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A new genus and species of Haplobainosomatidae (Diplopoda: Chordeumatida) from the MSS of the Sierra de Guadarrama National Park, central Spain

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Abstract

The chordeumatidan fauna of the Iberian Peninsula is far from being well known, but recent efforts are improving that knowledge. Samplings carried out in the *Milieu Souterrain Superficiel* (also known as the Mesovoid Shallow Substratum) on several screes of the Sierra de Guadarrama National Park (central Spain) have led to the discovery of a new species of chordeumatidan millipede. This new species belongs to the family Haplobainosomatidae, which is mainly known from the northern Iberian Peninsula, and thus this is the first record of the family in central Spain. However, the extremely simple gonopods of this species are so different from all other known species of the family that it must be placed in a new genus. In this work, a complete description of the species, named as *Guadarramasoma ramosae* **gen. & sp. nov**., with a detailed iconography based on scanning electron microscopy images is provided together with a distribution map and a brief discussion of the implications of this new finding.

Key words: Subterranean environments, orobiome, millipedes, Sierra de Guadarrama, new species

Introduction

Since Juberthie *et al*. (1980) first described the *Milieu Souterrain Superficiel* (MSS), many researchers have studied this peculiar environment (Mammola *et al*. 2016). The MSS consists of all the spaces formed by the network of fissures and interstices of the rocky debris and presents several special conditions, e.g., absence of light, high humidity throughout the year and attenuation of fluctuations of temperature and humidity compared to the surface (Giachino & Vailati 2010; Pipan *et al*. 2011; Jiménez-Valverde *et al.* 2015). The MSS may be formed by differing lithological processes in various types of rocks, giving rise to different types of MSS, such as volcanic, bedrock, colluvial or alluvial MSS (Juberthie *et al*. 1980, 1981; Oromí *et al*. 1986; Gers 1992; Juberthie 2000; Ortuño *et al*. 2013). The MSS is closely associated with the soil layers closest to the surface, allowing a relatively large flow of organic matter and energy, mainly from the surface to the subsoil (Gers 1998; Mammola *et al*. 2016). The fauna inhabiting the MSS is mainly constituted of arthropods (Rendoš *et al*. 2012; Ortuño *et al*. 2013; Jiménez-Valverde *et al.* 2015) and can be classified according to its level of specialization and adaptation to this habitat (Sket 2009). Thus, the MSS can harbour animals from the surface which come into this habitat searching for shelter during periods in which the external environmental conditions are adverse (Nitzu *et al*. 2010, 2014), but it can also harbour hypogean animals that permanently reside in this habitat. The fauna is stenoecious and hygrophilous with a high level of specialization and adaptation to its environment (Gers 1992; Ortuño & Toribio 1994; Hernando *et al*. 1999; Culver & Pipan 2008; Pipan *et al*. 2011).

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Although the MSS is a widespread subterranean environment, it has been very poorly studied. Nevertheless, research on the MSS in Spain has resulted in several findings in recent years (Barranco *et al.* 2013; Gilgado *et al*. 2014; Ortuño *et al*. 2014a, 2014b), including some related to Diplopoda (Enghoff & Reboleira 2013; Gilgado *et al*. 2015c), two of which concern Chordeumatida (Gilgado *et al*. 2015a, 2015b).

Chordeumatida is an order of Diplopoda with more than 1,100 described species (Brewer *et al*. 2012). Chordeumatidans are in general lithophilous (Verhoeff 1926-1932; Spelda 2015) and mostly adapted to living in cold environments (Golovatch 2009; Golovatch & Kime 2009). They are predominant in habitats like the 'montane tundra', or the high mountains (Mikhaljova 2004; Golovatch 2009), and several species have been described from cold caves (Mauriès 1986, 1988; Spelda 2015). Thus, and according to Spelda (1996), Chordeumatida are suitable tools for reconstructing zones that acted as climatic refugia during the glaciations.

Before the present work, 76 species of Chordeumatida were recorded from the Iberian Peninsula, distributed among eight families. The last checklist (Spelda 2015) included 74 species, but there are two recent additions: *Ceratosphys cryodeserti* Gilgado, Mauriès & Enghoff, 2015 (Gilgado *et al*. 2015c) and *Eopsychrosoma serrapradense* Serra & Mauriès, 2016 (Serra & Mauriès 2016). Nevertheless, Spelda (2015) considered that we know only approximately 20% of the Iberian species of Chordeumatida yet. So, it is indeed a poorly known group. Spelda (2015) also predicted that prospections in several mountain ranges of the Iberian Peninsula, like the Guadarrama Mountains of central Spain, would surely lead to new findings. Samplings in the MSS carried out by the authors of the present work resulted in the discovery of specimens of a new species of Chordeumatida of the family Haplobainosomatidae from the Guadarrama Mountains. Even if the structure of the gonopods clearly agrees with Haplobainosomatidae, this new species does not fit in any of the current genera of the family, so it must be assigned to a new genus, as detailed below. The 17 previously described species of this family are all endemic in northern Spain and Portugal and in the French Pyrenees, with exception of *Haplobainosoma lusitanum* Verhoeff, 1900, which has also been found on the Azores (Mauriès 1971, 2010, 2015; Spelda 2015). The discovery of a new Haplobainosomatidae in central Spain thus represents a notable extension of the distribution area of the family.

Material and methods

Sampling area: The mountain ranges that constitute the Sierra de Guadarrama are in the Central System of the Iberian Peninsula. The Central System crosses the Peninsula from west to east before reaching the Iberian System and constitutes a sharp environmental discontinuity between the two main plateaus of central Spain (northern sub-plateau and southern sub-plateau). The sampling area was mostly confined to the recently created protected area, Sierra de Guadarrama National Park (BOE 2013). The park's surface is 33,960 hectares, and it has a belt of 62,687.26 hectares as a 'peripheral protection area' (MAPAMA) (Fig. 1). Its lower limit is located on the slopes near the Puerto de la Morcuera (1,200–1,300 m asl) and the upper limit at the peak of Peñalara (2,428 m asl) (JCL & CAM 2010). The park is spread over three mountain ranges (Figs 1, 2) that start in a common area where Puerto de Cotos and Puerto de Navacerrada are located. From the Puerto de Cotos, where Peñalara rises, in a N-NE direction the Montes Carpetanos range starts, dividing the provinces of Segovia and Madrid. Another range, constituting of Siete Picos and La Mujer Muerta, runs from the Puerto de Navacerrada to the province of Segovia in a NW-N direction. Finally, the most complex range, formed by a set of mountain chains in almost parallel arrangement whose main axis is Cuerda Larga, starts in the Puerto de Navacerrada running in an E-NE direction through the Province of Madrid exclusively until reaching the Puerto de la Morcuera; towards the north of Cuerda Larga are Altos de la Morcuera and to the south the chains of Porrones and La Pedriza.

Sierra de Guadarrama is formed by rocks of varying origin but is mainly dominated by granite (plutonic rocks) and gneisses (quartz-feldspathic metamorphic rocks) (PNSG a; Díaz-Martínez *et al.* 2012). In the National Park of Guadarrama, the granites are limited exclusively to a part of Siete Picos and to nearly all of La Pedriza. Due to the massive character of these materials and their erosion by disintegration, these substrates have been excluded from the subterranean prospecting because they do not form screes. In contrast, gneisses, more specifically orthogneisses (Vialette *et al*. 1987; PNSG a), which are present in abundance in the three ranges, are a suitable substrate for the formation of MSS because of their facility to fracture, thus giving rise to morrenic and colluvial deposits caused by glacial (Pedraza & Carrasco 2005) and periglacial events (Sanz 1986). Most of the screes of the mountain range of Guadarrama where the sampling points chosen were located are thus constituted by gneisses.

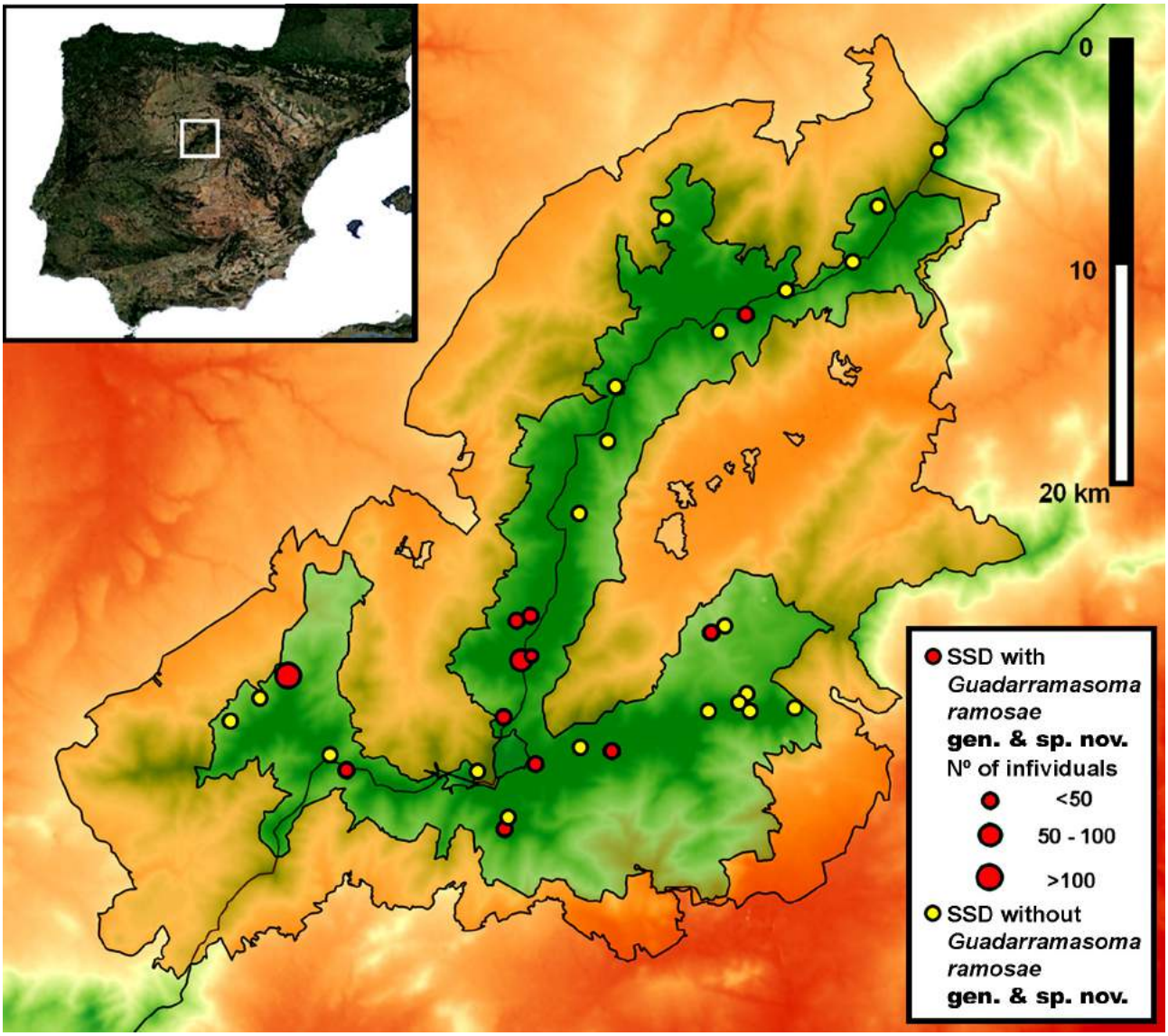

FIGURE 1. Distribution of *Guadarramasoma ramosae* **gen. & sp. nov**. in the Sierra de Guadarrama National Park. The red circles correspond to the sampling points where it was captured, and the size of the circles is related to the number of specimens captured. The yellow circles correspond to the sampling points where the species has not been captured. The inner area of the map corresponds to the limits of the National Park, and the surrounding area to the buffer zone ("Peripheral Protection Area").

The geography of the National Park and its modest altitudes (about 2,000 m asl) place the park in the typical bioclimatic model of a mountainous enclave of the Mediterranean region with the following bioclimatic stages:

1. In the supramediterranean stage (1,300–1,500 to 1,700 m asl, approximately), the presence of Pyrenean oak (*Quercus pyrenaica* Willd.) has been reduced by the progression of the Scots pine (*Pinus sylvestris* L.) giving rise to extensive pine forests (JCL & CAM 2010) which find their optimum in the upper supramediterranean stage, reaching the oromediterranean and crioromediterranean stages (Muñoz Municio *et al.* 2004).
2. In the oromediterranean stage (1,700–2,200 m asl), scrubland above the forest level predominates the most extensive vegetation in the National Park (JCL & CAM 2010), where species such as *Juniperus communis alpina* (Suter) Čelak (alpine juniper) and *Cytisus oromediterraneus* Rivas Martínez *et al.* stand out., to which can be added species such as *Adenocarpus hispanicus* (Lam.) DC. and *Erica arborea* L. These masses of shrub vegetation alternate with grasslands, rocky outcrops and screes.
3. In the crioromediterranean stage, where *Festuca curvifolia* Lag. ex Lange dominates psychroxerophilic grasslands, the vegetation from the screes (JCL & CAM 2010) extends through colluvial and morrenic deposits.

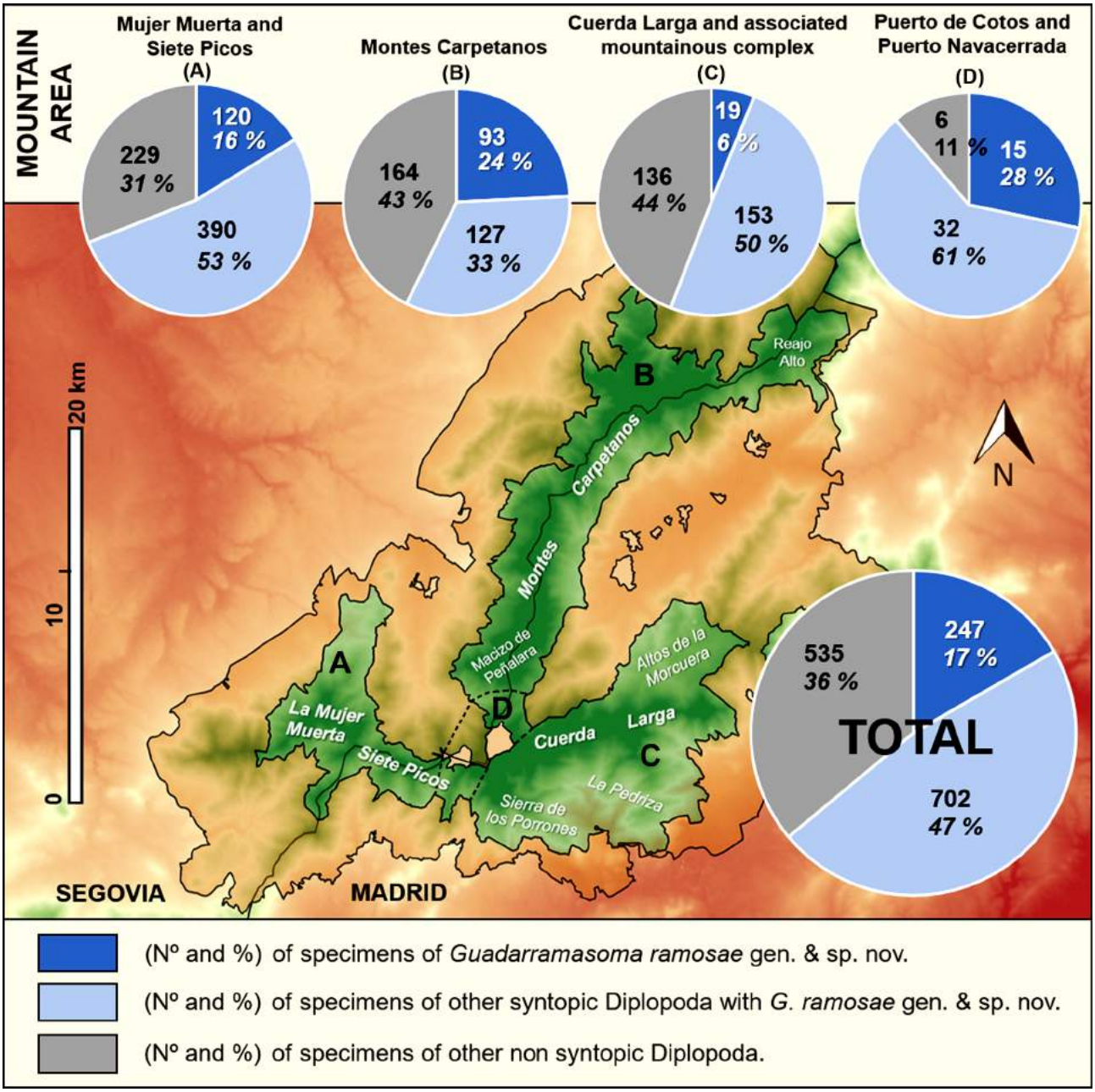

FIGURE 2. Map of the Sierra de Guadarrama National Park, with the names of the mountain chains, divided by areas, and with the number and percentage of *Guadarramasoma ramosae* **gen. & sp. nov**. captured in each area, specimens of other Diplopoda captured in the same traps ("syntopic"), and specimens of other Diplopoda captured in different traps ("non syntopic").

Although the climate of the interior of the Iberian Peninsula is of a continental type, characterized by dry and temperate summers, in the Sierra de Guadarrama it overlaps with the mountain climate which presents very cold winters and cool, dry summers. The distance to the Atlantic Ocean and the Mediterranean Sea causes a marked continentality; this characteristic, together with the special arrangement of the three mountain ranges, conditions the circulation of air masses as well as local topographic variability, decisively influencing meteorological parameters such as temperature, insolation, precipitation and snow accumulation and persistence (Palomo Segovia 2012). All these factors make the Sierra de Guadarrama an authentic mosaic of microclimates (PNSG b).

Sampling technique: Thirty-three sampling points were set up (Table 1). To collect the fauna that moves through the MSS, 'subterranean sampling devices' (SSD) were used. The design of the SSDs was based on the model described by López & Oromí (2010), used by Barranco *et al*. (2013) and Ortuño *et al*. (2013, 2014a), with some minor modifications.

The SSDs were composed of a PVC cylinder 1 m long and 11 cm in diameter with numerous perforations (8

mm in diameter) from the middle of the cylinder to the base. In addition, four SSDs of a second model were used (Figs. 3A, C). This second model measured only 50 cm and was perforated throughout its length except for the upper 20 cm. The shorter SSD model was designed to collect the fauna of the more superficial MSS (Fig. 3). SSDs were buried vertically, leaving the top part at the level of the surface. The pitfall trap was lowered into and retrieved from the bottom of the cylinder using a nylon cord. The pitfall trap contained 1,2-propanediol (preservative liquid) and an odorous bait, or attractant, in a vial. In this case, a strong-smelling cheese was used.

A single SSD was installed on each location, except for four instances where an SSD of the shorter model was installed along with one of the standard model (Fig. 3C) in order to discriminate the most superficial fauna from the more subterranean one. The SSDs were installed from 20/05/2015 to 09/07/2015 and were collected and renewed twice; the first recovery period was from 17/09/2015 to 06/11/2015 (traps working for four months), the second from 24/05/2016 to 13/07/2016 (traps working for eight months) (Table 1).

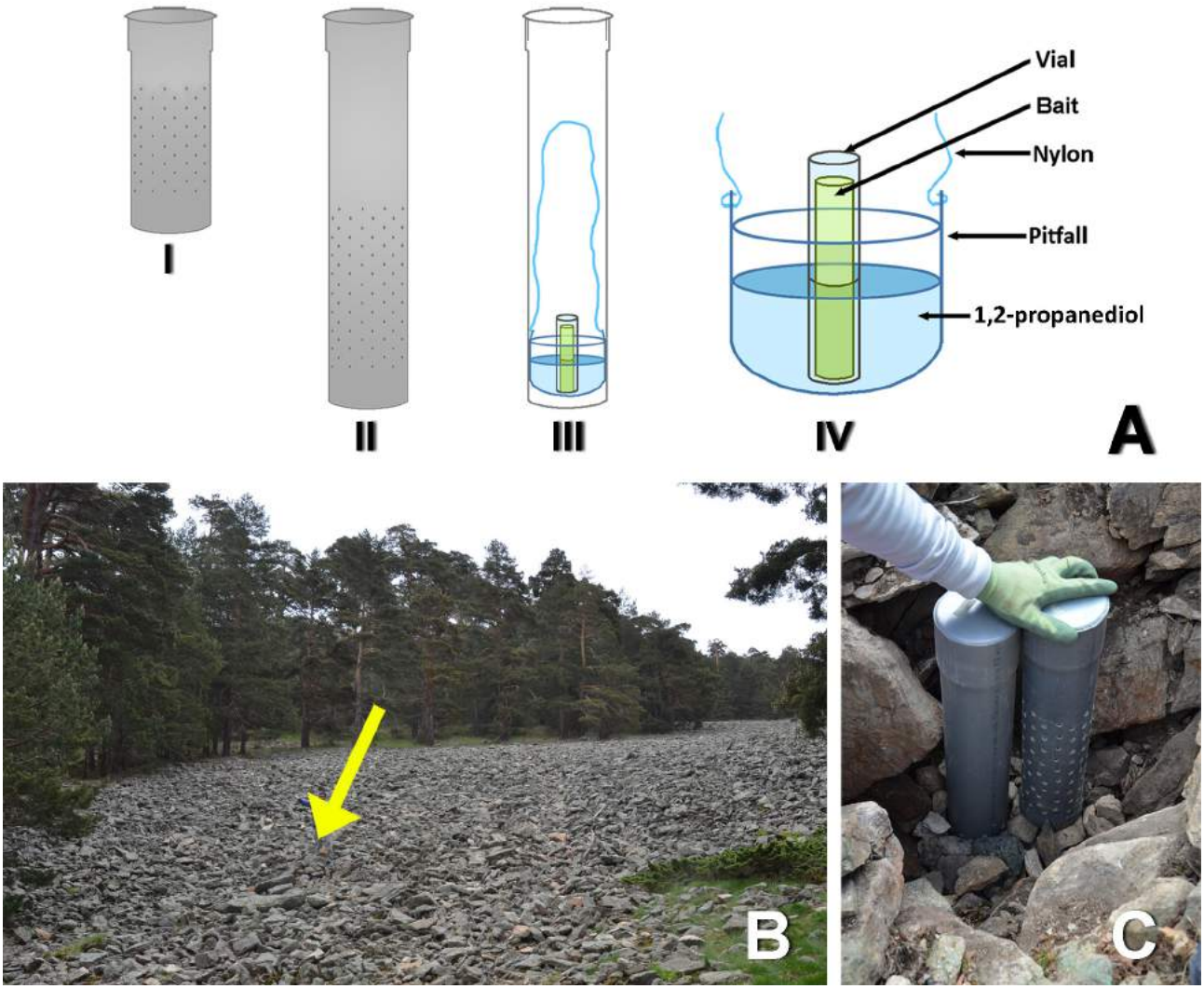

FIGURE 3. A) Schema of an SSD and installed devices. Exterior view of the 0.5 m SSD (I). Exterior view of the 0.5 m SSD (II). Longitudinal section of PVC tube where the inside of the SSD is observed with the internal devices (pitfall trap and data logger) (III). Detail of the pitfall trap (IV). B) Photograph of a scree where the SSD-1 and SSD-1 (0.5m) were placed. C) Photograph of installed SSDs. Figure modified from Ortuño *et al*. (2013).

Preservation and preparation of specimens. The millipedes were separated from the rest of the material in the laboratory and stored in 70% ethanol. Images of entire specimens of the new species were photographed with a Leica EZ4D stereo microscope with digital camera and the Leica Application Suite software version 2.1.0. The images were processed with Adobe Photoshop CS 2. Eight specimens were prepared for scanning electron microscopy (SEM) at the University of Alcalá. They were dehydrated with absolute ethanol, then transferred to

acetone (four hours) and mounted on aluminium stubs. The samples were coated with gold, observed and photographed with a SEM Hitachi TM-1000. One specimen was similarly prepared in Copenhagen but coated with platinum/palladium and observed and photographed with a JEOL JSM-6335F at the Natural History Museum of Denmark.

All specimens of the new species from the first sampling period are kept in the Natural History Museum of Denmark (ZMUC), and specimens from the second period are in the collection of the Department of Life Sciences-V.M. Ortuño (DZAF-UA/VMO) of the University of Alcalá (Spain).

The distribution map for the new species (Fig. 1) was generated with the software QGIS version 2.16.3. (Quantum GIS Development Team 2016). The nomenclature of the anatomy of the gonopods is based on that of Mauriès (2010, 2015).

Results

A total of 247 specimens of the new species were captured: 25 in the first sampling period and 222 in the second (Table 1).

Taxonomy

Class Diplopoda de Blainville in Gervais, 1844

Order Chordeumatida Pocock, 1894

Family Haplobainosomatidae Verhoeff, 1909

The following diagnosis of the family is a translation of that of Mauriès (1971), slightly modified to include the new genus which lacks the anterior formations in 'cupule' of the 'gonopodal floor' or 'plancher gonopodial' sensu Mauriès (2015) (angiocoxites or synangiocoxite) included in the original diagnosis.

Diagnosis. P. 8. (anterior gonopods): Basis of each telopodite forming an apodeme pseudoarticulated with tracheal pouch (forming a kind of cup or corolla around the basis of the telopodite together with a rest of the sternite); angiocoxite (synangiocoxite, or angiocoxosternite) between the two telopodites, of variable form, the most anterior part usually (but not in all cases) forming a cupule- or bowl-like structures; colpocoxites of variable form (rarely sclerotized, most frequently soft, more or less fused in midline) connected on the posterior margin of the angiocoxite, placed in a posterior position relative to that of telopodites.

P. 9. (posterior gonopods, or paragonopods): Variable, sometimes simple stumps, sometimes clearly articulated with terminal article directed laterad-shaped; sternite not modified.

Genus *Guadarramasoma* Gilgado, Ledesma, Enghoff & Mauriès gen. nov.

Etymology. The name refers to the mountain range and national park where this species was discovered: Sierra de Guadarrama National Park. Gender neuter.

Diagnosis. The genus being monotypic, a description of the genus is also a description of the sole species. Thus, we are including in the diagnosis only those general characters that distinguish this genus from other Haplobainosomatidae.

Gonopod telopodites simple and elongated, synangiocoxite with only two anterior, not protruding but flat expansions (a1), a second pair of expansions only vestigial (a2), and with a posterior pair of divergent laminar and acute structures fused at their basis (a3), laterally and basally covered at half its length by the laminar and membranous structures of the colpocoxite.

***Guadarramasoma ramosae* Gilgado, Ledesma, Enghoff & Mauriès n. sp.**

Type material. Holotype: 1 ♂ (zmuc00039881). SSD 28. MSS (-1m). Collado de Valdemartín, Cuerda Larga, Madrid, Spain. 40°47'43.48"N 3°57'20.81"W. 2,160 m asl. Trap working from 03/07/2015 to 06/11/2015. Gilgado, Ledesma, Ortuño *et al*. leg.

Paratypes:—4 ♂♂, 4 ♀♀ (DZAF-UA/VMO). SSD 9. MSS (-1m). Dos Hermanas, Peñalara, Madrid, Spain. 40°50'14.60"N 3°57'50.33"W. 2,200 m asl. Trap working from 05/10/2015 to 28/06/2016. Gilgado, Ledesma, Ortuño *et al.* leg.—4 ♂♂, 4 ♀♀ same data but (MNHN Collection Myriapodes-Onychophoresd, DA 292).—4 ♂♂, 4 ♀♀, same data but (MNCN 20.07/ 2009-2016).—6 ♂♂, 7 ♀♀ (zmuc00039882) SSD 1. MSS (-1m). Cancho del Río Peces; Mujer Muerta/Montón de Trigo; Segovia, Spain. 40°49'47.42"N 4° 5'18.95"E, 1,606 m asl. Trap working from 20/05/2015 to 17/09/2015. Gilgado, Ledesma, Ortuño *et al*. leg.—1 ♀ (zmuc00039883). SSD 7. MSS (-1m). Majada Hambrienta, Peñalara, Segovia, Spain. 40°51'12.19"N 3°57'59.95"W. 1,994 m asl. Trap working from 02/06/2015 to 17/09/2015. Gilgado, Ledesma, Ortuño *et al.* leg.—1 ♀ (zmuc00039884) SSD 9. MSS (-1m). Dos Hermanas, Peñalara, Madrid, Spain. 40°50'14.60"N 3°57'50.33"W. 2.200 m asl. Trap working from 03/06/2015 to 05/10/2015. Gilgado, Ledesma, Ortuño *et al*. leg.—1 ♀ (zmuc00039885) SSD 11. MSS (-1m). Cerro Ventoso, Siete Picos - La Maliciosa, Madrid, Spain. 40°47'28.36"N 4° 3'22.64"W. 1,876 m asl. Trap working from 09-VI-2015 to 17/09/2015. Gilgado, Ledesma, Ortuño *et al.* leg.—1 ♀, 2 juv. (zmuc00039886) SSD 23. MSS (-1m). Circo del Pico Nevero, Montes Carpetanos, Madrid, Spain. 40°58'42.11"N 3°50'44.00"W. 2,144 m asl. Trap working from 25/06/2015 to 06/10/2015. Gilgado, Ledesma, Ortuño *et al.* leg.—3 ♂♂, 1 ♀, 1 juv. (zmuc00039887) SSD 28. MSS (-1m). Collado de Valdemartín, Cuerda Larga, Madrid, Spain. 40°47'43.48"N 3°57'20.81"W. 2,160 m asl. Trap working from 03/07/2015 to 06/11/2015. Gilgado, Ledesma, Ortuño *et al*. leg.
Other studied material: Details of all captured specimens are shown in Table 1.

Etymology. The species is named in honour of Marian Ramos (Museo Nacional de Ciencias Naturales, Madrid), leader of the project 'Fauna Ibérica' and supporter of our research on Iberian millipedes.

FIGURE 4. Habitus of a male (A) and a female (B) of *Guadarramasoma ramosae* **gen. & sp. nov**. lateral view. **Scale bar** 2 mm.

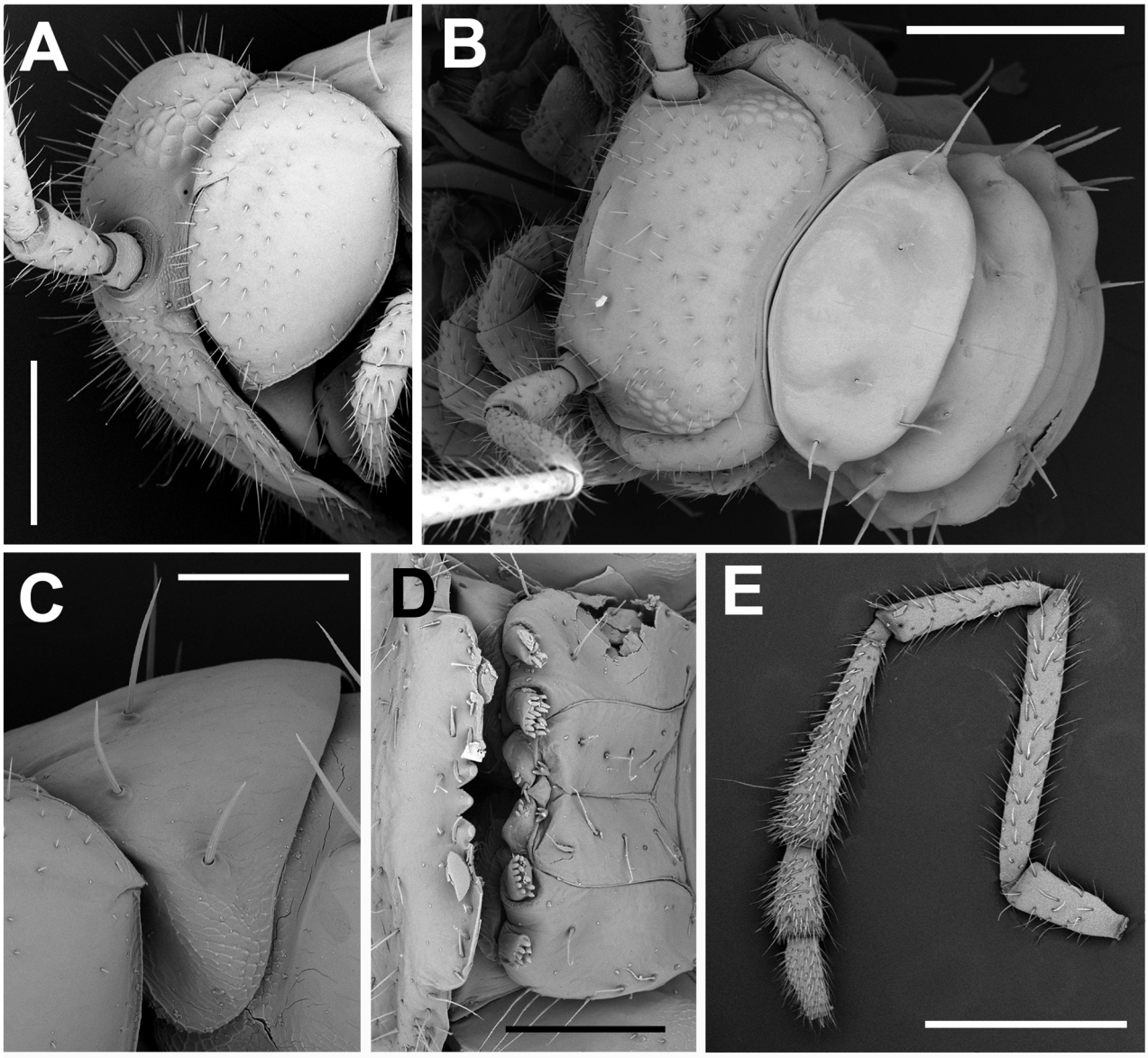

FIGURE 5. Details of the morphology of *Guadarramasoma ramosae* **gen. & sp. nov**. A) Head in lateral view. B) Head and collum in dorsal view. C) Collum in lateral view. D) Clypeus and gnathochilarium in ventral view. E) Antenna in lateral view, first antennomere missing. **Scale bars**: A = 0.3 mm; B–D = 0.2 mm; E = 0.5 mm.

Description. Colour pale, between ivory and beige (Fig. 4). Head and metazonites, including paraterga, with a slightly darker pigmentation. Adults with 30 'segments' (including collum and telson) and 50 pairs of legs (including the male gonopods). Males slightly longer (30 mm vs 29.5 mm), slenderer (1.4 mm vs 1.5 mm) and with a smaller maximum vertical diameter (1.05 mm vs 1.08 mm) than females.

Male: Head (Fig. 5A, B) convex: pilose, with setae of several sizes, some of them visibly longer than the others. Setae on vertex close to the collum arranged in two rows, other setae dispersed, in some regions with higher density, e.g., over the antennal insertions. Maximum width of gnathochilarial stipites 1.2 mm. Between 12 and 18 ommatidia per eye. Region posterior to the antennal insertion with a cobblestone paving-like microsculpture. Labrum with three teeth and 16 supralabral setae (Fig. 5D). Gnathochilarial stipites more setose anteriorly than posteriorly. Antennae pilose (Fig. 5E) with some visibly longer macrosetae and composed of eight antennomeres, the eighth only visible with SEM and telescoped into the seventh, antennomeres 1–7 measuring 0.08, 0.28, 0.73, 0.43, 0.60, 0.23 and 0.21 mm, respectively.

Collum (Fig. 5B, C): Without special modifications, maximum width 0.76 mm, with 3+3 similar-sized macrosetae (Fig. 5B, C). Anterior margin in dorsal view with elliptical outline.

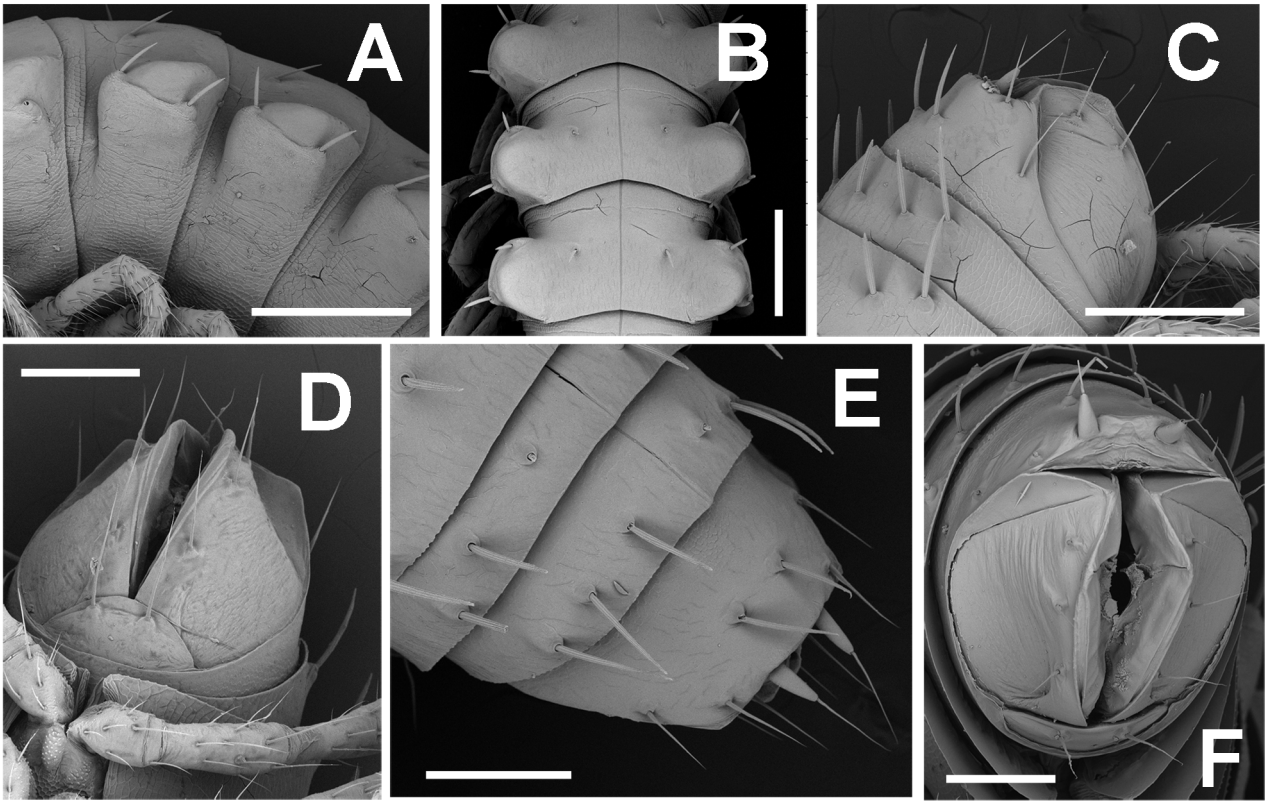

FIGURE 6. Details of the morphology of *Guadarramasoma ramosae* **gen. & sp. nov**. A) Pleurotergites in lateral view. B) Trunk pleurotergites in dorsal view. C) Telson in laterodorsal view. D) Telson in ventral view. E) Telson in dorsal view. F) Telson in posterior view. **Scale bars**: A, B = 0.5 mm; C = 0.3 mm; D–F = 0.2 mm.

Trunk (Fig. 6A, B): With conspicuous paranota. Pleurotergites 1–5 similar but increasing in size progressively. Pleurotergite 6 notably wider. Ensuing pleurotergites similar to 6 in width. Metazonites with 3+3 similar-sized macrosetae. On central pleurotergites (Fig. 6A, B), the inner seta placed halfway but slightly closer to central suture than to second seta; the second seta a little anteriorly, over the anterior lateral corner of the paranotum; and the third seta more laterally, on the posterior lateral corner of the paranotum. On posteriormost pleurotergites (Fig. 6C, E), the setae tend to be more aligned, with the inner seta halfway to the second one and the second and the third ones closer to each other than to the inner one. Posterior margin of metazonites slightly invaginated, forming a very obtuse angle. Prozonites and inferior region of metazonites with a scaly microsculpture as observed with the SEM (Fig. 5A).

Legs: Tarsus of legs 1 and 2 with a dense ventral row of long, modified setae (Fig. 7B, C). Similar setae also present but scarce and sparse on the tibiae, postfemora and femora of these legs. From legs 3–43, tarsus with a dense field of tongue-shaped modified setae ventrally (Fig. 7D-G). Coxae of leg 7 with a distal lobular laterad expansion (Fig. 7E). Prefemur of leg 10 slightly swollen ventrally; prefemur of leg 11 with a ventral and distal subtriangular blunt protuberance (Fig. 7F). Coxae of legs 10 and 11 with a conspicuous ventral pore (Fig. 7F–H). All coxae and sternal knobs with a scaly microsculpture as seen with the SEM but microsculpture not equally well developed and not very conspicuous in general (Fig. 7A).

Telson (Fig. 6C–F): Epiproct with 3+3 setae and two spinnerets, posterior margin truncate, almost slightly invaginated. Each paraproct with three setae in a vertical line, close to and parallel to the posterior margin, the uppermost seta slightly closer to the second than the second to the third. A semicircular crease close to the hypoproct, reaching the third seta (Fig. 6D, F). Hypoproct semicircular, with two long setae.

Anterior gonopods (Fig. 8A–E): Remarkably simple. Telopodites (T) long, slightly divergent, curved in their basal region (tb) resembling an elbow as seen in anterior view (Fig. 8A). From half its length, also slightly curved posteriad, as seen in lateral view (Fig. 8C, G, H). Each telopodite ending in a hook-shaped mace (ti), inner margin of (ti) somewhat serrulate, towards its tip this serrulate structure becoming just a row of thin and short spines. Tip

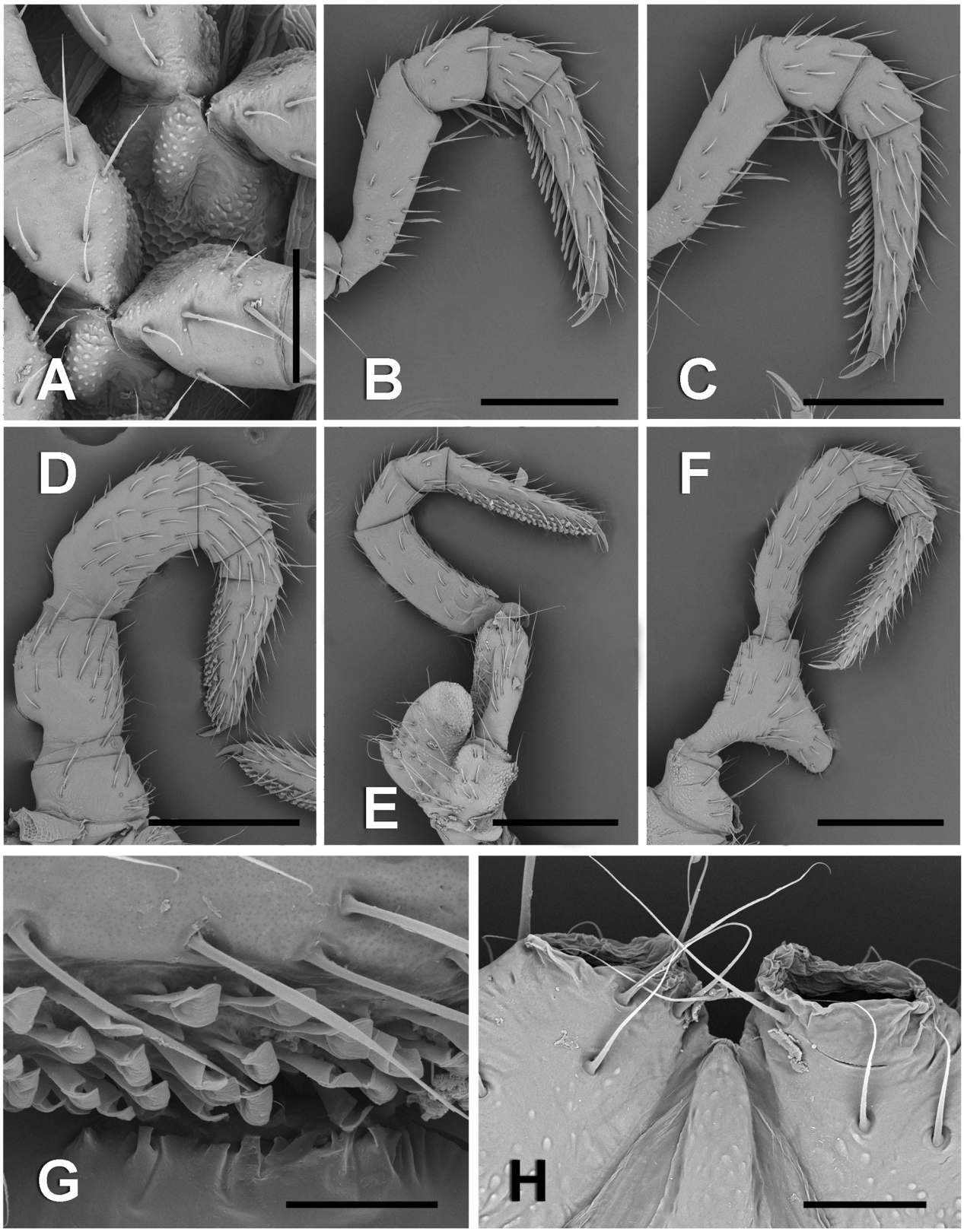

FIGURE 7. Details of the morphology of *Guadarramasoma ramosae* **gen. & sp. nov**. A) Sternal knobs and coxae of mid-segments in ventral view. B) Leg 1. C) Leg 2. D) Leg 3. E) Leg 7. F) Leg 11. G) Detail of the tongue-shaped papillae of leg 3. H) Detail of the pores on the coxae of leg 11. **Scale bars**: A = 0.1 mm; B, C = 0.2 mm; D–F = 0.3 mm; G = 0.03 mm; H = 0.05 mm.

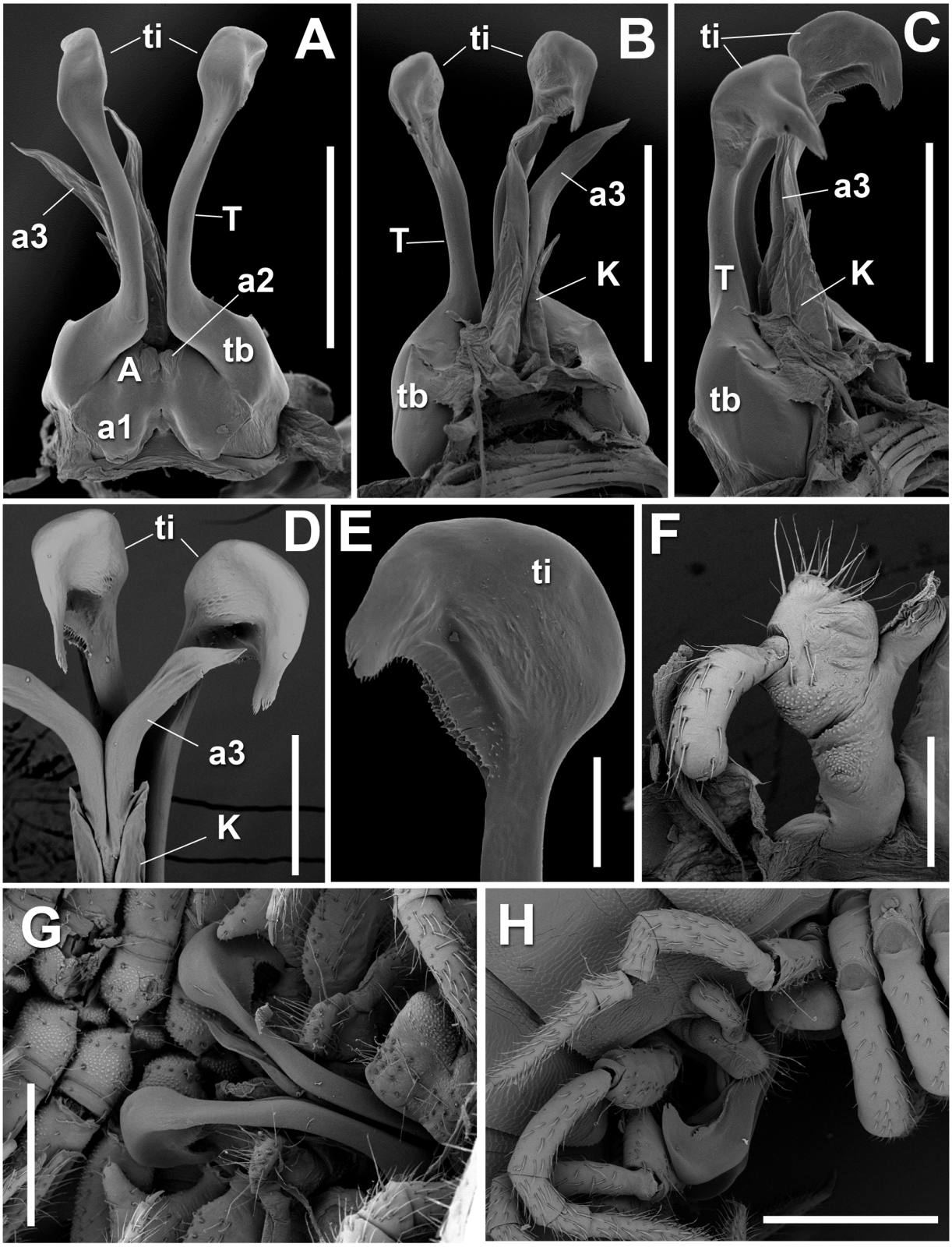

FIGURE 8. Details of the gonopods of *Guadarramasoma ramosae* **gen. & sp. nov**. A) Anterior gonopods in anterior view. B) Anterior gonopods in posterolateral view. C) Anterior gonopods in posterolateral view. D) Detail of the anterior gonopods in posterior view. E) Tip of telopodite. F) Posterior gonopod (paragonopod) in posterior view. G) Ventral view of male bearing gonopods in its natural position. H) Lateral image of male bearing gonopods in place. **Scale bars**: A–C, H = 0.5 mm; D, F = 0.2 mm; E = 0.1 mm; G = 0.3 mm. **Abbreviations**: T, telopodites; tb, basal part of telopodites; ti, tip of telopodite; A, synangiocoxite; a1, anterior lobe of synangiocoxite; a2, vestigial wart-like structure possibly corresponding to median lobe of synangiocoxite; a3, posterior structures of synangiocoxite; K, colpocoxite.

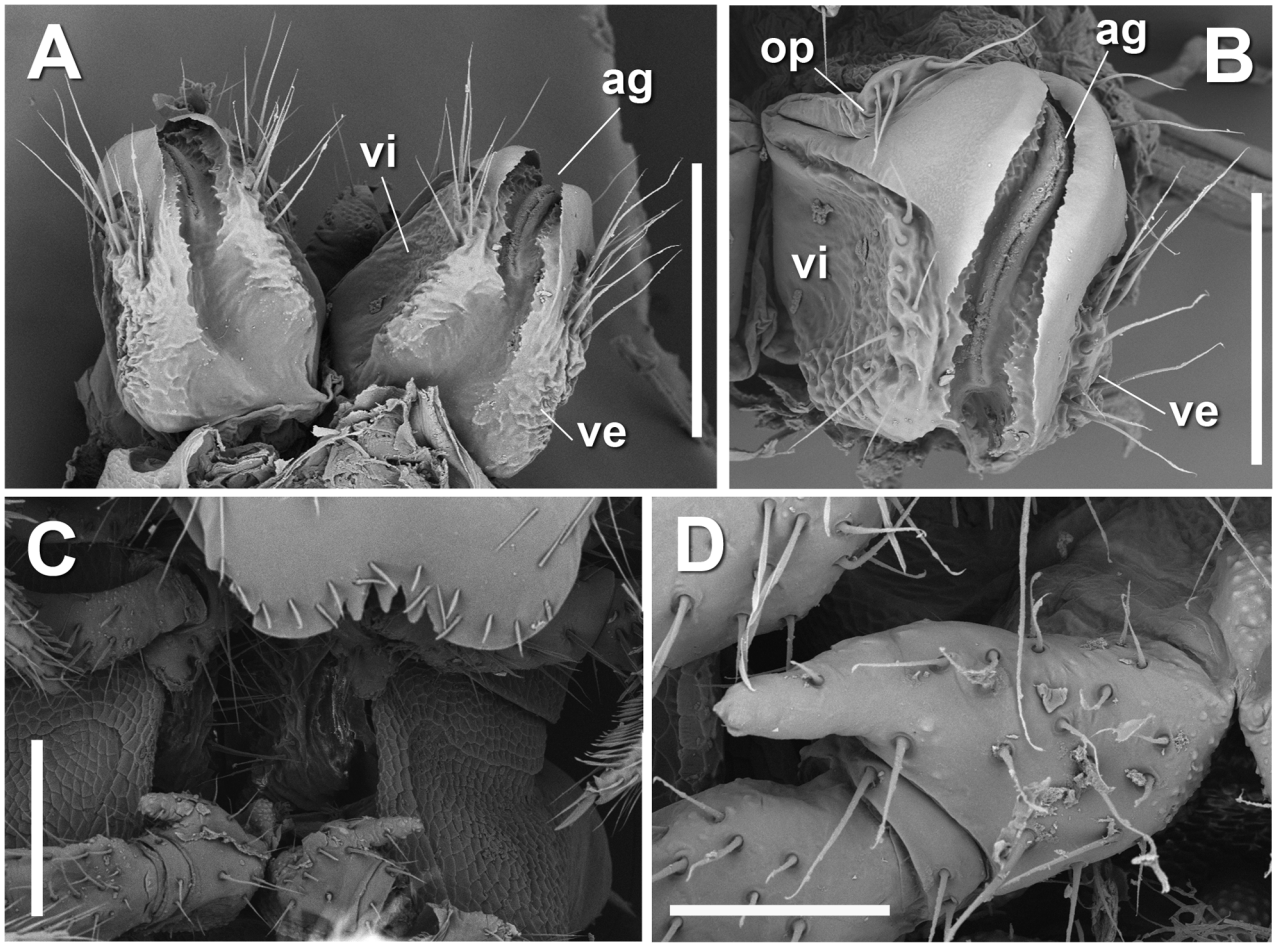

FIGURE 9. Details of the anatomy of the female of *Guadarramasoma ramosae* **gen. & sp. nov**. A) Vulvae in posterior position. B) Left vulva in ventral position. C) Ventral view of an undissected female, showing the space between the second and the third leg where the vulvae are hidden. D) Detail of the coxa of the third pair of legs. **Scale bars**: A = 0.3 mm; B, C = 0.2 mm; D = 0.1 mm. **Abbreviations**: Op, operculum; vi, mesal valve; ve, lateral valve; ag, apodematic groove.

of hook not acute, ending in a group of tiny spine-like expansions, placed above the end of the inner margin and its short spines (Fig. 8E). Base of telopodites separated by the wide antero-basal part of the synangiocoxite (A), the latter with a pair of subpyriform masses joined sagittally, each with an oral lobe (a1) and a vestigial wart-like structure (a2); the distal part represented by two divergent posterior long structures (a3), fused in their basal region (Fig. 8D), not as long as the telopodite, with a membranous aspect and ending in an acute tip (Fig. 8B, C). Adjacent laterally to and not as long as (a3), two subtriangular membranous and coarse structures corresponding to colpocoxites (K) (Fig. 8B–D). A true sternite remarkably absent, sternum may be reduced to a membranous strip.

Posterior gonopods (paragonopods): Telopodite constituted by three articles (Fig. 8F). Basal article with a lateral coarse region beside the insertion of the second article, and a distal mesal wrinkled prolongation. Second article rounded, with distal setae and a region of coarse microsculpture adjacent to those of first article. Third article inserted laterally and distally on second article, with setae, elongated, sausage-shaped, proximal third slenderer, ending in a blunt tip.

Female: Similar to male, but with some minor differences including a more robust aspect. Row of well-developed ventral setae on legs 1 and 2 present, but tongue-shaped setae on other legs lacking. Width of sixth and consecutive pleurotergites notably larger than the previous, although not as conspicuously as in males. Coxae of leg 3 with an anterior subconical expansion (Fig. 9C, D).

Vulvae (Fig. 9A, B): With no special characters. Operculum (op) setulose. Mesal (vi) and lateral (ve) valves each with ca. 9 setae adjacent to the posterior part of the apodematic groove (ag), their surface coarse as seen with the SEM, except for the apparently more sclerotized anterior zone, with a more serrulated margin surrounding the apodematic groove.

Discussion

In addition to its presence in the MSS of some of the highest mountains in central Spain, this species is quite remarkable because of the morphology of its gonopods. They differ from those of all other Chordeumatida from the Iberian Peninsula and Pyrenees in their extreme simplicity. The presence of a pair of independent membranous structures (colpocoxites) leads to its inclusion in the family Haplobainosomatidae. This species resembles some of those belonging to the genus *Pyreneosoma* Mauriès, 1959 (Figure 10). In fact, when applying the key of Mauriès (2015) for genera of Haplobainosomatidae to this species, this character leads to *Pyreneosoma.* However, the gonopods of *Guadarramasoma ramosae* **gen. & sp. nov.** differ significantly from those of all the species of *Pyreneosoma* because of their simplicity and the shape of the synangiocoxite. This synangiocoxite has no cupule-like expansions but a pair of vestigial wart-like structures and a pair of acute posterior laminar structures. The absence of these 'cupule-like structures', together with the presence of acute laminar posterior expansions of the synangiocoxite and the remarkable general simplicity of the gonopods justifies the description of a new genus for this species. However, the diagnosis of Mauriès (1971) of the family included the character '*avec les plus souvents des formations antérieures en cupule*', thus it was necessary to perform a mild modification in the diagnosis of the family, and in consonance we added '(but not in all cases) forming cupule- or bowl-like structures'. Nevertheless, separately, the different parts of the gonopods of *Guadarramasoma ramosae* **gen. & sp. nov.** slightly resemble those of other Haplobainosomatidae (see Mauriès 2010, 2015). For example, *Galicisoma biltoni* Mauriès 2015 (Fig 10B), *Cantabrosoma serrai* Mauriès & Vicente, 1977 (Fig 10D), *Pyreneosoma bessoni huescanus* Mauriès, 2010 (Fig 10E) and *Pyreneosoma consoranensis* Mauriès, 2010 (Fig 10F) have relatively narrow and simple telopodites; the colpocoxites of *Pyreneosoma consoranensis* (Fig. 10F) have a similar shape and size, although their position is different and not surrounding the synangiocoxite. The two angiocoxite pieces are fused forming one synangiocoxite, in contrast to species like *Pyreneosoma bessoni huescanus* (Fig. 10E) but similar to other genera and species of the family (Figs 10B, C, D, F, H). Despite these similarities, the affinity or relationship of the new genus with the other genera Haplobainosomatidae remains unclear. Further research is needed to clarify the systematics of the group.

Regarding the way of life of *Guadarramasoma ramosae* **gen. & sp. nov.**, we only know that it occurs in the MSS. Since no comparable sampling effort has been made on the surface, it is unknown if this species might inhabit the epigean environment as well or if it is nivicolous like certain other species of Haplobainosomatidae (see Mauriès 2010). In any case, it represents a significant part of the Diplopoda community of the study area, constituting 6–28% of the collected diplopod specimens (Fig. 2). The relatively small number of ommatidia (15) compared with those of *Pyreneosoma* (29) is a weak piece of evidence, but it might suggest a certain degree of affinity for the subterranean environment. Regarding the body size, *Guadarramasoma ramosae* **gen. & sp. nov.** is longer than an average *Pyreneosoma* species, but it is similar to *Pyreneosoma grandicoxae* Mauriès, 2010. However, it has a different degree of gracility. The ratio length/width of the species described here is around 20, while in *Pyreneosoma* it is between 9 and 13 (rarely 15). Thus, *Guadarramasoma ramosae* **gen. & sp. nov.** seems to be slenderer than the *Pyreneosoma* species. This may constitute an advantage for moving in the interstices in the MSS, even with some soil, which are probably narrower than those inhabited by *Pyreneosoma* species, among blocks and screes under snowdrifts.

The captures were made mostly in winter (Table 1), but since the second sampling period lasted nearly twice as long as the first one, we cannot infer that this species is mostly active during winter.

The discovery of this species is in consonance with the prediction made by Mauriès (2013) and Spelda (2015), who suggested that the mountains of central Spain, like the Sierra de Guadarrama, would be very promising for discovering new species of Chordeumatida. Also, it highlights the need for continued sampling to complete an inventory of the Iberian Chordeumatida fauna.

The Sierra de Guadarrama Mountains, now with a significant area converted into a national park, has a very rich fauna (Viejo Montesinos 2013) and harbours some of the most emblematic Iberian arthropod species: large coleopterans such as *Lucanus (Lucanus) cervus* (L., 1758) and *Cerambyx cerdo* Linnaeus, 1758, or the lepidopterans *Actias isabellae* (Graells, 1849) and *Parnassius apollo* (Linnaeus, 1758), a species exclusive to the high mountains.

TABLE 1. Capture and locality information of the sampling points where *Guadarramasoma ramosae* **gen. & sp. nov**. has been found.

Sampling point	Coordinates	Altitude (m asl)	Toponymy; mountain; province	Slope	First sampling			Second sampling			Total specimens
					Date installation of Traps	Date of trap recovery	Specimens captured and repository	Date installation of Traps	Date of trap recovery	Specimens captured and repository	
SSD-1	40°49'47.42"N 4°5'18.95"W	1,606	Cancho del Río Peces; Mujer Muerta/Montón de Trigo; Segovia	North	20/05/2015	17/09/2015	6 ♂-7 ♀ (ZMUC)	17/09/2015	24/05/2016	52 ♂-31 ♀ (DZAF-UA)	96
SSD-1 (0.5m)							_			7 ♂-11 ♀ (DZAF-UA)	18
SSD-6	40°48'52.12"N 3°58'20.87"W	1,787	La Pedriza; Navacerrada/Los Cotos; Segovia	Northwest	27/05/2015	22/09/2015	_	22/09/2015	24/05/2016	2 ♂-13 ♀ (DZAF-UA)	15
SSD-7	40°51'12.19"N 3°57'59.95"W	1,994	Majada Hambrienta; Peñalara; Segovia	Northwest	02/06/2015	17/09/2015	1 ♀ (ZMUC)	17/09/2015	28/06/2016	_	1
SSD-8	40°51'20.00"N 3°57'35.65"W	2,071	Majada Aranguez; Peñalara; Segovia	Northwest	02/06/2015	17/09/2015	_	17/09/2015	28/06/2016	4 ♀ (DZAF-UA)	4
SSD-9	40°50'14.60"N 3°57'50.33"W	2,208	Dos Hermanas; Peñalara; Madrid	East	03/06/2015	05/10/2015	1 ♀ (ZMUC)	05/10/2015	28/06/2016	13 ♂-44 ♀-2 juv. (DZAF-UA) 4 ♂-4 ♀ (MNHN) 4 ♂-4 ♀ (MNCN)	76
SSD-10	40°50'22.35"N 3°57'31.01"W	2,049	Hoya de la Laguna Grande; Peñalara; Madrid	East	03/06/2015	05/10/2015	_	05/10/2015	28/06/2016	4 ♂-4 ♀ (DZAF-UA)	8
SSD-11	40°47'28.36"N 4°3'22.64"W	1,876	Cerro Ventoso; Siete Picos - La Maliciosa; Madrid	East	09/06/2015	17/09/2015	1 ♀ (ZMUC)	17/09/2015	24/05/2016	5 ♀ (DZAF-UA)	6
SSD-13	40°46'6.74"N 3°58'20.51"W	2,113	Los Almorchones - Las Buitreras; La Maliciosa; Madrid	Southwest	10/06/2015	22/09/2015	_	22/09/2015	26/05/2016	1 ♀ (DZAF-UA)	1
SSD-15	40°50'58.59"N 3°51'45.24"W	1,375	Hueco de los Ángeles; Altos de la Morcuera; Madrid	Northeast	18/06/2015	05/10/2015	_	05/10/2015	02/06/2016	1 ♂-8 ♀ (DZAF-UA)	9
SSD-23	40°58'42.11"N 3°50'44.00"W	2,144	Circo del Pico Nevero; Montes Carpetanos; Madrid	Sourtheast	25/06/2015	06/10/2015	4 juv (ZMUC)	06/10/2015	13/06/2016	_	4
SSD-28	40°47'43.48"N 3°57'20.81"W	2,156	Collado de Valdemartín; Cuerda Larga; Madrid	North	03/07/2015	06/11/2015	3 ♂-1 ♀- 1 juv. (ZMUC)	06/11/2015	13/07/2016	_	5
SSD-30	40°48'2.32"N 3°54'58.07"W	2,233	Collado de Peña Vaqueros (Loma de Pandasco); Cuerda Larga; Madrid	Crest	03/07/2015	06/11/2015	_	06/11/2015	13/07/2016	4 ♀ (DZAF-UA)	4

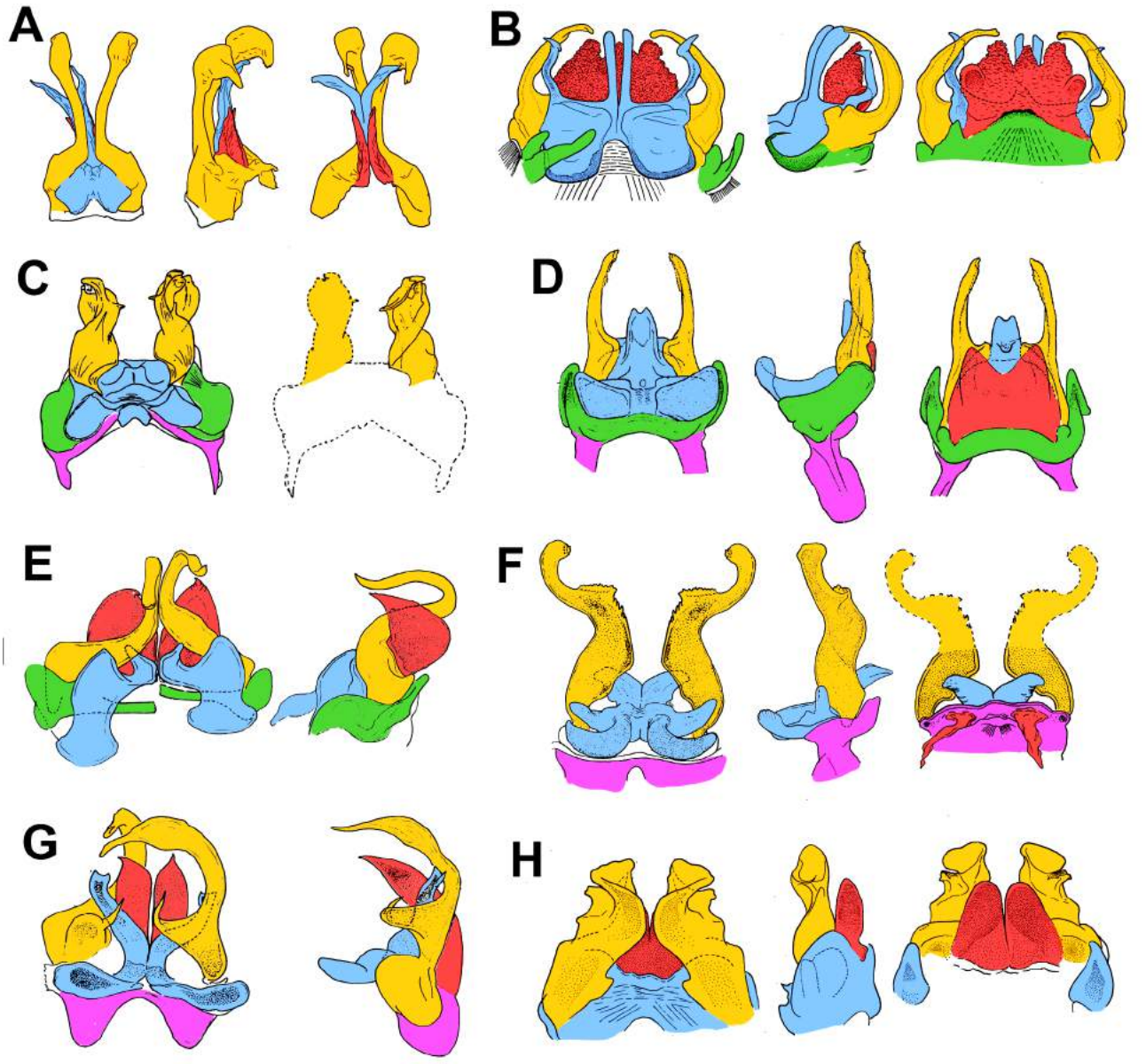

FIGURE 10. Schematic representation of the gonopods of at least one species per genus (but three *Pyreneosoma* species) of Haplobainosomatidae, modified from the drawings of Demange (1970), Mauriès (2010, 2015) and Mauriès & Vicente (1977). A) *Guadarramasoma ramosae* **gen. & sp. nov**. in anterior, right posterolateral and posterior view. B) *Galicisoma biltoni* Mauriès, 2015 in anterior, right lateral and posterior view. C) *Haplobainosoma lusitanum* Verhoeff, 1900 in anterior and posterior view (in the article of Demange -1970- only the tip of telopodite is represented in posterior view). D) *Cantabrosoma serrai* Mauriès & Vicente, 1977 in anterior, right lateral and posterior view. E) *Pyreneosoma bessoni huescanus* Mauriès, 2010 in anterior and right lateral view. F) *P. consoranensis* Mauriès 2010 in anterior, right lateral and posterior view. G) *P. aranensis* Mauriès, 2010 in anterior and right lateral view. H) *Turdulisoma galiciense* Mauriès, 2015 in anterior, right lateral and posterior view. Colours indicate provisional tentative hypothesis of homology based on names given to each structure in their descriptions and our observations: **yellow** = telopodites; **blue** = angiocoxites or synangiocoxite; **red** = colpocoxites; **green** =sternites; **purple** = tracheal pouch ("poche trachéenne" *sensu* Mauriès 2010).

These mountains are also inhabited by numerous endemic arthropods with very different life habits. However, endemicity in mountain areas is particularly pronounced in geophilic species, and examples of Guadarrama endemisms are certain coleopterans of the family Carabidae, such as *Trechus schaufussi pandellei* Putzeys, 1870; *Hypotyphlus guadarramus* (Ehlers, 1883); *Zabrus (Iberozabrus) seidlitzi seidlitzi* Schaum, 1864; *Calathus (Calathus) vuillefroyi* Gautier des Cottes, 1867 (see Serrano 2013); or others of the family Cerambycidae, such as various taxa of *Iberodorcadion* (Breuning, 1943) (see Hernández 2000). Other species of the Sierra de Guadarrama

are also present in other mountains of the Central System, so their endemicity shows a slightly higher range, such as some species of Carabidae as *Carabus (Oreocarabus) ghilianii* Laferté-Sénectère, 1847; *Leistus (Leistus) angusticollis* Dejean, 1826; *Leistus (Leistus) constrictus* Schaufuss, 1862; *Nebria (Nebria) vuillefroyi* Chaudoir, 1866; *Bembidion (Bembidionetolitzkya) gredosanum* (Jeanne, 1974); *Bembidion (Testediolum) carpetanum* Sharp, 1901; *Steropus (Corax) ghilianii* (Putzeys, 1846); *Amara (Leironotus) ooptera* (Putzeys, 1865); *Platyderus montanellus* Graells, 1851; *Platyderus varians Schaufuss*, 1862; *Laemostenus (Eucryptotrichus) pinicola* (Graells, 1851); *Licinus aequatus reymondi* Colas, 1949 and some Cerambycidae as *Vesperus brevicollis* Graells, 1858 (see Vives 2005). Regarding millipedes, *Guadarramasoma ramosae* **gen. & sp. nov.** lives in syntopy with two endemic species of the Central System only found in middle and high altitudes, namely *Archipolydesmus bedeli* (Brölemann, 1902) (see Gilgado *et al.* 2015b) and *Acipes continentalis* Enghoff, 1986 (see Enghoff 1986; Enghoff & Mauriès 1999).

Guadarramasoma ramosae **gen. & sp. nov.** is a new addition to the list of high-altitude Guadarrama endemic arthropods, and its discovery suggests that knowledge of the biodiversity of this national park is far from complete and emphasizes the importance of continuing with the study of the MSS, since it is an environment that harbours numerous species, and even genera, yet to be discovered. It is also possible that future samplings will reveal the presence of this species, or closely related ones, in different mountain areas of the Central System, such as the Sierra de Gredos or the Sierra de Ayllón.

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