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Research article

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Revision of the genus *Cerapanorpa* (Mecoptera: Panorpidae) with descriptions of four new species

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Abstract. The genus *Cerapanorpa* Gao, Ma & Hua, 2016 is taxonomically revised. *Cerapanorpa* is confirmed to be endemic to the mountain regions in central China. Nineteen species are recognized in the genus, including four new species: *Cerapanorpa baimaensis* sp. nov., *Cerapanorpa xuebaodinga* sp. nov., and *Cerapanorpa yanggashana* sp. nov. from the Minshan Mountains, and *Cerapanorpa taizishana* sp. nov. from the northeastern margin of the Qinghai-Tibetan Plateau. Six species are transferred from *Cerapanorpa* back to *Panorpa* Linnaeus, 1758. An updated key to species is presented.

Keywords. Biodiversity, central China, Minshan Mountains, scorpionfly, taxonomy.

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Introduction

The genus *Cerapanorpa* Gao, Ma & Hua, 2016 was erected for the *Panorpa centralis* group (Carpenter 1938; Cheng 1957) with *Panorpa obtusa* Cheng, 1949 as the type species (Gao *et al.* 2016). *Cerapanorpa* is primarily recognized by a single finger-like anal horn on the posterior margin of tergum VI in males, and a medigynium bearing two pairs of basal plates and a well-developed elongate axis in females (Gao *et al.* 2016; Miao *et al.* 2017). The species of *Cerapanorpa* have specific mating behaviors and copulatory strategies. The male usually secretes a salivary mass as a nuptial gift to attract the female prior to copulation, and uses its anal horn to clamp the female abdominal segment to maintain copulation (Tong *et al.* 2018). Their eggs are oval and bear polygonal net-like ridges on the chorion surface (Li *et al.* 2007; Ma *et al.* 2009). The saprophagous larvae are eruciform, possessing a pair of well-developed compound eyes (Chen *et al.* 2012) and eight pairs of abdominal prolegs, and usually overwinter as mature larvae in soil cavities (Li *et al.* 2007; Jiang & Hua 2015).

Twenty-two species were originally included in *Cerapanorpa*, which is distributed in central China and northeastern Asia, separately (Gao *et al.* 2016; Wang & Hua 2017). Soon after its establishment, *Cerapanorpa* was considered paraphyletic with *Panorpa* based on molecular phylogenetic and chromosomal data (Miao *et al.* 2019). The species of *Cerapanorpa* from central China have chromosome number $n = 22$, including *C. brevicornis* (Hua & Li, 2007), *C. byersi* (Hua & Li, 2007), *C. dubia* (Chou & Wang, 1981), *C. liupanshana* Gao, Ma & Hua, 2016, *C. nanwutaina* (Chou & Wang, 1981), *C. obtusa* (Cheng, 1949), *C. protrudens* Gao, Ma & Hua, 2016, *C. reni* (Chou & Wang, 1981) and *C. sinuata* Gao, Ma & Hua, 2016, whereas *P. acutipennis* Hua, 1998 from the Changbai Mountains in northeastern China has chromosome number $n = 23$ (Miao *et al.* 2017, 2019). The central Chinese species of *Cerapanorpa* form a monophyletic clade in phylogenetic analyses based on both morphological characters (Ma *et al.* 2012) and molecular data (Miao *et al.* 2017, 2019). In contrast, species from northeastern Asia are paraphyletic with *Panorpa* (Miao *et al.* 2019). Therefore, the genus *Cerapanorpa* needs a taxonomic revision.

Strictly speaking, the species of *Cerapanorpa* are primarily distributed in the Qinling-Bashan Mountains and their adjacent regions (Gao *et al.* 2016; Wang & Hua 2017). The westernmost end of Qinling-Bashan Mountains links with the Minshan Mountains and the northeastern margin of the Qinghai-Tibetan Plateau (QTP), respectively (Zhang *et al.* 2002). Mountains of the latter two regions are enigmatic and heterogeneous, generally harbour numerous neo-endemic species, and are renowned as crucial “biodiversity hotspots” in the northern hemisphere (Myers *et al.* 2000; Tang *et al.* 2006; Huang *et al.* 2006; Hu *et al.* 2019). Nevertheless, records of *Cerapanorpa* in the northeastern QTP, especially the Minshan Mountains, are considerably scarce.

Recently, four undescribed species of *Cerapanorpa* were discovered from these regions, and are described herein. We also utilized multiple characters to revise *Cerapanorpa*, reassessed its geographic distribution, and updated the identification key.

Material and methods

The specimens examined are preserved in 75% alcohol and stored at the Entomological Museum, Northwest A&F University, Yangling, China (NWAU) or Shanghai Normal University, Shanghai, China (SHNU). Specimens were observed and dissected under a Nikon SMZ1500 stereoscopic zoom microscope. Female genitalia were macerated in cold 6% NaOH solution for 3 min and rinsed with distilled water. Measurements of wings were conducted with a vernier calliper. Adult photographs were taken with a Nikon D7000 digital camera, other images were taken using a Scientific Digital micrography system ZEISS SteREO Discovery.V20 equipped with an Auto-montage imaging system AxioCam IC. All photographs were assembled with Adobe Photoshop CS4.

Abbreviations

A1 = the first abdominal segment (same as other abdominal segments)

T1 = the first tergum (same as other abdominal segments)

Repositories

NWAU = Entomological Museum, Northwest A&F University, Yangling, China

SHNU = Entomological Museum, Shanghai Normal University, Shanghai, China

Results

Class Insecta Linnaeus, 1758
 Order Mecoptera Packard, 1886
 Family Panorpidae Latreille, 1805

Genus *Cerapanorpa* Gao, Ma & Hua, 2016

Cerapanorpa Gao, Ma & Hua, 2016: 94. Type species: *Panorpa obtusa* Cheng, 1949.

Diagnosis

Cerapanorpa can be distinguished from other genera of Panorpidae by the following combination of characters: rostrum of adults slender; generally yellowish, brown and black frontally. Meso- and metanotum blackish brown to black. Wing membrane hyaline and held explanate V-shaped over

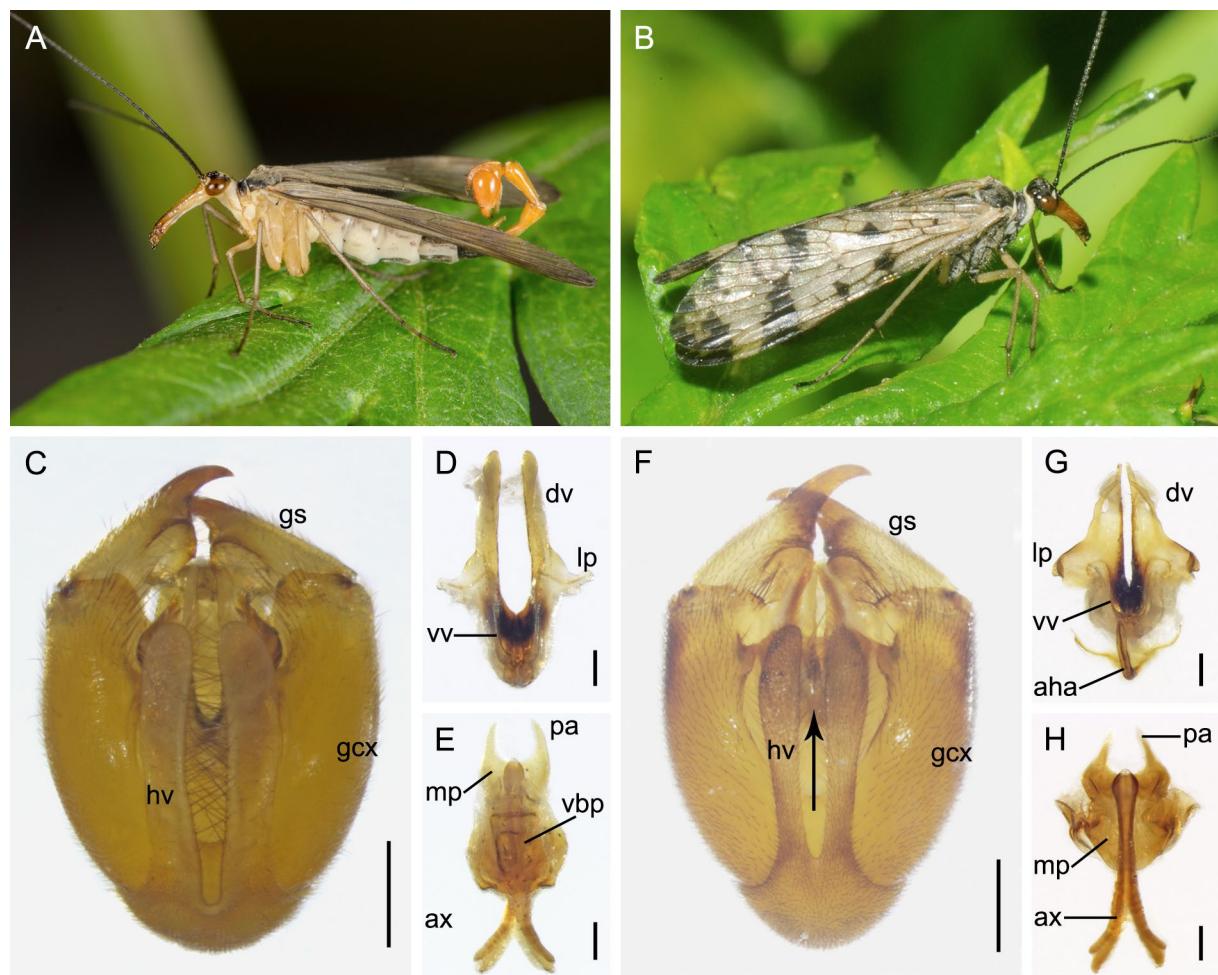


Fig. 1. Comparisons of *Cerapanorpa obtusa* (Cheng, 1949) (A, C–E) in central China and *Panorpa acutipennis* Hua, 1998 (B, F–H) from Northeast Asia. **A–B.** Male live habitus. **C, F.** Male genital bulb in ventral view. **D, G.** Aedeagus in ventral view, arrow indicates the aedeagal hamulus. **E, H.** Female medigynium in ventral view. Abbreviations: aha = aedeagal hamulus; ax = axis; dv = dorsal valve; gcx = gonocoxite; gs = gonostylus; hv = hypovalve; lp = lateral process; mp = main plate; pa = posterior arm; vbp = ventral basal plate; vv = ventral valve. Scale bars: C, F = 0.5 mm; D–E, G–H = 0.2 mm.

abdomen at rest (Fig. 1A). Notal organ on T3 short and semicircular; postnotal organ on T4 small, barb-shaped and pointed forward. T6 bearing a finger-like anal horn on posterior margin (Fig. 1A), T7 with a narrow groove on dorsal surface. Parameres differing in morphology, simple or seldom furcate, usually bearing spines along mesal margin (Fig. 1C). Aedeagus without aedeagal hamulus; ventral valves of aedeagus extremely short, membranous and transparent; dorsal valves elongated, curved ventrally and not bilobed, bearing a membranous dorsal process on its distal backside (Fig. 1D). Hypandrium (ninth sternum) almost completely represented by a pair of elongate hypovalves (Fig. 1C). Subgenital plate lingulate, slightly or deeply emarginate terminally, bearing long setae on distal portion. Medigynium of female extremely complicated, with a broad main plate, bearing a pair of separated dorsal basal plates on dorsal sides and membranous ventral basal plates on ventral sides (Fig. 1E).

Geographical distribution

Species of *Cerapanorpa* are exclusively restricted to the border between Palearctic and Oriental Regions in central China (Fig. 2). Their distribution ranges principally include the Qinling Mountains, the Bashan Mountains, the Liupan Mountains, the Minshan Mountains, the Zhongtiao Mountains, Mount Qiaoshan, Mount Huanglongshan and the northeastern margin of the QTP. Amongst these mountainous regions, the Qinling Mountains have the highest diversity, with a total of ten described species. The type species *C. obtusa* is widely distributed in the western Qinling Mountains, the Liupan Mountains, Mount Qiaoshan, Mount Huanglongshan and the northeastern margin of the QTP. The second widespread species *C. brevicornis* occurs widely in the Bashan Mountains, the western Qinling Mountains and the eastern Minshan Mountains. Other species are generally endemic to local limited range, present in a few sky islands in mountains.

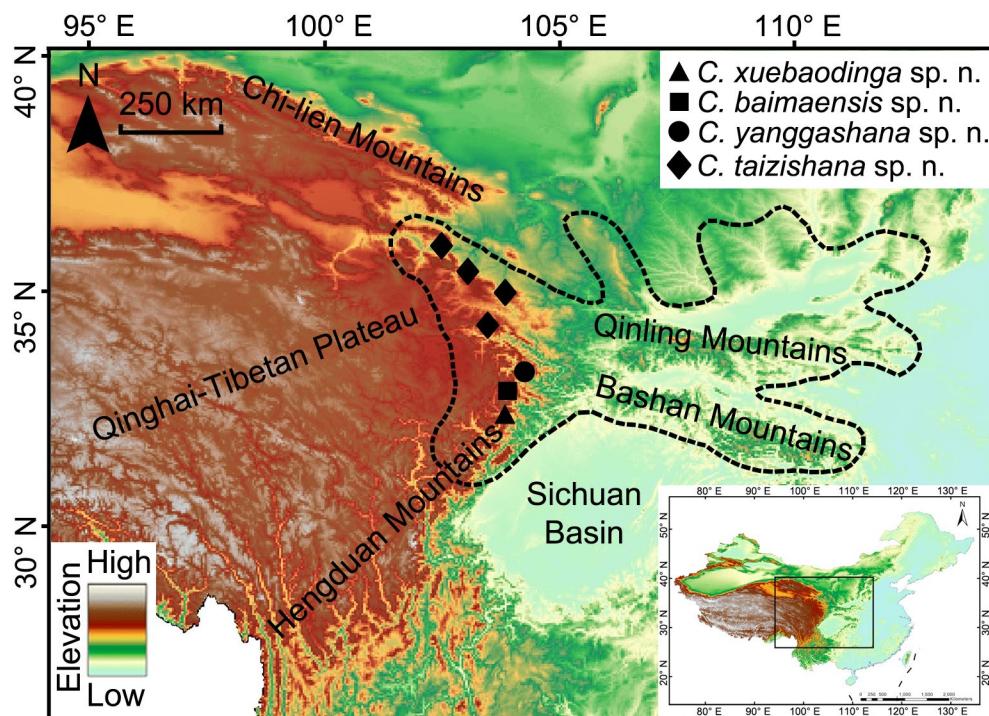


Fig. 2. Species distribution range of the genus *Cerapanorpa* Gao, Ma & Hua, 2016 and localities of new species. The limit shown is an approximation defined by collecting localities for specimens of *Cerapanorpa*. Triangle, *C. xuebaodinga* sp. nov. Square, *C. baimaensis* sp. nov. Circle, *C. yanggashana* sp. nov. Diamond, *C. taizishana* sp. nov.

Habitat

Species of *Cerapanorpa* are found in the central Chinese mountainous regions, with an altitude approximately from 1400 m to 2800 m. They generally live on the groundcover under broad-leaf forests (Fig. 3A), mixed forests (Fig. 3B), coniferous forests (Fig. 3C), and on the alpine shrub meadow (Fig. 3D). Their heterogenous microhabitats are universally cool or humid during their flight period.

Remarks

Gao *et al.* (2016) transferred *P. acutipennis* Hua, 1998 in northeastern China and four Japanese species, *P. arakavae* Miyaké, 1913, *P. cornigera* MacLachlan, 1887, *P. fulvicaudaria* Miyaké, 1910 and *P. gokaensis* Miyaké, 1910 to *Cerapanorpa* based mainly on the presence of a single anal horn on the posterior margin of T6 in males, but neglected other morphological features. However, these species can be notably differentiated from the true species of *Cerapanorpa* by the following features (Fig. 1B, F–H): rostrum short and thick (cf. rostrum slender); wings held roof-like (Fig. 1B) over the abdomen at rest (cf. explanate V-shaped (Fig. 1A)); aedeagus with aedeagal hamulus and bilobed dorsal valves (Fig. 1G), whereas the true species of *Cerapanorpa* lack these features (Fig. 1D). Furthermore, a recent multilocus phylogenetic analysis and cytogenetic evidence (Miao *et al.* 2019) also confirm that it is necessary to transfer these six species back to *Panorpa*.

It should be noted that *P. galloisi* Miyaké, 1911 was transferred to *Cerapanorpa* inadvertently by Gao *et al.* (2016) because it is not a valid species and had been synonymized with *P. cornigera* MacLachlan, 1887 by Penny & Byers (1979). Herein, we correct this unintentional error.

Panorpa horiensis Issiki, 1929 from Taiwan, China is also excluded in the amended *Cerapanorpa*. Gao *et al.* (2016) transferred *P. horiensis* to *Cerapanorpa* based only on the presence of a single anal horn on the posterior margin of T6 in males. However, *P. horiensis* shows conspicuous difference with the



Fig. 3. The habitats of *Cerapanorpa* Gao, Ma & Hua, 2016. **A.** Broad-leaf forest in the Bashan Mountains. **B.** Mixed forest in the Minshan Mountains. **C.** Coniferous forest in eastern margin of the QTP. **D.** Alpine shrub meadow in the Bashan Mountains.

Cerapanorpa species in appearance and genitalia. It can be easily distinguished from *Cerapanorpa* by the following features: vertex and occiput yellowish brown (Fig. 4A) (cf. blackish brown); A6 of male with a single reddish brown conical anal horn (Fig. 4B) (cf. yellowish brown finger-like anal horn); hypovalves of hypandrium broad (Fig. 4C) (cf. slender), with a few short stiff bristles on apex (cf. long bristles along inner margin); paramere stout and broad (Fig. 4C) (cf. slender); dorsal valves of aedeagus without outer apical process (cf. outer apical process unequal-sized). Hence, it is reasonable to transfer *P. horiensis* back to *Panorpa*.

A total of 19 valid species of *Cerapanorpa* are confirmed in this revisionary work. All species are distributed in the mountains of central China, including four new species: *C. baimaensis* sp. nov., *C. xuebaodinga* sp. nov., *C. yanggashana* sp. nov. from the Minshan Mountains, and *C. taizishana* sp. nov. from the northeastern margin of QTP (Fig. 2).

Key to male species of *Cerapanorpa* (♂, modified from Gao *et al.* 2016)

(Male of *C. bonis* is unknown)

1. T5 with an anal horn on posterior margin *C. bicornifera* (Chou & Wang, 1981)
- T5 without an anal horn on posterior margin 2
2. Finger-like anal horn on T6 short and stout, at most 0.2 times as long as T6 *C. brevicornis* (Hua & Li, 2007)
- Finger-like anal horn on T6 long, at least 0.3 times as long as T6 3

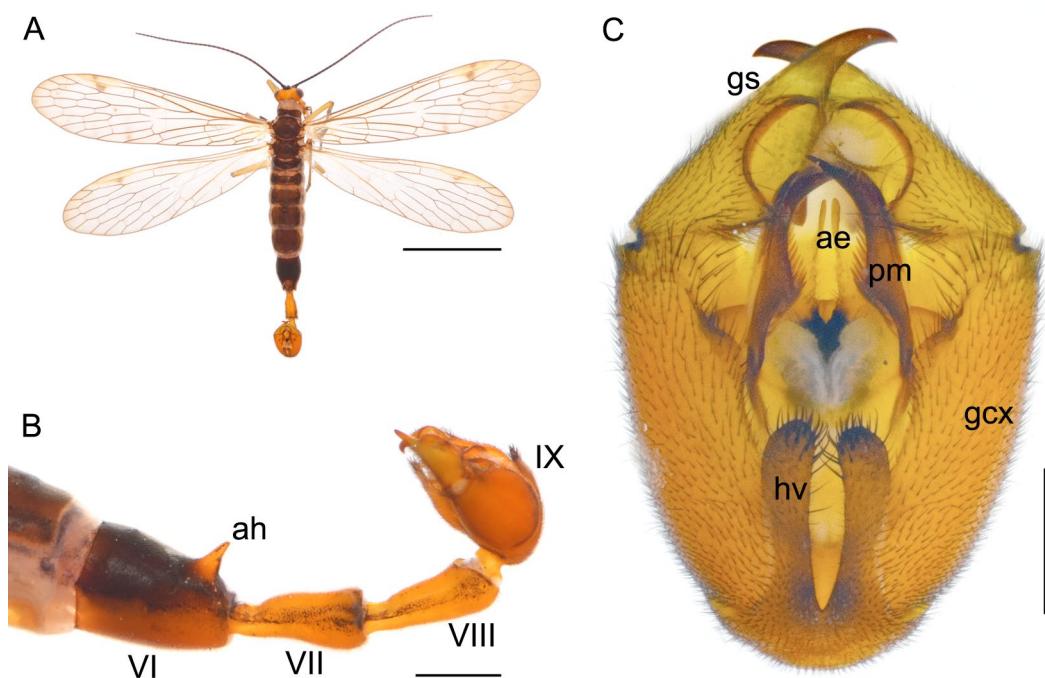


Fig. 4. *Panorpa horiensis* Issiki, 1929, male from Taiwan, China. **A.** Habitus in dorsal view. **B.** Abdomen in lateral view. **C.** Genital bulb in ventral view. Abbreviations: ae = aedeagus; ah = anal horn; gcx = gonocoxite; gs = gonostylyl; hv = hypovalve; pm = paramere. Scale bars: A = 5 mm; B = 1 mm; C = 0.5 mm.

3. Paramere with thin stalk, then abruptly swollen into broad plate from middle portion, bearing long stout spines along inner margin 4
 – Paramere slightly broader than its stalk, with apical portion lanceolate or slightly curved, bearing fine spines along inner margin 6
4. Paramere quite short, only reaching the base of dorsal valves, quadrate plate above the stalk, with an L-shaped subapical branch *C. byersi* (Hua & Li, 2007)
 – Paramere palmate in the middle, without subapical branch 5
5. Paramere reaching posterior margin of gonocoxite, lanceolate at apex, with spines much longer than width at where they inserted; dorsal valve tapering towards apex *C. centralis* (Tjeder, 1936)
 – Paramere exceeding posterior margin of gonocoxite, curved medially at apex; dorsal valve not tapering towards apex *C. baimaensis* sp. nov.
6. Paramere generally linear, only slightly thicker than stalk, bearing a column of very short spines ... 7
 – Paramere broad and flat above the stalk, significantly broader than its stalk 9
7. Paramere curved almost at a right angle at base; wing membrane with conspicuous dark-brown markings; middle and hind legs with coxae and trochanters brownish black
 *C. reni* (Chou & Wang, 1981)
 – Paramere slightly curved apically; wing membrane hyaline, only with faint apical band or without markings; all legs with coxae and trochanters yellowish 8
8. Paramere yellowish brown and blunt apically, reaching middle of gonostylus, bearing spines along inner margin *C. dubia* (Chou & Wang, 1981)
 – Paramere dark brown, reaching apex of gonocoxite, bearing a thorn at apex and spines on the dorsum *C. liupanshana* Gao, Ma & Hua, 2016
9. Paramere sinuate or geniculate 10
 – Paramere straight lanceolate, or somewhat bending medially 15
10. Paramere strongly sinuate and curved posteriorly, with dense spines along inner margin 11
 – Paramere slightly sinuate or geniculate on apical portion; dorsal valves of aedeagus long, reaching apex of gonocoxite or longer 12
11. Paramere nearly bow-shaped; dorsal valves of aedeagus with truncate apex and membranous apical process *C. sinuata* Gao, Ma & Hua, 2016
 – Paramere hook-shaped; dorsal valves of aedeagus tapering toward apex and with large L-shaped apical process *C. taizishana* sp. nov.
12. Paramere columnar and slightly sinuate dorsally on apical portion; hypovalves of hypandrium slender and dramatically elongate, extending to base of gonostylus *C. yanggashana* sp. nov.
 – Paramere geniculate on apical portion; hypovalves of hypandrium extending over middle of gonocoxite 13
13. Rostrum blackish brown to black; A6 entirely black; paramere bearing short ventral spines at apex ...
 *C. nanwutaina* (Chou & Wang, 1981)
 – Rostrum yellowish to reddish brown; paramere with comb-like long spines along medial margin 14

14. Hypovalves slender, with sparse stout bristles along inner margins; dorsal valves of aedeagus brawny, slightly expanded apically *C. xuebaodinga* sp. nov.
- Hypovalves broad, with dense long bristles along inner margins; dorsal valves of aedeagus elongated and slender apically *C. obtusa* (Cheng, 1949)
15. Paramere extending to middle of gonostylus 16
- Paramere extending nearly to apex of gonostylus or beyond 17
16. Wings only with faint indication pterostigma and apical band; hypovalve with a regular column of bristles on medial margin; paramere with spines from its middle length
..... *C. funiushana* (Hua & Chou, 1997)
- Wings with prominent pterostigmal band and apical band; hypovalve with bristles along medial margin; paramere bearing spines above its stalk *C. wangwushana* (Huang, Hua & Shen, 2004)
17. Wings without markings; paramere extending beyond gonostylus, with spines shorter than the width at where they inserted along its medial margin *C. protrudens* Gao, Ma & Hua, 2016
- Wings with clear pterostigmal band and apical band; paramere nearly reaching apex of gonostylus, bearing spines longer than wide at where inserted along medial margin
..... *C. emarginata* (Cheng, 1949)

Cerapanorpa baimaensis sp. nov.

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Figs 5–6

Diagnosis

The new species can be easily separated from its congeners by the following combination of features: rostrum uniformly darkish brown (Fig. 5C); parameres with dense long spines along inner margin, somewhat curved medially, exceeding apex of gonocoxites (Fig. 6A, D); female main plate flat and intensely broaden in basal half; ventral basal plates translucent and ridgy at medial base, covering two-thirds of the main plate; axis short, slightly extending beyond the main plate (Fig. 6F–G).

Etymology

The specific name refers to the type locality, Baima Town.

Type material

Holotype

CHINA • ♂; Sichuan Province, Pingwu County, Baima Town; 32°44'09" N, 104°18'48" E; 2000–2200 m a.s.l.; 23 Jul. 2017; Kai Gao & Yuan Hua leg.; NWAU.

Paratypes

CHINA • 1 ♂, 2 ♀♀; same collection data as for holotype; 5 Jun. 2018; Kai Gao & Yu-Ru Yang leg.; NWAU.

Description

Male

HEAD. Frons, vertex and occiput black. Rostrum uniformly darkish brown, mandibles brown; Maxillary and labial palpi brownish and darkening towards apex (Fig. 5C). Antennae black, with 40–43 segments.

THORAX. Pronotum black, with 8–12 stout setae along anterior margin. Meso- and metanotum entirely black (Fig. 5D). Pleura light ivory. Legs pale yellow, with distal tarsomere blackish. Forewing length 13.9–14.7 mm, width 3.4–3.8 mm. Wing membrane hyaline, only with significantly degenerated pterostigmal band; Hindwing length 12.5–13.8 mm, width 3.3–3.6 mm, similar to forewing in markings (Fig. 5A).

ABDOMEN. A1–A5 terga and sterna black. Notal organ on T3 not prominent, a hook-shaped postnotal organ on T4 projecting forward. A6 mostly black, with a yellow finger-like anal horn on its posterior margin. A7 and A8 yellowish brown and elongate; A7 with a narrow groove at base, slightly constricted at basal half and slightly wider toward apices. A8 as long as A7, gradually thickening apically (Fig. 5E).

GENITALIA. Genital bulb elliptical and yellowish brown (Fig. 6A–D). Epandrium with a deep U-shaped terminal emargination between two finger-like setose lobes, bearing long bristles on distal portion (Fig. 6C). Hypovalves slender, bearing neat and dense bristles along inner margin (Fig. 6A). Gonocoxite with two small protuberances on ventral submedian margin. Gonostylus much shorter than gonocoxite, with an indistinct middle tooth and a large basal process (Fig. 6A, D). Parameres somewhat curved medially, bearing dense long spines along inner margin, slightly exceeding apex of gonocoxite (Fig. 6D). Dorsal valves of aedeagus elongate and curved apically, reaching distal border of gonocoxite; ventral valves membranous, weakly developed; lateral process small, from base of dorsal valves (Fig. 6E).

Female

HEAD, THORAX AND ABDOMEN. Similar to males in coloration. Forewing length 13.5–15.4 mm, width 3.5–3.9 mm, similar to male in coloration and wing patterns; hindwing length 13.3–15.0 mm, width 3.3–3.6 mm, similar to forewing (Fig. 5B).

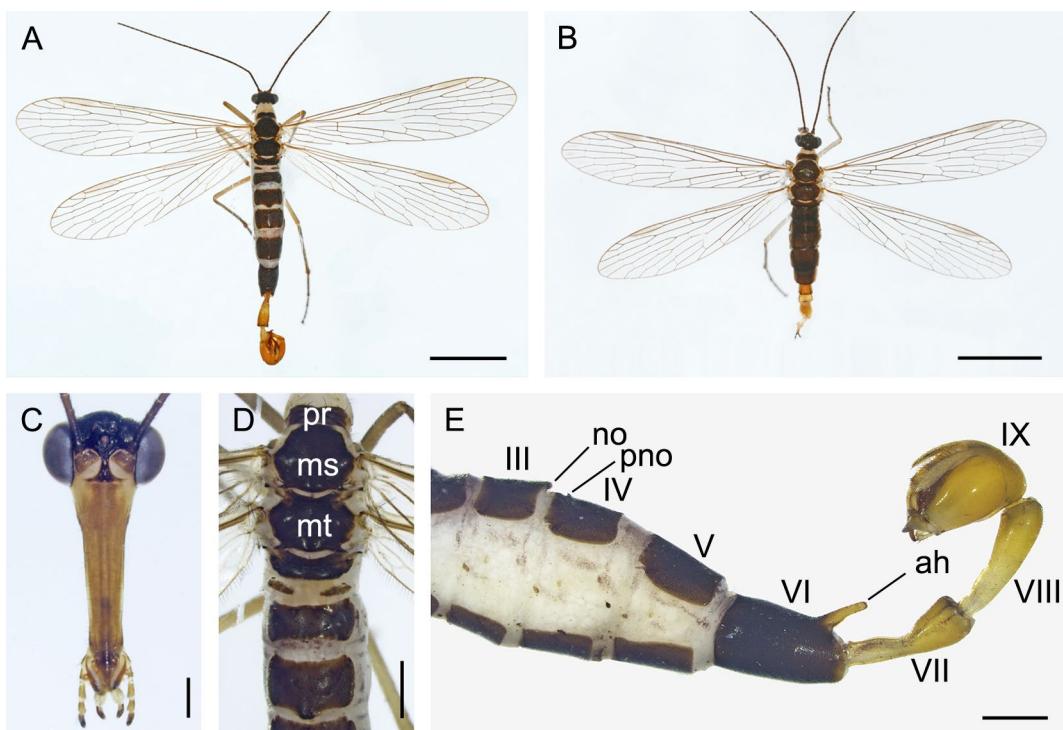


Fig. 5. Adults of *Cerapanorpa baimaensis* sp. nov. **A.** Male habitus in dorsal view. **B.** Female habitus in dorsal view. **C.** Male head in frontal view. **D.** Dorsum of male. **E.** Male abdomen in lateral view. Abbreviations: ah = anal horn; ms = mesonotum; mt = metanotum; no = notal organ; pno = postnotal organ; pr = pronotum. Scale bars: A–B = 5 mm; C = 0.5 mm; D–E = 1 mm.

GENITALIA. Subgenital plate elliptical, shallowly emarginate terminally, bearing long setae on distal portion (Fig. 6H). Medigynium small and weakly sclerotized; main plate flat, intensely broadened in basal half (Fig. 6G). Paired posterior arms gradually tapering apically, approximately forming a quadrate emargination (Fig. 6F–G). Ventral basal plates translucent and ridgy at medial base, covering two-thirds of the main plate (Fig. 6F). Paired dorsal basal plates reniform and membranous (Fig. 6G). Axis short and poorly developed, extending slightly beyond the main plate (Fig. 6F–G).

Distribution

Sichuan Province, China.

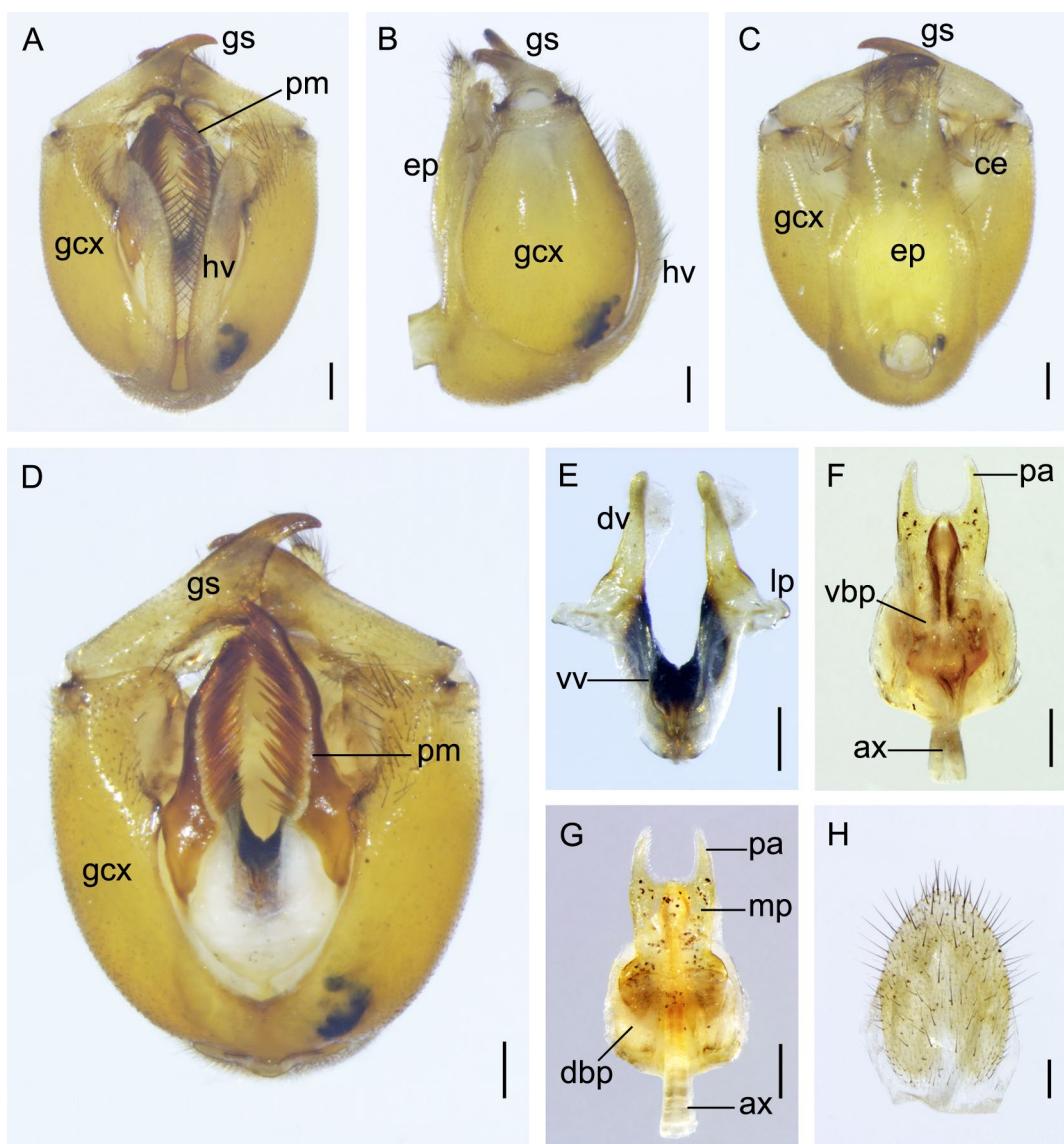


Fig. 6. Genitalia of *Cerapanorpa baimaensis* sp. nov. **A–C.** Male genital bulb in ventral, lateral, and dorsal views. **D.** Male genital bulb with hypandrium removed in ventral view. **E.** Aedeagus in ventral view. **F–G.** Female medigynium in ventral and dorsal views. **H.** Female subgenital plate in ventral view. Abbreviations: ax = axis; ce = cercus; dbp = dorsal basal plate; dv = dorsal valve; ep = epandrium; gcx = gonocoxite; gs = gonostylus; hv = hypovalve; lp = lateral process; mp = main plate; pa = posterior arm; pm = paramere; vbp = ventral basal plate; vv = ventral valve. Scale bars: 0.2 mm.

Remarks

Cerapanorpa baimaensis sp. nov. resembles *C. byversi* (Hua & Li, 2007) and *C. centralis* (Tjeder, 1936) in appearance, but can be easily identified by the specific shape of the male paramere and aedeagus, especially the ridgy ventral basal plates of medigynium in female.

Cerapanorpa taizishana sp. nov.

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Figs 7–8

Diagnosis

The new species differs from its congeners primarily in the following features: rostrum uniformly brownish black anteriorly (Fig. 7C); hypovalves thin at base, gradually broadened toward apex (Fig. 8A); parameres long, hook-shaped, bearing long spines along inner medial margin (Fig. 8A); dorsal valves of aedeagus tapering abruptly toward apex, curved ventrally, bearing a large L-shaped dorsal process (Fig. 8E–F); female medigynium with a pair of large and oblong dorsal basal plates, approximately as long as half the main plate.

Etymology

The specific epithet is derived from the type locality, Taizishan (Mount Prince).

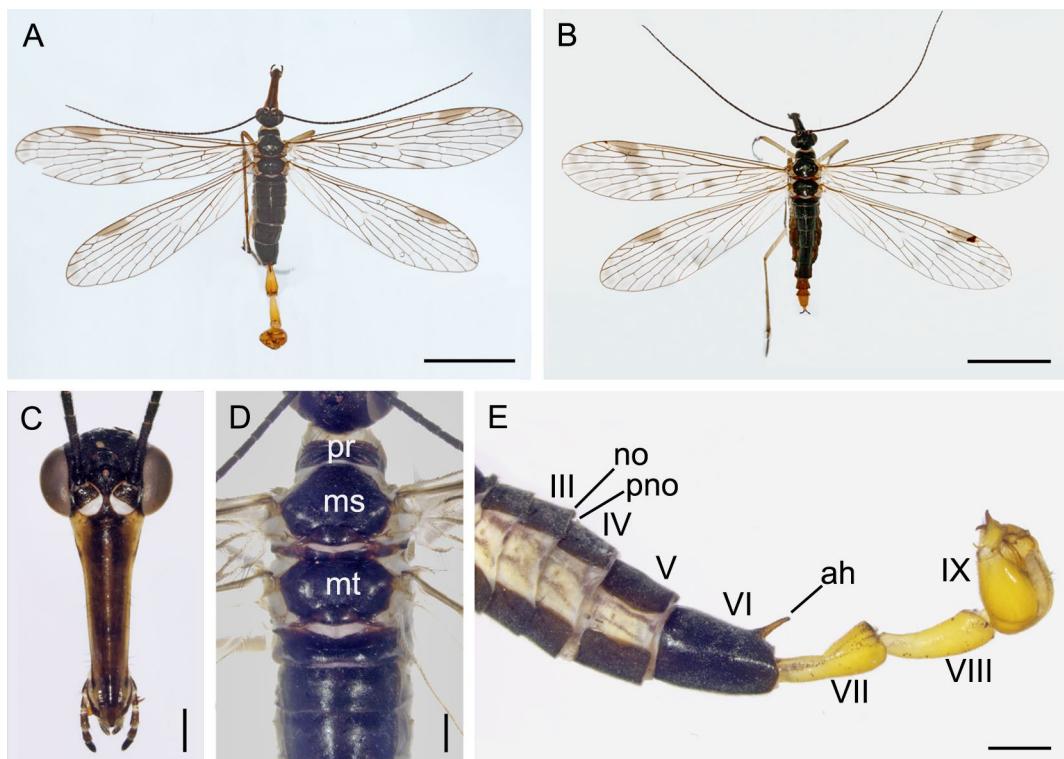


Fig. 7. Adults of *Cerapanorpa taizishana* sp. nov. **A.** Male habitus in dorsal view. **B.** Female habitus in dorsal view. **C.** Male head in frontal view. **D.** Dorsum of male. **E.** Male abdomen in lateral view. Abbreviations: ah = anal horn; ms = mesonotum; mt = metanotum; no = notal organ; pno = postnotal organ; pr = pronotum. Scale bars: A–B = 5 mm; C–E = 0.5 mm.

Type material

Holotype

CHINA • ♂; Gansu Province, Hezheng County, Songmingyan National Forest Park; 35°13'08" N, 103°24'17" E; 2400–2600 m a.s.l.; 1 Aug. 2018; Kai Gao & Yu-Ru Yang leg.; NWAU.

Paratypes

CHINA – **Gansu Prov.** • 5 ♂♂, 2 ♀♀; same data as for holotype; NWAU • 3 ♂♂, 1 ♀; Lintan County, Yeliguan National Forest Park; 34°55'19" N, 103°35'06" E; 2500–2600 m a.s.l.; 2 Aug. 2018; Kai Gao & Yu-Ru Yang leg.; NWAU • 1 ♂; Tewo County, Comai Peak; 34°04'19" N, 103°30'06" E; 2400–2600 m a.s.l.; 22 Jul. 2018; Kai Gao leg.; NWAU. – **Qinghai Prov.** • 1 ♂, 1 ♀; Xunhua County, Mengda Nature Reserve; 2200–2500 m a.s.l.; 24 Jul. 2004; Hu, Tang & Zhu leg.; SHNU.

Description

Male

HEAD. Frons, vertex and occiput black. Compound eyes dark grey. Rostrum brownish black anteriorly, light brown laterally, mandibles dark brown; labial and maxillary palps light brown with distal segments dark brown (Fig. 7C). Antennae filiform and black with 38–42 flagellomeres.

THORAX. Pronotum blackish brown, with 8–12 setae along its anterior margin; meso- and metanotum black (Fig. 7D). Pleura light grayish yellow. Legs pale yellow with a pair of black apical spurs; tarsi yellowish brown and darkened toward apices. Forewing length 11.8–12.3 mm, width 2.9–3.1 mm. Wing membrane hyaline, only with degenerated brown pterostigma and faint apical band. Hindwing length 11.6–12.0 mm, width 2.7–3.0 mm, similar to forewings in pattern (Fig. 7A).

ABDOMEN. A1–A5 terga and sterna entirely black, ivory on pleural membrane (Fig. 7E). Notal organ on posterior margin of T3 very short and not prominent. T4 bearing a small harb-shaped postnotal organ. T6 uniformly brownish black, with a brown finger-like anal horn on posterior margin (Fig. 7E). A7–A8 yellowish and elongate, slightly restricted at base, gradually wider toward apices. A7 with a narrow groove on dorsal surface (Fig. 7E).

GENITALIA. Genital bulb nearly globular, yellowish brown (Fig. 8A–C). Epandrium broad basally, narrowing toward apex, with a deep U-shaped terminal emargination between two stout setose lobes (Fig. 8C). Paired hypovalves thin basally, broadening toward apex, bearing long bristles along inner margins (Fig. 8A). Gonocoxite with very small concave area on apical inner margin. Gonostylus with a large basal process and an indistinct middle tooth on medial margin, and bearing a bundle of stout setae dorsally on basal process (Fig. 8D). Parameres long and hook-shaped, extending well beyond the apex of gonocoxite, bearing long spines along inner medial margin; apex of paramere bearing a brown stout spine, pointed apically (Fig. 8A). Dorsal valves of aedeagus short, tapering abruptly toward apex and curved ventrally, bearing a large L-shaped dorsal process (Fig. 8E–F); ventral valves membranous and short; lateral process prominent and curved ventrally (Fig. 8E–F).

Female

HEAD, THORAX AND ABDOMEN. Similar to male in coloration and patterns. Forewing length 12.9–13.2 mm, width 2.9–3.3 mm; wing pattern similar to male, except for more extensive wing markings. Hindwing length 11.8–12.2 mm, width 2.8–3.1 mm, similar to forewing (Fig. 7B).

GENITALIA. Subgenital plate lingulate, with a shallow V-shaped incision at apex, bearing long setae on lateral distal part (Fig. 8I). Main plate of medigynium narrow basally, gradually broadening toward apex. Paired posterior arms tapering toward apex, forming a broad trapeziform emargination (Fig. 8G–H); ventral basal plates translucent, folded ventro-laterally, covering two-thirds of main plate (Fig. 8G);

paired dorsal basal plates large and oblong, approximately as long as half the main plate, more sclerotized than ventral basal plates (Fig. 8H); anterior part of axis bifurcated, extending anteriorly less than half its length beyond main plate (Fig. 8G–H).

Distribution

Gansu and Qinghai Provinces, China.

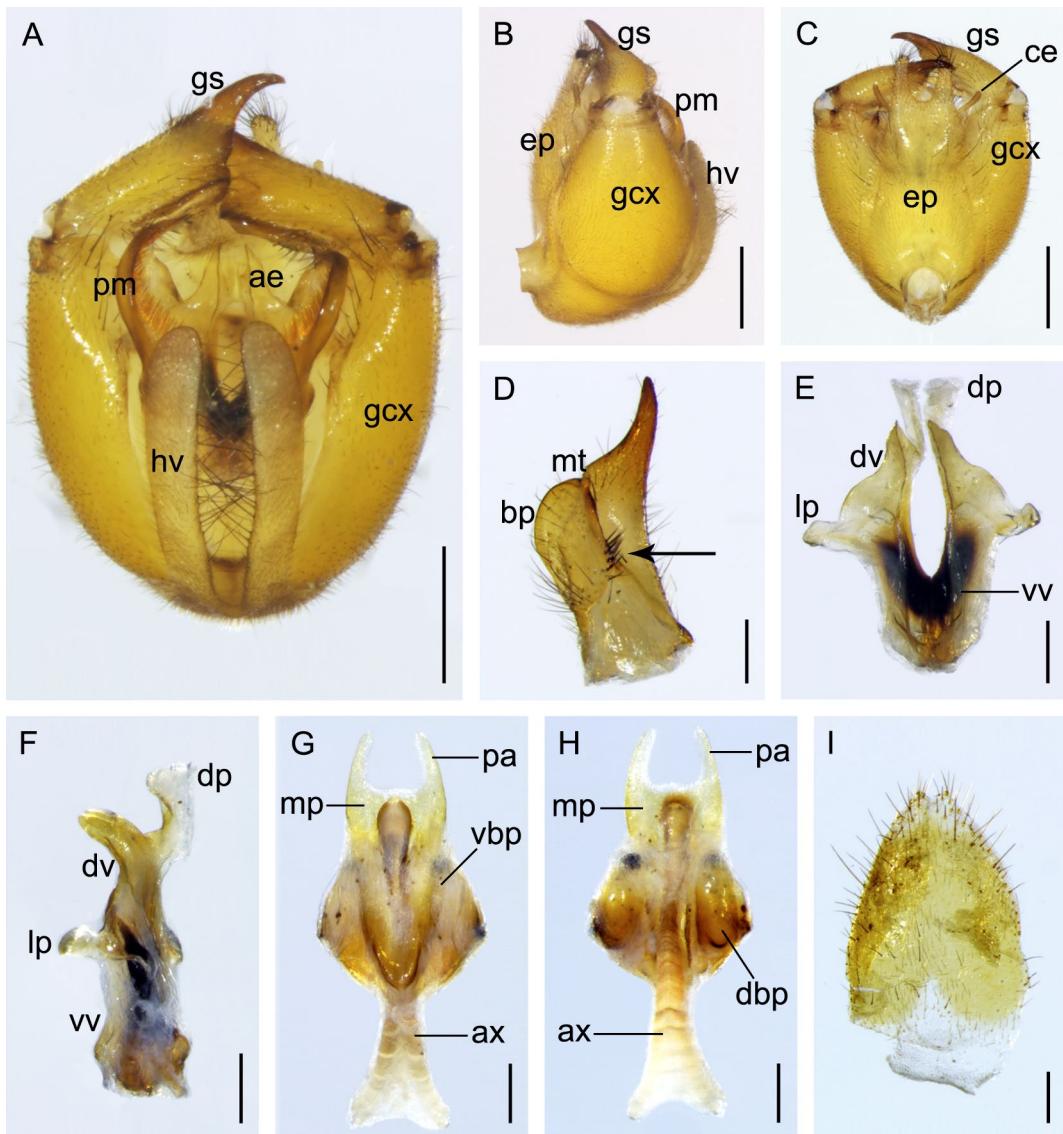


Fig. 8. Genitalia of *Cerapanorpa taizishana* sp. nov. **A–C.** Male genital bulb in ventral, lateral and dorsal views. **D.** Gonostylus in lateral views, arrow indicates the stout setae. **E–F.** Aedeagus in ventral and lateral views. **G–H.** Female medigynium in ventral view and dorsal views. **I.** Subgenital plate in ventral view. Abbreviations: ae = aedeagus; ax = axis; bp = basal process; ce = cercus; dbp = dorsal basal plate; dp = dorsal process; dv = dorsal valve; ep = epandrium; gcx = gonocoxite; gs = gonostylus; hv = hypovalve; lp = lateral process; mp = main plate; mt = median tooth; pa = posterior arm; pm = paramere; vbp = ventral basal plate; vv = ventral valve. Scale bars: A–C = 0.5 mm; D–I = 0.2 mm.

Remarks

Cerapanorpa taizishana sp. nov. resembles *C. nanwutaina* and *C. obtusa* in appearance from the Qinling Mountains, but is readily distinguished from the latter two species by the conspicuously hook-shaped paramere, L-shaped dorsal process of aedeagus, and specific medigynium.

Cerapanorpa xuebaodinga sp. nov.

urn:lsid:zoobank.org:act:E6D60D9A-F5EE-4B69-88E3-54628C6966C1

Figs 9–10

Diagnosis

The new species can be readily recognized by the following features: rostrum uniformly yellowish (Fig. 9C); hypovalves slender, with sparse short bristles along inner margins (Fig. 10A); parameres twisted in knee-shape, bearing long spines apically (Fig. 10D); dorsal valves of aedeagus brawny, expanded apically (Fig. 10E); main plate of medigynium flat, twice as long as wide, intensely constricted medially (Fig. 10G).

Etymology

The specific name refers to the type locality, Xuebaoding (Snow Treasure Peak) of the Minshan Mountains.

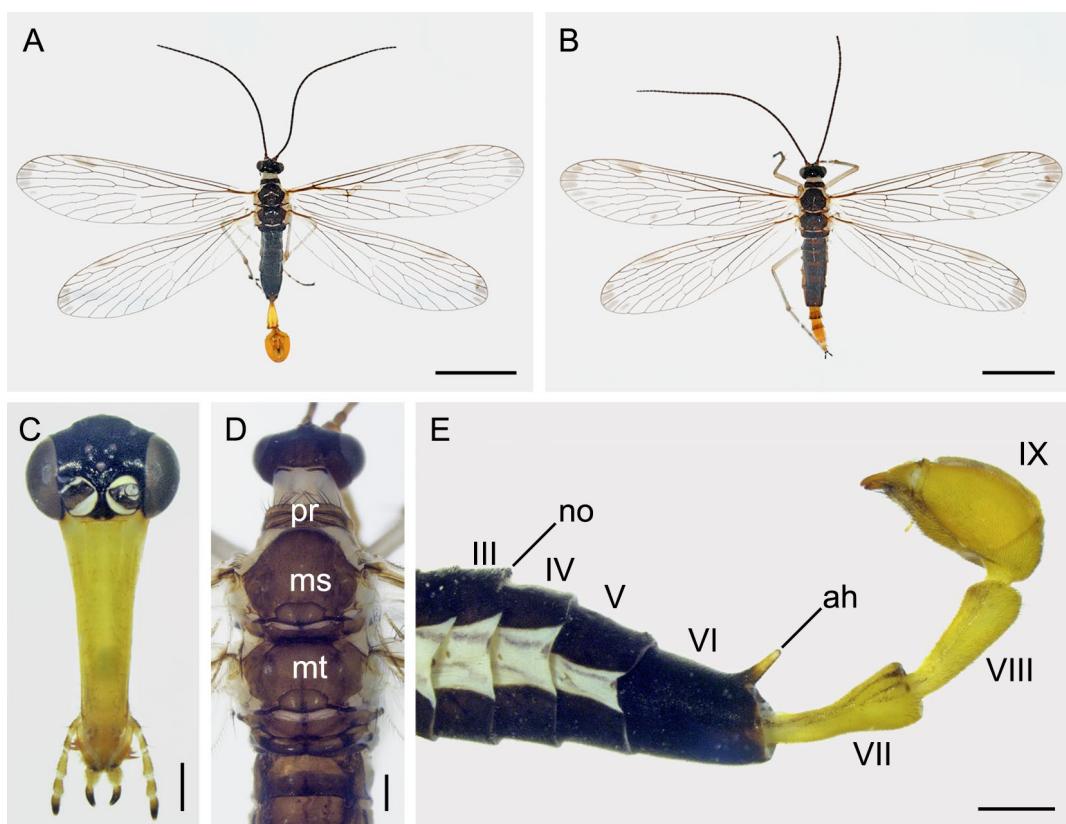


Fig. 9. Adults of *Cerapanorpa xuebaodinga* sp. nov. **A.** Male habitus in dorsal view. **B.** Female habitus in dorsal view. **C.** Male head with antennae removed in frontal view. **D.** Dorsum of male. **E.** Male abdomen in lateral view. Abbreviations: ah = anal horn; ms = mesonotum; mt = metanotum; no = notal organ; pr = pronotum. Scale bars: A–B = 5 mm; C–D = 0.5 mm; E = 1 mm.

Type material**Holotype**

CHINA • ♂; Sichuan Province, Pingwu County, Xuebaoding Nature Reserve; 32°30'14"N, 103°56'31"E; 2200–2500 m a.s.l.; 30 May 2018; Kai Gao & Yu-Ru Yang leg.; NWAU.

Paratypes

CHINA • 8 ♂♂, 5 ♀♀; same data as for holotype; NWAU.

Description**Male**

HEAD. Frons, vertex and occiput brownish black (Fig. 9C–D). Rostrum uniformly yellowish, mandibles yellowish brown; maxillary and labial palps yellow with distal segments dark brown (Fig. 9C). Antennae brownish with 39–42 segments.

THORAX. Pronotum brown, with 12–14 stout setae along anterior margin. Meso- and metanotum grayish brown (Fig. 9D). Pleura light creamy white. Legs pale yellow, tibia with a pair of brown apical spurs; tarsi deep brown at the distal portion. Forewing length 13.7–14.6 mm, width 3.3–3.6 mm. Wing broad and membrane hyaline, almost without markings, except for the weak pterostigmal band (Fig. 9A); apical band faint, only with dark gray trace at apical region. Hindwing length 12.2–13.7 mm, width 3.1–3.5 mm, similar to forewing in pattern (Fig. 9A).

ABDOMEN. T1–T5 blackish, pleura ivory (Fig. 9E). Notal organ on posterior margin of T3 not prominent, postnotal organ on T4 very small, hook-shaped and projecting forward. A6 less than twice as long as A5, with a finger-like anal horn on posterior margin (Fig. 9E). A7 yellowish brown, with a narrow groove at base, constricted at basal half and slightly thicker towards apex. A8 light yellow, as long as A7, gradually thickening apically (Fig. 9E).

GENITALIA. Genital bulb yellowish and elliptical (Fig. 10A–D). Epandrium extending beyond apex of gonocoxite, with a deep U-shaped terminal emargination between two stout setose lobes, bearing two clusters of dense long bristles on distal portion (Fig. 10C). Hypovalves of hypandrium slender, almost reaching apex of gonocoxite, with a column of sparse short bristles along inner margin (Fig. 10A). Gonocoxite approximately twice as long as gonostylus, with two subtriangular subapical teeth on ventral submedian margin. Gonostylus bearing a prominent basal process and an indistinct middle tooth on inner margin (Fig. 10A, D). Parameres yellowish brown and geniculate on apical portion, almost reaching apex of gonocoxite, bearing long spines apically (Fig. 10D). Dorsal valves of aedeagus brawny and inflated apically, almost reaching distal border of gonocoxite; ventral valves short, membranous; a small narrow lateral process from basal margin of dorsal valves (Fig. 10E).

Female

HEAD, THORAX AND ABDOMEN. Similar to those of male in coloration and patterns (Fig. 9B). Forewing length 14.0–15.3 mm, width 3.5–3.8 mm, markings and venations similar to male except for the more distinct pterostigmal band; hindwing length 13.9–15.1 mm, width 3.3–3.7 mm, similar to forewings (Fig. 9B).

GENITALIA. Subgenital plate lingulate, with a trapezoidal emargination terminally, bearing long setae on lateral distal margin (Fig. 10H). Medigynium small and sclerotized; the main plate flat, twice as long as wide, intensely constricted medially (Fig. 10G). Paired posterior arms gradually narrowing toward apex, forming a deep U-shaped emargination (Fig. 10F–G). Ventral basal plates translucent, covering approximately three-quarters of the main plate (Fig. 10H). At the base of the main plate, paired dorsal

basal plates circular and membranous (Fig. 10G). Axis elongate, with apex slightly extruding out of main plate, and base bifurcated, slightly extending beyond main plate (Fig. 10F–G).

Distribution

Sichuan Province, China.

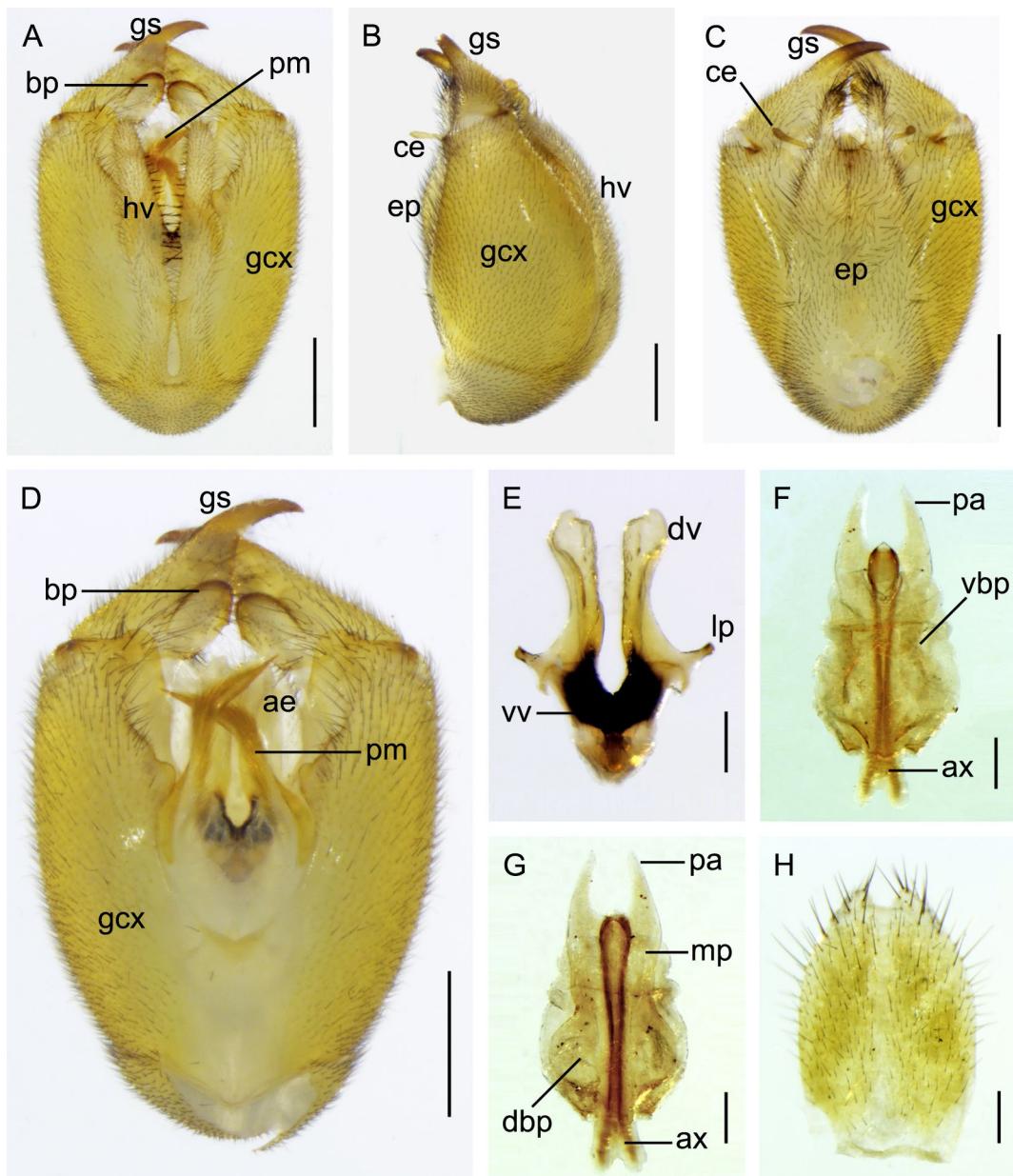


Fig. 10. Genitalia of *Cerapanorpa xuebaodinga* sp. nov. **A–C.** Male genital bulb in ventral, lateral and dorsal views. **D.** Male genital bulb with hypandrium removed in ventral view. **E.** Aedeagus in ventral view. **F–G.** Female medigynium in ventral and dorsal views. **H.** Female subgenital plate in ventral view. Abbreviations: ae = aedeagus; ax = axis; bp = basal process; ce = cercus; dbp = dorsal basal plate; dv = dorsal valve; ep = epandrium; gcx = gonocoxite; gs = gonostylus; hv = hypovalve; lp = lateral process; mp = main plate; pa = posterior arm; pm = paramere; vbp = ventral basal plate; vv = ventral valve. Scale bars: A–D = 0.5 mm; E–H = 0.2 mm.

Remarks

The new species resembles *C. brevicornis* (Hua & Li, 2007) from the Bashan Mountains in body coloration and the wings pattern, but is easily separated from the latter by the shape of geniculate parameres and the brawny dorsal valves of aedeagus.

Cerapanorpa yanggashana sp. nov.

urn:lsid:zoobank.org:act:3D6DAD98-3214-47D2-A9C9-CFAB08E58F80

Figs 11–12

Diagnosis

The new species can be readily distinguished from its congeners by the following characters: rostrum uniformly brownish black (Fig. 11C); hypovalves slender and prominently elongate, extending beyond the apex of gonocoxite (Fig. 12A); parameres columnar, bearing a column of long golden spines along dorsal side and a brown stout spine apically (Fig. 12A, E); the main plate of medigynium broad at basal half, gradually tapering distally, slightly infolded dorsad (Fig. 12F); ventral basal plates fused into membrane enfolding the main plate, covering almost two-thirds of the main plate in both ventral and dorsal views (Fig. 12F).

Etymology

The specific epithet refers to its type locality, Yanggashan, Wenxian County, Gansu Province.

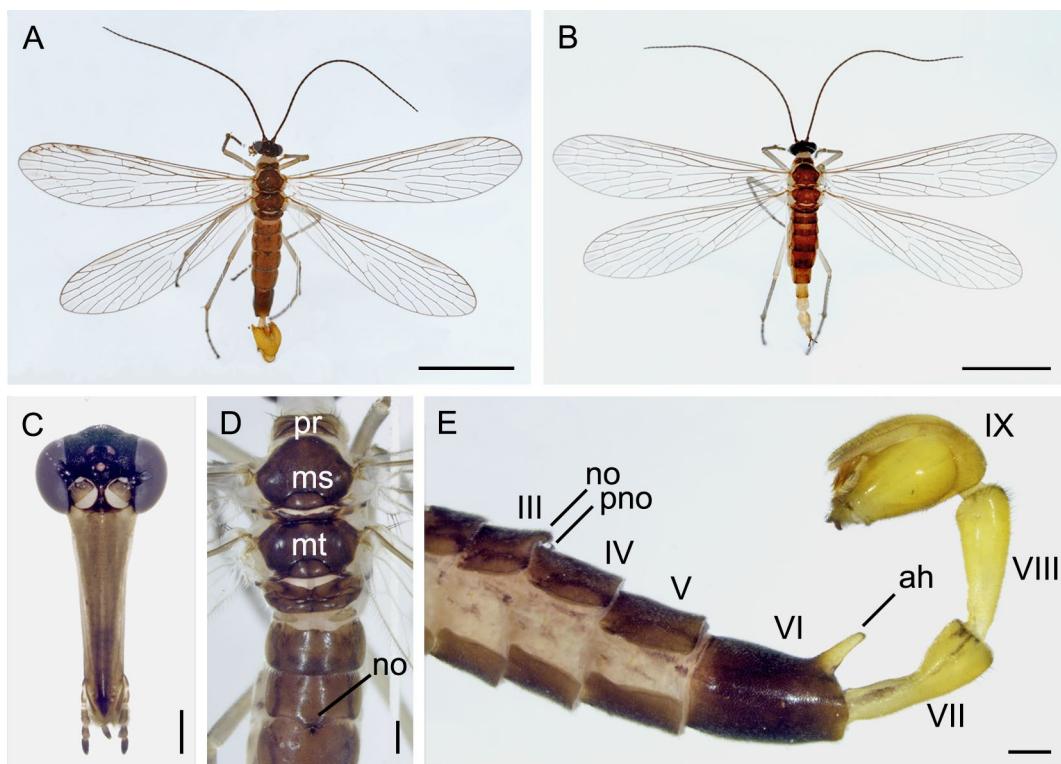


Fig. 11. Adults of *Cerapanorpa yanggashana* sp. nov. **A.** Male habitus in dorsal view. **B.** Female habitus in dorsal view. **C.** Male head with antennae removed in frontal view. **D.** Dorsum of male. **E.** Male abdomen in lateral view. Abbreviations: ah = anal horn; ms = mesonotum; mt = metanotum; no = notal organ; pno = postnotal organ; pr = pronotum. Scale bars: A–B = 5 mm; C–E = 0.5 mm.

Type material

Holotype

CHINA • ♂; Gansu Province, Wenxian County, Mount Yanggashan; 32°51'41" N, 104°33'13" E; 2100 m a.s.l.; 7 Jun. 2018; Kai Gao & Yu-Ru Yang leg.; NWAU.

Paratypes

CHINA • 7 ♂♂, 3 ♀♀; same data as for holotype; NWAU.

Description

Male

HEAD. Frons, vertex and occiput entirely brownish black. Rostrum uniformly brownish black, mandibles, labial and maxillary palps dark brown (Fig. 11C). Antennae filiform, brownish black, with 38–42 flagellomeres.

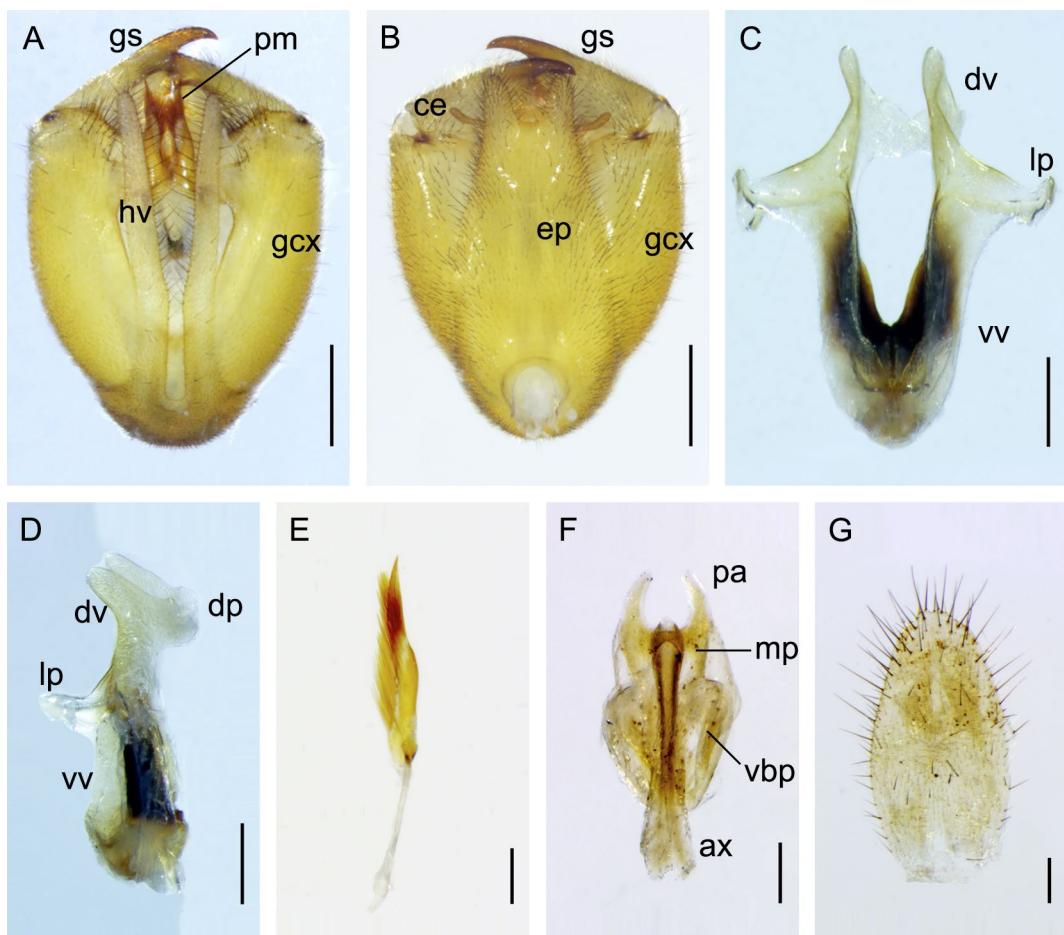


Fig. 12. Genitalia of *Cerapanorpa yanggashana* sp. nov. **A–B.** Male genital bulb in ventral and dorsal views. **C–D.** Aedeagus in ventral and lateral views. **E.** Left paramere in lateral view. **F.** Female medigynium in ventral view. **G.** Female subgenital plate in ventral view. Abbreviations: ax = axis; ce = cercus; dp = dorsal process; dv = dorsal valve; ep = epandrium; gcx = gonocoxite; gs = gonostylus; hv = hypovalve; lp = lateral process; mp = main plate; pa = posterior arm; pm = paramere; vbp = ventral basal plate; vv = ventral valve. Scale bars: A–B = 0.5 mm; C–G = 0.2 mm.

THORAX. Pronotum light brown, with 10–12 black setae along its anterior margin; Meso- and metanotum dark brown (Fig. 11D). Pleura pale and legs ivory, tibia with a pair of apical spurs; tarsi darkened toward apices. Forewing length 12.2–13.0 mm, width 3.0–3.3 mm. Wing membrane hyaline and almost without marking, pterostigmal band pale. Hindwing length 11.8–12.1 mm, width 2.9–3.2 mm, similar to forewings in pattern (Fig. 11A).

ABDOMEN. T1–T5 brownish black, the corresponding sterna slightly pale. Notal organ of T3 semicircular (Fig. 11E). T4 bearing a small barb-shaped postnotal organ near the anterior margin. T6 entirely brownish black, with a yellow finger-like anal horn on posterior margin. A7 and A8 yellowish and elongate, with basal half slightly constricted and gradually thickening toward the distal portion (Fig. 11E).

GENITALIA. Genital bulb globular and yellowish orange (Fig. 12A–B). Epandrium broad at base, gradually narrowing toward apex, with a nearly trapezoidal emargination distally (Fig. 12B). A pair of parallel hypovalves slender and dramatically elongate, extending beyond the apex of gonocoxite, with long bristles along inner margins (Fig. 12A). Gonocoxite bearing a bundle of long setae on inner portion of ventral apex, and two prominently subtriangular subapical teeth on ventro-distal apex (Fig. 12A). Gonostylus much shorter than gonocoxite, medially curved, with a large basal process and an indistinct median tooth on inner margin (Fig. 12A). Parameres columnar, slightly curved dorsal, extending to base of gonostylus, and bearing a column of long golden spines along dorsal side and a brown stout spine apically (Fig. 12A, E). Dorsal valves of aedeagus short, curved ventrally, with distal part pediform (Fig. 12C–D); ventral valves membranous; lateral process auriform and prominent (Fig. 12C–D).

Female

HEAD, THORAX AND ABDOMEN. Similar to males in coloration and patterns. Forewing length 13.0–13.4 mm, width 3.1–3.4 mm, markings and venations similar to male; hindwing length 12.8–13.1 mm, width 3.0–3.2 mm, similar to forewing (Fig. 11B).

GENITALIA. Subgenital plate long elliptical and not pointed, ended with a small V-shaped incision, bearing long setae on distal portion (Fig. 12G). Medigynium weakly sclerotized; main plate broad in basal half, gradually narrowing distally, slightly infolded dorsad. Paired posterior arms tapering apically, forming a deep U-shaped emargination (Fig. 12F). Ventral basal plates translucent, fused into membrane enfolding the main plate, covering approximately two-thirds of main plate in both ventral and dorsal side. Paired dorsal basal plates large, semicircular and poorly sclerotized. Axis elongate and bifurcate, slightly extending beyond the main plate (Fig. 12F).

Distribution

Gansu Province, China.

Remarks

Cerapanorpa yanggashana sp. nov. resembles *C. liupanshana* Gao, Ma & Hua, 2016 in appearance from the Liupan Mountains, Ningxia, but is readily recognized from the latter by the distinct slender and elongate hypovalves, the specific shape of parameres and the foot-shaped dorsal valves of aedeagus.

Cerapanorpa yanggashana sp. nov. has a similar geographical distribution in southern Gansu to *C. bonis* (Cheng, 1949), which was described based only on a single female specimen. The male of *C. bonis* remains unknown to date. *C. yanggashana* differs from the latter by subgenital plate long elliptical and not pointed at apex; main plate of medigynium broad at basal half, and slightly infolded dorsad (cf. subgenital plate is pointed; main plate is slender).

Discussion

The genus *Cerapanorpa* is taxonomically revised based on comparative morphology, molecular phylogeny, cytogenetics and geographical data. Four new species are described, and six species are transferred back to *Panorpa*. Therefore, a total of nineteen species are currently recognized in *Cerapanorpa*.

Five northeastern Asian species are transferred back to *Panorpa*, i.e., *P. acutipennis* Hua, 1998; *P. arakavae* Miyaké, 1913; *P. cornigera* MacLachlan, 1887; *P. fulvicaudaria* Miyaké, 1910 and *P. gokaensis* Miyaké, 1910. Although these species also bear a single anal horn on the posterior margin of T6 in males, they differ conspicuously from the true *Cerapanorpa* in genitalia (Issiki 1929; Hua 1998; Gao *et al.* 2016). A recent molecular phylogenetic analysis (Miao *et al.* 2019) reveals that the northeastern Asian species are paraphyletic with *Panorpa*, rather than forming a monophyletic clade with the true *Cerapanorpa*. *Panorpa acutipennis* from the Changbai Mountains in Jilin Province has a chromosome number $n = 23$, whereas true species of *Cerapanorpa* have the chromosome number $n = 22$ (Miao *et al.* 2017, 2019). In addition, the geographical distributions are distinctly separated from each other. The true *Cerapanorpa* is mainly distributed in the Qinling-Bashan Mountains, Minshan Mountains and their adjacent regions in central China (Gao *et al.* 2016; Wang & Hua 2017), whereas the northeastern Asian species are spread all over northeastern China, the Korean Peninsula, the Russian Far East and the Japanese archipelago (Gao *et al.* 2016; Miao *et al.* 2019). Hence, these species should be transferred back to *Panorpa*, at least temporarily.

The genus *Cerapanorpa* as amended currently consists of 19 valid species, which exclusively occur in the mountainous regions of central China. These closely related species not only have uniform appearance and internal anatomy (Hou & Hua 2008; Liu & Hua 2009; Ma *et al.* 2011), but also have a strongly supported monophyly by phylogenetic analyses (Ma *et al.* 2011; Hu *et al.* 2015; Miao *et al.* 2017). The salivary glands of males uniformly possess six secretory tubes with similar size and configuration (Ma *et al.* 2011). The female medigynium bears an elongate rod-like axis with a pair of weakly divergent arms and paired basal plates on both sides of the main plate (Ma *et al.* 2012; Gao *et al.* 2016). All the species of *Cerapanorpa* from central China are evolutionarily independent entities, and their monophyly is confirmed by phylogenetic analyses based on morphological characters and molecular data (Ma *et al.* 2012; Miao *et al.* 2017, 2019). Furthermore, species of *Cerapanorpa* not only display achiasmate meiosis, but also show a plesiomorphic karyotype with a diploid chromosome number of $2n = 43$ and an X0 sex chromosome system in males (Miao *et al.* 2017, 2019).

The species diversity of *Cerapanorpa* in the Minshan Mountains seems to have been greatly underestimated and poorly explored to date (Favre *et al.* 2015; Hu *et al.* 2019). During our investigations of recent years, four new species (*C. baimaensis* sp. nov., *C. taizishana* sp. nov., *C. xuebaodinga* sp. nov. and *C. yanggashana* sp. nov.) were discovered from the sky islands in the Minshan Mountains and adjacent regions. As a key biodiversity hotspot in the world (Myers *et al.* 2000; Huang *et al.* 2006), the Minshan Mountains have experienced drastic and rapid uplift between the late Miocene and late Pliocene, and built into disproportionate fraction of mountain terrain (Royden *et al.* 2008). The unique heteropical landform and diverse ecozones in this region might have provided a platform for genetic lineages to undergo independent evolution or speciation process owing to the lack of gene flow (Fjeldså *et al.* 2012; He & Jiang 2014; Xing & Ree 2017). In addition, climatic oscillations in the Quaternary had profound effects on organisms in this region, such as range shifts or extinctions, species-level diversification, and driving local adaptation (Hewitt 2000, 2004; Gu *et al.* 2013; Zhou *et al.* 2013; Hu *et al.* 2019). Therefore, with little doubt, additional new species or distribution records await to be discovered in the poorly explored Minshan Mountains and adjacent regions.

The genus *Panorpa* is regarded as a paraphyletic group based on morphological characters (Willmann 1977; Ma *et al.* 2011, 2012) and molecular data (Misof *et al.* 2000; Hu *et al.* 2015; Miao *et al.* 2019). Although several genera have recently been separated from *Panorpa*, including *Sinopanorpa* Cai & Hua, 2008; *Furcatopanorpa* Ma & Hua, 2011; *Dicerapanorpa* Zhong & Hua, 2013; *Cerapanorpa* Gao, Ma & Hua, 2016 and *Megapanorpa* Wang & Hua, 2019, the paraphyly problem of *Panorpa* has not been thoroughly resolved. More intensive phylogenetic analyses of Panorpidae at the global scale are needed to rationally solve the paraphyly of *Panorpa*.

Acknowledgments

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