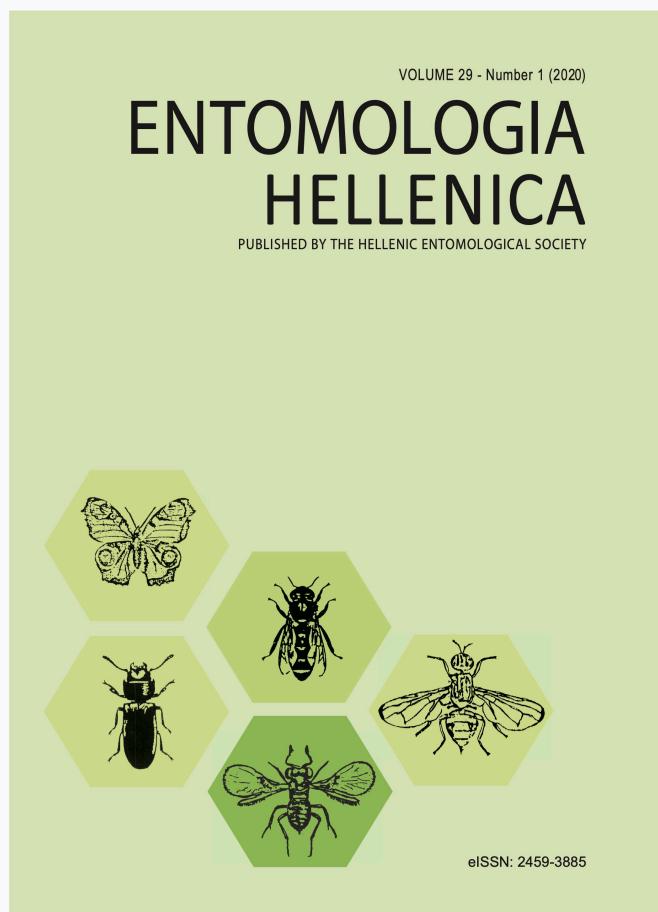


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Filling the gaps in the distribution of an alien species: The case of the feather-legged fly *Trichopoda pennipes* (Diptera: Tachinidae) in the Western Palearctic

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ABSTRACT

The feather-legged fly, *Trichopoda pennipes* (Fabricius, 1781) (Diptera: Tachinidae), is a parasitoid species introduced in several European countries over the last decades. This study provides new records for the presence of the tachinid in Mediterranean and Black Sea coastal areas. Four individuals were observed by the authors in Greece and Cyprus (2015–2019) and 11 additional records of the fly in Albania, Cyprus, Greece, Russia, and Turkey (2011–2019) were obtained from citizen science platforms. We provide the first records of the species on the aforementioned countries, contributing in the expansion of the current distribution range of the species. Current and future hypothetical expansion scenarios, as well as potential ecological implications are presented and discussed.

KEY WORDS: alien species, Cyprus, Greece, new records, *Trichopoda*, Turkey.

Introduction

In recent decades, globalization has led to a progressive increase in human-mediated introductions of alien species worldwide (Hulme 2009). This unprecedented rise in species translocations, beyond their native ranges, has altered the composition of biotas worldwide (Winter et al. 2009) and can have extensive effects on native biodiversity, ecosystem stability, human health, and economy (Hulme 2009, Pyšek and Richardson 2010, Simberloff et al. 2013). However, some species translocations may have no apparent consequences or have not yet been determined; e.g. the exotic sap beetle *Phenolia (Lasiodites) picta* (Macleay, 1825) (Coleoptera: Nitidulidae) in Greece (Kalaentzis et al. 2019).

Alien insect species represent one of the most numerous groups of introduced organisms in Europe (Roques et al. 2009). Many of them have dramatic economic or sanitary consequences, e.g. the red palm weevil, *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera: Curculionidae) (Ferry and Gomez 2002) or the Asian tiger mosquito, *Aedes albopictus* (Skuse, 1894) (Diptera: Culicidae) (Knudsen 1995). Some can have serious ecological impacts, by either displacing species of the native entomofauna, e.g. Asian ladybird, *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae) (Pell et al. 2008) or harming the local flora, e.g. the lantana plume moth, *Lantanophaga pusillidactylus* (Walker, 1864) (Lepidoptera: Pterophoridae) (Demetriou et al. 2020).

The feather-legged fly *Trichopoda pennipes* (Fabricius, 1781) (Diptera:

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Tachinidae) is a parasitoid species originating from North America (Salerno et al. 2002). It is an imaginal and occasionally a nymphal parasitoid of various hemipteran species (Harris and Todd 1981, Ruberson et al. 2010). In its natural geographic area, its host range includes several species of Alydidae, Coreidae, Pentatomidae, and Pyrrhocoridae (Francati et al. 2019). In addition, the introduction of the southern green shield bug, *Nezara viridula* (Linnaeus, 1758) (Hemiptera: Pentatomidae), into North America in the 1700s, rendered it as an additional host of *T. pennipes* in its natural range (Jones 1988). In Europe, the fly was accidentally introduced in Italy, around the 1980s, presumed through shipment carrying its host, *N. viridula* (Colazza et al. 1996). In addition, it has been introduced deliberately into several countries, such as Australia and Fiji, for biological control of *N. viridula* (Grenier 1988).

In Italy, the species has been recorded multiple times since its first record (Colazza et al. 1996, Salerno et al. 2002, Ceretti 2010, Cargnus et al. 2011, Tschorsnig et al. 2012, Francati et al. 2019). Until now, the species has also been reported from various European countries such as: Croatia (Bystrowski 2012), France (Tschorsnig et al. 2000, Zeegers 2010), Hungary (Sándor 2014), Malta (Darmanin and Ceretti 2019), the Netherlands (Zeegers 2010), Portugal (Tschorsnig et al. 2012), Slovenia (Groot et al. 2007), Spain (Peris 1998, Tschorsnig et al. 2000, Tschorsnig et al. 2012, Obrecht 2014) and Switzerland (Obrecht 2014, Pétremand et al. 2015). Skuhřavá et al. (2010) reported the fly's presence in Albania, yet no data were provided to support this claim. In addition, *T. pennipes* has been found in Africa (Egypt; El-Hawagry et al. 2020) and Asia (Israel; Freidberg et al. 2011), but it remains unknown whether it arrived there through direct spreading from Italy or by a separate introduction event (Bystrowski 2012).

In the present study, authors' observations as well as citizen records of *T.*

pennipes from Cyprus, Greece, Russia, and Turkey are provided, contributing in the expansion of the current distribution range of the species. A record from Albania confirms the parasitoid's presence in the area and hypothetical scenarios concerning the fly's spread across Europe and Western Asia are discussed.

Materials and Methods

On August 9 2015, a male *T. pennipes* was found and photographed in Agios Lavrentios, on Mt. Pelion of Central Greece (39.3613°, 23.0580°). The individual was observed in a meadow habitat, feeding on the nectar of wild mint flowers, *Mentha longifolia* (L.) Huds. In August 2018, a specimen was collected from Aiantio, Salamina (E. Koutsoukos, pers. comm.) and was deposited at the Museum of Zoology of the University of Athens (ZMUA; voucher number: ZMUA DIP 0000002), where it was later identified by the authors as *T. pennipes*. In addition, on August 31 2018, approximately 11 km away from the first locality (39.3893°, 23.1759°), an individual of *N. viridula* bearing an egg and a female individual of *T. pennipes* were recorded. On August 26 2019, a female individual was found near Lasa village in Cyprus (34.9288°, 32.5290°). The individual was collected and deposited in the collection of ZMUA (voucher number: ZMUA DIP 0000001). The identification of adult specimens was carried out by the authors using the determination keys of Cerretti (2010) and Worthley (1924).

Subsequently, the authors collected data derived from online sources (iNaturalist, diptera.info and "Insects of Greece & Cyprus", a social media content sharing platform) and requested permission to include the observations in the current study. In total, information on 11 citizen science based observations of *T. pennipes* from Albania, Cyprus, Greece, Russia, and Turkey were acquired.

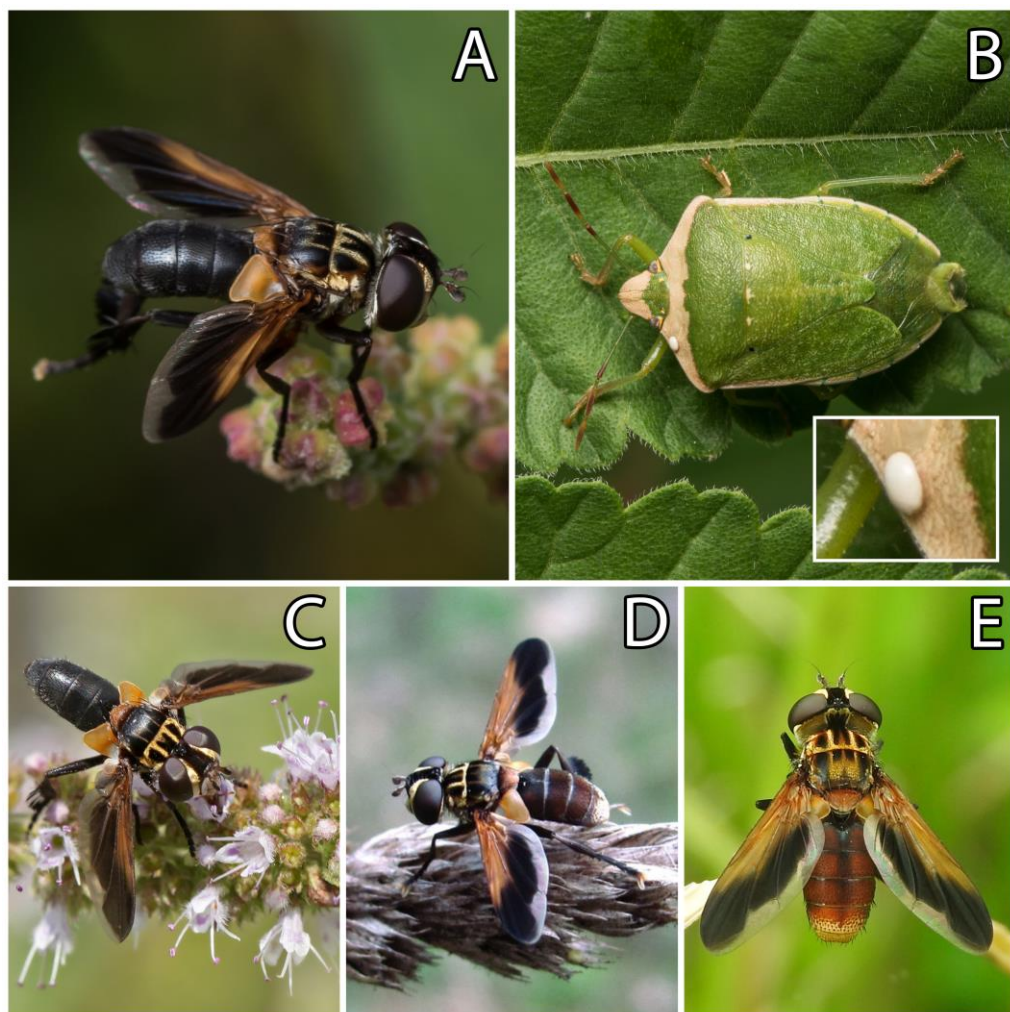


FIG. 1. Individuals of *Trichopoda pennipes* photographed *in situ* from: Greece (A), Cyprus (C), Russia (D), and Turkey (E). A specimen of *Nezara viridula* carrying an egg of *T. pennipes* from Greece (B). Photos by K. Kalaentzis (A, B), C. Makris (C), G. Okatov (D) and G. Eren (E).

Results

Based on the aforementioned determination keys, the collected specimens and all of the photographed individuals were identified as *T. pennipes*. All of our photographic records presented characters of a typical specimen of *T. pennipes* (i.e. yellow pronotum with black-striped markings, flattened bristles on hind tibiae, black wings with sub-hyaline posterior

margin and ferruginous markings in the forepart) and did not exhibit any morphological similarities to other tachinid species.

We collected the following data from personal observations and citizen-science platforms:

1. Greece, Corfu, Dassia (39.6799°, 19.8386°), 29.VIII.2011, M. Friedrich, 1 ♀, diptera.info

2. Greece, Mt. Pelion, Agios Lavrentios (39.3613°, 23.0580°), 9.VIII.2015, C. Kazilas, 1 ♂, direct sighting
3. Greece, Peloponnese, Nemea (37.8182°, 22.6699°), 30.V.2016, G. Gastouniotis, 1 ♂, "Insects of Greece and Cyprus" (IGC) social media platform
4. Greece, Crete, Chania (35.3776°, 23.8450°), 11.VI.2018, F. Samaritakis, 1 ♂, IGC social media platform
5. Greece, Salamina, Aiantio (37.9235°, 23.4653°), VIII.2018, E. Koutsoukos, 1 ♂ collected and deposited at the Museum of Zoology of the University of Athens (ZMUA), pers. comm.
6. Greece, Mt. Pelion, Tsagarada (39.3893°, 23.1759°), 31.VIII.2018, K. Kalaentzis and C. Kazilas, 1 ♀ (Fig. 1A) and 1 *N. viridula* bearing an egg of *T. pennipes*, direct sighting (Fig. 1B)
7. Greece, Crete, Heraklion (35.2982°, 25.3525°), 21.VI.2019, P. Lewis, 1 ♂, iNaturalist
8. Greece, Peloponnese, Nemea (37.8524°, 22.6448°), 25.VII.2019, G. Gastouniotis, 1 ♂, IGC social media platform
9. Greece, Crete, Heraklion (35.3371°, 25.1235°), 27.IX.2019, P. Bormpoudaki, 1 ♀, IGC social media platform
10. Cyprus, Lemesos, Alassa (34.7595°, 32.9316°), 7.VIII.2016, C. Makris, 1 ♀, IGC social media platform (Fig. 1C)
11. Cyprus, Pafos, Lasa (34.9288°, 32.5290°), 26.VIII.2019, J. Demetriou, 1 ♀ collected and deposited to the ZMUA, direct sighting
12. Turkey, Sakarya, Karasu Province (41.0750°, 30.6489°), 16.IX.2016, G. Eren, 1 ♀, diptera.info
13. Turkey, Sakarya, Karasu Province (41.0750°, 30.6489°), 14.IX.2018, G. Eren, 1 ♂, diptera.info (Fig. 1E)
14. Albania, Vlora (40.4700°, 19.4900°), 2.V.2019, A. Golemaj, 1 ♂, iNaturalist
15. Russia, Sochi, Khosta Microdistrict (43.5370°, 39.8822°), 1.XI.2015, G. Okatov, 1 ♂, iNaturalist (Fig. 1D)

Discussion

The specimens recorded from Albania, Cyprus, Greece, Russia, and Turkey constitute the first evidence for the presence of *T. pennipes* in these countries. Repeated sightings of the species and of an egg-bearing hemipteran host in Mt. Pelion suggest the existence of an established population in the area. Even though no other cases of parasitized individuals were reported, it is very likely that the tachinid is able to survive in these environments, since their most common host species, *N. viridula*, is present in the aforementioned areas (Fig. 2).

Decades after its accidental introduction in Italy (Colazza et al. 1996), *T. pennipes* not only established itself in the European continent, reaching as far north as the Netherlands (Zeegers 2010), it also managed to invade Asia, where it was recorded for the first time in Israel (Freidberg et al. 2011), and afterwards Africa, where it was recorded in Egypt (El-Hawagry et al. 2020). Bystrowski (2012) proposed two possible hypotheses concerning the presence of the species in Israel; the first being the expansion of *T. pennipes* from Italy through the coastal areas of Greece and Turkey, while the alternative hypothesis refers to an independent introduction event. Our records from Albania, Cyprus, Greece, and Turkey provide evidence to support the first biogeographic scenario, although the latter cannot be rejected. Considering the cosmopolitan distribution of *N. viridula* (Aukema et al. 2016, Panizzi and Lucini 2016, Hemala and Kment 2017), the parasitoid is expected to expand its range even further across Europe (e.g. Bulgaria, Romania, Ukraine), Asia (e.g. Syria), and other parts of North Africa in the future (Fig. 2).

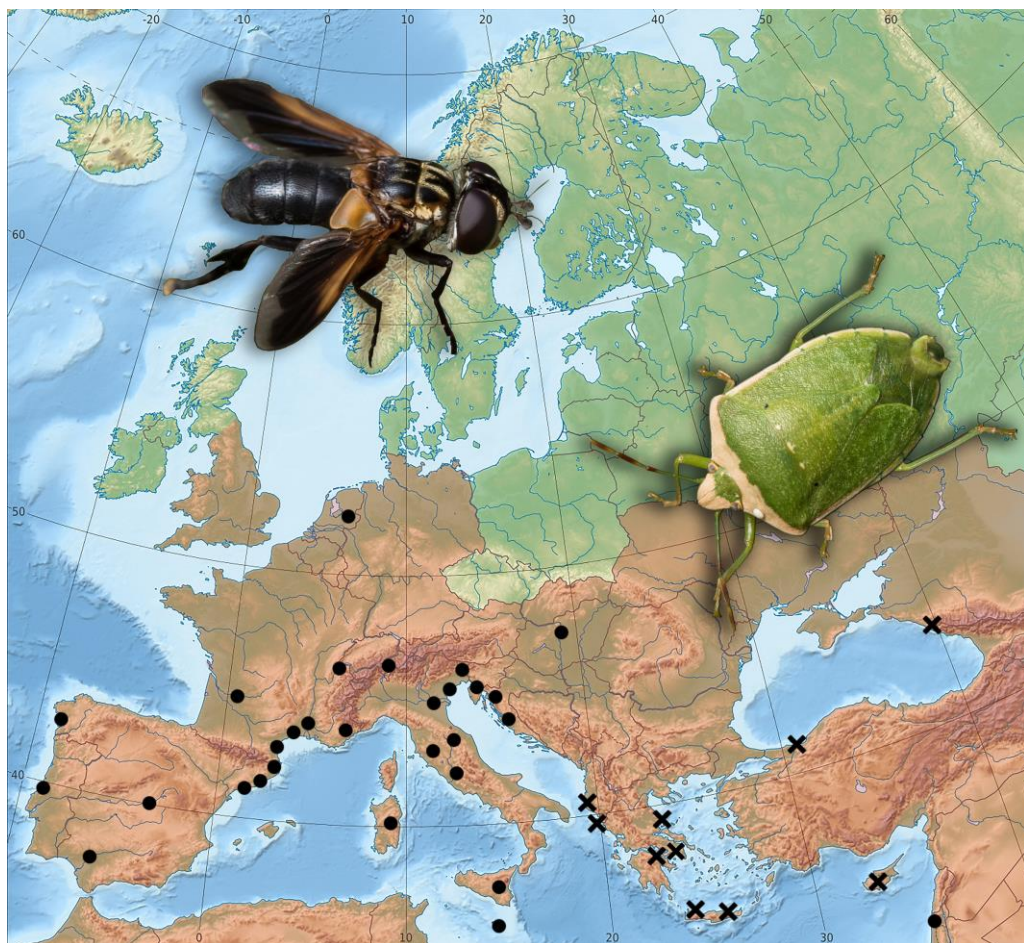


FIG. 2. Physical map of Europe and Western Asia, where *Trichopoda pennipes* has been recorded. Dots correspond to the records of *T. pennipes* based on literature data, while our observations are indicated with X. The shaded area represents the approximate distribution range of *Nezara viridula* in Europe (Aukema et al. 2016, Panizzi and Lucini 2016, Hemala and Kment 2017). Insets: *T. pennipes* and *N. viridula* bearing an egg of the parasitoid (Mt. Pelion, Greece); photos by K. Kalaentzis.

Although it has been more than three decades since the invasion of *T. pennipes* in Europe its host range data limit to *N. viridula* (Ceretti 2010, Groot et al. 2007, Pétremand et al. 2015, Francati et al. 2019) with a single case of (possible) parasitism of *Graphosoma italicum* (Müller, 1766) (Hemiptera: Pentatomidae) (Colazza et al. 1996). However, the fly could potentially parasitize

other pentatomid species as well, such as the brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855), a host of *T. pennipes* in North America (Rice et al. 2014; CABI 2019) that has been introduced in several parts of Europe, where *T. pennipes* is also present; e.g. Switzerland, France, Italy, and Greece (Wermelinger et al. 2008, Callot and Brua 2013, Pansa et al. 2013, Véték et al. 2014,

Milonas and Partsinevelos 2014, Pétremand et al. 2015, Andreadis et al. 2018). Despite the fact that *Trichopoda* parasitoids can significantly affect the populations of *N. viridula* (Coombs 2002), *T. pennipes* is known to be a generalist that parasitizes various species instead of a single target host (Groot et al. 2007). More research is needed in order to identify its potential host range in the recently invaded areas and determine its possible effects on native biodiversity.

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Συμπληρώνοντας τα κενά στην κατανομή ενός ξενικού είδους: Η περίπτωση του δίπτερου *Trichopoda pennipes* (Diptera: Tachinidae) στη Δυτική Παλαιαρκτική

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ΠΕΡΙΛΗΨΗ

Το δίπτερο *Trichopoda pennipes* (Fabricius, 1781) (Diptera: Tachinidae) είναι ένα παρασιτοειδές έντομο που εισήχθη τις τελευταίες δεκαετίες σε πολλές ευρωπαϊκές χώρες. Η τρέχουσα μελέτη παρέχει νέα στοιχεία για τον εντοπισμό του είδους σε παράκτιες περιοχές της Μεσογείου και της Μαύρης Θάλασσας. Τέσσερα άτομα παρατηρήθηκαν από τους συγγραφείς στην Ελλάδα και την Κύπρο (2015-2019) και χρησιμοποιήθηκαν 11 επιπλέον καταγραφές πολιτών από την Αλβανία, την Κύπρο, την Ελλάδα, τη Ρωσία και την Τουρκία (2011-2019). Παρέχουμε τις πρώτες καταγραφές του είδους στις προαναφερόμενες χώρες, συμβάλλοντας στην επέκταση της τρέχουσας κατανομής του είδους. Παρουσιάζονται και συζητούνται τρέχοντα και μελλοντικά υποθετικά σενάρια επέκτασης, καθώς και πιθανές οικολογικές επιπτώσεις.