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(REVIEW ARTICLE)

Diptera species ectoparasitic of mammals and parasitoid insect pests

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Abstract

Over the years the muscoid dipterans have always they were associated with man and domestic animals, due to the food resources found in the breeding stables. The aim of this study is to carry out a bibliographic summary about mammalian ectoparasites, phoresia, scorpion parasitoid flies (Arachnida: Scorpiones), ants and also the life cycle of these dipterans. The mini-review consists of a literature search on dipterans (Order: Diptera) and scorpion parasitoids (Arachnida: Scorpiones). The research was carried out in studies related to the theme with an emphasis on quantitative and conceptual aspects of Family, Subfamilies, Genera and Species (taxonomic groups). A literature search was carried out containing articles published from 2000 to 2021. The mini-review was prepared in Goiânia, Goiás, from July to August 2021, through the Online Scientific Library (Scielo) and internet.

Keywords: Arthropod; Insecta; Parasitism; Phoresia; Life cycle

1. Introduction

Over the years the muscoid dipterans have always they were associated with man and domestic animals, due to the food resources found in the breeding stables. With the decrease in the number of stables in urban areas, it was believed that the number of flies would decrease. However, this has not been observed, because as a result of population growth, man has maintained conditions for the development of dipterans, whether in the household waste produced daily, or also in the feces of pets, which serve as breeding substrates for the Diptera.

Objective

The aim of this study is to carry out a bibliographical summary about the ectoparasites of mammals ecological relationship in which an invertebrate species, called phoretic, parasitoid flies of scorpions, ants and also the life cycle of these dipterans.

2. Methods

The mini-review consists of bibliographical research on the dipterans (Order: Diptera) and scorpions (Arachnida: Scorpiones). The research was carried out in studies related to the theme with an emphasis on quantitative and conceptual aspects of Family, Subfamilies, Genera and Species (taxonomic groups). A literature search was carried out containing articles published from 2000 to 2021. The mini-review was prepared in Goiânia, Goiás, from July to August 2021, through the Online Scientific Library (Scielo) and internet.

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3. Studies performed

3.1. Study 1

Bats belong to the order Chiroptera. Bats are one of the most diverse groups of mammals in terms of eating habits, which is not surprising considering the diversity of species [1].

In Brazil, 81 species of flies from the Streblidae family and 24 species from the Nycteribiidae family have been recorded. Bat infestation by ectoparasites is related to intrinsic characteristics of the species, such as the size of the distribution area, colony formation or body size, in addition, the abundance of ectoparasites may be different for hosts with age, sex, reproductive condition and different health status (Figure 1) [1].

Figure 1 Diptera ectoparasites of bats; (Source: https://twitter.com/insetoland/status/1374846250017828866)

Bats maintain parasitic relationships, such as endoparasitism and ectoparasitism. In endoparasitism, the relationships occur with protozoa, helminths, flatworms, and nematodes. Cases of ectoparasite over population in bats are rare, as they would result in significant damage to the host, comprising from minor problems to severe injuries, such as blood loss, malnutrition, and skin and fur damage. Only two families of hematophagous dipterans, Streblidae and Nycteribiidae (Figure 2) [2, 3, 4].

About 220 species of Streblidae and 290 species of Nycteribiidae, the main ectoparasites of bats in the Neotropics, are recognized. These families are represented by individuals that reach up to about 5mm, with adults being obligatory hematophagous. A common feature to both families is adenotrophic viviparity, in which larval development takes place within the female's genital chamber, with bloating occurring soon after she leaves [5].

Some species of Streblidae: *Aspidoptera falcata* Wenzel, 1976, *Mastoptera minuta* (Costa Lima, 1921) and *Trichobius costalimai* Guimarães, 1938. *Trichobius costalimai, Trichobioides perspicillatus* (Pessôa & Galvão, 1937), *Trichobius phyllostomus* Guerrero, 1998, *Strebla hertigi* Wenzel 1966. *Trichobioides perspicillatus* (Pessôa & Galvão, 1937), *Mastoptera minuta* (Costa Lima, 1921) *Stizostrebla longirostris* Jobling, 1939, *Paratrichobius longicrus* (Miranda Ribeiro, 1907); *Trichobius parasiticus* Gervais, 1844, *Paradyschiria parvula* Falcoz, 1931; *Strebla tonatie* Kessel, 1924, *Strebla galindoi* Wenzel, 1966, *Megistopoda proxima* (Séguy, 1926), *Aspidoptera phyllostomatis* (Perty, 1833) *Phyllostomus discolor* Wagner 1843 and *Megistopoda aranea* (Coquillett, 1899) [5].

Figure 2 Specimen of Streblidae; (Source: https://link.springer.com/referenceworkentry/10.1007%2F978-3-662-43978-4_3463)

Some species of Streblidae: Aspidoptera falcata Wenzel, 1976, *Mastoptera minuta* (Costa Lima, 1921) and *Trichobius costalimai* Guimarães, 1938. *Trichobius costalimai, Trichobioides perspicillatus* (Pessôa & Galvão, 1937), *Trichobius phyllostomus* Guerrero, 1998, *Strebla hertigi* Wenzel 1966. *Trichobioides perspicillatus* (Pessôa & Galvão, 1937), *Mastoptera minuta* (Costa, Lima 1921) *Stizostrebla longirostris* Jobling, 1939, *Paratrichobius longicrus* (Miranda Ribeiro, 1907); *Trichobius parasiticus* Gervais, 1844, *Paradyschiria parvula* Falcoz, 1931; *Strebla tonatie* Kessel, 1924, *Strebla galindoi* Wenzel, 1966, *Megistopoda proxima* (Séguy, 1926*), Aspidoptera phyllostomatis* (Perty, 1833) *Phyllostomus* discolor Wagner 1843 and *Megistopoda aranea* (Coquillett, 1899) [5].

The Nycteribiidae family has representatives mainly in the old world and is quite specialized, showing absence of wings and flight muscle atrophy, which results in a reduced thorax, where there are dorsal attachments of the paws and head. The Streblidae family, on the other hand, presents a great morphological variability, since there are winged, brachypteral and apteral representatives. In addition, eyes may be small or absent.

Some species: *Basilia andersoni* Peterson & Maa, 1970, *Basilia carteri* Scott, 1936, *Basilia currani Guimarães*, 1943, *Basilia hughscotti* Guimarães, 1946, *Basilia lindolphoi* Graciolli, 2001, *Basilia speiseri* (Miranda-Ribeiro, 1907), *Basilia juquiensis* Guimarães, 1946, *Basilia ferruginea* Miranda-Ribeiro, 1903 and *Basilia ortizi* Machado-Allison, 1963 (Figure 3) [6].

Figure 3 Specimen of Nycteribiidae family; (Source: https://naturdata.com/especies-portugal/taxon/0@1-animalia:arthropoda:insecta:diptera:nycteribiidae/)

3.2. Study 2

3.2.1. Phoresia

Ecological relationship in which an invertebrate species, called phoretic, is transported by another, fixing itself to its surface, to an environment more favorable to colonization and/or development [7].

Many insects, especially those of agricultural importance, are infested by different species of mites and other organisms, making foretic transport (temporary or passive). This association, many times, has great biological importance, whether positive, with beneficial organisms, or negative, with pest organisms, causing the dispersion of these from one place to another. However, this association can vary from opportunistic (dispersion), parasitic or predatory [7, 8].

Among the examples of phoretic association are the Mesostigmata mites of the Diplogyniidae family. It is the most diverse family of Trigynaspida, whose adult stage is associated with adults of arthropods, about which they are always phoetic. The mites of this group are found on several hosts. Studies report examples of these in beetles of the family Curculionidae and Teneobridae, in addition to common cases in bees and in the order Blattodea [8].

In works carried out in bovine areas and farms, occurrences of mites of the Macrochelidae and Uropodidae families in flies and beetles were registered. Furthermore, studies demonstrate more than forty species of beetles from the Scarabaeidae family as hosts of Mesostigmata mites, with the Diplogyniidae family belonging to this group. This fact explains how, in a restricted collection area, with few samples, it was possible to register the occurrence of a new family for the first time in Brazil [8].

Adult females of *Dermatobia hominis* (Linnaeus Jr.,1781) (Diptera: Cuterebridae) are quite peculiar because they use other insects to carry their eggs, laying them on the abdomen or base of the wings of the organism called foretic, defined as that which is responsible for the active transport of another organism that is fixed, by period [9].

Adult females of *D. hominis* are quite peculiar because they use other insects to carry their eggs, laying them on the abdomen or base of the wings of the organism called foretic, defined as that which is responsible for the active transport of another organism that is fixed, for a limited period, on the surface of the first. Several Diptera families have been registered as *D. hominis* egg carriers throughout South America, among which are Anthomyiidae, Calliphoridae, Culicidae, Fanniidae, Muscidae, Sarcophagidae, Simuliidae and Tabanidae. Within Diptera, fanids stand out as vectors [9, 10].

Within Diptera, phanids stand out as vectors for two reasons: (i) they live within the same distribution area as the parasite, that is, in environments whose climate is hot and humid being more abundant in the margins of primitive or secondary forests, gallery forests or eucalyptus plantations open formations seem to be a barrier to the spread of *Dermatobia*); and due to (ii) the eating and behavioral habits of the phanids, which feed on feces (coprophages) or other fermented substrates that contain ammonia, one of the compounds that most attract them, favoring greater proximity and contact with herd creations. Bovine reported that 93 of the 94 phoretic dipterans captured in that study belonged to the genus *Fannia* [11, 12].

Egg masses adhered to the abdomen of *Fannia canicularis* (L. 1721) (Diptera, Fanniidae) and *Fannia punctipennis* (Albuquerque, 1954) (Diptera: Fanniidae) were identified as being from *D. hominis*, areas pastures close to the woods may represent greater risks of parasitism with regard to dermatobiosis. There were 13 and 16 eggs of *D. hominis* in the abdomen of *F. punctipennis* and *F. canicularis,* respectively be a barrier to the spread of *Dermatobia*); and due to (ii) the eating and behavioral habits of phanids, which feed on faeces (coprophages) or other fermented substrates that contain ammonia, one of the compounds that most attract them, favoring greater proximity and contact with herd creations bovine (relative to efficiency) [13, 14].

Egg masses adhered to the abdomen of *F. canicularis* and *F. punctipennis* (Albuquerque) were identified as being of *D. hominis,* due to the fact that pasture areas close to the forests may represent greater risks of parasitism with regard to dermatobiosis (Figures 4, 5 and 6) [15].

Figure 4 Pseudoscorpión being transported by nail fly of the genus *Leptopeza; (*Source: https://gl.wikipedia.org/wiki/Foresia#/media/Ficheiro:Acarinarium.png)

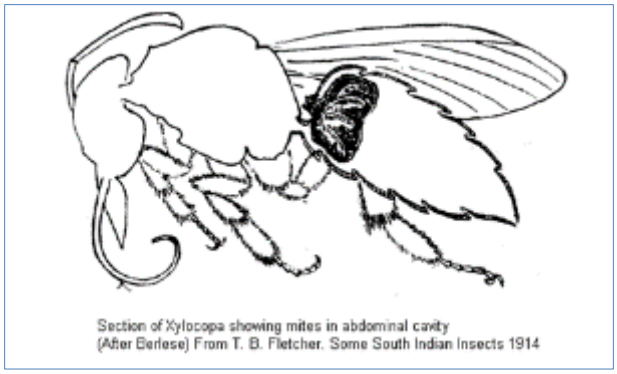

Figure 5 *Abella, Carpenter*, *Acarinario* and *Xylocopa*; (Source: https://gl.wikipedia.org/wiki/Foresia#/media/Ficheiro:Acarinarium.png)

Figure 6 Pseudoescorpião *Cordylochernes scorpioides* (Linnaeus, 1758) trapped by the pedipalp in the antenna of the *Hylletus* beetle *Hylletus coenobita* (Erichson, 1847); (Source: Photo taken from Bevilaqua, Soares and García, 2020)

Another habit of these beings is that of "hiking a ride" on other animals, known as phoresia. Pseudoscorpions have already been spotted “taking that little spin” in arthropods such as beetles and flies, as a way of colonizing new places (Figures 7, 8 and 9) [16].

Figure 7 Foresis between coleopterans and mites; (Source: https://www.ecologiaverde.com/foresis-que-es-y-ejemplos-2940.html)

Thus, the definition of phoresis is the following: action in which an organism adheres or is attached to the outside of the body of another, with no consequence other than transport. In this way, the phoron or pheric organism is distinguished, a term used to designate the organism that is transported, and host, used to refer to the transporting organism. The organism that is transported does not exert any negative consequence on the life of the organism that transports it, although there are cases in which it feeds on the transporting organism and gives rise to a part of a parasitic relationship and another part of a pheric one. This term arose in 1896, when it was observed how small arthropods use the largest ones to transport themselves from one place to another [17].

Figure 8 Eggs of *Dermatobia hominis* (Linnaeus Jr., 1781) (Diptera: cuterebridae) glued to the abdomen of a carrier fly; (Source: http://www.icb.usp.br/~marcelcp/Dermatobia.htm)

When the *Dermatobia* female is ready to oviposit she captures another insect - usually a fly - and glues her eggs to the captured insect's abdomen [17].

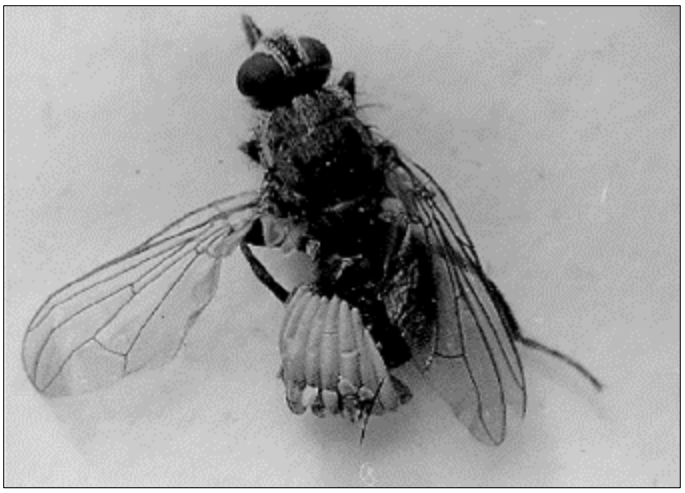

Figure 9 Transmission of eggs and larvae of the human bot fly *Dermatobia hominis* (Linnaeus Jr.,1781) by a female of the horn fly *Haematobia irritans* (Linnaeus, 1758) (Diptera: Muscidae); (Source: Researchgate.net/publication/13368485)

Biological transmission of eggs and larvae of the human bot fly *Dermatobia hominis* (Linnaeus Jr.,1781) by a female of the horn fly *Haematobia irritans* (Linnaeus, 1758) (Diptera: Muscidae) is reported for the first time in South America. Seventeen females of *H. irritans* were collected near the municipality of Morada Nova (19ºS, 45ºW) in the Três Marias, region of northwestern Minas Gerais in June 1993. One of the flies bore 21 viable eggs of *D. hominis*, which were incubated in a BOD oven at 27ºC, and 80% RH. Hatching of first instar larvae was observed after four days. The importance of this report lies in the fact that *H. irritans* had never been implicated in the transportation of eggs of *D. hominis* [18]. The importance of this report lies in the fact that *H. irritans* had never been implicated in the transportation of eggs of *D. hominis* (Figure10) [19].

Figure 10 Eggs of *Dermatobia hominis* (Linnaeus Jr., 1781) by a female of the horn fly *Haematobia irritans* (Linnaeus, 1758) (Diptera: Muscidae); (Source: Researchgate.net/publication/13368485)

Were collected 4 species of mosquitoes bearing eggs of the human botfly, *Dermatobia hominis* (Linnaeus Jr., 1781), in the Trabiju Municipal Reserve, Pindamonhangaba, São Paulo, Brazil. The mosquitoes were simultaneously collected in landing–biting catches by 2 collectors. From a total of 6,902 specimens collected from January through April 2010, the 15 females carrying *D. hominis* eggs belonged to *Aedes scapularis* Rondani, 1848 (Diptera: Culicidae), *Limatus durhamii* Theobald, 1901 (Diptera: Culicidae), *Onirion personatum* (Lutz, 1904) (Diptera: Culicidae) and *Wyeomyia* sp. (Roca-Garcia, 1944) (Diptera: Culicidae). The first 3 species are new reports of phoresy among mosquitoes and the human botfly (Figure 11) [19].

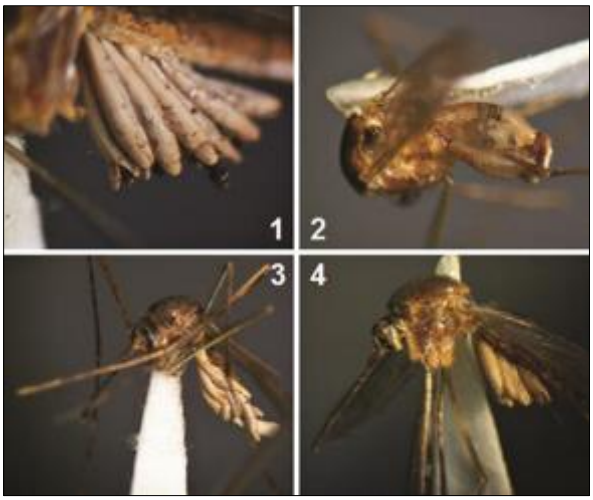

Figure 11 Phoresy among mosquitoes and the human botfly; (Source: https://bioone.org/journals/journal-of-medical-entomology/volume-53/issue-2/)

3.3. Study 3

3.3.1. Parasitoids

Parasitoids are organisms that parasitize other beings, and prevent them from reaching the reproductive stage of the adult. These organisms spend part of their lives attached to or inside a single host organism, which may be an insect pest. Invariably parasitoids kill or consume their hosts. Parasitism is similar to parasitism, except that the host is killed in the first case. Many parasitoids evolve simultaneously with their hosts and, therefore, become dependent on their existence [20].

The Tachinidae family, with more than 10,000 described species, is one of the most diverse and ecologically important in the Order Diptera (which includes more than 120,000 described species). Most species of the Tachinidae family are parasitoids (they lay eggs for larvae to develop in the bodies of other insects when in the larval stage), exerting an important control over the population of their hosts, usually herbivorous insects [21].

The Tachinidae family is divided into four subfamilies: Phasiinae, Dexiinae, Exoristinae and Tachininae

Scientific identification: (Diptera: Tachinidae)

Common name: parasitoid fly

Importance: Parasitoid flies of various insects found in different terrestrial environments. The phase immature in this group attacks moth and butterfly larvae (cartridge caterpillar, cane caterpillar, soybean caterpillar), bed bug nymphs and adults (green bug, spotting bug) larvae and adults of beetles (kitty and dung beetles), crickets, grasshoppers and wasps, although spiders and scorpions too can be parasitized. Adults lay their eggs directly in the host's body, or in the foliage, and feed mainly on pollen and nectar. Has relative importance in control biological, as it keeps many pest species under control. The flies of this group are also important pollinators of several plants [22].

Description: present complete metamorphosis, that is, from the eggs hatch larvae that pass from pupa to adulthood. They have different shapes and colors and varied sizes, measuring between 3 and 25 mm in length.

Long, with thick bristles (hair) all over the body (Figures 12 and 13) [22].

Figure 12 Adult of the Tachnidae family parasitoid (parasitoid fly) (Side view); (Source: https://commons.wikimedia.org/wiki/File:Diptera-Tachinidae-Pelatachina-tibialis-201206190008.JPG)

Figure 13 Adult of the Tachnidae family parasitoid (parasitoid fly) (Vista dorsal).(Source: https://www.researchgate.net/figure/Figura-1-Vista-dorsal-de-Adultos-de-a-A-marmoratus-y-b-V-rurales-Vista-)

3.4. Study 4

3.4.1. Life cycle

The flies in this family are parasitoids, i.e., the females lay their eggs on or in the bodies of other insects, and when the fly larvae hatch, they gradually consume the host until it dies, and the fly larvae pupate. Many tachinids attack larval moths and butterflies, although some species parasitize other insect groups (e.g., cucumber beetles). The adults often resemble large houseflies but have a bristlier abdomen. They sustain themselves on nectar and pollen, and so are often found on flowers during the summer (Figure 14) [23].

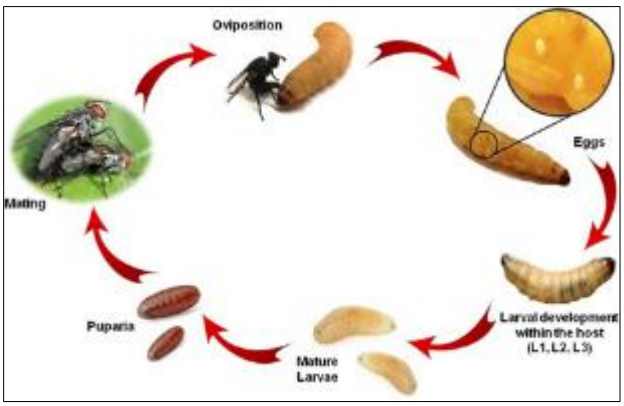

Figure 14 Scheme of the life cycle of *Exorista larvarum* (L. 1758) (Diptera: Tachnidae); (Source: https:/5www.researchgate.net/figure/Scheme-of-the-life-cycle-of-Exorista-larvarum_fig1_323481009)

3.5. Study 5

3.5.1. Studies related to Family, Genus, Species and life cycle

The Phoridae family belongs to the order Diptera, and the phorid name originates from the Greek word phora, which means fast movement, in reference to the speed during its characteristic displacement. They are small in size, around 0.5 to 5.5 mm in length, and are easily recognized by the characteristic venation, long posterior femurs, and humpbacked appearanc. The family has a wide distribution worldwide, having the greatest diversity of species in the tropics studied [23, 24, 25, 26].

They also exhibit a great diversity of larval lifestyles among insects, thus having different saprophagy, herbivory, predator or specialized parasitoid habits. In addition to its wide distribution, this family is quite diverse, with about 240 genera, approximately half of which have associations with social insects, of which 60 genera are exclusively associated with. The largest number of reported cases of parasitoidism by phorids occurs in ants, and interactions between ants *Solenopsis* spp. and phorids of the *Pseudacteon* genus have been the most studied (Figure 15) [23, 24, 25, 26].

Figure 15 Ant parasitoids predators and competitors; (Source: http://lloydm.com/AntParasitoidsPredatorsandCompetitors.html)

The parasitoid phorids of these ants belong to three genera*: Apocephalus, Myrmosicarius* and *Eibesfeldtphora*, the parasitism rates are relatively low, around 2 to 4%, depending on the host, phorid and location under study. However, the presence of phorids under the ant trails reduces the number of ants foraging. The parasitoid attack strategies against foragers and oviposition sites in the body of sauvas (ant) do not vary, the species *Eibesfeldtphora declinata* (Smith, 1958), *Eibesfeldtphora tonhascai* Brown, 2001 and *Myrmosicarius grandicornis* Borgmeier, 1928 chase and attack sauva (ant) workers along their foraging trails, oviposition on the ants' heads [27].

3.5.2. Taxon treatment

Dohrniphora Dahl 1898

3.5.3. Biology

All species of flies had similar behavior, documented in video clips. Approximately 10 decapitations per species have been observed. Flies arrived shortly after the ants were injured, usually arriving as in copula pairs in flight, cruising back and forth above the ants. After the pair landed, males immediately departed and females approached the injured *Odontomachus* [28].

Dohrniphora longirostrata (Enderlein, 1912) (Diptera Phoridae) species group exhibit highly specific “headhunting” behavior in which injured *Odontomachus* ants are decapitated, the heads dragged away, and females either feed on their contents or lay an egg nearby. Since most females studied lacked eggs in their ovaries, we conclude that this bizarrely specialized feeding is necessary to provide nutrients for reproduction in these flies (Figures 16, 17, 18, 19 and 20) [28].

Figure 16 A new type of ant-decapitation in the Phoridae (Insecta: Diptera); (Source: https://bdj.pensoft.net/article/4299/)

Figure 17 A female of *Dohrniphora longirostrata* (Enderlein, 1912) (Diptera Phoridae), lateral view; (Source: https://commons.wikimedia.org/wiki/File:Dohrniphora_longirostrata_female.jpg)

Figure 18 Ants and flies: Ant-decapitating flies/ Ant-decapitating flies; (Source: https://www.phorid.net/dohr_key/perpendicularis.htm)

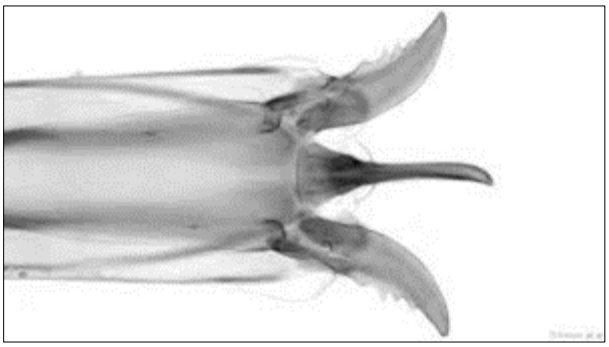

Figure 19 Tip of female *Dohrniphora longirostrata* (Enderlein, 1912) (Diptera Phoridae) proboscis; (Source: Ant-decapitating flies/ Ant-decapitating flies)

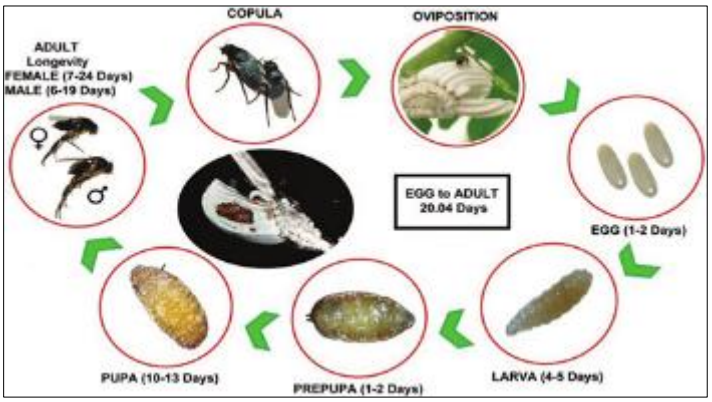

Figure 20 Life cycle of *Syneura cocciphila* (Coquillett, 1895) (Diptera: Phoridae) under laboratory conditions (26.6 ± 1.5°C; RH: 62.8 ± 6.17%). Photos: K. Muñoz; (Source: https://www.researchgate.net/figure/Life-cycle-of-Syneura-cocciphila-under-laboratory-conditions-266-15C-RH-628_fig1_322644315)

4. Conclusion

The Order Diptera is a group that is present in most habitats. They are holometabolites, occupy several food niches, and may be parasites, hematophagous, predators, in addition to feeding on leaves and fruit. Certain species are of great economic, forensic, medical and veterinary importance. Scorpions (Arachnida: Scorpiones) are animals that pose serious public health problems, due to the action of their venom in the event of an accident. Only 25 species of scorpions in the world, all belonging to Buthidae, are known to cause serious accidents.

Compliance with ethical standards

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