

Discovery of the First Webspinners (Embioptera, Insecta) in Iran and Associated Bristle Fly Parasitoid

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ABSTRACT

This is the first report of web or foot spinners (order Embioptera), particularly the *Haploembia tarsalis* (Ross, 1940), in Iran. This possible non-indigenous species was found in an urban area from the yard of a private property in Urmia, West Azarbaijan and in a suburban area near the Agark-Nordoz border crossing, East Azarbaijan Province, Iran. The genus *Haploembia* Verhoeff, 1904, seems apparently native to the Mediterranean. It is a unique and unusual insect order in cold and mountainous regions, perhaps related to the changing climate which facilitated a possible introduction. From the reared live culture of the webspinner, dipteran parasitoids pupae belonging to the family Tachinidae were obtained. Newly recorded species for Iran's fauna, *Rossimylops longicornis* (Kugler, 1972). This study documents presence of the webspinners in Iran, complemented by detailed photographic evidence of the species' habitus. Additionally, it provides a comprehensive description of its associated parasitoid and offers insights into the biological characteristics and ecological behavior of the parasitoid fly.

Keywords: *Haploembia tarsalis*, non-indigenous species, Parasitoid ecology, *Rossimylops longicornis*, Tachinidae, West & East Azarbaijan.

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INTRODUCTION

In today's world, the translocation of living species is increasingly influenced by a multitude of factors, leading to the occurrence of thousands of non-indigenous species, both plants and animals, in various regions across the globe. This phenomenon is largely driven by the expanding reach of human enterprises, transportation networks, and global travel (Dehshiri, 2018; Nozaki, Nakahama, Suehiro, & Namba, 2018).

Iran's vast extent and diverse climate contribute to its rich biodiversity. The country's varied habitats, shaped by climate change, support a wide range of vegetation cover, creating a unique ecological tapestry (Jowkar, Ostrowski, Tahbaz, & Zahler, 2016; Dehshiri, 2018; Yousefi et al., 2019). In Iran, one can encounter a fascinating mix of species, ranging from those typically found in Europe and colder regions to species native to India, Africa, and tropical areas. This convergence of wildlife highlights the country's importance as a meeting point for diverse ecosystems and species (Jowkar et al., 2016; Dehshiri, 2018).

Web-spinners (Foot-spinners)-Embioptera, Embiodea, or Embiidina, consist of a small and mysterious order within polyneopterous insects (Miller, Hayashi, Whiting, Svenson, & Edgerly, 2012) and are renowned for their ability to spin silk through glands located in their specialized front legs (Kočárek, Máslo, & Šťáhlavský, 2021). Despite the identification of approximately 400 species, many more species are probably awaiting classification (Miller et al., 2012; Badano et al., 2022; Hopkins, 2024). These intriguing insects are found in tropical and subtropical regions around the world, making them a globally distributed group. While Embioptera were relatively understudied until 2000 (Ross, 2000), recent research over the past two decades has greatly expanded our knowledge of their biology, including silk proteins, behavior, gland diversity, phylogeny, and genome variation. Edward S. Ross (1915-2016) played a significant role in advancing our understanding of the Embioptera, dedicating approximately 70 years to studying this group (Ross, 2000). Although Embioptera primarily found in tropical areas, it may have been introduced to other regions via the transportation of tropical plants (Nozaki et al., 2018). They face challenges in colder climates but can thrive in controlled environments such as greenhouses (Kim, Sung, Kim, & Shi, 2022).

Parasitoids are recognized as a key population-limiting factor for insects. In addition to tachinid flies (Stireman, O'Hara, & Wood, 2006), sclerogibbid wasps (Hymenoptera: Sclerogibbidae) are known as obligate ectoparasitoids of Embioptera nymphs (Olmi & van Harten, 2000). In addition, some sources also mention other parasitoids within the families Bethyridae and Braconidae (Callan, 1939, 1952; Shaw & Edgerly, 1985; Edgerly & Krombein, 1979; Edgerly, 1997; Zaldívar-Riverón et al. 2025). These parasitoids exhibit diverse strategies, from oviposition on or within hosts to host paralysis and provisioning for larval development. Despite these studies, the biology and ecology of these interactions remain partially unknown.

Occasionally, Edward S. Ross discovered dipteran parasitoids in his live webspinner cultures, all belonging to the Tachinidae family, a prominent clade of Calyptratan Diptera, comprising about 8500 described species that develop as endoparasitoids of various arthropod orders (Badano et al., 2022). Therefore, the webspinner-parasitizing Diptera are primarily reviewed based on the work of Edward S. Ross., and later

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Badano et al. (2022) provided an updated key to species. As of now, no webspinner has been documented in Iran, making this the first, possibly non-indigenous, species to be introduced, probably via human activities. This report details the presence of the webspinner in Iran, along with accompanying photographs of the species' habitus, a description of its parasitoid, and information on the biology of the parasitoid fly.

MATERIAL AND METHODS

The material for this study was gathered from 2023 to 2024 from Urmia, West Azarbaijan Province (in the courtyard of a residential house), and Nordooz, East Azarbaijan Province (on private property), Iran. Regarding specimens collected from Urmia, the exploration involved hand searching through leaf litter and silk dwellings in the yard garden soil. Correspondingly for the specimens belonging to Nordooz, the collection involved retrieving specimens from soil crevices under rocks (Fig. 1).

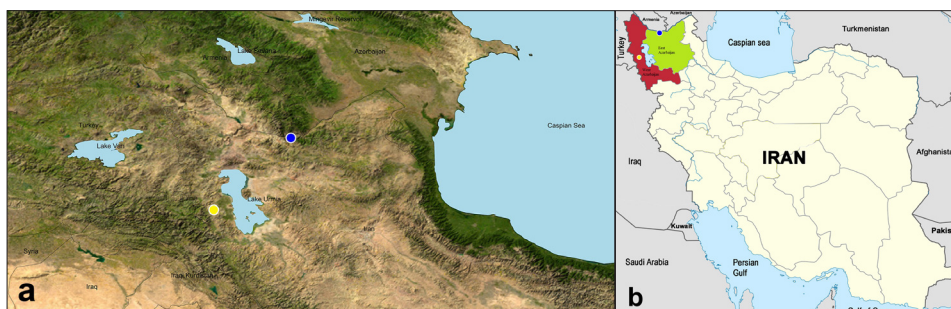


Figure 1. Geographical sampling locations of *Haploembia tarsalis* (Ross, 1940): a) The West and East Azarbaijan provinces, delineated by topographical boundaries; b) Iran and its adjacent nations (yellow andmark - Urmia, blue landmark - Nordooz).

During the initial sampling, nymphs and adult females were carefully gathered and preserved in 96% ethanol before being deposited in the collection of Urmia University for further analysis. The specimens were meticulously examined and digitally photographed using a Wild M5 stereomicroscope equipped with a U3CMOS14000KPA digital microscope camera. Live specimens and their silk domiciles in their natural habitats were captured using a Samsung Galaxy A7 2016 smartphone.

In the second sampling, embiid individuals were collected from shelter tunnels observed under rocks (Fig. 2a) or fallen leaves by delicately dissecting the tunnels and using surgical forceps. We transported these individuals to the laboratory and kept them alive in glass Petri dishes at 25 °C for morphological observations (Fig. 2b-c). To sustain the colony, crushed oak leaves and soil from the original habitat were collected. A colony was nurtured in the laboratory to obtain adults for morphological identification, focusing on characteristics, such as basidorsal papillae of the hind legs, body color patterns, and head and body length (Ross, 1940, 1966). During the study, a fascinating discovery was made of parasitoid growth inside the bodies of embiids, leading to their gradual demise. Dead individuals were separated from the colony and carefully examined, resulting in captivating photographs showcasing the developmental stages of the parasitoid fly.

For specific identification of embiidids the following keys were utilized: Ross (1966), Hodson, Cook, Edgerly, & Miller (2014), Nozaki et al. (2018), Kelly, Whittall, & Edgerly (2018), and for the identification of the Bristle Fly Parasitoid: Cerretti, De Biase, & Freidberg (2009) and Badano et al. (2022).

Part of the specimens has been deposited in the insect collection of the Hayk Mirzayans Insect Museum (HMIM), Tehran, Iran. A selection of specimens has also been deposited in the Plant Protection Department of Urmia University (PPDUU) to facilitate further study and ensure accessibility for other researchers.

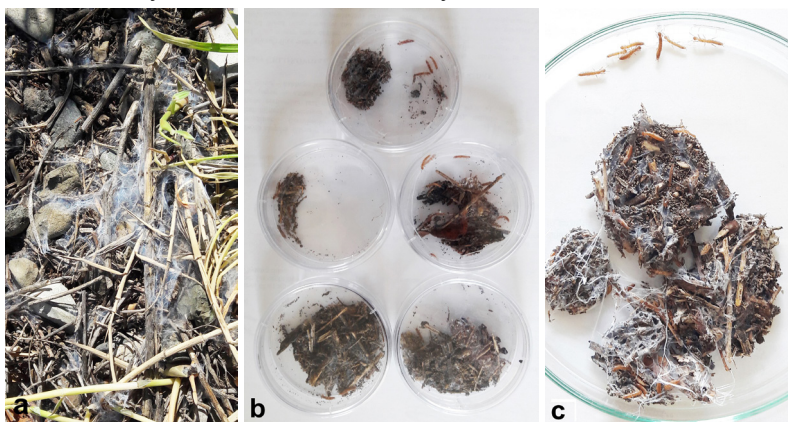


Figure 2. Microhabitat of *Haploembia tarsalis* (Ross, 1940). a). Silk tunnels (domiciles); b). Growth chambers including the embiopteran nests; c). A detailed view of the colony.

RESULTS AND DISCUSSION

The first observation of web-spinners in an urban area was made in Urmia (Fig. 1), within a garden and beneath plant debris, in May 2023. During this observation, 27 adult insects and nymphs (Figs. 3a-d) were collected for study and identification. The second observation took place outside the city in Nordooz (on the Iran-Armenia border) (Fig. 1) in March 2024, where a total of 98 web-spinners were collected from beneath rocks and within plant debris and subsequently transferred to the laboratory. The specimens from Urmia exhibited more vibrant coloration and larger body sizes compared with those from Nordooz, a difference attributed to the two-month gap in sampling. Due to a lack of awareness of the presence of parasitoids, the colony from Urmia was preserved in alcohol and mounted. In contrast, the specimens from Nordooz, along with their colony's habitat, were kept alive in the laboratory for biological studies. The discovered web-spinner species and its parasitoid fly, as well as some of their morphological and biological characteristics, are described as follows:

Embioptera: Family Oligotomidae Enderlein, 1909

Haploembia tarsalis (Ross, 1940) (Figs. 3-4)

Material examined. Iran, 27♀♀; Urmia (West Azarbaijan Province); 37°30'52"N, 45°02'55"E, 1387m a.s.l.; Amidst leaf litter in an urban area from yard of a private property; leg. Arian and Bardiya Razmi; 29.

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May 2023, 98♀♀; Nordooz (Village in Nowjeh Mehr Rural District, Siah Rud District, Jolfa County, East Azarbaijan Province, situated near Iran's sole border crossing with Armenia); 38°51'07"N 46°12'49"E, 540m a.s.l.; in soil crevices under the rocks; leg. Arian and Bardiya Razmi; 29. March 2024.

Female Diagnosis. The species *Haploembia tarsalis* was identified based on a combination of morphological characteristics, color patterns, body dimensions and also, the absence of males in the collected populations as well as in the laboratory-reared populations. The key diagnostic features for the genus *Haploembia* include the presence of two ventral papillae on the hind basitarsus (Figs. 4b-f), a pale prothorax (Fig. 4a) and uncarinated mandibles with slight basolateral elevation (Fig. 4b). *Haploembia tarsalis* is distinguished by its pale prothorax and legs, contrasting with the uniformly dark coloration of *H. palau*, and a head that is slightly longer than broad (Ross 1940, 1966). While most adult *Haploembia* species exceed 15 mm in body length, *H. solieri* is an exception, measuring less than 14 mm (Ross, 1966; Hodson et al., 2014). The specimens collected in this study were consistently shorter than 11.0 mm, further supporting their identification as *H. tarsalis*. The presence of two ventral papillae on the hind basitarsus, an autapomorphy of the genus *Haploembia* (Nozaki et al., 2018; Ross, 1966), was also observed in the immature instars examined (Fig. 4c). These diagnostic traits collectively suggests the species identification as *H. solieri*.

Distribution. Mediterranean countries, Madeira, Canary Islands, Crimea, southern Russia and Caucasus, Western USA, Japan (Cianferoni & Ceccolini, 2024) and possibly Iran (new record).

Remarks. Males of this specie, as described by Ross (1966), exhibit an apterous condition, characterized by sclerotization in the genital region with significant asymmetry. However, this study did not include male specimens, only immature and female adults (Figs. 3a-d).

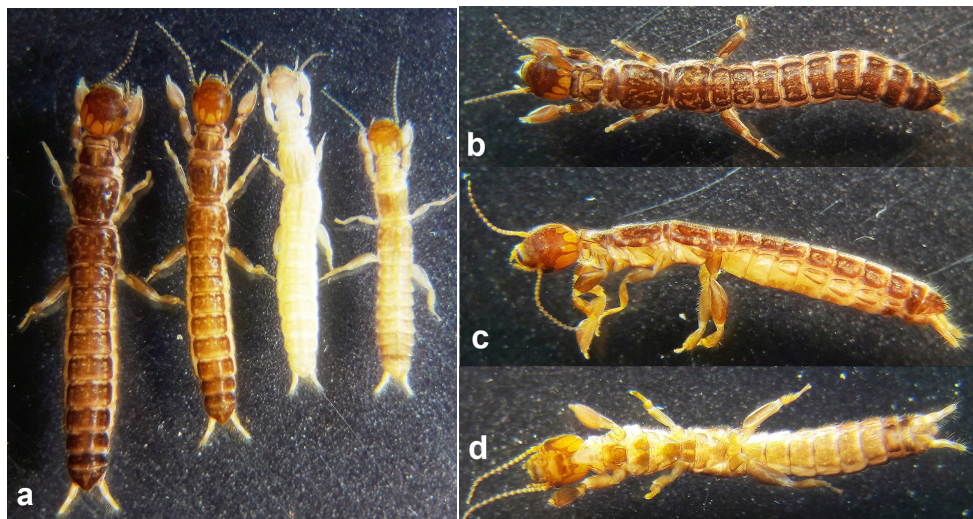


Figure 3. *Haploembia tarsalis* (Ross, 1940), female: a) Immature instars and adult, dorsal view; b–d. General habitus: b) Dorsal view; c). Lateral view; d) Ventral view.

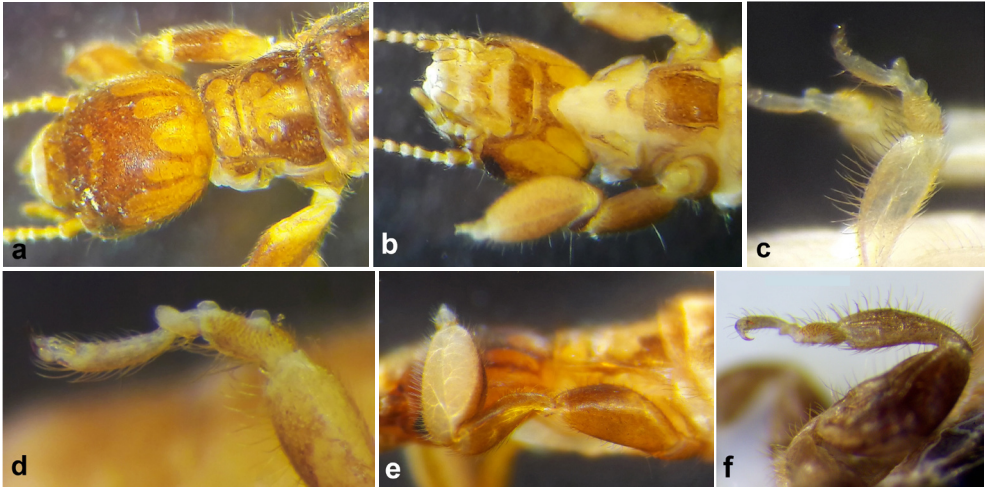


Figure 4. Morphological features of *Haploembia tarsalis* (Ross, 1940), female: a) Head and prothorax, dorsal view; b) Head and prothorax, ventral view; Hind leg basitarsus papillae: c) Nymph; d) Adult; e) Fore leg silk glands located in the fore tarsi, lateral view. f) Female hind leg from another perspective.

Diptera: Family Tachinidae Robineau-Desvoidy, 1830

Rossimylops longicornis (Kugler, 1972) (Figs. 5-8)

Material examined. Iran, 12♀♀, 10♂♂; Nordooz (Village in Nowjeh Mehr Rural District, Siah Rud District, Jolfa County, East Azarbaijan Province, situated near Iran's sole border crossing with Armenia); 38°51'07"N 46°12'49"E, 540 m a.s.l.; in silk tunnels (silk domiciles), which are the nests of embiopterans; leg. Mehdi Razmi; 17. April 2024.

Female Diagnosis. Body color predominantly black (In contrast to *R. exquisitus*, which has been documented in Iran and characterized by its yellow palpus, thorax, and femora) (Figs. 5a-c), has a long petiolate wing cell r4+5, with the petiole about 0.3-1.0 times the post-angular portion of the median vein (Fig. 6e). The presutural region of the scutum exhibits three broad longitudinal dark vittae, with the lateral pair being approximately equal in width to the medial vitta and extending posteriorly to the transverse suture (Figs 5a, 7b). The scutellum has two pairs of marginal setae (In contrast to *R. exquisitus*, which possesses three pairs of marginal scutellar setae (Fig. 7a). The mid tibia has one anterodorsal seta (Fig. 7c). Unlike the male, female has a wider vertex with two or more proclinate orbital setae, and the frontal vitta is more distinct (Figs 5a, 5c, 6a). The face is flat, the prementum is 2-3 times its diameter, and the antennal postpedicel is 3 times the pedicel length (Fig. 6f). Wings smoky anterodistally (Fig. 6e), the ventral calypter varies from brownish to dark brown, and the halter is yellow to light brown (Figs. 5c, 7c).

Male Diagnosis. Most morphological characteristics of males are similar to those of females, though some differences are also observed. The vertex is very narrow with no proclinate orbital setae, and the frontal vitta is extremely narrow, nearly indistinct anterior to the fore ocellus (Figs. 5d, 6b, 6d). The face is flat, the prementum is 2.5 times its diameter, and the antennal postpedicel is 2.5 times the pedicel length. The

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wing membrane is entirely hyaline. In the lateral view, the cerci appear predominantly straight and lack a distinctly hook-shaped morphology at their distal ends (Fig. 7d).

Hosts. Embioptera: *Haploembia solieri* (Badano et al., 2022) and *H. tarsalis* in this study.

Distribution. Bulgaria, Greece, Israel, Transcaucasia, Turkey (Badano et al., 2022; Cerretti et al., 2009) and Iran (new record).



Figure 5. *Rossimyops longicornis* (Kugler, 1972): a-c. General habitus, female: a) Dorsal view; b) Ventral view; c) Lateral view; d) General habitus of the male, lateral view.

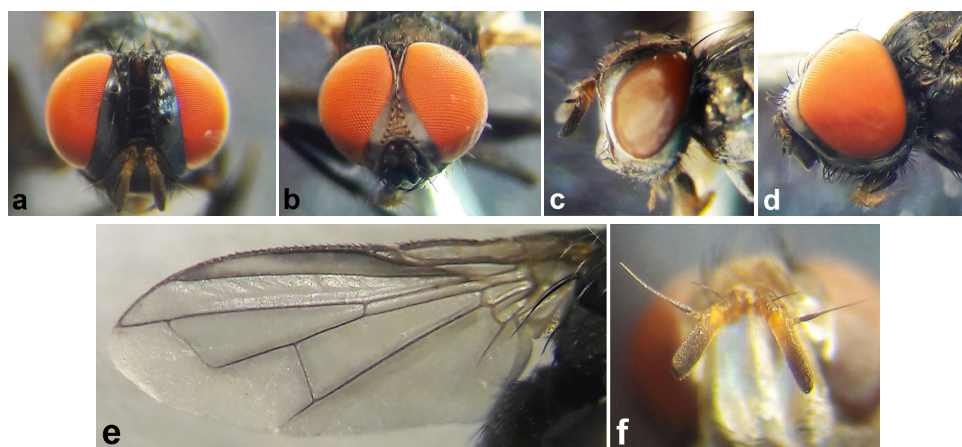


Figure 6. *Rossimyops longicornis* (Kugler, 1972): a-b. Head, frontal view: a) Female; b) Male; c-d. Head, lateral view: c) Female; d) Male; e) Fore wing; f) Female antennae.

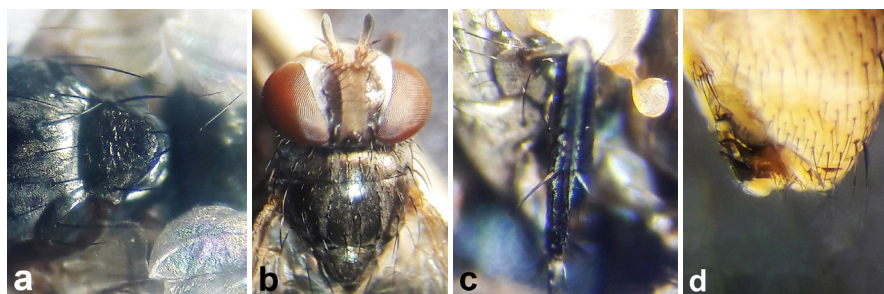


Figure 7. Morphological features of *Rossimyops longicornis* (Kugler, 1972): a-c. Female: a) Scutellum, dorsal view; b) Head, scutum and scutellum, dorsal view; c) Dorso-lateral view of the mid tibia; d) Cerci and surstylus of the male, lateral view.

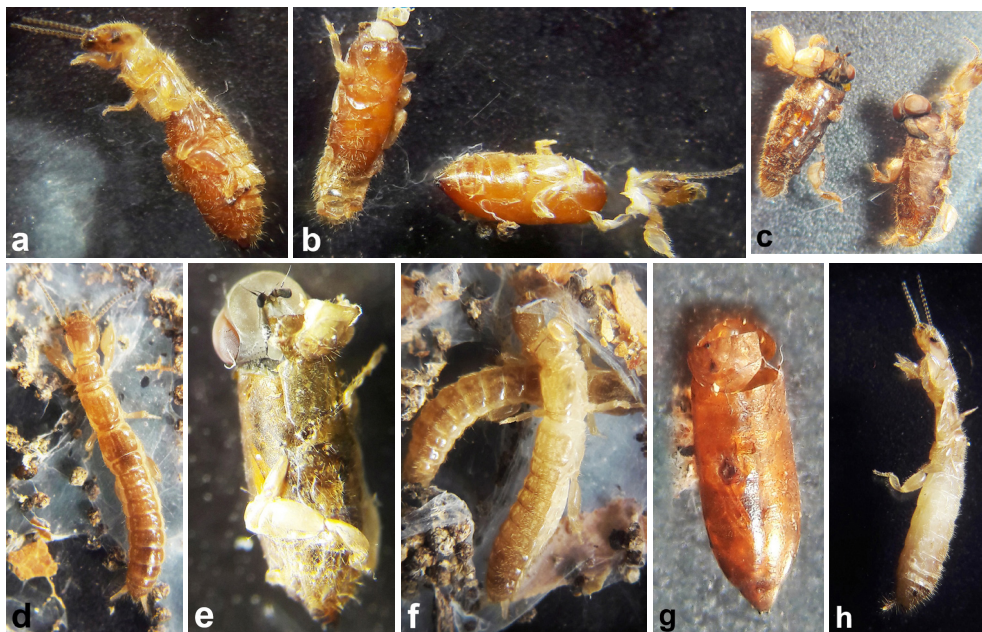


Figure 8. The biological cycle of *Rossimylops longicornis* (Kugler, 1972) Parasitism on webspinner: a) Bristle Fly pupa in the early stages of consuming Embioptera's internal organs; b) Bristle Fly pupation final stages; c) Bristle Fly adult emerging from pupa; d) Healthy embiopteran adult (in vitro); e) Freezing the moment of the Bristle Fly emerging from its pupa; f) Embiopteran infected by a Bristle Fly (in vivo); g) Puparium of the Bristle Fly; h) Embiopteran infected by a Bristle Fly (in vitro).

This study documents the first record of the order Embioptera in Iran, specifically the possibly non-indigenous species *Haploembia tarsalis*, along with its associated parasitoid, *Rossimylops longicornis* (family Tachinidae). The discovery was made in two distinct locations: an urban area in Urmia, West Azarbaijan Province, and a suburban area near the Agark-Nordoz border crossing in East Azarbaijan Province. This finding represents the first documented (establishment?) of an Embioptera colony in Iran, highlighting the possible potential influence of climate change on species distribution. The presence of *H. tarsalis* in the cold, mountainous regions of Iran is particularly significant, as Embioptera are typically associated with tropical and subtropical climates. This unusual distribution might be linked to changing climatic conditions, which facilitate the spread of species beyond their native ranges (Mediterranean). Similar patterns of species translocation have been observed globally, often driven by human activities and climate change (Dehshiri, 2018; Nozaki et al., 2018). The adaptability of *H. tarsalis* to diverse habitats, including urban and suburban environments, raises questions about its ecological impact as a non-indigenous species. Although no immediate threats have been identified, the introduction of new species can disrupt local ecosystems by competing with native organisms or altering habitat dynamics. Further studies are needed to assess the ecological role of *H. tarsalis* in Iran and its potential interactions with local flora and fauna.

The discovery of *H. tarsalis* in Iran's cold and mountainous regions aligns with growing evidence that climate change is influencing species distributions worldwide. As temperatures rise and habitats shift, species may expand into previously unsuitable areas. This finding underscores the importance of monitoring species distributions in the context of climate change, particularly in biodiversity-rich regions like Iran. Climate change is currently exerting a significant influence on the distribution, reproduction, and behavior of various species (Yousefi et al., 2019). All indications point to a worsening scenario, even if immediate actions are taken to reduce future GHG emissions. The anticipated changes include rising temperatures, alterations in precipitation patterns, increasing sea levels, and shifts in ocean chemistry (Mainka & Howard, 2010). The existing body of literature concerning the responses of insect species to climatic fluctuations offers a robust basis for forecasting the overall impact of climate warming on insect populations and their associated communities (Stange & Ayres, 2010). It is anticipated that climate warming will generally increase both the abundance and geographical distribution of many insect species. However, most evidence supporting this prediction is derived from studies focused on terrestrial insect herbivores located in mid- to high-latitude regions. Consequently, it is crucial for future research initiatives to investigate the effects of climate change on insect groups that are currently underrepresented in the existing literature, particularly those from tropical regions, aquatic environments, and higher trophic levels (Stange & Ayres, 2010).

Webspinners, including *Haploembia*, primarily feed on decaying plant material and rarely cause significant harm to living plants (Ross, 1970; 2000). The introduction of any non-indigenous webspinner species warrants careful attention, as these species may adapt to new food sources and cause ecological or economic damage. *Haploembia tarsalis* seems native to the Mediterranean region only; however, it, along with the closely related cryptic species *H. tarsalis*, which also originates from this area, has disseminated globally to various regions, including the Southwestern United States (Ross, 2000; Hodson et al., 2014), Japan (Nozaki et al., 2018), and Georgia (Seropian, Bulbulashvili, & Zukakishvili, 2023). These insects are predominantly a tropical group confined to warmer climates globally, making their presence in the mountainous regions of Iran particularly significant. *Haploembia* spp. and various other embiopterans are being increasingly observed beyond their native habitats (Nozaki et al., 2018; Kočárek et al., 2021; Curtiss, Skoda, Bossert, & Orpet, 2022; Kim et al., 2022; Seropian et al., 2023); however, the implications of their presence on ecosystems are still not well understood. Additional research could elucidate the ecological impacts of the introduced Embioptera. The precise method of introduction remains challenging to determine, yet it may be linked to anthropogenic activities. Apparently the same species has been documented (as *H. solieri*) in Georgia, as reported by Seropian et al. (2023), among other neighboring countries.

The species *Haploembia tarsalis* and *H. solieri* are cryptic species, which are difficult to distinguish due to their morphological similarities, despite being genetically distinct. In a recent integrative study by Kelly et al. (2018), the previously considered parthenogenetic population of *H. solieri* was reclassified as a distinct species, *H.*

tarsalis (Ross, 1940). This reclassification was supported by observable external characteristics, including the contrasting coloration of the venter and dorsum of the abdomen, as well as variations in social behavior, with asexual species exhibiting antisocial tendencies and differences in chromosomal counts.

Nevertheless, subtle diagnostic traits have been documented, such as the higher degree of melanization in *H. solieri* females compared with the more variable coloration observed in *H. tarsalis*. According to Kelly et al. (2018), *Haploembia* populations that lack males are consistently attributable to *H. tarsalis*. In the present study, no males of *H. solieri* were detected in the field-collected populations, and laboratory rearing likewise yielded exclusively female individuals. This consistent absence of males provides strong evidence that the Iranian populations under investigation belong to *H. tarsalis*. In addition, the behavioral assays conducted here further support this identification. Females exhibited pronounced irritability and consistently avoided the proximity of conspecific females; when direct encounters occurred, they frequently retreated backwards. Such avoidance behavior aligns closely with the diagnostic behavioral characteristics of *H. tarsalis* described by Kelly et al. (2018). Taken together, the absence of males in both natural and laboratory populations, coupled with the observed behavioral traits, strongly corroborates our conclusion that the species collected in Iran is *H. tarsalis*. Based on the evidence presented above, it seems highly plausible that the populations identified in Japan (Nozaki et al., 2018) and Georgia (Seropian et al., 2023), which were previously reported as *H. solieri*, may in fact correspond to *H. tarsalis*.

To some extent, it can be said that the classification of *Haploembia* is still ambiguous, with indications that several species could be classified under *H. solieri*. Although molecular and morphological analyses offer valuable information, a comprehensive reassessment of the genus is necessary to delineate species boundaries and clarify the nomenclature. Consequently, it is premature to assign all the parthenogenetic populations to *H. tarsalis*. Additional research is required to address these taxonomic ambiguities and to develop a solid classification framework.



Figure 9. Developmental stages of *Rossimylops longicornis* (Kugler, 1972) (from larva to adult): a) Freshly developed imago; b) Pupa (in vivo); c) Freshly developed pupa (in vitro); d) Larva extracted from Embioptera's body; e) Pupa, pre-emergence stage.

During the rearing of *H. tarsalis* colonies, parasitoid pupae belonging to the family Tachinidae were observed and identified as *R. longicornis*, marking the first record of this parasitoid in Iran. Tachinid flies are known for their role as endoparasitoids of various arthropods, and their association with Embioptera has been documented in limited studies, primarily by Edward S. Ross (Badano et al., 2022). In April 2024, the first pupae of the parasitoid flies were observed (Fig. 9b). The nymphs infected with parasitoids within the colony and tunnels were relatively immobile and inactive (Figs. 8d, 8f). Through dissection of the infected specimens, fully developed fly larvae (Fig. 9d) were extracted from their bodies and maintained separately. These larvae pupated within 48 h (Figs. 8a-b; 9b, 9c, 9e), and after 10 days, adult parasitoid flies emerged (Figs. 8c, 8e, 8g; 9a). From the parasitized specimens, nothing remains except an external shell containing a fly pupa inside (Fig. 8b). The fly pupae were observed within the exoskeletons of the web-spinners (Fig. 8a). In total, 28 pupae were extracted from the colony tunnels and maintained separately (among these, two pairs of fully mature males and females, along with ten females and eight immature males, were collected). The emergence of adult parasitoid flies occurred in the early hours of the day (Fig. 8e), and the process was documented on video.

The discovery of *R. longicornis* in Iran adds to the growing body of knowledge on parasitoid-host relationships and highlights the importance of studying these interactions in under-researched insect orders. A total of 28 parasitoid pupae were extracted from the colony tunnels, including 10 females, 8 immature males, and 2 pairs of mature males and females. This finding underscores the importance of studying host-parasitoid interactions in understudied insect orders such as Embioptera. The presence of *R. longicornis* as a parasitoid of *H. tarsalis* suggests a potential regulatory mechanism for Embioptera populations. Further research is needed to understand the full life cycle, host specificity, and ecological impact of *R. longicornis* in Iran.

Although this study provides valuable insights into the presence of Embioptera and their parasitoids in Iran, it has certain limitations. The sampling was restricted to two locations, which may not fully represent the distribution of Embioptera in the country. In addition, the ecological impact of this species and its other parasitoids remains unclear. Future studies should focus on broader geographical sampling, ecological interactions, and the potential effects of climate change on the distribution and behavior of Embioptera and their associated parasitoids.

This study reports the first record of Embioptera (*Haploembia tarsalis*) and its associated parasitoid (*Rossimylops longicornis*) in Iran. These findings contribute to the understanding of Iran's insect biodiversity and highlight the possible potential role of climate change in shaping species distributions. The discovery of *H. tarsalis* in a presumably non-native habitats underscores the need for continued monitoring of species translocations and their ecological impacts. Further research on the biology, ecology, and interactions of these species will provide valuable insights into their role in Iran's ecosystems and the broader implications of climate change on biodiversity.

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