Systematics of *Problepsis wiltshirei* (Prout, 1938), comb. nov. (Lepidoptera, Geometridae, Sterrhinae) – an endemic species to the Zagros Mountains in the Middle East

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Abstract. Within Iran, the Zagros Mountains show high biodiversity, with a wealth of endemic species. One of these is the geometrid moth *Somatina wiltshirei* Prout, 1938, originally described from Iran and Iraq. In the present study, one mitochondrial and up to nine protein-coding nuclear gene regions were used along with a comparative morphological examination to investigate the systematic position of this species. The results support the reclassification of this species as *Problepsis wiltshirei* **comb. nov.** Since the original species description is superficial, we provide a re-description supported by rich illustrations of morphological characters and distribution. In addition, *Problepsis wiltshirei* **comb. nov.** is reported as a new species for the fauna of Turkey. The importance of the habitat for the conservation of this species is discussed.

Introduction

In the traditional classification of Scopulini (Geometridae: Sterrhinae), species were classified into genera based on the number of forewing areoles. Genera with one areole included *Problepsis* Lederer, 1853 and *Scopula* Schrank, 1802, and species with two areoles were classified in *Somatina* Guenée, [1858] (Prout 1934–1939). Sihvonen (2005) found evidence for the view that the number of areoles in the forewing is homoplastic and therefore not valuable as the only diagnostic character, as the state of two areoles also occurs in some *Problepsis* and *Scopula* species. Thus, even today, quite a few species are erroneously placed in the genus *Somatina*. Some of those have recently been reclassified (e.g., Sihvonen 2005; Xue et al. 2018; Sihvonen et al. 2020). However, the classification of other species within *Somatina* (sensu Sihvonen 2005) need to be re-examined.

The type species of *Somatina* is *S. anthophilata* Guenée, [1858] described from India. Scoble (1999) listed 50 species within the genus, mainly distributed in Africa, Asia and Australia. Recent phylogenetic studies showed that many *Somatina* species belong to other genera: In a morphological phylogenetic study, Sihvonen (2005) transferred four *Somatina* species to *Scopula*, namely *S. indicataria* (Walker, 1861), *S. mendicaria* (Leech, 1897), *S. microphylla* (Meyrick, 1889), *S. nucleata* (Warren, 1905) and two species to *Problepsis* (*P. centrophora* (Prout, 1915), *P.*

triocellata Bastelberger, 1908). *Scopula microphylla* and *P. triocellata* were classified in *Somatina* by Hausmann and Scoble (2007), who listed 46 species within this genus. Xue et al. (2018) transferred *Somatina transvehens* (Prout, 1918) to *Problepsis*.

In a multi-gene phylogenetic analysis, two more species were transferred from *Somatina* to *Problepsis* namely, *P. figurata* (Warren, 1897) and *P. vestalis* (Butler, 1875), consequently decreasing the number of *Somatina* species at present to 41 (Sihvonen et al. 2020).

Somatina species share the following morphological characters (after Sihvonen 2005, none of those are unique synapomorphies): weak discal spots on fore- and hindwing, forewing with two areoles. The male hind tibia is characterized by the presence of a hair pencil. The male genitalia are characterized by socii being not fused, and sacculi and valvuli being asymmetrical. The juxta bears wing-like processes on the anterior margin, with the apex fused to the sacculus of the valva. Sternite 8 in males is variable, x-shaped and with weakly developed or absent mappa, normally without cerata.

The genus *Problepsis* was described based on the type species *Caloptera ocellata* Frivaldszky, 1845 and belongs to Scopulini, the largest tribe within the subfamily Sterrhinae (Sihvonen 2005; Müller et al. 2019; Sihvonen et al. 2020). This genus currently comprises 53 species distributed in the Old World and Australia (Hausmann 2004; Sihvonen and Siljander 2005; Stadie and Stadie 2016; Feizpour et al. 2018; Xue et al. 2018).

Problepsis species share the following morphological characters (none of those are unique synapomorphies): ocellate discal spots on fore- and hindwing, forewing mainly with one areole, occasionally with two areoles (Hausmann 2004; Sihvonen 2005). The male hind tibia is laterally flattened, spoon-shaped and characterized by the presence of a hair pencil (Sihvonen 2005; Feizpour et al. 2018). The male genitalia are characterized by fused socii and a dentate or smooth ventral margin of the tegumen (Sihvonen 2005; Xue et al 2018). Sternite 8 in males is elongated, the cerata are absent, rudimentary or fully developed; if present, then often fused to the mappa (Sihvonen 2005).

Recently, *Problepsis cinerea* (Butler 1886) was reported from the south Iranian province Hormozgan as the only species belonging to the genus *Problepsis* in Iran (Feizpour et al. 2018). Additionally, *Somatina wiltshirei* Prout, 1938 is the only species of the genus *Somatina* described from the Zagros Mountains in Iran and Iraq. Wiltshire (1957) considered *S. wiltshirei* to be restricted to the Zagros woodland belt.

The Zagros Mountains cover an area of 533,543 km^2, extending with a length of 2000 km from Eastern Turkey and Northern parts of Iraq to the whole Western and Southwestern parts of Iran (Mouthereau et al. 2011; Kazemi and Hosseinzadeh 2020). In Iran, these mountains show a high rate of endemism, including reptiles, amphibians and plants (Gholamifard 2011; Safaei-Mahroo et al. 2015; Noroozi et al. 2018; Kazemi and Hosseinzadeh 2020). Additionally, due to its location in low and middle latitudes (between 25–40°N) and milder climate conditions during the Last Glacial Maximum (LGM), this area played an important role as refugia for many biota (van Zeist and Bottema 1977; Rajaei et al. 2013; Ashrafzadeh et al. 2016; Mohammadi et al. 2021).

As a part of the revision of Iranian geometrid moths, the present study aims to clarify the systematic position of *S. wiltshirei*, using an integrative approach; to illustrate species-specific characters, and to give an overview of its distribution in the Zagros Mountains. To achieve this, we used a multi-gene molecular analysis along with the examination of external and internal morphological characters and distribution data. We also discuss the importance of the habitat for the conservation of this species.

Material and methods

Type specimens, as well as additional specimens used in this study, were borrowed and studied from the following collections (acronyms after Evenhuis 2007):

IMCA Insect and Mite Collection Ahvaz University, Iran;
NHMUK Natural History Museum London, United Kingdom;
PCPS Private Collection of Pasi Sihvonen, Veikkola, Finland;
PCWW Private Collection of Werner Wolf, Bindlach, Germany;
SMNK Staatliches Museum für Naturkunde Karlsruhe, Germany;
SMNS Staatliches Museum für Naturkunde Stuttgart, Germany;
ZFMK Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany;
ZSM Zoologische Staatssammlung München, Germany.

Criteria for the selection of taxa

To test the combination of *Somatina wiltshirei* with the genus *Problepsis*, we studied type material of *S. wiltshirei*, type species of *Problepsis* (*P. ocellata*), and type species of *Somatina* (*S. anthophilata*) using morphological and molecular data, and additional specimens of both genera were used in the molecular analysis. Moreover, we included *P. cinerea* in our investigations, as it is the only species of the genus *Problepsis* in Iran (Feizpour et al. 2018). For the molecular analysis, already available other Scopulini data were used (Murillo-Ramos et al. 2019, Sihvonen et al. 2020). Lissoblemmini was proposed as sister to Scopulini in a previous phylogenetic study and therefore it was chosen as the outgroup in our study (Sihvonen et al. 2020).

Morphological examinations

Type material and original descriptions were used for the identification of specimens. Documentation and photography of external characters were carried out using a Visionary Digital photography system (LK Imaging System, Dun. Inc., equipped with a Canon EOS 5DSR) and an Olympus E3 digital camera. Preparation of the genitalia was carried out following standard methods (e.g., Robinson 1976). The vesica was everted following the method described by Sihvonen (2001). Photography of the genitalia characters before embedding took place following the methods proposed by Wanke and Rajaei (2018), Wanke et al. (2019) and Wanke et al. (2021) using a Keyence VHX-5000 digital microscope. Genitalia structures were finally embedded in Euparal and photographed using a Keyence VHX-5000 digital microscope.

The morphology of male and female antennae, as well as the male hind leg, were studied using a Zeiss Scanning Electron Microscope (SEM, EVO-LS15). Antennae and hind leg were mounted on holders and sputter-coated with 6 nm gold-palladium using a Leica coating system (EM ACE 200), before imaging with SEM.

For the drawing of the wing venation, wings were placed on a microscope slide and covered with a drop of ethanol (70–96%). In this setup, all venation is visible and can be photographed. For the photography, we used a Visionary Digital photography system (LK Imaging System, Dun. Inc., equipped with a Canon EOS 5DSR). In Graphic (vers. 3.1 for Mac) these photographs served as templates for the vector drawing of the wing venation by tracing the veins from it.

Molecular techniques

For the extraction of DNA, the whole abdomen and a leg from a single dry collection specimen were used following the manufacture's protocol of the DNeasy Blood and Tissue kits (Qiagen, Hilden, Germany). Amplification of DNA was conducted following Wahlberg and Wheat (2008) and Wahlberg et al. (2016). We attempted to amplify one mitochondrial (cytochrome oxidase subunit I, COI) and up to nine protein-coding nuclear gene regions: Ribosomal Protein S5 (RpS5), wingless (wgl), cytosolic malate dehydrogenase (MDH), glyceraldehydes-3-phosphate dehydrogenase (GAPDH), Elongation factor 1 alpha (EF-1alpha), Arginine Kinase (ArgK), Isocitrate dehydrogenase (IDH), sorting nexin-9-like (Nex9), sarco/endoplasmic reticulum calcium ATPase (Ca-ATPase). Sequences were sent to Macrogen for sequencing. The Genbank accession numbers are provided in Appendix 1.

Phylogenetic analysis

In addition to the data generated in this study, we retrieved sequences of Scopulini taxa from the dataset of Sihvonen et al. (2020). The final dataset comprises 29 taxa. The concatenated length of the alignment was 6800 bp including gaps.

We ran maximum likelihood analyses with a data set partitioned by codon using RAxML-HPC2 V8.2.12 (Stamatakis 2014) on the web-server CIPRES Science Gateway (Miller et al 2010). We implemented the GTR+CAT option, and support for nodes was evaluated with 1000 rapid bootstrap (RBS) (Stamatakis et al 2008). The final tree was rooted with species of Lissoblemmini (Sihvonen et al. 2020). Trees were visualized and edited in FigTree v1.4.3 software (Rambaut 2012).

Distribution patterns

Tracing of geographical coordinates was conducted using 'Google Earth Pro' (vers. 7.3.3.7786 for Mac). Distribution patterns were plotted and prepared in QGIS (vers. 3.16.0 for Mac). The elevation profile in QGIS was prepared using Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) downloaded from https://earthexplorer.usgs.gov.

Results

In total, five genes of a single specimen of *S. wiltshirei*, six genes of a single specimen of *P. cinerea* and eight genes of a single specimen of *S. anthophilata* were successfully amplified and sequenced (see Appendix 1). As a result, *S. wiltshirei* clustered within the genus *Problepsis*, supporting its affiliation to this genus (Fig. 1). Additionally, according to the results of our morphological examination, *S. wiltshirei* shows the generic characters of the genus *Problepsis* (e.g., ocellate discal spots on the fore- and hindwing, the spoon-shaped hind tibia and the presence of a hair pencil in the male hind legs). The following morphological characters of the male genitalia also support the affiliation with *Problepsis*: fused socii and a smooth internal margin of the tegumen (compared against morphological data in Sihvonen 2005; Feizpour et al. 2018; Xue et al. 2018; Sihvonen et al. 2020) (see Figs 15–17). A re-description of this species is given in the taxonomy part of the discussion.

Discussion

Systematics

In sense of the traditional classifications of the genera *Problepsis* and *Somatina*, the latter genus was regarded as polyphyletic (see Sihvonen 2005). Recent studies based on morphology (Sihvonen

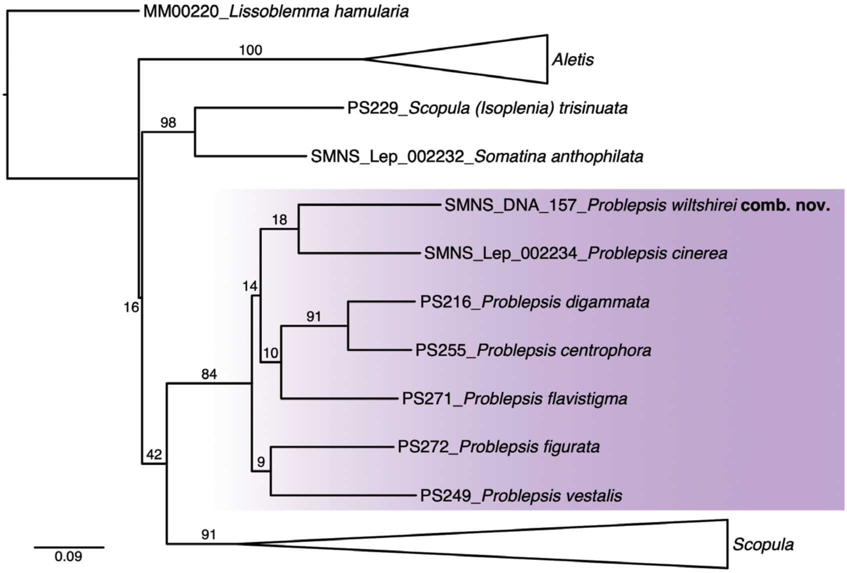


Figure 1. Phylogenetic position of *Problepsis wiltshirei* comb. nov. within the tribe Scopulini, supporting its combination in genus *Problepsis*. The numbers above the branches are Rapid Bootstrap support (RBS) on the best scoring ML tree (Stamatakis 2008). Values ≥ 85 (%) indicate supported clades.

2005; Xue et al. 2018), as well as multi-gene phylogenetic studies, resulted in the assignment of several *Somatina* species to *Problepsis* (Sihvonen et al. 2020). These results support the possibility of the monophyly of the genus *Somatina*, when non-*Somatina* species are reclassified (Sihvonen 2005; Xue et al. 2018; Sihvonen et al. 2020). In addition, Sihvonen (2005) identified three non-unique synapomorphies for *Somatina*, which support its monophyly (asymmetrical sacculi of valvae; asymmetrical valvuli of valvae; juxta with wing-like processes on anterior margin, with apex fused to sacculus of valva) (compare also Figs 15–17).

Our present results show *S. wiltshirei* nested within *Problepsis* (RBS = 84). Therefore, we transfer *S. wiltshirei* from *Somatina* to *Problepsis* comb. nov. Among the species included in our phylogenetic hypothesis, *P. cinerea* was recovered with low support as the sister species to *P. wiltshirei* (RBS = 18).

Additional *Problepsis* species and possibly more genetic data are needed to find the most closely related species of *P. wiltshirei*. Based on COI sequences, as available on BOLD database, the genetically closest neighbour of *P. wiltshirei* are *P. ocellata* and *P. cinerea*. Both with a genetic distance of 4.2%, calculated using K2P model: Kimura (1980) with MEGA X (Kumar et al. 2018; Stecher et al. 2020).

Taxonomy

Problepsis wiltshirei (Prout, 1938), comb. nov.

Figs 2–9, 14B, 15, 18, 21–25

Somatina wiltshirei Prout, 1938. In: Seitz, A. (Ed.), Die Großschmetterlinge der Erde. Supplement zu Band 4, 220. 2 ♂ Syntypes (Iraq: Kurdistan, Rowanduz [Rawanduz Gorge], Berserini [Berserini Gorge]) examined based on photo; 1 Syntype specimen [sex is not given in the original publication], [Iran]: Fars, Ardekan Talochosroe [Tall Khosrow, today in prov. Kohgiluyeh and Boyer-Ahmad]) (in NHMUK).

Material examined. 2 ♀, Iran, Esfahan, Gandoman S, Gerdeish-e, 200 m, 12./13.vi.2002, leg. J.-U. Meineke, A. Hofmann, Kallies et al., g.preps 0759, 0760/2020 D. Wanke; 1 ♀, Iran, Khuzestan [now Kohgiluyeh va Boyerahmad], Yassoudj [Yasuj], Sisakht, 2250 m, 13.vi.1972, leg. Ebert, Pazouki; 1 ♂, 2 ♀, same data, 13.–14.vi.1972, leg. Ebert & Falkner, g.prep. (♂) 0762/2020 D. Wanke; 2 ♂, same data, Sisakht 50 km NW, 15.–18.vi.1975, leg. Ebert, Falkner, g.prep. 0761/2020 D. Wanke; 1 ♂, same data, 15 km SE Yassudj [Yasuj], 2050 m, 15.vi.1972, leg. Ebert & Falkner, g.prep. 0907/2020 D. Wanke; 1 ♂, S-Iran, Prov. Fars, Tange Surkh, 50 km NW Ardekan, 2250 m NN, 12.–15.vi.1975, leg. Ebert, Falkner; 2 ♂, S-Iran, Fars, Daschte Ardjan, Kotal-Pirehsan, 2000 m, 18.vi.1972, leg. Ebert & Falkner; 1 ♀, S-Iran, Miyan-Kotal, östl. Kazerun, 51°40'E, 29°30'N, 1900 m, 4.–7.vi.1969, leg. G. Ebert; 1 ♀, S-Iran, Fars, Kaserun, Mian-Kotal, 1900 m, 11.vi.1972, leg. Ebert & Falkner; all in SMNK.

1 ♀, Iran, Kohkiluye va Boyerahmad, Yasuj, Sisakht, Dena, 2799 m, 30°57'23.6"N, 51°23'28.9"E, 30.vii.2016, leg. Sh. Feizpour, g.prep. 0712/2020 D. Wanke; in SMNS.

1 ♂/♀, Iran, Khuzestan, Emamzadeh, Abdollah-low altitude; Saite 4b, 31°22'24"N, 50°7'51"E, 1408 m, 23.ix.2018, Trap1, leg. Mohammad Ahmadi; 1 ♂/♀, Iran, Khuzestan, Emamzadeh, Abdollah-high altitude; Saite 4a, 31°23'10"N, 50°9'29"E, 2120 m, 13.vii.2018, Trap 2, leg. Mohammad Ahmadi; 1 ♂/♀, Iran, Prov. Khuzestan, Mal aqa, 1100 m, 31°35'57"N, 50°00'50"E, 30.vii.2011, leg. Mehdi Esfandiari; 1 ♂/♀, Iran, Prov. Fars, Bolhayat & Kotal-e-Pirzan, 2000 m, 29°36'48"N, 51°56'28"E, 2. & 9.vi.2011, leg. Mehdi Esfandiari; 1 ♂/♀, Iran, Prov. Fars, Kohmare Sorkhi, 1900 m, 29°28'11"N, 52°08'44"E, 28.iv.2011, leg. Mehdi Esfandiari; all in IMCA.

1 ♀, Türkei [Turkey], prov. Hakkari, Çığıl Suyu-Tal [Zap-Tal], 22 km SW Hakkari, 28.vi.1984, LF, leg. Werner Wolf; in PCWW.

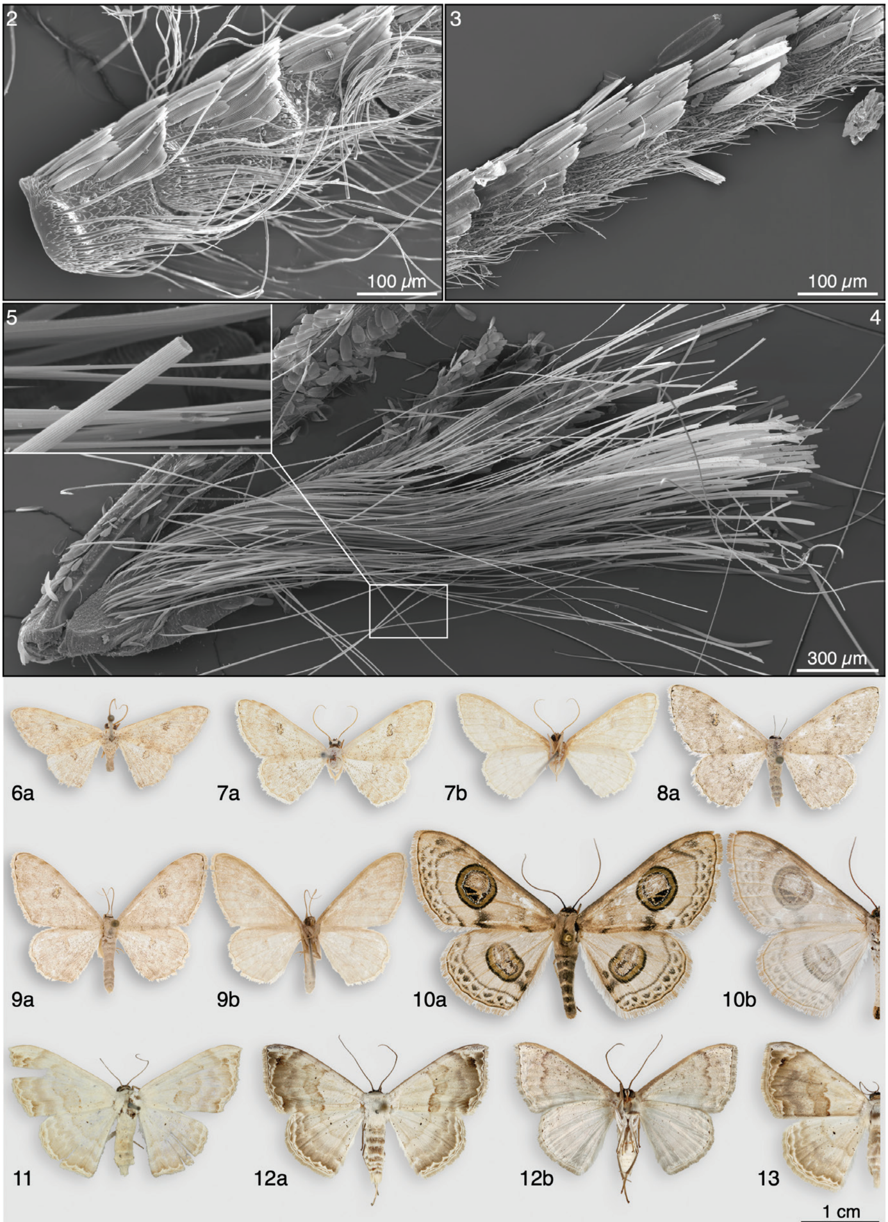
1 ♂, 1 ♀, Iran, Fars, Straße Ardekan-Talochosroe [Tall Khosrow, today in prov. Kohgiluyeh und Boyer Ahmad], Comé [Komehr], 7.viii.1937, 2600 m, coll. Brandt; in ZFMK.

1 ♂, Iran, Fars, Straße Ardekan-Talochosroe [Tall Khosrow, today in prov. Kohgiluyeh und Boyer Ahmad], Comèe [Komehr], 2600 m, viii.1937, coll. Brandt, ZSM g.prep. No. 1602; in ZSM.

Re-description. ***Wings and body*** (Figs 2–9). Wingspan ♂ 24–28 mm, ♀ 29–32 mm; females slightly larger than males. The proboscis well developed. The length of the labial palpi about equal to the diameter of the eye. Frons, thorax and abdomen concolorous with the wings. Chaetosemata arranged as two patches. Antennae ciliate-fasciculate in males and filiform in females (Figs 2, 3). Male hind tibia with reduced tarsal segments; flattened laterally; longitudinally spoon-shaped; with hair pencil. Hair pencil consisting of two types of differently modified scales as illustrated for *P. cinerea* by Feizpour et al. (2018). One type of scales apically flattened, while the other scales are tubular and hollow (Figs 4, 5). Ground colour of wings beige, intermixed with some slightly darker ochreous or brown scales; basal areas slightly lighter beige. Fore- and hindwing with a small, light yellowish ocellus, bordered with a thin dark outer line. Discal spots sometimes not visible; more pronounced in the forewings (Figs 6–9).

Venation (Fig. 14B). Two areoles present in forewing. Veins R1, the common stalk of R2–4 and R5 arising from the second areole. In hindwing Sc+R1 slightly curved in basal area, approximating to the cell in the postbasal area; A1+2 originating separately; A3 absent.

Male genitalia (Fig. 15). Uncus absent. Socii strongly developed fused at apex. Internal margin of tegumen smooth. Valva with two curved arms (dorsal and ventral arm of valva), both slerotized, narrow and long, apically pointed (Fig. 15a, d). Aedeagus strongly sclerotized, slender, tapering towards the apex; its basal part dorso-ventrally flattened; vesica without cornuti (Fig. 15b). Sternum A8: anterior margin with two indentations; lateroanteriorly on both sides pointed. Lateral sides towards posterior part concave; posterior margin curved. Cerata located in posterior half of sternum A8, directed towards centre (Fig. 15c).



Figures 2–13. Morphological characters of Iranian *Problepsis* species and *Somatina anthophilata*. **2–5.** SEM photos of *Problepsis wiltshirei* comb. nov.; **2.** Part of ciliate-fasciculate antennae of male (Iran, Yasuj, Sisakht, g.prep. 0762/2020 D. Wanke); **3.** Detail of filiform antennae of female (Iran, Fars, Mian-Kotal); **4.** Male hind tibia with hair pencil (Iran, Yasuj, Sisakht, g.prep. 0761/2020 D. Wanke); **5.** Close up on tubular and hollow modified scale of hair pencil (Iran, Yasuj, Sisakht, g.prep. 0761/2020 D. Wanke); **6–9.** Wing pattern of *Problepsis wiltshirei* comb. nov.; **6.** Male paratype (Iraq, Kurdistan, Berserini); **7.** Male (Iran, Fars, Straße Ardekan-Talochosroe, g. prep. 1602 ZSM); **8.** Female (Iran, Yasuj, Sisakht, g.prep. 0712/2020 D. Wanke); **9.** Male (Iran, Yasuj, Sisakht, g.prep. 0761/2020 D. Wanke); **10.** Female of *Problepsis cinerea* (Iran, Hormozgan, Geno protected area); **11–13.** Wing pattern of *S. anthophilata*; **11.** Paralectotype (India); **12.** Male (Thailand, Lampang, Muban Phichai); **13.** Female (Thailand, Lampang, Muban Phichai). a = upperside; b = underside.

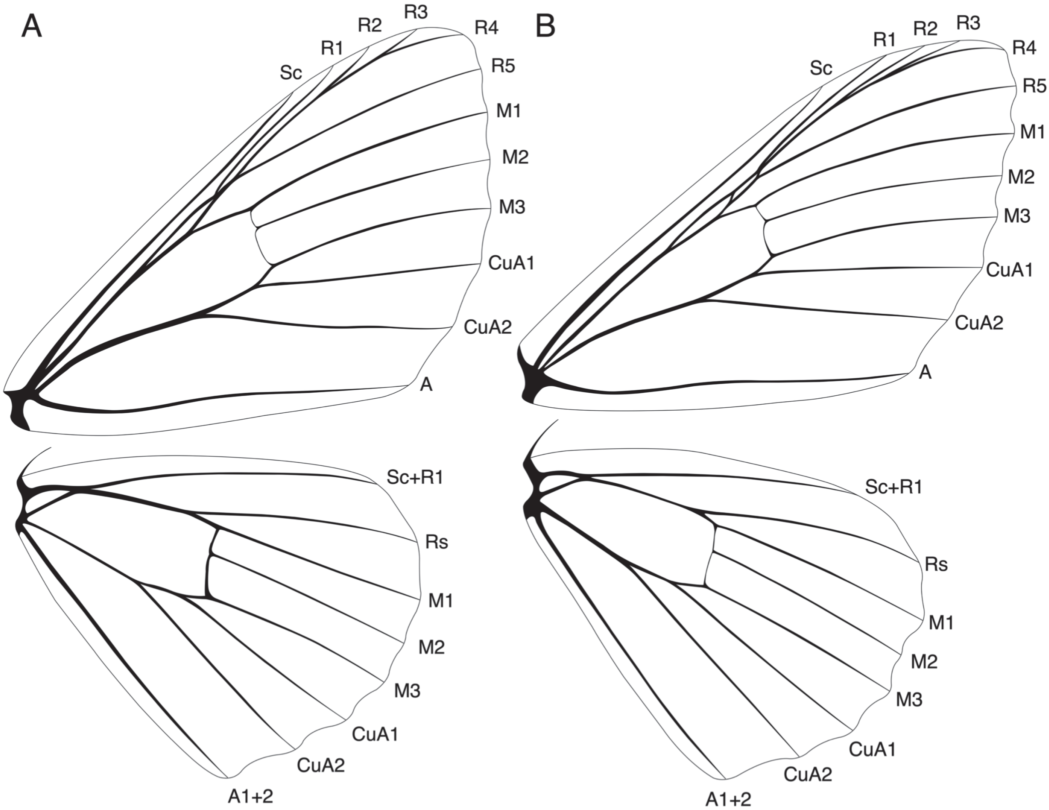


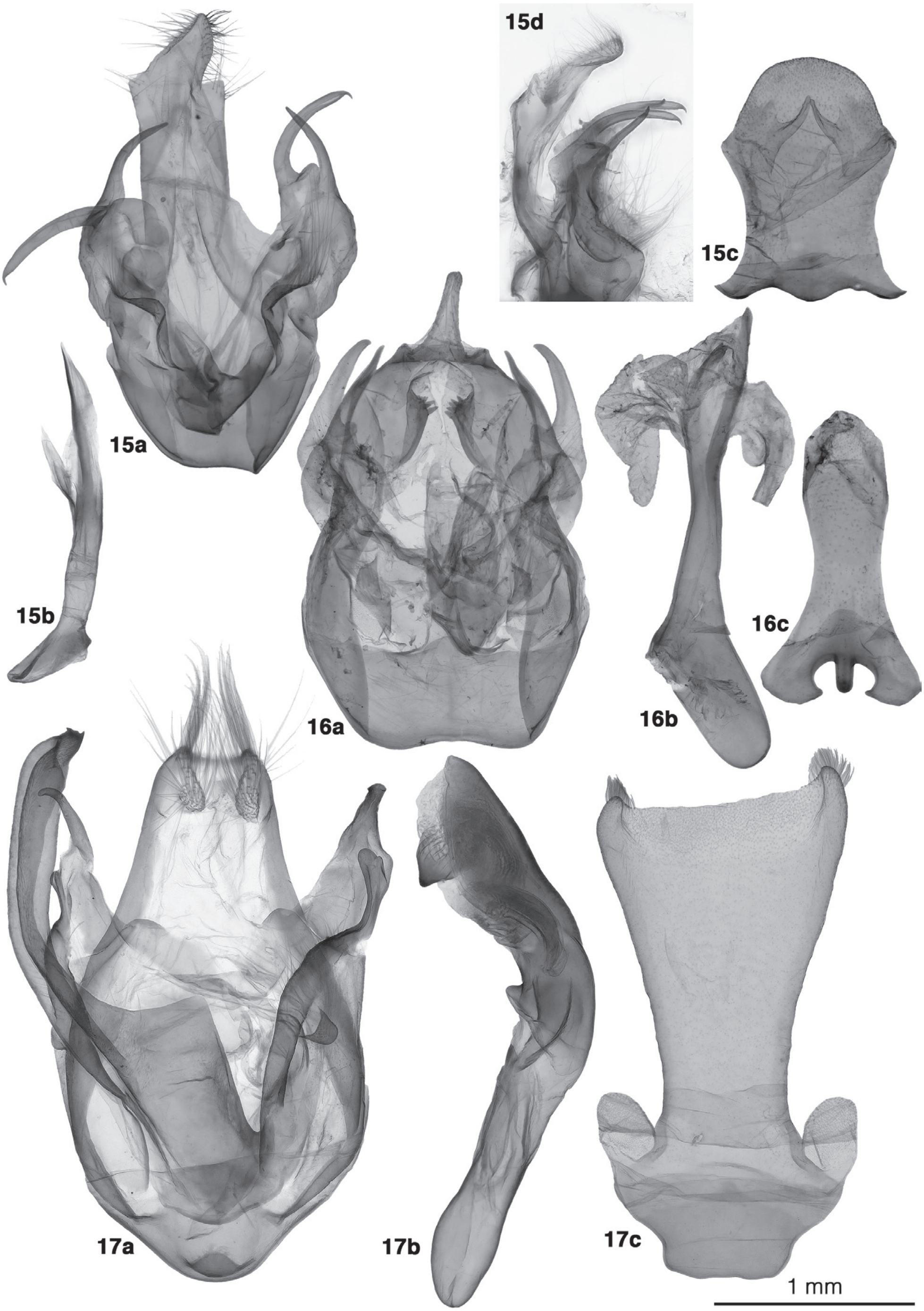
Figure 14. Wing venation of male specimens of *Problepsis* species; **A.** *Problepsis ocellata* (type species for the genus) and **B.** *Problepsis wiltshirei* comb. nov. Note: *Problepsis ocellata* (**A.**) with one areole in the forewing and *Problepsis wiltshirei* comb. nov. (**B.**) with two areoles in the forewing.

Female genitalia (Fig. 18). Papillae anales short and broad. Apophyses anteriores 2/3 length of apophyses posteriores. Antrum strongly sclerotized. Lamella antevaginalis strongly sclerotized; basal part broad, laterally extended; posteriorly curved, folded, tapered to lateral side. Ductus bursae short, strongly sclerotized. Corpus bursae membranous; signum present as a sclerotized, narrow and dentate ridge.

Diagnosis. *P*. *wiltshirei* cannot be confused with any other *Problepsis* or *Somatina* species within this region. In Iran only *Problepsis cinerea* is known from South Iran and it does not occur within the range of *P. wiltshirei* comb. nov. Additionally, it cannot be confused with this species, as it differs strongly by wing pattern (see Figs 6–10) and by genitalia (Figs 16, 19). *Somatina pythiaria nigrimacula* Hausmann, 2009; a species distributed in Oman has been shown differing by a greyer suffusion on wing pattern, the different structure of the sternum A8 and molecular data (Hausmann 2009).

Phenology. Flying from July to October, possibly in two generations (Wiltshire 1943). This coincides with the investigated specimens, but can be expanded from April to October.

Biology. Larva described by Wiltshire (1943) as grayish, intermixed with a complex pattern of grey dots and marks. Pale grey dorsal and ventral lines, the latter rather whitish on somites 4–8. Pupal period lasting 8 to 15 days. The cocoon is woven between leaves and litter (Wiltshire 1943).



Figures 15–17. Male genitalia of Iranian *Problepsis* species and *Somatina anthophilata*; **15.** *Problepsis wiltshirei* comb. nov. (**a.** Iran, Yasuj, Sisakht, g.prep. 0762/2020 D. Wanke; **b, c.** Iran, Yasuj, Sisakht, g.prep. 0761/2020 D. Wanke; **d.** Iran, Yasuj, g.prep. 0907/2020 D. Wanke); **16.** *Problepsis cinerea* (**a–c.** Pakistan, Kaghan-Tal, 375/2017, S. Feizpour); **17.** *Somatina anthophilata* (**a–c.** Thailand, Lampang, Chae Hom, g.prep. 1177/2021 D. Wanke). a = genitalia capsule; b = aedeagus; c = sternum A8; d = genitalia capsule lateral view.

Wiltshire (1943) noted *Fraxinus* sp. (Oleaceae) and *Acer* sp. (Sapindaceae) as food plants for *P. wiltshirei*. As *Problepsis* species have been observed feeding on Oleaceae species (Robinson et al. 2002; Stadie and Stadie 2016) *Acer* sp. is an exceptional food plant, which needs confirmation.

Habitat. This species occurs in the Middle Heights of the mountains, especially the woodland zone (Wiltshire 1957) and mountain steppe, at elevations from 1100 m up to 2800 m (Figs 21–25). The habitat is covered with different herbaceous plants and shrubs, dominated by *Prunus* sp. (Rosaceae), *Artemisia* sp. (Asteraceae), *Astragalus* sp. (Fabaceae) and *Acantholimon* sp. (Plumbaginaceae).

Distribution. So far recorded in the Zagros Mountains, from northern Iraq (Kurdistan) into south-western Iran (Kohgiluyeh-va-Boyer-Ahmad and across the border to the provinces, Khuzestan, Esfahan and Fars) (Fig. 25). Additionally, here we record this species for the first time for the fauna of Turkey (see examined material). The large gap between the populations in northern Iraq, Turkey and central Zagros in Iran is possibly caused by insufficient sampling in these areas.

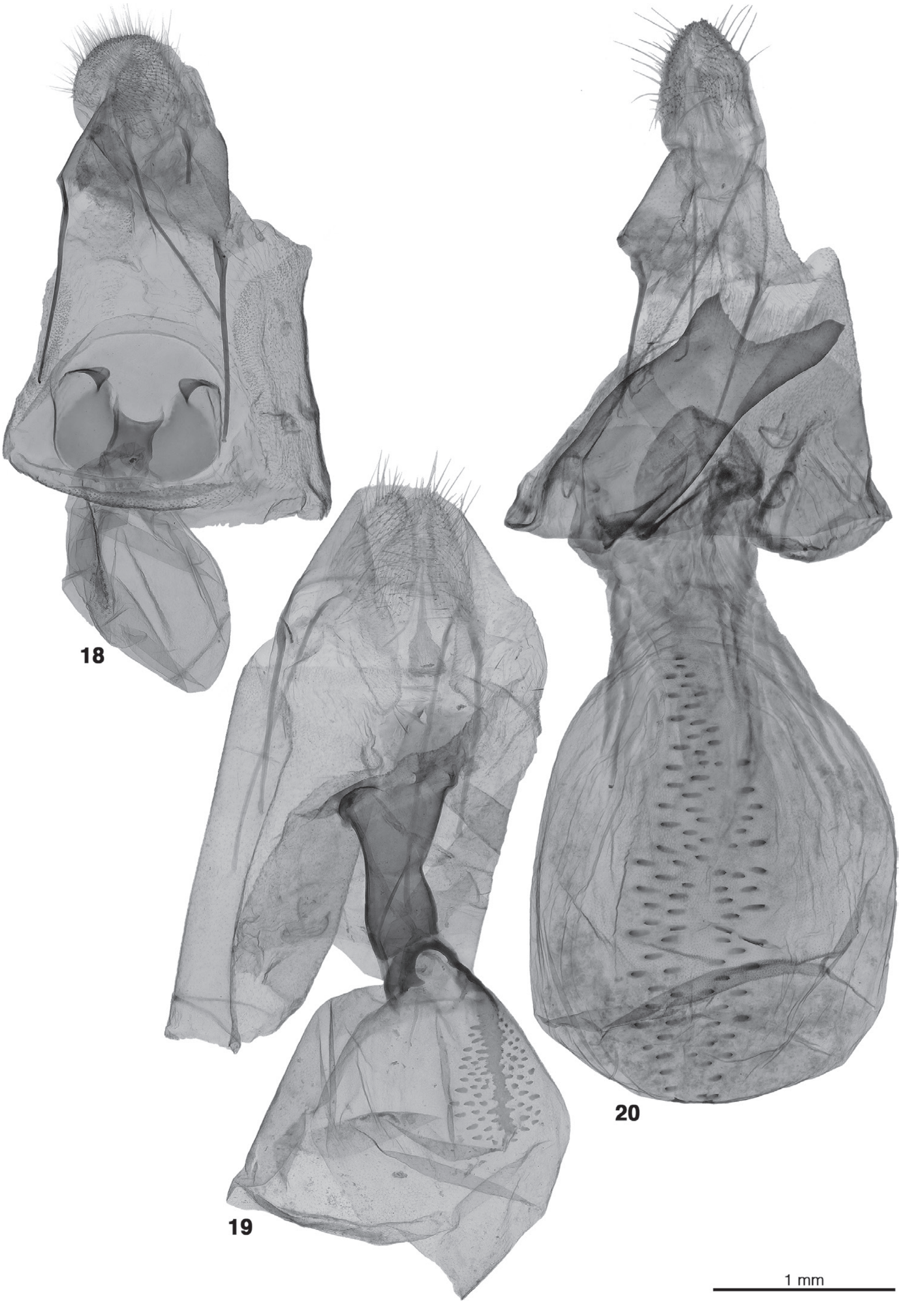
Zagros Mountains as a refuge for *Problepsis wiltshirei*

Major issues in conservation biology for protection efforts are the identification of areas with high biodiversity, high rates of endemism and past events, like glacial refugia or environmental changes (Médail and Diadema 2009; Cañadas et al. 2014; Noroozi et al. 2018; Kazemi and Hosseinzadeh 2020).

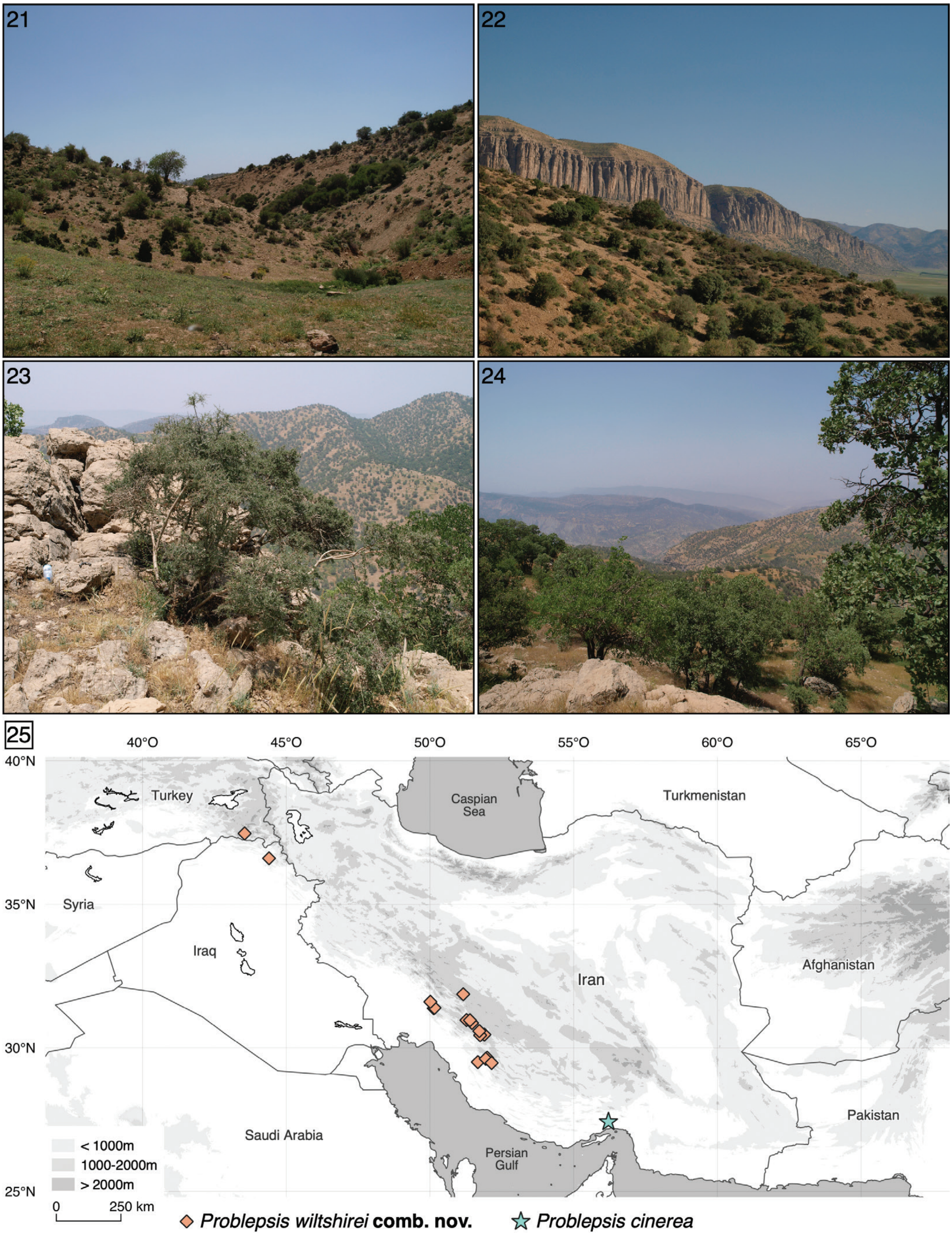
The Zagros Mountains have been identified as an area with a high species diversity of flora and fauna (Rechinger 1963–2015; Firouz 2005; Noroozi et al. 2008; Sayadi and Mehrabian 2016). Akbarirad et al. (2016) showed that brush-tailed mice of the genus *Calomyscus* (Calomyscidae: Rodentia) are highly diverse, due to the topography of these mountains which cause their geographic isolation. Similar findings were made for the Iranian herpetofauna, where the mountains and their diverse environmental conditions play an important role in the separation and isolation of species (Gholamifard 2011; Kazemi and Hosseinzadeh 2020). The important role of the Zagros Mountains can also be seen through various groups of arthropods (e.g., Paknia et al. 2008; Marusik and Zamani 2015; Zamani et al. 2018). For Lepidoptera, high species diversity of different families has been observed in the Zagros Mountains (e.g., Nazari 2003; Trusch and Hausmann 2008; Rajaei et al. 2012; Tshikolovets et al. 2014; Keil 2015; Yakovlev 2015; Wanke et al. 2020).

Regarding the endemism rate, the Zagros Mountains show the highest richness compared to other Iranian mountain ranges (Akhani 2004; Noroozi et al. 2016; Kazemi and Hosseinzadeh 2020; Khajoei Nasab and Khosavi 2020). It has been shown that 45% of Zagros vascular plants are restricted to this region (Noroozi et al. 2019). Additionally, this applies to endemic alpine plant species, where the highest rates of endemism were found in the Zagros (Noroozi et al. 2016). Comparably high endemism has been found in Lepidoptera (e.g., Rajaei 2012; Tshikolovets et al. 2014; Keil 2015).

Moreover, the Zagros Mountains have played a crucial role as a refuge for diverse fauna and flora during glaciation events. Malekoutian et al. (2020) found in a phylogeographic analysis, the occurrence of the Yellow-spotted Mountain Newt (*Neurergus derjugini*) derives from three different refugia in the Zagros mountains. Similar findings for the survival of Iranian Brown Bears (*Ursus arctos*) in Zagros refugia during the Last Glacial Maximum (LGM) were proved by Ashrafzadeh et al. (2016). Based on genetic and paleo-bioclimatic data, Rajaei et al. (2013) found this region to be a refuge for two *Gnopharmia* species and their host plants (*Prunus scoparia*) during the LGM 23,000–18,000 years ago). Furthermore, it has been shown that the highest haplotype diversity of these two *Gnopharmia* species is present in southwestern parts of the Zagros Mountains and served as a population source for the postglacial expansion of these species (Rajaei et al. 2013).



Figures 18–20. Female genitalia of Iranian *Problepsis* species and *Somatina anthophilata*; **18.** *Problepsis wiltshirei* comb. nov. (Iran, Esfahan, Gandoman, g.prep. 0759/2020 D. Wanke); **19.** *Problepsis cinerea* (g.prep. 374/2017, S. Feizpour); **20.** *Somatina anthophilata* (Thailand, Lampang, Muban Phichai, g.prep. 1176/2021 D. Wanke).



Figures 21–25. Habitat in the Zagros Mountains and distribution map of Iranian *Problepsis* species; **21, 22.** Iran, Fars, Dasht-e Arjan at 2158 m altitude; **23, 24.** Iran, Kohkiluye va Boyerahmad, Tange-Tamoradi at 2254 m altitude; **25.** Distribution pattern of Iranian *Problepsis* species.

The results of our study confirm that *P. wiltshirei* is an endemic species in the Zagros mountains and has so far been restricted to two areas of this mountain range. The first area in northern Iraq and south-eastern of Turkey falls into the Irano-Anatolian biodiversity hotspot, a region of remarkable species endemism, covering high elevations of central and eastern Turkey, Armenia, NE Iraq and Iran (Mittermeier et al. 1999; Noroozi et al. 2018). In its second area of distribution, *P. wiltshirei* inhabits the southwestern parts of the Zagros Mountains, a habitat outstanding for its rich biodiversity (e.g., Hosseinzadeh et al. 2014; Farashi and Shariati 2017; Noroozi et al. 2018).

Although several areas are protected in the Zagros Mountains (e.g., Arjan, Bakhtegan, Karkheh, Bamu etc.), this unique nature reserve is currently threatened, mainly by human activity. Every year 15,000 ha of Iranian forests burn (in 2020 wildfires burned down over 50,000 ha of oak forests in the Zagros Mountains) and centuries-old trees are destroyed in the process (Kheshti 2020). In ecosystems such as the Zagros Mountains, these high fire intensities threaten its species diversity and richness (Heydari et al. 2016). Further threats to biodiversity are overgrazing by sheep and goats in the marginal arid areas, as well as the land erosion caused by agriculture (Jowkar et al. 2016). Also, poaching and sporadic poisoning of animals occurs from time to time, even within protected areas, causing significant damage to its fauna (Jowkar et al. 2016). *P. wiltshirei* is distributed in this threatened area of high biodiversity and we still know only very little about its distribution and biology. Our study emphasizes the importance of further investigations of the Lepidoptera fauna of the Zagros, to better understand biodiversity hotspots and areas of endemism in the context of species conservation.

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References

Ahmadzadeh F, Carretero MA, Rödder D, Harris DJ, Freitas SN, Perera A, Böhme W (2013) Inferring the effects of past climate fluctuations on the distribution pattern of *Iranolacerta* (Reptilia, Lacertidae): Evidence from mitochondrial DNA and species distribution models. Zoologischer Anzeiger 252: 141–148. https://doi.org/10.1016/j.jcz.2012.05.002

Akbarirad S, Darvish J, Aliabadian M (2016) Increased species diversity of brush-tailed mice, genus *Calomyscus* (Calomyscidae, Rodentia), in the Zagros Mountains, western Iran. Mammalia 80: 549–562. https://doi.org/10.1515/mammalia-2014-0162

Akhani H (2004) A new spiny, cushion-like *Euphorbia* (Euphorbiaceae) from South–West Iran with special reference to the phytogeographic importance of local endemic species. Botanical Journal of the Linnean Society 146: 107–121. https://doi.org/10.1111/j.1095-8339.2004.00310.x

Ashrafzadeh MR, Kaboli M, Naghavi MR (2016) Mitochondrial DNA analysis of Iranian brown bears (*Ursus arctos*) reveals new phylogeographic lineage. Mammalian Biology 81: 1–9. https://doi.org/10.1016/j.mambio.2015.09.001

Cañadas EM, Fenu G, Peñas J, Lorite J, Mattana E, Bacchetta G (2014) Hotspots within hotspots: Endemic plant richness, environmental drivers, and implications for conservation. Biological Conservation 170: 282–291. https://doi.org/10.1016/j.biocon.2013.12.007

Evenhuis NL (2007) The Insect and Spider Collections of the World website of the Bishop Museum, Honolulu, Hawaii. http://hbs.bishopmuseum.org/codens/ [Accessed 10 February 2021]

Farashi A, Shariati M (2017) Biodiversity Hotspots and Conservation Gaps in Iran. Journal for Nature Conservation 39: 37–57. https://doi.org/10.1016/j.jnc.2017.06.003

Feizpour S, Fekrat L, Namaghi HS, Stadie D, Rajaei H (2018) Combination of morphological characters and DNA-barcoding confirms *Problepsis cinerea* (Butler, 1886) (Geometridae: Sterrhinae: Scopulini) as a new genus and species for the fauna of Iran. Integrative Systematics 1: 47–57. https://doi.org/10.18476/insy.v01.a6

Firouz E (2005) The Complete Fauna of Iran. I.B. Tauris & Co. Ltd, London, 327 pp. https://doi.org/10.5040/9780755612215

Gholamifard A (2011) Endemism in the reptile fauna of Iran. Iranian Journal of Animal Biosystematics 7(1): 13–29.

Hausmann A (2004) Sterrhinae. In: Hausmann A (Ed.) The Geometrid Moths of Europe Vol. 2. Apollo Books, Stenstrup, 600 pp. https://doi.org/10.1163/9789004322554

Hausmann A (2009) New and interesting geometrid moths from Dhofar, southern Oman. Mitteilungen der Münchner Entomologischen Gesellschaft 99: 109–126.

Heydari M, Faramazi M, Pothier D (2016) Post-fire recovery of herbaceous species composition and diversity, and soil quality indicators one year after wildfire in a semi-arid oak woodland. Ecological Engineering 94: 688–697. https://doi.org/10.1016/j.ecoleng.2016.05.032

Hosseinzadeh MS, Aliabadian M, Rastegar-Pouyani E, Rastegar-Pouyani N (2014) The roles of environmental factors on reptile richness in Iran. Amphibia-Reptilia 35: 215–225. https://doi.org/10.1163/15685381-00002946

Jowkar H, Ostrowski S, Tahbaz M, Zahler P (2016) The Conservation of Biodiversity in Iran: Threats, Challenges and Hopes. Iranian Studies 49(6): 1065–1077. https://doi.org/10.1080/00210862.2016.1241602

Kazemi SM, Hosseinzadeh MS (2020) High Diversity and Endemism of Herpetofauna in the Zagros Mountains. Ecopersia 8(4): 221–229.

Keil T (2014) Die Widderchen des Iran. Biologie und Verbreitung (Lepidoptera, Zygaenidae). 17. Beiheft Entomologische Nachrichten und Berichte, Dresden, 462 pp.

Khajoei Nasab F, Khosavi AR (2020) Identification of the areas of endemism (AOEs) of the genus *Acantholimon* (Plumbaginaceae) in Iran. Plant Biosystems – An International Journal Dealing with all Aspects of Plant Biology 154(5): 726–736. https://doi.org/10.1080/11263504.2019.1686078

Kheshti M (2020) Protect Iran's Zagros forests from wildfires. Science 369(6507): 1066. https://doi.org/10.1126/science.abd2967

Kimura M (1980) A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. Journal of Molecular Evolution 16: 111–120. https://doi.org/10.1007/BF01731581

Kumar S, Stecher G, Li M, Knyaz C, Tamura K (2018) MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. Molecular Biology and Evolution 35 (6): 1547–1549. https://doi.org/10.1093/molbev/msy096

Malekoutian M, Sharifi M, Vaissi S (2020) Mitochondrial DNA sequence analysis reveals multiple Pleistocene glacial refugia for the Yellow-spotted mountain newt, *Neurergus derjugini* (Caudata: Salamandridae) in the mid- Zagros range in Iran and Iraq. Ecology and Evolution 10: 2661–2676. https://doi.org/10.1002/ece3.6098

Marusik YM, Zamani A (2015) The spider family Filistatidae (Araneae) in Iran. ZooKeys 516: 123–135. https://doi.org/10.3897/zookeys.516.10146

Médail F, Diadema K (2009) Glacial refugia influence plant diversity patterns in the Mediterranean Basin. Journal of Biogeography 36: 1333–1345. https://doi.org/10.1111/j.1365-2699.2008.02051.x

Mittermeier RA, Myers N, Gil PR, Mittermeier CG (1999) Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. Cemex, Conservation International and Agrupacion Sierra Madre, Monterrey.

Mohammadi Z, Ghorbani F, Kami HG, Khajeh, A, Olsson U (2021) Molecular Phylogeny of the Subgenus *Karstomys* Reveals Genetic Signature of Post-glacial Colonization of *Apodemus mystacinus* (Rodentia: Muridae) in the Zagros Mountains from Different Refugia. Zoological Science 38: 72–81. https://doi.org/10.2108/zs200065

Mouthereau F (2011) Timing of uplift in the Zagros belt/Iranian plateau and accommodation of late Cenozoic Arabia-Eurasia convergence. Geological Magazine 148(5–6): 726–738. https://doi.org/10.1017/S0016756811000306

Murillo-Ramos L, Brehm G, Sihvonen P, Hausmann A, Holm S, Reza Ghanavi H, Õunap E, Truuverk A, Staude H, Friedrich E, Tammaru T, Wahlberg N (2019) A comprehensive molecular phylogeny of Geometridae (Lepidoptera) with a focus on enigmatic small subfamilies. PeerJ 7: e7386. https://doi.org/10.7717/peerj.7386

Müller B, Erlacher S, Hausmann A, Rajaei H, Sihvonen P, Skou P (2019) Ennominae II. In: Hausmann A, Rajaei H, Sihvonen P, Skou P (Eds) The Geometrid Moths of Europe. Vol. 6. Brill, Leiden, 906 pp. https://doi.org/10.1163/9789004387485_001

Nazari V (2003) Butterflies of Iran. Department of the Environment, I.R. Iran. National Museum of Natural History of the Islamic Republic of Iran, 568 pp.

Noroozi J, Akhani H, Breckle SW (2008) Biodiversity and phytogeography of the alpine flora of Iran. Biodiversity and Conservation 17: 493–521. https://doi.org/10.1007/s10531-007-9246-7

Noroozi J, Moser D, Essl F (2016) Diversity, distribution, ecology and description rates of alpine endemic plant species from Iranian mountains. Alpine Botany 126: 1–9. https://doi.org/10.1007/s00035-015-0160-4

Noroozi J, Talebi A, Doostmohammadi M, Rumpf SB, Linder HP, Schneeweiss GM (2018) Hotspots within a global biodiversity hotspot–Areas of endemism are associated with high mountain ranges. Scientific Reports 8(10345): 1–10. https://doi.org/10.1038/s41598-018-28504-9

Noroozi J, Talebi A, Doostmohammadi M, Manafzadeh S, Asgarpour Z, Schneeweiss GM (2019) Endemic diversity and distribution of the Iranian vascular flora across phytogeographical regions, biodiversity hotspots and areas of endemism. Scientific Reports 9(1): 1–12. https://doi.org/10.1038/s41598-019-49417-1

Paknia O, Radchenko A, Alipanah H, Pfeiffer M (2008) A Preliminary Checklist of the Ants (Hymenoptera: Formicidae) of Iran. Myrmecological News 11: 151–159.

Prout LB (1912–1916) Die spannerartigen Nachtfalter. In: Seitz A (Ed.) Die Gross-Schmetterlinge der Erde Vol. 4. A. Kernen Verlag, Stuttgart, 479 pp.

Prout LB (1934–1939) Die Spanner des Palaearktischen Faunengebietes. In: Seitz A (Ed.) Die Gross-Schmetterlinge der Erde, Supplement zu Band 4. A. Kernen Verlag, Stuttgart, 253 pp.

Rajaei Sh H, Stüning D, Trusch R (2012) Taxonomic revision and zoogeographical patterns of the species of *Gnopharmia* Staudinger, 1892 (Geometridae, Ennominae). Zootaxa 3360: 1–52. https://doi.org/10.11646/zootaxa.3360.1.1

Rajaei Sh H (2012) Modules to the Biodiversity of the Geometridae of Iran (Lepidoptera), using classical methods and DNA techniques (Larentiinae and Ennominae partim). PhD thesis, University of Bonn, Bonn.

Rambaut A (2012) Figtree 1.4.3. http://tree.bio.ed.ac.uk/software/figtree/

Rechinger KH [Ed.] (1963–2015) Flora Iranica: Flora des iranischen Hochlandes und der umrahmenden Gebirge, Persien, Afghanistan, Teile von West-Pakistan, Nord-Iraq, Azerbaidjan, Turkmenistan. Vols 1–181, Akademische Verlagsanstalt, Graz, Naturhistorisches Museum, Wien.

Robinson GS (1976) The preparation of slides of Lepidoptera genitalia with special reference to the Microlepidoptera. Entomologist's Gazette 27: 127–132.

Robinson GS, Ackery PR, Beccaloni GW, Kitching IJ, Hernandez LM (2002) HOSTS – The Natural History Museum's database of the hostplants of the moth and butterfly caterpillars of the world. https://www.nhm.ac.uk/our-science/data/hostplants/

Safaei-Mahroo B, Ghaffari H, Fahimi H, Broomand S, Yazdanian M, Najafi-Majd E, Hosseinian Yousefkhani SS, Rezazadeh E, Hosseinzadeh MS, Nasrabadi R, Rajabizadeh M, Mashayekhi M, Motesharei A, Naderi A, Kazemi SM (2015) The Herpetofauna of Iran: Checklist of taxonomy, distribution and conservation status. Asian Herpetological Research 6(4): 257–290.

Sayadi S, Mehrabian A (2016) Diversity and distribution patterns of Solanaceae in Iran: implications for conservation and habitat management with emphasis on endemism and diversity in SW Asia. Rostaniha 4(2): 57–64.

Sihvonen P (2001) Everted vesicae of the *Timandra griseata* group: methodology and differential features (Geometridae, Sterrhinae). Nota Lepidopterologica 24(3): 57–64.

Sihvonen P (2005) Phylogeny and classification of the Scopulini moths (Lepidoptera: Geometridae, Sterrhinae). Zoological Journal of the Linnean Society 143: 473–530. https://doi.org/10.1111/j.1096-3642.2005.00153.x

Sihvonen P, Siljander M (2005) Species diversity and geographical distribution of the Scopulini moths (Lepidoptera: Geometridae, Sterrhinae) on a worldwide scale. Biodiversity and Conservation 14: 703–721. https://doi.org/10.1007/s10531-004-3921-8

Sihvonen P, Murillo-Ramos L, Brehm G, Staude H, Wahlberg N (2020) Molecular phylogeny of Sterrhinae moths (Lepidoptera: Geometridae): towards a global classification. Systematic Entomology 45: 606–634. https://doi.org/10.1111/syen.12418

Stamatakis A (2014) RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. Bioinformatics 30(9): 1312–1313. https://doi.org/10.1093/bioinformatics/btu033

Stamatakis A, Hoover P, Rougemont J (2008) A rapid bootstrap algorithm for the RAxML Web servers. Systematic Biology 57(5): 758–771. https://doi.org/10.1080/10635150802429642

Stecher G, Tamura K, Kumar S (2020) Molecular Evolutionary Genetics Analysis (MEGA) for macOS. Molecular Biology and Evolution 37(4): 1237–1239. https://doi.org/10.1093/molbev/msz312

Trusch R, Hausmann A (2008) A new species of *Rhodostrophia* Hübner, 1823 from Iran (Geometridae: Sterrhinae). Nota Lepidopterologica 30: 7–16.

Tshikolovets V, Naderi A, Eckweiler W (2014) Butterflies of Iran and Iraq. Tshikolovets, Pardubice, 440 pp.

van Zeist W, Bottema S (1977) Palynological investigations in western Iran. Palaeohistoria 19: 19–85.

Wahlberg N, Wheat CW (2008) Genomic outposts serve the phylogenomic pioneers: designing novel nuclear markers for genomic DNA extractions of Lepidoptera. Systematic Biology 57: 231–242. https://doi.org/10.1080/10635150802033006

Wahlberg N, Peña C, Ahola M, Wheat CW, Rota R (2016) PCR primers for 30 novel gene regions in the nuclear genomes of Lepidoptera. ZooKeys 596: 129–141. https://doi.org/10.3897/zookeys.596.8399

Wanke D, Bigalk S, Krogmann L, Wendt I, Rajaei H (2019) The Fixator–A simple method for mounting of arthropod specimens and photography of complex structures in liquid. Zootaxa 4657(2): 385–391. https://doi.org/10.11646/zootaxa.4657.2.11

Wanke D, Hausmann A, Krogmann L, Petrányi G, Rajaei H (2020) Taxonomic revision of the genus *Nychiodes* Lederer, 1853 (Geometridae: Ennominae: Boarmiini) with description of three new species – an integrative approach. Zootaxa 4812(1): 001–061. https://doi.org/10.11646/zootaxa.4812.1.1

Wanke D, Rajaei H (2018) An effective method for the close up photography of insect genitalia during dissection: a case study on the Lepidoptera. Nota Lepidopterologica 4: 219–223. https://doi.org/10.3897/nl.41.27831

Wanke D, Ulmer JM, Wendt I, Rajaei H (2021) Updates on the Fixator—Facilitating the investigation, mounting, and photography of structures and specimens in liquid. Zootaxa 4999(4): 397–400. https://doi.org/10.11646/zootaxa.4999.4.9

Wiltshire EP (1943) Early stages of oriental palearctic Lepidoptera. V. Journal of the Bombay Natural History Society 43: 621–634.

Wiltshire EP (1957) The Lepidoptera of Iraq. Ministry of Agriculture, Government of Iraq, Baghdad, 162 pp.

Xue DY, Cui L, Jiang N (2018) A review of *Problepsis* Lederer, 1853 (Lepidoptera: Geometridae) from China, with description of two new species. Zootaxa 4392(1): 101–127. https://doi.org/10.11646/zootaxa.4392.1.5

Yakovlev R (2015) Patterns of geographical distribution of carpenter moths (Lepidoptera: Cossidae) in the old world. Contemporary Problems of Ecology 8(1): 36–50. https://doi.org/10.1134/S1995425515010151

Zamani A, Marusik Yu M, Malek-Hosseini MJ (2018) A new species of *Tegenaria* Latreille, 1804 (Araneae: Agelenidae) from western Iran. Zootaxa 4444(1): 95–97. https://doi.org/10.11646/zootaxa.4444.1.7

Appendix 1

Table A1. Sterrhinae taxa used in this study, with identification, process code, and GenBank accession numbers for each gene. Data from Sihvonen et al. (2020)[1] & Wanke et al. (current paper)[2].

Taxon identification	Code	ArgK	Ca-ATPase	COI-begin	COI-end	EFla-begin	EFla-end	GAPDH	IDH	MDH	Nex9	RpS5	WntGeo
Lissoblemma hamularia[1]	MM00220	–	–	JF784708	–	–	JF785331	–	–	–	–	–	–
Aletis helcita[1]	PS268	MK738556	MK738887	MK739619	–	MK740001	MK740001	MK740647	–	–	MK741674	MK742030	MK742585
Aletis monteironis[1]	PS270	MK738557	MK738888	MK739620	–	–	–	–	–	–	–	–	MK742586
Aletis variabilis[1]	0x17	–	–	MG767890	MG767890	–	MG768276	MG767671	–	–	–	MG767479	MG767344
Aletis forbesi[1]	0x28	–	–	MG767889	MG767889	–	MG768275	–	–	–	–	MG767478	MG767343
Scopulo (*Isoplenia*) *trisinuata*[1]	PS229	–	MK738851	MK739391	MK739391	MK739967	MK739967	MK740614	MK740872	MK741191	MK741640	MK742000	MK742550
Somatina anthophilata[2]	SMNS_Lep_002232	MZ798167	MZ798169	MZ753906	MZ753906	MZ798171	MZ798171	–	MZ798173	MZ798174	–	MZ798175	MZ798177
Problepsis wiltshirei[2]	SMNS-DNA-157	MZ798179	–	MW803363	–	MW803364	MW803364	–	–	–	–	MW803365	MW842913
Problepsis cinerea[2]	SMNS_Lep_002234	MZ798168	MZ798170	MZ753905	–	MZ798172	MZ798172	–	–	–	–	MZ798176	MZ798178
Problepsis vestalis[1]	PS249	MK738538	MK738869	MK739406	MK739406	MK739983	MK739983	MK740630	MK740881	–	MK741657	MK742014	MK742568
Problepsis figurata[1]	PS272	MK738559	MK738890	MK739424	MK739424	MK740003	MK740003	MK740649	–	–	MK741676	MK742032	MK742588
Problepsis flavistigma[1]	PS271	MK738558	MK738889	MK739423	MK739423	MK740002	MK740002	MK740648	MK740896	–	MK741675	MK742031	MK742587
Problepsis digammata[1]	PS216	MK738512	MK738839	MK739614	–	MK739958	MK739958	MK740605	MK740860	MK741179	MK741628	MK741990	MK742538
Problepsis centrophora[1]	PS255	MK738544	MK738875	MK739411	MK739411	MK739989	MK739989	MK740636	MK740886	–	MK741663	MK742019	MK742573
Scopula nemorivagata[1]	PS232	MK738524	MK738853	MK739616	–	MK739968	MK739968	MK740616	–	MK741193	MK741642	MK742001	MK742552
Scopula johnsoni[1]	R1872	–	–	MG767915	MG767915	–	MG768299	–	MG768488	MG768103	–	MG767500	MG767348
Scopula tenera[1]	SH1155	–	–	MG767781	MG767781	MG768176	MG768176	–	MG768396	MG768017	–	MG767408	–
Scopula immorata[1]	MM00586	–	–	GU828645	GU828443	GU828978	GU829261	–	GU830032	GU830351	–	GU830646	GU829536
Scopula nr *karischi*[1]	SH0432	–	–	MG767773	MG767773	MG768170	MG768170	MG767575	MG768391	MG768013	–	MG767404	–
Scopula punctilineata[1]	PS251	MK738540	MK738871	MK739407	MK739407	MK739985	MK739985	MK740632	MK740883	–	MK741659	MK742016	MK742570
Scopula nr *laevipennis*[1]	R1050	–	–	MG767897	MG767897	MG768281	MG768281	MG767677	–	MG768090	–	–	–
Scopula nr *vitellina*[1]	SH0448	–	–	MG767771	MG767771	MG768168	MG768168	MG767573	MG768389	MG768011	–	MG767402	–
Scopula sp[1]	PS241	MK738532	MK738861	MK739617	–	MK739976	MK739976	MK740623	–	MK741201	MK741650	MK742008	MK742560
Scopula nr *calcarata*[1]	SH0421	–	–	MG767770	MG767770	MG768167	MG768167	–	MG768388	MG768010	–	MG767401	MG767318
Scopula nr *serena*[1]	PS 243	MK738533	MK738863	MK739618	–	MK739978	MK739978	MK740625	–	MK741203	MK741652	MK742010	MK742562
Scopula amala[1]	USNM664273	–	–	KY370874	–	–	–	–	–	–	–	LT674233	LT674262
Scopula nr *nigrinotata*[1]	PS262	MK738550	MK738881	MK739417	MK739417	MK739995	MK739995	MK740642	MK740892	–	MK741668	MK742024	MK742579
Scopula ternata[1]	MM08463	–	–	MK739598	–	MK740231	–	MK740574	–	MK741142	–	MK741945	–
Scopula frigidaria[1]	MM10459	–	–	–	–	MK740233	–	–	–	MK741144	–	MK741947	MK742493