17/II/2018, E. Recuero leg. (n=6); **Cuenca:** Saelices, 39°54'05"N 2°47'46"W, in forest of *Quercus ilex*, 9/XII/2012, E. Recuero, M. García leg. (n=5); **Cuenca:** Puerto de Cabrejas, 40°04'19"N 2°18'39"W, in forest of *Pinus nigra*, 9/XII/2012, E. Recuero, M. García

leg. (n=1); **Cuenca:** Cuenca, 40°05'06"N 2°08'25"W, in forest of *Pinus nigra*, 3/VI/2018, P. Rodríguez-Flores, E. Recuero leg. (n=2); **Cuenca:** Villamayor de Santiago, 39°42'30"N 2°53'53"W, 3/III/2021, N. Cardo leg. (n=2); **Albacete:** 2 Km SW Munera, 39°00'33"N 2°30'59"W, 22/X/2017, A. Sánchez, R. González, K. López, M. García leg. (n=3); **Valencia:** El Rebollar, 39°28'03"N 1°01'05"W, 728 m, in forest of *Pinus halepensis*, 21/II/2021, P. Rodríguez-Flores, E. Recuero leg. (n=1); **Canary Islands. Spain:** Santa Cruz: **El Hierro:** Villa de Valverde, 27°48'04"N 17°54'55"W, under plank pieces in *Euphorbia* scrub, 14/I/2018, P. Rodríguez, E. Recuero leg. (n=5).

COMMENTS. The wide, disjunct distribution of the species in Europe, North Africa and particularly the Canary Islands could be indicative of long-distance dispersals probably associated to human activity.

Lophoproctus pagesi Condè, 1981 (Fig. 3)

Lophoproctus pagesi Condè, 1981: 314.

Lophoproctus cf. *pagesi* Condè: Cardoso *et al.*, 2008: 360.

GENERAL DISTRIBUTION. The species is only known with certainty from a few caves in Mallorca (Vadell *et al.*, 2007). The identity of the population found in Portugal still needs to be studied in more detail (Cardoso *et al.*, 2008).

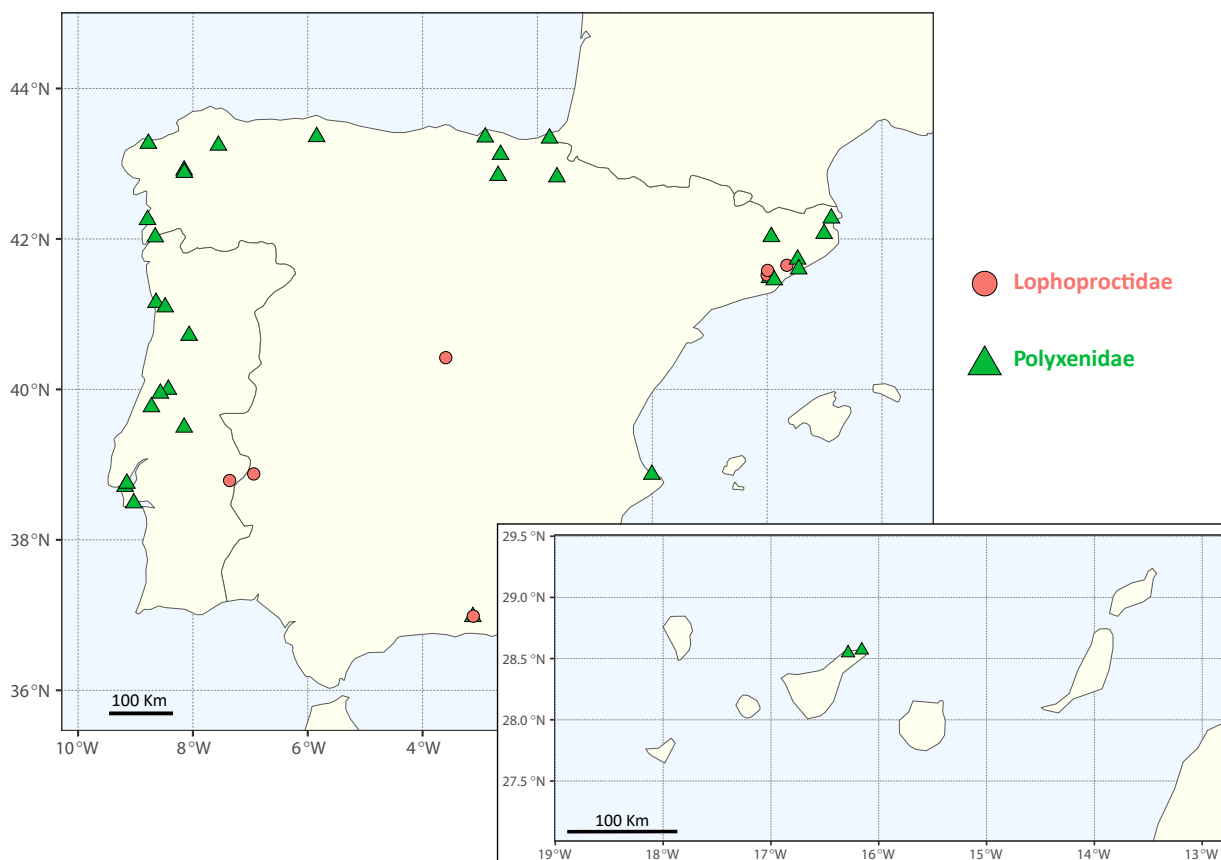


Fig. 5.– Map showing observations of Iberian, Balearic, and Canary Polyxenida from iNaturalist (<https://www.inaturalist.org/>).

Fig. 5.– Mapa que muestra las observaciones de Polyxenida ibéricos, baleares y canarios de iNaturalist (<https://www.inaturalist.org/>).

RECORDS FROM THE IBERIAN PENINSULA, BALEARIC ISLANDS
AND/OR CANARY ISLANDS

PUBLISHED DATA. **Balearic Islands.** Spain: Illes Balears: Mallorca: Cueva de Genova, near Palma (Condè, 1981); Illes Balears: Mallorca: Cova des Pas de Vallgornera (Sala de les Arrels) (Vadell *et al.*, 2007). **Iberian Peninsula. Portugal:** Setubal: Gruta do Fumo (Parque Natural da Arrabida) (Cardoso *et al.*, 2008).

Discussion

With about 150 species present in all continents but Antarctica, Polyxenida is one of the smallest orders among Diplopoda (Nguyen Duy-Jacquemin & Geoffroy, 2003; Short, 2015a). Its diversity in the European Mediterranean and Macaronesian regions is moderate, as only 19 species have been recorded (Kime & Enghoff, 2011). The diversity of the Iberian Peninsula, the Balearic Islands, and the Canary Islands is characterized by the presence of a few relatively widespread species and only three to four endemic taxa, two in the Canary Islands (Nguyen Duy-Jacquemin, 1996) and one from the Balearic Islands and the Iberian Peninsula (Cardoso *et al.*, 2008), which probably correspond to two different cryptic species.

The number of published records of Polyxenida from the geographical regions considered in this study is very low. This could reflect the rarity of these species, but is most likely the result of a general lack of studies of the group. Increased efforts in sampling and identification of these tiny millipedes will certainly increase the known distribution of the species and perhaps also increase the known diversity with new records and new taxa.

In this sense, Citizen science projects such as iNaturalist could be useful to get a more or less accurate idea of the distribution, phenology, and abundance of such poorly known invertebrate species (e.g., Mesaglio *et al.*, 2021; Rosa *et al.*, 2022), and they are increasingly being used for research projects in disciplines as ecology, taxonomy, biogeography, conservation, etc. (e.g., Poisson *et al.*, 2020; Krueger *et al.*, 2023; Whittaker *et al.*, 2023). However, the data gathered through such initiatives have some limitations, especially for taxonomically challenging groups such as millipedes. For instance, with the available information, it is impossible to identify most Polyxenida species without a proper examination of microscopic characters that are not visible when using standard macrophotography, as the number and disposition of basiconic sensillae of the 6th antenomere (e.g., Short, 2015b, 2020). In the case of the faunas studied here, identification based on the available pictures is only possible with certainty to Family level. For instance, among the Lophoproctidae recorded in iNaturalist for the Iberian Peninsula,

two of them were tentatively assigned to *L. coecus*, but apparently without close examination of the specimens. This species has been found in Italy and adjacent south-eastern France, Crimea, the Caucasus and isolated records from Iran and Kyrgyzstan (Short, 2015b), and its presence in Granada province would be surprising, and for now these identifications should be regarded as invalid. The identification of these samples, as well as others proposed in iNaturalist (*Lophoproctus*, *Polyxenus lagurus*, *P. fasciculatus*) should be confirmed by examining specimens under a microscope. Nevertheless, the information obtained from citizen science projects can be useful to increase our knowledge on groups as Polyxenida. For instance, some general patterns can be seen, such as a predominant distribution of Lophoproctidae across eastern and southern areas of the Iberian Peninsula mostly characterized by limestone substrates and Mediterranean climate, whereas Polyxenidae seems more generalistic and present in different soil types and climate conditions, although with a higher number of observations in areas with Atlantic influence. Large interior areas in the Iberian Peninsula have no records, but it is hard to know if this reflect a real trend for the group or if observations are geographically biased. From our own data we know that both *Polyxenus* and *Lophoproctus* have populations in many interior provinces in Spain, but we still do not know how fragmented their distributions are.

Many of the species present in the studied regions present a wide distribution range, but most of them are known only from a few scattered localities (Kime & Enghoff, 2011). This is the case with *Phryssonotus platycephalus*, *Lophoproctinus inferus*, *Lophoproctus lucidus*, *Lophoproctus jeanneli* and *Macroxenus rubrimarginatus*, which have been found in different areas of the Western Mediterranean and the Canary Islands. There are different possible explanations for this pattern of geographic distribution. First, it is likely that our current knowledge on the actual distribution of these species is far from complete and that they have not been found yet in large areas between known localities. For instance, in the case of *Lophoproctus jeanneli* and *L. lucidus*, records from southern France, where Polyxenida fauna has been thoroughly studied, are abundant, while their records from other, not so well studied areas, are scarce and often isolated. It is possible that, as is the case for other taxa, increasing research efforts in these regions will increase the number of records and will show a more continuous distribution (e.g., Recuero & Rodríguez-Flores 2019). However, the disjunct distribution pattern observed in these species could be real. In this case, it could be that the current distribution is the result of the fragmentation of a much larger and continuous ancestral distribution. Recurrent range fragmentations in the Palaearctic have been frequent and triggered by climatic changes associated to glacial cycles during the

Pleistocene (Schmitt, 2007). If this was the case, it is logical to assume that the optimal climatic conditions for these species occurred during glacial maxima and that they are currently restricted to interglacial refugia. However, considering that most records are found in warm Mediterranean areas it is unlikely that this is the case, as these localities are very different to the usually recognized interglacial refugia areas (Teixeira *et al.*, 2018; Sánchez-Montes *et al.*, 2019; Rodríguez-Flores *et al.*, 2020).

As an alternative to the fragmentation of former continuous distribution ranges, it is possible that these species can complete long-distance dispersal processes, colonizing new geographical areas even across the sea. Even if their dispersal abilities seem quite limited, it has been postulated that at least some Polyxenida species may be able to perform aerial dispersal, by being blown in the wind, or by phoresy as they could get accidentally attached to bird feathers (Short *et al.*, 2020). This could explain the frequently observed disjunct distribution patterns, as new populations could colonize distant regions by air, while expansion in newly colonized areas would be slow due to limited terrestrial dispersal abilities. However, there is no data on how common or how far can aerial dispersal occur, if it is possible at all, and which species are able to disperse that way.

Another way for long-distance dispersal is associated with human activities. There are known cases where Polyxenida species have colonized new biogeographical regions accidentally dispersed by humans. *Polyxenus lagurus*, a species native to Europe, can now be found in large areas of North America and even in Australia (Short & Vahtera, 2017). Likewise, the presence of *Polyxenus fasciculatus* in the Canary Islands is thought to be caused by an involuntary introduction (Arndt *et al.*, 2008). The population of *Lophoproctus jeanneli* found in urban areas in Barcelona and Madrid could have originated from individuals traveling in plant pots used to revegetate those gardens. The population of *Lophoproctus lucidus* found in El Hierro Island, found over 1000 Km from the nearest known localities, could also have originated from an accidental introduction, as has also been hypothesized for the populations of *L. lucidus* found in Morocco (Short, 2015b).

However, much more data is necessary to discern among these possible explanations, including collecting more data on the distribution of the species and using molecular data to reconstruct the evolutionary history of the species and identify dispersal processes and routes among populations.

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