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First song descriptions of some Anatolian species of Tettigoniidae Krauss, 1902 (Orthoptera, Ensifera)

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Abstract

Fourteen endemic and two sub-endemic species belonging to three subfamilies of Tettigoniidae (Tettigoniinae, Bradyporinae and Saginae) were sampled during field trips throughout the different ranges of Anatolia between the years of 2004 and 2013. Acoustic parameters of these 16 species affiliated to 8 genera (*Anterastes*, *Apholidoptera, Gampsocleis*, *Parapholidoptera*, *Pezodrymadusa, Psorodonotus, Bradyporus* and *Saga*) have been described for the first time in this study. Acoustical analysis showed that song characters are species-specific in the genera *Saga* and *Psorodonotus*. On the other hand, we could not find big differences among species of the genus *Pezodrymadusa* and *Parapholidoptera castaneoviridis* species-group.

Keywords

Acoustic analysis, Tettigoniinae, Bradyporinae, Saginae, Anatolia

Introduction

Orthoptera is one of the most well-known acoustically active insect orders (Heller 2006). The taxa of Tettigoniidae produce specific songs, which allow the recognition, location and selection of conspecific mating partners (e.g., Walker 1964, Heller 1988, Ewing 1989, Heller 1990, Robinson and Hall 2002, Heller 2006). Almost all species have a specific song structure, hence the useful and functional taxonomic character (Heller 2006) which allows the discrimination of morphologically similar

species (Ingrisch 1991, Ragge and Reynolds 1998, Heller et al. 2004, Kolics et al. 2012). On the other hand, some genera of *tettigoniids,* such as *Parapholidoptera* (Heller 1988) and *Eupholidoptera* (Çıplak et al. 2009) exhibit, characteristic songs and uniform intrageneric song patterns.

The researchers of the last century were able to document many of the singing Orthoptera that are distributed in certain areas, such as North America (Walker and Moore 2004), Eastern United States (Alexander 1956) and Europe (Heller 1988, Ragge and Reynolds 1998). The history of studies that include song analysis in Anatolian Orthoptera began with Stumpner and Helversen (1992) for Caelifera and Heller (1988) for Ensifera. Up to now, as many as 55 songs of endemic *tettigoniids* from Anatolia have been already described and these studies can be divided into three main categories: (i) single species song description (Çıplak and Heller 2001, Çıplak et al. 2002, Çıplak and Heller 2005, Çıplak et al. 2006, Sevgili et al. 2012a); (ii) song descriptions of species-group and/or groups in a genus (Heller 2004, Sevgili 2004, Heller and Sevgili 2005, Heller et al. 2006, Sevgili et al. 2006, Çıplak et al. 2009, Heller et al. 2008, Heller and Korsunovskaya 2009, Sevgili et al. 2010, Kaya et al. 2011, Kaya and Çıplak 2011, Kaya et al. 2012, Chobanov et al. 2013); and (iii) songs of orthopteran species in a certain area (Sevgili et al. 2011). Moreover, a huge part of Anatolian *tettigoniids* has not been studied with regards to the song characteristics until now.

The family Tettigoniidae Krauss (1902) is the largest family of the Orthoptera and it displays species richness in Anatolia of about 360 taxa (Karabağ 1958, Çıplak et al. 2002, Ünal 2013a). More than 60% of Tettigoniidae taxa (e.g. Karabağ 1958, Ünal 2002) recorded from Turkey are endemic to Anatolia (Çıplak et al. 1993, Çıplak and Demirsoy 1995, Çıplak et al. 2002). A possible explanation for the richness of the Tettigoniidae species and its high endemism rate in Anatolia is that this region is one of the most important refugium in Palearctic (Hewitt 1996, Çıplak 2003, Şirin et al. 2010). However, the studies on the lineages represented in this peninsula are still far from explaining this phenomenon.

In the present study, we aim (i) to obtain the first ever records of song characteristics of 14 endemic and 2 sub-endemic species belonging to 8 genera (*Anterastes*, *Apholidoptera, Gampsocleis*, *Parapholidoptera*, *Pezodrymadusa, Psorodonotus, Bradyporus* and *Saga*) from different parts of Anatolia and (ii) to understand the relation between the distribution and song diversity of the species under discussion.

Methods

Specimens collecting

In the present study, 16 species of 8 genera belonging to three different subfamilies of Tettigoniidae (Tettigoniinae, Bradyporinae and Saginae) were sampled during field trips throughout the different ranges of Anatolia between 2004 and 2013. Male calling songs were recorded in the field or in laboratory from live animals. Then, the recorded

specimens were collected, labelled and deposited in 96% ethyl alcohol. Specimens examined in this study are deposited Aksaray University Central Research Laboratory, Entomological Museum, ASUBTAM (Aksaray/Turkey), Namık Kemal University, Department of Biology, Entomological Museum NKUEM (Tekirdağ, Turkey), and the personal collection of M.S. Taylan.

Song recording and analysis

Song recordings of collected animals were made in the field and laboratory. All song records were carried out by TASCAM DR-100 recorder using Philips-SBC ME 570 condenser microphone (frequency response flat up to 18 kHz) and SONY RECORDER with a shotgun microphone (the upper frequency limit was 15 kHz). The microphone was kept about 5–15 cm away from the calling male. The male songs were analyzed with custom-designed software (W. Schulze) developed in LabVIEW 7 (National Instruments, Austin, TX, USA) and Turbolab 4.0 (Stemmer AG). The traditional Ensifera song terminology (Heller 1988, Ragge and Reynolds 1998, Heller et al. 2006) is slightly modified to describe the songs of *tettigoniids* more accurately.

The following terms were used: *Calling song*, song produced by an isolated male; *phrase*, a first-order assemblage of syllables; *syllable*, the song produced by one opening-closing movement cycle of the tegmina; *syllable interval*, time from end of last impulse to beginning of first impulse of the next syllable; *impulse*, a simple undivided transient train of sound waves; *pulse*, a long train of sound waves, resulting from the fusion of several impulses (Figure 1). In song descriptions (minimum value-maximum value (mean value ± standart deviation)), seconds (s) or milliseconds (ms) were used for duration/intervals.

Results

Tettigoniinae Krauss, 1902

***Anterastes tolunayi* Karabağ, 1951**
http://species-id.net/wiki/Anterastes_tolunayi

Distribution. *Anterastes tolunayi* has been recorded from Aydın and İzmir provinces of Turkey (Figure 2a) (Karabağ 1951, 1958, Çıplak 2004).

Song recording. Males collected from İzmir, Bozdağ, Günalan yaylası-millik mevkii, 38°21.110'N, 28°06.245'E, 1545 m, 15.VI.2010 (by D. Şirin) and calling song recorded from two males at 26 °C in laboratory (by D. Şirin).

Description of song. Eight records from two males were analyzed. The calling song consists of sequences of polysyllabic phrases of different duration (Figure 2b, 2c), each of the phrases repeated regularly and lasting 94–150 ms (124 ± 0.03). Amplitudes of syllables getting louder from the first syllable to last one (Figure 2d). Therefore gen-

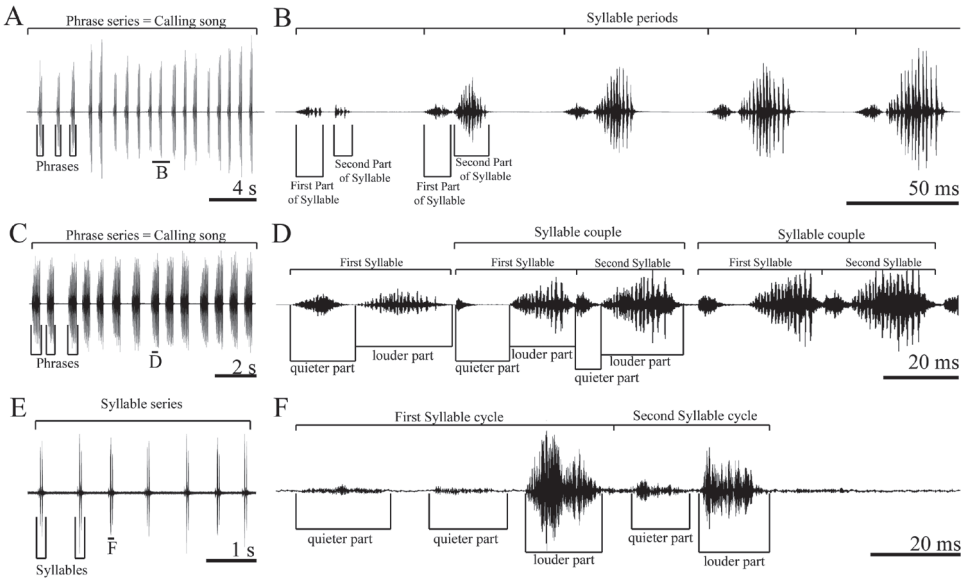

Figure 1. Terminology for three complex song types in studied *tettigoniids*. *Parapholidoptera bolkarensis* - total song (**A**) and one phrase in detail (**B**) *Pezodrymadusa kurmana* - total song (**C**) and several syllable couples in detail (**D**) *Psorodonotus davisi* – syllable series (**E**) and syllable cycles in detail (**F**).

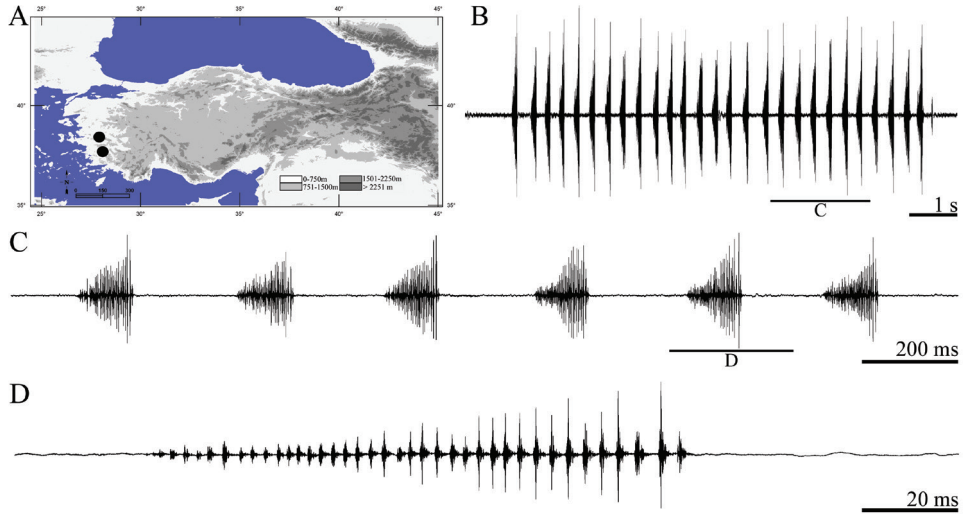

Figure 2. Distribution map (**A**) and male calling song of *Anterastes tolunayi* (**B** one complete phrase **C** a group of syllables and **D** one complete syllable).

eral song type of the phrase is typical crescendo. The number of syllables within 100 ms is 29–40 (34.62 ± 2.21) (Figure 2d). Syllable duration varies between 2 and 5 ms (3.67 ± 0.34) with an interval of 0–1 ms (0.56 ± 0.06).

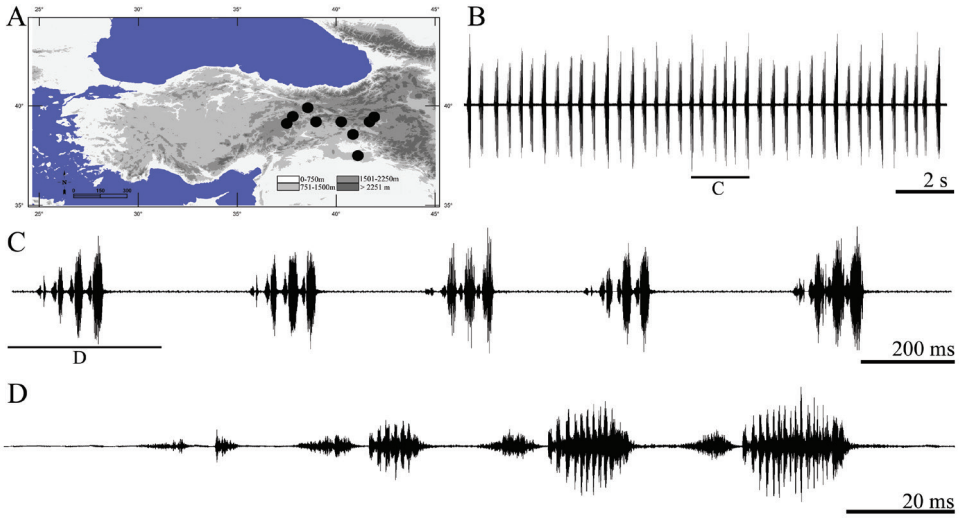

Figure 3. Distribution map (**A**) and male calling song of *Apholidoptera pietschmanni* (**B** sequences of phrases **C** a group of phrases and **D** one complete phrase).

***Apholidoptera pietschmanni* (Ebner, 1912)**
http://species-id.net/wiki/Apholidoptera_pietschmanni

Distribution. Turkey and Iraq (Figure 3a) (Karabağ 1958, Sevgili and Çıplak 2000, Ünal 2006).

Song recording. Male specimens collected from Turkey, Erzincan, Kemaliye, Ocak köyü, 39°08.732'N, 38°35'.296'E, 1485 m, 3.VII.2012 (by D. Şirin & A. Mol) and calling song recorded from one male at 32 °C in laboratory (by D. Şirin).

Description of song. Eight records from one male were evaluated. The calling song consists of a series of regular phrases (Figure 3b) each of which lasting 138–168 ms (152 ± 0.01) and consisting of 3–5 (4.01 ± 0.37) syllables. Syllables generally consist two uneven parts (Figure 3c, 3d). The number of syllables in 100 ms is 2.5–3 (2.62 ± 0.02). The first syllable at the beginning of the phrase is quieter (lower amplitude) than other syllables (Figure 3c, 3d). Syllable duration varies between 17 and 36 ms (29.25 ± 4.15) with an interval of 0–13 ms (5.22 ± 1.78).

***Gampsocleis recticauda* Werner, 1901**
http://species-id.net/wiki/Gampsocleis_recticauda

Distribution. Endemic for Turkey-Western Anatolia (Figure 4a) (Karabağ 1958, Karabağ et al. 1971).

Song recording. Male specimens collected from Turkey, Antalya, Elmalı, Bozöyük köyü-Uzunkarış Tepe arası, 36°43.509'N, 30°09.298'E, 1768 m, 9.VII.2008

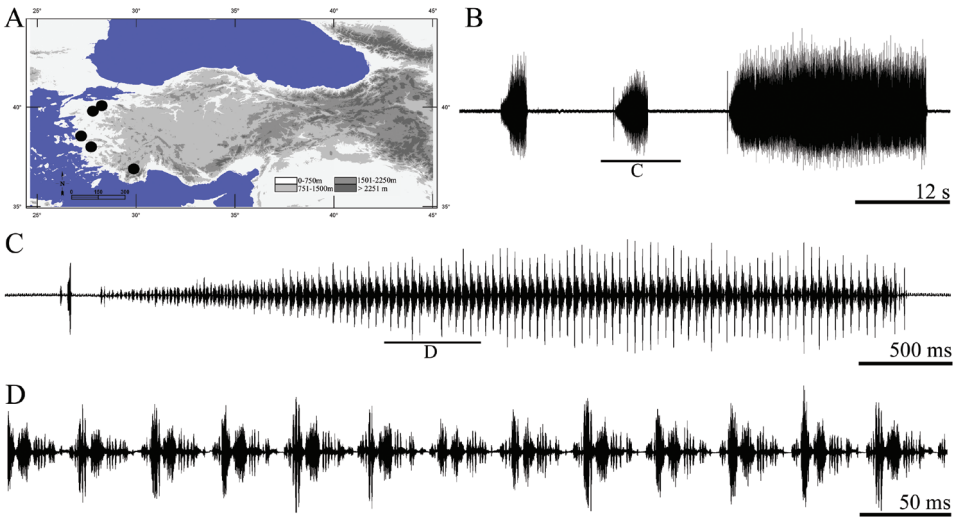

Figure 4. Distribution map (**A**) and male calling song of *Gampsocleis recticauda* (**B** a complete song **C** a complete phrase and **D** a group of syllables).

(by D. Şirin & U. Şirin) and calling song recorded from two males at 33 °C in the field (by D. Şirin).

Description of song. Total of the six records from two males was analyzed. The calling song consists of several phrases in different duration (Figure 4b). The phrases begin with thick pulse and continue with low intensity in the first part of the phrase. The following part of phrases consists of song elements with higher intensity (Figure 4c). Phrases duration varies between 3.53–25.95 s (11.32 ± 5.53). Syllable duration varies between 33 and 40 ms (36.72 ± 1.28) with an interval of 0–3 ms (1.52 ± 0.09). Oscillographic analyses showed that each syllable contains different number of parts which are divided by the very short interval (lower than 2 ms). First and last part of a syllable generally consist of 2–4 shorter elements (each of 1 ms), while middle part consists of two longer elements (each of 6–8 ms).

Parapholidoptera bolkarensis Çıplak, 2000

http://species-id.net/wiki/Parapholidoptera_bolkarensis

Distribution. Endemic for Turkey, Bolkar Mountains (Figure 5a) (Çıplak 2000).

Song recording. Male specimens collected from Turkey, Niğde, Ulukışla, Karagöl Yolu, Bolkar Dağları, 2285 m (type locality), 12.VIII.2011 (by M. S. Taylan, A. Aydın) and calling song recorded from two males at 25 °C in the field (by M. S. Taylan).

Description of song. Total of the six records from two males was examined. The calling song consists of a series of regular phrases (Figure 5b) with an interval of 509–1259 ms (0.76 ± 0.10). Phrase durations vary between 219–346 ms (294 ± 0.04) and

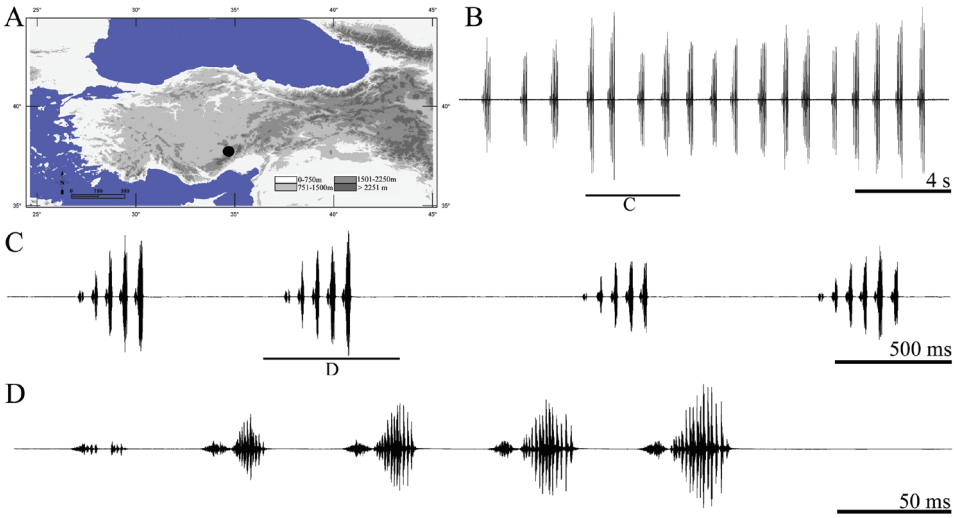

Figure 5. Distribution map (**A**) and male calling song of *Parapholidoptera bolkarensis* (**B** sequences of phrases **C** a group of phrases and **D** one complete phrase).

phrases consist of 4–6 (5.21 ± 0.54) syllables. The first and second syllables at the beginning of the phrase are quieter and shorter (having low amplitudes) than the following ones (Figure 5c). Syllable duration varies between 17 and 41 ms (30.74 ± 4.08) with an interval of 21–47 ms (28.52 ± 3.13). Oscillographic analyses showed that each syllable contains two parts. First part of syllables relatively short and consist of comprised song elements (Figure 5d). First parts generally last 8–13 ms (11.71 ± 1.16) and are followed by second part after an interval of 0–5 ms (1.22 ± 0.48). The second syllable part includes several high amplitudes elements (Figure 5d). These elements number is always 3–4 in first syllable and following respectively 9–10, 12–13, 13–15, 16–18 and 16–18 in last syllable. The second syllable part is much louder (except of the first syllable) and longer than the first part and duration varies between 9 and 27 ms (16.71 ± 3.76).

Parapholidoptera intermixta Karabağ, 1961

http://species-id.net/wiki/Parapholidoptera_intermixta

Distribution. Endemic for Turkey, Binboğa-Mountains (Figure 6a) (Karabağ 1961, Çıplak 2000).

Song recording. Male specimens collected from Turkey, Adana, Saimbeyli, Obruk Saksağan boğazı, 1410 m, 03.VII.2010 (by D. Şirin) and calling song recorded from five males at 28 °C in the field (by D. Şirin).

Description of song. Ten records from five males were examined. The calling song consists of a series of regular phrases (Figure 6b) with an interval of 681–895

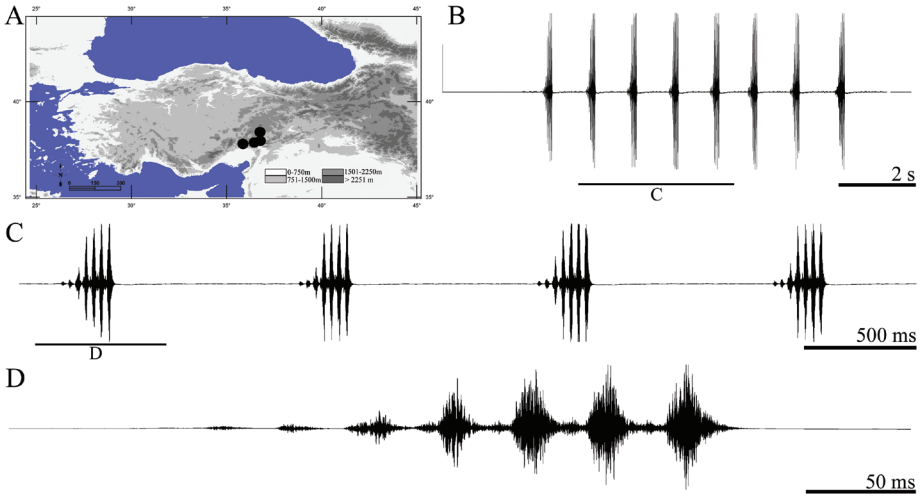

Figure 6. Distribution map (**A**) and male calling song of *Parapholidoptera intermixta* (**B** sequences of phrases **C** a group of phrases and **D** one complete phrase).

ms (810 ± 0.07). Phrase durations vary between 239–254 ms (246 ± 0.05) and phrases consist of 6–7 (6.12 ± 0.35) syllables. Syllables consisting of denser and hardly distinguishable impulses (Figure 6d). The first and second syllables at the beginning of the phrase are quieter and shorter (having low amplitudes) than the following syllables (Figure 6c, d). Syllable duration varies between 29 and 60 ms (38.59 ± 5.78) without any silent interval [except between the first and second syllables (6–12 ms)].

Parapholidoptera salmani Çıplak, 2000

http://species-id.net/wiki/Parapholidoptera_salmani

Distribution. Endemic for Central Anatolia and the Black Sea area of Turkey (Figure 7a) (Çıplak 2000, Ünal 2006).

Song recording. Male specimens collected from Turkey, Tokat, Çamlıbel Geçidi, 1960 m., 02.VIII.2011 (by M.S. Taylan) and calling song recorded from three males at 30 °C in the field which is type locality of species (by M.S. Taylan).

Description of song. Six records from three males were examined. The calling song consists of a series of regular phrases (Figure 7b) with an interval of 522–845 ms (612 ± 0.09). Phrase durations vary between 220–304 ms (265 ± 0.02) and phrases consist of 5–8 (6.35 ± 0.63) syllables. Syllables consist of several high amplitudes elements (Figure 5d). These elements number is always uncountable in first syllable, 9–13 in second syllable and 17–24 (generally 20–22) in following syllables. The phrase begins with 2–3 low amplitude syllables and the maximum

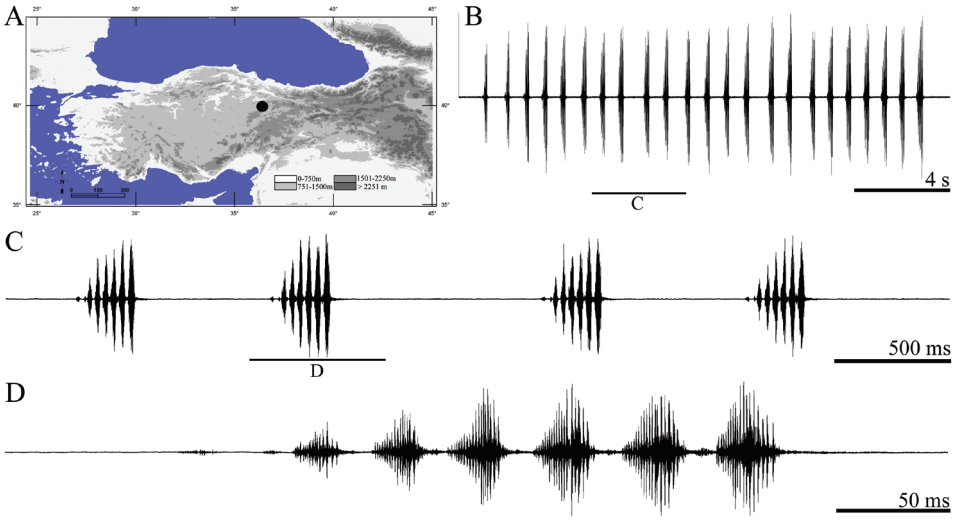

Figure 7. Distribution map (**A**) and male calling song of *Parapholidoptera salmani* (**B** sequences of phrases **C** a group of phrases and **D** one complete phrase).

intensity is usually reached between 3/8–3/5 of the phrase (Figure 7c, 7d). Syllable duration varies between 23 and 43 ms (35.01 ± 5.78) with an interval of 0–3 ms (2.21 ± 0.17).

***Pezodrymadusa konowi* (Bolivar, 1899)**
http://species-id.net/wiki/Pezodrymadusa_konowi

Distribution. Endemic for Turkey-East Anatolia (Figure 8a) (Karabağ 1961, Sevgili et al. 2012b).

Song recording. Male specimens collected from Turkey, Elazığ, Keban çıkışı 15 km, 38°42.790'N, 38°57.428'E, 1376 m, 03.VII.2012 (by D. Şirin & A. Mol), and calling song recorded from two males at 32 °C in laboratory (by D. Şirin).

Description of song. Five records from two males were evaluated. The calling song consists of a series of irregular number of phrases (Figure 8b) with an interval of 297–615 ms (376 ± 0.09). Phrases are consisting of 9–11 (9.84 ± 0.99) syllables. The phrase begins with a quiet syllable (Figure 8c). Oscillographic analyses showed that each phrase involves two syllable couples (Figure 8d). Syllable couple duration varies between 53–67 ms (54.10 ± 1.97) with an interval of 5–19 ms (8.37 ± 2.17). First syllable in these couples lasts 19–25 ms (22.33 ± 1.67) and contains a louder beginning part [17–23 ms (21.12 ± 2.27)] and a quieter part [1–4 ms (1.97 ±0.78)]. First syllable in these couples is followed by a second syllable (except the first syllable in a phrase) after an interval of 6–12 ms (8.22 ± 1.63). Duration of the second syllable in these couples varies between 26–34 ms (28.57 ± 2.15).

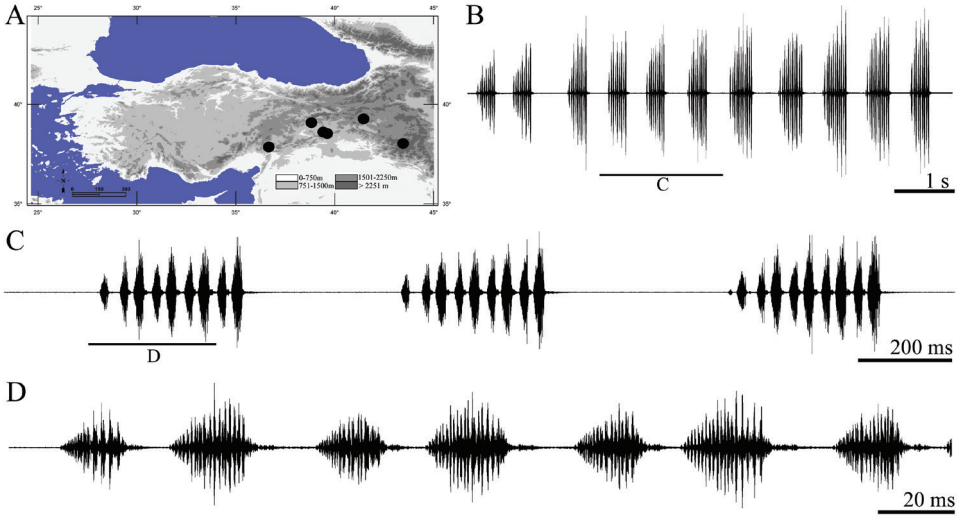

Figure 8. Distribution map (**A**) and male calling song of *Pezodrymadusa konowi* (**B** sequences of phrases groups **C** two complete phrase and **D** a group of syllable couples).

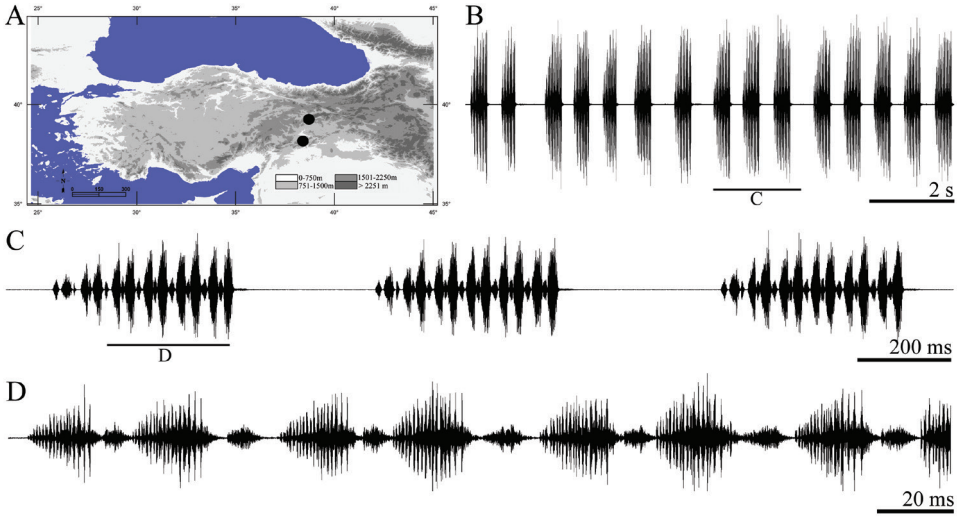

Figure 9. Distribution map (**A**) and male calling song of *Pezodrymadusa kurmana* (**B** sequences of phrases groups **C** three complete phrase and **D** a group of syllable couples).

Pezodrymadusa kurmana (Ramme, 1939)

http://species-id.net/wiki/Pezodrymadusa_kurmana

Distribution. Endemic for Turkey-East Anatolia (Figure 9a) (Karabağ 1961, Sevgili et al. 2012b).

Song recording. Male specimens collected from Turkey, Malatya, Yeşilyurt, Gündüzbey–Adıyaman yolu, Bürücek Yaylası, 38°11.425'N, 38°19.102'E, 1862 m, 02.VI.2010 (by D. Şirin), Doğanşehir, Çığlık, Gürobası köyü üstleri, 38°05.138'N, 37°58.576'E, 1791 m, 04.VII.2012 (by D. Şirin & A. Mol) and calling song recorded from three males at 32 °C in laboratory (by D. Şirin).

Description of song. Eight records from three males were evaluated. The calling song consists of a series of phrases (Figure 9b) with an interval 256–693 ms (392 ± 0.13). Phrases are consisting of 9–13 (10.40 ± 0.98) syllables. The phrase begins with a quiet syllable (Figure 9c). Oscillographic analyses showed that each phrase involves a few couples of syllables (Figure 9d). Syllable couple duration varies between 50–72 ms (61.61 ± 4.79) with an interval of 2–5 ms (3.24 ± 0.97). First syllable in these couples lasts 23–33 ms (28.23 ± 1.93) and contains a quieter beginning part (6–8 ms (7.17 ±0.77)) and a louder part (17–22 ms (21.52 ± 2.33)). First syllable in these couples is followed by a second syllable (except first syllable). Duration of the second syllable varies between 32–42 ms (34.85 ± 2.33).

***Pezodrymadusa lata* Karabağ, 1961**
http://species-id.net/wiki/Pezodrymadusa_lata

Distribution. Endemic for Turkey-East Anatolia (Figure 10a) (Karabağ 1961).

Song recording. Male specimens collected from Turkey, Malatya, Doğanşehir, Çığlık, 1791 m, 4.VII.2012 (by D. Şirin & A. Mol), and calling song recorded from one male at 30 °C in the field (by A. Mol).

Description of song. A total of six records from one male were examined. The calling song consists of a series of regular phrases (Figure 10b) with an interval of 262–604 ms (332 ± 0.11). Phrases are consisting of 11–15 (12.84 ± 0.83) syllables and the number of syllables in 100 ms is approximately two. The phrases begin with a quiet (low amplitude) syllable (Figure 10c). Oscillographic analyses showed that each phrase involves a few couples of syllables (Figure 10d). Syllable couple duration varies between 46–54 ms (50.85 ± 4.79) with an interval of 3–5 ms (4.74 ± 0.77). First syllable in these couples lasts 17–23 ms (21.23 ± 1.88) and contains a louder beginning part (15–18 ms (16.73 ± 1.03)) and a quieter part [3–6 ms (5.02 ± 0.97)]. First syllable in these couples is followed by a second syllable (except first syllable) after an interval of 1–3 ms (1.42 ± 0.11). Duration of the second syllable varies between 28–33 ms (30.15 ± 2.13).

***Pezodrymadusa subinermis* Karabağ, 1961**
http://species-id.net/wiki/Pezodrymadusa_subinermis

Distribution. Endemic for Turkey-East Anatolia (Figure 11a) (Karabağ 1961).

Song recording. Male specimens collected from Turkey, Elazığ, Sivrice, Hazarbaba Kayak Merkezi civarı, 38°25.029'N, 39°18.766'E, 1790 m, 3.VII.2012 (by D. Şirin

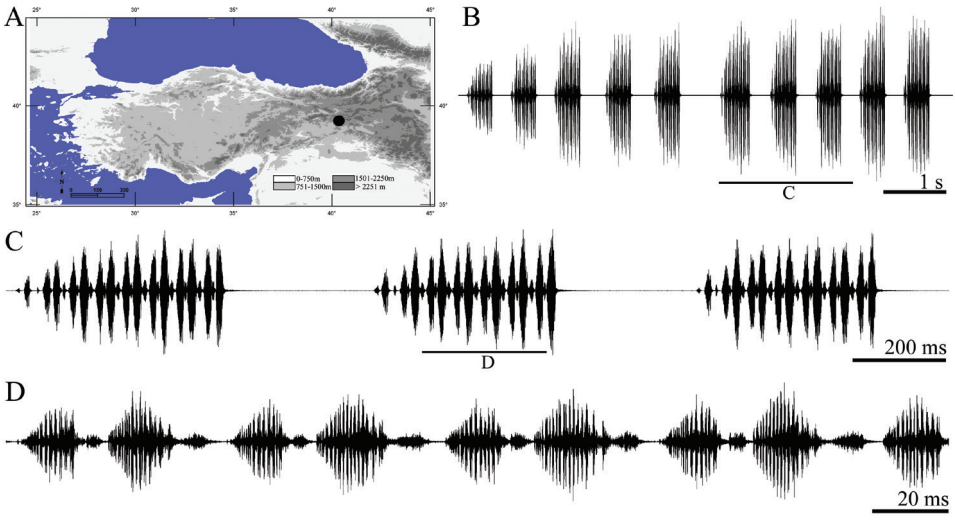

Figure 10. Distribution map (**A**) and male calling song of *Pezodrymadusa lata* (**B** sequences of phrases groups **C** three complete phrase and **D** a group of syllable couples).

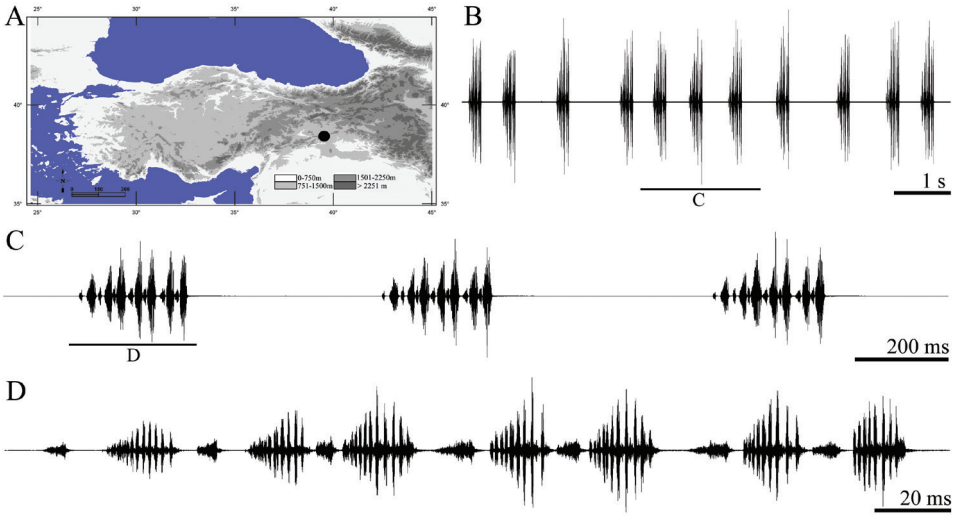

Figure 11. Distribution map (**A**) and male calling song of *Pezodrymadusa subinermis* (**B** sequences of phrases groups **C** three complete phrase and **D** a group of syllable couples).

& A. Mol), and calling song recorded from two males at 30 °C in the field which is type locality of species (by D. Şirin).

Description of song. Totally five records from two males were examined. The calling song consists of a series of regular phrases (Figure 11b) with an interval 355–903 ms (567 ± 0.20). Phrases are consisting of 7–9 (7.23 ± 0.63) syllables. The

phrases begin with a quiet (low amplitude) syllable (Figure 11c). Oscillographic analyses showed that each phrase involves a few couples of syllables (Figure 11d). Syllable couple duration varies between 54–65 ms (59.85 ± 2.72) with an interval of 3–6 ms (4.97 ± 0.73). First syllable in these couples last 22–27 ms (24.73 ± 1.58) and contain a louder beginning part [15–18 ms (16.67 ± 1.12)] and a quieter part [4–8 ms (6.62 ± 1.07)]. First syllable in these couples is followed by a second syllable (except first syllable) after an interval of 1–3 ms (1.22 ± 0.09). Duration of the second syllable varies between 31 and 37 ms (33.95 ± 2.17) and includes a louder part [19–23 ms (21.95 ± 1.36)] and a pulse like quieter part (except last syllable) with duration of 8–12 ms (10.72 ± 1.43).

***Psorodonotus davisi* Karabağ, 1956**
http://species-id.net/wiki/Psorodonotus_davisi

Distribution. Endemic for Turkey-North East Anatolia (Figure 12a) (Karabağ 1956, Karabağ 1958)

Song recording. Male specimens collected from Turkey, Rize, Ovit Dağı, 1600 m, 20.X.2005, 40°38.626'N, 40°44.234'E, (by A. Mol) and calling song recorded from two males at 24 °C in the field (by A. Mol).

Description of song. Totally six records from two males were examined. The calling song includes rarely one usually several isolated syllables (Figure 12b) with an interval 387–632 ms (526 ± 0.07). Syllable duration varies between 101–117 ms (110 ± 4.21). Oscillographic analyses showed that each syllable follows generally two cycles (Figure 12c, 12d). First cycle lasts 65–71 ms (68.71 ± 2.42) and contains two similar quieter parts (each of 15–20 ms) and a louder part [20–28 ms (24.28 ± 2.57)]. Second cycle of syllables varies between 31–40 ms (36.72 ± 2.23) and includes a pulse like quieter part [8–14 (11.45 ± 2.89)] and a louder part which lasts 16 to 24 ms (18.72 ± 3.12).

***Psorodonotus ebneri* Karabağ, 1952**
http://species-id.net/wiki/Psorodonotus_ebneri

Distribution. Endemic for Turkey-Southwest Anatolia (Figure 13a) (Karabağ 1952, Karabağ 1958).

Song recording. Male specimens collected from Turkey, Antalya, Saklıkent, Bakırlıdağ-Pozan arası (It is type locality of species.), 36°49.615'N, 30°17.215'E, 1765 m, 30.VII.2010 (by A. Mol) and calling song recorded from two males at 31 °C in laboratory (D. Şirin).

Description of song. Totally five records from two males were examined. The calling song includes isolated syllables (Figure 13b, c) with an interval 1.76–2.52 s (2.18 ± 0.15). Syllable duration varies between 73–88 ms (80.41 ± 4.96). Oscillo-

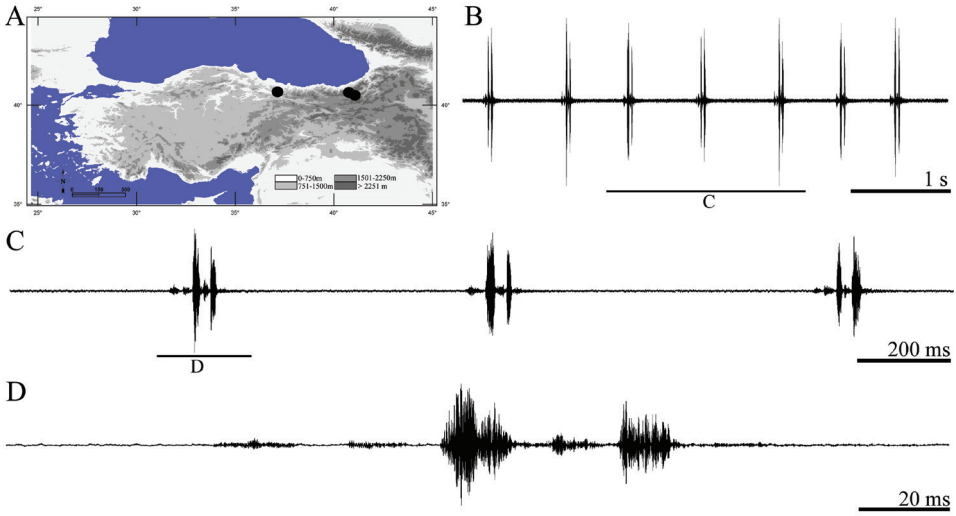

Figure 12. Distribution map (**A**) and male calling song of *Psorodonotus davisi* (**B** sequences of syllables **C** three complete syllables and **D** a complete syllable).

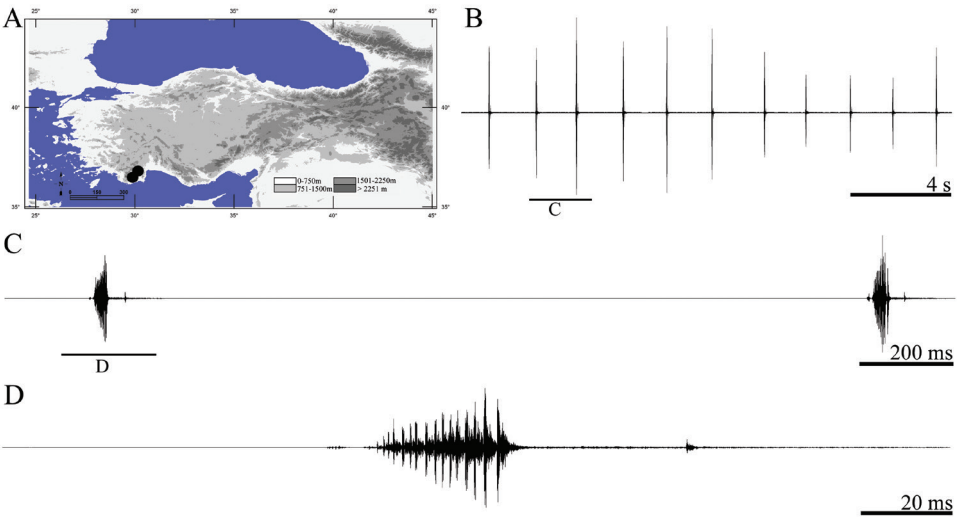

Figure 13. Distribution map (**A**) and male calling song of *Psorodonotus ebneri* (**B** sequences of syllables **C** two complete syllables and **D** a complete syllable).

graphic analyses showed that each syllable includes three elements (quieter-louder-quieter) (Figure 13d). First element of a syllable (rarely absent) is a quieter part and its duration varies between 3–6 ms (3.67 ± 0.29). The first element of syllable is followed by a louder part after an interval of 4–7 ms (5.57 ± 0.81). The louder part (middle element) of syllable consists of 12–18 (15.33 ± 1.96) pulses and its duration varies from

33 to 38 ms (35.26 ± 1.88). The louder part is followed by another quieter part (last element) after an interval of 25–32 ms (27.83 ± 2.40) and its duration varies between 2 and 4 ms (3.10 ± 0.60).

***Psorodonotus rugulosus* Karabağ, 1952**
http://species-id.net/wiki/Psorodonotus_rugulosus

Distribution. Endemic for Turkey- North East Anatolia, East Anatolia (Figure 14a) (Karabağ 1952, 1958, Ünal 2006).

Song recording. Male specimens collected from Turkey, Erzincan, Kelkit-Pöske yolu, Ahmetli çıkışı, 2016 m, 30.VI.2013, 39°53.392'N, 39°21.588'E, (by D. Şirin, A. Mol & M.S. Taylan) and calling song recorded from two males at 28 °C in the field (by D. Şirin).

Description of song. Totally six records from two males were examined. The calling song includes isolated syllables (Figure 14b, c) separated by intervals of 456–1915 ms (833 ± 0.25). Syllable duration varies between 62 and 90 ms (78.83 ± 4.68). Oscillographic analyses showed that each syllable includes generally two elements (quieter and louder) (Figure 14d). First element of a syllable (rarely absent) is a quieter part and its duration varies between 5 and 6 ms (5.77 ± 0.19). The first element of syllable is followed by a louder part with an interval of 4–6 ms (5.27 ± 0.62). The louder part (second element) of syllable consists of 24–32 (27.63 ± 3.13) pulses and its duration lasts from 48 to 56 ms (51.21 ± 2.14). Sometimes the louder part is followed by another quieter part with an interval of 13–19 ms (16.03 ± 2.24) and duration of 4–8 ms (5.20 ± 0.72) (Figure 14c).

Bradyporinae Burmeister, 1838

***Bradyporus* (*Callimenus*) *avanos* Ünal, 2011**
http://species-id.net/wiki/Bradyporus_avanos

Distribution. Endemic for Turkey, widespread in central Anatolia (Figure 15a) (Ünal 2011).

Song recording. Male specimens collected from Turkey, Tokat, Çamlıbel, Artova yol ayrımı, 40°09.680'N, 35°54.309'E, 1280 m, 17. VII. 2004, (by A. Mol) and calling song recorded from two males at 32.8 °C in the field (by A. Mol).

Description of song. Total of five records from two males was examined. The calling song consists of polysyllabic sequences of variable duration (Figure 15b) with an interval of 5.80–8.02 s (mean 6.82). Sequences are consisting of 215–350 (262 ± 38.76) syllables. Nearly all syllables are in same amplitude (Figure 15c); rarely syllables in begin or end point of sequences are in low amplitude. General syllables shape is a kind of crescendo (Figure 15d). Syllable period durations vary between 21 and 28 ms (25.68 ± 1.89). The number of syllables in 100 ms is approximately four (Figure 15d). Each syllable includes 14–23 impulses (16 ± 2.14).

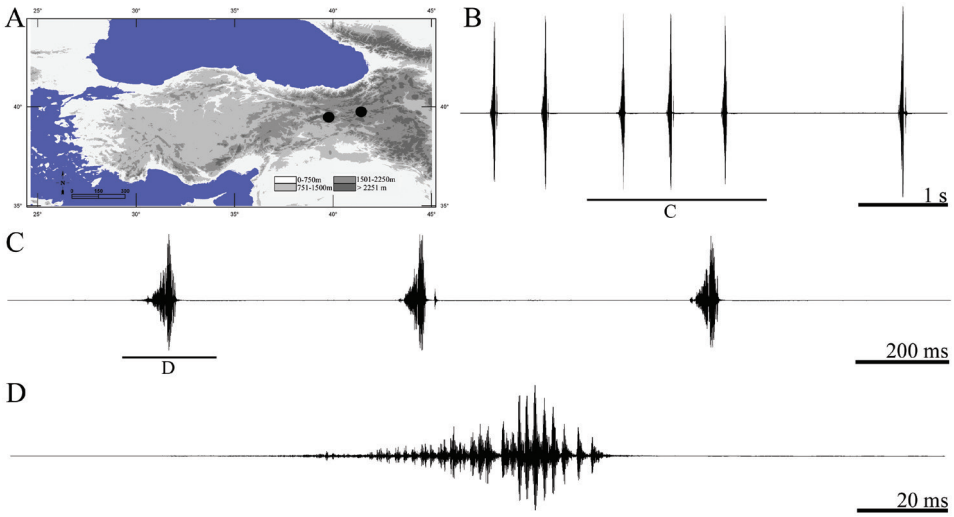

Figure 14. Distribution map (**A**) and male calling song of *Psorodonotus rugulosus* (**B** sequences of syllables **C** three complete syllables and **D** a complete syllable).

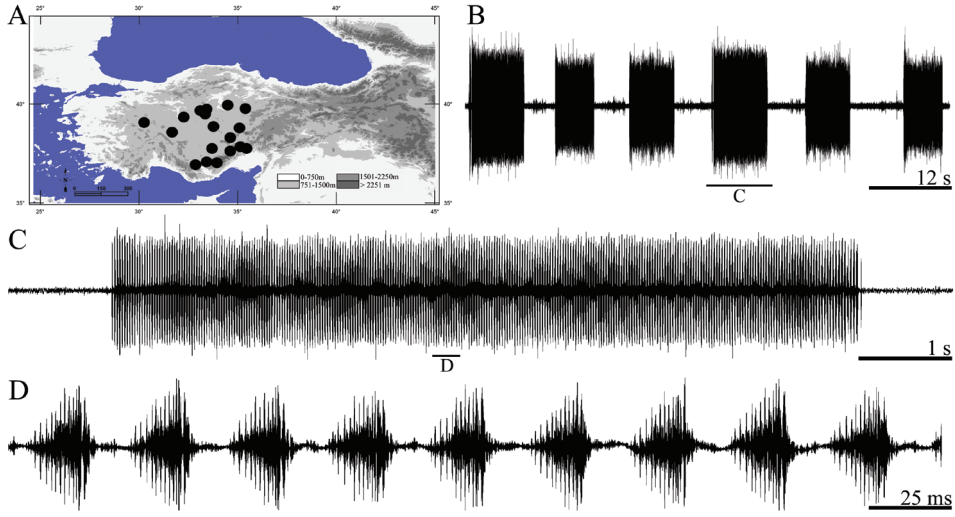

Figure 15. Distribution map (**A**) and male calling song of *Bradyporus (Callimenus) avanos* (**B** a group of sequences of syllables **C** a complete sequences of syllables and **D** a group of syllables).

Saginae Brunner von Wattenwyl, 1878

Saga cappadocica Werner, 1903

http://species-id.net/wiki/Saga_cappadocica

Distribution. Endemic for Turkey - central Anatolia (Figure 16a) (Kaltenbach 1967, 1970).

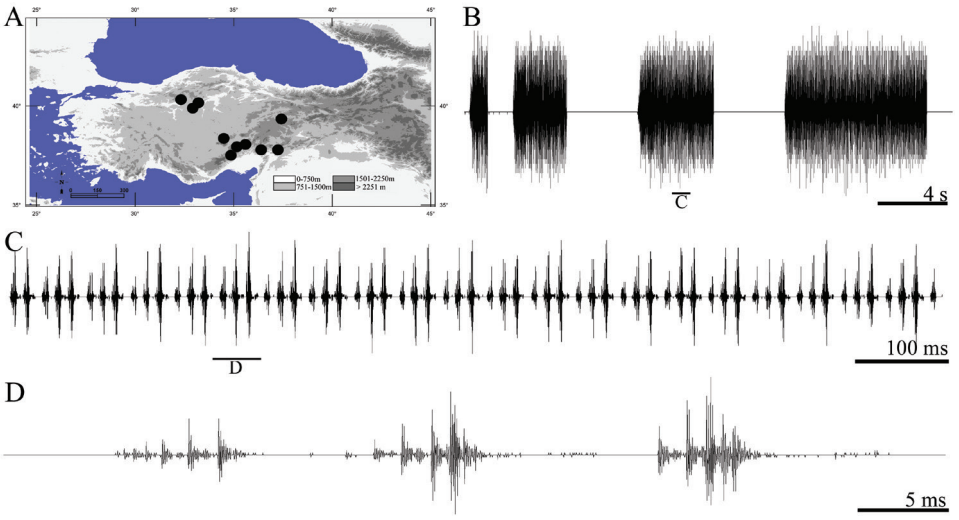

Figure 16. Distribution map (**A**) and male calling song of *Saga cappadocica* (**B** sequences of repetitive units **C** a group of repetitive units and **D** a complete repetitive unit).

Song recording. Male specimens collected from Turkey, Ankara, Çubuk-Şabanözü yolu 6 km, Mutlu köyü yolu, 40°14.760'N, 33°05.199'E, 1090 m, 10.VII.2011 (by D. Şirin) and calling song recorded from 3 males at 24 °C in the field (by D. Şirin).

Description of song. Total of six records from three males was examined. Oscillographic analyses showed that two possibilities (i) each syllable contains three similar elements (usually crescendo) and phrase consists of a great number of them or (ii) there are micro-phrases of three syllables in a crescending sequence and phrase consists of a great number of this micro-phrases (Figure 16c). So, repetitive unit term was used for this situation to describe the song. The calling song consists of repetitive unit sequences of variable duration (Figure 16b). The phrase begins with 1–2 repetitive units that are quieter than the following ones. Phrase duration varies between 1.02 and 8.12 s (4.15 ± 1.29). The number of repetitive unit in 100 ms is approximately 2.5 and repetitive unit duration varies between 36 and 42 ms (39.11 ± 1.90) with an interval of 6–9 ms (6.72 ± 0.19). Each element includes 4–8 impulses and the duration of each element (Figure 16d) varies between 5 and 9 ms (7.16 ± 0.79).

Saga rhodiensis Salfi, 1929

http://species-id.net/wiki/Saga_rhodiensis

Distribution. Anatolia and Rhodos (Figure 17a) (Kaltenbach 1967, 1970).

Song recording. Male specimens collected from Turkey, Antalya, Kemer, Tahtalı Dağları, Gürleyik mevkii, 36°33.067'N, 30°25.001'E, 1479 m, 2.VIII.2010 (by D. Şirin & U. Şirin) and calling song recorded from two males at 31 °C in the field (by D. Şirin).

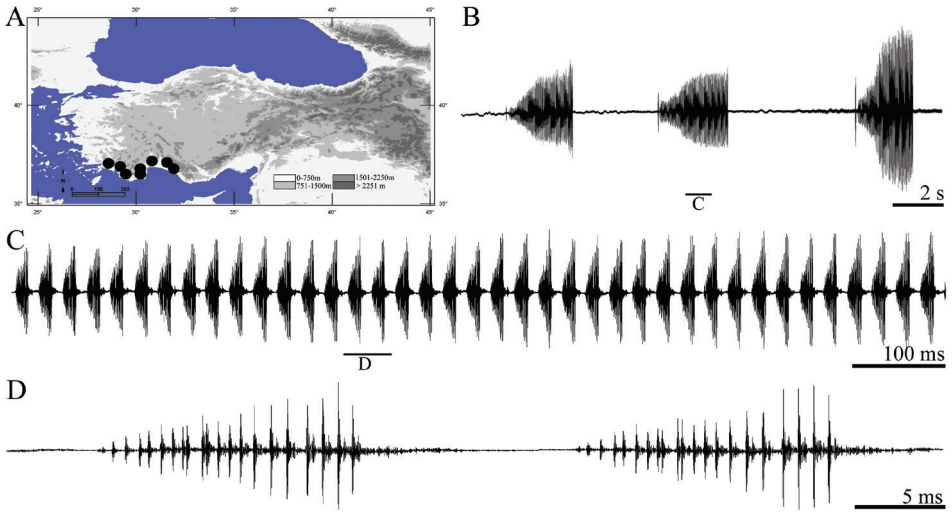

Figure 17. Distribution map (**A**) and male calling song of *Saga rhodiensis* (**B** sequences of phrases groups **C** a group of syllable sequences and **D** two complete syllable).

Description of song. Total of five records from two males was examined. The calling song consists of regular phrases (Figure 17b) with an interval of 3.25–4.50 s. The phrase begins with characteristic high amplitude syllable in the all phrases. After this syllable phrases continue with a quiet beginning and maximum intensity is usually reached between 1/4 and 1/3 of the phrase, however, in some of the phrases there is often a more gradual crescendo roughly up to half of the phrase (Figure 17c). Phrases contain 86–103 syllables (94.2 ± 7.02) and duration varies between 2.27 and 2.77 s (2.55 ± 2.54). Amplitude of the impulses of each syllable from beginning to end of it is getting louder (Figure 17d). Therefore general song shape shows crescendo type (Figure 17c, 17d). The number of syllables in 100 ms is 4–5 (4.18 ± 0.19). Syllable duration varies between 14 and 28 ms (20.92 ± 1.79) with an interval of 3–7 ms (5.62 ± 0.11). Oscillographic analyses showed that each syllable consists of a single element and includes easily countable impulses 16–22 (19.72 ± 1.87) in a crescending structure (Figure 17d).

Discussion

This study is the first one to reveal the descriptions of the acoustic parameters (amplitude-temporal pattern) of 14 endemic and two sub-endemic species in Anatolia. Also, this data could be used as an archive to determine the species in the field (Oliveira et al. 2001) which is important for species having local distribution in nature, among which the endemics studied herewith.

Remarks on song patterns: This part of our discussion focuses only on *Parapholidoptera*, *Pezodrymadusa*, *Psorodonotus* and *Saga*, because we posses sufficient amount of

comparative data only on these genera. The four species of genus *Pezodrymadusa* show very similar song patterns, similar to the song pattern in genus *Eupholidoptera* (Heller 2006, Çıplak et al. 2009). *Eupholidoptera* is a well known genus and all the species in the genus have uniform song pattern, but a different morphology (Heller 2006, Çıplak et al. 2009). All four species, *Pezodrymadusa konowi* (Bolivar, 1899), *Pezodrymadusa kurmana* (Ramme, 1939), *Pezodrymadusa lata* Karabağ, 1961, and *Pezodrymadusa subinermis* Karabağ, 1961, produce a multi-syllable song with syllable groups (Figures 8b, 9b, 10b, 11b). Within these four species, *Pezodrymadusa subinermis* has the lowest syllable number (Figures 11b–c), whereas *Pezodrymadusa lata* has the highest syllable number in a phrase (Figures 10b–c). *Pezodrymadusa subinermis* shows partially differences in the fine structure of syllables than the other species in this study.

Parapholidoptera is the second species-rich genus of the tribe Pholidopterini (including *Pholidoptera, Eupholidoptera, Apholidoptera, Uvarovistia, Parapholidoptera, Exopholidoptera*) in Anatolia (Çıplak 2000, Çıplak et al. 2002, Eades et al. 2013). Genus *Parapholidoptera* was studied morphologically by Çıplak (2000) and acoustically by Heller (2006). Songs of six species have already been described in the *P. castaneoviridis* and *P. distincta* groups (Heller 2006). Song records of three *Parapholidoptera* species are the members of the *P. castaneoviridis* group according to cladograms obtained based on the morphological data (Çıplak 2000). Heller (2006) indicated that only *P. salmani* presumably has a differentiated song pattern within *P. castaneoviridis* group. However, the results of this study show that the general song pattern of *P. salmani* is similar to the *P. castaneoviridis* group song pattern (Figures 7b–c). On the other hand, *P. castaneoviridis* group syllable pattern consists of coupled pulses; however, the syllables of *P. salmani* song consist of one continuous impulse series without any interval (Figure 7d).

Genus *Psorodonotus* has 11 species and eight of them are endemic/subendemic to Anatolia (especially north-east Anatolia) (Çıplak 2008, Ünal 2013a, Eades et al. 2013). The recorded song data in this study show interspecific differences. According to the song results in this study, *Psorodonotus ebneri* Karabağ, 1952 and *Psorodonotus rugulosus* Karabağ, 1952 exhibit a similar song pattern (Figures 13c–d, 14c–d). The song of *Psorodonotus davisi* Karabağ, 1956 shows different syllable composition (Figure 12). However, the song pattern indicates a close relationship between *Psorodonotus ebneri* and *Psorodonotus rugulosus,* although they are not close geographically. On the other hand, *P. davisi* and *P. rugulosus* are located close to each other and far away from the *P. ebneri*.

The saw-legged bush-crickets are among the largest insect species in the Palaearctic. The range of most species of this genus covers the Balkan Peninsula and Asian Turkey (Kaltenbach 1967, 1970). Seven of these species are found in Asian Turkey (*S. beieri*, *S. cappadocica*, *S. longicaudata*, *S. ephippigera*, *S. natoliae, S. puella* and *S. rhodiensis*) (Karabağ 1958, Çıplak et al. 2002). Five European taxa (*S. campbelli, S. gracilis, S. helenica, S. rammei* and *S. natoliae*) were discussed in detail using songs characteristics (Kolics et al. 2008). The songs of *Saga rhodiensis* Salfi, 1929 and *Saga cappadocica* Werner, 1903 are described in this study. The song of *S. rhodiensis* shows a similar song pattern with these five species, but differs in length and impulse number of the syllables from them. On the other hand, *S. cappadocica* shows distinct syllable

elements composition (Figures 16b–d, 17b–d). According to the results of this study and Kolics et al. (2008), the song patterns in genus *Saga* are distinct between taxa and they could be used for taxonomic purposes.

Remarks on the relation of distribution and song diversity: Genus *Pezodrymadusa* is distributed in Anatolia with 14 endemic taxa, in Caucasia with *P. magnifica,* and in Iran with *P. grisea* (Eades et al. 2013). Anatolian species are distributed in a narrow area separated by short distances especially in the eastern part of central Anatolia and the eastern Anatolia (Karabağ 1961, Sevgili et al. 2012b, Ünal 2013b). This distribution gives us a hint on why the species of this genus have a uniform-like song pattern but a different morphology. Heller (2006) mentions a similar situation in different allopatric groups or genera, such as *Psorodonotus fieberi* ssp. or *Eupholidoptera*, and suggests as the most possible explanation the fact that the changes in song in these groups appear slower than the changes in morphology. Similarly, *Pezodrymadusa* shows the same pattern for the recorded taxa.

Parapholidoptera castaneoviridis species-group has 16 members (Eades et al. 2013). Up to now, the songs of the four species of this group have been described showing identical pattern (Heller 2006). The song pattern of the three species described in the present study and belonging to the same species-group, also corresponds to the latter. The general distribution of the species in genus *Parapholidoptera* shows allopatric pattern, but only *P. distincta* and *P. signata* occur parapatrically (Heller 2006). These two parapatric species have a very different song pattern (see detail in Heller 2006). When the distribution and song diversity of *Parapholidoptera* species are considered, parapatric taxa develop stronger acoustic specializations than allopatric taxa.

However, though in *P. castaneoviridis* species-group and genus *Pezodrymadusa* "*changes in song appear more slowly than changes in morphology*"(Heller 2006), genus *Psorodonotus* tells us a different story. The distribution of *Psorodonotus* shows in general an allopatric pattern, but *P. davisi* and *P. specularis* occur parapatrically (Karabağ 1958, Ünal 2006, Ünal 2013b, unpublished data of Deniz Şirin). Heller (2006) shows that the three subspecies of *Psorodonotus fieberi* songs do not differ. However, the song diversity of *Psorodonotus* species recorded in this study discloses that the song is applicable to species identification. Besides, the males of the studied species also differ in matter of comparison with the titilators (Karabağ 1952, Karabağ 1956). These data about *Psorodonotus* appear in the case of "allopatric forms differ in song and also morphology".

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RESEARCH ARTICLE

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On cicadas of *Hyalessa maculaticollis* complex (Hemiptera, Cicadidae) of China

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Abstract

The genus *Hyalessa* China is reviewed based on the discovery of male of the type species *H. ronshana* China as well as the description of one new species (*H. batangensis* **sp. n.**). The species formerly included in the genus *Sonata* Lee are removed to *Hyalessa* as new combinations. Intraspecific variations of *H. maculaticollis* are enumerated based on materials collected from various locations from China. The identity of *Sonata* and the systematic placement of *Hyalessa* are discussed. A key to all species of *Hyalessa* is provided**.**

Keywords

Cicadomorpha, *Oncotympana*, *Sonata*, variability, morphology, new combination

Introduction

The *Oncotympana* was established by Stål in 1870 as a subgenus of *Pomponia* Stål, 1866. Distant (1905a) raised *Oncotympana* to generic level and redescribed it. Later, Ishihara (1961) established the tribe Oncotympanini to accommodate it, and Hayashi

(1978, 1984) reviewed this genus. Chou et al. (1997) recorded four species of *Oncotympana* from China, but two of them (*O. stratoria* and *O. virescens*) were just listed in their checklist. Recently, Lee (2010) found that nine species of *Oncotympana* from the continental East Asia, Japan and India aren't congeneric with the type species *O. pallidiventris*, so he established the genus *Sonata* to accommodate these species, i.e., *S. fuscata* (Distant), *S. maculaticollis* (Motschulsky), *S. ella* (Lei & Chou), *S. expansa* (Walker), *S. mahoni* (Distant), *S. melanoptera* (Distant), *S. obnubila* (Distant), *Sonata stratoria* (Distant), and *S. virescens* (Distant). More recently, Lee (2011) established the tribe Sonatini in the subfamily Cicadinae to contain the genus *Sonata,* and synonymised Oncotympanini with Cicadini and included the Philippine genera *Oncotympana* Stål and *Neoncotympana* Lee, 2011 in the subtribe Oncotympanina of Cicadini. However, Hayashi (2011) synonymised *Sonata* Lee with *Hyalessa* China, and transferred *Oncotympana maculaticollis* to the genus *Hyalessa*. Hayashi and Saisho (2011) recognized *Oncotympana fuscata* (Distant), the type species of *Sonata*, as a synonym of *Hyalessa maculaticollis* (Motschulsky).

In the present paper we review the genus *Hyalessa* based on the discovery of male of the type species *H. ronshana* China and the description of one new species, *H. batangensis* sp. n. from Southeast China. In addition, we transfer the species of *Sonata* to *Hyalessa,* bringing the species number of *Hyalyssa* to 10. Furthermore, the phenotypic variability of *H. maculaticollis*, the most widely distributed species among its congeners, is investigated based on materials collected from different locations.

Materials and methods

This study is mainly based on specimens deposited in the following institutions abbreviated in the text as follows:

NWAFU Entomological Museum, Northwest A&F University, Yangling, China
BMNH The Natural History Museum, London, UK
MNHN Muséum National d'Histoire Naturelle, Paris, France

External morphology was observed using the Olympus SZX10 stereomicroscope, and photographed with a Nikon Coolpix P100 digital camera. The pygofer was carefully extracted from the terminal abdominal segments of relaxed specimen and observed and photographed using a Scientific Digital micrography system equipped with an Auto-montage imaging system and a QIMAGING Retiga 4000R digital camera (CCD). The extracted pygofer, if necessary, was dissected and placed in 10% KOH boiled for 2–5 minutes, washed, and transferred to glycerin for observation, and the aedeagus were photographed using CCD similarly. Terminology for morphological features follows that of Moulds (2005). All measurements are in millimeter.

The type specimens of the new species are deposited in the Entomological Museum, Northwest A&F University (NWAFU), Yangling, China.

Systematics

Family Cicadidae Latreille
Subfamily Cicadinae
Tribe Cicadini Latreille, 1802

Genus *Hyalessa* China, 1925
http://species-id.net/wiki/Hyalessa

Pomponia (*Oncotympana*) Stål, 1870: 710. Type species: *Pomponia (Oncotympana) pallidiventris* Stål
Oncotympana: Distant 1905: 60, 70. Type species: *Pomponia (Oncotympana) pallidiventris* Stål
Sonata Lee, 2010: 20. Type species: *Oncotympana fuscata* Distant

Type species. *Hyalessa ronshana* China.

Body small to large, head including eyes wider than pronotum. Anterolateral pronotal collar not dentate. Medial pronotal collar about one-fourth to one-third the length of inner area. Wings hyaline; fore wing with 8 apical cells, with fuscous spots at bases of apical cells second, third, fifth, and seventh, a marginal series of minute pale fuscous spots near apices of longitudinal veins to apical cells in most species; hind wing with 6 apical cells. Male operculum wider than long, lateral margin roundly produced laterad, overlapped or nearly touching to the other one centrally. Male abdomen slightly shorter than distance from head to cruciform elevation. Posterior margin of male abdominal tergite III much wider than mesonotum. Timbal concealed by timbal cover in dorsal view; timbal cover globolised, projecting beyond corresponding lateral margin of abdomen. Aedeagus thick and curved apically; apex with pair of sclerotized lateral processes and pair of (membranous) saccate hooks between them. Uncal lobe large, separated from the other one distally or connected to the other one from near base to subapex.

Remarks. This genus is closely similar to *Oncotympana* Stål in habitus, but differs from the latter in the following characteristics: pronotum about or more than twice as long as head; anterolateral pronotal collar not dentate; male operculum shorter than wide but very large; uncal lobes bifurcated; aedeagus very thick, with apex with a pair of sclerotized lateral processes and a pair of (membranous) saccate hooks between them.

Key to the species of *Hyalessa*

1 Fore wing with a faint spot merely at bases of apical cells second, third, fifth, and seventh, respectively **2**
– Fore wing with a distinct large fuscous spot at bases of apical cells second, third, fifth, and seventh and a marginal series of minute pale fuscous spots near apices of longitudinal veins to apical cells, respectively **3**

2 Uncal lobes separated from the other one from middle of uncus, with posterior margin rounded and outer margin weakly convex ..... ***H. ronshana***
– Uncal lobes connected to each other closely from near base to apex, with lateral margin slightly concave basally and convex to distal margin ..... ***H. batangensis* sp. n.**
3 Male opercula well separated from each other, or close to each other but not overlapping **4**
– Male opercula overlapping medially **5**
4 Male opercula entirely dark greenish ochraceous, and abdomen (both in males and females) with broad olivaceous or ochraceous markings ..... ***H. mahoni* comb. n.**
– Male opercula entirely much infuscated to black.. ***H. melanoptera* comb. n.**
5 Body smaller, body length<26.0 mm **6**
– Body larger, body length>30.0 mm **9**
6 Male opercula not reaching hind margin of abdominal sternite II ..... ***H. stratoria* comb. n.**
– Male opercula extending to hind margin of abdominal sternite II **7**
7 Mesonotum green or ochraceous; opercula pale yellowish green ..... ***H. virescens* comb. n.**
– Mesonotum black; opercula testaceous **8**
8 Body smaller, body length about 13.0 mm; uncal lobes separated from each other from near base of uncus ..... ***H. expansa* comb. n.**
– Body larger, body length about 25.0 mm; uncal lobes separated from each other from middle of uncus ..... ***H. ella* comb. n.**
9 Head narrower, about 0.73 times as wide as pronotum; uncal lobes broad, with outer margins convexly sinuate and inner margins nearly straight ..... ***H. obnubila* comb. n.**
– Head broader, about 0.79 times as wide as pronotum; uncal lobes long, with inner margins parallel to outer margins ..... ***H. maculaticollis***

***Hyalessa ronshana* China**
http://species-id.net/wiki/Hyalessa_ronshana
Figs 1–3

Material examined. Holotype: ♀ (BMNH), China: Yunnan Prov., 31.VII.1922. 1♂ (NWAFU), China: Hutiaoxia, Xianggelila County, Yunnan Prov., 2.VII.2007, coll. Cong Wei; 10♂♂, 4♀♀ (NWAFU), China: Hutiaoxia, Xianggelila County, Yunnan Prov., 27.VII.2007, coll. Cong Wei; 7♂♂, 8♀♀ (NWAFU), China: Hutiaoxia, Xianggelila County, Yunnan Prov., 6.VIII.2010, coll. Meng Zhang; 1♀ (NWAFU), China: Hutiaoxia, Xianggelila County, Yunnan Prov., 6.VIII.2010, coll. Silong Xu; 1♂ (NWAFU), China: Hutiaoxia, Xianggelila County, Yunnan Prov., 7.VIII.2010, coll. Meng Zhang.

Figure 1. *Hyalessa ronshana* (female, holotype), habitus, dorsal view.

Measurements of types. (18 ♂♂, 12 ♀♀). Body length: male 31.3–37.8, female 32.6–35.7; fore wing length: male 45.6–50.3, female 46.6–53.3; fore wing width: male 15.2–17.6, female 15.4–17.5; width of head including eyes: male 11.0–12.0, female 10.4–12.0; pronotum width (including pronotal collar): male 14.0–16.0, female 14.0–16.2; mesonotum width: male 11.7–13.3, female 11.5–13.4.

Description of male. Body almost black, with short yellow-green hairs.

Head (Fig. 2A, C) about 0.77 times as wide as pronotum; eyes fuscous, ocellus red. Postclypeus moderately swollen, black, with greenish transverse grooves on each side; lateral margin greenish. Anteclypeus black, with yellowish green medially. Rostrum long, extending to posterior trochanter.

Thorax (Fig. 2A, C). Pronotum generally black, with central longitudinal greenish yellow spot near anterior margin, smaller greenish yellow spot on disc, and central round greenish yellow spot near posterior margin; lateral margins of pronotal collar ampliate. Mesonotum black, with pair of greenish markings on anterior angles of cruciform elevation. Metanotum and lateral part of cruciform elevation yellowish green. Thoracic sternites greenish to black.

Legs (Fig. 2E). Black, fore femur with large ochraceous patch medially and smaller ochraceous patch near posterior margin in lateral view. Fore tibia and mid femur mostly black. Hind legs mostly ochraceous. Fore femur with primary spine longest and oblique to femur, secondary spine of intermediate size and subapical spine shortest, both angled slightly.

Wings (Fig. 2A–B). Hyaline, fore wing with distinct infuscation at bases of apical cells second, third, fifth, and seventh; a marginal series of minute pale fuscous spots near apices of longitudinal veins to apical cells.

Abdomen (Fig. 2A, D). Generally black dorsally, with white pollinosity between tergite II and III. Timbal cover black, prominently globolised. Opercula greyish green, centrally overlapping, with rounded posterior margin extending to abdominal sternite II. Abdominal sternites mostly black, with greenish speckle on sternite III, VII and VIII, sparsely covered with white pollinosity.

Genitalia (Fig. 2F, G, H). Pygofer barrel-shaped in ventral view. Uncal lobes broad and well developed, separated from the other one from middle of uncus, with poste-

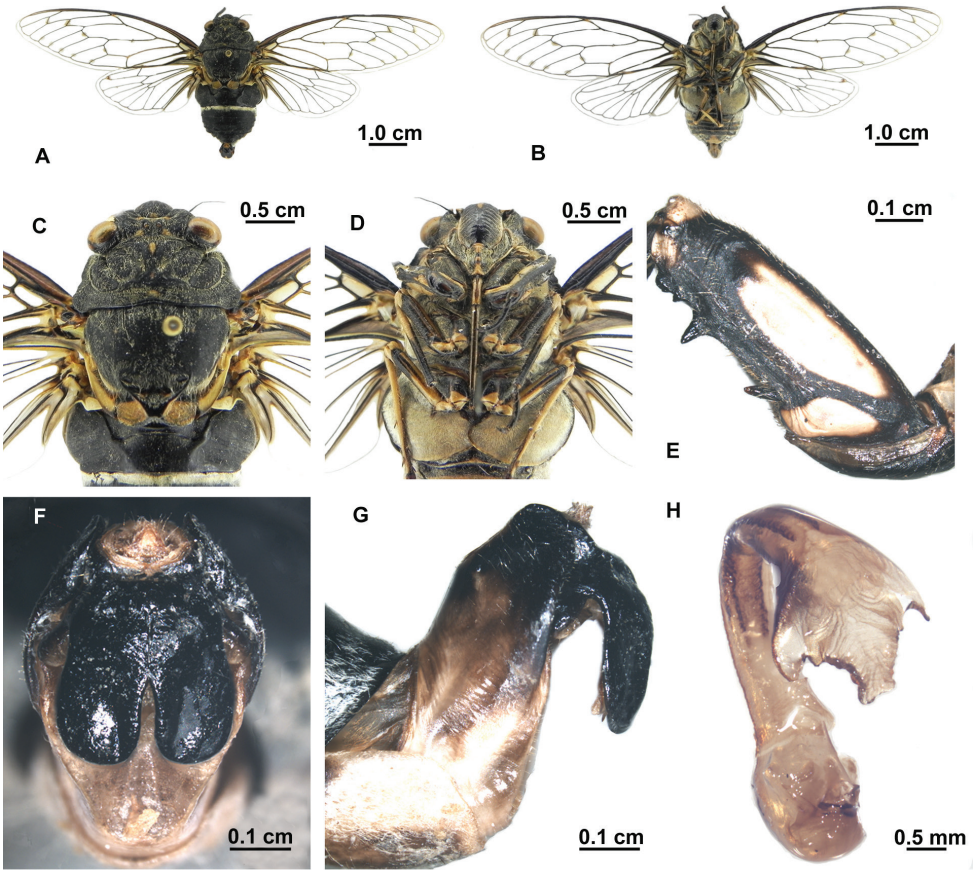

Figure 2. *Hyalessa ronshana* (male). **A** habitus, dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** head and thorax, ventral view **E** left foreleg, showing the spines on fore femur **F** male pygofer, ventral view **G** male pygofer, lateral view **H** aedeagus.

rior margin rounded and outer margin weakly convex. Basal lobe of uncus shorter, ca 1/2 length of uncal lobe. Aedeagus with apical one third strongly curved ventrally, expended subapically; sclerotized lateral processes acute, large medial (membranous) saccate hook somewhat truncate with a pair of small lateral membranous processes between sclerotized lateral processes.

Description of female. (Figs 1, 3). Opercula smaller than those of male, broadly separated from each other. Abdominal segment IX (pygofer) greenish; ovipositor sheath not extending beyond segment IX, posterior margin of segment VII incised at middle. Other characteristics similar to male.

Distribution. China (Yunnan).

Remarks. *Hyalessa* China formerly included only the type species *H. ronshana* which was established on a single female collected from Yunnan Prov., China. Re-

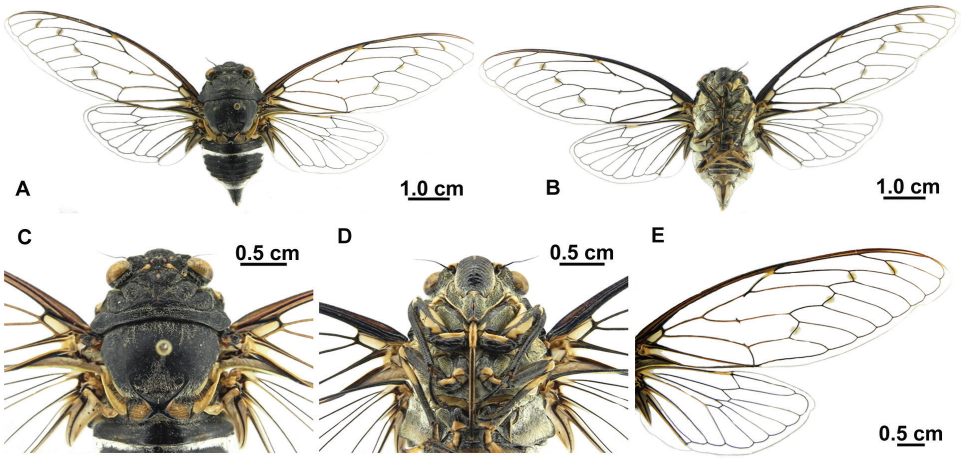

Figure 3. *Hyalessa ronshana* (female). **A** habitus, dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** head and thorax, ventral view **E** fore and hind wings.

cently, when we investigated materials of this genus collected from different locations from China, some specimens also from Yunnan Province were found very similar to *H. ronshana*, but they can be distinguished from the holotype of *H. ronshana* by the concoloured mesonotum (blackish, without paired large spots adjacent to the anterior margin of mesonotum), the normal nodal line of fore wing (absent in the ulnar cell 3 and the medial cell), the fuscous spots at bases of apical cells second, third, fifth, and seventh of fore wing, and a marginal series of minute pale fuscous spots near apices of longitudinal veins to apical cells. However, the holotype of *H. ronshana* is an unusual form, representing a kind of deformation on the forewing vein, i.e., the veins are somewhat asymmetric and particularly, the long nodal line presented on the ulnar cell 3 and the medial cell. In addition, the condition of the holotype is not good in condition, e.g., the faint markings on mesonotum are not strict, and only one very faint spot appeared at the base of apical cell second of fore wing (other infuscations on the veins of fore wing seem to be diminished due to the poor condition of the specimen). This is probably due to that the holotype was rather teneral and/or it has been deposited in the collection for a long time. Herein, judging from the adjacency of the forementioned materials collected from Yunnan Prov. and the holotype of *H. ronshana* as well as the common characters shared by them, particularly the transverse pollinosity-like band on base of abdominal tergite III, coloration of veins (both upperside and underside), maculation on fore femur, hind tibia, opercula and pygofer, we conclude that the new materials are conspecific with the holotype of *H. ronshana*, and redescribe this species based on the discovery of the male for the first time. *H. ronshana* is similar to *H. maculaticollis*, but can be distinguished from the latter by the generally black pronotum and mesonotum, the rounded apex of the broad uncal lobes of male pygofer, and the shape of apical hooks of aedeagus.

***Hyalessa batangensis* sp. n.**
http://zoobank.org/F42CAD01-CECC-408F-A4EB-11B74EE23C34
http://species-id.net/wiki/Hyalessa_batangensis
Figs 4–5

Type material. Holotype: ♂ (NWAFU), China: Batang County, Sichuan Prov., 12.VIII.2001. Paratype: 1♂ (NWAFU), China: Batang County, Sichuan Prov., 12.VIII.2001.

Measurements of types. (2♂♂): Body length: 26.6–31.8; fore wing length: 37.1–43.5; fore wing width: 12.4–15.2; width of head including eyes: 8.6–10.3; pronotum width (including pronotal collar): 11.3–14.0; mesonotum width: 9.4–10.9.

Etymology. The species name is derived from the location of the types.

Description of male. Head (Fig. 4A, C) about 0.74 times as wide as pronotum. Compound eye greenish brown, ocellus red. Postclypeus moderately swollen, with black medial longitudinal fasciae and greenish yellow transverse grooves on each side. Anteclypeus black, with yellowish green fasciae medially. Rostrum with black apex extending to posterior trochanter.

Thorax (Fig. 4A, C). Pronotum and mesonotum almost black, pronotum with pair of submedian markings and pair of lateral markings yellow greenish. Mesonotum with pair of submedian markings and lateral markings respectively, or without distinct markings. Cruciform elevation black, with pair of yellow greenish markings on anterior angles. Metanotum and lateral part of cruciform elevation yellowish green. Thoracic sternites yellow greenish, with ochraceous patches.

Legs (Fig. 4E). Dark brown, fore femur with large yellowish ochraceous patch medially and smaller ochraceous patch near posterior margin in lateral view. Fore tibia and mid femur, tibia mostly dark brown. Fore femur with primary spine conical and less angled; secondary and subapical spines erect and pointed.

Wings (Fig. 4A, B). Hyaline, fore wing with indistinct infuscation at bases of apical cells second and third; no fuscous spots near apices of longitudinal veins to apical cells.

Abdomen (Fig. 4A, D). Black, with white pruinosity between tergite II and III. Timbal cover brownish ochraceous, circular and globose. Opercula yellow greenish, centrally overlapping, with rounded apex extending to posterior margin of sternite II. Abdominal sternites mostly black, with sternite VII, VIII and posterior margin of III, IV, V and VI yellow greenish.

Genitalia (Fig. 4F, G, H). Pygofer barrel-shaped in ventral view. Uncal lobes connected to each other closely from near base to apex; lateral margin of uncal lobe slightly concave basally and convex to distal margin. Aedeagus with apex curved ventrally, expended subapically; apex with sclerotized lateral processes very broad and rounded, pair of (membraneous) saccate hooks between sclerotized lateral processes.

Female. Unknown.

Distribution. China (Sichuan).

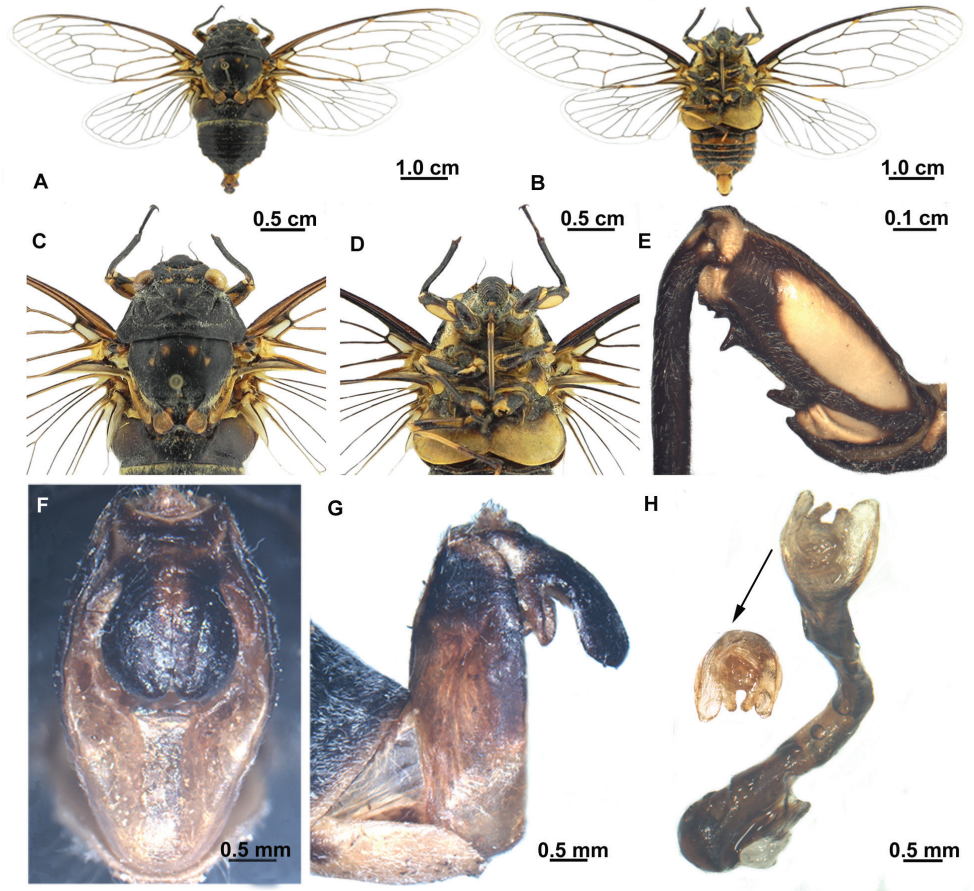

Figure 4. *Hyalessa batangensis* sp. n. (male, holotype). **A** habitus, dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** head and thorax, ventral view **E** left foreleg, showing the spines on fore femur **F** male pygofer, ventral view **G** male pygofer, lateral view **H** aedeagus.

Remarks. This new species can be distinguished from its congeners by the combination of the following characters: slender body, without fuscations on veins of fore wing, and uncal lobes connected to each other closely from near base to apex. There are slight differences of body size, markings on mesonotum, and the shape of aedeagus presents between the holotype and the paratype: the holotype has a bigger body size (31.8 mm), a pair of submedian markings and a pair of lateral markings on mesonotum, and a pair of broad, rounded sclerotized lateral processes on aedeagus (Fig. 4); the paratype has a smaller body size (26.6 mm), without distinct markings on mesonotum, and the sclerotized lateral processes on aedeagus are short and acute (Fig. 5). We tentatively treat the latter as an intraspecific variation of this species, and its identity needs to be confirmed when more materials are available.

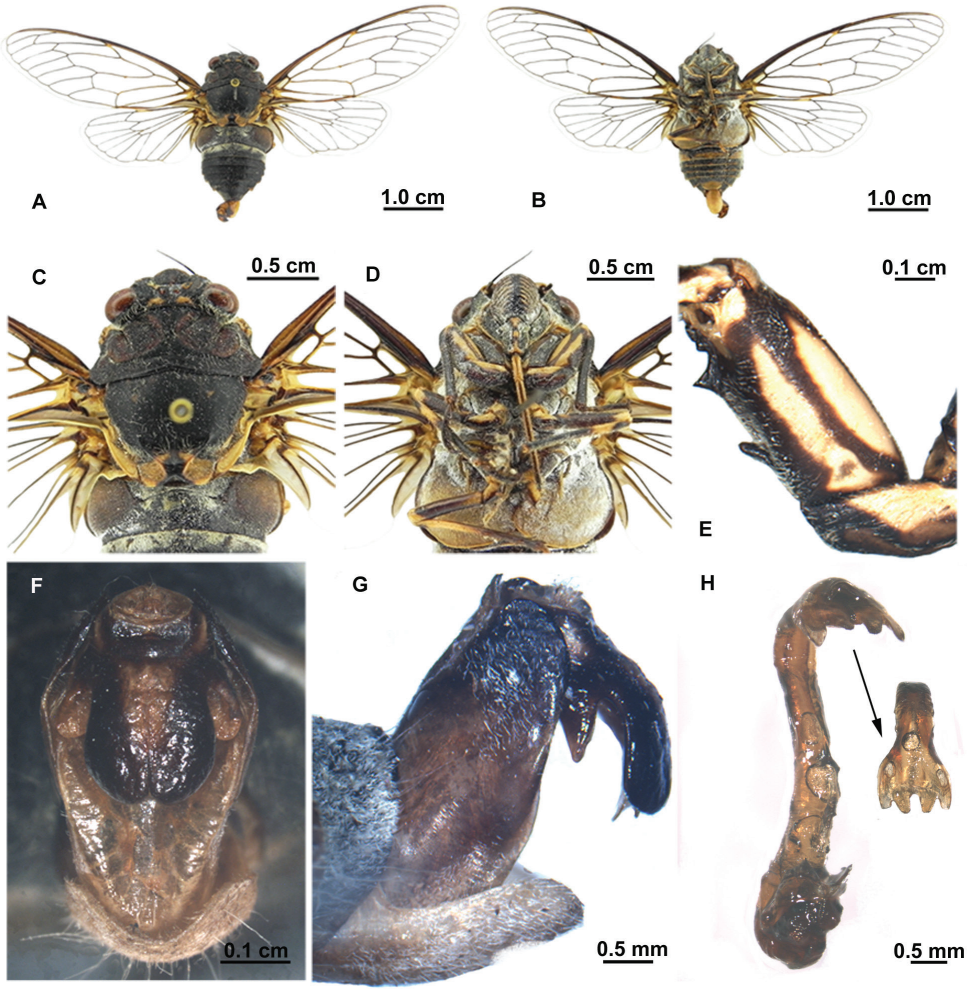

Figure 5. *Hyalessa batangensis* sp. n. (male, paratype). **A**. habitus. dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** head and thorax, ventral view **E** left foreleg, showing the spines on fore femur **F** male pygofer, ventral view **G** male pygofer, lateral view **H** aedeagus.

***Hyalessa maculaticollis* (Motschulsky)**
http://species-id.net/wiki/Hyalessa_maculaticollis

Cicada maculaticollis Motschulsky, 1866: 185.
Pomponia maculaticollis Distant, 1888: 296.
Oncotympana maculaticollis: Distant 1905: 559.
Oncotympana fuscata Distant, 1905: 558.
Oncotympana coreanus Kato, 1925: 27.
Sonata maculaticollis Lee, 2010: 20.

Material examined. 1♂ (NWAFU), China: Mt. Emei, Sichuan Prov., 5.V.1957; 1♂ (NWAFU), China: Mt. Emei, Sichuan Prov., 22.VII.1974; 8♂♂ (NWAFU), China: Mt. Emei, Sichuan Prov., 22.VII.1991; 4♂♂ (NWAFU), China: Mt. Emei, Sichuan Prov., 26.VII.1991; 1♂ (NWAFU), China: Mt. Emei, Sichuan Prov., 23.VII.2009; 1♂ (NWAFU), China: Beijing, 14.VII.1961; 1♂ (NWAFU), China: Beijing, 18.VII.1961; 3♂♂ (NWAFU), China: Qingdao, Shandong Prov., 29.VII.2010; 3♂♂ (NWAFU), China: Qingdao, Shandong Prov., 2.VIII.2010; 3♂♂ (NWAFU), China: Qingdao, Shandong Prov., 4.VIII.2010; 5♂♂ (NWAFU), China: Qingdao, Shandong Prov., 8.VIII.2010; 1♂ (NWAFU), China: Chunhua County, Shaanxi Prov., 6.VIII.1981; 1♂ (NWAFU), China: Guangdong Prov., 5.VIII.1957; 2♂♂ (NWAFU), China: Mts. Shennongjia, Hubei Prov., 11.VIII.2004; 1♂ (NWAFU), China: Mts. Shennongjia, Hubei Prov., 15.VIII.2004; 2♂♂ (NWAFU), China: Huoditang, Ningshan County, Shaanxi Prov., 5.VIII.2008; 2♂♂ (NWAFU), China: Mt. Nanwutai, Xi'an, Shaanxi Prov., 25.VII.1951; 2♂♂ (NWAFU), China: Mt. Nanwutai, Xi'an, Shaanxi Prov., 26.VIII.1957; 1♂ (NWAFU), China: Mt. Nanwutai, Xi'an, Shaanxi Prov., 13.VII.1959; 1♂ (NWAFU), China: Mt. Tianmu, Zhejiang Prov., 15.VIII.1965; 1♂ (NWAFU), China: Mt. Tianmu, Zhejiang Prov., 26.VII.2003; 2♂♂ (NWAFU), China: Mt. Tianmu, Zhejiang Prov., 28.VII.2003; 1♂ (NWAFU), China: Mt. Tianmu, Zhejiang Prov., 29.VII.2003; 31♂♂ (NWAFU), China: Mt. Huping, Hunan Prov., 26.VII.2013; 4♂♂ (NWAFU), China: Mt. Qingcheng, Sichuan Prov., 9.VIII.2013.

Main characters. Body large, head slightly shorter than base of mesonotum in dorsal view. Rostrum extending to the posterior trochanter. Mesonotum black with following green markings: two large central obconical spots, three pairs of large greenish spots around them and pair of greenish spots on each lateral margin. Abdomen black; timbal cover ochraceous. Wings hyaline; fore wing with large fuscous spot at bases of apical cells second, third, fifth, and seventh; a marginal series of minute pale fuscous spots near apices of longitudinal veins to apical cells. Opercula in male broad, convex, extending to posterior margin of second abdominal segment, and overlapping; opercula in female smaller than those of male and broadly separated from each other. Aedeagus thick and curve ventrally, expended subapically, with a pair of sclerotized lateral processes apically as well as a pair of (membraneous) saccate hooks when everted.

Remarks. After examining the holotype (male) of *Oncotympana fuscata* Distant preserved in the Muséum National d'Histoire Naturelle (by MH) and investigating the intraspecific variability of *H. maculaticollis*, we reconfirm that *H. fuscata* is a junior synonym of *H. maculaticollis*, as previously proposed by several authors. Among the species of *Hyalessa*, *H. maculaticollis* has the widest range of distribution, from the Russian Maritime Territory, Korean Peninsula, Japan to China. This species mainly occurs in the forests, and the calling song of males is very loud with a complex transposition. *H. maculaticollis* is noted for its great intraspecific variability, including body size, markings on thorax, timbal cover, opercula and aedeagus, which has been recorded by Hayashi and Saisho (2011) based on materials collected from Japan. In this study, based on more materials collected from different locations in China, we further investigate the intraspecific variability of this species. For details, see below.

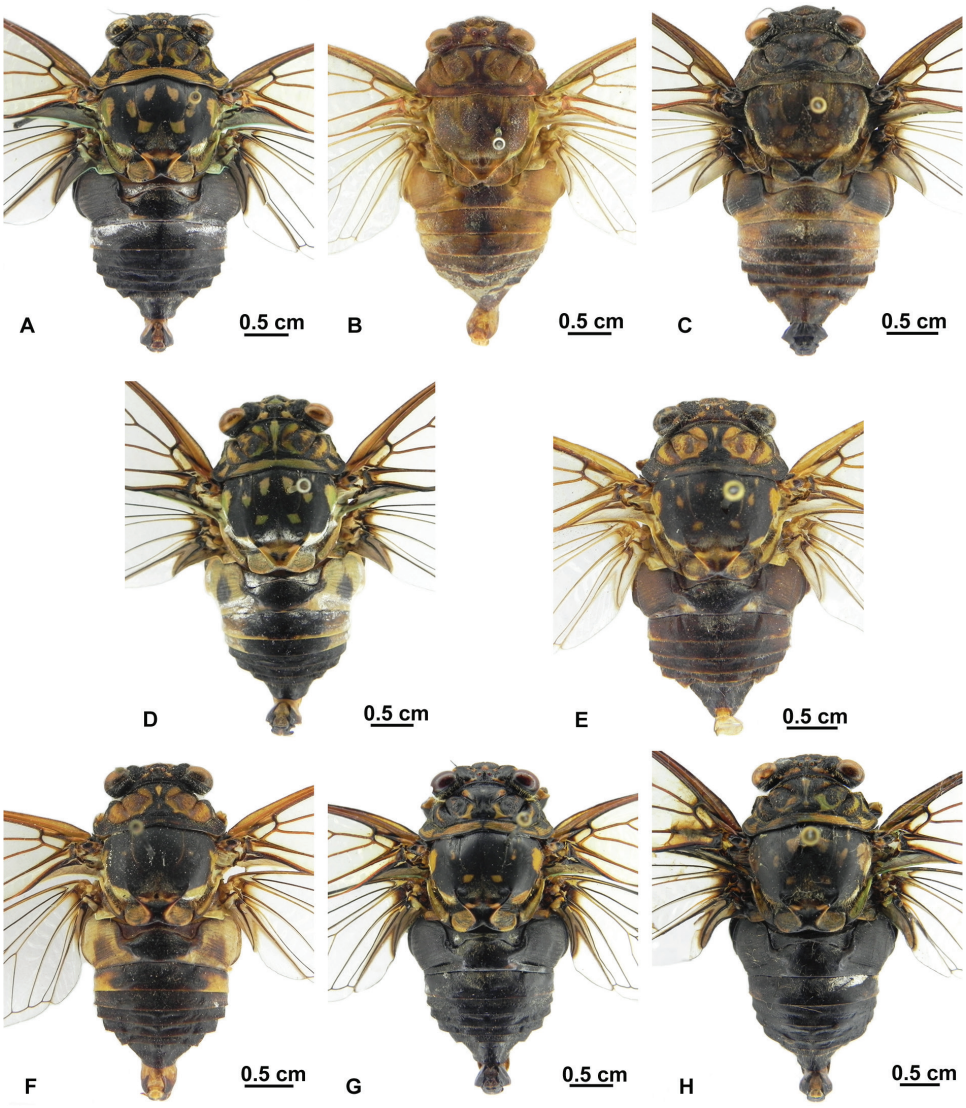

Figure 6. *Hyalessa maculaticollis* (male). Habitus, dorsal view, showing intraspecific variability in Chinese populations. **A** material from Mt. Emei, Sichuan Prov. **B** material from Beijing **C** material from Qingdao, Shandong Prov. **D** material from Qingdao, Shandong Prov. **E** material from Chunhua County, Shaanxi Prov. **F** material from Guangdong Prov. **G** material from Mts. Shennongjia, Hubei Prov. **H** material from Huoditang, Ningshan County, Shaanxi Prov.

Intraspecific variability. Body size. (1) Medium, about 30 mm in length (Fig. 6F); (2) Large, about 36 mm in length (Fig. 6A).

Coloration of body. (1) Generally black with green or ochreous markings (Fig. 6A, D, G, H); (2) Generally yellowish with dark ochreous markings (Fig. 6B); (3) Variegated (Fig. 6C, E, F).

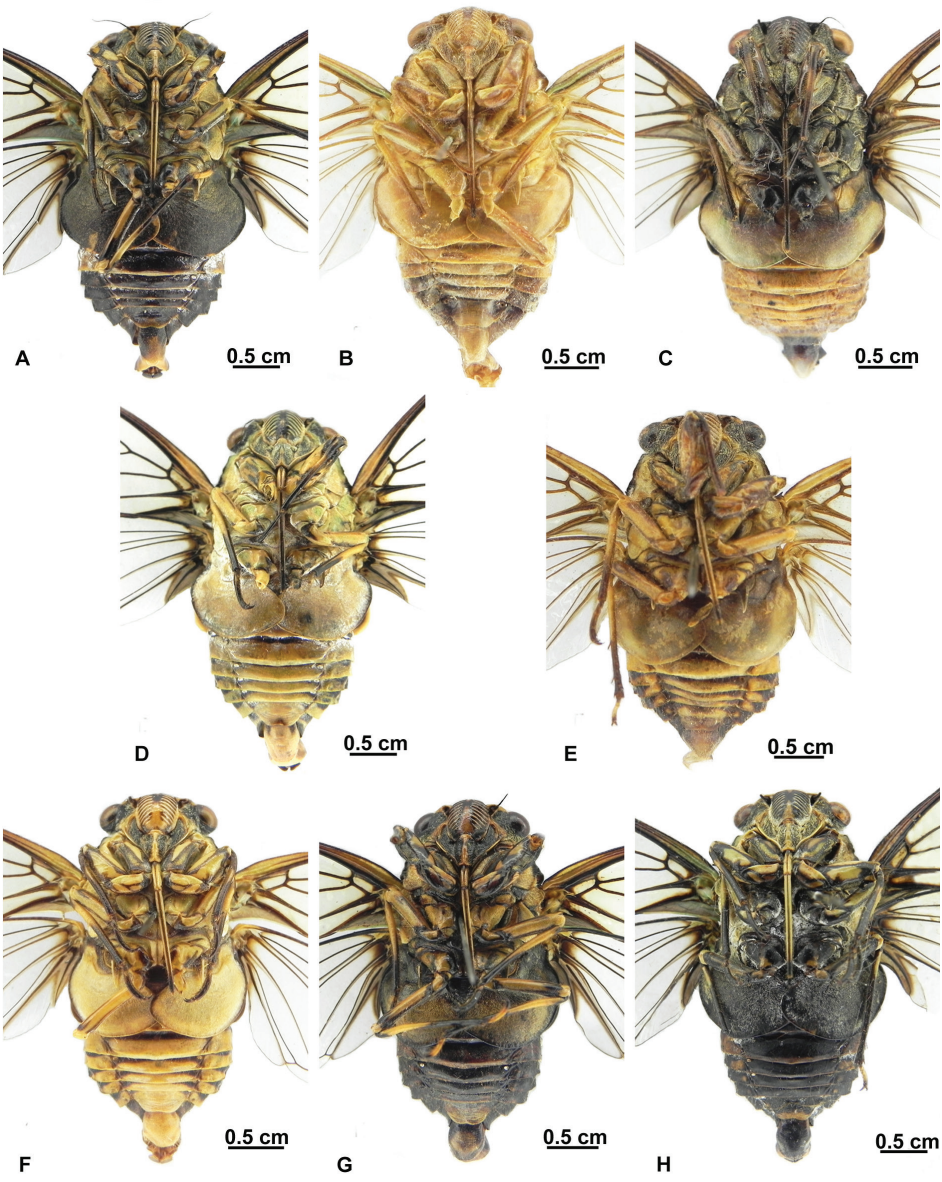

Figure 7. *Hyalessa maculaticollis* (male). Habitus, ventral view, showing intraspecific variability in Chinese populations. **A** material from Mt. Emei, Sichuan Prov. **B** material from Beijing **C** material from Qingdao, Shandong Prov. **D** material from Qingdao, Shandong Prov. **E** material from Chunhua County, Shaanxi Prov. **F** material from Guangdong Prov. **G** material from Mts. Shennongjia, Hubei Prov. **H** material from Huoditang, Ningshan County, Shaanxi Prov.

Markings on mesonotum. (1) Mesonotum with 5 pairs of greenish spots: a pair of very small ones near anterior margin, three large spots on disc, and a pair of very lagre spots on lateral margins, (Fig. 6A, D); (2) Above mentioned 5 pairs of spots on

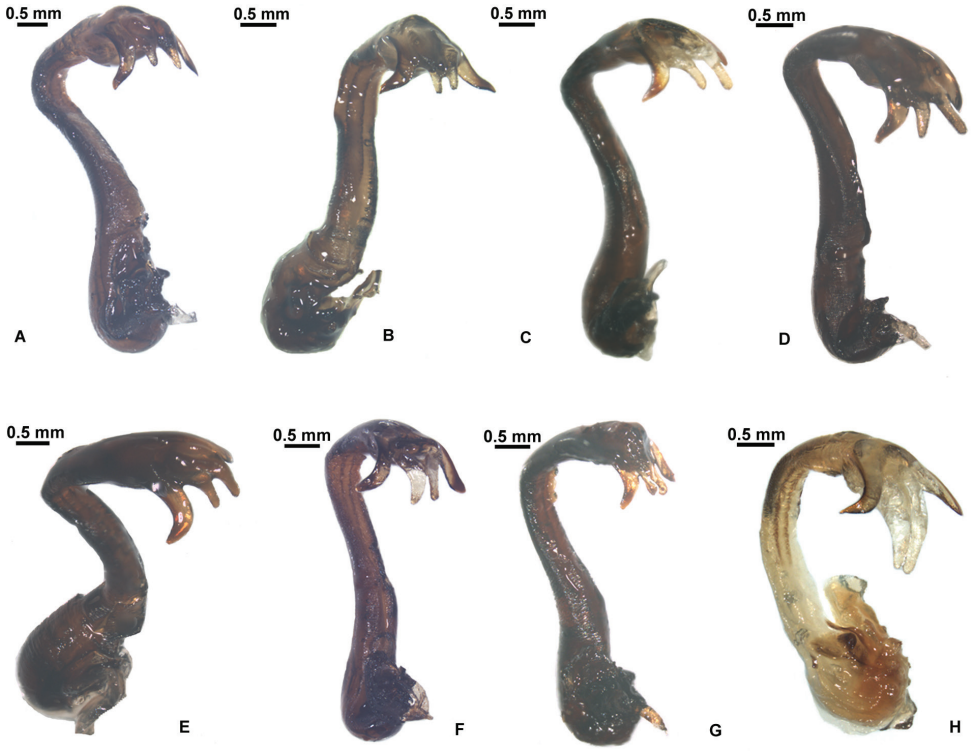

Figure 8. *Hyalessa maculaticollis* (male). Aedeagus, lateral view, showing intraspecific phenotypic variability in Chinese populations. **A** material from Qingdao, Shandong Prov. **B** material from Mt. Tianmu, Zhejiang Prov. **C** material from Huoditang, Ningshan County, Shaanxi Prov. **D** material from Mt. Qingcheng, Sichuan Prov. **E** material from Mt. Huping, Hunan Prov. **F** material from Mts. Shennongjia, Hubei Prov. **G–H** material from Mt. Nanwutai, Xi'an, Shaanxi Prov.

mesonotum obscure or reduced (Fig. 6C, E, G, H); (3) Mesonotum with no distinct markings on disc (Fig. 6B, F).

Timbal cover. (1) Black (Fig. 6A, G, H); (2) Ochreous or greenish yellow, with dark ochreous to black patch on posterior area (Fig. 6C, D, F); (3) Dark ochreous or yellow (Fig. 6B, E).

Male opercula. (1) Black (Fig. 7A, H); (2) Light ochreous or brown (Fig. 7B, F); (3) Variegated (Fig. 7C, D, E, G).

Shaft of aedeagus. (1) Aedeagal shaft slightly S-shaped in lateral view (Fig. 8A, B, C, D, F, G); (2) Aedeagal shaft S-shaped in lateral view (Fig. 8E); (3) Aedeagal shaft C-shaped in lateral view (Fig. 8H).

Apex of aedeagus. (1) Paired saccate hooks much shorter than the sclerotized lateral processes (Fig. 8A, B, E); (2) Paired saccate hooks slightly shorter than the sclerotized lateral processes (Fig. 8C, D, F, G); (3) Paired saccate hooks much longer than the sclerotized lateral processes (Fig. 8H).

Discussion

The genus *Hyalessa* formerly included only the type species *H. ronshana* which was established on a single female collected from Yunnan Province of China. Herein, we re-address the identity of this species based on the discovery of the male for the first time and treat *Sonata* as a junior synonym of *Hyalessa*. This genus is retained in the tribe Cicadini, and its tribal and sub-tribal status awaiting further phylogenetic studies.

Regarding the validity of *Oncotympana fuscata*, Distant (1905) stated that *O. fuscata* is allied to *O. maculaticollis* but can be distinguished from the latter by the coloration of body, the narrower fore wings and the broader cruciform elevation. Kurosawa (1969) treated the populations in Korea and Far East Russia as a subspecies, *O. maculaticollis fuscata*. However, *O. fuscata* was treated as a junior synonym of *O. maculaticollis* by Chou et al. (1997). Lee (1999) applied the name *O. fuscata* to the Korean population because of substantial differences in song. Recently, Lee (2008) also treated *O. fuscata* and *O. maculaticollis* as two separated species and synonymized *O. maculaticollis fuscata* with *O. fuscata.* More recently, Lee (2010) proposed the genus *Sonata* with *O. fuscata* as its type species. However, Hayashi and Saisho (2011) synonymised *Sonata* with *Hyalessa* and treated *H. fuscata* as a junior synonym of *H. maculaticollis* based on examination of related holotypes deposited in the Muséum National d'Histoire Naturelle.

According to Hayashi and Saisho (2011), *H. maculaticollis* shows a high degree of variability in coloration. Based on more materials collected from China, we investigate further the variability of *H. maculaticollis* in this study, and the results show that greater intraspecific variations occur in this species, with respect to body size, markings on thorax, coloration of timbal cover and opercula and, in particular, the morphology of aedeagus that has never been described in detail for this species and its allies. Remarkably, the aedeagus of *H. maculaticollis* is furnished with a pair of apical sclerotized processes as well as a pair of saccate hooks. The relative lengths of the paired saccate hooks and the sclerotized lateral processes on aedeagus may be variable due to the scalability of the saccate hooks, which forms a continuous variation as a cline. Furthermore, the condition of curvature at apical 1/3 of aedeagus is also variable, particularly the aedeagal shaft of specimen collected from Mt. Nanwutai of Xi'an, Shaanxi Province (Fig. 8H) is C-shaped in lateral view, which is unique and can be easily distinguished from others with aedeagal shaft S-shaped (Fig. 8A–G). We tentatively treat this specimen as a variation of *H. maculaticollis*, but it may represent a new species of *Hyalessa*, which merits further studies using multiple sources such as morphology, acoustics, biology and molecular data, *etc*.

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RESEARCH ARTICLE

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The leafhopper genus *Multiproductus* Xing, Dai & Li in China (Hemiptera, Cicadellidae, Deltocephalinae, Paralimnini), with description of one new species

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Abstract

General characteristics of *Multiproductus* and a new species *Multiproductus complantus* **sp. n.** are described and illustrated. A key is given to distinguish all species of the genus.

Keywords

Homoptera, morphology, taxonomy, distribution

Introduction

The Oriental leafhopper genus *Multiproductus* belonging to Paralimnini of Deltocephalinae (Hemiptera: Cicadellidae), was established by Xing et al. (2011) for a single species, *M. ramosus* Xing, Dai & Li, 2011, from China. Here we describe and illustrate a second new species: *Multiproductus complantus* Xing & Li, sp. n. from Guizhou Province, China. A key is given to distinguish all species of the genus.

Material and methods

Specimens were collected by sweeping net. Dry specimens were used for the description and illustration. External morphology was observed under a stereoscopic microscope and characters were measured with an ocular micrometer. The genital segments of the examined specimens were macerated in 10% NaOH and drawn from preparations in glycerin jelly using a Leica MZ 12.5 stereomicroscope. Illustrations were scanned with Canon CanoScan LiDE 200 and imported into Adobe Photoshop CS3 for labeling and plate composition.

Terminology of morphological and genital characters follow Xing et al. (2011) and Rakitov (1998). The examined specimens and type specimens of the new species are deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

Taxonomy

***Multiproductus* Xing, Dai & Li**
http://species-id.net/wiki/Multiproductus

Multiproductus Xing, Dai & Li, 2011: 65.

Type species. *Multiproductus ramosus* Xing, Dai & Li, 2011.

Remarks. For the relationship and diagnosis of *Multiproductus* Xing, Dai & Li, 2011 see Xing et al. (2011: 65). *Multiproductus* is distributed in China (Oriental Regions). This genus is especially well differentiated from other genera of Paralimnini in Deltocephalinae by the unique forewing with outer subapical cell extended to costal margin, branches of vein R recurved distally, resulting in fifth (outer) apical cell. The two species of this genus are very similar in appearance. This situation is similar to the paralimnine genus *Paralaevicephalus* wherein all species are essentially the same in external appearance and several different species can be collected in the same location.

Distribution. China (Guizhou, Yunnan, Hainan).

Key to species (♂) of *Multiproductus*

1 Aedeagal shaft with three pairs of lateral preapical processes; apical process of style narrow, tubular shape (see Xing et al. 2011: Figs 9,10, 13) ... ***M. ramosus***

– Aedeagal shaft with two pairs of lateral preapical processes; apical process of style wide and flat, sword shape (Figs 9, 10, 13) ..... ***M. complantus* sp. n.**

Taxonomy of species

***Multiproductus ramosus* Xing, Dai & Li, 2011**
http://species-id.net/wiki/Multiproductus_ramosus

Multiproductus ramosus Xing, Dai & Li, 2011: 66–67, figs 1–15.

Material examined. China: 1♂ (Holotype), Guizhou Prov., Guanling County, Huajiang, 16 August 2009, coll. Jichun Xing; 2♂♂4♀♀, Guizhou Prov., Guanling County, Huajiang, 16 August 2009, coll. Jichun Xing; 1♂, Guizhou Prov., Ziyun County, Baishiyan, 28 July 2008, coll. Jichun Xing; 1♀, Guizhou Prov., Yanhe County, Mayanghe, 10 June 2007, coll. Jichun Xing; 1♀, Yunnan Prov., Menghai County, Mannong, 24 July 2008, coll. Yuehua Song; 1♂, Yunnan Prov., Baoshan City, Baihualing, 7 May 2010, coll. Yanli Zheng; 1♂1♀, Hainan Prov., Bawangling, 16 April 2013, coll. Jichun Xing.

Distribution. China (Guizhou, Yunnan, Hainan).

***Multiproductus complantus* Xing & Li, sp. n.**
http://zoobank.org/28A036CA-70C0-48B7-8410-D0D405913F75
http://species-id.net/wiki/Multiproductus_complantus
Figs 1–13

Description. Yellowish-brown species, with light veins on forewings. Crown yellowish brown with four dark brown marks on anterior margin and orange–yellow longitudinal band midway between midline and eye extending to posterior margin of pronotum. Eyes black, fairly large. Ocelli pale yellow. Face black, frontoclypeus with yellowish brown transverse stripes on both sides. Forewings pale yellow. Hind macropterous. Legs marked with brown.

Head slightly wider than greatest width of pronotum. Vertex with fore margin produced triangularly, median length longer than width between eyes. Ocelli on anterior margin, separated from corresponding eye by approximately their own diameter. Frontoclypeus distinctly longer than wide, anteclypeus slightly narrowed apically. Antennae arising near lower corner of eye. Pronotum with anterior margin strongly and roundly produced, posterior margin slightly concave. Scutellum triangular, slightly shorter than pronotum, with transverse suture curved and depressed. Forewing with outer subapical cell extended to costal margin, branches of vein R recurved distally, resulting in fifth (outer) apical cell, and veins of clavus appear to extend to the claval suture, 4 times as long as wide, appendix present. Hind wings with three apical cells and two anteapical cells. Profemur with 2 dorsoapical setae. Hind femur apical setal formula 2+2+1. Hind tibia flattened and nearly straight, with PD setae very long, several supernumeral setae present between AD and AV rows; AD row with somewhat thin setae between very thick macrosetae. Metabasitarsomere with three platellae and

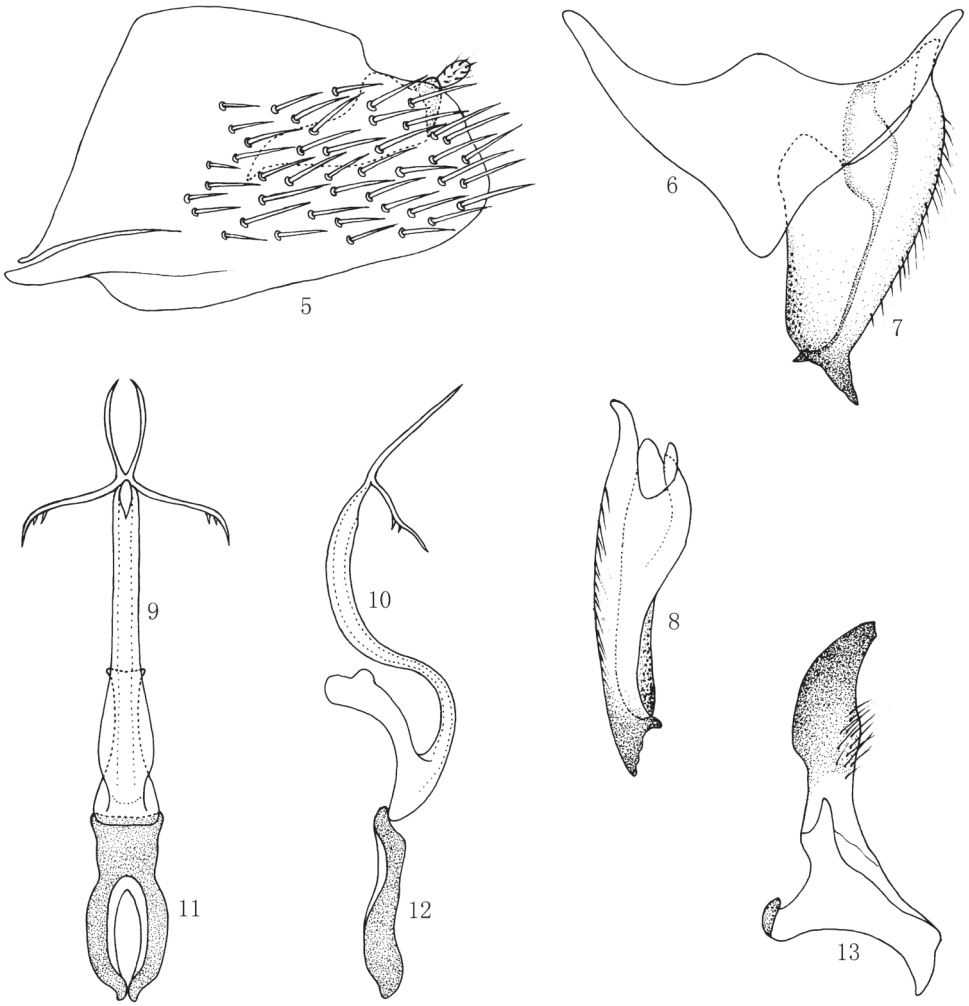
Figures 1–4. *Multiproductus complantus* sp. n. **1** ♂, dorsal view **2** ♂, lateral view **3** Head and thorax, dorsal view **4** ♂, face.

two setae on apical transverse row; plantar surface with one row of five stout setae at middle and one row of four stout setae at lateral margin.

Male genitalia. Male pygofer side elongate with many large setae medially; without processes (Fig. 5). Valve subtriangular with anterior margin produced and posterior margin strongly produced medially (Fig. 6). Subgenital plate wide, with uniseriate row of macrosetae along lateral margin, internal appendage short and mucronate (Figs 7, 8). Aedeagal shaft elongate and sinuate; with two pairs of lateral preapical processes, proximal pair with two small spines; gonopore subapical on ventral surface (Figs 9, 10). Connective loop–shaped with arms fused apically; stem present, articulated with the aedeagus (Figs 11, 12). Apical process of style wide and flat, sword shape (Fig. 13).

Measurement. Length (including tegmen): ♂, 3.0 mm.

Host. Grasses.



Figures 5–13. *Multiproductus complantus* sp. n. **5** Male pygofer side, lateral view **6** Valve, ventral view **7** Subgenital plate, ventral view **8** Subgenital plate, lateral view **9** Aedeagus, ventral view **10** Aedeagus, lateral view **11** Connective, ventral view **12** Connective, lateral view **13** Style, dorsal view.

Type material. Holotype ♂, China: Guizhou Prov., Ziyun County, Baishiyan, Kazha, 2 October 2013, coll. Jichun Xing (GUGC).

Diagnosis. This new species is similar to *Multiproductus ramosus* Xing, Dai & Li, 2011 in appearance, but can be distinguished from the latter by the aedeagal shaft with two pairs of lateral preapical processes, the apical process of style wide and flat, sword shape, and the valve subtriangular and subgenital plate wide.

Etymology. The species name is derived from the Latin word "*complantus*", referring to the apical process of style wide and flat.

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Two new species of *Archaeohelorus* (Hymenoptera, Proctotrupoidea, Heloridae) from the Middle Jurassic of China

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| *http://zoobank.org/D507ABBD-6BA6-43C8-A1D5-377409BD3049*

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Abstract

Two new fossil species, *Archaeohelorus polyneurus* **sp. n.** and *A. tensus* **sp. n.**, assigned to the genus *Archaeohelorus* Shih, Feng & Ren, 2011 of Heloridae (Hymenoptera), are reported from the late Middle Jurassic, Jiulongshan Formation of Inner Mongolia, China. Based on the well-preserved forewings and hind wings of these specimens, the diagnosis of the *Archaeohelorus* is emended: forewing 2cu-a intersecting Cu and Rs+M at the same point or postfurcal, and hind wing may have tubular veins C, Sc+R, R, Rs, M+Cu, M and Cu distinct, or simplified venation. The new findings also elucidate the evolutionary trend of forewing and hind wing venation and body size for the Heloridae from the late Middle Jurassic to now.

Keywords

Fossil wasps, Heloridae, *Archaeohelorus*, Middle Jurassic, China

Introduction

Proctotrupoidea Latreille, 1802, including 11 extant families, is a significant group within Hymenoptera for their long evolutionary history, special morphology and diversity (Grimaldi and Engel 2005). Most extant species of Proctotrupoidea are small wasps except for the giants of the family Pelecinidae (Shih et al. 2010). Heloridae, a small family in Proctotrupoidea, have the earliest fossil records from the late Middle Jurassic (Shih et al. 2011).

Up to date, fossil Heloridae contains 8 genera and 12 species, which have been summarized by Shi et al. (2012). These species have been described from the late Middle Jurassic of Daohugou Ningcheng, China (Shih et al. 2011); the Late Jurassic of Karatau, Russia (Rohdendorf 1938), and of Laiyang, China (Zhang 1992); the Early Cretaceous of Turga, Russia (Rasnitsyn 1990), of Beipiao, China (Zhang and Zhang 2001; Shi et al. 2012); and of Gurvan-Ereny-Nuru, Western Mongolia (Rasnitsyn 1986).

So far, 7 species of Heloridae from China have been reported, including *Archaeohelorus hoi* Shih, Feng & Ren, 2011; *Gurvanhelorus beipiaoensis* Shi, Shih & Ren, 2012; *Protocyrtus validus* Zhang & Zhang, 2001; *Sinohelorus elegans* Shi, Shih & Ren, 2012; *Spherogaster coronata* Zhang & Zhang, 2001; and *Spherogaster saltatrix* Shi, Shih & Ren, 2012.

Extant helorids contains only one genus, *Helorus* Latreille, 1802, with 12 known valid species mostly in the Holarctic Region. They are parasitoids of larvae of chrysopid lacewings (Neuroptera: Chrysopidae: Chrysopinae: *Chrysopa* species) (van Achterberg 2006). Among the known species, only *Helorus chinensis* He, 1992 was described from China (He 1992).

Recently, we collected two well-preserved fossil specimens referable to Heloridae from the late Middle Jurassic Jiulongshan Formation at Daohugou Village, Ningcheng County, Inner Mongolia, China. Based on these new findings, the diagnosis of *Archaeohelorus* Shih, Feng & Ren, 2011 is emended and two new species, *Archaeohelorus polyneurus* sp. n. and *A. tensus* sp. n., are described. This is the second report of Heloridae in the late Middle Jurassic.

The age of the Daohugou fossil-bearing beds is interpreted to be late Middle Jurassic (*ca* 165 Ma; Ren et al. 2010). This deposit is interpreted to have accumulated in streams and lakes within a humid and warm-temperate climate (Ren et al. 2002). It is rich in well-preserved fossils, especially a high level of insect diversity have been reported including Ephemeroptera (Huang et al. 2008), Odonata (Li et al. 2011), Plecoptera (Liu et al. 2011), Blattodea (Wei et al. 2012), Orthoptera (Gu et al. 2012), Homoptera (Wang et al. 2012), Heteroptera (Lu et al. 2011), Neuroptera (Wang et al. 2010; Shi et al. 2011), Raphidioptera (Engel & Ren, 2008), Coleoptera (Tan et al. 2012), Mecoptera (Ren et al. 2009; Wang et al. 2012), Hymenoptera (Wang et al. 2012), and Diptera (Liu et al. 2012).

Materials and methods

All the materials have been collected near Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China; the late Middle Jurassic (Bathonian-Call-

ovian boundary, 165 Ma). All fossil specimens are housed in the Key Lab of Insect Evolution & Environmental Changes, College of Life Sciences, Capital Normal University, Beijing, China.

The specimens were examined dry or under alcohol using a M165 C dissecting microscope (Leica) and are illustrated with the aid of a drawing tube attachment. The figures were drawn by Adobe Photoshop CS5 and CorelDraw 12.0. Morphological terminology and the system used here follow those of Huber and Sharkey (1993) and Rasnitsyn and Zhang (2010).

Systematic Paleontology

Class Insecta L., 1758
Order Hymenoptera L., 1758
Suborder Apocrita Gerstaecker, 1867
Superfamily Proctotrupoidea Latreille, 1802
Family Heloridae Foerster, 1856
Subfamily Mesohelorinae Rasnitsyn, 1990

Genus *Archaeohelorus* Shih, Feng & Ren, 2011
http://species-id.net/wiki/Archaeohelorus

Type species. *Archaeohelorus hoi* Shih, Feng & Ren, 2011

Emended diagnosis. Forewing 2cu-a intersecting Cu and Rs+M at the same point or postfurcal. Hind wing may have tubular veins C and Sc+R separated at base, R developed, M+Cu robust and forking at the basal part, M and Cu distinct, or simplified venation.

Species included. *A. hoi* Shih, Feng & Ren, 2011, *A. polyneurus* sp. n. and *A. tensus* sp. n.

Remarks. This genus was established by Shih et al. 2011 based on a holotype, allotype and six paratypes from the Middle Jurassic of Daohugou, Inner Mongolia, China. Due to lack of discernible hind wings on the fossils of holotype and allotype, the hind wing venation was not described. With the new forewing and hind wing venational information on our new materials, we emended the generic diagnosis.

***Archaeohelorus polyneurus* sp. n.**
http://zoobank.org/BFECD83C-516A-4F08-BBB3-72A5EB6DFF41
http://species-id.net/wiki/Archaeohelorus_polyneurus
Figures 1, 2

Etymology. The specific name is from Greek word "*polyneurus*", means "many veins", referring to the complete venation of the hind wing preserved.

Type material. Holotype, CNU-HYM-NN2012052, dorsal view, gender unknown. A well-preserved body with almost complete forewings and hind wings and

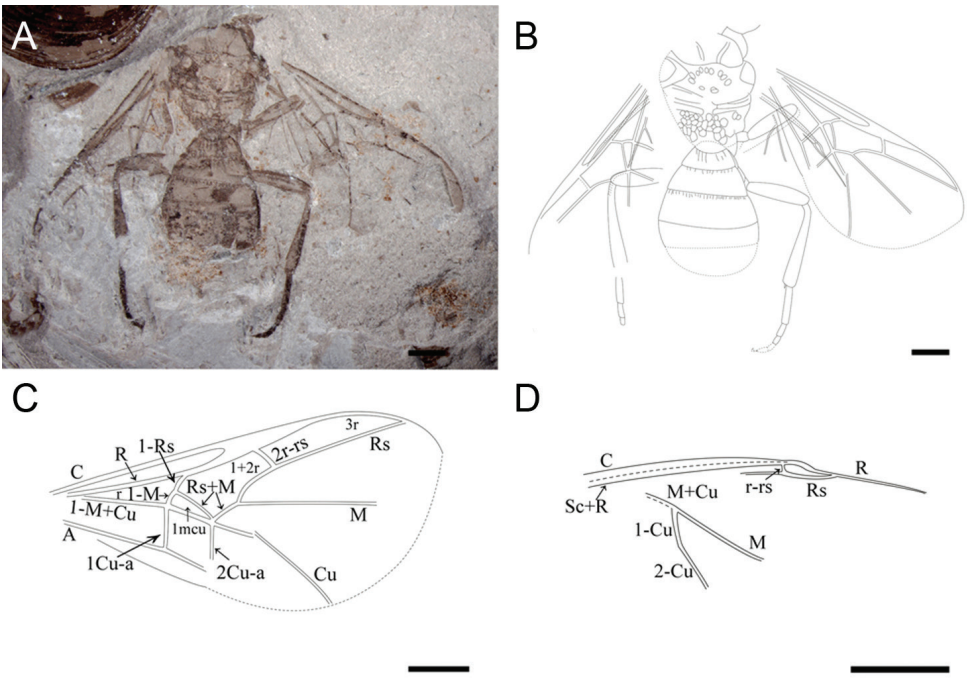

Figure 1. Holotype of *Archaeohelorus polyneurus* sp. n. CNU-HYM-NN-2012052. **A** Photo **B** line drawing **C** line drawing of forewing **D** line drawing of hind wing. Scale bars: 1 mm. (Online figure in color.)

part of legs, but head missing. Paratype: CNU-HY-NN2008010, dorsal view, a well-preserved almost complete body with forewings and right hind wing and part of legs, previously mis-identified as a paratype of *A. hoi*.

Locality and age. Jiulongshan Formation, Middle Jurassic, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China.

Diagnosis. In forewing, 2cu-a intersecting Cu and Rs+M at the same point and cell r obtuse-angled triangular (vs. approximately right-angled triangular in *A. hoi*). Hind wing with Sc+R confluent with C and extended to costal margin, R developed. M+Cu distinct and forking at the basal part, M and Cu robust.

Remarks. Upon further examination, we found that a paratype of *A. hoi*, CNU-HYM-NN2008010, has forewing 2cu-a intersecting Cu and Rs+M at the same point and cell r obtuse-angled triangular (vs. approximately right-angled triangular in *A. hoi*); and hind wing with tubular vein C parallel with Sc+R at base, M+Cu robust and forking at the basal section, M long, 1-Cu, 2-Cu distinct. These venational characters are consistent with the diagnostic characters of *A. polyneurus* sp. n., hence we transfer CNU-HYM-NN2008010 as a paratype of *A. polyneurus* sp. n.

Description of holotype. A medium-sized body with both forewings and hind wings well-preserved, but, without head (Fig. 1). Forewing broad. Mesosoma suboval, nearly 1.35 times as long as wide; mesoscutum trapezoidal with notauli distinct and

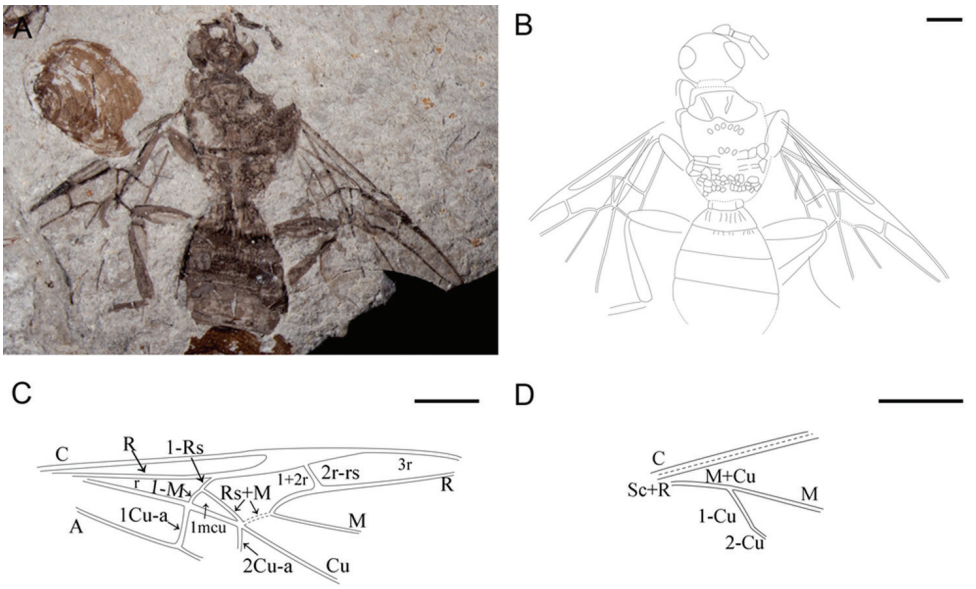

Figure 2. Paratype of *Archaeohelorus polyneurus* sp. n. CNU-HYM-NN-2008010. **A** Photo **B** line drawing **C** line drawing of forewing **D** lLine drawing of hind wing. Scale bars: 1 mm. (Online figure in color.)

concave; tegula triangular; scutellum broad with two rows of pits; metanotum relatively wide with plenty of pits; propodeum transverse, 2.89 times as broad as long.

Metasoma suboval with six segments; first metasomal segment transverse, second segment with several longitudinal ridges; third and fourth segments trapezoidal with shorter longitudinal ridges anteriorly; other ones smooth; the end of terminal segment not preserved.

Forewing broad and subtriangular. Pterostigma long and acute apically, not widened beyond mid-length. C robust and extending to apex of forewing. 2r-rs arising from basal one third of pterostigma, slightly oblique apicad, slightly longer than pterostigmal width. R robust, cell r obtuse-angled triangular and closed by R, M+Cu, 1-Rs and 1-M; Rs straight and intersecting with distal part of C. Cell 1+2r six-sided and surrounded by R, 1-Rs, 1-Rs+M, 2-Rs+M, 2-Rs, and 2r-rs. M+Cu straight and distinct; M and Cu distinct, M straight, Cu break after 1m-cu. 1-Rs as long as 1-M and slightly inclined toward wing base. Cell 1mcu small and subtriangular. M and Rs branching at 30% from 1m-cu of the length between 1m-cu and 2r-rs. 1cu-a and 2cu-a distinct and reaching A. 1cu-a in line with 1-M; and 2cu-a intersecting Cu and Rs+M at the same point.

Hind wing with tubular veins C parallel with Sc+R at base; R developed and Rs preserved; M+Cu robust and forking at the basal section, M and 1-Cu long and distinct, 2-Cu long.

Right foreleg with only coxa and femur partially preserved. Right midleg with partial trochanter, spindle-shaped femur and partial tibia preserved. Right hindleg with partial coxa, trochanter trapezoidal and small, robust spindle-shaped femur, long tibia

swollen distally with spurs, tarsi with five segments, basitarsus longest and two claws fixing the end of pretarsus.

Measurements (in mm). Mesosoma length 3.36, width 2.48; metasoma >3.38 long; lengths of the first to fifth metasomal segments are 0.34, 0.51, 0.72, 0.94, and 0.55; forewing length 6.52, width >3.05.

Description of paratype. Body medium-sized (Fig. 2). Head oval and antennae filiform and thick, scape swollen and bell-shaped, only first and second flagellomeres preserved. Mesosoma, forewing and metasoma same as holotype, the end of terminal segment not preserved. Hind wing with tubular vein C parallel with Sc+R at base, M+Cu robust and forking at the basal section, M long, 1-Cu, 2-Cu distinct. Left foreleg and right midleg with only coxa and femur partially preserved. Left midleg with femur robust and tibia long, left hindleg with femur robust and spindle-shaped, long tibia swollen distally. Right hindleg with femur robust and spindle-shaped, tibia partially preserved.

Measurements (in mm). Body length >14.6; head length 1.89, width 1.53; mesosoma length 3.58, width 2.52; metasoma length 3.68; forewing length >6.54, width >2.88.

Comparison. This species can be assigned to *Archaeohelorus* Shih, Feng & Ren, 2011 by its metasoma with six segments and the first segment narrow and transverse. Forewing 1-Rs as long as 1-M. Cell 1mcu small and subtriangular, 1cu-a in line with 1-M; and 2cu-a intersecting Cu and Rs+M at the same point. Compared with *A. hoi*, *A. polyneurus* has preserved hind wing with Sc+R confluent with C and extended to costal margin, R developed. M+Cu distinct and forking at the basal part, M and Cu robust; in forewing, cell r obtuse-angled triangular (vs. approximately right-angled triangular in *A. hoi*). Besides, *A. polyneurus* has a much larger body size than *A. hoi,* length of forewing 6.52 mm or >6.54 mm (vs. 3.17 mm in *A. hoi*).

***Archaeohelorus tensus* sp. n.**
http://zoobank.org/84E4B637-E6E6-4799-929E-1536DA5213A5
http://species-id.net/wiki/Archaeohelorus_tensus
Figure 3

Etymology. The specific name "*tensus*" means stretching and long, referring to the shape of the forewing.

Type material. Holotype, CNU-HYM-NN2012056p/c, part and counterpart, dorsal view, male. A well-preserved almost complete body with antenna, forewings and part of legs and partial hind wings.

Locality and age. Jiulongshan Formation, Middle Jurassic, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China.

Diagnosis. Forewing 2cu-a postfurcal with intersection of Cu and Rs+M. First abscissa of Rs (1-Rs) and basal section of M (1-M) arched toward basal of wing. Hind wing with tubular veins C, Sc+R, and Rs preserved.

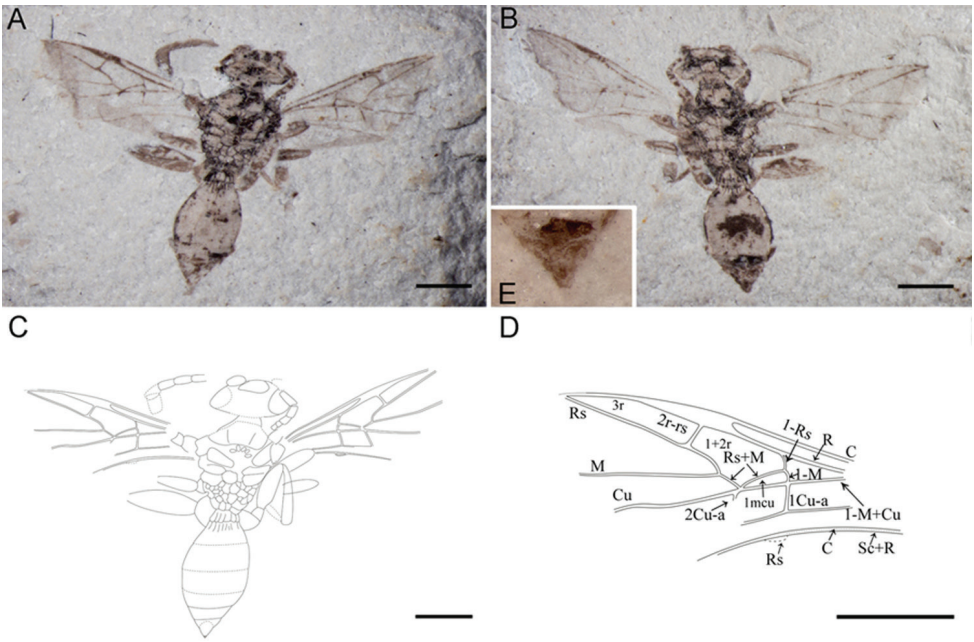

Figure 3. Holotype of *Archaeohelorus tensus* sp. n. CNU-HYM-NN-2012056 p/c, part and counterpart. **A** Photo of part **B** photo of counterpart **C** line drawing of part **D** line drawing of forewing **E** terminal segments of counterpart (under alcohol). Scale bars: 1 mm. (Online figure in color.)

Description. A small adult specimen with a total body length of 4.4 mm. Head suboval and large relative to mesosoma in width. Eyes large, and located at the both sides of the head.

Antennae filiform, thick, with 6 segments preserved on left and 5 segments preserved on right. Scape swollen and bell-shaped; pedicel short and quadrate; subsequent flagellomeres not well preserved.

Mesosoma subhexagonal and broader than head; pronotum narrower than head, short, probably covered by mesonotum; mesoscutum distorted in the middle and trapezoidal with notauli not distinct but preserved; tegula large and subtriangular; scutellum round with pits anteriorly; propodeum narrow, transverse and areolated.

Metasoma suboval with seven segments; first metasomal segment transverse with several longitudinal ridges; second segment trapezoidal with less longitudinal ridges anteriorly; other ones smooth; the male terminalia triangular, partially covered by the previous segment.

Forewing broad and subtriangular. Pterostigma long and acute apically, not widened beyond mid-length. C robust and extending near the apex of forewing. 2r-rs arising from basal one third of pterostigma, slightly longer than the width of pterostigma, and slightly oblique apicad. R robust and cell r closed with C, R and 1-RS. Rs straight and intersecting with distal part of C. Cell 1+2r longer and narrower relatively and six-sided

surrounded by R, 1-Rs, 1-Rs+M, 2-Rs+M, 2-Rs, and 2r-rs. M+Cu straight and distinct; M and Cu distinct, almost straight. 1-Rs as long as 1-M and slightly inclined toward wing base. Cell 1mcu small, subtriangular and relatively slender with 2-M+Cu 4.3 times as long as 1-M. M and Rs branching at 30% from 1m-cu of the length between 1m-cu and 2r-rs. 1cu-a and 2cu-a distinct and reaching A. 1cu-a in line with 1-M; and 2cu-a postfurcal with Rs+M distinctly.

Hind wing, with tubular veins C parallel with Sc+R at base, Rs short, intersecting distal part of C.

Left foreleg, midleg and hindleg and right foreleg with only coxa and femur partially preserved, hind femur much thicker, nearly three times as long as wide; right midleg with partial spindle-shaped femur and partial tibia preserved, right hindleg with partial coxa, trapezoidal trochanter, robust spindle-shaped femur and relatively thin tibia and some parts of tarsus preserved.

Measurements (in mm): Body length 4.67, head length 1.39, width 0.68, mesosoma length 1.68, width 1.36; metasoma 2.23 long; lengths of metasomal segments are 0.20, 0.39, 0.48, 0.38, 0.25 and 0.32; forewing length >2.96, width >1.36.

Remarks and comparison. This species is assigned to *Archaeohelorus* Shih, Feng & Ren, 2011 by its seven separated metasomal segments, the first metasomal segment transverse with several longitudinal ridges. Forewing 1-Rs as long as 1-M. Cell 1mcu small and subtriangular, 1cu-a in line with 1-M. Compared with *A. hoi, A. tensus* has preserved hind wing with tubular veins C, Sc+R, R, and Rs preserved; in forewing, 2cu-a distinctly postfurcal with intersection of Cu and Rs+M (vs. 2cu-a intersecting Cu and Rs+M at the same point in *A. hoi*); cell 1mcu distinctly slender, 4.3 times as long as wide (vs. 2.4 times in *A. hoi*); 1-Rs and 1-M arched toward basal of wing (vs. 1-Rs and 1-M straight in *A. hoi*). It also differs from *A. polyneurus* by its postfurcal 2cu-a, slender cell 1mcu.

Discussion

In the vast and extensive Daohugou fossil insect collection (>200,000 insect fossil specimens) at the Capital Normal University, only ten helorids are collected so far: two are *Archaeohelorus polyneurus* sp. n., one is *Archaeohelorus tensus* sp. n., and seven specimens are previously described *Archaeohelorus hoi* Shih, Feng & Ren, 2011. It is likely that helorids might have been a very small group in the Middle Jurassic.

As a relict family, helorids have survived from the Middle Jurassic to now. Among all the fossil specimens, only *A. polyneurus* has distinct and complicated hind wing venation, which were unknown before. Therefore, the new findings are important supplement to helorid record and suggest that the trend for the morphological evolution of the Heloridae is as follows:

In the Middle Jurassic, *A. polyneurus* had forewing cell r obtuse-angled triangle, and hind wing venation clear and more complex (C and Sc+R separated at base, M+Cu short and robust, forking at the basal part, M and Cu distinct) and a much larger body

(forewing length>6.52mm). On the other hand, *A. hoi* and *A. tensus* had forewing cell r approximately right-angled triangular, and hind with simplified venation (only C and Sc+R and/or R preserved) and smaller body (forewing length≈3 mm). In the Late Jurassic to the Early Cretaceous, *Spherogaster coronata* Zhang & Zhang, 2001 had hind wing with only C, R and M present, costal area extremely narrow, and a much larger body size with forewing length of 12 mm. In extant helorids, forewing cell r approximately right-angled triangular, and hind wings have tubular veins C and Sc+R and nebulosus veins of M+Cu, M, Cu and A (Goulet and Huber 1993). The body size is small with forewing about 3.3 mm long (van Achterberg 2006).

Acknowledgments

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Revision of the genus *Parasapyga* Turner (Hymenoptera, Sapygidae), with the description of two new species

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Abstract

Two new species, *Parasapyga boschi* **sp. n.** from Vietnam and *P. yvonnae* **sp. n.** from Indonesia are described. *Parasapyga walshae* van der Vecht, 1940, is treated as a valid species instead of a subspecies of *P. moelleri* Turner, 1910. A key to the species of the genus is added and all species are illustrated.

Keywords

Revision, Sapygidae, Parasapyga, key, new species, Oriental, Indonesia, Vietnam

Introduction

The little known aculeate family Sapygidae (Hymenoptera) is rarely collected and wide-spread in the Holarctic Region, but rare in other regions and unknown from the Australian Region. There are approx. 70 described extant species distributed among 12 extant genera (Kurzenko 1995, 1996, Bennett and Engel 2005, Huber 2009) in two subfamilies. Despite belonging to the Aculeata the females possess an ovipositor; in the subfamily Sapyginae with a serrate dorso-apical part (Figs 3, 12, 40) and the sheath without setae subapically (Figs 1, 3), vein 2r-m of the fore wing is distinctly sinuate (Fig. 4) and the eyes deeply incised at the inner side (Fig. 1). In the subfamily

Fedtschenkiinae the ovipositor has no serrate part and the sheath has subapical setae, vein 2r-m of the fore wing is weakly curved and the eyes are not incised. Sapyginae occur where its host is nesting, including the home-made bee hotels in gardens; Fedtschenkiinae occur in deserts or salt steppes. According to Brothers (1975) Sapygidae are the sister-group of the Mutillidae *sensu lato*. Recent research indicates that the sister-group of the Sapygidae is the family Myrmosidae and together they are sister to the Mutillidae (Pilgrim et al. 2008). There are only keys to genera for the Palaearctic, Holarctic and Neotropical regions by Kurzenko and Gusenleitner (1994), Kurzenko (1996) and Brothers (2006), respectively.

In the Oriental Region Sapygidae are very rarely collected and with few species in only three genera present (Kurzenko 1996): *Sapyga* Latreille, 1796 (one species) and *Parasapyga* Turner, 1910, with only the type species *P. moelleri* Turner, 1910, India (Sikkim) and one additional known subspecies from Indonesia (Sumatra; *P. m. walshae* van der Vecht, 1940), and "*Polochrum*" *flavicolle* Cameron, 1899, from North India (Sikkim). The generic position of the latter is uncertain (Kurzenko in litt.). However, the oldest known fossil of the Sapygidae is known from the Oriental Region; *Cretosapyga resinicola* Bennett & Engel, 2005. It was found in mid-Cretaceous (latest Albian, ca. 100 Mya) amber from Myanmar (Bennett and Engel 2005). The fossil is placed in the new extinct subfamily Cretosapyginae Bennett & Engel, 2005. The genus *Parasapyga* can be recognised from the Holarctic genera of Sapyginae by having the clypeus extending dorsally to the frontal shelf anteriorly (Figs 9, 41), the head without calli or welts and the ocelli medium-sized (Figs 10, 42).

The biology of *Parasapyga* species is unknown, but other Sapyginae are cleptoparasitoids (or predator-inquilines) of solitary bees (belonging to Apinae *sensu lato* and Megachilinae *sensu lato*). The female wasp oviposits into the nest cell of host, the larva consumes first the host egg or larva followed by the food supply of the bee larva (Rozen and Kamel 2009). Members of the small monotypic subfamily Fedtschenkiinae parasitize larvae of ground-nesting Eumeninae (Vespidae) after the larva has spun its cocoon.

Taxonomy

***Parasapyga* Turner, 1910**
http://species-id.net/wiki/Parasapyga
Figs 1–43

Parasapyga Turner 1910: 405; van der Vecht 1940: 45; Kurzenko 1996: 90. Type species (by monotypy): *Parasapyga moelleri* Turner, 1910.

Diagnosis. Clypeus extending dorsally to the frontal shelf anteriorly, resulting in absence of face medially (Figs 9, 41); inner orbit of eye without callus or welt (Figs 41, 42); ocelli medium-sized (Figs 10, 42); outer side of eye evenly convex medially (Fig. 41-43); occipital carina absent; length of malar space about half apical width of scapus

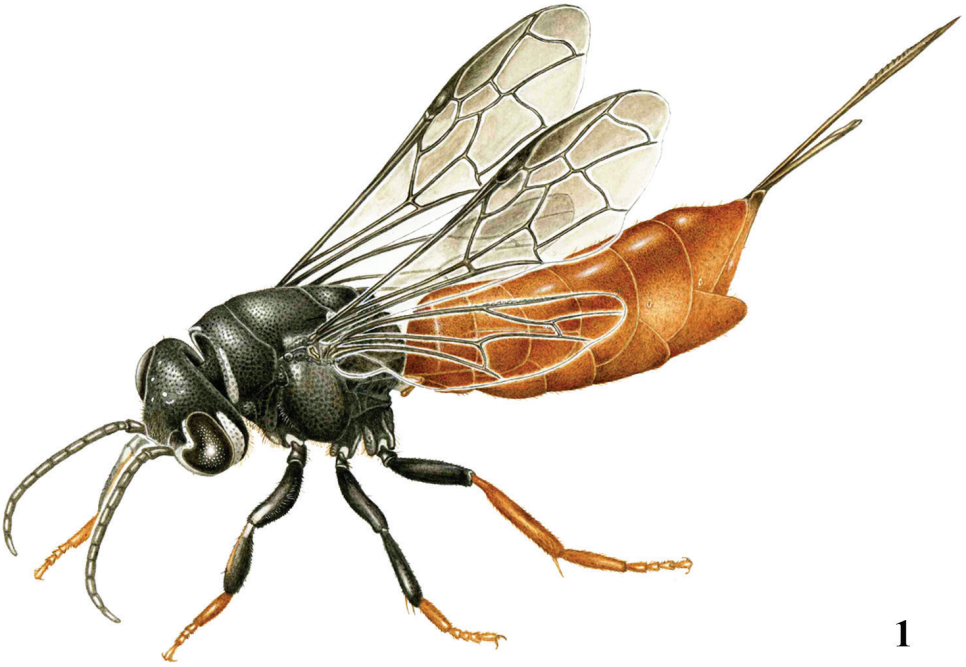


Figure 1. *Parasapyga boschi* sp. n., holotype, ♀, habitus dorso-lateral. Illustration: Erik-Jan Bosch.

(Fig. 9); entire propodeum densely and rather coarsely reticulate-rugose (Figs 5, 26, 36); third submarginal cell of fore wing anteriorly distinctly narrower than posteriorly and vein 2r-m distinctly sinuate (Figs 4, 25, 35); vein cu-a of fore wing interstitial and inclivous (Figs 4, 25); hind coxa without longitudinal carina dorsally (Fig. 34); hypopygium of female evenly convex ventrally. Males unknown.

Biology. Unknown.

Distribution. Oriental (four species).

Key to species of the genus *Parasapyga* Turner

1 Clypeus with narrow anchor-shaped black patch medially (Fig. 41); ovipositor with rather widely separated serrations (Fig. 40); metasoma rather slender in dorsal view (Fig. 33); first discal cell of fore wing subhyaline (Fig. 35); North Sumatra..... ***P. yvonnae* sp. n.**

– Clypeus with wide anchor-shaped black patch medially (Figs 9, 20, 30); ovipositor densely serrate dorsally (Fig. 12); metasoma rather wide in dorsal view (Figs 13, 23), but slenderer in *P. boschi* (Fig. 2); first discal cell of fore wing at least laterally distinctly infuscate (Figs 4, 15, 25)..... **2**

2 Ivory patch at incision of eye extended nearly up to level of posterior ocelli (Fig. 9); pair of ivory spots besides posterior ocellus present (Fig. 10); penultimate antennal segment of female 1.1 times as wide as apical segment in

dorsal view (Fig. 8); smooth interspaces between punctures of pronotum and metanotum medio-dorsally about equal to diameter of punctures (Fig. 5); ivory transverse stripe of pronotum narrowly interrupted medio-dorsally (Fig. 5); five apical segments of antenna partly brown ventrally (Fig. 8); first subdiscal of fore wing laterally darker than medially (Fig. 4); hind tibia reddish-brown (Fig. 7); South Vietnam ..... ***P. boschi* sp. n.**

– Ivory patch at incision of eye at most extended up to level of anterior ocellus (Figs 20, 30); pair of ivory spots besides posterior ocellus absent (Fig. 31), at most with a minute patch (Fig. 21); penultimate antennal segment of female 1.2 times as wide as apical segment in dorsal view (Fig. 28); smooth interspaces between punctures of pronotum and metanotum medio-dorsally distinctly narrower than diameter of punctures (Figs 16, 26); ivory transverse stripe of pronotum widely interrupted medio-dorsally (Figs 16, 26); at most one apical segment of antenna brown ventrally and other segments black (Fig. 18); first subdiscal of fore wing laterally as dark as medially (Figs 15, 25); hind tibia dark brown or black (Figs 19, 29) **3**

3 Ivory patch at incision of eye remains far from level of anterior ocellus (Fig. 30); dorsally pronotum without smooth and shiny interspaces (Fig. 26); propodeum with irregular ivory patch latero-dorsally (Fig. 27); hind basitarsus rather robust (Fig. 29); clypeus ivory latero-dorsally (Fig. 30); first discal cell of fore wing subhyaline (Figs 23, 25); South Sumatra..... ***P. walshae* van der Vecht, 1940**

– Ivory patch at incision of eye at most extended nearly up to level of anterior ocellus (Fig. 20); dorsally pronotum with smooth and shiny convex interspaces (Fig. 16); propodeum entirely black latero-dorsally (Fig. 17); hind basitarsus less robust (Fig. 19); clypeus largely black latero-dorsally (Fig. 20); first discal cell of fore wing dark brown (Figs 13, 15); North India (Sikkim) .... ***P. moelleri* Turner, 1910**

Parasapyga boschi sp. n.

http://zoobank.org/28DE635A-46B2-4E7E-896D-8FBC576FB0F1
http://species-id.net/wiki/Parasapyga_boschi
Figs 1–12

Type material. Holotype, ♀ (RMNH), "S. Vietnam: Dông Nai, Cát Tien N. P., c. 100 m, 19–25.iv.2007, Mal. traps, Dong trail, Mai Phu Quy & Nguyen Thanh Manh, RMNH'07".

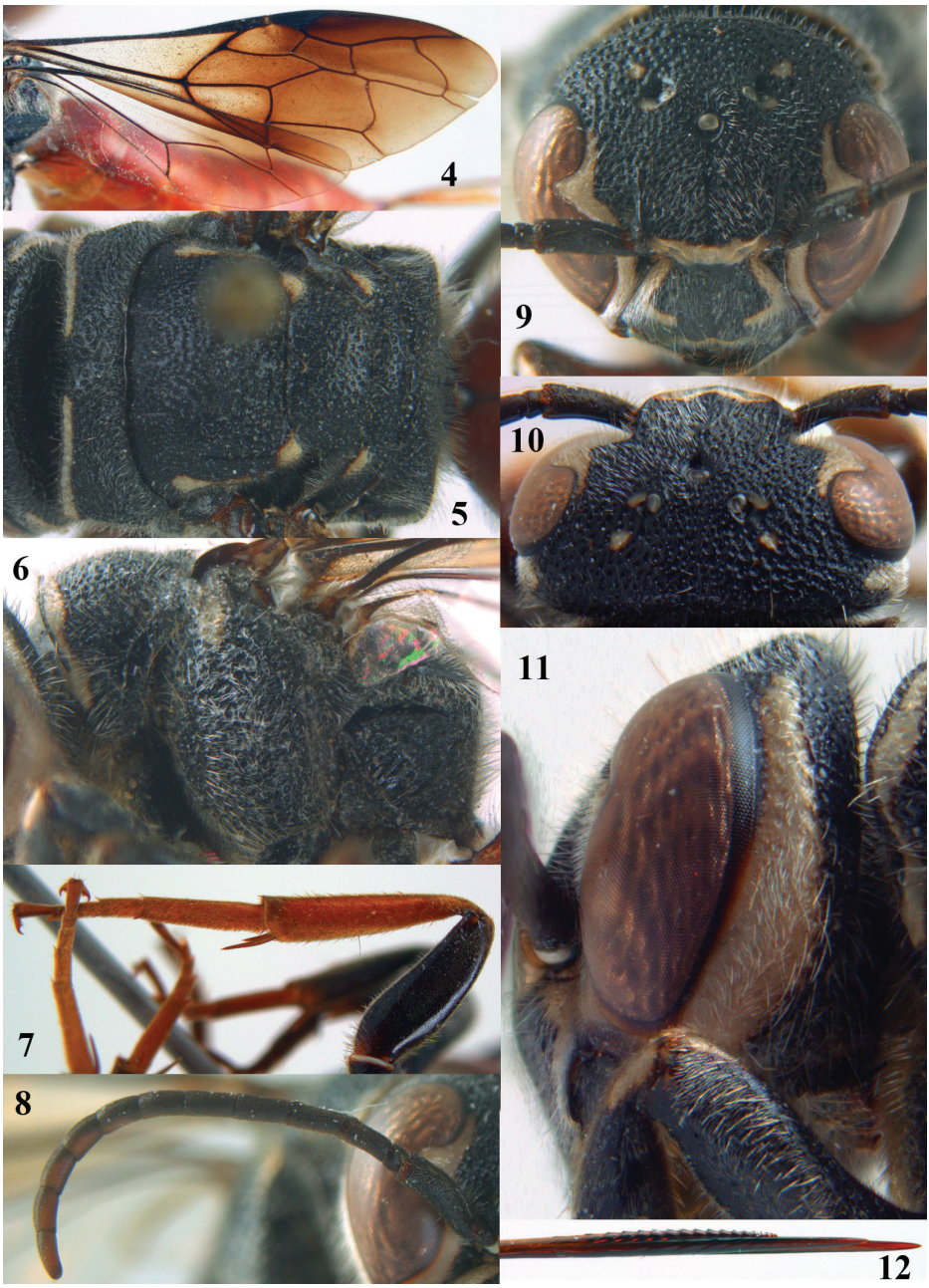
Diagnosis. Clypeus with wide anchor-shaped black patch medially (Fig. 9); ivory patch at incision of eye extended nearly up to level of posterior ocelli (Fig. 9); pair of ivory spots besides posterior ocellus present (Fig. 10); smooth interspaces between punctures of pronotum and metanotum medio-dorsally about equal to diameter of punctures (Fig. 5); ivory transverse stripe on pronotum narrowly interrupted medio-dorsally and comparatively wide ventrally (Figs 5, 6); first discal cell of fore wing dis-

Figures 2–3. *Parasapyga boschi* sp. n., holotype, female. **2** habitus dorsal **3** habitus lateral.

tinctly infuscate (Fig. 4); first subdiscal of fore wing laterally darker than medially (Fig. 4); hind tibia reddish-brown (Fig. 7); ovipositor densely serrate dorsally (Fig. 12). Resembles most *P. walshae* and *P. moelleri*; it can be easily separated by the larger ivory patch at the incision of the eye (Fig. 9 vs Figs 20, 30) and the reddish-brown hind tibia (Fig. 7 vs Figs 19, 29).

Description. Holotype, ♀, length of body 18.7 mm (of fore wing 11.8 mm).

Head. Antenna with 12 segments and penultimate segment 1.1 times as wide as apical segment in dorsal view (Fig. 8); frons coarsely reticulate; vertex coarsely punc-



Figures 4–12. *Parasapyga boschi* sp. n., holotype, female. **4** wings **5** mesosoma dorsal **6** mesosoma lateral **7** hind leg lateral **8** antenna lateral **9** head anterior **10** head dorsal **11** head lateral **12** apex of ovipositor lateral.

tate and with distinct smooth interspaces (Fig. 10); temple coarsely punctate and with wide smooth interspaces; malar space densely punctulate; head narrowed behind eyes (Fig. 10); clypeus spaced punctate and with complete median crest (Fig. 9).

Mesosoma. Length of mesosoma 1.5 times its height (Fig. 3); mesopleuron largely coarsely reticulate-punctate with narrow smooth interspaces; metapleuron densely punctulate anteriorly and coarsely obliquely rugose posteriorly, with a narrow smooth shiny band above it (Fig. 6); pronotum, mesoscutum, scutellum and metanotum coarsely punctate, medially interspaces between punctures about as wide as punctures and sparsely punctulate (Fig. 5); metanotum medially moderately convex and not protruding above level of scutellum (Fig. 3); entire propodeum densely and coarsely reticulate-punctate, medially hardly coarser than laterally (Fig. 5).

Wings. Fore wing: vein 2m-cu moderately postfurcal (Fig. 4).

Legs. Hind basitarsus rather robust (Fig. 7).

Metasoma. Metasoma rather slender in dorsal view (Fig. 2); basal tergites finely punctate and shiny, with smooth interspaces wider than diameter of punctures (Fig. 2); hypopygium 1.3 times as long as fifth sternite ventrally (Fig. 3); ovipositor densely serrate (Fig. 12); ovipositor sheath and ovipositor far exserted (Figs 1, 3).

Colour. Black; ivory: pair of L-shaped lateral patches on clypeus (resulting in a wide black anchor medially), patch at inner orbita of eye extended nearly up to level of posterior ocelli (Fig. 9), shelf of frons anteriorly between antennal sockets, temple largely except narrowly dorsally (Fig. 11), pair of small spots besides posterior ocellus, transverse stripe on pronotum (but narrowly interrupted medially; Fig. 5) and ventrally widened (Fig. 6), small patch on pronotum postero-dorsally, elongate patch on mesopleuron antero-dorsally, elongate patch near tegula, axilla, lateral patch of metanotum and elongate apical patch on fore femur; metasoma orange red; inner side of fore femur and tibia, tarsi and hind tibia largely reddish-brown; fore coxa densely yellowish setose ventrally; veins and pterostigma, dark brown; basal cells, middle of first subdiscal cell and basal half of first submarginal cell of fore wing subhyaline or slightly infuscate; remainder of fore wing dark brown (Fig. 4).

Male. Unknown.

Distribution. Vietnam.

Etymology. Named in honour of the scientific illustrator, Erik-Jan Bosch (Leiden) because of his excellent illustrations of Hymenoptera.

***Parasapyga moelleri* Turner, 1910**

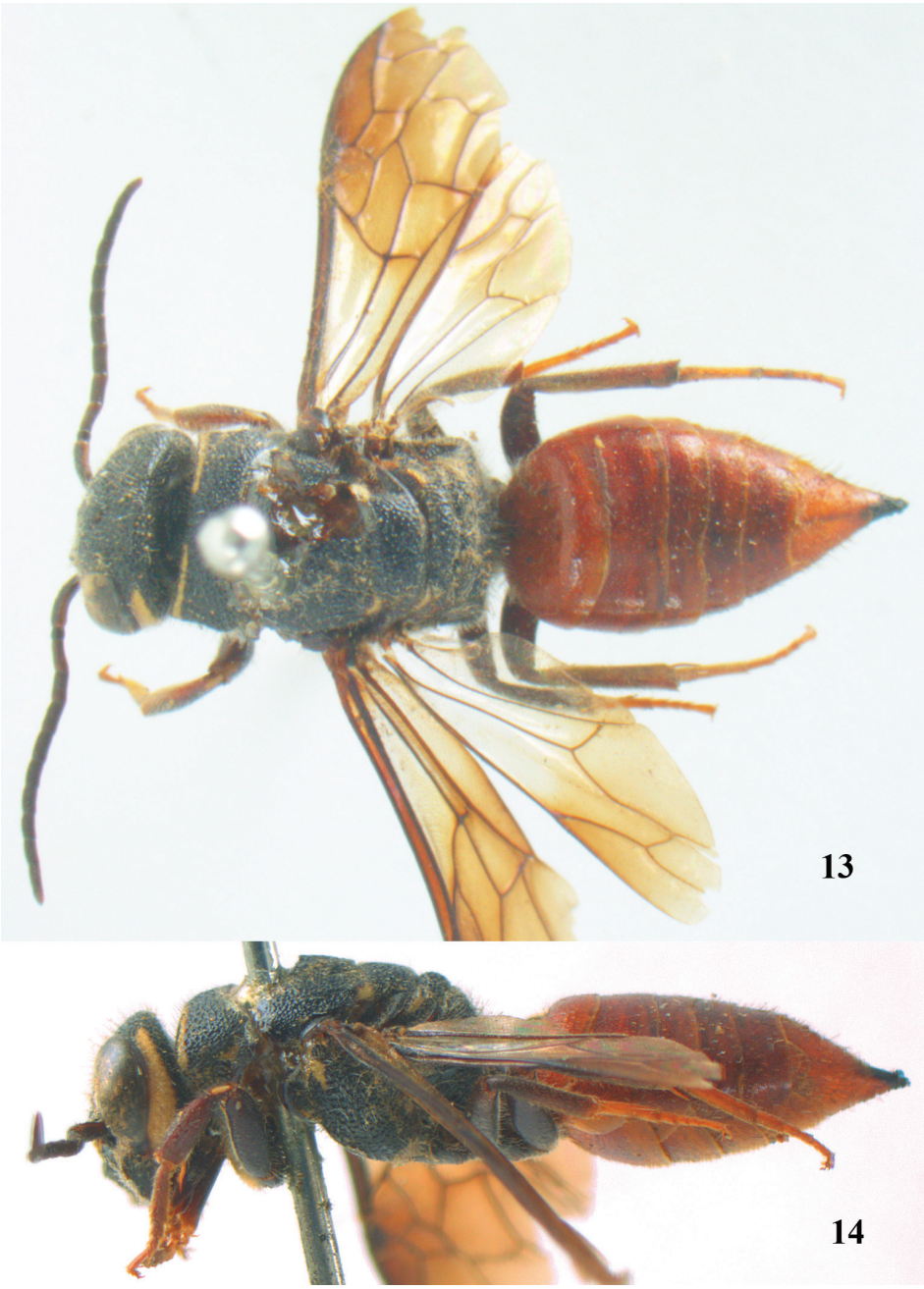
http://species-id.net/wiki/Parasapyga_moelleri

Figs 13–22

Parasapyga mölleri Turner 1910: 405–406, Pl. L-8; van der Vecht 1940: 45.

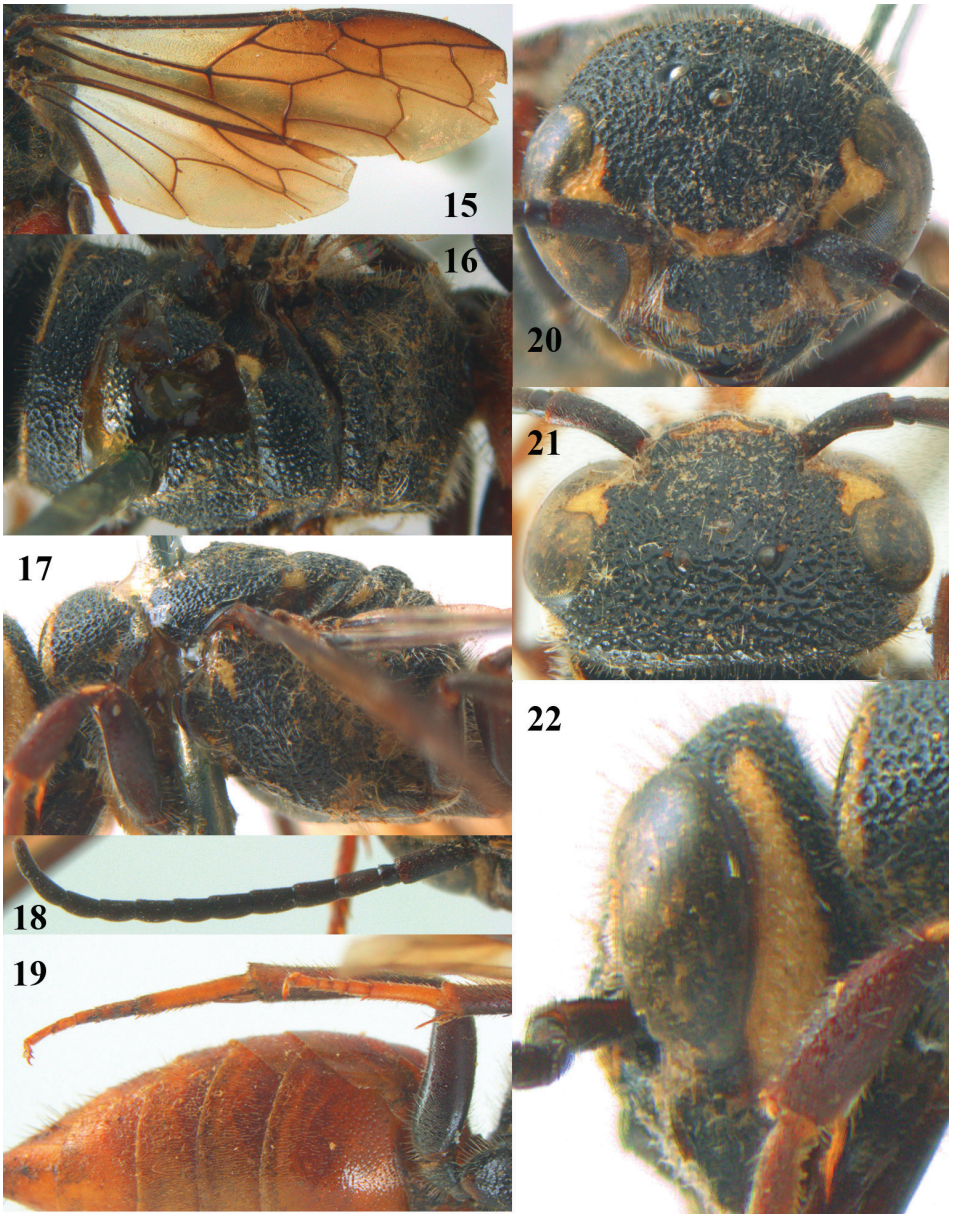
Type material. Holotype, ♀ (BMNH), "Type", "[India], Sikkim, Tukvar, 4000 '[ft], iv.[19]01, ex Möller, Bingham Coll.", "*Parasapyga mölleri* Turn., Type", "B.M. Type Hym. 15.1268".

Diagnosis. Clypeus with wide anchor-shaped black patch medially and largely black latero-dorsally (Fig. 20); ivory patch at incision of eye nearly extending up to



Figures 13–14. *Parasapyga moelleri* Turner, holotype, female. **13** habitus dorsal **14** habitus lateral.

level of anterior ocellus (Fig. 20); pair of ivory spots besides posterior ocellus absent (Fig. 21); ivory transverse stripe on pronotum widely interrupted medio-dorsally and narrow ventrally (Figs 16, 17); propodeum entirely black latero-dorsally (Fig. 17); first



Figures 15–22. *Parasapyga moelleri* Turner, holotype, female. **15** wings **16** mesosoma dorsal **17** mesosoma lateral **18** antenna lateral **19** hind leg lateral **20** head anterior **21** head dorsal **22** head lateral.

discal cell of fore wing distinctly infuscate and first subdiscal laterally as dark as medially (Figs 13, 15); metasoma rather wide in dorsal view (Fig. 13).

Description. Holotype, ♀, length of body 15.2 mm (of fore wing 10.6 mm).

Head. Antenna with 12 segments and penultimate segment 1.2 times as wide as apical segment in dorsal view (Fig. 18); frons rather coarsely reticulate-rugose; vertex

coarsely reticulate-punctate (Fig. 21); temple coarsely punctate; malar space densely punctulate; head directly narrowed behind eyes (Fig. 21); clypeus coarsely punctate and dorsally with median crest (Fig. 20).

Mesosoma. Length of mesosoma 1.5 times its height (Fig. 14); mesopleuron largely coarsely reticulate; metapleuron densely punctulate anteriorly and coarsely obliquely costate posteriorly, with a moderately wide smooth shiny band above it (Fig. 17); pronotum, mesoscutum, scutellum and metanotum coarsely reticulate-punctate, smooth interspaces between punctures of pronotum and metanotum medio-dorsally mostly distinctly narrower than diameter of punctures (Fig. 16); metanotum medially distinctly convex and distinctly protruding above level of scutellum (Figs 14, 17); entire propodeum densely and rather coarsely reticulate-rugose (Fig. 16).

Wings. Fore wing: vein 2m-cu far postfurcal (Fig. 15).

Legs. Hind basitarsus rather slender (Fig. 19).

Metasoma. Metasoma rather wide in dorsal view (Fig. 13); basal tergites finely punctate and shiny, with smooth interspaces wider than diameter of punctures (Fig. 13); hypopygium 1.2 times longer than fifth sternite ventrally (Fig. 14); ovipositor unknown (broken in holotype).

Colour. Black; ivory: L-shaped lateral patch on clypeus, patch at incision of eye extending nearly up to level of anterior ocellus (Fig. 20), shelf of frons anteriorly between antennal sockets, temple (except posteriorly) and up to upper level of eye (Fig. 22), transverse stripe on pronotum (except wide interruption medially; Fig. 16, and narrowed ventrally), small patch on mesopleuron antero-dorsally, minute patch near tegula, axilla, lateral patch on metanotum, apical patch on fore femur and small basal patch on fore tibia; metasoma dark red; palpi brown; tarsi yellowish-brown; remainder of femora and tibiae, veins and pterostigma, dark brown; fore coxa densely golden setose; apical 0.6 of fore wing dark brown and remainder subhyaline (Fig. 15).

Male. Unknown.

Distribution. India (Sikkim).

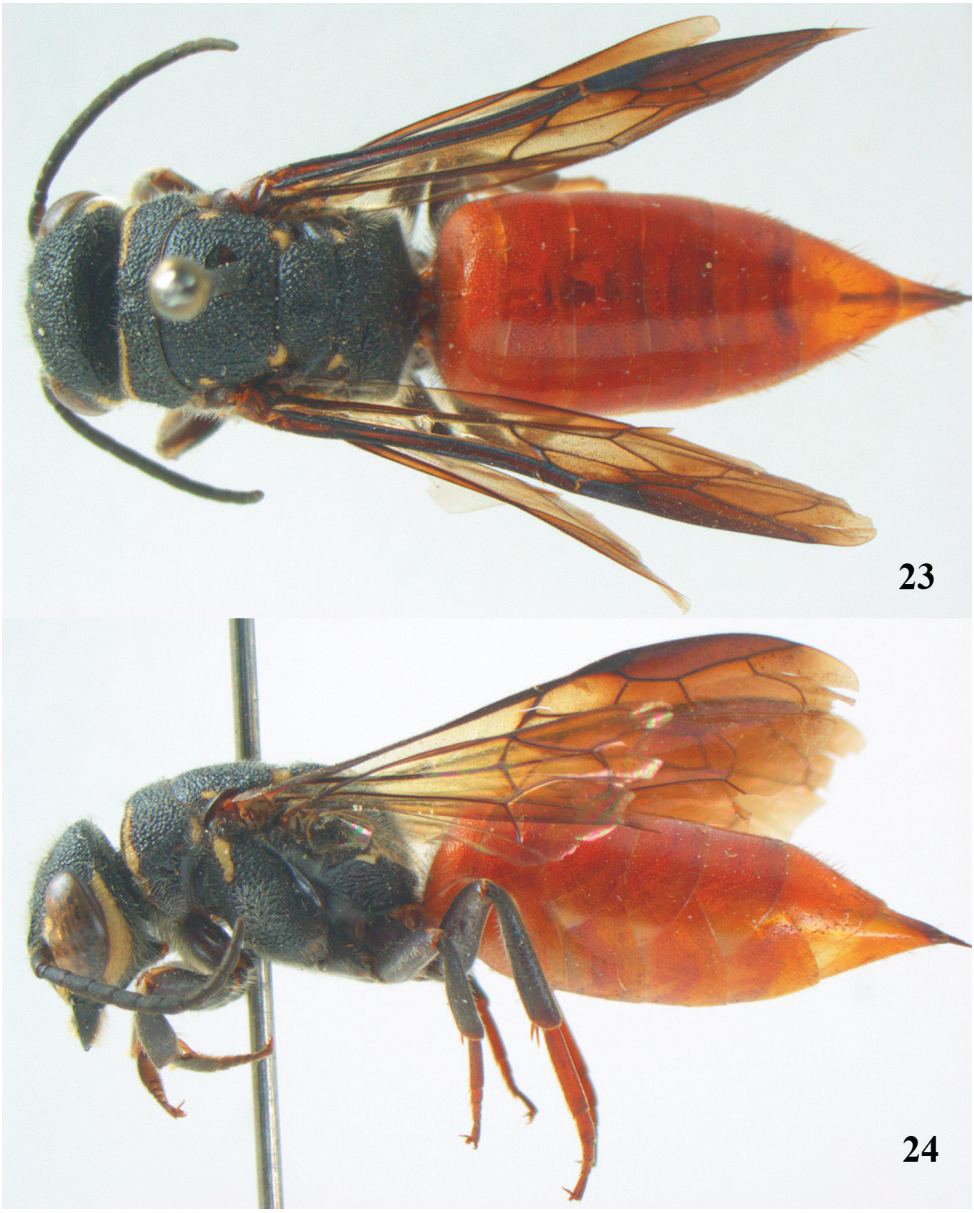
Parasapyga walshae van der Vecht, 1940, stat. n.

Figs 23–32

Parasapyga mölleri walshae van der Vecht, 1940: 45–46, fig.

Type material. Holotype, ♀ (RMNH), "[Indonesia:] S. Sumatra, Res. Lampongs, Mt. Tanggamoes, 22.vii–5.viii.1935, M.E. Walsh", "*Parasapyga mölleri* Turn. subsp. *walshae* v. d. Vecht, ♀", "Holotype of subsp. n. *walshae*".

Diagnosis. Clypeus with wide anchor-shaped black patch medially and ivory latero-dorsally (Fig. 30); ivory patch at incision of eye remains far from level of anterior ocellus (Fig. 30); pair of ivory spots besides posterior ocellus absent (Fig. 31); ivory transverse stripe on pronotum widely interrupted medio-dorsally (Fig. 26) and narrow ventrally (Fig. 27); propodeum with irregular ivory patch latero-dorsally

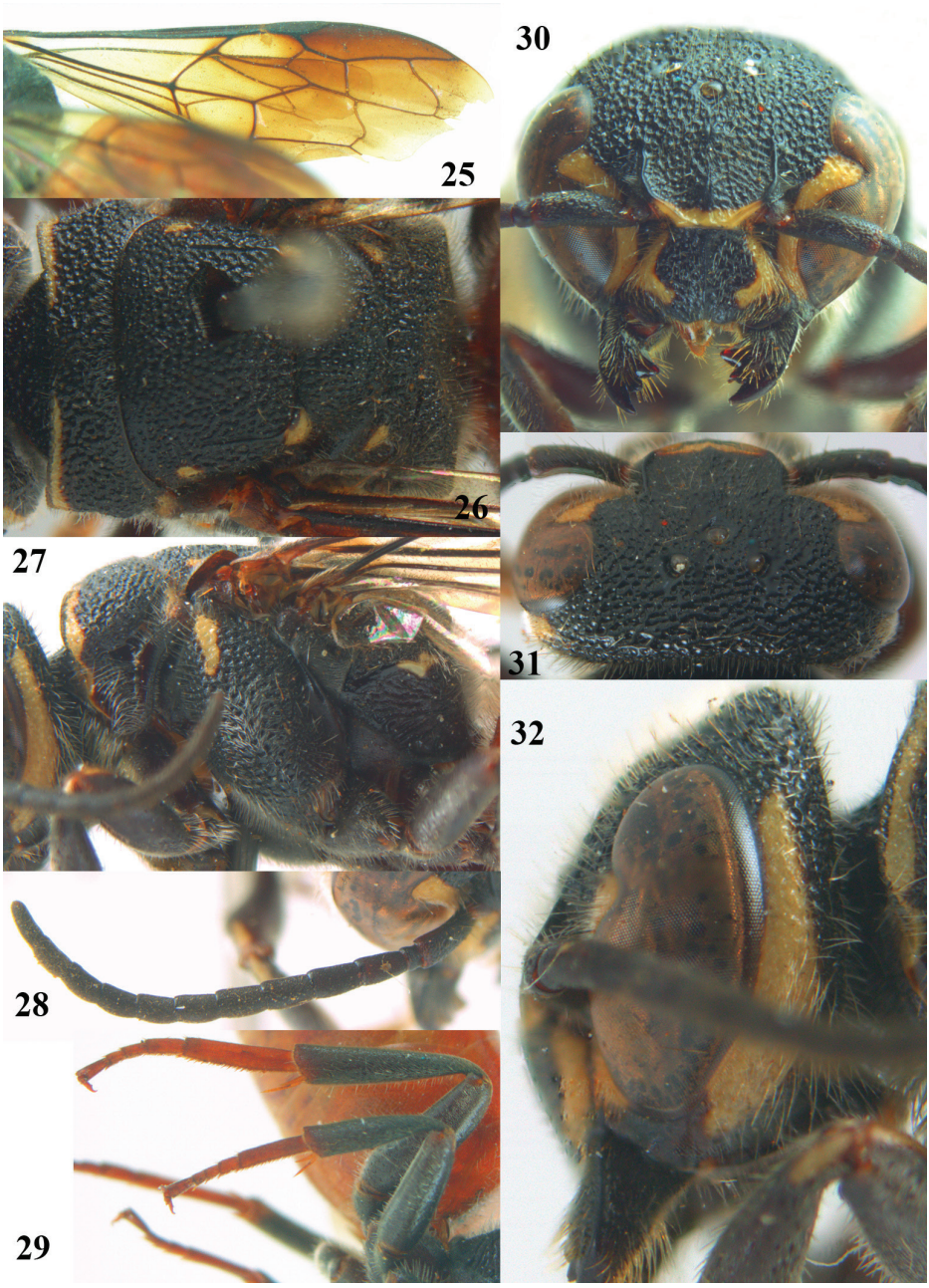


Figures 23–24. *Parasapyga walshae* van der Vecht, holotype, female. **23** habitus dorsal **24** habitus lateral.

(Fig. 27); first discal cell of fore wing subhyaline and first subdiscal laterally as pale as medially (Figs 23, 25); metasoma rather wide in dorsal view (Fig. 23); ovipositor densely serrate dorsally.

Description. Holotype, ♀, length of body 18.7 mm (of fore wing 11.9 mm).

Head. Antenna with 12 segments and penultimate segment 1.2 times as wide as apical segment in dorsal view (Fig. 28); frons moderately reticulate; vertex coarsely



Figures 25–32. *Parasapyga walshae* van der Vecht, holotype, female. **25** wings **26** mesosoma dorsal **27** mesosoma lateral **28** antenna lateral **29** hind leg lateral **30** head anterior **31** head dorsal **32** head lateral.

reticulate-punctate (Fig. 31); temple coarsely punctate; malar space densely punctulate; head directly narrowed behind eyes (Fig. 31); clypeus coarsely punctate and with complete median crest (Fig. 30).

Mesosoma. Length of mesosoma 1.5 times its height (Fig. 24); mesopleuron largely coarsely reticulate; metapleuron densely punctulate anteriorly and coarsely obliquely costate posteriorly, with a narrow smooth shiny band above it (Fig. 27); pronotum, mesoscutum, scutellum and metanotum coarsely punctate-reticulate, interspaces between punctures of pronotum and metanotum medio-dorsally mostly absent (Fig. 26); metanotum medially slightly convex and not protruding above level of scutellum (Fig. 24); entire propodeum densely and rather coarsely reticulate-rugose (Fig. 26).

Wings. Fore wing: vein 2m-cu just postfurcal (Fig. 25).

Legs. Hind basitarsus rather robust (Fig. 29).

Metasoma. Metasoma comparatively wide in dorsal view (Fig. 23); basal tergites finely punctate and shiny, with smooth interspaces wider than diameter of punctures (Fig. 23); hypopygium 1.4 times longer than fifth sternite ventrally (Fig. 24); ovipositor densely serrate dorsally.

Colour. Black; ivory: pair of L-shaped lateral patches on clypeus, patch at inner orbita up to top of incision of eye (Fig. 30), shelf of frons anteriorly between antennal sockets, temple except dorsally (Fig. 32), transverse stripe on pronotum (except wide interruption medially; Fig. 26, and narrowed ventrally), small patch on pronotum postero-dorsally, elongate patch on mesopleuron antero-dorsally, patch on border of propodeum and metapleuron, small patch near tegula, axilla, lateral patch on metanotum, elongate apical patch on fore and middle femora and elongate basal patch of fore tibia; metasoma orange red; palpi brown; middle and hind tarsi yellowish-brown; remainder of femora and tibiae, veins and pterostigma, dark brown; fore coxa densely golden setose; first submarginal cell apically, marginal cell and second and third submarginal cells of fore wing dark brown, area below it brown and remainder largely subhyaline (Fig. 25).

Male. Unknown.

Distribution. Indonesia (Sumatra).

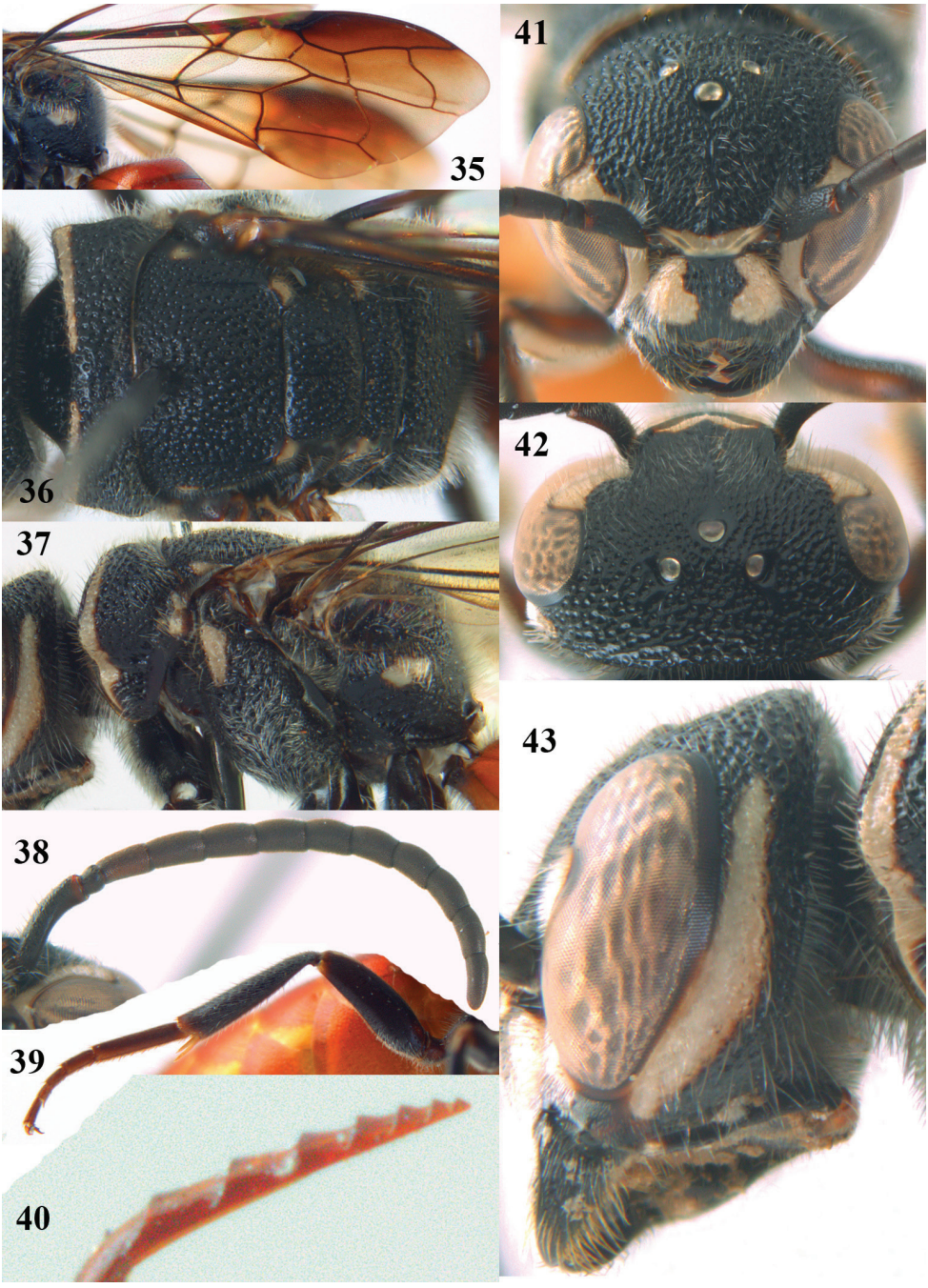
***Parasapyga yvonnae* sp. n.**
http://zoobank.org/A9B25C5D-7796-44C5-B14C-8514FFADEEA6
http://species-id.net/wiki/Parasapyga_yvonnae
Figs 33–43

Type material. Holotype, ♀ (RMNH), "Indonesia: N. Sumatra, Ketambe, c 400 m, near N. P. Gn. Leuser, Mal. trap, vi.1994, Y. v. Nierop & C. v. Achterberg, RMNH'95".

Diagnosis. Clypeus with rather narrow anchor-shaped black patch medially (Fig. 41); (Fig. 36) and comparatively wide ventrally (Fig. 37); first discal cell of fore wing subhyaline (Fig. 35); hind tibia black; metasoma comparatively slender in dorsal view (Fig. 33); ovipositor with comparatively widely separated serrations (Fig. 40). Differs from the other known species by the rather narrow anchor-shaped black patch of the clypeus, the narrowly interrupted ivory transverse stripe on the pronotum and the dark brown hind tarsus.

Description. Holotype, ♀, length of body 13.9 mm (of fore wing 9.8 mm).

Figures 33–34. *Parasapyga yvonnae* sp. n., holotype, female. **33** habitus dorsal **34** habitus lateral.



Figures 35–43. *Parasapyga yvonnae* sp. n., holotype, female. **35** wings **36** mesosoma dorsal **37** mesosoma lateral **38** antenna lateral **39** hind leg lateral **40** apex of ovipositor lateral **41** head anterior **42** head dorsal **43** head lateral.

Head. Antenna with 12 segments and penultimate segment 1.2 times as wide as apical segment in dorsal view (Fig. 38); frons moderately reticulate; vertex coarsely reticulate-punctate (Fig. 42); temple coarsely punctate; malar space densely punctulate; head narrowed behind eyes (Fig. 42); clypeus rather coarsely reticulate and with nearly complete median crest (Fig. 41).

Mesosoma. Length of mesosoma 1.6 times its height (Fig. 34); mesopleuron largely coarsely reticulate-punctate; metapleuron densely punctulate anteriorly and coarsely obliquely rugose posteriorly, with a wide smooth shiny band above it (Fig. 37); pronotum, mesoscutum, scutellum and metanotum coarsely reticulate-punctate, interspaces between punctures of pronotum and metanotum medio-dorsally present, sparsely punctulate and usually 0.5–1.0 times as wide as punctures (Fig. 36); metanotum medially moderately convex and not protruding above level of scutellum (Fig. 34); entire propodeum densely and rather coarsely reticulate-rugose, medially coarser than laterally (Fig. 36).

Wings. Fore wing: vein 2m-cu just postfurcal (Fig. 35).

Legs. Hind basitarsus comparatively slender (Fig. 39).

Metasoma. Metasoma comparatively slender in dorsal view (Fig. 33); basal tergites finely punctate and shiny, with smooth interspaces wider than diameter of punctures (Fig. 33); hypopygium as long as fifth sternite ventrally (Fig. 34); ovipositor with rather widely separated serrations (Fig. 40).

Colour. Black; ivory: pair of wide c-shaped lateral patches on clypeus (resulting in a comparatively narrow black anchor medially; Fig. 41), patch at inner orbita up to top of incision of eye (Fig. 41), shelf of frons anteriorly between antennal sockets, temple largely except narrowly dorsally (Fig. 43), transverse stripe on pronotum (but comparatively narrowly interrupted medially (Fig. 36) and ventrally comparatively wide (Fig. 37)), small patch on pronotum postero-dorsally, elongate patch on mesopleuron antero-dorsally, patch on border of propodeum and metapleuron, small patch near tegula, axilla, lateral patch on metanotum, elongate apical patch on femora, fore femur largely ventrally and elongate basal patch on fore and middle tibiae and outer side of fore tibia subapically largely; metasoma orange red; inner side of fore femur and tibia brown; tarsi largely, veins and pterostigma, dark brown; fore coxa densely silvery setose; first submarginal cell apically, marginal cell and second and third submarginal cells of fore wing dark brown, area below it brown and remainder largely subhyaline (Fig. 35).

Male. Unknown.

Distribution. Indonesia (Sumatra).

Etymology. Named in honour of one of the collectors, Yvonne van Nierop (Leiden) for all her collecting efforts in N. Sumatra.

Acknowledgements

I am grateful to Dr Gavin Broad (London) for the loan of the holotype of *P. moelleri* and to Dr Nickolay Kurzenko (Vladivostok) for the information about Oriental Sapygidae.

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Description and biology of two new species of Neotropical *Liriomyza* Mik (Diptera, Agromyzidae), mining leaves of *Bocconia* (Papaveraceae)

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Abstract

Liriomyza mystica Boucher & Nishida, **sp. n.**, and *Liriomyza prompta* Boucher & Nishida, **sp. n**. are described from Costa Rica. Both species were reared from leaves of *Bocconia frutescens* L. (Papaveraceae). The latter species was also reared from *B. arborea* S. Watson. Larvae of *L. mystica* mine primary veins of large, relatively old, mature leaves, and *L. prompta* mine blades of small to large, mature leaves. These represent the first record of agromyzids feeding on *Bocconia*. Biological information is also given and illustrated.

Keywords

Biocontrol of weeds, *Bocconia arborea*, *Bocconia frutescens*, leaf miner, *Liriomyza mystica*, *Liriomyza prompta*, Hawai`i, Neotropical, parasitoid wasps, systematics, taxonomy, Tree poppy

Introduction

Liriomyza Mik is the second largest genus of agromyzid flies (after *Phytomyza* Lioy) with approximately 390 described species worldwide. Due to its high diversity, small size and mostly uniform external characters, identification at the species level is sometimes difficult for this genus. Host plant association is often an important tool for species identification especially for host-specific species. Host plants are known for 177 species (45%) of *Liriomyza* (Benavent-Corai et al. 2005) with almost all species feeding as leaf miners, except a few species that develop in stems, flower buds or potato tubers (Parrella 1987). Most species are monophagous or oligophagous, although several of the most highly polyphagous agromyzid species belong to this genus. As many as 76 plant families have been recorded as hosts for *Liriomyza* species, which is the widest host range known among Agromyzidae (Spencer 1990). In the Neotropical region, *Liriomyza* is the dominant genus with 92 species described (*L. avicenniae* Martinez; *L. pectinimentula* Sasakawa and *L. pervensis* Zlobin added to species list in Martinez and Etienne 2002). Host plants are known for approximately one-third of these species (Benavent-Corai et al. 2005) with some considered to be of major economic importance due to the damage they cause to ornamental plants and cultivated crops (Spencer 1973) or for their highly polyphagous habits (Boucher 2010). Species of Papaveraceae have previously been recorded as host plants for six agromyzid species (Benavent-Corai et al. 2005): *Phytomyza horticola* Goureau (on *Eschscholzia* Cham., *Glaucium* Miller, *Papaver* L.) *Liriomyza strigata* (Meigen) (on *Glaucium*, *Meconopsis* Viguier and *Papaver*), *Calycomyza jucundacea* (Blanchard) (on *Papaver*), *Liriomyza huidobrensis* (Blanchard) (on *Papaver*), *Liriomyza xanthocera* (Czerny) (on *Papaver*), and *Phytomyza parvicella* (Coquillett) (on *Papaver*), but none were previously recorded from the genus *Bocconia*.

Bocconia frutescens L., commonly known as Tree poppy, Parrotweed, Plume poppy, Sea oxeye daisy or simply *Bocconia* is a large shrub to small tree native to tropical America occurring from Mexico to Argentina, and Bahamas (Wagner et al. 1999; Hammel et al. 2007). It is easily recognized by its relatively dry and soft trunk and deeply lobed leaves reaching 30 cm wide and 55 cm long or larger (90 cm) (Hammel et al. 2007, K. Nishida, pers. observation). The species was intentionally introduced as an ornamental plant in Hawai`i in the early 1900's (Wester 1992), but has now been listed as a noxious weed by the State of Hawai`i (Benitez and Saulibio 2007). In Costa Rica, the species has been recorded between 100 and 3300 m on both Atlantic and Pacific slopes (INBio 1997–2006; Hammel et al. 2007), and is commonly found in middle to high elevation cloudforests, along road sides, river banks, open fields, and light gaps (K. Nishida, pers. observation). According to Hammel et al. (2007), a second species of *Bocconia*, *B. arborea* S. Watson occurs in Costa Rica—it has the same appearance as *B. frutescens* except for deeper lobed foliage with more whitish texture on the underside. It has a smaller distributional range,

occurring from Mexico to Costa Rica, possibly to Panama at an elevation varying from 1100 to 1600 m.

Here we describe two new species of *Liriomyza* reared from *Bocconia* at various localities in Costa Rica.

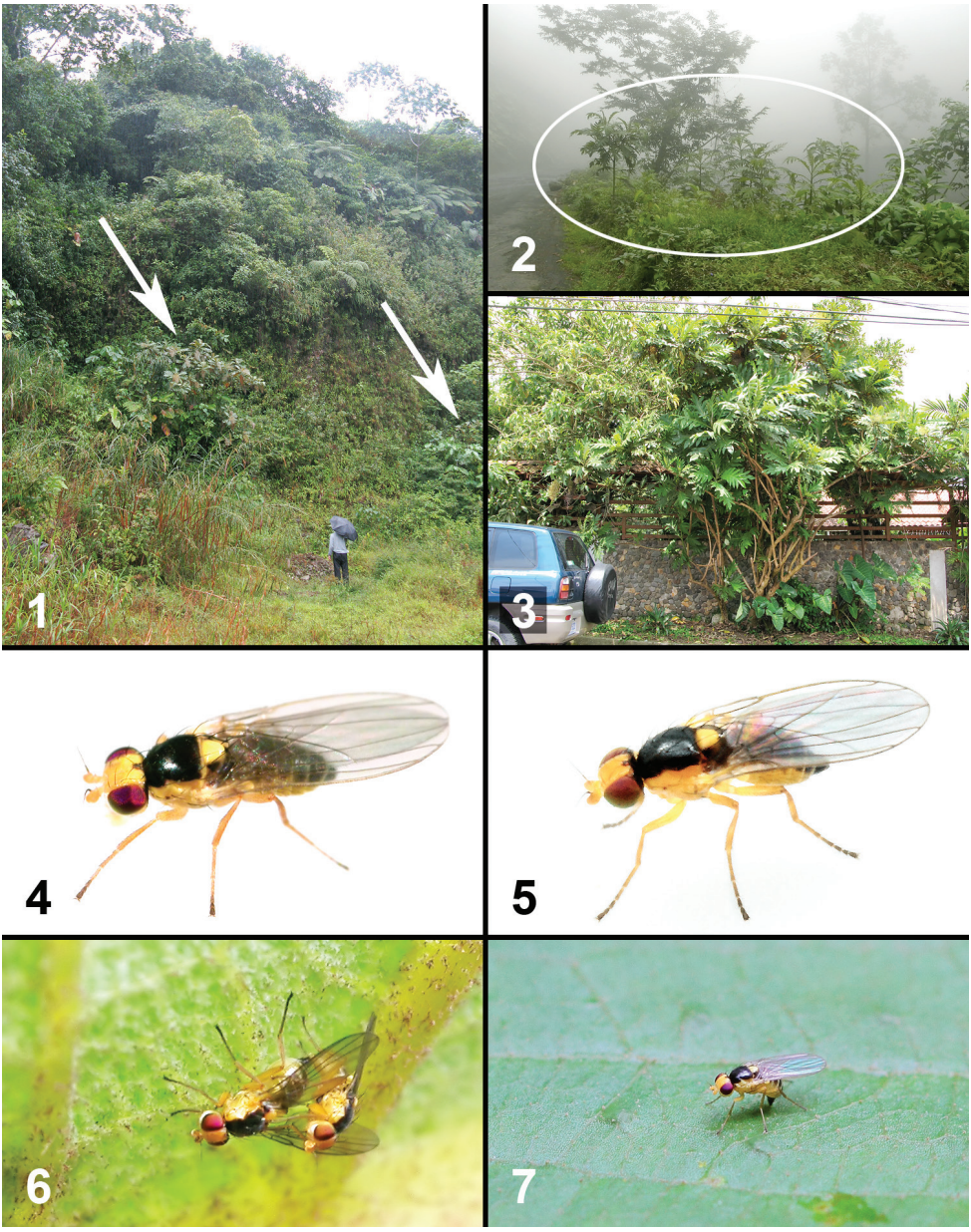
Materials and methods

Leaves of *Bocconia frutescens* and *B. arborea* infested by the *Liriomyza* species have been collected at multiple localities in Costa Rica (Figs 1–3, Table 1). Most of the observation, collecting and rearing was conducted between April 2007 and July 2011. The leaves collected were taken back to a laboratory in San Isidro de Coronado (Table 1, site 15) for rearing. Approximate average temperature of the rearing chamber was 25 °C (day) and 18 °C (night). Infested parts of the leaf blade were separated from the primary vein in order to separate the two fly species, which are site-specific on the leaf. The leaf blade and the primary veins were placed either in large transparent plastic bags or translucent Tupperware for observation and rearing of the larvae, puparia and parasitoids. Most adults were obtained from rearing, except a few caught while mating on *Bocconia frutescens* at site 13. For some of the sites, only leaf mines were recorded via observations. Larvae, puparia, adults and parasitoids were preserved in 75% ethanol. Most adults were dried using HMDS (hexamethyldisilazane). Photographs of the life histories and live specimens of both adults and immature stages were taken with digital cameras (Nikon Coolpix 4500, 8700, and Canon PowerShot G7). The final digital images were processed using Adobe Photoshop CS4. Type specimens are deposited in the following collections (acronyms used in the text are in parentheses): Canadian National Collection of Insects, Arachnids & Nematodes, Ottawa, ON, Canada (CNC); Museo de Zoología, Universidad de Costa Rica, San José, Costa Rica (MZUCR); Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica (INBio); Lyman Entomological Museum, McGill University, Ste-Anne-de-Bellevue, QC, Canada (LEM); National Museum of Natural History, Smithsonian Institution, Washington, DC, USA (NMNH).

Specimens of immature stages are deposited in CNC and MZUCR, and parasitoid wasps in MZUCR.

Results

Both species of *Liriomyza* were present at most of the field sites, sometimes containing larvae of the two species on the same leaf. A total of 127 adult specimens representing two new species of *Liriomyza* were obtained from nine localities in Costa Rica (Table 1). Most of these specimens were reared from *Bocconia frutescens* except four specimens that were collected while mating under leaves of *Bocconia frutescens*, and



Figures 1–7. Life history of two new species of *Liriomyza*. **1–3** Habitats **1** Open area in a valley near Reserva Biológica Manuel Alberto Brenes in San Ramón (site 2). Arrows indicate *Bocconia frutescens* trees **2** *B. frutescens* saplings (in circle) growing along the road after land slides caused by 2009 earthquake in Cinchona-Vara Blanca area (site 10) 3 Ornamental *B. frutescens* tree (in middle) in urban area of San Isidro de Coronado (site 15) **4** *Liriomyza mystica* female (from site 5) **5** *Liriomyza prompta* female (from site 13) **6** Mating couple of *L. prompta* on the underside of *B. frutescens* leaf at 7:00 am (30.v. 2009, site 13) **7** *L. prompta* ovipositing on the upper side of *B. frutescens* leaf blade at 3:00 pm (17.vi.2011, site 2).

Table 1. *Liriomyza* species occurrence at different site localities in Costa Rica. All from host plant *Bocconia frutescens* L., unless specified otherwise.

Sites	Province	Locality, Lat.-Long.	Elevation	Species	Imago ♂	Imago ♀	Comments/ immature stages
1	Alajuela	Parque Nacional Volcán Arenal, 10°27'57"N, 084°45'18"W	600 m	*L. prompta*	0	0	1 puparium
	Alajuela	Parque Nacional Volcán Arenal, 10°27'54"N, 084°45'15"W	605 m	*L. prompta*	0	0	leaf mine
2	Alajuela	Reserva Biológica Manuel Alberto Brenes, open valley area, (Fig. 1) 10°13'43"N, 084°34'10"W	796 m	*L. mystica*	0	0	1 puparium
	Alajuela	Reserva Biológica Manuel Alberto Brenes, open valley area, (Fig. 1) 10°13'43"N, 084°34'10"W	796 m	*L. prompta*	2	2	larvae, puparia
	Alajuela	Reserva Biológica Manuel Alberto Brenes, 10°13'07"N, 084°35'49"W	850 m	*L. mystica*	0	0	1 puparium
	Alajuela	Reserva Biológica Manuel Alberto Brenes, 10°13'07"N, 084°35'49"W	850 m	*L. prompta*	0	1	oviposition, 1 puparium
3	Alajuela	Laguna de Hule, 10°18'14"N, 084°12'26"W	809 m	*L. mystica*	0	0	1 larva
	Alajuela	Laguna de Hule, 10°18'14"N, 084°12'26"W	809 m	*L. prompta*	0	0	1 puparium
4	Alajuela	Bajo del Toro, 10°08'27"N, 084°19'60"W	1380 m	*L. prompta*	0	0	leaf mines
5	Cartago	San Ramón de Tres Ríos, 09°56'20"N, 083°58'55"W	1500 m	*L. mystica*	1	5	larvae, puparia
	Cartago	San Ramón de Tres Ríos, 09°56'18"N, 083°58'38"W	1600 m	*L. mystica*	35	35	larvae, puparia
	Cartago	San Ramón de Tres Ríos, 09°56'18"N, 083°58'38"W	1600 m	*L. prompta*	13	7	larvae, puparia
	Cartago	San Ramón de Tres Ríos, 09°56'27"N, 083°58'16"W	1670 m	*L. mystica*	0	0	larvae
6	Cartago	Cervantes, 09°52'46"N, 083°49'07"W	1500 m	*L. prompta*	1	0	larvae, puparia
	Cartago	Cervantes, 09°52'46"N, 083°49'07"W	1500m	*L. mystica*	0	0	larvae
7	Cartago	Llano Grande, 09°54'41"N, 083°53'09"W	2100 m	*L. prompta*	0	0	leaf mines
8	Cartago	Chicuá, Irazú Volcano, 09°56'49"N, 083°52'00"W	2765 m	*L. mystica*	0	0	1 larva
9	Heredia	Santo Domingo de Heredia, 09°58'21"N, 084°05'29"W	1133 m	*L. prompta*	0	1	larvae, puparia, on *Bocconia arborea*
10	Heredia	Cinchona-Vara Blanca, (Fig. 2) 10°13'26"N, 084°09'47"W–10°11'02"N, 084°09'18"W	1200–1800m	*L. mystica*	0	0	larvae, puparia
	Heredia	Cinchona-Vara Blanca, (Fig. 2) 10°13'26"N, 084°09'47"W–10°11'02"N, 084°09'18"W	1200–1800m	*L. prompta*	0	0	larvae, puparia
11	Limón	Guácimo, 10°08'34"N, 083°42'27"W	480 m	*L. prompta*	0	0	leaf mines
12	Puntarenas	Bosque Eterno de los Niños, Bajo del Tigre, 10°30'31"N, 084°49'12"W	1130 m	*L. prompta*	0	2	larvae, puparia

Sites	Province	Locality, Lat.-Long.	Elevation	Species	Imago ♂	Imago ♀	Comments/ immature stages
13	Puntarenas	Estación Biológica Monteverde, 10°19'09"N, 084°48'32"W	1538 m	*L. prompta*	1	1	mating (Fig. 6)
	Puntarenas	Estación Biológica Monteverde, 10°19'09"N, 084°48'32"W	1538 m	*L. mystica*	1	1	mating, larvae and puparia
14	San José	San Pedro de Montes de Oca, 09°56'27"N, 084°02'36"W	1236 m	*L. prompta*	0	0	larvae, puparia
15	San José	San Isidro de Coronado, (Fig. 3) 09°58'18"N, 084°00'22"W	1420 m	*L. prompta*	6	12	larvae, puparia
	San José	San Isidro de Coronado, (Fig. 3) 09°58'18"N, 084°00'22"W	1420 m	*L. mystica*	0	1	larvae, puparia
16	San José	San Gerardo de Rivas area, 09°28'13"N, 083°35'07"W–09°27'51"N, 083°34'15"W	1457–2031 m	*L. prompta*	0	0	leaf mines
17	San José	Parque National Chirripó, forest fire area approx. 09°27'20"N, 083°31'59"W	ca. 2700 m	*L. mystica*	0	0	1 puparium, 1 larva

two reared from *B. arborea* (Table 1). No adult specimens were successfully reared from some of the sites, but species identification was still possible with larvae and/or puparia obtained. Species description and details on biology follow.

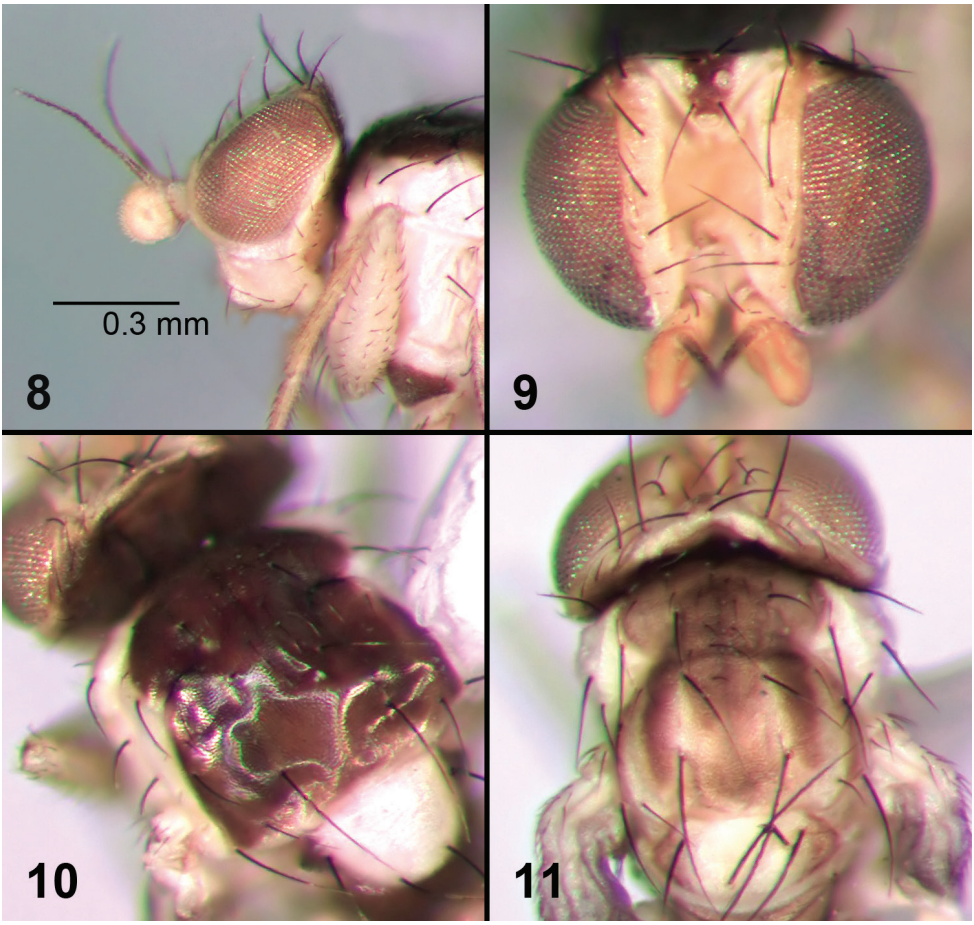
***Liriomyza mystica* Boucher & Nishida, sp. n.**
http://zoobank.org/48883C22-4ED7-438D-B6F4-1A290B51763F
http://species-id.net/wiki/Liriomyza_mystica
Figs 4, 8–27, 48, 50

Type material. Holotype ♂: COSTA RICA: Cartago: San Ramón de Tres Ríos, 1600 m, (09°56'18"N, 083°58'38"W), ex. *Bocconia frutescens*, larva exited 5–9.vii.2010; adult emerged 21–26.vii.2010, Kenji Nishida (LEM).

Paratype: same data as holotype (9 ♂; 8 ♀: LEM); same except larva exited: 25–28. vi.2010, adult emerged: 20–22.vii.2010 (14 ♂; 15 ♀: INBio); same except larva exited 29.vi–4.vii.2010, adult emerged 15–24.vii.2010 (8 ♂; 7 ♀: NMNH); same except adult emerged 21–25.vii.2010 (4 ♂; 4 ♀: CNC); same except along main road, (09°56'20"N 083°58'55"W), 1500 m, collected 19.xii.2008, emerged 16–20.i.2009, K. Nishida & T. Johnson (1 ♂; 5 ♀: MZUCR). San José: San Isidro de Coronado, Centro. 1420 m, (09°53'18"N, 084°00'22"W), ex. *Bocconia frutescens*, adult emerged 17.vi.2010, Kenji Nishida (1 ♀: LEM). Puntarenas: Monteverde. Estación Biológica Monteverde. 1538 m, (10°19'09"N, 084°48'32"W), mating on *Bocconia* leaf. 18.vii.2010, Kenji Nishida (1 ♂; 1 ♀: MZUCR).

Diagnosis. This species can be distinguished from other Neotropical species of *Liriomyza* by its completely yellow head and anepisternum, mesonotum almost completely brown to margin of scutellum, usually 2 + 1 dc, legs completely yellow, calypter brown on apical half with margin and fringe brown, and by the shape of the male genitalia and the shape of the anterior and posterior larval spiracles.

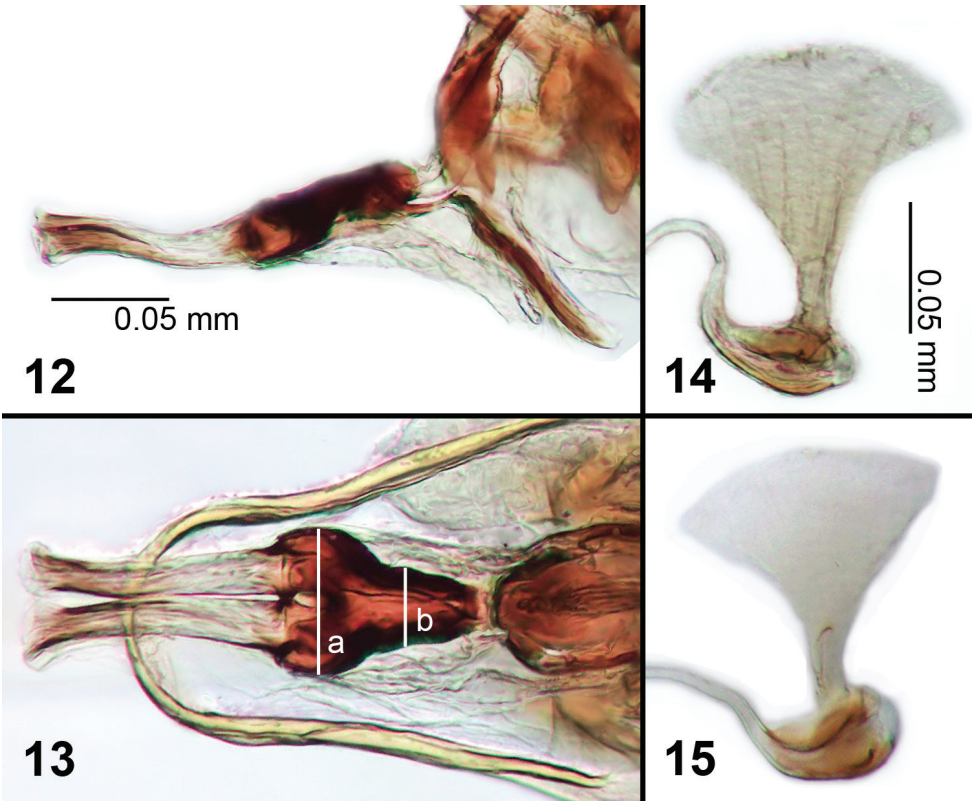
Description. Frons width 0.25 mm; ratio of frons width to eye width 2.3; orbit 0.23 times width of frons at midpoint; frons slightly projecting above or in front of eye in profile (Fig. 8), forming a distinct ring (cheek) below eye; 2 reclinate *ors* and 2 inclinate *ori* (Fig. 9) (lower ori sometimes reduced or missing on one side); orbital setulae reclinate, varying in number from about 4–8; first flagellomere rounded, not enlarged in males, with slight apical pubescence; arista 0.30–0.40 mm, with short but dense pubescence; gena deep, slightly extended at rear (Fig. 8); gena height at midpoint: 0.44 times maximum eye height. Eye oblique, bare. Normally 2+1 dc (except 4 specimens with 2+0 dc and 3 specimens with 3+1 dc); acrostichals in about 4 irregular rows; prescutellar acrostichal bristles absent; 2 notopleural bristles; 1 strong postpronotal bristle with 1 or 2 small setulae; anepisternum with 1 strong bristle on posterior margin at midpoint, sometimes with a few extra setulae; katepisternum with one strong bristle on posterodorsal corner, on yellow ground. Fore and mid-tibia without lateral bristle. Wing length 1.50–1.95 mm in male and 1.85–2.20 mm in females; M_{1+2} ending at wing tip; costa extending to M_{1+2}; last section of CuA_1: 1.5–1.9 times length of



Figures 8–11. External morphology of adult *Liriomyza mystica*. **8** Head, lateral **9** Head, dorso-frontal **10** Thorax, dorsal **11** Thorax, dorsal (teneral specimen).

penultimate. Cross-vein r-m located at midpoint of cell dm. Stridulatory mechanism apparently absent.

Colour. Head (including frons, orbit, face, antenna, palp) entirely bright yellow. Hind margin of eye black for a small section beyond vte; both vt on yellow ground. Occiput black. Eye sometimes with a slight bluish or greenish reflection (not as pronounced as in *L. prompta*, Fig. 29); mesonotum almost completely dark brown except for narrow yellow margin posteriorly (Fig. 10), prescutellar area and intra-alar area sometimes slightly paler brown resulting in a weakly defined banded pattern on thorax, most visible in teneral specimen (Fig. 11); scutellum completely yellow with small brown patches laterally. Basal scutellar bristles on brown ground (but at the limit of yellow). Postpronotum, notopleuron and anepisternum completely yellow (at most with a very small pale brown patch on one or two of the sclerites). Katepisternum mostly brown except for upper margin yellow. Calypter brown on apical half, margin



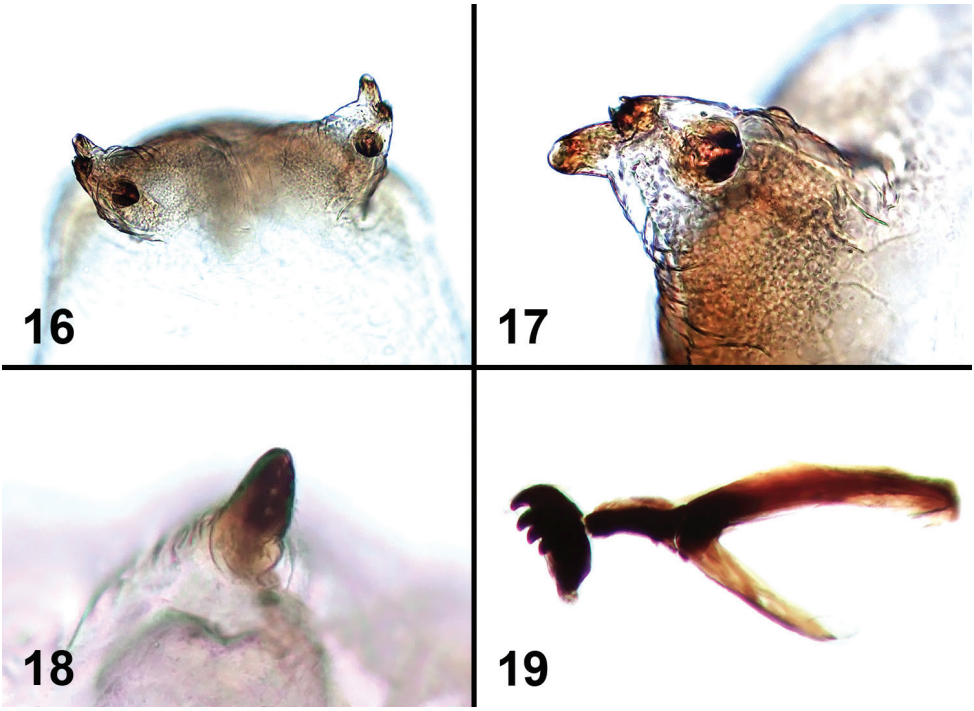
Figures 12–15. Male genitalia of *Liriomyza mystica*. **12** Phallus, lateral **13** Phallus, ventral (see text for lines 'a' and 'b') **14, 15** Ejaculatory apodeme.

and fringe also brown; halter completely white. Legs completely yellow. Abdominal tergites pale brown.

Male genitalia. Distiphallus in the form of two narrow tubules, slightly diverging apically in ventral view (Fig. 13). Mesophallus widest apical section (Fig. 13a), about 1.5–2 times larger than basal narrower tubular section (Fig. 13b). Mesophallus in lateral view with small indent at midpoint (Fig. 12). Surstylus absent. Epandrium without chitinized margin and without spines. Ejaculatory apodeme (Figs 14, 15) weakly sclerotized, symmetrical or sometimes asymmetrical with blade more expanded on one side.

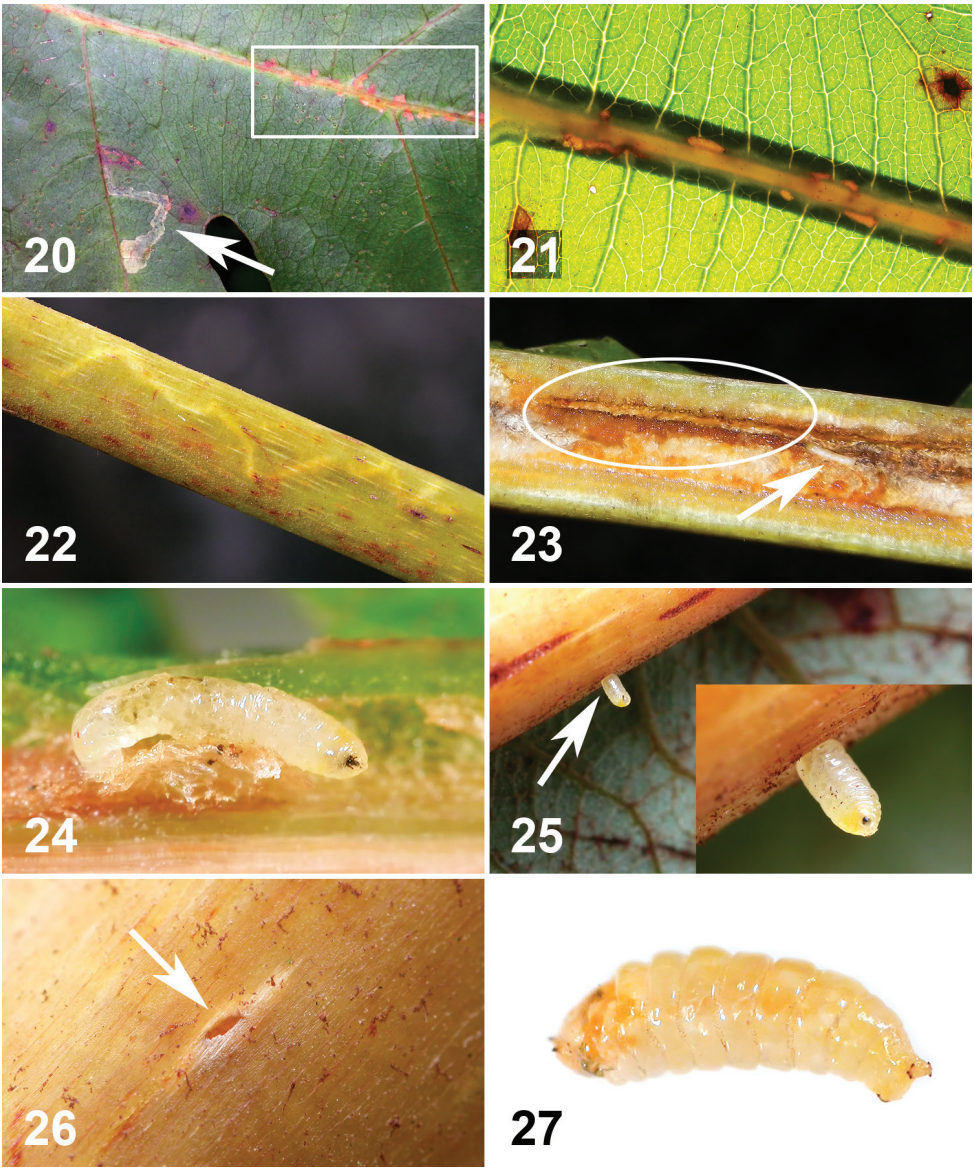
Early stages. Larval length (at maturity): 3.2–4.0 mm, slightly larger than *L. prompta* larva. White to creamy white with an internal orange spot at head (live specimens, Figs 24, 25, 27). Anterior spiracles about 0.13–0.23 mm distance from each other; fan-shaped and each with 5 small openings in a single row (Fig. 18). Posterior spiracles divided into 3 subequal projecting bulbs (Figs 16, 17). Cephalopharyngeal skeleton with wide arms (Fig. 19), Each mandible with 2 large teeth. Puparium pale brown to transparent (Fig. 48).

Host plant. *Bocconia frutescens* L. (Papaveraceae).



Figures 16–19. Larval characters of *Liriomyza mystica*.**16** Posterior spiracles **17** Posterior spiracle (close-up) **18** Anterior spiracle (note angle of view is different from Fig. **38**) **19** Cephalopharyngeal skeleton.

Biology. The larvae feed on spongy parenchyma and other tissues of primary veins and petioles of large, relatively old, mature leaves. Most of the larvae were in leaves of >30 cm long, with >10 mm petiole width and >10 mm thickness (n=120). The larvae were more frequently found mining in the thicker part of the primary vein including the petiole (i.e. less frequently near the leaf apex). One larva was found mining inside of a 2.2 mm width primary vein near the leaf apex. A few larvae were mining thick secondary veins. The mining appears to occur longitudinally, mostly near the upper leaf surface; the larvae left some brown to reddish brown scars along the leaf blade where the vein and blade join (Figs 20, 21, 23). These scars were more easily seen with a strong transmitted light (Fig. 21). The mines (internal tunnels) can also be distinguished by narrow pale lines (Fig. 22). When infested veins were longitudinally dissected, usually one to a few white *Liriomyza prompta* larvae were observed mining singly and scattered (n=12 leaves) (Figs 23, 24). Some solitary parasitoid wasp pupae were also found among the spongy parenchyma (Fig. 50). The mature fly larvae exited from either the upper side or underside of the veins (n=12 holes) (Fig. 25), each larva making a small oval-shaped hole of 1.1–1.3 mm wide (n=12) (Fig. 26). The tissue around the old exit holes was brown to reddish brown (n=5). The newly emerged larvae wiggled around in rearing plastic bags/cases for a couple of hours to a few hours before settling (Fig. 27) and starting to form a puparium. The larvae readily pupated on



Figures 20–27. Life history of *Liriomyza mystica* larvae on *Bocconia frutescens.* **20–22** External evidence caused by internal larval feeding on vein and petiole **20** Brown to reddish brown spots (ca. 1–2 mm long) on upperside along primary vein, marked by rectangular line. Arrow indicates *L. prompta* mine **21** Pale brown linear spots along the primary vein seen through strong sunlight from the back. Note that lower part of vein (underside) is thicker and shown as shadow **22** Mine in pale colour zigzag, approximately 30 mm long **23** Longitudinally opened primary vein with linear mine (circle) and late instar larva (arrow) **24** Late instar larva in situ, ventral view. Cephalopharyngeal skeleton on right. Notice orange spot at head **25** Mature larva exiting from underside of vein (arrow). Close-up view, lower right. Notice orange spot at head **26** Exit hole (ca. 1 mm wide) on underside of primary vein **27** Mature larva in pre-puparial stage. Posterior on right.

the plastic surfaces. In general, the puparia (Fig. 48) were more translucent (translucent pale brown) than those of *L. prompta* (translucent brown to dark brown) and the pupa inside was visible. Duration of the larval stage was not recorded. The larvae that exited from veins pupated between 26 to 29.vi.2010 and the adults emerged between 20 to 22.vii.2010, i.e. the pupal stage lasted approximately 25 days (n=29). A mating pair was observed on the underside of a leaf around 7:00 am (site 13). No oviposition behavior was observed for this species.

Parasitoids. Two species of Pteromalidae: Pteromalinae: sp. 01 from sites 5, 10, 15, parasitizing late instar larva, pupating inside the leaf vein (Fig. 50); Pteromalinae sp. 02 from sites 5, 10, 13, parasitizing larva and pupating inside the host puparium; one species of Braconidae: Opiinae: *Opius* sp. from site 10, parasitizing larva and pupating inside the host puparium.

Comments. *Liriomyza mystica* is most similar to *L. prompta* described below and to the Neotropical species *L. commelinae* (Frost) and *L. robustae* Spencer, especially in the form of the phallus with paired tubules. But these two latter species differ from *L. mystica* in a number of characters, including their host plants (both known from plants in the family Commelinaceae); mesonotum with a distinctive black and yellow pattern; surstylus with a distinct spine; third antennal segment enlarged in males; shape of both anterior and posterior spiracles and pupation occurring inside the mine (Silva and Oliveira 1952, Spencer 1984, Valladares 1984). The anterior and posterior spiracles of *L. mystica* are most similar to those of *L. caesalpiniae* Valladares reared from a Caesalpiniaceae, *Caesalpinia gilliesii* Benth. (Valladares 1984: figs 14, 15).

Most adult specimens of *L. mystica* were reared from site 5, but it was also found at other sites, up to an elevation of 2765 m (Table 1). Considering that *L. mystica* larvae feed inside primary veins and petiole of large, mature leaves, it made it difficult to establish *Bocconia arborea* as possible host due to the problems in studying large trees with large leaves. In sapling trees of ca. 1 m tall (n=2) at Santo Domingo de Heredia (site 9), no larvae or evidence of feeding was observed.

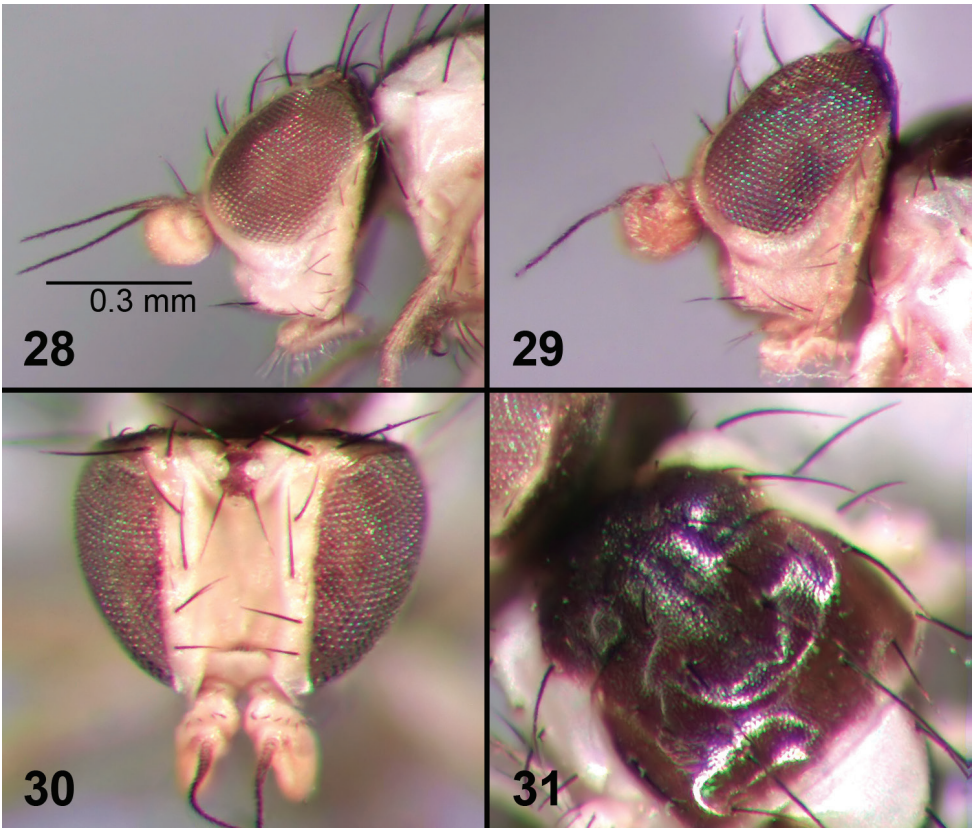
Etymology. The species name is derived from the Latin *mysticus* (secret, mystic), referring to the hidden and inconspicuous leaf mines in primary vein and petiole.

Liriomyza prompta Boucher & Nishida, sp. n.

http://zoobank.org/5933AA4E-ACDE-4A2F-8F66-4CD9AA55F1C6
http://species-id.net/wiki/Liriomyza_prompta
Figs 5–7, 20, 28–47, 49, 51

Type material. Holotype ♂: COSTA RICA: Cartago: San Ramón de Tres Ríos, 1600 m (09°56'18"N, 083°58'38"W), ex. leaf mine *Bocconia frutescens*, larva exited 5–9. vii.2010, adult emerged 21–26.vii.2010, Kenji Nishida (LEM).

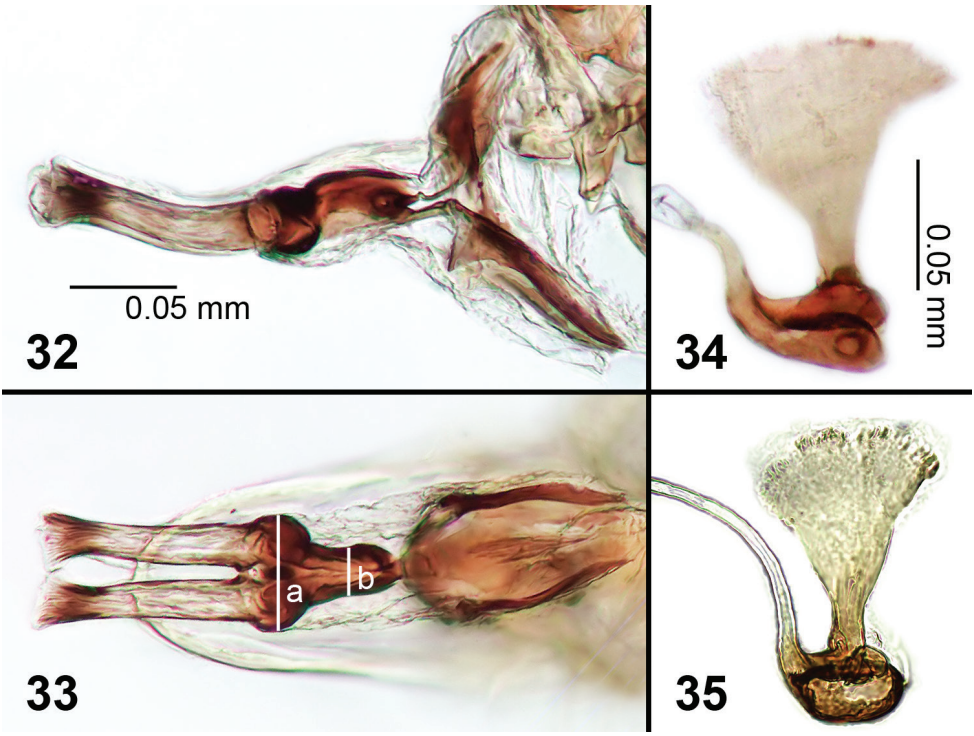
Paratype. same data as holotype (2 ♀: LEM); same except: ex. leaf mine *Bocconia frutescens*, emerged 1.vi.2010, Kenji Nishida (1 ♀: LEM); same except larva exited 29.vi.2010, adult emerged 20.vii.2010 (1 ♀: LEM); same except larva exited



Figures 28–31. External morphology of adult *Liriomyza prompta*. **28** Head, lateral **29** Head, lateral (variation of eye colour) **30** Head, dorsal **31** Thorax, dorsal.

29.vi–4.vii.2010, adult emerged 15–24.vii.2010 (7 ♂; 1♀: LEM); same except larva exited 25–28.vi.2010, adult emerged 20–22.vii.2010 (1 ♀: NMNH); same except larva exited 29.vi–4.vii.2010, adult emerged 21–25.vii.2010 (5 ♂; 1 ♀: NMNH); Cartago: Cervantes, 1500 m (09°52'46"N, 083°49'07"W), ex. *Bocconia frutescens*, emerged 11.vi.2010, Kenji Nishida (1 ♂: CNC); San José Province: San Isidro de Coronado, Centro 1420 m (09°58'18"N, 084°00'22"W), ex. *Bocconia frutescens*, adult emerged 11.vi.2010, Kenji Nishida (1 ♀: MZUCR); same except puparia formed 10–12.v.2010, adult emerged 12.vi.2010, Kenji Nishida (1 ♀: MZUCR); same except emerged 10.vi.2010 (1 ♂: INBio); same except pupation 6.vi.2010, emerged 26.vi.2010, Kenji Nishida (1 ♀: INBio); same except collected 15.v.2009, emerged 8.vi.2009, K. Nishida (4 ♂; 6 ♀: MZUCR), same except (1 ♂; 3 ♀: CNC); Puntarenas Prov., Monteverde, Estación Biológica, 1538 m (10°19'09"N, 084°48'32"W), mating on *Bocconia frutescens* leaf, 30.v.2009, Kenji Nishida (1♂; 1♀: INBio).

Diagnosis. This species can be distinguished from other Neotropical species of *Liriomyza* by its completely yellow head and anepisternum, mesonotum almost completely brown to margin of scutellum, usually 3 + 1 dc, legs completely yellow, calypter



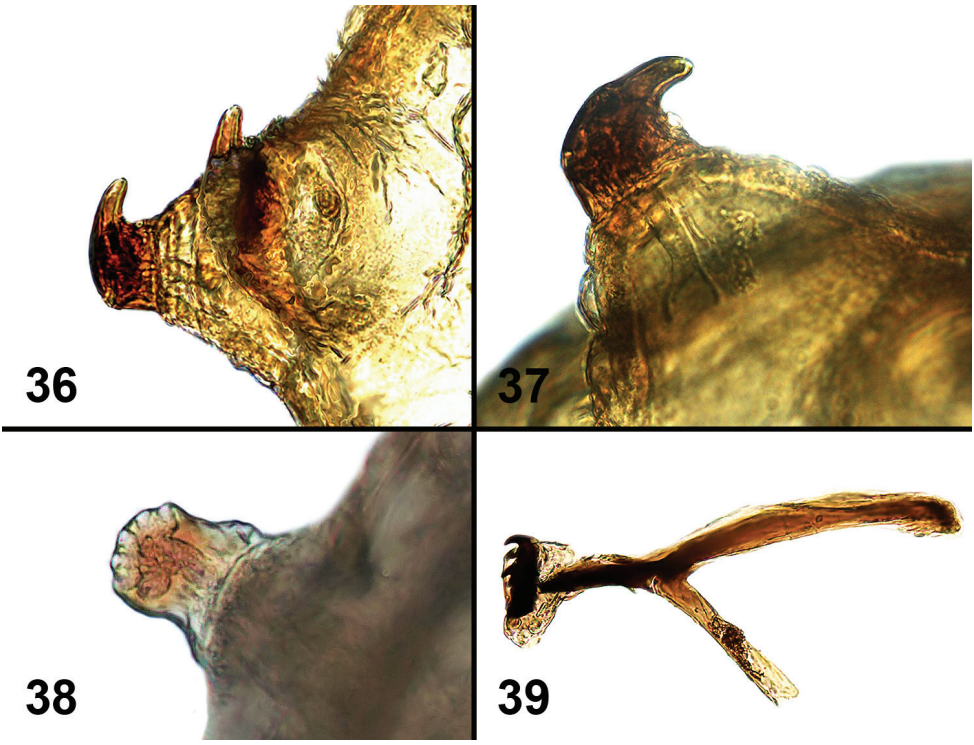
Figures 32–35. Male genitalia of *Liriomyza prompta.* **32** Phallus, lateral **33** Phallus, ventral (see text for lines 'a' and 'b') **34, 35** Ejaculatory apodeme.

brown on apical half with margin and fringe brown, and by the shape of the male genitalia and the shape of the anterior and posterior larval spiracles.

Description. As in *Liriomyza mystica* Boucher and Nishida (described above) except as follows: arista shorter (Figs 28, 29), 0.23–0.3 mm; normally 3+1 dc (except one male specimen with 2+1 dc); generally smaller: wing length 1.4–1.7 mm in males and 1.6–2.2 mm in females; eye often with a more extensive bluish reflection (Fig. 29).

Male genitalia. Similar to *L. mystica*, but tubules of distiphallus more sclerotized, slightly wider, parallel sided (not diverging in ventral view). Mesophallus widest apical section (Fig. 33a), more than twice as large as narrower basal tubular section (Fig. 33b). Mesophallus in lateral view with a prominent curve near midpoint. Surstylus absent. Ejaculatory apodeme (Figs 34, 35) slightly more sclerotized than in *L. mystica*, and with blade slightly less expanded.

Early stages. Larval length: 1.95–2.70 mm, slightly smaller than *L. mystica* larva. White to creamy white with an internal orange spot at head (Fig. 47). Anterior spiracles about 0.1 mm distance from each other. Similar to *L. mystica*: fan-shaped with 5 small openings. Posterior spiracles with apparently 3 bulbs, but two very small and 1 much longer, curving toward anal segment (Figs 36, 37). Cephalopharyngeal skeleton

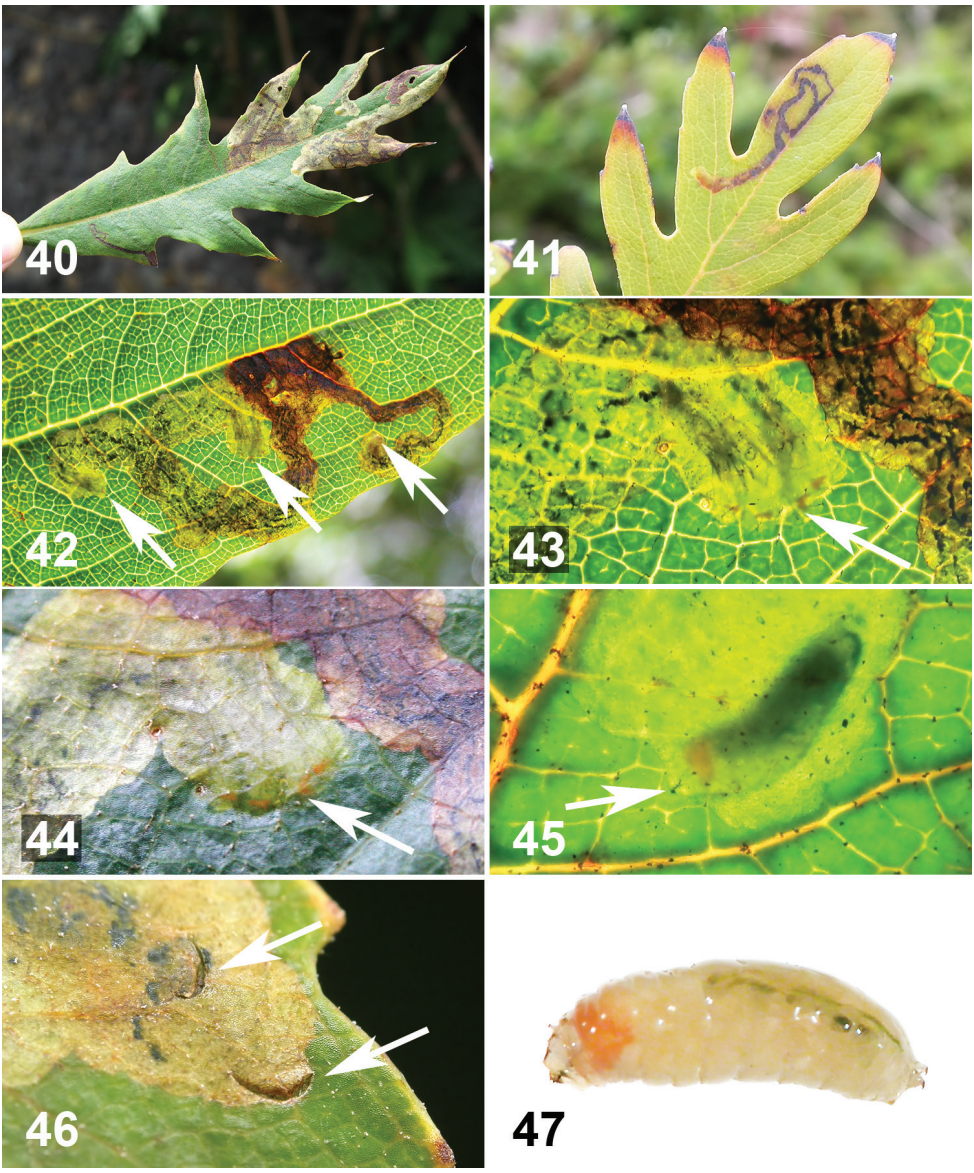


Figures 36–39. Larval characters of *Liriomyza prompta.* **36** Posterior spiracles **37** Posterior spiracle (close-up) **38** Anterior spiracle (note angle of view is different from Fig. **18**) **39** Cephalopharyngeal skeleton.

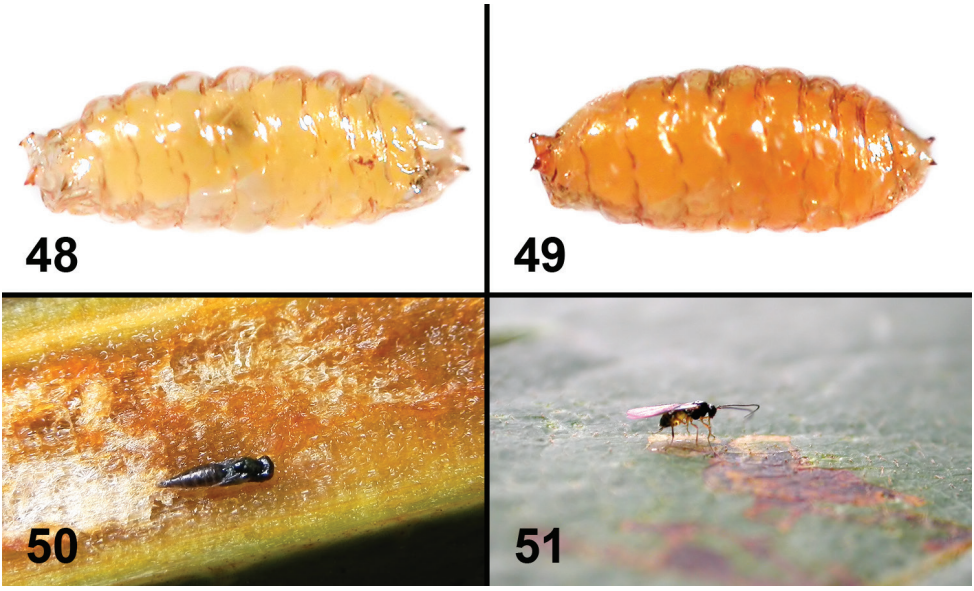
(Fig. 39) more elongated with side arms narrower than in *L. mystica*. Puparium translucent brown to dark brown (Fig. 49).

Host plants. *Bocconia frutescens* L. and *B. arborea* S. Watson (Papaveraceae)

Biology. At site 15 in late October 2012 a few males were perched on small young leaves at the apical shoot of a 2 m host tree in the morning between 6:00 and 7:00 am. The males were either sitting or flying and perching on apical young leaves. A mating couple was observed on the underside of host leaf at 7:00 am (site 13, Fig. 6). Oviposition was observed a few times by two females at site 2. At 3:00 pm (17. vi.2011), overcast with slight drizzle, the two females were walking on the upper side of leaves of a *Bocconia frutescens* sapling, ca. 50 cm tall. The females either oviposited in the leaf tissue at the edge of the leaf margin (n=2) or along narrow leaf veins on the upper side of the leaf blade (n=3) (Fig. 7). It was difficult to locate the eggs because of their small size and translucent colour (n=1). After oviposition, the leaf was collected and a small larva was found on 28.vi.2011. Also at site 5, three leaves were randomly collected on 24.vi.2010, and newly started mines were observed on 2–3.vii.2010 (n=6 mines). These observations suggest that the duration of the egg stage is approximately 10 days. The larvae mine mesophyll of the leaf blade either singly or gregariously (up



Figures 40–47. Life history of *Liriomyza prompta* larva on *Bocconia frutescens* leaves **40** Leaf mines on upperside of mature, but relatively small leaf. Note that there are both single (narrow linear) and gregarious (blotch) mines **41** Active single larval mine at site 17. Note that early part of the mine becomes brown **42** Close-up of active mine with 7 larvae, seen with transmitted light (arrows indicate groups of late instar larvae): 2, 4, and 1 larvae from left to right). Early part of mine brown. Frass in dark green to black linear dots **43** Close-up of middle arrow area of Figure **42**, arrow indicates four actively mining larvae. Notice four orange spots **44** Same as Figure **43**, but without transmitted light **45** Close-up of actively mining late instar larva. Arrow indicates cephalopharyngeal skeleton **46** Exit holes (arrows), approximately 1.2 mm wide, near or at end of mine **47** Mature larva recently exited from mine. Posterior on right.



Figures 48–51. Life history of two new species of *Liriomyza*. **48** Puparium of *Liriomyza mystica*, in situ **49** Puparium of *L. prompta*, in situ **50** Pupa of Pteromaline parasitoid wasp (sp. 01) inside *Bocconia frutescens* leaf vein parenchyma **51** Braconid parasitoid wasp, most likely *Opius* sp., attempting to oviposit in mature *L. prompta* larva at site 13.

to 7 larvae) (n=70 mines) (Figs 40–45). Mines were found on very small mature leaves of ca. 1.5 cm (n=5, at site 13) to 90 cm long (n=10, at site 10). The mature mines with a single larva were narrow and more or less linear (Figs 20, 40, 41), and mines with multiple larvae were blotch-shaped (Figs 40, 42). These mines were conspicuous on the upper side of leaves. With regard to location of mines on leaves, no patterns were noticed; mines appear to occur on any part of the leaf blade — some mines were found near the primary vein, leaf apex, or anywhere in between (uncounted). Presence of the larva in the mine can be recognized by the orange spot of the larval anterior end (Figs 43–45, 47). The early part of the mine becomes brown and the frass is seen in dark green to black linear dots (Figs 42–44). The mature larvae each made an elliptical exit hole 1.1–1.3 mm wide on the upper side of the leaves, (n=7 holes) (Fig. 46). Under rearing conditions, from the time of recognizing very early mines, the larvae completed mining within 3 to 4 days, and on the 5th day the puparia were usually formed on the plastic surface of rearing bags or containers. Young pupae were observed within a day or two after forming of the puparium (n=16). The puparia (Fig. 48) were less translucent than those of *L. mystica*. The pupa becomes dark 2–3 days prior to adult emergence. A cohort of larvae from site 5 which pupated on 20–23.xii.2008 emerged as adults on 16–20.i.2009 (n=6, 1 ♂, 5 ♀), other data as follows: pupation 28.vi.2011, adult emergence 24.vii.2011 (a cohort, n=4, 2 ♂, 2 ♀, site 2); pupation 12–13.ii.2012, emergence 8.ii.2012 (n=2, site 12); pupation 20.iv.2012, emergence

14.v.2012 (n=2, site 15); i.e. the pupal stage lasted nearly a month under the rearing conditions. A small population of *Bocconia arborea* was found at site 9; however, it was only possible to access two saplings, which were about 1 meter tall and infested by *L. prompta* larvae (mostly old mines). Also at sites 7, 9 and 15, populations of weedy Papaveraceae, *Argemone mexicana* L. were found in close proximity to *B. frutescens* and *B. arborea*; however, no leaf mines of *L. prompta* were observed.

Parasitoids. Three species of Eulophidae: Entedoninae: sp. 01 and sp. 02 from sites 5, 6, 13, and 15, Entedoninae sp. 03 from site 15, all these were parasitizing larva and pupating inside the host puparium; Eulophinae: sp. 01 from sites 13 and 15, parasitizing late instar larva, pupating inside the host leaf mine; and two species of Pteromalinae as mentioned in *Liriomyza mystica*, sp. 01 from site 5 and 15, and sp. 02 from site 13 and 15. A species of Braconidae, probably an Opiinae: *Opius* sp. was observed parasitizing a mature *L. prompta* larva at site 13 (Fig. 51).

Comments. An important character differentiating larvae of this species from *L. mystica* described above, is that the posterior spiracles each have an elongated, somewhat hook-like bulb. These posterior spiracles are similar to those found in the Neotropical species *L. commelinae* and *L. robustae*, but the uniformly coloured mesothorax, absence of surstyli, and unforked anterior spiracles, differentiate this new species from these other Neotropical species. This species appears to be more common than *L. mystica* with a wider elevation range (Table 1).

Etymology. The species name is derived from the Latin *promptus* (visible, apparent), referring to their conspicuous and common leaf mines.

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