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Discovery of *Neopanorpa chillcotti* Byers (Mecoptera: Panorpidae) from Tibet, China, with discussion of its generic status

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Abstract

Neopanorpa chillcotti Byers, 1971 was originally described from Kathmandu in Nepal and is now found to be distributed in Gyirong, Tibet in China. The species is redescribed and illustrated based on new material from China and Nepal. The generic status of this species is briefly discussed.

Key words: Insecta, *Leptopanorpa*, new record, Nepal

Introduction

Panorpidae (Insecta: Mecoptera) are characterized mainly by their male genital bulb superficially resembling the tail of scorpions, thus being commonly called scorpionflies. They are widely distributed in the northern continents and usually occur in dense forests or in mountainous areas with high humidity. Males generally provide a soft-bodied arthropod prey or salivary mass to the female as a nuptial gift during mating (Byers & Thornhill 1983; Engels & Sauer 2006; Palmer 2010). Recent studies have shown that the notal organ (posterior process of tergum III) and the anal horn(s) on tergum VI of males play significant roles during the copulation of scorpionflies (Thornhill & Sauer 1991; Zhong & Hua 2013; Zhong *et al.* 2015).

Neopanorpa Weele, 1909 is the second largest genus in Panorpidae and is limited to the Oriental Region, including China, Japan, India, Indochina, Myanmar, Nepal, and Indonesia. It is characterized by slender wings and a greatly developed notal organ (like a clamp to grasp the anterior edge of the female's wings during copulation) (Mickoleit 1971; Zhong & Hua 2013). Approximately 133 species are described in this genus worldwide, of which 75 species are recorded from China (Cai & Hua, 2009).

Neopanorpa chillcotti Byers, 1971 was originally described from Kathmandu in Nepal, and is the third species found in the Himalaya area bearing an elongated male abdomen similar to that of *Leptopanorpa* MacLachlan, 1875 (Lieftinck 1936; Chau & Byers 1978). In July 2013 the species was discovered in Gyirong, Tibet, China for the first time, bringing up again the argument about its generic assignment, whether to *Leptopanorpa* or *Neopanorpa*. Herein detailed redescriptions and photographs are provided and the generic status of this species is briefly discussed. A distribution map of this species is also provided (Fig. 1).

Material and methods

Adult specimens were collected in the mountainous areas of Gyirong (Figs. 1–2), Tibet, China and Kathmandu, Nepal in late July 2013 and were preserved in 75% ethanol.

For light microscopy, adult specimens were dissected under a Nikon SMZ1500 Stereoscopic Zoom Microscope (Nikon, Tokyo, Japan). Photographs were taken with a QImaging Retiga 2000R Fast 1394 Digital CCD camera (QImaging, Surrey, Canada) attached to the microscope and stacked with Syncroscopy Auto-Montage software.

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FIGURE 1. Distribution map of *Neopanorpa chillcotti* Byers.

FIGURE 2. Habitat of *Neopanorpa chillcotti* Byers from Gyirong, Tibet in China.

***Neopanorpa chillcotti* Byers, 1971**
(Figs. 3–9**)**

Neopanorpa chillcotti Byers, 1971: 534, figs. 1–10; Rust & Byers, 1976: 45, figs. 27–34.

Specimens examined. 6♂, 5♀, CHINA: TIBET: Gyirong (28°23′N, 85°21′E, elev. 2750 m), 28.VII.2013, leg. Tao Li; 5♂, 3♀, NEPAL: KATHMANDU (27°41′N, 85°31′E, elev. 2150 m), 24.VII.2013, leg. Tao Li.

Diagnosis. *Neopanorpa chillcotti* can be readily recognized from its congeners by the following characters: body yellowish brown; vertex entirely blackish brown; wings strongly tinged with yellow; male abdomen prominently longer than wings; notal organ extended shortly beyond the posterior margin of tergum IV; hypovalves slender, widely divergent, elongated to the caudal end of gonocoxite, slightly expanded and convergent at tips; epandrium tapering to the tip, ended with a rounded apex; female superficially distinct with two black spots on the middle of each of terga III–V.

Redescription. Male (Fig. 3A): Body yellowish brown. Vertex blackish brown (Fig. 4A); rostrum long, slender, yellowish brown with two diffuse brown longitudinal stripes along the lateral margin and a cluster of setae along the inferior margin of clypeus (Fig. 4A); mandibles reddish brown with three teeth, maxillary palpus and labial palpus brown, darkened at tips; antennal scape yellowish brown, pedicel blackish brown, flagellum blackish brown with 52 flagellomeres.

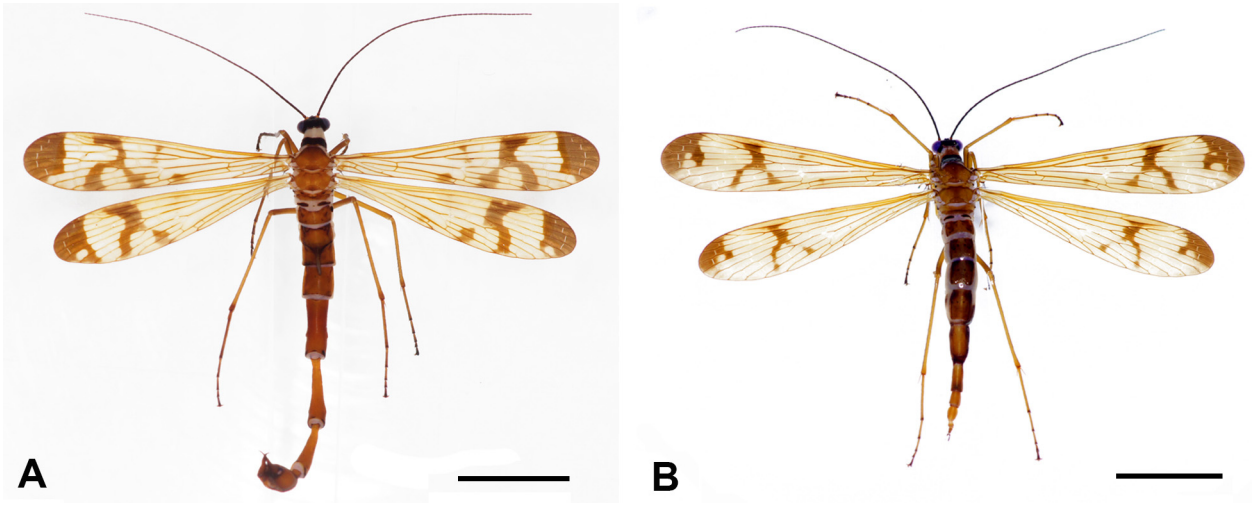

FIGURE 3. *Neopanorpa chillcotti* Byers from Gyirong, Tibet in China, dorsal view. (A) Male; (B) Female. Scale bars = 0.5 mm.

Thorax (Fig. 4B) yellowish brown; pronotum black with short black setae along the anterior margin; meso- and metascutum yellowish brown with dense setae on scutum and scutellum; the lateral margin of mesoscutum bearing dense setae before pleural wing process; pleura and coxa whitish yellow, femur yellowish, darkened at tips, a cluster of short setae along the lateral margin of tibia, two long reddish spurs of equal length at the end of tibia; tarsus blackish brown with five tarsomeres, pretarsus with two claws; claws strongly curved with five pectinate teeth.

Wings (Figs. 3, 5, 6) slender and long, narrow at base, strongly tinged with yellow, wing markings dark brown; pterostigma dark yellow with dense setae; wing venation brown; vein Sc ending at the pterostigma; R_2 three-branched; 1A ending before the origin of Rs (Fig. 5). Forewings with 5–7 jugal bristles, hind wings with 2–3 frenular bristles.

Wing markings are highly variable and can be categorized into four distinct types of wing patterns (Fig. 6). Type I (Fig. 6A; 6♂, 2♀ from China and 3♂, 2♀ from Nepal) is the most common pattern. Other types of wing patterns are compared with type I. In the forewings of type I, the apical band is incomplete, ending posteriorly near M_1, and with a projection prolonging posteriorly beyond R_4; the pterostigmal band is Y-shaped, with the basal branch often interrupted at base and the apical branch complete; the basal spot is absent; the marginal spot is very small and vague, only extending to R_{4+5}; the submedian band is faintly indicated by a spot between CuA and CuP.

Sometimes the marginal spot and submedian band are too obscure to be seen. Hind wings are similar to forewings, with only the apical band and pterostigmal band present. Type II (Fig. 6B; 1♂, 2♀ from Nepal) is comparatively complete in wing pattern. In forewings, the pterostigmal band is complete; the apical band is complete with a hyaline window posterior to vein R_5; the marginal spot and the submedian band are distinct. In hind wings the pterostigmal band is also complete; the apical band is notched at the inner-posterior corner with a small hyaline window between veins R_{2a2} and R_3 (Fig. 6B). Type III (2♀ from China) is very similar to type I, but in the forewings the basal branch of the pterostigmal band is complete, and the apical band has a small hyaline window between veins R_{2b} and R_3; in the hind wings an anterior and a posterior notch render the apical band anchor-shaped (Fig. 6C). Type IV (1♂ from Nepal) is greatly reduced in its wing markings in that the basal branch of the pterostigmal band is almost absent, and the apical band is reduced to the apical area (Fig. 6D).

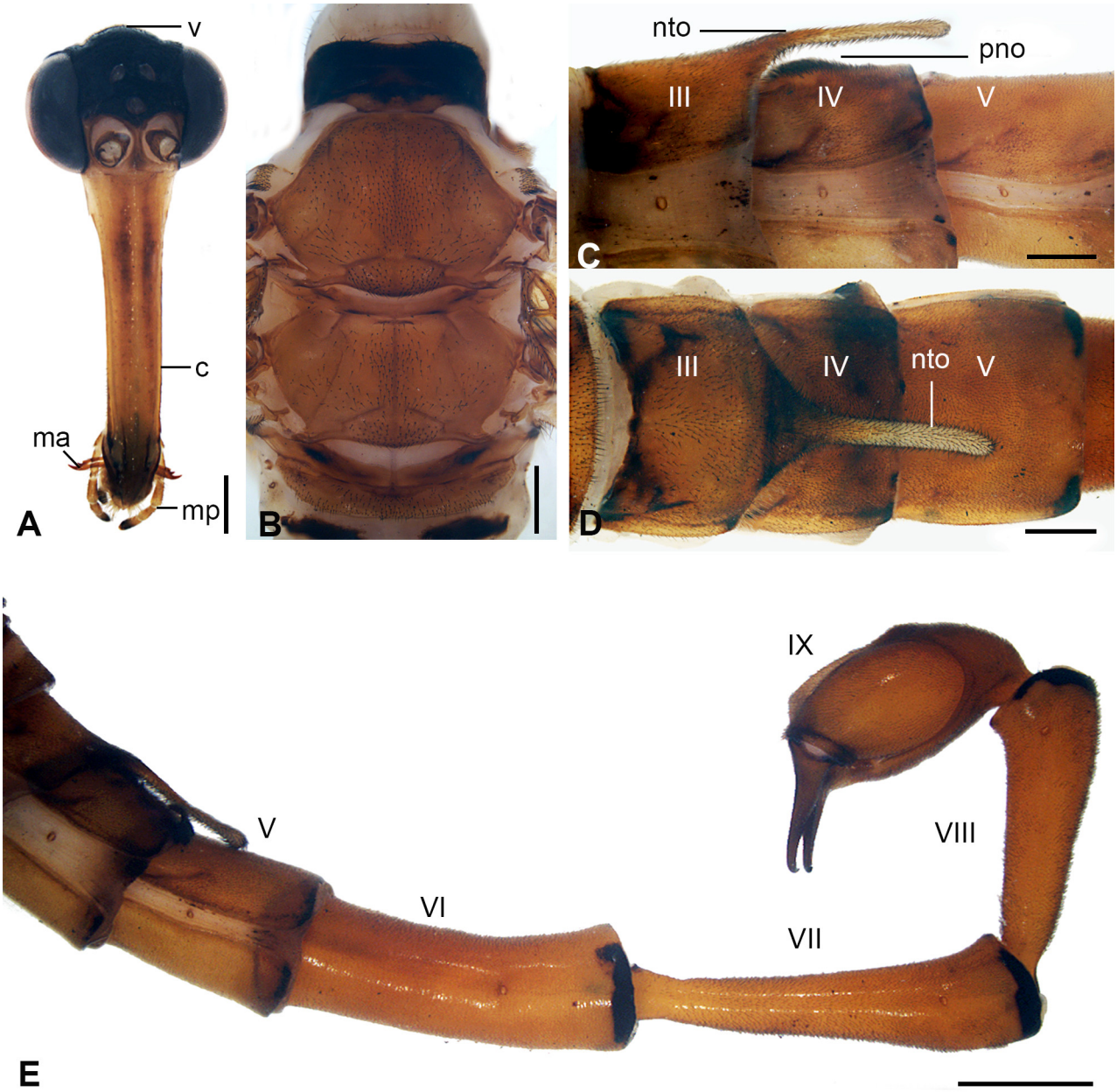

FIGURE 4. *Neopanorpa chillcotti* Byers, male. (A) Head, frontal view; (B) Thorax, dorsal view; (C) Notal organ, lateral view; (D) Notal organ, dorsal view; (E) male abdominal segments III–IX, lateral view; Abbreviations: c, clypeus; ma, mandible; mp, maxillary palp; nto, notal organ; pno, post-notal organ; v, vertex. Scale bars: A–D = 0.5 mm; E = 1 mm.

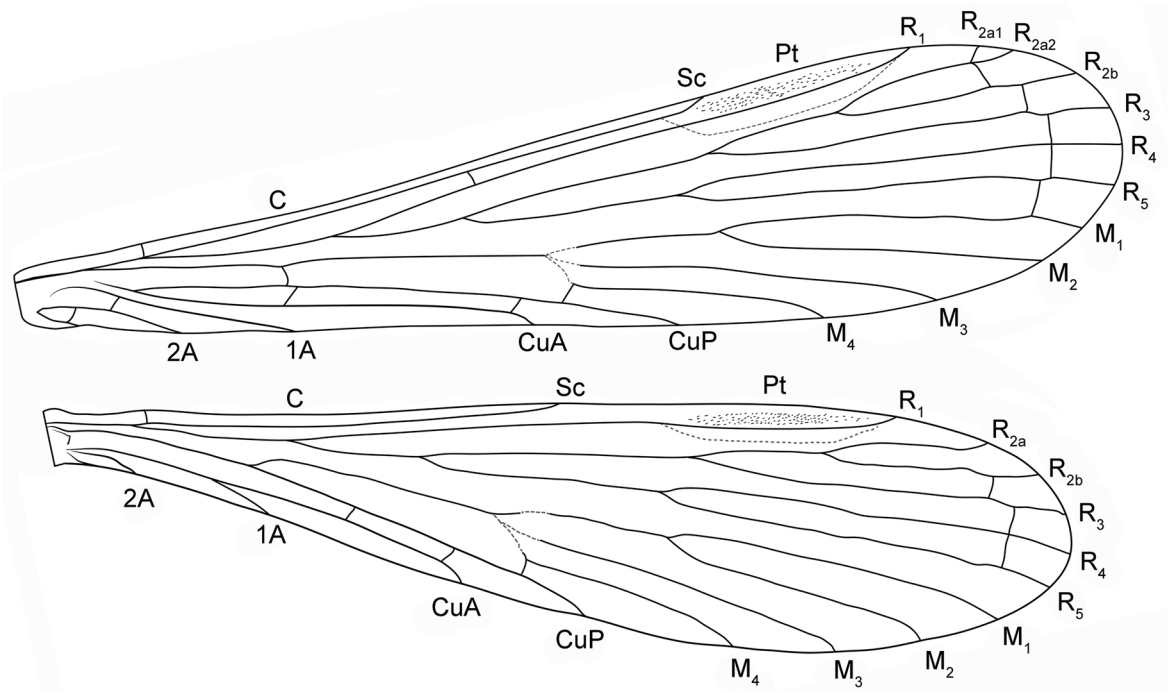

FIGURE 5. Wing venation of *Neopanorpa chillcotti* Byers. Abbreviations: A, Anal; C, Costa; CuA, Cubitus anterior; CuP, Cubitus posterior; M, Media; Pt, Pterostigma; R, Radius; Sc, Subcosta.

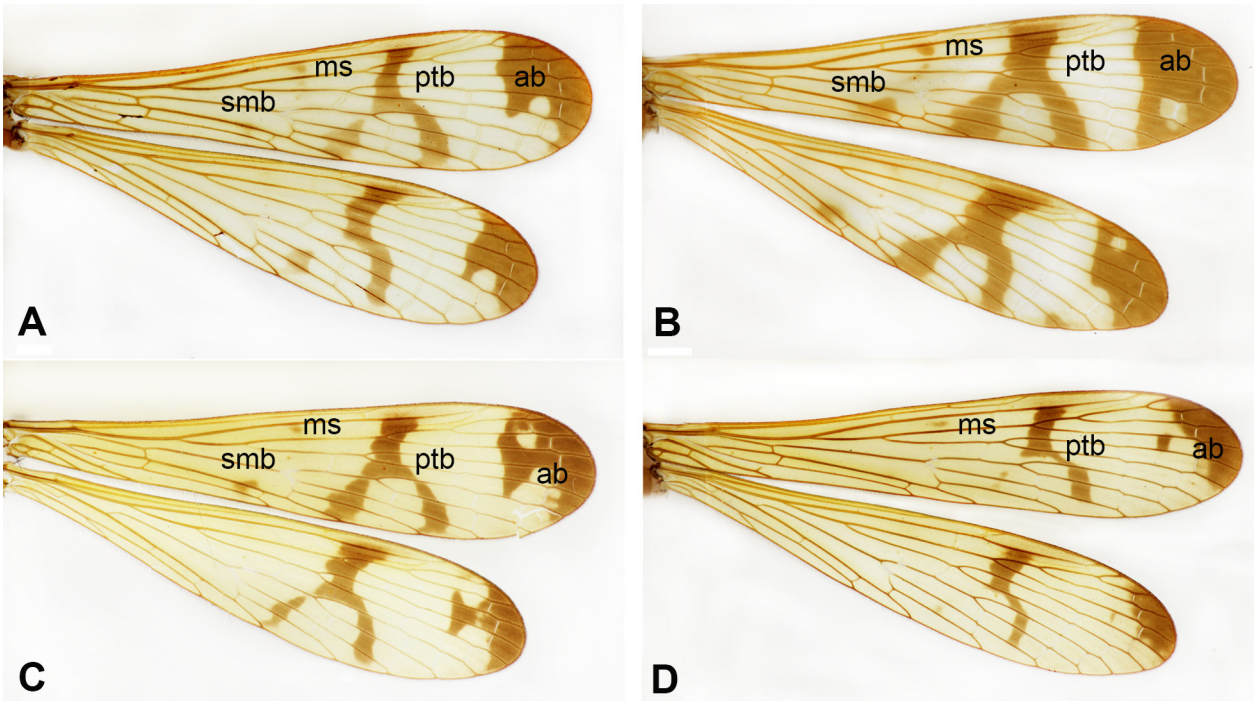

FIGURE 6. Wing marking variations of *Neopanorpa chillcotti* Byers. (A) Type I; (B) Type II; (C) Type III; (D) Type IV; Abbreviations: ab, apical band; ms, marginal spot; ptb, pterostigmal band; smb, submedian band.

Abdomen prominently longer than wings (Fig. 3A); terga I–V sordid yellowish brown, corresponding sterna light yellow (Figs. 4C–E); notal organ on tergum III broad at base, abruptly narrow near the middle of tergum IV and extending posterad beyond tergum IV; a minor flat projection (post-notal organ) on tergum IV with dense setae, projected forwards (Figs. 4C–D); terga VI–VIII yellowish brown bordered with black pigment on pleuro-caudal margin (Fig. 4E), each of VI–VIII greatly elongated, about twice the length of segment V, segments VII and VIII constricted at base (Fig. 4E).

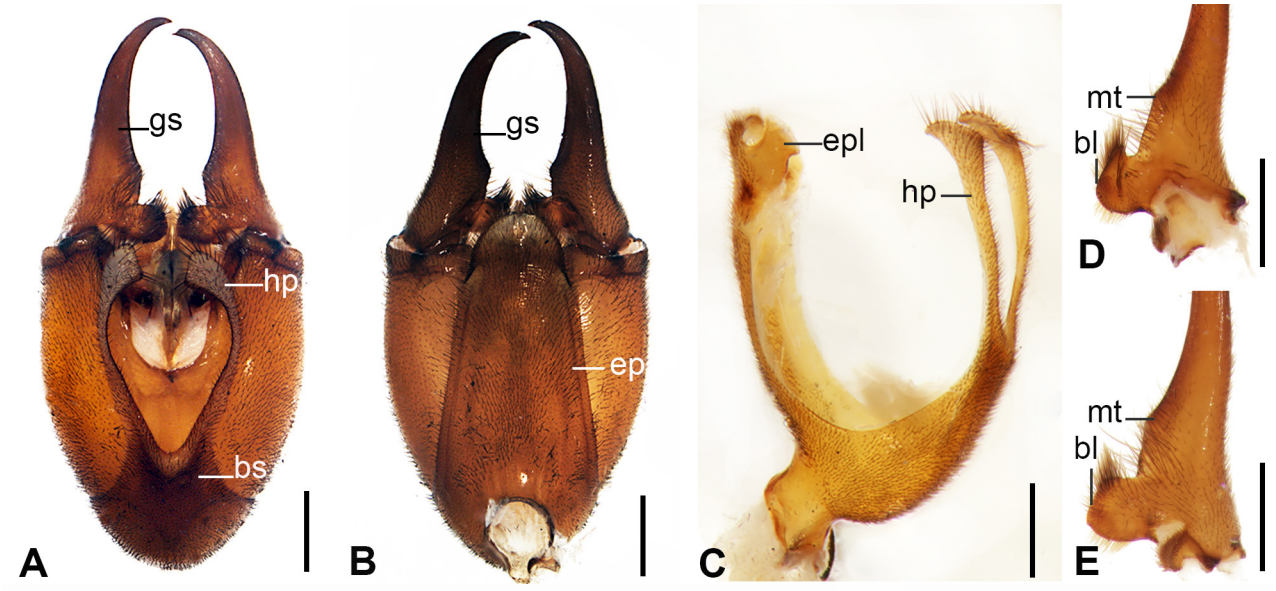

FIGURE 7. *Neopanorpa chillcotti* Byers, male genitalia. (A) Genital bulb, ventral view; (B) Genital bulb, dorsal view; (C) 9th tergum and sternum, lateral view; (D) Gonostylus, dorsal view; (E) Gonostylus, ventral view; Abbreviations: bl, basal lobe; bs, basal stalk; ep, epandrium; epl, epandrial lobe; gs, gonostylus; hp, hypovalve; mt, mesal tooth. Scale bars = 0.5 mm.

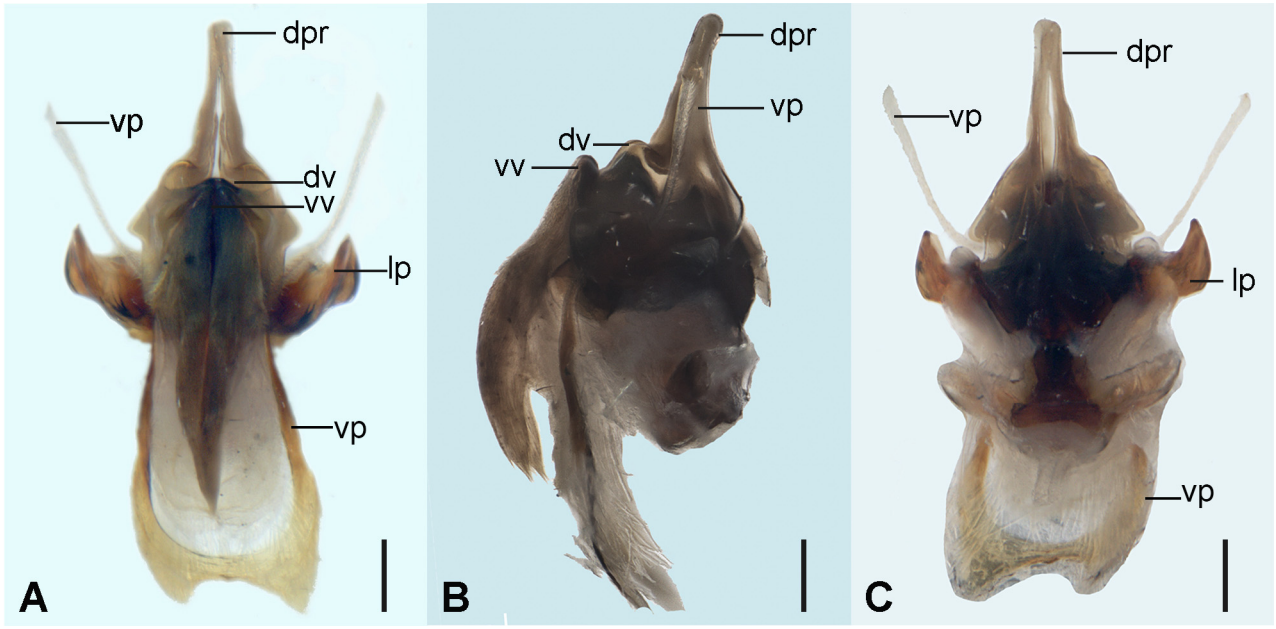

FIGURE 8. *Neopanorpa chillcotti* Byers, aedeagal complex. (A) Ventral view; (B) Lateral view; (C) Dorsal view; Abbreviations: dpr, dorsal process; dv, dorsal valve; lp, lateral process; vp, ventral paramere; vv, ventral valve. Scale bars = 0.2 mm.

Male genitalia yellowish brown, long elliptical (Figs. 7A–B); gonostylus long and slender, concaved inwards at basal third, hook-like at tips; basal lobe large, bearing dense setae at apex; mesal tooth blunt with a minor triangular setiferous projection (Figs. 7D–E); hypandrium (sternum IX) broad with a short basal stalk (Fig. 7A); hypovalves slender, widely divergent at base, prolonged to the end of gonocoxite, apex slightly expanded and convergent, bearing numerous long setae (Figs. 7A, C); epandrium (tergum IX) tapering apically, apex rounded, laterally bearing broad projections (epandrial lobes) concealed in the genital bulb (Figs. 7B–C).

Aedeagus sclerotized (Fig. 8); ventral valve divided mesally and tapering downward to slender, membranous hirsute structure (Figs. 8A–B); dorsal valve stout and indistinct (Figs. 8A–B); dorsal process conspicuous, base expanded, laterally with a triangular protuberance, apically prolonged, slightly expanded and overlapped near

apices (Figs. 8A–C); lateral process distinct, apex acute, projecting ventroapically (Figs. 8A–C); ventral paramere slender, elongated, composed of two distinct parts: the basal part, attached near base of lateral process, strongly sclerotized, rectangular, with two pointed apices posteriorly, and the distal part free, membranous, whitish, with minute pale hairs, passing ventral curved surface of lateral process and extending distad (Figs. 8A, C).

Female (Fig. 3B): Same coloration as in the male with the following supplements. Sterna I–VI yellowish brown, terga III–V sordid dark brown, each with a pair of small black spots in the middle, segments VII–X dark brown (Fig. 9A); cerci blackish brown, two-segmented (Fig. 9B). Subgenital plate yellowish brown, medially membranous, terminated with a deep V-shaped emargination at apex, dorsally with two rounded membranous processes contacting the genital plate (Figs. 9C–D). Genital plate with axis slightly extended beyond the main plate; posterior arms well-developed, broad spatulate in the apical half (Fig. 9E).

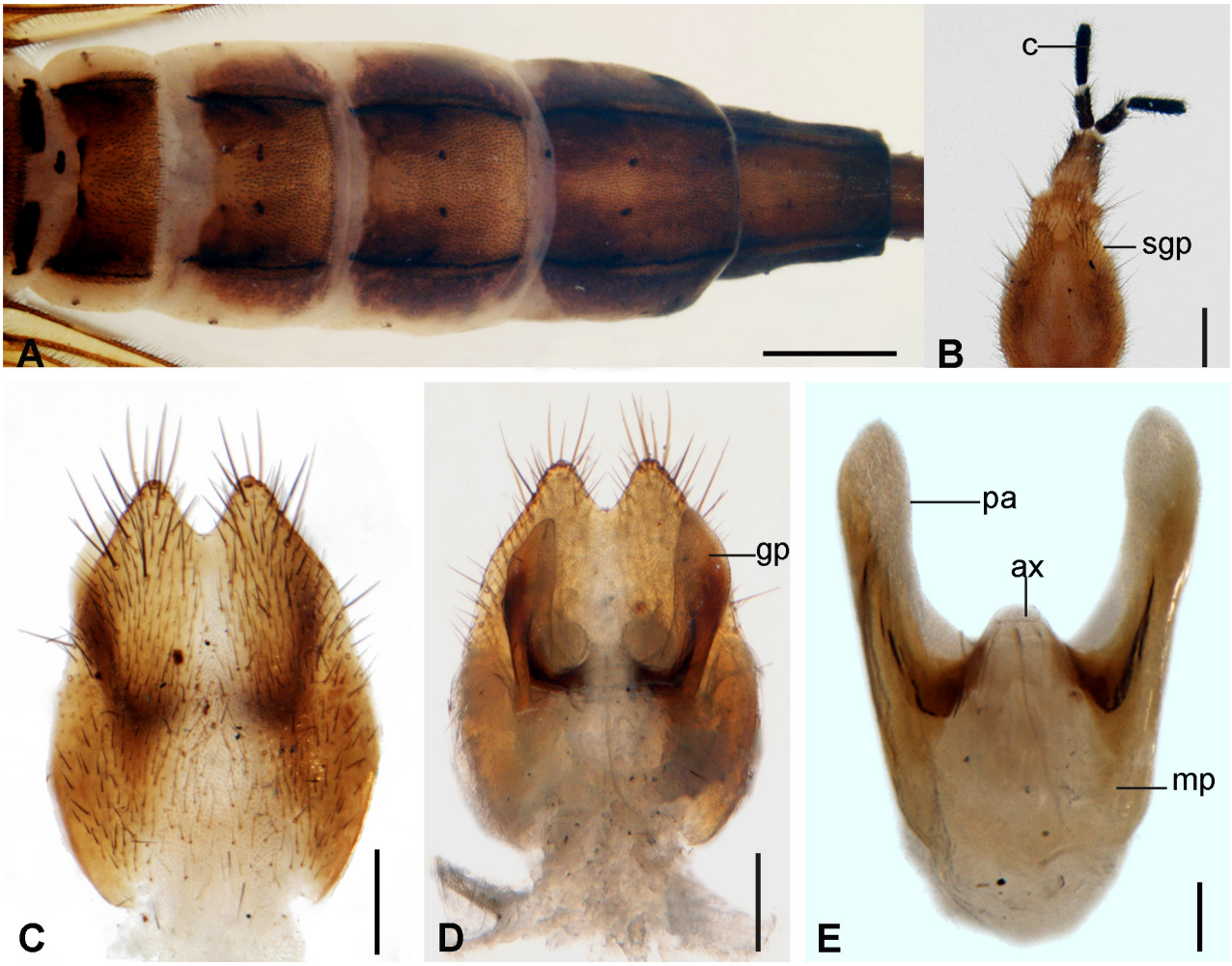

FIGURE 9. *Neopanorpa chillcotti* Byers, female abdomen and genitalia. (A) Abdominal segments I–VI, dorsal view; (B) Abdominal segments IX–XI, ventral view; (C) Subgenital plate, ventral view; (D) Subgenital plate conjoint with genital plate, dorsal view; (E) Genital plate, ventral view; Abbreviations: ax, axis; c, cercus; gp, genital plate; mp, main plate; pa, posterior arms; sgp, subgenital plate. Scale bars: A = 1 mm, B = 0.25 mm; C–D = 0.2 mm; E = 0.1 mm.

Measurements. Body length, male 22.38 ± 1.36 mm (n = 9); female 16.06 ± 2.30 mm (n = 7). Male (n = 11), forewing length 14.84 ± 0.89 mm, width 3.32 ± 0.32 mm; hind wing length 13.76 ± 0.86 mm, width 2.96 ± 0.32 mm. Female (n = 8), forewing length 15.12 ± 0.98 mm, width 3.29 ± 0.25 mm; hind wing length 14.04 ± 0.93 mm, width 3.05 ± 0.23 mm.

Distribution. China (Gyirong, Tibet); Nepal (Kathmandu).

Habitat. Gyirong in Tibet is adjacent to Nepal with an average elevation of 2600 m (Fig. 1). Rainfall occurs primarily between May and September, with more than 1000 mm precipitation annually. The landscape is conjoint with lush forests and deep ravines. Most adults were captured on low shrubs or shaded herbs at the edge of broad-leaved forest mixed with coniferous trees (Fig. 2).

Remarks. This is the first record of *N. chillcotti* from Tibet, China since it was reported from Nepal by Byers (1971). Based on our observations of a series of specimens preserved in ethanol, several variations were found to differ from the original description. Firstly, a remarkable line of short black setae was observed along the anterior margin of the pronotum in our specimens (Fig. 4B), conflicting with a lack of spines along the anterior margin given in the original description (Byers 1971). Additionally, possibly due to strong shrinkage of dry pinned specimens, the female subgenital plate and genital plate illustrated by Byers (1971) are narrower and more slender than those in our figures (Figs. 9C–E).

Details of the postnotal organ are added as well because Byers (1971) only dealt with the process on tergum III. The anterior part of the aedeagus is not visible in the original illustration. Here we add illustrations of the aedeagus from different aspects (Figs. 8A–C).

Discussion

Leptopanorpa is a genus endemic to Indonesia, and is characterized by the extremely elongated abdomen in males (Chau & Byers 1978). This genus is commonly considered to be the sister group of *Neopanorpa* based on the phylogenetic analyses of morphological characters (Willmann 1989; Ma *et al*. 2012), and is differentiated from the latter mainly by the male abdomen being much longer than the wings (Esben-Petersen 1921; Cheng 1957).

However, *N. chillcotti* is a peculiar case in *Neopanorpa.* Although Byers (1971) assigned it to *Neopanorpa* rather than *Leptopanorpa* due to the wide wing base and the robustness of the abdominal segments, the great elongation of the male abdomen strongly resembles the condition in *Leptopanorpa*, possibly calling into question *N. chillcotti*'s generic status, as well as the reliability of the boundary between the two closely related genera.

Apart from the two characters mentioned above (Byers 1971), careful comparative morphological analysis of *N. chillcotti* reveals additional characteristics that support its placement within *Neopanorpa.* Firstly, *N. chillcotti* is differentiated from *Leptopanorpa* in body size and length of wings. As Byers (1971) pointed out, most *Leptopanorpa* species in Indonesia are slender in overall body form and with short forewings ranging from 11 to 13 mm (Lieftinck 1936), but *N. chillcotti* is larger and robust, with its forewing length ranging from 14 to 16 mm. Also, although *N. chillcotti* has the vein R_2 three-branched as in *Leptopanorpa*, this condition can also be found in several species of *Neopanorpa*, such as *N. brisi* (Navás), *N. nielseni* Byers, and *N. spatulata* Byers.

With respect to the male genitalia, *Leptopanorpa* is characterized by the slender elliptical shape of the genital bulb, bilobed basal lobes of the gonostylus, and a fairly long basal stalk (Lieftinck 1936; Chau & Byers 1978). *Neopanorpa chillcotti*, however, displays a broad oval shape of the genital bulb, an unbranched gonostylus, and a lack of a stalk at the base of hypandrium. In addition, *N. chillcotti* differs greatly from *Leptopanorpa* in the aedeagus. *Leptopanorpa* normally bears indistinct ventral valves, a pair of small lateral processes, and complicated ventral parameres. In contrast, *N. chillcotti* bears conspicuously large ventral valves, broad lateral processes, and simple ventral parameres. All of these are typical characters of *Neopanorpa*. Other characters of males, such as the notal organ, hypandrium, and epandrium, as well as the female genitalia, are much alike in the two genera and only differ slightly in several peculiar cases. In spite of the similarity in the elongation of the male abdomen, the Himalayan *N. chillcotti* appears to have more in common with *Neopanorpa* than *Leptopanorpa*.

A similar situation applies to some other *Neopanorpa* species occurring in the Himalayas, namely *N. furcata* (Hardwicke) and *N. effusa* (Navás), both of which are remarkable by the exceeding elongation of the male abdomens. They had long been regarded as representatives of *Leptopanorpa* uniquely distributed outside of Indonesia (Esben-Petersen 1921; Lieftinck 1936). However, the discovery of *N. chillcotti,* an additional species with elongated abdomens in males around the Himalaya area, caused Byers (1971) to transfer the two species from *Leptopanorpa* to *Neopanorpa* (Rust & Byers 1976).

Elongation of the male abdomen is also seen in the fossil groups Holcorpidae, Orthophlebiidae, and *Baltipanorpa* (Panorpidae) (Willmann & Novokschonov 1998; Archibald 2010; Krzeminski & Soszynska-Maj 2012), and the extant species *Panorpa japonica* Thunberg (Miyaké 1913). The different degrees of elongation and diverse forms indicate that the elongation of the male abdomen is likely a homoplasious character independently evolved several times during the evolutionary history of Mecoptera. Moreover, the elongation of male abdominal segments is not consistent within *Leptopanorpa* (Lieftinck 1936). Some species like *L. erythrura, L. javanica*, and *L. inconspicua* are overall robust, certainly separable from other *Leptopanorpa* species in wing shape and male genitalia (Lieftinck 1936).

Collectively, these observations suggest that length of the male abdomen alone is not suitable as a clear morphological boundary between *Neopanorpa* and *Leptopanorpa*, and their generic descriptions ought to be rewritten.

It should be noted that a recent molecular phylogenetic analysis of Panorpidae (Hu *et al*. 2015) placed *N. chillcotti* as the sister taxon of all the other species of *Neopanorpa*, suggesting that it is greatly divergent from the remaining species. However, no species of *Leptopanorpa* were involved in the analysis, and thus the generic status of *N. chillcotti* remains in question. Further integrative approaches based on molecular and morphological data for both *Leptopanorpa* and *Neopanorpa* are needed to clarify the relationship between them and establish reliable definitions of generic boundaries.

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