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(REVIEW ARTICLE)

Survey of conceptual and taxonomic characteristics of the Families Acartophthalmidae, Canacidae and Carnidae (Insecta: Diptera)

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Abstract

The Acartophthalmidae family includes tiny to small dark flies with hyaline or infuscate wings along the coast. Adults live in the forest, where they are associated with decaying substances such as wood, fungi, carrion, excrement and rotten meat. The Canacidae are found along the sea coasts, on the surface of small bodies of water, saline and fresh, in places protected from the wind. They feed on infusoria and other tiny organisms. In Carnidae, the larvae are saprophagous or coprophagous (they live in the litter of birds' nests). Pupae are enclosed within a puparium and bird nests are micro-ecosystems with diverse communities of invertebrates, from ectoparasitoids to commensal species. The objective of this manuscript was to carry out a survey of the Families Acartophthalmidae, Canacidae and Carnidae regarding their biology, ecology, geographic distribution, and taxonomy. The systematized bibliographic study, of the descriptive and exploratory type of the Families Acartophthalmidae and Canacidae. The bibliographic search included the LILACS databases at: http://www.bireme.br/, in electronic journals available at the SciELO and USP databases: http: //www.usp.br/ and in theoretical books, these banks, university dissertations, national and international scientific articles, scientific journals, documents. The main terms used were: Diptera, flies, Acartophthalmidae, Canacidae and Carnidae.

Keywords: Saprophagous; Decaying substances; Wood; Carrion droppings; Rotten meat; Bird; Ectoparasitoids

1. Introduction

1.1. Description

The family Acartophthalmidae (Diptera: Brachycera) includes minute to small dark flies with the wing either hyaline or infuscate along the costa. Species from this family are distinguished by large, divergent postocellar bristles, absence of true vibrissae, tibiae without dorsal preapical bristle, and costa with only a humeral break and closed anal cell (Figures 1-4) [1,2,3].

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

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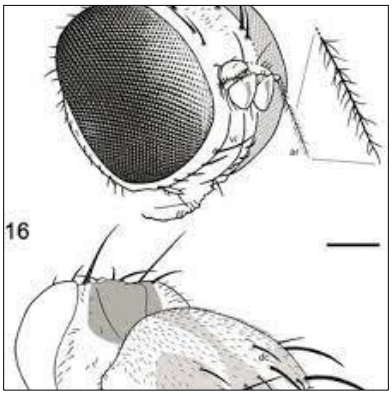
Figure 1 Representative of the Acartophthalmidae Family

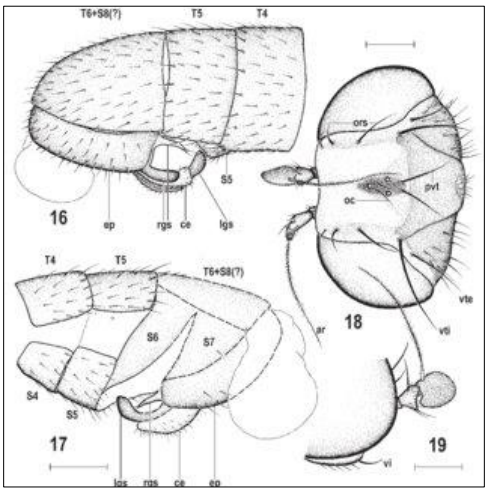


Source: file:///C:/Users/USUARIO/Downloads/A_new_Acartophthalmites_Hennig_from_Eocene_Baltic_.pdf

Figure 2 *Camera lucida* drawings of *Acartophthalmites willii* sp. n., holotype ♂ MCZ-PALE-19475 in Baltic amber (mid-Eocene). 15 Head front laterally view with the cephalic chaetotaxy tagged; note the inset of the distal half of the left arista 16 Head and thorax in posterolateral view, with the thoracic chaetotaxy tagged

Source: file:///C:/Users/USUARIO/Downloads/Stelviana_Tschirnhaus.pdf

Figure 3 *Tanypeza longimana* Fallén, 1820, one of the rarest flies of Europe. Scale bar 0.4 mm Reproduced from Lindner (1949), with the agreement of the publishing house



Source: file:///C:/Users/USUARIO/Downloads/2016RohacekAcartophthalmitesclusioides%20(1).pdf

Figure 4 Figs 16–19. *Acartophthalmites clusioides* sp. nov., male holotype. 16 – the apex of the abdomen laterally, right side; 17 – the same, left side; 18 – head, dorsally; 19 – anteroventral part the of head with antenna, right, laterally. Reconstructed parts in dashed lines. All scales = 0.2 mm. For abbreviations see text (p. 411)

1.2. Biology

Adults live in woodland, where they are associated with decaying substances such as wood, fungi, carrion, droppings and rotten meat. The larvae are in saprophagous and immature stages (Figures 5-6B) [4,5,6].

Source: http://sea-entomologia.org/PDF/Boletin54/167170BSEA54DipteraPortugal.pdf

Figure 5 One of the male specimens of *Acartophthalmus bicolor* Oldenberg, 1910 (Acartophthalmidae), collected while perching in a grass leaf near dead *Procambarus clarkii* (Girard, 1852) (Crustacea, Decapoda, Cambaridae), probably defending the territory from other males; b) one of the specimens of *Pseudopomyza atrimana* (Meigen, 1830) (Pseudopomyzidae) collected; c) the female specimen of *Solva marginata* (Meigen, 1820) (Xylomyidae) collected

Source: http://sea-entomologia.org/PDF/Boletin54/167170BSEA54DipteraPortugal.pdf

Figure 6A Habitat Locations where the specimens referred to in this study were collected: a) Marachão, Brazil; b) Parque Biológico de Gaia and c) Canelas e Fermelã

Source: https://insektarium.net/diptera-2/acarthophthalmidae/acartophthalmus-bicolor/

Figure 6B *Acartophthalmus* associated with organic matter in decomposition

1.3. Taxonomy

The family is represented by the single genus *Acartophthalmus* Czerny, 1902, with three species known from Europe. Two species are present in Spain and recently the family was reported from Portugal for the first time with the record of *Acartophthalmus bicolor* Oldenberg, 1910 (Figure 7) [7,8,9].

Source: https://www.wikiwand.com/en/Acartophthalmus

Figure 7 *Acartophthalmus* is a genus of flies and the only genus with confident placement in the family Acartophthalmidae. They are 1.0–2.5 millimeters (0.04–0.10 in) long, and grey or black in color, with pubescent arista. Only five species are included

The Acartophthalmidae: *Acartophthalmus nigrinus* (Zetterstedt,1848). The two specimens from 2014 were collected with a vial near several dead Louisiana crawfish *Procambarus clarkii* (Girard, 1852), an exotic crustacean pest very common in the area. The area is a cattle pasture adjacent to a marshland. Among the most common plant species are Salicaceae, *Alnus glutinosa* (L.) (Betulaceae), *Frangula alnus* Mill (Rhamnaceae), *Rubus* sp. (Rosaceae). and *Hedera* sp. (Araliaceae) (Figure 8) [11,12,13].

Source: https://waarneming.nl/species/240103/

Figure 8 *Acartophthalmus nigrinus* (Zetterstedt,1848)

1.3.1. Species of Acartophthalmidae

Acartophthalmus bicolor Oldenberg, 1910 — Holarctic

Acartophthalmus coxata (Zetterstedt, 1848) — Europe

Acartophthalmus latrinalis Ozerov, 1986 Russian Far East

Acartophthalmus. nigrinus (Zetterstedt, 1848) — Holarctic (common)

Acartophthalmus pusio Frey, 1947 — Europe

Two of the species occur in the United Kingdom. Source: https://www.wikiwand.com/en/Acartophthalmus

Objectives

The objective of this manuscript was to carry out a survey of the Families Acartophthalmidae Canacidae and Carnidae regarding their biology, ecology, geographic distribution and taxonomy.

2. Methods

The systematized bibliographic study, of the descriptive and exploratory type of the Families Acartophthalmidae, Canacidae and Carnidae. The bibliographic search included the LILACS databases (Latin American and Caribbean Literature in Health Sciences) at: http://www.bireme.br/, in electronic journals available at the SciELO and USP databases: http: //www.usp.br/ and in theoretical books, theses banks, university dissertations, national and international scientific articles, scientific journals, documents. The main terms used were: Diptera, s, and Acartophthalmidae, Canacidae and Carnidae.

3. Selected Studies

3.1. Study 1

3.1.1. Family Acartophthalmidae (Diptera: Brachycera) of Finland

The superfamily includes seven families. The largest by far is Chloropidae, treated in a separate article in this issue. Four of the remaining six are found in Finland: Acartophthalmidae, Canacidae, Carnidae and Milichiidae. The remaining two families, Inbiomyiidae and Australimyzidae, are respectively restricted to the Neotropical and Australasian Regions [14].

Checklist suborder Brachycera Macquart, 1834: Clade *Eremoneura* Lameere, 1906, Clade Cyclorrhapha Brauer, 1863, Infraorder: Schizophora Becher, 1882, Clade *Muscaria* Enderlein, 1936, Parvorder Acalyptratae Macquart, 1835, Superfamily Carnoidea Newman, 1834, Acartophthalmidae Czerny, 1928, *Acartophthalmus* Czerny, 1902, *Acartophthalmus bicolor* Oldenberg, 1910, *Acartophthalmus nigrinus* (Zetterstedt, 1848), *Acartophthalmus pusio* Frey, 1947 (Figure 9) [14].

Source: https://insektarium.net/diptera-2/acarthophthalmidae/acartophthalmus-bicolor/

Figure 9 *Acartophthalmus bicolor* Oldenberg, 1910

3.1.2. Features

- Number. Not rare, but usually unnoticed.
- Biotope. Preferably humid forests, but also many other environments.
- Dimensions. Body length 2-2.2 mm.
- Activity. May-August,
- Location. Lodz. It probably occurs throughout Poland, although it is not shown in many regions.
- Food. Pollen, nectar, honeydew, sap oozing from wounds on trees. Mycetophagous larvae (preferring polypores and other parasitic fungi) or saprophagous (decaying plant material, excrement); presumably they can also develop in carrion.
- Like. In the second domestic species – *A. nigrinus* - the forehead and antennae are black or brownish-black.
- Comments. Identification by Paul Beuk and Roger Thomason.
- Comments. Author of the observations.

3.2. Study 2

There are four morphologically similar species in the Holarctic genus *Acartophthalmus* Czerny, the only genus confidently placed in the family Acartophthalmidae, with *Acartophthalmites* only tentatively allied. This small grayish family is often found in association with rotting fungi and carrion in damp woodlands, but adults have also been collected on dung sap and flowers [15].

Acartophthalmus bicolor Oldenberg,1910 has been observed ovipositing on a dead snake in Russia, and larvae have been reared from decaying meat. Males have been observed waiting for females on decaying organic matter, protecting patches of territory from other males; resident males met invaders by flapping wings, with the smaller male usually retreating (Figure 10) [15].

Source: https://insektarium.net/diptera-2/acarthophthalmidae/acartophthalmus-bicolor/

Figure 10 *Acartophthalmus bicolor* Oldenberg,1910: Decaying organic matter

The Holarctic *Acartophthalmus nigrinus* (Zetterstedt1, 1848) is by far the most commonly collected species. It can be found in relatively large numbers in some habitats and appears to be more abundant in the boreal region (Figure 11) [15].

Source: http://www.spessart-fliegen.de/diptera/acartophthalmidae/acartophthalmus/acartophthalmus_nigrinus/acartophthalmus_nigrinus.htm

Figure 11 *Acartophthalmus nigrinus* (Zetterstedt1,1 848): Lateral, dorsal and wing view

3.3. Study 3

3.3.1. Diptera of the Netherlands

Only the above two species occur in the Netherlands. The family Acartophthalmidae is called "shaved-eye flies" in English. This is probably because of the short fur on the forehead between the eyes and the slanting ridges next to the triangle of eyes. They don't have a Dutch name yet. You could call them "stubble heads" or "stubble head flies (Figure 12) [16,17,18].

Source: http://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=467352

Figure 12 The family Acartophthalmidae

Little is known about these flies. There are only four species worldwide. Their relationship with other families is not so clear. They are probably most closely related to the Chloropidae (Halfflies) and Milichiidae. The larvae are unknown. The flies have been observed to lay their eggs on snails and dead mammals [16,17,18].

They are believed to feed on decaying organic matter in forests. We found a female *Acartophthalmus nigrinus* (Zetterstedt1, 1848) on a black wood fungus (*Inonotus hispidus* (Bull., 1879) that was sitting at a height of 3 m on a dead beech tree in the Hoge Veluwe. She may have been laying eggs on the underside of the fungus so that the larvae of the rotting fungus can eat. Another sighting of *A. nigrinus* was also on the Hoge Veluwe, now on a lying fallen trunk with wood fungi [16,17,18].

Acartophthalmus bicolor Oldenberg, 1910, was caught on a freshly sawn stump ole with still bleeding from the tree. A. pusio is also found further in Europe. This one is smaller and has clear wings and completely dark legs (Figure 13) [16,17,18].

Source: https://www.texasmushrooms.org/en/inonotus_hispidus.htm

Figure 13 *Inonotus hispidus* (Bull., 1879)

4. Family Canacidae

4.1. Introduction

The coastal fly (family Canacidae) is a small family that was previously included in the Ephydridae family. There is some controversy in taxonomy, some classifications include Tethininae as a subfamily, while others classify Tethinidae as a family and Canaceinae as a subfamily. Called in English "beach flies", "surf flies" or "surge flies", they are found almost exclusively on marine coasts (Figures 15A-15B) [19,20].

Source: https://elp.tamu.edu/ipm/bugs/order-diptera-flies/diptera-canacidae-pelomyia-flies-a/

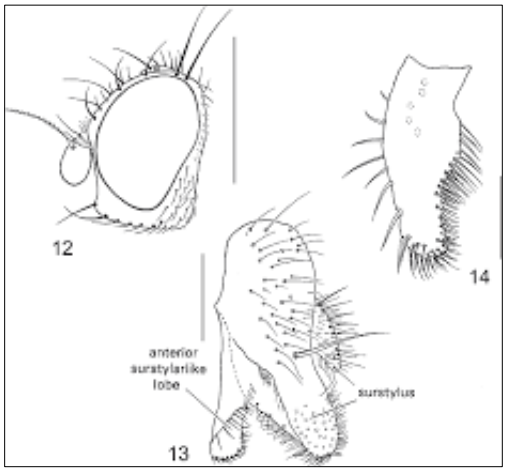
Figure 15A Diptera-Canacidae-*Pelomyia*-Flies

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

Figure 15B *Tethina lusitanica* Munari, 2009

4.2. Description

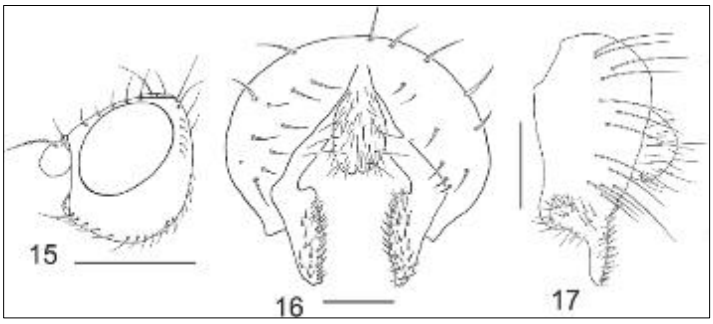
Tiny (1.6–5 mm) yellow, tan, or brownish-brown with branchy to ribbed spots. The head is large with small antennae with a pubescent ridge. There are three or four pairs of orbital bristles on the head turned outwards. The genes are tall with 1 or more bristles curved to the top. The tibias are without a dorsal preapical bristle (Figure 16). [21].



Source: https://www.semanticscholar.org/paper/A-conspectus-on-the-Canacidae-(Diptera)-of-Brazil-Mathis-Marinoni/ae6d30a07335b547e436ce5caa7fab06ab85015d/figure/1

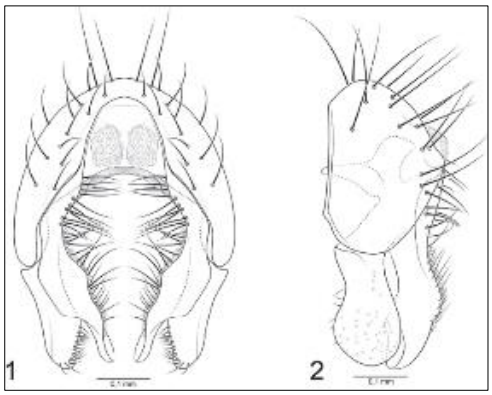
Figure 16 figs.12–14. *Dasyrhicnoessa insularis* (Aldrich, 1931) 12 head, lateral view 13 epandrium, surstylus and anterior surstylarlike lobe, lateral view 14 anterior surstylarlike lobe, posterior view

The handle is not marked in almost all species. At the cost I had a subcostal rupture; The subcoast is parallel to vein R1 and merges with that vein logo before the coast. Dorsal preapical tibiae without bristles (Figures 17-20) [21].



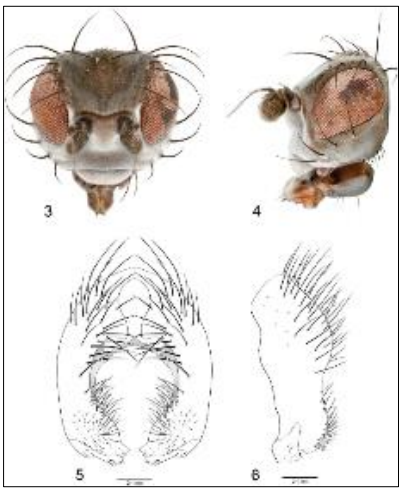
Source: https://www.semanticscholar.org/paper/A-conspectus-on-the-Canacidae-(Diptera)-of-Brazil-Mathis-Marinoni/ae6d30a07335b547e436ce5caa7fab06ab85015d/figure/1

Figure 17 figs.15–17. *Tethina Williston* (Melander, 1913) 15 head, lateral view 16 epandrium, cerci and surstylus, posterior view 17 same, lateral view



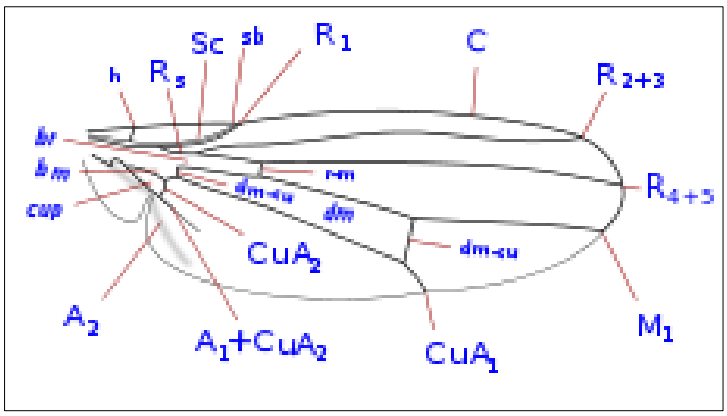
Source: https://www.semanticscholar.org/paper/A-conspectus-on-the-Canacidae-(Diptera)-of-Brazil-Mathis-Marinoni/ae6d30a07335b547e436ce5caa7fab06ab85015d/figure/1

Figure 18 figs.1–2. *Nocticanace packhamorum* sp. nov. 1 epandrium, posterior view 2 same, left lateral view



Source: https://www.semanticscholar.org/paper/A-conspectus-on-the-Canacidae-(Diptera)-of-Brazil-Mathis-Marinoni/ae6d30a07335b547e436ce5caa7fab06ab85015d/figure/1

Figure 19 3–6. *Nocticanace austra* Mathis & Marinoni, 2012 3 head, anterior view 4 same, lateral view 5 epandrium, posterior view 6 same, left lateral view

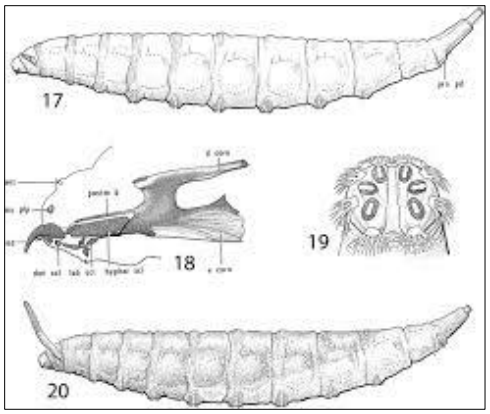


Source: https://en.wikipedia.org/wiki/Canacidae

Figure 20 A1 -first branch of anal vein; bm -basal medial cell; cua -anterior cubital cell; CuA+CuP -anterior branch of cubital vein + posterior branch of cubital vein; dm -discal medial cell; M1 -first branch of media; M4 -fourth branch of media; R1 -anterior branch of radius; R2+3 -second branch of radius; R4+5 -third branch of radius; Sc -subcostal vein; sp –spine

4.3. Biology, Habitat and Geographic distribution

Canacidae are mostly intertidal flies. They are found along sea coasts, on the surface of small water bodies, saline and fresh, at places protected from the wind. They feed on Infusoria and other minute organisms (Figure 21) [22].



Source: Proceedings of the Biological Society of Washington, 120(4):387-428 (2007). https://doi.org/10.2988/0006-324X(2007)120[387:CDFTDS]2.0.CO;2

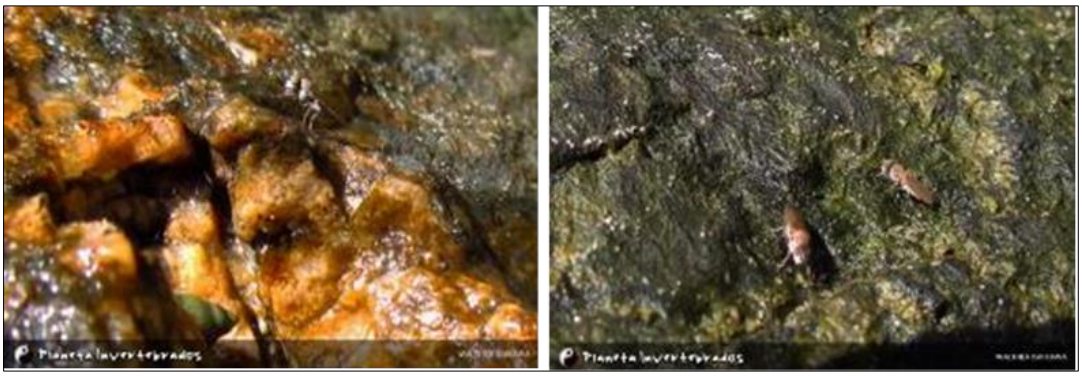
Figure 21 figs. 17 larvae with a breathing tube, 18 buccal processes, 19 breathing spiracles and 20 mature larvae with the breathing tube still present

The Canacidae are found along sea coasts, on the surface of small water bodies, saline and fresh, at places protected from the wind. They feed on infusoria and other minute organisms. True flies of the family Canacidae occur in cool-temperate and tropical zones of the world, primarily on or near seashores with oceanic climates. A few species are found inland, usually in saline or alkaline environments, but occasionally in meadow-like habitats in freshwater streams of Hawaii (Figure 22) [23,24].

Source: https://bugguide.net/node/view/1268299/bgimage

Figure 22 They feed on infusoria and other minute organisms

There are few descriptions of larvae, they are known to be aquatic, again maintaining many similarities with Ephydridae. They are tapered at both ends and have a retractable abdominal breathing tube. Abdominal projecting edges are used for crawling on the substrate (Figure 23) [24,25].



Source: http://www.planetainvertebrados.com.br/index.asp?pagina=especies_ver&id_categoria=28&id_subcategoria=&com=1&id=193&local=2

Figure 23 Coastal Canacidae flies found on a marine rocky shore, at Praia da Riviera, Bertioga, SP. Pictures by Walther Ishikawa

4.4. Taxonomy

4.4.1. Subfamilies

Apetaeninae, Canacinae, Horaismopterinae, Nocticanacinae, Tethininae and Zaleinae.

The subfamily Apetaeninae is endemic in the subantarctic archipelagos. Worldwide there are 307 species in the family (6 subfamilies 27 genera)

Subfamily Pelomyiinae Foster, 1976. Genus: *Pelomyiella* Hendel, 1934 and Specie *Pelomyiella cinderella* (Haliday, 1837) (Figures 24-27) [26,27,28].

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

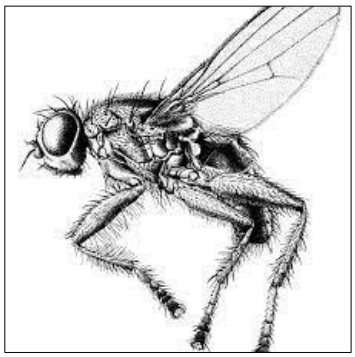
Figure 24 Subfamily Apetaeninae; Genus *Apetaenus;* Specie: *Apetaenus australis* (Hutton, 1902)

Sources: Photograph © Maimon Hussin, National University of Singapore and file:///C:/Users/USUARIO/Downloads/2018-MunariL.-Allocanacegibba.pdf

Figure 25 Subfamily Canacinae, Genus: *Allocanace*, the habitus of a paratype. Specie: *Allocanace gibba* gen. nov., sp. nov. (Specimen photographed in alcohol before being double mounted)

Sources: Photo 13304088, (c) Steve Kerr, some rights reserved (CC BY), uploaded by Steve Kerr and https://uk.inaturalist.org/photos/13304088

Figure 26 Subfamily Horaismopterinae; Genus *Tethinosoma*; Specie *Tethinosoma fulvifrons* (Hutton, 1901



Sources: Drawing by G. D'Este and https://www.researchgate.net/figure/Thitena-cadaverina-ngen-and-nsp-habitus-Drawing-by-G-DEste_fig9_228760289

Figure 27 Subfamily Tethininae, Genus *Thitena*; Specie *Thitena cadaverina* nov. gen. and nov. sp., habitus

5. Selected Studies

5.1. Study 1

The new genus is a *Canacine* fly belonging to the tribe Canacini, subtribe Canacina, the latter so far regarded as a small monotypic subtribe, with only the genus *Canace* Haliday, in Curtis, 1837 as the unique representative. *Canace includes* Curtis, 1837 six species known exclusively from the Mediterranean and the eastern Atlantic coast north of the Equator [29].

This description of a new genus and species of surf fly collected by the team, "Singapore Mangrove Insect Project", in Singapore's mangrove forest [29].

5.1.1. Family Canacidae Jones

1906 Subfamily Canacinae Jones, 1906

Tribe Canacini Jones, 1906

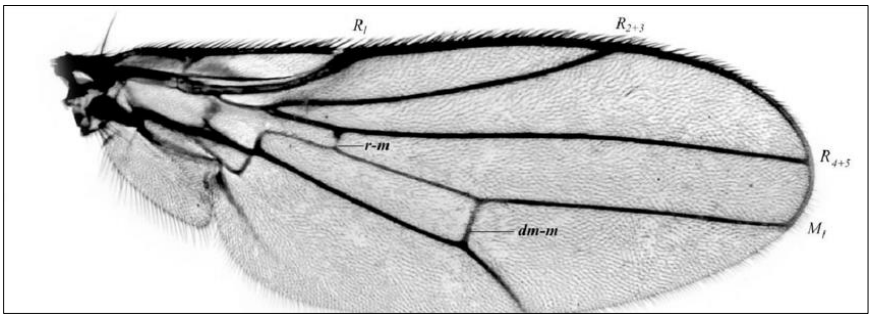
Subtribe Canacina Jones, 1906

Allocanace gen. nov. (Figure 28) [29].

Source: file:///C:/Users/USUARIO/Downloads/2018-MunariL.-Allocanacegibba.pdf

Figure 28 The new genus is a Canacine fly belonging to the tribe Canacini, subtribe Canacina, the latter so far regarded as a small monotypic subtribe, with only the genus *Canace* Haliday, in Curtis, 1837 as the unique representative. Canace includes six species known exclusively from the Mediterranean and the eastern Atlantic coast north of the Equator

Allocanace gibba sp. nov. (Figure 29).



Sources: Photo by L. Munari and file:///C:/Users/USUARIO/Downloads/2018-MunariL.-Allocanacegibba.pdf

Figure 29 Wing of *Allocanace gibba* gen. nov., sp. nov., paratype ♂, wing length 2.68 mm. Abbreviations. dm-m: discal medial crossvein; M 1: first branch of media; M 4 : fourth branch of media; R 1: anterior branch of radius; R 2+3: second branch of radius; R4+5: third branch of radius; r-m: radial-medial crossvein

Distribution. Known only from Singapore's mangrove forest [29].

6. Family Carnidae

6.1. Introduction

The superfamily Carnoidea includes seven families. The largest by far is Chloropidae, treated in a separate article in this issue. Four of the remaining six are found in Finland: Acartophthalmidae, Canacidae, Carnidae and Milichiidae. The remaining two families, Inbiomyiidae and Australimyzidae, are respectively restricted to the Neotropical and Australasian Regions (Figures 30-32) [30,31].

Source: https://en.wikipedia.org/wiki/Carnus_%28fly%29

Figure 30 *Carnus* (fly) Family Carnidae

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

Figure 31 *Carnus hemapterus* (Nitzsch, 1818)

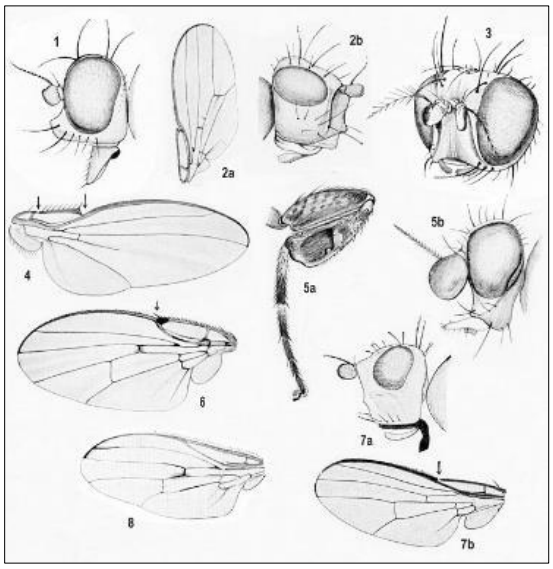
Source: https://diptera.myspecies.info/carnidae/content/introduction-carnidae

Figure 32 *Carnus hemapterus* (Nitzsch, 1818). One notable exception is *C. hemapterus*, which is parasitic on birds, and was therefore the center of several studies. Most species of the Carnidae are saprophagous and are associated with carrion, feces, or bird's nests. Adults can be collected on flowers of Apiaceae, Asteracea, Rosaceae and some other families

6.2. Description

Antennae 2–6 segmented; 'modified'; aristate. The second antennal segment is not grooved. The ptilinal suture is clearly defined. Post-vertical orbital bristles present, or absent; parallel, or divergent. Mouthparts functional. The maxillary palps 1 segmented; porrect. Thorax without a continuous dorsal suture; without well-defined posterior calli. The wing venation is incomplete, in the sense of lacking one or more of the cells. Wings without a discal cell; without a sub-apical cell; without a closed anal cell [30,31].

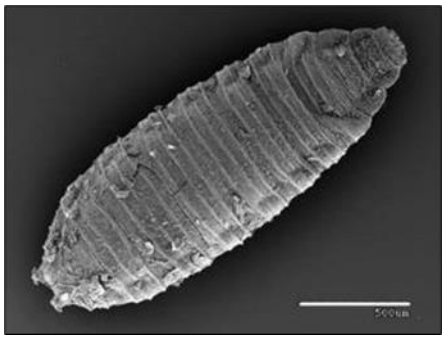
Wing vein 4 is very short, extending little beyond the end of the first basal cell. Wing vein 6 is present (but only as a shadowy fold); falling short of the wing margin. Hind tibiae without strong bristles in the basal 4/5. Parasitic (Carnus hemapterus is a bloodsucker, residing in the nests of birds) (Figure 33) [30,31].



Source: https://www.delta-intkey.com/britin/dip/www/carnidae.htm

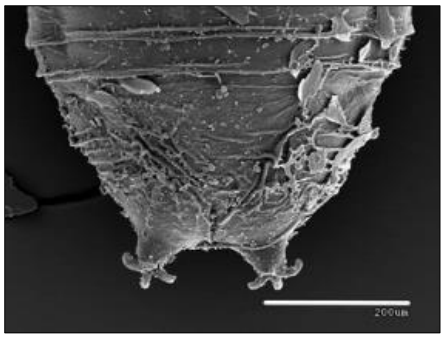
Figure 33 *Carnus.* 1, Aulacigastridae: head of *Aulacigaster leucopeza* (Meigen, 1830). 2a and 2b, Canacidae: wing and head of *Canace nasica* (Haliday, 1839). 3, Diastatidae: head of a *Diastata* species. 4, Carnidae: *Carnus* sp., wing. 5a and 5b, Milichiidae: leg of *Leptometopa latipes* (Meigen, 1930) (5a), and head of *Phyllomyza* (5b). 6, Odiniidae: *Odinia* sp., wing. 7a and 7b, Tethinidae: *Tethina* sp., head and wing. 8, Periscelididae: *Periscelis winnertzii* Egger 1862, wing. From Colyer and Hammond (1951) Note: Carnidae. Formerly in Milichiidae

6.3. Biology



Source: https://www.researchgate.net/figure/Puparium-of-Carnus-hemapterus-Spiracles-with-short-curved-finger-like-projections-are_fig2_322345248

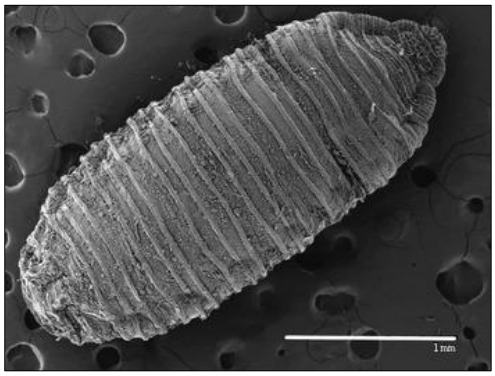
Figure 34 Puparium of Carnus *hemapterus* Nitzsch, 1818



Source: https://www.researchgate.net/figure/Puparium-of-Carnus-hemapterus-Spiracles-with-short-curved-finger-like-projections-are_fig2_322345248

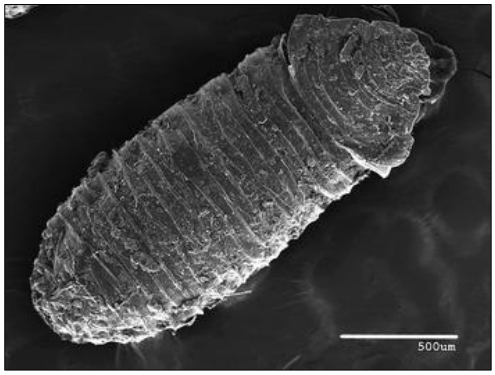
Figure 35 Puparium of spiracles with short curved finger-like projections is evident

Larvae and pupae. The larvae are saprophagous, or coprophagous (living in refuse in birds' nests); acephalic. The pupae are enclosed within a puparium (Figures 34-39) [31,32].



Source: https://www.researchgate.net/figure/Puparium-of-Carnus-hemapterus-Spiracles-with-short-curved-finger-like-projections-are_fig2_322345248

Figure 36 Puparium of *Hemeromyia anthracina* Collin, 1949



Source: https://www.researchgate.net/figure/Puparium-of-Carnus-hemapterus-Spiracles-with-short-curved-finger-like-projections-are_fig2_322345248

Figure 37 Puparium of *Hemeromyia longirostris* Carles-Tolrá, 1992

Source: https://www.researchgate.net/figure/Puparium-of-Carnus-hemapterus-Spiracles-with-short-curved-finger-like-projections-are_fig2_322345248

Figure 38 Puparium of Carnus *hemapterus* Nitzsch, 1818

(Left), *Hemeromyia anthracina Collin, 1949* (middle) and *Hemeromyia longirostris* Carles-Tolrá, 1992 (right)

Veiga VFJ, Sandoval A, Moreno E. Coexistence, habitat associations and puparia description of three dipteran species of the Family Carnidae. Parasitology Open. 2018; 4, E1.

Source: Figures 34-39. https://www.cambridge.org/core/journals/parasitology-open/article/coexistence-habitat-associations-and-puparia-description-of-three-dipteran-species-of-the-family-carnidae/E732079C4B5A097D57E3AAEDFEEC0027

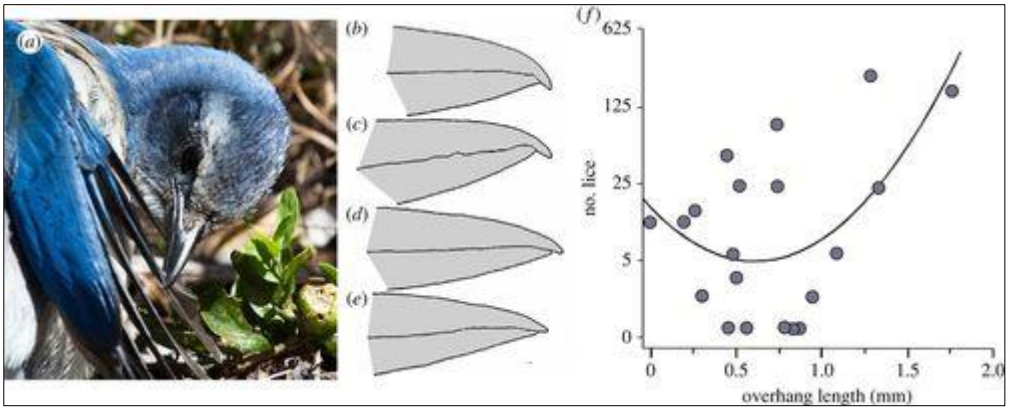
Figure 39 Detail of the caudal end of the puparia of Carnus *hemapterus* Nitzsch, 1818 (left), *Hemeromyia anthracina* Collin, 1949 (middle) and *Hemeromyia longirostris* Carles-Tolrá, 1992 (right)

Bird nests are micro-ecosystems with diverse communities of invertebrates, from ectoparasites to commensal species. Most studies of the arthropods in bird nests have focused on the presence and impact of ectoparasites like the family Carnidae [32,33].

The Family Carnidae (Diptera, Schizophora) is a poorly investigated group of flies that includes parasitic species genus *Carnus* Nitzsch 1818 as well as non-parasites belonging to the genus *Meoneura* (Rondani, 1856) and *Hemeromyia* (Coquillet 1902) [34,35].

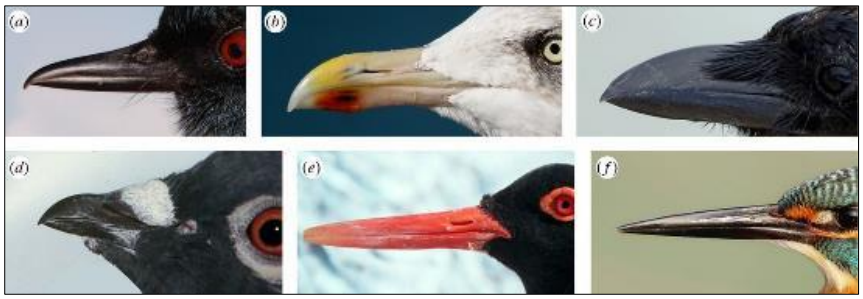
6.4. Anti-parasite behavior of birds

Birds have many kinds of internal and external parasites, including viruses, bacteria and fungi, as well as protozoa, helminths and arthropods. Because parasites have negative effects on host fitness, selection favors the evolution of anti-parasite defenses, many of which involve behavior (Figures 40-42).



Source: https://royalsocietypublishing.org/doi/epdf/10.1098/rstb.2017.0196

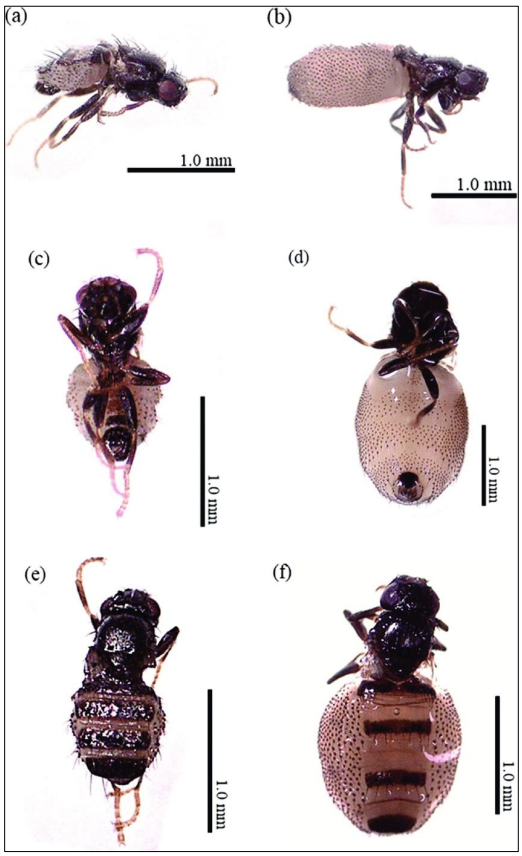
Figure 40 Scrub jay preening with bill tips (photo by Bob Montanaro). (b–e) Four examples of scrub jay bills from the western USA show the range of morphological variation within the species (redrawn from [34]. (f) The intensity of feather lice in relation to about length of western scrub jays (redrawn from [2]. Among 20 infested birds, those with intermediate overhangs had the fewest lice. This relationship suggests that lice may exert stabilizing selection for intermediate overhang length, presumably because intermediate overhangs are better at controlling lice



Sources: Andres Cuervo wikimedia.org., Picasa, pexels.com, Philip Hockey, Boris Smokrovic, unsplash.com and wikime-dia.org)https://rwikimecietypublishing.org/doi/epdf/10.1098/rstb.2017.0196

Figure 41 Most species of birds have a small mandibular overhang at the tip of their bill (a–d); however, some species of birds do not have an overhang (e,f). (a) *Diglossa caerulescens* Sclater, 1856. (b) *Larus argentatus* Pontoppidan, 1763. (c) *Corvus splendens* Vieillot, 1817). (d) *Columba livia* Gmelin, 1789). (e) *Haematopus moquini* Bonaparte, 1856. (f) *Alcedo atthis* (Linnaeus, 1758). The overhang is often missing in cases where it would presumably interfere with feeding, as in the case of the oystercatcher and the kingfisher

Carnidae (bird flies, filth flies): Scavenge within burrows and nests; *Carnus hemapterus* (Nitzsch, 1818), adults scavenge between feathers of birds and break down wings. One notable exception is C. hemapterus, which is parasitic on birds, and was therefore the center of several studies. Most species of the Carnidae are saprophagous and are associated with carrion, feces, or bird's nests. Worldwide there are six genera with 93 extant and two fossil species (Figure 42) [36,37].



Source: https://www.researchgate.net/figure/Carnus-hemapterus-Diptera-Carnidae-in-white-cheeked-starling-Sturnus-cineraceus-a_fig1_352293966

Figure 42 *Carnus hemapterus* (Nitzsch, 1818) (Diptera: Carnidae) in white-cheeked starling *Sturnus cineraceus* Temminck, 1835. (a) male (lateral view); (b) female with the distended abdomen (lateral view); (c) male (ventral view); (d) female with distended abdomen (ventral view); (e) male (dorsal view); (f) female with the distended abdomen (dorsal view)

6.5. Taxonomy

All four families are rather poorly studied in Finland. The presence of additional, even undescribed, species is very likely in Carnidae and Milichiidae. The identification of all species of *Meoneura* was verified from male genitalia during the preparation of this checklist with one exception: the male of *Meoneura elongella* (Zetterstedt, 1838) remains undescribed. It is the only North European *Meoneura* with black halteres and as such easily recognized [38,39].

The Nearctic species of the genus *Meoneura* and the genus *Carnus* and phylogenetic analysis Carnidae belong to the superfamily Carnoidea. The only genus of the *Australimyza* Harrison has previously been included in the Carnidae. Worldwide there are six genera with 93 extant and two fossil species [40,41].

Genus: *Carnus, Enigmocarnus, Meoneura* and *Neomeoneurites*.

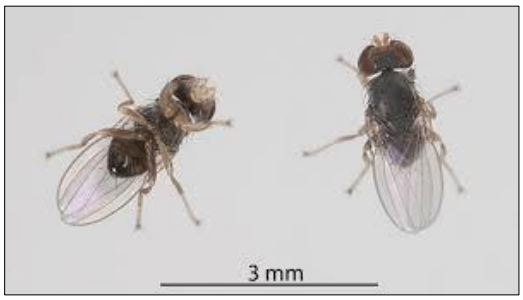
Specie: *Carnus hemapterus* Nitzsch, 1818 (Figures 43-46) [42,43,44].

Source: https://diptera.myspecies.info/node/2517/revisions/11622/view

Figure 43 Genus *Canus* (Carnidae)

Source: https://bugguide.net/node/view/219980

Figure 44 Genus *Meoneura* (Carnidae)



Source: https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 45 Genus *Australimyza* (Carnidae)

Source: https://waarneming.nl/species/546940/

Figure 46 *Carnus hemapterus* Nitzsch, 1818

7. Selected studies

7.1. Study 1

The Carnidae are quite small (1-2 mm) black flies and probably due to their small size, they have not attracted a great degree of study. One notable exception is *Carnus hemapterus* Nitzsch, 1818, which is parasitic on birds, and was therefore the center of several studies. Most species of the Carnidae are saprophagous and are associated with carrion, feces, or bird's nests [45,46].

7.1.1. Carnidae

Camus hemapterus Nitzsch, 1818 = *Cenchridobia eggeri* Schiner, 1862. Austria = *Camus setosus* Stobbe, 1913.

Meoneura algerica Hennig, 1937. Algeria

Meoneura furcata Hennig, 1937. Algeria

Meoneura obscurella (Fallen, 1823) = *Agromyza pectinata* Meigen, 1830. *Agromyza infuscata* Meigen, 1830. Austria (Figure 47) [45,46].

Source3: https://diptera.myspecies.info/category/diptera-classification/meoneura-obscurella

Figure 47 *Meoneura obscurella* (Fallen, 1823)

7.2. Study 2

Carnus hemapterus Nitzsch, 1818 (Diptera, Carnidae) is a tiny (about 2 mm long) fly species that lives predominantly in birds' nests. The range of bird species that *C. hemapterus* associates with are wide, missing at least 52 species. The larvae feed on the organic debris in the nests while the adults are ectoparasites of the nestlings, feeding on blood, epidermal cells, and skin secretions (Figure 48) [47,48,49].

Source: https://desinsectador.com/2018/05/16/mosca-parasita-carnus-hemapterus-en-halcon-peregrino/

Figure 48 *Carnus hemapterus* Nitzsch, 1818 (Diptera, Carnidae)

Following pupation, emerging adults can remain in the nest or disperse in search of hosts, losing the wings once they find a suitable host. Dispersing adults is quite short-lived or second and copulation takes place on the hosts. Female *C. hemapterus* exhibit physiatry, a morphological modification of the abdomens which become greatly distended to accommodate the blood or oil ingested [48,49].

The known distribution of *C. hemapterus* includes Europe and North America. In Spain, *C. hemapterus* was recorded from the provinces of (ordered chronologically according to the earliest record): Zaragoza. Here we record *C. hemapterus* from Portugal for the first time, based on 33 adult specimens collected on 24 April 2020 from three nestlings of the barn owl, *Tyto alba* (Scopoli, 1769) (Aves: Tytonidae) (Figure 49) [50].

Source: https://www.nativealimentos.com.br/sustentabilidade/biodiversidade/animais/aves/suindara-ou-coruja-de-igreja/347

Figure 49 *Tyto alba* (Scopoli, 1769) (Aves: Tytonidae)

7.3. Study 3

Parasitic fly *Carnus hemapterus* Nitzsch, 1818 (Diptera, Carnidae) in *Falco peregrinus* (Tunstall, 1771) (Aves: Falconiformes: Falconidae). Since years ago, the falcon-peregrine was created on this cliff overlooking the sea. In a hole in the vertical rock, there is established a pair that each year brings new individuals to this species (Figure 50) [51,52].

Source: https://desinsectador.com/2018/05/16/mosca-parasita-carnus-hemapterus-en-halcon-peregrino/

Figure 50 *Carnus hemapterus* Nitzsch, 1818 (Diptera, Carnidae)

Parasites that were shaped like a fly but with a higy developed abdomens were found with four specimens captured. The flies were female Carnidae that, during the two days they were inside the vial, were laying eggs [51,52].

In the Iberian Peninsula, there are 30 species divided into three genera. And the only genus of fly parasitic on birds is *Carnus*, which has a single species called *C. hemapterus*. It is widely distributed across Europe. Also, to Asia and America [51,52].

This dipteran parasite has about 30 species of medium and large birds, including hawks, owls, bee-eaters and starlings. Adult females measure about 2 millimeters. Males are smaller. It seems that the adult female feeds on the blood of the offspring. She lays her eggs in her host's nest and the larvae feed on all the remains of organic matter found there. It is no small matter: excrements, secretions, corpses, etc. (Figure 51) [51,52].

Source: https://desinsectador.com/2018/05/16/mosca-parasita-carnus-hemapterus-en-halcon-peregrino/

Figure 51 Eggs of *Carnus hemapterus* Nitzsch, 1818 (Diptera, Carnidae)

The flies hatch from the pupae during the same year, which leads to a nest with large numbers of parasites at the end of the brooding period. Or they stay in this stadium during the winter to overcome the cold and the lack of chickens. Adults emerge with functional wings that they use to move to new nests (Figure 52) [51,52].

Source: https://ebird.org/species/perfal4?siteLanguage=pt_BR

Figure 52 *Falco peregrinus* (Tunstall, 1771) (Aves: Falconiformes: Falconidae)

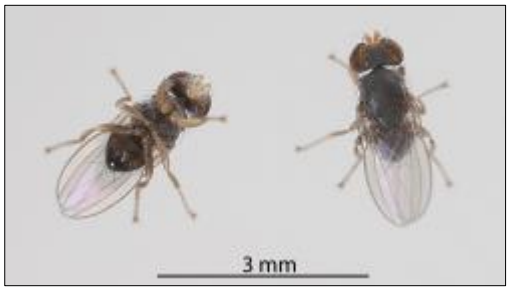
Of course, they will also use flight to locate a partner to copulate with. Adults settle into a nest when their hosts lay eggs. And there it is circulating through the nest and the feathers of the chicks. It is in this phase of dragging that they lose their wings due to friction with the feathers [51,52].

7.4. Study 4

7.4.1. Australasian coastal fly-Australimyza sp.

The flies in the family Australimyzidae are only found in Australia, New Zealand and associated subantarctic islands. The family contains only one genus, *Australimyza*. The genus was established by Harrison in 1959 in his major work on the Acalypterate Diptera of New Zealand. The flies in this genus are associated with low-growing plants in coastal habitats. Larvae have been reared from seaweed, plant leaves that were probably decaying and material from a sooty

albatross nest. Three species have been found on the North & South Islands of New Zealand. Two others are on the Chatham Islands and the subantarctic Islands (Figure 53) [53,54,55].



Sources: Image: Tim Holmes © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

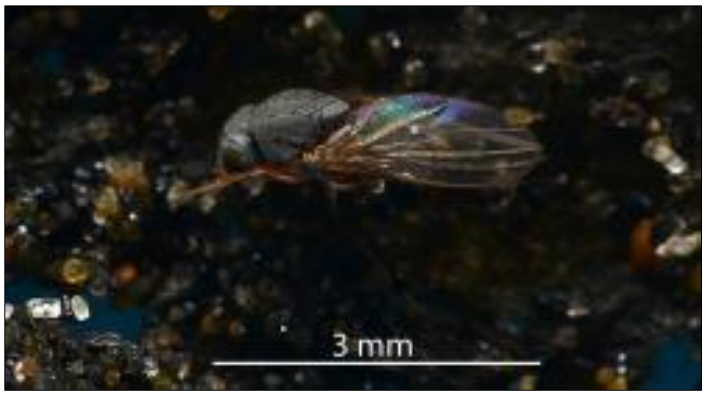
Figure 53 Underside and top of an adult Australasian coastal fly, *Australimyza* sp.

Endemic flies in the genus *Australimyza a*re found in coastal areas of the North and South Islands. Other species are found on the Chatham Islands and subantarctic Islands. There are species in Australia. Adults may be found on flowers. Larvae feed on decaying vegetation (Figure 54) [53,54,55].

Sources: Image: Tim Holmes © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

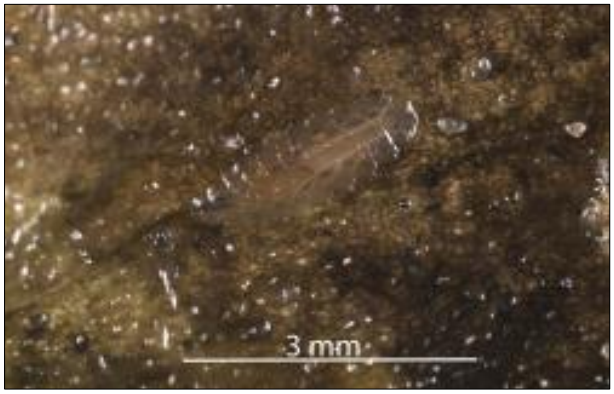
Figure 54 Larva of an Australasian coastal fly, *Australimyza* sp.

- Conservation status: The genus is widespread around the coast of New Zealand and on many off-shore Islands, the species do not appear to be threatened [53,54,55].
- Adult fly: The grey-brown-bodied adult flies are small, about 2.0 mm long and the wings are about 3.0 mm long. The flies are smaller than vinegar flies, *Drosophila*, that are seen around rotting [53,54,55].
- Eggs and larvae: After mating, it is presumed that the female lays eggs on or near dead or decaying leaves on plants such as New Zealand celery or New Zealand climbing spinach. The larva is a small pale maggot that feeds on decaying leaves. When the first instar (stage) larva is fully grown it moults [53,54,55].
- Pupa: The fully grown larva stays on or near the rotten leaves. The larva pupates inside its larval skin, which darkens and hardens. This structure is called a puparium. The puparium retains the sharp backward-pointing edge to most body segments. The upper side of the head appears to have short blunt spines (Figures 55-58) [53,54,55].



Sources: Image: Nicholas A. Martin © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 55 A dead adult Australasian coastal fly, *Australimyz*a sp. note the many tiny setae on the thorax



Sources: Image: Tim Holmes © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 56 Larva of an Australasian coastal fly, *Australimyza* sp. on a dead leaf of New Zealand climbing spinach, *Tetragonia implexicoma* (Miq.) Hook.f. (Aizoaceae)

Sources: Image: Tim Holmes © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 57 A puparium of Australasian coastal fly, *Australimyza* sp. by a dead leaf of New Zealand climbing spinach, *Tetragonia implexicoma* (Miq.) Hook.f. (Aizoaceae)

Sources: Image: Tim Holmes © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 58 Large larvae of Coastal *Scaptomyza* fly, *Scaptomyza flavella* Harrison, 1959 (Diptera: Drosophilidae) the feeding in leaf of New Zealand Celery, *Apium prostratum* Labill. ex Vent. (Umbeliferae): note the entrance holes and the toothed mandible and skeleton of the left larva

7.4.2. Natural Enemies

One parasitoid, *Asobara albiclava* Berry, 2007 (Hymenoptera: Braconidae) has been reared from an *Australimyza* sp. larva living on decaying leaves of New Zealand climbing spinach, *Tetragonia implexicoma* (Miq.) Hook. f. (Aizoaceae) [53,54,55].

There are no reports of any pathogens or predators of *Australimyza* species They are likely that they are preyed upon by birds, spiders and predatory insects (Figure 59) [53,54,55].

Sources: Image: Nicholas A. Martin © Plant & Food Research © Plant & Food Research and
https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 59 Upper side of an adult parasitoid, *Asobara albiclava* Berry, 2007 (Hymenoptera: Braconidae) that emerged from a pupa of an Australasian coastal fly, *Australimyza* sp.

7.4.3. Host Plants

Adult flies of *Australimyza* species have been found feeding on or associated with flowers of a variety of herbs and shrubs. One species was found around dead stingrays. Larvae have been reared from seaweed, plant leaves that were probably decaying and material from a sooty albatross nest [53,54,55].

On the west coast of Auckland, flies have been reared from larvae living on decaying leaves of New Zealand climbing spinach, *Tetragonia implexicoma* (Aizoaceae) and New Zealand celery, *Apium prostratum* (Umbelliferae). The larvae were living on leaves still attached to the plants (Figure 60) [53,54,55].

Sources: Image: Nicholas A. Martin © Plant & Food Research © Plant & Food Research and https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Australasian-coastal-fly---Australimyza-sp.html

Figure 60 leaf of New Zealand Celery, *Apium prostratum* (Umbeliferae), with feeding damage by Coastal *Scaptomyza flavella* Harrison, 1959 (Diptera: Drosophilidae)

8. Conclusion

A qualitative study was carried out with the elaboration of a bibliographical review, using academic and scientific journals available online and in printed versions as a means of theoretical foundation, gathering and comparing the different data found in the sources that were consulted and listing the characteristics such as biology, ecology, geographic distribution and taxonomy of Families Acartophthalmidae, Canacidae and Carnidae.

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