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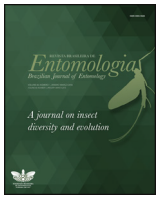

New geographical records and key to the species of *Eumerus* Meigen, 1823 (Diptera, Syrphidae) introduced into the Americas and Hawaii

Bolívar R. Garcete-Barrett[1,2], Mírian N. Morales[3], Martin Hauser[4], John T. Smit[5], Luis González[6], María Bernarda Ramírez De López[6], Osmar Arias[6], Marcial Adorno[6], Gerald Sormanti[6], Adriana Mereles[6]

[1] *Museo Nacional de Historia Natural del Paraguay, San Lorenzo, Paraguay.*
[2] *Universidad Nacional de Asunción, Facultad de Ciencias Exactas y Naturales, Departamento de Biología c/o Dirección de Investigación, San Lorenzo, Paraguay.*
[3] *Universidade Federal de Lavras, Departamento de Entomologia, Lavras, MG, Brasil.*
[4] *California Department of Food and Agriculture, Plant Pest Diagnostics, Sacramento, USA.*
[5] *European Invertebrate Survey - the Netherlands, Naturalis Biodiversity Center, Leiden, the Netherlands.*
[6] *Universidad Nacional de Asunción, Facultad de Ciencias Agrarias, Departamento de Protección Vegetal, Carrera de Ingeniería Agronómica, San Lorenzo, Paraguay.*

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ABSTRACT

Eumerus Meigen, 1823 is a very speciose genus of flower flies from the Eastern Hemisphere. Several reports of introduced species of this genus in the Americas have been recorded since early in the twentieth century, with a present list of six species recorded to date from the Americas and the US territory of Hawaii. In this paper we give new geographical records for the African-native species *Eumerus obliquus* (Fabricius, 1805), which reflect the expansion of this fly through Brazil and Paraguay along the last twenty years. At the same time, we report a second species from Paraguay, *Eumerus aurifrons* (Wiedemann, 1824), being this the first Western Hemisphere record for this Asian-native species. We finally provide an identification key to all of the species of *Eumerus* presently known from the Americas and Hawaii.

Introduction

Eumerus Meigen, 1822, is one of the largest genera of flower flies (Diptera: Syrphidae), including nearly 300 species currently recognized (Thompson, 2018). It is primarily distributed throughout the Old World, with most of its species naturally occurring in the Palearctic (over 170 spp.) and Afrotropical (77 spp.) regions (Peck, 1988; Kuznetzov, 1992; Whittington, 2003; Speight et al., 2013; Grković et al., 2015; Ricarte et al., 2017).

The genus belongs to the tribe Merodontini (Eristalinae) (Young et al., 2016), and unlike most Eristalinae whose larvae are mainly saprophagous, species of *Eumerus* and few other genera (*e.g.: Alipumilio* Shannon, *Cheilosia* Meigen, *Merodon* Meigen, *Portevinia* Goffe) are phytophagous. There are records of *Eumerus* larvae feeding on living bulbs, tubers, stems, rhizomes, and decaying vegetal tissue (Ricarte et al., 2017, and references therein).

Because of their feeding behavior, associated with commercialized plants, some species have been unintentionally transported by human trade outside their natural ranges and are now causing damage to crops in their new range. In the Americas four species have been introduced so far, three from the Nearctic region: *Eumerus funeralis* Meigen, *E. narcissi* Smith and *E. strigatus* (Fallén) (Johnson, 1910; Gibson, 1917; Jones, 1917; Weiss and Nicolay, 1919; Mackie, 1922; Smith, 1928; Wirth et al., 1965; Miranda et al., 2013; Speight et al., 2013). Two of those species have also been introduced in the neotropics: *E. funeralis*

* Corresponding author.
E-mail: john.smit@naturalis.nl (J.T. Smit).

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was recorded from Colombia (Thompson et al., 1976; Montoya, 2016), and *E. strigatus* from Chile (Gerding et al., 1999). The fourth species, *E. obliquus* (Fabricius), has been recorded from Brazil (Marinoni and Morales, 2007; Morales and Marinoni, 2019) Additionally two species have been recorded from Hawaii: *Eumerus aurifrons* (Wiedemann) and *E. figurans* Walker (Fullaway and Krauss, 1945; Carter, 1968; Asquith and Messing, 1993).

Recent fieldwork in Paraguay yielded material of two species of *Eumerus* (Figs. 1 and 2), extending the known distribution of *E. obliquus* within South America from Brazil into Paraguay and representing the first record of *E. aurifrons* for South America. During 2016 and 2017 the FCAPY carried out an insect fauna inventory on bean plots (*Phaseolus vulgaris* L.) at the locality of Choré, San Pedro, Paraguay. The plots were surrounded by small fragments of the semideciduous inner Atlantic forest, which dominated most of Eastern Paraguay decades ago. Yellow pan traps were the selected method and a number of *Eumerus* specimens, belonging to two different species, were collected. Additional specimens have been found in 2018 at Ybycui National Park, placed about 200 km away from the previous locality and mainly covered with semideciduous inner Atlantic forest.

Here we present the new data from Paraguay, provide distribution of *Eumerus obliquus* in South America over time, record *E. aurifrons* for the Americas for the first time, illustrate the most salient morphological differences between these species and give an identification key to the six introduced species in the Americas and Hawaii.

Material and methods

The following acronyms are herein used for depositary scientific institutions of the listed material:

CCT-UFMG: Centro de Coleções Taxonômicas, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil.

CEUFLA: Coleção Entomológica da Universidade Federal de Lavras, Lavras, MG, Brazil.

DZUB: Coleção Entomológica do Departamento de Zoologia, Instituto de Ciências Biológicas da Universidade de Brasília, Brasília, DF, Brazil.

DZUP: Coleção Entomológica Pe. Jesus Santiago Moure, Universidade Federal do Paraná, Curitiba, PR, Brazil.

FCAPY: Facultad de Ciencias Agrarias, Universidad Nacional de Asunción, San Lorenzo, Paraguay

LACM: Los Angeles County Museum, Los Angeles, California, USA.

MNHN: Muséum National d'Histoire Naturelle, Paris, France.

MNHNPY: Museo Nacional de Historia Natural del Paraguay, San Lorenzo, Paraguay.

NMB: Naturhistorisches Museum Basel, Basel, Switzerland.

RMNH: Naturalis Biodiversity Center, Leiden, the Netherlands.

ZMUC: Zoological Museum, University of Copenhagen, Copenhagen, Denmark.

Results

Eumerus obliquus (Fabricius)

Milesia obliqua Fabricius, 1805 (Holotype ZMUC00026496: http://daim.snm.ku.dk/digitized-type-collection-details-simple?catno=zmuc00026496). Type locality: "Guinea".

Eumerus cilitarsis Loew, 1848. Type-locality: "angeblich Oestreich" (Austria).

Eumerus crassitarsis Costa, 1885: Rendiconto dell' Accademia delle Scienze Fisiche e Matematiche, Napoli, 23(12): 173 and Atti della Reale Accademia delle Scienze Fisiche e Matematiche di Napoli, (2a) 2(13): 30 and Bollettino della Società Entomologica Italiana, 17(1885): 254 (*Eumerus*). Type-localities: "vicinanze di Oristano e ... campagna di Samassi" [= Oristano and Samaxis: Sardinia] (Italy).

Eumerus lugens Wiedemann, 1830. Type-locality: "Sct. Helena"

Distribution: AFRICA: Angola, Cape Verde Islands, Ghana, Guinea-Bissau, Kenya, Madagascar, Mauritius, Nigeria, Rhodesia, St. Helena, Senegal, Sierra Leone, South Africa, Tanzamia, Uganda, Zaire; EUROPE: Canary Islands, Corfu, Sardinia; MIDDLE EAST: Yemen; OCEANIA: Australia; SOUTH AMERICA: Brazil, Paraguay* (Paramonov, 1957; Peck, 1988; Barkemeyer, 2002; Marinoni and Morales, 2007; Grković et al., 2015; Thompson and Vockeroth, 2016; Ricarte et al., 2017; Smit et al., 2017).

Material examined: PARAGUAY: San Pedro: Choré, XII.2016–I.2017, from beans plot (*FCA*) [8 females and 5 males: MNHNPY; 8 females and 5 males: FCAPY; 1 female and 1 male: CEUFLA]; Santa Rosa, Laguna Blanca, 23°48'00.2" S 56°17'27.3", W 8.I–29.I.2011, mainly from cerrado vegetation [8 females and 7 males: RMNH]; Paraguarí: Parque Nacional Ybycuí, 18.VIII.2018 (*B. Garcete*) [1 female and 3 males: MNHNPY]. BRAZIL: Paraná: Morretes, 24.II.1990, Zanella, F. leg [1 male, DZUP]; Minas Gerais: Belo Horizonte, Estação Ecológica UFMG. 17.VI.1998. D. Yanega (col.), UFMG idi 1300011 [1 male: CCT-UFMG]; nr. Timoteo, 15.-31.Mar.1999, Eurico R. DePaula [1 male: LACM]; Ingaí, Reserva Biológica do Boqueirão, ~1050-1059m, 20.VII.2013, 21º20'44"S / 44º59'29"W., M.N.Morales (leg.) [1 female: CEUFLA]; Lavras, campus UFLA, 21°13'58"S / 044°59'39"W, 842m, leg. A. Ssymank, 08.IX.2017 [2 females: CEUFLA]; Mato Grosso do Sul: Dourados, Fazenda Coqueiro, 18.II.2009, 22º12'S / 54º54'W, 438m, Grossi & Parizotto cols. [1 female: CEUFLA]; Distrito Federal: Gama, XI.2016, Savino AG (col.), 15°59'15.5"S / 48°06'10.5"W, Malaise trap [1 male: DZUB].

Illustrations: Both female (Fig. 1A) and male (Fig. 1B) are illustrated. Characters to separate it from *Eumerus aurfrons* are the abdominal pattern, (Fig. 1C), as well as the pattern of mesonotal pollinosity (Fig. 2A). Males have the eyes holoptic (Fig. 2B) and the hind tarsus is laterally compressed (Fig. 2C). In the female the scutellar rim is not serrate (Fig. 1D).

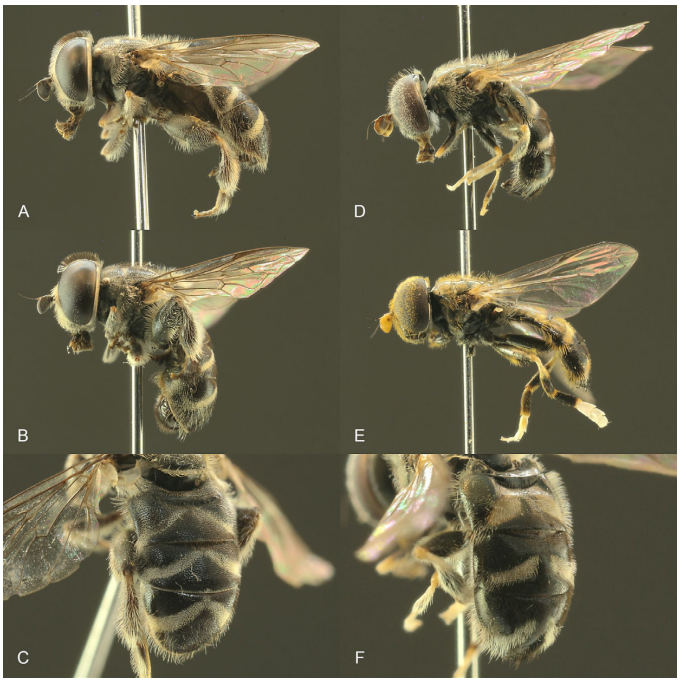

Figure 1. *Eumerus* species. A–C *Eumerus obliquus* (Fabricius). D–F *Eumerus aurifrons* (Wiedemann). A, C, D, F Female. B, E Male. A, B, D, E Habitus. C, F Abdomen in latero-dorsal view.

Comments: The original description by Fabricius (1805: 194) establishes the provenance of the type material: "*Habitat in Guinea Mus. Dom. Lund*". According to Zimsen (1964), Tønder Lund's collection was one of the most important ones studied by Fabricius. Tønder Lund and his pupil Ove Sehested held high posts in the Civil Service of Denmark and amassed an important joint collection of insects through their official contacts in the Danish colonies in Guinea (Africa), Tranquebar (India) and the West Indies (Insular Central America). At that time, Denmark held some colonial settlements (collectively known as *Danske Gulkyst* or *Dansk Guinea*), which endured from 1661 to 1850, along the coast of what is now Ghana (Weiss, 2013), so we can effectively affirm that Lund's specimens from "Guinea" came from present day Ghana. Lyneborg et al. (2015) further restricted the type locality to the city of Teshie.

In Loew's (1848: 120) description of *E. cilitarsis* it reads "angeblich Oestreich" [="supposedly Austria"], and he added: "ich erhielt in derselben Sendung und unter derselben Vaterlandsangabe einige brasilianische Insekten, kann also die Richtigkeit derselben nicht verbürgen; die Nadel glich denen, mit welchen mehrere der notorisch europäischen Insekten gespiesst waren." [= "I have received in the same shipment and under the same country name some Brazilian insects, so I cannot guarantee the correctness [of the origin]; the pin resembled those with which many of the notorious European insects were pinned"]. Loew received the specimen, which he described as *E. cilitarsis*, together with some Brazilian and some European species - all of them supposed to be from Austria. The pin resembled the European specimens but recognizing that this is a mixed batch of species from different parts of the world, he had some doubts about the origin of this specimen. He did not mention from whom he received the insects and what other species were in the shipment and therefore we can only speculate about the material. It is more than likely that the material was not well labeled, and it represented a collection of mixed origin, including at least Brazilian and European material. It is very unlikely that the holotype of *E. cilitarsis* was collected in Austria, and it is also very unlikely that this species was collected in Brazil, where it is not native. The most likely explanation is that the specimen came from Africa without having a label, and it was given by an insect collector to Loew together with some other insects (likely Diptera).

Since the oldest collecting record in Brazil (1990 in Morretes, State of Paraná), this species has been spreading 700 km eastward and 1000 km northward across Brazil and entering Paraguay, where it was found as early as 2011, as far as collecting records had shown (Fig. 3).

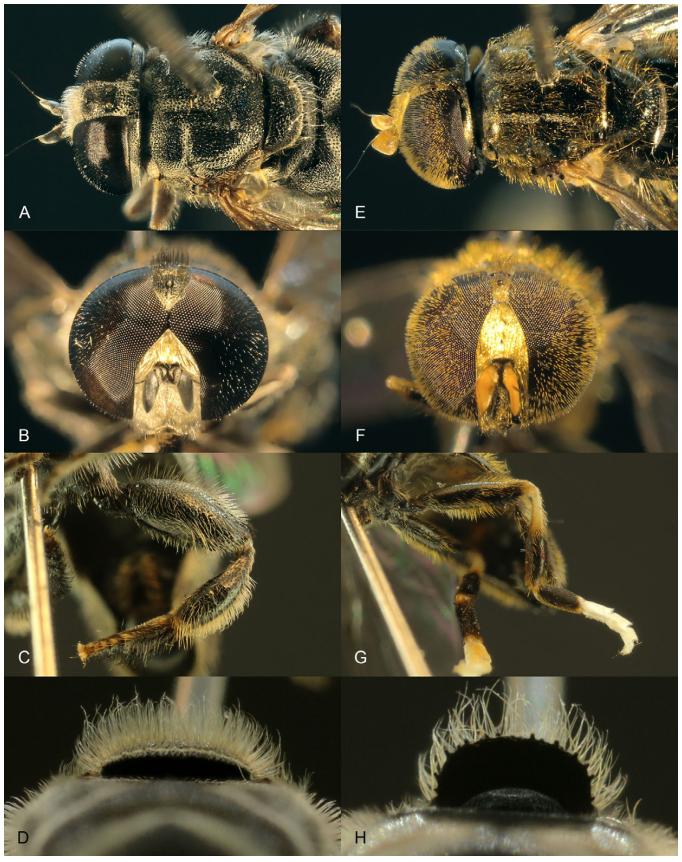

Figure 2. A–H. *Eumerus* species. A–D *Eumerus obliquus* (Fabricius). E–H *Eumerus aurifrons* (Wiedemann). A, D, H Female. B, C, E–G Male. A, E Head and thorax in dorsal view. B, F Head in frontal view. C, G Hind leg in anterior view. D, H Scutellum in postero-ventral view.

Eumerus aurifrons (Wiedemann)

Pipiza aurifrons Wiedemann, 1824. Type locality: 'W. India' (Lectotype ZMUC00024836: http://daim.snm.ku.dk/digitized-type-collection-details?catno=zmuc00024836).

Eumerus albipes Keiser, 1971. Type locality: Madagascar, Nosy Be, Ambanoro. Holotype, male: 'Nosy Be: Ambanoro, 15.5.58 (F. Keiser)' (MNHN - Paris ?); Paratypes, 3 females (NMB); 'Ost-Madagaskar: Mananjary (Fia.), 6.viii.58, Ile Saint-Marie. (F. Keiser)' (Allotype); 'West Madagaskar: Ankarafantsika (Maj.), 18.vi.58. (F. Keiser)'; 'Ost-Madagaskar: Ile Sainte-Marie, Ambatoroa, v.59 (in. coll. I.R.S.M., Razafimandiby)'.

Distribution: ASIA: India, Indonesia, Philippines; **AFRICA:** Ghana, Madagascar, Nigeria, Tanzania; **OCEANIA:** Australia, Hawaii. **SOUTH AMERICA:** Paraguay* (Bigot, 1892; Paramonov, 1957; Smith and Vockeroth, 1980; Ôhara and Kusigemati, 1985; Mitra et al., 2015; Thompson and Vockeroth, 2016).

Material examined: PARAGUAY: San Pedro: Choré, XII.2016–I.2017, from beans plot (*FCA*) [1 female: MNHNPY; 1 female: CEUFLA]; Paraguarí: Parque Nacional Ybycuí, 18.VIII.2018 (*B. Garcete*) [1 male: MNHNPY].

Illustrations: Both female (Fig. 1D) and male (Fig. 1E) are illustrated. Characters to separate it from *Eumerus obliquus* are the abdominal pattern, (Fig. 1F), as well as the pattern of mesonotal pollinosity (Fig. 2E). Males have the eyes dichoptic (Fig. 2F) and the hind tarsus is dorsoventrally flattened, enlarged and covered in silver reflecting

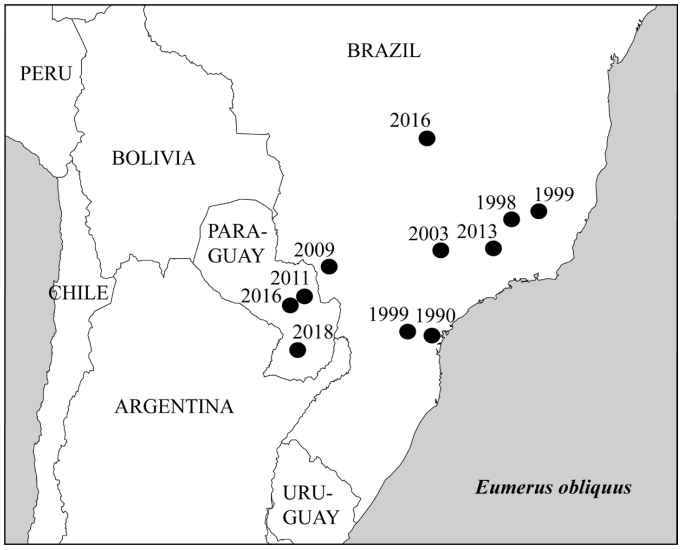

Figure 3. *Eumerus obliquus* (Fabricius) locations in South America indicating the collecting years for each one.

setae (Fig. 2G). In the female the scutellar rim is clearly, albeit shortly, serrate (Fig. 1H).

Comments: *Eumerus aurifrons* was originally described from India and its presence there has been corroborated by records from several places across the subcontinent by subsequent authors (Bigot, 1892; Mitra et al., 2015). Nevertheless, we should note that at least the record of this species from West Bengal by Sengupta et al. (2018), based on a single specimen, is a missidentification, as the specimen depicted in their Fig. 1D clearly shows a different species, probably *Eumerus figurans* Walker. The finding of specimens of *E. aurifrons* in Paraguay represents the first record of this species in the Americas.

Key to the introduced species of *Eumerus* in the Americas and Hawaii

While *E. figurans*, *E. obliquus* and *E. aurifrons* are very distinct and easy to identify by external morphology, the other three species (*E. funeralis, E. strigatus* and *E. narcissi*) are very similar and more difficult to distinguish. This is especially true for the females, while the males can be identified with certainty by examining the sternite 4 and the male genitalia. The following papers have illustrations of the male genitalia: *E. narcissi* (Smith, 1928; Speight et al., 2013), *E. funeralis* (partially under its synonymous name *E. tuberculatus*: (Smith, 1928; Vujić and Šimić, 1998; Grković et al., 2017), *E. obliquus* (DeMoor, 1973), *E. strigatus* (Smith, 1928; Vujić and Šimić, 1998; Grković et al., 2017).

1. Scutellum rectangular with chitin on the posterior margin white, nearly translucent (Fig. 4A); robust larger species; widespread in SE Asia, introduced to Hawaii ..... ***figurans*** Walker, 1859
– Scutellum trapezoid or rounded, chitin completely black, often with metallic reflections (Fig. 4C), sometimes with a white margin, which consist of short dense microtrichia along the hind margin (Fig. 4B) 2
2. Scutellum with narrow margin of short dense white setae (Fig. 4B); male hind tarsus, and (tarsomeres 2-4) laterally compressed forming a crest, which is covered with stiff black erect setae (Fig. 4E); widespread in Africa, in Europe known from the Canary isles, Corfu and Sardinia, introduced into Australia, Brazil and Paraguay ... . ***obliquus*** Fabricius, 1805
– Scutellum completely black, often with metallic reflections (Fig. 4C); male hind tarsus often swollen (typical for the genus), but without such modifications (Figs. 5A and 5D) 3
3. Tergites 2 and 3 with yellowish white spots (Fig. 1F); eyes with very abundant peg-like ommatrichiae, which are golden in males and white in females (Figs. 2E and 2F); male eyes dichoptic, by the distance equals to the distance of the hind ocelli (Fig. 2F); male hind tarsomeres 2-5 dorsoventrally flattened, enlarged and covered in silver reflecting setae (Fig. 2G); widespread in SE Asia, introduced to Australia, Madagascar, Hawaii and Paraguay ... . ***aurifrons*** Wiedemann, 1824
– Tergites 2 and 3 without yellowish white spots, only with transverse white dusted markings (Fig. 1C); eyes with less dense, always white ommatrichiae, sometimes nearly bare (Fig. 4C); male eyes holoptic (Fig. 4C); hind tarsus not dorsoventrally flattened, nor covered with silver reflecting setae (Figs. 5A and 5D) 4
4. Base of hind femur with a ventro-basal projection (Fig. 5A); female tergite 5 with a distinct baso-lateral ridge (Fig. 5B); Widespread in the Western Palaearctic, introduced into North America and New Zealand ..... ***funeralis*** Meigen, 1822
– Base of hind femur without a ventro-basal projection (Fig. 5D); female tergite 5 without a distinct baso-lateral ridge (Fig. 5C) ... 5
5. Distance from hind ocelli to posterior margin of head less than twice that to the front ocellus (Fig. 5F); Widespread in the Palaearctic region, Chile, North America, New Zealand, Australia .... ***strigatus*** (Fallen, 1817)

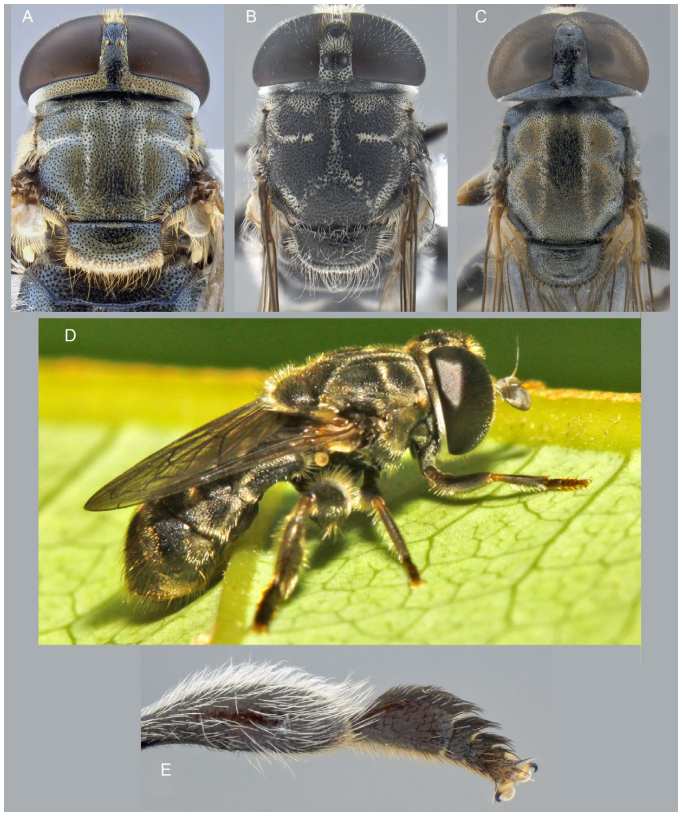

Figure 4. A-E. *Eumerus* species, males. A *Eumerus figurans* Walker. B, D, E *Eumerus obliquus* (Fabricius). C *Eumerus strigatus* (Fallen). A–C Head and thorax in dorsal view. D Living individual from Laguna Blanca, Paraguay [copyright J. Smit]. E Hind tibia and tarsus.

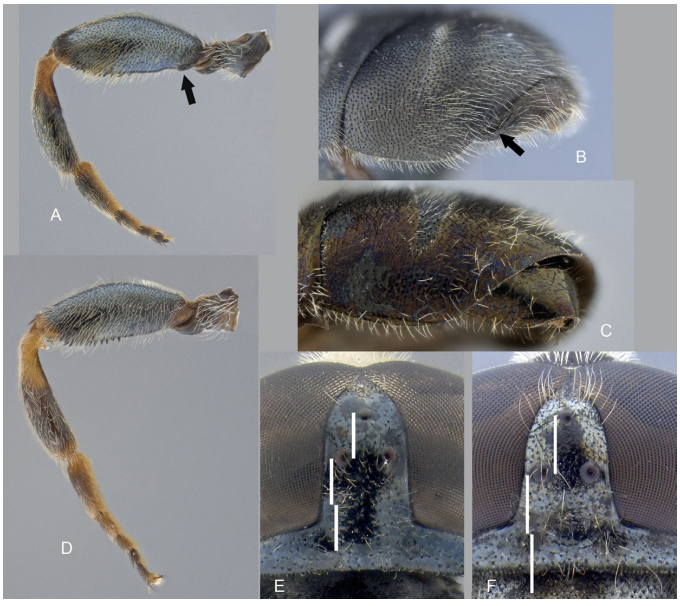

Figure 5. A-F. *Eumerus* species. A, B *Eumerus funeralis* Meigen. C, E *Eumerus narcissi* Smith. D, F *Eumerus strigatus* (Fallen). A, D–F Male. B, C Female. A, D Hindleg [arrow indicates ventro-basal projection]. B, C Posterior visible abdominal tergites [arrow indicates ridge on tergite 5]. E, F Vertex of head in dorsal view [bars indicating distance between posterior ocellus and margin of head is more than twice the distance of anterior to posterior ocelli].

– Distance from hind ocelli to posterior margin of head more than twice that to the front ocellus (Fig. 5E); Europe and California ... .***narcissi*** Smith, 1928

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Conflicts of interest

The authors declare no conflicts of interest.

Compliance with ethical standards

The specimens were collected in accordance to national legislation and its regulatory resolutions, Ley 96/92 de Vida Silvestre, and part of the material is deposited in the Museo Nacional de Historia Natural del Paraguay as imposed by the law.

Author contribution statement

BRGB, LG, MBRDL, OA, MA, GS, AM conceived the research and conducted the fieldwork. BRGB, MNM, MH, JTS wrote the paper and contributed equally, all authors critically reviewed the manuscript. All authors approved the final version of this paper.

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