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Larvae of the Family Eupelmidae as parasitoids of arthropods (Arthropoda: Insecta: Hymenoptera)

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Abstract

According to the current classification there are 905 described species in 45 genera. The larvae of most are parasitoids, especially of beetle larvae, although they also attack other hosts, including spiders. Some species parasitize a wide variety of species. Their biology varies a lot. Some parasitize eggs, others larvae, and still others are hyperparasitic (use other parasites as hosts). They are found on all continents and in all types of habitats. The purpose of this article is to carry out an inventory of the Eupelmidae Family (Insecta: Hymenoptera). To this end, a bibliographic survey of Eupelmidae was carried out in the years 1937 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international scientific events, Doctoral Thesis and Master's Dissertation were considered. Data were also obtained from platforms such as: Academia.edu, Frontiers, Qeios, Pubmed, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science and ERIC.

Keywords: Hyperparasitic; Beetle; Habitats; Spider; Eggs

1 Introduction

According to the current classification there are 905 described species in 45 genera. The larvae of most are parasitoids, especially of beetle larvae, although they also attack other hosts, including spiders. Some species parasitize a wide variety of species. Their biology varies a lot. Some parasitize eggs, others larvae, and still others are hyperparasitic (use other parasites as hosts). They are found on all continents and in all types of habitats (Figures 1, 2A and 2B) [1,2].

They have a varied appearance, although most are relatively easy to differentiate from other Chalcidoidea because they have a concave mesonotum. Long body with metallic shine. Some species lack wings or have them very reduced. They have an unusual tendency to arch their bodies upwards after death, with the head and metasoma practically touching above the thorax (Figures 3, 4, 5, 6, 7 and 8) [3,4].

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Source: https://www.researchgate.net/figure/Figures-2-4-Eupelmidae-2-Eupelmus-Macroneura-schmiedeknechti-Ruschka-3-Eupelmus_fig2_317392028

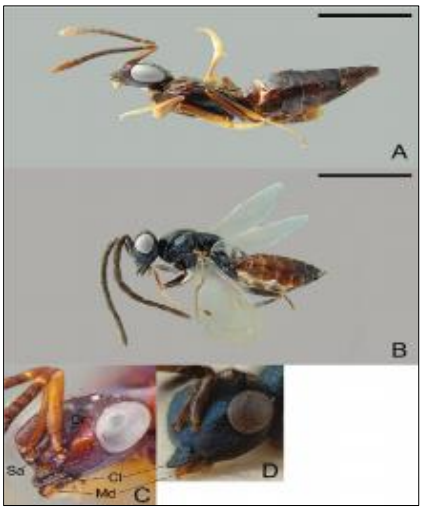
Figure 1 Eupelmidae. 2, *Eupelmus (Macroneura) schmiedeknechti* Ruschka, 1921. 3, *Eupelmus (Macroneura) seculatus* (Ferrière, 1954). 4, *Merostenus bolivari* (Kalina, 1988)

Source: https://jhr.pensoft.net/article/68556/zoom/fig/12/

Figure 2A Adult females of *Eupelmidae messene* Walker, 1839. Scale bars: 0.5 mm

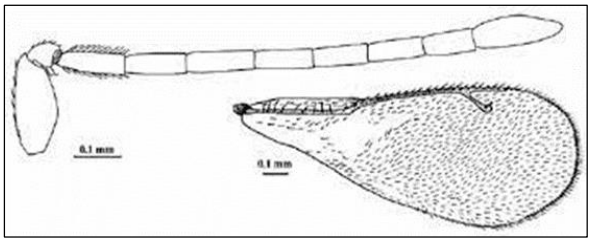
Source: https://www.flickr.com/photos/learn-to-remember/29492426884

Figure 2B Male of Eupelmidae



Source: https://www.researchgate.net/figure/Calymmochilus-dispar-female-in-lateral-view-A-head-C-male-in-lateral-view-B_fig2_236201010

Figure 3 *Calymmochilus dispar* Boucek & Andriescu, 1967, female in lateral view (A), head (C); male in lateral view (B), head (D). Abbreviations: Cl: clypeus; Cr: crest; Sa: supraclypeal area; Md: mandible. Scale = 1 mm



Source: https://www.researchgate.net/figure/Antenna-and-fore-wing-in-the-male-of-Eupelmus-aloysii_fig3_287912033

Figure 4 Antenna and fore wing in the male of *Eupelmus aloysii* Russo, 1938

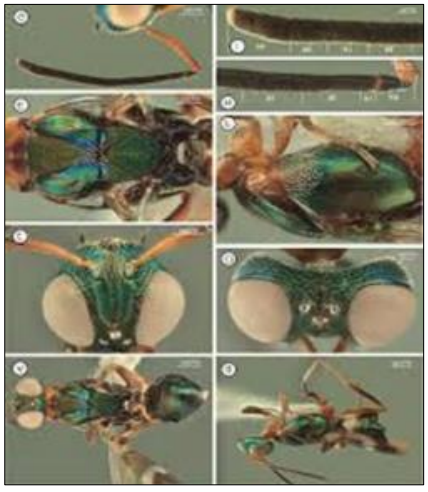
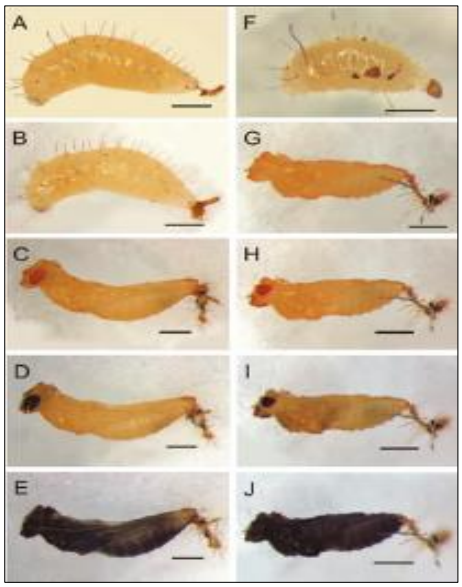


Figure 5 *Anastatus fulloi* Sheng & Wang, 1997: A–E female: A dorsal habitus (13) B lateral habitus (12) C dorsal mesosoma (13) D lateral mesosoma (12) E fore wing (14). F–H male: F lateral habitus (22) G antenna (32) H clava and apical three funiculars (32) (three lower bars indicate length of clava compared to combined length of apical funiculars). Abbreviations: clv = clava, flx = flagellomere number



Source: https://www.researchgate.net/figure/Antenna-and-fore-wing-in-the-male-of-Eupelmus-aloysii_fig3_287912033

Figure 6 *Calymmochilus dispar* Boucek & Andriescu, 1967, mature larva (A, B, F) and pupa (C–E, G–J). Female final instar larva (A, B); female pupa after two days (C), six days (D), nine days (E). Male final instar larva (F). Male pupa after one day (G), four days (H), six days (I), nine days (J). Scale = 1 mm

Source: Chen Y-M, Gibson GAP, Peng L-F, Iqbal A, Zang L-S Anastatus Motschulsky (Hymenoptera, Eupelmidae): egg parasitoids of *Caligula japonica* Moore (Lepidoptera, Saturniidae) in China. ZooKeys. 2019 881: 109–134

Figure 7A a, b and c eggs; d, e and f larvae; g, h, i, j, k and m; n adult. Parasitoid venom is composed of a complex mixture of various active substances with different biological functions and is injected in the host during the parasitoid oviposition. *Anastatus japonicus* Ashmead, 1904 Hymenoptera: Eupelmidae) is an egg parasite of *Tessaratoma papillosa* (Drury, 1770) (Hemiptera: Tessaratomidae). Although the venom of this egg parasitoid plays an important role in the parasitic process, relatively little work has been done to address the mechanism.

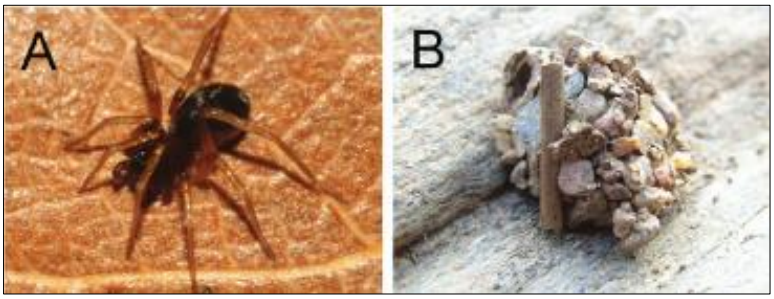
Source: Chen Y-M, Gibson GAP, Peng L-F, Iqbal A, Zang L-S Anastatus Motschulsky (Hymenoptera, Eupelmidae): egg parasitoids of *Caligula japonica* Moore (Lepidoptera, Saturniidae) in China. ZooKeys. 2019 881: 109–134

Figure 7B Immature stages of *Eupelmus microzonus* Förster, 1860: A egg B final-instar larva C male pupa. Scale bars: 0.1 mm (A); 0.4 mm (B); 0.5 mm (C).

Source: Chen Y-M, Gibson GAP, Peng L-F, Iqbal A, Zang L-S Anastatus Motschulsky (Hymenoptera, Eupelmidae): egg parasitoids of *Caligula japonica* Moore (Lepidoptera, Saturniidae) in China. ZooKeys. 2019

Figures 8 *Caligula japonica* Moore (Lepidoptera, Saturniidae) in China

Several species of Eupelmidae are being indicated for use in biological control programs. The species *Lecaniobius utilis* Compere 1939 was reported in association with the mealybug *Saissetia oleae* (Olivier, 1791) Hemiptera: Coccidae) in Minas Gerais, and later in the states of Bahia, Mato Grosso, São Paulo and Rio de Janeiro (Figures 9, 10, 11A and 11B [5, 6].



https://www.researchgate.net/figure/Spider-host-juvenile-Zodarion-styliferum-A-igloo-shaped-retreat-B_fig1_236201010

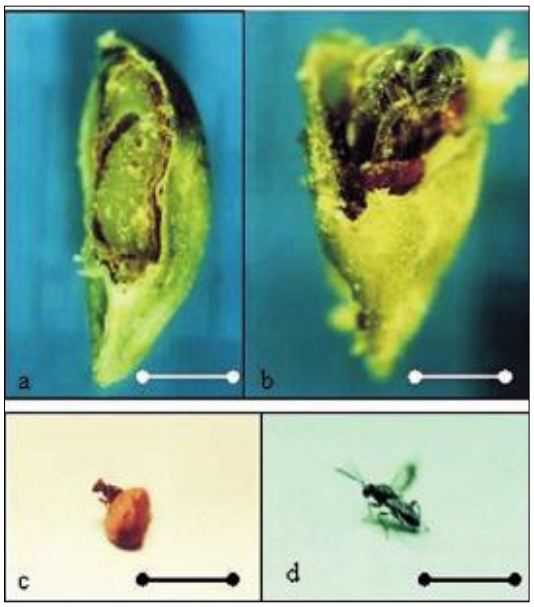
Figure 9 Spider host, juvenile *Zodarion styliferum* (Simon, 1870) (Araneae, Zodariidae) (A), igloo-shaped retreat (B): Hymenopteran parasitoids of the ant-eating spider *Z. styliferum*

Source: https://bugguide.net/node/view/901623/bgpage

Figure 10 Female of *Lecaniobius utilis* Compere 1939 (Eupelmidae)

Source: Credit: Lyle Buss, UF/IFAS

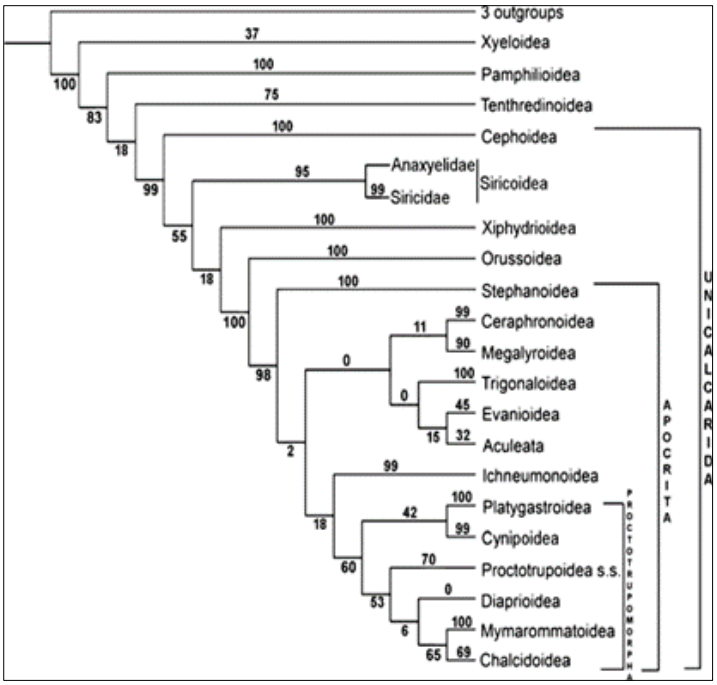
Figure 11A Adult female black scales, *Saissetia oleae* (Olivier) on cultivated olive (*Olea europaea* L.) (Oleaceae)



Source: https://www.researchgate.net/figure/Figura-2-Avispa-de-la-familia-Eupelmidae-encontrada-en-las-semillas-de-Ilex-kunthiana_fig2_262545594

Figure 11B Wasp of the family Eupelmidae found in the seeds of *Ilex kunthiana* Triana & Planchon (Aquifoliaceae). a) Larval stage (Bar = 30 mm.) b) Opening of the seed. (Bar = 30 mm.) c) The wasp is emerging from the seed. (Bar = 1.5 cm.) d) Adult specimen. (Bar = 2.0 cm.)

Eupelmidae is a family of parasitic wasps in the superfamily Chalcidoidea. It is possibly a polyphyletic group, although the sub-families appear to be monophyletic. It is possible that they will be raised to the rank of families in the future (Figure 12) [7,8,9].



Source: Cladistics, Volume: 28, Issue: 1, Pages: 80-112, first published: 21 July 2011, DOI: (10.1111/j.1096-0031.2011.00366.x)

Figure 12 Phylogenetic relationships among superfamilies of Hymenoptera

Subfamilies: Calosotinae, Eupelminae and Neanastatinae (Figures 13, 14 and 15) [10,11,13].

Source: https://www.researchgate.net/figure/Calosota-aestivalis-Eupelmidae-Calosotinae-a-species-newly-recorded-from-Germany-A_fig1_328738501

Figure 13 *Calosota aestivalis* Curtis 1836 (Eupelmidae: Calosotinae), a species newly recorded from Germany. A. female; B. male; C. female during oviposition. Live pictures are not from voucher specimen

Distribution	**Worldwide**
Biology	Ectoparasitoids of wood-boring Coleoptera or primary or hyper parasitoids of Hymenoptera, Diptera or Lepidoptera.

Source: Photographed by Josef Dvořák

Figure 14 Mating pair of *Eupelmus vesicularis* (Retzius, 1783)

Distribution	Worldwide
Biology	Primary or hyper parasitoids of insect and spider eggs and larvae.

Source: http://www.waspweb.org/chalcidoidea/eupelmidae/Neanastatinae/index.htmMaterial and methods

Figure 15 *Metapelma* Westwood 1835

Distribution	Worldwide, but most diverse in the Old World
Biology	Parasitoids or hyper parasitoids (through Platygastridae) of Cecidomyiidae larvae (Diptera), or parasitoids of larvae of wood-boring beetles (Cerambycidae, Buprestidae).

Objective

The purpose of this article is to carry out an inventory of the Eupelmidae Family (Insecta: Hymenoptera).

2 Methods

The method used to prepare this mini review was Marchiori 2021 methodology [13].

3 Studies conducted and selected

3.1 Study 1

Objective: Evaluate the importance of *Dittrichia viscosa* L. Asteraceae for its use in integrated pest management in olive groves. To determine if the parasitic complex associated with the galls is influenced by the location of *D. viscous* with respect to the culture (Figures 16, 17, 18 and 19) [14].

Source: https://pt.wikipedia.org/wiki/Dittrichia_viscosa

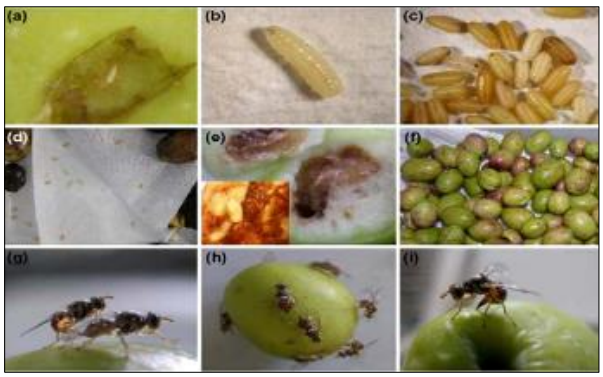
Figure 16 *Dittrichia viscosa* L. Asteraceae

Agricultural intensification causes a reduction in habitats and a decline in biodiversity. One of the recommendations to increase biodiversity in agrosystems is the promotion of infrastructures adequate ecological and thus enhance the populations of beneficial organisms and favor the control biology of pests. *Dittrichia viscosa* is a species associated with olive groves, the blooms in September and whose flowers are very sensitive to the attack of the Diptera *Myopites stylatus* (Fabricius, 1794) (Diptera: Tephritidae) that causes gills. The larvae serve as hosts to numerous parasitoids, some of great interest for be associated with the olive fruit fly *Bactrocera oleae* (Rossi, 1790) (Diptera: Tephritidae) [14].

Source: https://en.wikipedia.org/wiki/Myopites

Figure 17 *Myopites stylatus* (Fabricius, 1794) (Diptera: Tephritidae)

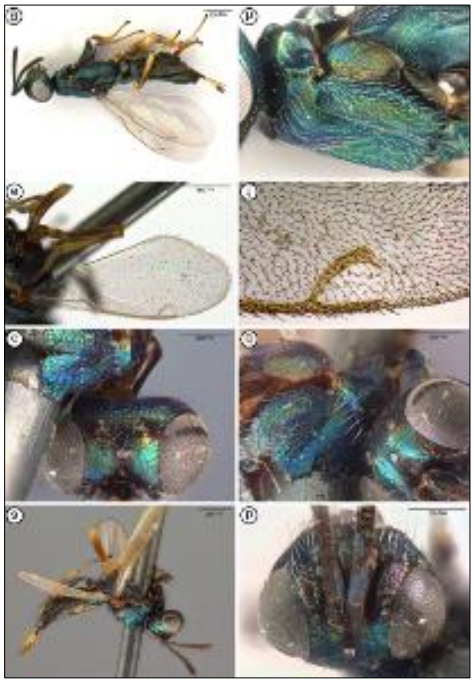
The number of parasitoids obtained during the entire study period was 2929 corresponding to 8 families The Pteromalidae family was the most abundant (61.1%) and with the highest species richness (9), followed by Eurytomidae (21.1%).



Source: https://www.semanticscholar.org/paper/Maintaining-Bactrocera-oleae-(Gmelin.)- (Diptera%3A-on-Gen%C3%A7-Nation/8236627e9df6fbe36a302ab640912011ec27dc45/figure/1

Figure 18 A composite picture of some developmental stages of the olive fruit, *Bactrocera oleae* (Rossi, 1790) (Diptera: Tephritidae, an egg inside the fruit, b newly hatched wrst instar, c pupae, d laboratory reared colony pupae beneath the paper towel; and larval damage inside the fruit; f several oviposition stings on the fruits; g the mating pair; h females on the fruits searching for place for oviposition; i a female depositing an egg collapse

The Eupelmidae family accounted for 9% and *Eupelmus urozonus* Dalman, 1820 was the dominant species. Others Families identified with less relevance were Torymidae, Ichneumonidae, Eulophidae, Braconidae and Ormyridae. The four most abundant families were present in the galls collected in the three study sites, where the Teromalidae family was the dominant one. The main families of parasitoids are found in the three locations, so this factor does not seem to significantly affect the parasitic complex associated with the galls caused by *M. stylata* in *D. viscosa* [14].



Source: © Gary A. P. Gibson; Lucian Fusu

Figure 19 *Eupelmus urozonus* Dalman, 1820, ♀. a–f (lectotype): a, lateral habitus; b, head, frontal; c, head (dorsal) and pronotum (dorsolateral); d, frontovertex and pronotum (dorsolateral), prepectus and right half of mesoscutum; e, fore wing; f, stigmal and postmarginal veins. g, h (*Eupelmus urozonus* Dalman 1820 neotype): g, lateral habitus; h, pronotum, mesoscutum and prepectus, lateral.

3.2 Study 2

The objective of this work was to survey parasitoids in hemipteran eggs in corn. The Eupelmidae family presents greater diversity in the Neotropical region and is composed of three subfamilies, and some species of Eupelminae, especially those that attack insect eggs, develop as idbiont endoparasitoids. Several species have been used in biological control programs (Figure 20).

Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=480206

Figure 20 *Brasema* (Eupelmidae)

The genus *Brasema* belongs to this sub-family, it is an ectoparasitoid of coleopteran larvae and other hosts inside plant tissues.

Leptoglossus zonatus (Dallas, 1852) (Hemiptera: Coreidae), a common hemipteran in corn, sorghum, bean, soybean, tomato and citrus crops, sucks the grains and fruits causing wilting, rotting and, consequently, a drop in production. In maize, losses can reach 15%. (Figure 21).

Source: https://www.ipmimages.org/browse/detail.cfm?imgnum=5203057

Figure 21 *Leptoglossus zonatus* (Dallas, 1852) (Hemiptera: Coreidae)

A total of 41 eggs of *L. zonatus* were collected, from which 30 nymphs hatched and 9 parasitoids of the genus *Gryon* (Hymenoptera: Scelionidae) and two of the genus *Brasema* (Hymenoptera: Eupelmidae) emerged. Total parasitism was 26.8%, with 4.8% caused by *Brasema* sp. [15,16,17,18].

3.3 Study 3

From the study we carried out on the complex of parasitoids associated with *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775) (Lepdoptera: Notodontidae) in the pine forests of the province of Valencia —research carried out in part by the R&D Project GV99-129-1-03 subsidized by the Generalitat Valenciana —, and from the monitoring of a series of egg clutches collected over several years in different enclaves, we were able to confirm the presence of *Eupelmus seculatus* (Ferrière, 1954) (Hymenoptera, Chalcidoidea, Eupelmidae) as an phagus of the "pine processionary" on *Pinus halepensis* (Mill.) (Pinaceae) (Figures 22A, 22B, 23 and 24) [19].

Source: https://www.researchgate.net/figure/Thaumetopoea-pityocampa-male-wingspan-30-40-mm-A-mature-larvae-about-40-mm-B_fig1_337134086

Figure 22A *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775) (Lepdoptera: Notodontidae)

Source: https://www.researchgate.net/figure/Thaumetopoea-pityocampa-male-wingspan-30-40-mm-A-mature-larvae-about-40-mm-B_fig1_337134086

Figure 22B *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775): male (wingspan 30-40 mm) (A), mature larvae (about 40 mm) (B), winter nest (about 20 cm) (C) and urtication produced in humans (D)

Source: http://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=481406

Figure 23 *Eupelmus seculatus* (Ferrière, 1954) (Hymenoptera, Chalcidoidea, Eupelmidae)

In this way, from the study of 200 clutches with an average of 156 eggs each, we obtained a sex ratio of 7 males to 1 female, and very low parasitism rates (0.06%). Despite this, as we have been collecting specimens for several years from Lepidoptera clutch collections, we are in a position to conclude that *E. seculatus* turns out to be a regular host of the "pine processionary" in the area studied [19].

Source: https://www.flickr.com/photos/helicongus/10089386753

Figure 24 *Pinus halepensis* (Mill.) (Pinaceae)

Likewise, we do not know the degree of polyphagia of this parasitoid and if it uses *T. pityo*campa as an alternative host, and we also do not know if it acts as a sporadic primary parasitoid or as a hyperparasitoid of any of the primary oophagous species of the complex [19].

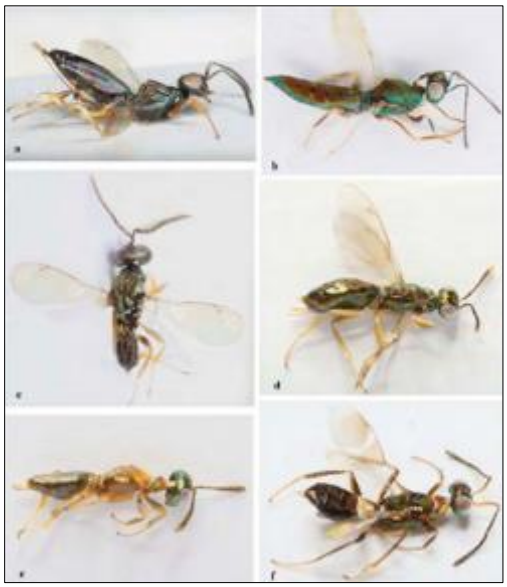
3.4 Study 4

The family Eupelmidae presents greater diversity in the Neotropical region and is composed of three subfamilies, being that some species of Eupelminae, especially those that attack insects, develop as idibiont endoparasitoids. Several species have been used in biological control programs.

According to the current classification there are 905 described species in 45 genera. The larvae of most are parasitoids, especially of beetle larvae, although they also attack other hosts, including spiders. Some species parasitize a wide variety of species. Their biology varies a lot. Some parasitize eggs, others larvae, and still others. They are found on all continents and in all types of habitats.

3.4.1 Genders

Anastatus, Arachnophaga, Archaeopelma, Argaleostatus, Australoodera, Balcha, Brasema, Calosota, Calymmochilus, Cervicosus, Coryptilus, Ecnomocephala, Eenigmapelma, Eopelma, Eueupelmus, Eupelmus, Eusandalum, Eutreptopelma, Lambdobregma, Lecaniobius, lycroids, Lutnes, Macreupelmus, Merostenus, Mesocomys, Metapelma, Neanastatus, Omeganstatus, Ooderella, Oozetetes, Paraeusandalum, Paranastatus, Pentacladia, Phenaceupelmus, Phlebopenes, Psomizopelma, Reikosiella, Rhinoeupelmus, Tanythorax, Taphronotus, tineobius, Uropelma, Xenanastatus and Zaischnopsis (Figure 25) [20,21,22,23].



Source: https://www.researchgate.net/figure/Habitus-of-adult-Eupelmidae-a-Eupelmus-vindex-z-b-Eusandalum-walkeri-z-c_fig2_287912033

Figure 25 Habitus of adult Eupelmidae: a – *Eupelmus*; b - *Eusandalum*; c – *Eupelmus*. d - *Eupelmus*; e – *Eupelmus*; f- *Anastatus*

3.5 Study 5

Aspidopleura is an extinct monotypic genus of parasitic wasp in the Eupelmidae subfamily Neanastatinae and at present, which contains the only species *Aspidopleura baltica* Gibson, 2009. The genus is known exclusively from the early Eocene Baltic amber deposits in the Baltic Sea region of Europe.

Time range: Lower Eocene

Baltic aspidopleura Gibson, 2009 (dorsal habitus)

3.5.1 Scientific classification

Kingdom: Animalia, Phylum: Arthropoda, Class: Insecta, Request: Hymenoptera, Family: Eupelmidae, Genus: † *Aspidopleura,* Gibson, 2009.

Species: † A. baltica, binomial name, † *Baltic aspidopleura*, Gibson, 2009

3.5.2 History and classification

Aspidopleura is known from only two fossils, the holotype and the paratype. The holotype, number "AMNH-JWJ-409", is a single female specimen preserved in a nearly flattened amber block 24 by 18 millimeters (0.94 by 0.71 in) in size. The paratype, number "AMNH-JWJ-410", is also a single female specimen and preserved in a nearly triangular amber block 19 by 14 millimeters (0.75 by 0.55 in) in size. Both amber blocks are currently residing in the paleoentomology collections of the American Museum of Natural History in New York City, USA. Specimens of *Aspidopleura baltica* were first studied by Gary AP Gibson, with his 2009 type description published in the journal ZooKeys. The generic name wash coined by Gary Gibson as a combination of the supposed Greek words aspido meaning "shield" and pleuro meaning "side". This refers to the general shape and structure of the acropleuron. The proper words for "shield" and "side" in Greek are, however (aspis) and (pleuron) or (pleura). The specific epithet "Baltica" was designated as a reference to the origin of the amber specimens from the Baltic region.

3.5.3 Description

Aspidopleura baltica is 4.2 millimeters (0.17 in) long when the ovipositor is included and is a uniform dark brown color. Several areas on each of the females are obscured or absent, with the dorsal view and right side not visible on the holotype, while the paratype shows areas of white mold. The forewings are hyaline in color with a large brown spot covering the area behind the marginal and post-marginal veins, but disappearing towards the apex of the wing. In general, *Aspidopleura* does not look much like extant members of the subfamily Neanastatinae, with a very large speculum on the forewings and having a distinct frenulum. These traits are most similar to females in the Eupelminae subfamily. However, the sine pattern on the legs of *Aspidopleura* is much closer to that of extant Neanastatinae.

Source: Gibson, 2009

Figure 26 *Aspidopleura baltica* Gibson, 2009 (Hymenoptera: Eupelmidae)

Although the life habit of *A. baltica* is unknown, the short length of the ovipositor and the shape of the mandibles, both similar to the genus Anastatus in the subfamily Eupelminae, suggest that *Aspidopleura* was possibly a parasite of insect eggs [24, 25, 26].

4 Conclusion

The Eupelmidae family presents greater diversity in the Neotropical region and is composed of three subfamilies, and some species of Eupelminae, especially those that attack insect eggs, develop as idbiont endoparasitoids. Several species have been used in biological control programs.

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