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Teloganopsis sirindhornae sp. nov. (Ephemeroptera: Ephemerellidae), A New Species of Thai Mayfly Revealed by the Integrative Taxonomy

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ABSTRACT.– In the present study, a new species of the genus *Teloganopsis* Ulmer, 1939, *T. sirindhornae* sp. nov., is described based on specimens collected and reared in Thailand. The new species is distinguished from other Thai *Teloganopsis* species by its abdominal color pattern, which is consistent across all developmental stages. Both morphology characteristics and molecular analysis support its designation as a new species. A concatenated phylogenetic tree based on COI and 28S rDNA confirms its monophyly and clearly separates it from other *Teloganopsis* species. Additionally, a description of the chorionic structure of *T. sirindhornae* sp. nov., a distribution map of known *Teloganopsis* species in Thailand and a dichotomous key for both larval and imaginal stages of known Oriental *Teloganopsis* species are provided.

KEYWORDS: 28S rDNA, COI, Ephemerellinae, Systematics, Thailand

INTRODUCTION

The genus *Teloganopsis* Ulmer, 1939 belonged to the tribe Hyrtanellini Allen, 1980 of the family Ephemerellidae (Jacobus and McCafferty, 2008). *Teloganopsis media* Ulmer, 1939 was the first species described in the genus, originally from Java and Sumatra (Ulmer, 1939). The genus *Teloganopsis* is one of the most variable and widely distributed genera in the family Ephemerellidae (Zhang et al., 2017). In total, 17 species of *Teloganopsis* are distributed across the Holarctic and the Oriental realms (Jacobus and McCafferty, 2008; Ubero-Pascal and Sartori, 2009). In the Oriental region, five species have been reported, including *T. media* Ulmer, 1939, *T. jinghongensis* (Xu & Hsu, 1984), *T. oriens* (Jacobus & McCafferty, 2006), *T. puigae* Ubero-Pascal & Sartori, 2009 and *T. setosa* Zhang & Zhou, 2017 (Ulmer, 1939; Xu et al., 1984; Jacobus and McCafferty, 2006; Ubero-Pascal and Sartori, 2009; Zhang et al., 2017)

In Thailand, the genus *Teloganopsis* was first recorded only at the generic level from southern Thailand. These specimens represent two distinct morphospecies, differing in the color pattern on the dorsal surface of the abdomen (Sites et al., 2001). Subsequently, *T. oriens* was described as belonging to the genus *Uracanthella* Belov, 1979 and later, it was combined into the genus *Teloganopsis* (Jacobus and McCafferty, 2006; 2008). The other species, *T. jinghongensis*, is most abundant in Chiang Mai and Mae Hong Son provinces (Jacobus and McCafferty, 2008; Martynov et al., 2021). Although, this genus has a wide distribution in the Oriental region, *Teloganopsis* has been recorded only in southern and northern Thailand (Sites et al., 2001; Jacobus and McCafferty, 2008; Martynov et al., 2021).

Based on our specimens, three distinct morphospecies were identified according to their abdominal color patterns. These include *T. oriens*, which lacks any color pattern on dorsal abdominal surface and two other morphospecies with distinct abdominal patterns. Of these two, one most likely corresponds to *T. jinghongensis* (Martynov et al., 2021), while the other exhibits a clearly different abdominal structure from all other known species in Thailand. This structural difference is consistently observable across all developmental stages. However, abdominal color patterns alone are not sufficient for species delimitation between these two morphospecies, as they may represent intraspecific variation, similar to what has been previously described in *T. jinghongensis.* (Jacobus and McCafferty, 2008; Martynov et al., 2021; Ding and Zhou, 2023).

Accordingly, this study aims to determine whether the character represents intraspecific variation or a diagnostic trait for Thai *Teloganopsis*, through an integrative taxonomy. Morphological comparisons of both larval and winged stages were conducted. Additionally, a molecular phylogeny was reconstructed based on concatenated COI and 28S rDNA sequences to support morphological differentiation. Also, the chorionic

structure and distribution were considered. The distribution map was constructed using our data combined with other references constructed by the SimpleMappr website and GPS coordinates (Shorthouse, 2010).

MATERIALS AND METHODS

Ethical statement

The present study was approved by the ethics committee of Silpakorn University (approval no. 8/2566) for collecting the mayfly specimens.

Specimen Collection, Preservation and Morphological Analysis

The larvae were collected using a D-frame kick net in the riffle of moderately fast flowing streams from northern and western Thailand. The larvae were preserved in absolute ethanol and kept under refrigeration for description and DNA extraction. Some mature larvae of *Teloganopsis* species were kept into laboratory and reared in an earth pot to winged stages. The larval morphology of the new species was observed from five permanent slide preparation using Euparal as a mounting medium. The morphology observations of larvae and adults were studied and photographed under a microscope camera. The chorionic structures were also observed from egg dissection of a female imago**.** The chorionic structure was investigated by drying the eggs, coating them with gold and observing them by SEM with a FEI Quanta 450. Final plates were prepared with Adobe Photoshop® CC 2020. Holotype and paratypes of the new species are deposited in the collections of the Insect Collection at Silpakorn University [ICSU] in Nakhon Pathom Province, Thailand. Other paratype specimens are deposited in the Zoological Museum at Kasetsart University in Bangkok, Thailand [ZMKU] and the Department of Zoology of Naturéum in Lausanne, Switzerland [MZL].

Material Examined

***Teloganopsis* cf. *jinghongensis*: Thailand, Chiang Mai Province**, Chiang Dao District, Mae Sai River, 19°19'13.08"N, 98°53'25.98"E, 742 m above sea level (a.s.l.) 11.III.2016, four larvae, B. Boonsoong leg. Mae Taeng district, Chang Tai River, 19°11'02.1"N, 98°58' 04.9"E, 403 m a.s.l. 21.XI.2018, three larvae, C. Auychinda leg. Mueang Chiang Mai, Montha Than Waterfall, 18°49'05.3"N, 98°55'59.9"E, 370 m a.s.l. 3.XII.2017, three larvae, one on slide, C. Auychinda leg. All specimens are deposited in ICSU.

***Teloganopsis oriens*: Thailand, Chiang Mai Province**, Chiang Dao District, Mae Sai River, 19°19' 13.08"N, 98°53'25.98"E, 742 m a.s.l. 11.III.2016, three larvae, B. Boonsoong leg. Chiang Dao District, Mae Sai River, 19°19'18.7"N, 98°52'50.8"E, 728 m a.s.l. 20.XI.2018, one larva, C. Auychinda leg. Mae Kam Pong District, Mae Kam Pong Waterfall, 18°51' 54.8"N, 99°20'59.9"E, 1,016 m a.s.l. 21.XI.2018, one larva. C. Auychinda leg. **Nan Province**, Bo Kluea District, Wa River, 19°16'22.6"N, 101°10'48.2"E, 848 m a.s.l. 20.XI.2018, two larvae, C. Auychinda leg. Bo Kluea District, Mae Mang River, 19°09'09.4"N, 101° 09'16.4"E, 669 m a.s.l. 26.XI.2019, one larva B. Boonsoong leg. Pua District, Khwang River, 19°10'53.8"N, 100°59'08.3"E, 367 m a.s.l. 25.XI.2019, three larvae, B. Boonsoong leg. All specimens are deposited in ZMKU.

***Teloganopsis sirindhornae* sp. nov.:** See type materials.

Molecular Analysis

Total DNA extraction was performed using a genomic DNA purification kit (TIANamp Genomic DNA Kit, China) following the manufacturer's protocol. A 658 bp fragment of the mitochondrial cytochrome oxidase I (COI) gene was amplified using the forward primer LCO1490 (5′–GGT CAA ATC ATA AAG ATA TTG G–3′) (Folmer et al., 1994). Three reverse primers were tested: HCO2198 (5′–TAA ACT TCA GGG TGA CCA AAA AAT CA–3′) (Folmer et al., 1994), Nancy (5′–CCT GGT AAA ATT AAA ATA TAA ACT TC–3′) (Caterino and Sperling, 1999) and dgHCO2198 (5′–TAA ACT TCA GGG TGA CCA AAR AAY CA–3′) (Specchia, 2020). The amplicons with a successful amplification was used for sequencing. The 28S rDNA was amplified using primers 28S DD (5′-GGG ACC CGT CTT GAA ACT C-3′) and 28S FF (5′-TTA CAC ACT CCT TAG CGG AT-3′) (Pons et al., 2004). Polymerase chain reaction (PCR) conditions were as follows: a 25 µl final reaction volume containing 2.5 µl of 10X Vibuffer (Vivantis®), 2 µl of dNTP mixed (2.5 µM of each), 1 µl of each primer (10 µM), 1 µl of genomic DNA. PCR of both COI and 28S was performed in the same condition as follows: 5 minutes at 94°C, then 30 seconds at 94°C, 30 seconds at 48°C and 30 seconds at 72°C (40 cycles) and a final elongation step at 72°C for 10 minutes (Gattolliat et al., 2015). Both COI and 28S rDNA sequences were obtained using Sanger sequencing.

The details of our COI and 28S rDNA sequences, including those obtained from GenBank and the Barcode of Life Data System (BOLD), are presented in Table 1. The COI and 28S rDNA sequences were

TABLE 1. List of the COI and 28S rDNA sequences of *Teloganopsis* species use for molecular phylogenetic tree reconstruction.

Species	COI sequences GenBank accession number /BOLD process ID	28S rDNA Sequence accession number	References
Teloganopsis chinoi (Gose, 1980)	KP970704	-	Wakimura et al. (2016)
	KP970705	-	Wakimura et al. (2016)
	OQ649799	-	Jung et al. (2023)
Teloganopsis deficiens (Morgan, 1911)	KR146531	-	Hebert et al. (2016)
	KR144974	-	Hebert et al. (2016)
	HQ151807	-	Pilgrim et al. (2011)
	MG381097	-	Unpublished
	HM399138	-	Unpublished
	HM399139	-	Unpublished
	GU661110	-	Unpublished
	GU682351	-	Unpublished
Teloganopsis cf. *jinghongensis* (Xu & Hsu, 1984)	PV819793	PV820518	This study
	PV819794	-	This study
	PV819795	-	This study
	HQ581580	-	Unpublished
	HQ581581	-	Unpublished
	THMAY140-12	-	Unpublished
	THMAY143-12	-	Unpublished
Teloganopsis media Ulmer, 1939	-	GQ214043	Ogden et al. (2009)
Teloganopsis oriens (Jacobus & McCaffefty, 2006)	PV819796	PV820519	This study
	PV819797	PV820520	This study
	PV819798	-	This study
Teloganopsis punctisetae (Matsumura, 1931)	LC797308	-	Hayashi and Ooi (2022)
	LC644394	-	Hayashi and Ooi (2022)
	LC644395	-	Hayashi and Ooi (2022)
	MK774364	-	Wakimura et al. (2020)
	LC461324	-	Jo and Tojo (2019)
Teloganopsis sirindhornnae sp. nov.	PV819799	PV820521	This study
	PV819800	PV820522	This study
	PV819801	-	This study
	PV819802	-	This study
	PV819803	-	This study
	PV819804	-	This study
Torleya major (Klapálek, 1905)	PP402722	GQ214045	Macko et al. (2024), Ogden et al. (2009)

concatenated manually. Sequence alignment and editing were performed using Clustal Omega. Maximum likelihood (ML) phylogenetic tree reconstruction protocol followed Souto et al. (2021) and the resulting tree was visualized using FigTree V.14.4.4 (http://tree.bio.ed.ac.uk/software/figtree/). The genetic distances were also performed using K2P parameter by MEGA11: Molecular Evolutionary Genetics Analysis version 11 (Tamura et al., 2021).

RESULTS

Taxonomy

***Teloganopsis sirindhornae* sp. nov.**

http://zoobank.org/urn:lsid:zoobank.org:act: B208777D-80D4-4977-A62B-FAEEE34CC06E

(Figs 1–10)

Type Materials.– Holotype: mature larva (in ethanol, ICSU-Ephe-06.h01), Thailand, Ratchaburi Province, Suan Phueng District, Phachi River, Phawothai, 13°30'57.3"N, 99°20'40.1"E, 118 m a.s.l. 20.XI.2022, C. Auychinda leg. [ICSU]. **Paratypes:** Three larvae (in ethanol, ICSU-Ephe-06.p02) same data as holotype [ICSU]. **Thailand**, **Ratchaburi Province**, Suan Phueng District, Phachi River, Phawothai, 13°30' 57.3"N, 99°20'40.1"E, 118 m a.s.l. (ICSU-Ephe-06.p03), 14.II.2016, five larvae; 25.XI.2018, 17 larvae, l1 female imagoes, three male imagoes, four larvae on slide (ICSU-Ephe-06.ps04), B. Boonsoong leg. [ICSU]; 25.XI.2018, 10 larvae, B. Boonsoong leg. [GBIFCH00673102, MZL]; 7.IV.2022, 17 larvae, one female subimago, one male subimago; 25.XI.2023, seven larvae, C. Auychinda leg. [ICSU]. Suan Phueng District, Phachi River, Kaeng Som Maew, 13°24'35.2" N, 99°16'08.5"E, 207 m a.s.l. (ICSU-Ephe-06.p05), 13.II.2016, three larvae, B. Boonsoong leg. [ICSU];

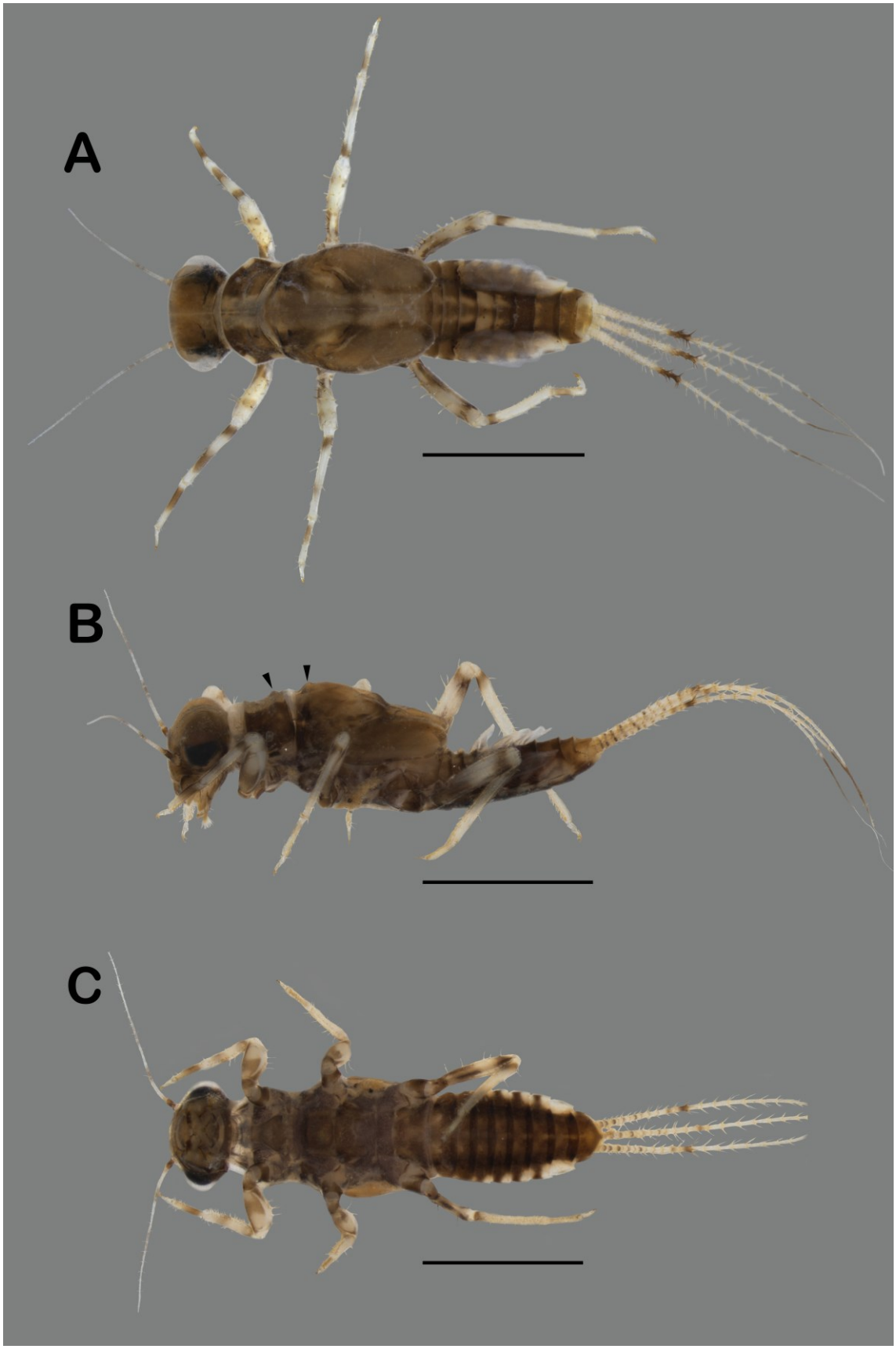

FIGURE 1. *Teloganopsis sirindhornae* sp. nov. Habitus. **A**. dorsal view. **B.** lateral view. **C.** ventral view. Arrows indicate the position of the tubercles on the hemi-thorax. Scale bars = 1 mm.

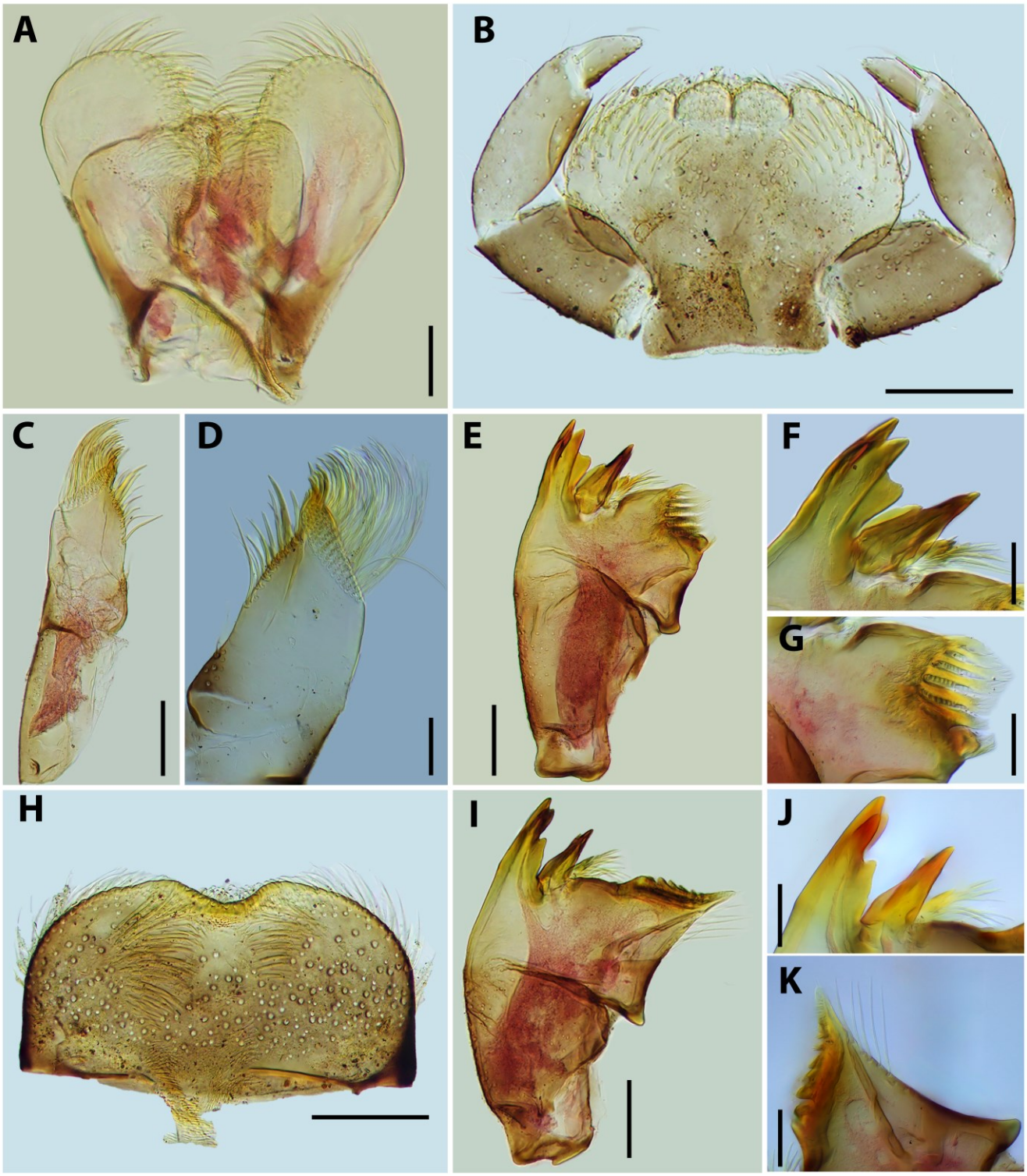

FIGURE 2. *Teloganopsis sirindhornae* sp. nov. **A**. hypopharynx. **B**. labium. **C, D.** maxilla. **E–G**. left mandible. **H.** labrum. **I–K.** right mandible. Scale bars: A, D, F, G, J, K = 50 µm; B, C, E, H, I = 100 µm.

24.XI.2018, one larva; 8.IV.2022, five larvae, one female imago, B. Boonsong leg. [ICSU]; 25.II.2024, 21 larvae, one on slide (ICSU-Ephe-06.ps06), C. Auychinda leg. [ICSU]; 15.III.2025, 37 larvae, three female imagoes, three male imagoes, B. Boonsoong leg. [ICSU]. Suan Phueng District, Phachi River, 13° 30'25.4"N, 99°16'42.5"E, 118 m a.s.l. (ICSU-Ephe-06.p07), 8.IV.2022, three larvae; 25.XI.2022, 14 larvae, three male imagoes, C. Auychinda leg. [ICSU]; 25.XI.2022, four larvae, C. Auychinda leg. [GBIFCH 00902496, MZL]. Suan Phueng, Phachi River, head water stream, 13°20'11.3" N, 99°14'24.9"E, 258 m

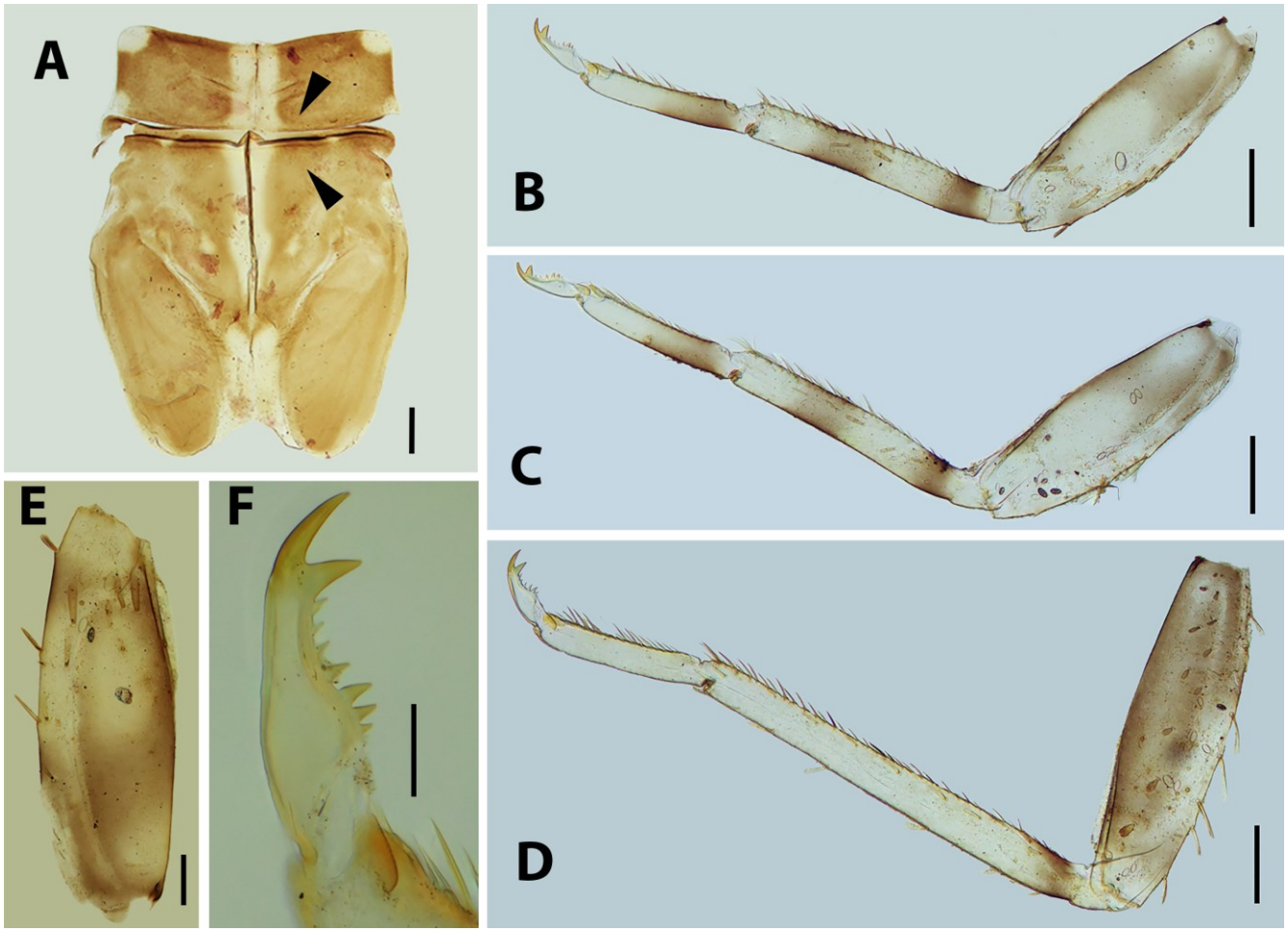

FIGURE 3. *Teloganopsis sirindhornae* sp. nov. **A.** pronotum and mesonotum. **B**. foreleg. **C.** middle leg. **D.** hind leg. **E.** forefemur. **F.** fore-tarsal claw. Arrows indicate the position of the tubercles on the right hemi-thorax. Scale bars: A–D = 200 µm; E = 100 µm; F = 50 µm.

a.s.l. (ICSU-Ephe-06.p08), 24.II.2023, two larvae; 8.IV.2022, three larvae, C. Auychinda leg. [ICSU]. **Phetchaburi Province**, Kaeng Krachan District, Mae Khamoei River, 12°58'41.5"N, 99°34'55.4"E, 119 m a.s.l. (ICSU-Ephe-06.p09), 25.II.2018, four larvae, C. Auychinda leg. [ICSU]. Kaeng Krachan District, Sat Yai, 12°38' 13.5"N, 99°30'59.3"E, 162 m a.s.l. (ICSU-Ephe-06.p10), 25.II.2018, one larva, one female imago; 11.XII.2022, one larva, one female imago, C. Auychinda leg. [ICSU]. **Prachuap Khiri Khan Province**, Hua Hin District, Satue River, 12°27'15.0"N, 99°32' 26.0"E, 197 m a.s.l. (ICSU-Ephe-06.p11), 10.XII.2023, 10 larvae, C. Auychinda leg. [ICSU]. **Chiang Mai Province**, Chiang Dao District, Mae Chaem River, 18°29'31.0"N, 98°21'49.0"E, 420 m a.s.l. (ICSU-Ephe-06.p12), 16.XII.2023, one female imago, nine larvae; 29.III.2025 four larvae, one female subimago, seven female imago, two male subimago, one male imago, C. Auychinda leg. [ICSU]; 29.III.2025, eight larvae (Ephe-048), C. Auychinda leg. [ZMKU].

Etymology.–The name '*sirindhornae*' honors Her Royal Highness Princess Maha Chakri Sirindhorn, who has a deep passion for natural history and plays a vital role in promoting biodiversity conservation and environmental protection in Thailand. The year 2025 marks her 70th birthday, making this tribute particularly meaningful.

Diagnosis.– Larvae: Head without tubercles. Dorsal surface with broad, continuous pale stripe from head to abdominal segment VI. Abdominal tergum IV with paired brown spots; segment VII with brown smear. Forefemur with transverse row of paddle-like setae on dorsal surface and posterior margin. Labial palp segment III stout, cone-shaped. Articulation between labial palp segments II and III with 2–3 feather-like setae. Pronotum with a median pair of small tubercles. Caudal filaments with dark band at middle and subapical parts. **Male imago:** Dorsal part of eyes orange, ventral part brownish. Dorsolateral projections of penis small, not visible in ventral view. Abdominal tergum IV with paired brown spots. Forewing with Y-shaped branched crossvein between C and Sc. Hindwing with

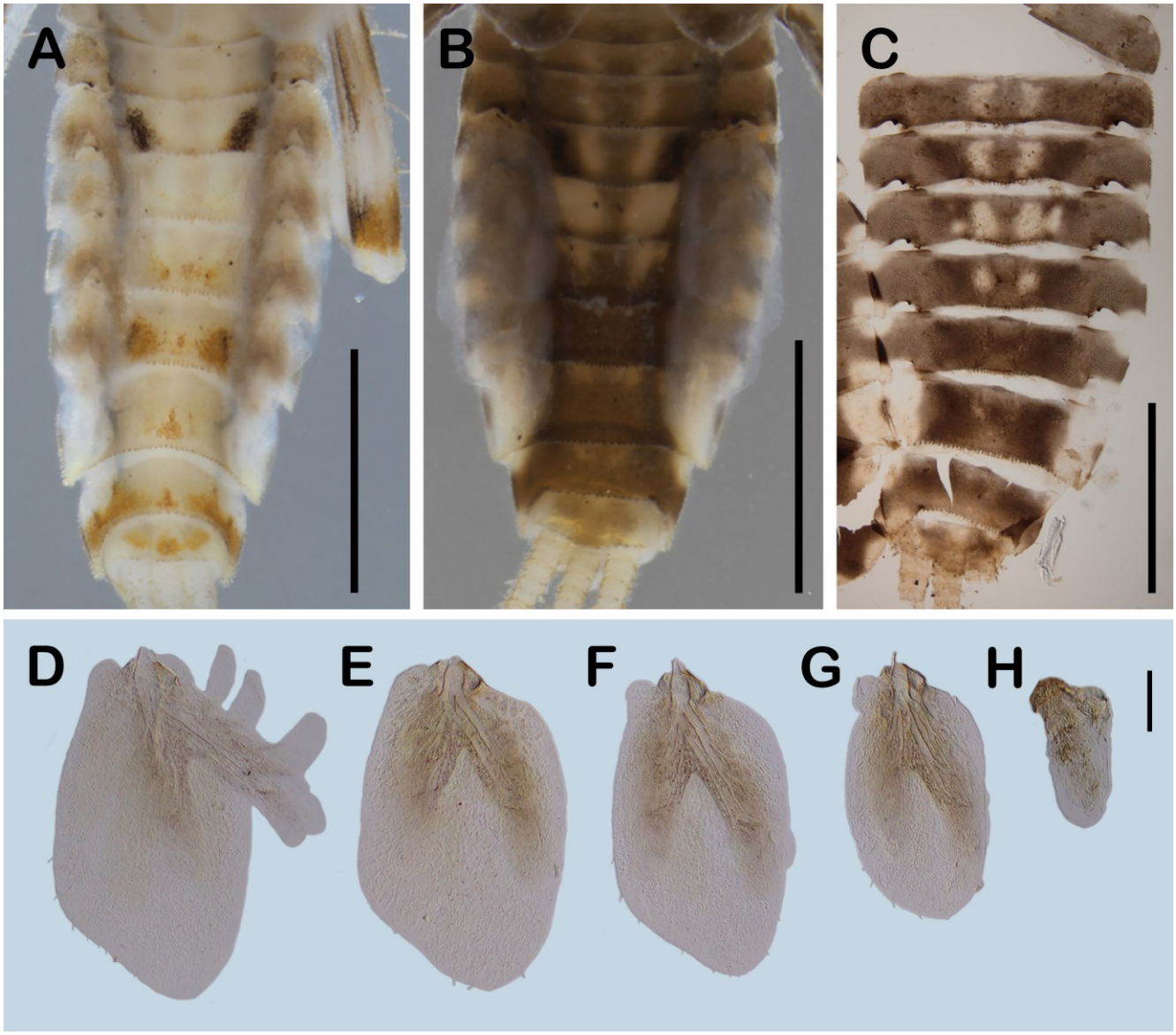

FIGURE 4. *Teloganopsis sirindhornae* sp. nov. **A.** abdomen of early instar larva. **B.** abdomen of last larval instar. **C.** abdomen of exuviae. **D–H**. gills on abdominal segment III–VII, respectively. Scale bars: A–C = 1 mm; D–H = 0.1 mm.

Sc ending near costal projection. **Female imago:** Body color pattern and wing venation similar to male.

Description of larva (in ethanol, Fig. 1; life habitus, Fig. 9C).– Body length (excluding caudal filaments) 2.7–3.0 mm; caudal filaments 2.0–2.6 mm. Cerci subequal to paracercus. Body brownish to blackish. Dorsal surface of pronotum and mesonotum with a broad median pale stripe. **Head:** Hypognathous, without tubercles (Fig. 1B). Antennal length approximately 1.5X head width (Fig. 1A). Hypopharynx with superlinguae bearing setae along anterior and inner margins; lingua with short setae (Fig. 2A). Labium covered with short setae; paraglossae broad, semicircular, covered with stout setae; glossae as wide as long; labial palpi three-segmented; segment I broad, length: width=1.5; segment II, length: width = 2.3, apical part with 2–3 feather-liked setae; segment III stout, cone-shaped, length: width at base = 1.5, apex with fine setae (Fig. 2B). Maxillae without palpi (Fig. 3C), dense setae on apex (Fig. 3D). Left mandible with three outer incisors and two inner incisors (Fig. 3E, F), prostheca with numerous thick setae, molar area with a row of thick teeth (Fig. 3G); right mandible (Fig. 3I, J) with three outer incisors and two inner incisors, prostheca with numerous thick setae, molar with a row of 6–7 setae below inner molar margin (Fig. 3K). Labrum rectangular, anterolateral margin rounded, anterior margin with a shallow notch, surface covered with short setae (Fig. 3H). **Thorax:** brownish with a broad median pale stripe on notum, continuing from head to

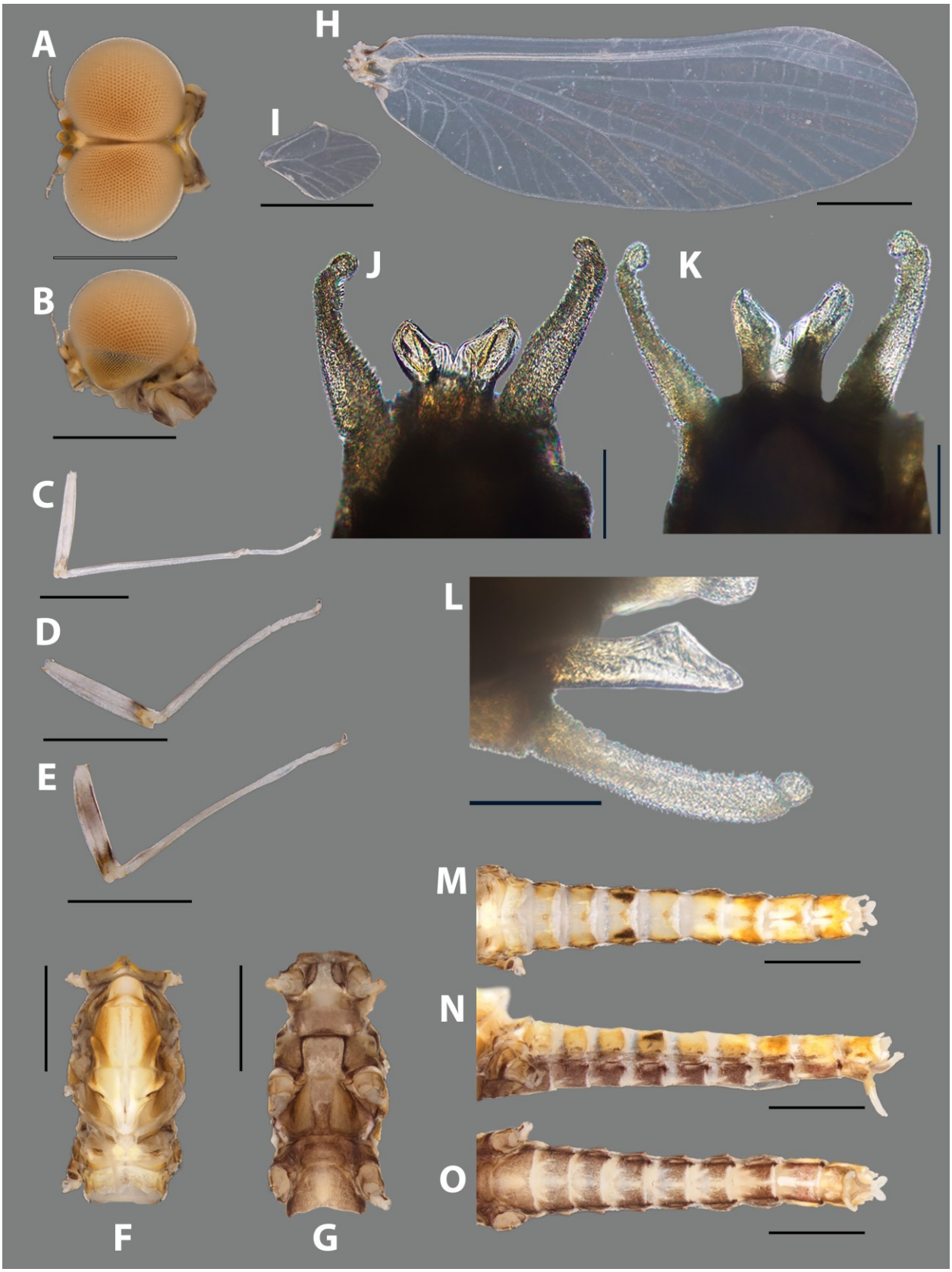

FIGURE 5. *Teloganopsis sirindhornae* sp. nov. Male imago. **A**. head dorsal view. **B.** head lateral view. **C.** foreleg. **D.** middle leg. **E.** hind leg. **F.** thorax dorsal view. **G.** thorax ventral view. **H.** forewing. **I.** hindwing; **J.** genitalia dorsal view. **K.** genitalia ventral view. **L.** genitalia lateral view. **M.** abdomen dorsal view. **N.** abdomen lateral view. **O.** abdomen ventral view. Scale bars: A–I, M–O = 0.5 mm; J–L = 0.1 mm.

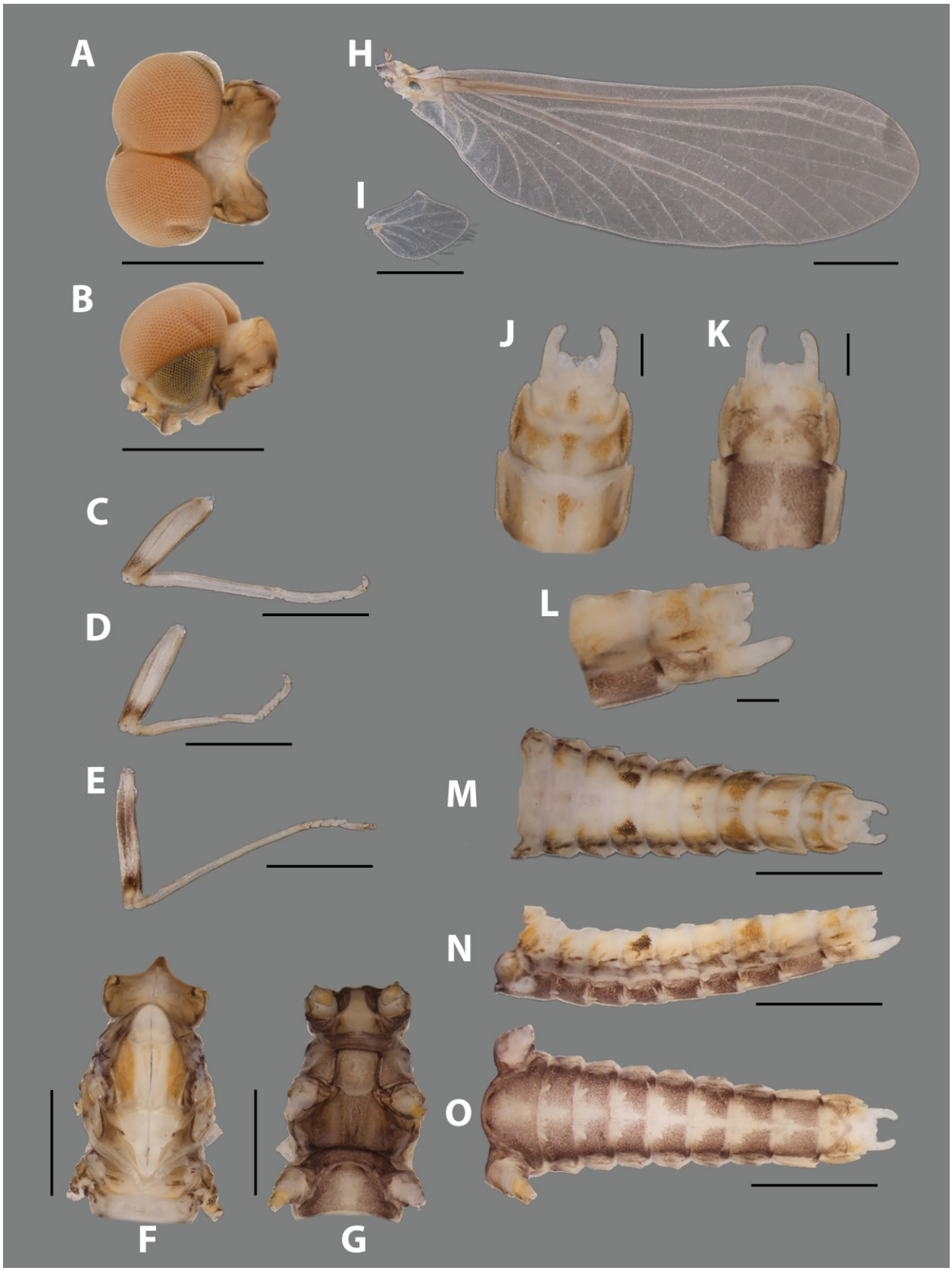

FIGURE 6. *Teloganopsis sirindhornae* sp. nov. Male subimago. **A**. head dorsal view. **B.** head lateral view. **C.** foreleg. **D.** middle leg. **E.** hind leg. **F.** thorax dorsal view. **G.** thorax ventral view. **H.** forewing. **I.** hindwing; **J.** genitalia dorsal view. **K.** genitalia ventral view. **L.** genitalia lateral view. **M.** abdomen dorsal view. **N.** abdomen lateral view. **O.** abdomen ventral view. Scale bars: A–I, M–O = 0.5 mm; J–L = 0.1 mm.

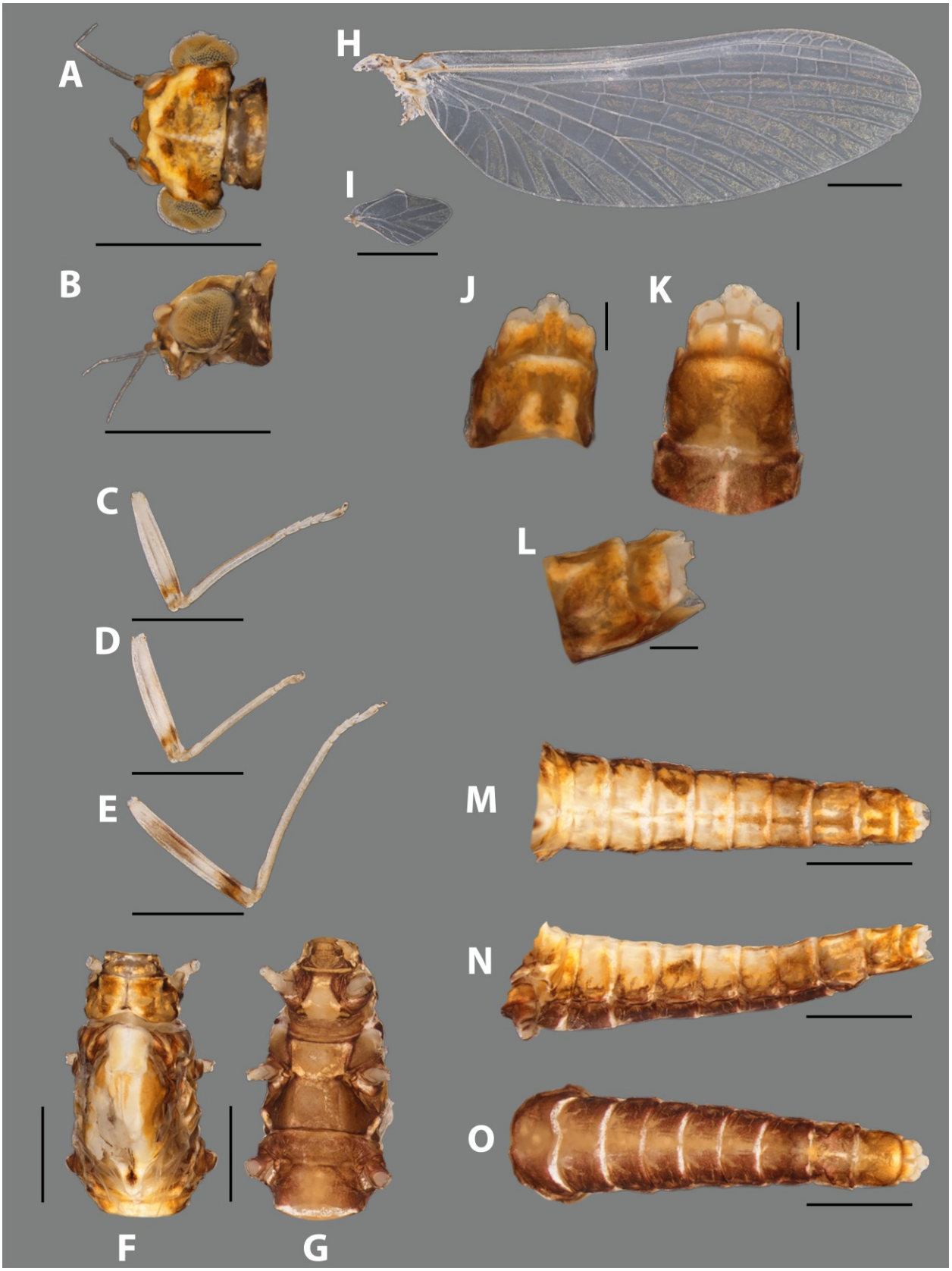

FIGURE 7. *Teloganopsis sirindhornae* sp. nov. Female imago. **A.** head dorsal view. **B.** head lateral view. **C.** foreleg. **D.** middle leg. **E.** hind leg. **F.** thorax dorsal view. **G.** thorax ventral view. **H.** forewing. **I.** hindwing. **J.** abdominal segment IX–X ventral view. **K.** abdominal segment IX–X ventral view. **L.** abdominal segment IX–X lateral view. **M.** abdomen dorsal view. **N.** abdomen lateral view. **O.** abdomen ventral view. Scale bars: A–I, M–O = 0.5 mm; J–L = 0.1 mm.

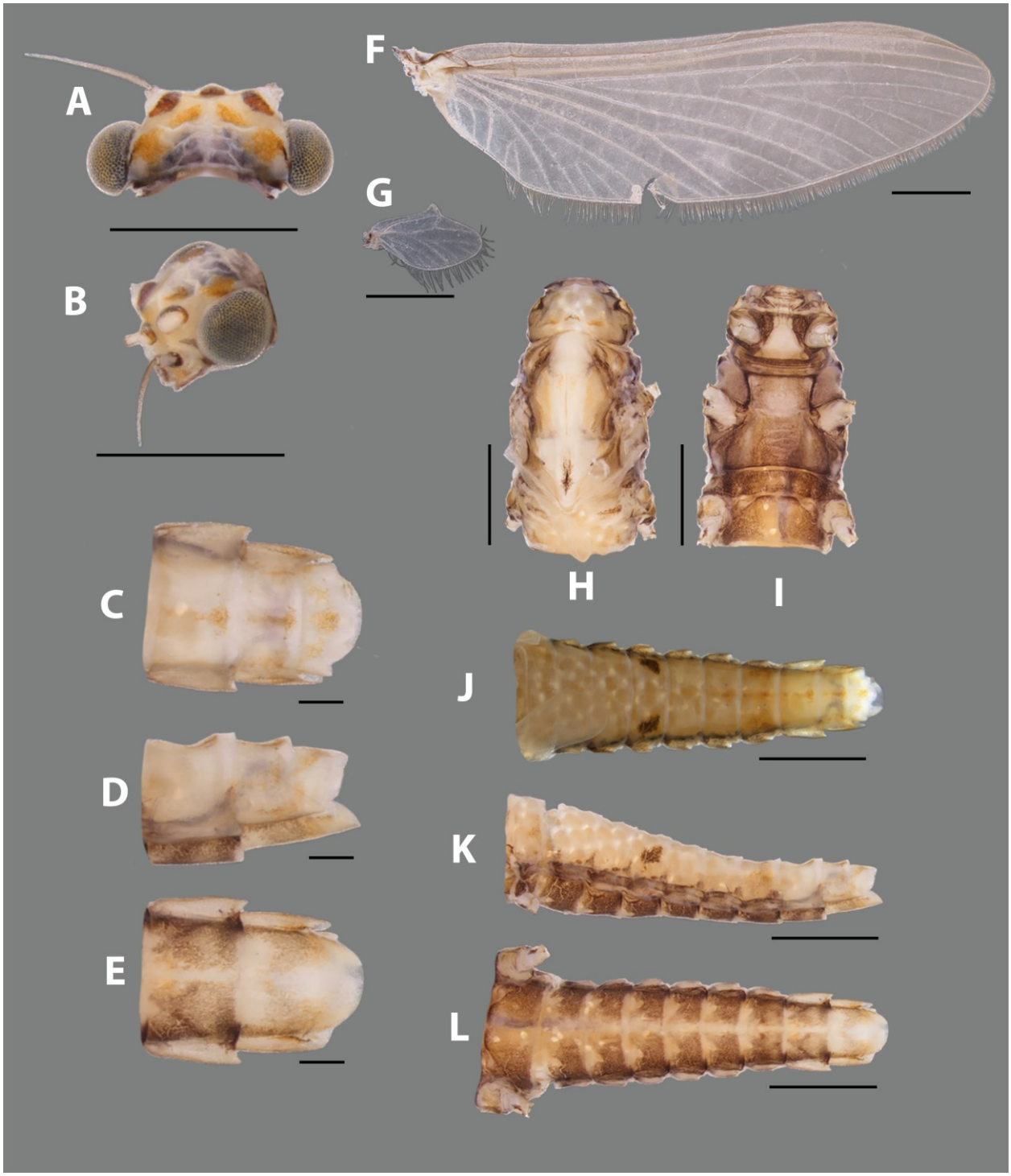

FIGURE 8. *Teloganopsis sirindhornae* sp. nov. Female subimago. **A.** head dorsal view. **B.** head lateral view. **C.** abdominal segment VIII–X dorsal view. **D.** abdominal segment VIII–X lateral view. **E.** abdominal segment VIII–IX ventral view. **F.** forewing. **G.** hindwing. **H.** thorax dorsal view. **I.** thorax ventral view. **J.** abdomen dorsal view. **K.** abdomen lateral view. **L.** abdomen ventral view. Scale bars: A, B, F–L = 0.5 mm, C–E = 0.1 mm.

posterior margin of wing pad (Figs 1A, 3A). Pronotum rectangular with four pale spots on each corner (Fig. 3A) and with a median pair of small tubercles (Fig. 1B). Mesonotum with a median pair of small tubercles (Fig. 1B). Forefemora with a dorsal transverse row of 5–6 long paddle-like setae, posterior margin with a row of paddle-like setae (Fig. 3B, E). Middle femora as long as forefemora, posterior margin with a row of paddle-like setae (Fig. 3C). Hind femora longer than others, posterior margin with a row of paddle-like setae, dorsal surface with several short paddle-like setae (Fig. 3D). All claws similar, with 8–10 denticles,

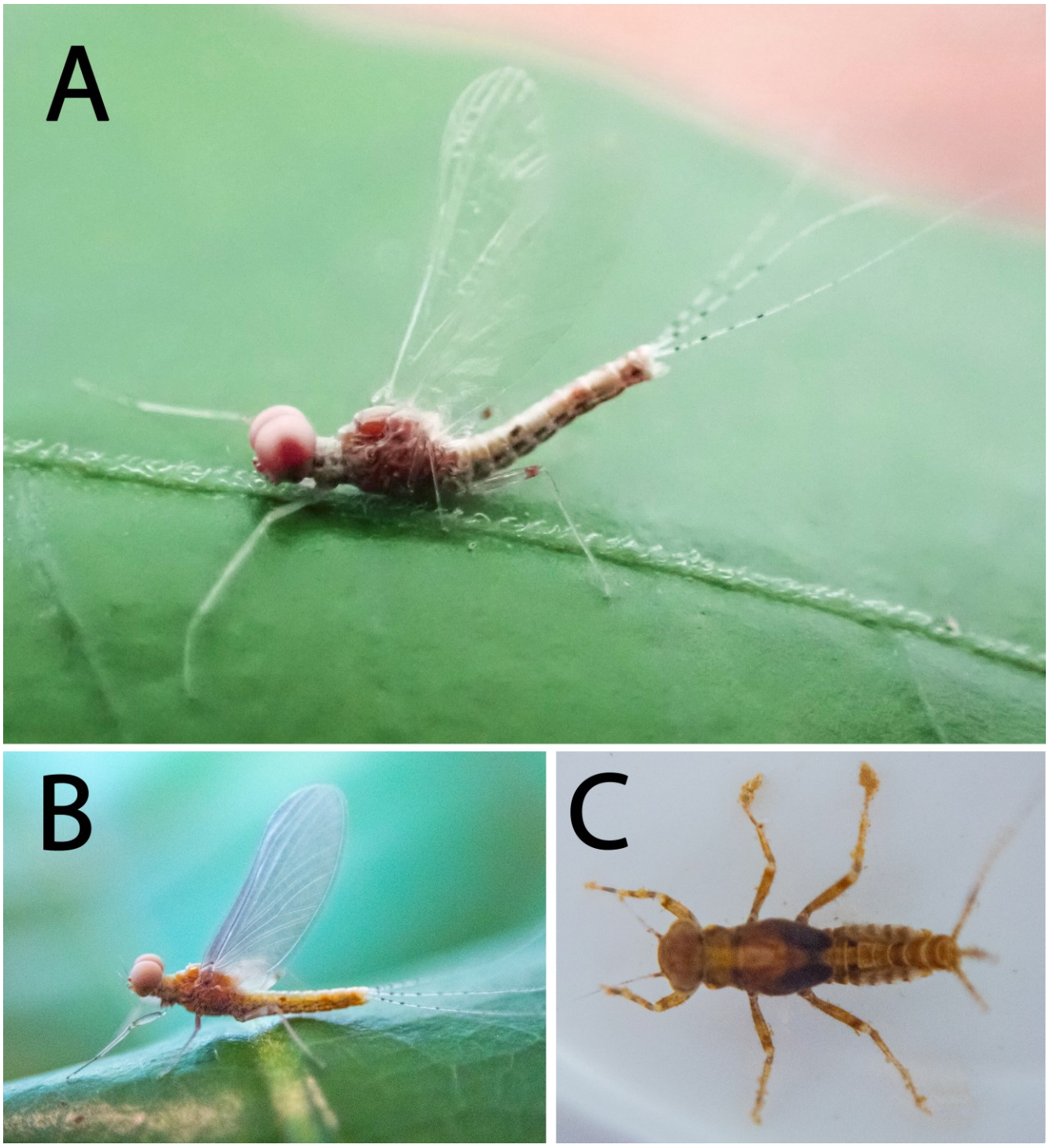

FIGURE 9. *Teloganopsis sirindhornae* sp. nov. Life habitus. **A.** male imago. **B.** male subimago. **C.** male last instar larva.

subapical denticle large and acute (Fig. 3F). **Abdomen:** Abdominal terga with a median pair of pale strips on terga I–IV, VI; tergum IV with two brown spots laterally; tergum V with a pair of broad pale smears; terga VIII–IX with or without a pair of pale stripes (Figs 1A, 4A–C, 9C). Posterior margin of abdominal terga with obovoid setae. Gills present on segments III–VII (Fig. 4D–H). Gills with a bilamellated, ventral lamella; gills on segment III–VI bifurcated; gill VII smaller than others (Fig. 4H).

Description of male imago (in ethanol, Fig. 5; life habitus, Fig. 9A).– Body length 3.0–4.0 mm (excluding caudal filaments); forewings 2.5–2.9 mm; hindwing only approx. 1/5 of forewing in length. **Head:** Eyes rounded with dorsal part orange (Figs 5A, B, 9A) ventral part orange-brown (Fig. 5B). **Thorax:** Forelegs

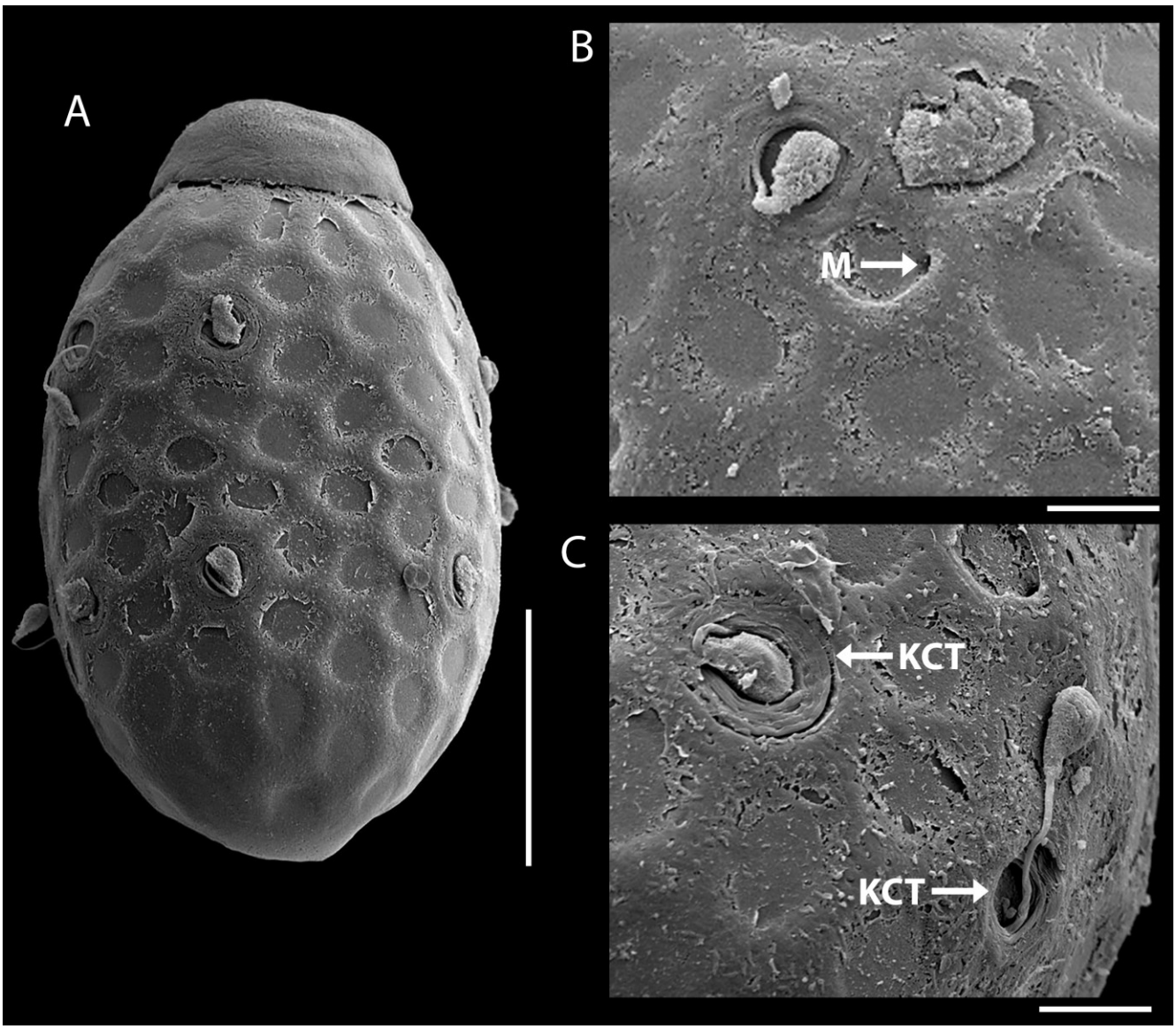

FIGURE 10. *Teloganopsis sirindhornae* sp. nov. Chorionic structure. **A.** overview of egg. **B.** micropyle (M). **C.** knob-terminated coiled Threads (KCTs). Scale bars: A = 50 µm; B, C = 10 µm.

whitish, longer than other legs, tibia length equal to twice femora length, five-segmented tarsus, with the first tarsomere fused with tibia (Fig. 5C). Middle legs similar to forelegs, with dark band on distal part of femora (Fig. 5D). Hind legs darker than others, with dark band on basal and distal part of femora (Fig. 5E). Mesonotum with a notable median longitudinal suture, surface with median white strip (Fig. 5F). Mesosternum with a square basisternum, broad furcasternum (Fig. 5G). Forewings hyaline, crossveins in stigmatic area oblique, some crossveins branched as Y-shaped (Fig. 5H). Hindwings costal projection at middle of costal margin, Sc ending near costal projection (Fig. 5I). **Genitalia:** Forceps three segmented, first segment = 0.07 mm, second segment = 0.17 mm, apical segment= 0.02 mm, small and nearly rounded; Penes fused at 2/3 base and widely separated at apex, each penis with small dorsolateral projections, invisible in ventral view (Fig. 5J–L). **Abdomen:** Terga segment I–V pale; segment VI–XI yellowish; tergum IV with two brown spots laterally; tergum VII with brown smear (Figs 5M, N, 9A). Sterna blackish with a median pale line, anterolateral of each segment with white smear (Fig. 5O).

Description of male subimago (in ethanol, Fig. 6; life habitus, Fig. 9B).– Body length 2.8–3.0 mm (excluding caudal filaments); forewings 2.5–3.0 mm; hindwings only approx. 1/5 of forewing in length. Overall body most similar to those of male imagoes but abdomen more stout than imaginal stage (Fig. 6A–O). **Genitalia**: Similar to that imago stage but shorter and stouter than imago (Fig. 6J–L). **Abdomen:** Terga and sterna with body and color pattern similar to imago stage. (Fig. 6M–O).

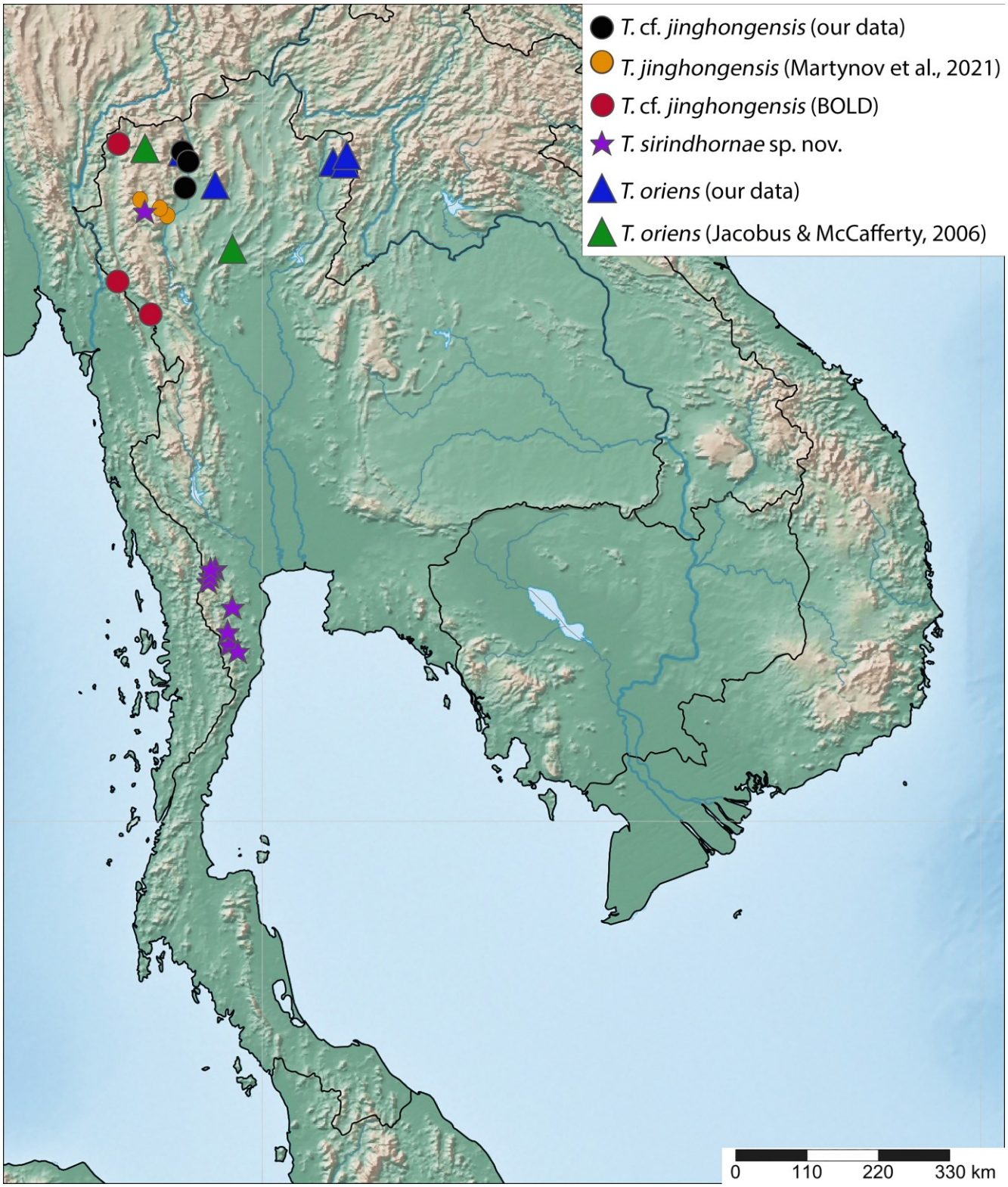

FIGURE 11. Distribution map of Thai *Teloganopsis* species. This map represents the distribution of known *Teloganopsis* species that include our data and previously records. The different shape indicated the different species and different color indicated the source of data. The reference or source of distribution is shown in brackets.

Description of female imago (in ethanol, Fig. 7).– Body length 2.9–3.2 mm (excluding caudal filaments); forewings 3.0–3.4 mm, hindwings only approx. 1/5 of forewing in length. **Head:** Eyes rounded, orange-brown (Fig. 7A, B). **Thorax:** Forelegs whitish, tibia length as long as femora, with dark band on distal part of femora, four-segmented tarsus (Fig. 7C). Middle legs similar to forelegs (Fig. 7D). Hind legs longer and darker than others, with dark band on basal and distal part of femora (Fig. 7E). Mesonotum and mesosternum similar to male imago (Fig. 7F, G). Forewings similar to forewings of male imago but stigmatic area with higher number of crossveins than male imago (Fig. 7H). Hindwings with pattern similar to hindwing of male imago but somewhat narrow (Fig. 7I). **Genitalia:** Subanal plate with transverse brown line parallel to posterior margin (Fig. 7K) Subgenital plate weakly developed (Fig. 7O). **Abdomen:** Terga and sterna similar color pattern to those other winged stages but darker than male (Fig. 7J–O).

Description of female subimago (in ethanol, Fig. 8).– Body length 2.5–3.0 mm (excluding caudal filaments); forewings 3.6–3.7 mm, hindwings only approx. 1/5 of forewing in length. **Head:** Eyes rounded, yellow-brown, without dorsal eyes (Fig. 8A, B). Overall body most similar to those of female imagoes but body color lighter than their imagoes (Fig. 8C–L).

Description of eggs (dissected from female imago).– Oval, length 150 µm, width 90 µm; with one polar cap, chorionic surface dimples, posterior end smooth (Fig. 10A). Micropyle tagenoform-type, distributed at equator (Fig. 10A, B). Knob-terminated coiled threads (KCT) rounded, arranged in sub-equatorial area (Fig. 10A, C)

Distribution.– Western and northern parts of Thailand. The first species-level distribution map of the genus *Teloganopsis* in Thailand was constructed using our data, combined with both published and unpublished previous records (Fig. 11). Most *Teloganopsis* species are distributed in the northern part of Thailand. In contrast, *T. sirindhornae* sp. nov. is most abundant in the western region, although a few specimens were also collected from the Mae Chaem River in northern Thailand. Notably, *T. sirindhornae* sp. nov. was not found co-occurring with any other *Teloganopsis* species at any of the sampled localities.

Habitat.– *Teloganopsis sirindhornae* sp. nov. was collected from moderately fast-flowing streams in western Thailand at elevations ranging from 118 to 258 m a.s.l. (Fig. 12A, C–F). These streams had depths of 20–30 cm and were slightly disturbed by human activities. The larvae of the new species were found in flowing sections of the streams, primarily beneath pebble and cobble substrates (Fig. 12E, F). Specimens from northern Thailand, collected at 420 m a.s.l. from the Mae Chaem River in Chiang Mai Province, were found near the river's coastal dunes at depths of approximately 50–60 cm, where the substrate of river bed consisted mainly of gravel (Fig. 12B).

Remark.–The body color pattern of *Teloganopsis sirindhornae* sp. nov. is particularly interesting, as it remains unique and consistently displayed throughout all developmental stages. Notably, brown spots on abdominal tergum IV are easily observed across all stages. In contrast, tergum V features white spots that are difficult to distinguish in younger larvae but becomes more pronounced in mature larvae and remains in exuviae. Additionally, abdominal tergum VII exhibits prominent brown smears in younger larvae; however, in mature larvae, the tergum VII darkens significantly. In the same way, the color of abdominal tergum VII can still be observed in the adult stage, although it varies in shade and may be difficult to distinguish in some individuals.

Molecular Analysis

Phylogenetic analyses were performed using mitochondrial COI and nuclear 28S rDNA sequences. The COI-based tree revealed a consistent clustering pattern, with *T. sirindhornae* sp. nov. forming a distinct clade. (data not shown, but its topology was broadly similar to that of Fig. 13A). Similarly, the 28S rDNA phylogeny (Fig. 13B) showed congruent topology and no evident conflict with the COI tree. A concatenated phylogenetic analysis of combined COI and 28S sequences provides clearly separated *T. sirindhornae* sp. nov. from all other examined taxa (Fig. 13A).

Genetic distances were calculated based on COI and concatenated COI + 28S rDNA sequences. The inter-specific distances ranged from 13.13% to 24.11%, while intraspecific distances ranged from 0% to 1.54%. When using 28S rDNA alone, the highest observed genetic distance was 12.60% found between *Torleya major* and *Teloganopsis media*. The distance between *T. media* and *T. oriens* was 9.43%. In contrast, the genetic distances among *T. media*, *T.* cf. *jinghongensis* and *T. sirindhornae* sp. nov., were relatively low, ranging from 1.37% to 1.60%. However, these values still exceed the intraspecific distances (0–0.45%) observed within *T. oriens* and *T. sirindhornae* sp. nov.

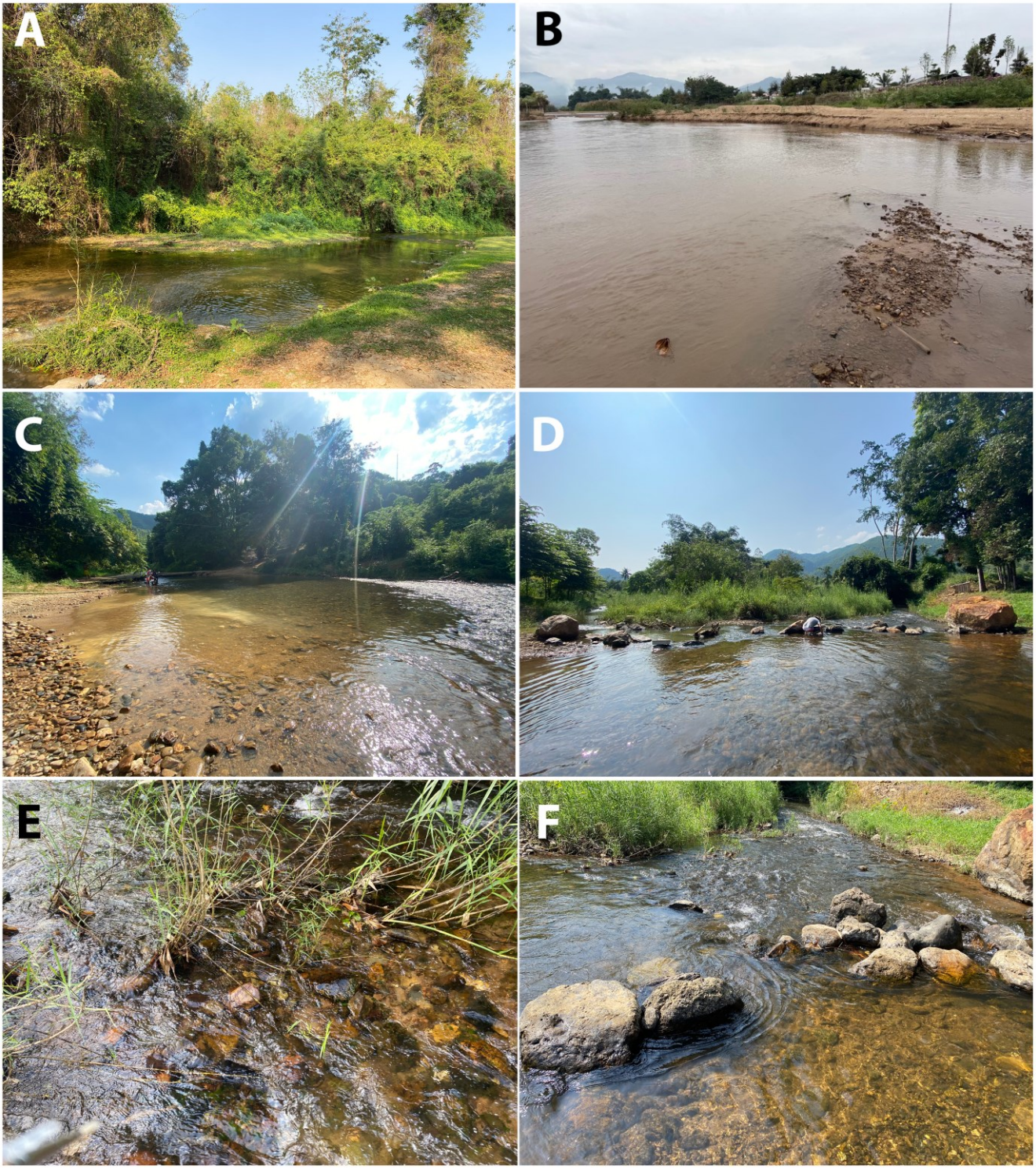

FIGURE 12. Type locality. **A.** Phachi stream, Ratchaburi Province. **B.** Mae Chaem River, Chiang Mai Province. **C.** Sat Yai stream, Phetchaburi Province. **D.** Satue stream, Prachuap Khiri Khan Province. **E, F.** microhabitat of the larvae of *Teloganopsis sirindhornae* sp. nov.

DISCUSSION

Two valid *Teloganopsis* species have been previously recorded in Thailand: *T. oriens* and *T. jinghongensis* (Jacobus and McCaffefty, 2006; Martynov et al., 2021). In addition, two morphospecies have been documented in southern Thailand, which may represent either two putative new species or *T. media*. However, *T. sirindhornae* sp. nov. is unique and distinct from all

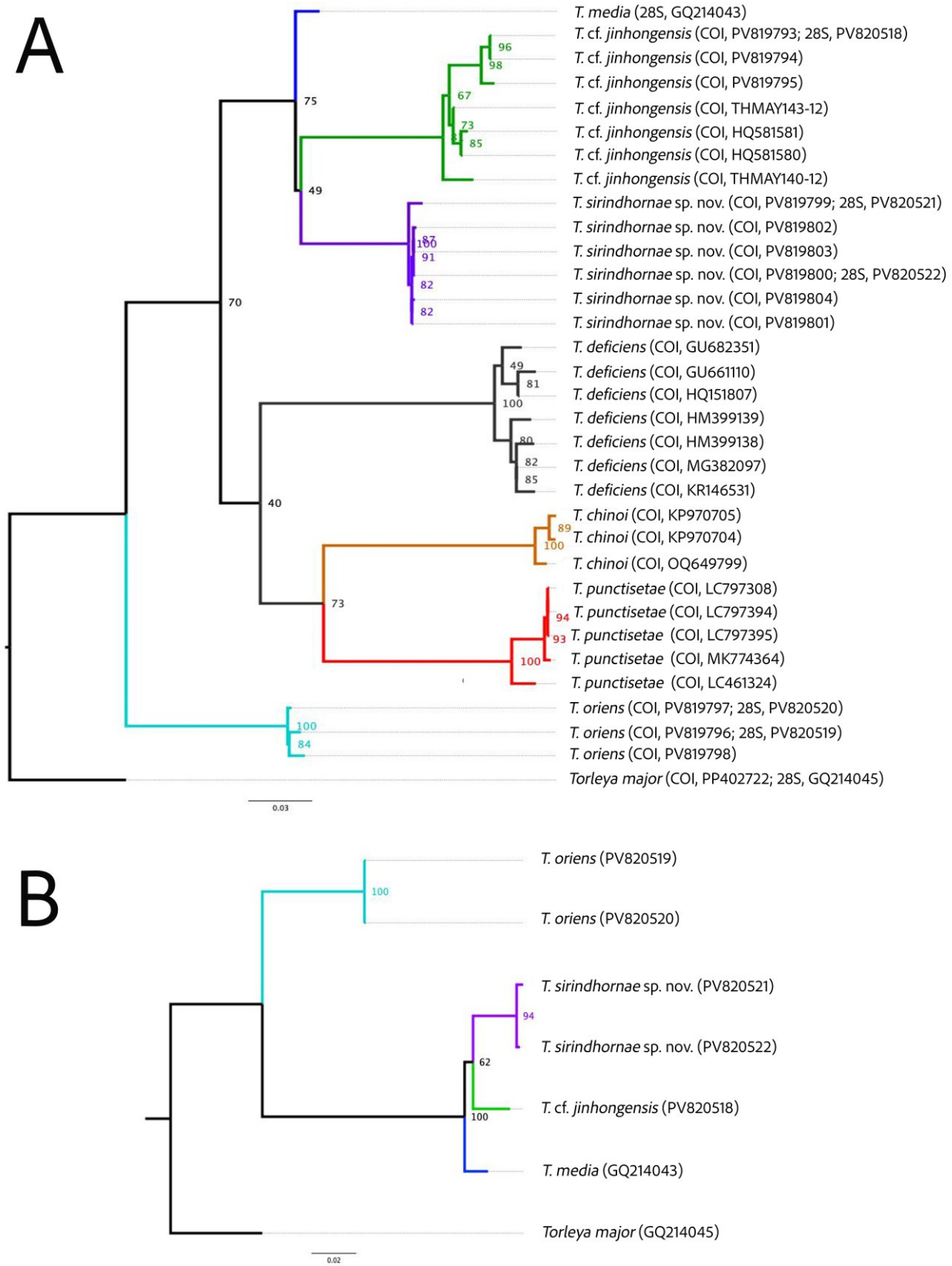

FIGURE 13. The Maximum likelihood phylogeny of *Teloganopsis* species. **A.** phylogeny based on concatenated COI and 28s rDNA sequences. **B.** phylogeny based on 28S rDNA alone. Branch support values are indicated by bootstrap percentages. Accession number from GenBank or BOLD process ID are shown in brackets. *Torleya major* was used as the outgroup.

previously recorded specimens of the genus *Teloganopsis* (Sites et al., 2001; Jacobus and McCafferty, 2006; Martynov et al., 2021). This is the first *Teloganopsis* species formally described from Thailand, with a distribution in both western and northern regions (Fig. 11).

Interestingly, some specimens of the new species from northern Thailand were collected in the Mae Chaem River (Fig. 12B), which features a distinct microhabitat compared to other locations (Fig. 12A, C–F). Our observations suggest that the genus *Teloganopsis* exhibits a high degree of adaptability, allowing it to disperse widely. Although this genus exhibits a relatively wide distribution, physical environmental factors still play a role in limiting the distribution of certain species. For instance, *T. sirindhornae* sp. nov. was discovered in broad rivers or streams at elevations ranging from 110 to 420 m a.s.l., whereas *T.* cf. *jinghongensis* was typically found in headwater or waterfall streams at higher elevations between 370 and 740 m a.s.l. (Martynov et al., 2021; Ding and Zhou, 2023)

Our observations indicate that certain color patterns can reliably distinguish *Teloganopsis* species in Thailand, regardless of sampling locality. Although this abdominal color pattern is useful for species identification within the country, it may be ambiguous when comparing with other Oriental *Teloganopsis* species. For instance, this pattern is present in both larval and imaginal stages of *T. setosa* (Zhang et al., 2017), but only in the larva of *T. jinghongensis* from China (Ding and Zhou, 2023). Therefore, identification of Oriental *Teloganopsis* species requires a combination of characters, including the presence of tubercles on the pronotum and labial palps. Additionally, structures such as the male genitalia and wings at imaginal stage are also informative. Herein, we provide a dichotomous key for the known larvae and imagoes of the genus *Teloganopsis* in the Oriental region.

The chorionic structures of four Oriental *Teloganopsis* species— *T. jinghongensis*, *T. media*, *T. puigae*, *T. setosa*— have been previously described (Jacobus and McCafferty, 2008; Ubero-Pascal and Sartori, 2009; Zhang et al., 2017; Ding and Zhou, 2023). Herein, we describe the chorionic structure of *T. sirindhornae* sp. nov. While overall chorionic surface is similar among species, *T. setosa* is distinct in having a smooth chorion with faint markings (Zhang et al., 2017). In contrast, the other species exhibit polygonal or hexagonal surface reticulations. Based on posterior pole structure, they can be grouped into two categories: smooth in *T. media* (Jacobus and McCafferty, 2008), *T. jinghongensis* (Ding and Zhou, 2023) and *T. sirindhornae* sp. nov.; ornamented in *T. puigae* (Ubero-Pascal and Sartori, 2009). Therefore, the chorionic structure appears unsuitable for identification at the species or even genus level, due to the chorionic patterns shared across some species and genera within the family Epheme-rellidae (Jacobus and McCafferty, 2008).

The phylogenetic analysis supports the monophyly of *T. sirindhornae* sp. nov., which is morphologically characterized by the presence of brown spots on abdominal tergum IV. In contrast, *T. media* as reported by Ubero-Pascal and Sartori (2009) and Sartori (2014) and *T.* cf. *jinghongensis* from this study lack these markings. This coloration pattern may represent a unique feature within specific lineages of *Teloganopsis*. However, the hypothesis remains unconfirmed, as DNA sequences of *T. setosa* or additional specimens of *T. jinghongensis* are not currently available in public databases. Further molecular studies are therefore necessary to clarify the phylogenetic relationships and character evolution within the genus.

The genetic distances were also calculated based on COI and 28S rDNA sequences. Distances derived from COI and concatenated COI and 28S rDNA clearly provided strong support for species delimitation. In contrast, the 28S rDNA alone exhibited lower interspecific values, particularly among *T. media*, *T.* cf. *jinghongensis* and *T. sirindhornae* sp. nov., which ranged from 1.37% to 1.60%. However, these values are still higher than maximum intraspecific divergence observed within *T. sirindhornae* sp. nov. (0.45%) and *T. oriens* (0%) supporting their interpretation as interspecific distances. Furthermore, the 28S rDNA is more conserved and indicative of generic or higher taxonomic level identification (Chan et al., 2021; Wu et al., 2025), resulting in lower genetic distance values within the genus.

Key to the known male imagoes of *Teloganopsis* species in the Oriental (Excluding *T. puigae* and *T. oriens*, which lack imaginal stage descriptions)

1. abdominal tergum IV with prominent brown spots ……. 2
– abdominal tergum IV without prominent brown spots ……..…..……...….. 3
2. dorsolateral projection of penis invisible in ventral view ……..….. *T. sirindhornae* sp. nov.
– dorsolateral projection of penis visible in ventral view. ……..…….. *T. setosa* Zhang & Zhou, 2017
3. apical area of hindwing narrows from costal to posterior margin, apex pointed (Fig. 3C, Ubero-Pascal and Sartori, 2009) ….. *T. media* Ulmer, 1939
– apical area of hindwing broad from costal to posterior margin, apex rounded (Fig. 5B, Ding and Zhou, 2023) .....…. *T. jinghongensis* (Xu & Hsu, 1984)

Key to the known larvae of *Teloganopsis* species in the Oriental

1. pronotum with two small or four round tubercles ……..……. 2
– pronotum without tubercles ……..…… 3

2. abdominal tergum IV with brown or reddish spots …..……. *T. sirindhornae* sp. nov.
– abdominal tergum IV without brown or reddish spots ……...……. *T. media* Ulmer, 1939

3. labial palp segment II slender and curved, with numerous long setae, length equals 6.8–7.0 times of width …… *T. setosa* Zhang & Zhou, 2017
– labial palp segment II broader, with 2–3 feather-like setae, length equals 2.3–2.5 times of width 4

4. notum with median pale line or tergum VIII with white spots …… *T. jinghongensis* (Xu & Hsu, 1984)
– notum without line and tergum VIII without white spots ……..……. 5

5. posterior margin of forefemur with setae from initial-length to apical end ……...……..…..
……..…..… *T. oriens* (Jacobus & McCaffefty, 2006)
– posterior margin of forefemur with setae from middle-length to apical end (Fig. 6Q, Ubero-Pascal & Sartori, 2009) ……...…….
……..…. *T. puigae* Ubero-Pascal & Sartori, 2009

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