

An Updated Overview of the Genus *Eumerus* Meigen, 1822 (Diptera: Syrphidae) in the Iberian Peninsula †

Pablo Aguado-Aranda *, Antonio Ricarte and M^a Ángeles Marcos-García

Research Institute CIBIO (Centro Iberoamericano de la Biodiversidad). Science Park. University of Alicante. Ctra. San Vicente del Raspeig s/n. 03690-San Vicente del Raspeig (Alicante), Spain.

* Correspondence: pablo.aguado@ua.es

† Presented at the 1st International Electronic Conference on Entomology (IECE 2021), 1–15 July 2021; Available online: <https://iece.sciforum.net/>.

Abstract: The genus *Eumerus* Meigen, 1822 (Eristalinae: Merodontini) is one of the most diverse hoverfly genera in the west Palaearctic Region with 89 confirmed species and 77 occurring in the European continent. It is also highly diverse in the Iberian Peninsula plus Balearic Islands with 36 species. Recent descriptions of four new species have increased the number of species endemic to the Iberian Peninsula up to five. Nowadays, taxonomy, distribution and biology of the Iberian *Eumerus* are still far to be fully understood. The aim of this work is to present an updated overview of the *Eumerus* checklist in the Iberian area, addressing main topics pending of resolution in the genus.

Keywords: Eristalinae; Merodontini; diversity; Spain

Citation: Aguado-Aranda, P.; Ricarte, A.; Marcos-García, M.A. An Updated Overview of the Genus *Eumerus* Meigen, 1822 (Diptera: Syrphidae) in the Iberian Peninsula. *Proceedings* **2021**, *68*, x. <https://doi.org/10.3390/xxxxx>

Published: 14 July 2021

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1. General introduction

Hoverflies (Diptera: Syrphidae) constitute a diverse family with more than 6000 described species worldwide [1] which attracted the interest of Spanish entomologists since XIX century [2]. Adults are highly conspicuous and skilled fliers. They feed on nectar and pollen of flowers that they visit regularly. This fact makes them specially important pollinating agents for a big number of plant taxa, both in the wild and cultivated [3]. On the contrary, larvae feed on a great spectrum of organisms like fungus, plant tissues, other insect species and decaying organic matter [3,4]. These interactions reveal the elevated potential of syrphids as bioindicators [5] and their important role in pollination and pest control [6].

The Mediterranean Basin is a hotspot due to the high level of endemism [7,8]. The Iberian Peninsula comprises two biogeographical regions, the Eurosiberian and Mediterranean [9]. The insects represent up to 81% of the total known fauna in the Spanish territory [4]. Recent works indicate that 421 hoverfly species of 72 genera are present in Spain [4]. *Eumerus* has 140 species in the Palaearctic Region and 77 species in Europe [10]. With this account of species, *Eumerus* becomes one of the most diverse hoverfly genera in the Palaearctic. The aim of this work is to provide an updated of the checklist and general outlook of the *Eumerus* biodiversity in the Iberian Peninsula, as well as the main research lines that are being carried out currently by the authors of the present paper.

2. Taxonomy and systematics of *Eumerus*

Eumerus was described by the German entomologist Johann Wilhelm Meigen [11] in order to accommodate species with eyes touching at a point or along a line (in males), a thorax with two white pollinose vittae on the anterior part of the scutum, an elongated abdomen with a pair of lunulate, white-pollinose maculae on terga II-IV and two rows of thin spinae on the ventral half of the metafemora. More than a century later, Stackelberg

[12] performed a review of the Palaearctic species of *Eumerus* and supplied an updated diagnosis of the genus summarized as follows: Medium size, stocky flies with more or less thickened metafemora bearing spinae on the ventral side, a face without protuberances, a usually dark metallic-green body, a more or less reddish abdomen (in some species) but in most species with three pairs of white, half-moon shaped maculae on it and a vein M1 bent inwards. Nowadays, modern identification keys added more diagnostic characters to the diagnosis of the genus such as an arista present at the base of the baso-flagellomere and always bare, a vein R₄₊₅ moderate to strongly sinuate, a cell R₂₊₃ open at wing margin and a tergum V not visible in dorsal view (in males) [3].

Eumerus belongs to the tribe Merodontini Edwards, 1915 of the subfamily Eristalinae Newman, 1834. This tribe represents a monophyletic clade which comprises six genera in total: *Azpeytia* Walker, 1865, *Cepa* Thomson & Vockeroth, 1999 [13,14], *Eumerus*, *Lynneborgimyia* Doczkal & Pape, 2009, *Megatrigen* Johnson, 1898, *Merodon* Meigen, 1803 and *Platynochaetus* Wiedemann, 1830 [15,16]. Nevertheless, it should be noted that Doczkal and Pape [15] did not include the genus *Cepa* in their revision of the Merodontini. The genus *Eumerus* is distinguished from *Azpeytia* by a shorter scutellum and the presence of short extensions on the apical part of vein M [3], from *Cepa* by a short baso-flagellomere that does not exceed twice the length of the scape and the pedicel together [17], from *Lynneborgimyia*, *Merodon* and *Platynochaetus* by the absence of a triangular expansion on the apicoventral part of the metafemur [15] and from *Megatrigen* by the presence of pilosity on the lateral sides of tergum I and the absence of a triangular bare area on tergum II anterolaterally, among others characters [16].

Due to the high species diversity found in the genus, *Eumerus* taxonomy and systematics are complex and difficult. New methodologies such as phylogenetic approaches using molecular markers proved to be a rather useful tool in the framework of species delimitation within this genus. Chroni *et al.* [18] undertook the first species group delimitation in *Eumerus* through molecular characters, revealing the following 'molecular' species groups: (1) *E. basalis* group, (2) *E. minotaurus* group, (3) *E. ornatus* group, (4) *E. pulchellus* group, (5) *E. strigatus* group, (6) *E. sulcitibius* group and (7) *E. tricolor* group. After Chroni *et al.* [18], some species groups have focused the attention of researchers carrying out the morphological diagnoses [19–22] while new groups have been defined, such as the *E. clavatus* group [21]. Despite of the fact that molecular techniques have had a positive contribution in the *Eumerus* systematics, the phylogenetic relationships between most *Eumerus* species are still pending of study.

3. *Eumerus* in the Iberian Peninsula

The first monograph dealing with the Iberian hoverflies was carried out by the Spanish entomologist Juan Gil-Collado [23] who registered 14 species of *Eumerus* from Spain: *E. amoenus* Loew, 1848, *E. barbarus* (Coquebert, 1804) (= *E. australis* Meigen, 1838), *E. caballeroi* Gil-Collado, 1929, *E. grandis* Meigen, 1822 (= *E. annulatus* (Panzer, 1798)), *E. micans* (Fabricius, 1798), *E. nudus* Loew, 1848, *E. ovatus* Loew, 1848, *E. pauper* Becker, 1921, *E. pulchellus* Loew, 1848, *E. ruficornis* Meigen, 1822, *E. sabulonum*. (Fällen, 1817), *E. strigatus* (Fällen, 1817), *E. tarsalis* Loew, 1848 and *E. tricolor* (Fabricius, 1798). In addition, he provided dichotomous identification keys both for males and females of these species.

The most recent checklist of Spanish hoverflies reported the presence of 31 species of *Eumerus* in this country (including Balearic Islands) [4]. In the last years, four new species have been described mainly from the southern Iberian Peninsula: *E. azabense* Ricarte & Marcos-García in Ricarte *et al.* [24], *E. bifurcatus* van Steenis & Hauser in Grković *et al.* [19], *E. gibbosus* van Steenis, Hauser & van Zuijlen, 2017 [25] and *E. grallator* Smit in Grković *et al.* [26]. While *E. azabense*, *E. grallator* and *E. hispanicus* inhabit *Quercus* dehesas or forests, *E. bifurcatus* and *E. gibbosus* are present in pine forests (*Pinus nigra*/*P. halepensis*) [10]. All these findings increased to five the number of endemic species to the Iberian area. *Eumerus truncatus* Rondani, 1868 was recently recorded from Spain as well [25]. At present, the total number of *Eumerus* species from the Iberian Peninsula plus Balearic Islands has

increased up to 36 of nine species groups (see Figure 1) (see Table 1). The reported recent increment in the number of species suggests the need of further research on *Eumerus* taxonomy, distribution and biology in the Iberian Peninsula. In fact, this is particularly urgent for the developmental stages since larva and/or puparium are known only for ten species of those 36 species: *E. alpinus*, *E. etnensis*, *E. funeralis*, *E. hungaricus*, *E. nudus*, *E. obliquus*, *E. pulchellus*, *E. pusillus*, *E. strigatus* and *E. tricolor*. Furthermore, information bias represents a serious problem in order to establish conservation actions for endangered hoverflies. Since some hoverflies have been catalogued in the Spanish Red Lists [27] no research has been conducted yet to determine the conservation status of any of the Iberian *Eumerus*. The vast majority of *Eumerus* species in Europe are greatly associated to a no threatened status, but some species populations, as those of *E. clavatus* Becker, 1923 or *E. ruficornis* Meigen, 1822, are thought to be descending [28]. Therefore, an extensive assessment of the conservation status of the Iberian *Eumerus* is required to better understand their actual threaten situation in this geographic region and design conservation plans if necessary.

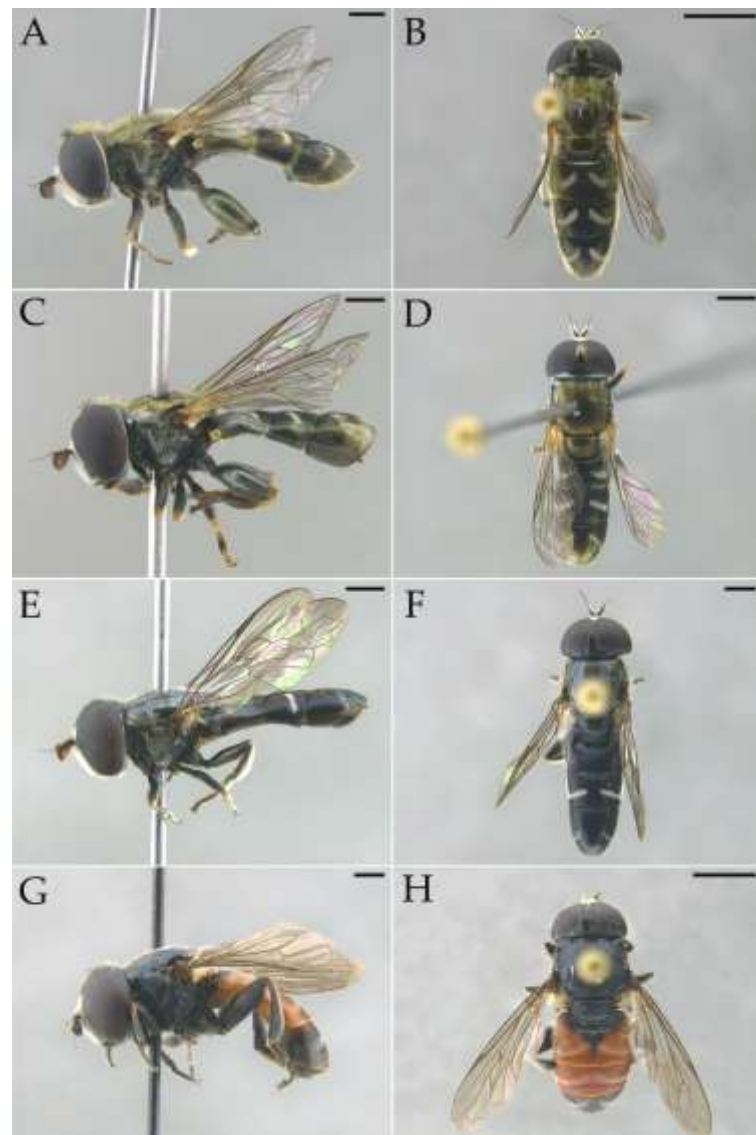


Figure 1. Representatives of Iberian species of *Eumerus*: *E. barbarus* (male) (A) Lateral view; (B) Dorsal view; *E. pusillus* (male) (C) Lateral view; (D) Dorsal view; *E. argyropus* (male) (E) Lateral view; (F) Dorsal view; *E. tricolor* (male) (G) Dorsal view; (F) Lateral view. Scale bars = (A, D-G) 1 mm; (B, H) 2 mm; (C) 750 μ m.

Table 1. Iberian-Balearic species of the genus *Eumerus* organised in species groups according to current literature. Individual species are those that are not affiliated with any group so far.

Group	Species
<i>E. barbarus</i>	<i>E. barbarus</i> (Coquebert, 1804)
	<i>E. gibbosus</i> van Steenis, Hauser & van Zuijen, 2017
	<i>E. sulcitibius</i> Rondani, 1868
<i>E. basalis</i>	<i>E. pusillus</i> Loew, 1848
<i>E. clavatus</i>	<i>E. clavatus</i> Becker, 1923
<i>E. obliquus</i>	<i>E. obliquus</i> (Fabricius, 1805)
<i>E. olivaceus</i>	<i>E. alpinus</i> Rondani, 1868
	<i>E. caballeroi</i> Gil-Collado, 1929
	<i>E. nudus</i> Loew, 1848
<i>E. ornatus</i>	<i>E. argyropus</i> Loew, 1848
	<i>E. flavitarsis</i> Zetterstedt, 1843
	<i>E. ornatus</i> Meigen, 1822
	<i>E. subornatus</i> Claussen, 1989
<i>E. pulchellus</i>	<i>E. emarginatus</i> Loew, 1848
	<i>E. pulchellus</i> Loew, 1848
<i>E. strigatus</i>	<i>E. amoenus</i> Loew, 1848
	<i>E. bifurcatus</i> van Steenis & Hauser in Grković <i>et al.</i> (2019)
	<i>E. consimilis</i> Šimić & Vujić, 1996
	<i>E. funeralis</i> Meigen, 1822
	<i>E. pauper</i> Becker, 1921
	<i>E. sogdianus</i> Stackelberg, 1952
<i>E. tricolor</i>	<i>E. strigatus</i> (Fallén, 1817)
	<i>E. azabense</i> Ricarte & Marcos-García in Ricarte <i>et al.</i> (2018)
	<i>E. gallator</i> Smit in Grković <i>et al.</i> (2019)
	<i>E. grandis</i> Meigen, 1822
	<i>E. hispanicus</i> van der Goot, 1966
	<i>E. ovatus</i> Loew, 1848
	<i>E. tarsalis</i> Loew, 1848
	<i>E. sabulonum</i> (Fallén, 1817)
	<i>E. tricolor</i> (Fabricius, 1798)
Individual species	<i>E. bayardi</i> Séguy, 1961
	<i>E. etnensis</i> van der Goot, 1964
	<i>E. hungaricus</i> Szilády, 1940
	<i>E. purpurariae</i> Báez, 1982
	<i>E. ruficornis</i> Meigen, 1822
	<i>E. truncatus</i> Rondani, 1868

4. Current research lines and future in the research of Iberian *Eumerus*

The first research line involves the taxonomic and systematic revision of species groups of *Eumerus*. Our ongoing research is focused on the *E. barbarus* and *E. olivaceus* groups. The first one has four species in the Western Mediterranean Basin: *E. barbarus*, *E. gibbosus*, *E. schmidegeri* van Steenis, Hauser & van Zuijen, 2017 and *E. sulcitibius*. However, preliminary results indicate that other undescribed species might also be involved in this group [22]. While *E. barbarus*, *E. gibbosus* and *E. sulcitibius* are present in the Iberian Peninsula (see Table 1), *E. schmidegeri* is restricted to Algeria, Morocco and Tunisia. *Eumerus barbarus* group was revised by van Steenis *et al.* [25] provided identifications keys both for males and females of all the species. Nevertheless, they did not test the monophyly of the group using neither morphological characters nor molecular data. *Eumerus olivaceus* group was proposed by Grković [22] and has three species: *E. alpinus*, *E. nudus* and *E. olivaceus* Loew, 1848. The first two species are present in the Iberian Peninsula (see

Table 1) while *E. olivaceus* is endemic to Sicily. Grković *et al.* [29] revised the holotype of *E. alpinus* together with type material of *E. olivaceus*. In their work, they concluded that *E. alpinus* is a valid species excluding it from the synonym list of *E. olivaceus*. However, they did not provide a list of morphological differences nor illustrated the male genitalia of *E. olivaceus* in comparison with the male genitalia of *E. alpinus* [30]. In addition, as with the *E. barbarus* group, the monophyly of the *E. olivaceus* group was not tested either. We aim to explore the species concepts and the monophyly of these groups assessing molecular data, as sequences of the mitochondrial COI-5' region and other nuclear or mitochondrial genes if necessary, together with morphological characters. The analyses of robust phylogenetic and morphological trees will let to perform much more accurate species delimitation, over all, if we are dealing with possible cryptic species. On the other hand, taxonomic and systematic research on *Eumerus* is mainly based on male specimens. In males, one of the most diagnostic body parts for species delimitation is the morphology of the genitalia. Nevertheless, female genitalia are not as accessible as that of male. Moreover, *Eumerus* females exhibit external characters which show a great spectrum of phenotypic variation. These facts make difficult species delimitations based on females only and aggravated if we are dealing with possible cryptic species. Therefore, we aim to carry out an extensive review of the Iberian *Eumerus* in order to provide reliable and precise identification keys for males but also females.

The second research line entails the construction of a barcode sequence library of the Iberian representatives of *Eumerus*. We commented in the second section of this work that DNA sequences have proven useful for species delimitation in *Eumerus*. Unfortunately, the number of molecular data available on public databases as BOLD [31] or GenBank is rather limited as there are only data of a few species. This fact involves that genetic diversity of the Iberian *Eumerus* is almost unknown which is not the case for other Mediterranean areas like Greece [32]. A reference barcode library is useful for future research involving the identification of larva and/or adult stages of *Eumerus*. Furthermore, supplying DNA sequences of Iberian *Eumerus* will allow having a comprehensive knowledge about the genetic diversity of *Eumerus* in future taxonomic and systematic studies.

The third research line aims to carry out an analysis of the distribution of the genus *Eumerus* in the Iberian Peninsula. Since the hoverfly faunas of some Iberian regions have been well studied, others are poorly known. In the case of the Iberian *Eumerus*, while some species as *E. amoenus* are present in several areas, others like *E. azabense*, *E. bifurcatus* or *E. clavatus* are restricted to one area [4]. The potential new records of *Eumerus* species in areas where species diversity is underestimated will mitigate the negative effect of information bias about the distribution ranges in the Iberian region. In addition, updating the species distributions would enable the assessment of the conservation status of *Eumerus* species more accurately. This is particularly important for those species that are endemic to the Iberian Peninsula or whose distributions are restricted to a limited area.

Finally, the last research line is focused on the early stages of the Iberian *Eumerus*. *Eumerus* larvae feed on decaying plant tissues or underground storage organs such as bulbs. That is the reason why some species are considered pests like *E. funeralis* or *E. strigatus*, causing agricultural damage and economic loss [33]. Despite their important role in ecosystems, the developmental stages are known only for 13 *Eumerus* species worldwide [33] of which 10 are present in the Iberian territory (see section 3). We aim to perform samplings of *Eumerus* larvae, for instance, in *Amaryllidaceae* or *Xanthorrhoeaceae* plants [34], in order to complete the knowledge about the life cycles and the trophic requirements for the larval stages of the Iberian *Eumerus*.

Funding: This research is part of Pablo Aguado-Aranda's PhD thesis (Ref. PRE2019-087508) and is funded by the 'Fauna Ibérica' project (Ref. PGC2018-095851-A-C65), 'Ministerio de Ciencia e Innovación', Spain; Antonio Ricarte's position at the University of Alicante (Ref. UATALENTO17-08) is funded by the 'Vicerrectorado de Investigación y Transferencia del Conocimiento'.

Conflicts of Interest: The authors declare no conflict of interest.

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