New species records of flower flies (Diptera, Syrphidae) for Iran

Nuevos registros de especies de sírfidos (Diptera, Syrphidae) de Irán

Ximo Mengual[1,*], Farzaneh Kazerani[2] and Seyedeh Masoumeh Zamani[3]

1. Zoologisches Forschungsmuseum Alexander Koenig, Leibniz-Institut für Biodiversität der Tiere, Bonn, Germany. x.mengual@leibniz-zfmk.de, https://orcid.org/0000-0002-6185-9404; *Corresponding author
2, 3. Research Institute of Forests and Rangelands, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran. 2 farzane.kazerani@gmail.com, https://orcid.org/0000-0003-1968-3350; 3.-zamani832003@yahoo.com, https://orcid.org/0000-0002-4654-7023

Recibido: 23-11-2020. Aceptado: 11-02-2021.
ISSN: 0210-8984 (versión impresa).

Publicado online: 16-03-2021.
ISSN: 2792-2456 (versión online).

ABSTRACT

New records of flower flies (Diptera, Syrphidae) from Iran are reported. The species *Criorhina talyshensis* (Stackelberg) is reported for the first time from Iran, and a female of *Caliprobola aurea* Sack from Mazandaran Province represents the second record of the species from this country. DNA barcodes are provided for both species, together with images and an identification key to *Caliprobola* species.
Key words: Syrphidae; hover flies; flower flies; *Caliprobola*; *Criorhina*; Iran; new record; DNA barcode.

RESUMEN

En este estudio se presentan nuevos registros de moscas de las flores (Diptera, Syrphidae) de Irán. Se cita la especie *Criorhina talyshensis* (Stackelberg) por primera vez en Irán y se presenta una hembra de *Caliprobola aurea* Sack, capturada en la provincia de Mazandaran, como el segundo registro de esta especie en este país. Se proporcionan códigos de barras de ADN para ambas especies, junto con imágenes y una clave de identificación para las especies de *Caliprobola*.

Palabras clave: Syrphidae; hover flies; flower flies; *Caliprobola*; *Criorhina*; Irán; nuevo registro; código de barras de ADN.

INTRODUCTION

Syrphidae (Insecta, Diptera) is a speciose family of true flies with more than 6,300 described species worldwide (SKEVINGTON *et al*., 2019). Commonly known as hover or flower flies, adults feed on pollen and nectar (LARSON *et al*., 2011; ROTHERAY & GILBERT, 2011) while larvae have a large array of different natural histories, such as phytophagy (including fungivory), saprophagy, and predation including parasitoidism (ROTHERAY & GILBERT, 1999, 2011; ROJO *et al*., 2003; PÉREZ-LACHAUD *et al*., 2014). Flower flies provide important ecosystem services, like pollination in natural and agricultural systems (SSYMANK & KEARNS, 2009; INOUYE *et al*., 2015), biological control of pests (TENHUMBERG, 1995; ARCAYA *et al*., 2017) and decomposition of organic matter (LARDÉ, 1989; MORALES & WOLFF, 2010). Moreover, some species are of economical and medical significance (MAGNI *et al*., 2013; HEO *et al*., 2020; PÉREZ-BAÑÓN *et al*., 2020).

Iran has a rich fauna of flower flies with more than 226 recorded species and growing (VAN STEENIS & GHARALI, 2016; GILASIAN *et al*., 2017; KAZERANI *et al*., 2017; VUJIĆ *et al*., 2017; VAN STEENIS *et al*., 2018). Many new records and new species have been reported during the last two decades (see KAZERANI *et al*., 2017) as a result of active Iranian researchers, extensive field campaigns and international collaboration.

In the present work, we report new flower fly records from Iran, including a new *Criorhina* species record.

MATERIAL AND METHODS

Study area, terminology and imaging

Studied flower flies were collected in northern Iran (Mazandaran and Gilan Provinces) using Malaise traps during 2018, within the project "Biodiversity of insects in Hyrcanian Forest". The Hyrcanian Forest (also known as Caspian Forest), dating back some 50 million years, is composed mostly of deciduous forest dominated by *Fagus orientalis* Lipsky and ranges from the Talysh Mountains in the Republic of Azerbaijan to the northern slopes of the Alborz Mountains in North Iran (in the provinces of Gilan, Mazandaran and Golestan). This remarkably intact ecosystem is highly valued by the high number of endemic species, with 3,234 species belonging to 856 genera and 148 families of vascular plants until now (AKHANI *et al*., 2010; JALILI & JAMZAD, 1999).

Morphological terminology follows THOMPSON (1999). We used the following published references for identification: SPEIGHT (2020a) for the genus, VAN STEENIS & GHARALI (2016) for *Criorhina* Meigen, 1822, and SACK (1910) for *Caliprobola* Rondani, 1845.

Photographs were taken with a Canon EOS 7D® mounted on a P–51 Cam-Lift (Dun Inc., VA, USA) and imported with the help of Adobe Lightroom® (version 5.6). Later, images were stacked with Zerene Stacker® 1.04 (Richland, Washington, USA) and edited with Adobe Photoshop® CS5.1. The studied material is deposited in the Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany (ZFMK).

Molecular methods

We sequenced the Folmer region (5' end) of the mitochondrial cytochrome c oxidase subunit I (COI), the so-called DNA barcode (HEBERT *et al*., 2003), of the studied specimens. One leg of ethanol-preserved specimens was used for DNA extraction. The extraction protocol follows MENGUAL *et al*. (2018). Entire specimens were preserved and labelled as DNA voucher specimens for the purpose of morphological studies and deposited at the ZFMK.

The COI sequence fragment was amplified using the forward primer LCO-1490 (5'-GGTCAACAAATCATAAAGATATTG-3') and the reverse primer 780R (5'-CCAAAAAATCARAATARRTGYTG-3'). PCR amplification protocol follows ROZO-LOPEZ & MENGUAL (2015). All new sequences were submitted to GenBank using BOLD (www.boldsystems.org) and GenBank Accession Numbers are indicated for each specimen.

A Neighbour-Joining analysis with the Jukes-Cantor model was carried out with the newly obtained COI sequences we used together with other published COI sequences from GenBank (https://www.ncbi.nlm.nih.gov/genbank/) and in BOLD systems (http://www.boldsystems.org/index.php). Sequences were aligned using Geneious R7 (version 7.1.9, Biomatters Ltd.). Then, we run the Neighbour-Joining analysis using the same software and 1,000 bootstrapping replicates were performed (Figures S1 and S2 in Supplementary material).

RESULTS

Caliprobola aurea Sack, 1910

Examined material. IRAN: Mazandaran Province: Noor, 36.56331 N 52.07111 E, 0 m, 15 May 2018, F. Kazerani leg. (1♀, ZFMK-DIP-00067273).

Differential diagnosis (Figs. 1A, 1B). Easy to identify as there is no other flower fly like this large, shiny golden-metallic green genus. This species can be distinguished from *Caliprobola speciosa* (Rossi, 1790) by the entirely yellow legs (femora partly black in *C. speciosa*), longer abdominal pilosity, and wing entirely yellow tinted (with a dark macula on apical cell r_{2+3} in *C. speciosa*).

Distribution. Azerbaijan and Iran.

Genetics. A female specimen was sequenced (GenBank Accession Number MW128362). The obtained COI sequence is similar (between 97.853% and 98.006%) to the COI sequences of *Caliprobola speciosa* from Germany and Georgia (see Table SI and Fig. S1 in Supplementary material). This is the first published DNA barcode for *C. aurea*.

Remarks. This is the second specimen record of *C. aurea* from Iran and the fourth time that this species is reported in the literature. SACK (1910) described this species based on an unknown number of males and females from the Talysh Mountains (south-eastern Azerbaijan and north-western Iran within Ardabil and Gilan Provinces). PECK (1988) mentioned the Azerbaijani Lankaran District for the distribution of this species. HAUSER (1998) collected a male specimen from Lankaran District and a female specimen from Astara District, both in south-eastern Azerbaijan. Specimens reported by HAUSER (1998) were collected in June and the newly reported female from Mazandaran Province was collected on May. More recently, GILASIAN (2004) reported a male specimen from Mazandaran Province. The record from GILASIAN (2004) and our new female specimen were collected outside the Talysh Mountains.

SACK (1910) provided an identification key for the two species of *Caliprobola*, but he also included in the key *Hadromyia cimbiciformis* (Portschinsky, 1879) as *Caliprobola cimbiciformis*. Since then, no identification key has been published. Here we provide an updated identification key for the only two *Caliprobola* species in the world.

Key to Caliprobola *species*

1. Femora and tibiae entirely yellow (at most the basal 1/20 of the femora dark) (Figs. 1A, 1B). Wing remarkably yellow tinted anteriorly (Fig. 1A). Abdominal pilosity longer, usually covering the posterior half of the tergite so the background colour is not visible (Fig. 1A).....*C. aurea* Sack
— Femora black at least on basal half, usually black on basal 2/3; tibiae yellow (Figs. 1C, 1D). Wing remarkably yellow tinted anteriorly with a dark maculae at apex, between cells r_1 and r_{4+5} (Figs. 1C, 1D). Abdominal pilosity shorter, with longer pile at posterior margin only (Figs. 1C, 1D).....*C. speciosa* (Rossi)

Criorhina talyshensis (Stackelberg, 1960)

Examined material. IRAN (new record): Gilan Province: Shafarood, 37.47167 N 48.82306 E, 1114 m, 22 July 2018, F. Kazerani leg. (1♂, ZFMK-DIP-00067345).

Differential diagnosis (Figs. 1E, 1F). Members of this genus are large bumble bee and bee mimics with the face produced ventrally and the basoflagellomere broader than long. As indicated by VAN STEENIS & GHARALI (2016),

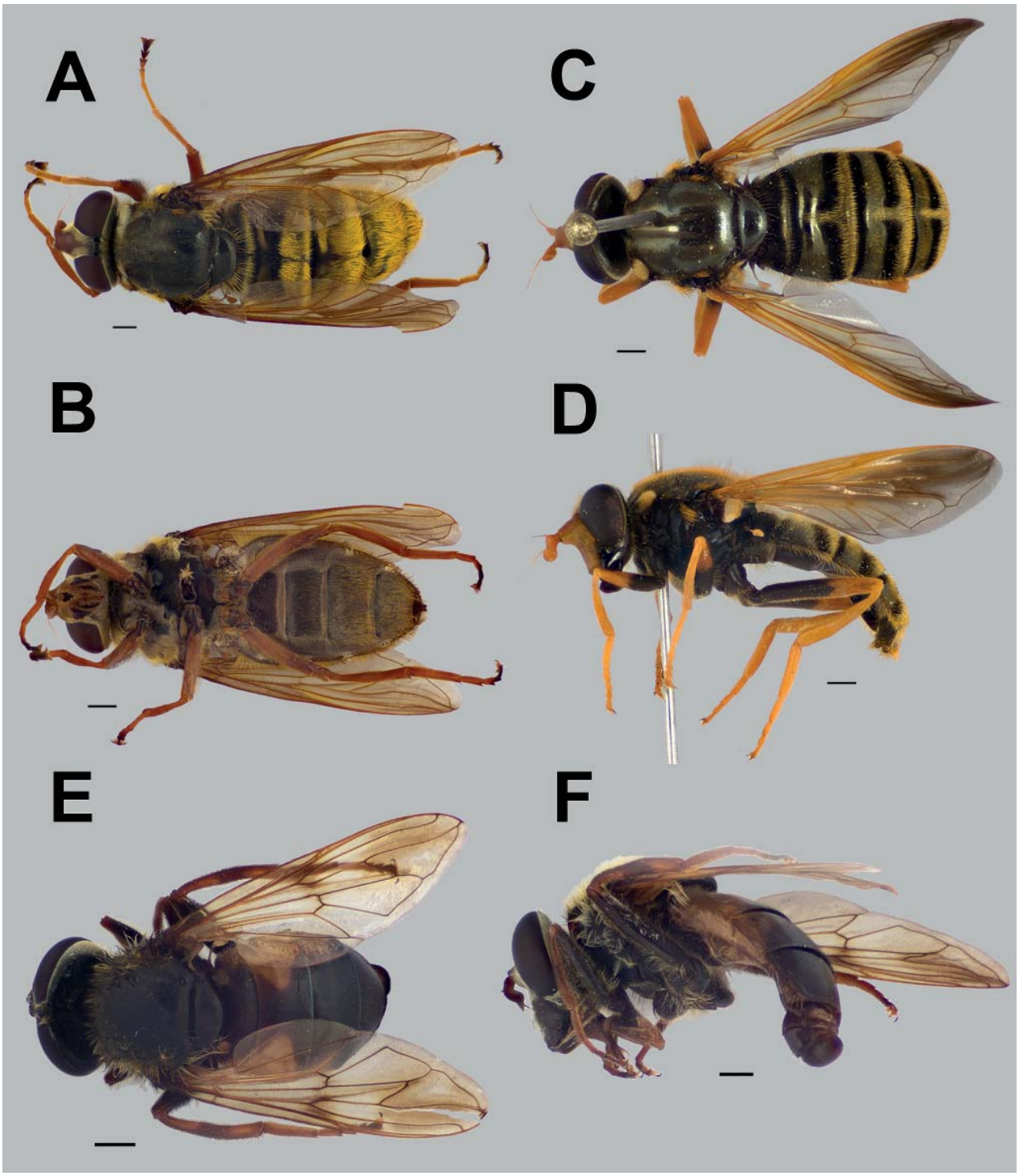

Fig. 1. *Caliprobola aurea* female, Iran (ZFMK-DIP-00067273). A) dorsal view; B) ventral view. *Caliprobola speciosa* female, Georgia (ZFMK-DIP-00063082). C) dorsal view; D) lateral view. *Criorhina talyshensis* male, Iran (ZFMK-DIP-00067345). E) dorsal view; F) lateral view. Scale bars = 1.0 mm.

Fig. 1. *Caliprobola aurea* hembra, Irán (ZFMK-DIP-00067273). A) vista dorsal; B) vista ventral. *Caliprobola speciosa* hembra, Georgia (ZFMK-DIP-00063082). C) vista dorsal; D) vista lateral. *Criorhina talyshensis* macho, Irán (ZFMK-DIP-00067345). E) vista dorsal; F) vista lateral. Barras de escala = 1.0 mm.

Fig. 2. *Criorhina talyshensis,* male genitalia (ZFMK-DIP-00067345). Scale bar = 0.5 mm.
Fig. 2. *Criorhina talyshensis,* genitalia del macho (ZFMK-DIP-00067345). Barra de escala = 0.5 mm.

C. talyshensis can be distinguished from other *Criorhina* species by having the katepimeron bare like *C. berberina* (Fabricius, 1805) and *C. floccosa* (Meigen, 1822) and by the presence of two large, triangular yellow maculae on tergite 2 (also in tergite 3 in male) (Figs 1E, 1F), which are absent in *C. berberina* and *C. floccosa*. Male genitalia is figured in Fig. 2.

Distribution. Known from south-eastern Azerbaijan and Iran (new record).

Genetics. The male specimen from Iran was sequenced (GenBank Accession Number MW128352) and its COI sequence is very similar (98.75% similarity) to other published COI sequences of the same species from Azerbaijan (GenBank Accession Number MK155108). In the Neighbour-Joining analysis both COI sequences of *C. talyshensis* grouped together (see Fig. S2 in Supplemental material). As MENGUAL *et al*. (2020) noted, the nearest neighbour of *C. talyshensis* in BOLD systems is *C. berberina*.

Remarks. Reported for Iran for the first time. Our specimen is the fifth ever published individual after the type series (STACKELBERG, 1960) and the couple collected by HAUSER (1998). All previous records were from Azerbaijan. This is the third *Criorhina* species recorded from Iran, after *C. portschinskyi* (Stackelberg, 1955) (VAN STEENIS & GHARALI, 2016) and *C. ranunculi* (Panzer, 1804) (GILASIAN *et al*., 2017). The occurrence of this species in Iran was hypothesised by VAN STEENIS & GHARALI (2016) and confirmed with our record. The flight period of *C. talyshensis* based on published records was

from end April to mid June (STACKELBERG, 1960; HAUSER, 1998), but this new male record is from end July.

DISCUSSION

The faunistic and floristic biodiversity of the Hyrcanian Region is on a global level significant. Approximately 44% (over 3,200 species) of known vascular plants in Iran occurs in the Hyrcanian Region, which covers only 7% of Iran's territory (AKHANI *et al*., 2010). About 280 taxa are endemic and sub-endemic for the Hyrcanian Region and almost 500 plant species are Iranian endemics as well as a total of 80 native tree species have been registered from Hyrcanian forest (TOHIDIFAR *et al*., 2016). The invertebrate diversity in the Hyrcanian Forests is still under research, but nobody would be surprised with similar numbers of endemic taxa. In a study about diversity of saproxylic insects in Hyrcanian forest, 361 beetle and 7 true bug species were identified; of these, 56 species were endemic (MÜLLER *et al*., 2018). Recently, a new endemic syrphid was described from the Hyrcarian Forests (GILASIAN *et al*., 2017).

The biology of the two flower fly species here reported is unknown. Known larvae of the genera *Caliprobola* and *Criorhina* are saproxylic and are found in coniferous and deciduous forests with overmature trees (ROTHERAY & GILBERT, 2011; SPEIGHT, 2020b). PROKHOROV & SHPARYK (2019) indicated that larvae of *C. speciosa* develop in soft, moist, rotting wood of old oak and beech trees. HAUSER (1998) stated that the two collected specimens of *C. aurea* flew from hollows in oak (*Quercus*) logs. VAN STEENIS & GHARALI (2016) noted that *Criorhina talyshensis* "has been collected in open, heavily grazed mixed oak forest (*Quercus petraea* (Matt.) Liebl. and *Fagus orientalis*) with small streams and south-facing dry slopes." In the present study, *C. aurea* and *C. talyshensis* were collected in temperate broadleaf and mixed forests (Hyrcanian Forests) covered mostly by the Oriental Beech (*Fagus orientalis*) followed by oak, alder, hornbeam, maple, elm, etc. (MARVIE MOHADJER, 2005). Published records of both species are very low in numbers, a fact that may indicate that these species have a limited distribution and/or a very specific ecological niche.

Overmature and senescent trees are vital for saproxylic species (MORADI *et al*., 2012; MICÓ *et al*., 2013). Saproxylic species, including flower flies, have been used as bioindicators in conservation studies (SPEIGHT, 1989; REEMER, 2005; FAYT *et al*., 2006; RICARTE *et al*., 2009; RADENKOVIĆ *et al*., 2013; RAMÍREZ-HERNÁNDEZ *et al*., 2014; VUJIĆ *et al*., 2016). We do not have biological data for *C. aurea*, but we can assume that its biology and conservation status may reflect those of *C. speciosa*, with the aggravating of a more restricted distributional range. PROKHOROV & SHPARYK (2019) considered *C. speciosa* as rare throughout Europe and its range is extremely fragmented. Moreover, these authors said that this species requires constant monitoring and is a typical and generally accepted bioindicator species of ancient oak and beech forests (SPEIGHT, 1989, 2020b), the area of which is declining. In Great Britain, this species is considered as Near Threatened (BALL & MORRIS, 2014) and in Ukraine, it is proposed as Vulnerable (PROKHOROV & SHPARYK, 2019). In Spain *C. speciosa* is regarded as Endangered (MARCOS-GARCÍA, 2006; MARCOS GARCÍA & RICARTE, 2012), and one of the main threats is the removal and logging of old trees (MARCOS-GARCÍA, 2006, 2009). In Europe, isolated populations may disappear due to forest degradation due to anthropogenic factors (MARCOS-GARCÍA, 2006; BARTSCH *et al*., 2009; BALL & MORRIS, 2014; PROKHOROV *et al*., 2018). Thus, the new flower fly records of these saproxylic genera and the first record of *C. talyshensis* from Iran, together with endemic new species (GILASIAN *et al*., 2017), point out the relevance of the Hyracanian Forests, declared UNESCO World Heritage Site in 2019 (UNESCO, 2019), for saproxylic Syrphidae and emphasize the exceptional importance of the overmature trees for the protection and conservation of biodiversity.

ACKNOWLEDGEMENTS

We thank Claudia Etzbauer for help obtaining molecular sequences in the lab. We are grateful to Jana Thormann and Björn Rulik for obtaining the GenBank Accession Numbers of the new sequences. We thank Mª Ángeles Marcos García and Antonio Ricarte for their helpful comments as reviewers. We extend our heartfelt gratitude to Wouter Dekoninck (Royal Belgian Institute for Natural Sciences) for his kind help and support during this project. This study was conducted as part of the collaboration project "The use of Dolichopodidae (Insecta, Diptera) as indicators for biodiversity and conservation status of the Hyrcanian forest biome" between the Research Institute of Forests and Rangelands (Iran) and Royal Belgian Institute for Natural Sciences (RBINS). The study was financially supported by the Research Institute of Forests and Rangelands, Tehran, Iran.

REFERENCES

AKHANI, H., M. DJAMALI, A. GHORBANALIZADEH & E. RAMEZANI, 2010. Plant biodiversity of Hyrcanian relict forests, N Iran: An overview of the flora, vegetation, palaeoecology and conservation. *Pakistan Journal of Botany*, 42: 231-258.

ARCAYA, E., C. PÉREZ-BAÑÓN, X. MENGUAL, J.J. ZUCOFF-VALLEJO & S. ROJO, 2017. Life table and predation rates of the syrphid fly *Allograpta exotica*, a control agent of the cowpea aphid *Aphis craccivora*. *Biological Control*, 115: 74-84.

BALL, S.G. & R.K.A. MORRIS, 2014. *A review of the scarce and threatened flies of Great Britain. Part 6: Hoverflies family Syrphidae*. Species Status No. 9, Joint Nature Conservation Committee, Peterborough. 130 pp.

BARTSCH, H., E. BINKIEWICZ, A. KLINTBJER, A. RÅDÉN & E. NASIBOV, 2009. *Tvåvingar: Blomflugor. Diptera: Syrphidae: Eristalinae & Microdontinae*. Nationalnyckeln till Sveriges flora och fauna. ArtDatabanken, Sveriges lantbruksuniversitet, Uppsala. 478 pp.

FAYT, P., M. DUFRÊNE, E. BRANQUART, P. HASTIR, C. PONTÉGNIE, J.-M. HENIN & V. VERSTEIRT, 2006. Contrasting responses of saproxylic insects to focal habitat resources: the example of Longhorn Beetles and Hoverflies in Belgian deciduous forests. *Journal of Insect Conservation*, 10: 129-150.

GILASIAN, E., 2004. The first report of 6 genus and 21 species of syrphid flies from Iran. *Newsletter of Entomological Society of Iran*, 23: 1.

GILASIAN, E., A. VUJIĆ, M. HAUSER & M. PARCHAMI-ARAGHI, 2017. New data on the Syrphidae (Diptera) of Iran, with descriptions of two new species. *Zootaxa*, 4303(1): 27-50.

HAUSER, M., 1998. Zur Schwebfliegenfauna (Diptera, Syrphidae) Aserbaidschans, mit der Beschreibung von zwei neuen Arten. *Volucella*, 3: 15-26.

HEBERT, P.D.N., A. CYWINSKA, S.L. BALL & J.R. DEWAAR, 2003. Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London B*, 270: 313-321.

HEO, C.C., R. RAHIMI, X. MENGUAL, M.S.M. ISA, S. ZAINAL, P.N. KHOFAR & W.A. NAZNI, 2020. *Eristalinus arvorum* (Fabricius, 1787) (Diptera: Syrphidae) in human skull: a new fly species of forensic importance. *Journal of Forensic Science*, 65: 276-282.

INOUYE, D., B.M.H. LARSON, A. SSYMANK & P.G. KEVAN, 2015. Flies and flowers III: Ecology of foraging and pollination. *Journal of Pollination Ecology*, 16(16): 115-133.

JALILI, A. & Z. JAMZAD, 1999. *Red data book of Iran. A preliminary survey of endemic, rare and endangered plant species in Iran*. Research Institute of Forests and Rangelands, Tehran. 748 pp.

KAZERANI, F., A.A. TALEBI & X. MENGUAL, 2017. First record of *Chrysotoxum baphyrum* Walker from West Palaearctic (Diptera: Syrphidae), with key to species of *Chrysotoxum* Meigen from Iran. *Bonn zoological Bulletin*, 66(2): 95-106.

LARDÉ, G., 1989. Investigation on some factors affecting larval growth in a coffee-pulp bed. *Biological Wastes*, 30: 11-19.

LARSON, B.M., P.G. KEVAN & D.W. INOUYE, 2001. Flies and flowers: taxonomic diversity of anthophiles and pollinators. *The Canadian Entomologist*, 133(4): 439-66.

MAGNI, P., C. PÉREZ-BAÑÓN, M. BORRINI, & I. DADOUR, 2013. *Syritta pipiens* (Diptera: Syrphidae), a new species associated with human cadavers. *Forensic Science International*, 231: e19-e23.

MARCOS GARCÍA, M.A. & A. RICARTE, 2012. Segunda localidad ibérica conocida para *Caliprobola speciosa* (Rossi), especie UICN - «En peligro» (Diptera, Syrphidae). *Boletín de la Asociación española de Entomología*, 36(1-2): 207-210.

MARCOS-GARCÍA, M.A., 2006. *Caliprobola speciosa* (Rossi, 1790). In VERDÚ, J.R. & E. GALANTE (Eds.): *Libro Rojo de los Invertebrados de España*: 173-174. Dirección General de Conservación de la Naturaleza, Madrid.

MARCOS-GARCÍA, M.A., 2009. *Caliprobola speciosa* (Rossi, 1790). In VERDÚ, J.R. & E. GALANTE (Eds.): *Atlas de los Invertebrados Amenazados de España (Especies En Peligro Crítico y En Peligro)*: 142-144. Dirección General para la Biodiversidad, Ministerio de Medio Ambiente, Madrid.

MARVIE MOHADJER, M.R., 2005. *Silviculture*. University of Tehran Press, Tehran. 378 pp.

MENGUAL, X., G. STÅHLS, P. LÁSKA, L. MAZÁNEK & S. ROJO, 2018. Molecular phylogenetics of the predatory lineage of flower flies *Eupeodes-Scaeva* (Diptera: Syrphidae), with the description of the Neotropical genus *Austroscaeva* gen. nov. *Journal of Zoological Systematics and Evolutionary Research*, 56: 148-169.

MENGUAL, X., S. BOT, T. CHKHARTISHVILI, A. REIMANN, J. THORMANN & L. VON DER MARK, 2020. Checklist of hover flies (Diptera, Syrphidae) of the Republic of Georgia. *ZooKeys*, 916: 1-123.

MICÓ, E., J. QUINTO & M.A. MARCOS-GARCÍA, 2013. In MICÓ, E., M.A. MARCOS-GARCÍA & E. GALANTE (Eds): *Los insectos saproxílicos del Parque Nacional de Cabañeros*: 33-52. Organismo Autónomo de Parques Nacionales, Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

MORADI, M., M.R. MARVIE MOHADJER, K. SEFIDI, M. ZOBIRI & A. OMIDI, 2012. Over-mature beech trees (*Fagus orientalis* Lipsky) and close-to-nature forestry in northern Iran. *Journal of Forestry Research*, 23: 289-294.

MORALES, G.E. & M. WOLFF, 2010. Insects associated with the composting process of solid urban waste separated at the source. *Revista Brasileira de Entomologia*, 54(4): 645-653.

MÜLLER, J., H. VARANDI, M. BABAII, M. FARASHIANI, K. SAGEB-TALEBI, F. LANGE, M. GOSSNER, A. JARZABEK-MÜLLER, N. ROTH, S. THORN & S. SEIBOLD, 2018. The diversity of saproxylic insects (Coleoptera, Heteroptera) on four tree species of the Hyrcanian forest in Iran. *Journal of Insect Conservation*, 22: 607-625.

PECK, L.V. 1988. Family Syrphidae. In SOÓS, Á. & L. PAPP (Eds.): *Catalogue of Palaearctic Diptera, volume 8*: 11-230. Akadémiai Kiadó, Budapest.

PÉREZ-BAÑÓN, C., C. ROJAS, M. VARGAS, X. MENGUAL & S. ROJO, 2020. A world review of reported myiases caused by flower flies (Diptera: Syrphidae), including the first case of human myiasis from *Palpada scutellaris* (Fabricius, 1805). *Parasitology Research*, 119: 815-840.

PÉREZ-LACHAUD, G., M.A. JERVIS, M. REEMER & J.-P. LACHAUD, 2014. An unusual, but not unexpected, evolutionary step taken by syrphid flies: the first record of true primary parasitoidism of ants by Microdontinae. *Biological Journal of the Linnean Society*, 111: 462-472.

PROKHOROV, A.V., G.V. POPOV & M.I. ZAIKA, 2018. Rare species of hoverflies (Diptera: Syrphidae) from Ukraine. II. Callicerini, Cerioidini and Milesiini. *Ukrainska Entomofaunistyka*, 9(2): 15-22.

RADENKOVIĆ, S., Z. NEDELJKOVIĆ, A. RICARTE, A. VUJIĆ & S. ŠIMIĆ, 2013. The saproxylic hoverflies (Diptera: Syrphidae) of Serbia. *Journal of Natural History*, 47: 87-127.

RAMÍREZ-HERNÁNDEZ, A., E. MICÓ, M.A. MARCOS-GARCÍA, H., BRUSTEL & E. GALANTE, 2014. The "dehesa", a key ecosystem in maintaining the diversity of Mediterranean saproxylic insects (Coleoptera and Diptera: Syrphidae). *Biodiversity and Conservation*, 23: 2069-2086.

REEMER, M., 2005. Saproxylic hoverflies benefit by modern forest management (Diptera: Syrphidae). *Journal of Insect Conservation*, 9: 49-59.

RICARTE, A., T. JOVER, M. A. MARCOS-GARCÍA, E. MICÓ & H. BRUSTEL, 2009. Saproxylic beetles (Coleoptera) and hoverflies (Diptera: Syrphidae) from a Mediterranean forest: towards a better understanding of their biology for species conservation. *Journal of Natural History*, 43(9): 583-607.

ROJO, S., F. GILBERT, M.A. MARCOS-GARCÍA, J.M. NIETO & M.P. MILLER, 2003. *A world review of predatory hoverflies (Diptera, Syrphidae: Syrphinae) and their prey*. CIBIO Ediciones, Alicante. 319 pp.

ROTHERAY, G.E. & F. GILBERT, 1999. Phylogeny of Palaearctic Syrphidae (Diptera): evidence from larval stages. *Zoological Journal of the Linnean Society London*, 127: 1-112.

ROTHERAY, G.E. & F. GILBERT, 2011. *The natural history of hoverflies*. Forrest Text, Tresaith. 334 pp.

ROZO-LOPEZ, P. & X. MENGUAL, 2015. Mosquito species (Diptera, Culicidae) in three ecosystems from the Colombian Andes: identification through DNA barcoding and adult morphology. *ZooKeys*, 513: 39-64.

SACK, P., 1910. Neue und wenig bekannte Syrphiden des palaearktischen Faunen-gebietes. *Beilage zum Programm des Wöhler-Realgymnasiums in Frankfurt am Main*, 1910: 1-42.

SKEVINGTON, J.H., M. LOCKE, A.D. YOUNG, K. MORAN, W.J. CRINS & S.A. MARSHALL, 2019. *Field Guide to the Flower Flies of Northeastern North America*. Princeton University Press, Princeton. 512 pp.

SPEIGHT, M.C.D., 1989. *Saproxylic invertebrates and their conservation*. Nature and Environment Series, 42. Council of Europe, Strasbourg. 79 pp.

SPEIGHT, M.C.D., 2020a. StN key for the identification of the genera of European Syrphidae 2020. *Syrph the Net, the database of European Syrphidae (Diptera)*, 105, 1-46.

SPEIGHT, M.C.D., 2020b. *Species accounts of European Syrphidae, 2020*. Syrph the Net, the database of European Syrphidae (Diptera), vol. 104. Syrph the Net publications, Dublin, 1-314.

SSYMANK, A. & C. KEARNS, 2009. Flies-pollinators on two wings. In SSYMANK, A., A. HAMM & M. VISCHER-LEOPOLD (Eds.): *Caring for pollinators - safeguarding agro-biodiversity and wild plant diversity*.: 39-52. Bundesamt für Naturschutz, Bonn.

STACKELBERG, A.A., 1960. New Syrphidae (Diptera) from the Caucasus. *Entomologicheskoe Obozrenie*, 39: 438-449 [in Russian].

TENHUMBERG, B., 1995. Estimating predatory efficiency

of *Episyrphus balteatus* (Diptera: Syrphidae) in cereal fields. *Environmental entomology*, 24(3): 687-691.

THOMPSON, F.C., 1999. A key to the genera of the flower flies of the Neotropical Region including the descriptions of genera and species and a glossary of taxonomic terms. *Contributions on Entomology, International*, 3: 319-378.

TOHIDIFAR, M., M. MOSER, B. ZEHZAD & T. GHADIRIAN, 2016. *Biodiversity of the Hyrcanian Forests: A synthesis report*. FRWO/UNDP/GEF Caspian Hyrcanian Forest Project. 41 pp.

UNESCO. 2019. World Heritage list, Hyrcanian Forests. Available from: https://whc.unesco.org/en/list/1584/ (Accessed: October 17, 2020).

VAN STEENIS, J. & B. GHARALI, 2016. The first record of the genus *Criorhina* Meigen (Diptera: Syrphidae) from Iran, with a key to the West-Palaearctic species. *Studia dipterologica*, 22(1): 123-129.

VAN STEENIS, J., B. GHARALI, T. ZEEGERS & H.S. NAMAGHI, 2018. *Trichopsomyia ochrozona* (Stackelberg, 1952) (Diptera: Syrphidae) recorded from Iran for the first time with a key to the West Palaearctic *Trichopsomyia* Williston, 1888 species. *Zoology in the Middle East*, 64(4): 345-359.

VUJIĆ, A., Z. NEDELJKOVIĆ, R. HAYAT, O. DEMIRÖZER, X. MENGUAL & F. KAZERANI, 2017. New data on the genus *Chrysotoxum* Meigen (Diptera: Syrphidae) from North-East Turkey, Armenia, Azerbaijan and Iran including descriptions of three new species. *Zoology in the Middle East*, 63(3): 250-268.

VUJIĆ, A., S. RADENKOVIĆ, T. NIKOLIĆ, D. RADIŠIĆ, S. TRIFUNOV, A. ANDRIĆ, Z. MARKOV, S. JOVIČIĆ, S. MUDRI STOJNIĆ, M. JANKOVIĆ & P. LUGONJA, 2016. Prime Hoverfly (Insecta: Diptera: Syrphidae) areas (PHA) as a conservation tool in Serbia. *Biological Conservation*, 198: 22-32.

Suplementary material at
<www.entomologica.es/cont/publicaciones/complementos/1856_suplemento.pdf> Appendix 1-4