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(REVIEW ARTICLE)

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Establishing the phenology of the Bombyliidae Family (Insecta: Diptera)

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Abstract

Despite the high number of species of this family, the biology of juveniles of most species is poorly understood. The postembryonic development is of the type hypermetamorphic, with parasitoid or hyperparasitoid larvae. Exceptions are the larvae of Heterotropinae, whose biology is similar to that of other Asiloidea, with predatory larvae that do not undergo hypermetamorphosis. Hosts of bee flies belong to different orders of insects, but mostly are among the holometabolous orders. The objective of this work is to research the biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology, parasitoidism (parasitism) and predatism of the Bombyliidae family (Insecta: Diptera). The research was carried out in studies related to quantitative aspects taxonomic and conceptual aspects. A literature search was carried out containing articles published from 1937 to 2021. The mini review was prepared in Goiânia, Goiás, from September to October 2021. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through, SEEK education, Periodicals CAPES, Google Academic, Bioline International, VADLO, Scopus, Web of Science, LILACS, Medline, LIS and Portal of Scientific Journals in Health Sciences.

Keywords: Biogeography; Phenology; Parasitoidism; Taxonomy; Insecta

1 Introduction

The Bombyliidae are a family of brachycephalic diptera. It is a very large family with hundreds of genders. Its life cycle is not yet well understood. Adults feed on nectar and pollen from flowers and are thus pollinators. They mimic bees and in English, they are called bee flies, which means bee fly. Possibly this gives them some protection against predators who fear a bee sting (Figures 1 and 2) [1,2,3].

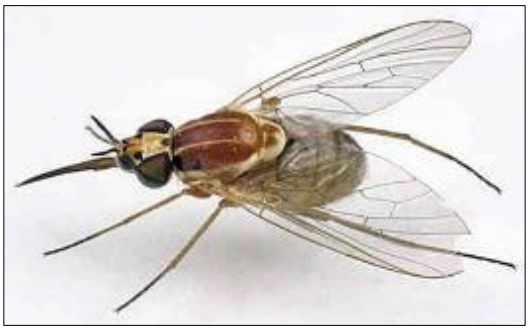

Figure 1 Specimen of Bombyliidae Family;
(Source:https://www.opsu.edu/Academics/SciMathNurs/NaturalScience/PlantsInsectsOfGoodwell/bombyliidae/default.html)

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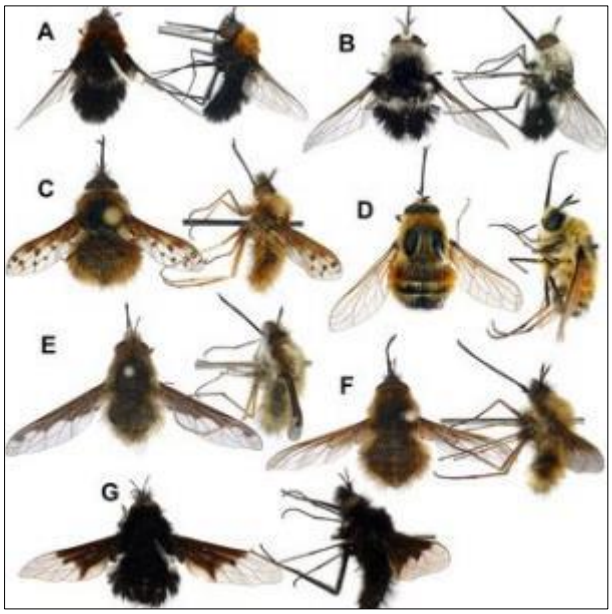

Figure 2 Male and female of Bombyliidae: Body, dorsal view and lateral view; A, *Bombylius ambustus* Eversmann, 1834, male; B, Bls*. Ambustus*, female; C, Bls. *Callopterus*; D, Bls. *Erythropleurus* sp. nov.; E, *Bls.* Major; F, Bls. Shibakawae; G, *Bombylella koreanu* (Paramonov, 1926); (Source: esearchgate.net/publication/319923581_Taxonomic_review_of_the_genera_Bombylius_and_Bombylella_Diptera_Bombyliidae_in_Korea/link/59d4676aaca2721f436cf86c/download)

Although it is a family with many species, the individuals are not very abundant. Perhaps therefore it is a very poorly studied family. More than 5000 species (in 230 genera) have been described and possibly thousands remain to be described [4,5].

Most have a long, thin proboscis that in a few species becomes longer than the body. They cannot retract it like butterflies. They are usually fast flying. They are often seen visiting flowers or flying close to the ground. Most species have hypermetamorphism, in which the first larval stage is a planidium, which can actively seek its host; the following stages are sedentary. The larvae are predators of the eggs and larvae of other insects, such as caterpillars, bees, and beetles. The females lay their eggs in the proximity of the nests of other insects, especially solitary bees. Some species are highly specialized with respect to the host, but others are opportunistic and parasitize a wide variety of species. The first larval instar is a planidium that is more active than the other instars and capable of finding its host *(*Figures 3A and 3B*)* [6,7,8,9].

Figure 3A *Poecilanthrax arethusa* (Osten Sacken, 1886). (Bombyliidae) on flower of *Thelosperma megapotamicum* (Spreng) (Aster Family) (rayless greenthread) polymization; (Source; https://beetlesinthebush.com/category/arthropoda/insecta/diptera/bombyliidae/)

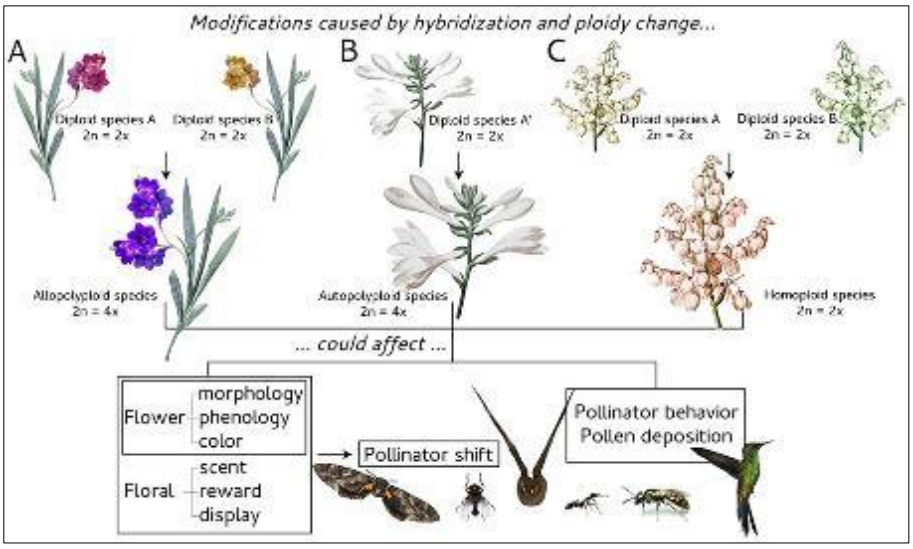

Figure 3B A. Allopolyploidy, B. Autopolyploidy, C. Homoploidy. Below follow the main floral traits affected by hybridization and polyploidy and the main traits affected in the pollinator taxa; (Source: (in the absence of pollinator shift). Figures were modified from Freepik (https: /www.freepik.com/), except by hummingbird, bat, and hawkmoth photos, which were supplied by F.W. Amorim)

1.1 Phases of the biological cycle

1.1.1 Egg

The eggs of the Bombyliidae, in so far as they are known, present no adaptive modifications whatever. They are oblong in form, are at times slightly curved, have both ends smoothly rounded, and are 2-4X longer than broad is. They are relatively large, measuring 1.0 by 0.25 mm. in *Hyperalonia morio* Fabricius, 1775 and *Bombylius fugax* Wiedemann in Meigen, 1820. Apparently, all species cover the egg with a coating of mucilaginous material to which soil particles adhere at the time of deposition.

1.1.2 Larvae

The larval stages are predators or parasitoids of the eggs and larvae of other insects. The adult females usually deposit eggs in the vicinity of possible hosts, quite often in the burrows of beetles or wasps/solitary bees. Although insect parasitoids usually are host-specific, often highly host-specific, some Bombyliidae are opportunistic and will attack a variety of hosts.

Larvae of antlions of genus *Myrmeleon* Linnaeus, 1767 (Neuroptera, Myrmeleontidae) are “sit-and-wait” predators that build traps in the form of a pit dug into sandy soil to capture prey. *Myrmeleon brasiliensis* (Navás, 1914) larvae build traps with a mean. In the family Myrmeleontidae, cases of parasitoidism by dipterans of the family Bombyliidae and hymenopterans of the family Chalcididae. The results of the present study demonstrated that the parasitoid *Paravilla* sp. only attacked *M. brasiliensis* larvae in the second and third instars and exerted an influence on development, as demonstrated by the increase in the pupal stage of the antlion. Although parasitoids exhibit a high degree of diversity, studies on parasitoids of *Myrmeleon* in tropical regions are extremely scarce. Based on the present results, new questions regarding the development of parasitized and non-parasitized larvae can be clarified.

1.1.3 Pupa

Length: 21.17 mm. Head width: 3.36 mm. Thorax width: 3.09 mm. Abdominal width: 5.00 mm, tapering to 0.45 mm at width of anal segment. Coloration: predominantly light brown. Without cephalic spines, tubercles or setae, only a reduced transverse sharp ridge above antennal sheaths, both dark brown; antennal sheaths external, long, almost reaching tip of labrum, united dorsally on the median line forming a low ridge mouth-parts long, apex of labellum almost reaching wing tip (Figures 4A and 4B).

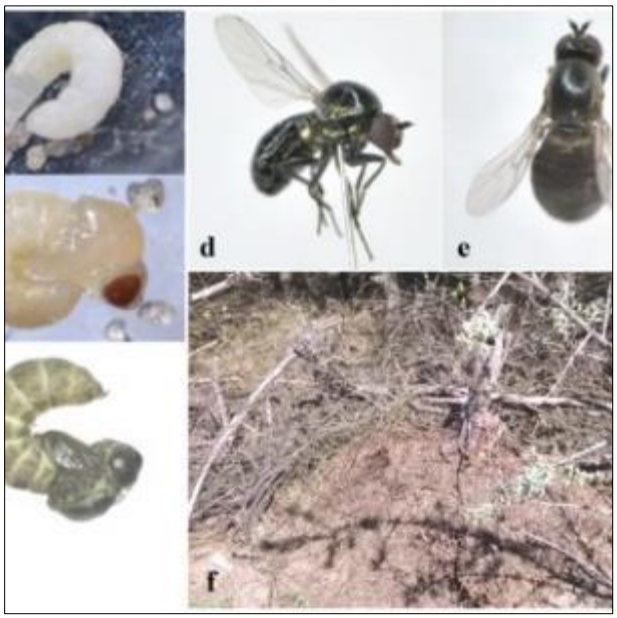

Figure 4A *Glabellula arctica* (Zetterstedt, 1838), a- larva, b- fresh pupa, c- mature pupa, d- lateral view of imago, e- dorsal view of imago, f- anthill of *Formica polyctena* Förster, 1850; (Source: Photo by Ł. Mielczarek)

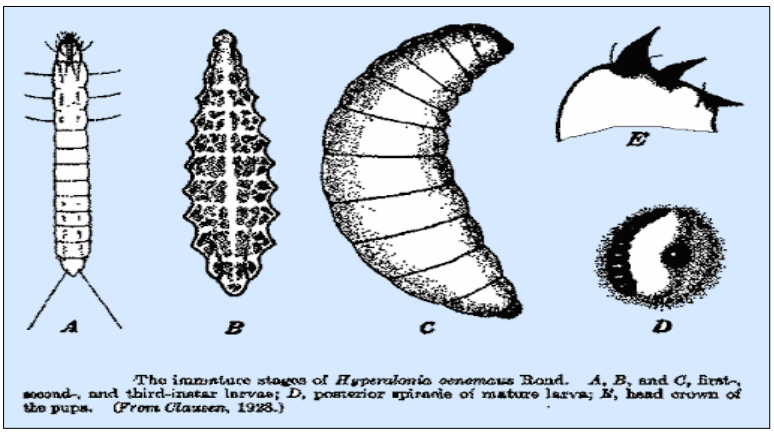

Figure 4B Immature Stages of Bombyliidae; (Source: http://www.faculty.ucr.edu/~legneref/immature/gif/bomby1.ima.htm)

1.1.4 Adult

Adults favor sunny conditions and dry, often sandy, or rocky areas. Unlike butterflies, bee flies hold their proboscis straight, and cannot retract it. In parts of East Anglia, locals refer to them as beewhals, thanks to their tusk-like appendages. Many Bombyliidae superficially resemble bees and accordingly the prevalent common name for a member of the family is bee fly (Figure 5).

Possibly the resemblance is *Batesian mimicry* Bates (1862), affording the adults some protection from predators. A similar trophic behavior occurs among the hoverflies, another important family of Diptera pollinators. Most are stout, hairy, and up to 40mm in size; others are thin with little hairiness, and a few are small, no more than 1.2 mm. Some have markings on the wings (Figures 6A and 6B) [10,11,12,13,14].

Figure 5 Bee Flies are hairy, most of them mimic wasps or bees. They have stout and woolly body, but they do not have the narrowed waist. Their wings are easily recognized with distinct vein pattern, usually dark in color, some with patterns or spots. When at rest, their wings are flat in outspread position. Their head is occupied by their large eyes, in hemispherical shape. Their legs are slender and without bristles. Their claws are small; (Source: https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm)

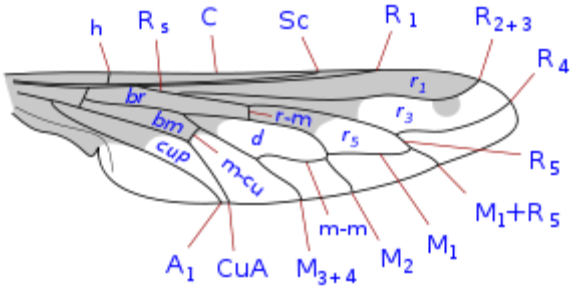

Figure 6A The Bee Flies (Diptera: Bombyliidae) of Ontario, with a key to the species of Eastern Canada provided by EOL authors The bee flies (Diptera: Bombyliidae) of Ontario, with a Key to the Species of Eastern Canada Illustrated dichotomous keys to the 73 bee fly species of 25 genera occurring in or adjacent to Eastern Canada are presented. Thirty-two of these species represent new or previously unrecognized records for Ontario. We review the distributions of these species in Ontario, focusing on rarely collected and habitat-restricted species, and summarize host use when known; (Source: https://eol.org/pages/497/articles?locale_code=show_all)

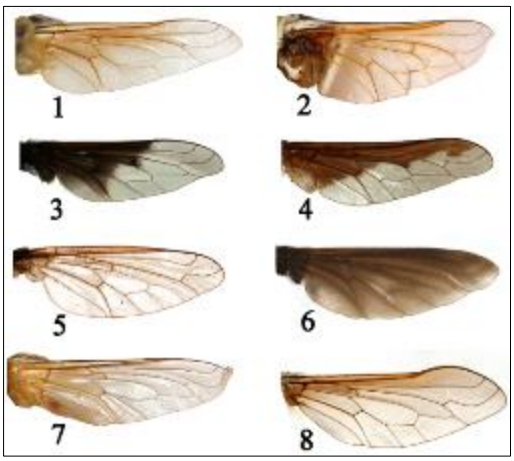

Figure 6B *Anastoechus chinensis* Paramonov, 1930; 2. *Bombomyia discoidea* (Fabricius, 1794); 3. *Bombylella nubilosa* Yang, Yao & Cui, 2014; 4. *Bombylius major* Linnaeus, 1758; 5. *Conophorus chinensis* Paramonov, 1929; 6. *Euchariomyia dives* Bigot, 1888; 7. *Systoechus ctenopterus* (Mikan, 1796); 8. *Tovlinius pyramidatus* Yao, Yang & Evenhuis, 2011; (Source: https://zenodo.org/record/261629#.yzpwjgdmliu)

1.2 Life cycle

Larvae are mainly parasites of locust eggs, although they can also feed on larvae or pupae of some species of moths and butterflies, bees, beetles, and flies. Adults feed on pollen and females necessarily feed on nectar, so they are considered important pollinators of many plant species. Fly actively and can be found on flowers, grasses, stones, branches or in vegetation in open areas present complete metamorphosis during development, that is, they develop the starting from an egg, they go through the larval and pupae stages before becoming adults. When they reach the adult stage have varied sizes and can measure between 2 and 20 mm in length are usually robust and covered with fine hair. They have a wide, rounded or elongated and cylindrical abdomen. Your wings, with dark spots, are generally longer than the body length, and when they are at rest, they remain extended. Very little is known about the biology and behavior of family of that species (Figures 7A and 7B) [15,16].

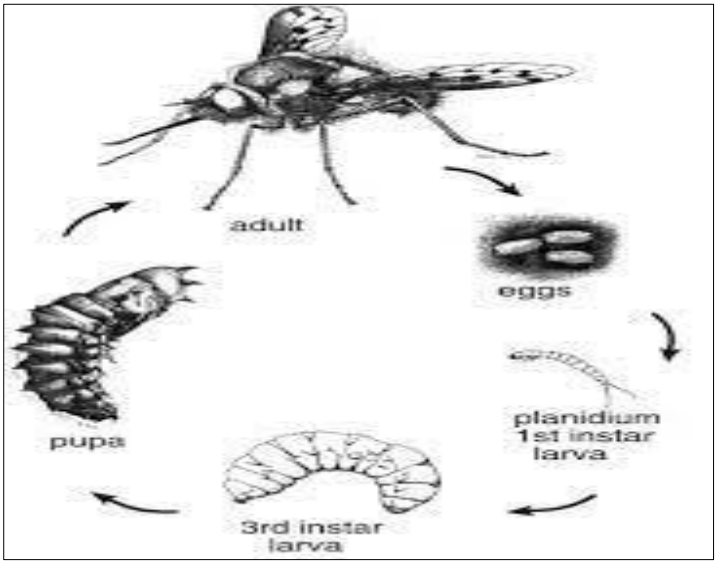

Figure 7A Generalized life-history of a parasitoid bee fly; (Source: https://www.researchgate.net/figure/Generalized-life-history-of-a-parasitoid-bee-fly_fig1_229684494)

1.3 Mating behavior

Mating behavior has only been observed in a handful of species. It can vary from fairly generic swarming or unsolicited mid-air interception, as is common in many Diptera, to courtship behavior involving a context-specific flight pattern and wingbeat pitch of the male, with or without repeated proboscis contact between male and female. Males often seek out smaller or larger clearings on the ground, presumably in vicinity of flowering plants or host nesting habitats that are likely attractive to females. They can return to their chosen perch or patch after every feeding bout or after pursuit of other insects flying over, or they can instead survey their chosen territory while hovering one or more meters above the bare patch [17,18].

Despite the high number of species of this family, the biology of juveniles of most species is poorly understood. The postembryonic development is of the type hypermetamorphic, with parasitoid or hyperparasitoid larvae. Exceptions are the larvae of Heterotropinae, whose biology is similar to that of other Asiloidea, with predatory larvae that do not undergo hypermetamorphosis. Hosts of bee flies belong to different orders of insects, but mostly are among the holometabolous orders [17,18].

Pregnant females seek out host habitats and may spend many minutes inspecting, for example, entrances to smaller burrows in the ground. In some species, this behavior consists of repeatedly moving and touching the ground with the forepaws within a fraction of a second near the edge of the burrow entrance, presumably to detect biochemical clues about the burrow builder, such as identity, hit length. The bee fly can land and insert its posterior abdomen into the ground, laying one or more eggs on or near the edge. In some females they can release their eggs from the air with rapid movements of the abdomen as they hover. Above the entrance to the burrow [19,20].

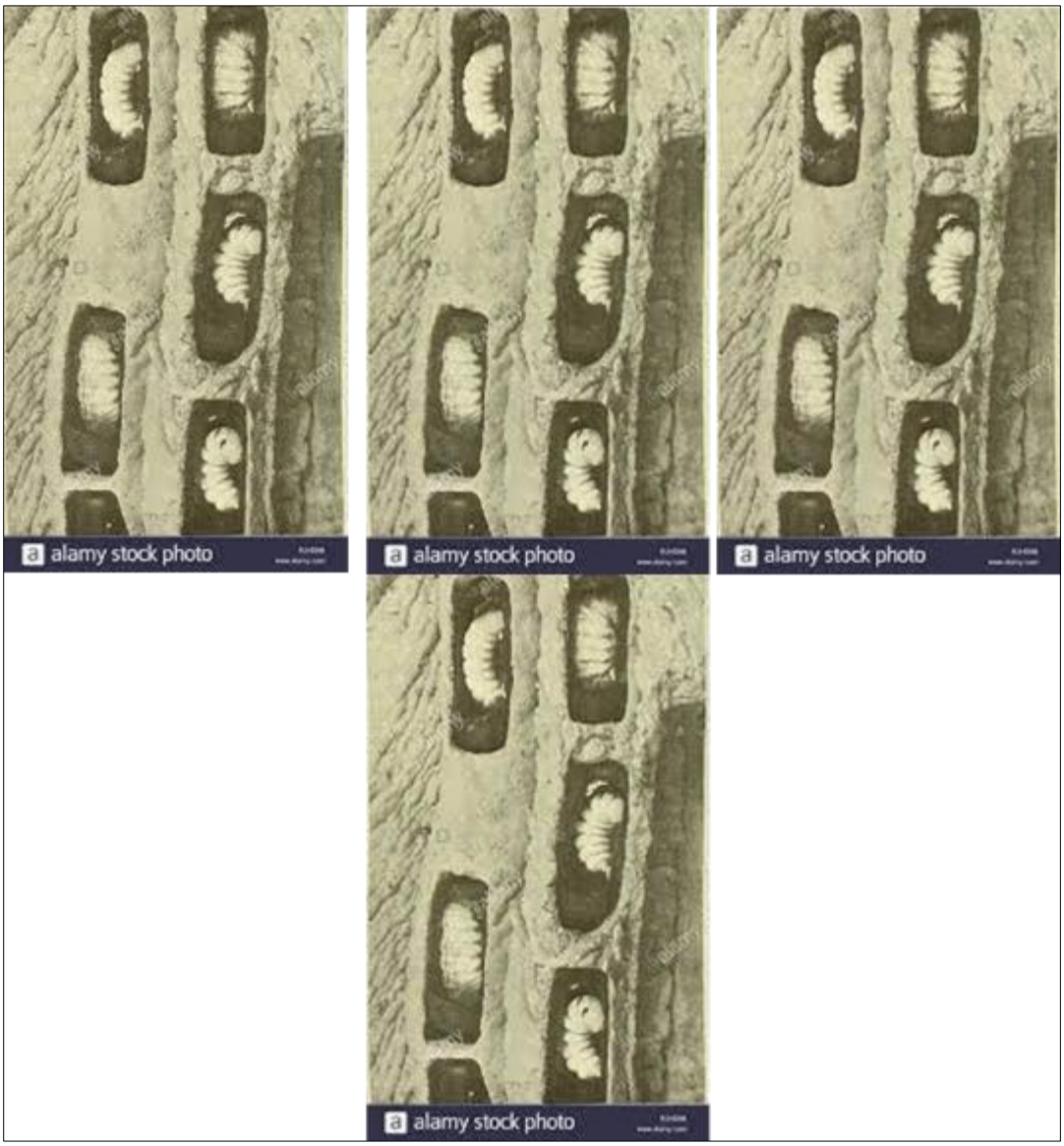

Figure 7B Bee flies of the world: the genera of the family Bombyliidae. Bombyliidae; Parasites. C D 1. Eggs, larvae, and pupae of *Anthrax limatulus* Say, 1829; D, larvae, quot; in situ & quot; within wasp nest. Please note that these images are extracted from the scanned page images that may have been digitally enhanced for read ability - coloration and appearance of these illustrations may not perfectly resemble the original work; (Source: Hull FM. (Frank Montgomery), 1901-1982. Washington, Smithsonian Institution Press)

1.4 Geographic distribution

Brazil: Amapá, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraná, Rio de Janeiro, Santa Catarina and São Paulo. Perhaps the best known genus is *Bombylius*, well represented in Europe and North America with numerous species. Large bee-flies are the most common species of the genus and are found across the northern hemisphere. There have been 23 subspecies recorded in the Ethiopian, 150 in the Palearctic, 109 in the Nearctic, 12 in the Neotropical, and 11 in the Oriental regions. [20,21].

1.5 Habitat

Bee-flies are found in warm regions where flowering plants live. They can be seen on the ground, near flowers, and in bushes during the day. At night, they shelter in the crowns of trees [20,21].

1.6 Bioecology

Bee-flies from around the world, clockwise from top left: *Systropus, Bombylius, Cephalopdromia* and *Ligyra.* Adults are flower feeders; the larvae are parasitoids of other insects [20,21].

1.7 Taxonomy

1.7.1 Subfamilies

Anthracinae, Antoniinae, Bombyliinae, Crocidiinae, Ecliminae, Heterotropinae, Lomatiinae, Mariobezziinae, Oligodraninae, Oniromyiinae, Phthiriinae, Tomomyzinae, Toxophorinae, Usiinae and Xenoprosopinae [21].

Objective

The objective of this work is to research the biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology, parasitoidism (parasitism) and predatism of the Bombyliidae family (Insecta: Diptera).

2 Methods

The research was carried out in studies related to quantitative aspects taxonomic and conceptual aspects. A literature search was carried out containing articles published from 1937 to 2021. The mini review was prepared in Goiânia, Goiás, from September to October 2021, through the. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the ResearchGate, Academia.edu, Frontiers, Publons, Qeios, Pubmed, Online Scientific Library (Scielo), internet, Biological Abstract, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periodicals CAPES, Google Academic, Bioline International, VADLO, Scopus, Web of Science, LILACS, Medline, LIS and Portal of Scientific Journals in Health Sciences.

3 Studies conducted and selected

3.1 Study 1

3.1.1 Scientific identification: (Diptera: Bombyliidae)

3.1.1.1 Common name: bee-like fly

Importance: larvae are mainly parasites of locust eggs, although they can also feed on larvae or pupae of some species of moths and butterflies, bees, beetles and flies. Adults feed on pollen and females necessarily feed on nectar, so they are considered important pollinators of many plant species. Fly actively and can be found on flowers, grasses, stones, branches or in vegetation in open areas (Figure 8).

Figure 8 Bees and flies (Diptera: Bombyliidae); (Source: https://www.msnucleus.org/membership/ngss/third_ngss/03bees_flies.html)

Description: present complete metamorphosis during development, that is, they develop the starting from an egg, they go through the larval and pupae stages before becoming adults. When they reach the adult stage have varied sizes and can measure between 2 and 20 mm in length are usually robust and covered with fine hair. They have a wide, rounded or elongated and cylindrical abdomen. Your wings, with dark spots, are generally longer than the body length, and when they are at rest, they remain extended. Very little is known about the biology and behavior of family of that species [22].

3.2 Study 2

Bombylius (Diptera: Bombyliidae) (Figures 9A and 9B).

Figure 9A *Bombylius* (Diptera: Bombyliidae); (Source: https://animaldiversity.org/accounts/Bombylius/)

3.2.1 Terrestrial

Regions temperate habitat. Terrestrial biomes savanna or grassland forest.

3.2.2 Physical Description

Bee-flies are a genus that imitates various bees, such as bumblebees. Similar to bumblebees, bee-flies are densely hairy with body colorings ranging from black to orange. The hairs are often a lighter color than the body, except one subspecies that is covered with black hair. Unlike bees, bee-flies have a long proboscis, four long legs, short antennae, and two wings. They do not have a stinger. Bee-flies are medium-sized, but subspecies vary in size from 8-16 mm. The females of some subspecies are larger than the males. Larvae look like grubs [23,24,25].

3.2.3 Other Physical Features ectothermic bilateral symmetry. Sexual dimorphism female larger. Development

Eggs are laid individually at the entrances of solitary bee nests. The eggs hatch and the larvae seek out and feed upon stored pollen, bee eggs, and bee larvae. Once the larvae are grown, they pupate and remain in the bee nest until the next spring [23,24,25].

3.2.4 Development

Life Cycle metamorphosis,

3.2.5 Reproduction

Bee-flies mate and lay eggs during the spring to early summer. After mating, they seek out the nests of solitary bees to lay eggs. Once a nest has been found, the female hovers over the entrance and drops an individual egg. This process repeats. The eggs hatch, feed, pupate, then wait for the next spring to arrive. The larvae are parasitic. Key Reproductive Features seasonal breeding gonochoric/gonochoristic/dioecious (sexes separate) sexual fertilization internal oviparous.

3.2.6 Parental investment parental involvement. Lifespan/Longevity

Little information is available on the lifespan of bee-flies due to their high mobility. The lifespan has been determined to be greater than two weeks because eggs appear at the earliest two weeks after adults. Bee-flies are found during spring to early summer [23,24,25].

3.2.7 Behavior

Bee-flies are a genus of solitary flies. They make a buzzing sound when flying, are very fast flyers, and can hover in mid-air. Members of the genus are most active during the day when the weather is sunny and warm. They are typically found on the ground and flying in forests and bushes. When the weather is cloudy, bee-flies will sit on the ground to warm themselves. If the sun reappears, the bee-flies will start to fly again. At night, they avoid the ground and bushes, as they seem to hide in the crowns of trees.

3.2.8 Key Behaviors fly's diurnal motile nomadic solitary. Communication and perception

Bee-flies use the sense of sight, touch, sound, and chemical receivers to get information and communicate [13,14,15].

3.2.9 Perception Channels visual tactile acoustic chemical. Food Habits

Adults feed primarily on nectar. Pollen has been found in the systems of adults, but it is unknown if it was eaten intentionally. Larvae are parasitoids that feed on the eggs, larvae, and stored pollen of host bees.

3.2.10 Primary Diet herbivore nectarivore. Predation

Bee-flies are mimics of bumblebees (*Bombus* spp.).

3.2.11 Anti-predator Adaptation's mimic. Known Predators

Western Kingbirds *Tyrannus verticalis* Say, 1822 (Passeriformes: Tyrannidae) [23,24,25].

Figure 9B *Tyrannus verticalis* Say, 1822 (Passeriformes: Tyrannidae); (Source: https://ast.wikipedia.org/wiki/Tyrannus_verticalis)

3.2.12 Ecosystem Roles

Adults are pollinators of a large variety of flowers. Larvae are parasitoids of bees and feed on bee larvae. Instead of bees, the larvae of some species are parasitic to the eggs and larvae of locusts, fly pupa, and caterpillars. Ecosystem Impact pollinates parasite.

3.2.13 Species Used as Host

Furrow bees (*Halictus* species), Plaster bees (*Colletes* species) Mining bees (*Andrena* species).

3.2.14 Economic Importance for Humans: Positive

Bee-flies are important pollinators. They visit purple, violet, blue, and white flowers more often than other colors. Lungwort, purple gromwell, common bugloss, and European stickseed are commonly visited plants.

3.2.15 Positive Impacts pollinates crops. Economic Importance for Humans: Negative

There are no known adverse effects of bee-flies on humans [23,24,25].

3.3 Study 3

3.3.1 Subfamily Toxophorinae - Slender Bee Flies

Bee Flies in the subfamily usually have the slender body covered with short hairs. They also have long and slender proboscis to feed on flowers (Figure 10).

Figure 10 Subfamily Toxophorinae**;** (Source: https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm)

3.3.2 Subfamily Bombyliinae - True Bee Flies

Bee Flies in the subfamily Bombyliinae usually have the stout and hairy body. They have long and slender proboscis. The wing vein M1 meets R5 before the wing margin. Sometimes this subfamily is called True Bee Flies because their hairy body resembles bee (Figure 11).

Figure 11 Specimens from the Subfamily Bombyliinae; (Source: https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm)

3.3.3 Subfamily Lomatiinae - Brown Bee Flies

In this subfamily, the bee flies have relatively long wings and slender body. Their wing vein Rs forks well before r-m, with R4 and R5 strongly looped. They usually have the narrower and flattened abdomen. They are brown to dark brown in colors (Figure 12).

Figure 12 Specimens from the Subfamily Lomatiinae; (Source: https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm)

3.3.4 Subfamily Anthracinae - Black Bee Flies and Stout Bee Flies

Anthracinae is a very large subfamily. We found quite a number of species in this subfamily and listed in different tribes as below;

3.3.5 Tribe Anthracini - Black Bee Flies

Bee Flies in this tribe have their wing vein Rs forks very close to cross vein r-m. They are close to the Exoprosopini except they have a pencil of hairs at the tip of antenna. They are from small to medium in size. Most of them are dark brown to black in colour, with patterned wings (Figure 13).

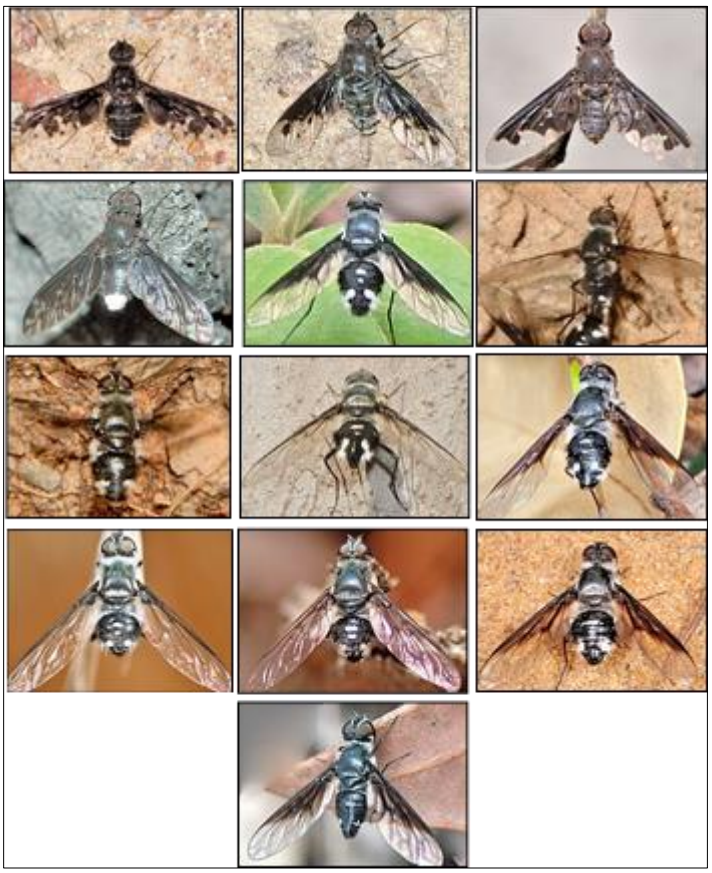

Figure 13 Specimens from the Subfamily Anthracinae, Tribe Anthracini; (Source: https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm)

3.3.6 Tribe Exoprosopini - Stout Bee Flies

In this tribe, the Bee flies also have their wing vein Rs forks very close to cross vein r-m. They have stout body comparing with Bee Flies in other groups (Figure 14).

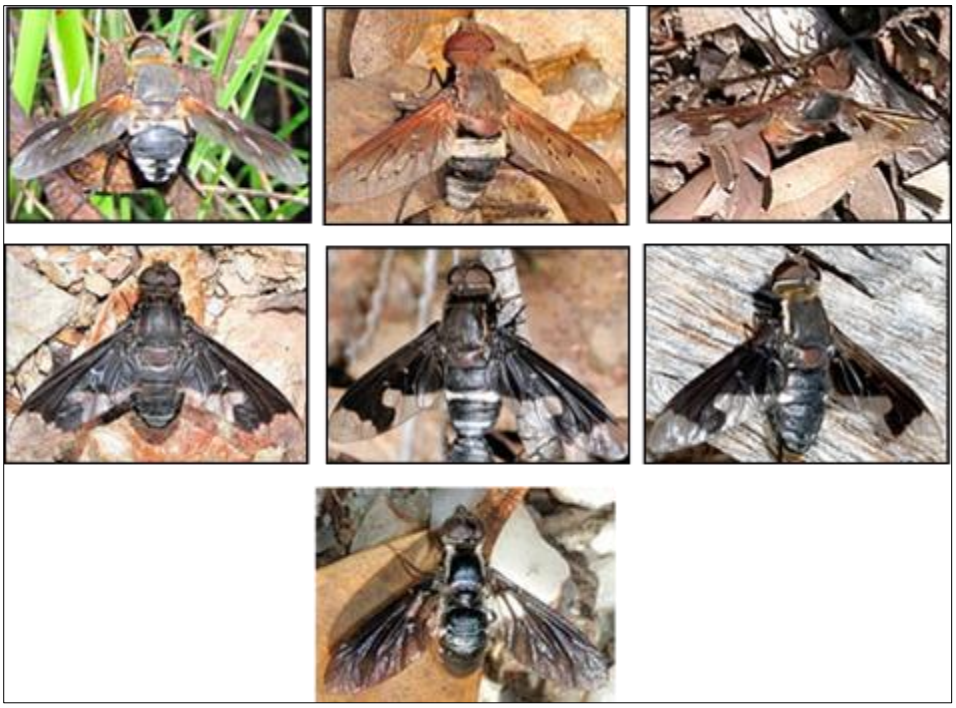

Figure 14 Specimens from the Tribe Exoprosopini

https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm

3.3.7 *Tribe Villini – Banded Bee Flies* (Figure 15).

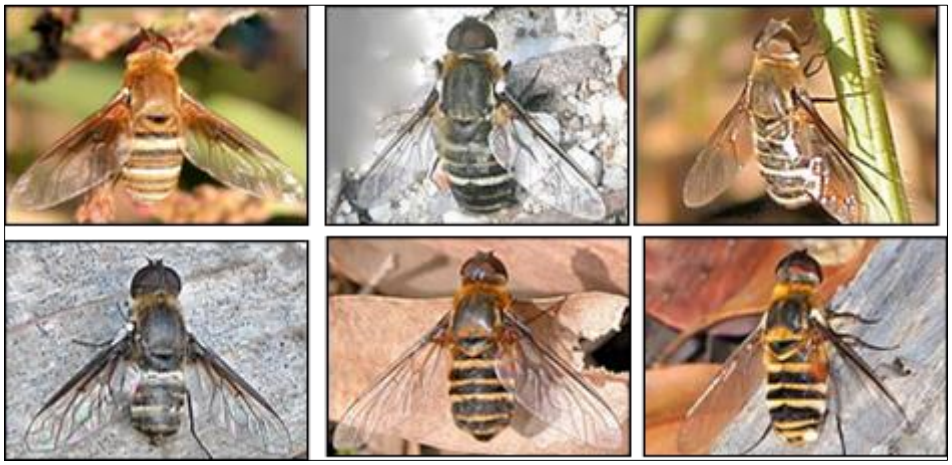

Figure 15 Specimens from the Tribe Villini; (Source: https://www.brisbaneinsects.com/brisbane_robbers/bombyliidae.htm

3.4 Self-Mimicry

In April 2009 in Anstead Forest neat the hilltop, we found this male *Thraxan* bee Fly and noticed its interesting behavior. The fly was hovering and resting on a large smooth bark gum tree trunk. When rested, it faces upwards with abdomen tip raised. With the black and white patterns on abdomen, it looked exactly like a Tachinid fly resting on tree trunk

facing downwards. We do not sure what is the advantage of mimicking a Tachinid Fly resting on tree trunk (Figure 16) [23,24,25].

Figure 16 *Thraxan* Bee Fly; (Source: https://www.brisbaneinsects.com/brisbane_robbers/BOMBYLIIDAE.htm)

3.5 Study 4

3.5.1 Reproduce

When looking to mate, female bee flies fly to high places such as the top of hills. Males also gather at these high places. This is called "hill topping". Females usually choose male mates, but sometimes males will just grab females as they fly past. Mating takes about 100 minutes on average. Males have territories that they defend from other evils. They will get in fights while flying and collide in mid-air. The males have spines on their wings which cause cuts on the bodies of the other males that they fight with (Figure 17) [24,25,26].

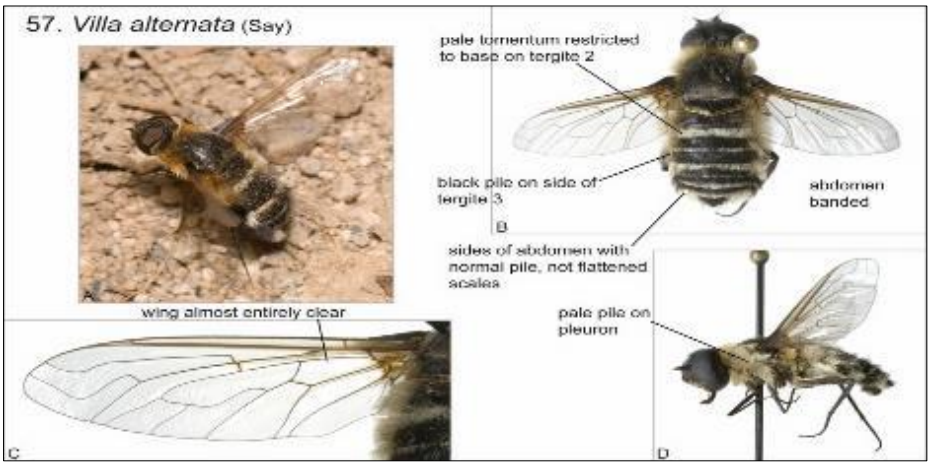

Figure 17 *Alternata villa* (Say, 18230 Diptera: Bombyliidae); (Source: https://biologicalsurvey.ca/ejournal/kme_06/villa.html)

After mating, *Alternata villa* (Say, 1823) Diptera: Bombyliidae) females find a crack or hole in the ground and position themselves to make a chamber in the sand. The females then fill this chamber with sand, dust, saw-dust, or other fine particles. This is meant to prevent the eggs from sticking together. To lay her eggs, the female flicks the end of her abdomen so that the eggs fly off into the sand chamber. Hundreds of eggs are laid in the sand chamber in a couple of hours. *A. villa* appears commonly in the months of May to August in North American temperate climates, so reproduction likely takes place in the spring and summer (Figures 18A and 18B) [24,25,26].

Figure 18A *Alternata villa* (Say, 1823) Diptera: Bombyliidae); (Source: https://bugguide.net/node/view/1880036)

Sexual fertilization internal oviparous and breeding season and mating takes place in the spring and summer.

Male bee flies might supply nutrients to the female during mating, which would be used for the development of the offspring. Females make a sand chamber for the eggs, and collect small particles like sand or saw dust for the eggs will not stick together. After the eggs are laid, neither parent provides any more care Adults likely live for about a month after emerging from pupation, but this is not known for sure and average lifespan, status: wild 1 months [24,25,26].

Bee flies are very mobile, hovering or flying in their adult life. Bee flies spend their time alone except when they mate or when males partake in territorial fights. Males fight with other males over their territories, by crashing in the air. Bee fly males have spines on their wings that can cut into the bodies of males they are fighting. Bee flies are active during the day, especially sunny days. Larvae stay in groups in the host insect before emerging. Key behaviors fly's diurnal parasite motile sedentary solitary [24,25,26].

How these bee flies communicate or how they sense the environment around them. They will likely use vision and detect chemicals. First stage larvae have to find insects somehow that they can parasitize to survive, but it is not known how the larvae find the hosts. Communication Channels visual chemical and Perception Channels visual chemical [24,25,26].

Villa alternate Gardening 1838, feeds on nectar and pollen. It feeds on small flowers such as *Chrysothamnus viscidiflorus* (Hooker, 1834) in the common Asteraceae family. Female bee flies spend large amounts of time feeding, up to 8 times. Primary Diet herbivore nectarivore, Animal Foodsinsects and Plant Foods nectar pollen [24,25,26].

Figure 18B *Chrysothamnus viscidiflorus* (Hooker, 1834) (Asteraceae); (Source: https://en.wikipedia.org/wiki/Chrysothamnus_viscidiflorus)

Birds are predators of *A. villa*. Bee flies can escape predators sometimes because they look like bees and wasps. They have similar colors and similar body shapes as many wasps and bees. If a predator thinks an insect is a wasp or bee, which can sting and cause pain for the predator, then they will usually avoid trying to eat it. This is helpful for bee flies, since predators may avoid eating them, thinking they are bees. These animal colors help protect themmimic, Known predators and birds [24,25,26].

Villa alternata larvae are parasites of Noctuidae moths and Tenebrionidae beetles. Noctuidae moths are crop pests, just by being parasites of these moths, *A. villa* can decrease their population size and prevent damage to the crops and other plants. Tenebrionidae beetles feed on a variety of grasses, so *V. alternata* can prevent the beetles from eating these grasses, allowing the grasses to grow. These bee flies are also eaten by bird [24,25,26,27].

3.6 Study 5

3.6.1 Big Bee Flies (Family Bombyliidae)

The bug Lady enjoys Bee Flies; she especially admires the little flying teddy bears in the genus *Bombylius* and *Systoechus* and can never resist trying to photograph one (to her camera's dismay). Bee flies (Family Bombyliidae) also come in larger, more robust models. As a group, they are big-eyed, with long legs, and long wings that are often strongly patterned and are held out to the sides like a "V" when at rest. Because they hover, they're mistaken for Flower-Hover-Syrphid flies. Like Syrphid flies they are bee mimics, but where Syrphids are smooth, BFs are characteristically hairy. Their long proboscis allows them sip nectar from flowers; they do not sink it into mammalian flesh (Figure 19) [28,29,30,31].

Figure 19 *Bombylius* sp.; (Source: https://uwm.edu/field-station/big-bee-flies/)

It's a big family that's been around for about 140 million years, and so there are BFs everywhere, but they're especially diverse in dry country. Their lifestyles are somewhat similar, though there are gaps in the life histories of many species.

Adults, which are diurnal (active in the daytime), feed blamelessly on pollen and nectar from flowers (they do like composites), but most BF larvae are external parasites/parasitoids on the larvae of ground-nesting insects—insects that practice, like the BFs themselves, Complete Metamorphosis (wasps, bees, flies, beetles, moths, and butterflies). Some oddball BFs feed inside the egg pods of Short-horned grasshoppers. Female BFs hover as they hunt for the nests of their offspring's hosts. When they see a likely-looking tunnel in the ground, they lay eggs on the soil nearby [28,29,30,31].

Like the blister beetle (of recent BOTW fame), BF larvae are unusually active when they first hatch, using the extra mobility that characterizes *hypermetamorphosis* to secure a place at the table in the host's nest. During their subsequent sedentary instars, they consume their host from the outside-in (different species of BFs favor different hosts), and then pupate on site. According to the wonderful bugguide.net, the pupa is equipped with spines or spikes to drill out of the host's nest [28,29,30,31].

Here are some of the larger local BFs. Caveat: the BugLady once again admits the limitations of "picture-keying"—she thinks these IDs are "close."

3.6.2 Chrysanthrax cypris (Meigen 1820).

Chrysanthrax cypris doesn't have a common name. Kaufman and Eaton in their field guide to insects of north America, advise us to "look for adults on low-growing composite flowers. The larvae are parasitic on white grubs, the larvae of Phyllophaga scarab beetles" (the May/June beetle/bugs) (Figure 20) [28,29,30,31].

Figure 20 *Chrysanthrax cypris* (Meigen 1820); (Source: https://uwm.edu/field-station/big-bee-flies/)

3.6.3 Progressive Bee Fly

Progressive Bee Fly (*Exoprosopa* sp.*,* possibly *Entomobrya decora* (Nicolet, 1847). The Bug Lady didn't see any explanation as to why some/all members of the genus *Exoprosopa* are called "Progressive." Members of the genus are among the largest BFs, with some measuring three-quarters of an inch long. This species is about a half-inch; one source describes its head as "loosely attached," and another calls the clear patch in the middle of the wing a "Snoopy-shaped spot" (Figure 21) [28,29,30,31].

Figure 21 *Exoprosopa* sp. (Source: https://uwm.edu/field-station/big-bee-flies/)

The larvae are apparently parasitic on other parasites of bee, wasp, or beetle larvae living in the soil, including, apparently, robber fly larvae. A parasite of a parasite is called a hyperparasite or an epiparasite.

3.6.4 Chocolate Bee Fly

The Latin name of the Chocolate Bee Fly *Hemipenthes sinuosa* (Wiedemann, 1821) comes from *hemi* (half) and penthos (mourning) referring to a wing that is half draped in black, and *sinus* meaning curving or undulating, referring to the wavy border of the dark wing patch. It is also called the *Sinuous* bee fly. Chocolate bee flies are also hyperparasites who specialize in larval ichneumon wasps and tachinid flies, which parasitize caterpillars (Figure 22) [28,29,30,31].

Figure 22 *Hemipenthes sinuosa* (Wiedemann, 1821); (Source: https://uwm.edu/field-station/big-bee-flies/)

3.6.5 Anthrax irroratus Say, 1823

Anthrax irroratus (maybe) takes a little explaining. *Irror* means freckled-speckled-bedewed and refers to the sprinkling of spots on the wings. The more alarming *Anthrax* comes originally from the Greek for carbuncle or coal, and possibly refers to the rough surface or fleshy looking "hairs" on the abdomen (Figure 23A) [28,29,30,31].

Figure 23A *Anthrax irroratus* Say, 1823; (Source: https://uwm.edu/field-station/big-bee-flies/)

Most *Anthrax* larvae parasitize the young of solitary, ground-nesting wasps, but one species feed on tiger beetle grubs. *Anthrax* is nicknamed "Bombers" for their habit of hovering at the entrance of a tunnel and tossing eggs into it while in flight (with fingers crossed that the hole is occupied. A wing and a prayer). There are accounts of *Anthrax* landing on people and of females mistaking a dark spot-on clothing for a likely tunnel and lobbing eggs at it [28,29,30,31].

Remember, the convention for spelling insect names says that True Flies (order Diptera) like bee flies or deer flies, are spelled as two words. Non-Dipterans "flies" like Scorpionflies, Mayflies, Butterflies, and Dragonflies are single words [28,29,30,31].

3.7 Study 6

To analyze the guilds of natural enemies associated with wasp and bee nests from studies in forest fragments in the north-northwest region of the state of Rio de Janeiro and evaluate the terminology proposed for the description of their behavior.

The guilds of natural enemies were composed of 1,284 individuals emerging from nests and 80 individuals collected in an entomological network, totaling 74 species distributed in 11 families: Apidae, Megachilidae, Chrysididae, Chalcididae, Ichneumonidae, Braconidae, Mutillidae (Hymenoptera), Meloidae (Coleoptera), Bombyliidae, Sarcophagidae (Diptera) and a family of Lepidoptera. The most abundant families were Chrysididae (40% of individuals collected) and Sarcophagidae (15%), with Chrysididae also being the richest in species. The phytophysiognomy with greater richness

and abundance was the Seasonal Semideciduous Forest of Tabuleiros; the lowest species richness was recorded in the Restinga area (Figure 23B).

Figure 23B Bombyliidae as “Parasite”; (Source: https://pixabay.com/photos/wollschweber-parasite-insect-5072847/)

The term “parasite” was used in 16 of the 30 scientific articles analyzed to classify the natural enemies associated with Hymenoptera nests and found in the study areas. One work cited Bombyliidae as “Parasite”, nine cited *Coelioxoides*, *Exaerete*, 1XI Congress of Ecology of Brazil, September 2013, Porto Seguro - BA *Mesocheira, Nomada, Pseudepeolus, Rhathymus, Thalestria, Coelioxys, Hoplostelis,* Bombyliidae and Sarcophagidae as being “Cleptoparasita” and 12 cited Chrysididae, Chrysis, *Caenochrysis, Ipsiura, Neochrysis*, Chalcididae, Ichneumonidae, Braconidae, Mutillidae, *Cephalomutilla, Dasymutilla, Hippocrates, Sphaeropthalma* and Bombyliidae as "Parasitoid" [32].

3.8 Study 7

The aim of the present study was to determine the influence of parasitoidism of *Paravilla* sp. on the development of larvae of the antlion *Myrmeleon brasiliensis* (Návas, 1914) (Neuroptera, Myrmeleontidae). For such, the following aspects were evaluated to parasitized and non-parasitized larvae: in which antlion larval instars the parasitoid oviposition occurs; development time of larvae and pupae; body length (head-abdomen) of *M. brasiliensis* larvae parasitized and non-parasitized; the sex ratio of male and female adults emerged from no parasitized larvae (Figure 24).

Figure 24 *Paravilla* sp. (Source: https://uwm.edu/field-station/big-bee-flies/)

During five sampling campaigns, 596 larvae were collected. Forty of first instar, 71 of second instar and 130 of third instar larvae survived through the emergence of adults, corresponding to a 59.56% mortality rate (241/596). The emergence of 20 female parasitoids (*Paravilla* sp.) was observed (nine from larvae captured in the second instar and 11 from larvae captured in the third instar). In the parasitoids emerged from *M. brasiliensis* pupae that had been captured in the first instar (Figure 25).

Figure 25 *Myrmeleon brasiliensis* (Návas, 1914) (Neuroptera, Myrmeleontidae); (Source: https://en.wikipedia.org/wiki/Myrmeleon)

The frequency of parasitoidism was 8.30% in the overall sample (20/241), 12.68% among second instar larvae (9/71) and 8.46% among third instar larvae (11/130). Regarding the influence of parasitoidism on the behavior of the larvae, no significant difference was found between parasitized and non-parasitized larvae about the time in which the specimens formed in the pit (W=338.5; N1=62; N2=9; p= 0.059) or total development time in the third instar (pit time + pupal time) (W= 313.5; N1=62; N2= 9; p= 0.556). However, a significant different was found about pupal time (W=627; N1=221; N2=20; p=1.129 e-07). No significant differences in body length were found between parasitized and non-parasitized larvae (W=2238; N1=221; N2=20; p = 0.927). No significant difference was found in the number of males[1] and females[2] that emerged from non-parasitized larvae (X^2 cálc. =2.42; N^1=89; N^2=111; p = 0.11979) (Figure 26) [33,34,35].

Figure 26 Larva of the Bombyliidae Family – Genus *Paraviila; (*Source: https://www.dpughphoto.com/flies.htm)

4 Conclusion

They have powerful wings and are found typically in flight over flowers or resting on the bare ground exposed to the sun. They significantly contribute to cross pollination of plants, becoming the main pollinators of some plant species of desert environments. Unlike the majority of glyciphagous dipterans, the bee flies feed on pollen (from which they meet their protein requirements). A similar trophic behavior occurs among the hoverflies, another important family of Diptera pollinators.

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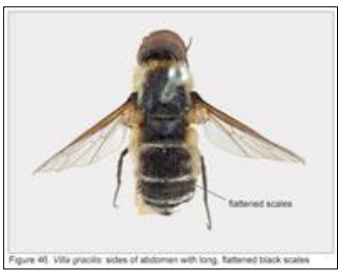
Key to the *Villa* species of Ontario and eastern Canada

Larvae are mostly parasitoids of noctuid moths, and may also attack tenebrionid beetles. Key based in part on Painter (1926).

This genus needs to be revised based on male genitalia; the characters used in this key may not be reliable and identifications based on them should be regarded as tentative. Some forms treated here may not be good species.

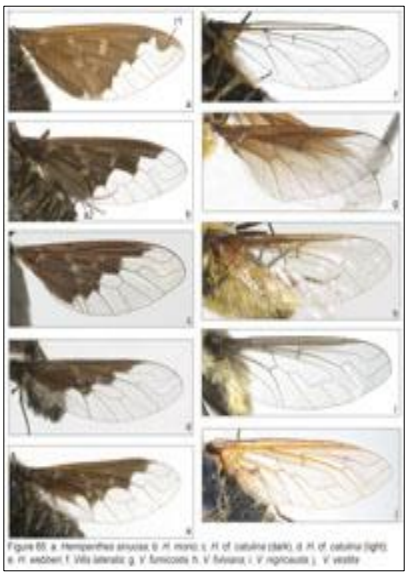
1.	Tarsal claws of forelegs similar in size to those of other legs (Figure 45a). Fore tibia with prominent spines, sides of abdomen with long, flattened black scales (Figure 46)	*gracilis**
	11 mm. Not recorded from Ontario (apparently extremely rare, recorded from Pennsylvania, Florida).	
-	Tarsal claws of forelegs much smaller than those of other legs (Figure 45b). Fore tibia with prominent spines or sides of abdomen with long, flattened scales, but never with both characters	2



2.	Sides of abdomen with long flattened scales (Figure 47a). Fore tibia usually without spines, or with tiny spines	3
-	Sides of abdomen with normal pile only, not flattened scales (Figure 47b). Fore tibia usually with robust spines	9

3.	Wing extensively smoky brown (Figure 65g). Abdomen with distinct bands of black and yellow tomentum (Figure 48)	*fumicosta*
	7-8 mm. Rarely collected, known from near Guelph and Ottawa (uncommon, known only from Ohio, Florida, Georgia, Texas and Coahuila in Mexico). Adults recorded in July and Aug.	
-	Wing mostly clear, costa and subcosta sometimes brownish (Figure 65f). Abdomen pattern variable	4

Figure 48. *Villa fumicosta*: abdomen banded black and yellow



4.	Sides of thorax and first three abdominal segments with deep orange pile (Figure 49a), tomentum of face black (Figure 50a)	***shawii****
	7 mm. Not recorded from Ontario (occurs on the east coast of the U.S. north to New Hampshire).	
-	Sides of thorax and first three abdominal segments with yellow pile sometimes mixed with black (Figure 49b), tomentum of face pale (Figure 50b) or black	5

Figure 49. a. *Villa shawi*: sides of thorax and first 3 abdominal segments with orange pile; b. *V. nigra*: sides of thorax and first 3 abdominal segments with yellow pile

5.	Abdomen uniformly colored or with narrow bands of light-coloured tomentum; thorax with black tomentum dorsally (Figure 51a)	6
-	Abdomen with wide bands of light-coloured tomentum ; thorax with a triangle of light tomentum in front of scutellum (Figure 51b)	8

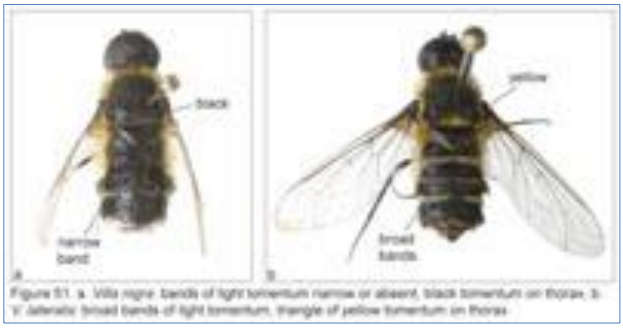


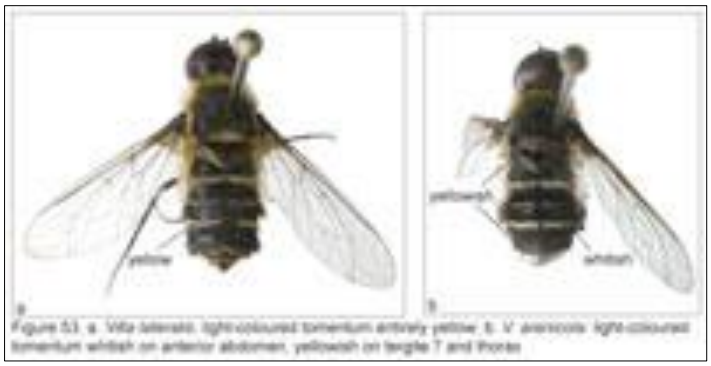
Figure 51. a. *Villa nigra*: bands of light tomentum narrow or absent, black tomentum on thorax; b. *V. lateralis*: broad bands of light tomentum, triangle of yellow tomentum on thorax

6.	Pile on pleuron (side of thorax) entirely pale (Figure 52a)	7
-	Patch of black pile present on lower pleuron (Figure 52b)	*nigra*
	6-12 mm. Widespread in Ontario, collected as far north as Moosonee. (widespread in eastern U.S.; also Colorado). Adults fly June – Aug.	

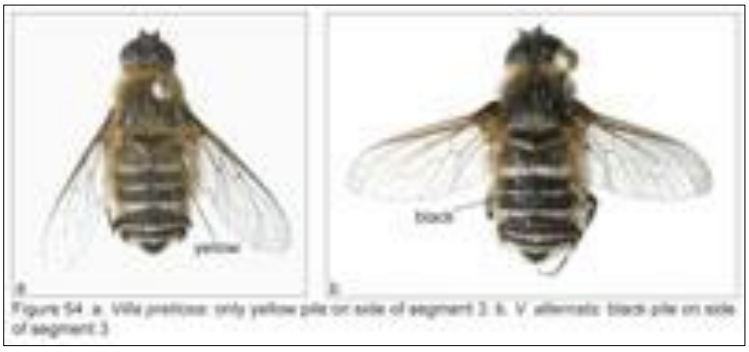
Figure 52. a. *Villa atra*: pleuron with entirely yellow pile; b. *V. nigra*: patch of black pile on pleuron

7.	Tomentum of face pale (Figure 50b)	*atra*
	6-9 mm. Southern Ontario, rarely collected (eastern U.S. southwest to New Mexico). Adults recorded in July and August.	
-	Tomentum of face black	*johnsoni**
	Not recorded from Ontario (eastern U.S.). Not illustrated.	

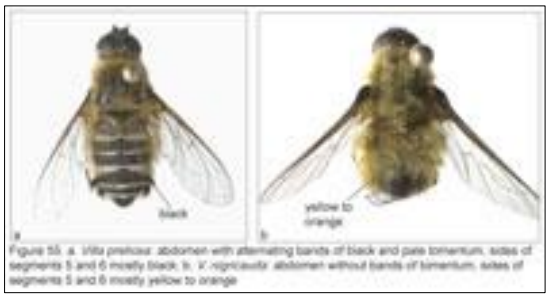
8.	Light-coloured tomentum uniformly yellowish (Figure 53a)	*lateralis*
	5-13 mm. Widespread in Ontario, north to Thunder Bay District (widespread Canada south to Panama and Caribbean). Adults fly June – Sept.	
-	Light-coloured tomentum white on anterior part of abdomen, yellow on abdominal segment 7 and pre-scutellar triangle (Figure 53b)	*arenicola*
	5-9 mm. Rarely collected in Ontario, but widespread (also northern U.S.). Adults fly July – Aug.	



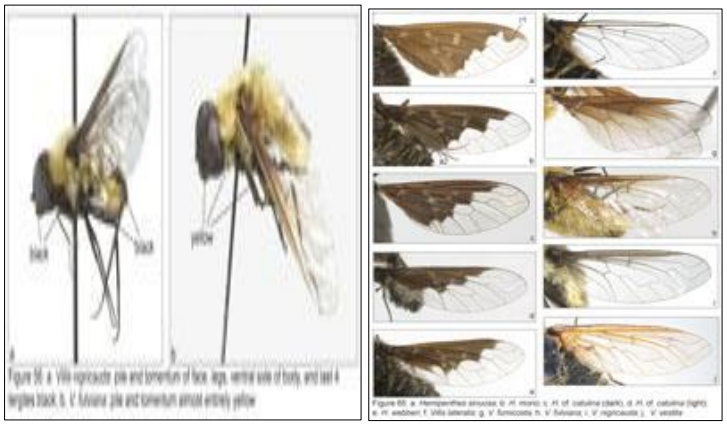
9.	Abdomen with only yellow pile on sides of segment 3 (Figure 54a)	10
-	Abdomen with black pile on the sides of segment 3 (Figure 54b)	12



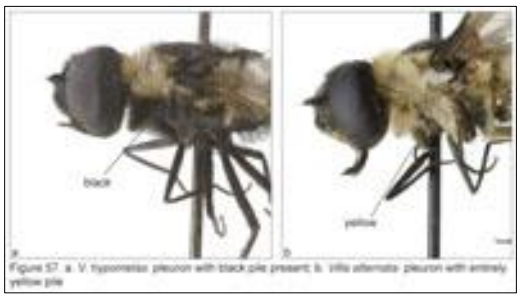
10.	Abdomen with alternating bands of black and pale tomentum; pile on sides of segments 5 and 6 mostly black (Figure 55a)	*pretiosa*
	9-16 mm. Widespread, recorded north to Thunder Bay District (Canada south to Utah and California). Adults fly June – July. We are uncertain if this northeastern population is conspecific with true *V. pretiosa*, but in the absence of a generic revision we are treating it under this name.	
-	Abdomen without alternating bands of tomentum; pile on sides of segments 5 and 6 mostly yellow to orange, occasionally with some black pile mixed in (Figure 55b)	11



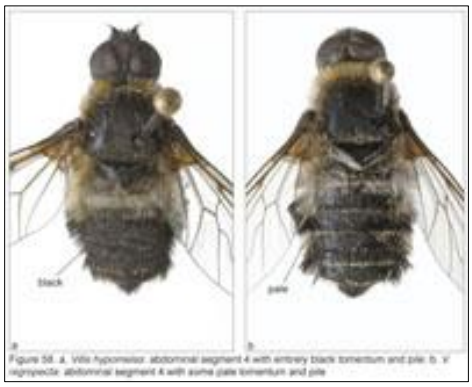
11.	Pile and tomentum on face, legs, ventral side of body, and dorsum of last 4 abdominal segments black (Figure 56a); leading edge of wings dark smoky grey (Figure 65i)	*nigricauda*
	8-15 mm. Widespread, north to Thunder Bay District (northeastern U.S.; also Colorado). Adults fly July – Sept.	
-	Pile and tomentum on body almost entirely yellow (Figure 56b); leading edge of wings pale brown to clear (Figure 65h)	*fulviana*
	11-14 mm. One Ontario record from near Kenora (July) (widespread southern Canada, western, northern, and northeastern U.S.).	



12.	Dark pile present on pleuron (Figure 57a)	13
-	Pleuron with only pale pile (Figure 57b)	14



13.	Abdominal segment 4 without pale tomentum or pile (Figure 58a)	*hypomelas*
	13-16 mm. Southern Ontario, north to Algonquin Provincial Park, St. Joseph Is. (southern Canada south to central and eastern U.S.). Adults fly July – Sept.	
-	Abdominal segment 4 with pale tomentum and pile (Figure 58b)	*nigropecta*
	13-15 mm. Southern Ontario, north to Algonquin Provincial Park (also present, but uncommon, in the central U.S.). Adults fly late June – Sept.	



14.	Wings almost entirely clear, slightly brownish at base (Figure 65f)	15
-	Wings mostly clear but with brownish colour extending to vein M, crossvein r-m, and tip of vein R1 (Figure 65j)	*vestita**
	Known only from the type locality in Nova Scotia.	
.	Abdomen distinctly banded, tergite 2 with pale tomentum only on anterior half (Figure 59a)	*alternata*
	10-17 mm. South of Canadian Shield in Ontario (northern and eastern U.S.). Adults fly July – Sept.	
-	Abdomen without distinct bands, tergite 2 with pale tomentum throughout (Figure 59b)	*handfordi*
	12-15 mm. Widespread but rarely collected in Ontario (also known from Manitoba). Adults recorded in July and Aug.	

Figure 24 The Bee Flies (Diptera: Bombyliidae) of Ontario, with a Key to the Species of Eastern Canada; (Source: Kits JH, Stephen A, Marshall, Venhuis NL. The Bee Flies (Diptera: Bombyliidae) of Ontario, with a Key to the Species of Eastern Canada. Canadian Journal Arthropod Identification. 2008; 6)