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ARTHROPODS AND MEDICAL ENTOMOLOGY - ORIGINAL PAPER

A world review of reported myiases caused by flower flies (Diptera: Syrphidae), including the first case of human myiasis from *Palpada scutellaris* (Fabricius, 1805)

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Abstract
Rat-tailed larvae of the syrphid species *Palpada scutellaris* (Fabricius, 1805) are documented causing an enteric human myiasis in Costa Rica. This is the first time that the genus *Palpada* is recorded as a human myiasis agent. We report a 68-year-old woman with intestinal pain and bloody diarrhea with several live *Palpada* larvae present in the stool. Using molecular techniques (DNA barcodes) and both electronic and optical microscopy to study the external morphology, the preimaginal stages of the fly were unambiguously identified. An identification key to all syrphid genera actually known as agents of human and animal myiases is provided for larvae, puparia, and adults. Moreover, a critical world review of more than 100 references of Syrphidae as myiasis agents is also given, with emphasis on the species with rat-tailed larvae.

Keywords Hover flies · Hoverflies · Flower flies · Costa Rica · Rat-tailed maggots · Myiasis · *Palpada* · Syrphidae

Introduction

Myiasis is the term proposed by Hope (1840) to define the presence of the larvae of flies (Insecta: Diptera) in the body of humans and other animals. However, the term was more precisely defined by Zumpt (1965) as the parasitic infestation of organs or tissues of humans and other live vertebrates by dipteran larvae which feed on a host's necrotic or living tissue, liquid body substances, or ingested food. This definition is currently followed unanimously in all main reviews of this pathology (e.g., Noutsis and Millikan 1994; Hall and Wall 1995; Francesconi and Lupi 2012; Singh and Singh 2015; Bernhardt et al. 2019). If the host is human, myiasis may have medical and public health importance. Myiasis has a widespread incidence among domestic and wild animals all over the world with relatively high biological and economic importance, especially in tropical countries. The incidence of myiasis in humans may be correlated with the existing level of sanitation, the density of prevailing fly population, and the economic status of individuals (Singh and Singh 2015). Despite this, myiasis is diagnosed more frequently in temperate regions and is less correlated with the previously mentioned factors due to increasing travel to exotic destinations, as noted by Noutsis and Millikan (1994).

Myiases can be classified based on the behavior of the fly species involved and the nature of the parasitic relationship, i.e., they can be divided into obligatory and facultative myiases if the involved species can complete their development exclusively parasitizing live hosts, or if the species can develop on both living and dead organic matter, respectively. Four families of flies are responsible for most cases of myiasis, namely Muscidae, Oestridae, Sarcophagidae, and Calliphoridae. These are all calyptrate flies (Diptera, Cyclorrhapha, Schizophora, Calyptratae), a monophyletic group that shares a common evolutionary ancestor (Zhang et al. 2016). Members of the family Muscidae are not involved in obligatory myiases but the other three families include both obligatory and facultative myiasis species, and their natural

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histories have been analyzed comparing them with their phylogenetic relationships (Stevens and Wallman 2006; Stevens et al. 2006). A third type of myiasis named accidental myiasis or pseudomyiasis (Patton 1921; James 1947; Zumpt 1963) has been documented from a variety of fly families, many not related to calyptrates. Accidental myiasis occurs when the larvae of a normally free-living species are swallowed with contaminated food, passing through the alimentary canal where they may cause pathological reactions (Zumpt 1965; Leclercq 1969).

Syrphidae is a speciose family of true flies with more than 6200 valid species (Thompson 2013), absent only from some remote islands and Antarctica (Thompson and Rotheray 1998). Commonly known as flower flies or hover flies, syrphids are favorites among citizen scientists and nature lovers. Adults play an important role as potential pollinators (Larson et al. 2001; Inouye et al. 2015) as they feed on pollen and nectar and are frequent flower visitors. The larvae of these flies present a large array of natural histories and feeding modes, including phytophagy, saprophagy, mycophagy, and predation (Rotheray and Gilbert 2011), but also some more specialized trophic strategies (e.g., Pérez-Lachaud et al. 2014; Fleischmann et al. 2016). The family is currently divided into four subfamilies (Mengual et al. 2015), the largest of which (Eristalinae) has the highest number of larval feeding modes. Rat-tailed maggots are members of the tribe Eristalini that form part of this subfamily and mostly include species with saprophagous larvae in decaying liquid or semisolid matter (Rotheray and Gilbert 2011). These larvae have a characteristic elongated anal segment with the posterior respiratory process at the tip, which allows them to breathe air while submerged in ponds and mud with accumulations of decaying vegetation or from farmyard manure or silage (Rotheray 1993). Some species with rat-tailed maggots are fairly tolerant of pollution and water bodies with high organic content and low oxygen concentration. The adults are commonly known as drone flies because they mimic bees and play an important role as pollinators of both natural and hand-managed ecosystems, making them economically important as the decline in the numbers of insect pollinators has significant environmental and economic consequences (Golding et al. 2001; Ratnieks and Carreck 2010; Potts et al. 2010).

The common drone fly, *Eristalis* (*Eristalis*) *tenax* (Linnaeus, 1758), an extraordinary mimic of the honeybee *Apis mellifera* Linnaeus, 1758 (Atkins 1948), is probably the best studied representative of the eristaline flies and, with human assistance, is now a cosmopolitan species (Thompson 2013). Because of its importance as pollinator and its potential economic usefulness for the biodegradation of organic animal waste, its genetic and phenotypic diversity have been studied in both wild and captive populations (Francuski et al. 2011, 2014). On the other hand, rat-tailed larvae have been reported in several forensic case reports (Lee 1994; Archer and Ranson 2005), and indeed, larvae of *E. tenax* and related species have a relevant role in forensic entomology, typically in cases where the corpse is found in fresh aquatic environments (Salleh et al. 2007; Lindgren et al. 2015; Heo et al. 2019). Additionally, the larval ability to survive in aquatic habitats with high content of organic matter and rich in microorganisms such as drains, sewage pools, or manure storage pits prompted the study of the immune-inducible transcriptome of the common drone fly in order to find genes related to septic injury (Altincicek and Vilcinskas 2007).

The medical importance of Syrphidae is almost null for most species. However, larvae of *E. tenax* have been reported in cases of nuisance as urban and farm pests due to high concentrations that occur when prepupal larvae seek suitable pupation sites (Gil Collado 1961; Wilson et al. 2009). They can become health and sanitary issues as they have been associated with viruses and amoebae that are present in freshwater (Boughalmi et al. 2013), and porcine pathogenic intracellular bacteria (McOrist et al. 2011) and imagoes of this species may act as potential mechanical vectors of pathogens causing mycobacterial infections in cattle farms (Fischer et al. 2005, 2006; Boughalmi et al. 2013).

Despite this, there are scattered in the literature many references of drone flies as accidental myiasis agents in humans and livestock around the world, although Mathison and Pritt (2014) stated that there is no evidence of saprophagous syrphid larvae causing clinical disease in humans. Most of these cases are considered as intestinal myiasis that were probably caused by the drinking of putrid water-containing eggs or small larvae, or by ingestion of contaminated food (Rotheray and Gilbert 2011). Clinical presentation is varied, and although it may be asymptomatic, some patients experience abdominal pain, nausea, and vomiting (Aguilera et al. 1999; Derraik et al. 2010). Other authors proposed an alternative hypothesis, called "rectal myiasis" (Zumpt 1963; see also Graham-Smith 1913). In this hypothesis, flies, attracted to feces, may deposit their eggs or larvae near or into the anus and the larvae then penetrate further into the rectum. Although more than 200 species with rat-tailed maggots have been described and the preimaginal stages of most of them remain undescribed (Pérez-Bañón et al. 2003a, 2013; Campoy et al. 2017), the common drone fly is cited in virtually all reported cases of myiasis occasioned by flower flies around the world.

In the present study, the first human myiasis caused by an eristaline species of the genus *Palpada* Macquart, 1834 is reported. In order to identify the species of this genus, DNA barcoding techniques (Hebert et al. 2003a, 2003b) as well as morphological inspection of a pre-adult were carried out. Along with this new report, a critical world review of myiasis occasioned by syrphid species, with special reference to the New World, is given after an exhaustive literature research, as well as the first identification key to syrphid genera cited as myiasis agents for third instar larvae, puparia, and adults.

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Material and methods

Case report

The patient, a 68-year-old woman, sought consultation on May 17th, 2015 for bloody diarrhea and strong spasmodic abdominal pain at the colon level in the Centro de Atención Primaria Estatal (Barrio San José, Alajuela, Costa Rica). She did not have any other abdominal or general symptoms, and her physical examination was normal. The complementary studies, including blood analysis, abdominal X-ray films, and abdominal ultrasonography, also were normal. No specific treatment was given to the patient, but she returned on July 3rd, 2015 with the same symptoms and a sample of mucus-bloody stool. In this sample, two larval forms were found with a rat-tailed morphology, compatible with the larval morphology of eristaline species. The patient was treated with an anthelmintic and the sample was sent to the Santa Lucia Laboratory (Heredia, Costa Rica) for microscopic analysis, and later referred to the Universidad de Costa Rica for morphological study. The first morphological studies confirm that the larval morphology is compatible with eristaline flies. During this time, one of the larvae pupated before being transferred to pure ethyl alcohol. Later, the immatures were sent to the Universidad de Alicante for their identification using electronic and optical microscopy. Finally, the pupa with a pre-adult was sent to the Zoologisches Forschungsmuseum Alexander Koenig (ZFMK) for molecular study.

Morphological studies

In order to identify the pupa and larvae, numerous larvae and pupae of syrphid species cited as accidental myiasis agents were studied from collections. Most of the material examined was collected in natural conditions and preserved in 70% ethyl alcohol. In all cases, larvae and pupae were unambiguously identified because larvae were captive-reared. For preparation of the identification key to third instar larvae, puparia, and adults of syrphid genera causing myiasis, voucher specimens in the entomological collections of Universidad de Alicante (CEUA) and ZFMK were studied.

Terminology for adult morphology follows Thompson (1999) and Thompson et al. (2010). Terminology used in the identification key of the immature stages follows Hartley (1961) and Rotheray (1993). Because many of the preimaginal stages of Central and South American flower flies remain undescribed, a diagnostic key to genera with potential role as myiasis agent in the New World was developed. All the syrphid genera reported in the world literature as potential myiasis agents were included in the identification key, including species with rat-tailed maggots but also other saprophagous species without this characteristic morphology. There is a need for medical professionals to have a reliable identification key as shown by Rojas Soto et al. (2017), who used an identification key more than 50 years old (OPS, Organización Panamericana de la Salud 1962) where all rat-tailed larvae were assigned to the genus *Eristalis* Latreille, 1804.

Illustrations and measurements (mean ± standard error) were made on preserved material using a binocular microscope with an eyepiece micrometer and FSA 25 PE drawing tube. The photographs were taken with a scanning electron microscope (SEM) operated at 20 kV.

Molecular studies

A pre-adult from inside a puparium was used to obtain a DNA barcode in order to identify the species. The DNA barcoding method described by Hebert et al. (2003a, 2003b) is a DNA sequence-based approach for the accurate identification of specimens and for species discovery. In most animal groups, the standard is a 658-base pair (bp) fragment of the mitochondrial cytochrome c oxidase subunit I (COI) gene.

Whole-body extractions were carried out using the NucleoSpin Tissue DNA Extraction kit (Machery-Nagel, Düren, Germany) following the manufacturer's instructions; samples were resuspended in 100 μl ultra-pure water. Remnants of specimens were preserved and labeled as DNA voucher specimens for the purpose of morphological studies and deposited at the ZFMK (ZFMK-DIP-00017477). PCR amplification protocols for mitochondrial COI gene were the same as described in Mengual et al. (2008, 2012) and Rozo-Lopez and Mengual (2015). The COI fragment was amplified using the forward primer LCO1490 (5'-GGTCAACA AATCATAAAGATATTGG-3') and the reverse primer C1N2191 (alias Nancy) (5'CCCGGTAAAATTAAAATATA AACTTC-3') (Simon et al. 1994). PCR products were cleaned using the commercially available QIAquick PCR Purification Kit (QIAgen®). Bidirectional sequencing reactions were carried out by Macrogen© Inc. Chromatograms were edited in Geneious 7.0.6 (Biomatters© Ltd). New sequence was submitted to GenBank (accession number KU216217).

For identification, primer sequences were removed from the edited contig and the sequence was trimmed to 658 bp for comparison in the Barcoding of Life Database Systems database (BOLD; http://www.boldsystems.org/). BOLD uses a tree-based approach to identify sequence queries (Ratnasingham and Hebert 2007), where a distance matrix based on nucleotide sequences is generated and subjected to a tree building operation using the neighbor-joining (NJ) algorithm (Saitou and Nei 1987; Howe et al. 2002). This NJ tree represents a summary of divergence percentages, and itself is taken to represent both a statement of proximity of a given specimen to other (named) biological entities and a graphical tool with which to delimit species boundaries (Goldstein and DeSalle 2011).

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Results

Species identification

Morphological inspection of the pre-adult extracted from puparium revealed that it belongs to a male of the genus *Palpada*. Species identification based on morphological characters was not possible due to underdevelopment of the individual.

The obtained COI sequence from the pre-adult was checked against the BOLD database, and the BLAST-ID reported a 100% sequence similarity with the COI haplotypes of four *Palpada scutellaris* (Fabricius, 1805) (Process IDs: ASIND2348-12, ASIND2498-12, GMACF009-15, SRCNC068-16).

Identification keys to Syrphidae genera cited as myiasis agents in the New World

Based on the literature and on the present study, four flower fly genera are included in the identification keys to myiasis agents in the Neotropical region (i.e., Central America, the Caribbean, and South America), namely *Eristalis*, *Eristalinus* Rondani, 1845, *Ornidia* Le Peletier & Audinet-Serville, 1828, and *Palpada*. The genus *Helophilus* Meigen, 1822 does not occur in Central or South America (Thompson 1999; Thompson et al. 2010), but 11 species occur in the Nearctic Region (Skevington et al. 2019). Thus, identification keys here given are also useful to identify all syrphid genera with species related with myiasis around the world. Nonetheless, caution should be taken if a new genus is reported in the future as more genera might be involved in accidental myiasis in the New World due to the unknown larval biology of many groups and the important diversity of species of this region (see Thompson 1997; Nunes Morales and Marinoni 2009).

Three different identification keys were developed during this study for third larval instar, puparia, and adults of these five genera. Identification keys exist for larvae of myiasis-causing fly species (e.g., Gil Collado 1956), to families, genera, and even species of Diptera based on adult morphology (James 1947; Zumpt 1965; Hall and Smith 1993), but there is no existing key dealing with all flower fly species that may become accidental myiasis agents. Previously, Dušek (1971) presented larval keys to known synanthropic eristaline species of the Palearctic region. van Doesburg (1962) illustrated but did not describe the puparium of *P. scutellaris*, and more recently, Pérez-Bañón et al. (2003b) provided a key for third instar larvae of all the Neotropical genera with long-tailed larva (see also Thompson et al. (2010) for a key of syrphid genera of Central America). The two subgenera of *Eristalis*, i.e., *Eristalis* and *Eoseristalis* Kanervo, 1938, were keyed out separately based on adult characters to facilitate the identification of *Eristalis* (*Eristalis*) *tenax*.

Identification key to myiasis-causing flower fly genera based on the third larval stage

1. Short-tailed larvae (not rat-tailed maggots), anal segment not extended (Fig. 1c). Anal segment with three pairs of well-developed and about equally long lappets. Spiracular plate with central scars separated and three pairs of very convoluted spiracular openings (Fig. 2b)............ *Ornidia*

- Long-tailed larvae, anal segment extended (more than half of the body length); with three pairs of very weakly developed lappets (Fig. 1a, b). Spiracular plate with central scars joined and three pairs of straight and short spiracular openings (Fig. 2a)....... 2

2. Transverse row of spicules just in front of last pair of prolegs (Fig. 2c).. *Eristalinus*

- Transverse row of spicules in front of the last pair of prolegs not present (Fig. 2d), although a few scattered spicules may be present between the prolegs....................... 3

3. Ventro-lateral surface of abdominal segments bearing two lines of long setae: first one with long and densely aggregated setae at level of sensilla 7–8, and second one with shorter and more scarce setae extended along the lateral margins of the prolegs (Fig. 3a)........................ *Palpada*

- Ventro-lateral surface of abdominal segments without two lines of long setae (Fig. 3b)... 4

4. Last pair of prolegs with most of the large primary crochets facing toward the front of the body. Anal segment in the region just before the "tail" with three pairs of ventro-lateral fleshy projections (Fig. 1a).................. *Helophilus*

- Last pair of prolegs with most of the large primary crochets facing toward the lateral margin of the body. Anal segment in the region before the narrow "tail" without fleshy projections (Fig. 1b)... *Eristalis* (including subgenus *Eoseristalis*)

Identification key to myiasis-causing flower fly genera based on puparia

1. Short-tailed larvae, anal segment not extended (Fig. 1c). Spiracular plate with three pairs of very convoluted spiracular openings (Fig. 2b)................................... *Ornidia*

- Long-tailed larvae, anal segment extended (more than half of the body length) (Fig. 1a, b). Spiracular plate with three

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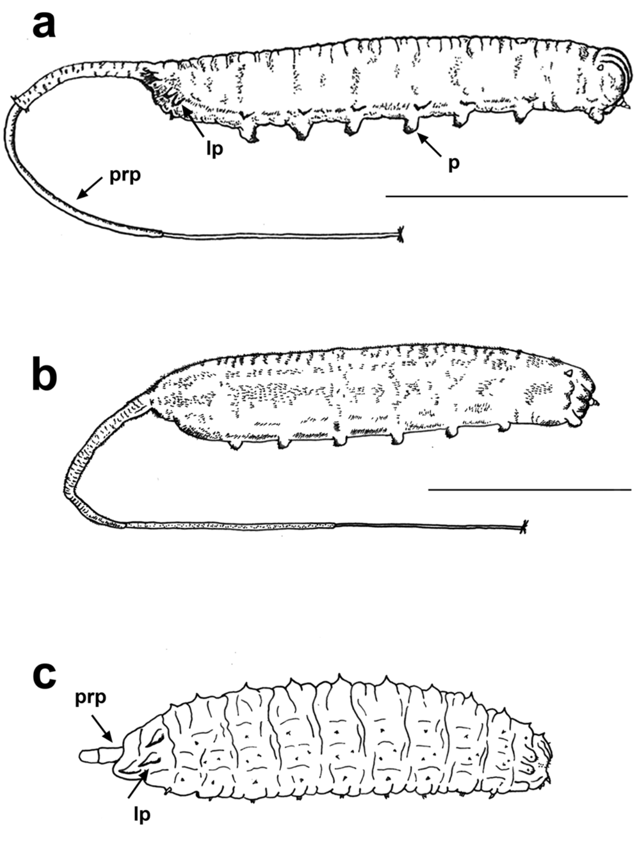

Fig. 1 Lateral view of third instar larvae. **a** Long-tailed larva *Helophilus* sp. **b** Long-tailed larva *Eristalis* sp. **c** Short-tailed larva *Ornidia* sp. Scale for all is 1 cm. Figures modified from Sasaki and Mikami (2007) (**a**, **b**) and Rotheray et al. (2005) (**c**). Arrow indicates the presence of the pairs of fleshy projections or lappets (lp), the posterior respiratory process at the tip of the anal segment (prp), and the pairs of locomotory organs or prolegs (p)

pairs of straight and short spiracular openings (Fig. 2a)... 2

2. Anterior spiracles: facets arranged in more than one row on the clear area (Fig. 4b)............................... *Eristalinus*

- Anterior spiracles: facets arranged in one row at edge of the clear area (Fig. 4a)... 3

3. Anterior spiracles: clear area not well defined with less than 15 facets (see also Hartley 1961: figs 83, 86–87)... *Helophilus*

- Anterior spiracles: clear area well defined with more than 15 facets... 4

4. Pupal spiracles almost straight, 1–1.5 mm in length, projecting forward and then bending sharply downward (Fig. 4c).. ....*Eristalis* (including subgenus *Eoseristalis*)

- Pupal spiracles curved, 2–2.5 mm in length, projecting upward and forward (Fig. 4d)....... *Palpada scutellaris*

Identification key to myiasis-causing flower fly genera based on adult morphology

1. Metallic green, bluish, or purple flies (Fig. 5a, b). Vein R_{4+5} straight, not sinuate (Fig. 5a). Hind femur without basoventral patch of black setulae (Fig. 5b).......... *Ornidia*

- No such metallic flies (Figs. 5c and 6a–d). Vein R_{4+5} strongly sinuate (Fig. 5c). Hind femur with basoventral patch of black setulae (Fig. 5d, e)......... 2

2. Cell r_1 open to wing margin (Fig. 6a)............ *Helophilus*

- Cell r_1 petiolate, closed before reaching wing margin (Fig. 5b).. 3

3. Eyes with spots or with bands (Fig. 6b). Anepimeron with dorsomedial portion (triangular portion) pilose (see Thompson 2003: figs 1–5). Postalar pile tuft present.. *Eristalinus*

- Eyes without markings (Figs. 5c and 6c). Anepimeron with dorsomedial portion bare (see Thompson 2003: figs 1–5). Postalar pile tuft absent............................ 4

4. Katepimeron bare (Fig. 7a). Eye uniformly pilose (Fig. 6c)................................ *Eristalis* (*Eoseristalis*)

- Katepimeron pilose (Fig. 7b). Eye pilosity uniform or with two bands of darker, contrasting hairs (Figs. 5c and 6d).....5

5. Eye with contrasting bands of light and dark colored pile (Fig. 5c). Meron and metaepisternum without any pile near spiracle (Fig. 7c). Wing bare...... *Eristalis* (*Eristalis*)

- Eye uniformly pilose (Fig. 6d). Meron and metaepisternum with pile anterior to and/or ventral to metathoracic spiracle (Fig. 7d). Wing with or without microtrichia... *Palpada*

Discussion

Historical background of rat-tailed maggots as myiasis agents

The presence of dipteran larvae in the digestive tract of human and other animals dates back to the seventeenth century [see

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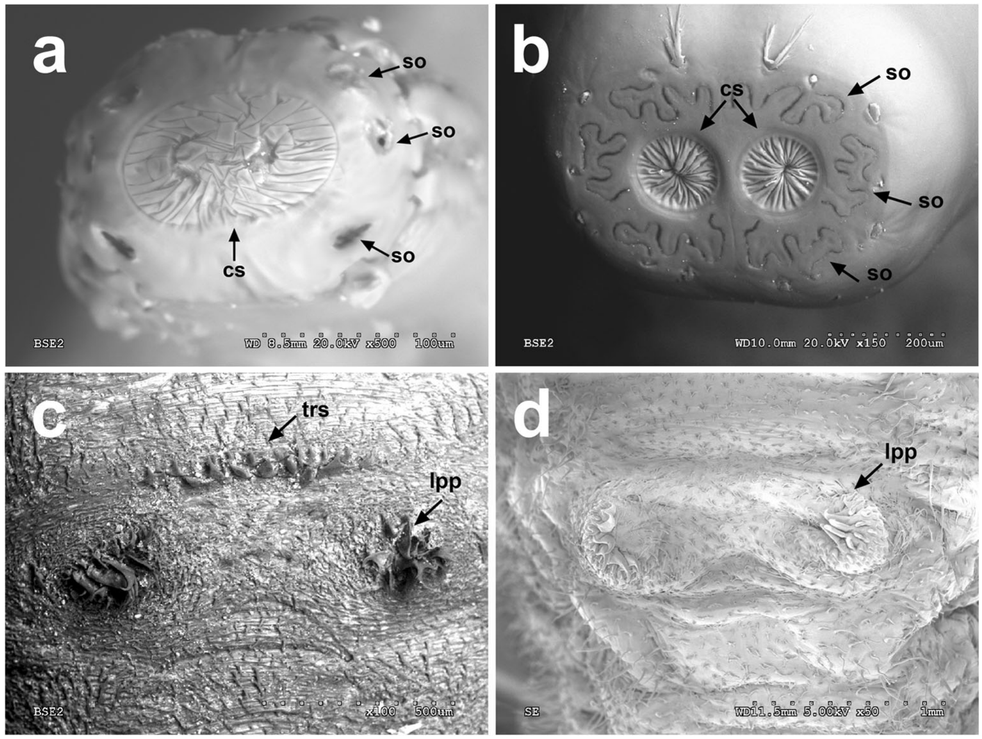

Fig. 2 SEM photos of the spiracular plate (**a**, **b**) of the larval posterior respiratory process and detail of the ventral view of the last pair of prolegs (**c**, **d**). **a** *Eristalis* sp. **b** *Ornidia* sp. **c** *Eristalinus* sp. **d** *Eristalis* sp. Arrow indicates the central scars (cs), the spiracular openings (so), and the presence of a transverse row of spicules (trs) in front of the last pair of prolegs (lpp)

Del Río 1902 citing Redi's work about human intestines in 1684, and Hall 1918 citing Blundeville's work with horses in 1609], but the term *myasis* [sic] or "the fly-disease" was introduced by Hope (1840). The first documented case report of rat-tailed maggots as myiasis agents was published by the physician Johan Odhelius (1789) from Sweden. He received several larvae that had been passed by a young girl suffering from strong stomach pains. Larvae were expelled over several months and stopped after several weeks of treatment with large amount of mineral water to ingest medications. Odhelius hypothesized that the patient could have ingested the insect's eggs in her food, which would have subsequently developed into the larval stage. Odhelius (1789) used the term "råtterumpor," a translation of the French term "vers à queue de rat" proposed by Réaumur (1738) literally meaning rat-tailed maggot, and indicated the similarity of the expulsed larvae with the drawings of Réaumur (1738, p. 443, plate 30).

Years later, Canali (1808) published the presence of a mobile larva, with a very long and thin tail, excreted from the urethra of a woman. The specimen was initially identified as a "coda di sorcio" (rat-tailed) syrphid larva by Valeriano Luigi Brera, a reputed Italian physician expert on parasitic worms (helminths), who compared it with the drawings of Réaumur (1738), but after some microscopic examination, Brera (1811)

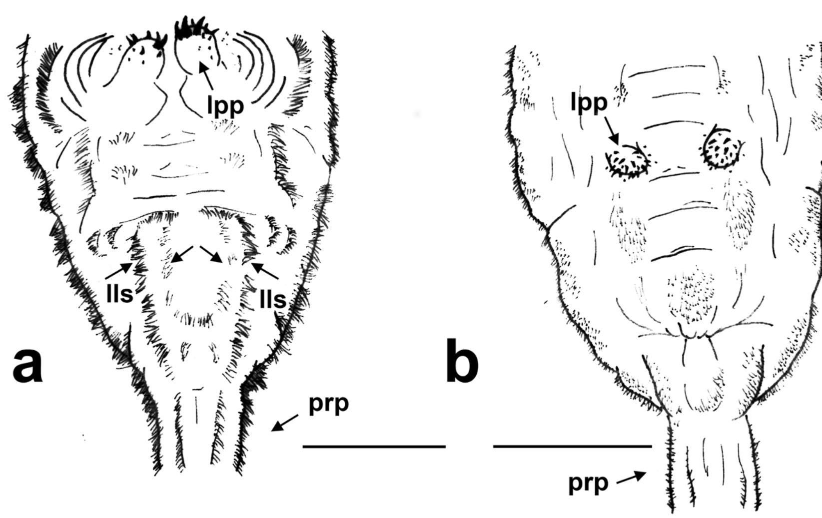

Fig. 3 Ventral view of the abdominal segments of long-tailed larvae and detail of the two lines of long setae (lls), the last pair of prolegs (lpp), and the anal segment with the posterior respiratory process (prp) at the tip. **a** *Palpada* sp. **b** *Helophilus*/ *Eristalis* sp. Scale for all is 2 mm

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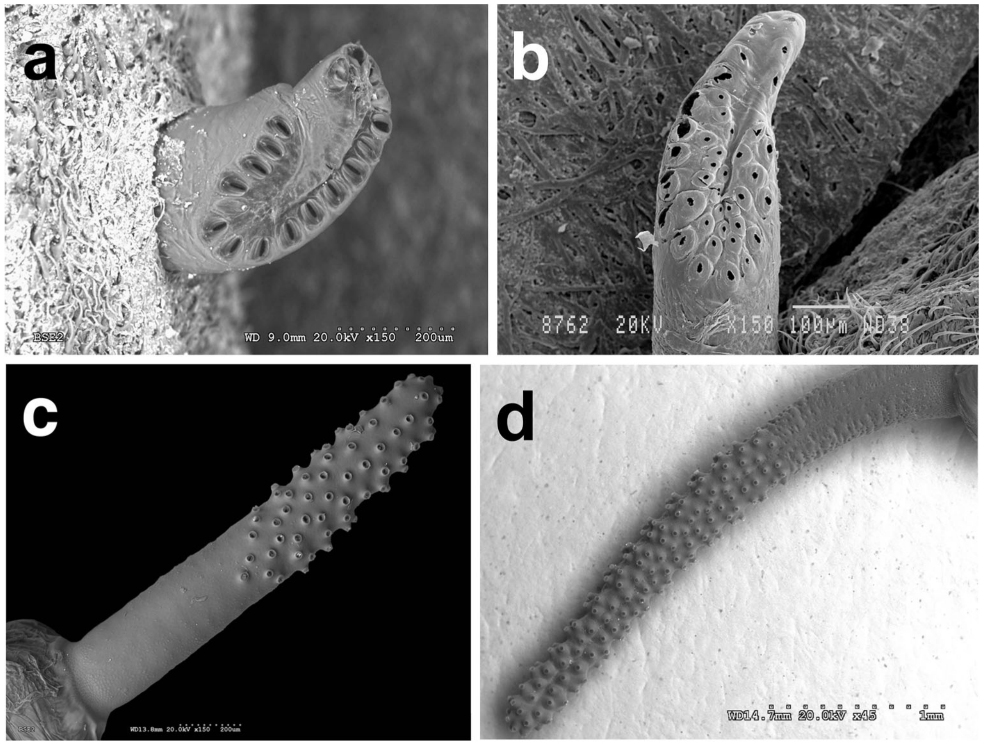

Fig. 4 SEM photos of the anterior spiracles of the third instar larvae (**a**, **b**) and pupal spiracles (**c**, **d**). **a** *Eristalis tenax*. **b** *Eristalinus taeniops*. **c** *Eristalis tenax*. **d** *Palpada scutellaris*

decided to erect a new genus of helminth based on this specimen, *Cercosoma* Breral, 1811. Bremser (1819) pointed out the misidentification by Brera and stated that the "langgeschwänzte Figur" (long-tailed figure) was a syrphid larva of the genus *Eristalis* after asking his entomologist colleague Ziegler. Several authors published *Cercosoma* (misquoted by some authors as *Conosoma*) as a junior synonym of *Eristalis* (Dujardin 1845; Cobbold 1864; Davaine 1877; Hanby 1905; Stiles and Hassall 1905), but this synonymy is not listed in the latest database (Thompson 2013). Although species identification at this time was not possible, in 1908, Gilbert (1908) listed larvae of four "*Eristalis* species" reported to have been passed from the human bowels, namely *E. dimidiatus* (now *E. dimidiata* Wiedemann, 1830 because the nomenclatural gender of this name is currently considered as feminine; see Chandler et al. 2004; ICZN 2006), *E. tenax*, *E. arbustorum* (Linnaeus 1758), and *E. pendulus* (now *Helophilus pendulus* (Linnaeus 1758)).

There is a remarkable ambiguity when characterizing the identity of the species involved in the first works mentioning the myiasis caused by rat-tailed larvae (Odhelius 1789; Canali 1808; Hope 1840). This confusion has not been critically reviewed in the medical literature and errors or inaccuracies in the species identification have been repeated many times in subsequent papers. In fact, the taxonomical nomenclature of the species of Syrphidae with rat-tailed larvae was not fixed until many years after the first cases of myiasis were published and, even nowadays, the unequivocal morphological identification of Syrphidae larvae is difficult without the help of a specialist and the associated imago.

In this section, we review all syrphid species cited in the literature in connection with cases of myiasis and discuss the likelihood of the identifications based on taxonomic characters and the known biology of the immatures. The results of this review are divided into four parts: (1) myiasis caused by *Eristalis tenax*, the common drone fly; (2) myiasis caused by other species with rat-tailed larvae; (3) myiasis caused by non-rat-tailed larvae; and (4) myiasis wrongly attributed to rat-tailed larvae.

Myiasis caused by *Eristalis tenax*, the common drone fly

Eristalis tenax is a highly anthropophilic and almost ubiquitous species in a wide spectrum of habitats. This synanthropic species is highly migratory and almost cosmopolitan after being widely introduced by humans. It is now the most widely distributed flower fly species in the world, known from all regions except the Antarctic (Greenberg 1971; Speight 2018). The common drone fly is cited as a cause of myiasis in almost all medical and veterinary cases where flower fly species are involved reported around the world; however, unambiguous species identification based exclusively on larval morphology has been not possible until recently because the preimaginal stages of most eristaline species remain undescribed (Hartley 1961; Pérez-Bañón et al. 2013; Campoy et al. 2017). In the same line of argumentation, we

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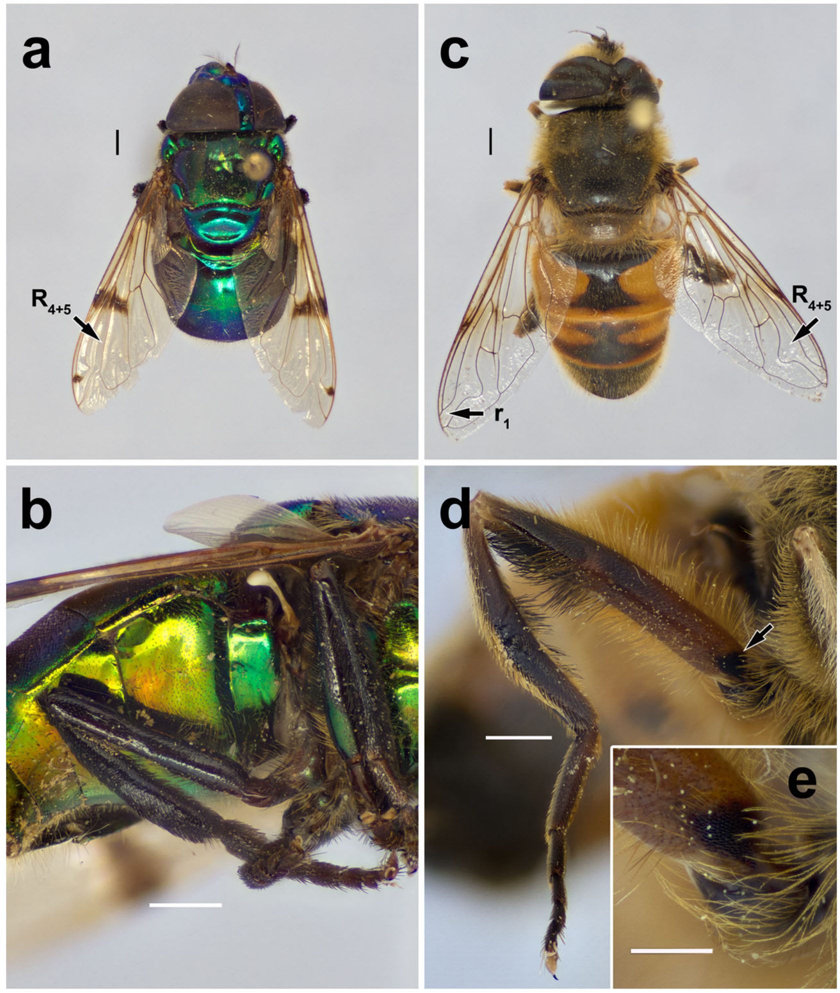
Fig. 5 Habitus of flower flies. **a** *Ornidia obesa* (female, ZFMK-DIP-00061223), dorsal view. **b** *O. obesa*, hind leg, lateral view. **c** *Eristalis* (*Eristalis*) *tenax* (male, ZFMK-DIP-00053688), dorsal view. **d** *E. tenax*, hind leg, lateral view. Arrow indicates the basoventral patch of black setulae. **e** *E. tenax*, hind leg, detail of the basoventral patch of black setulae. Scale for all is 1 mm, except in **e** that is 0.5 mm



agree with other authors (e.g., Metcalf 1916; Zumpt 1965; Goldsmid and Phelps 1977) that the name *Eristalis tenax* is used for all rat-tailed maggots found in connection with true or supposed cases of myiasis, and it would not be a surprise that under this name other species or even other genera of Eristalinae are involved.

There is an old taxonomical confusion between two valid species of flower flies, *Helophilus pendulus* and *Eristalis tenax* (type species of the genera *Helophilus* and *Eristalis*, respectively), originating with the first case reported of syrphids as myiasis agents (Odhelius 1789). Both species belong to the group of flower flies with rat-tailed larvae, but unfortunately, they had been considered as synonyms in many papers for a long time. Part of the confusion comes from the original descriptions made by Linnaeus in 1758, when he proposed the original names of *Musca tenax* and *Musca pendula* for each of them (Linnaeus 1758). In both cases, Linnaeus used information about the biological cycle of the "*mouches abeilliformes*" (bee-like flies) published 20 years earlier by Réaumur (1738), but referred only to the drawings of the larvae of Réaumur in his description of *Musca pendula* Linnaeus 1758 to indicate the larval biology and morphology of this species. As mentioned above, Odhelius (1789) compared the rat-tailed maggot of his study with the same drawings of Réaumur (1738) and identified the material as the same species that Linnaeus called *Musca pendula* and De Geer (1776) called "*Mouche pendante*". Later, *Musca pendula* was transferred to the genus *Helophilus* and nowadays is known as *Helophilus pendulus*, but the work of Odhelius (1789) was cited by other authors and the species was referred under different names, with *Eristalis pendulus* the most common, but also as *Helophilus pendulus*, *Helophilus pendulinus*, *Tubifera pendula*, or *Elophilus pendulus* (Hall and Muir 1913). As an example, in his review of larvae occasionally found in the human body, Hope (1840) used *Elophilus pendulus* for the case reports of Odhelius (1789) and Canali (1808), and wrongly cited as case reports three other works that merely cited the case of Odhelius (1789). Bremser (1819) identified *Cercosoma* as a larva of *Eristalis* and added that most likely it was "*Eristalis pendulus* Fabric. (Syst. Entliat. n.7 p. 233)". Fabricius (1805) listed *Helophilus* under *Eristalis* as a synonym and the taxonomic confusion

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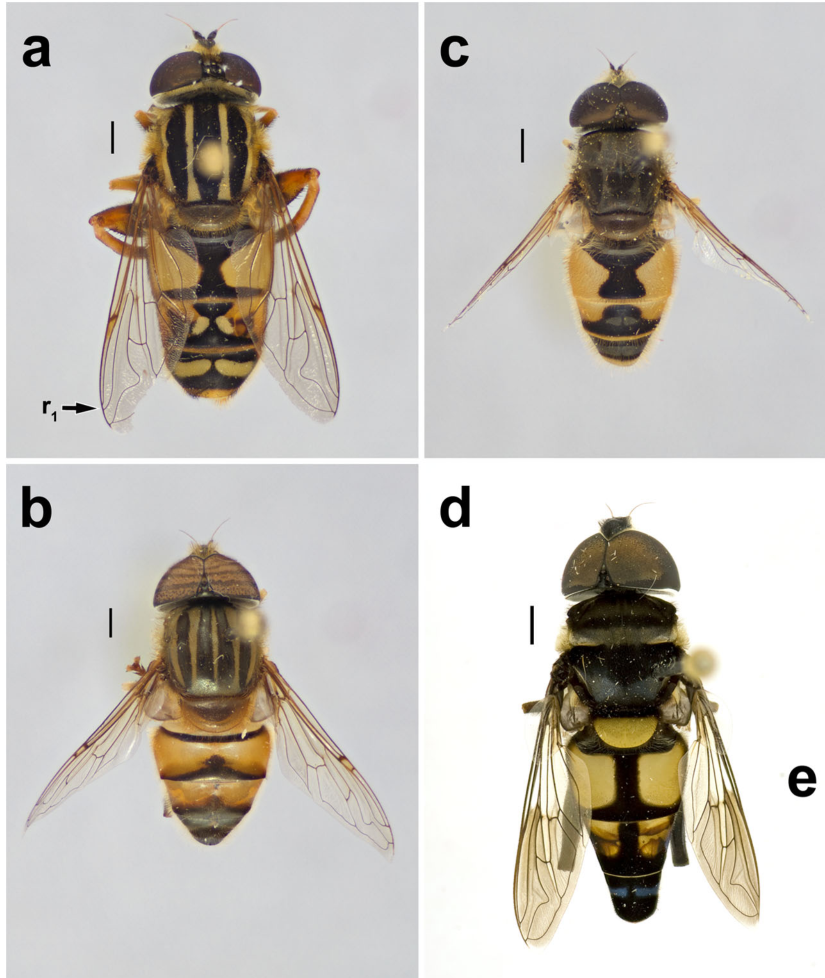

Fig. 6 Habitus of flower flies. **a** *Helophilus pendulus* (male, ZFMK-DIP-00061222), dorsal view. **b** *Eristalinus taeniops* (male, ZFMK-DIP-00015921), dorsal view. **c** *Eristalis* (*Eoseristalis*) *arbustorum* (male, ZFMK-DIP-00053708), dorsal view. **d** *Palpada scutellaris* (male, from http://syrphidae.myspecies.info/taxonomy/term/979). Scale for all is 1 mm

continued with the validity of the names published by Meigen in two of his works (Meigen 1800; Meigen 1803). To summarize more than 40 years of disputes among taxonomists in one sentence (see Smart 1944; Sabrosky 1952, 1999; Melville 1961), *Tubifera* Meigen 1800 was suppressed by the International Code of the Zoological Nomenclature (ICZN 1963) and *Elophilus* Meigen 1803 was considered a junior synonym of *Eristalis* (Thompson 2013).

Due to this taxonomic confusion, many of the very old records of rat-tailed maggots causing myiasis were identified as *Helophilus pendulus*, and some workers cited the original reference of Odhelius (1789) as synonym of *Tubifera tenax*, now *Eristalis tenax*. We cannot discard the genus *Helophilus* as a potential myiasis agent because it is also present in polluted water close to human activities (Sasaki and Mikami 2007), but we agree with James (1947) and consider that identifications of *H. pendulus* based on larvae without emerged adults were most likely erroneous as immature stages of many species are unknown and very similar to the larvae of *Eristalis tenax*. The natural history of *E. tenax*, its presence in polluted water, and its close association with human activities [see Gil Collado 1961 as an example of a larval massive invasion of human dwellings or Guizzardi et al. 1989 for a larval outbreak in a dairy cattle farm] makes this species the most likely candidate to be involved in Odhelius's case. This also fits with a critical examination of the drawings by Réaumur (1738), which makes us think that they were based on *Eristalis* larvae and not on immatures of *Helophilus*. Both taxa are separated by the presence (in *Helophilus*) of the three pairs of fleshy projections between the anal opening and the base of the breathing tube (Rotheray 1993, see also Fig. 1a). In the very detailed drawings of Réaumur (1738), there is no presence of these fleshy projections, but curiously, this feature is present in the figures of the larvae of *Eristalis* in classical papers (e.g., Miall 1895, p. 199, fig. 70; Natvig 1924) or specifically as *Eristalis tenax* in the medical and veterinary manual of Patton and Evans (1929, p. 330, fig. 193) and repeated by Gil Collado (1956) under the name of *Tubifera tenax*. Furthermore, there is other evidence that confirms that *Eristalis* species were called *Helophilus* at the nineteenth- to twentieth-century boundary; for example, Brumpt (1910, p. 586, fig. 432) illustrated the wing of a syrphid that he named

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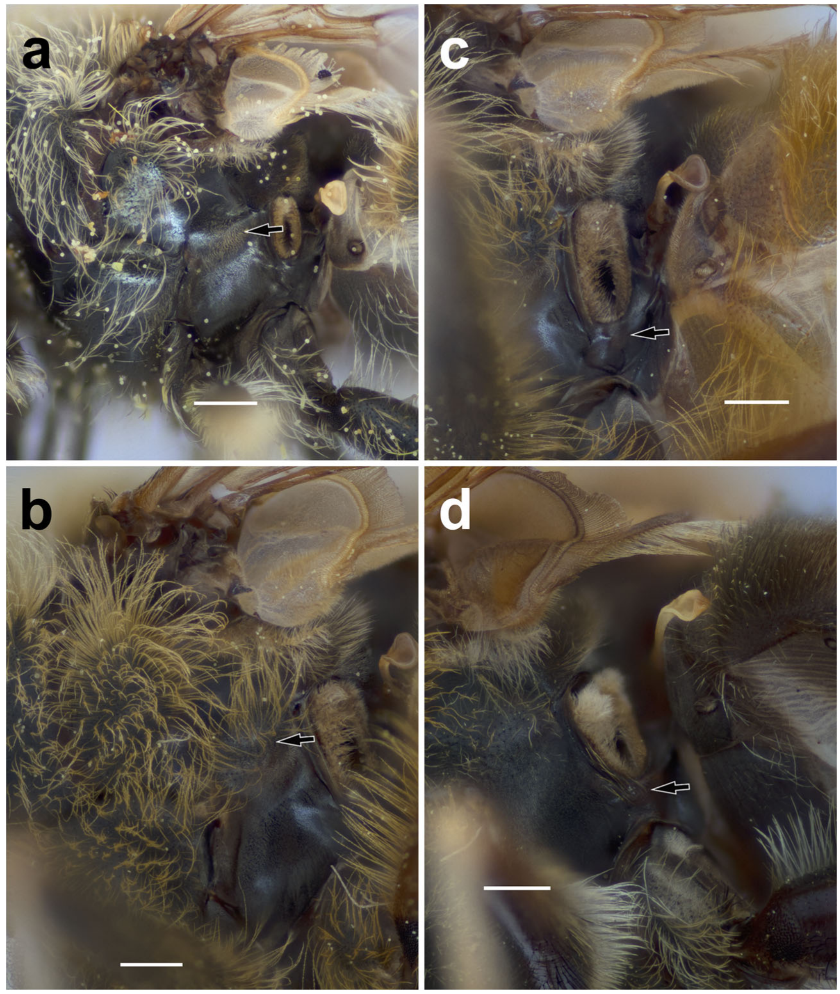

Fig. 7 Detail of the pleuron, lateral view. **a** *E. arbustorum*. Arrow indicates the bare katepimeron. **b** *E. tenax*. Arrow indicates the pilose katepimeron. **c** *E. tenax*. Arrow indicates the bare metaepisternum. **d** *Palpada mexicana* (Macquart, 1847) (male, ZFMK-DIP-00061224). Arrow indicates the pile near the posterior respiratory spiracle

Helophilus, but the figure shows clearly that the cell r_1 is closed, not matching the *Helophilus* wing venation that has the cell r_1 open. This wing venation with a closed cell r_1, though, fits the genera *Eristalinus* and *Eristalis* among others. Therefore, until the appearance of new refutable cases, we consider all the quotations of *H. pendulus* in myiasis as doubtful and consider they be referred as *E. tenax*. At the end, it seems that Osten Sacken (1894) was right when, explaining the resemblance of *E. tenax* with the honeybee, he defined *E. tenax* as an insect "for man's confusion born."

Myiasis caused by other species with rat-tailed larvae

Wagner (1870) reported *Eristalis arbustorum* from larvae said to be passed with feces by a woman in Germany, after identifying the reared adults from larvae. In this publication and subsequent reviews (e.g., Austen 1912), the possibility is indicated of the flower fly eggs being swallowed by the patient with polluted drinking water. This Palaearctic species was introduced in the USA around 1885 and it is ubiquitous in that continent (Skevington et al. 2019). Due to human activities such as international trading and its larval development in anthropized environments, it is likely that *E. arbustorum* may be involved in other cases of human myiasis as this species is already involved in forensic cases (Lindgren et al. 2015).

Carpaneto and Vigna Taglianti (1995) reported the first case of *Eristalinus taeniops* (Wiedemann, 1818) from a larva that was passed by a 24-year-old woman in Italy, after identifying the reared adult. The most likely reason of this accidental myiasis was the ingestion of eggs or small larvae present in liquid media related with agricultural work and the use of manure by the woman. This taxon is widely distributed throughout Africa and the Oriental region (Knutson et al. 1975; Smith and Vockeroth 1980) and is also present in the Mediterranean basin (Speight 2018). It has been subsequently established in the New World (Thompson et al. 1990; Thompson 1999). To date, no new cases of myiasis with this species have been published, although Dutto and Maistrello (2017) reported the presence of a mature larva in the feces of a 4-year-old child from Piedmont (Italy), without indicating a relationship with a possible case of myiasis. This *Eristalinus*

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species shares the ecological plasticity of *E. tenax* and *E. arbustorum*, as well as its dispersal ability derived from the adaptation to human environs.

Riley (1890) reported larvae of *Eristalis* (*Eoseristalis*) *dimidiata* that were passed from the bowels of a young woman from Evansville (Indiana, USA). In the same paper, this author also reported a similar case with larvae of *E. tenax*. The life cycle of *E. dimidiata* is similar to the one of *E. tenax* and its distribution coincides with the location of the case report (Skevington et al. 2019). Until now, this is the only record of this species as a myiasis agent in the scientific literature. This record is probably a misidentification as the larval stages of *E. dimidiata* are still unknown (Campoy et al. 2017). It is interesting to note that a few years before the publication of Riley (1890), several papers were published indicating a rapid expansion of *E. tenax* throughout North America, mainly because of involuntary transport due to human activities and its high degree of adaptation to polluted water derived from the development of rural and urban areas. In the USA, *E. tenax* had a rapid expansion since 1870, possibly after its arrival from Eastern Siberia to the Pacific coast (Williston 1886). In all likelihood, the rapid east–west expansion could not be completed until rural and urban development (with drains, sewers, and cesspools for the development of the larvae) allowed the union of both areas (Osten Sacken 1894). Since 1875, *E. tenax* was a common species in the USA associated primarily with water media directly or indirectly related to human activity (Osten Sacken 1886). It is notable that all cases of myiasis caused by rat-tailed maggots in the USA were reported after 1870, which coincides with the beginning of the distribution of *E. tenax* throughout the country. Riley's case report is dated in 1890, so the involved fly species in the myiasis is plausibly *E. tenax* and not *E. dimidiata*.

Soler Cruz (2000) listed *Eristalis diminuta* [sic] in her review of the myiasis in Spain as an occasional myiasis agent found in the entire Iberian Peninsula. There is no species with this name, and it might be a misspelling of *E. dimidiata*. But *E. dimidiata* does not occur in Europe (Speight 2017, 2018) and there is no record or case report of *E. dimidiata* as myiasis agent except the one mentioned in Riley (1890).

A very interesting report from the Caribbean Antigua (current Antigua and Barbuda) cited *Eristalis vinetorum* (Fabricius, 1799) [now *Palpada vinetorum* (Fabricius, 1799)] in a list of myiasis-producing flies in humans and other animals (Goodwin 1925). This report is probably the reason why *Eristalis* is listed by Berger (2019). Goodwin (1925) is a very uncommon publication, and after several attempts via different libraries, we conclude that this work is not held in North America or Europe. Without the original text, it is not possible to know if the species listed in the abstract by Goodwin (1925) were compiled from myiasis case reports, if the reports were from humans or other animals, or if the larvae were reared into adults for identification. There are no records of *E. tenax* from the Lesser Antilles and *E. tenax* is rarely collected in the Neotropics, but *P. vinetorum* is found in Antigua (Thompson 1981). Without adults to confirm the identification, we believe that a species name for a rat-tailed larva is not possible to assure, and was much more difficult back in 1925 with many species still to be described. Consequently, the identity of the material studied by Goodwin (1925) remains unknown, as well as the host and the type of myiasis.

Myiasis caused by non-rat-tailed larvae

Larvae of other species groups of Syrphidae (without a rat-tailed morphology) have been reported as causative of myiasis in humans and animals. There are two different flower fly groups reported in the literature: a species with saprophagous larvae, *Ornidia obesa* (Fabricius, 1775), and a group with nonsaprophagous larvae that are very likely unable to survive in the human digestive tube.

Several authors have reported *Ornidia obesa* as a myiasis agent in humans in the New World. Machado (1937) and Monteiro et al. (2008) reported *O. obesa* from larvae passed by patients in Brazil, while Yang (2014) reported this species in connection with an intestinal myiasis from Hawaii. More recently, López et al. (2017) cited two cases of myiasis caused by *O. obesa*. After the study of the original work, we confirm that only the case of a 70-year-old patient was due to *O. obesa*. The second reported case was clearly caused by some other dipteran as figures 2–7 in López et al. (2017) do not represent a syrphid larva. Martins et al. (2010) studied *O. obesa* breeding in pig carcasses in Brazil in order to evaluate the importance of this species in forensic entomology. López Millán et al. (2015) documented several cases of myiasis in pigs and cited *Ornidia robusta* [sic] as one of the three dipteran species collected. This species name does not exist. Adults of the so-called *O. robusta* are easy to identify from the pictures in the original publication and they belong to *O. obesa*.

Ornidia is a small group of brilliant metallic green or purple flies, originating from the New World, which has been spread extensively in the Pacific and across the Orient to the east of Africa due to human activities (Thompson 1991). Like rat-tailed larvae involved in myiasis, the larva of this species is known from numerous synanthropic habitats including human latrines, animal dung, decaying fruits, and other semiliquid media such as agri-food wastes (Lardé 1989; Whittington and Rotheray 1997). Due to its highly synanthropic habits, *O. obesa* might be a common species involved in human/animal myiasis, but the use of specific identification keys based on preimaginal morphology is recommended for unambiguous identification (see Rotheray et al. 2005; Da Silva Carvalho Filho and Esposito 2009).

On the other group with non-rat-tailed larvae, Austen (1912) reported three cases where the dipteran larvae causing

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the myiasis were identified as belonging to *Syrphus* Fabricius, 1775 or *Scaeva* Fabricius, 1805. In two cases, larvae were discharged through the rectum, while in the third one, a larva was removed from the ear of a boy. As already explained by Austen (1912) and later on by James (1947), the occurrence of a larva within the ear (auditory meatus) was probably accidental and should not be regarded as myiasis. The other two records are difficult to accept as the larvae of these genera are predaceous on soft-body insects, most commonly aphids (Metcalf 1916; Rojo et al. 2003). James (1947) guessed that larvae could be ingested with Brussels sprouts or other vegetables harboring aphid colonies, although it is highly doubtful whether they could cause enteric disturbances or pass through the digestive tract alive.

Myiasis wrongly attributed to rat-tailed larvae

There are several collations of myiasis agents based on previous reports [e.g., see Bernhardt et al. 2019 as the most recently published], and there are some works compiling the reports of *Eristalis*-caused myiasis from published literature (e.g., Desoubeaux et al. 2014; Singh and Singh 2015). No access to the original publications or simply citing other collations, especially if their main focus is the medical aspects of the reports, can perpetuate in the literature mistakes and inaccurate identifications of the species involved in myiasis. In the present review, the risk of the collated list (Table 1) is to convey the impression that the majority of myiasis-causing flower flies are *Eristalis* species (especially *E. tenax*) due to misidentifications of larvae in the literature and the fact that we cannot study that material for reassessment. For the elaboration of Table 1, some of these incorrect or inaccurate records, as well as country of origin of these myiasis, have been corrected based on the original texts of the publications, and in this section, we mention some myiasis reports that were wrongly attributed to syrphid flies. For example, Utsalo and Ahmed Khalifa (1985) presented an interesting case of urinary myiasis caused by rat-tailed larvae but also mentioned that Gil Collado (1961) encountered larvae of *E. tenax* as causing agents of intestinal myiasis. Gil Collado (1961) did not discuss myiasis and only reported a case of massive invasion of *E. tenax* larvae in several houses in Madrid, Spain, due to the prepupal migratory behavior of this species.

The work of Nagakura et al. (1991) is cited by other authors (e.g., Mumcuoglu et al. 2005; Desoubeaux et al. 2014; Lewis et al. 2015 as *E. tenax*) as an example of gastrointestinal myiasis caused by *Eristalis*-like or rat-tailed larvae. However, Nagakura et al. (1991) reported three cases of intestinal myiasis in Japan caused by larvae of two species of Sarcophagidae and by larvae of the black soldier fly, *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae). In the original article, there is a photo of a black soldier fly mature larva that typically presents the long and narrow head capsule on the dorsal side.

Oluwatosin and Fadahunsi (2003) mentioned a cutaneous myiasis due to *Eristalis luteola* [sic] involving breast tissue invasion in a female. No species exist with this name and the name *luteola* might refer to *Auchmeromyia luteola* (Fabricius, 1805), currently known as *Auchmeromyia senegalensis* Macquart, 1851 (Diptera: Calliphoridae) or the “Congo floor maggot”, which causes sanguinivorous myiasis and can feed for up to 20 min on the human body (Zumpt 1965). Oluwatosin and Fadahunsi (2003) also reported a case of a 9-year-old girl who vomited two living larvae, identified as *Eristalis* sp. The morphological description of these immature stages, i.e., “larvae had globular anterior regions and tail-like retractile posterior ends fringed with setae”, fits with the general description of an unidentified rat-tailed maggot. Finally, this work also cited an enteric myiasis by *Eristalis* from Egypt originally reported by Mandour and Omran (1978). We read the original report by Mandour and Omran (1978) and the enteric myiasis was due to second instar larvae of Sarcophagidae from Sudan.

In the studied literature, we have found that sometimes rat-tailed maggots have been cited as nematode parasites and vice versa. Axe (1874) reported rat-tailed larvae being expulsed by horses, but Cobbold (1879) pointed out that this case report was spurious and the so-called rat-tailed maggot by Axe was “merely a very stout and pregnant *Oxyuris curvula* Rudolphi, 1803” [currently known as *Oxyuris equi* (Schrank, 1788)], the horse pinworm. We also found a case where the causative agent of the myiasis was a rat-tailed larva, but the authors of the case report attributed the myiasis to another species. Förstl et al. (2002) reported a 27-year-old woman with severe spasmodic abdominal pain after a 2-week trip to Tunis. Once back in Czech Republic, the patient passed a rat-tailed larva (photographed and illustrated in the article), which was erroneously identified as the human whipworm nematode parasite *Trichuris trichiura* (Linnaeus, 1771). Förstl (2003) used the same photographs in his book to illustrate *T. trichiura*, but the larva belongs to *Eristalis* sp.

Types of myiasis

In Table 1, we summarize all known literature of accidental myiasis caused by flower fly species including the original reference, the host, the syrphid species, and the myiasis type. To date, the present review is the most exhaustive regarding Syrphidae as myiasis agents, and in total, it comprises almost three and a half times the number of references with respect to the previous large review on *E. tenax* as a myiasis agent (Desoubeaux et al. 2014). In order to present the reviewed data in a more efficient way, we subdivided the myiasis into various types according to the tissue and region of the body infested (James 1947; Singh and Singh 2015): (i) traumatic

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Table 1 Revised and annotated literature list with reported cases of syrphid species as myiasis agents. We did not include the enteric myiasis in horse reported by Blundeville in 1609 from the UK because the original author mentioned a bot-fly, although Hall (1918) stated that the description is of one rat-tailed larva. Hall (1918) also indicated that larvae might not have been passed from the horse but lived in horse manure

Region/ country	Causative species	Host	Myiasis type	Reference	Comments
Africa					
Cameroon	*Eristalis* sp.	Human	Enteric	Achenjang et al. (2003; unpubl. data)	See https://www.unionky.edu/directory/dr-fidelis-achenjang/rat-tailed-maggot-rtm-pearls
Ethiopia	*Eristalis* sp.	Human	Enteric	D'Ignacio and Giaquinto Mira (1941)	32-year-old woman after several days with abdominal pain expulsed several living larvae
Morocco	*Eristalis tenax*	Human	Enteric	Moutaj et al. (2000)	2-year-old girl, with abdominal pain, vomiting, and queasiness, vomited a living larva. Wrongly cited from France by Cazorla Perfetti et al. (2011)
Nigeria	*Eristalis* sp.	Human	Enteric	Oluwatosin and Fadahunsi (2003)	9-year-old girl vomited 2 motile larvae. Wrongly cited from Egypt caused by inexistent *Eristalis luteola* (see main text)
Nigeria	*Eristalis* sp.	Human	Urogenital	Utsalo and Ahmed Khalifa (1985)	Male patient; 2 larvae were recovered from the urethra
South Africa	*Eristalis tenax*	Human	Enteric	Pick (1984)	9-year-old boy with loose stools passed living larvae
Sudan	*Eristalis tenax*	Human	Nasal	Adam (2012)	33-year-old man expelled a maggot during a bout of sneezing through his left nostril
Tunisia	*Eristalis* sp.	Human	Enteric	Förstl et al. (2002), Förstl (2003)	Rat-tailed larvae erroneously identified as the human whipworm nematode parasite *Trichuris trichiura* (Linnaeus, 1771). A 27-year-old woman spent 2 weeks in Tunis. Four weeks after returning (Czech Republic), severe spasmodic abdominal pain appeared and a larvae (photographed) was found in the stool
Zambia	*Eristalis tenax*	Human	Enteric	Hira (1977)	29-year-old man, with anal rash for 2 years and intermittent dull abdominal pain, passed a larva
Zimbabwe	*Eristalis* sp.	Human	Urogenital	Goldsmid and Phelps (1977)	Larvae removed at surgery from the blocked ureter
Australasia					
Australia	*Eristalis* sp.	Human	Enteric	Lee (1968)	After probably accidental ingestion, a larvae passed in the feces of a child, aged 12 months, in March 1955 and pupated
Australia	*Eristalis tenax*	Human	Enteric	Whish-Wilson (2000)	42-year-old woman saw 1–3 larvae in 5 occasions over a 2-week period
New Zealand	*Eristalis tenax*	Human	Enteric	Derraik et al. (2010)	Two cases of enteric myiasis were recorded from personal comments (pers. com. Graeme Paltridge, Canterbury Health Laboratories).
Central and South America					
Antigua and Barbuda	*Palpada vinetorum*?	Unknown	Unknown	Goodwin (1925)	N.A.—in the abstract (published in *The Review of Applied Entomology* 1926) *Eristalis vinetorum* is cited as representative of myiasis-producing flies in Antigua
Argentina	*Eristalis tenax*	Human	Enteric	Faggioli (1927)	15-month-old boy expulsed living larvae in the stool. Erroneously cited from Italy by Zumpt (1965)
Argentina	*Eristalis tenax*	Human	Enteric	Bacigalupo et al. (1941)	13-year-old boy with colic expulsed 30 larvae. Two specimens pupated and adults were identified
Argentina	*Eristalis tenax*	Human	Enteric	Stiles and Cleland (1953)	15-month-old child evacuating larvae after treatment (pers. com. Pratt, H.D. 1951)
Argentina	*Eristalis tenax*	Human	Enteric	Kun et al. (1998)	Presence of several larvae in 2 case reports
Argentina	*Eristalis tenax*	Human	Enteric	Oliva (2002)	(Mariluis, pers. com. as *Tubifera tenax*)
Argentina	*Eristalis* sp.	Human	Enteric	Iches (1914)	7–8-year-old girl expulsed 2 larvae from the rectum after purgative treatment

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Table 1 (continued)

Region/country	Causative species	Host	Myiasis type	Reference	Comments
Argentina	*Ornidia obesa*	Pig	Traumatic	López Millán et al. (2015)	Presence of larvae in vulva, ear, and back injuries on 7 individuals from 50 sampled. Recorded incorrectly as *Ornidia robusta*
Brazil	*Eristalis tenax*?	Human	Enteric	Rivarola (1944)	(Zeferino Vaz pers. com., Hospital at São Paulo)
Brazil	*Eristalis tenax*	Human	Enteric	Garcia-Zapata et al. (2005)	Two case reports: 11-month-old girl with 4 larvae (ingestion of decay fruits); 27-year-old man with 1 larva
Brazil	*Eristalis tenax*	Human	Enteric?	Fernandes et al. (2009)	The patient vomited larvae
Brazil	*Eristalis* sp.	Human	Urogenital	Magalhães (1908)	Female patient. The author also refers skeptically to another case report of intestinal myiasis
Brazil	*Ornidia obesa*	Human	Enteric	Machado (1937)	N.A.—species cited as *Volucella obesa*
Brazil	*Ornidia obesa*	Human	Enteric	Monteiro et al. (2008)	8-year-old child; several larvae and pupae were expulsed
Chile	*Eristalis tenax*	Human	Enteric	Silva-Campos (1950)	Several case reports from patients with diarrhea and other digestive problems were mentioned
Chile	*Eristalis tenax*	Human	Enteric	Silva-Campos (1955)	2 mature and 1 immature larvae (from different case reports) were reported as expulsed with the stool
Chile	*Eristalis tenax*	Human	Urogenital	González et al. (2009)	27-year-old woman; 2 larvae (a week between both samples)
Colombia	*Eristalis tenax*	Human	Enteric	Desoubeaux et al. (2014)	42-year-old French woman as tourist in Colombia. One larva in her stools plus 3 more after treatment
Colombia	*Ornidia obesa*	Human	Enteric	López et al. (2017)	70-year-old woman expulsed larvae. A second case is attributed to *Ornidia* larvae during first larval instar, but included photos are from another type of dipteran, not Syrphidae
Costa Rica	*Eristalis tenax*	Human	Enteric	Rivera Barquero and Sánchez Rodríguez (2015)	45-year-old woman; 2 larvae with a day of difference
Costa Rica	*Eristalis tenax*	Human	Enteric	Rojas Soto et al. (2017)	23-year-old woman; 2 larvae expulsed
Costa Rica	*Palpada scutellaris*	Human	Enteric	This study	68-year-old woman; 2 larvae sampled
Paraguay	*Eristalis tenax*	Human	Enteric	Canese (1970)	62-year-old man expulsed 30 mobile larvae
Paraguay	*Eristalis* sp.	Human	Enteric	Rivarola (1944)	11-year-old girl; several larvae expulsed
Uruguay	*Eristalis* sp.	Cattle	Enteric	Cassamagnaghi (1945)	Female bovine affected by bovine malignant catarrhal fever; 2 larvae
Uruguay	*Eristalis* sp.	Human	Enteric	Vogelsang (1926)	30-year-old man expulsed about 20 live larvae
Venezuela	*Eristalis tenax*	Human	Enteric	Rivero de Rodríguez et al. (2007)	10-year-old boy with cerebral palsy; 2 larvae (expulsed 1 year apart)
Venezuela	*Eristalis tenax*	Human	Enteric	Cazorla Perfetti et al. (2011)	39-year-old woman passed a living larva with the stool
Europe					
Belgium	*Eristalis* sp.	Human	Enteric	van den Berghe and Boné (1944)	47-year-old man passed more than 40 larvae on the first day and 10–30 on each of the 6 following days. Identified as probably *E. tenax*
Belgium	*Eristalis* sp.	Human	Enteric	Muller (1946)	An adult man, with epigastric pain, dizziness, cramps, and hot flushes for more than 2 months, passed a living larva in his stool. Drinking water from uncovered rainwater tank is hypothesized as a likely source
Belgium	*Eristalis tenax*	Human	Enteric	Leclercq (1981)	A man from Gouvy (Belgian Luxembourg), suffering from dyspeptic disorders and colitis, eliminated 5–6 last instar larvae
Belgium	*Eristalis tenax*	Human	Enteric	Dubois et al. (2004)	36-year-old man; larvae were emitted on several occasions
Belgium	*Eristalis tenax*	Human	Enteric	Verhelst et al. (2013)	60-year-old woman with broken down septic tank

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Table 1 (continued)

Region/ country	Causative species	Host	Myiasis type	Reference	Comments
Croatia	*Eristalis tenax*	Cattle	Enteric	Rajković Janje et al. (2010)	Live larvae found in the lungs of a dead cow
Croatia	*Eristalis tenax*	Pig	Enteric	Rajković Janje et al. (2010)	Big quantities of larvae found in the large intestine of corpses of dead pigs
Denmark	*Eristalis tenax*	Human	Enteric	Rathe and Ozeraityte (2009)	N.A.—10-year-old boy with intermittent nonspecific abdominal pain expulsed a larva
Denmark	*Eristalis tenax*	Pig	Traumatic	Jensen (1929)	3 larvae reached the 4th vertebra presumably via lymph stream from a skin wound
France	*Eristalis* sp.	Human	Enteric	D'Ignacio and Giaquinto Mira (1941)	Authors cited this case and referred to Surmont, Desoie, and Tiprez (1921), an unknown reference to us
France	*Eristalis tenax*	Human	Enteric	Shattock (1908)	Woman from the UK that had previously visited France (ingestion watercress), expulsed several larvae during weeks
France	*Eristalis tenax*	Human	Enteric	Chabasse et al. (1981)	N.A.—35-year-old woman expulsed several larvae
France	*Eristalis tenax*?	Human	Enteric	Marjolet (1983)	35-year-old man, who was operated on for rectal cancer, expulsed several larvae for 3 days. The case was presented on the Réunion annuelle de la Société Française de Parasitologie, Créteil, 17–18 décembre 1982
France	*Eristalis tenax*	Human	Enteric	Raffray and Malvy (2014)	53-year-old woman that had visited France expulsed several larvae
France	*Eristalis tenax*	Human	Enteric	Lewis et al. (2015)	Patient from the UK that had visited previously France
Germany	*Eristalis arbustorum*	Human	Enteric	Wagner (1870)	Half dozen living larvae were voided by a woman. Identification with adult after emergence from pupa
Germany	*Eristalis tenax*	Human	Enteric	Meissner (1950)	N.A.
Italy	*Eristalinus taeniops*	Human	Enteric	Carpaneto and Vigna Taglianti (1995)	Identification with adult after emergence from pupa
Italy	*Eristalis* sp.	Human	Enteric	Scuderi (1964)	A 22-year-old woman noted that 2 mature rat-tailed larvae were passed in her stools in August 1959. It is estimated that larvae stayed 2 and a half months in the patient's intestine
Italy	*Eristalis* sp.	Human	Urogenital	Canali (1808)	A woman with a mobile larva that was initially identified as a "coda di sorcio" (rat-tailed), later as *Cercosoma* and finally *Eristalis* (see main text)
Italy	*Eristalis tenax*	Cattle	Nasal, urogenital, enteric?	Guizzardi et al. (1989)	Infestation of larvae in dairy cattle farm. The larvae settled around the nostrils and on the muzzle, localized around the eyes and vulva, causing intense annoyance
Italy	*Eristalis tenax*	Horse	Enteric	Lia et al. (1999)	Horse (mare 4 years old) after parasitological treatment presented profuse diarrhea with the presence of numerous larvae. Some larvae pupated and imagoes were obtained and identified
Italy	*Eristalis tenax*	Human	Enteric	Verdura and Romeo (1968)	62-year-old woman, after violent discharge of diarrheal feces, expulsed around 300 larvae. Potentially ingestion of syrphid eggs was suggested
Italy	*Eristalis tenax*	Human	Enteric	Delmastro et al. (1989)	58-year-old woman with dyspeptic troubles, diarrhea, and brucellosis expulsed a larvae after medical treatment
Italy	*Eristalis tenax*	Pig	Enteric	Ambrosi (1995)	Cow affected by larvae dead; stomach and intestine full of larvae
Norway	*Eristalis tenax*	Cattle	Enteric?	Natvig (1924)	Cow calved months ago, with stomach disease, passed quite a number of larvae
Norway	*Eristalis* sp.	Horse	Enteric?	Natvig (1939)	A horse refused to eat for a long time and lost weight and expulsed several larvae. The author

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Table 1 (continued)

Region/ country	Causative species	Host	Myiasis type	Reference	Comments
					suggests that the infection may have been caused by drinking water or with the feed
Spain	*Eristalis tenax*	Human	Enteric	Del Río (1902)	5-year-old boy died after expulsion of larvae
Spain	*Eristalis tenax*	Human	Enteric	Pérez-Zúñiga (1908)	Short note with case report of a boy that expulsed various larvae
Spain	*Eristalis tenax*	Human	Enteric	Sarandeses (1951)	2 case reports with several larvae involved
Spain	*Eristalis tenax*	Human	Enteric	Aguilera et al. (1999)	64-year-old woman with presence of several larvae
Spain	*Eristalis tenax*	Human	Enteric	Clavel et al. (2011)	51-year-old woman with presence of larvae in May and November; autofluorescence as parasitological feature of the larva
Spain	*Eristalis tenax*	Human	Enteric	Ferrer Bradley et al. (2010)	36-year-old woman under immunosuppressive therapy expulsed several larvae
Sweden	*Eristalis tenax*	Human	Enteric	Odhelius (1789)	First published case report as *Helophilus pendulus*, most likely a misidentification of *Eristalis tenax*
Sweden	*Eristalis tenax*	Human	Enteric	Spångberg (1886)	
Switzerland	*Eristalis* sp.	Human	Enteric	Galli-Valerio (1931)	Intestinal myiasis in a woman from Martigny
UK	*Eristalis tenax*	Horse	Enteric	Cobbold (1879)	Rat-tailed maggots reported from horse intestine (cited as *Helophilus pendulus*)
UK	*Eristalis tenax*	Human	Enteric	Hope (1840)	Woman with stomach affected by larvae. Cited as *Elophilus pendulus*. Case report from Rev W. Kirby (Phil. Mag. Vol ix p. 336)
UK	*Eristalis tenax*	Human	Enteric	Thomson (1896)	3 larvae were passed *per anum* by a patient
UK	*Eristalis tenax*	Human	Enteric	Cobbold (1879)	Rat-tailed maggots reported from human intestine (cited as *Helophilus pendulus*)
UK	*Eristalis tenax*	Human	Enteric	Cookson and Oldroyd (1937)	36-year-old man expulsed a large number of larvae
UK	*Eristalis tenax*	Human	Urogenital	Nash (2005)	A last instar larva was removed from the vagina of a drug-dependent and often comatose woman in 1971
UK	*Eristalis tenax*	Pig	Enteric	Cameron (1924)	Larvae were found in the stomach, where they had caused a fatal gastritis
UK	Syrphid larvae	Human	Enteric	Mumford (1926)	38-year-old woman; dipterous larvae probably syrphid larva because of the structure of posterior spiracular tubes
UK	*Syrphus* or *Scaeva*	Human	Enteric	Austen (1912)	A larva removed from the ear reported in this work is not considered myiasis
Unknown	*Eristalis tenax*	Human	Enteric	Brossard and Moddle 1985	A larva was found by coprological diagnosis and reported in the Institut de zoologie, Neuchâtel, Switzerland
Middle East					
Iran	*Eristalis tenax*	Human	Enteric	Youssefi et al. (2010)	22-year-old woman excreted 2–5 larvae daily over a 2–3-week period. An imago was obtained
Iran	*Eristalis tenax*	Human	Enteric	Hamed et al. (2017)	4-year-old girl with anal itching passed a living larva with the stool
Iran	*Eristalis tenax*	Human	Nasal	Salimi et al. (2010)	14-year-old girl suffered myiasis for 5 months. A pulpy mass was released during sneezing from the left nasal cavity and contained 1 larva
Israel	*Eristalis* sp.	Human	Urogenital	Korzets et al. (1993)	33-year-old man with urogenital myiasis apparently giving rise to acute ureteric obstruction. Most likely *Eristalis tenax*
Turkey	*Eristalis* sp.	Human	Enteric	Töreci et al. (1980)	N.A—most likely *Eristalis tenax*
Turkey	*Eristalis tenax*	Dog	Traumatic	Dik et al. (2012)	Larvae located perianal
Turkey	*Eristalis tenax*	Human	Nasal	Yalçınkaya (1976)	N.A.—nasal myiasis in a woman
Turkey	*Eristalis tenax*	Human	Urogenital	Mumcuoglu et al. (2005)	58-year-old woman emitted a live larva in her urine. She had seen other larvae in her urine 10 days prior

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Table 1 (continued)

Region/ country	Causative species	Host	Myiasis type	Reference	Comments
North America					
Canada	*Eristalis* sp.	Human	Enteric	Drisdelle and Forward (2006)	36-year-old man; 2 mature larvae in fecal sample; histoplasmosis and HIV serology positive. The authors refer skeptically the case
Canada	*Eristalis tenax*	Cattle	Urogenital	Bruce (1917)	Several larvae from cow calved about 2 months ago
Canada	*Eristalis tenax*	Human	Enteric	Chagnon and Leclercq (1949), Chagnon (1949)	Several larvae were evacuated by a patient; *E. tenax* adults emerged from pupae after 12 days of development. Sometimes appear erroneously cited from Belgium (e.g., Leclercq 1981; Singh and Singh 2015)
Canada	*Eristalis tenax*	Human	Enteric	Croll et al. (1976)	7-year-old boy expulsed a living larva with the stool
USA	*Eristalis* sp.	Cattle	Urogenital	Hall and Muir (1913)	
USA	*Eristalis* sp.	Human	Nasal	Leidy (1874)	A larva was removed from the cavity of the nose of a patient
USA	*Eristalis* sp.	Human	Enteric	D'Ignacio and Giaquinto Mira (1941)	The authors cited four cases reported by Howard and Clifton, an unknown reference to us
USA	*Eristalis* sp.	Human	Enteric	Hall and Muir (1913)	5-year-old boy expulsed several larvae. Important review of previous case reports
USA	*Eristalis* sp.	Human	Enteric	Riley (1939)	General report
USA	*Eristalis* sp.	Human	Enteric	Swartzwelder and Cali (1942)	6-year-old girl vomited 1 larva and expelled 6 more after treatment. Most likely *Eristalis tenax*
USA	*Eristalis tenax*	Cattle	Urogenital	McCulloch and McCoy (1941)	3 months after calving, for about a month with almost every urination the cow passed pus with 1–5 larvae
USA	*Eristalis tenax*	Human	Enteric	Riley (1890)	2 cases, 1 involving larvae of *E. dimidiata* (probably misidentification) and other case with *E. tenax*
USA	*Eristalis tenax*	Human	Enteric	Hanby (1905)	18-month-old boy expulsed 24 live larvae and 4 more dead after treatment
USA	*Eristalis tenax*	Human	Enteric, urogenital	McCampbell and Corper (1909)	72-year-old woman expulsed (mainly in a watery discharge) a large number of larvae, together with larvae of *Fannia canicularis* (Linnaeus, 1761) and *Musca domestica* Linnaeus 1758
USA	*Eristalis tenax*	Human	Enteric	Hall (1918)	18-year-old man expulsed 2 larvae, 1 year after he continued expulsing larvae
USA	*Eristalis tenax*	Human	Enteric	Pumpelly (1925)	30-year-old man; 6 larvae of different sizes after treatment, same diagnostic a year before. Typing error for the species name as *Eristalis tenex*
USA	*Eristalis tenax*	Human	Enteric	Chandler (1943)	3 case reports, involving boys 4–6 years old
USA	*Eristalis tenax*	Human	Enteric	Stiles and Cleland (1953)	45-year-old woman passed numerous larvae over 3 years. Pictures illustrate eristaline larvae, but adults reared from some larvae belong (according to photography) to Sarcophagidae. Mixed myiasis
USA	*Eristalis tenax*	Human	Urogenital	Supple (1958)	16-year-old girl; 1 week after pregnancy. Two larvae over a period of 24 h
USA	*Eristalis tenax*	Human	Enteric, urogenital	Scott (1964)	3 cases of myiasis without more details were reported
USA (Hawaii)	*Ornidia obesa*	Human	Enteric	Yang (2014)	42-year-old woman expulsed several alive larvae
Orient					
India	*Eristalis tenax*	Cattle	Enteric	Rajamohanan (1987)	2 case reports (cow and bullock) of animals with gastrointestinal disturbances as evidenced by diarrhea. Several mature larvae collected from dung
India	*Eristalis tenax*	Human	Enteric	Lakshminarayana et al. (1975)	35-year-old man noticed 2–3 larvae were passed in his stools on 3 occasions
Malaysia	*Eristalis* sp.	Human	Urogenital	Lee (1989)	

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Table 1 (continued)

Region/country	Causative species	Host	Myiasis type	Reference	Comments
					25-year-old woman complained of passing out "tadpole-like worm" in the urine monthly. A puparium was obtained
Malaysia	*Eristalis tenax*	Human	Enteric	Stiles and Cleland (1953)	(pers com. Pratt, H.D. 1951)
Pakistan	*Eristalis tenax*	Human	Enteric	Jabbar Khan and Jabbar Khan (1987)	N.A.
Pakistan	*Eristalis tenax*	Human	Enteric	Jabbar Khan (1987)	N.A.
Pakistan	*Eristalis tenax*	Human	Enteric	Jabbar Khan and Jabbar Khan (1992)	N.A.
Thailand	*Eristalis tenax*	Human	Enteric	Kruatrachu and Chinachoti (1957)	N.A.
Thailand	*Eristalis tenax*	Human	Enteric	Bhaibulaya (1982)	N.A.
Thailand	*Eristalis tenax*	Human	Enteric	Siripoonya et al. (1993)	N.A.

N.A. means the full original paper is not available to us, or only the abstract or short summary referenced by other authors was consulted

myiasis or myiasis of wounds; (ii) oral myiasis or infestation of the oral cavity; (iii) nasal myiasis or infestation of the nose; (iv) aural myiasis or ear infestation; (v) ophthalmomyiasis or larvae in the eye; (vi) enteric or gastrointestinal myiasis, or infestation of the stomach and intestine; (vii) urogenital myiasis or the presence of maggots in or near the genitals or urethra; and (viii) rectal myiasis or anus infestation. Contrary to other fly larvae, syrphid species have not been reported for oral myiasis, aural myiasis, or ophthalmomyiasis.

Since Zumpt (1962), several authors cited the rat-tailed larvae of syrphids as causative of true rectal myiasis. Zumpt (1963) was skeptical about the so-called generically "intestinal myiasis" recorded from humans, as he considered that they were frequently wrongly interpreted if only the presence of larvae in the stool or the vomit was considered. He recognized that except the obligatory myiasis species such as botflies (Oestridae), the rest could live with difficulty in the human alimentary tract and only under certain circumstances were they able to survive. Thus, Zumpt (1963) affirmed that some cases of myiasis caused by *Eristalis* are due to contamination after defecation, as Hall (1918) did previously, and suggested that most dipteran larvae could not survive in the conditions of the digestive tube. The rectal myiasis as defined by Zumpt (1962, 1963) happens when adult flies lay the eggs into or near the anus and larvae penetrate into the posterior part of anus. Zumpt and other authors (e.g., Leclercq 1969) accepted that the typical morphology of the *Eristalis* larvae, with the anal segment extended, would help them to breathe once in the anus area as they do in nature. In the present review work we consider as enteric myiasis all case reports where syrphid larvae were passed in the feces or vomit of the patient (or animal). We doubt that rectal myiasis is possible for rat-tailed maggots and this explanation fails to explain how the larvae of *Ornidia obesa* (without "tail") can survive in the digestive tract. If we assume that myiases involving syrphid flies are due to the accidental ingestion of eggs or first instar larvae, but expulsed maggots are 2.5–3 cm long and close to pupation, this can only be explained if those species complete the larval development inside the digestive system of vertebrates. Thus, syrphid larvae would need to be considered as true facultative myiasis agents instead of accidental agents or pseudomyiasis.

Myiasis-causing flower flies are reported in the literature from livestock (cattle, pig, and horse), pets (dog), and humans, but no records from wild animals exist. We found some works (Lever 1957; Richards 1977; Robertson and Whelan 1987; Urios 1990) where numerous rat-tailed maggots were mentioned from stomachs and scats of the wild red fox, *Vulpes vulpes* Linnaeus, 1758. Larvae of *Eristalis tenax* (Robertson and Whelan 1987) and empty eristaline puparia (Richards 1977) have been reported from fox scats and larvae of *Myathropa florea* (Linnaeus, 1758), a flower fly with rat-tailed larvae associated with wet decaying vegetation in rot-holes and in decaying heartwood (Rotheray 1993), were identified from the fox intestine (Lever 1957). The presence of syrphid larvae in the vulpine diet can be explained either by accidental ingestion while drinking or deliberate ingestion, as invertebrates are commonly reported in the fox's diet (Southern and Watson 1941; Scott 1943; Richards 1977 among others). Independently of the reason of the ingestion, the massive amount of rat-tailed maggots in the large intestine (Lever 1957), the large amounts of "ghost skins" (= puparia)

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found in scats (Richards 1977), and the fact that they were identified to species level (i.e., the larvae preserve their morphology to be identifiable) indicate a possible myiasis in the red fox. Lever (1957) did not mention if the larvae were alive or not, and this topic deserves further investigation.

During the literature review, we corrected some errors or mistakes present in other reviews, for example, indicating the country where the myiasis or infection took place instead of citing the country where the patient received treatment, not including some works where the original text do not mention any flower fly but have been referred by subsequent authors to *E. tenax* (e.g., de Groot 1956; Bryan 1937 cited in Supple 1958), and corroborating the identifications when images were available. In some cases, we could not verify the identifications, i.e., myiases in South America reporting *E. tenax* as the agent are very unlikely, but see an exception by Desoubeaux et al. (2014). Based on the present work, only five flower fly species can be unambiguously assigned as the cause of myiasis in humans and animals: *Eristalis tenax*, *Eristalis arbustorum*, *Eristalinus taeniops*, *Palpada scutellaris*, and *Ornidia obesa*.

The majority of the reported myiases caused by flower flies are gastrointestinal or enteric (104 out of 126), with the other types much less reported: urogenital (13 and another 3 together with other myiasis types), nasal (4 and 1 together with a urogenital myiasis), and traumatic (3). Interestingly, urogenital myiasis in humans has been reported for male and female individuals, and 5 mammal species have been recorded as accidental hosts: cattle (cow) (8), pig (4), dog (1), horse (3), and human (114). The common drone fly is the causative species in ca. 68% of the reported cases, *Eristalis* sp. and other species with rat-tailed larvae represent ca. 27% of the cases, and *Ornidia* is involved in 4% of the cases. The identity of the causative species, though, cannot be corroborated without voucher specimens and detailed morphological studies of adults and/or larvae. We suggest that future studies of myiasis always deposit vouchers into national museums and that DNA barcodes of the agents are obtained and published as surrogate vouchers.

Species identification using DNA barcodes

DNA barcoding is a molecular tool that aims to help in the identification of biological species (Hebert et al. 2003a, 2003b). Although often used to support the description of new species (e.g., Ståhls et al. 2009; Grković et al. 2015 for flower flies), DNA barcodes also allow the association of all life stages and genders of a single species or to identify organism from parts/pieces (Casiraghi et al. 2010). For instance, DNA barcoding was successfully applied on Syrphidae to associate phytophagous larvae with adults and identify them as *Merodon avidus* Rossi, 1790 (Andrić et al. 2014), or to associate unknown sex to species for which only one of the sexes is known (Jordaens et al. 2015a). More frequently, DNA barcoding is used to identify species when the query DNA barcode is compared against a library of sequences. In this respect, Jordaens et al. (2015b) corroborated the identification of a Neotropical syrphid species in Benin and Cameroon (West and Central Africa), and GilArriortua et al. (2014) confirmed the presence of the obligate amphibian parasite *Lucilia bufonivora* Moniez, 1876 (Diptera: Calliphoridae) in the Basque Country (Spain). Moreover, DNA barcodes are more often used to identify myiasis species (Otranto and Stevens 2002; Severini et al. 2015; Zhang et al. 2017), and DNA barcode libraries have been established for other myiasis dipterans such as the species of Oestridae (Otranto et al. 2003) or dipteran species of forensic importance (Sonet et al. 2013; Fuentes-López et al. 2019).

We applied a similar approach and identified the pre-adult inside the puparium from the stool as *Palpada scutellaris*, reporting the first case of the genus *Palpada* causing an intestinal myiasis. We think that as long as the DNA barcode databases grow in number of sequences and species represented in them, the utility of DNA barcoding to identify biological species will improve and their use and accuracy will increase. Assembling a public dataset of barcodes for all myiasis agents will be very valuable for medical professionals. That way, matches can be assessed, and new agents can be clearly identified. We strongly believe that medical colleagues will benefit enormously from this molecular tool in order to obtain an accurate species identification and recommend their use and promotion.

Conclusions

The present case report is the first time where the genus *Palpada*, and the species *P. scutellaris*, has been shown to cause intestinal myiasis. *Palpada* larvae are filter-feeding "rat-tailed maggots" living in semi-aquatic environments rich in decaying organic matter, including dung or decaying plant material (Thompson et al. 2010), and they can be found in open dumpsite (Solange Sánchez et al. 2010) and in refuse dumps (detritus) of nests of the leaf-cutter ant *Atta cephalotes* (Linnaeus, 1758) (van Doesburg 1962). Moreover, saprophagous larvae of the genera *Palpada* and *Ornidia* have been used to recycle wastes from coffee and orange juice production (Thompson et al. 2010; Pérez-Bañón et al. 2013).

This study also corroborates the arguments of James (1947) and Zumpt (1965) when saying that the name *Eristalis tenax* was indiscriminately used for any rat-tailed larva involved in a myiasis, and that other eristaline genera may be involved. Due to the lack of immature descriptions from Central and South America, almost nothing is known about the larval morphology of some eristaline genera (but see Thompson et al. 2010), and the use of out-of-date literature (see Rojas Soto et al.

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2017) perpetuates the name of *E. tenax* in the medical literature as myiasis agent. We strongly suggest that samples from myiasis are examined by a taxonomic specialist and, if possible, to try to rear the immatures into adults in order to corroborate the taxonomic identification. In case of unsuccessful rearing, we advise to preserve the immatures or their remnants into 95% or pure ethylic alcohol for molecular analysis. It is also recommended to publish a photograph of the larvae for each medical case report.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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