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Pompilidae Family (Insecta: Hymenoptera) as a parasitoid of spiders (Arachnida: Araneae)

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Abstract

Pompilidae is a family of solitary wasps, cosmopolitan, but predominates in tropical regions. They are popularly known as "spider hunting wasps" due to the egg laying behavior of paralyzed spiders that females of most species exhibit. The aim of this manuscript was to carry out an inventory of the Pompilidae Family (Insecta: Diptera) related to its biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology and taxonomic and conceptual aspects of the Family, Subfamilies and Species. To this end, a bibliographic survey of Pompilidae was carried out in the years 1979 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. The knowledge of the Neotropical fauna is fragmented and still presents many taxonomic problems. Pinpelidae not only have significant interactions with the local spider fauna, but adults largely subsist on nectar and therefore also serve pollinators.

Keywords: Scielo; ResearchGate; Control; Traps; Biocontrol

1. Introduction

Figure 1 Side view of a specimen from the Pompilidae family (Hunter wasps); (Source: Andreas Kaysome rights reserved (CC BY-NC-SA)

Pompilidae is a family of Hymenoptera that hunt spiders. They are medium or large, usually black or dark blue with metallic highlights. The characteristically coiled antennas. They usually fly close to the ground. They are spider

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predators, on which they lay an egg. Larval development occurs in the captured spider Many of these wasps (Pimpilidae) feed on various flower species that pursue generalist pollination strategies, but several plants from Africa, Central and South America and Australia have been documented to form specific pollination relationships with species of pompilid (Figures 1, 2 and 3) [1].

Figure 2 Side view of a specimen from the Pompilidae family (Hunter wasps); (Source: Ferran Turmo Gort, some rights reserved (CC BY-NC-SA)

Figure 3 Front of a specimen from the Pompilidae Family; (Source: Pierre Anquetsome rights reserved (CC BY-NC-ND)

Pompilidae is a family of solitary wasps, cosmopolitan, but predominates in tropical regions. They are popularly known as "spider hunting wasps" due to the egg laying behavior of paralyzed spiders that females of most species exhibit. The pompilid fauna of the world is made up of about 4,200 species. The Neotropical fauna is formed by 60 genera and about 1,000 species. The knowledge of the Neotropical fauna is fragmented and still presents many taxonomic problems. Pinpelidae not only have significant interactions with the local spider fauna, but adults largely subsist on nectar and therefore also serve pollinators (Figures 4, 5, 6, 7, and 8) [1,2,3].

Figure 4 *Sphictostethus nitidus* (Fabricius, 1775) (Hymenoptera: Pompilidae); (Source: Emma & Amp; Tom, some rights reserved (CC BY-NC)

Figure 5 *Tachypompilus analis* Fabricius, 1781); (Source: Source: https://www.biodiversity4all.org/observations/7609258)

Figure 6 *Tachypompilus analis* (Fabricius, 1781) attacking a spider; (Source: https://www.biodiversity4all.org/observations/13146391)

Red-tailed Spider Wasp, *Tachypompilus analis* (Fabricius, 1781), Insecta, Hymenoptera**,** Pompilidae, *Tachypompilus,* Durgapur, Barddhaman, West Bengal, India.

Figure 7 *Anoplius depressipes* Banks, 1919 a member of the Pompilidae common wasp hunters "mode of transportation" with preyand one of my all-time favorite wasps; (Source: https://www.biodiversity4all.org/observations/7609258)

A family of specialist spiders for parasitoid wasps, Pompilidae has achieved a global distribution and plays an important role in most subarctic ecosystems. Solitary asps Pompilidae during the collections, a total of 108 specimens were found for the 4 subfamilies that occur in the neotropical region: 15 specimens of Ceropalinae, 16 specimens of Pepsinae, 37 specimens of Notocyphinae and 40 specimens of Pompilinae, the latter showing the most representative subfamily in terms of specimens collected. The subfamilies with the smallest number of genera were Ceropalinae and Notocyphinae, with 1 genus each; and the subfamilies with the highest number of genera were Pompilinae and Pepsinae, with 3 genera each. Based on the apparent similarity of the collected insects, several species were established [3,4,5,6].

Figure 8 *Sphictostethus* sp. member of hunting wasps tribe Pepsini Female catching future food from her larva

Specimens of the subfamily Ceropalinae were identified as belonging to the genus *Ceropales* Latreille, 1796, comprising only one species. The insects of the subfamily Notocyphinae were subdivided into 4 species, all of the genus *Notocyphus* Smith, 1855. The subfamily Pompilinae presented the genera *Allochares* Banks, 1917, with 4 species; *Psorthaspis* Banks, 1912, with two species; and the genus *Cheloporus* Bradley,1944 with one species. And finally, the subfamily Pepsinae, presenting the genera *Minagenia* Banks, 1934, with one species; the genus *Digopon* Fox, 1897, with three species; and individuals of the genus *Pepsis* Fabricius, 1804 - the only genus that had identification keys for the species (Figures 9, 10, 11,12, 13, 14, 15A and 15B) [7,8,9,10].

Figure 9 Female of *Auplopus* cf. *rufipes.* Scale bar = 1 mm. (B) Male of *Auplopus* cf. *brasiliensis.* Scale bar = 3 mm;

(Source: https://www.scielo.br/j/paz/a/6SsnbLLxcVH4HLDth9NqXVn/?lang=en)

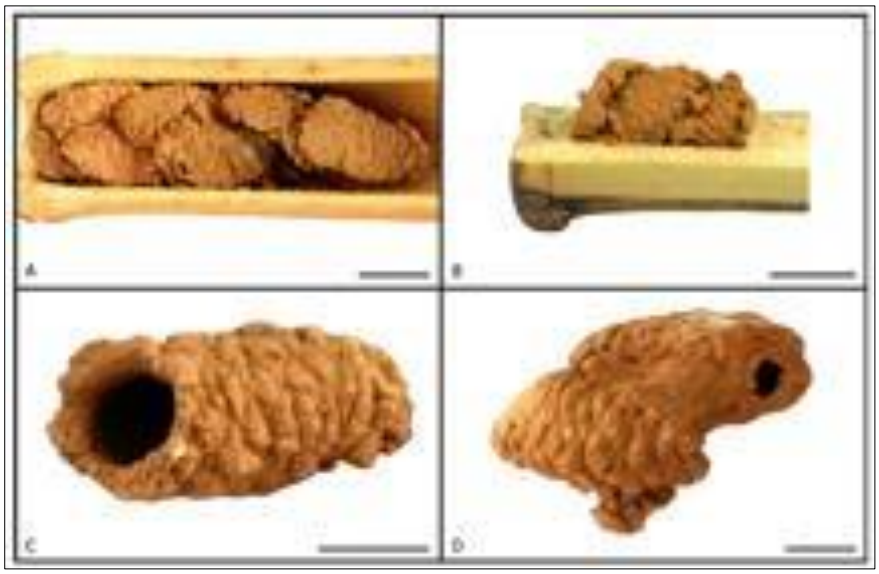

Figure 10 Nest of *Auplopus* cf. *rufipes.* (A) Arrangement of cells inside the trap nest. Scale bar = 1 cm. (B) Nest in profile showing an overlay on the first cell and the cells leaning. Scale bar = 1 cm. (C) Cell lip-shaped structure before provision. Scale bar = 0.5 cm. (D) Brood cells glued together, one of them with an emergence hole. Scale bar = 0.5 cm; (Source: https://www.scielo.br/j/paz/a/6SsnbLLxcVH4HLDth9NqXVn/?lang=en)

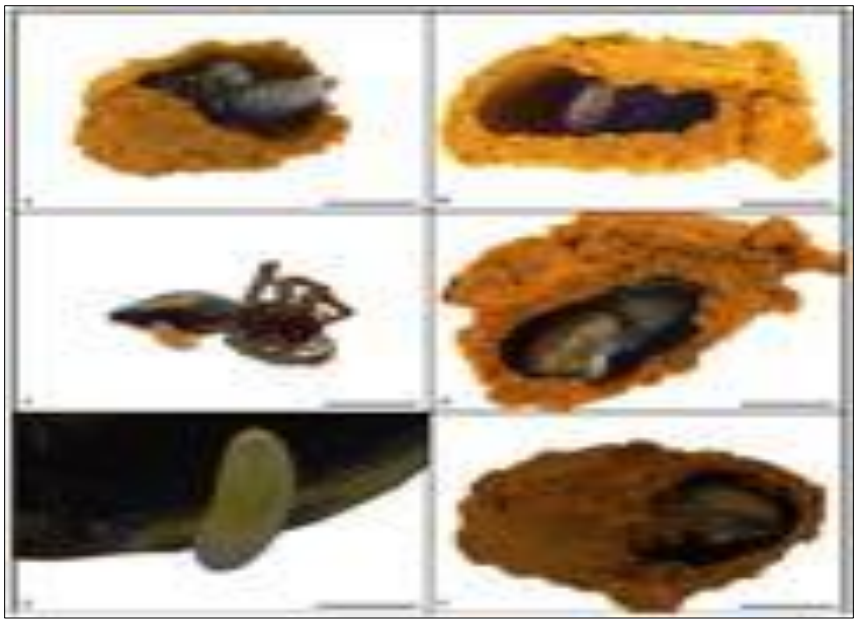

Figure 11 Development stages of *Auplopus* cf. *rufipes.* (A) Larva almost entirely developed feeding on a spider. Scale bar = 0.5 cm. (B) Larva probably in its third instar feeding. Scale bar = 0.5 cm. (C) Second instar larva. Scale bar = 0.5 cm. (D) Prey tightly trapped in the brood cell and egg placed on its opistosoma. Scale bar = 0.5 cm. (E) Egg in detail. Scale bar = 0.1 cm. (F) Last cell built with the prey and the egg placed on it. Scale bar = 0.5 cm; (Source: https://www.scielo.br/j/paz/a/6SsnbLLxcVH4HLDth9NqXVn/?lang=en)

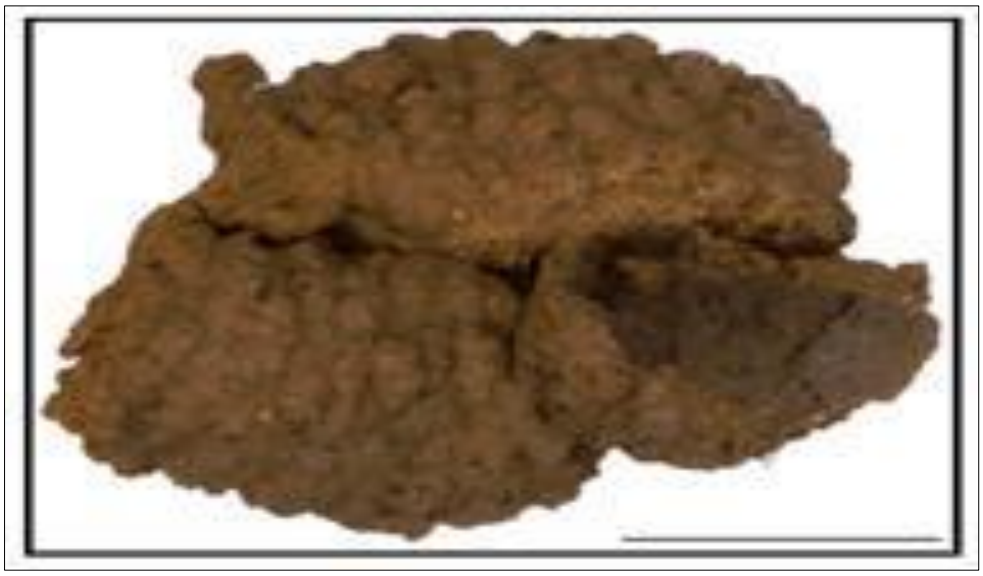

Figure 12 Nest of *Auplopus* cf. *brasiliensis.* The third cell broke during handling. Note the arrangement of the cells forming a cluster, the papillated surface suggesting the employment of several mud pellets to construct the cells. Scale bar = 0.5 cm; (Source: https://www.scielo.br/j/paz/a/6SsnbLLxcVH4HLDth9NqXVn/?lang=en)

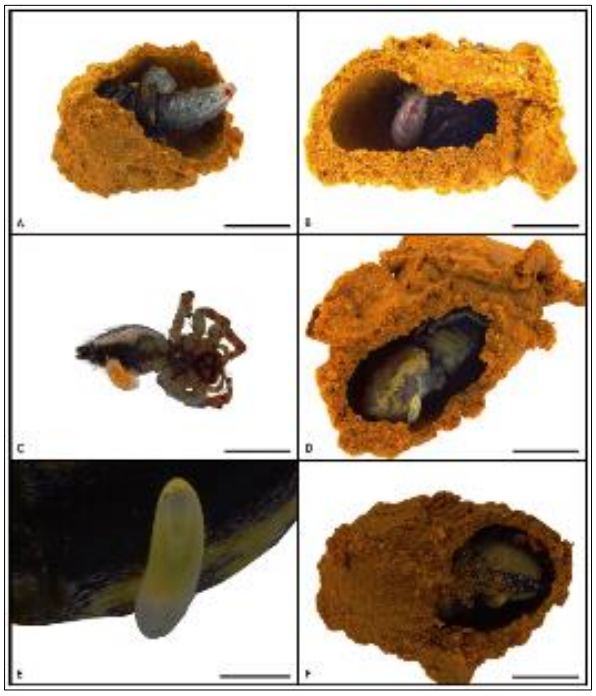

Figure 13 A, B: larvae C prey, D, E: pupae, F: egg. Notes on the bionomy of two spider wasp species in an urban forest fragment in Brazil; (Source: Scielo)

Figure 14 *Cyphononyx peregrinus* (Turner 1920): (A) general habitus (B) head - front face (C) fore wing (D) thorax from dorsal (E) hind tibia showing arrangement of spines; (Source: file:///C:/Users/Sti/Downloads/virtual%20poster_samrat%20(2).pdf)

Figure 15A *Macromerella* nest 1 with overlap of generation on the nesting site (8 June 2006); (Source: https://www.researchgate.net/figure/Macromerella-Nest-1-with-overlap-of-generation-on-the-nesting-site-8-June-2006_fig2_271182407)

Spider wasps (Hymenoptera: Pompilidae) are an interesting aculeate family, especially due to their diverse and varied natural histories with species ranging from ectoparasitoids of spiders to cleptoparasitic species, and from solitary to communal or parasocial. Species of the tribe Ageniellini (Pepsinae) are known to exhibit some of the most intricate nesting behaviors within the family, particularly concerning nest construction. There is a consensus on the steps that may have led from soil nesting to the building of more complex nests above ground, in some cases occupied by several

Figure 15B Male *Auplopus* sp., lateral view;(https://www.researchgate.net/figure/Male-Auplopus-sp-lateral-view_fig15_271182407)

individuals, in Ageniellini. Here we add to this knowledge by providing comparative field observations on the nesting behavior of two common pepsine wasps in Hong Kong, *Macromerella honesta* (Smith, 1855) and *Auplopus* sp., of which both display possible communal nesting behavior [11,12,13,14].

Nests of *M. honesta* were composed of two rows of exposed ovoid mud cells, affixed to broad leafs while nests of *Auplopus* sp. were constructed as variable masses of mortar affixed to a linear substrate (thorns, wire-mesh, etc.). Cells of the nests of *Auplopus* sp. were cylindrical and covered with a layer of hardened mud finished with a plant gum coating. Both species used a single dismembered spider, transported ventrally to the nesting site, for cell provisioning. Active guarding was observed at all nesting sites. Overlap of generation was also recorded with active nest cooperation (construction and prey provisioning) between individuals of different generations on the same nesting site [14].

Pompilid venoms are notoriously painful, and the genus *Pepsis* is one of the few taxa that has been rated four (out of four) on the Schmidt's Bite Pain Index (a subjective rating of pain caused by multiple insect bites). However, this defensive use is not the primary evolutionary goal of these poisons. Stereotypically, pompilids reproduce by biting a spider to paralyze it and dragging it along the ground (or through water in some exceptional cases to a den where an egg is deposited in it before being sealed; when the larva hatches, it consumes the spider paralyzed before pupae and emerging from the burrow as an adult [15,16].

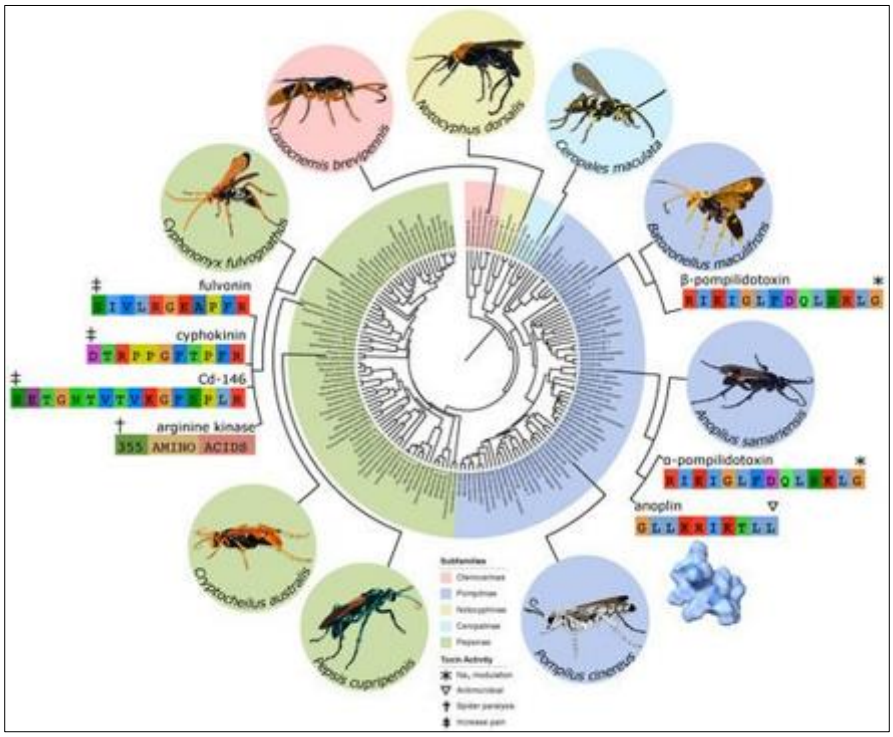

Figure 16 Phylogeny of Pompilidae with subfamilies highlighted and images to show species and toxins of interest; (Source: Topology adapted from Waichert C, Rodriguez J, Wasbauer MS, von Dohlen CD, Pitts JP. Filogenia molecular e

sistemática de vespas-aranha (Hymenoptera: Pompilidae): Redefinindo os limites da subfamília e a origem da família. Zoological Journal of the Linnean Society. 2015; 175: 271–287)

Objective

The purpose of this paper is to understand the Biology, Ecology and Phenology of the Pompilidae ((Hymenoptera: Pompilidae).

2. Methods

The method used to prepare this mini review was Marchiori 2021 methodology [17].

3. Studies carried out

3.1 Study 1

This work contemplates the results of a survey of social and solitary wasps (Insecta, Hymenoptera) aiming to characterize the fauna in a remnant of terra firme forest, in the coastal region of the state of Pará. The study, carried out in the Mãe Grande de Extractive Reserve area Curuçá is part of the second stage of the Casa da Virada -Mata Atlântica Project, which aims to generate values for the conservation of the biodiversity of the coast of Northeast Pará.

Analyzing the traps used, the most efficient was the Malaise trap flight interception trap, which collected 90 of the 108 specimens, being the species *Allochares* sp. 1*, Psorthaspis* sp. 1, *Psorthaspis* sp. 2*, Chelaporus* sp., *Ceropales* sp., *Digopon* sp. 1, *Digopon* sp. 3, *Notocyphus* sp. 1, *Notocyphus* sp. 2, *Notocyphus* sp. 3 and *Notocyphus s*p. 4, collected exclusively through this method. The active search collected 16 specimens and proved to be satisfactorily efficient to collect specimens belonging to the genus *Pepsis*, since all insects belonging to this group were collected using this method. The species *Minagenia* sp. and *Allochares* sp.4 were collected exclusively through active search, demonstrating that the method cannot be discarded to inventory the Pompilidae family wasps (Figure 17),

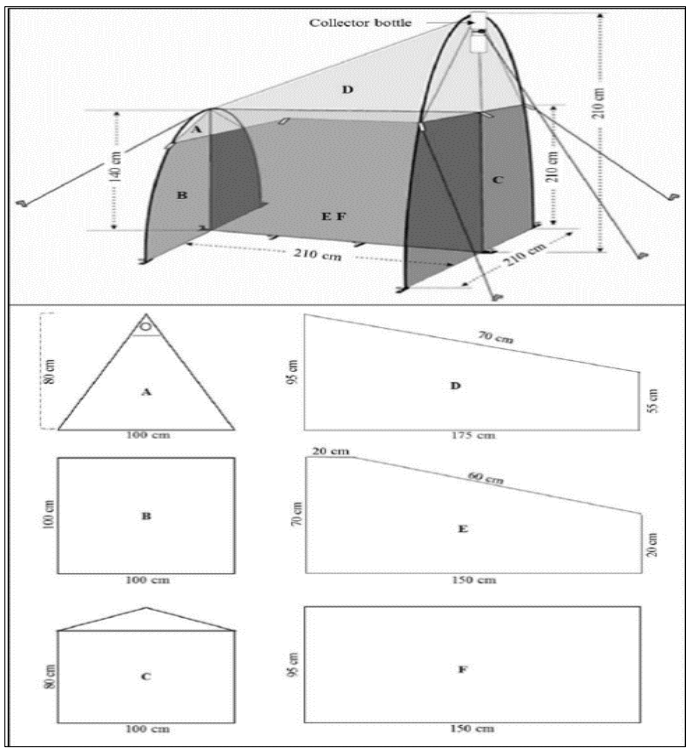

Figure 17 Malaise trap, assembled in the field; (Source: https://www.researchgate.net/figure/Malaise-trap-assembled-in-the-field_fig1_283237896)

The species *Allochares* sp. 2 had only one specimen collected and was the only one to be collected by hanging trap, not being collected exclusively through this method. The species *Digopon* sp. 2 also had only one specimen collected, exclusively by the Moerick trap. Most specimens were collected in closed forest by Malaise trap; however some species were only collected in open areas. Comparing the collection periods, the first campaign was the most representative, with 70 specimens being collected, 64.81% of the total. On this occasion, the regions of dense forest were explored with more effort. In the second campaign, the sampling was smaller, being collected, on this occasion, 38 specimens of insects, 35.19% of the total. Through this study, we can observe the great diversity of species found in the studied region, with the occurrence of four subfamilies present in the Neotropical region, with a significant variety of genera and species [18].

3.2 Study 2

3.2.1 *Sphictostethus nitidus* (Fabricius, 1775) (Hymenoptera: Pompilidae):

Characteristics - Males emerge 3–8 days prior to the females; copulation usually occurs in foliage, often in the crowns of bushes, the males running over leaves in a distinctive manner pursuing any females that appear. Habitat: *S. nitidus* shows a preference for open, exposed places and tolerates a wide range of habitats. It has shown itself to be adaptable and is common in suburban back yards, dunes, dry riverbeds, forest clearings, grasslands, and clay banks. Geographical Distribution: This species is endemic to New Zealand on both the North and South Islands and some offshore islands. Prey: recorded include *Uliodon frenatus* (L. Koch, 1873) (Arachnida; Araneae), *Porrhothele antipodiana* (Walckenaer, 1837) Arachnida; Araneae). and *Neoramia otagoa* Forster & Wilton, 1973 (Arachnida; Araneae).

3.3 Prey capture

The prey is usually detected by sight and pursued into the open. *S. nitidus* varies the attack depending on the species and size of spider. When Uliodon frenatus of any size is the prey, the wasp springs on to the back of the spider and stings the abdomen first before curving its abdomen and stinging the midventral region of the prosoma. Porrhothele antipodiana is attacked when it stands and faces the wasp with the first two pairs of legs held towards its attacker and upwards. The wasp moves forward until it is about 22 cm (9 in) in front the spider, then it makes a sudden leap towards it (Figure 18).

Figure 18 *Sphictostethus nitidus* (Fabricius, 1775) (Hymenoptera: Pompilidae); (Source: https://www.biodiversity4all.org/taxa/397328-Sphictostethus-nitidus)

The wasp and the spider grapple with each other, rolling over and over. The wasp apparently stings the spider indiscriminately in the abdomen until the spider ceases to struggle. The wasp then stings the spider in the midventer of the prosoma, and then between the chelicerae. The wasp then examines the spider's mouthparts before stinging it again at the base of the chelicerae. It finishes by brushing the tip of its own abdomen with alternate strokes of the entire hind tibia and tarsus for 3–8 minutes. The spider's paralysis is permanent. *Sphictostethus nitidus* is kleptoparasitic on other members of its own species, and on other spider wasps, including *Priocnemis monachus* (Smith, 1855) (Hymenoptera: Pompilidae) [18,19].

3.4 Study 3

3.4.1 *Tachypompilus analis* (Fabricius, 1781) (Hymenoptera: Pompilidae)

3.4.1.1 Characteristics

Tachypompilus analis is a medium to large wasp, with females in mainland China measuring between 16 and 21 mm, while smaller males measuring 11 mm in length; island populations tend to be smaller. It is almost entirely black, except for the last four in females or the last five in males, metasomic segments, which are orange or bright red and give rise to the common name red-tailed spider wasp (Figure 19).

Figure 19 *Tachypompilus analis* (*Fabricius*, 1781) (Hymenoptera: Pompilidae); (Source: https://bioone.org/browse)

3.5 Biology

Tachypompilus analis attacks spiders from the Sparassidae, Agelenidae and Amaurobiidae families. In Japan, Heteropoda venatoria has been reported to be preyed on by this species. The wasp can easily penetrate the most complex webs and the prey is chased away and chased; the web provides some protection for the spider, but the wasp persists in attacking until the spider drops from the web to the ground, where the wasp stings and paralyzes the spider. Once captured, the prey is dragged back by its pedipalps, sometimes leaving the prey to inspect the route or nest, at which point the prey can be kleptoparasitized by other *T. analis* females, although the females fight to defend theirs. Trapped in these circumstances.

The prey is placed in a conical cavity excavated by the female, who can bend her legs to fit it, and once oviposition has occurred, the spoil is used to cover the nest, although pre-existing cavities can also be used. As with other spider wasps, males often patrol the nesting areas so that they can mate with newly emerged females.

Irenangelus luzonensis (Rohwer, 1919) is recorded as a kleptoparasitizer of *T. analis* in the Philippines, while other species of *Irenangelus* are also recorded as a kleptoprasitis of *T. analis*. Tachinid flies are known to attack and consume spiders that have been immobilized by *T. analis*, and satellite flies can also consume spiders preyed on by these wasps.

3.6 Geographic distribution

Tachypompilus analis is a widely distributed species, found in the Nansei Islands of Japan, passing through Taiwan and the Philippines, and in Southeast and South Asia; it is found in Hawaii [20].

3.7 Study 4

Tachypompilus analis (Fabricius, 1781) (Pompilinae: Pompilini) (Continuation of Study 3).

Preys on spiders from the families Sparassidae, Agelenidae, and Amaurobiidae. In Japan, *Heteropoda venatoria* has been recorded being preyed on by this species. The wasp can easily penetrate the most complex webs and the prey is flushed and pursued; the web does provide some protection for the spider, but the wasp persists in attacking until the spider drops out of the web to the ground, where the wasp stings and paralyses the spider. Once captured, the prey is dragged backwards by its pedipalps, sometimes leaving the prey to inspect either the route or the nest at which point the prey

could be kleptoparasitised by other females of *T. analis*, although females will fight to defend their prey in these circumstances. The prey is placed in a conical cavity excavated by the female, which may fold its legs to fit it in, and once oviposition has taken place the spoil is used to cover the nest, although pre-existing cavities may also be used. As in other spider wasps, the males often patrol the nesting areas so that they can mate with the newly emerged females (Figures 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29) [20,21,22,23,24, 25, 26].

Figure 20 Nesting site selection and nest conntruction; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 21 Searching; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 22 Flushing Multiple attacks, Stinging and Prey transportation; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 23 Prey position; (file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 24 Prey position; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 25 Entrance to nest; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 26 Oviposition; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 27 Exit from the nest; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 28 Nest closure; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

Figure 29 Depature; (Source: file:///C:/Users/Sti/Downloads/BarthelemyHKEB22.pdf)

4. Conclusion

The importance of these data in the context of urban cities, especially regarding the rearing and management of these key organisms for the sake of ecosystemic functions. Wasps are very important control agents of several arthropod populations, like insects and spiders. We still need to fully understand how these interactions are taking place in biomes that have been ravaged by human activity such as the Atlantic Forest. Unfortunately, little data is available for these organisms, especially for wasps like the Pompilidae.

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