



## An introduced species, though remarkable: first record of Sepsidae (Diptera: Schizophora) from Chile

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The unique insect fauna from Chile has attracted the attention of numerous entomologists and collectors for over 150 years (Cortés & Herrera 1989; O'Hara *et al.* 2021; Amorim *et al.* 2022). Sepsidae (Diptera: Schizophora), quite surprisingly, has been entirely missing so far in the list of families of flies found in Chile.

Sepsids correspond to a small, rather morphologically and ecologically uniform family of acalyptrate flies. Here, the larvae of most species are saprophagous, but more typically feed on mammalian and waterfowl feces (Pont & Meier 2002). The World Catalogue of the family contains 37 accepted genera and 318 valid species (Ozerov 2005). The Neotropical region presently includes 45 described valid species in 12 genera (Silva 2016). Indeed, there are only two main clades of the entire family (Zhao *et al.* 2013) present in the Neotropics. The group referred to as “Neotropical clade” by Zhao *et al.* (2013) includes *Archiseptis* Silva, *Microsepsis* Silva (both these genera with three species each in the Nearctic region), *Palaeosepsis* Duda, *Meropliosepsis* Duda, and *Pseudopalaeosepsis* Ozerov. *Palaeosepsoides* and *Lateosepsis* Ozerov also have a Neotropical species and may belong to this clade, but were not included in the analysis by Zhao *et al.* (2013). The other clade corresponds to a species of *Meroplius* Rondani, a genus also found in the Nearctic, Palaearctic, Afrotropical, Australasian/Oceanian and Oriental regions. The other three genera found in the Neotropical region—*Sepsis* Fallén, *Saltella* Robineau-Desvoidy, *Themira* Rondani—are extensions of the Nearctic fauna of the family, present a bit further south into northern Mexico and Central America (Ozerov 2005).

*Sepsis* is a well-defined, monophyletic genus widely distributed in the world. It is also the largest genus in the family, with *ca.* 90 species (Ozerov 2021). Adult *Sepsis* can be recognized in both sexes by the very weak postalar seta and often by a conspicuous dark spot at the distal end of the wings; males have ornated forelegs and the abdominal sternite 4 is absent (Pont & Meier 2002). Six species of the genus have been reported to Mexico: *Sepsis biflexuosa* Strobl, *S. flavimana* Meigen (a species largely distributed in the world), *S. luteipes* Melander & Spuler, *S. neglecta* Ozerov, *S. neocynipsea* Melander & Spuler, and *S. punctum* (Fabricius).

In 2017, we began a study of the southern Chile temperate rainforest insect fauna, with an intensive single-site collecting approach (Amorim *et al.* 2022). Most collecting spots are in the Parque Nacional Puyehue (PNP), with some samples from additional close by areas. The park has 1,070 Km<sup>2</sup> and is at the latitude of Osorno, about 40.7°S. The west border of the PNP is five kilometers east of Lake Puyehue, extending to the border between Chile and Argentina. Different collecting techniques—Malaise traps, baited Shannon trap, light trap, sweeping, yellow pan trap etc. (Amorim *et al.* 2022)—have been used in five expeditions. Most of the field work was covered in three main stages: (1) a four-weeks period in January–February 2017, using different collecting techniques; (2) Malaise trapping from November 2019 to July 2021 in two different sites in the park; and (3) from June to October 2022 with Malaise traps, followed again by the use of different collecting techniques in November 2022.

We have the samples of these stages of the project largely sorted via morphology to family level. For the 2017 field trip, we have 14 different samples and for the second stage we have 75 two-weeks Malaise trap samples. We never found a single specimen of sepsids in these samples, not even in the samples that also had human feces as bait in Shannon traps. During our last expedition, five specimens of sepsids were collected in two sites in the park (3 males, Chile, Osorno, Parque Nacional Puyehue, Antillanca, (higher limit of vegetation), 1,050 m, bait with human feces, 24.xi.2022, J.A.

Rafael, V.C. Silva & D.S. Amorim cols; 1 female, Chile, Osorno, Parque Nacional Puyehue, Termas de Aguas Calientes, 470 m, sweeping, 27.xi.2022, D.S. Amorim, V.C. Silva & J.A. Rafael cols.—2 males and 1 female, MNHN; 1 male, MZUSP). This note reports this first finding and addresses the question of absence of endemic sepsids in Chile.

Specimens were collected in 80% ethanol. One male was dehydrated using amyl acetate (banana oil) (Austin & Dillon 1997) and double-pinned. Species identification was done using Munari & Vienna (1982), Pont & Meier (2002), Ozerov (2000, 2005), and the high-quality photographs of the digital reference collection “SepsidNet” (<https://sepsidnet.biodiversity.online/>; Ang *et al.* 2013). The female and two males were kept in ethanol (80%) for sequencing.

Additional records of sepsids in the PNP were made more recently by Sebastián Maitre Cea and Stephanie Gutiérrez Báez (pers. comm.), after our November 2022 fieldwork. A large population of sepsids was found close to the top of Volcan Puyehue, around a large amount of cattle feces. We still did not examine these specimens, but photographs suggested them to be conspecific with our specimens.

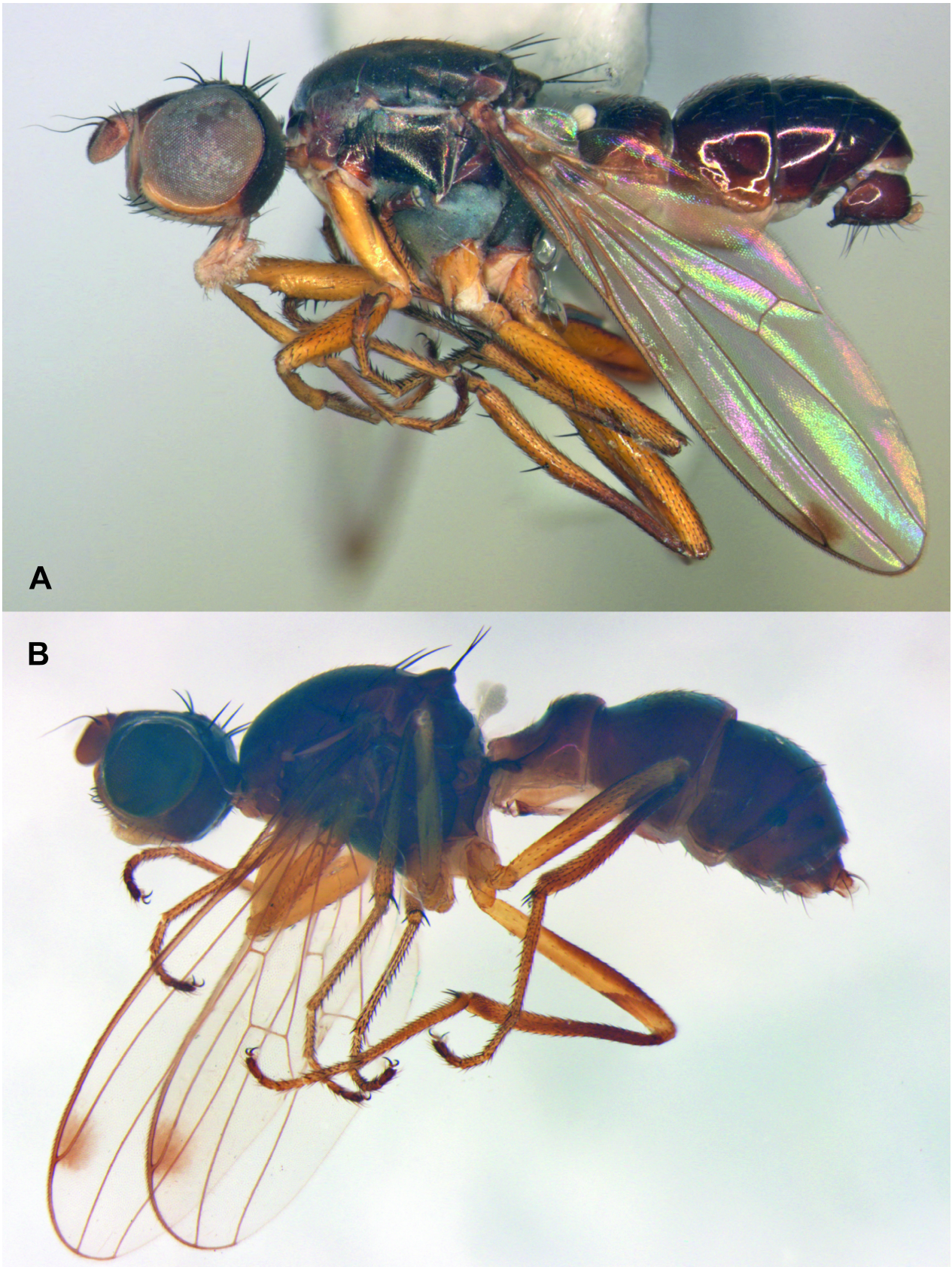
*Sepsis punctum* (Fabricius) has been reported from the Nearctic, Palaearctic (including Asia and northern Africa), and Oriental Regions and, as mentioned above, Mexico (see Ozerov 2005, <https://www.gbif.org/pt/species/1676063>). This is the first record of the species for the southern hemisphere. There is very close resemblance of our specimens to the descriptions and illustrations available in the literature (Munari & Vienna 1982; Pont & Meier 2002; <https://sepsidnet.biodiversity.online/>). This concerns leg color (Figs. 1A–B), fore femur ornamentation (Figs. 2A–B), scutum dorsocentrals (Fig. 2C), pruinosity of the anepimeron (Fig. 2D), wings (Fig. 2E), and the details of the male terminalia (Figs. 2F–G). Munari & Vienna (1982) and Pont & Meier (2002) pointed out the large variability in this species. This concerns as well size dimorphism, pre- vs. post-copulatory traits (Punniamoorthy *et al.* 2012a, b), and mating strategies (Dmietriew & Blanckenhorn 2012). Different studies, summarized by Pont & Meier (2002), have shown a large variation in the breeding habits of this species. *S. punctum* is a generalist, breeding in a variety of mammal dung: rabbit, sheep, dog, horse, fox, red deer, brown bear, human, but the main breeding substrate is cow dung.

There is no question about the identification of this species of sepsid and, hence, it should be added as an introduced species to the Chilean fauna. It is worth mentioning, however, that sepsids had not showed up in any of our samples from the Puyehue National Park since 2017. Furthermore, sepsids were knowingly absent from whatever collecting or report for Chile along the last one and a half century of dipterology.

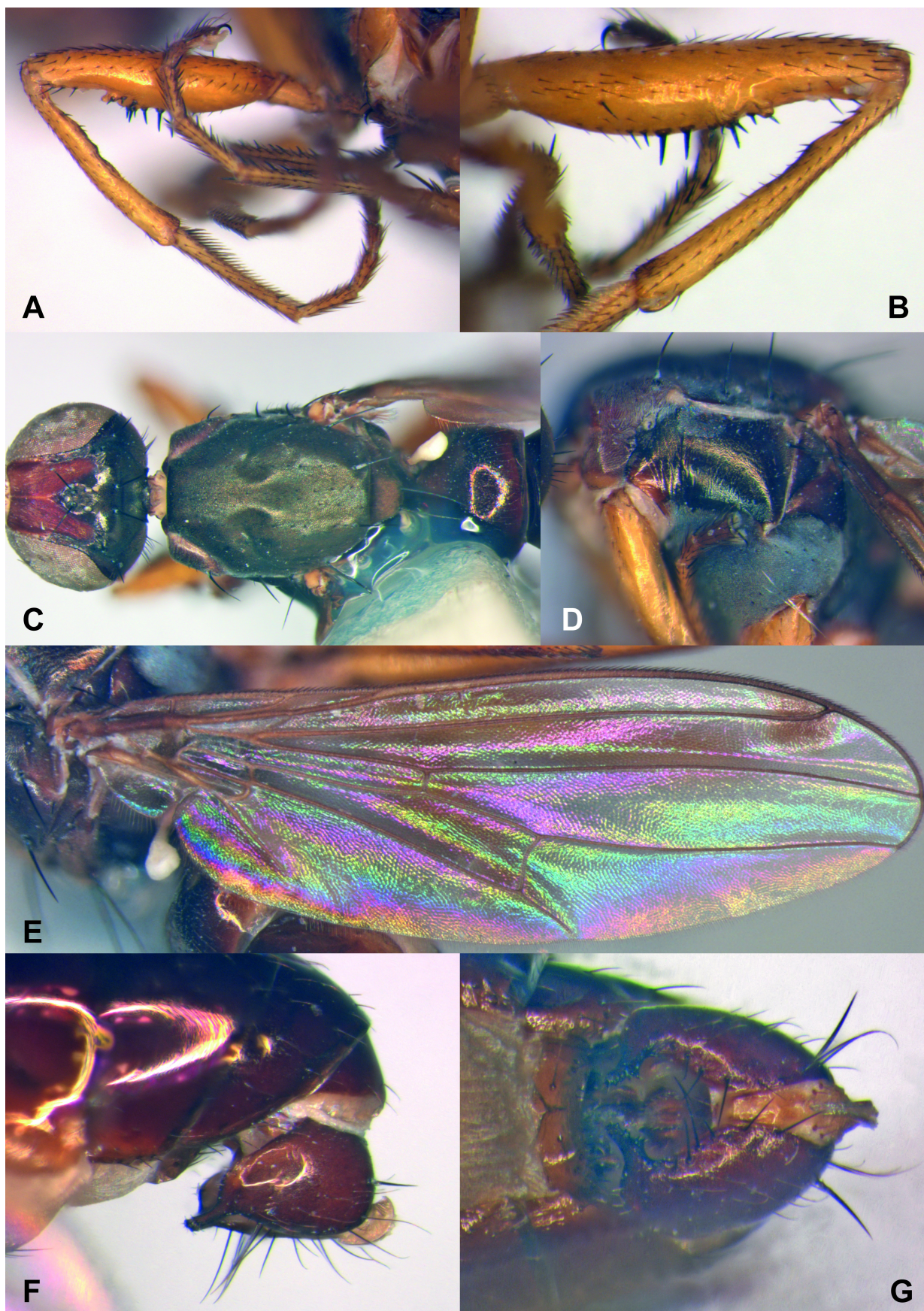
Recent history of sepsid distribution in the world is closely tied to the history of cattle introduction. Cattle were introduced in the New World as early as 1493, mostly from Andalusia, Canary Islands, Portugal, the Islands of Cape Verde. Later, there was rapid expansion of the use of cattle throughout the Americas, occupying a wide range of environments, including mountains, grasslands, and tropical landscapes (Hoyt 1982–1984; Armstrong *et al.* 2022). There are records of cattle and sheep in Chile at least since 1543. In the 17<sup>th</sup> century, there was great commercial exchange of cattle between Chile and what now is Argentina. At that time, the region of San Juan in Argentina (more to the north, when compared to the latitude of Osorno) became the main supplier of cattle to Chile (Costa 2011). Cattle would grow in Argentina and were taken on foot across mountain passes in the Andes. Horses, mules, and donkeys were also exported from Argentina to Chile (Costa 2011).

Philippi (1895), already at the end of the XIX<sup>th</sup> century, listed *ca.* 25 insect species introduced to Chile since the Spanish occupation, three of which were flies. In a recent paper, López *et al.* (2023) expanded this list to include 531 non-native insect species established in Chile—28 species of 16 different families belonging to Diptera. In terms of origin of these non-native fly species in Chile, most are from the Palearctic Region (over 50%), with a good number from Africa and from other Neotropical countries (López *et al.* 2023).

Commercial exchange of cattle between Chile and Argentina is still ongoing and could be the best explanation for this finding of *Sepsis punctum*. The Parque Nacional Puyehue is cut by the Ruta Internacional 213, the main connection between Chile and Argentina at the latitude of Osorno and Bariloche. The Shannon-Edwards expedition in 1926 went from Argentina to Chile through the *paso* Rosales, slightly south to the Parque Nacional Puyehue (Edwards 1929), and they did not have either any records of sepsids. An origin of the Parque Nacional Puyehue population of *Sepsis punctum* from Argentina could be confirmed barcoding populations from both sides, if they are present at all in the Argentinian side. There are over 280 barcode sequences of *Sepsis punctum* in GenBank (<https://www.ncbi.nlm.nih.gov/nucleotide>) and it would be particularly interesting to see the origin of the Chilean population of this species in relation to its overall distribution in the world.



**FIGURE 1.** *Sepsis punctum* (Fabricius), habitus. **A.** Male, Chile, Parque Nacional Puyehue, Antillanca. **B.** Female, Chile, Parque Nacional Puyehue, Termas Aguas Calientes.



**FIGURE 2.** *Sepsis punctum* (Fabricius), male, Chile, Parque Nacional Puyehue, Antillanca. **A.** Fore femur, anterior view. **B.** Same, posterior view. **C.** Head and thorax, dorsal view. **D.** Thoracic pleura, lateral view. **E.** Wing. **F.** Male terminalia, lateral view. **G.** Same, ventral view.

Species introduction is itself an issue. Hulme (2009) refers to a “third phase” of biological invasions in the world, in the Era of Globalization—the first, at the end of the Middle Ages, with the European rediscovery of the Americas; the second during the Industrial Revolution. Hulme (2009) pointed that global trade is now dominated by dry cargo (46%), with alien species entering new habitats as contaminant of traded goods. Global trade is reportedly an important source of alien species invasion, with invertebrates being introduced mostly unintentionally (Jenkins 1997; Kobelt & Nentwig 2008). For Banks *et al.* (2015), features of the species determine whether its populations can survive in sufficient numbers during transportation to reach a new habitat. Later, trade and transport network topology determine how far the invasive species can spread in a new area. Kauffman & Pyke (2001) stressed that the final direct influence of livestock is the dispersal of undesirable exotic organisms.

There is also a record of an introduced Neotropical species of sepsid elsewhere: *Archisepsis discolor* Bigot has been introduced to the Azores Islands. It was first described as a new species, *Sepsis mequignoni*, by Séguy (1936), later synonymized and considered as an introduction in the islands by Ozerov (2005).

It is hard to predict whether the presence of a sepsid species in Chile would displace native coprophilous species. Sepsids are often associated with introduced cattle, while the feces of some indigenous mammals in Chile (see, *e.g.*, Muñoz Pedreros & Yáñez Valenzuela 2009) could be too dry for sepsid larvae. The evidence now at hands suggests this to be a case of recent species introduction. The presence of *Sepsis punctum* in Chile seems to be an interesting case to investigate the process of a species spreading into a different geographic and ecological context—including, *e.g.*, the question of access to the feces of native mammal species.

Another issue that still stands are the reasons for the absence of native sepsids in Chile. Not even species of the typically “Neotropical clade” of sepsids are established or have survived west to the Andes in Chile at the end of the Cenozoic. Evolution of schizophorans is still not fully solved in terms of relationships among main clades (see, *e.g.*, Wiegmann *et al.* 2011; Bayless *et al.* 2021 *etc.*) or in terms of the age of these main clades and families. Grimaldi & Cumming (1999) admit a very late Cretaceous origin of the stem Schizophora, with diversification only in the Cenozoic. It is quite certain that most extant acalyptrate families originated in the late Paleocene or early Eocene. Radiation of oestroids, among the calyptrates, a clade sister of ephydroids (see, *e.g.*, Bayless *et al.* 2021), would have begun in the early Eocene, 50 mya (Cerretti *et al.* 2017), as well as the early diversification of muscids (Li *et al.* 2023). A Baltic amber fossil originally proposed to be a stem sepsid—*Protorygma electricum* Hennig, 1965—was later seen potentially as a stem Ropalomeridae or even a stem (Ropalomeridae + Sepsidae) (Pont & Meier 2002). This means that the diversification of the main clades of sepsids could have occurred in the late Eocene or even in the early Miocene, already in the initial cooling of the planet, in the second half of the Cenozoic. This suggests that the presence of the “Neotropical clade” of sepsids, an obvious case of secondary distribution expansion, may have occurred already in the scenario of a cooling southern South America.

The presence of the “Neotropical clade” of sepsids fits well in the scenario of a tropical Laurasian fauna that secondarily extends southwards in the Americas, Africa and Australasia (Amorim *et al.* 2018b), producing a “pantropical” pattern that has not a Gondwanan origin. The fauna of some acalyptrate families in Chile—as drosophilids, ephydrids, clusiids, sciomyzids, *etc.*—may fit into this pattern of southern extensions of “pantropical” elements in South America, which were able to establish in Chile. Another layer of the fauna in Chile corresponds to groups with southern affinities. A physical connection between South America and Australia (and its shared biota) was effective until late Eocene/early Miocene (Amorim *et al.* 2009; Almeida *et al.* 2012; Lessard *et al.* 2013), and between Australia and New Zealand until about 80 m.y.a (see, *e.g.*, Amorim *et al.* 2018a). Some stratiomyids (*e.g.*, Chyromyzinae), empidooids (*e.g.*, *Gondwanamyia* Sinclair, Cumming, Brooks, Plant & Saigusa) and some acalyptrate families—as heleomyzids, spherocerids, helosciomyzids, paraleucopids, teratomyzids *etc.*—are examples of clades that have elements on both, South America, Australia and/or New Zealand.

Sepsids would fit in the first of these two patterns. They seem to either have not reached Chile because it was already too cold or may have been present in more northern areas in Chile and were extinct afterwards. It should not be a surprise to see *Sepsis punctum* establishing itself in Chile, since it is present in many subtropical or temperate areas in other parts of the world.

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