





Little-known wingless crickets of Bhutan (Rhaphidophoridae): discovery and description of nine new species



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ABSTRACT

We present the results of a survey of rhaphidophorids in Bhutan more than half a century since the first systematic exploration of orthoptera by the Natural History Museum Basel Expedition to Bhutan in 1972. Only one of two species previously described from Bhutan was resampled. A total of nine new species are described belonging to the family Rhaphidophoridae: five species in genus *Diestramima* Storozhenko (subfamily Aemodogryllinae), and four species in genus *Rhaphidophora* Serville (subfamily Rhaphidophorinae). We provide details of morphological structures for all newly described species and their known distribution and habitat. The phylogenetic relationships of the rhaphidophorids from Bhutan are inferred from mitochondrial DNA sequences (COI). New species of *Diestramima* are not assigned to subgenera because the shape of their paraproct is intermediate when compared to the shapes described for each subgenera. Keys to the Bhutan species based on male epiproct (*Rhaphidophora*) and posteromedian projection of 7th abdominal tergite (*Diestramima*) are provided. New species are *Diestramima matermagna* **sp. nov.**, *D. minjiwoonga* **sp. nov.**, *D. multidenticuli* **sp. nov.**, *D. samkhara* **sp. nov.**, and *D. phubdorjia* **sp. nov.**; *Rhaphidophora bhutanensis* **sp. nov.**, *R. bicuspis* **sp. nov.**, *R. bilobata* **sp. nov.**, and *R. piscicauda* **sp. nov.**.

Key words: *Diestramima*, *Rhaphidophora*, phylogeny, cave cricket, camel crickets, rhaphidophorids

INTRODUCTION

Rhaphidophorids (Camel crickets) are wingless Ensifera with undeveloped stridulatory structures. They are nocturnal, usually restricted to dark and moist environments and often associated with caves. Most species are capable of climbing tree trunks and rocks, and some survive winter freezing (Hegg *et al.*, 2022; Richards, 1965). The family Rhaphidophoridae has a global distribution with subfamilies restricted to particular geographic regions (Kim *et al.*, 2024). Of nine subfamilies, three are found in Asia, primarily inhabiting tropical regions of southeast Asia (Fig. 1A). The subfamily Aemodogryllinae is found from eastern Russia to east and southeast Asia, while the related subfamily Rhaphidophorinae is more southern with a distribution stretching from east Asia and central China to the Samoan Archipelago (Gorochoy & Storozhenko, 2015) (Fig. 1A). Both Aemodogryllinae and Rhaphidophorinae are recorded in temperate and tropical forests of Bhutan (Ingrisch, 2002; Würmli, 1973). Subfamily Anoplophilinae is restricted to Korea and Japan (Fig. 1A).

Molecular phylogenetic studies support the division of the family Rhaphidophoridae into nine subfamilies (Kim *et al.*, 2024). However, current taxonomy at the level of tribe and genus is largely based on morphology, often using traits only possessed by adult males (e.g. Dawwrueng *et al.*, 2020, 2020; Gorochoy, 2010; Qin *et al.*,

2018). The tribe Diestramimini of subfamily Aemodogryllinae consists of seven genera (Gorochov & Storozhenko, 2015), of which *Tamdaotettix* and *Mimadiestra* are characterized by a spine-like posteromedian projection on the 6th abdominal tergite and a pair of deeply divided spines on the 7th abdominal tergite, respectively. *Gigantettix* and *Adiestramima* are differentiated from *Diestramima* and *Megadiestramima* by the presence of ventral spines on the fore femora. Whereas *Diestramima* is easily distinguishable from other genera of this tribe by the presence of a long posteromedian projection of the 7th abdominal tergite that completely covers the paraprocts and by the eight lobed membranous genitalia. The only monotypic genus *Arboramima* is differentiated from others by “dark green and moss like” coloration, found inhabiting trees covered with moist moss (Zong *et al.*, 2021). Further division of *Diestramima* into three subgenera (*Baculitettix* n=11, *Diestramima* n=6, and *Excisotettix* n=5) has been proposed on the basis of paraproct shape (Gorochov & Storozhenko, 2019).

Genera in subfamily Rhaphidophorinae are morphologically homogeneous. Six of the eight genera are characterised by the position of posteromedian projections on abdominal tergites 6 to 10. The other two, *Rhaphidophora* and *Neorhaphidophora*, lack posteromedian projections on abdominal tergites. *Rhaphidophora* is the most speciose genus in the subfamily with >150 species across Asia and Oceania (Cigliano *et al.*, 2023). *Rhaphidophora* males have a simple or weakly specialized epiproct bearing a process or a curved, narrowed, or bifurcate apical area (Bian & Shi, 2016; Gorochov, 2011) and few distinctive genitalic traits. Five species are recognised in *Neorhaphidophora* based on the specialised shape of the male epiproct (Bian *et al.*, 2017; Dawwrueng *et al.*, 2020; Gorochov, 2011).

The kingdom of Bhutan on the southern slopes of the Himalaya is bordered by Tibet and India (Fig. 1A) but is geopolitically relatively isolated. More than 50% of Bhutan’s land area has national protected status and about 70% is covered in native forest (Royal Government of Bhutan, 2022). The government of Bhutan imposes strict regulations to prevent the collection of flora and fauna which limits access to biological material by international researchers. These regulations have left Bhutan as a biodiversity hotspot in the eastern Himalaya waiting to be explored by the locals. The only foreign expedition to study Orthoptera in Bhutan was carried out by the Natural History Museum of Basel in 1972. The results published in 1973 included descriptions of a some species of Gryllacridoidea and a single rhaphidophorid *Diestramima tsongkhapa* (Würmli, 1973). Thirty years later, specimens from the expedition were examined and a checklist of 69 Orthoptera from Bhutan including description of a second rhaphidophorid *Rhaphidophora angulata* was reported (Ingrisch, 2002). As much of Bhutan is remote and difficult to access there remains much to learn about the biodiversity of this country.

This is the first study of Rhaphidophoridae in Bhutan since the Basel expedition, and Orthoptera were sampled from 15 sites across the country (Fig. 4). We describe nine new rhaphidophorid species belonging to two well-recognised genera from Asia under two subfamilies. For systematic inference we used morphological traits and molecular phylogenetics. For the first time, more than 45 samples representing Bhutanese rhaphidophorids are genetically sequenced and their phylogenetic relationships determined.

MATERIALS AND METHODS

Sampling

We explored some of the well-known caves and nearby forest in the remote part of eastern Bhutan (Fig. 1B). Although caves are rare, they have remained unexplored for centuries. Internal cave systems and entrances were investigated during the day for the presence of rhaphidophorids, and searches were made in nearby forest habitat under leaf litter, fallen logs, crack and crevices, and boulders and rocks. Detailed habitat descriptions are provided under each taxonomic account.

Specimens were collected during April 2022 prior to the onset of monsoon, under the authorization of research permit number 7008186946225A7A8C6D0B granted by the Ugyen Wangchuck Institute for Forestry Research and Training (UWIFoRT), Bhutan. A total of 75 specimens were collected by hand-picking from cave entrances and forest habitats predominantly located in the central and eastern region. To ensure their preservation, all samples were stored in ethanol. Transfer of samples to Massey University, New Zealand was conducted in accordance with the Material Transfer Agreement reference number NBC/BRD/7/2022-2023/197 issued by the National Biodiversity Centre, Serbithang, Thimphu, Bhutan. Currently, all the specimens examined are housed in Phoenix collection, Massey University, Palmerston North (MPN). All type specimens will be housed at the invertebrate repository museum at National Biodiversity Centre, Bhutan (NBCB).

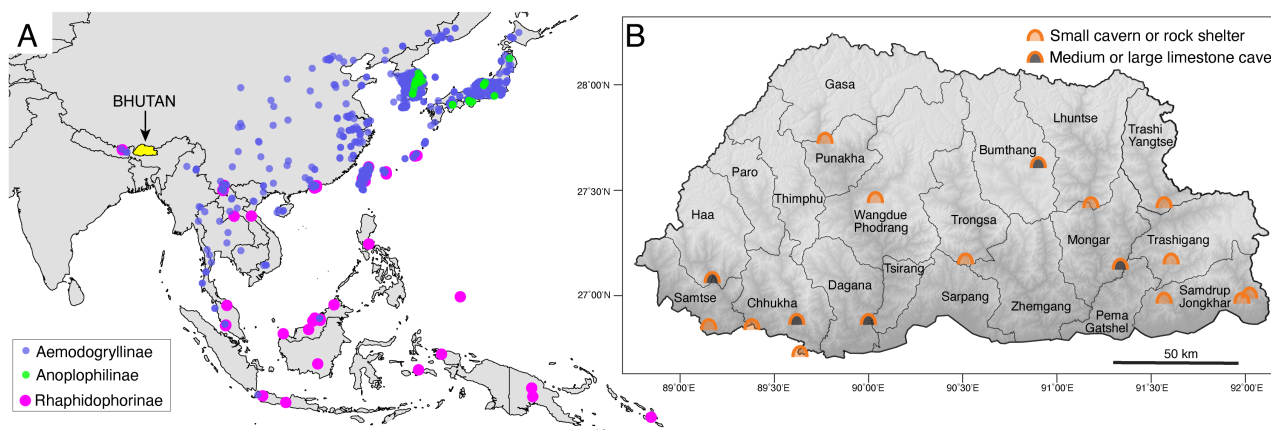


FIGURE 1. (A) Records of three Rhaphidophoridae subfamilies present in Asia and Oceania, with the Kingdom of Bhutan highlighted in yellow. Data from iNaturalist (<https://www.inaturalist.org/>) and BOLD system (<https://boldsystems.org>) processed in QGIS and Inkscape. (B) Cave systems searched for Rhaphidophoridae among districts (=dzongkhag) of Bhutan.

Genetic data

For haplotype analysis, DNA was extracted from leg muscle tissue using Quantabio (Beverly, MA, USA) Extracta DNA Prep using 30 μ L of the extraction reagent in 1.5 mL microfuge tube containing a small piece of leg and incubated at 95 $^{\circ}$ C for 15 minutes in a thermal shaker. After incubation and cooling for 5 minutes, 30 μ L of stabilizing solution was added. Segments of the mitochondrial gene cytochrome oxidase I (COI) were amplified using polymerase chain reaction (PCR) with primers C1-J-2195 (Simon *et al.*, 1994) and mtd12_wetaR (Bulgarella *et al.*, 2014) and/or LCO1490 and HCO2198 (Folmer *et al.*, 1994). Each 10 μ L PCR reaction consisted of 1.0 μ L of 10x PCR buffer, 0.8 μ L of 25mM $MgCl_2$, 0.2 μ L of each 2mM dNTP, 0.4 μ L of each 10 μ M primer, 0.08 μ L of DreamTaq DNA polymerase (Thermo Scientific, Waltham, MA, USA), and 1.0 μ L of DNA template. Thermocycling used initial denaturation of 95 $^{\circ}$ C for 90 s with 38 cycles of: 94 $^{\circ}$ C for 15 s, 52 $^{\circ}$ C for 15 s and 72 $^{\circ}$ C for 90 s. Reactions were visualised by electrophoresis on 1% TAE agarose gels and PCR products of expected size were subject to Sanger sequencing. Sequences were checked for insertion/deletions, reading frame anomalies and ambiguities then aligned in Geneious v.9 (Kearse *et al.*, 2012). Phylogenetic inference used Neighbor-Joining (Saitou & Nei, 1987) in Geneious, and Maximum Likelihood (ML) implemented in IQTree2 (Minh *et al.*, 2020) with the ultrafast bootstrap option (Hoang *et al.*, 2018).

Morphology, measurement, and identification

Specimens were examined, measured and photographed under stereo-microscope Olympus XZS7 with an Olympus camera and inbuilt software Olympus Cellsens Dimension v.4.4.4. Final images were processed using Inkscape v.1.3.2. We followed Zhu & Shi (2018) for measurement of external structures with some additions (Table 1, Fig. 3Left). Identification and interpretation of *Diestramima* and *Rhaphidophora* drew upon relevant literature (Dawwrueng *et al.*, 2020; Gorochoy, 1998, 2001, 2010; Gorochoy & Storozhenko, 1992, 2015, 2019; Liu *et al.*, 2021; Qin *et al.*, 2016; Storozhenko & Dawwrueng, 2014; Wang *et al.*, 2019; Zhu & Shi, 2018). Detailed counts of leg spines are presented for each species (Tables 3 & 5; supplementary table S1 & S2). For *Rhaphidophora* species, we explored ventral part of epiproct (here by referred as basal plate) which usually remain inserted in genital cavity. The detail structure illustration and description are also presented.

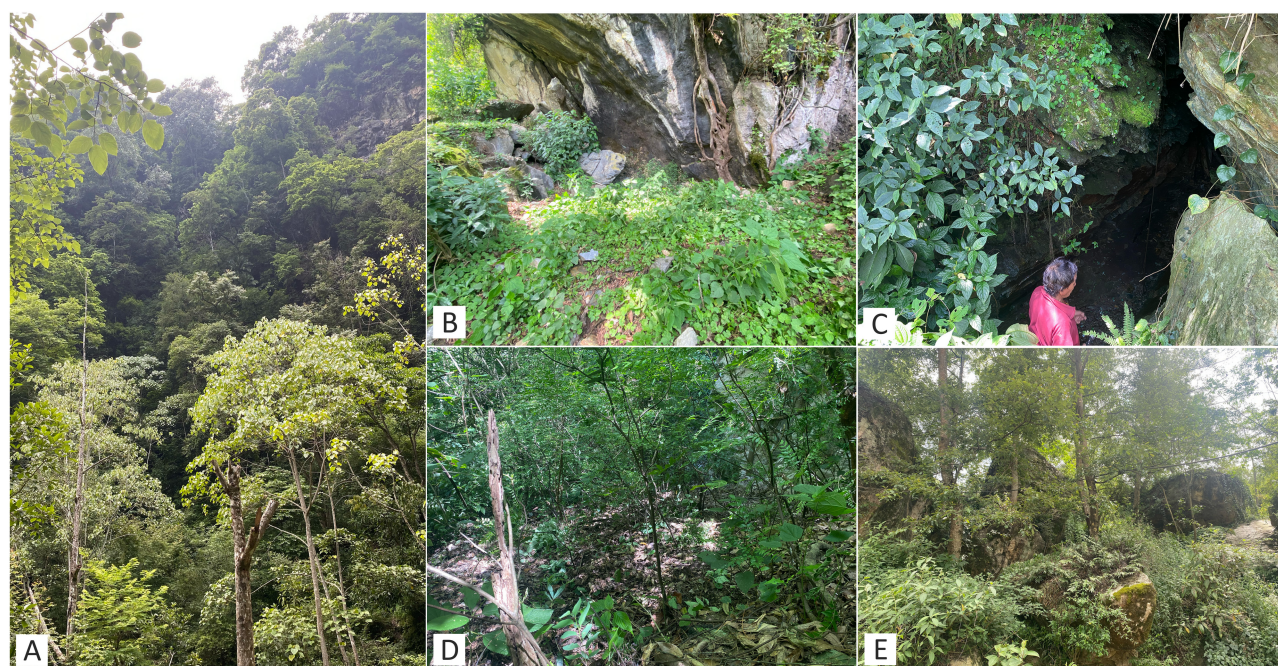


FIGURE 2. Typical habitats of rhabdiphorids in eastern Bhutan. (A) Samdrup Jongkhar: Wangphu, 1028 meter above sea level (m asl), typical subtropical broadleaf forest: *Diestramima matermagna* **sp. nov.** (B) Trashigang: Kharungla, 2038 m asl, grazed open shelter of cool broadleaf forest: *D. matermagna* **sp. nov.** (C) Samdrup Jongkhar: Minjiwoong, 833 m asl, rock cave entrance: *D. minjiwoonga* **sp. nov.** (D) Pema Gatshel: Marung, 571 m asl, under canopy vegetation with abundant of leave litter: *D. matermagna* **sp. nov.**, *Rhaphidophora bhutanensis* **sp. nov.** (E) Trashi Yangtse: Bawoong, 1581 m asl, boulders with surrounding vegetation: *D. multidenticuli* **sp. nov.**

TABLE 1. Measurement details and abbreviations used for description of species belonging to genera *Rhaphidophora* and *Diestramima*.

Morphometric	Abbreviation	Description
Body Length	BL	Body Length from fastigium to posterior margin of 10 th abdominal tergite.
	PL	Pronotum Length from anterior to the posterior margin.
Leg Length	FFL/MFL/HFL	Fore/Middle/Hind Femur Length from base to the apex, measured in lateral view.
	FTL/MTL/HTL	Fore/Middle/Hind Tibiae Length from base to the apex.
	FBL/MBL/HBL	Fore/Middle/Hind Basitarsus Length from base to the apex of apical spine.
Eye Width/Length	Eye W/L	Eye Width and its vertical Length from the centre.
Maxillary Palpi Length	MPL	Maxillary Palp Length from base to the apex of each segment.
Subgenital plate Width/Length	Sgp W/L	Subgenital plate lateral Width and Length from base to the apex.
Styli Length	SL	Styli Length from base to the apex (straight line distance on lateral view).
Cerci Length	CL	Cerci Length from base to the apex, measured in later view.
Ovipositor Length	OvL	Ovipositor Length from base to apex (straight line distance on lateral view).

RESULTS

Distribution and habitat

Searches of caves and rock shelters at 50 sites across 17 districts of Bhutan (Fig. 1B), in habitats ranging from subtropical to cool broadleaf forest (150–3300 m asl) revealed rhabdiphorids at 15 sites (Fig. 4). The habitats

featured warm, humid tropical and cool, wet temperate climate with abundant canopy vegetation. The highest recorded elevation for raphidophorids was approximately 2800 m asl, where *R. bicuspis* **sp. nov.** was found on the southern aspect of Lamperi (27.498°N, 89.767°E), Thimphu. In contrast, the lowest recorded elevation was 570 m asl, where *D. maternmagna* **sp. nov.** was collected near the Marung bridge in Pema Gatshel (27.040°N, 91.380°E).

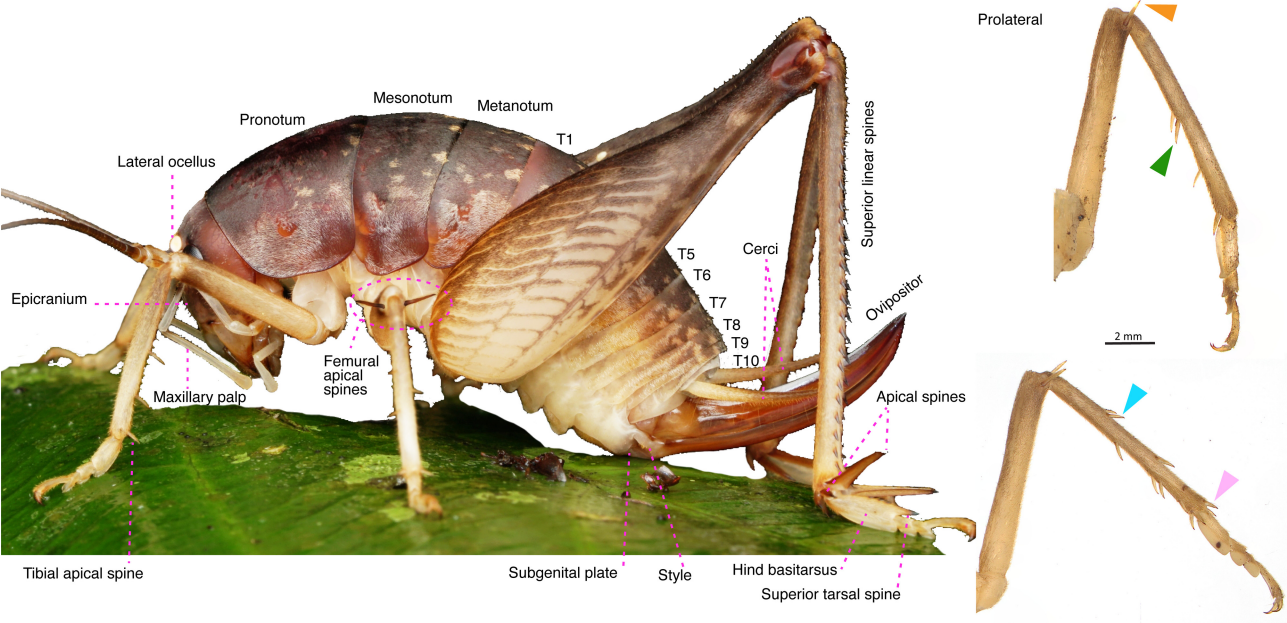


FIGURE 3. (Left) External structures referred to descriptions of new *Rhaphidophora* and *Diestramima* species. Original image of *Rhaphidophora taiwana* (adult female) by Do-yoon Kim, <https://www.inaturalist.org/people/galois>. (Right) Spine arrangement on fore (top) and mid (bottom) tibiae in prolateral view: prolateral apical spine on femur (orange arrow), inferior linear spines (green arrow), superior linear spines (blue arrow), apical spines (pink arrow).

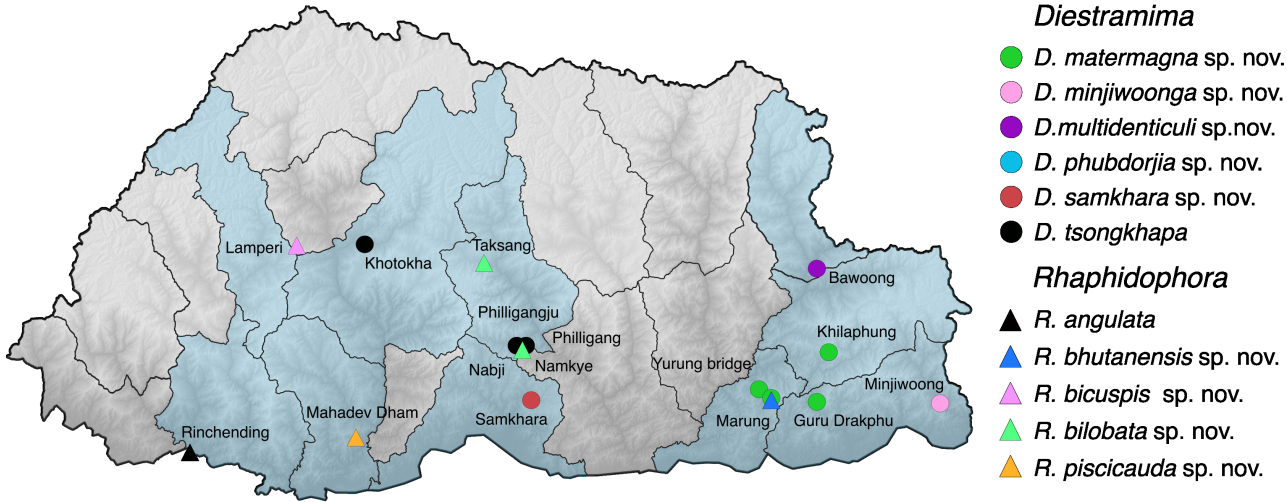


FIGURE 4. Type localities of nine newly described *Rhaphidophoridae* from ten districts in Bhutan. *Rhaphidophora angulata* was collected in 1970 but not encountered in the present study.

Systematics

Using mitochondrial DNA (mtDNA) sequences, camel cricket samples from Bhutan clustered to form the two clades *Diestramima* (Aemodogryllinae) and *Rhaphidophora* (Rhaphidophorinae). Within the *Diestramima* clade, six lineages were identified based on genetic clusters and sequence divergence, including a representative of the species *D. tsongkhapa*. These six lineages correspond to distinct morphological differences in the shape of 7th

abdominal tergite of males. Based on the concordance of mtDNA variation and morphology we describe five new *Diestramima* species (Fig. 5). Within the Rhaphidophorinae clade, five lineages were identified based on genetic clusters and sequence divergence, including a representative of the species *R. quadrispina* Liu & Bian. These five lineages were represented by individuals with distinct morphology so we describe here four new species belonging to the well-known Asian genus *Rhaphidophora* (Fig. 13). All genetic data used for phylogenetic analysis can be found in GenBank with accession number PV593656–PV593700.

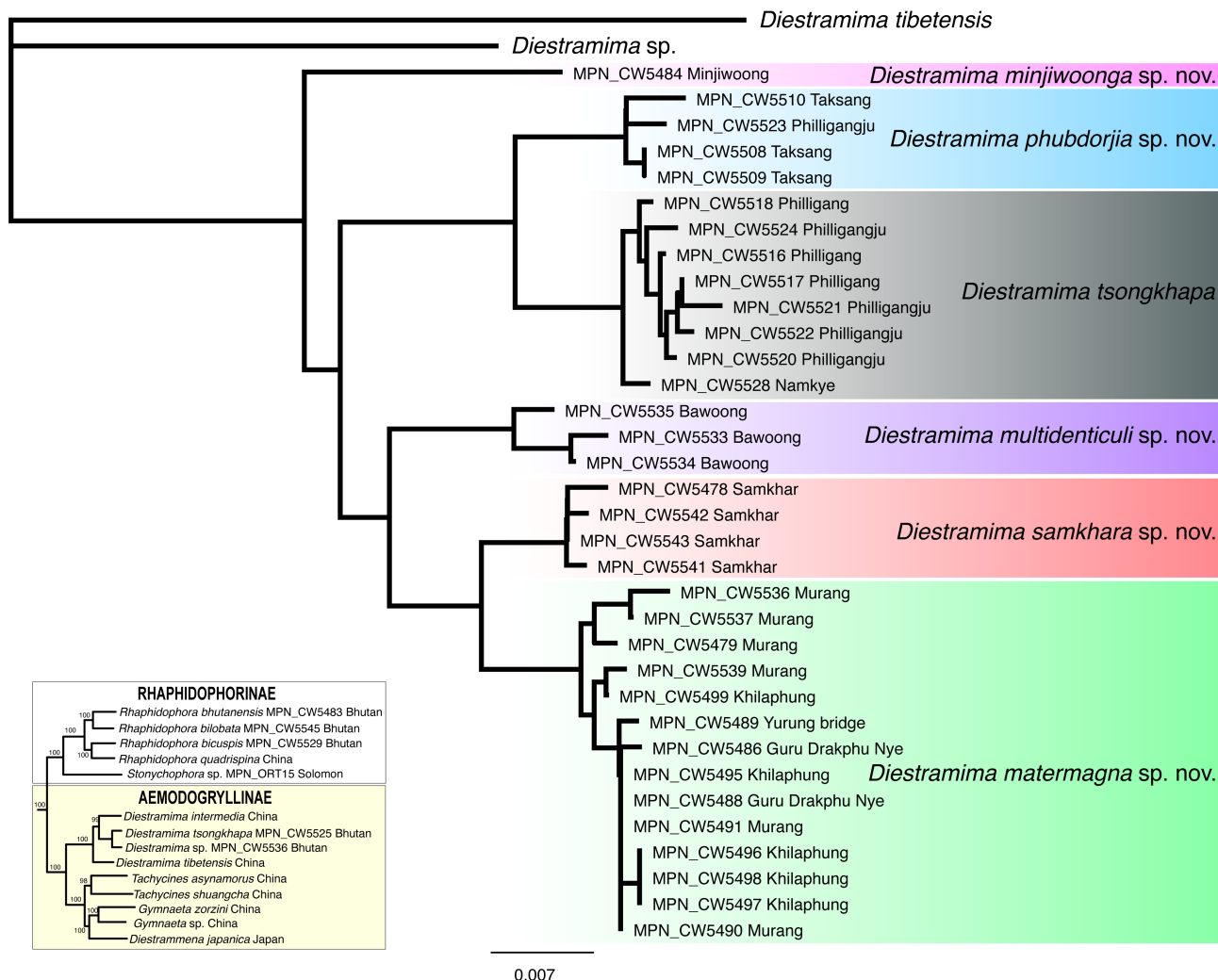


FIGURE 5. Neighbor-Joining (HKW) phylogeny of *Diestramima* raphidophorids from Bhutan using 780bp alignment of mtDNA COI sequences. Inset: Phylogenetic relationships of genera within subfamily Rhaphidophorinae and Aemodogryllinae resulting from ML analysis of mtDNA sequences (COI) of 1455 bp.

Subfamily AEMODOGRYLLINAE

Tribe **DIESTRAMIMINI** Gorochoy, 1998

Genus **DIESTRAMIMA** Storozhenko, 1990

Type species: *Diestrammena palpata* Rehn, 1906, by original designation

The genus *Diestramima* was defined by Storozhenko (1990) and has 42 recognised species divided among a number of subgenera (Cigliano *et al.* 2025). The general characteristics that unite the species within this genus, such as the projection from 7th abdominal tergite of males are described here.

HEAD. Oval in shape. Face smooth and shiny, and usually with short hair on the dorsal surface of head, maxillary palps and antennae. Fastigium vertici always projecting forward, dividing into apical half of conical tubercles. Bases of tubercles drawn together with obtuse apices. Eyes oval, almost the size of antennal scapi. Median ocellus oval to oblong, and lateral ocelli oval or almost circular situated on lateral surface of basal fastigium vertici.

THORAX. Body medium in size with abundant fine black and brown hairs (Table 2). Anterior margin of the pronotum straight, posterior margin protruding and obtusely rounded, posterolateral margins almost rounded. The posterior margin of mesonotum obviously protruding backward, lateral margins angular; posterior margin of metanotum rather straight with almost circular lateral margins. Posteromedian projection of 7th abdominal tergite variable from short to long covering distal half or entire part of paraproct (Fig. 7 & 8). The shape of the 7th abdominal tergite projection is described under each species account. The paraproct variable with short to long almost finger-like structure (Fig. 7 & 8). The cerci usually slender, conical, and have acute apices.

TABLE 2. Length of body elements of adult *Diestramima* type specimens from Bhutan (mm). Abbreviations and method of measuring applied are provided in table 1.

Trait	Sex	<i>D. matermagna</i> sp. nov. 2 males 2 females	<i>D. minjiwoonga</i> sp. nov. 1 male	<i>D. multidenticuli</i> sp. nov. 2 males 2 females	<i>D. phubdorjia</i> sp. nov. 2 males 1 female	<i>D. samkhara</i> sp. nov. 1 male 2 females	<i>D. tsongkhapa</i> 2 males 2 females
BL	Male	11.9–16	12.6	15.6–16.2	10.4–12.7	12	18.2–20.9
	Female	13.8–18.5	-	13.3–15	12.9	12.6–13.2	13.1–15.1
PL	Male	4.7–5.2	5.1	5.2–5.5	4.4	4.5	5.3–6.5
	Female	5.8	-	4.7–5.6	4.8	3.2–5.5	5.7–6
FFL	Male	9.5	13.1	10–10.3	10.5	9.7	11.8–15.5
	Female	13.4–13.8	-	8.1–9.7	11.5	7.6–12.6	11.7–13.3
FTL	Male	9.6–10.8	12.5	10.3–10.4	11.2–11.3	10.1	12.3–15.8
	Female	13.8–13.9	-	7.4–10.2	12.1	7.7–11.5	12.1–14.6
FBTL	Male	2.9–3.5	4.4	3.1–4.1	3.9	3.5	4.7–5.4
	Female	4.3–4.8	-	3.3	4.1	2.7–4.2	4.2–4.8
MFL	Male	8.2–10.2	10	8.8–9.3	8.4–9.5	8	9.9–13
	Female	11.1–11.6	-	7.3–8.7	10	5.9–9.2	10.1–11.6
MTL	Male	7.7–11	10.3	8.4–9.4	9.1–10.1	8.9	11–13.9
	Female	11.5–12.7	-	7.3–8.9	10.3	6.6–11	11–14.5
MBTL	Male	2.4–2.7	3.2	2.7–2.9	2.1–3	2.7	3.4–3.7
	Female	3.2–3.4	-	2.2–2.3	2.9	2–2.4	3.4–3.9
HFL	Male	18.2–21.2	21.5	20.4	18.9–19.1	18.2	23.6–29.7
	Female	23.5–24.4	-	17.1–20.6	21.4	13.6–22.3	19.2–22.6
HTL	Male	19.4–22.3	23	22–22.4	21.2–21.8	20.3	30.1–32.2
	Female	27–27.1	-	18–22.5	24.6	14.7–23.8	22.2–25.7
HBTL	Male	3.9–4.2	4.6	4–4.4	4.3–4.6	4	5.3–5.6
	Female	4.3–5.5	-	3.5–4	4.1	2.8–4.5	4.5–6.1
Eye W/L	Male	0.8/1.2–1.4	1–1.1/ 1.4–1.7	0.7–0.8/1–1.2	0.9/1.4	0.7/1.3	1–1.1/ 1.4–1.7
	Female	0.8–0.9/1.5–1.6	-	0.8–0.9/1.3–1.4	1.3/0.7	0.6–1/1–1.7	0.9/1.7–1.8
MPL	Male	2.5–4.2/ 3.2– 4.9/ 4.5–6.6	11 (3, 3.1, 4.8)	3/3.5/49– 5.1	2.6–2.7/ 3.2– 3.4/ 3.6–4.7	(2.7, 2.5, 3.9)	3.8–4.3/ 3.9– 4.4/ 5.4–6.3
	Female	3.4–3.9/3.8– 4.3/ 5.8–6	-	2.9–3.1/ 3.1/ 5–5.2	2.7/ 3.6/ 3.6	2–3.4/ 3.5– 4.9/ 4.7–6.6	3.2–4.5/3.4– 5.2/3.6–7.6
Sgp L	Male	1.2–1.6/0.7–1	1.2/1.1	2–2.1/1.5–1.6	1.6–2/1.3–1.4	1.2/0.9	2.8/1.5
	Female	0.5	-	1.4/0.7	1.7/1.4	-	1.4/ 1.6
CL	Male	3.7–4.2	4.8	4.1	3.1–3.2	2.5	4.5
	Female	4.8–5.2	-	2.3–4.2	3.4	2.3–4.5	5.7
OvL	Female	10.8–17.2	-	6.8–17.1	15	5.7–8.6	15.8–22.5

LEGS. Legs long compared to *Rhaphidophora* (Table 2). Fore femora with single short, retrolateral, apical spine and mid femora with a pair of prominent apical spines (one prolateral and one retrolateral). Hind femora with 5–13 inferior retrolateral spines (Table 3). Fore and mid tibiae each with four inferior linear spines (two prolateral and two retrolateral), three inferior apical spines (one prolateral, one ventral and one retrolateral) and with one superior apical spine on fore tibiae (retrolateral) and two superior apical spines on mid tibiae (one prolateral and one retrolateral). Hind tibiae with variable number of linear, short, fixed spines on superior surface (in two rows of prolateral and retrolateral) (Table 3), and typical eight, articulated apical spines. The longest pair of these (sometimes referred to as spurs) are shorter than 1st and/or 2nd segments of hind tarsi combined. The 1st tarsal segment of hind tibiae have between one to four superior spines.

COLOURATION. Head with short brown or black hairs. Face white and glabrous always with 4 vertical black stripes below eyes and inner sides of antennal scapes, and a pair of lateral marks on clypeus (Fig. 8A). Body usually black with small brown or yellowish spots on thoracic (dorsolateral) and abdominal tergites, covered in black and brown short hairs. Legs dark and pale speckled, hind femur dark to pale speckled especially at proximal half.

TABLE 3. Number of spines on hind leg of *Diestramima* type specimens from Bhutan. The number of spines and arrangement on the fore and mid legs are as per the generic description (supplementary table S1). Where left and right legs differ in the number of spines the count from the second limb is provided in parenthesis.

Leg element	Spines	<i>D. matermagna</i> sp. nov.		<i>D. minjiwoonga</i> sp. nov.		<i>D. multidenticuli</i> sp. nov.		<i>D. phubdorjia</i> sp. nov.		<i>D. samkhara</i> sp. nov.		<i>D. tsongkhapa</i>	
		1 male	1 female	1 male		1 male	1 female	1 male	1 female	1 male	1 female	1 male	1 female
Hind femur	Inferior (retro)	9	9	13		7	5	6	8	11	11	8	7
Hind tibia	Superior linear (pro)	41	44(41)	38 (36)		55(53)	49	30(32)	36(38)	36	36	45(40)	45(42)
	Superior linear (retro)	37(36)	37(38)	39(37)		54(49)	52	26(29)	34(38)	35	35	46	46(43)
	Superior subapical (pro, retro)	1,1	1,1	1,1		1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
	Apical spines	6	6	6		6	6	6	6	6	6	6	6
Hind basitarsus	Superior spines on 1 st tarsus	3	4	4		2	2	1	2	3	2	3	4

***Diestramima tsongkhapa* (Würmli, 1973)**
(Figure 6A–K)

Thirteen specimens in our collections were identified as *D. tsongkhapa*. These were collected from four sites in central Bhutan, increasing the known distribution of this species (Fig. 4). Here we present images and summary of the key traits of this species (Fig. 6).

Material examined. BHUTAN • 5 adult females; Philligang, Nabji, Korphoog, Trongsa; 27.178°N, 90.535°E; 1381 m asl; 30 Jul. 2022; Sanjit Rai leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5516, MPN_CW5520, MPN_CW5517, MPN_CW5518, MPN_CW5519. • 4 adult males; Philligangju, Nabji, Korphoog, Trongsa; 27.180°N, 90.535°E; 1305 m asl; 30 Jul. 2022; Sanjit Rai leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5522, MPN_CW5521, MPN_CW5523, MPN_CW5524. • 2 male and 2 female adults; Namkye, Nabji, Korphoog, Trongsa; 27.165°N, 90.562°E; 2252; m asl; 22 Jul. 2022; Sanjit Rai leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5525, MPN_CW5526, MPN_CW5527, MPN_CW5528.

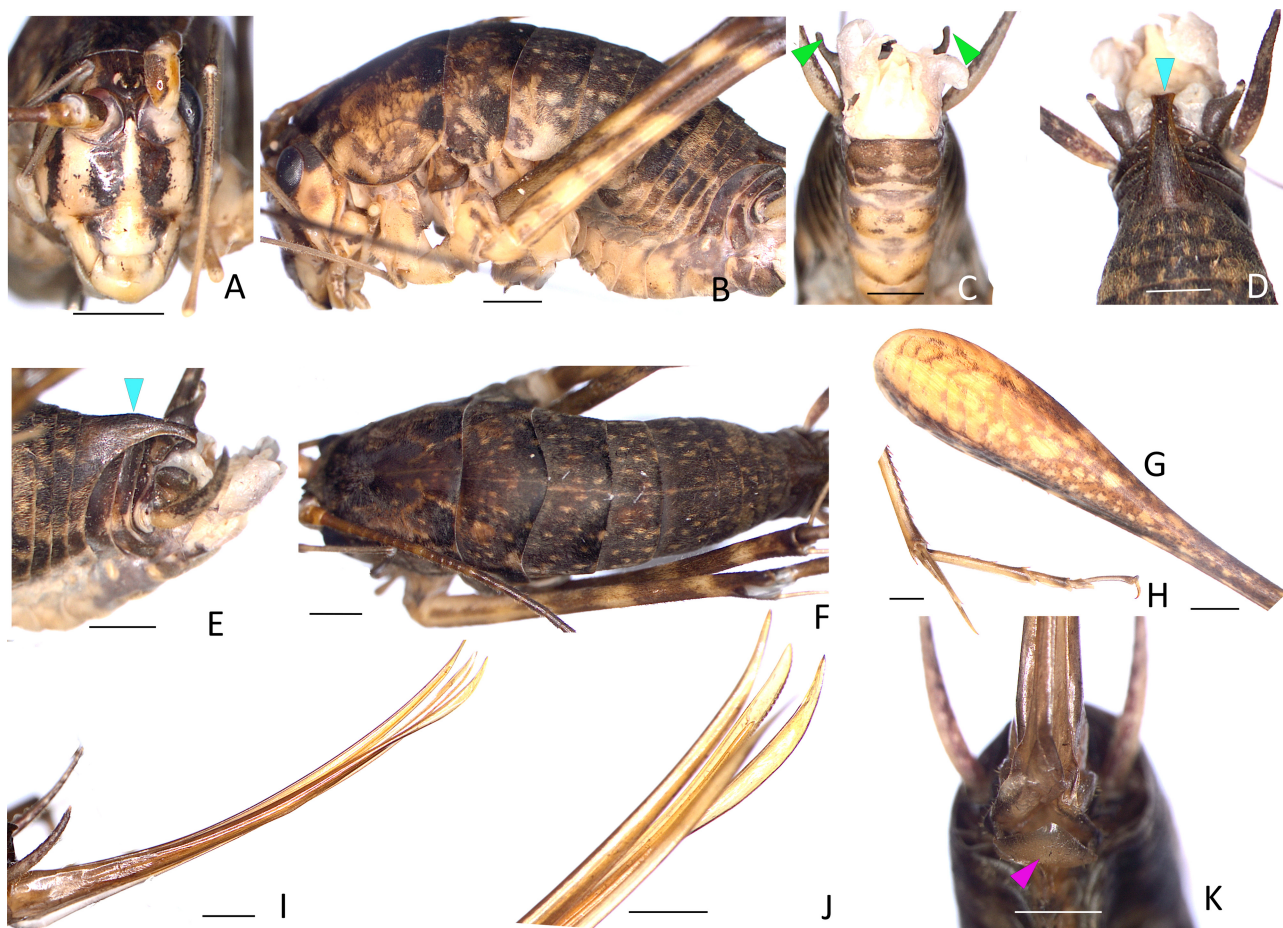


FIGURE 6. *Diestramima tsongkhapa*. Male: (A) Anterior view of head. (B) Lateral view of body. (C) Ventral view of lower abdomen showing finger-like distal part of paraproct (green arrows). (D) Dorsal view of lower abdomen showing notched apex of 7th abdominal tergite (blue arrow). (E) Lateral view of lower abdomen showing high profile 7th abdominal tergite (blue arrow). (F) Dorsal view abdomen. (G) Lateral view of hind femur and (H) basitarsus. Female: (I) Lateral view of ovipositor and (J) crenulated apex on lower valves. (K) Ventral view of lower abdomen showing subgenital plate (pink arrow). Scale bars = 2 mm.

Male. Body medium in size (~ 20 mm). Median ocellus oval and lateral ocelli circular situated on lateral surface of basal fastigium vertici. Posteromedian projection of 7th abdominal tergite rather high in profile and long (Fig. 6E), obviously surpassing apices of paraproct, gradually narrowing towards apex when viewed dorsally, apex slightly extended with distinct notch (Fig. 6D). Paraproct with broad proximal half tapering abruptly and curved upward, apex obtuse (Fig. 6C & D). Subgenital plate large, curved, posterior edge slightly crimped, apex rounded (Fig. 6C). Cerci slender, conical, apices almost acute. Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Head dorsally brown with abundant short brown hair. Body black with many small brown or yellowish spots on thoracic and abdominal tergites, covered in black and brown short hairs. A pale, thin median line present but inconspicuous (Fig. 6F). Paraproct black when viewed dorsally. Cerci white with black spots on dorsal side with short yellowish-brown hair and longer hair.

Female. The general appearance is similar to male. Posteromedian projection of 7th abdominal tergite short and angular with posteromedial apex obtusely rounded completely covering 8th abdominal tergite, 9th tergite broader and more rounded. Subgenital plate almost translucent, simple, triangular, apex obtusely rounded, slightly curved upward (Fig. 6K). Ovipositor slender and longer than body, slightly curved, apices acute, distal half of lower valves crenulated, upper valves smooth (without hair along the margins) (Fig. 6I & J). Size of body elements (Table 2) and combination of leg spines (Table 3) are similar to male.

***Diestramima matermagna* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 7A–K)

Holotype. BHUTAN • 1 adult male; Guru Drakphu Nye, Wangphu, Gomdar, Samdrup Jongkhar; 26.982°N, 91.584°E; 1028 m asl; 29 May 2022; C. Dorji & Jigme leg.; Subtropical forest: limestone cave entrance; MPN_CW5486; NBCB146.

Paratype. BHUTAN • 1 adult female; Guru Drakphu Nye, Wangphu, Gomdar, Samdrup Jongkhar; 26.982°N, 91.584°E; 1028 m asl; 29 May 2022; C. Dorji & Jigme leg.; Subtropical forest: limestone cave entrance; MPN_CW5487; NBCB152.

Other material. BHUTAN • 2 adult females; Guru Drakphu Nye, Wangphu, Gomdar, Samdrup Jongkhar; 26.982°N, 91.584°E; 1028 m asl; 29 May 2022; C. Dorji & Jigme leg.; Subtropical forest: limestone cave entrance; MPN_CW5485, MPN_CW5488. • 1 adult male; Yurung bridge, Khar, Pema Gatshel, 27.040°N, 91.380°E; 571 m asl; 31 May 2022; C. Dorji, Tshewang Namgay & Jigme leg.; Subtropical forest: cliff base under leaf litter and small rocks; MPN_CW5489. • 6 male and 5 female adults; Murang bridge, Khar, Pema Gatshel; 27.011°N, 91.420°E; 923 m asl; 25 May 2022, 31 May 2022; C. Dorji, Tshewang Namgay & Jigme leg.; Subtropical forest: cliff base under leaf litter and small rocks; MPN_CW5479, MPN_CW5480, MPN_CW5481, MPN_CW5482, MPN_CW5536, MPN_CW5537, MPN_CW5538, MPN_CW5539, MPN_CW5540, MPN_CW5490, MPN_CW5491. • 3 male and 5 female adults; Khelaphung, Kharungla, Brekha, Trashigang; 27.155°N, 91.628°E; 2039 m asl; 1 Jul. 2022; C. Dorji & Jigme leg.; Cool broadleaf forest: surrounding huge boulders and nearby vegetation; MPN_CW5492; MPN_CW5493, MPN_CW5494, MPN_CW5495, MPN_CW5496, MPN_CW5497, MPN_CW5498, MPN_CW5499.

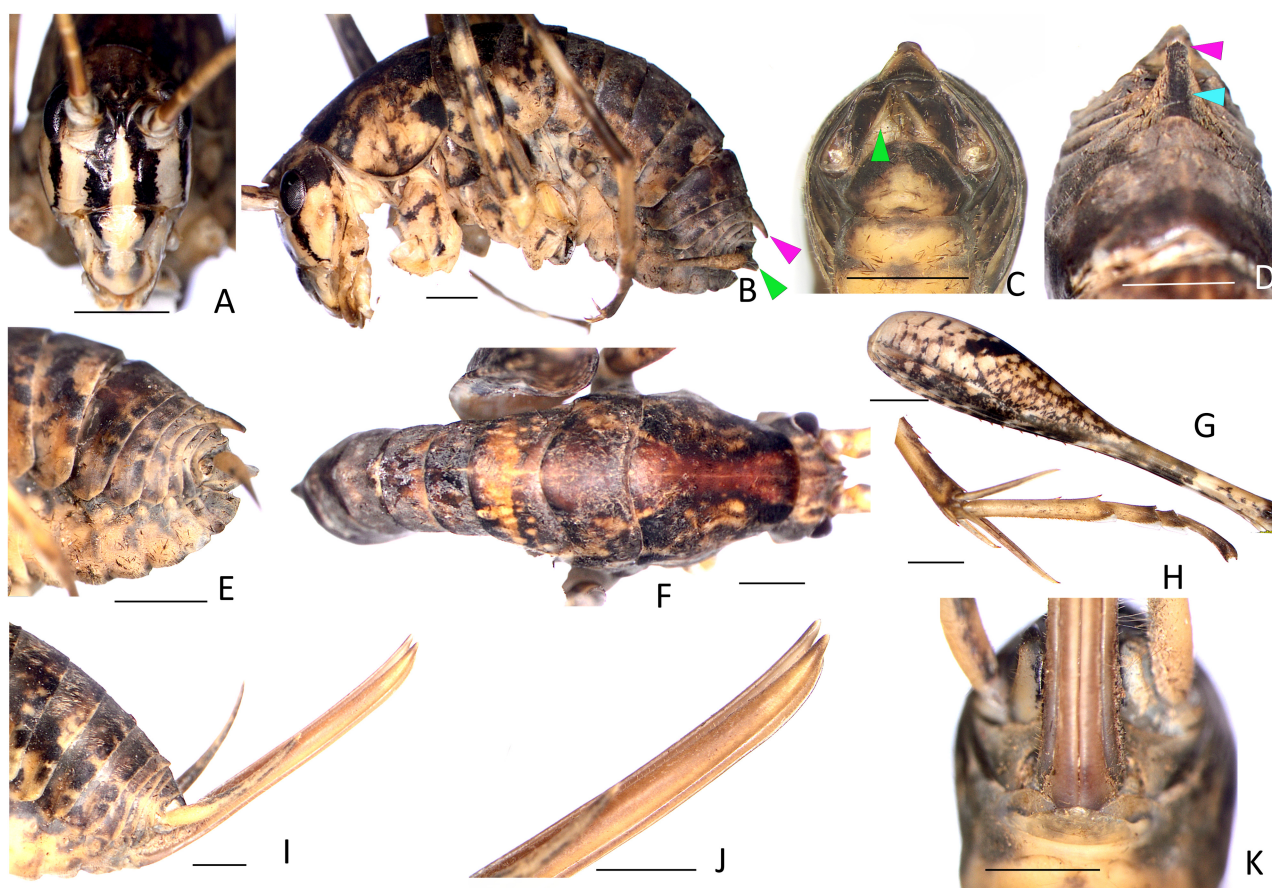


FIGURE 7. *Diestramima matermagna* sp. nov. Male holotype (MPN_CW5486; NBCB146): (A) Anterior view of head. (B) Lateral view of body showing short 7th abdominal tergite (pink arrow) and paraproct (green arrow). (C) Ventral view of lower abdomen showing short triangular paraproct (green arrow). (D) Dorsal view of lower abdomen showing narrowing 7th abdominal tergite (blue arrow) and truncate or slightly convex apex (pink arrow). (E) Lateral view of lower abdomen. (F) Dorsal view of body. (G) Lateral view of hind femur and (H) basitarsus. Female (MPN_CW5487; NBCB152): (I) Lateral view of ovipositor and (J) finely serrated apex. (K) Ventral view of lower abdomen showing subgenital plate. Scale bars = 2 mm.

Description. Male. Body small in size (<17 mm). Median ocellus oblong and lateral ocelli circular. Posteromedian projection of 7th abdominal tergite very short never extending beyond tenth abdominal tergite, gradually narrowing when viewed from above (Fig. 7B & D), truncate or slightly convex apex (Fig. 7D). Paraproct rather short and almost triangular, apices acute (Fig. 7B & C). Cerci conical, apices acute. Subgenital plate similar to *D. tsongkhapa*. Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Female. General appearance is similar to male but larger (body >14 mm long, hind legs 7 mm longer than male's; Table 2). Posteromedian projection of 7th abdominal tergite short and angular with posteromedial apex obtusely rounded covering 8th abdominal tergite. Ovipositor narrow and almost straight (slightly curved upward at distal half), and as long as body (Fig. 7I). Lower valves are finely serrated at distal end, with acute apices (Fig. 7J). Upper valves with equally spaced short hair along dorsal margins (almost starting from the base) (Fig. 7J), gradually narrowing with slightly acute apex (Fig. 7I). Subgenital plate broad and triangular with obtusely angular apical part (Fig. 7K). Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Colouration. Head dorsally brown with abundant short brown-yellow hairs. Body brown with few small yellowish spots along posterior edge thoracic and abdominal tergites, covered in black and brown short hairs. Paraproct black dorsally, and white ventrally. Cerci white with brown spots on dorsal side. The distal half of cerci are covered by short yellowish-brown hair and fewer longer hairs at proximal and mid areas.

Etymology. “*Maternagana*” is Latin for ‘great mother’— because adult females have larger bodies and longer hind legs than males.

***Diestramima minjiwoonga* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 8A–H)

Holotype. BHUTAN • 1 adult male; Khandro Yeshe Tshogyel Nye, Minjiwoong peg, Serthi, Samdrup Jongkhar; 26.988°N, 92.012°E; 833 m asl; 28 May 2022; C. Dorji, Tshering Dorji & Jigme leg.; Subtropical forest: cave entrance; MPN_CW5484; NBCB147.

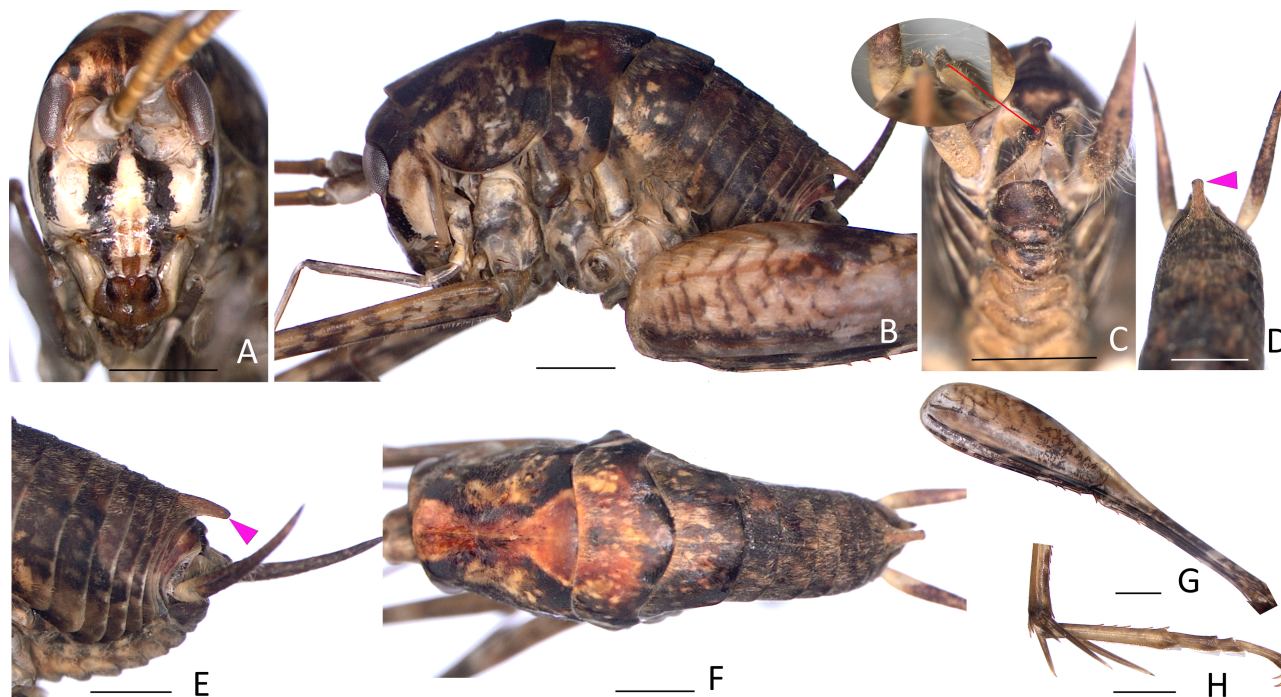


FIGURE 8. *Diestramima minjiwoonga* sp. nov. Male holotype (MPN_CW5484; NBCB147): (A) Anterior view of head. (B) Lateral view of body. (C) Ventral view of lower abdomen showing characteristic black spots on dorsal side of paraprocts. (D) Dorsal and (E) lateral view of lower abdomen showing 7th abdominal tergite (pink arrow). (F) Dorsal view of body. (G) Lateral view of hind femur and (H) basitarsus. Scale bars = 2 mm.

Description. Male. Body medium in size (~12 mm). Median ocellus oval, and lateral ocelli almost circular situated on lateral surface of basal fastigium vertici. Posteromedian projection of 7th abdominal tergite is short covering only distal half of paraproct with lateral sides nearly parallel (Fig. 8E), lateral and apical margins slightly curved inwards with truncate apex (Fig. 8D). Paraproct rather short and triangular on lateral view, apices acute. Cerci slender, conical, apices acute. Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Colouration. Head dorsally black with abundant short brown-black hairs. Body black with small brown or yellowish spots on thoracic (dorsolateral) and abdominal tergites, covered in black and brown hair. A pale, thin median line is present but inconspicuous (Fig. 8F). Paraproct white with black spots at the distal end when viewed dorsally (Fig. 8C). Cerci with two-thirds end black with dense short yellowish-brown hairs and fewer longer hairs in the mid region.

Female. Unknown.

Etymology. The new species is named for the type locality Minjiwoong under Serthi geog, Samdrup Jongkhar district.

***Diestramima multidenticuli* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 9A–K)

Holotype. BHUTAN • 1 adult male; Bawoong, Ramjar, Trashi Yangtse; 27.416°N 91.586°E; 1582 m asl; 2 Jul. 2022; C. Dorji & Jigme leg.; Temperate forest: under boulders and surrounding vegetation; MPN_CW5500; NBCB148.

Paratype. BHUTAN • 1 adult female; Bawoong, Ramjar, Trashi Yangtse, 27.416°N, 91.586°E; 1582 m asl; 2 Jul. 2022; C. Dorji & Jigme; leg.; Temperate forest: under boulders and surrounding vegetation; MPN_CW5534; NBC153.

Other material. BHUTAN • 3 male and 5 female adults; Bawoong, Ramjar, Trashi Yangtse; 27.416°N 91.586°E; 1582 m asl; 2 Jul. 2022; C. Dorji & Jigme leg.; Temperate forest: under boulders and surrounding vegetation; MPN_CW5501, MPN_CW5502, MPN_CW5503, MPN_CW5504, MPN_CW5531, MPN_CW5532, MPN_CW5533, MPN_CW5535.

Description. Male. Body medium in size (~16 mm). Median ocellus oval and lateral ocelli circular situated on lateral surface of basal fastigium verticis. Posteromedian projection of 7th abdominal tergite short covering only two-thirds of paraproct (Fig. 9B & E), narrowing to apex (Fig. 9D), lateral margins not curved inwards, apex truncate with slight downward bend (Fig. 9E). Paraproct rather short and triangular on lateral view, apices acute (Fig. 9C & E). Cerci conical, apices acute. This species is morphologically similar to *D. tsongkhapa* but differs by its smaller body (15.6–16.2 mm), shorter 7th abdominal tergite with truncated apex, and relatively shorter paraproct. This species is not phylogenetically sister to *D. tsongkhapa* (Fig. 7). Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Colouration. Head dorsally brown covered by brown and black hairs. A pale, thin median line present but inconspicuous (Fig. 9F). Rostral tubercles black from above and white on lateral sides and apices. Body brown with small brown spots along posterior edges of thoracic abdominal tergites, covered in black and brown short hairs. Paraproct black when viewed dorsally. Cerci white with black colouration on dorsal part with short yellowish-brown hairs and fewer longer at proximal half.

Female. Body colour much lighter than males with few larger dark black spots along posterior edge of thoracic and abdominal tergites (Fig. 9I). Same body size and leg length as male (Table 2). Posteromedian projection of 7th abdominal tergite short and angular with posteromedial apex obtusely rounded completely covering 8th and 9th abdominal tergite. Subgenital plate membranous, broad and short, almost triangular, apex obtusely rounded, slightly curved upward (Fig. 9K). Ovipositor narrow and as long as body (Fig. 9J). Combination of leg spines is similar to males.

Etymology. The name refers to the very large number of tiny linear spines on the superior surface of the hind tibiae.

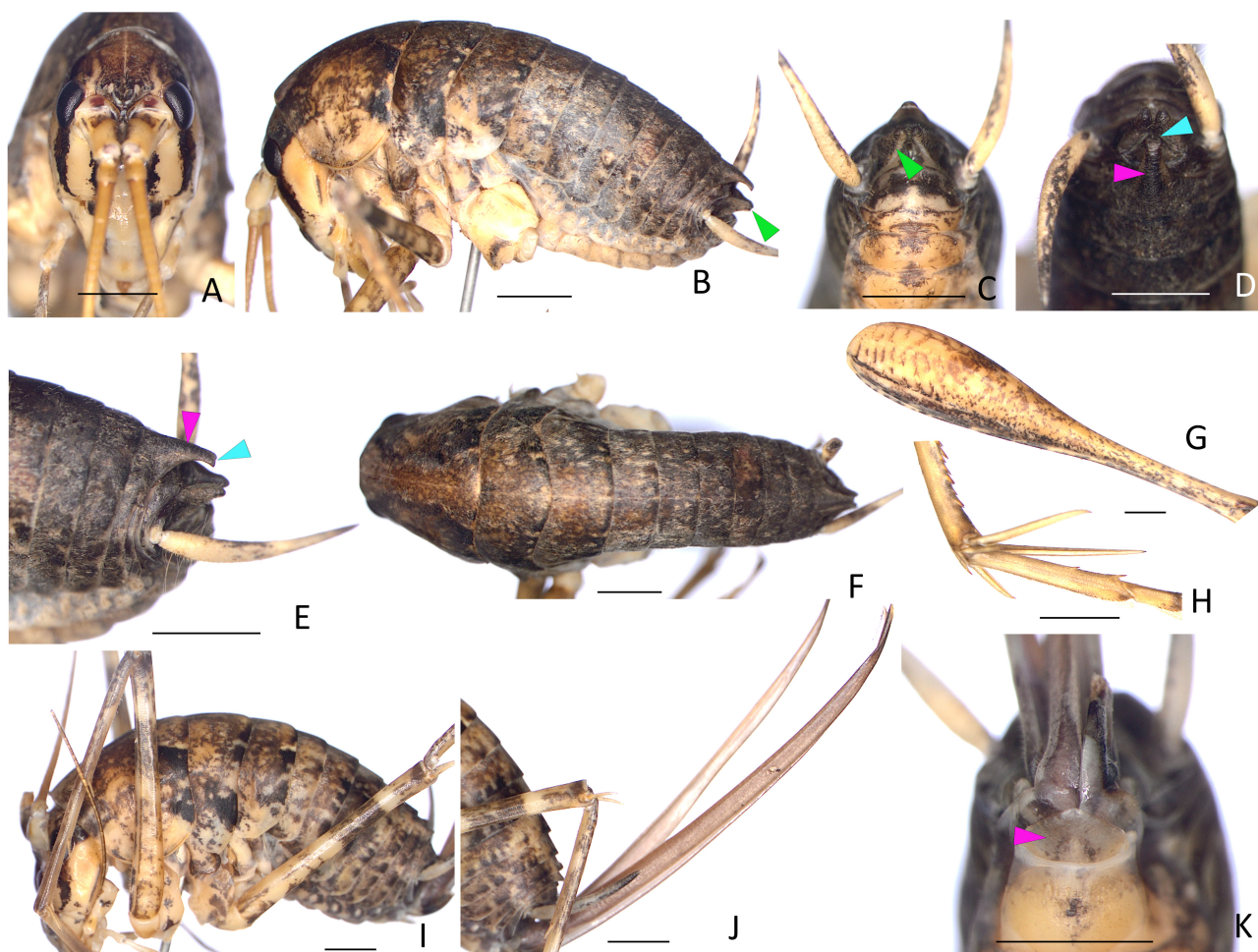


FIGURE 9. *Diestramima multidenticuli* sp. nov. Male holotype (MPN_CW5500; NBCB148): (A) Anterior view of head. (B) Lateral view of body showing short paraproct (green arrow). (C) Ventral view of lower abdomen showing short triangular paraproct (green arrow). (D) Dorsal and (E) lateral view of lower abdomen showing short narrowing 7th abdominal tergite (pink arrow) and truncated apex (blue arrow). (F) Dorsal view body. (G) Lateral view of hind femur and (H) basitarsus. Female (MPN_CW5534; NBCB153): (I) Lateral view of abdomen. (J) Lateral view of ovipositor. (K) Ventral view of lower abdomen showing subgenital plate (pink arrow). Scale bars = 2 mm.

***Diestramima phubdorjia* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 10A–H and Figure 11A–F)

Holotype. BHUTAN • 1 adult male; Tshangkha, Tangsibji, Trongsa; 27.440°N, 90.420°E; 2161 m asl; 6 Jul. 2022; C. Dorji, Karma Chorten & Jigme leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5509; NBCB149.

Paratype. BHUTAN • 1 adult female; Tshangkha, Tangsibji, Trongsa; 27.440°N, 90.420°E; 2161 m asl; 6 Jul. 2022; C. Dorji, Karma Chorten & Jigme leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5510; NBCB154.

Other material. BHUTAN • 1 adult male; Tshangkha, Tangsibji, Trongsa; 27.440°N, 90.420°E; 2161 m asl; 6 Jul. 2022; C. Dorji, Karma Chorten & Jigme leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5508. • 1 adult female; Philligang, Nabji, Korphoog, Trongsa; 27.178°N, 90.535°E; 1381 m asl; 30 Jul. 2022; Sanjit Rai leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5515.

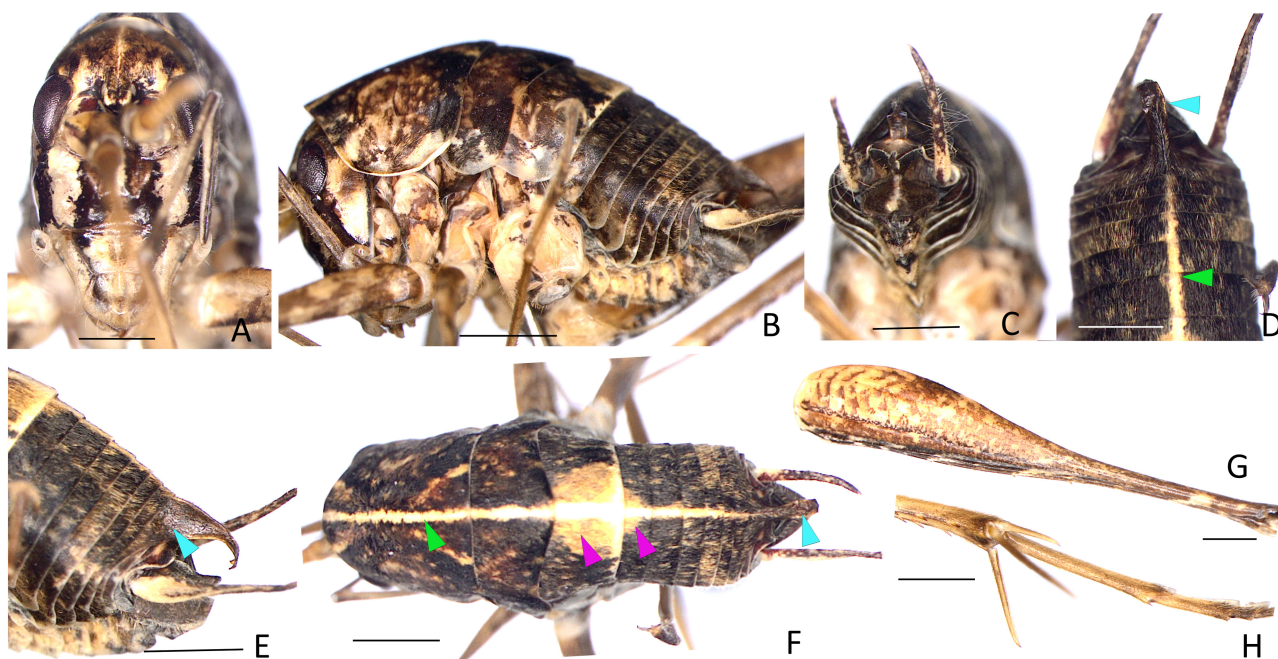


FIGURE 10. *Diestramima phubdorjia* sp. nov. Male holotype (MPN_CW5509; NBCB149): (A) Anterior view of head. (B) Lateral view of body. (C) Ventral view of lower abdomen. (D) Dorsal view of lower abdomen showing flat and parallel distal half of 7th abdominal tergites (blue arrow) and dorsal pale medial line on abdomen (green arrow). (E) Lateral view of lower abdomen showing lateral curving (blue arrow) and dichotomous apex of 7th abdominal tergite. (F) Dorsal view of body, showing pale median line (green arrow), dorsal median white spot on metanotum and 1st tergite (pink arrows), and long 7th abdominal tergite projection (blue arrow). (G) Lateral view of hind femur and (H) basitarsus. Scale bars = 2 mm.

Description. Male. Body small (10–13 mm). Median ocellus oval and lateral ocelli circular situated on lateral surface of basal fastigium verticis. Posteromedian projection of 7th abdominal tergite long, obviously surpassing apices of paraproct (Fig. 10E & F; Fig. 11A). The first half concaved laterally from the sides (Fig. 10E; Fig. 11A), second half flat and parallel curving downwards. The apex slightly curved inwards or downward (Fig. 10E; Fig. 11C), apical area of posteromedian projection dichotomous and acute when viewed from ventral side (Fig. 10C & E; Fig. 11C). Paraproct rather long (not as long as *D. tsongkhapa*), proximal half broad, narrowing towards apex, obtuse, slightly curved from middle directing backward. Subgenital plate similar to sister species *D. tsongkhapa* (Fig. 6). Cerci slender, conical, apices obtuse. Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Colouration. Head dorsally yellowish or white and black. The body is mostly very dark to black with or without small pale spots and numerous short black and yellow hairs. A pale dorsomedial stripe (thin or thin) extends from the pronotum to the 2nd or 6th abdominal tergite (Fig. 10F). White spots possible on metanotum and 1st tergite (Fig. 10F). Paraproct black. Cerci black with white on ventral and basal parts, and with dense short yellowish-brown hairs and few long pale hairs at the base (Fig. 10C).

Female. Body colour darker than male without white spots on metanotum and 1st abdominal tergite. Median line is rather thin extending only until 2nd abdominal tergite. Posteromedian projection of 7th abdominal tergite short and angular with posteromedial apex rounded completely covering 8th abdominal tergite (Fig. 11D). Subgenital plate almost translucent, broad and short, almost convex with obtusely rounded apex (Fig. 11F). Ovipositor slightly longer than body length, thin. Upper valves broad and apex acute. Lower valves with numerous fine teeth from below the apex (Fig. 11). Size of body elements (Table 2) and leg spine combination (Table 3) are similar to male.

Etymology. The new species is named in honour of late Dr. Phub Dorji, the first president of the College of Natural Resources, Royal University of Bhutan.

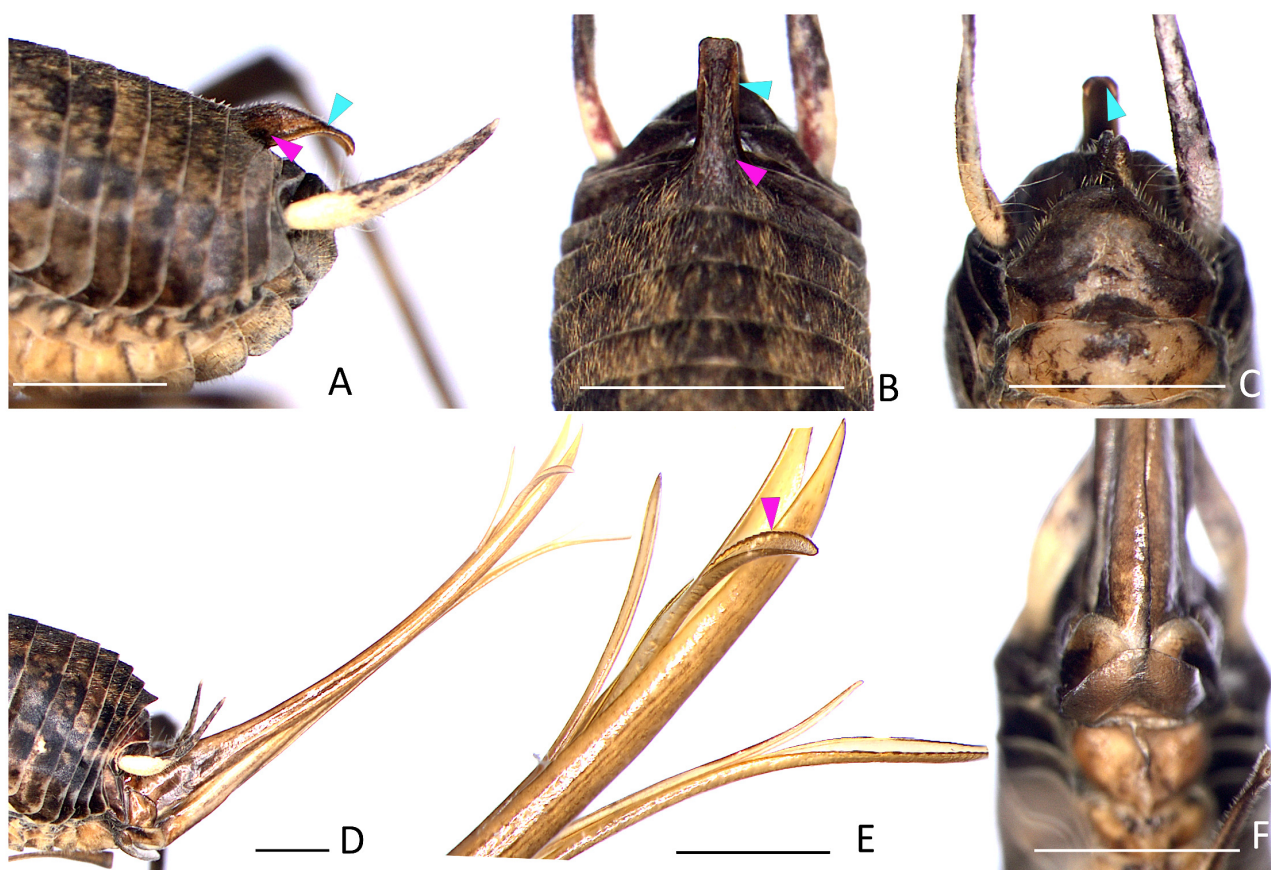


FIGURE 11. *Diestramima phubdorjia* sp. nov. Male (MPN_CW5508): (A) Lateral and (B) dorsal views of lower abdomen showing lateral curving (pink arrow) on proximal half and flat apex on distal half (blue arrow) of 7th abdominal tergite projection. (C) Ventral view of lower abdomen showing dichotomous apex (blue arrow). Female (MPN_CW5510; NBCB154): (D) Lateral view of lower abdomen. (E) Lateral view of ovipositor showing fine serration on lower valve (pink arrow). (F) Ventral view of subgenital plate. Scale bars = 2 mm.

***Diestramima samkhara* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figures 12A–K)

Holotype. BHUTAN • 1 adult male; Samkhar bridge, Gelephu, Sarpang; 27.009°N, 90.581°E; 942 m asl; 22 May 2022; C. Dorji & Jigme leg.; Subtropical forest: under boulders above bridge; MPN_CW5541; NBCB150.

Paratype. BHUTAN • 1 adult female; Samkhar bridge, Gelephu, Sarpang; 27.009°N, 90.581°E; 942 m asl; 22 May 2022; C. Dorji & Jigme leg.; Subtropical forest: under boulders above bridge; MPN_CW5478; NBCB155.

Other material. BHUTAN • 2 adult females; Samkhar bridge, Gelephu, Sarpang; 27.009°N, 90.581°E; 942 m asl; 22 May 2022; C. Dorji & Jigme leg.; Subtropical forest: under boulders above bridge; MPN_CW5542, MPN_CW5543.

Description. Male. Body small (<14 mm). Median ocellus oblong and lateral ocelli circular. Posteromedian projection of 7th abdominal tergite short covering only proximal part of paraproct (Fig. 12B & E), shallowly grooved from dorsomedial until apex (Fig. 12C), barely wider, almost parallel lateral edges and truncate with small notch at median part of apex (Fig. 12C). Paraproct rather short and almost triangular on lateral view, apices acute (Fig. 12D & E). Cerci conical, apices acute, Subgenital plate similar to *D. tsongkhapa*. Linear measures of body elements (Table 2). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 3).

Colouration. Head dorsally brown covered by brown-yellow hairs. Rostral tubercles brown from above. Maxillary palps brown with white in mid region of each segment. Body brown with few small brown/white spots along posterior edges of thoracic and abdominal tergites, covered in black and brown short hairs. A pale, thin median line present but inconspicuous extending only up to 2nd or 3rd tergites (Fig. 12F). Paraproct black when viewed

dorsally. Cerci white with black spots on dorsal side of distal half, and with short yellowish-brown hair and fewer longer hair at proximal half.

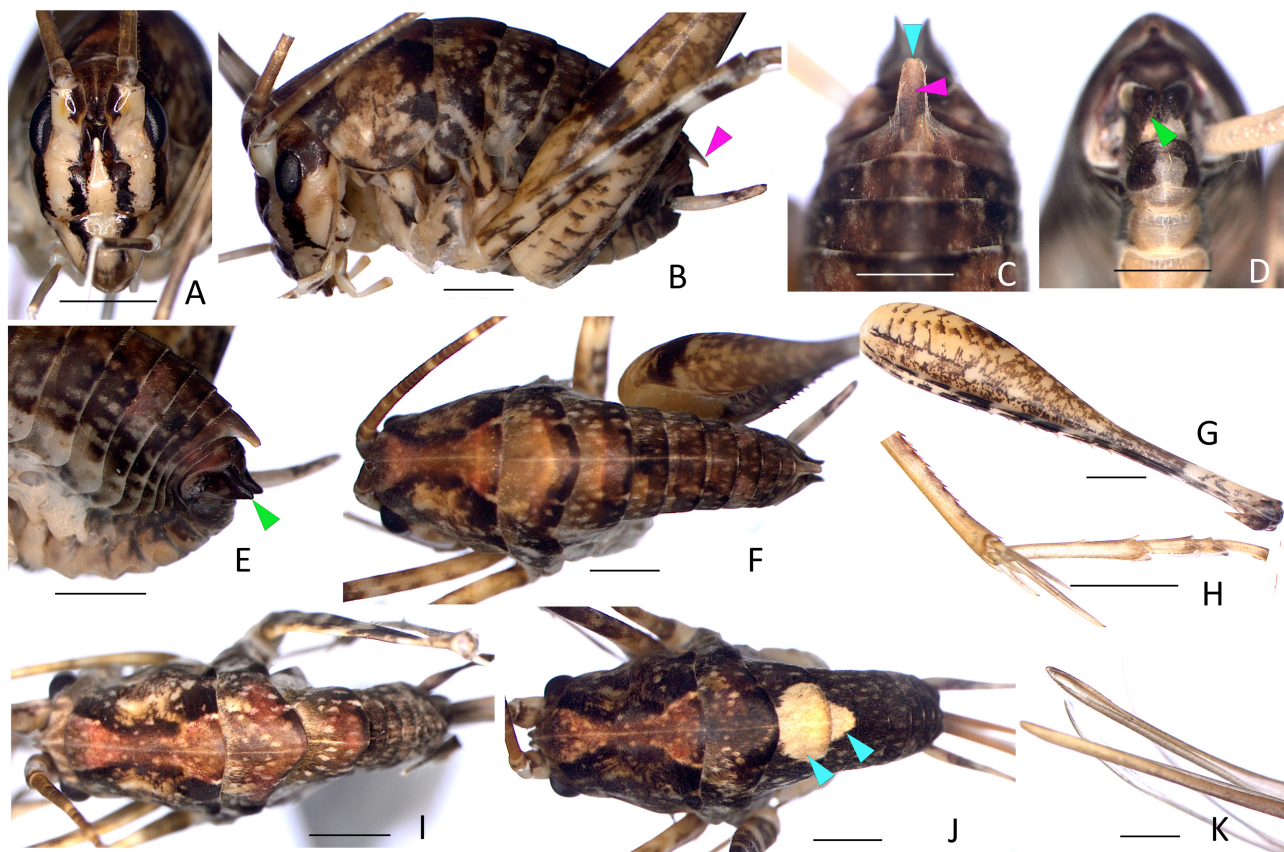


FIGURE 12. *Diestramima samkhara* sp. nov. Male holotype (MPN_CW5541; NBCB150): (A) Anterior view of head. (B) Lateral view of body showing short projection of 7th tergite (pink arrow). (C) Dorsal view of lower abdomen showing dorsal shallow groove (pink arrow) and little notched apex (blue arrow) on projection of 7th abdominal tergite. (D) Dorsal and (E) lateral views of lower abdomen showing short triangular paraproct (green arrow). (F) Dorsal view of body. (G) Lateral view of hind femur and (H) basitarsus. Female (MPN_CW5478; NBCB155): (I) Dorsal view of body. (J) Female variation: Dorsal view of body showing metanotum and 1st tergite dorsomedial white spots (blue arrows). (K) Lateral view of ovipositor. Scale bars = 2 mm.

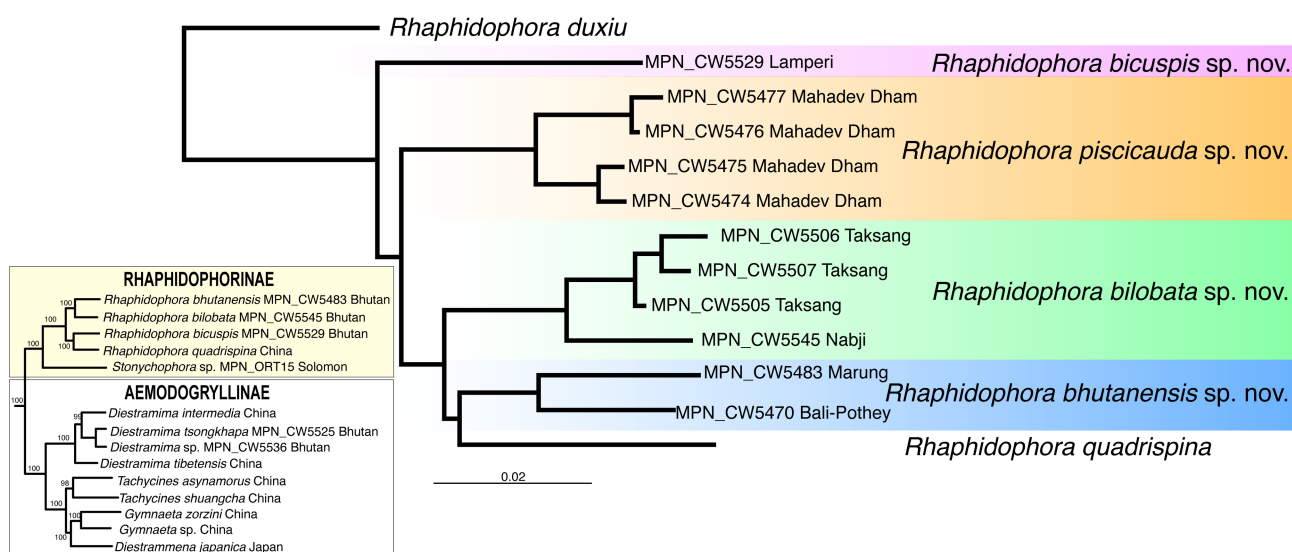


FIGURE 13. Neighbor-Joining (HKW) phylogeny of *Rhaphidophora* raphidophorids from Bhutan using 722bp alignment of mtDNA COI sequences. Inset: Phylogenetic relationships of genera within subfamily Rhaphidophorinae and Aemodogrillinae resulting from ML analysis of mtDNA sequences (COI) of 1455 bp.

Female. General appearance is similar to male, but body colour can be lighter with reddish brown on dorsal parts of thoracic tergites. White spots dorsomedial or along posterior edges of thoracic and abdominal tergites (Fig. 12J). Posteromedian projection of 7th abdominal tergite short and angular with posteromedial apex obtusely rounded completely covering 8th abdominal tergite. Ovipositor narrow and almost straight, and shorter than body, slightly curved at apex. Lower valves without serration, acute. Upper valves with hair along the margins, slightly acute at apex. The size of body elements and combination of leg spines are similar to male.

Etymology. The species is named after the type locality Samkhar, Sarpang district.

Subfamily RHAPHIDOPHORINAE

Genus **RHAPHIDOPHORA** Serville, 1838

Type species *Rhaphidophora picea* Serville, 1838

The genus *Rhaphidophora* was defined in 1838 with a single female specimen of one species and now includes 129 species (Cigliano *et al.* 2025). The general characteristics of the genus are agreed (Gorochoy, 1999, 2012) and here we summarise the appearance of *Rhaphidophora* species considering traits that are shared.

HEAD. Oval, smooth and shiny except for maxillary palps and antennae covered in dense short hair. Fastigium projecting forward with longitudinal furrow along midline on dorsal surface, partially dividing apical half into a pair of rostral tubercles. Eyes oval, slightly bigger than antennal scapi. Median ocellus situated in between ventral margins of antennal scapi and, lateral ocelli occupying basal two-thirds of lateral surface of rostral tubercles.

THORAX. Body medium size and with abundant fine black or brown hairs. Anterior margin of pronotum generally straight and posterior margin obtusely convex or nearly straight. The posterolateral margin of pronotum straight or concave while posterolateral margins of mesonotum and metanotum are slightly oblique or almost rounded.

LEGS. Legs moderately long (Table 4). Fore femora with single short, prolateral, apical spine and mid femora with a pair of prominent apical spines (one prolateral and one retrolateral). Hind femora unarmed but with apical inferior spine (retrolateral). Fore tibiae with three inferior linear spines (one prolateral and two retrolateral), and two apical spines (one prolateral and one retrolateral). Mid tibiae with four superior linear spines (two prolateral and two retrolateral) and five inferior linear spines (three prolateral and two retrolateral), and two apical spines on inferior and superior sides (one prolateral and one retrolateral). Hind tibiae with variable number of linear, short, fixed spines on superior surface (in two rows of prolateral and retrolateral) (Table 4), and typical eight, articulated apical spines. The longest pair of these (= spurs) are longer than 1st and/or 2nd segments of hind tarsi combined. The 1st tarsal segment of hind tibiae have variable number of superior spines.

MALE TERMINALIA. Adult male terminalia show significant differences among species and are widely used as a key morphological trait for diagnosing species within this genus. A description of terminalia is provided for each newly described species.

Abdominal tergites usually without distinct posterior projections. The epiproct is weakly specialised, broad always projecting behind body. The posterior margin may bear one to two sclerotised spines of variable size and shape. Genitalia membranous without any sclerotization. Cerci slender, conical and usually longer than epiproct, covered in both short and long hairs. Subgenital plate is broad and fairly similar. Styli variable from stout to somewhat long in short hairs.

COLOURATION. Head and pronotum dorsally dark brown, face and mouthparts brownish. Rostral tubercles usually dark brown. Compound eyes small and black, brown or sometimes with maculation of black and white. Maxillary palps usually pale or with black and white distinct band on each segment. Antennae longer than body mostly pale brown in colour. Body dark brown or yellowish brown with irregular white patches along the posterior of abdominal tergites from above and slightly yellowish brown from beneath. Legs are general yellowish with somewhat darker colouration in joints. Hind femur paler speckled at proximal end and darker to distal end. Cerci and styli either black or white or both.

NYMPHS. General appearance of the nymph is usually similar to adults but terminalia used for distinguishing species are not well developed.

TABLE 4. Length of body elements of *Rhaphidophora* type specimens from Bhutan (mm). Abbreviations and method of measuring each element provided in table 1.

Trait	<i>R. bhutanensis</i> sp. nov. 1 male	<i>R. bicuspis</i> sp. nov. 1 male	<i>R. bilobata</i> sp. nov. 1 male	1 female	<i>R. piscicauda</i> sp. nov. 1 male
BL	25.1	14.2	15.2	26.7	18.2
PL	7.8	3.1	4.8	6.5	5.8
FFL	9.1	5.4	6	7.3	6.3
FTL	9.8	5.9	6	6.9	6.2
FBTL	2.4	1.7	1.7	2	1.7
MFL	8.4	5.5	5.9	7.2	5.9
MTL	8.5	6.1	6.4	7.6	6.4
MBTL	2.1	1.4	1.5	1.3	1.2
HFL	24.2	12.4	15	19.1	15.9
HTL	21.9	12.1	12.3	16.1	14.9
HBTL	4.6	2.9	2.9	4.4	3.9
Eye W/L	1.2/1.6	0.8/1	0.9/1.3	1.1/1.7	0.8/1.4
MPL	2.9/3.5/4.5	1.7/1.8/2.7	2.3/2.4/3.6	3.5/2.6/3.3	2/ 2.2/ 3
Sgp W/L	3.2/1.3	2/0.7	2.8/0.6	1.6/0.6	2.8/0.9
SL	1.7	0.9	1.3	-	1
CL	8.1	6.4	4.3	6.4	5.1
OvL	-	-	-	14.1	-

***Rhaphidophora bhutanensis* Dorji, Morgan-Richards & Trewick sp. nov.**
(Figure 14A–G)

Holotype. BHUTAN • 1 adult male; Marung bridge, Khar, Pema Gatshel; 27.011°N, 91.420°E; 923 m asl; 25 May 2022; C. Dorji, Tshewang Namgay & Jigme leg.; Subtropical forest: cliff base under leaf litter and small rocks; MPN_CW5483; NBCB145.

Other material. BHUTAN • 1 nymph female; Bali-Pothey, Kilkhorthang, Tsirang; 27.464°N, 90.059°E; 1266 m asl; 1 May 2022; C. Dorji & Yeshi Phuntsho leg.; Temperate forest: under two huge boulders; MPN_CW5470.

Description. Male. Body medium in size (~25 mm). Median and lateral ocelli oval. Epiproct oval when viewed dorsally, not strongly curved but deeply grooved with a conspicuous pair of projections on the distal end directed slightly backwards (Fig. 14E). Ventral part of epiproct triangular, with a pair of large swollen lobes directed upward and triangular sclerotised apical lobe that usually remains inserted into genital cavity (Fig. 14E & F). Cerci almost twice as long as epiproct. Paraproct obtusely rounded (Fig. 14F). Subgenital plate with two ovoid lobes not completely divided (Fig. 14E). Styli stout (as short as the length of subgenital plate), more cylindrical than conical (Fig. 14F & G). Linear measures of body elements (Table 4). Fore and mid leg spine details as per the generic description except mid tibiae with two linear superior spines (one prolateral and one retrolateral). Hind leg spine details (Table 5).

Colouration. Body brownish from above and yellowish brown from beneath. Legs light to medium brown. Head brownish dorsally, face yellowish with 4 short vertical black stripes on epicarnium below eyes and antennae scapi (Fig. 14C). Epiproct white/yellowish with light black lining along groove. Cerci and styli white with dense yellowish brown short hair and fewer longer hair along cerci.

Female. Unknown.

Etymology. The new species is named in recognition of the Bhutan nation.

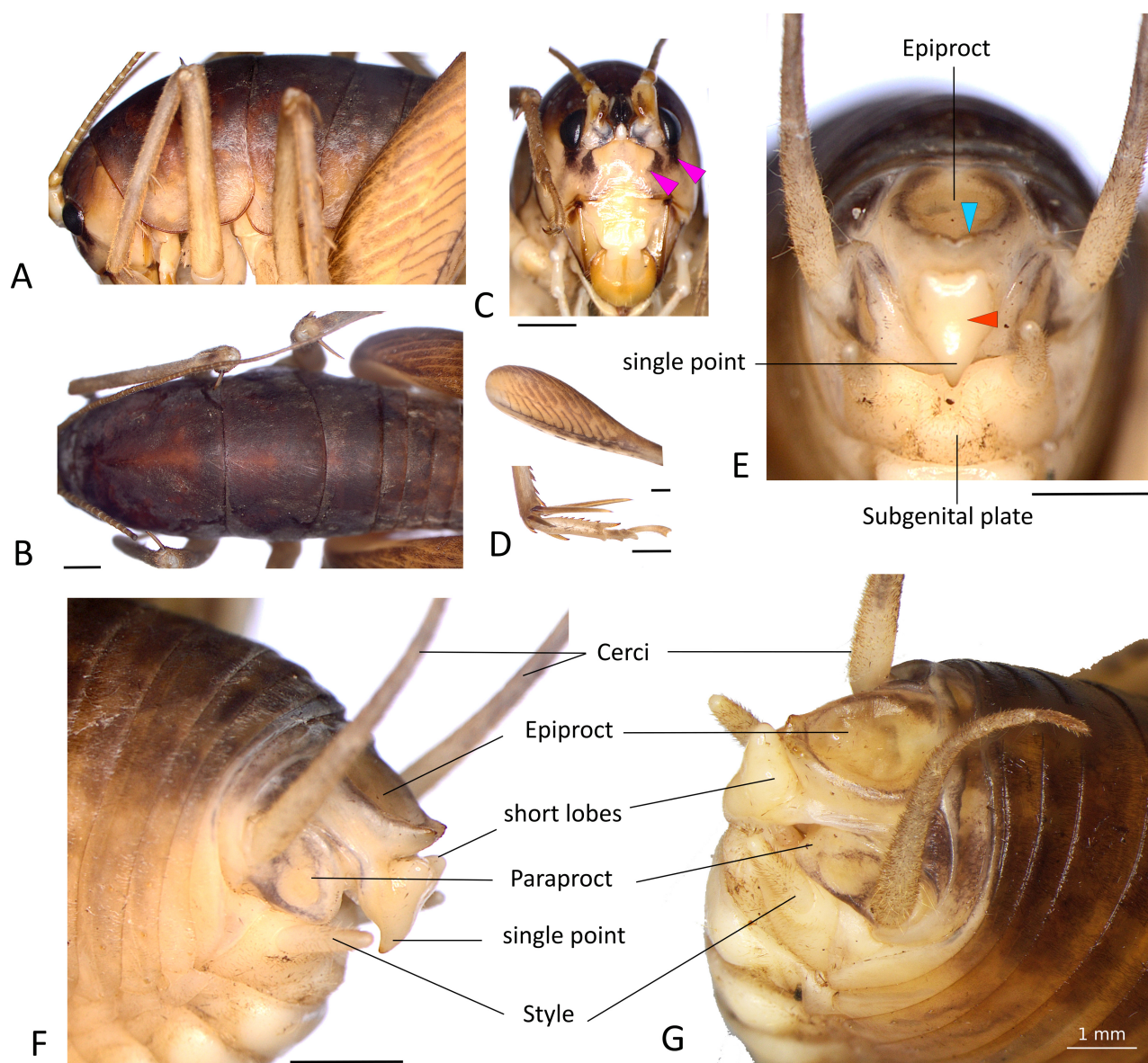


FIGURE 14. *Rhaphidophora bhutanensis* sp. nov. Male holotype (MPN_CW5483; NBCB145): (A) Lateral and (B) dorsal views of body. (C) Anterior view of head showing 4 vertical short black strips on the face. (D) Lateral view of hind femur and basitarsus. (E) Ventral view of lower abdomen showing epiproct projection (blue arrow) and ventral triangular basal plate of epiproct (red arrow). (F) Lateral and (G) latero-posterior views of lower abdomen. Scale bars = 2 mm.

***Rhaphidophora bicuspis* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 15A–G)

Holotype. BHUTAN • 1 adult male; Botanical Park, Lamperi, Thimphu; 27.498°N, 89.767°E; 2761 m asl; 22 Aug. 2022; C. Dorji leg.; Cool broadleaf forest: forest floor under leaf litter; MPN_CW5529; NBCB144.

Description. Male. Body small in size (<15 mm). Median and lateral ocelli almost oval and same in size. Lateral surface of a pronotum with central dark brown spots but inconspicuous (oval) (Fig. 15A). All abdominal tergites without distinct posterior projections. Posterior margin of tenth abdominal tergite concave. Epiproct simple, broad, oval, narrowing towards apex with carinated margin bearing a pair of sclerotised ventral spines (Fig. 15F & G). Ventral basal plate of epiproct triangular, forming a large single sclerotised apical spine (Fig. 15E). Cerci slender, conical and three times longer than epiproct. Styli stout and cylindrical with obtuse apex. Linear measures of body elements (Table 4). Fore and mid leg spine details as per the generic description. Hind leg spine details (Table 5).

TABLE 5. Number of spines on hind leg of type specimens from Bhutan (Genus *Rhaphidophora*). The number of spines and arrangement on the fore and mid legs are as per the generic description (supplementary table S2). When left and right legs differ in spine number the count from the second limb is provided in parenthesis.

Leg element	Spines	<i>R. bhutanensis</i>	<i>R. bicuspis</i>	<i>R. bilobata</i>		<i>R. piscicauda</i>
		sp. nov.	sp. nov.	sp. nov.		sp. nov.
		1 male	1 male	1 male	1 female	1 male
Hind femur	Inferior apical (retro)	1	0	0	0	0
Hind tibia	Superior linear (pro)	23(24)	21 (20)	22	23(20)	25 (22)
	Superior linear (retro)	23(23)	19 (20)	20	20(22)	22(23)
	Superior subapical (pro, retro)	1,1	1,1	1,1	1,1	1,1
	Apical	6	6	6	6	6
Hind basitarsus	Superior spines on 1 st tarsus	6	6	5	6	5

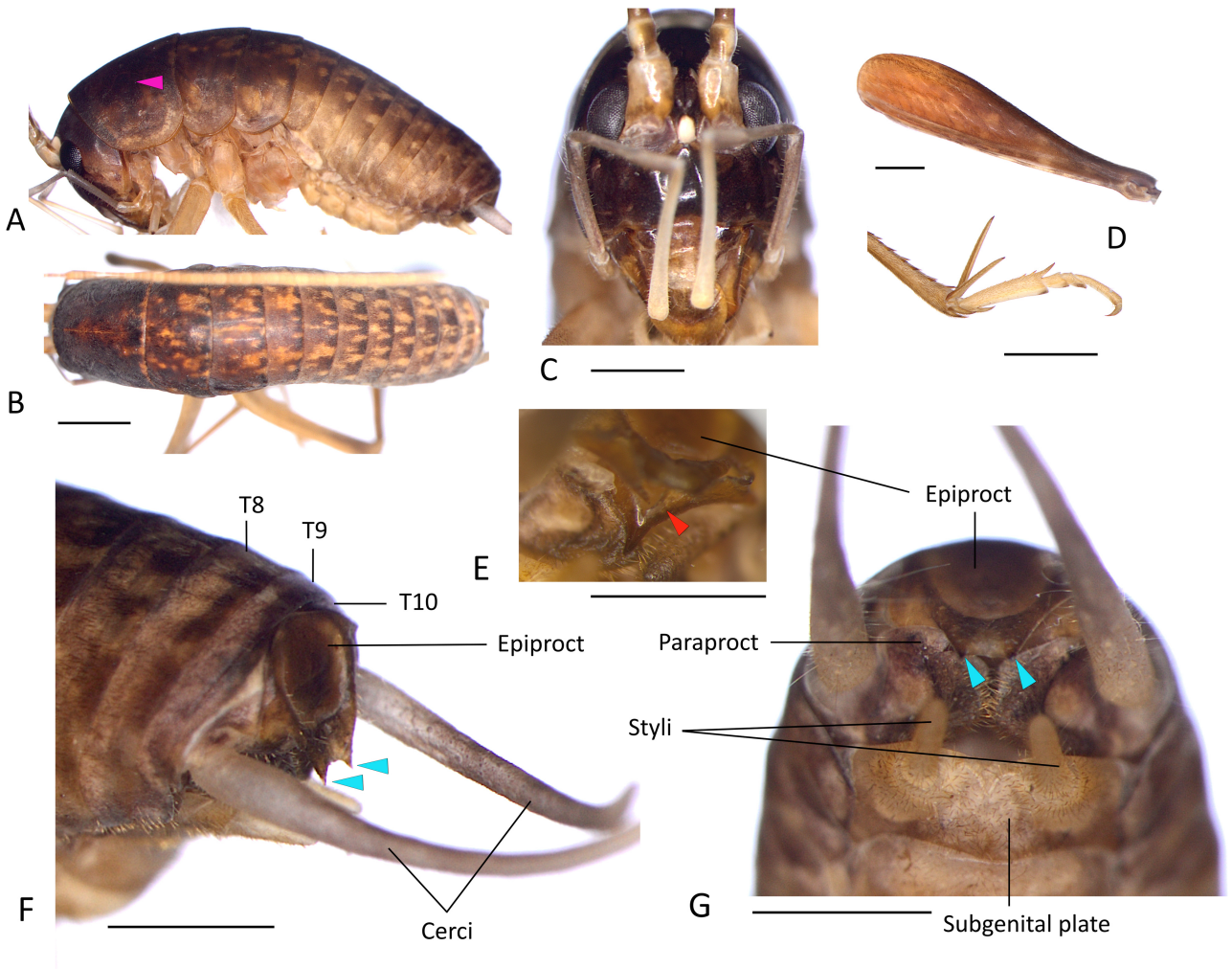


FIGURE 15. *Rhaphidophora bicuspis* sp. nov. Male holotype (MPN_CW5529; NBCB144): (A) Lateral and (B) dorsal views of body showing pronotal brown spot (pink arrow). (C) Anterior view of head. (D) Lateral view of hind femur and basitarsus. (E) Ventral view of epiproct showing triangular ventral basal plate with triangular sclerotised apical spine (red arrow). (F) Lateral and (G) ventral views lower abdomen showing a pair of sclerotised points (cusps) on distal margin of epiproct (blue arrows). Scale bars = 2 mm.

Colouration. Body yellowish brown with dark brown irregular patches along the posterior of abdominal tergites dorsally (Fig. 15A & B) and slightly yellowish brown from beneath. Cerci and styli with dense yellowish brown short hair and fewer longer hair along the cerci.

Female. Unknown.

Etymology. “*Bicuspis*” is Latin for ‘two sides’ or ‘two cusps’– derived from the paired spines on the ventral margin of male epiproct.

***Rhaphidophora bilobata* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 16A–K)

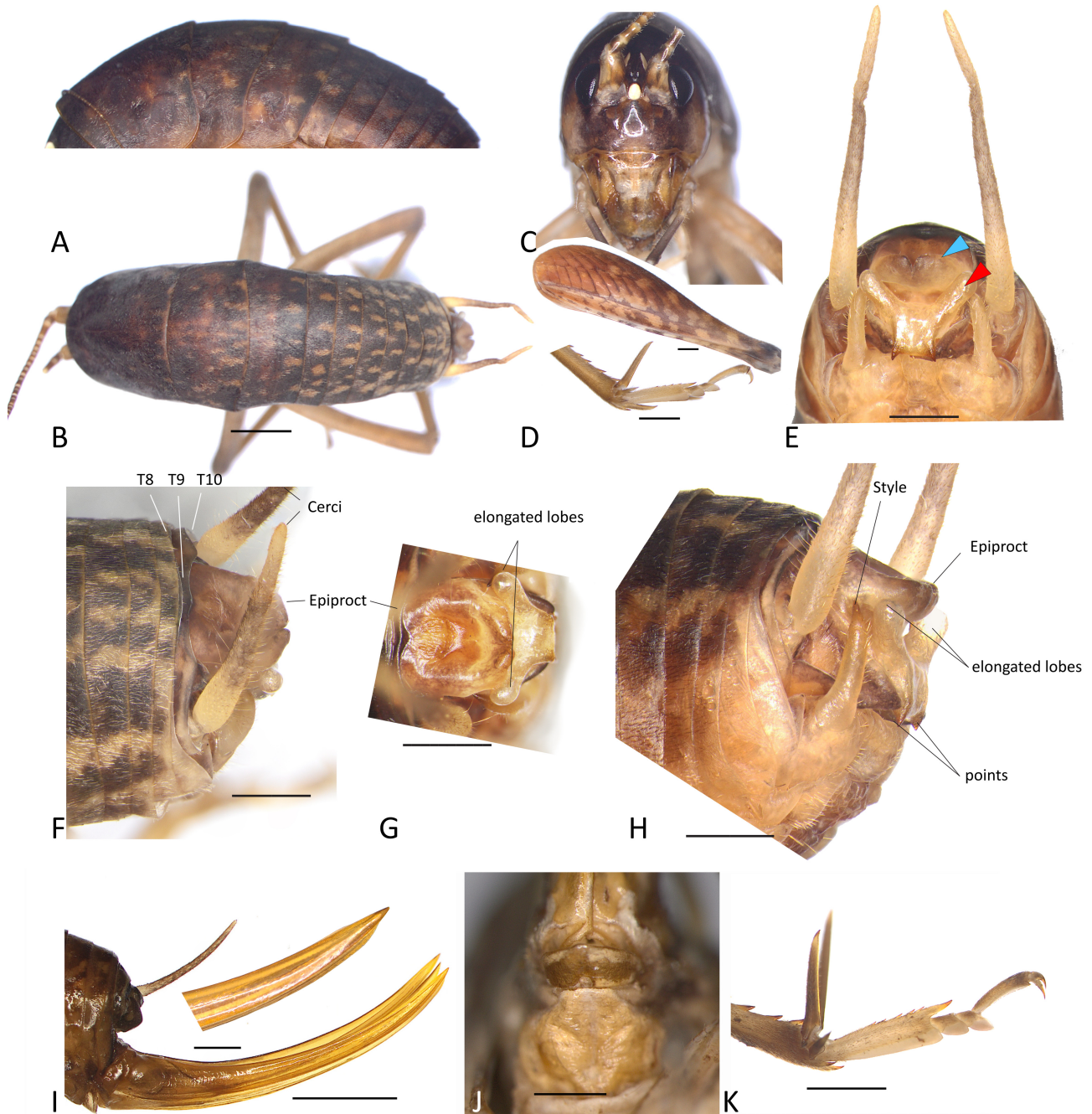


FIGURE 16. *Rhaphidophora bilobata* sp. nov. Male holotype (MPN_CW5505; NBCB142): (A) Lateral and (B) dorsal views of body. (C) Anterior view of head. (D) Lateral view of hind femur and basitarsus. (E) Ventral view of lower abdomen showing a pair of distal projections of epiproct (blue arrow) and elongated ventral basal plate lobes of epiproct (red arrow). (F) Dorsal view of lower abdomen. (G) Dorsal part of epiproct. (H) Lateral view of lower abdomen. Female (MPN_CW5544; NBCB151): (I) Lateral view of ovipositor. (J) Ventral view of subgenital plate. (K) Lateral view of hind basitarsus. Scale bars = 2 mm.

Holotype. BHUTAN • 1 adult male; Tshangkha, Tangsibji, Trongsa; 27.440°N, 90.420°E; 2161 m asl; 6 Jul. 2022; C. Dorji, Karma Chorten & Jigme leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5505; NBCB142.

Paratype. BHUTAN • 1 adult female; Namkye, Nabji, Korphoog, Trongsa; 27.166°N, 90.562°E; 2252 m asl; 11 Aug. 2022; Sanjit Rai leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5544; NBCB151.

Other material. BHUTAN • 2 nymph males; Tshangkha, Tangsibji, Trongsa; 27.440°N, 90.420°E; 2161 m asl; 6 Jul. 2022; C. Dorji, Karma Chorten & Jigme leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5506, MPN_CW5507. BHUTAN • 1 female; Namkye, Nabji, Korphoog, Trongsa; 27.166°N, 90.562°E; 2252 m asl; 11 Aug. 2022; Sanjit Rai leg.; Cool broadleaf forest: under fallen tree branches and leaf litter; MPN_CW5545

Description. Male. Body small in size (<16 mm). Median ocellus oval and lateral ocelli slightly oblong or oval, occupying basal two-thirds of lateral surface of the rostral tubercles. Posterior median margin of 9th abdominal tergite less rounded, embedded within 8th abdominal tergite (Fig. 16F). Tenth abdominal tergite with obtuse projection at the posterolateral margin with more convex shaped projection in the middle (Fig. 16F). Epiproct broad, less strongly curved but with two distinct grooves on the dorsal surface (Fig. 16F & G), with a pair of distal projections on the posterior median curved slightly upwards (Fig. 16E & G). Ventral basal plate of epiproct quadrate, with a pair of large lobes directed upward away from each other (usually backward when inserted to genitalia cavity) (Fig. 16E). These lobes are as long as the length of ventral basal plate of epiproct, with a pair of short sclerotised apical margin spines (Fig. 16E & H). Cerci slender and cylindrical, apices obtuse. Subgenital plate much wider than long forming oval lobes with wide space in between. Styli short, conical, arcuate with sclerotised acute apices (Fig. 16H).

Linear measures of body elements (Table 4). Fore and mid leg spine details as per the generic description except mid tibiae with three superior linear spines (one prolateral and two retrolateral). Hind leg spine details (Table 5).

Colouration. Head and pronotum mostly dark brown or reddish and black dorsally. Body brown with numerous small pale brown or yellowish spots along posterior edges of thoracic and abdominal tergites (Fig. 16E), and slightly yellowish brown from beneath. Rostral tubercles dark brown. Cerci blackish in the centre and white on the ends.

Female. Larger than male (Table 4), body medium in size (>25 mm). Median and lateral ocelli same as male holotype. Subgenital plate much wider than long, simple, more convex than triangular, basal with small depression in the centre (Fig. 16J). Ovipositor base not so broad, long and gradually narrowing towards apex, curved, apices acute. Lower valves serrated on distal area of ventral margin, and upper valves smooth. The general colouration is similar to male except body with more small brown/yellowish spots along posterior edges of thoracic and abdominal tergites. Linear measures of body elements (Table 4). Fore and mid leg spine details as per the generic description except mid tibiae with only three inferior linear spines (retrolateral). Hind leg spine details (Table 5).

Etymology. “*Bilobata*” from the Latin for ‘two lobes’ – referring to the specialised ventral basal plate of epiproct, which forms a pair of long lobes.

***Rhaphidophora piscicauda* Dorji, Morgan-Richards & Trewick sp. nov.**

(Figure 17A–H)

Holotype. BHUTAN • 1 adult male; Mahadev Dham, Tashiding, Dagana; 26.899°N, 89.975°E; 915 m asl; 21 May 2022; Jigme Wangchuk & Galey leg.; Subtropical forest: surrounding limestone cave under leaf litter; MPN_CW5475; NBCB143.

Other material. BHUTAN • 2 male and 1 female nymphs; Mahadev Dham, Tashiding, Dagana; 26.899°N, 89.975°E; 915 m asl; 21 May 2022; Jigme Wangchuk & Galey leg.; Subtropical forest: surrounding limestone cave; MPN_CW5474, CW5476, CW5477.

Description. Male. Body medium in size (<20 mm). Median ocellus elliptic or oblong (Fig. 17C) slightly longer than its width; lateral ocelli oval, occupying basal two-thirds of lateral surface of the rostral tubercles. Posterolateral margins on left side of mesonotum and metanotum are different from the right possibly because of incomplete ecdysis during nymph stages or early-stage injuries (Fig. 17A & B). Epiproct broad and long, fishtail shaped when view dorsally. The dorsal surface of epiproct is shallowly grooved (Fig. 17G), slightly curved laterally, projecting behind body. In about proximal half gradually narrowing with apical margin obtusely excised from the

centre forming two lateral obtuse apices (Fig. 17G). Ventral surface of basal plate of epiproct is almost quadrate with slightly angled from middle on lateral view with a pair of small sclerotised marginal spines slightly projecting outwards, separated by traverse ridge (Fig. 17E). Cerci slender, conical and slightly longer than epiproct. Paraproct acutely triangular (Fig. 17F). Subgenital plate width as wide as length, with two distinct large lobes (Fig. 17E). Styli stout and simple, conical and apical obtuse without sclerotization. Linear measures of body elements (Table 4). Fore and mid leg spine details as per the generic description except mid tibiae with only three inferior linear spines (retrolateral). Hind leg spine details (Table 5).

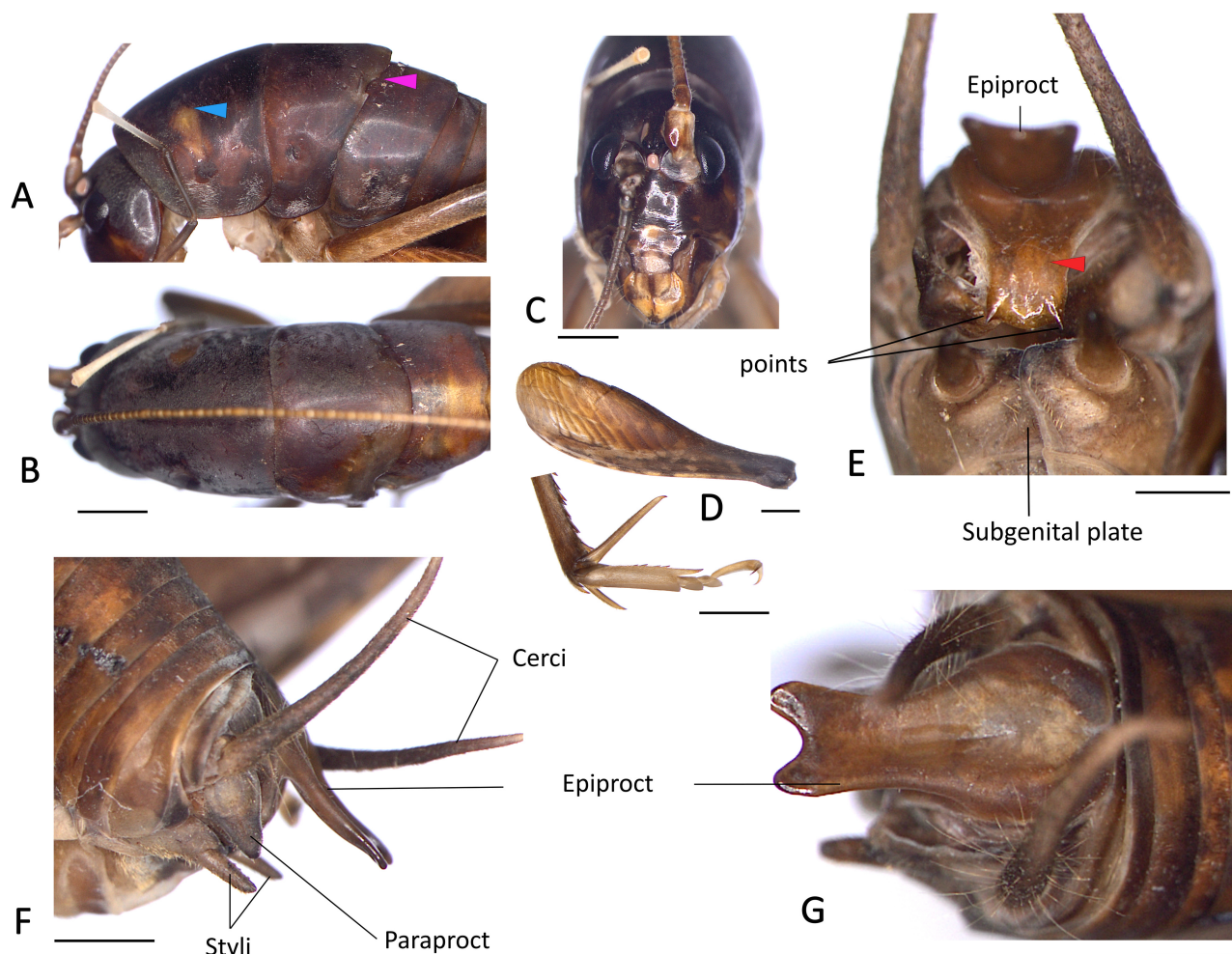


FIGURE 17. *Rhaphidophora piscicauda* **sp. nov.** Male holotype (MPN_CW5475; NBCB143): (A) Lateral and (B) dorsal views of body. (C) Anterior view of head. (D) Lateral view of hind femur and basitarsus. (E) Ventral view of lower abdomen showing quadrate shaped ventral basal plate of epiproct (red arrow) with a pair of sclerotised apical spines. (F) Lateral and (G) dorsal views of lower abdomen. Scale bars = 2 mm.

Colouration. Head dorsally back with brownish face and mouthparts. Rostral tubercles dark black. Eyes silver white and black forming maculation of white and black connecting spots. Body dark brownish from above and slightly yellowish brown from beneath when compared to other species. Epiproct brownish. Cerci dark brown with one-third end white. Cerci and styli white with dense yellowish brown short setae, and fewer longer hairs along first half of the cerci.

Female. Adult unknown.

Etymology. Name is derived from fishtail shape of male epiproct, when viewed from above.

Key to the known Rhaphidophoridae of Bhutan

- Superior apical spines of hind tibiae shorter than 1st and 2nd segments of hind tarsi combined. Male subgenital plate without styli. Subfamily **Aemodogryllinae** Jacobson, 1905
Superior apical spines of hind tibiae longer than 1st and 2nd segments of hind tarsi combined. Male subgenital plate with styli. Subfamily **Rhaphidophorinae** Walker, 1869

Subfamily Aemodogryllinae: Key to the known male Bhutanese *Diestramima*

- 1) Male posteromedian projection of 7th abdominal tergite long covering paraproct from above (Fig. 6E & Fig. 8E) 2
- Male posteromedian projection of 7th abdominal tergite short covering only proximal half of paraproct (Fig. 7E, Fig. 9E & Fig. 12E) 4
- 2) Male posteromedian projection of 7th abdominal tergite without prominent formation of lateral ridges (concave) in proximal half surface, apex obtusely rounded with inconspicuous notch; paraproct triangular with a short finger-like projection (Fig. 8C–E) *D. minjiwoonga* **sp. nov.**
- Male posteromedian projection of 7th abdominal tergite rather high with lateral ridges in proximal half, apex distinctly notched (Fig. 6E, Fig. 10E, & Fig. 11A); paraproct long and finger-like projection in distal half (Fig. 6C, Fig. 10C, & Fig. 11C) 3
- 3) Male posteromedian projection of 7th abdominal tergite gradually narrowing with distinct expanded notched apex; paraproct long with finger-like projection in distal half (Fig. 6C–E). *D. tsongkhapa* (Würmli, 1973)
- Male posteromedian projection of 7th abdominal tergite long, obviously surpassing paraproct, parallel from both sides, almost flat and curved downwards in distal half with apex curved inwards and acutely notched (Fig. 10C–F & Fig. 11B–C). *D. phubdorjia* **sp. nov.**
- 4) Male posteromedian projection of 7th abdominal tergite straight and flat but shallowly grooved from dorsomedial until apex, almost parallel lateral edges and truncate with small notch at median part of apex (Fig. 12B–C) *D. samkhara* **sp. nov.**
- Male posteromedian projection of 7th abdominal tergite high and slightly curved gradually narrowing towards apex (Fig. 7E & 9E) 5
- 5) Male posteromedian projection of 7th abdominal tergite very short not extending beyond tenth tergite, gradually narrowing, truncate or slightly convex apex (Fig. 7B–D). Adult female larger than adult male *D. maternagana* **sp. nov.**
- Male posteromedian projection of 7th abdominal tergite short covering proximal half of paraproct, narrowing to form almost parallel edges towards apex, truncate apex with slightly bent downwards (Fig. 9B–E). Superior prolateral and retrolateral edges of hind tibiae bear >50 minute spines *D. multidenticuli* **sp. nov.**

Subfamily Rhaphidophorinae: Key to the known male Bhutanese *Rhaphidophora*

- 1) Male epiproct more or less specialised bearing a projection or a curved, narrowed or bifurcate apex (Fig. 14C, Fig. 16H & Fig. 17G) 2
- Male epiproct simple without long projection, disc oval, carinated all around, only at apex almost flat surface with a pair of short lateral spines directing downwards (Fig. 15F–G); ventral basal plate of epiproct triangular, gradually forming into single sclerotised spine (Fig. 15E) *R. bicuspis* **sp. nov.**
- 2) Male epiproct less specialised, longer than wide; ventral basal plate of epiproct without any evident projections or specialisation 3
- Male epiproct short slightly curved upward at apex (Fig. 14E & Fig. 16F), ventral basal plate of epiproct specialised (Fig. 14F & Fig. 16H) 4
- 3) Male epiproct acute-triangular, disc carinated all around with a longitudinal groove towards apex, apex projecting behind elevated disc and with 2 obtuse dorsal small lobes *R. angulata* Ingrisch, 2002
- Male epiproct longer than wide, dorsal surface shallowly curved projecting behind body; basal half broad and almost parallel thereafter with 2 obtuse lateral apices (Fig. 17F–G). *R. piscicauda* **sp. nov.**
- 4) Male epiproct oval, lateral margins not strongly curved but grooved dorsally with a conspicuous pair of projections on distal end directed slightly backwards; ventral basal plate of epiproct with a pair of swollen lobes directed upward and a small triangular sclerotised apical lobes (Fig. 14E–G) *R. bhutanensis* **sp. nov.**
- Male epiproct oval, lateral margins less curved but deeply grooved in dorsal view and with a pair of projections on the distal end directed slightly upwards; ventral basal plate of epiproct with a pair of large lobes directed upward away from each other, apical with a pair of sclerotised ventral margin spines (Fig. 16E–H) *R. bilobata* **sp. nov.**

DISCUSSION

Systematics

More than half of the global rhaphidophorid diversity is within Asian lineages with about 800 different species

in 38 genera (Cigliano *et al.*, 2023). Only two species were reported from Bhutan; *Diestramima tsongkhapa* and *Rhaphidophora angulata* (Ingrisch, 2002; Würmli, 1973). Here we describe nine new species taking the total rhaphidophorid diversity to 11 species native to the eastern Himalaya of Bhutan. This was possible by searching a wider range of habitats and a larger area within Bhutan than ever before. The true number of species in the country is undoubtedly much higher, as vast areas of Bhutan's territory remain insufficiently studied.

Our phylogenetic inference based on mtDNA aligns with morphological findings, demonstrating that species within the two subfamilies Rhaphidophorinae and Aemodogryllinae form distinct clades. The genus *Diestramima* is distinguished from other genera within the tribe Diestramimini by the presence of a long male posteromedian projection on the 7th abdominal tergite, which typically extends over the paraprocts from above, and by membranous male genitalia featuring eight lobes (Gorochov & Storozhenko, 2015). Based on the male 7th abdominal tergite, 12 of 45 specimens closely aligned with this description: *D. phubdorjia* **sp. nov.** (n = 4), and *D. tsongkhapa* (n = 8). The remaining specimens had a relatively short 7th abdominal tergite, extending only to the proximal half of the paraprocts without completely covering them. Despite this variation from what is regarded as a diagnostic trait for the genus our mtDNA sequences support all specimens as part of the same genus. Morphological variation in the shape of abdominal tergites concordant with the genetic clusters resolved five new species in the genus *Diestramima*: *D. matermagna* **sp. nov.**, *D. minjiwoonga* **sp. nov.**, *D. multidenticuli* **sp. nov.**, *D. phubdorjia* **sp. nov.**, and *D. samkhara* **sp. nov.**

The genus *Diestramima* has been further subdivided into three subgenera based on the distinct shapes of paraprocts (Gorochov & Storozhenko, 2019). The distal half of male paraproct of subgenus *Baculitettix* is curved, long and finger-like, with the proximal half triangular. In subgenus *Diestramima* the male paraproct is rather short and plate-like with distal part truncate, angular or having hooks and/or teeth, whereas male paraproct of subgenus *Excisotettix* is moderately short, almost S-shape in profile, with proximal and distal parts more or less equal to each other in height, and with angular or almost spinose apex. However, all the species described from Bhutan possess a simple triangular paraproct without distinct structural morphology that can be associated to either of the subgenera (Fig. 18). *D. matermagna* **sp. nov.**, *D. minjiwoonga* **sp. nov.**, and *D. multidenticuli* **sp. nov.** have paraprocts somewhat similar to that of subgenus *Baculitettix* but they are more acutely triangular without any finger-like distal part. Instead, it gradually and evenly narrows towards the apex with slight curvature at the dorsal mid region. *D. samkhara* **sp. nov.** male paraproct is comparatively stout, and more triangular with slight dorsal curve towards apex. *D. phubdorjia* **sp. nov.** is the only species which can be grouped into subgenus *Baculitettix* that has a finger-like distal half of paraproct but not long as much as in *D. tsongkhapa*. Due to the variation in paraproct morphology in *Diestramima* species in Bhutan, these species could not be assigned to existing subgenera, nor was a new subgenus proposed. Molecular phylogenetics does not resolve the subgenera classification providing another reason to be cautious of this taxonomic level (Fig.5).

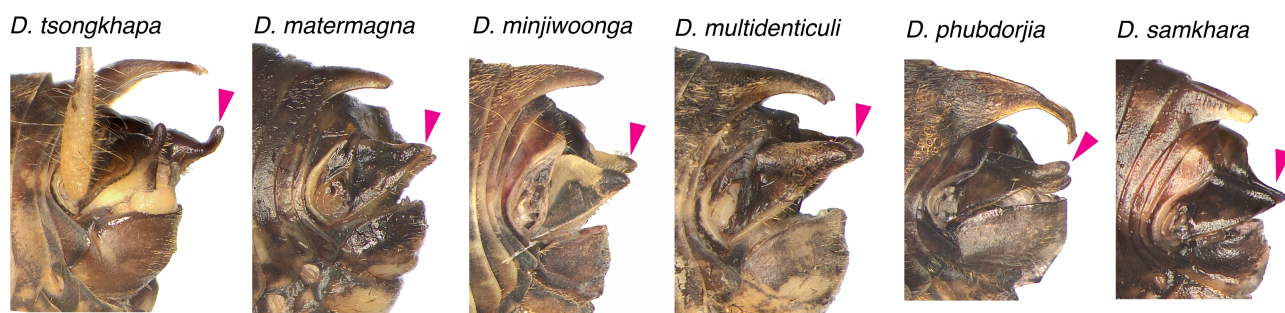


FIGURE 18. Lateral view of terminalia of males of *Diestramima* species from Bhutan showing differences in paraproct shape (pink arrows).

Genus classification within Rhaphidophorinae is based on the presence or absence of a projection on the abdominal tergites in male. Among these, *Rhaphidophora*, characterized by the absence of abdominal projections and a simple epiproct is the most speciose. Specimens from Bhutan, represented by mtDNA sequences were resolved into clusters concordant with morphology and confirming association of females, nymphs, and adult males. Thus, four new species are described within the genus *Rhaphidophora* based on the distinct shape of the epiproct and our genetic evidence. The epiproct of male *R. bicuspis* **sp. nov.** is the simplest in shape of the four species, with two distinct marginal spines at its apex. Four specimens were collected from Mahadev Dham (Dagana), and these form a

distinct genetic cluster (Fig. 13). Three specimens were nymphs, but the single adult male allowed us to describe *R. piscicauda* **sp. nov.** based on its distinct large, elongated, fishtail epiproct (Fig. 17). *R. piscicauda* **sp. nov.** resembles the Nepalese *R. stridulans* but differs in the shape of styli and epiproct (Ingrisch, 2006). *R. stridulans* styli are more curved and sclerotized with compress and acute apices. The proximal half of epiproct is more triangular than oval with the dorsal surface curved rather than almost flat or shallowly grooved in the case of new species. Moreover, the ventral basal plate of epiproct of the *R. piscicauda* **sp. nov.** is quadrate with the surface not concaved but instead flat or slightly angled at the midpoint in lateral view. The epiprocts of *R. bilobata* **sp. nov.** and *R. bhutanensis* **sp. nov.**, somewhat resemble that of genus *Neorhaphidophora*. The epiproct is short and grooved dorsally with apices slightly curved upward, whereas the ventral plate of epiproct is specialised to form a pair of lobes which is quite distinct in *R. bilobata* **sp. nov.** (Fig. 15 & Fig. 17). The genus *Neorhaphidophora* was established for species characterized by a strongly modified male epiproct featuring a pair of large basal projections directed backwards and slightly upwards, with bent downward and forward so that it remains inserted in the genital cavity (Gorochoy, 2011). Currently, *Neorhaphidophora* is known from countries neighbouring Bhutan such as Myanmar, China and Thailand suggesting a high likelihood that it is also present in Bhutan. Currently there are no genetic data available that would allow comparison of our specimens to species placed within *Neorhaphidophora*, so despite minor modification of epiproct, *R. bilobata* **sp. nov.** and *R. bhutanensis* **sp. nov.** are here placed into *Rhaphidophora*. Furthermore, all the *Rhaphidophora* species described in this study fall within Group 1 (Gorochoy, 2012), characterized by the presence of only two apical spines on fore tibia and more or less specialised male epiproct with a projection or a curved, narrowed or bifurcate apical area.

Distribution and habitat

Rhaphidophorids in arid and semi-arid habitats are often associated with caves, though many species are known to inhabit open forests, seldom using caves for refuge. Asian lineages of Aemodogryllinae, Rhaphidophorinae, and Anoplophilinae primarily dwell in temperate and tropical forests, with the exception of certain *Tachycines* and *Diestrammena* species, which are obligate cave dwellers across East Asia. To sample cave-adapted rhaphidophorids we explored three cave systems in Bhutan with well-developed dark zones: Rangtsi (southwest), Meritsemu (south), and Dugphu (central). However, we found few rhaphidophorids in caves of Bhutan but instead collected individuals among rocks at cave entrances. In Bhutan camel crickets were most commonly found in forest leaf litter, beneath fallen branches and rocks, within cliff crevices, and near cave entrances.

We conducted our survey across more than 50 sites in 17 districts, but despite extensive search effort, we encountered rhaphidophorids at only 15 sites across 10 districts (Fig. 4) in central and eastern regions. It is likely that our failure to find rhaphidophorids in other sites is largely due to searching during daylight. Notably, a recent night survey of a previously explored site at Rangtsi Nye (Haa), resulted in detection of many individuals of *Diestramma* species. Similarly, *D. tsongkhapa*, described from Khotokha (Wangdue Phodrang) was also resampled from Nabji (Trongsa) and Wangphu (Samdrup Jongkhar). This suggests that their distribution may be broader than our initial surveys indicated, emphasizing the need for further nocturnal investigations. However, due to inaccessibility of motor road and the remoteness of the area, night search often poses risks from wild animals and the dangers of monsoon torrential rain.

The study of Bhutanese rhaphidophorids remains in its early stage, and a comprehensive understanding of their diversity and geographical distribution is yet to be established. Rhaphidophorids of Bhutan represent the western extent of the group in the eastern Himalaya. The findings from our recent survey indicate that *D. tsongkhapa* is widely distributed across central and eastern Bhutan, where it occurs sympatrically with *R. bilobata* **sp. nov.** (Trongsa). *D. matern magna* **sp. nov.** was found in sympatry with *R. bhutanensis* **sp. nov.** at Marung (Pema Gatshel) and appears to be more abundant in parts of the eastern region, with its presence recorded across three adjacent districts (Trashigang, Samdrup Jongkhar, and Pema Gatshel). The remaining species, particularly those of the genus *Rhaphidophora*, have been found in only a single locality which may indicate these are restricted to much smaller geographical regions.

Among the species described, *R. bicuspis* **sp. nov.** was found to be in the northernmost region of Bhutan, on south-facing slope of Lamperi (Thimphu) at an elevation of 2600 metres. Lamperi lies just below Dochula Pass (3,300 m asl) sub-alpine zone characterized by extreme cold and prolonged snow cover during the winter months.

Rhaphidophorids are known for their ability to withstand harsh environmental conditions, including extreme heat and prolonged freezing temperatures (Hegg *et al.*, 2022). The presence of *R. bicuspis* **sp. nov.** in such an environment suggests that the species may either possess physiological adaptations that allow it to survive freezing temperatures or might synchronise its life cycle to avoid seasonal extremes in temperatures. This discovery indicates the potential existence of cold tolerant rhaphidophorid species in the Himalayan mountains, a region where alpine biodiversity remains largely unexplored. Future research and exploration in these high-elevation ecosystems may lead to significant discoveries, contributing to a deeper understanding of insect adaptation and survival strategies in extreme environments.

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AUTHOR COTRIBUTIONS

Cheten Dorji: Conceptualization, collection of biological material and generation of DNA sequences, analysis, writing original draft, figure visualization, and photography.

Steven A. Trewick and Mary Morgan-Richards: Conceptualization, supervision, resource facilitation, reviewing, editing, figure visualization, and formatting.

REFERENCES

- Bian, X. & Shi, F. (2016) Contribution to the Chinese subfamily Rhaphidophorinae Walker, 1869 (Orthoptera: Rhaphidophoridae; Rhaphidophorinae): New additions to the genera *Eurhaphidophora* and *Stonychophora*. *Zootaxa*, 4109 (1), 46–58.
<https://doi.org/10.11646/zootaxa.4109.1.4>
- Bian, X., Zhu, Q. & Shi, F. (2017) Contribution to the Chinese Rhaphidophorinae Walker, 1869 (Orthoptera: Rhaphidophoridae; Rhaphidophorinae): New species of *Rhaphidophora* Serville, 1838 from China. *Zootaxa*, 4317 (2), 261–278.
<https://doi.org/10.11646/zootaxa.4317.2.4>
- Bulgarella, M., Trewick, S.A., Minards, N.A., Jacobson, M.J. & Morgan-Richards, M. (2014) Shifting ranges of two tree weta species (*Hemideina* spp.): Competitive exclusion and changing climate. *Journal of Biogeography*, 41 (3), 524–535.
<https://doi.org/10.1111/jbi.12224>
- Cigliano, M.M., Braun, H., Eades, D.C. & Otte, D. (2023) *Orthoptera Species File*. [<http://Orthoptera.SpeciesFile.org>]
- Dawwrueng, P., Gorochoy, A.V., Tanomtong, A. & Suwannapoom, C. (2020) Contribution to the knowledge of Rhaphidophorinae (Orthoptera: Ensifera: Rhaphidophoridae) from Thailand: three genera *Neorhaphidophora*, *Eurhaphidophora* and *Minirhaphidophora*. *Zootaxa*, 4853 (2), 235–253.
<https://doi.org/10.11646/zootaxa.4853.2.5>
- Folmer, O., Black, M., Hoeh, W., Lutz, R. & Vrijenhoek, R. (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Molecular Marine Biology and Biotechnology*, 3 (5), 294–299.
- Gorochoy, A.V. (1998) *Material on the fauna and systematics of Stenopelmatoidea (Orthoptera) from Indochina and some other territories. I. [in Russian]*. 77 (1), 73–105.
- Gorochoy, A.V. (1999) *Material on the fauna and systematics of Stenopelmatoidea (Orthoptera) from Indochina and some other territories. II. [in Russian]*. 78 (1), 60–78.
- Gorochoy, A.V. (2001) The higher classification, phylogeny and evolution of the superfamily Stenopelmatoidea. In: Field, L.H. (Ed.), *The biology of wetas, king crickets and their allies*. CABI Publishing, pp. 3–33.
<https://doi.org/10.1079/9780851994086.0003>
- Gorochoy, A.V. (2010) *New species of the families Anostomatidae and Rhaphidophoridae (Orthoptera: Stenopelmatoidea) from China. - Far Eastern Entomologist*. 206, 1–16.
- Gorochoy, A.V. (2011) Contribution to the fauna and systematics of the Stenopelmatoidea (Orthoptera) of Indochina and some other territories: IX. *Entomological Review*, 91 (1), 71–89.
<https://doi.org/10.1134/S0013873811010064>
- Gorochoy, A.V. (2012) Contribution to the knowledge of the Fauna and systematics of the Stenopelmatoidea (Orthoptera) of

- Indochina and some other territories: X. *Entomological Review*, 92 (7), 747–772.
<https://doi.org/10.1134/S0013873812070032>
- Gorochov, A.V. & Storozhenko, S.Y. (1992) On the fauna of the subfamily Aemodogryllinae (Orthoptera, Rhaphidophoridae) in Vietnam. 245, 17–34.
- Gorochov, A.V. & Storozhenko, S.Y. (2015) New and little-known taxa of the tribe Diestramimini (Orthoptera: Rhaphidophoridae: Aemodogryllinae) from Southeast Asia. Part 1. *Zoosystematica Rossica*, 24 (1), 48–84.
<https://doi.org/10.31610/zsr/2015.24.1.48>
- Gorochov, A.V. & Storozhenko, S.Y. (2019) New and little-known taxa of the tribe Diestramimini (Orthoptera: Rhaphidophoridae: Aemodogryllinae) from Southeast Asia. Part 2. *Zoosystematica Rossica*, 28 (1), 132–154.
<https://doi.org/10.31610/zsr/2019.28.1.132>
- Hegg, D., Morgan-Richards, M. & Trewick, S.A. (2022) High alpine sorcerers: Revision of the cave wētā genus *Pharmacus* Pictet & de Saussure (Orthoptera: Rhaphidophoridae: Macropathinae), with the description of six new species and three new subspecies. *European Journal of Taxonomy*, 808.
<https://doi.org/10.5852/ejt.2022.808.1721>
- Hoang, D.T., Chernomor, O., von Haeseler, A., Minh, B.Q. & Vinh, L.S. (2018) UFBoot2: Improving the Ultrafast Bootstrap Approximation. *Molecular Biology and Evolution*, 35 (2), 518–522.
<https://doi.org/10.1093/molbev/msx281>
- Ingrisch, S. (2002) Orthoptera from Bhutan, Nepal, and North India in the Natural History Museum Basel. *Entomologica Basiliensia*, 24, 123–159.
- Ingrisch, S. (2006) Orthoptera (Insecta) fauna of the Nepal Himalayas: Current knowledge. In *Biodiversität Und Naturlausstattung Im Himalaya*. Erfurt, 2, 73–118.
- Kearse, M., Moir, R., Wilson, A., Stones-Havas, S., Cheung, M., Sturrock, S., Buxton, S., Cooper, A., Markowitz, S., Duran, C., Thierer, T., Ashton, B., Meintjes, P. & Drummond, A. (2012) Geneious Basic: An integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics*, 28 (12), 1647–1649.
<https://doi.org/10.1093/bioinformatics/bts199>
- Kim, D.-Y., Kim, S., Song, H. & Shin, S. (2024) Phylogeny and biogeography of the wingless orthopteran family Rhaphidophoridae. *Communications Biology*, 7 (1), 1–11.
<https://doi.org/10.1038/s42003-024-06068-x>
- Liu, J., Li, Z. & Bian, X. (2021) Contribution to the Chinese subfamily Rhaphidophorinae Walker, 1869 (Orthoptera: Rhaphidophoridae: Rhaphidophorinae): One new species of *Rhaphidophora*. *Zootaxa*, 5027 (4), 597–599.
<https://doi.org/10.11646/zootaxa.5027.4.8>
- Minh, B.Q., Schmidt, H.A., Chernomor, O., Schrempf, D., Woodhams, M.D., von Haeseler, A. & Lanfear, R. (2020) IQ-TREE 2: New Models and Efficient Methods for Phylogenetic Inference in the Genomic Era. *Molecular Biology and Evolution*, 37 (5), 1530–1534.
<https://doi.org/10.1093/molbev/msaa015>
- Qin, Y., Jiang, H., Liu, X. & Li, K. (2018) A new genus of Rhaphidophorinae (Orthoptera, Rhaphidophoridae) from China. *Zootaxa*, 4500 (2), 179–194.
<https://doi.org/10.11646/zootaxa.4500.2.2>
- Qin, Y., Wang, H., Liu, X. & Li, K. (2016) A taxonomic study on the species of the genus *Diestramima* Storozhenko (Orthoptera: Rhaphidophoridae: Aemodogryllinae). *Zootaxa*, 4126 (4), 514–532.
<https://doi.org/10.11646/zootaxa.4126.4.4>
- Richards, A.M. (1965) The effect of weather on Rhaphidophoridae (Orthoptera) in New Zealand and Australia, 20, 391–400.
- Royal Government of Bhutan (2022) *Forest Cover Mapping Report 2022*. Forest monitoring and information division, Department of forests and park services, Thimphu, Bhutan. [unknown pagination]
- Saitou, N. & Nei, M. (1987) The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution*, 4 (4), 406–425.
<https://doi.org/10.1093/oxfordjournals.molbev.a040454>
- Simon, C., Frati, F., Beckenbach, A., Crespi, B., Liu, H. & Flook, P. (1994) Evolution, Weighting, and Phylogenetic Utility of Mitochondrial Gene Sequences and a Compilation of Conserved Polymerase Chain Reaction Primers. *Annals of the Entomological Society of America*, 87 (6), 651–701.
<https://doi.org/10.1093/aesa/87.6.651>
- Storozhenko, S.Y. & Dawwrueng, P. (2014) New genus of the tribe Diestramimini (Orthoptera: Rhaphidophoridae) from Thailand. *Zootaxa*, 3765 (3).
<https://doi.org/10.11646/zootaxa.3765.3.5>
- Wang, P., Zhu, Q. & Shi, F. (2019) Supplement of the genus *Diestramima* Storozhenko, 1990 (Orthoptera: Rhaphidophoridae: Aemodogryllinae) from China. *Zootaxa*, 4615 (3), 577–584.
<https://doi.org/10.11646/zootaxa.4615.3.10>
- Würmli, M. (1973) Ergebnisse der Bhutan-Expedition 1972 des Naturhistorischen Museums in Basel. Orthoptera: Gryllacridoidea. *Verh. Naturf. Ges. Basel*, 83, 337–347.
- Zhu, Q. & Shi, F.-M. (2018) Review of the genus *Diestramima* Storozhenko, 1990 (Orthoptera: Rhaphidophoridae: Aemodogryllinae) from China. *Zootaxa*, 4450 (2), 249–274.

TABLE S1. Number of fore and mid leg spines of type specimens from Bhutan (genus *Diestramima*).

Leg element	Spines	<i>D. maternagana</i> sp. nov.		<i>D. minjiwoonga</i> sp. nov.		<i>D. multidenticuli</i> sp. nov.		<i>D. phubdorjia</i> sp. nov.		<i>D. samkhara</i> sp. nov.		<i>D. tsongkhapa</i>	
		1 male	1 female	1 male		1 male	1 female	1 male	1 female	1 male	1 female	1 male	1 female
Fore femur	Apical (retro)	1	1	1		1	1	1	1	1	1	1	1
Fore tibia	Inferior linear (pro, retro)	2,2	2,2	2,2		2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
	Superior apical (retro)	1	1	1		1	1	1	1	1	1	1	1
	Inferior apical (pro, ventral, retro)	1,1,1	1,1,1	1,1,1		1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1
Mid femur	Apical (pro, retro)	1,1	1,1	1,1		1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
Mid tibia	Inferior linear (pro, retro)	2,2	2,2	2,2		2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
	Superior subapical (pro, retro)	1,1	1,1	1,1		1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
	Apical inferior (pro, central, retro)	1,1,1	1,1,1	1,1,1		1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1

TABLE S2. Number of fore and mid leg spines of type specimens from Bhutan (Genus *Rhaphidophora*).

Leg element	Spines	<i>R. bhutanensis</i> sp. nov.	<i>R. bicuspis</i> sp. nov.	<i>R. bilobata</i> sp. nov.	<i>R. piscicauda</i> sp. nov.
		1 male	1 male	1 male	1 female
Fore femur	Inferior apical (pro)	1	1	1	1
Fore tibia	Inferior linear (pro, retro)	1,2	1,2	1,2	1,2
	Apical (pro, retro)	1,1	1,1	1,1	1,1
Mid femur	Inferior apical (pro, retro)	1,1	1,1	1,1	1,1
Mid tibia	Superior linear (pro, retro)	2,2	1,1	1,2	2,2
	Inferior linear (pro, retro)	3,2	3,2	3,2	3,0
	Inferior subapical (pro, retro)	1,1	1,1	1,1	1,1
	Apical superior (pro, retro)	1,1	1,1	1,1	1,1

TABLE S3. Summary of genetic data submitted to GenBank with accession numbers (submission on progress-all the accession numbers will be provided in final submission).

Subfamily	Species	Locality	Voucher Code	GenBank Ac. no.
Aemodogryllinae	<i>Diestramima matern magna</i> sp. nov.	Marung Bridge, Pema Gatshel	MPN_CW5479	PV593689
			MPN_CW5490	PV593700
			MPN_CW5491	PV593698
			MPN_CW5536	PV593687
			MPN_CW5537	PV593688
			MPN_CW5539	PV593690
		Wangphu, Samdrup Jongkhar	MPN_CW5486	PV593699
			MPN_CW5488	PV593697
		Yurung Bridge, Pema Gatshel Kharungla Trashigang	MPN_CW5489	PV593696
			MPN_CW5495	PV593692
			MPN_CW5496	PV593693
			MPN_CW5497	PV593695
			MPN_CW5498	PV593694
			MPN_CW5499	PV593691
	<i>Diestramima minjiwoonga</i> sp. nov.	Minjiwoong Peg, Samdrup Jongkhar	MPN_CW5484	PV593667
	<i>Diestramima phubdorjia</i> sp. nov.	Nabji, Trongsa Tshangkha, Trongsa	MPN_CW5523	PV593669
			MPN_CW5508	PV593670
			MPN_CW5509	PV593671
	<i>Diestramima multidenticuli</i> sp. nov.	Bawoong, Trashy Yangtse	MPN_CW5510	PV593668
			MPN_CW5533	PV593681
			MPN_CW5534	PV593682
	<i>Diestramima samkhara</i> sp. nov.	Samkhar Bridge, Sarpang	MPN_CW5535	PV593680
			MPN_CW5478	PV593683
			MPN_CW5541	PV593684
			MPN_CW5542	PV593685
	<i>Diestramima tsongkhapa</i>	Philligang, Nabji, Trongsa	MPN_CW5543	PV593686
			MPN_CW5516	PV593675
			MPN_CW5517	PV593676
			MPN_CW5518	PV593672
		Philligangju, Nabji, Trongsa	MPN_CW5520	PV593677
			MPN_CW5521	PV593679
			MPN_CW5522	PV593678
			MPN_CW5524	PV593673
		Namkye, Nabji, Trongsa	MPN_CW5528	PV593674
			MPN_CW5529	PV593662
Rhaphidophorinae	<i>Rhaphidophora bhutanensis</i> sp. nov.	Marung Bridge, Pema Gatshel	MPN_CW5483	PV593660
		Bali-Pothey, Tsirang	MPN_CW5470	PV593661
	<i>Rhaphidophora bicuspis</i> sp. nov.	Lamperi, Thimphu	MPN_CW5529	PV593662
	<i>Rhaphidophora bilobata</i> sp. nov.	Nabji, Trongsa Tshangkha, Trongsa	MPN_CW5545	PV593659
			MPN_CW5505	PV593658
			MPN_CW5506	PV593656
			MPN_CW5507	PV593657
	<i>Rhaphidophora piscicauda</i> sp. nov.	Mahadev Dham, Dagana	MPN_CW5474	PV593666
			MPN_CW5475	PV593664
			MPN_CW5476	PV593665
			MPN_CW5477	PV593663

TABLE S4. Details of Rhaphidophoridae specimens collected in Bhutan in 2022.

Locality Name	Gewog	District	Latitude	Longitude	Elevation (m)	Date	leg	Habitat description	Unique code
Bali-Pothey	Kilkhorthang	Ts	27.464°N	90.059°E	1266	1.v.2022	C. Dorji & Yeshi Phuntsho	Temperate forest: Under two huge rock boulders.	MPN_CW5469 MPN_CW5470 MPN_CW5471 MPN_CW5472 MPN_CW5473
Mahadev Dham	Tashiding	Da	26.899°N	89.975°E	915	21.v.2022	Jigme Wangchuk & Galey	Subtropical forest: surrounding limestone cave.	MPN_CW5474 MPN_CW5475
Mahadev Dham	Tashiding	Da	26.899°N	89.975°E	916	21.v.2023	Jigme Wangchuk & Galey	Subtropical forest: surrounding limestone cave.	MPN_CW5476 MPN_CW5477
Samkhar Bridge	Gelephu	Sp	27.009°N	90.581°E	942	22.v.2022	C. Dorji & Jigme	Subtropical forest: Under boulders above bridge.	MPN_CW5478
Marung Bridge	Khar	PG	27.011°N	91.420°E	923	25.v.2022	C. Dorji, Tshewang Namgay & Jigme	Subtropical forest: cliff base under leaf litter and small rocks.	MPN_CW5480 MPN_CW5481 MPN_CW5482
Marung Bridge	Khar	PG	27.011°N	91.420°E	924	25.v.2023	C. Dorji, Tshewang Namgay & Jigme	Subtropical forest: cliff base under leaf litter and small rocks.	MPN_CW5483
Minjiwoong Peg	Serthi	SJ	26.988°N	92.012°E	833	28.v.2022	C. Dorji, Tshering Dorji & Jigme	Subtropical forest: cave entrance.	MPN_CW5484
Wangphu	Gomdar	SJ	26.982°N	91.584°E	1028	29.v.2022	C. Dorji & Jigme	Subtropical forest: limestone cave entrance	MPN_CW5485 MPN_CW5486 MPN_CW5487 MPN_CW5488
Yurung Bridge	Khar	PG	27.040°N	91.380°E	571	31.v.2022	C. Dorji, Tshewang Namgay & Jigme	Subtropical forest: cliff base under leaf litter and small rocks.	MPN_CW5489
Marungri	Khar	PG	27.011°N	91.420°E	923	31.v.2022	C. Dorji & Jigme	Subtropical forest: cliff base under crevices and leaf litter.	MPN_CW5490 MPN_CW5491
Kharungla	Brekha	TG	27.155°N	91.628°E	2039	1.vi.2022	C. Dorji & Jigme	Cool broad leaf forest: surrounding huge boulders and nearby vegetation.	MPN_CW5492 MPN_CW5493 MPN_CW5494 MPN_CW5495 MPN_CW5496 MPN_CW5497 MPN_CW5498 MPN_CW5499

.....continued on the next page

TABLE S4. (Continued)

Locality Name	Gewog	District	Latitude	Longitude	Elevation (m)	Date	leg	Habitat description	Unique code
Bawoong	Ramjar	TY	27.416°N	91.586°E	1582	2.vi.2022	C. Dorji & Jigme	Temperate forest: under boulders and surrounding vegetation.	MPN_CW5500 MPN_CW5501 MPN_CW5502 MPN_CW5503 MPN_CW5504
Tshangkha	Tangsibji	Tr	27.440°N	90.420°E	2161	6.vi.2022	C. Dorji, Karma Chorten & Jigme	Cool broadleaf forest: under fallen tree branches and leaf litter.	MPN_CW5505 MPN_CW5506 MPN_CW5507 MPN_CW5508 MPN_CW5509 MPN_CW5510
Namkha	Korphoog	Zh	27.117°N	90.799°E	1089	9.iv.2022	Tenzin Drukgyel		MPN_CW5511 MPN_CW5512 MPN_CW5513
Nabji	Korphoog	Tr	27.178°N	90.535°E	1381	30.vi.2022	Sanjit Rai	Cool broadleaf forest: under fallen tree branches and leaf litter.	MPN_CW5515 MPN_CW5516 MPN_CW5517 MPN_CW5518 MPN_CW5519 MPN_CW5520
Nabji	Korphoog	Tr	27.180°N	90.535°E	1305	30.vi.2022	Sanjit Rai	Cool broadleaf forest: under fallen tree branches and leaf litter.	MPN_CW5521 MPN_CW5522 MPN_CW5523 MPN_CW5524
Nabji	Korphoog	Tr	27.165°N	90.562°E	2252	22.vi.2022	Sanjit Rai	Cool broadleaf forest: under fallen tree branches and leaf litter.	MPN_CW5525 MPN_CW5526 MPN_CW5527 MPN_CW5528
Lamperi		Th	27.498°N	89.767°E	2761	22.vii.2022	C. Dorji	Cool broadleaf forest: forest floor under leaf litter.	MPN_CW5529
Bawong	Ramjar	TY	27.416°N	91.586°E	1582	2.vi.2022	C. Dorji & Jigme	Temperate forest: under boulders and surrounding vegetation.	MPN_CW5531 MPN_CW5532 MPN_CW5533 MPN_CW5534 MPN_CW5535
Marung Bridge	Khar	PG	27.009°N	91.421°E	936	31.v.2022	C. Dorji & Jigme	Subtropical forest: cliff base under leaf litter and small rocks.	MPN_CW5536 MPN_CW5537 MPN_CW5538 MPN_CW5539 MPN_CW5540
Samkhar Bridge	Gelephu	SP	27.009°N	90.581°E	942	22.v.2022	C. Dorji & Jigme	Subtropical forest: Under boulders above bridge.	MPN_CW5541 MPN_CW5542 MPN_CW5543
Nabji	Korphoog	Tr	27.166°N	90.562°E	2252	11.vii.2022	Sanjit Rai	Cool broadleaf forest: under fallen tree branches and leaf litter.	MPN_CW5544 MPN_CW5545