

# Review of the genus *Panorpa* Linnaeus from the Nanling Mountains with descriptions of three new species (Mecoptera: Panorpidae)

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**Abstract:** The scorpionfly fauna of the genus *Panorpa* Linnaeus, 1758 in the Nanling Mountains, southern China is reviewed, including three new species: *Panorpa filititilana* **sp. nov.** from Mangshan, *Panorpa muricata* **sp. nov.** from Jintongshan and Mao'ershan, and *Panorpa yuechenglingensis* **sp. nov.** from Mao'ershan. The species number of *Panorpa* is raised to 13 in the Nanling Mountains region. A key to species of *Panorpa* in the Nanling Mountains is provided.

**Key words:** biodiversity; China; fauna; Oriental Region; scorpionfly; taxonomy

## 南岭蝎蛉属回顾及三新种记述（长翅目：蝎蛉科）

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**摘要:** 回顾了中国南岭的蝎蛉属 *Panorpa* Linnaeus, 1758 昆虫分类，并描述 3 新种：采自莽山的细突蝎蛉 *Panorpa filititilana* **sp. nov.**，采自金童山和猫儿山的尖齿蝎蛉 *Panorpa muricata* **sp. nov.**和采自猫儿山的越城岭蝎蛉 *Panorpa yuechenglingensis* **sp. nov.**。南岭地区蝎蛉属物种数目增加至 13 种。提供了蝎蛉属南岭种类分种检索表。

**关键词:** 生物多样性；中国；区系；东洋区；蝎蛉；分类

## Introduction

The Nanling Mountains region forms an important geographical division between the southern subtropical and the median subtropical regions in south China, consisting of Yuecheng, Dupang, Mengzhu, Qitian and Dayu Ridges (Wang 1993; Chen *et al.* 2015). The Nanling Mountains region is a famous diversity hotspot in the world and contains numerous species of Mecoptera (Zhang *et al.* 2020; Wang & Gong 2021). So far, 27 species of Mecoptera have been recorded in the Nanling Mountains, including 22 species of Panorpidae and five species of Bittacidae (Chou *et al.* 1987, 1988; Chen *et al.* 2013; Zhang *et al.* 2020; Wang & Gong 2021).

Panorpidae is the largest family of Mecoptera with more than 500 extant species in eight genera. They are commonly called scorpionflies due to the enlarged and recurved upward

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male genitalia resembling a scorpion's tail (Byers & Thornhill 1983; Byers 2009; Zhong & Hua 2013a; Wang & Hua 2019, 2021; Gao & Hua 2021; Li *et al.* 2021). The adults are saprophagous (Byers 2009; Jiang *et al.* 2019), mainly feeding on dead arthropods and occasionally on other organic matter (Palmer 2010). They normally inhabit high-elevated humid forests, valleys and other densely vegetation areas, and typically stay on the upper surfaces of leaves of herbs and shrubs (Byers & Thornhill 1983; Wang & Hua 2016, 2019; Bicha 2018). The wings are folded in a V-shape or are roof-like at rest (Ma & Hua 2011). Scorpionflies usually exhibit a nuptial feeding behavior during mating (Byers & Thornhill 1983; Zhong & Hua 2013b; Tong & Hua 2019).

*Panorpa* Linnaeus, 1758 is the largest genus in Panorpidae, with over 270 known species in the world and approximately 120 described species in China (Penny & Byers 1979; Wang & Hua 2017, 2019; Bicha 2018; Wang *et al.* 2019; Li & Hua 2020). Ten species of *Panorpa* have been recorded from the Nanling Mountains to date (Chou *et al.* 1987; Wang & Hua 2017; Wang & Gong 2021).

Recently, we participated in the project of the Insect Fauna of the Nanling Mountains. Three new species of *Panorpa* are discovered and described here, raising the species number of *Panorpa* to 13 in the Nanling Mountains. We also provide a distributional map and a key to species of *Panorpa* in the Nanling Mountains.

## Material and methods

Specimens were collected using collecting nets from the Nanling Mountains in southern China (Fig. 1), and are preserved in 75% ethanol at the Entomological Museum, Northwest A&F University (NWAU). Specimens were dissected under a Nikon SMZ 1500 Stereoscopic Zoom microscope. Genitalia were macerated in cold 10% NaOH solution for 3–5 min and rinsed with distilled water. Adult photographs were taken with a Nikon D7100 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 CC 2019 SP.

Terminology follows Byers (1989) and Wang and Hua (2021). The abbreviations and acronyms are as follows: ae — aedeagus; ax — axis; bp — basal process; ce — cercus; dpr — dorsal process; ep — epandrium; gcx — gonocoxite; gs — gonostylus; hv — hypovalve; lpr — lateral process; mp — main plate; ms — mesonotum; mt — metanotum; mth — median tooth; no — notal organ; pa — posterior arm; pm — paramere; pno — postnotal organ; pr — pronotum; sgp — subgenital plate; sth — stalk of hypovalve; stp — stalk of paramere; vv — ventral valve; A1 — first abdominal segment (and so forth for other segments); T1 — first tergum (and so forth for other segments); S1 — first sternum (and so forth for other segments).

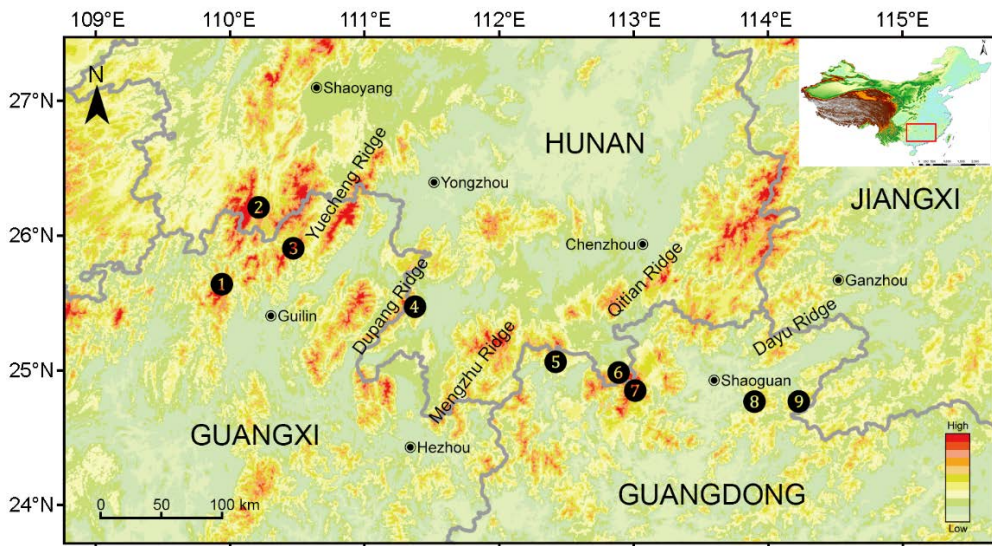


Figure 1. Distribution map of *Panorpa* in the Nanling Mountains. ① Longsheng: *P. quadrifasciata* Chou & Wang, 1987; *P. sextaenia* Zhou & Bao, 2002; *P. tritaenia* Chou & Wang, 1987. ② Chengbu: *P. muricata* sp. nov. ③ Xing'an: *P. caowei* Wang, 2021; *P. muricata* sp. nov.; *P. obliquifascia* Chou & Wang, 1987; *P. quadrifasciata* Chou & Wang, 1987; *P. sextaenia* Zhou & Bao, 2002; *P. yuechenglingensis* sp. nov. ④ Daoxian: *P. filina* Chou & Wang, 1987; *P. quadrifasciata* Chou & Wang, 1987. ⑤ Lianzhou: *P. guidongensis* Chou & Li, 1987; *P. kiautai* Zhou & Wu, 1993. ⑥ Yizhang: *P. filititilana* sp. nov.; *P. mangshanensis* Chou & Wang, 1987; *P. obliquifascia* Chou & Wang, 1987; *P. quadrifasciata* Chou & Wang, 1987. ⑦ Ruyuan: *P. obliquifascia* Chou & Wang, 1987. ⑧ Qujiang, ⑨ Shixing: *P. gressitti* Byers, 1970.

## Taxonomy

### Key to species of *Panorpa* in the Nanling Mountains (male)

1. A6 with a single anal horn on dorsal apex ..... *P. kiautai* Zhou & Wu  
A6 lacking anal horns ..... 2
2. Wings hyaline ..... 3  
Wings pale or dark yellow ..... 10
3. Parameres bi- or trifurcated ..... 4  
Parameres simple ..... 7
4. Parameres trifurcated ..... *P. guidongensis* Chou & Li  
Parameres bifurcated ..... 5
5. Parameres with dorsal branch as long as lateral branch ..... *P. filina* Chou & Wang  
Parameres with dorsal branch longer than lateral branch ..... 6
6. Wings with pterostigmal band diagonally downward, basal branch intact, and apical branch broken .....  
..... *P. obliquifascia* Chou & Wang  
Wings with basal and apical branches indistinct, basal branch broken and apical branch degraded .....  
..... *P. caowei* Wang
7. Gonostylus with basal process divided into two small processes ..... *P. gressitti* Byers  
Gonostylus with basal process simple ..... 8

8. Gonostylus with sharp hook-like tooth and large depression ..... *P. mangshanensis* Chou & Wang  
 Gonostylus without depression ..... 9
9. Forewings with apical, pterostigmal, and basal bands distinct ..... *P. tritaenia* Chou & Wang  
 Forewings with apical band indistinct, pterostigmal band triangular, and basal band reduced .....  
 ..... *P. filititilana* **sp. nov.**
10. Gonocoxite with inner protrusion triangular or wide finger-shaped ..... 11  
 Gonocoxite without protrusion ..... 12
11. Gonocoxite with triangular protrusion ..... *P. quadrifasciata* Chou & Wang  
 Gonocoxite with wide finger-shaped protrusion ..... *P. yuechenglingensis* **sp. nov.**
12. Forewings without apical band, pterostigmal band narrower with basal branch integral and apical branch disconnected or absent; basal band slender ..... *P. sextaenia* Zhou & Bao  
 Forewing with apical and basal bands; pterostigmal band without apical branch ..... *P. muricata* **sp. nov.**

1. *Panorpa filititilana* **sp. nov.** (Figs 2, 3)

Description. Male (Fig. 2A). Head (Fig. 2C). Vertex, occiput and rostrum yellowish brown, ocellar triangle black. Antenna dark brown, with 41–45 flagellomeres.

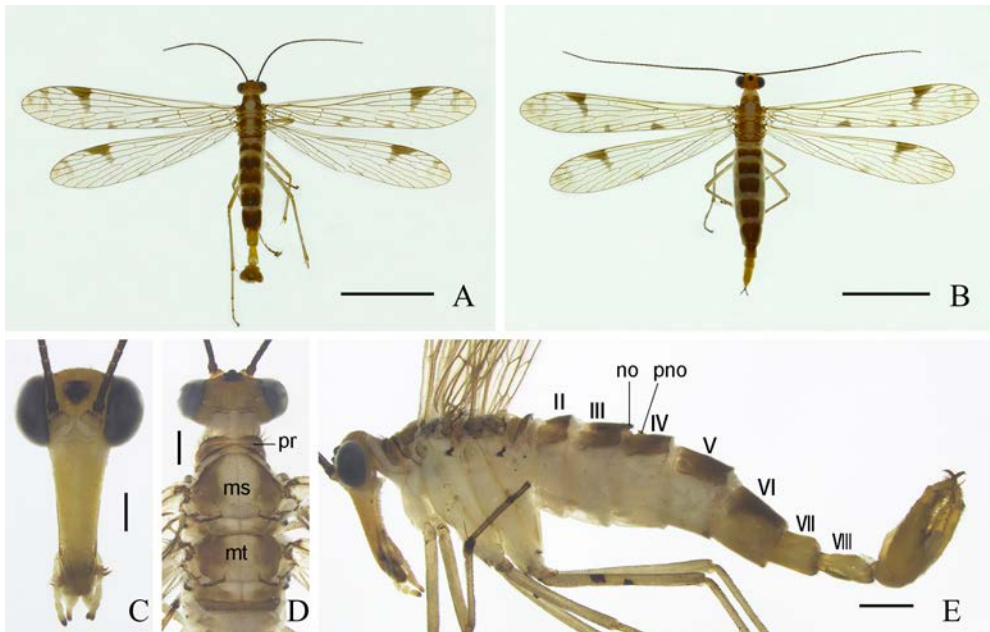


Figure 2. Adults of *Panorpa filititilana* **sp. nov.** A. Male habitus, dorsal view; B. Female habitus, dorsal view; C. Head, frontal view; D. Male head and thorax, dorsal view; E. Male abdomen, lateral view. Scale bars = 5 mm (A, B); 0.5 mm (C, D); 1 mm (E).

Thorax (Fig. 2D). Pronotum brown with anterior and posterior margins darkish, 8–10 stout setae along anterior margin. Meso- and metanotum brown laterally with a broad irregular pale stripe medially. Pleura light brown, and legs light brown with distal tarsomeres darker.

Wings (Fig. 2A). Forewing length 11.2–12.0 mm, width 2.3–2.5 mm. Hindwing length 10.0–10.8 mm, width 2.1–2.4 mm. Membrane hyaline, markings brown. Pterostigma blackish brown. Forewing apical band clouded. Pterostigmal band triangular, with basal and apical

branches greatly reduced into spots along posterior margin. Marginal and basal spots absent. Sc extending slightly beyond middle of wing. 1A ending beyond ORs, two cross-veins between 1A and 2A. Hindwings similar to forewing but pterostigmal band with apical branch absent and basal branch degenerate.

Abdomen (Fig. 2E). T1–T6 blackish brown. Notal organ on posterior margin of T3 slightly developed, postnotal organ acute on T4. S1–S5 light brown, pleura pale. A6 blackish brown, cylindrical. A7 and A8 yellowish brown, A7 nearly cylindrical, A8 constricted basally and beveled apically.

Male genitalia (Figs 3A–C). Genital bulb yellow, long oval. Epandrium extended beyond middle of gonostylus, slightly tapering toward apex, with a deep U-shaped terminal emargination forming two parallel fingerlike processes. Hypandrium Y-shaped, approximately 2/3 as long as gonocoxites, with long basal stalk and a pair of short hypovalves. Hypovalves slender, divergent, and tapering toward apex, with sparse bristles along inner margin. Aedeagal concavity wide, U-shaped. Paramere slender and extremely elongated, far beyond the gonocoxite. Dorsal process of aedeagus slender, dented inward in middle, extending to apex of gonocoxite. Gonostylus shorter than half length of gonocoxite. Median tooth slightly obtuse. Basal process large, auricular, approximately 1/3 as long as gonostylus.

Description. Female (Fig. 2B). Female genitalia (Figs 3D–F). Subgenital plate approximately square, truncated apically. Medigynium slender with main plate half as long as axis. Main plate sunken inward medially. Posterior arm short, approximately 1/4 length of main plate. Axis sunken inward at median and proximal 1/4, and bifurcate at basal 1/4 with distinct apodeme.

**Holotype.** ♂, **China**, Hunan, Mangshan, 1780 m, 24°55'45"N, 112°59'13"E, 06-IX-2020, leg. Mengdi LI; **Paratypes.** 2♀, same data as the holotype.

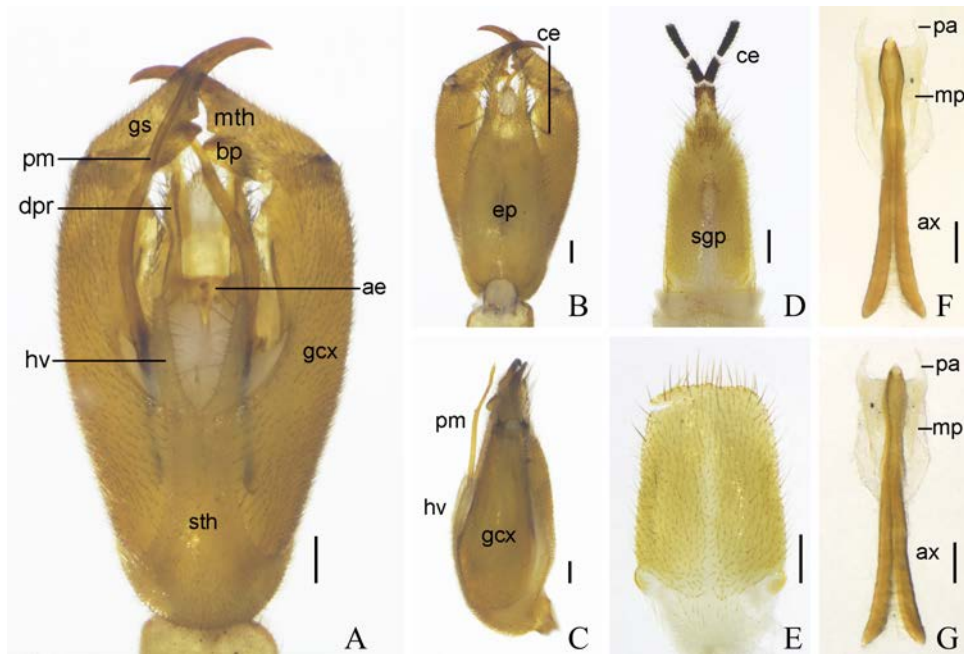


Figure 3. Genitalia of *Panorpa filititilana* sp. nov. A, B, C. Genital bulb, ventral, dorsal and lateral views; D. Terminalia, ventral view; E. Subgenital plate, ventral view; F, G. Medigynium, ventral and dorsal views. Scale bars = 0.2 mm.

**Etymology.** The specific epithet is derived from the Latin “*filum*” (string) and “*titilana*” (titillator), referring to the very slender paramere.

**Diagnosis.** This new species can be distinguished from its congeners by the elongated paramere extending beyond the median tooth of gonocoxite.

**Remarks.** *Panorpa filititilana* **sp. nov.** belongs to the *Panorpa guttata* group. This new species resembles *P. caowei* Wang, 2021 and *P. filina* Chou & Wang, 1987 in general appearance, but can be readily separated from the former by paramere simple and extending beyond median tooth of gonostylus (*cf.* paramere bifurcated with dorsal branch extending to apex of gonocoxites); and separated from the latter by relatively straight parameres (*cf.* bifurcated paramere with dorsal branch strongly curved outwards at base).

## 2. *Panorpa muricata* **sp. nov.** (Figs 4, 5)

**Description.** Male (Fig. 4A). Head (Fig. 4C). Vertex and occiput black, rostrum yellowish brown. A black broad transverse band via ocellar triangle to compound eyes. Antenna black with 42–44 flagellomeres.

**Thorax** (Fig. 4D). Pronotum blackish brown with 10–12 stout setae along anterior margin. Meso- and metanotum blackish brown anteriorly and brown posteriorly. Pleura pale brown. Coxa yellow, gradually darkening toward tarsus. Tarsus yellowish brown.

**Wings** (Fig. 4A). Forewing length 12.5–15.0 mm, width 2.8–3.7 mm. Hindwing length 11.3–13.8 mm, width 2.8–3.5 mm. Membrane yellow. Markings dark brown. Forewings apical band wide with inner margin flat and diagonally running from end of  $R_1$  to between  $R_5$  and  $M_1$ . Pterostigmal band wide and simple. Basal band wide, running from costa to posterior margin. Basal and marginal spots absent. Sc extending to pterostigma. 1A ending beyond ORs, and two cross-veins between 1A and 2A. Hindwings similar to forewing but basal band narrower than in forewings.

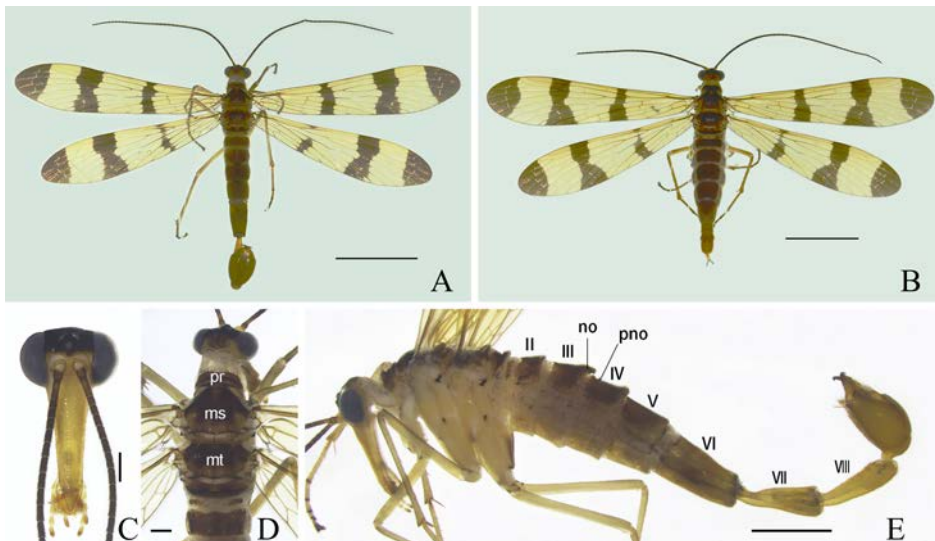


Figure 4. Adults of *Panorpa muricata* **sp. nov.** A. Male habitus, dorsal view; B. Female habitus, dorsal view; C. Male head, frontal view; D. Male head and thorax, dorsal view; E. Male abdomen, lateral view. Scale bars = 5 mm (A, B); 0.5 mm (C, D); 2 mm (E).

Abdomen (Fig. 4E). T1–T5 darkish brown and pleura yellowish brown. Notal organ on posterior margin of T3 slightly developed, postnotal organ on T4 acute. A6 dark brown, cylindrical. A7 and A8 yellowish brown, constricted basally and A8 beveled apically.

Male genitalia (Figs 5A–C). Genital bulb long oval. Epandrium parallel laterally, recessed inward slightly in middle, with a deep U-shaped terminal emargination forming two parallel fingerlike processes. Hypandrium slender, approximately 3/4 as long as gonocoxites, with short basal stalk and a pair of hypovalves. Hypovalves slender, divergent. Aedeagal concavity nearly semicircular and deep to 1/3 of gonocoxite. Gonostylus shorter than gonocoxite, with triangular protrusion between large triangle basal process and extremely sharp median tooth. Paramere flaky.

Description. Female (Fig. 4B). Female genitalia (Figs 5D–F). Subgenital plate oval, with semicircular bulging apex, bearing sparse long setae on distal margin. Main plate wider and both sides tightly healed with laterotergites. Posterior arms nearly parallel at base, gradually tapering toward apex.

**Holotype.** ♂, **China**, Hunan, Jintongshan, 1100 m, 26°8'30"N, 110°12'48"E, 23-VIII-2020, leg. Mengdi LI; **Paratypes.** 7♀, Guangxi, Mao'ershan, Huilong Temple, 1590 m, 25°49'46"N, 110°30'14"E, 30-VIII-2020, leg. Mengdi LI.

Etymology. The specific epithet is derived from the Latin “*muricatus*” (pointed), referring to the prominent tooth on the male gonostylus.

Diagnosis. This new species can be readily recognized by the following characters: (1) wing markings consisting of basal band, pterostigmal band without branches, and apical band; (2) a pointed process between basal process and median tooth on gonostylus.

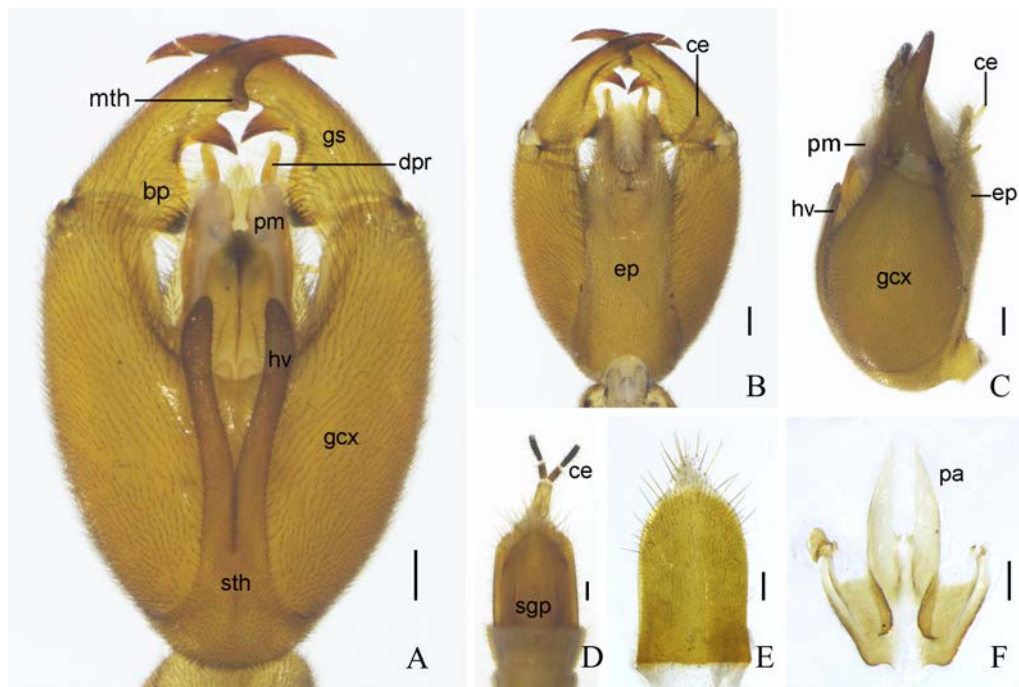


Figure 5. Genitalia of *Panorpa muricata* sp. nov. A–C. Genital bulb, ventral, dorsal and lateral views; D. Terminalia, ventral view; E. Subgenital plate, ventral view; F. Medigynium, ventral view. Scale bars = 0.2 mm.

Remarks. *Panorpa muricata* **sp. nov.** belongs to the *Panorpa cheni* group. The pointed process between the basal process and median tooth is very different from other scorpionflies. *Panorpa muricata* **sp. nov.** resembles *P. tritaenia* Chou & Wang, 1987 in appearance, but can be readily separated from the latter by the following characters: (1) wings membrane yellow, hindwings basal band evident (*cf.* wings membrane hyaline, hindwings basal band lacking); (2) gonostylus with a blunt triangular process and a pointed process basal to the median tooth (*cf.* gonostylus with a developed basal process, in a hook-like prominence); and (3) epandrium with a deep U-shaped terminal emargination forming two elongate fingerlike processes (*cf.* epandrium with trapezoidal terminal emargination forming two short processes).

### 3. *Panorpa yuechenglingensis* **sp. nov.** (Figs 6, 7)

Description. Male (Fig. 6A). Head (Fig. 6C). Vertex and rostrum yellowish brown, ocellar triangle darkish brown. V-shaped transverse band across ocellar triangle extending to compound eyes. Antenna blackish brown, with 44–46 flagellomeres.

Thorax (Fig. 6D). Pronotum blackish brown with 10–12 stout setae along anterior margin. Meso- and metanotum blackish brown. Procoxa yellowish brown, meso- and metacoxa blackish brown. Remaining portion yellowish brown.

Wings (Fig. 6A). Forewing length 14.6–16.3 mm, width 3.4–3.8 mm. Hindwing length 13.2–14.8 mm, width 3.2–3.7 mm. Membrane dark yellow, markings brown. Pterostigma orange. Forewing apical band wide, with 3–4 transparent windows. Pterostigmal band broad, with basal and apical branches. Marginal spot triangular. Basal band broad, extending from costa to posterior margin. Basal spot rounded, extending from vein R to posterior margin and broken medially. Sc extending to pterostigma. 1A ending beyond ORs, and two cross-veins between 1A and 2A. Hindwing similar to forewing but marginal spot and basal spot absent, basal band reduced.

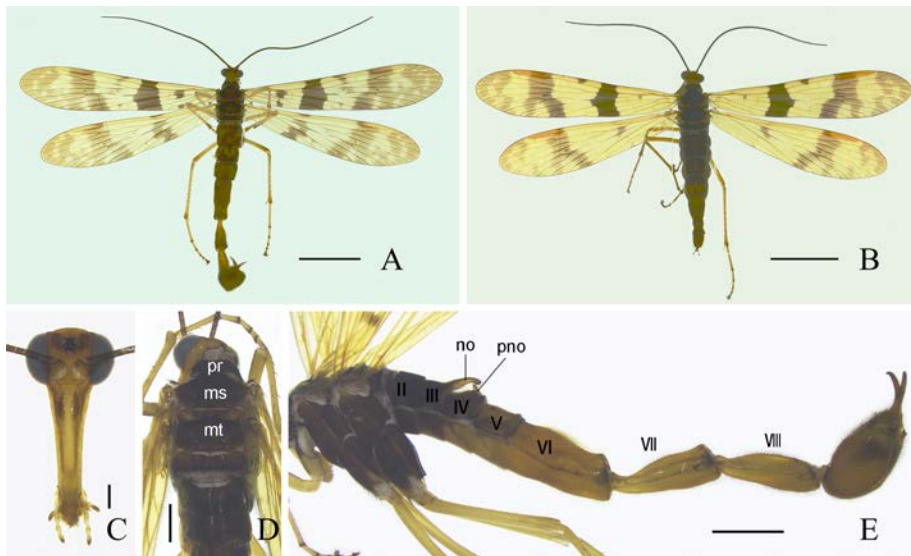


Figure 6. Adults of *Panorpa yuechenglingensis* **sp. nov.** A. Male habitus, dorsal view; B. Female habitus, dorsal view; C. Male head, frontal view; D. Male head and thorax, dorsal view; E. Male abdomen, lateral view. Scale bars = 5 mm (A, B); 0.5 mm (C); 1 mm (D); 2 mm (E).



Abdomen (Fig. 6E). T1–T4 dark brown, T5 brown. Notal organ on posterior margin of T3 elongate, covering acute postnotal organ on T4. Notal organ wider at base and gradually narrowing from middle. S1–S3 blackish brown, S4 and S5 brownish yellow. A6–A8 brownish yellow. A6 approximately 2.5 times as long as A5, A7 and A8 constricted basally, and A8 beveled apically.

Male genitalia (Figs 7A, 7B, 7D–G). Genital bulb yellowish brown, long oval. Outer margins of epandrium approaching parallel, with a deep U-shaped terminal emargination forming two parallel fingerlike processes. Hypandrium Y-shaped with narrow stalk. Hypo valve slender, gradually widening toward apex. Gonocoxite with broad wedge-shaped subapical mesal lobe. Gonostylus shorter than gonocoxite, with median tooth blunt and basal process large auricular. Paramere bifurcated with dense and short hairs apically. Lateral branch bent backward. Ventral valve of aedeagus membranous and short. Dorsal process slender, tapering towards subacute apex. Lateral process developed, fingerlike.

Description. Female (Fig. 6B). Female genitalia (Figs 7C, 7H, 7I). Subgenital plate oval, with sparse long setae on distal part. Main plate of medigynium wide, constricted at proximal 1/4. Posterior arms extremely slender. Main plate constricted subapically. Axis slender.

**Holotype.** ♂, China, Guangxi, Yuecheng Ridge, Mao'ershan, 1970 m, 25°53'12"N, 110°25'11"E, 31-VIII-2020, leg. Mengdi LI; **Paratypes.** 4♂4♀, same data as the holotype.

Etymology. The specific epithet is derived from the type locality, the Yuecheng Ridge (Yuechengling).

Diagnosis. This new species can be distinguished from its congeners by the following characters: (1) A6 approximately 2.5 times as long as A5, A7 and A8 constricted basally; (2) the basal band of forewings broader and darker; (3) gonocoxite with a broad wedge-shaped subapical mesal lobe; and (4) paramere bifurcated with two sub-equal branches.

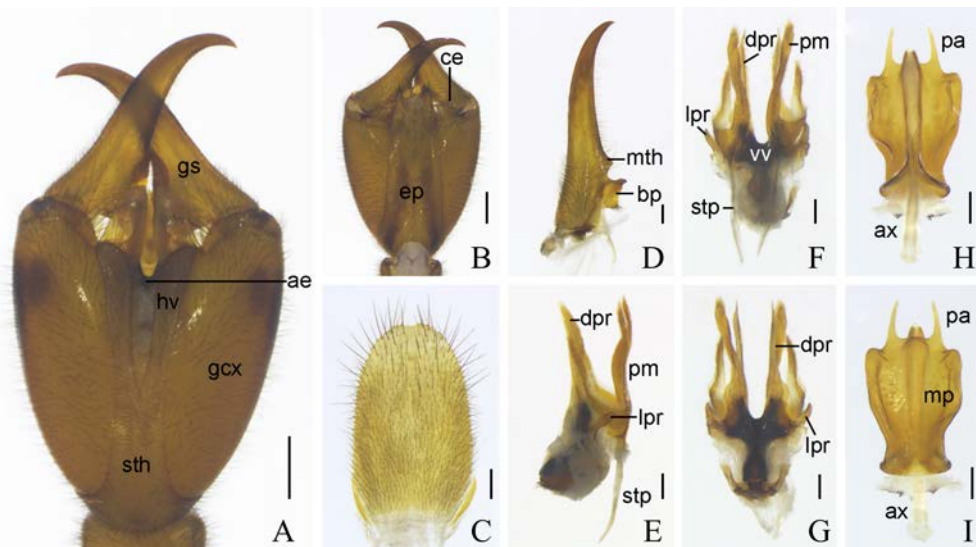


Figure 7. Genitalia of *Panorpa yuechenglingensis* sp. nov. A, B. Genital bulb, ventral and dorsal views; C. Female subgenital plate, ventral view; D. Gonostylus, ventral views; E–G. Aedeagal complex, left-lateral, ventral and dorsal views; H, I. Medigynium, ventral and dorsal views. Scale bars = 0.5 mm (A, B); 0.2 mm (C–I).

Remarks. *Panorpa yuechenglingensis* **sp. nov.** belongs to the *Panorpa stigmalis* group. The most important character to recognize *Panorpa yuechenglingensis* **sp. nov.** is the developed and wide fingerlike prominence in the gonocoxite of male.

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### References

- Bicha W. 2018. Biodiversity of Mecoptera. In: Footitt RG & Adler PH (Eds.), *Insect Biodiversity: Science and Society, II*. John Wiley & Sons, Hoboken, pp. 705–720.
- Byers GW. 1970. New and little known Chinese Mecoptera. *Journal of the Kansas Entomological Society*, 43: 383–394.
- Byers GW. 1989. Homologies in wing venation of primitive Diptera and Mecoptera. *Proceedings of the Entomological Society of Washington*, 91: 497–501.
- Byers GW. 2009. Mecoptera: scorpionflies, hangingflies. In: Resh VH & Cardé RT (Eds.), *Encyclopedia of Insects. Second Edition*. Academic Press, Cambridge, pp. 611–614.
- Byers GW & Thornhill R. 1983. Biology of the Mecoptera. *Annual Review of Entomology*, 28: 203–228.
- Chen J, Tan JL & Hua BZ. 2013. Review of the Chinese *Bittacus* (Mecoptera: Bittacidae) with descriptions of three new species. *Journal of Natural History*, 47: 1463–1480.
- Chen ZM, Gong YN, Zhang M & Lu XL. 2015. Construction and development of the protected area system in Nanling. *Guangdong Forestry Science and Technology*, 31(3): 82–86.
- Cheng FY. 1957. Revision of the Chinese Mecoptera. *Bulletin of the Museum of Comparative Zoology*, 116: 1–118.
- Chou I, Wang SM, Li ZD & Tong XW. 1987. New species of Mecoptera from Hunan Province (I). *Entomotaxonomia*, 9(1): 31–42.
- Chou I, Wang SM, Li ZD & Tong XW. 1988. New species of Mecoptera from Hunan Province (II). *Entomotaxonomia*, 10(3): 201–212.
- Gao K & Hua BZ. 2021. A new species of the genus *Cerapanorpa* (Mecoptera, Panorpidae) from the eastern Bashan Mountains. *Biodiversity Data Journal*, 9: e72451.
- 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.
- 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.
- Li N, Wang JS & Hua BZ. 2021. Morphological phylogenetic analyses and taxonomic revision of the *Panorpa davidi* group (Mecoptera: Panorpidae). *Arthropod Systematics & Phylogeny*, 79: 309–342.
- Ma N & Hua BZ. 2011. *Furcatopnorpa*, a new genus of Panorpidae (Mecoptera) from China. *Journal of Natural History*, 45: 2251–2261.
- Palmer CM. 2010. Diversity of feeding strategies in adult Mecoptera. *Terrestrial Arthropod Reviews*, 3: 111–128.
- Penny ND & Byers GW. 1979. A check-list of the Mecoptera of the world. *Acta Amazonica*, 9: 365–388.

- Tong X & Hua BZ. 2019. Nuptial feeding and genital coupling of *Neopanorpa* scorpionflies (Insecta: Mecoptera: Panorpidae) with notal organs of various lengths. *Contributions to Zoology*, 88: 498–512.
- Wang CL. 1993. Formation and evolution of Nanling Range. *Tropical Geomorphology*, 14(2): 46–52.
- 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.
- Wang JS & Gong YJ. 2021. Taxonomy of the *Panorpa guttata* group (Mecoptera: Panorpidae), with descriptions of fourteen new species from China. *Zootaxa*, 4981: 241–274.
- Wang JS & Hua BZ. 2016. Two new species of the genus *Panorpa* Linnaeus (Mecoptera, Panorpidae) from Yunnan, China. *ZooKeys*, 587: 151–162.
- Wang JS & Hua BZ. 2017. An annotated checklist of the Chinese Mecoptera with description of male *Panorpa guttata* Navás, 1908. *Entomotaxonomia*, 39(1): 24–42.
- Wang JS & Hua BZ. 2019. *Megapanorpa*, a new genus with a single anal horn in males from Oriental China (Mecoptera: Panorpidae). *Entomological Science*, 22(1): 64–79.
- Wang JS & Hua BZ. 2021. Morphological phylogeny of Panorpidae (Mecoptera: Panorpoidea). *Systematic Entomology*, 46: 526–557.
- Zhang YN, Du W & Hua BZ. 2020. Three new species of the genus *Bittacus* Latreille, 1805 (Mecoptera: Bittacidae), with a key to the species of Bittacidae in South China. *Zootaxa*, 4718: 381–390.
- Zhong W & Hua BZ. 2013a. *Dicerapanorpa*, a new genus of East Asian Panorpidae (Insecta: Mecoptera: Panorpidae) with descriptions of two new species. *Journal of Natural History*, 47: 1019–1046.
- Zhong W & Hua BZ. 2013b. Mating behaviour and copulatory mechanism in the scorpionfly *Neopanorpa longiprocessa* (Mecoptera: Panorpidae). *PLoS ONE*, 8: e74781.