



Morphological phylogenetic analyses and taxonomic revision of the *Panorpa davidi* group (Mecoptera: Panorpidae)

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Abstract

The Chinese *Panorpa* species without anal horn are normally assigned to the *Panorpa davidi* group. Here, we taxonomically revise the *P. davidi* group, which currently includes 17 known species and four new species: *P. gaokaii* sp. nov., *P. huayuani* sp. nov., *P. uncinata* sp. nov. and *P. yaoluopingensis* sp. nov. *Panorpa shanyangensis* Chou & Wang, 1981 and *P. sexspinosa zhongnanensis* Chou & Ran, 1981 are treated as junior synonyms of *P. sexspinosa* Cheng, 1949. We describe for the first time the male of *P. stigmosa* Zhou, 2006, and the females of *P. curva* Carpenter, 1938, *P. davidi* Navás, 1908, *P. difficilis* Carpenter, 1938, *P. fructa* Cheng, 1949, and *P. jinchuana* Hua, Sun & Li, 2001. A key to species of the group is provided. Phylogenetic analyses of maximum parsimony and maximum likelihood based on 79 morphological characters show that the newly defined *P. davidi* group is a well-supported monophyletic group and is sister to the genus *Cerapanorpa* Gao, Ma & Hua, 2016.

Key words

Oriental Region, *Panorpa*, phylogeny, synonym, taxonomy

Introduction

Panorpidae, the largest family of Mecoptera, consist of approximately 500 extant species in eight genera (Gao and Hua 2019; Wang et al. 2019; Hu and Hua 2020). The genus *Panorpa* Linnaeus, 1758 is the largest taxon in Panorpidae, comprising approximately 270 extant species widely distributed in Asia, Europe, and North America (Esben-Petersen 1921; Wang et al. 2019). *Panorpa* has been confirmed to be paraphyletic based on molecular data (Whiting 2002; Hu et al. 2015; Miao et al. 2019) and morphological characters (Willmann 1989; Ma et al.

2012; Wang and Hua 2020), and needs continued taxonomic revision.

The species of *Panorpa* are divided into various species groups for local faunas based on different morphological criteria (Esben-Petersen 1921; Carpenter 1931, 1938; Issiki 1933; Cheng 1957; Willmann 1977; Byers 1993). The European species are divided into three groups (Willmann 1977). The North American species are categorized into three (Carpenter 1931) or four groups (Byers 1993). The Japanese-East Asiatic species are cat-

egorized into four (Esben-Petersen 1921) or nine groups (Issiki 1933). Based on the number of anal horns on the posterior margin of tergum VI in males, the Chinese fauna is assigned to three species groups: the *P. davidi* group (without anal horn), the *P. centralis* group (with a single anal horn), and the *P. diceras* group (with two anal horns) (Carpenter 1938; Cheng 1957). The *P. diceras* and *P. centralis* groups have been raised to generic status as *Dicerapanorpa* Zhong & Hua, 2013 and *Cerapanorpa* Gao, Ma & Hua, 2016, respectively. Another genus, *Sinopanorpa* Cai & Hua, 2008 is established for *P. tinctoria* Navás, 1931 and related species, former members of the *P. davidi* group (Cai et al. 2008).

The *P. davidi* group is considerably diverse in morphology (Ma et al. 2009, 2011, 2012; Jiang et al. 2019; Miao et al. 2019). Their eggs differ mainly in the ridges of the extrachorion, protuberances within the cells and arranged pattern of the pole area (Ma et al. 2009). Male salivary glands are varied markedly in the number and shape of secretory tubes (Ma et al. 2011). The female genitalia vary distinctly in the developed degree of the main plate and axis; the relative length of the main plate and posterior arm; and the number, shape and position of the basal plates among species (Ma et al. 2012). The first-instar larvae exhibit prominent differences in chaetotaxy on the head and body (Cai and Hua 2009; Jiang and Hua 2013, 2016; Jiang et al. 2019). Morphological and molecular phylogenetic analyses suggest that the *P. davidi* group is paraphyletic (Ma et al. 2012; Hu et al. 2015; Miao et al. 2019). Therefore, a taxonomic revision is urgently needed.

In this study, we present a taxonomic revision of the *P. davidi* group, propose two new synonyms and describe for the first time the male of one species and females of five species. Four species are described as new to science. A key to species of the *P. davidi* group is provided. Phylogenetic analyses of the *P. davidi* group were conducted using maximum parsimony and maximum likelihood based on morphological characters.

Material and methods

Taxonomy

More than 1000 adult specimens in the *P. davidi* group were examined. The specimens are mainly stored in the Entomological Museum, Northwest A&F University, China (NWAU), except *P. jinchuana* Hua, Sun & Li, 2001 in the Tianjin Natural History Museum, China (TJNH). Specimens were dissected under a Nikon SMZ 1500 Stereoscopic Zoom microscope. Wings were measured with a vernier caliper. Male aedeagal complex and female medigynia were macerated in cold 5% NaOH for 5 min. Pictures of adult habitus were taken with a Canon EOS 70D digital camera, and pictures of dissections were taken using an advanced Stereo Microscope System (Discovery V20, Zeiss; an auto-montage imaging system

Axio ICc5). Photographs were assembled and annotated with Adobe Photoshop CS6. Detailed illustrations are provided for new species, known species whose male or female are described for the first time, and *P. sexspinosa* with new synonyms.

Terminology follows Willmann (1989) and Wang and Hua (2020). The following acronyms are used in the main text: **A1** –abdominal segment I (and so forth for other segments); **T1** –tergum I (and so forth for other terga); **FL** – forewing length; **FW** – forewing width; **HL** – hindwing length; **HW** – hindwing width. The following abbreviations are used in figures: **ax** – axis; **bst** – basal stalk; **ce** – cercus; **dp** – dorsal process; **dv** – dorsal valve; **ep** – epandrium; **gex** – gonocoxite; **gs** – gonostylus; **hv** – hypovalve; **lbp** – lateral basal plate; **lp** – lateral process; **mp** – main plate; **no** – notal organ; **pa** – posterior arm; **pm** – paramere; **pno** – postnotal organ; **sgp** – subgenital plate; **stp** – stalk of paramere; **vv** – ventral valve.

Phylogenetic analyses

Phylogenetic trees were reconstructed using maximum parsimony (MP) and maximum likelihood (ML). A total of 38 species were selected for character coding and phylogenetic analyses, including 21 species of the *P. davidi* group, five species of other Chinese *Panorpa* without anal horn, *P. communis* Linnaeus, 1758 (the type species of *Panorpa*) and its closely related species *P. sibirica* Esben-Petersen, 1915, ten species of other genera of Panorpididae. *Panorpodes kuandianensis* Zhong, Zhang & Hua, 2011 in Panorpididae was selected as outgroup. A data matrix containing 79 characters coded for 39 taxa was created using Mesquite v. 3.61 (Tables S1–S2) (Maddison and Maddison 2019).

All characters were equally weighted. Traditional search with 100 replications was conducted with TNT 1.1 (Goloboff et al. 2008). Bremer support values (BR) (Bremer 1994) and bootstrap support (MPBS) values (Felsenstein 1985) were calculated with TNT. The unambiguous characters were mapped on the most parsimonious tree and the strict consensus tree using WinClada version 1.00.08 (Nixon 2002). The ML analysis was performed with IQ-TREE (Nguyen et al. 2015) under Ultrafast bootstrap. Bootstrap support (MLBS) values were evaluated with 5000 replicates.

Results

Panorpa davidi group Esben-Petersen, 1921

Panorpa davidi group Esben-Petersen, 1921: 14; Carpenter, 1938: 268; Cheng, 1957: 5.

Emended diagnosis. The *Panorpa davidi* group can be differentiated from other groups of *Panorpa* by the following features: in males, (1) flat notal organ on posterior

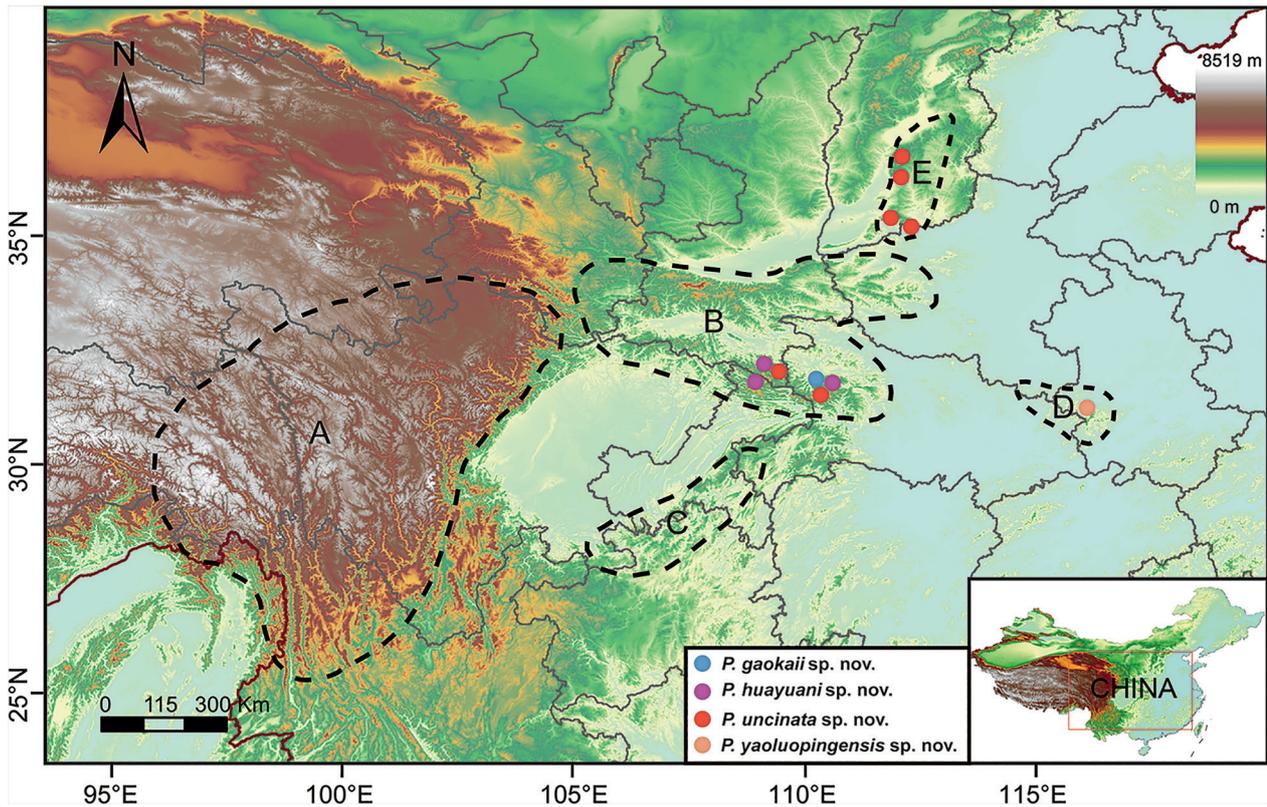


Figure 1. Main distribution range of the *Panorpa davidi* group. A. Hengduan Mountains. B. Qinling-Bashan Mountains. C. Dalou Mountains. D. Dabie Mountains. E. Taihang Mountains.

margin of T3 covering acute postnotal organ on anterior portion of T4; (2) A6 cylindrical, lacking anal horns, mostly projected and setose on dorsal apex; (3) gonostylus with obtuse triangular median tooth and large basal cup on inner margin, (4) elongated dorsal valves of aedeagus with enlarged dorsal processes; and (5) parameres simple, unfurcated, elongated, mostly twisted and crossed mesally; in females, (6) medigynium elongated, broad, with posterior arms distinctly shorter than main plate; and (7) paired lateral basal plates mostly well-developed.

Distribution. Species of the *P. davidi* group are distributed in the mountainous regions of China, mainly in the Hengduan, Qinling-Bashan, Dalou, Dabie and Taihang mountains (Fig. 1).

Remarks. The *P. davidi* group was proposed by Esben-Petersen (1921) to contain *P. sibirica* and *P. davidi*. Martynova (1957) later transferred *P. sibirica* to the *P. communis* group. According to Carpenter (1938) and Cheng (1957), this species group consisted of 19 Chinese species of *Panorpa* without anal horn on the posterior margin of T6 in males. Of these, *Panorpa tincta* Navás, 1931 was transferred to *Sinopanorpa* (Cai et al. 2008), and 12 species that differ remarkably from *P. davidi* are herein removed from this group. In this paper, 21 species are recognized in the newly defined *P. davidi* group, including 17 known species and four new species.

Key to species of the *Panorpa davidi* group (males)

- 1. Pleura blackish brown to black2
- Pleura yellowish to yellowish brown3
- 2. Forewings with apical band splitting into a series of small spots; pterostigmal band complete anteriorly, with discrete basal branch and faint apical branch posteriorly; basal band split into two spots; marginal spot prominent; basal spot greatly reduced (Figs 10B, 11A) *P. fructa* Cheng, 1949
- Forewings with pterostigmal band usually reduced, basal and apical branches absent; apical band indistinct and extremely reduced (Fig. 8B) *P. diqingensis* Li & Hua, 2020
- 3. Meso- and metanotum black brown to black4
- Meso- and metanotum black with yellow mesal stripe or mostly yellow, only darker laterally6
- 4. Wings without markings *P. curvata* Zhou, 2006
- Wings with reduced markings5
- 5. Gonocoxites bearing 3–5 long setae, with acute protuberance on inner apex (Fig. 21G) ... *P. stigmosa* Zhou, 2006

- Gonocoxites with cluster of stout dark brown setae and 3–5 long setae along oblique inner apex ventrally; without acute protuberance (Fig. 9B).....*P. dispersgens* Li & Hua, 2020
- 6. Wing with 1A ending before or at level of origin of Rs.....7
 - Wing with 1A ending beyond origin of Rs9
- 7. Wing with 1A ending before origin of Rs (Fig. 2C) *P. bashanicola* Hua, Tao & Hua, 2018
 - Wing with 1A ending at level of origin of Rs8
- 8. Wings tinged with yellow, markings yellowish brown, reduced; parameres stout, extending nearly to apex of gonocoxites (Fig. 12B)..... *P. fulvastra* Chou, 1981
 - Wing membrane hyaline, without markings; parameres slender, intensely curved, reaching middle of aedeagus (Fig. 3B).....*P. chengi* Chou, 1981
- 9. Meso- and metanotum pale brown, with broad pale to pale yellow mesal stripe, extending to T3 (Figs 13B, 14A) *P. gaokaii* sp. nov.
 - Meso- and metanotum blackish brown to black, with yellow mesal stripe only extending to scutellum.....10
- 10. Parameres greatly curved, hook-like on apical half, reaching two-thirds of gonocoxites11
 - Parameres thick, nearly twisted in S-shape, exceeding or reaching apex of gonocoxites12
- 11. Meso- and metanotum with extremely broad yellow mesal stripe; basal spot large and conspicuous.....
 - Meso- and metanotum with narrow yellow mesal stripe; basal spots extremely reduced and faint (Fig. 22A).....*P. uncinata* sp. nov.
- 12. Gonocoxites with process on inner margin of ventral apex.....13
 - Gonocoxites without process on inner margin of ventral apex.....15
- 13. Gonocoxites with normal triangular process on inner apex, bearing 1 or 2 long setae on inner margin subapically *P. qinlingensis* Chou & Ran, 1981
 - Gonocoxites with elongated process on inner apex, bearing short setae14
- 14. Forewings with basal band split into two large spots; basal spot reduced (Fig. 5A).....*P. davidi* Navás, 1908
 - Forewings with basal band complete; basal spot absent (Fig. 4A).....*P. curva* Carpenter, 1938
- 15. Forewing with basal band reduced into middle spot, extending from M to anal margin (Fig. 23A)
 - Forewing with broad basal band complete or split into two spots.....16
- 16. Dorsal valves of aedeagus slender and stalked, each with intensively enlarged circular dorsal process on apical portion (Fig. 7G)*P. difficilis* Carpenter, 1938
 - Dorsal process of aedeagus not extending to apical portion of dorsal valves.....17
- 17. Forewing with basal band split into two spots18
 - Forewing with basal band complete.....19
- 18. Hypovalves slightly broadened towards rounded apexes *P. typicooides* Cheng, 1949
 - Hypovalves with apical third widest, then tapered towards apex (Fig. 17E)..... *P. jinchuana* Hua, Sun & Li, 2001
- 19. Forewings without basal spot (Figs 18B, 19A) *P. sexspinosa* Cheng, 1949
 - Forewings with basal spot.....20
- 20. Gonocoxites bearing 4–5 setae on inner apex ventrally, with triangular emarginated subapical portion (Fig. 16G) *P. huayuani* sp. nov.
 - Gonocoxites bearing 4–7 (usually 6) long setae along beveled inner apex ventrally, without triangular emarginated subapical portion *P. neospinosa* Chou & Wang, 1981

Taxonomy

Panorpa bashanicola Hua, Tao & Hua, 2018

Fig. 2

Panorpa bashanicola Hua, Tao & Hua, 2018: 111, figs 1–6. Type locality: Nangongshan, Bashan Mountains, Lan'gao County, Shaanxi, China.

Diagnosis. This species can be recognized by the following features: (1) occiput black, with two pale submedian stripes and two eye-shaped speckles on lateral regions;

(2) wing membrane hyaline, pterostigma prominent yellow, almost without markings (Fig. 2C–D); (3) 1A ending before origin of Rs (Fig. 2C); (4) meso- and metanotum pale with yellowish brown laterally, and pale color extending to T3 in V-shape (Fig. 2C); in males, (5) inner apex of gonocoxite bearing 3–6 long black bristles; (6) parameres crossed, twisted in S-shape, reaching apex of gonocoxites; in females, (7) medigynium with main plate twice as long as wide; a pair of small lateral basal plates near middle; axis extending beyond main plate one-third its length anteriorly.

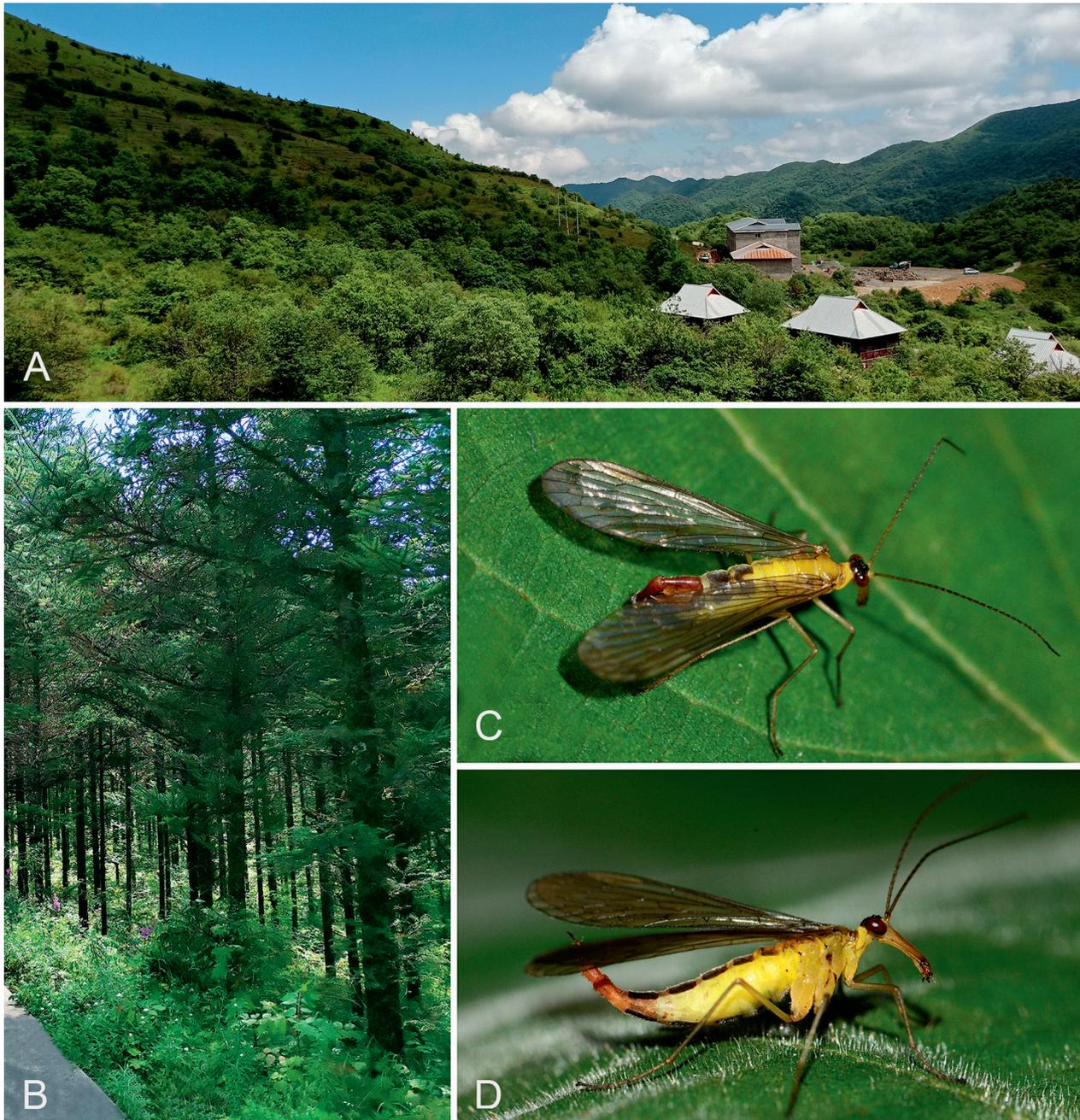


Figure 2. Live adult habitus and habitat of *Panorpa bashanicola* Hua, Tao & Hua, 2018. **A.** Habitat in Huang'anba, Chengkou, Chongqing. **B.** Habitat in Hualongshan, Shaanxi. **C.** Male, dorsal view. **D.** Female, lateral view. Photos by Kai Gao (A, C, and D) and by Le-Le He (B).

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype); Lan'gao, Nangongshan; 1200–2025 m a.s.l.; 24–25 Jun. 2007; Bao-Zhen Hua & Jiang-Li Tan leg. • 26♂♂, 22♀♀ (Paratypes); same data as holotype • 8♂♂, 9♀♀; Hualongshan; 2200 m a.s.l.; 24 Jun. 2018; Kai Gao & Yuan Hua leg. – Chongqing • 8♂♂, 9♀♀; Chengkou, Shentian Alpine Shrub Meadow; 2400–2500 m a.s.l.; 22 Jun. 2018; Kai Gao, Yuan Hua & Yu-Ru Yang leg. • 11♂♂, 7♀♀; Huang'anba Alpine Shrub Meadow; 2400 m a.s.l.; 22 Jun. 2018; Kai Gao, Yuan Hua, & Yu-Ru Yang leg. – Hubei Prov. • 2♂♂; Shennongjia, Hongping; 28 Jun. 2007; Bao-Zhen Hua & Jiang-Li Tan leg. • 1♂, 8♀♀; Yanziya; 1950 m a.s.l.; 30 Jun. 2018; Kai Gao leg. • 3♂♂, 4♀♀; Hongping Airport; 2150 m a.s.l.; 30 Jun. 2018; Kai Gao & Yu-Ru Yang leg.

Measurements. Male: FL = 11.1–12.1 mm, FW = 2.8–3.0 mm; HL = 10.0–11.1 mm, HW = 2.7–2.9 mm. Female: FL = 11.2–12.6 mm, FW = 2.8–3.1 mm; HL = 10.2–11.6 mm, HW = 2.7–3.0 mm.

Distribution. China: Chongqing, Hubei, Shaanxi.

Remarks. This species resembles *P. chengi* in appearance, but can be differentiated from the latter by vein 1A ending before (cf. at) the origin of Rs.

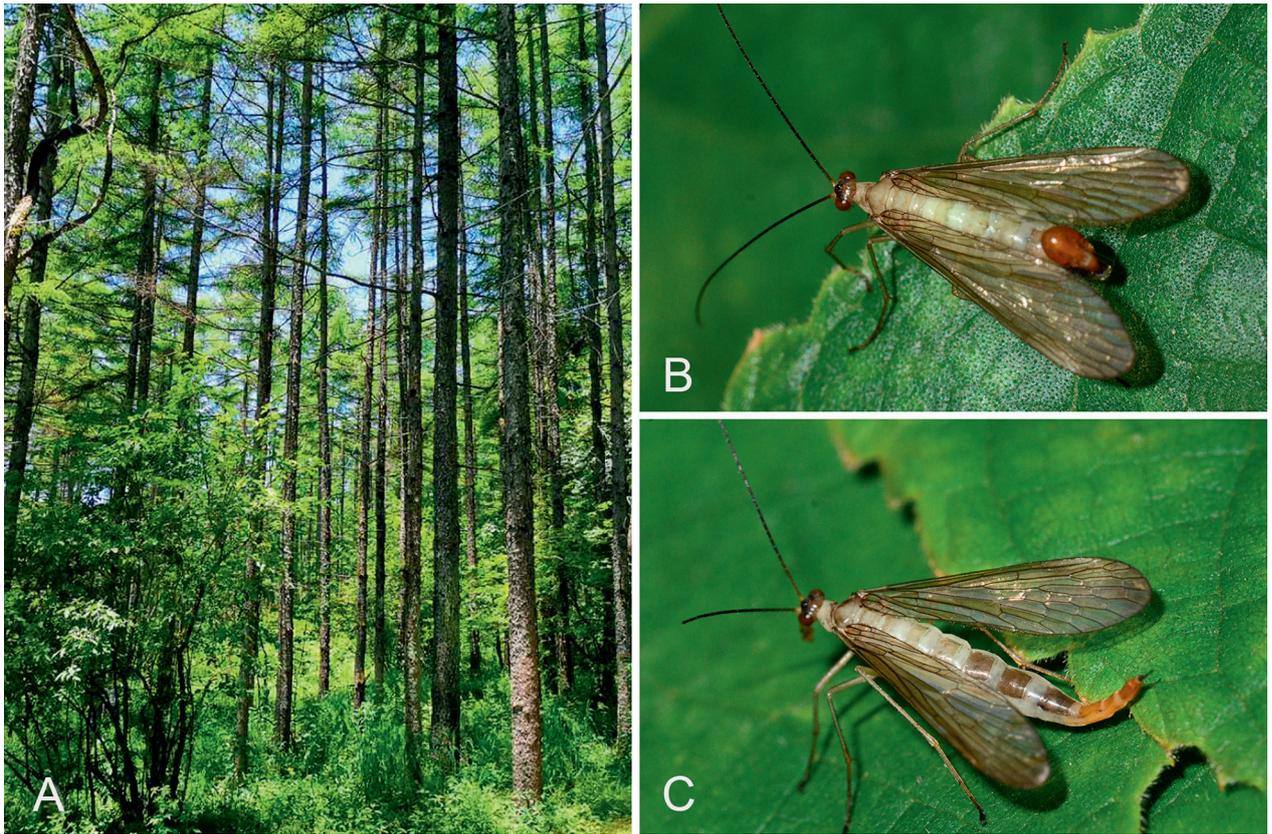


Figure 3. Live adult habitus and habitat of *Panorpa chengi* Chou, 1981. **A.** Habitat in Huoditang, Ningshan, Shaanxi. **B.** Male, dorsal view. **C.** Female, dorsal view. Photos by Xin Tong (A) and by Kai Gao (B–C).

Panorpa chengi Chou, 1981

Fig. 3

Panorpa chengi Chou in Chou et al., 1981: 16, figs 63–64. Type locality: Qinling, Shaanxi, China; Wang & Hua, 2018: 315, figs 5-109-1–5-109-2.

Diagnosis. This species can be readily recognized by the following characters: (1) wings devoid of markings, pterostigma faint (Fig. 3B–C); (2) vein 1A ending at level of origin of Rs; (Fig. 3B–C) (3) pro-, meso-, and metanotum yellowish, darkened laterally (Fig. 3B–C); in males, (4) gonostylus with broad row of stout setae on inner margin; (5) gonocoxites bearing 4–6 short setae along beveled inner apex ventrally, with small protuberance below setae; (6) parameres slender, intensely curved, reaching half length of aedeagus; in females, (7) medigynium with main plate oblong; axis extending beyond main plate more than half its length anteriorly; lateral basal plates absent.

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype); Qinling; 13 Jul. 1951; Io Chou leg. • 1♀; Huashan; 30 Aug. 1983; Xiao-Lin Lu leg. • 1♂; Zhouzhi, Taibaishan, Tiejia shu; 1770 m a.s.l.; 17 Jul. 2002; Xiao-Ni Nie & Wu Dai leg. • 35♂♂, 32♀♀; Ningshan, Huoditang; 5 May–13 Jul. 2019; Xin Tong & Peng-Yang Wang leg. • 2♂♂, 2♀♀; Zhuque National Forest Park; 2000 m a.s.l.; 23 Aug. 2008; Bao-Zhen Hua & Qiang Fu leg. • 9♂♂, 12♀♀; Hanyin, Fenghuangshan, Leigutai; 1800 m a.s.l.; 27 Jun. 2018; Kai Gao leg.

Measurements. Male: FL = 11.3–12.6 mm, FW = 2.9–3.2 mm; HL = 10.3–11.6 mm, HW = 2.8–3.1 mm. Female: FL = 11.6–13.1 mm, FW = 3.1–3.3 mm; HL = 10.8–12.0 mm, HW = 2.8–3.3 mm.

Distribution. China: Shaanxi.

Remarks. This species can be readily identified from other members of the *P. davidi* group by the gonostylus with a broad row of stout setae on inner margin.

Panorpa curva Carpenter, 1938

Fig. 4

Panorpa curva Carpenter, 1938: 269, figs 1 & 8. Type locality: “O-er, 26 miles of Li Fan” [now Lixian], “Szechwan” [now Sichuan], China; Cheng, 1957: 43, figs 52–53; Wang & Hua, 2018: 323, figs 5-113-1–5-113-2.

Diagnosis. This species can be readily recognized by the following characters: (1) forewing apical band broad, with small hyaline spot posteriorly; pterostigmal band with basal branch broad and apical branch mostly absent; basal band complete, broad; marginal and basal spots absent (Fig. 4A–B); (2) meso- and metanotum black, with prominent pale yellow mesal stripe (Fig. 4A–B); in males, (3) gonocoxites with elongated process, bearing short stout setae on inner margin (Fig. 4E); (4) parameres

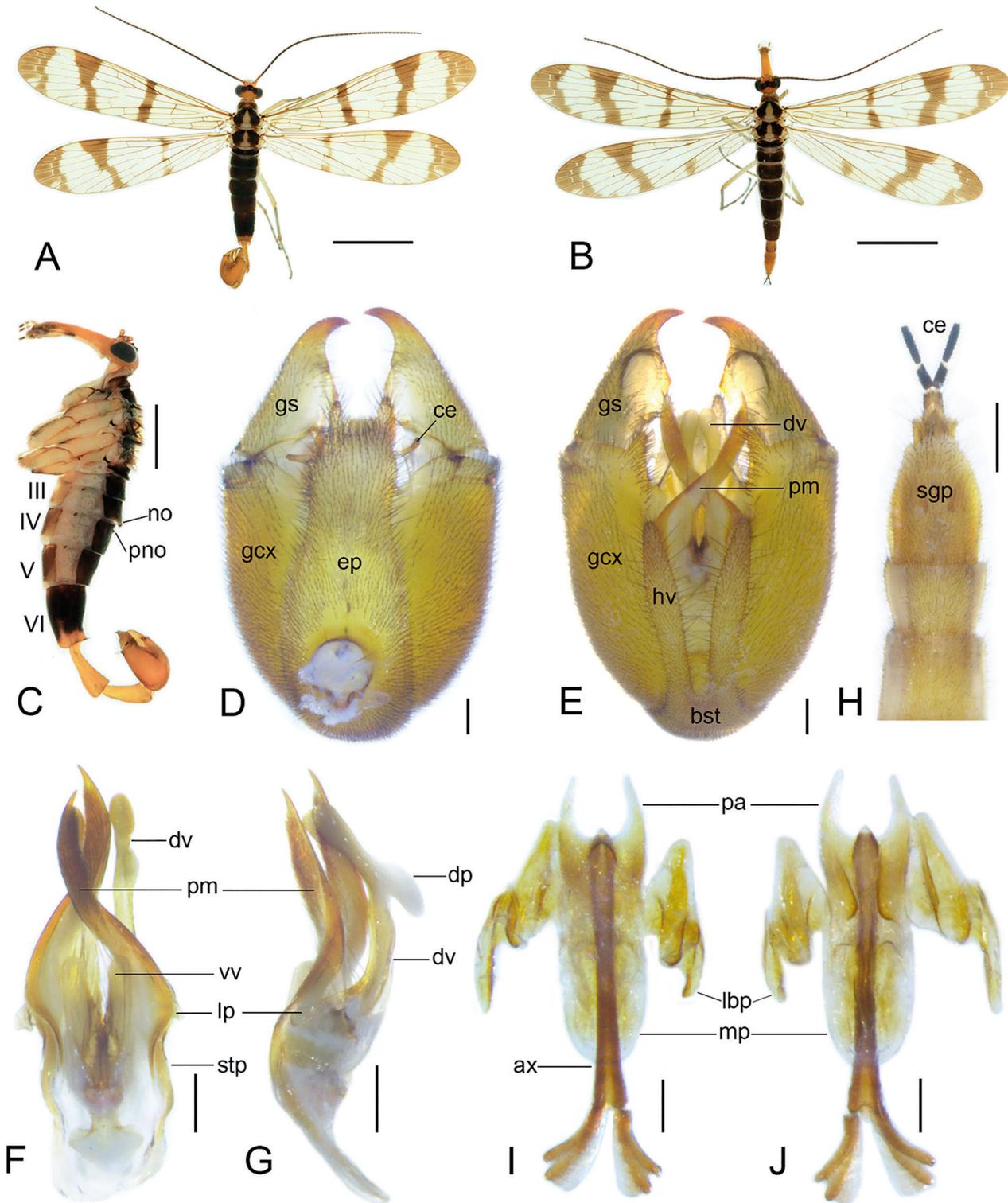


Figure 4. *Panorpa curva* Carpenter, 1938 from Wolong, Sichuan. **A, C–G.** Male. **A.** Habitus, dorsal view. **C.** Habitus, lateral view. **D–E.** Genital bulb, dorsal and ventral views. **F–G.** Aedeagal complex, ventral and lateral views. **B, H–J.** Female. **B.** Habitus, dorsal view. **H.** Terminalia, ventral view. **I–J.** Medigynium, dorsal and ventral views. Scale bars: A–B = 5 mm; C = 2 mm; D–G, I–J = 0.2 mm; H = 0.5 mm.

elongate, crossed mesally, and twisted in S-shape (Fig. 4F); and in females; (5) medigynium with main plate rectangular, three times as long as wide, with pair of large lateral basal plates near middle portion; axis extending beyond main plate for two-fifths its length anteriorly (Fig. 4I–J).

Material examined. CHINA – Sichuan Prov. • 6♂♂, 7♀♀; Wolong; 31°02'12"N, 103°12'35"E; 1940–2060 m a.s.l.; 9–10 Aug. 2018; Ning Li, Lu Liu & Lu-Yao Yang leg. • 5♂♂, 7♀♀; Pingwu, Laohegou; 1800 m a.s.l.; 25 May 2018; Kai Gao leg. • 1♂; Heishui, Dagubingchuan; 2700 m a.s.l.; 6 Jun. 2019; Kai Gao leg. • 1♂; Lixian, Bipenggou; 2600 m a.s.l.; 6 Jun. 2019; Kai Gao leg. – Shaanxi Prov. • 1♀; Baoji, Fengx-

ian, Tiantaishan Forest Park; 1 Jun. 2015; Ji-Shen Wang & Lu Jiang leg. • 1♂, 1♀; Baoji, Fengxian, Tongtianhe Forest Park; 34°11'03"N, 106°40'15"E; 10 Jun. 2015; Lu Jiang leg. • 15♂♂, 21♀♀; Ningshan, Huoditang; 5 May–13 Jul. 2019; Xin Tong & Peng-Yang Wang leg.

Measurements. Male: FL = 11.4–13.9 mm, FW = 2.9–3.5 mm; HL = 10.3–12.0 mm, HW = 2.7–3.2 mm. Female: FL = 11.3–14.1 mm, FW = 3.0–3.6 mm; HL = 10.3–12.1 mm, HW = 2.9–3.3 mm.

Description. Female: Head (Fig. 4B): Frons, vertex, and occiput yellowish brown. Black transverse band passing through ocellar triangle, extending to inner margins of compound eyes. Rostrum yellow, slender, with labrum dark brown. Maxillary and labial palps mostly pale brown, with distal segments dark brown. Antennal scape yellowish brown; pedicel dark yellowish brown; flagellum blackish brown, filiform. **Thorax** (Fig. 4B): Pronotum black, with 12–16 setae along anterior margin. Meso- and metanotum black, with pale yellow mesal stripe; scutella totally pale yellow. Pleura yellowish; legs yellowish brown, with distal tarsomere blackish. **Wings** (Fig. 4B): Wing membrane hyaline, with black brown markings. In forewing, broad apical band with small hyaline spot posteriorly; pterostigmal band with broad basal branch, apical branch absent; broad basal band complete; marginal and basal spots almost absent. Hindwing similar to forewing, with relatively reduced markings; basal band usually narrower and incomplete. **Abdomen** (Fig. 4B): T2–T6 black. A7–A10 brown. **Genitalia** (Fig. 4H–J): Subgenital plate ligulate, with V-shaped distal emargination, bearing long setae on distal quarter. Medigynium with rectangular main plate, three times as long as wide; pair of large wing-like lateral basal plates near middle portion; paired posterior arms forming broad U-shaped emargination; axis slightly extruded posteriorly, extending beyond main plate for two-fifths of its length anteriorly.

Distribution. China: Shaanxi, Sichuan.

Remarks. This species resembles *P. davidi* in appearance, but can be readily identified by complete basal band (cf. split into two spots) in forewing and elongated process on gonocoxites with the base 1.5 times (cf. twice) as wide as the apex.

Panorpa curvata Zhou, 2006

Panorpa curvata Zhou, 2006: 273, figs 1–3. Type locality: Chishui Suolu National Nature Reserve, Guizhou, China.

Diagnosis. This species can be recognized by the following features: (1) frons, vertex, occiput, and ocellar triangle blackish brown; (2) wing membrane hyaline, without markings; (3) pro-, meso-, and metanotum black; (4) hypovalves slender with rounded apices, almost extending to apex of gonocoxites; (5) row of setae on ventral

apex of gonocoxites; (6) parameres slender, intensively curved, twisted in S-shape.

Female. Unknown.

Measurements. Male: FL = 11 mm, FW = 2 mm; HL = 10 mm, HW = 2 mm.

Distribution. China: Guizhou.

Panorpa davidi Navás, 1908

Fig. 5

Panorpa davidi Navás, 1908: 415, fig. 19. Type locality: “Mou-Pin, Tibet” [now Baoxing, Sichuan], China; Esben-Petersen, 1921: 29, figs 21–23; Cheng, 1957: 25, fig. 57; Rust & Byes, 1976: 84, fig. 156; Wang & Hua, 2018: 325, figs 5-114-1–5-114-2.

Diagnosis. This species can be readily recognized by the following characters: (1) forewing markings well-developed, apical band broad and scattered posteriorly; pterostigmal band with basal branch complete and apical branch separated or absent; basal band split into two spots; basal spot greatly reduced (Fig. 5A–B); (2) meso- and metanotum black, with narrower pale yellow mesal stripe (Fig. 5A–C); in males, (3) gonocoxites with protruding process bearing short black setae on inner apex (Fig. 5E); (4) parameres elongate, crossed mesally, and twisted in S-shape (Fig. 5E); and in females (5) medigynium with main plate oblong, three times as long as wide; axis extending beyond main plate for half its length anteriorly (Fig. 5G).

Material examined. CHINA – Sichuan Prov. • 1♀; Baoxing, Qingyi River Source; 2500 m a.s.l.; 13 Aug. 2018; Ji-Shen Wang leg. • 1♂, 2♀♀, collecting data missing.

Measurements. Male: FL = 13.0 mm, FW = 3.0 mm; HL = 11.5 mm, HW = 2.9 mm. Female: FL = 13.0–14.0 mm, FW = 3.0–3.2 mm; HL = 11.6–12.5 mm, HW = 3.0–3.1 mm.

Description. Female: Head (Fig. 5B–C): Frons yellowish brown, occiput yellowish brown with two black spots laterally. Vertex with broad black transverse stripe passing through ocellar triangle and extending to inner margins of compound eyes. Rostrum yellow, slender. Maxillary and labial palps mostly pale brown, with distal segments black brown. Antennal scape yellowish brown; pedicel dark brown; flagellum black, filiform. **Thorax** (Fig. 5 B–C): Pronotum black, with 12–16 setae along anterior margin. Meso- and metanotum black, with narrower pale yellow mesal stripe; scutella totally pale yellow. Pleura and legs light yellowish brown, with distal tarsomere blackish. **Wings** (Fig. 5B): Wing membrane hyaline, with dark brown markings. In forewing, apical band broad and scattered posteriorly; pterostig-

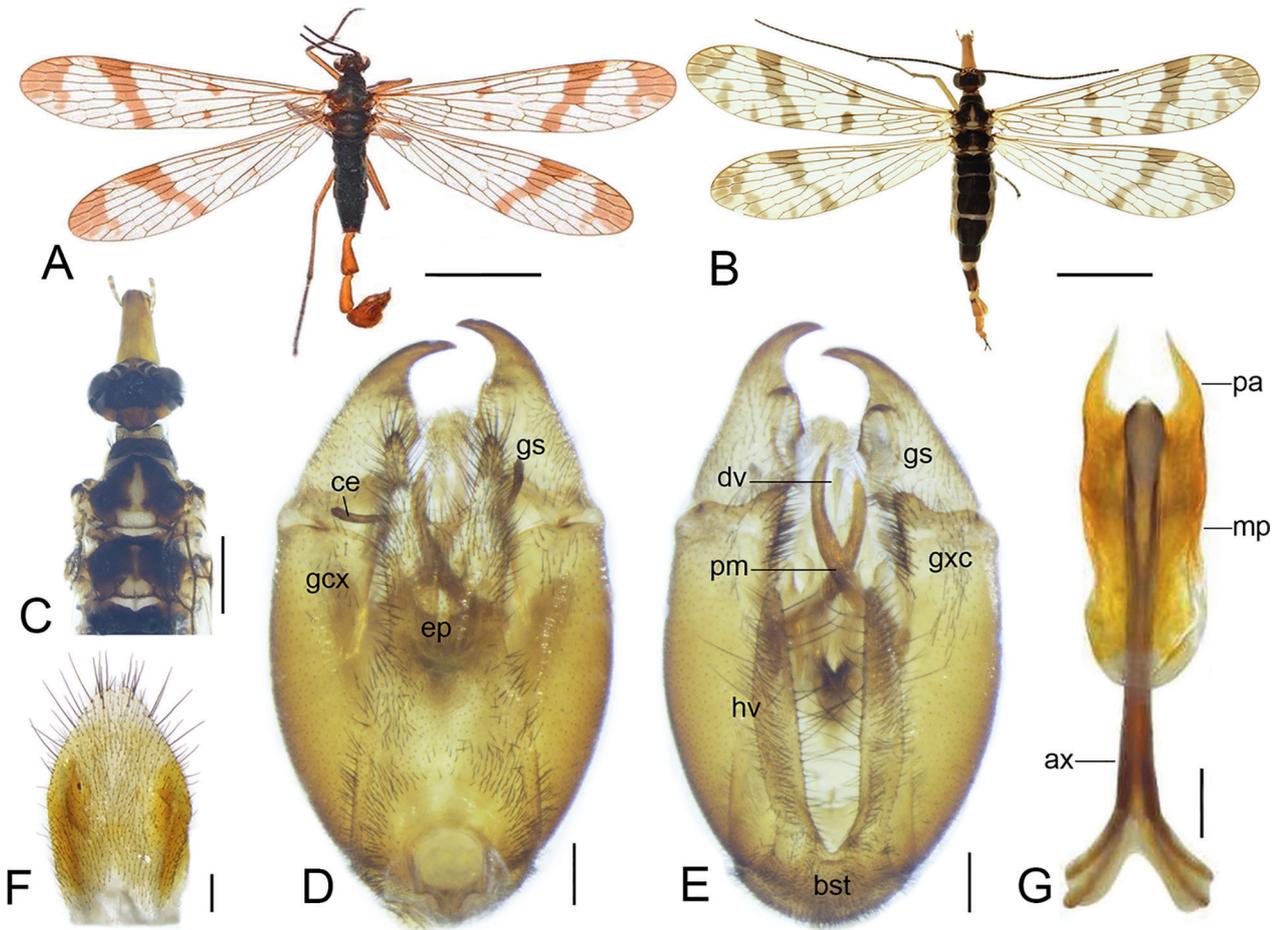


Figure 5. *Panorpa davidi* Navás, 1908 from Baoxing, Sichuan. **A, D–E.** Male. **A.** Habitus, dorsal view. **D–E.** Genital bulb, dorsal and ventral views. **B–C, F–G.** Female. **B.** Habitus, dorsal view. **C.** Dorsum, dorsal view. **F.** Subgenital plate, ventral view. **G.** Medigynium, ventral view. Scale bars: A–B = 5 mm; C = 2 mm; D–G = 0.2 mm.

mal band with broad basal branch, apical branch absent or reduced to small spot posteriorly; marginal spot absent or reduced to small spot; basal band split into two spots; basal spot greatly reduced on base of CuA and CuP. Hindwing similar to forewing, with relatively reduced markings; basal spot absent. **Abdomen** (Fig. 5B): T2–T6 black. A7–A10 brown. **Genitalia** (Fig. 5F–G): Subgenital plate elliptical, with V-shaped distal emargination, bearing long setae on distal part. Medigynium with oblong main plate, three times as long as wide, and lateral margin emarginate at basal one-third; paired posterior arms quarter as long as main plate, forming broad U-shaped emargination; axis slightly extruded posteriorly, extending beyond main plate for half of its length anteriorly.

Distribution. China: Sichuan.

Remarks. Only a single male (holotype) of *P. davidi* from Baoxing, Sichuan was known previously. A female specimen was erroneously treated as *P. davidi* by Navás (1908), but was later designated as the holotype of *P. guttata* Navás, 1908 (Esbén-Petersen 1915). A female of *P. davidi* captured recently from the type locality can be differentiated from that of *P. guttata* by the well-developed

(cf. greatly reduced) wing markings and by meso- and metanotum black (cf. yellowish brown), with a narrower (cf. broad) pale yellow mesal stripe.

Panorpa difficilis Carpenter, 1938

Figs 6–7

Panorpa difficilis Carpenter, 1938: 269, figs 4 & 6. Type locality: “Chengtú, Szechwan” [now Chengdu, Sichuan], China; Cheng, 1957: 29, figs 42 & 46.

Diagnosis. This species can be readily recognized by the following characters: (1) wings with well-developed variable markings (Figs 6A–B, 7A–B); (2) meso- and metanotum black, with prominent pale yellow mesal stripe (Figs 6A–B, 7A–B); in males, (3) gonocoxites with a row of long setae along slightly beveled inner apex (Fig. 7E); (4) parameres crossed subapically, twisted in S-shape (Fig. 7G); (5) dorsal valves slender, stalked, each with an intensively enlarged dorsal process on apical portion dorsally (Fig. 7F–G); and in females, (6) medigynium bearing a pair of auricular lateral basal plates on middle portion (Fig. 7I–J).

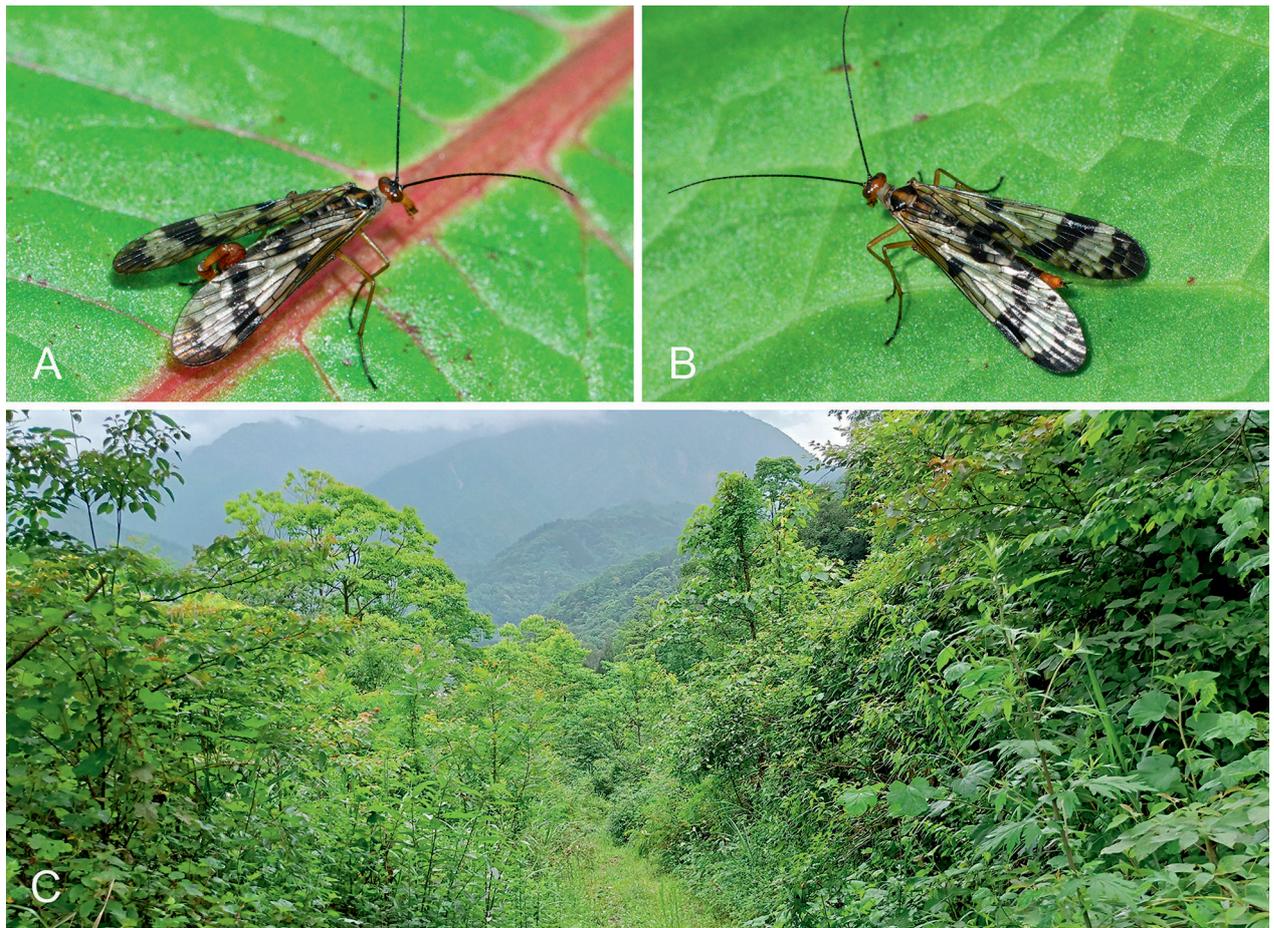


Figure 6. Live adult habitus and habitat of *Panorpa difficilis* Carpenter, 1938. **A.** Male, dorsal view. **B.** Female, dorsal view. **C.** Habitat in Maoxian, Tudiling, Sichuan. Photos by Kai Gao.

Material examined. CHINA – **Chongqing** • 1♀; Beibei, Longfengxi; 27 Oct. 1984; Xin Yue leg.; • 18♂♂, 21♀♀; Beibei, Xiema, Damotan; 230 m a.s.l.; 5 Apr. 2013; Jian-Yue Qiu & Hao Xu leg. – **Shaanxi Prov.** • 2♀♀; Nanzheng, Liping; 32°54′09″N, 106°36′36″E; 1530 m a.s.l.; 11 Jul. 2019; Ying Miao & Yue Pan leg. • 2♂♂; Liping; 2018; Zheng Wei. – **Sichuan Prov.** • 6♂♂, 8♀♀; Maoxian, Tudiling; 2050 m a.s.l.; 31 May 2019; Kai Gao.

Measurements. Male: FL = 10.9–12.8 mm, FW = 2.9–3.1 mm; HL = 10.0–11.8 mm, HW = 2.7–3.0 mm. Female: FL = 11.3–12.9 mm, FW = 2.9–3.2 mm; HL = 10.3–12.1 mm, HW = 2.9–3.1 mm.

Description. Female: Head (Figs 6B, 7B): Frons, vertex, and occiput yellowish brown. Broad black band passing through ocellar triangle to inner margins of compound eyes. Rostrum yellow, slender, with labrum dark brown. Maxillary and labial palps mostly pale brown with distal segments dark brown. Antennal scape dark brown; pedicel blackish brown; flagellum black, filiform. **Thorax** (Figs 6B, 7B): Pronotum black, with 10–16 setae along anterior margin. Meso- and metanotum black, with pale yellow mesal stripe; scutella totally pale yellow. Pleura and legs yellowish brown, with distal tarsomere blackish. **Wings** (Figs 6B, 7B): Wing membrane hyaline, with markings black brown. In forewing, broad

apical band scattered on posterior margin, several small hyaline spots along apical crossveins; pterostigmal band with broad basal branch, apical branch usually detached and thin; marginal spot as one or two small spots; basal band generally split into two large spots, complete in a few individuals; basal spot prominent. Hindwing similar to forewing, with relatively reduced markings; marginal spot usually faint and basal spot absent. **Abdomen** (Figs 6B, 7B): T2–T6 black. A7–A10 yellowish brown. **Genitalia** (Fig. 7H–J): Subgenital plate ligulate, with V-shaped distal emargination, bearing long setae on distal half. Medigynium with broad, long main plate, lateral margin emarginate medially, distal portion broader than base; pair of auricular lateral basal plates on middle part, each basal plate consisting of sclerotized middle structure enclosing very small one; axis slightly extruded posteriorly, extending beyond main plate for half of its length anteriorly.

Distribution. China: Chongqing, Shaanxi, Sichuan.

Remarks. *Panorpa difficilis* was previously known only by the male holotype. A series of male and female specimens were captured recently from Chongqing and Shaanxi. This species should be a bivoltine insect in Chongqing at low elevations.

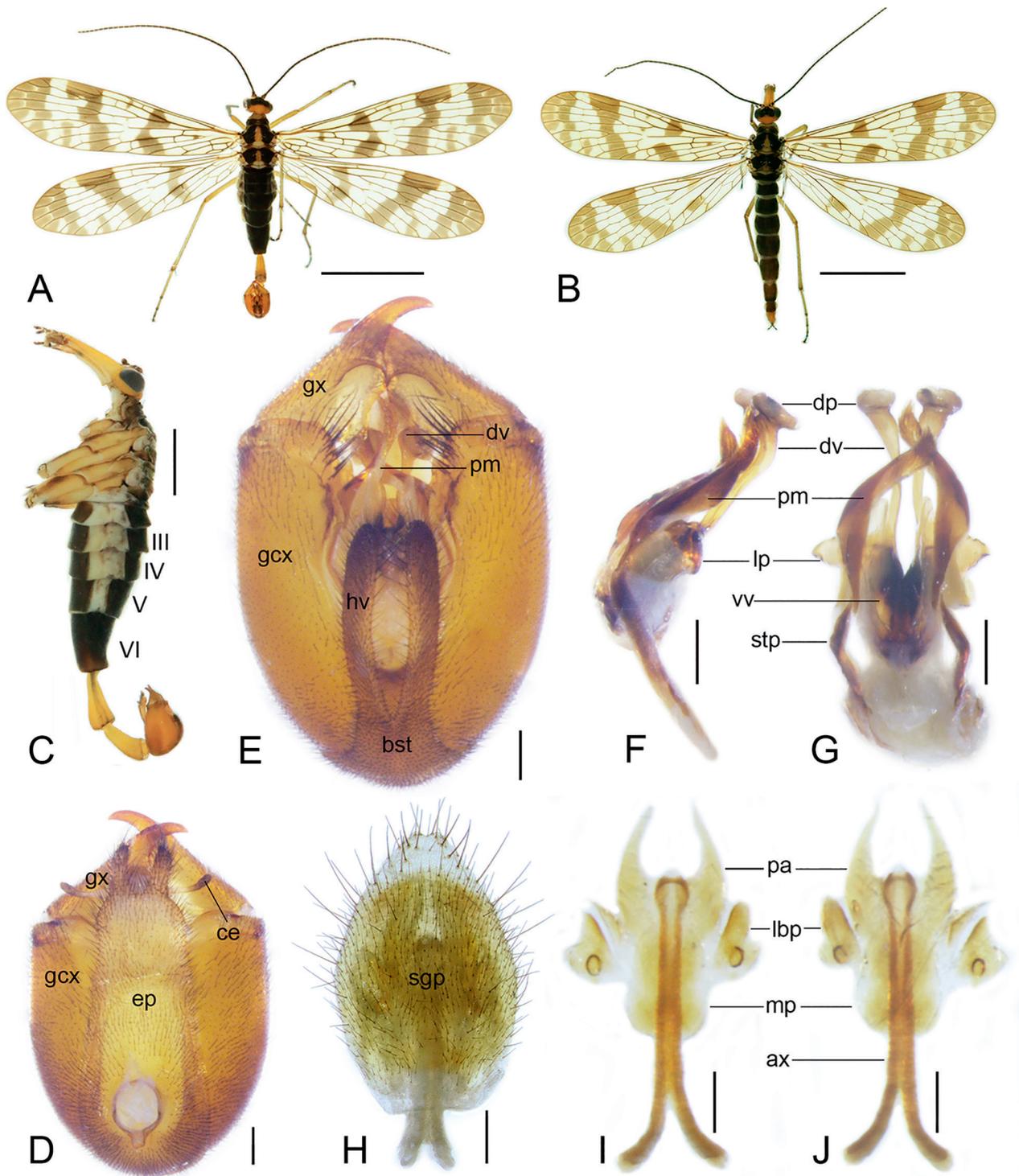


Figure 7. *Panorpa difficilis* Carpenter, 1938 from Maoxian, Sichuan. **A, C–G.** Male. **A.** Habitus, dorsal view. **C.** Habitus, lateral view. **D–E.** Genital bulb, dorsal and ventral views. **F–G.** Aedeagal complex, lateral and ventral views. **B, H–J.** Female. **B.** Habitus, dorsal view. **H.** Subgenital plate, ventral view. **I–J.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C = 2 mm; D–J = 0.2 mm.

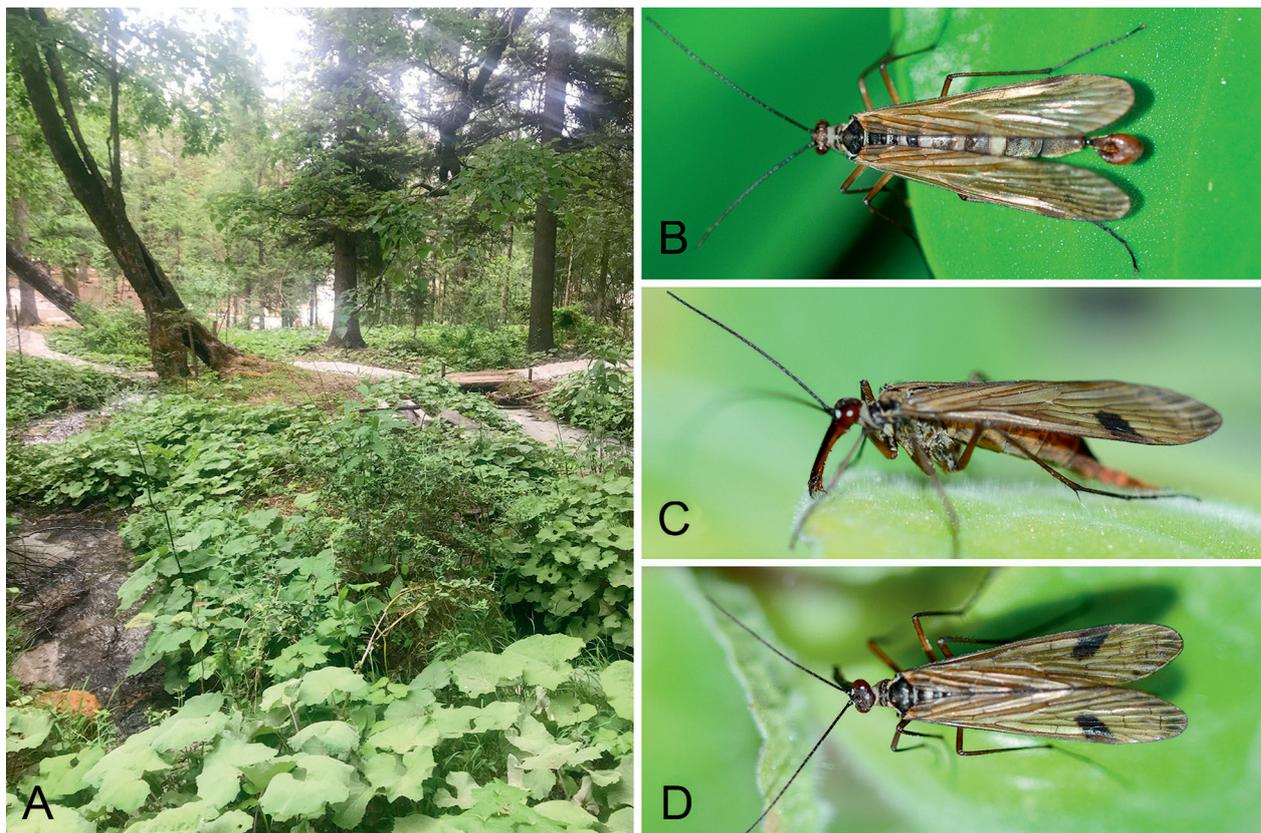


Figure 8. Live adult habitus and habitat of *Panorpa diqingensis* Li & Hua, 2020. **A.** Habitat in Haba, Shangri-La, Yunnan. **B.** Male, dorsal view. **C–D.** Female, lateral and dorsal views. Photos by Ning Li (A) and by Xin Tong (B–D).

Panorpa diqingensis Li & Hua, 2020

Fig. 8

Panorpa diqingensis Li & Hua, 2020: 141, figs 2–4. Type locality: Diqing, Shangri-La, Yunnan, China.

Diagnosis. This species can be recognized by the following features: (1) pleura blackish brown to black (Fig. 8C); (2) wing with pterostigmal band usually reduced to anterior half in females, males with relatively reduced markings; apical band incomplete, scattered, faint (Fig. 8B–D); (3) pro-, meso- and metanotum blackish brown, scutella dark brown (Fig. 8B, D); in males, (4) gonocoxites with triangular process on inner apex ventrally, bearing tuft of long black setae; (5) parameres crossed and twisted in S-shape; and in females, (6) medigynium with main plate three times as long as wide; lateral basal plates absent; axis extending beyond main plate for a quarter length anteriorly.

Material examined. CHINA – Yunnan Prov. • 1♂ (Holotype); Diqing, Shangri-La, Haba; 2600–2700 m a.s.l.; 20 Jun. 2014; Chao Gao & Mei Liu leg. • 33♂♂, 25♀♀ (Paratypes); same data as holotype • 5♂♂, 7♀♀; Shangri-La, Haba; 27°22'14"N, 100°7'49"E; 2730 m a.s.l.; 27–28 May 2019; Ning Li & Lu Liu leg.

Measurements. Male: FL = 13.2–14.1 mm, FW = 3.0–3.2 mm; HL = 12.1–13.0 mm, HW = 3.0–3.1 mm. Female: FL = 13.6–14.6 mm, FW = 3.3–3.5 mm; HL = 12.6–13.6 mm, HW = 3.2–3.4 mm.

Distribution. China: Yunnan.

Remarks. This species resembles *P. fructa* with its blackish brown pro-, meso- and metanotum; darker pleura; roof-like wings at repose, but can be differentiated from the latter by pterostigmal band reduced and not reaching R_{2+3} (cf. scattered); axis of female main plate extended beyond main plate for a quarter (cf. half) of its length.

Panorpa dispersgens Li & Hua, 2020

Fig. 9

Panorpa dispersgens Li & Hua, 2020: 142, figs 5–7. Type locality: Diqing, Shangri-La, Yunnan, China.

Diagnosis. This species can be recognized by the following features: (1) frons, vertex, ocellar triangle and occiput dark brown (Fig. 9B–C); (2) wing membrane hyaline; pterostigma prominent; apical band absent in a few specimens, nearly elliptical with small hyaline spot inside in most individuals (Fig. 9B–C); (3) nota blackish brown to black (Fig. 9B–C); in males, (4) gonocoxites with cluster of stout dark brown setae and 3–5 long setae along oblique inner apex ventrally; (5) parameres crossed mesally, twisted in S-shape; and in females, (6) medigynium with main plate oblong, middle part bearing pair of lateral basal plates; axis extending beyond main plate for half of its length anteriorly.

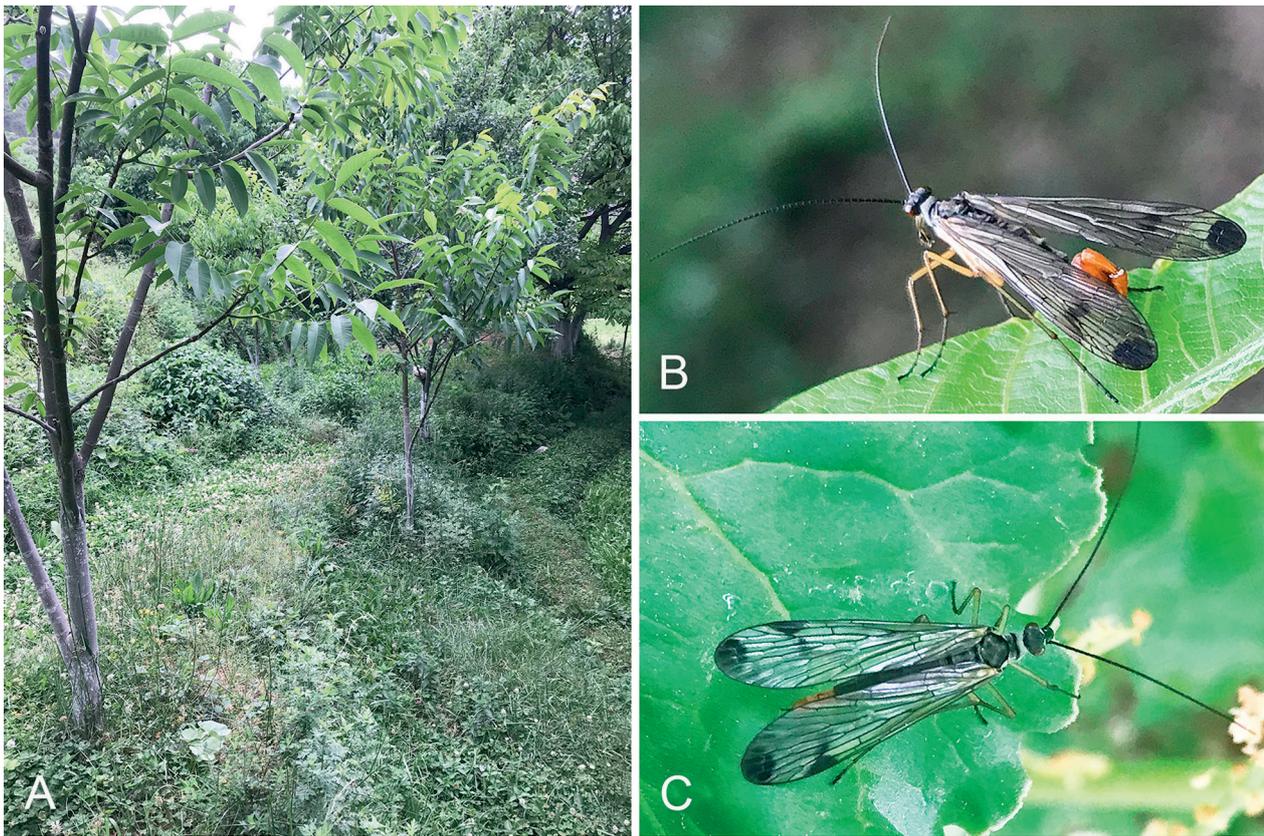


Figure 9. Live adult habitus and habitat of *Panorpa dispergens* Li & Hua, 2020. **A.** Habitat in Baishuitai, Shangri-La, Yunnan. **B.** Male, dorsal view. **C.** Female, dorsal view. Photos by Ning Li (A) and by Lu Liu (B–C).

Material examined. CHINA – Yunnan Prov. • 1♂ (Holotype); Diqing, Shangri-La, Haba; 27°22'12"N, 100°7'48"E; 2700 m a.s.l.; 2 Jun. 2016; Gui-Lin Hu & Wei Du leg. • 1♂, 3♀♀ (Paratypes); same data as holotype; • 13♂♂, 12♀♀ (Paratypes); Diqing, Shangri-La, Haba; 2600–2700 m a.s.l.; 20 Jun. 2014; Chao Gao & Mei Liu leg. • 31♂♂, 25♀♀; Diqing, Shangri-La, Baishuitai; 27°30'2"N, 100°2'36"E; 2500 m a.s.l.; 28–29 May 2019; Ning Li & Lu Liu leg.

Measurements. Male: FL = 12.6–14.4 mm, FW = 3.1–3.5 mm; HL = 11.8–13.4 mm, HW = 3.0–3.4 mm. Female: FL = 13.7–14.5 mm, FW = 3.2–3.6 mm; HL = 12.6–13.4 mm, HW = 3.1–3.5 mm.

Distribution. China: Yunnan.

Remarks. This species resembles *P. curva* in female medigynium, but can be differentiated from the latter by the black meso- and metanotum (cf. black, with prominent pale yellow mesal stripe); and reduced (cf. well-developed) wing markings.

Panorpa fructa Cheng, 1949

Figs 10–11

Panorpa fructa Cheng, 1949: 144, figs 5–7. Type locality: “Wakiakeng, 50 miles west of Tachienlu, Sikang” [now Kangding, Sichuan], China; Cheng, 1957: 30, figs 29, 35 & 38; Wang & Hua, 2018: 339, figs 5-121-1–5-121-2.

Diagnosis. This species can be readily recognized by the following characters: (1) pleura blackish brown to black (Figs 10B, 11C); (2) wing markings reduced into series of scattered dark brown spots (Fig 10B–C); (3) meso- and metanotum black, without pale mesal stripe (Fig 11A–B); (4) inner apex of gonocoxites projected inwards, bearing cluster of long black setae (Fig. 11E); (5) hypovalves gradually broadened towards rounded apices, extending to apex of gonocoxites (Fig. 11F); and in females, (6) medigynium with main plate broad, long; pair of lateral basal plates subbasally extended to three-quarters length of main plate (Fig. 11J–K).

Material examined. CHINA – Sichuan, Garze • 1♂ (Holotype); “Wakiakeng, 50 miles west of Tachienlu” [now Kangding]; 9 Sep. 1939; Fung Ying Cheng, Io Chou & Tein Ho Hei leg. • 1♂; Kangding, Gongga Temple; 3650–4000 m a.s.l.; 3 Sep. 1982; Shu-Yong Wang leg. • 1♂; Yajiang Military Station; 3600 m a.s.l.; 28 Aug. 1982; Huai-Cheng Cai leg. • 1♀; Yajiang Military Station; 3350 m a.s.l.; 25 Jul. 1982; Xue-Zhong Zhang leg. • 1♀; Yajiang Military Station; 3380 m a.s.l.; 6 Aug. 2018; Ning Li & Lu Liu leg. • 2♀♀; same data as previous; 3 Jul. 2019 • 2♂♂; Luhuo, Zhuwo; 3 Jun. 2009; Jiang-Li Tan leg. • 23♂♂, 28♀♀; Xinduqiao; 30°03'28"N, 101°28'58"E; 3480 m a.s.l.; 29 Jun. 2019; Ning Li & Lu Liu leg. • 1♂; Tagong grassland; 30°19'13"N, 101°28'58"E; 3760 m a.s.l.; 3 Aug. 2018; Lu-Yao Yang leg.

Measurements. Male: FL = 11.3–12.2 mm, FW = 2.8–3.2 mm; HL = 10.2–11.0 mm, HW = 2.7–3.0 mm. Female: FL = 12.0–12.5 mm, FW = 2.9–3.2 mm; HL = 10.4–11.3 mm, HW = 2.9–3.2 mm.

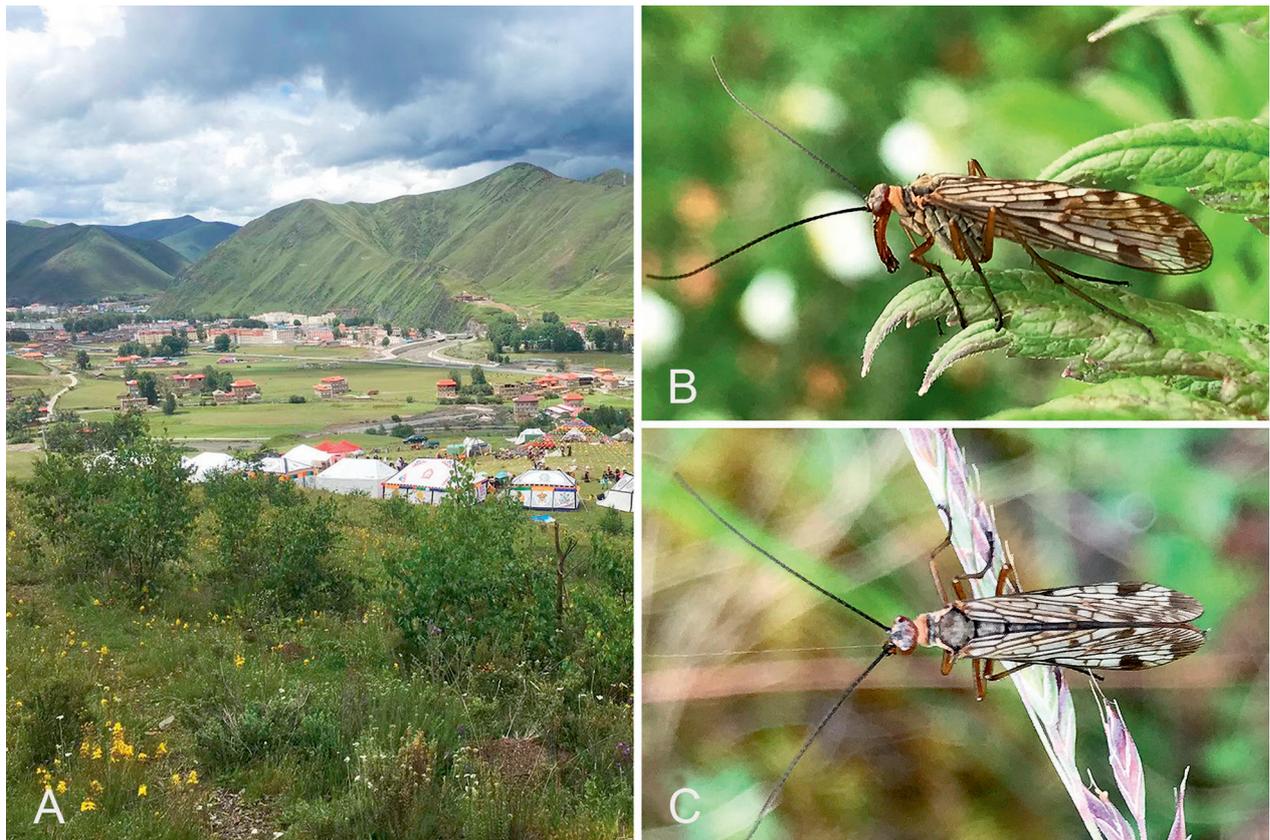


Figure 10. Live adult habitus and habitat of *Panorpa fructa* Cheng, 1949. **A.** Habitat in Xinduqiao, Sichuan. **B.** Male, lateral view. **C.** Female, dorsal view. Photos by Lu-Yao Yang (A) and by Ning Li (B–C).

Description. Female: Head (Figs 10C, 11B): Frons and occiput reddish brown. Vertex with broad black transverse band passing through ocellar triangle and extending to inner margins of compound eyes. Rostrum reddish brown, with two blackish brown submedian stripes. Labrum black brown. Maxillary and labial palps dark brown, with distal segments black. Antennal scape, pedicel black brown; flagellum black, filiform. **Thorax** (Figs 10C, 11B): Pronotum black, with 10–16 stout setae along anterior margin. Meso- and metanotum black, without pale mesal stripe; scutella black brown. Pleura black brown to black. Legs reddish brown, with distal tarsomere black. **Wings** (Figs 10C, 11B): Wing membrane hyaline, with dark brown markings. Forewing with broad apical band split into large spot anteriorly and series of small spots posteriorly; pterostigmal band complete anteriorly, with discrete basal branch and faint apical branch posteriorly; marginal spot prominent; basal band split into two spots; basal spot small and faint. Hindwing similar to forewing, but with relatively reduced markings; marginal spot and basal band extremely faint or absent; basal spot absent. **Abdomen** (Fig. 11B): T2–T6 black. A7–A10 reddish brown. **Genitalia** (Fig. 11I–K): Subgenital plate ligulate, with V-shaped distal emargination, bearing long setae in distal half. Medigynium with broad, long main plate, lateral margin concaved; each lateral basal plate subbasally consisting of three pieces of sclerotized structure, extended to three-quarters length of main plate. Posterior arms slender, one-third as long as main plate; axis slightly extruded posteriorly, extending beyond main plate for half of its length anteriorly.

Distribution. China: Sichuan.

Remarks. *Panorpa fructa* was originally described based on a single male specimen. Over two dozen female specimens from Kangding, the type locality, are determined here as members of this species. The specimens were collected at high-altitude from 3300 to 4000 m in alpine shrub meadow (Fig. 10A). The darker body may help absorb solar heating to adapt the cold environment. The adults hold wings roof-like at repose (Fig. 10B), which may be adapted to the strong wind environment in the alpine region.

Panorpa fulvastra Chou, 1981

Fig. 12

Panorpa fulvastra Chou in Chou et al., 1981: 4, figs 10–13. Type locality: Taibai Mountain, Shaanxi, China; Wang & Hua, 2018: 343, figs 5-123-1–5-123-2.

Diagnosis. This species can be readily recognized by the following characters: (1) wing membrane tinged with yellow, reduced markings (Fig. 12B–C); (2) vein 1A ending at level of origin of Rs (Fig. 12B–C); (3) meso- and metanotum black brown with yellowish mesal stripe (Fig. 12B–C); in males, (4) arcuate inner apex of ventral gonocoxites bearing cluster of extremely long setae; (5) parameres slender, twisted in S-shape, crossed once or

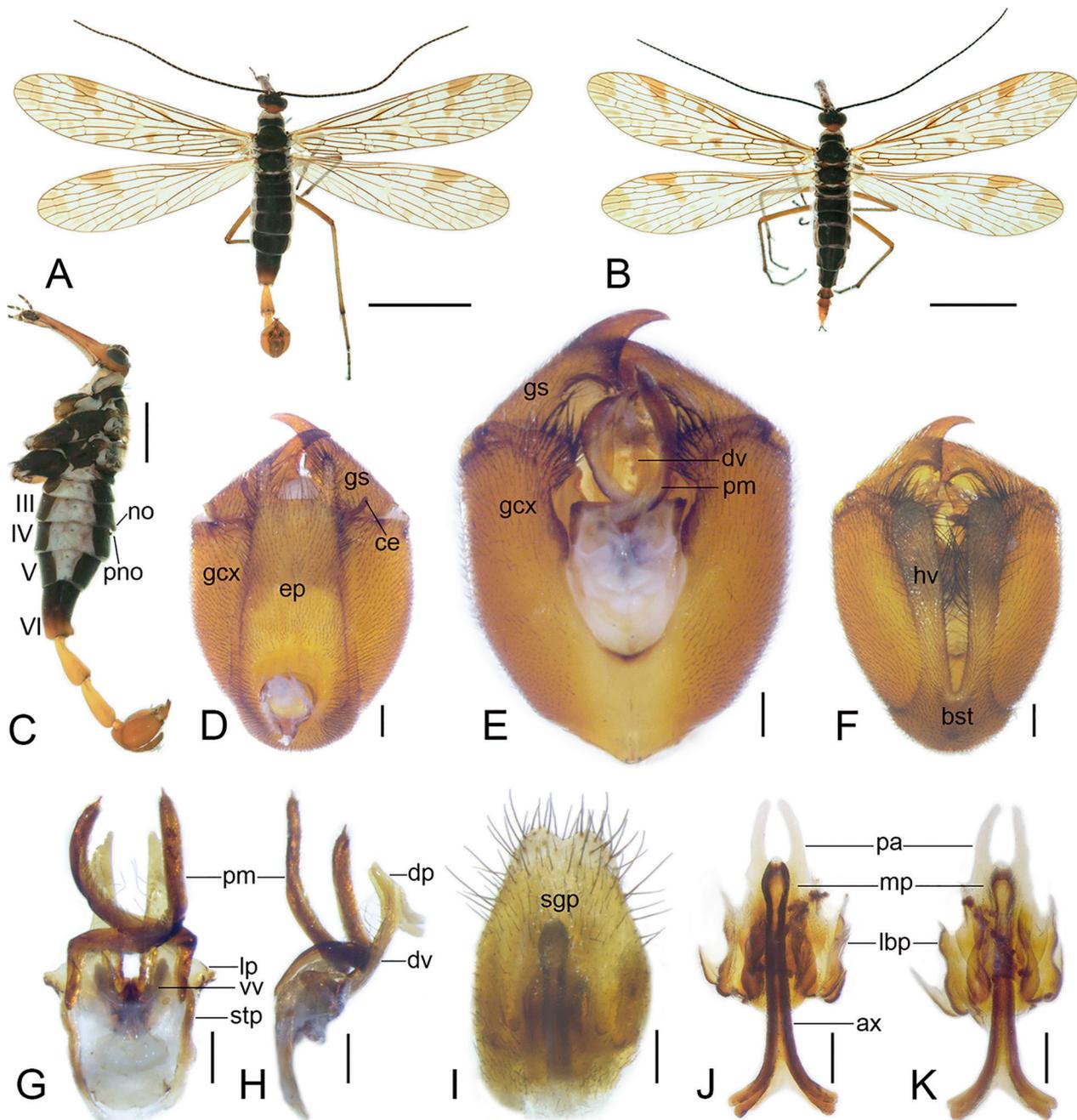


Figure 11. *Panorpa fructa* Cheng, 1949 from Xinduqiao, Sichuan. **A, C–H.** Male. **A.** Habitus, dorsal view. **C.** Habitus, lateral view. **D–F.** Genital bulb, dorsal, ventral (removing hypandrium), and ventral views. **G–H.** Aedeagal complex, ventral and lateral views. **B, I–K.** Female. **B.** Habitus, dorsal view. **I.** Subgenital plate, ventral view. **J–K.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C = 2 mm; D–K = 0.2 mm.

twice; in females, (6) main plate of medigynium broad; pair of large lateral basal plates extending from base to two-thirds of length of main plate; axis extended beyond main plate one-third of its length anteriorly.

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype); Tai-baishan; 22 Jul. 1956; Io Chou leg.; • 4♂♂, 5♀♀ (Paratypes); same data as holotype; • 9♂♂, 5♀♀; Ningshan Huoditang; 20 Jul. 2018; Ying Miao & Xiao-Yan Wang leg.; • 5♂♂, 4♀♀; Liuba; 1200–1600 m a.s.l.; 3 Aug. 2004; Peng-Ying Huang leg.; • 2♂♂, 14♀♀; • 16♂♂, 20♀♀; Liping National Forest Park, Qixingge; 1500 m a.s.l.; 12 Jul. 2018; Zheng Wei leg.; • 4♂♂, 3♀♀; Hanyin, Fenghuangshan, Leigutai, 1800 m a.s.l.;

27 Jun. 2018; Kai Gao leg. • 2♀♀; Zhouzhi, Houzhenzi; 2030 m a.s.l.; 24 Jul. 2019; Kai Gao leg. • 2♀♀; Foping, Liangfengya; 2200 m a.s.l.; 26 Jul. 2019; Kai Gao leg. • 12♂♂, 16♀♀; Qinling Railway Station; 34°14'13"N, 106°55'08"E; 1440 m a.s.l.; 18 Aug. 2019; Ning Li & Yue Pan leg.

Measurements. Male: FL = 10.4–11.9 mm, FW = 2.9–3.1 mm; HL = 9.4–11.0 mm, HW = 2.7–3.1 mm. Female: FL = 11.2–12.6 mm, FW = 3.0–3.3 mm; HL = 10.1–11.5 mm, HW = 2.9–3.2 mm.

Distribution. China: Shaanxi.

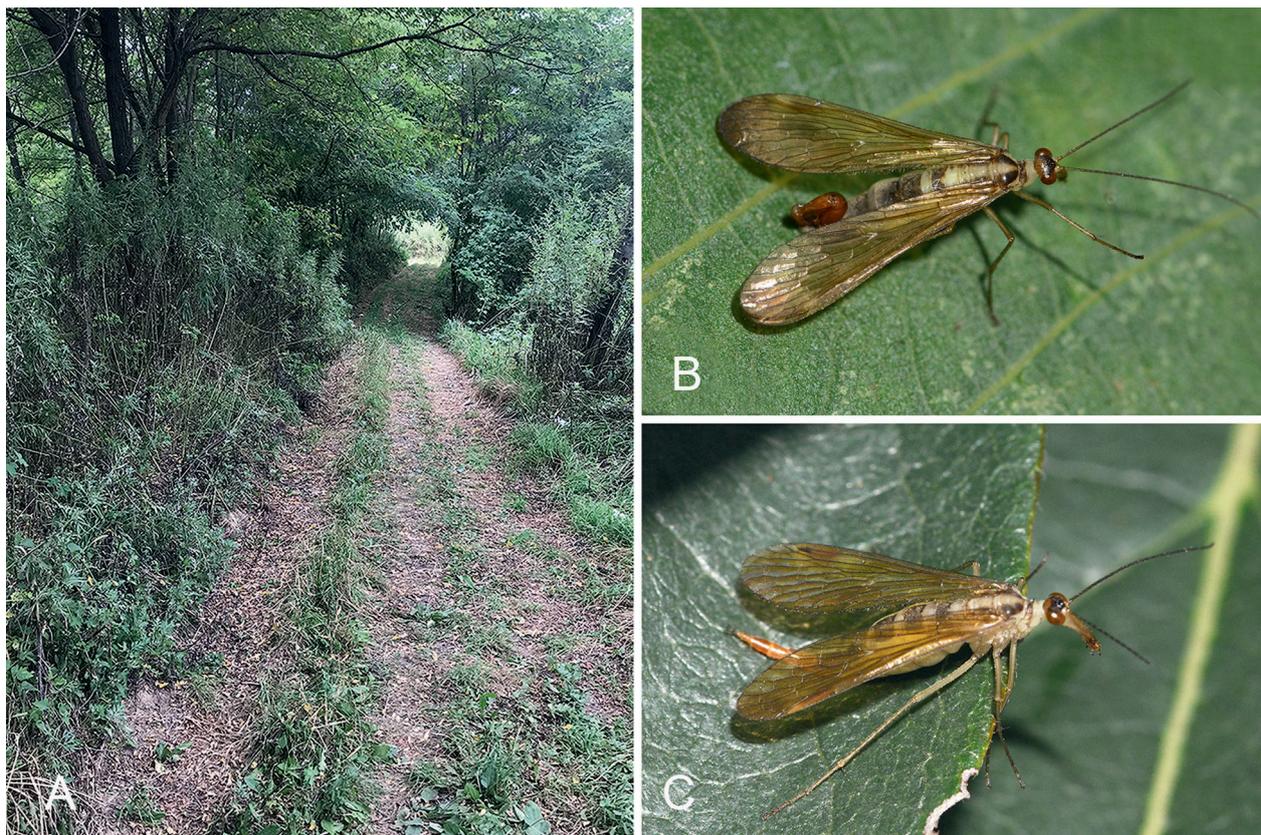


Figure 12. Live adult habitus and habitat of *Panorpa fulvastra* Chou, 1981. **A.** Habitat in Qinling Railway station, Fengxian, Shaanxi. **B.** Male, dorsal view. **C.** Female, dorso-lateral view. Photos by Ning Li (A) and by Kai Gao (B–C).

Panorpa gaokaii sp. nov.

Figs 13–14

Diagnosis. This species can be recognized by the following features: (1) frons and occiput yellowish brown (Fig. 14A–C); (2) vertex with broad black transverse band passing through ocellar triangle, extending to inner margins of compound eyes (Fig. 14A–C); (3) forewing with pterostigma brown; apical band indistinctly faint brown, greatly reduced; other bands and spots absent (Figs 13A–B, 14A–B); in males, (4) meso- and metanotum pale brown, with broad pale yellow mesal stripe extending to T3 (Figs 13B, 14A); (5) A6 uniformly black, projected on dorsal apex with sparse long brown setae (Fig. 14D); (6) gonocoxites bearing cluster of black setae on inner apex (Fig. 14F–G); (7) parameres crossed, twisted in S-shape, reaching apex of gonocoxites (Fig. 14H); in females, (8) medigynium with main plate broad, long, twice as long as wide; a pair of large lateral basal plates reaching three-fourths of length of main plate; posterior arms half length of main plate; axis extended beyond main plate for half of its length anteriorly, extruded posteriorly (Fig. 14K–L).

Etymology. The specific epithet is dedicated to Kai Gao, the collector of the type specimens, for his support to this research.

Material examined. **Holotype:** CHINA – Hubei Prov. • ♂; Shennongjia National Nature Reserve; 1800 m a.s.l.; 1 Jul. 2018; Kai Gao leg. **Paratypes:** CHINA – Hubei Prov. • 7 ♂♂, 10 ♀♀; same data as holotype.

Measurements. Male: FL = 13.3–14.3 mm, FW = 3.7–3.9 mm; HL = 12.0–13.0 mm, HW = 3.5–3.6 mm. Female: FL = 13.9–14.2 mm, FW = 3.7–3.8 mm; HL = 2.8–13.1 mm, HW = 3.4–3.5 mm.

Description. **Male: Head** (Figs 13A–B, 14A, C): Frons and occiput yellowish brown; vertex with broad black transverse band passing through ocellar triangle and extending to inner margins of compound eyes. Rostrum yellow, with labrum brown; labial and maxillary palps yellowish brown basally, gradually darkening toward apex, with apical segment dark brown. Antennal scape uniformly brownish black; pedicel and flagellum dark brown, filiform, with 35–39 flagellomeres. **Thorax** (Figs 13A–B, 14A, D): Pronotum unevenly pale brown, with two dark-brown transverse stripes, bearing 10–14 black setae along anterior margin; meso- and metanotum pale brown, with broad pale to pale yellow mesal stripe. Pleura pale yellow. Legs yellowish brown with tarsi darkened toward apices. **Wings** (Figs 13A–B, 14A): Membrane hyaline. Forewing with pterostigma reddish brown. Apical band indistinctly faint brown, greatly reduced, arranged between R_{2+1} and R_5 or M_1 . Hindwing similar to forewing, but slightly smaller with reduced markings. **Abdomen** (Figs 13A–B,

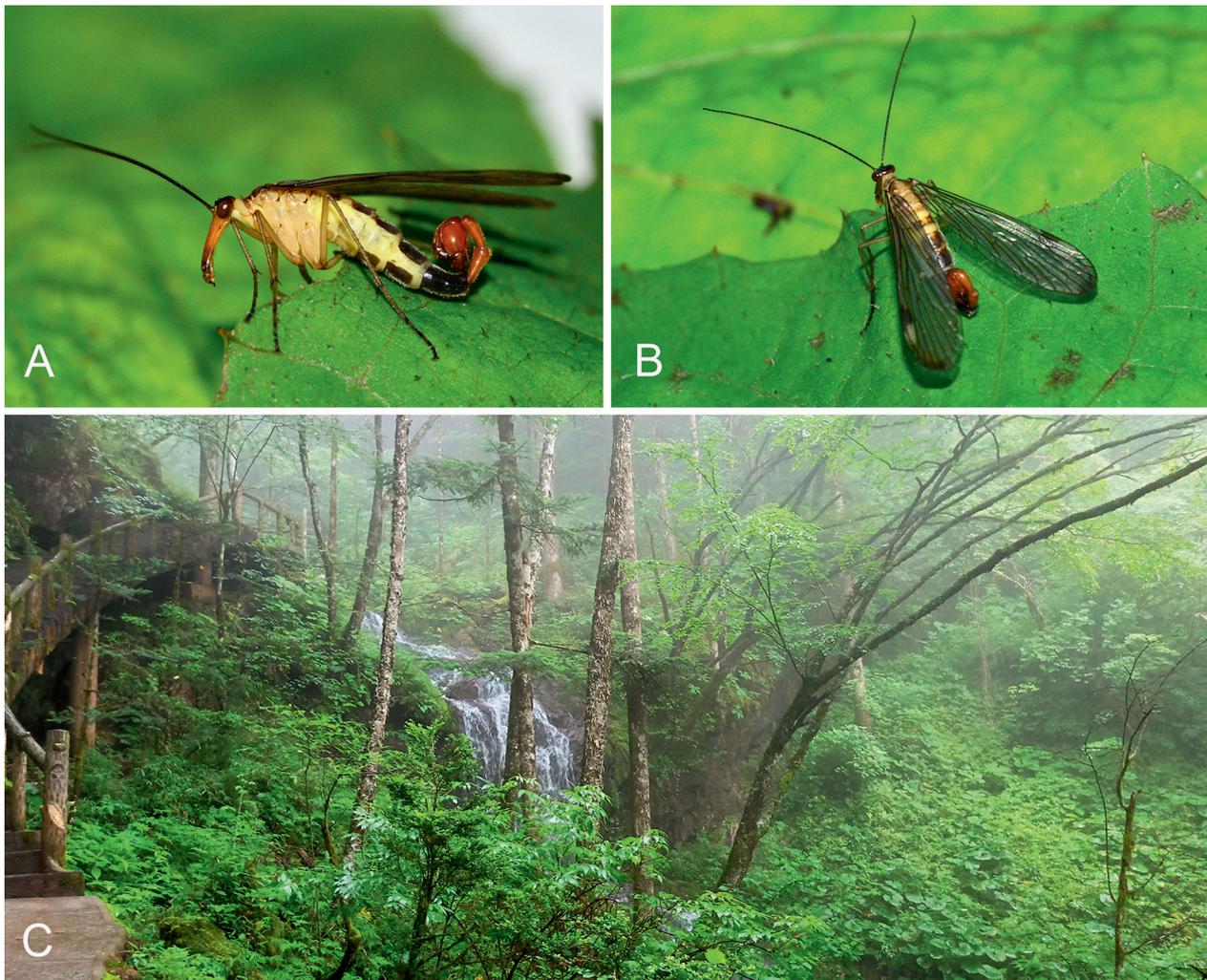


Figure 13. Live adult habitus and habitat of *Panorpa gaokaii* sp. nov. **A–B** Male, lateral and dorsal views. **C.** Habitat in Shennongjia, Hubei. Photos by Kai Gao.

14A, D): T2 and T3 unevenly pale with lateral and posterior margins dark brown. Notal organ of T3 flat rectangular, covering acute postnotal organ on anterior portion of T4. T4–T6 black brown. A6 projected on dorsal apex with long brown setae. A7 and A8 elongate, uniformly yellow, constricted basally. **Genitalia** (Fig. 14E–I): Genital bulb oval, yellow. Epandrium broad basally, bearing dense setae distally, with deep terminal emargination. Cercus long clavate, slightly expanded towards apex. Hypandrium with shortened basal stalk; hypovalves long and broad, reaching apex of gonocoxites; each hypovalve rounded at apex, bearing long dense setae along apical half and shorter setae along basal half on inner margin. Gonocoxites bearing cluster of stout black setae on inner apex. Gonostylus with large basal cup and obtuse triangular median tooth. Parameres twisted in S-shape, crossed mesally, bearing dense short spines on inner margin. Dorsal valves of aedeagus slender, strongly curved ventrally; with circular dorsal process on middle portion. Ventral valves shortened. Lateral process distinctly triangled. — **Female:** Similar to male in body coloration except, T3 uniformly dark brown in most females and small portion

pale in a few specimens. Wing markings similar to males (Fig. 14B). **Genitalia** (Fig. 14J–L): Subgenital plate broad subbasally, narrowing into subtriangular and indistinctly distal emarginate, bearing long setae on caudal and lateral margins. Medigynium with well-developed main plate, nearly rectangular, twice as long as wide; lateral basal plates broad, long, reaching three-fourths length of main plate, each basal plate formed by two pieces of sclerotized structures basally connected by membrane; posterior arms half length of main plate, forming deep U-shaped emargination; axis elongated, bifurcated anteriorly, extended beyond main plate for half of its length, with posterior slightly extruded.

Distribution. China: Hubei.

Remarks. This new species resembles *P. bashanicola* in appearance, but can be readily differentiated from the latter by the following characters: (1) wing with apical band narrow (cf. absence); (2) 1A ending beyond (cf. before) the origin of Rs; (3) forewing usually longer than 13 mm (cf. shorter than 13 mm).

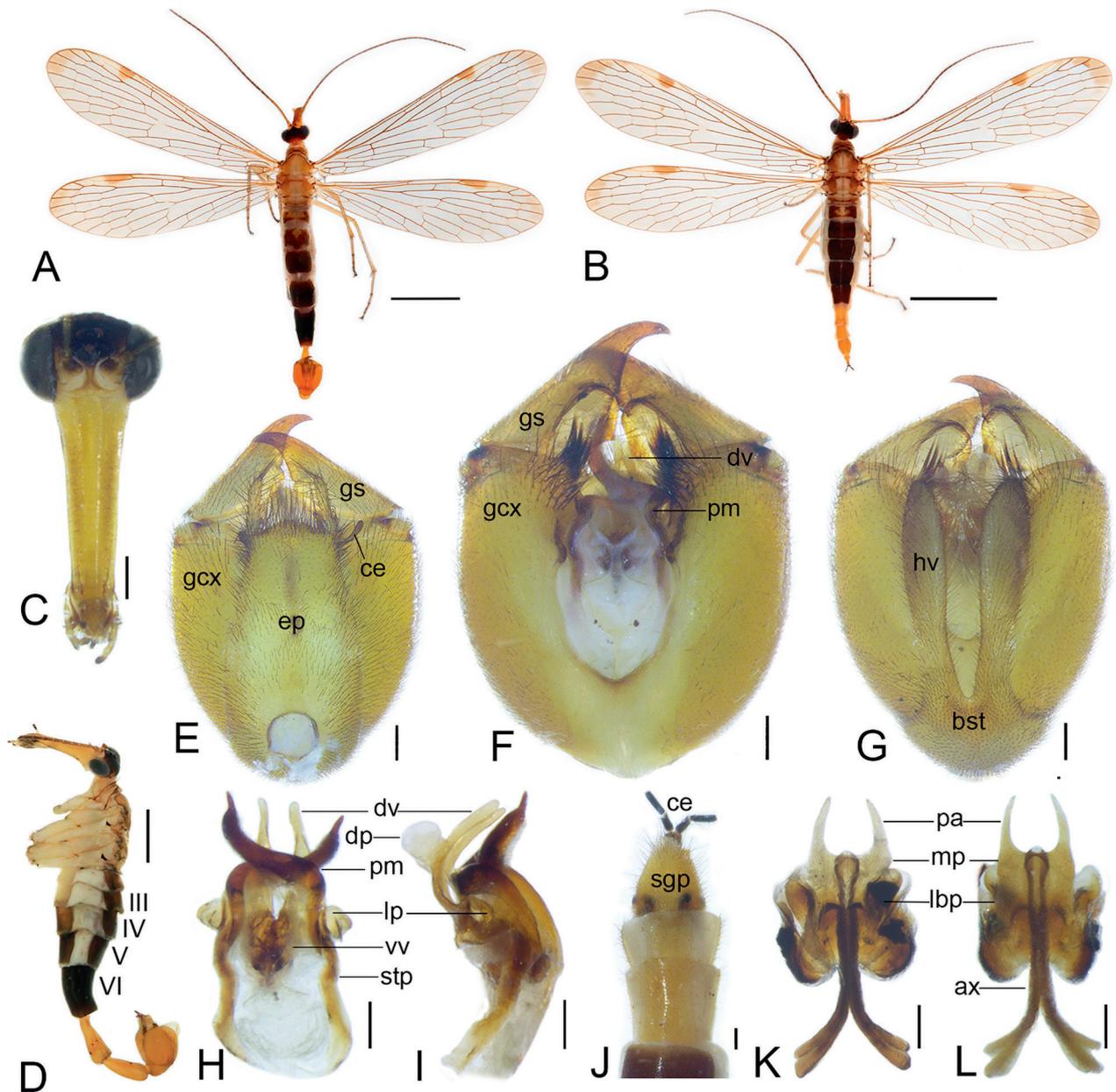


Figure 14. *Panorpa gaokaii* sp. nov. from Shennongjia, Hubei. **A, C–I.** Male. **A.** Habitus, dorsal view. **C.** Head, frontal view. **D.** Habitus, lateral view. **E–G.** Genital bulb, dorsal, ventral (removing hypandrium), and ventral views. **H–I.** Aedeagal complex, ventral and lateral views, respectively. **B, J–L.** Female. **B.** Habitus, dorsal view. **J.** Terminalia, ventral view. **K–L.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C = 0.5 mm; D = 2 mm; E–L = 0.2 mm.

Panorpa huayuani sp. nov.

Figs 15–16

Diagnosis. This species can be recognized by the following features: (1) forewing apical band broad with large hyaline spot posteriorly; pterostigmal band with broad basal branch and thin or incomplete apical branch; marginal spot conspicuous; basal band broad; basal spots greatly reduced, faint (Figs 15C–D, 16A–B); (2) meso- and metanotum black brown to black, with narrow or indistinct yellow mesal stripe (Figs 15C–D, 16A–B); in males, (3) gonocoxites with 4–5 stout setae on inner apex ventrally, and triangular notch on subapical portion (Fig. 16G); (4) parameres crossed mesally, twisted in S-shape

(Fig. 16G, I); in females, (5) medigynium with main plate broad, elongate, twice as long as wide; a pair of lateral basal plates on middle part of main plate; axis extended beyond main plate for half of its length anteriorly (Fig. 16K–L).

Etymology. The specific name is dedicated to Yuan Hua, the collector of the type specimens.

Material examined. **Holotype:** CHINA – Shaanxi • ♂; Ankang, Hualongshan; 2200 m a.s.l.; 24 Jul. 2018; Yuan Hua leg. **Paratypes:** CHINA – Shaanxi Prov. • 4♂♂, 2♀♀; same data as holotype; 24 Jul. 2018; Yuan Hua leg. • 1♂, 3♀♀; same data as holotype; 4 Aug. 2020; Lu-Yao Yang & Le-Le He leg. – Chongqing • 2♂♂, 3♀♀; Chengkou, Huang'anba Alpine Shrub Meadow; 2400 m a.s.l.; 22 Jun. 2018; Yuan

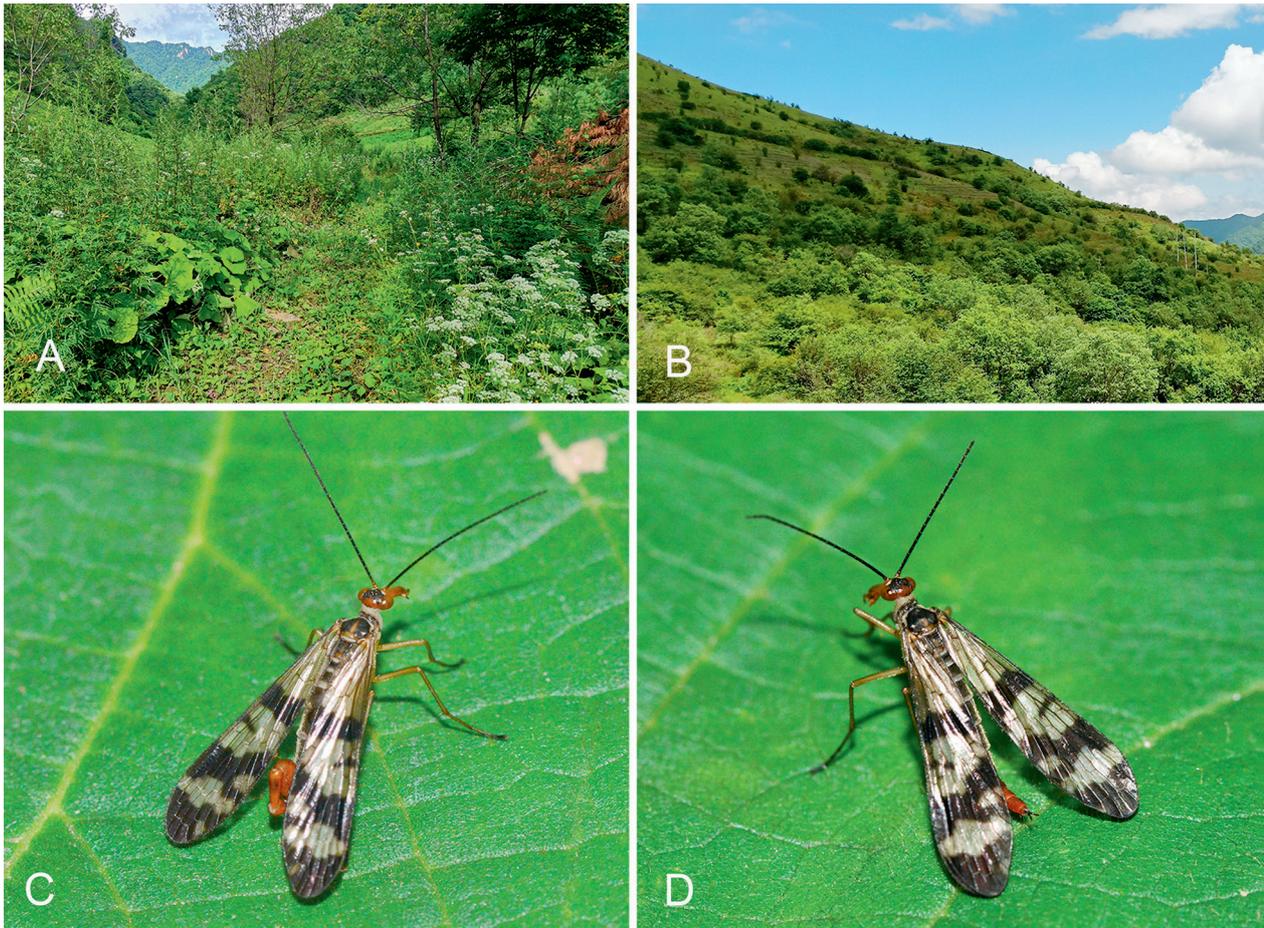


Figure 15. Live adult habitus and habitat of *Panorpa huayuani* sp. nov. **A.** Habitat in Hualongshan, Shaanxi. **B.** Habitat in Huang'amba, Chengkou, Chongqing. **C.** Male, dorsal view. **D.** Female, dorsal view. Photos by Le-Le He (A) and by Kai Gao (B–D).

Hua & Kai Gao leg. – **Hubei Prov.** • 1♀; Shennongjia, Jiuhuping; 24 Jun. 2018; Yuan Hua leg.

Measurements. Male: FL = 10.0–10.9 mm, FW = 2.7–3.1 mm; HL = 9.0–9.9 mm, HW = 2.6–2.9 mm. Female: FL = 10.9–11.3 mm, FW = 3.0–3.1 mm; HL = 10.0–10.4 mm, HW = 2.9–3.0 mm.

Description. Male: Head (Figs 15C, 16A, C–D): Frons, vertex and occiput yellowish brown; broad black transverse band passing through ocellar triangle and extending to inner margins of compound eyes. Rostrum yellow, with labrum brown; labial and maxillary palps yellow basally and gradually darkened towards apex, with apical segment dark brown. Antennal scape unevenly yellowish brown; pedicel and flagellum dark brown, filiform, with 35–37 flagellomeres. **Thorax** (Figs 15C, 16A, D): Pronotum brownish black, bearing 10–12 black setae along anterior margin; meso- and metanotum unevenly black, bearing narrow yellow mesal stripe, with scutellum dark brown. Pleura and coxae pale. Legs yellowish, with tarsi darkened toward apices. **Wings** (Figs 15C, 16A): Forewing membrane hyaline, with wing markings dark brown. Apical band broad, with hyaline inner spot. Pterostigmal band complete, with basal branch approximately three times as wide as apical branch; basal band broad; marginal spot separated, thin, striped or absent;

basal spot greatly reduced. Hindwing similar to forewing, but with relatively reduced markings and slightly smaller. **Abdomen** (Figs 15C, 16A, E): T2–T5 black. Notal organ of T3 flat triangular, covering acute postnotal organ on T4. A6 cylindrical, basal three-fourths brownish black, distal third yellowish brown, slightly projected on dorsal apex with sparse long dark brown setae. A7 and A8 elongate, usually yellow, constricted basally, gradually wider toward apices. **Genitalia** (Fig. 16F–I): Genital bulb long oval, yellow. Epandrium broad basally, narrowed towards apex, with U-shaped terminal emargination, bearing dense setae. Cercus long clavate, expanded apically, yellowish brown, with slightly darker apex. Hypandrium with reduced stalk and pair of slender hypovalves, extending two-thirds length of gonocoxites; hypovalve bearing separated long setae on inner margin. Gonocoxite bearing 4–5 stout setae on inner apex ventrally and triangular notch on subapical portion. Gonostylus with large basal cup and obtuse triangular median tooth on inner margin. Parameres twisted in S-shape, mesally crossed, bearing dense short spines on inner margin and whole distal portion; apex long, acute. Ventral valves greatly shortened. Dorsal valves of aedeagus elongated, bearing bundle of long hairs ventrally on base and enlarged dorsal process on subapical portion dorsally. Lateral process distinctly triangular. — **Female:** Similar to male except, relatively denser wing markings (Figs 15D, 16B). **Genitalia** (Fig.

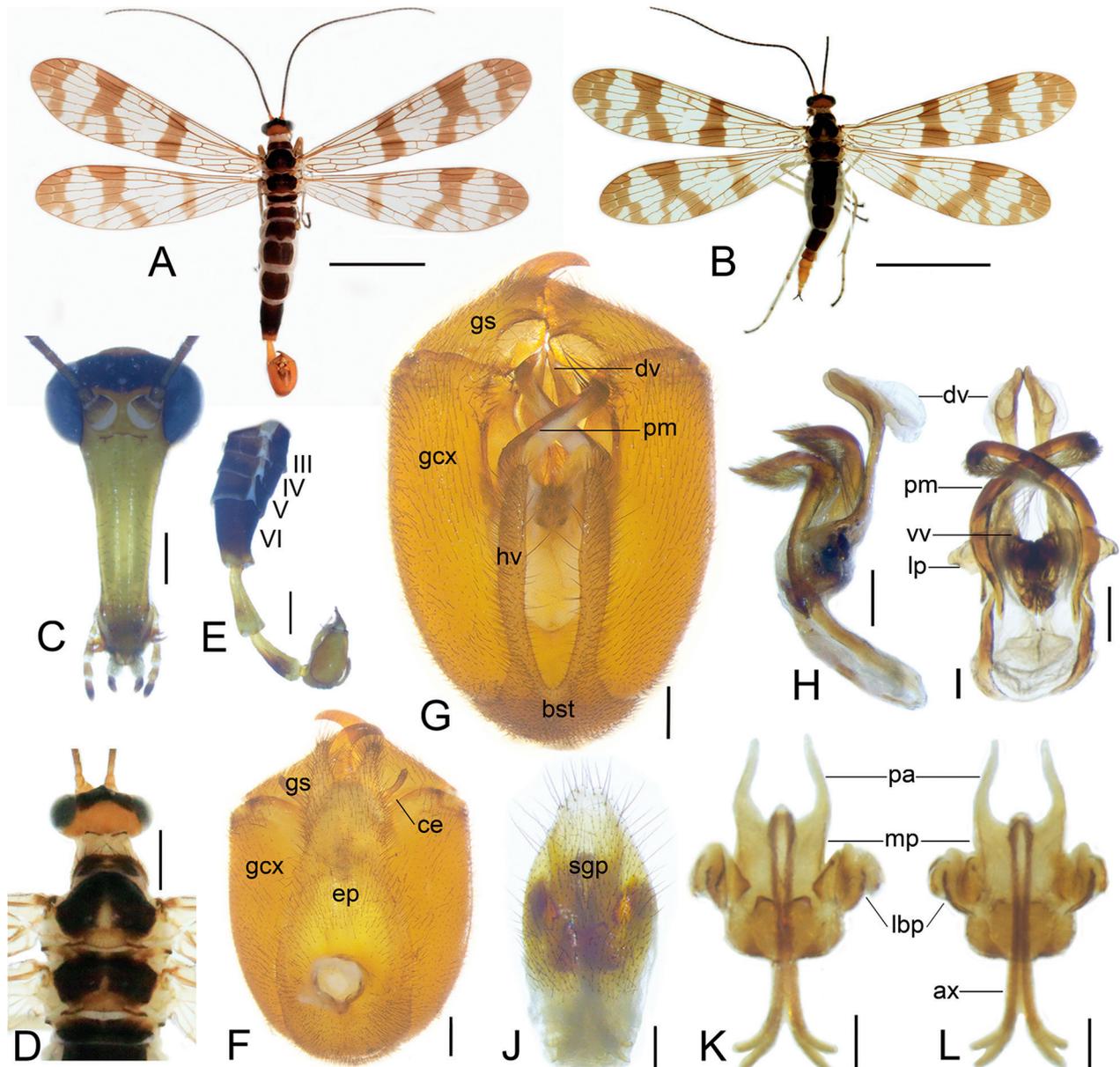


Figure 16. *Panorpa huayuani* sp. nov. from Ankang, Shaanxi. **A, C–I.** Male. **A.** Habitus, dorsal view. **C.** Head, frontal view. **D.** Dorsum, dorsal view. **E.** Abdomen, lateral view. **F–G.** Genital bulb, dorsal and ventral views. **H–I.** Aedeagal complex, lateral and ventral views. **B, J–L.** Female. **B.** Habitus, dorsal view. **J.** Subgenital plate, ventral view. **K–L.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C = 0.5 mm; D–E = 1 mm; F–L = 0.2 mm.

16J–L): Subgenital plate broad subbasally, narrowed towards apex, with V-shaped terminal emargination, bearing long setae on distal third laterally. Medigynium with well-developed main plate, twice as long as wide; middle part bearing pair of lateral basal plates; posterior arms slender, half length of main plate, forming large, deep U-shaped emargination; axis elongated, bifurcated anteriorly, extended beyond main plate for half of its length, with posterior distinctly extruded.

Distribution. China: Chongqing, Hubei, Shaanxi.

Remarks. This new species resembles *P. sexspinosa* in appearance, but can be readily differentiated from the latter by: (1) meso- and metanotum unevenly black, bearing an indistinct narrow (cf. distinct) yellow mesal stripe;

(2) basal spot greatly reduced (cf. absent); (3) hypovalve extremely slender (cf. broad); separated (cf. dense) long setae on inner margin; (4) middle (cf. basal) region of medigynium bearing a pair of lateral basal plates.

Panorpa jinchuana Hua, Sun & Li, 2001

Fig. 17

Panorpa jinchuana Hua, Sun & Li, 2001: 121, fig. 1A–B. Type locality: Jinchuan, Sichuan, China; Wang & Hua, 2018: 355, figs 5-129-1–5-129-2.

Diagnosis. This species can be readily recognized by the following characters: (1) wing markings well-devel-

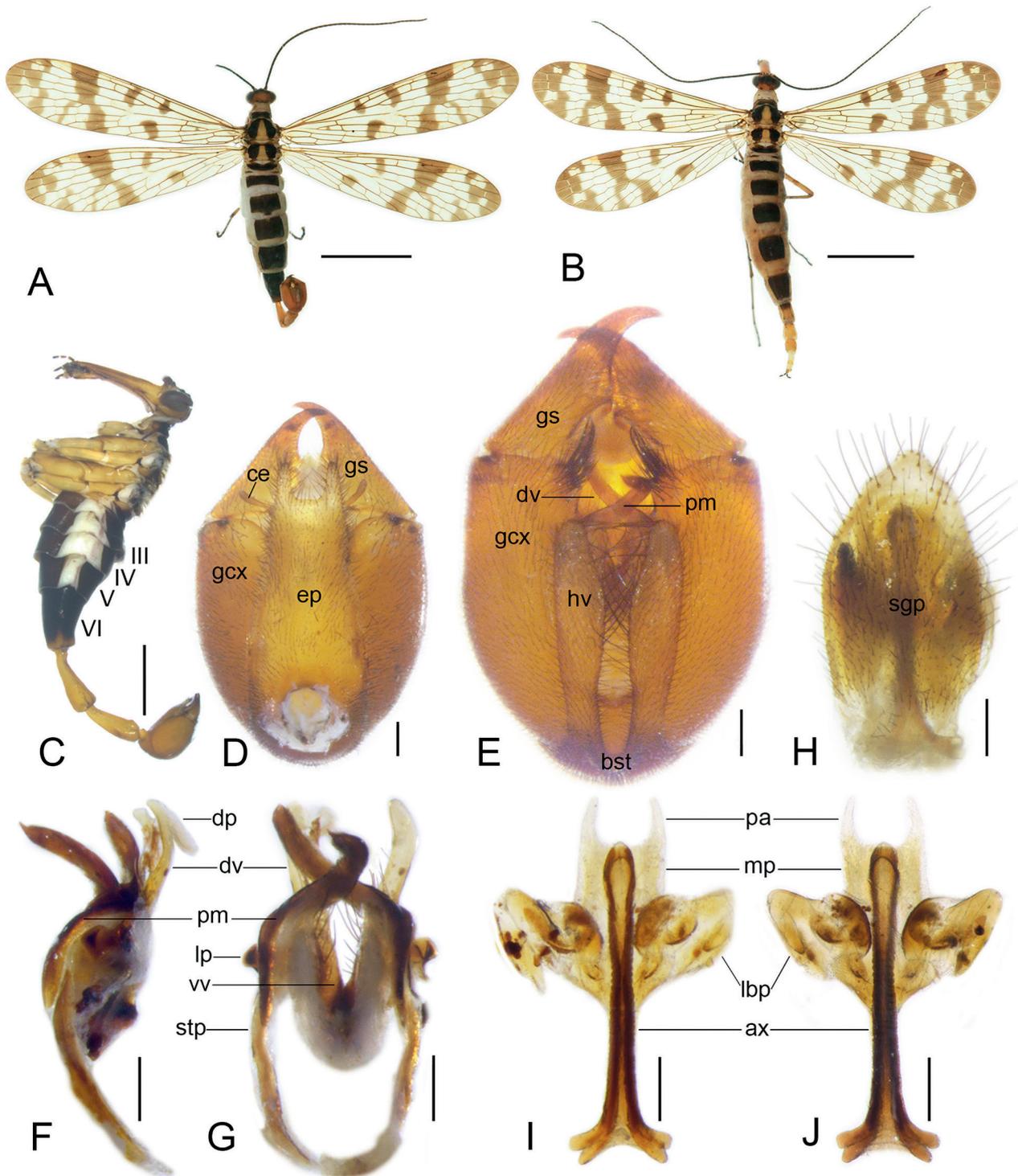


Figure 17. *Panorpa jinchuana* Hua, Sun & Li, 2001 from Danba, Sichuan. **A, C–G.** Male. **A.** Habitus, dorsal view. **C.** Habitus, lateral view. **D–E.** Genital bulb, dorsal and ventral views. **F–G.** Aedeagal complex, lateral and ventral views. **B, H–J.** Female. **B.** Habitus, dorsal view. **H.** Subgenital plate, ventral view. **I–J.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C = 2 mm; D–J = 0.2 mm.

oped, forewing apical band with two inner hyaline spots; pterostigmal band complete, with broad basal branch and thinly connected or detached apical branch; marginal spot large; basal band split into two spots; basal spot greatly reduced (Fig. 17A–B); (2) meso- and metanotum black, with broad pale mesal stripe (Fig. 17A–B); in males, (3) gonocoxites with cluster of long setae along slightly oblique inner apex ventrally (Fig. 17E); (4) parameres

crossed mesally, twisted in S-shape (Fig. 17G); in females, (5) main plate of medigynium three times as long as posterior arms; axis extended beyond main plate for half of its length anteriorly (Fig. 17I–J).

Material examined. CHINA – Sichuan Prov. • 1♂ (Holotype); Jinchuan; 10 Sep. 1963; Sheng-Li Liu leg. • 1♂ (Paratype); Jinchuan; 8 Sep. 1963; Jiang Xiong leg. • 4♂♂, 9♀♀; Danba, Maoniuhe; 26 Jul. 2006;

Xiao-Yan Hou et al. leg. • 1♂, 1♀; Zhonglu; 30°53'46"N, 101°55'50"E; 2230 m a.s.l.; 7 Jul. 2019; Ning Li & Lu Liu leg. • 11♂♂, 13♀♀; Donggu; 30°46'37"N, 101°43'48"E; 2230 m a.s.l.; 8 Jul. 2019; Ning Li & Lu Liu leg.

Measurements. Male: FL = 11.8–13.0 mm, FW = 3.0–3.2 mm; HL = 10.9–12.0 mm, HW = 2.8–3.1 mm. Female: FL = 12.2–14.0 mm, FW = 3.0–3.4 mm; HL = 11.0–13.0 mm, HW = 2.9–3.3 mm.

Description. Female: Head (Fig. 17B): Frons, vertex and occiput yellowish brown. Black transverse band passing through ocellar triangle, extending to inner margins of compound eyes. Rostrum yellow, slender, with labrum dark brown. Maxillary and labial palps mostly pale brown, with distal segments dark brown. Antennal scape yellowish brown; pedicel dark yellowish brown; flagellum blackish brown, filiform. **Thorax** (Fig. 17B): Pronotum black, with 12–16 stout setae along anterior margin. Meso- and metanotum black, with prominent pale yellow mesal stripe; scutella totally pale yellow. Pleura yellowish; legs yellowish brown, with distal tarsomere blackish. **Wings** (Fig. 17B): Membrane hyaline, with black brown markings. Forewing apical band with two hyaline spots inside; pterostigmal band complete, with broad basal branch and thinly connected or detached apical branch; marginal spot large; basal band split into two spots; basal spot greatly reduced between veins CuA and CuP. **Abdomen** (Fig. 17B): T2–T6 black. A7–A10 uniformly yellowish brown. **Genitalia** (Fig. 17H–J): Subgenital plate ligulate, bearing long setae on distal quarter. Medigynium with main plate oblong, broad; three times as long as posterior arms; pair of large wing-like lateral basal plates on basal half; axis slightly extruded posteriorly, extended beyond main plate for half of its length anteriorly.

Distribution. China: Sichuan.

Remarks. *Panorpa jinchuan* was described from two males from Jinchuan, Sichuan. The male and female specimens obtained from Danba, Sichuan match the characters of this species. Here, the female is described and illustrated for the first time.

Panorpa neospinosa Chou & Wang, 1981

Panorpa neospinosa Chou & Wang in Chou et al., 1981: 7, figs 19–23.

Type locality: Qinling Railway Station, Shaanxi, China; Wang & Hua, 2018: 374, figs 5-138-1–5-138-2.

Diagnosis. This species can be readily recognized by the following characters: (1) wing markings well-developed, forewing apical band broad with one or two large inner hyaline spots; pterostigmal band with broad basal branch and thin apical branch; marginal spot large; broad basal band complete; basal spots large; (2) meso- and metanotum blackish brown, with prominent pale yellow mesal stripe; in males, (3) gonocoxites bearing 4–7 (usually 6) long setae along beveled inner apex ventrally; (4) param-

eres crossed mesally, twisted in S-shape, extended beyond gonocoxites; in females, (5) medigynium with main plate long, broad; a pair of lateral basal plates reaching two-thirds of main plate; axis extended beyond main plate for one-third of its length anteriorly.

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype); Fengxian, Qinling Railway Station; 1600–2000 m a.s.l.; 18 Aug. 1965; Io Chou & Jin-Sheng Lu leg. • 8♂♂, 10♀♀ (Paratypes); same data as holotype • 1♀ (Paratype); Zhouzhi, Tianyu; 18–19 Aug. 1951; Io Chou leg.

Measurements. Male: FL = 10.0–11.1 mm, FW = 3.0–3.2 mm; HL = 9.1–10.0 mm, HW = 2.9–3.1 mm. Female: FL = 10.5–11.5 mm, FW = 3.0–3.3 mm; HL = 9.6–10.5 mm, HW = 2.9–3.2 mm.

Distribution. China: Shaanxi.

Remarks. *Panorpa neospinosa* resembles *P. sexspinosa*, but differs from the latter in the conspicuous (cf. absent) basal spot.

Panorpa qinlingensis Chou & Ran, 1981

Panorpa qinlingensis Chou & Ran in Chou et al., 1981: 9, figs 30–33.

Type locality: Qinling, Shaanxi, China; Wang & Hua, 2018: 388, figs 5-145-1–5-145-2.

Diagnosis. This species can be readily recognized by the following characters: (1) forewing with apical band broad, bearing large hyaline spot posteriorly; pterostigmal band complete, with broad basal branch and thin apical branch; marginal spot long and narrow or inconspicuous; basal band broad; basal spot extremely reduced or absent; (2) meso- and metanotum blackish brown with conspicuous yellowish mesal stripe; in males, (3) gonocoxites with triangular process on inner apex ventrally, bearing 1 or 2 long setae on inner margin subapically; (4) parameres crossed mesally, twisted in S-shape; in males, (5) medigynium with main plate almost oblong in shape, twice as long as wide; a pair of large basal plates reaching the middle of main plate; axis extended beyond main plate for two-fifths of its length anteriorly.

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype); Qinling; 18 Aug. 1965; Io Chou & Jin-Sheng Lu leg. • 9♂♂, 10♀♀ (Paratypes); same data as holotype • 7♂♂, 5♀♀; Nanzheng, Liping Village; 1650 m a.s.l.; 9 Aug. 2011; Shuang Xue leg. • 9♂♂, 3♀♀; Liping National Forest Park, Qixingge; 1500 m a.s.l.; 30 Jun. 2018; Zheng Wei leg. • 2♂♂, 3♀♀; Zibaishan; 27 Jul. 2019 Kai Gao leg. • 1♂, 1♀; Qinling Railway Station; 34°14'13"N, 106°55'08"E; 1440 m a.s.l.; 18 Aug. 2019; Ning Li leg. – Sichuan Prov. • 3♂♂, 2♀♀; Wanyuan, Huaeshan; 1200 m a.s.l.; 16 Jun. 2018; Kai Gao & Yu-Ru Yang leg.

Measurements. Male: FL = 10.2–12.2 mm, FW = 2.8–3.1 mm; HL = 9.0–11.4 mm, HW = 2.7–3.0 mm. Female: FL = 10.4–12.7 mm, FW = 2.9–3.2 mm; HL = 9.4–11.6 mm, HW = 2.8–3.1 mm.



Figure 18. Live adult habitus and habitat of *Panorpa sexspinoso* Cheng, 1949. **A.** Habitat in Tiantaishan Forest Park, Baoji, Shaanxi. **B.** Male, dorso-lateral view. **C.** Female, dorso-lateral view. Photos by Ning Li (A) and by Xin Tong (B–C).

Distribution. China: Shaanxi, Sichuan.

Remarks. This species is bivoltine, overwintering in the prepupal stage in the soil. Adults emerge from mid-May to early June and from late July to mid-August in Liping, Shaanxi (Cai & Hua 2009).

Panorpa sexspinoso Cheng, 1949

Figs 18–19

Panorpa sexspinoso Cheng, 1949: 145, figs 4, 8, 9, 15 & 16. Type locality: “Taipaishan, Shensi” [now Taibaishan, Shaanxi], China; Cheng, 1957: 49, figs 81, 87, 89, 123, 124 & 278; Chou et al. 1981: 5, figs 14–18; Wang & Hua, 2018: 396, figs 5-149-1–5-149-3.

Panorpa sexspinoso zhongnanensis Chou & Ran in Chou et al., 1981: 6. Type locality: Zhongnanshan, Shaanxi, China, **syn. nov.**

Panorpa shanyangensis Chou & Wang in Chou et al., 1981: 8, figs 28–29. Type locality: Cuipingshan, Shanyang, Shaanxi, China; Wang & Hua, 2018: 400, figs 5-151-1, **syn. nov.**

Diagnosis. This species can be readily recognized by the following characters: (1) wing markings well-developed, forewing apical band broad with large hyaline spot posteriorly; pterostigmal band with broad basal branch, and thin or no apical branch; marginal spot slender or absent; basal band broad; basal spot absent (Figs 18B–C, 19A–B); (2) meso- and metanotum blackish brown to black, with broad pale yellow mesal stripe (Fig. 19A–B); in

males, (3) gonocoxites bearing 4–8 (usually 6) long setae along beveled inner apex ventrally (Fig. 19E–F); (4) parameres crossed mesally, twisted in S-shape, extending beyond gonocoxites (Fig. 19E, G); in females, (5) medigynium with main plate broad, pair of lateral basal plates reaching two-thirds length of main plate, each basal plate formed by three sclerotized structures connected by membrane; axis extended beyond main plate for one-third of its length anteriorly (Fig. 19J–K).

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype of *P. sexspinoso*); Taibaishan; Jul. 1942; Io Chou leg. • 1♀ (Holotype of *P. shanyangensis*); Shanyang, Cuipingshan; 14 Aug. 1973; Chou Tian, Tian-Yin Zeng & Man-Sheng Ruan leg. • 1♂ (Holotype of *P. sexspinoso zhongnanensis*); Nanwutai; 28 Aug. 1980; Su-Mei Wang leg. • 15 ♀♀ (Paratypes of *P. sexspinoso zhongnanensis*); same data as previous; Su-Mei Wang et al. leg. • 2♂♂, 2♀♀ (Paratypes of *P. sexspinoso zhongnanensis*); Nanwutai; 8 Jul. 1979; Chou Tian & Tong Chen leg. • 1♂, 2♀♀; Taibaishan; 5 Jul. 2020; Bao-Zhen Hua & Xiao-Yan Wang leg. • 1♂; Qinling Railway Station; 18 Aug. 1965; Io Chou & Jin-Sheng Lu leg. • 32♂♂, 40♀♀; Ningshan, Huoditang; 5 May–13 Jul. 2019; Xin Tong & Peng-Yang Wang leg. • 35♂♂, 42♀♀; Zhuque National Forest Park; 3 Sep. 2009; Yan-Kai Li & Jie Meng leg. • 1♂, 2♀♀; same data as previous; 8 Aug. 2020; Wan-Ruo Ma leg. • 3♂♂, 1♀; Tiantaishan Forest Park; 1500 m a.s.l.; 17 Jul. 2012; Qiong-Hua Gao & Yan-Yan Feng leg. • 3♀♀; Niubeiliang National Forest Park; 2200 m a.s.l.; 29 Jul. 2019; Kai Gao leg. – Gansu Prov. • 3♂♂, 2♀♀; Tianshui, Baihua Forest Farm; 7 Aug. 2011; Na Ma leg. • 1♂; Pingliang, Kongtongshan, Xiangshanding; 2090 m a.s.l.; 19 Jul. 2019; Yan-Na Zhang leg. – Henan Prov. • 1♂; Pingdingshan, Lushan, Yaoshan; 1200–1400 m

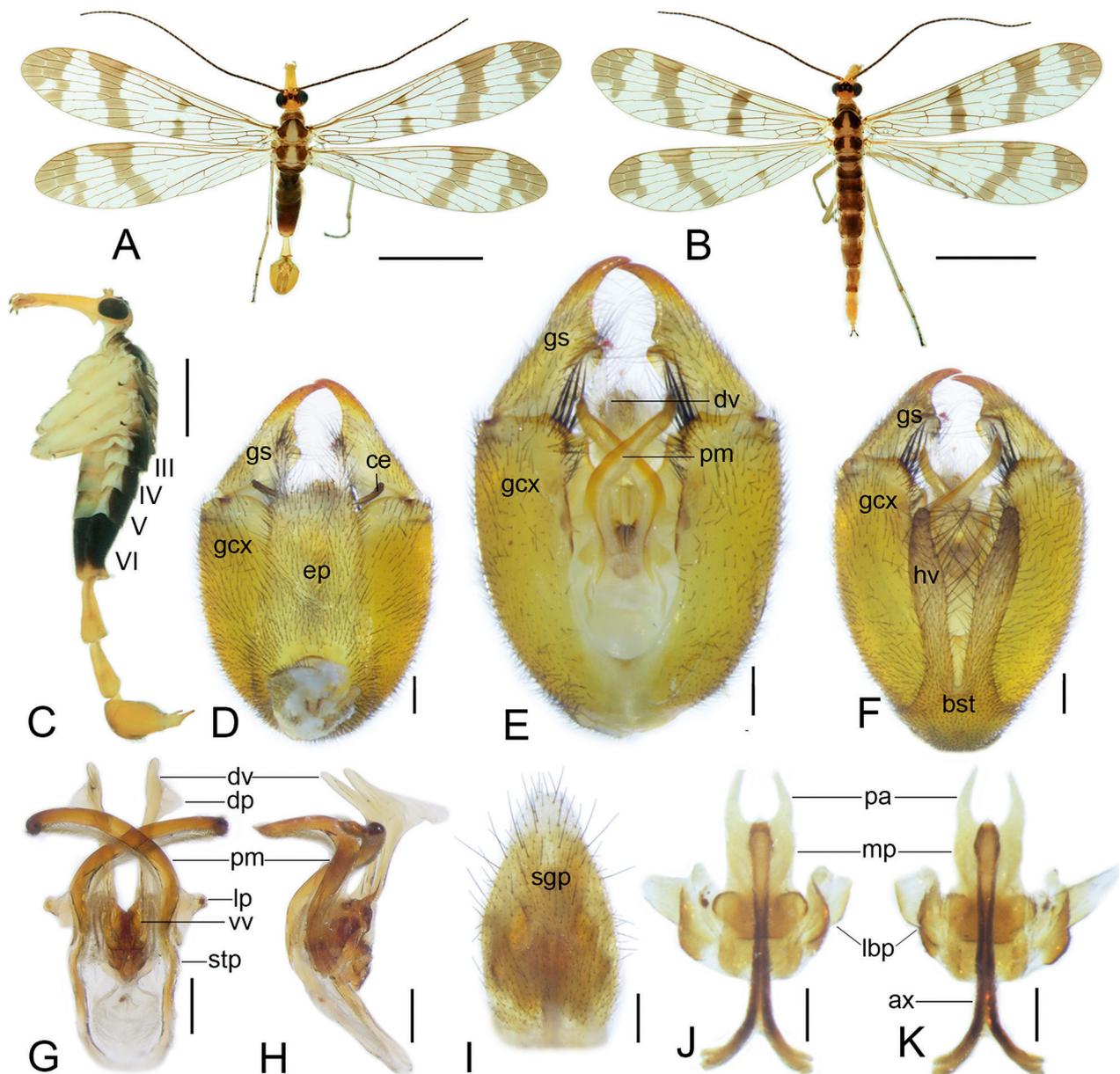


Figure 19. *Panorpa sexspinosa* Cheng, 1949 from Ningshan, Shaanxi. **A, C–H.** Male. **A.** Habitus, dorsal view. **C.** Habitus, lateral view. **D–F.** Genital bulb, dorsal, ventral (removing hypandrium), and ventral views. **G–H.** Aedeagal complex, ventral and lateral views. **B, I–K.** Female. **B.** Habitus, dorsal view. **I.** Subgenital plate, ventral view. **J–K.** Medigynium, dorsal and ventral views. Scale bars: A–B = 5 mm; C = 2 mm; D–K = 0.2 mm.

a.s.l.; 20 Jul. 2012; Bao-Zhen Hua leg. – **Hubei Prov.** • 1♂; Shennongjia, Badong, Tianshanping.

Measurements. Male: FL = 11.3–14.3 mm, FW = 3.0–3.5 mm; HL = 10.4–13.2 mm, HW = 2.8–3.3 mm. Female: FL = 11.6–14.7 mm, FW = 3.1–3.6 mm; HL = 10.5–13.6 mm, HW = 2.9–3.4 mm.

Distribution. China: Gansu, Henan, Hubei, Shaanxi.

Remarks. *Panorpa sexspinosa zhongnanensis* was described from Nanwutai, Shaanxi. Based on our observations, no significant differences from the nominotypical subspecies have been found in morphological characters, including body colour, wing markings, and male and female genitalia. Therefore, *P. sexspinosa zhong-*

nanensis is here treated as a junior synonym of *P. sexspinosa*.

Panorpa shanyangensis was described from a single female specimen from Cuipingshan, Shanyang, Shaanxi. It resembles *P. sexspinosa* in gross morphology, although it can be distinguished from the latter by three pairs (cf. a pair) of lateral basal plates, three spots, and incomplete apical band with three separated small spots near the inner margin (cf. apical band broad with a large hyaline spot posteriorly). After dissecting series of female specimens of *P. sexspinosa* from the type locality and other localities, we found that each complete basal plate is formed by three sclerotized structures connected by membrane. After comparing the female genitalia of *P. shanyangensis* and *P. sexspinosa*, we found these two nominal species share highly similar lateral basal plates and outline of



Figure 20. Live adult habitus and habitat of *Panorpa stigmosa* Zhou, 2006. **A.** Habitat in Pantiangang, Weixi, Yunnan. **B.** Male, dorsal view. **C.** Female, dorso-lateral view. Photos by Ning Li.

the main plate. It is reasonable to consider that the apical band with three separated small spots near the inner margin in *P. shanyangensis* is variation of wing markings, thus *P. shanyangensis* and *P. sexspinosa* are very likely conspecific. Consequently, *P. shanyangensis* is treated as a junior subjective synonym of *P. sexspinosa*. In addition, according to the collection records, *Panorpa sexspinosa* is very likely a bivoltine insect in Shaanxi.

Panorpa stigmosa Zhou, 2006

Figs 20–21

Panorpa stigmosa Zhou, 2006: 274. Type Locality: Chishui Suoluo National Nature Reserve, Guizhou, China. Wang & Hua, 2018: 420, figs 5-154-1–5-154-2.

Diagnosis. This species can be recognized by the following features: (1) frons, vertex, occiput and ocellar triangle black brown to black (Figs 20B–C, 21B–D); (2) wing membrane hyaline, with markings scattered into series of spots or only with pterostigma black brown in some males (Fig 21A–C); (3) pro-, meso- and metanotum blackish brown (Fig 20B–C); in males, (4) ventral termination of gonocoxites bearing 3–5 long setae and acute protuberance on inner apex (Fig. 21G); (5) param-

eres crossed mesally, twisted in S-shape (Fig. 21G, I); in females, (6) main plate of medigynium broad, long, basal half narrow, distal half broad; small lateral basal plates on basal half not extended to the base; axis extended beyond main plate quarter of its length anteriorly, not extruded posteriorly (Fig. 21K–L).

Material examined. CHINA – Yunnan Prov. • 19♂♂, 21♀♀; Yulong Snow Mountain; 6 Jun. 2009; Jiang-Li Tan leg. • 23♂♂, 31♀♀; Weixi, Pantiangang; 2600 m a.s.l.; 13 Jun. 2016; Gui-Lin Hu & Wei Du leg. • 35♂♂, 28♀♀; Pantiangang; 27°19'27"N, 99°12'50"E; 2530 m a.s.l.; 3–4 Jun. 2019; Ning Li & Lu Liu leg.

Measurements. Male: FL = 11.0–11.7 mm, FW = 2.4–2.7 mm; HL = 10.0–10.7 mm, HW = 2.3–2.6 mm. Female: FL = 11.2–12.1 mm, FW = 2.5–2.8 mm; HL = 10.4–11.1 mm, HW = 2.4–2.7 mm.

Description. Male: Head (Figs 20B, 21B, D): Frons, vertex, occiput and ocellar triangle blackish brown; rostrum dark brown, with labrum blackish brown. Maxillary and labial palps dark brown, with distal segments darker. Antenna blackish brown. **Thorax** (Figs 20B, 21B, D): Pronotum black, with 10–16 stout setae along anterior margin. Meso- and metanotum black, without pale mesal stripe; scutella blackish brown. Pleura yellow. Legs pale yellowish brown with distal tarsomere black. **Wings**

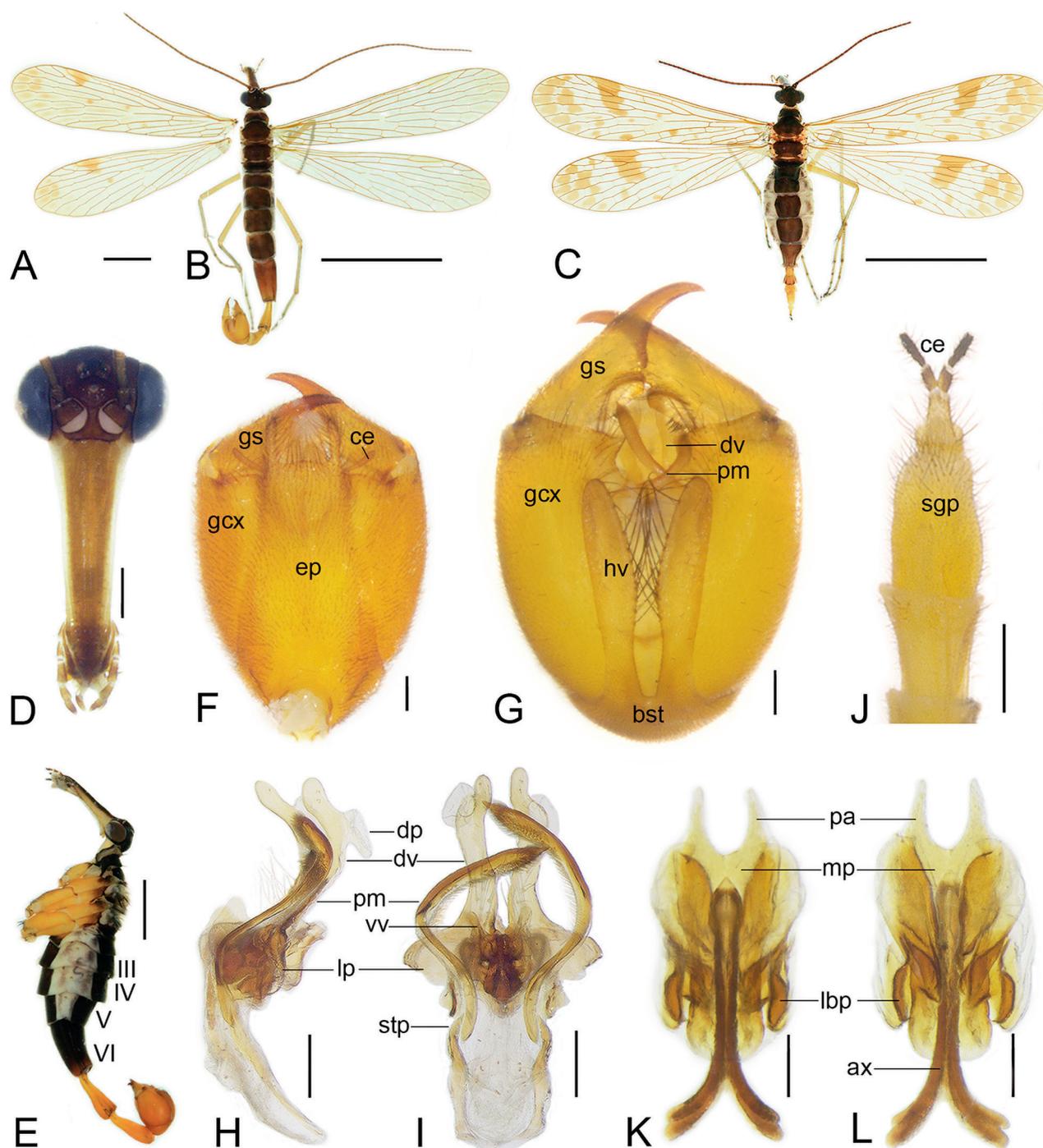


Figure 21. *Panorpa stigmosa* Zhou, 2006 from Yulong Snow Mountain (A) and Weixi (B–L), Yunnan. A–B, D–I. Male. A. Left forewing. B. Habitus, dorsal view (removing left forewing). D. Head, frontal view. E. Habitus, lateral view. F–G. Genital bulb, dorsal and ventral views. H–I. Aedeagal complex, lateral and ventral views. C, J–L. Female. C. Habitus, dorsal view. J. Terminalia, ventral view. K–L. Medigynium, ventral and dorsal views. Scale bars: B–C = 5 mm; D = 0.5 mm; A, E = 2 mm; F–L = 0.2 mm.

(Figs 20B, 21A–B): Membrane hyaline, with markings dark brown to black brown. Wing markings variable: only with pterostigma in some males; scattered into series of spots in most individuals. Forewing apical band broad, split into series of spots arranged in two rows; pterostigmal band broad, complete anteriorly, scattered into series of small spots posteriorly; marginal spot represented by small rounded spot between R and M; basal band incomplete, reduced to irregular spot usually between CuA and CuP; basal spot usually faint or absent. **Abdomen** (Figs

20B, 21B, E): T2–T5 black. Notal organ of T3 covering acute postnotal organ of T4. A6 cylindrical with basal two-thirds black and distal one-third reddish brown. A7 and A8 yellowish brown, constricted basally. **Genitalia** (Fig.21E–I): Genital bulb oval, yellowish brown. Epanandrium long, broad, slightly tapered towards deep square terminal emargination, bearing numerous long dense setae. Hypandrium with shortened basal stalk and pair of hypovalves; hypovalves broadened from middle, extending to four-fifths length of gonocoxites, bearing row

of long black bristles along inner margin of distal half. Gonocoxite bearing 3–5 long setae on inner apex ventrally, inner margin bearing acute protuberance. Gonostylus with obtuse triangular median tooth and large basal cup on inner margin. Parameres crossed, reaching apex of gonocoxites. Dorsal valves of aedeagus with enlarged dorsal process on subapical portion dorsally. Ventral valves greatly shortened. Lateral processes distinct, triangular.

Distribution. China: Guizhou; Yunnan.

Remarks. This species was described from a single female specimen from Chishui, Guizhou with prominent scattered wing markings. The specimens obtained from Yunnan match the characters of *P. stigmosa*. Here, the male of this species is described for the first time.

Panorpa typicoides Cheng, 1949

Panorpa typicoides Cheng, 1949: 143, figs 3, 13, 14, 28 & 31. Type locality: “Tachielu, Sikang” [now Kangding, Sichuan], China; Cheng, 1957: 40, figs 26, 36, 39, 66, 67, & 276; Wang & Hua, 2018: 416, figs 5-159-1–5-159-2.

Diagnosis. This species can be readily recognized by the following characters: (1) wing markings well-developed, forewing apical band with two hyaline spots inside; pterostigmal band complete, with broad basal branch and connected or detached thin apical branch; marginal spot large; basal band split into two spots; basal spot prominent; (2) meso- and metanotum black, with broad pale mesal stripe; in males, (3) gonocoxites with cluster of long setae along oblique inner apex ventrally; (4) parameres crossed mesally, twisted in S-shape; in females, (5) main plate of medigynium twice as long as posterior arms; axis extended beyond main plate for half of its length anteriorly.

Material examined. CHINA – Sichuan Prov. • 1♂ (Holotype); “Tachielu” [now Kangding]; 5000–8500 ft; 27 Aug. 1939; Fung Ying Cheng, Io Chou & Tein Ho Hei leg. • 1♀ (Paratype); same data as holotype • 1♀; Kangding; 2500 m a.s.l.; 28 May 1983; Yuan-Qing Chen leg. • 1♂, 1♀; Kangding; 2650 m a.s.l.; 29 May 1983; Shu-Yong Wang leg. • 1♀; Kangding; 2600 m a.s.l.; 4 Jun. 1983; Yuan-Qing Chen leg. • 4♀♀; Kangding, Paomashan; 30°02'41"N, 101°57'40"E; 2600 m a.s.l.; 27 Jun. 2019; Ning Li & Lu Liu leg. • 1♂; Kangding, Jintang; 30°25'33"N, 102°17'03"E; 2200 m a.s.l.; 5 Jul. 2019; Ning Li leg.

Measurements. Male: FL = 12.1–13.1 mm, FW = 2.9–3.2 mm; HL = 11.1–12.2 mm, HW = 2.8–3.0 mm. Female: FL = 12.3–13.9 mm, FW = 3.0–3.3 mm; HL = 11.3–13.1 mm, HW = 2.8–3.2 mm.

Distribution. China: Sichuan.

Remarks. This species resembles *P. jinchuana*, but is different from the latter by the posterior arms half (cf. one-third) length of the main plate.

Panorpa uncinata sp. nov.

Fig. 22

Diagnosis. The new species can be recognized by the following features: (1) forewing with broad apical band occasionally bearing two inner hyaline spots; pterostigmal band with broad basal branch and thin apical branch; marginal spot narrow or reduced; basal band broad; basal spots extremely reduced and faint (Fig. 22A–B); (2) meso- and metanotum black, with narrow yellow brown mesal stripe (Fig. 22A–B); (3) gonocoxites with approximately four stout setae on inner apex ventrally (Fig. 22F); (4) paramere intensively curved, hook-like on apical half, reaching two-thirds of gonocoxite (Fig. 22G); (5) main plate of medigynium broad; a pair of lateral basal plates extended from base to middle of main plate; extended beyond main plate for half of its length anteriorly (Fig. 22K–L).

Etymology. The specific name is derived from the Latin *uncinata* (hooked), referring to the hooked parameres.

Material examined. Holotype: CHINA – Shanxi Prov. • ♂; Yuncheng, Shunwangping; 2000 m a.s.l.; 30 Jun. 2019; Kai Gao leg. Paratypes: CHINA – Shanxi Prov. • 1♀; same data as for holotype. • 1♂, 2♀♀; Linfen, Anziping Forest Farm; 1800 m a.s.l.; 1 Jul. 2019; Kai Gao leg. • 2♂♂, 2♀♀; Huozhou, Qiliyu; 2 Jul. 2019; Kai Gao leg. – Shaanxi Prov. • 1♀; Ankang, Zhenping; 18 Aug. 2018; Lin Lyu leg. – Henan Prov. • 2♂♂; Jiyuan, Wangwushan; 1700 m a.s.l.; 29 May 2019; Kai Gao leg. – Hubei Prov. • 1♂; Shennongjia, Yemahe; 1600 m a.s.l.; 29 Jul. 2016; Ji-Shen Wang leg. • 1♂; Badong, Tiechanghuang; 8 Jun. 2016; Ji-Shen Wang leg.

Measurements. Male: FL = 12.1–12.9 mm, FW = 3.2–3.4 mm; HL = 10.9–11.5 mm, HW = 3.1–3.3 mm. Female: FL = 12.1–13.6 mm, FW = 3.1–3.4 mm; HL = 11.0–12.3 mm, HW = 2.9–3.2 mm.

Description. Male: Head (Fig. 22A, C): Frons, vertex and occiput yellowish brown. Black band through ocellar triangle not extending to compound eyes. Rostrum yellow, with labrum dark brown. Maxillary and labial palps mostly brown, with distal segments dark brown. Antennal scape yellowish brown basally and dark brown apically; flagellum dark brown, filiform, with 33–38 flagellomeres. **Thorax** (Fig. 22A, D): Pronotum black, with 10–12 stout setae along anterior margin. Meso- and metanotum black, with narrower yellow brown mesal stripe; scutella yellow brown. Pleura pale yellow. Legs light yellowish brown, with distal tarsomere blackish. **Wings** (Fig. 22A): Membrane hyaline, with markings dark brown. Forewing with apical band broad, bearing one or two hyaline spots, smaller one between R_{2b} and R_3 , and larger one between R_5 and M_2 ; pterostigmal band complete, with basal branch approximately twice as wide as apical branch; marginal spot variable: slender; split into two spots, not extended to M ; or greatly reduced in some individuals; basal band broad; basal spots greatly reduced. Hindwing similar to forewing in coloration and pattern, but with

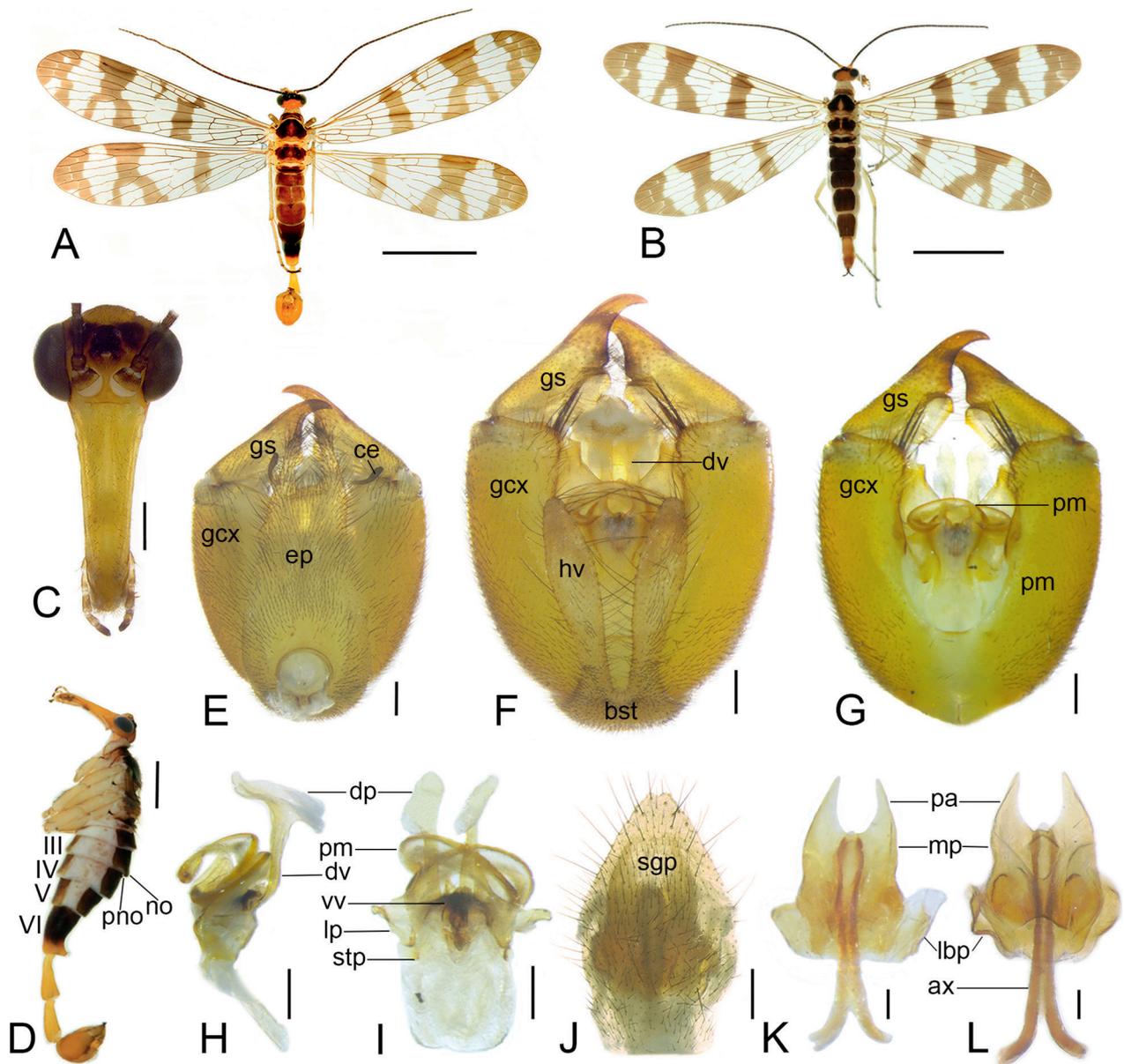


Figure 22. *Panorpa uncinata* sp. nov. from Yuncheng (A) and Huozhou (B–L), Shanxi. **A, C–I.** Male. **A.** Habitus, dorsal view. **C.** Head, frontal view. **D.** Habitus, lateral view. **E–G.** Genital bulb, dorsal, ventral, and ventral (removing hypandrium) views. **H–I.** Aedeagal complex, lateral and ventral views. **B, J–L.** Female. **B.** Habitus, dorsal view. **J.** Subgenital plate, ventral view. **K–L.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C = 0.5 mm; D = 2 mm; E–L = 0.2 mm.

marginal and basal spots much reduced, apical band usually bearing one hyaline spot in posterior portion. **Abdomen** (Fig. 22A, D): T2–T5 black brown to black. Notal organ of T3 flat triangular, covering acute postnotal organ on T4. A6 with basal two-thirds black, distal third yellow, projected and setose on dorsal apex. A7 and A8 uniformly yellow, slightly constricted basally. **Genitalia** (Fig. 22E–I): Genital bulb elliptical, yellow. Epandrium broad, with deep terminal emargination, bearing numerous setae. Cercus clavate, yellow brown basally and dark brown distally. Hypandrium with shortened basal stalk and pair of hypovalves; hypovalves broad, with basal half narrower, extending to three-quarters length of gonocoxites, bearing row of long bristles along inner margin. Gonocoxite mostly with four stout setae on inner apex ventrally. Gonostylus with obtuse triangular median tooth

and large basal cup. Parameres slender, crossed mesally, intensively curved, hook-like, reaching two-thirds length of gonocoxites. Dorsal valves of aedeagus elongate, each with enlarged dorsal process on subapical portion dorsally. Ventral valves shortened. Lateral processes distinct, triangular. — **Female:** Similar to male in wing markings (Fig. 22B). **Genitalia** (Fig. 22J–L): Subgenital plate ligulate, narrow basally, broadest medially, and narrowed towards apex, with shallow V-shaped terminal emargination, bearing long setae on caudal and lateral margins. Medigynium with well-developed broad main plate. Pair of lateral basal plates extended from base to middle of main plate. Posterior arm one-third length of main plate, forming broad U-shaped emargination. Axis bifurcated, elongated, extended anteriorly beyond main plate for half of its length, with posterior slightly extruded.

Distribution. China: Henan, Hubei, Shaanxi, Shanxi.

Remarks. This new species resembles *P. yangi*, especially in the intensively curved, hook-like parameres, but can be readily differentiated from the latter by: (1) meso- and metanotum black, bearing a narrow (cf. very broad) yellow mesal stripe; (2) basal spots extremely reduced and faint (cf. large and distinct).

Panorpa yangi Chou, 1981

Panorpa yangi Chou in Chou et al., 1981: 8, figs 24–27. Type locality: Qingquangou, Ganquan, Shaanxi, China; Wang & Hua, 2018: 420, figs 5-161-1–5-161-2.

Diagnosis. This species can be recognized from by the following features: (1) forewing with broad apical band bearing one hyaline spot posteriorly; pterostigmal and basal bands complete, broad; marginal and basal spots large, conspicuous (2) meso- and metanotum mostly yellowish brown and anterior margin blackish brown laterally; in males, (3) ventral termination of gonocoxites wavy, bearing 3–6 long setae on inner portion; (4) parameres very slender, intensively curved, hook-like on apical halves, reaching two-thirds length of gonocoxites; in females, (5) main plate of medigynium approximately rectangular, twice as long as wide; a pair of simple lateral basal plates extending from base to middle of main plate; axis extended beyond main plate for two-thirds of its length anteriorly.

Material examined. CHINA – Shaanxi Prov. • 1♂ (Holotype); Ganquan, Qingquangou; 13 Aug. 1971; Chi-Kun Yang leg.; • 2♂♂ (Paratypes); same data as holotype • 5♂♂, 2♀♀; Shibao Forest Farm, Dayuangou; 1433 m a.s.l.; 5 Aug. 2016; Kai Gao & Shi-Xiang Jiang leg. • 1♀; Qigan Temple; 35°44'59"N, 109°53'33"E; 1622 m a.s.l.; 4 Jul. 2020; Kai Gao leg. • 12♂♂, 10♀♀; Fuxian, Zhangjiawan Forest Farm; 36°3'36"N, 108°51'25"E; 1027 m a.s.l.; 28 Jul. 2016; Kai Gao & Shi-Xiang Jiang leg. • 4♂♂, 11♀♀; Niuwu Forest Farm, Shaowan Reservoir; 36°5'17"N, 109°30'02"E; 1042–1078 m a.s.l.; 1 Aug 2016; Kai Gao & Shi-Xiang Jiang leg. • 1♂; Xunyi, Shimen, Liangjiawan; 35°3'43"N, 108°32'16"E; 1520 m a.s.l.; 3 Jul. 2019; Meng-Di Li leg. • 3♂♂, 4♀♀; Ziwuling; 1–4 Jul. 2019; Jian Shen leg.

Measurements. Male: FL = 9.4–10.6 mm, FW = 2.4–2.6 mm; HL = 8.4–9.5 mm, HW = 2.3–2.5 mm. Female: FL = 9.6–11.5 mm, FW = 2.5–2.8 mm; HL = 8.7–10.5 mm, HW = 2.4–2.7 mm.

Distribution. China: Shaanxi.

Remarks. This species resembles *P. neospinosa* in wing markings, but can be differentiated from the latter by meso- and metanotum mostly yellowish brown (cf. blackish brown with pale yellow mesal stripe) and hook-like (cf. S-shaped) parameres.

Panorpa yaoluopingensis sp. nov.

Fig. 23

Diagnosis. This species can be readily recognized by the following characters: (1) forewing with apical band broad, bearing large hyaline spot on posterior margin; pterostigmal band with basal branch broad, and apical branch greatly reduced; basal band reduced into large spot near anal margin; marginal spot absent or as 1–3 small spots (Fig. 23A–B); (2) meso- and metanotum blackish brown, with prominent pale yellow mesal stripe (Fig. 23A–B); in males, (3) inner apex of gonocoxites oblique, with 6–8 dark brown setae (Fig. 23E); (4) parameres twisted in S-shape, crossed mesally (Fig. 23E–F); in females, (5) medigynium with broad main plate and pair of lateral basal plates on middle portion; posterior arms one-third as long as main plate, axis extended beyond main plate for half of its length, with posterior slightly extruded (Fig. 23J–K).

Etymology. The specific name refers to the type locality, Yaoluoping, Yuexi, Anhui.

Material examined. Holotype: CHINA – Anhui Prov. • ♂; Yuexi, Yaoluoping National Nature Reserve; 18 Aug. 2013; Qiu-Lei Men leg. Paratypes: CHINA – Anhui Prov. • 3♂♂, 5♀♀; same data as holotype.

Measurements. Male: FL = 11.4–12.0 mm, FW = 2.9–3.1 mm; HL = 10.3–11.2 mm, HW = 2.8–3.0 mm. Female: FL = 11.3–12.1 mm, FW = 3.1–3.2 mm; HL = 10.1–11.1 mm, HW = 3.0–3.1 mm.

Description. Male: Head (Fig. 23A, C): Frons, ocellar triangle, vertex and occiput dark brown. Rostrum yellowish; labrum yellowish brown. Labial and maxillary palps yellowish basally, gradually darkening toward apex, with apical segment dark brown. Antennal scape yellowish brown; flagellum brownish black, filiform with 39–42 flagellomeres. **Thorax** (Fig. 23A, D): Pronotum dark brown, with 10–14 black setae along anterior margin; meso- and metanotum dark brown, with pale yellow fusiform mesal stripe; scutella pale yellow. Pleura yellow. Legs yellowish brown, with distal tarsomere dark brown. **Wings** (Fig. 23A): Membrane hyaline, with brown markings. Forewing with apical band broad, bearing large hyaline spot on posterior margin; pterostigmal band with basal branch broad and apical branch greatly reduced; marginal spot absent or divided into 1–3 small spots; basal band reduced into large spot from M to anal margin; basal spot absent. Hindwing similar to forewing, but with relatively reduced markings. Marginal spot absent or faint; basal band smaller, usually not reaching anal margin. **Abdomen** (Fig. 23A, D): T2–T5 dark to black brown. Notal organ of T3 flat, covering acute post-notal organ on T4. A6 dark brown on basal two-thirds and yellow distally, projected on dorsal apex, with sparse long yellow setae. A7 and A8 elongate, uniformly yellow, constricted basally. **Genitalia** (Fig. 23E–G): Genital bulb oval, yellow. Epandrium broad basally, with square,

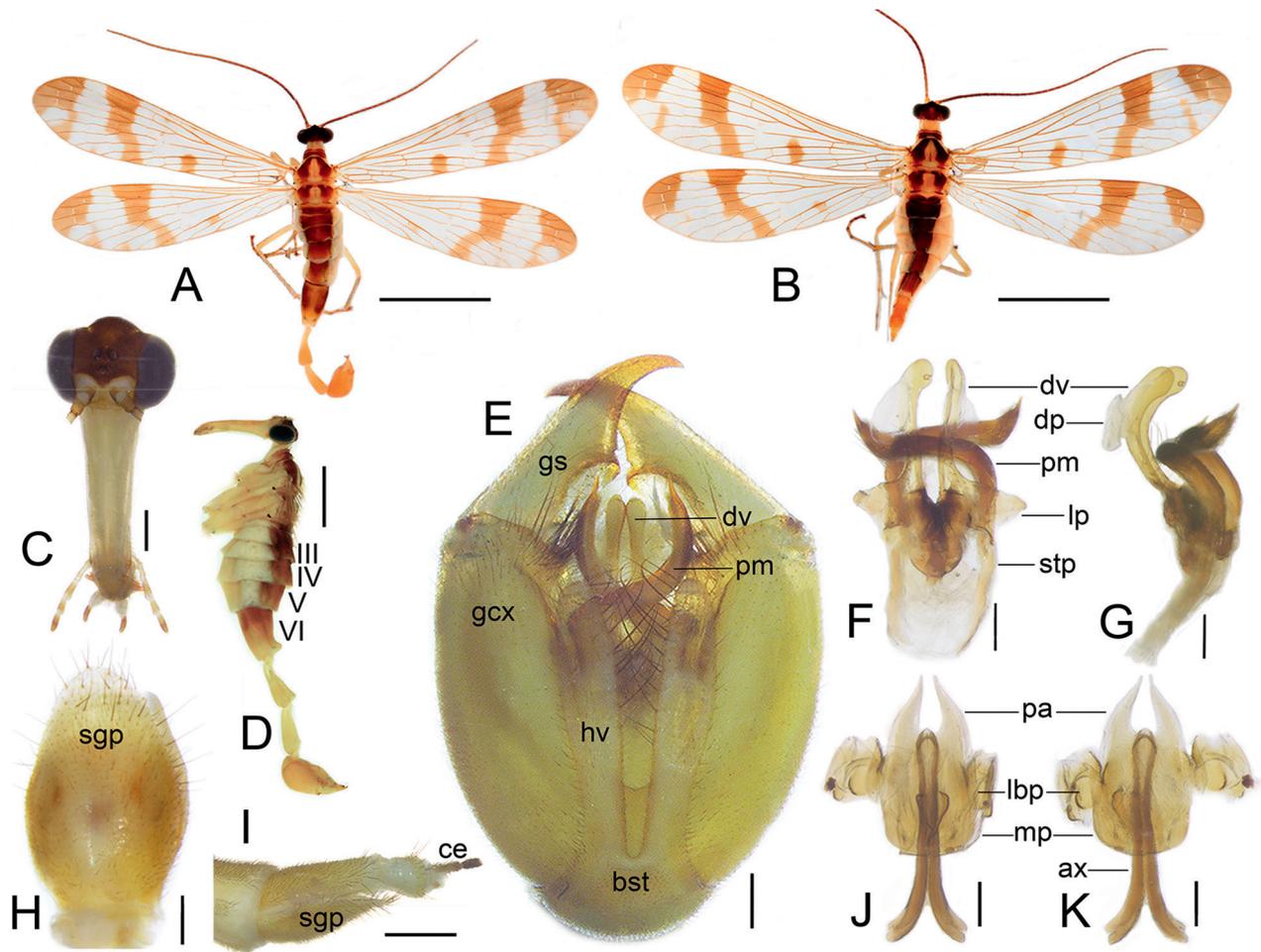


Figure 23. *Panorpa yaoluopingensis* sp. nov. from Yuexi, Anhui. **A, C–G.** Male. **A.** Habitus, dorsal view. **C.** Head, frontal view. **D.** Habitus, lateral view. **E.** Genital bulb, ventral views. **F–G.** Aedeagal complex, dorsal and lateral views. **B, H–K.** Female. **B.** Habitus, dorsal view. **H–I.** Subgenital plate, ventral and lateral views. **J–K.** Medigynium, ventral and dorsal views. Scale bars: A–B = 5 mm; C, I = 0.5 mm; D = 2 mm; E–H, J–K = 0.2 mm.

deep terminal emargination, bearing dense setae distally. Cercus long clavate, slightly expanded towards apex. Hypandrium with shortened basal stalk, with pair of long strip-like hypovalves; each hypovalve rounded at apex, bearing long bristles along apical half on inner margin, not reaching apex of gonocoxites. Inner margin of gonocoxite oblique apically, with 6–8 stout setae. Gonostylus with large basal cup and obtuse triangular median tooth on inner margin. Parameres twisted in S-shape, crossed mesally, bearing dense short spines on inner margin and whole distal portion, with apex pointed. Aedeagus with ventral valves greatly shortened; dorsal valves greatly elongated, strongly curved dorsally, constricted basally and expanded towards rounded apex; bearing bundle of long hairs ventrally on basal third and enlarged dorsal process near middle. Lateral process distinctly triangular. — **Female:** Similar to male in wing patterns (Fig. 23B). **Genitalia** (Fig. 23H–K): Subgenital plate broad subbasally, narrowed towards apex, bearing long setae on caudal and lateral margins. Medigynium with broad main plate, pair of lateral basal plates on middle portion; posterior arms one-third as long as length of main plate, forming “water drop”-shaped emargination; axis with pair of small sclerotized structures near central position of main

plate, extended beyond main plate for approximately half of its length, with posterior slightly extruded.

Distribution. China: Anhui.

Remarks. This new species resembles *P. huayuani* and *P. sexspinosa* in general appearance, but can be readily differentiated from the latter two species by the following characters: (1) wing markings with basal band reduced into a large spot extending from M to anal margin in forewing (cf. complete); (2) occiput dark brown (cf. yellowish brown).

Phylogenetic analyses

Maximum parsimony analysis yielded eight most parsimonious trees, with tree length of 128, consistency index (CI) of 0.70 and retention index (RI) of 0.88. The strict consensus tree is shown in Figure 24 with bootstrap values and characters annotated. The monophyly of the newly defined *P. davidi* group is well supported (MPBS

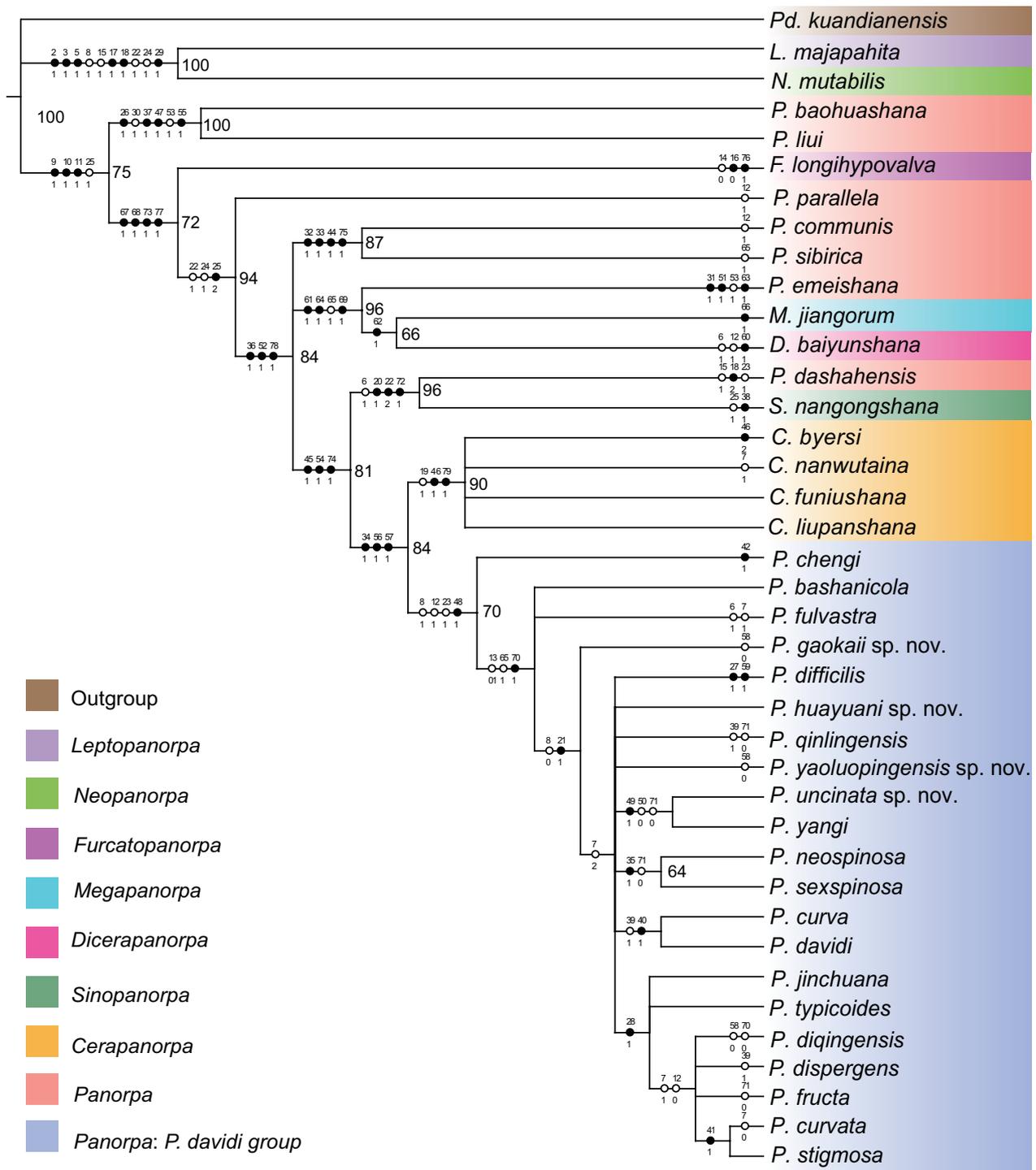


Figure 24. Strict consensus tree obtained from most parsimony (MP) analysis. MP bootstrap values (MPBS > 50) are indicated at internal nodes.

= 70) by three homoplasies (characters: 8:1, 12:1, 23:1) and one synapomorphy (char. 48:1) (Fig. 24). The sister group relationship between the *P. davidi* group and *Cerapanorpa* is well supported (MPBS = 84) by three synapomorphies (characters: 34:1, 56:1, and 57:1). The relationships among species of the *P. davidi* group are usually weakly supported (MPBS < 50) in the MP analysis. *Panorpa chengi* is the sister taxon to other species of the *P. davidi* group. *Panorpa fulvastra* and *P. bashanicola* occupy the more basal lineages. One monophyletic clade consists of all four species from Yunnan and Guizhou, *P.*

diqingensis, *P. dispergens*, *P. stigmosa*, *P. curvata*; and three species from Sichuan, *P. fructa*, *P. typicoide*, and *P. jinchuana* (Fig. 24).

The phylogenetic trees are similar in topology between the MP and ML analyses, although the ML tree (Fig. 25) has higher support values than the strict consensus tree of the MP trees. The ML tree shows that the *P. davidi* group is a well-supported monophyletic group (MLBS = 94) and is sister to *Cerapanorpa* (MLBS = 95). The incongruence between the analyses is restricted to the relationship of some species of the *P. davidi* group.

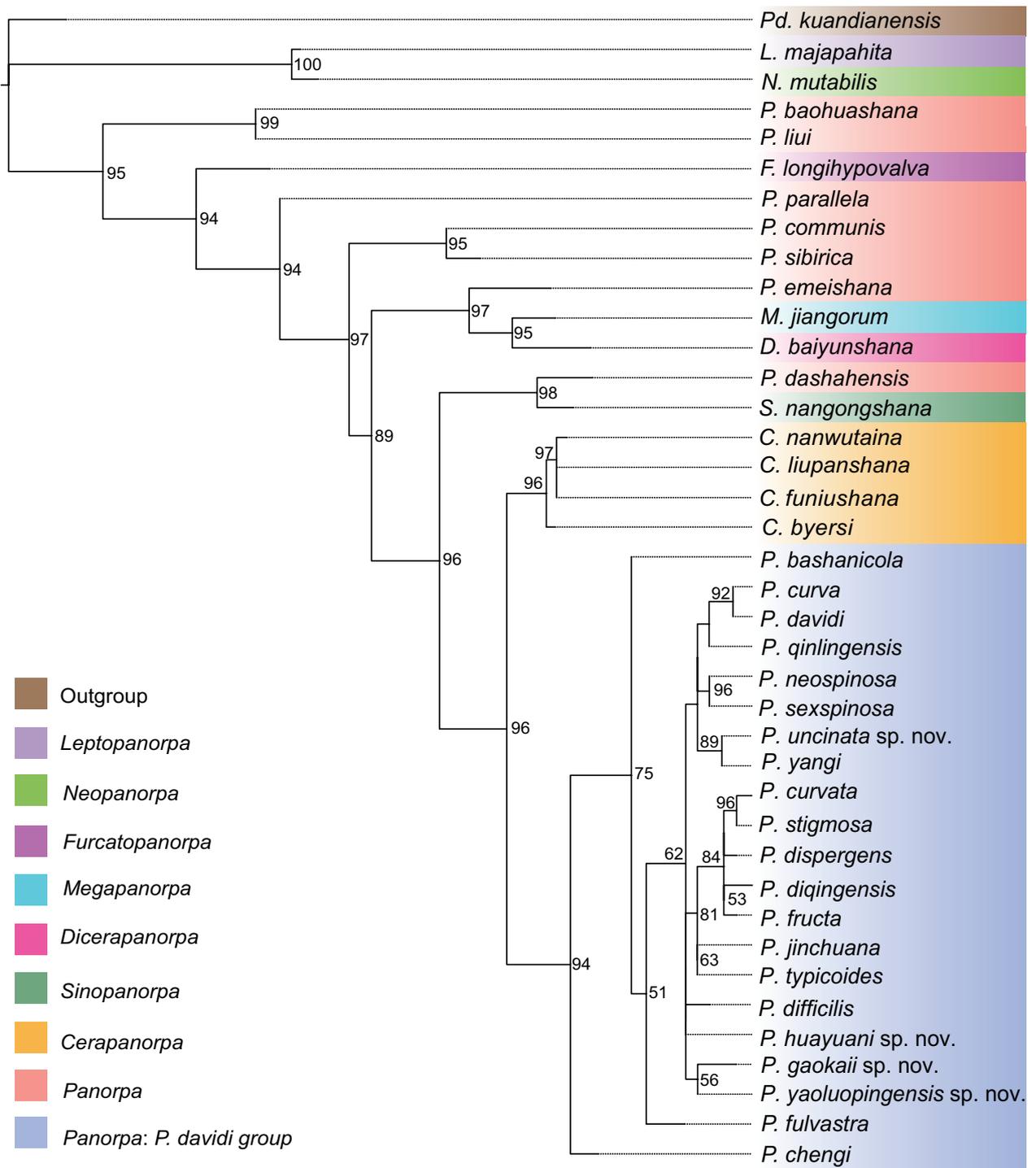


Figure 25. Phylogenetic tree obtained from maximum likelihood (ML) analysis. ML bootstrap values (MLBS > 50) are indicated at internal nodes.

Based on the cladograms, *Sinopanorpa* Cai & Hua, *Furcatanorpa* Ma & Hua, *Dicerapanorpa* Zhong & Hua, *Cerapanorpa* Gao, Ma & Hua, and *Megapanorpa* Wang & Hua are all nested within *Panorpa* Linnaeus (Figs 24–25). The Chinese species of *Panorpa* without anal horn in males were previously treated as the *P. davidi* group, which is here reconfirmed to be paraphyletic, since they are scattered on the phylogenetic tree of the Panorpidae (Figs 24–25). *Panorpa sibirica* and *P. communis* are well-supported sister taxa, distant from the newly defined *P. davidi* group.

Discussion

In the present study, phylogenetic reconstruction was conducted for all the eight genera of Panorpidae based on 79 morphological characters. The *P. davidi* group sensu Carpenter (1938) and Cheng (1949, 1957) is reconfirmed to be a paraphyletic group. *Panorpa davidi* and 20 species are clustered into a well-supported monophyletic clade, sister group to *Cerapanorpa*. In the present study we newly defined the *P. davidi* group based on morphol-

ogy and phylogeny. Four new species are described and two synonyms are proposed. Consequently, 21 species are currently recognized in the *P. davidi* group.

In a morphological phylogenetic analysis, Ma et al. (2012) found that three species of the *P. davidi* group (*P. chengi*, *P. fulvastra*, and *P. sexspinosa*) did not form a monophyletic group, possibly owing to insufficient characters encoded. In contrast molecular phylogenetic analyses by Hu et al. (2015) and Miao et al. (2019) found six species of this group formed a monophyletic group. Based on our present phylogenetic study, the monophyly of the newly defined *P. davidi* group is confirmed.

Previously, the *P. davidi* group sensu Carpenter (1938) and Cheng (1949, 1957) consisted of the Chinese species that lack the anal horn in males. Herein, however, we assign only 21 species to the *P. davidi* group. These species share a similar morphology, especially the male and female genitalia. According to recent phylogenetic analyses (Hu et al. 2015; Miao et al. 2017, 2019; Jiang et al. 2019; Wang and Hua 2020), this new definition of the *P. davidi* group constitutes a well-supported monophyletic group, sister to *Cerapanorpa*.

The species of the *P. davidi* group are normally found in the groundcover of moist forests in mountainous regions, with a broad spectrum of elevations. *Panorpa difficilis* inhabits ranges from 230 to 2050 m in elevation, whereas *P. fructa* is found only at high-altitude from 3300 to 4000 m in the Hengduan Mountains, exhibiting strong cold-adaptation. The *P. davidi* group not only exhibits a discrete distribution in the Taihang and Dabie Mountains, but also displays a circular distribution pattern around the Sichuan Basin, similar to that of *Dicerapanorpa* (Hu and Hua 2020). It would be a fascinating issue to explore the distribution pattern and mechanism in future research.

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References

- Bremer K (1994) Branch support and tree stability. *Cladistics* 10: 295–304. <https://doi.org/10.1006/clad.1994.1019>
- Byers GW (1993) Autumnal Mecoptera of southeastern United States. *University of Kansas Science Bulletin* 55: 57–96.
- Byers GW, Thornhill R (1983) Biology of the Mecoptera. *Annual Review of Entomology* 28: 203–228. <https://doi.org/10.1146/annurev.en.28.010183.001223>
- Cai LJ, Hua BZ (2009) Morphology of the immature stages of *Panorpa qinlingensis* (Mecoptera: Panorpidae) with notes on its biology. *Entomologica Fennica* 20: 215–224. <https://doi.org/10.33338/ef.84480>
- Cai LJ, Huang PY, Hua BZ (2008) *Sinopanorpa*, a new genus of Panorpidae (Mecoptera) from the Oriental China with descriptions of two new species. *Zootaxa* 1941: 43–54. <https://doi.org/10.11646/zootaxa.1941.1.4>
- Carpenter FM (1931) Revision of the Nearctic Mecoptera. *Bulletin of the Museum of Comparative Zoology* 72: 205–277.
- Carpenter FM (1938) Mecoptera from China, with descriptions of new species. *Proceedings of the Entomological Society of Washington* 40: 267–281.
- Cheng FY (1949) New species of Mecoptera from northwest China. *Psyche* 56: 139–173.
- Cheng FY (1957) Revision of the Chinese Mecoptera. *Bulletin of the Museum of Comparative Zoology* 116: 1–117.
- Chou I, Ran RB, Wang SM (1981) Studies on the classification of Chinese Mecoptera (I, II). *Entomotaxonomia* 3: 1–18.
- Esben-Petersen P (1921) Mecoptera. Monographic revision: Collections zoologiques du Baron Edm. de Selys Longchamps. *Catalogue systematique et descriptif* 5: 1–172.
- Felsenstein J (1985) Phylogenies and the comparative method. *The American Naturalist* 125: 1–15. <https://doi.org/10.1086/284325>
- Gao K, Hua BZ (2019) Revision of the genus *Cerapanorpa* (Mecoptera: Panorpidae) with descriptions of four new species. *European Journal of Taxonomy* 537: 1–23. <https://doi.org/10.5852/ejt.2019.537>
- Gao C, Ma N, Hua BZ (2016) *Cerapanorpa*, a new genus of Panorpidae (Insecta: Mecoptera) with descriptions of three new species. *Zootaxa* 4158: 93–104.
- Goloboff PA, Farris JS, Nixon KC (2008) TNT, a free program for phylogenetic analysis. *Cladistics* 24: 774–786. <https://doi.org/10.1111/j.1096-0031.2008.00217.x>
- Hu GL, Hua BZ (2020) Review of the scorpionfly genus *Dicerapanorpa* Zhong & Hua (Mecoptera: Panorpidae), with descriptions of two new species. *European Journal of Taxonomy* 711: 1–13. <https://doi.org/10.5852/ejt.2020.711>
- Hu GL, Yan G, Xu H, Hua BZ (2015) Molecular phylogeny of Panorpidae (Insecta: Mecoptera) based on mitochondrial and nuclear genes. *Molecular Phylogenetics and Evolution* 85: 22–31. <https://doi.org/10.1016/j.ympev.2015.01.009>
- Hua BZ, Sun GH, Li ML (2001) Sichuan Panorpidae (Mecoptera) kept in the Tianjin Natural History Museum. *Entomotaxonomia* 23: 120–123.
- Hua Y, Tao SH, Hua BZ (2018) An enigmatic new species of *Panorpa* Linnaeus from the Bashan Mountains (Mecoptera, Panorpidae). *ZooKeys* 777: 109–118. <https://doi.org/10.3897/zookeys.777.26056>
- Issiki S (1933) Morphological studies on the Panorpidae of Japan and adjoining countries and comparison with American and European forms. *Japanese Journal of Zoology* 4: 315–416.
- Jiang L, Hua BZ (2013) Morphology and chaetotaxy of the immature stages of the scorpionfly *Panorpa liui* Hua (Mecoptera: Panorpidae) with notes on its biology. *Journal of Natural History* 47: 41–42. <https://doi.org/10.1080/00222933.2013.791885>
- Jiang L, Hua BZ (2016) Morphology of the immature stages of *Panorpa macrostyla* Hua (Mecoptera: Panorpidae) with notes on its biology. *Acta Entomologica Sinica* 59: 1004–1012. <https://doi.org/10.16380/j.kcxb.2016.09.011>
- Jiang L, Hua Y, Hu GL, Hua BZ (2019) Habitat divergence shapes the morphological diversity of larval insects: insights from scorpionflies. *Scientific Reports* 9: 12708. <https://doi.org/10.1038/s41598-019-49211-z>
- Li N, Hua BZ (2020) Two new species of *Panorpa* (Mecoptera, Panorpidae) from the Hengduan Mountains in Yunnan, China. *Journal of*

- Asia-Pacific Entomology 23: 138–145. <https://doi.org/10.1016/j.aspen.2019.12.005>
- Linnaeus C (1758) *Systema Naturae*. Per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima, reformata. Holmiae, Laurentius Salvius, pp. 1–824. <https://doi.org/10.5962/bhl.title.542>
- Ma N, Cai LJ, Hua BZ (2009) Comparative morphology of the eggs in some Panorpidae (Mecoptera) and their systematic implication. *Systematics and Biodiversity* 7: 403–417. <https://doi.org/10.1017/S1477200009990107>
- Ma N, Liu SY, Hua BZ (2011) Morphological diversity of male salivary glands in Panorpidae (Mecoptera). *European Journal of Entomology* 108: 493–499. <https://doi.org/10.14411/eje.2011.064>
- Ma N, Zhong W, Gao QH, Hua BZ, (2012) Female genital plate diversity and phylogenetic analyses of East Asian Panorpidae (Mecoptera). *Systematics and Biodiversity* 10: 159–178. <https://doi.org/10.1080/14772000.2012.683459>
- Maddison WP, Maddison DR (2016). Mesquite: a modular system for evolutionary analysis. Version 3.61. <http://www.mesquiteproject.org/>
- Martynova OM (1957) Skorpionnitzy (Mecoptera) fauny SSSR II. Semejstvo Panorpidae. *Entomologischeskoe Obozreni* 36: 721–747.
- Miao Y, Ma N, Hua BZ (2017) Cytotaxonomy and molecular phylogeny of the genus *Cerapanorpa* Gao, Ma & Hua, 2016 (Mecoptera: Panorpidae). *Scientific Reports* 7: 4493. <https://doi.org/10.1038/s41598-017-04926-9>
- Miao Y, Wang JS, Hua BZ (2019) Molecular phylogeny of the scorpionflies Panorpidae (Insecta: Mecoptera) and chromosomal evolution. *Cladistics* 35: 385–400. <https://doi.org/10.1111/cla.12357>
- Navás L (1908) Neurópteros nuevos. *Memorias de la Real Academia de Ciencias y Artes de Barcelona* 6: 401–423.
- Navás L (1931) Decadas de insectos nuevos. *Revista de la Real Academia de Ciencias Exactas, Físicas y Naturales de Madrid* 26: 60–86.
- Nixon KC (2002) WinClada ver. 1.0000. Published by the Author, Ithaca, New York.
- Wang JS, Hua BZ (2018) A color atlas of the Chinese Mecoptera. Henan Science and Technology Press, Zhengzhou, pp. 315–420.
- Wang JS, Hua BZ (2020) Taxonomic revision and phylogenetic analysis of the enigmatic scorpionfly genus *Leptopanorpa* MacLachlan (Mecoptera: Panorpidae). *Journal of Zoological Systematics and Evolutionary Research* 58: 900–928. <https://doi.org/10.1111/jzs.12363>
- Wang JS, Gao XT, Hua BZ (2019) Two new species of the genus *Panorpa* (Mecoptera, Panorpidae) from eastern China and a new synonym. *ZooKeys* 874: 149–164. <https://doi.org/10.3897/zookeys.874.36314>
- Whiting MF (2002) Mecoptera is paraphyletic: multiple genes and phylogeny of Mecoptera and Siphonaptera. *Zoologica Scripta* 31: 93–104. <https://doi.org/10.1046/j.0300-3256.2001.00095.x>
- Willmann R (1977) Zur Phylogenie der Panorpiden Europas (Insecta, Mecoptera). *Zeitschrift für Zoologische Systematik und Evolutionsforschung* 15: 208–231.
- Willmann R (1989) Evolution und phylogenetisches System der Mecoptera (Insecta: Holometabola). *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* 554: 1–153.
- Zhong W, Hua BZ (2013) *Dicerapanorpa*, a new genus of East Asian Panorpidae (Insecta: Mecoptera: Panorpidae) with descriptions of two new species. *Journal of Natural History* 47: 1019–1046. <https://doi.org/10.1080/00222933.2012.752540>
- Zhou WB (2006) Mecoptera. In: Jin DC, Li ZZ (Eds) *Insects from Chishui Suoluo Landscape*. Guizhou Science and Technology Publishing House, Guiyang, pp. 273–375.

Supplementary material

File 1

Authors: Li N, Wang JS and Hua BZ (2021)

Data type: .doc

Explanation note: Seventy-nine morphological characters of adults were encoded.

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Link: <https://doi.org/10.3897/asp.79.e65179.suppl1>

File 2

Authors: Li N, Wang JS and Hua BZ (2021)

Data type: .doc

Explanation note: Data matrix of morphological characters.

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