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RESEARCH

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New fly records of potential biological control importance in Saudi Arabia (order Diptera)

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Abstract

Background The Ministry of Environment, Water and Agriculture in Saudi Arabia has begun funding some projects to set up some agricultural pest control programs. Therefore, it is very important to enumerate all the predacious or parasitic insects that live on or in other agricultural insect pests and have the potential to become biological control agents against these pests.

Results In the present study, nine fly species of potential importance in biological pest control are recorded for the first time from Saudi Arabia, namely, *Spogostylum ventrale* Bezzi, 1924, *Prothaplocnemis anthracina* (Becker, 1902) [family Bombyliidae], *Alloxytropus anomalus* Bezzi, 1925, *Scenopinus minusculus* (Séguy, 1934) [family Scenopinidae], *Actorthia frontata* Kröber, 1912, *Hoplosathe brevistyla* Lyneborg & Zaitzev, 1980 [family Therevidae], *Hilara* sp. [family Empididae], *Tomosvaryella demeyeri* Kuznetzov, 1993 [family Pipunculidae] and *Orchisia costata* (Meigen, 1826) [family Muscidae]. In addition, this is the first time to record the four genera *Prothaplocnemis* Bezzi, *Alloxytropus* Bezzi, *Hilara* Meigen and *Orchisia* Rondani from Saudi Arabia. World and local distributions, diagnoses, feeding behaviors and some colored photographs of recorded species are provided.

Conclusion In the present study, nine species of predacious and parasitic flies belonging to nine genera and six families are recorded for the first time in Saudi Arabia.

Keywords Predators, Parasitoids, Bombyliidae, Scenopinidae, Therevidae, Pipunculidae, Muscidae

Background

Traditional management of agricultural pests using pesticides has damaging effects on many non-target terrestrial arthropods in agro-ecosystems, including the natural enemies (predators and parasitoids) of these agricultural pests (El-Wakeil et al. 2013). Insecticide treatments are also challenged by the stringent residue levels applied in export markets, in the broader context of the adverse effects that have been recognized on human and ecosystem health. As a result, management practice has evolved toward alternative methods such as biological control techniques (Bourguet and Guillemaud 2016). Biological control has been the most researched control tactic within any management programs, and parasitoids have been the main natural enemies used against pestiferous arthropod species (Dias et al. 2018). However, although predators are not the focus of many biological control programs, they play an important role in conservation biological control, and studies that evaluate or use agricultural techniques that do not affect an assemblage of predators of some pests, such as the use of selective pesticides, must be intensified (Garcia et al. 2020). Also, predators are the key natural enemies important in the

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biological control of certain pests as aphids (Bugg et al. 2008).

There are many essential integrated elements and steps for any successful classical biological control program. The preliminary taxonomy and survey studies of candidate natural enemies as predators and parasitoids are among the most essential of these steps. Although all other steps are necessary in any program, the major research objectives concentrate on the preliminary taxonomic and survey of natural enemies (Van Driesche and Bellows 1996).

In the present study, nine species of predacious and parasitic flies belonging to nine genera and six families have been recorded for the first time in Saudi Arabia. Four of the genera have been also recorded for the first time, giving taxonomic and faunistic significance to the study, namely *Prothaplocnemis* Bezzi (family Bombyliidae), *Alloxytropus* Bezzi (family Scenopinidae), *Hilara* Meigen (family Empididae) and *Orchisia* Rondani (Family Muscidae).

Considering the southwestern part of Saudi Arabia as affiliated to the Afrotropical Region, *Actorthia frontata* Kröber (family Therevidae) has been recorded herein for the first time from the Afrotropical Region, as it was collected from Najran Province.

Only two families, out of the six treated, were extensively studied in Saudi Arabia, Bombyliidae [by El Hawagry and Al Dhafer (2019a) and El-Hawagry et al. (2022)] and Muscidae [by Dawah et al. (2020)]; however, only a few number of species from the remaining four families were separately recorded in some miscellaneous papers.

Methods

Material was collected since 2018 by the authors and/or their coworkers using aerial nets from various locations in Saudi Arabia. Only three specimens of *Tomosvaryella demeyeri* were also collected using Malaise traps from Tabuk in 2021. Specimens were identified by the first author using relevant keys, and identifications of the Therevidae and Muscidae were confirmed by Dr. Martin Hauser and Dr. Adrian Pont, respectively.

The type locality for each recorded species is given. For recorded species, world distributions as reported in world catalogs and related studies, local distributions, diagnoses, comments on feeding behaviors and some colored photographs are provided.

Photographs were taken using a Leica MZ 125 stereo microscope (Leica Microsystems Ltd, St. Gallen, Switzerland), fitted with a digital camera (Q-imaging Micro Publisher 5.0 RTV; Zerene Systems LLC, Richland, WA, USA) at the Plant Protection Department, College of Food and Agriculture Sciences, King Saud University. Photograph auto-montage was performed using the Zerene stacker program version 1.04 (Innovative Solutions, Bucharest, Romania).

Since Saudi Arabia has no distinct ecological zones, administrative divisions (also called regions or provinces) are used instead, namely: Al-Baha, Al-Jawf, Al-Madinah, Al-Qasim, Jazan, Najran, Riyadh, Tabuk, etc. Countries in world distributions and regions in local distributions are listed alphabetically. Localities within each region are written after a colon, followed by the coordinates in parentheses, followed by the governorates to which they belong within square brackets, e.g., "Al-Jawf: Baseita (29.872219° N, 38.306257° E) [Tabarjal Gov.]."

Results

Superfamily Asiloidea

Family Bombyliidae

Spogostylum ventrale Bezzi 1924

Spongostylum ventrale Bezzi 1924: 174. Type locality: Kenya & Ethiopia.

World distribution AF: Eritrea, Ethiopia, Kenya, Oman, Saudi Arabia [as "southwestern part"] (first record), Yemen (Abd-el-Kuri). PA: Egypt. [Sources: El-Hawagry (2018) and present study]

Local distribution Al-Baha: Aqabet Al-Baha (19.906183° N, 41.440414° E) [Al-Mekhwa Gov.].

Material examined 1 female, 1 male, Aqabet Al-Baha, 12.5.2022, Al-Ghamdi, leg., MSHC.

Diagnosis Large flies, about 10 mm in length (Fig. 1); frons with black hairs, usually mixed with white or yellowish-white hairs and scales; lower part of face with long white hairs mixed with few black ones; thorax with scutum and scutellum clothed with yellowish-white tomentum, with black bristles at margins; wings hyaline, with only two submarginal cells, with inconspicuous ill-defined brownish spots on cross-veins and origin of vein R_{2+3}; abdomen covered with yellowish-brown scales and black hairs, with tufts of long flattened black or dark brown hairs and scaly hairs on sides of 2nd and

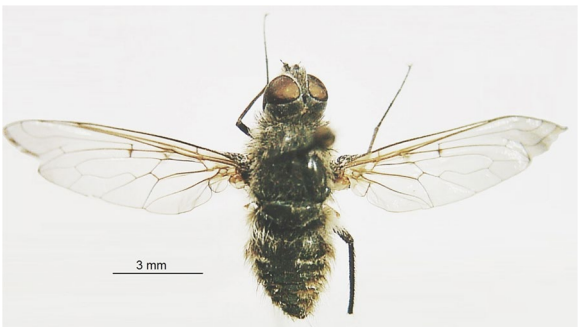

Fig. 1 *Spongostylum ventrale* Bezzi male habitus, dorsal view

4th tergites, with long hairs on sides of last three tergites predominantly white.

Feeding behavior Species of the genus *Spogostylum* are known as ectoparasitoids of solitary bees, wasps, egg pods of Acrididae and cocoons of pyralid moths (Yeates and Greathead 1997).

Prothaplocnemis anthracina (Becker 1902)

Argyromoeba anthracina Becker 1902: 29. Type locality: Egypt.

World distribution AF: Oman, Saudi Arabia [as "southwestern part"] (first record). PA: Egypt, Israel. [Sources: Evenhuis and Greathead (2015) and present study]

Local distribution Al-Baha: Aqabet Al-Baha (19.906183° N, 41.440414° E) [Al-Mekhwa Gov.].

Remark This is the first time to record the genus *Prothaplocnemis* Bezzi and its species *P. anthracina* Becker from Saudi Arabia.

Material examined 1 female, Aqabet Al-Baha, 12.5.2022, Al-Ghamdi, leg., MSHC.

Diagnosis Small fly, about 3 mm in length; cuticle shining black with patches of white hairs and scales and glossy black scales; frons and lower part of face with short black hairs; face slightly gray pollinose; occiput with some white scales; wings iridescent, hyaline; legs black, covered with faint yellowish scales; fore tibiae smooth; laterotergite with a tuft of white hairs; 1st abdominal tergite covered with white scales, its sides with tufts of white hairs; other tergites covered with only sparse black hairs and traces of white scales on the last two tergites, their sides with white hairs.

Feeding behavior This species is thought to be a predator of the eggs of Acrididae and the pupae of noctuid moths (Greathead and Evenhuis 2001).

Family Scenopinidae

Alloxytropus anomalus Bezzi 1925

Alloxytropus anomalus Bezzi 1925: 187. Type locality: Egypt (Qena and Wadi Hoff).

World distribution AF: Saudi Arabia [as "southwestern part"] (first record), Sudan. PA: Egypt, Israel. [Sources: Winterton and Kerr (2006), El-Hawagry (2015) and present study].

Local distribution Najran: Uruq Bani Ma'arid (19.107986° N, 45.191925° E) [Yadamah Gov.].

Remark This is the first time to record the genus *Alloxytropus* Bezzi and its species *A. anomalus* Bezzi from Saudi Arabia.

Material examined 1 male, 1 female, Uruq Bani Ma'arid, 31.V.2021, Al-Dhafer H., Soliman A., Rassol I., leg., KSMA.

Diagnosis Small- to medium-sized fly, about 4 mm in length (Fig. 2); head entirely yellowish; ocellar triangle prominent and brownish; proboscis, palpi and antennae

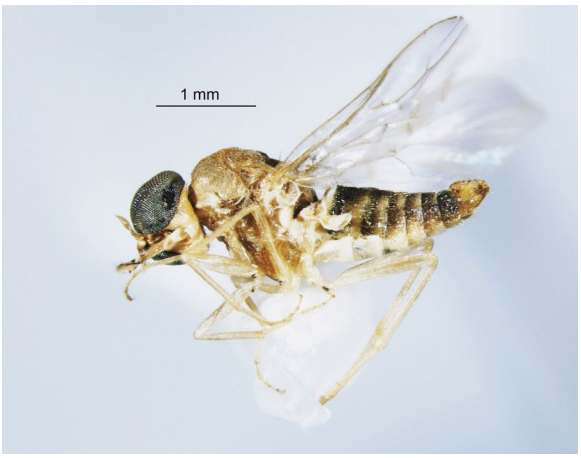

Fig. 2 *Alloxytropus anomalus* Bezzi male habitus, lateral view

yellowish; mesonotum yellowish or pale yellowish-brown, occasionally with two obscure indistinct darker longitudinal stripes, without any pubescence; scutellum uniformly yellowish; wings hyaline; legs entirely whitish-yellow, with femora sometimes brownish; abdomen with tergites whitish-yellow to brownish, with short whitish-yellow hairs; hypopygium brownish-orange to yellowish-brown; sternites uniformly yellowish-white.

Feeding behavior In general, the larvae of the family Scenopinidae are all predaceous on other arthropods (Kelsey 1969).

Scenopinus minusculus (Séguy 1934)

Omphrale minusculus Séguy 1934: 74. Type locality: Madagascar.

World distribution AF: Madagascar, Seychelles. PA: Saudi Arabia (first record). [Sources: Kelsey (1969) and present study].

Local distribution Tabuk: Tadco3 farm (28.62315° N, 36.19008333° E) [Tabuk Gov.].

Material examined 1 female, Tadco3 farm, 22.V.2018, Al-Dhafer et al., leg., KSMA.

Diagnosis Small fly, about 2.5 mm in length; head dark brown; frons shining with central depression; ocellar triangle slightly prominent; antennae black with flagellum covered with short hairs; thorax shining; wings smoky white; halter white; legs brownish, with tarsi yellowish; abdomen dark brown, with 8th sternum short.

Feeding behavior In general, the larvae of the family Scenopinidae are all predaceous on other arthropods (Kelsey 1969).

Family Therevidae

Actorthia frontata Kröber 1912

Actorthia frontata Kröber 1912: 30. Type locality: Egypt (Tourrah).

Gyrophthalmus khedivialis Becker 1912: 312. Type locality: Egypt (Cairo).

World distribution AF: Saudi Arabia [as "southwestern part"] (first record). PA: Egypt. [Sources: El-Hawagry (2015) and present study]

Remark Considering the southwestern part of Saudi Arabia including Najran Province as affiliated to the Afrotropical Region, this species is recorded herein for the first time from the Afrotropical Region.

Local distribution Najran: Uruq Bani Ma'arid (19.024408° N, 45.197168° E) [Yadamah Gov.].

Material examined 1 female, Uruq Bani Ma'arid, 6.III.2021, Abdel-Dayem M., Soliman A., Sharaf M., leg., KSMA.

Diagnosis Medium-sized fly, about 6.5 mm in length (Fig. 3); head dusted light ash gray, with short white hairs; antennae yellowish, with flagellum somewhat darkened; thorax black in ground color, dusted yellowish-gray, with fine pale yellow hairs, with basal half of scutellum velvety black-brown; thoracic pleura light ash gray; halter creamy-white; legs blackish with, with basal half of mid and hind tibia reddish-yellow, with coxae and femora gray dusted; anterior cubital cell (*cua*) and third medial cell (m_3) cell closed and long stalked; abdomen reddish brown at basal half, shiny black at apical half; abdominal tergites with creamy apical margins, with short white hairs.

Feeding behavior Larvae are important predators of soft bodied arthropods in agricultural and forestry ecosystems, attacking a wide variety of pest insect larvae (Hauser 2017a and Hauser et al. 2017b).

Hoplosathe brevistyla Lyneborg & Zaitzev 1980

Hoplosathe brevistyla Lyneborg & Zaitzev 1980: 88. Type locality: Iran (Belutschistan).

World distribution AF: United Arab Emirates. PA: Iran, Saudi Arabia (first record). [Sources: Hauser (2017a) and present study]

Local distribution Al-Jawf: Baseita (29.872219° N, 38.306257° E) [Tabarjal Gov.]. Al-Madinah: Al-Ushayrah (24.036572° N, 39.668434° E) [Al-Madinah Gov.]. Al-Qassim: Ar Rass (25.71861111° N, 43.40972222° E) [Ar Rass Gov.].

Material examined 1 female, Nadco3, National Agricultural Development Company, Baseita, 24.V.2018, Al-Dhafer et al., leg., KSMA; 1 male, Al-Dahabiah farm, Al-Ushayrah, 19.V.2018, Al-Dhafer et al., leg., KSMA; 2 males, Al-Aofi farm, Ar Rass, 3.V.2018, Al-Dhafer et al., leg., KSMA.

Diagnosis Large fly, about 10 mm in length (Fig. 4); head whitish-gray tomentose, tinged yellowish on upper part of occiput; antennae yellowish, with terminal stylus blackish; flagellum at most 2.5 × as long as wide from lateral view; mesonotum with three brownish-gray vittae, all three vittae with same color; scutellum brownish, slightly darkened on dorsal surface; wings banded; femora predominantly grayish, yellowish-brown apically and at extreme bases; abdomen with orange coloration on the first five tergites; postero-lateral corners of 2nd, 3rd and 5th abdominal tergites with small white pollinose spots; halter yellowish-brown with knob darkened at tip.

Feeding behavior Larvae are important predators of soft bodied arthropods in agricultural and forestry ecosystems, attacking a wide variety of pest insect larvae (Hauser 2017a and Hauser et al. 2017b).

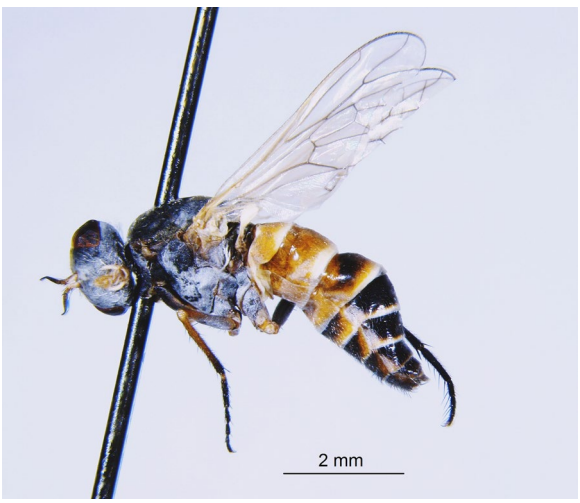

Fig. 3 *Actorthia frontata* Kröber female habitus, lateral view

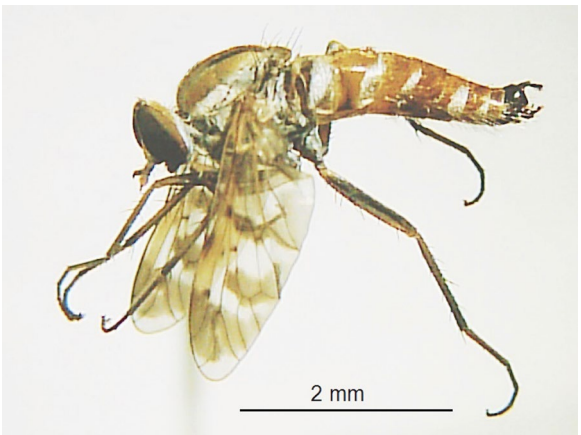

Fig. 4 *Hoplosathe brevistyla* Lyneborg & Zaitzev female habitus, lateral view

Superfamily Empidoidea

Family Empididae

Hilara sp.

Local distribution Al-Jawf: Baseita (30.05769444°N, 38.27827778°E); Dawmat Al-Jandal (29.87666667° N, 39.56888889° E) [Dawmat Al-Jandal Gov.]; Nabk Abu Qasr (30.33047222° N, 38.71775° E [Tabarjal Gov.].

Remark This is the first time to record this genus from Saudi Arabia; however, more specimens are required for identification to the level of species.

Material examined 1 male, Abdullah Al-Rwais farm, Baseita, 9.III.2022, Al Ansi et al., leg., KSMA; 1 male, Mohammed Salim farm, Nabk Abu Qasr, 7.III.2022, Al Ansi et al., leg., KSMA; 1 male, Aladarea farm, Dawmat Al-Jandal, 7.III.2022, Al Ansi et al., leg., KSMA.

Diagnosis Male: Medium-sized fly, about 5 mm in length (Fig. 5); antenna with 1st flagellomere shorter than proboscis, distinctly tapered, stylus about 1/3 length of 1st flagellomere; laterotergite bare; costa circumambient; subcostal vein (*Sc*) complete, reaching costal vein (*C*) vein; anterior branch of radius (R_1) distinctly dilated before joining costal vein (*C*); third branch of radius (R_{4+5}) forked at an angle less than 45°; first and second branches of media (M_1 and M_2) extend to wing margin; first tarsomere in male fore leg enlarged.

Feeding behavior Larvae are predaceous and live in the soil. The adult males are predaceous as well; usually search for small preys floating on the surface of pools, ponds, brooks or streams (Grootaerf and Kiatsoonthorn 2001).

Superfamily Syrphoidea

Family Pipunculidae

Tomosvaryella demeyeri Kuznetzov 1993

Tomosvaryella demeyeri Kuznetzov 1993: 157. Type locality: Egypt (Aswan).

World distribution PA: Egypt, Iran, Saudi Arabia (first record). [Sources: El-Hawagry et al. (2019a, b) and present study].

Local distribution Al-Jawf: Baseita (29.8464° N, 38.49733333° E) [Tabarjal Gov.]. Al-Madinah: Al-'Ula (26.70222222° N, 38.06083333° E) [Al-'Ula Gov.]; Yanbu Al-Nakhel (24.358° N, 38.43725° E) [Yanbu Gov.]. Al-Qassim: Al-Badayea (25.95444444° N, 43.80166667° E) [Al-Badayea Gov.]; Al-Shimasiyah (26.3575° N, 44.2275° E) [Al-Shimasiyah Gov.]; Ar Rass (25.71861111° N, 43.40972222° E) [Ar Rass Gov.]; Riyadh Al-Khabra (26.03333333° N, 43.55472222 °E) [Riyadh Al-Khabra Gov.]; Unaizah (26.1585333° N, 43.974333° E) [Unaizah Gov.]. Jazan: Al-Aridhah (17.04633333° N, 43.07572222 ° E) [Al-Aridhah Gov.]. Riyadh: Al-Majma'ah (25.83944444° N, 45.42861111° E) [Al-Majma'ah Gov.]; Hawtat Bani Tamim (23.26398333° N, 46.72183333° E). Tabuk: Tabuk (28.693213° N, 36.365619° E) [Tabuk Gov.].

Material examined 1 male, Jadco3, Baseita, 20.VI.2021, Al-Dhafer et al., leg., KSMA; 1 male, 1 female, Ibrahim Alzahoti farm, Al-'Ula, 20.III.2022, M. Alharbi et al., leg., KSMA; 1 female, Faisal Alqadhi farm, Yanbu Al-Nakhel, 8.II.2022, M. Alharbi et al., leg., KSMA; 1 male, Abdulrahman Algudiri farm, Al-Majma'ah, 20.X.2021, H. Chebbi & H. Abbad leg., KSMA; 1 female, Wadi Birk 2, Hawtat Bani Tamim, 8.V.2018, Aldafer et al. leg., KSMA;

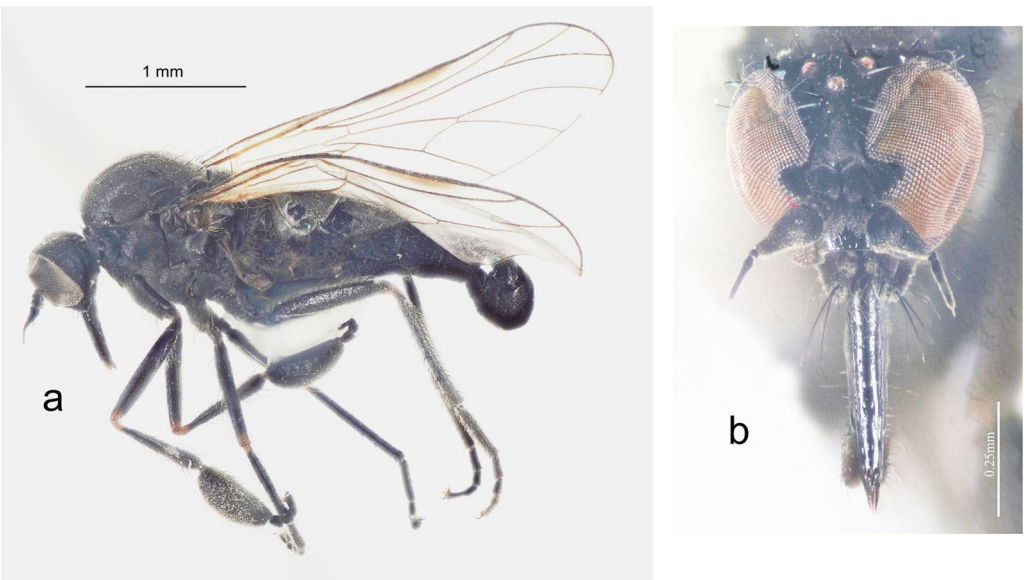

Fig. 5 *Hilara* sp. **a** male habitus, lateral view. **b** head, frontal view

1 female, Tabuk, Astra 5 farm, 17-19.VII.2021, Aldafer & Soliman leg., KSMA; 1 female, Abdullah Alatibi farm, Al-Badayea, 12.X.2021, H. Chebbi & H. Abbad leg., KSMA; 1 female, Salah Alanazi farm, Riyadh Al-Khabra, 24.VIII.2021, H. Chebbi & H. Abbad leg., KSMA; 1 male, Salah Azzaidi, Ar Rass, 7.VI.2022, H. Chebbi & H. Abbad leg., KSMA; 1 female, Saleh Faqih farm, Jazan, 8.XII.2021, U. El-Ghiet & B. Bu Salem leg., KSMA.

Diagnosis Small fly, about 2.3 mm in length (Fig. 6); head spherical; face almost equal in width to lower part of frons; frons not swollen when seen from lateral view; occiput swollen, clearly visible from lateral view; flagellum dark brown with yellowish tip, distinctly larger than pedicel; wing without pterostigma; discal medial cell (*dm*) expanded convexly distally after *r-m* cross-vein; cross-vein *r-m* located at middle of cell *dm*; legs mainly dark brown, yellowish or tawny brown at tips of femora, bases and tips tibiae and basal tarsomeres; hind femur with distinct ventro-basal protuberance, with some distinct spines; epandrium longer than wide; surstyli short, widened in the middle and gradually tapering toward the tip when viewed from the dorsal view.

Feeding behavior Larvae are endoparasitoids of nymphs and adults of the hemipteran suborder Auchenorrhyncha, including Cercopidae, Cicadellidae, Cixiidae, Delphacidae, Flatidae, Issidae and Membracidae (El-Hawagry et al. 2019a, b).

Superfamily Muscoidea

Family Muscidae

Orchisia costata (Meigen 1826)

World distribution AF, AU and OR: Widespread. PA: China, Europe (widespread), Japan, Korea, Saudi Arabia (first record). [Sources: *Suh* and Kwon (*2017) and present study]*

Remark This is the first time to record the genus *Orchisia* Rondani and its species *O. costata* (Meigen) from Saudi Arabia.

Local distribution Al-Jawf: Sakaka (29.96° N, 40.32186111° E) [Sakaka Gov.]. Al-Madinah: Al-Utheeb (26.68777778° N, 37.91083333° E) [Al-'Ula Gov.]. Al-Qassim: Al-Bukayriyah (26.20611111° N, 43.62777778° E) [Al-Bukayriyah Gov.]; Al-Mithnab (25.77416667°N, 44.25916667° E) [Al-Mithnab Gov.]; Unaizah (26.05166667° N, 43.92138889° E) [Unaizah Gov.]. Riyadh: Al-Kharj (24.29361111° N, 47.15555556° E) [Al-Kharj Gov.]; Ouyayna (24.89361111° N, 46.43083333° E) [Diriyah Gov.]; Wadi El-Dawaser (20.46805556° N, 44.84944444° E) [Wadi El-Dawaser Gov.]. Tabuk: Taymaa (27.49483333° N, 38.57869444° E & 27.65669444° N, 38.60738889° E) [Taymaa Gov.].

Material examined 1 male, 1 female, Abdullah Alsalamah sons farm, Taymaa, 11.II.2022, Al Ansi et al., leg., KSMA; 1 male, 1 female, Alshareef farm, Al-Utheeb, 21.III.2022, M. Alharbi et al., leg., KSMA; 1 female, Abdulmohsen Arrasiss farm, Al-Kharj, 6.IV.2022, H. Chebbi & H. Abbad leg., KSMA.

Diagnosis Small- to medium-sized fly, about 4 mm in length (Fig. 7); head yellowish in ground color, with frontal vitta brownish to orange; fronto-orbital plates with grayish dust; parafacialia and cheeks yellowish with grayish dust; antenna yellowish with flagellum slightly darkened and arista short plumose along its entire length; palpi yellowish; thorax black in ground color, gray dusted; scutellum with only the apical pair of setae strong; legs predominantly yellowish-brown; wings pale smoky-brown, conspicuously darkened along costal margin, with spinules along costa strong and erect; halter yellowish-brown to orange; abdomen predominantly yellowish-brown, grayish dusted, darkened at last three tergites.

Feeding behavior As members of the muscid subfamily Coenosiinae, adults are predaceous (Gregor et al. 2002).

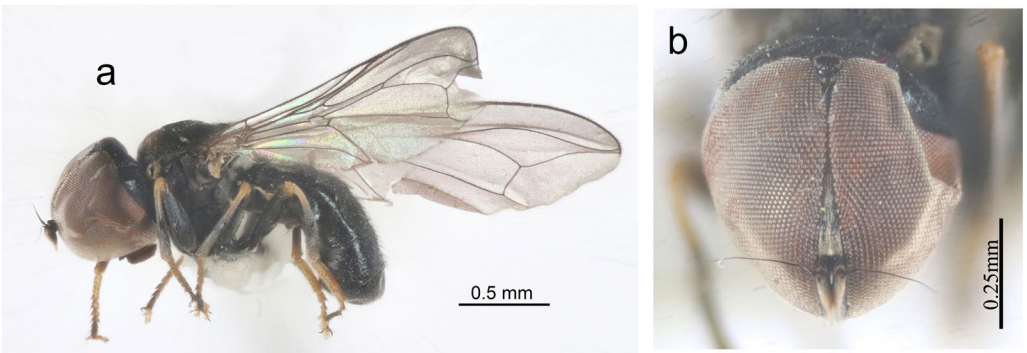

Fig. 6 *Tomosvaryella demeyeri* Kuznetzov **a** Male habitus, lateral view. **b** Head, frontal view

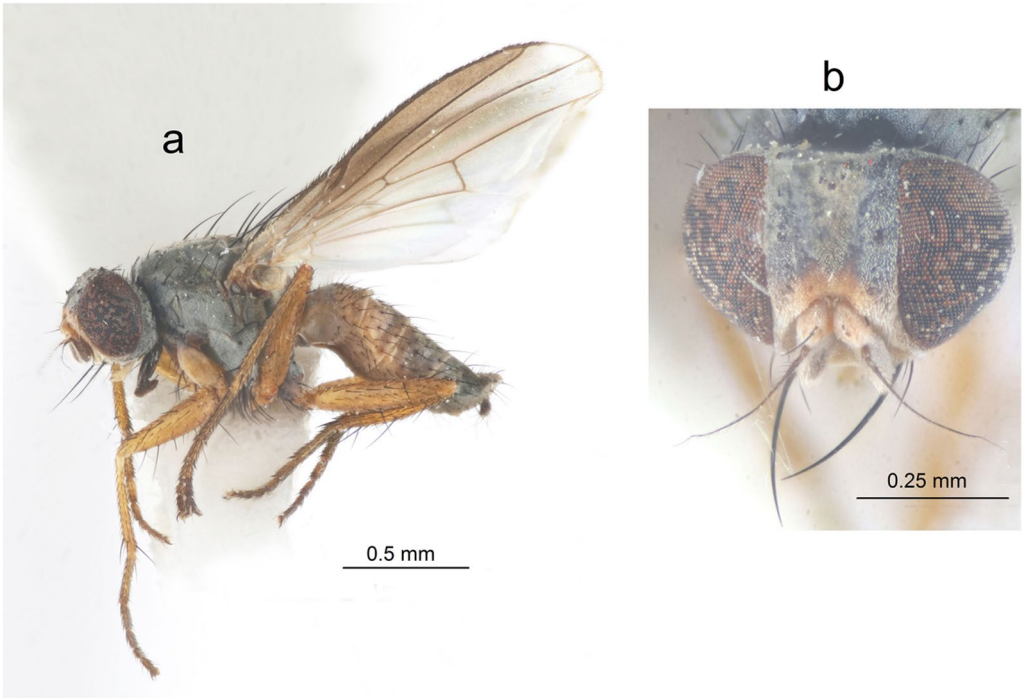

Fig. 7 *Orchisia costata* (Meigen). **a** male habitus, lateral view. **b** head, frontal view

Discussion

The present paper is a part of serial studies planned in the Kingdom of Saudi Arabia aiming to enumerate all the predacious or parasitic flies living on or in other agricultural insect pests. These flies have the potential to be used as biological control agents against these pests and as a key component in any agricultural pest management (El-Hawagry and Al Dhafer 2019).

Native parasitoid and predator species surely adapt better to natural environmental conditions and can even be used to complement exotic parasitoid and predator species that may be introduced from other places for biological control programs (Miranda et al. 2015).

In different farming systems, various parasitic and predatory insects play important roles in reducing problems with agricultural pests (Bugg et al. 2008), and biological control has been the most researched control tactic within many pest management programs (Garcia et al. 2020). Information regarding the diversity of parasitoids and predators on agricultural pests in Saudi Arabia is still limited; therefore, this study may help in compiling a list of parasitoid and predator species associated with agricultural pests and have the potential to be used as biological control agents against these pests and a key component in any future agricultural pest management.

Although the family Bombyliidae, for instance, was studied intensively in Saudi Arabia and 123 different species were recorded by El-Hawagry and Al Dhafer (2019) and El-Hawagry et al. (2022), two other species have been recorded for the first time in the present study. This certainly indicates that the data on fly distribution in Saudi Arabia are still scanty, and more efforts are highly desired in the future.

Conclusions

In the present study, nine species of predacious and parasitic flies belonging to nine genera and six families have been recorded for the first time from Saudi Arabia and added to the country's fly fauna.

Abbreviations

AF	Afrotropical region
AU	Australasian region
OR	Oriental region
PA	Palearctic region
Gov.	Governorate
KSMA	King Saud University Museum of Arthropods, Riyadh, Saudi Arabia
MSHC	Personal collection of M. El-Hawagry

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Author contributions

ME collected and identified flies and drafted the manuscript. AS participated in identifying the flies and drafting the manuscript. MA collected and photographed flies. HA participated in collecting and identifying some flies. All

authors participated in the study design and coordination and interpreted the data. All authors have read and approved the manuscript.

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Data supporting the conclusions of this article are presented in the main manuscript.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

Becker T (1902) Aegyptische dipteren. Mitt Zool Mus Berl 2(2):1–66
Becker T (1912) Beitrag zur Kenntnis der Thereviden. Verh Zool-Bot Ges Wien 62:289–319
Bezzi M (1924) The Bombyliidae of the Ethiopian region. British Museum (Natural History), London, p 390
Bezzi M (1925) Quelques notes sur les bombyliides (Dipt.) d'Egypte, avec description d'espéces nouvelles. Bull Soc R Entomol Egypte 8:159–242
Bourguet D, Guillemaud T (2016) The Hidden and external costs of pesticide use. Springer International Publishing, Berlin, pp 35–120
Bugg RL, Colfer RG, Chaney WE, Smith HA, Cannon J (2008) Flower flies (Syrphidae) and other biological control agents for aphids in vegetable crops. University of California Division of Agriculture and Natural Resources, Los Angeles, p 8285
Dawah HA, Abdullah MA, Deeming JC (2020) The Muscidae (Diptera) of Saudi Arabia, descriptions of two new species, new records and updated list of species. Zootaxa 4869(1):1–54. https://doi.org/10.11646/zootaxa.4869.1.1
Dias NP, Zotti MJ, Montoya P, Carvalho IR, Nava DE (2018) Fruit fly management research: a systematic review of monitoring and control tactics in the world. J Crop Prot 112:187–200
El-Hawagry MS (2015) Catalogue of Superfamily Asiloidea (Diptera: Brachycera) of Egypt. LAP Lambert Academic Publishing, Saarbrücken, p 196
El-Hawagry MS (2018) A new species and an updated checklist of the genus *Spogostylum* Macquart. (Bombyliidae: Diptera) from Egypt. Egypt J Biol Pest Control 28:85. https://doi.org/10.1186/s41938-018-0090-8
El-Hawagry MS, Al Dhafer HM (2019a) The family Bombyliidae in the Kingdom of Saudi Arabia (Diptera: Brachycera: Asiloidea). Zootaxa 4590(1):59. https://doi.org/10.11646/zootaxa.4590.1.3
El-Hawagry MS, El-Azab SA, Gilbert F (2019b) Catalogue of the family Pipunculidae in Egypt (Diptera: Cyclorrhapha). Afr Entomol 27(1):238–244. https://doi.org/10.4001/003.027.0238
El-Hawagry MS, Al-Khalaf AA, Soliman AM, Abdel-Dayem MS, DhaferAl HM (2022) Seven new records of bee flies (Bombyliidae, Diptera) from Saudi Arabia. Egypt J Biol Pest Control 32:58. https://doi.org/10.1186/s41938-022-00554-2
El-Wakeil N, Gaafar N, Sallam A, Volkmar C (2013) Side effects of insecticides on natural enemies and possibility of their integration in plant protection strategies. In: Trdan S (ed) Agricultural and biological sciences "insecticides—development of safer and more effective technologies." Intech, Rijeka, pp 1–56
Evenhuis NL, Greathead DJ (2015) World catalog of bee flies (Diptera: Bombyliidae). Revised September 2015. Available from: http://hbs.bishopmuseum.org/bombcat. Accessed 1 June 2022
Garcia FRM, Ovruski SM, Suárez L, Cancino J, Liburd OE (2020) Biological control of tephritid fruit flies in the Americas and Hawaii: a review of the use of parasitoids and predators. InSects 11:662. https://doi.org/10.3390/insects11100662
Greathead DJ, Evenhuis NL (2001) Annotated keys to the genera of African Bombylioidea (Diptera: Bombyliidae; Mythicomyiidae). Afr Invertebr 42:105–224
Gregor F, Rozkošný R, Barták M, Vaňhara J (2002) The Muscidae (Diptera) of Central Europe. Folia Fac Sci Nat Univ Masaryk Brun Biol 107:1–280
Grootaerf P, Kiatsoonthorn V (2001) First record of the dance fly genus *Hilara* in Thailand with descriptions of five new species (Insecta, Diptera, Empididae). Nat Hist Bull Siam Soc 49:17–27
Hauser M (2017a) Order Diptera, family Therevidae. In: van Harten A (ed) Arthropod fauna of the UAE. Department of President's Affairs, Abu Dhabi, pp 538–564
Hauser M, Winterton SL, Kirk-Spriggs AH, Holston KC (2017b) 49. Therevidae (Stiletto Flies). In: Kirk-Spriggs AH, Sinclair BJ (eds) Manual of Afrotropical Diptera. Suricata5. South African National Biodiversity Institute Pretoria, pp 1183–1208
Kelsey LP (1969) A revision of the Scenopinidae (Diptera) of the world. Bull U. S. Natl Mus 277:1–336
Kröber O (1912) (1912) Monographie der palälarktischen und afrikanischen Thereviden. Deutsche Entomologische Zeitschrift 1–32(109–140):251–266
Kuznetzov SY (1993) A new *Tomosvaryella* Aczél from Egypt, with redescription of *T. disjuncta* (Becker) (Diptera, Pipunculidae). Dipterol Res 4:151–162
Lyneborg L, Zaitzev VF (1980) *Hoplosathe*, a new genus of palaearctic Therevidae (Diptera), with descriptions of six new species. Entomol Scand 11:81–93
Meigen JW (1826) Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten. Fünfter Theil. Schultz, Hamm, p 412
Miranda M, Sivinski J, Rull J, Cicero L, Aluja M (2015) Niche breadth and interspecific competition between *Doryctobracon crawfordi* and *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae), native and introduced parasitoids of *Anastrepha* spp. fruit flies (Diptera: Tephritidae). Biol Control 82:86–95
Séguy E (1934) Diptères d'Afrique. Encycl Entomol, Série b, II, Dipt 7:63–80
Suh SJ, Kwon YJ (2017) A new record of the Genus Orchisia (Diptera: Muscidae) from Korea. Anim Syst Evol Divers 33(3):200–202
Van Driesche RG, Bellows TS (1996) Biological control. Chapman and Hall, New York, p 539
Yeates DK, Greathead DJ (1997) The evolutionary pattern of host use in the Bombyliidae: a diverse family of parasitoid flies (Diptera). Biol J Linn Soc 60(2):149–185

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