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Present and future of the knowledge about the genus *Eumerus* Meigen, 1822 (Diptera: Syrphidae) in the Iberian Peninsula

Presente y futuro del conocimiento sobre el género *Eumerus* Meigen, 1822 (Diptera: Syrphidae) en la Península Ibérica

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ABSTRACT

The genus *Eumerus* Meigen, 1822 (Diptera: Syrphidae) is one of the most diverse hoverfly genera in the west Palaearctic Region with 140 confirmed species and 80 occurring in the European continent. It is also highly diverse in the Iberian Peninsula plus the Balearic and Canary Islands with 43 species. Recent works on this genus have increased the number of species endemic to the Iberian Peninsula up to five. Nowadays, taxonomy, distribution and biology of the Iberian *Eumerus* taxonomy are still far to be fully understood. The aim of this work is to present an updated overview of the *Eumerus* taxonomy and diversity in the Iberian area, addressing main topics pending of resolution in the genus.

Keywords: *Diptera; Syrphidae; Eumerus; diversity; Spain.*

RESUMEN

El género *Eumerus* Meigen, 1822 (Diptera: Syrphidae) es uno de los géneros de sírfidos más diversos en la Región Paleártica con 140 especies confirmadas y 80 presentes en el continente Europeo. Es también muy diverso en la Península Ibérica e Islas Baleares y Canarias con 43 especies. Recientes publicaciones sobre este género han aumentado a cinco el número de especies endémicas para la Península Ibérica. En la actualidad, la taxonomía, distribución y biología de los *Eumerus* ibéricos están lejos de ser comprendidas completamente. El objetivo de este trabajo es presentar una visión actualizada de la taxonomía y diversidad de *Eumerus* en el área Ibérica, enfocando los principales temas pendientes de ser resueltos en este género.

Palabras clave: *Diptera; Syrphidae; Eumerus; diversidad; España.*

GENERAL INTRODUCTION

Hoverflies (Diptera: Syrphidae) constitute a diverse family with more than 6000 described species worldwide (Rotheray & Gilbert, 2011). 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 high number of plant taxa, both in the wild and cultivated (Thompson & Rotheray, 1998). On the contrary, larvae feed on a great spectrum of organisms like fungus, plant tissues, other insect species and decaying organic matter (Ricarte & Marcos-García, 2017; Thompson & Rotheray, 1998). These interactions reveal the elevated potential of syrphids as bioindicators (Sommaggio, 1999) and their important role in pollination and pest control (Bellefeuille *et al.*, 2019).

The Iberian Peninsula comprises two biogeographical regions, the Eurosiberian and Mediterranean (Rivas-Martínez *et al.*, 2014). The insects represent up to 81% of the total known fauna in the Spanish territory (Ricarte & Marcos-García, 2017). Recent works indicate that 421 hoverfly species of 72 genera are present in Spain (Ricarte & Marcos-García, 2017). *Eumerus* Meigen, 1822 comprises +250 known valid species in the world (Souba-Dols *et al.*, 2020). It has 140 species in the Palaearctic Region (Peck, 1988) and 80 species in Europe (Grković *et al.*, 2021; Speight, 2020). 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 view of the genus *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.

TAXONOMY AND SYSTEMATICS OF *EUMERUS*

Eumerus was described by the German entomologist Johann Wilhelm Meigen (1822) 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 (1961) 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, an 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 wing 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 basoflagellomere and always bare, a wing 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) (Thompson & Rotheray, 1998).

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* Thompson & Vockeroth, 1999 (Barahona-Segovia & Barceló, 2019; Thompson, 1999), *Eumerus*, *Lyneborgimyia* Doczkal & Pape, 2009, *Megatrigon* Johnson, 1898, *Merodon* Meigen, 1803 and *Platynochaetus* Wiedemann, 1830 (Doczkal & Pape, 2009; Doczkal *et al.*, 2016). Nevertheless, it should be noted that Doczkal and Pape did not include the genus *Cepa* in their revision of the Merodontini (Doczkal & Pape, 2009). The genus *Eumerus* is distinguished from *Azpeytia* by a shorter scutellum and the presence of short extensions on the apical part of vein M (Thompson & Rotheray, 1998), from *Cepa* by a short basoflagellomere that does not exceed twice the length of the scape and the pedicel together (Parada-Marín *et al.*, 2021), from *Lyneborgimyia, Merodon* and *Platynochaetus* by the absence of a triangular expansion on the apicoventral part of the metafemur (Doczkal & Pape, 2009) and from *Megatrigon* 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 (Doczkal *et al.*, 2016).

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.* (2017) undertook the first species group delimitation in *Eumerus* through molecular characters, revealing the following 'molecular' species groups: (1) *E. basalis*, (2) *E. minotaurus*, (3) *E. ornatus*, (4) *E. pulchellus*, (5) *E. strigatus*, (6) *E. sulcitibius* and (7) *E. tricolor* group. After Chroni *et al.* (2017), some species groups have focused the attention of researchers carrying out the morphological diagnoses (Chroni *et al.*, 2018; Grković *et al.*, 2017: Grković, 2018; Grković *et al.*, 2019a; Grković *et al.*, 2019b; Grković *et al.*, 2021) while new groups have been defined, such as the *E. clavatus* group (Grković *et al.*, 2017). These works have contributed to better understand the diversity and distribution of the species of *Eumerus* in the Eastern Mediterranean Region. 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.

EUMERUS IN THE IBERIAN PENINSULA

The first monograph dealing with the Iberian hoverflies was carried out by the Spanish entomologist Juan Gil Collado (Gil Collado, 1930) who reported 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. bayardi* Séguy, 1961 (= *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* (Fállen, 1817), *E. strigatus* (Fallén, 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, but he did not illustrate the male genitalia of any species.

The most recent checklist of Spanish hoverflies reported the presence of 39 *Eumerus* species in this country (including Balearic and Canary Islands) (Ricarte & Marcos-García, 2017). In the last years, four new endemic species have been described mainly from the southern Iberian Peninsula (Grković *et al.*, 2019a; Grković *et al.*, 2019b; Ricarte *et al.*, 2018; van Steenis *et al.*, 2017). While *E. azabense* Ricarte & Marcos-García *in* Ricarte *et al.*, 2018, *E. grallator* Smit *in* Grković *et al.*, 2019a and *E. hispanicus* van der Goot, 1966 inhabit *Quercus* forests (including dehesas), *E. bifurcatus* van Steenis & Hauser *in* Grković *et al.*, 2019b and *E. gibbosus* van Steenis, Hauser & van Zuijen, 2017 are present in pine forests (*Pinus nigra/P. halepensis*) (Speight, 2020). All these findings increased to five the number of endemic species to the Iberian mainland area (see Table 1). At present, the total number of *Eumerus* species from the Iberian Peninsula plus Balearic and Canary Islands has increased up to 43 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 43 species: *E. alpinus* Rondani, 1857, *E. etnensis* van der Goot, 1964, *E. funeralis* Meigen, 1822, *E. hungaricus* Szilády, 1940, *E. nudus*, *E. obliquus* (Fabricius, 1805), *E. pulchellus*, *E. pusillus* Loew, 1848, *E. strigatus* and *E. tricolor*.

Furthermore, information bias (distribution ranges, life cycles and developmental stages) represents a serious problem in order to establish conservation actions for endangered hoverflies. The conservation status of all European *Eumerus* were evaluated recently and 19 species under one of the threatened IUCN categories are present in the Iberian Peninsula (IUCN, 2022) (see Table 1). Therefore, it is required to design conservation plans for these species in order to prevent their disappearance in the future.

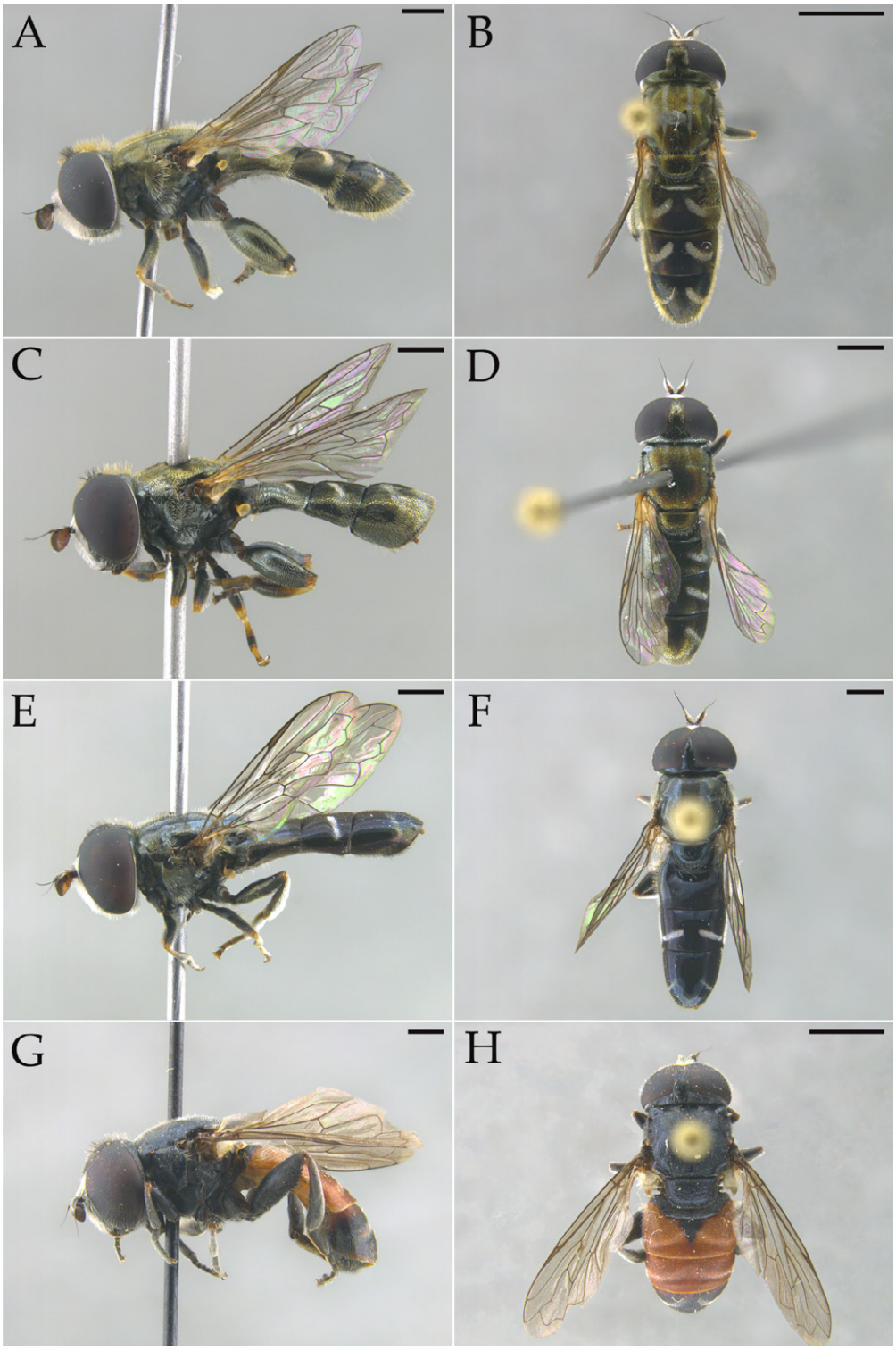

Figure 1: Representatives of Iberian species groups of *Eumerus*: *E. barbarus* (male) (A) Lateral view; (B) Dorsal view; *E. pusillus* (male) (C) Lateral view; (D) Dorsal view; *E. argyropus* (male) (E) Lateral view; (F) Dorsal view; *E. tricolor* (male) (G) Dorsal view; (F) Lateral view. Scale bars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

Table 1: Iberian 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. Mainland Iberian-endemic species are highlighted in bold. Legend: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Vulnerable (VU), Endangered (EN), Critically Endangered (CR).

Group	Species	IUCN Red List category
E. barbarus	*E. barbarus* (Coquebert, 1804)	LC
	***E. gibbosus* van Steenis, Hauser & van Zuijen, 2017**	EN
	E. sulcitibius Rondani, 1868	LC
E. basalis	*E. pusillus* Loew, 1848	LC
E. clavatus	*E. clavatus* Becker, 1923	LC
E. obliquus	*E. obliquus* (Fabricius, 1805)	LC
E. olivaceus	*E. alpinus* Rondani, 1857	LC
	E. caballeroi Gil Collado, 1929	NE
	E. nudus Loew, 1848	LC
E. ornatus	*E. argyropus* Loew, 1848	LC
	E. flavitarsis Zetterstedt, 1843	LC
	E. ornatus Meigen, 1822	LC
	E. subornatus Claussen, 1989	EN
E. pulchellus	*E. emarginatus* Loew, 1848	NE
	E. pulchellus Loew, 1848	LC
E. strigatus	*E. amoenus* Loew, 1848	LC
	***E. bifurcatus* van Steenis & Hauser *in* Grković *et al.*, 2019b**	CR
	E. consimilis Šimić & Vujić, 1996	LC
	E. funeralis Meigen, 1822	LC
	E. pauper Becker, 1921	DD
	E. sogdianus Stackelberg, 1952	LC
	E. strigatus (Fallén, 1817)	LC
E. tricolor	***E. azabense* Ricarte & Marcos-García *in* Ricarte *et al.*, 2018**	CR
	E. etnensis van der Goot, 1964[(1)]	VU
	***E. grallator* Smit *in* Grković *et al.*, 2019a**	VU
	E. grandis Meigen, 1822	LC
	***E. hispanicus* van der Goot, 1966**	VU
	E. ovatus Loew, 1848	EN

E. tricolor	*E. tarsalis* Loew, 1848	EN
	E. sabulonum (Fallén, 1817)	LC
	E. tricolor (Fabricius, 1798)	LC
Individual species	*E. bayardi* Séguy, 1961	NE
	E. canariensis Báez, 1982	EN
	E. dubius Báez, 1982	EN
	E. hungaricus Szilády, 1940	EN
	E. latitarsis Macquart *in* Webb & Berthelot, 1839	VU
	E. nivariae Báez, 1982	CR
	E. purpurariae Báez, 1982	EN
	E. purpureus Macquart *in* Webb & Berthelot, 1839	VU
	E. ruficornis Meigen, 1822	EN
	E. santosabreui Báez, 1982	EN
	E. terminalis Santos Abréu, 1924	NE
	E. truncatus Rondani, 1868	EN

(1) According to Grković *et al.* (2021), this species belongs to the *E. tricolor* group but its systematic position together with that of similar species are still pending to be solved.

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*. The *Eumerus barbarus* group has four species in the Western Mediterranean Basin: *E. barbarus, E. gibbosus, E. schmideggeri* van Steenis, Hauser & van Zuijen, 2017 and *E. sulcitibius*. However, preliminary results indicate that other undescribed species might also be involved in this group (Grković, 2018). While *E. barbarus, E. gibbosus* and *E. sulcitibius* are present in the Iberian Peninsula (see Table 1), *E. schmideggeri* is restricted to Algeria, Morocco and Tunisia. *Eumerus barbarus* group was revised by van Steenis *et al.* (2017), who provided identification 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 (2018) and includes 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.* (2015) 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* (Vujić & Šimić, 1998). 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 (Ratnasingham & Hebert, 2007) 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 (Chroni *et al.*, 2019). 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. Nowadays, 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 (Ricarte & Marcos-García, 2017). 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 (Souba-Dols *et al.*, 2020). Despite their important role in ecosystems, the developmental stages are known only for 13 *Eumerus* species worldwide (Souba-Dols *et al.*, 2020) of which 10 are present in the Iberian territory. We aim to perform samplings of *Eumerus* larvae, for instance, in *Amaryllidaceae* or *Xanthorrhoeaceae* plants (Ricarte *et al.*, 2017), in order to complete the knowledge about the life cycles and the trophic requirements for the larval stages of the Iberian *Eumerus*.

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