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The imaginal morphology of the species *Kangella brocha* (Kang and Yang, 1995) from southern China (Ephemeroptera: Ephemerellidae)

MANQING DING[1,2], DEWEN GONG[1,3] & CHANGFA ZHOU[1,4]
[1]*College of Life Sciences, Nanjing Normal University, Nanjing 210023, China*
[2] *13868819415@163.com; https://orcid.org/0000-0001-5715-8093*
[3] *nnudwyane@163.com; https://orcid.org/0000-0002-3740-7125*
[4] *zhouchangfa@njnu.edu.cn; https://orcid.org/0000-0001-8785-5228*

Abstract

Kangella brocha (Kang & Yang, 1995), a mayfly species known on nymphs only, has been previously placed in three different genera. Here, their first-found adults and additional nymphs from southern China reveal some new characteristics. Apart from its elongated mouthparts, extended outer incisors, widened prothorax, and shortened caudal filaments in the nymph stage, the adult exhibits a robust thorax, straight forceps, and large penes with dorsal projections. These distinct features, observed in both immature and alate stages, provide compelling evidence that this species deserves an independent genus. Therefore, the genus *Kangella* Sartori, 2004 is reinstated, and this species is reclassified under it. Functionally, the outstanding outer incisor likely serves purposes such as digging or capturing prey. Our finding not only narrows the distribution gap between two populations of this species but also enriches the diversity of ephemerellids in terms of ecological adaptations.

Key words: imago, distribution, evolution, mayfly, China

Introduction

The species *Kangella brocha*, which was originally named by Kang and Yang (1995) as *Eburella brocha* from Chinese Taiwan island based on nymphs, was also recorded in Thailand (Jacobus *et al.* 2005; Boonsoong 2022). Furthermore, it was mentioned and described by several other researchers (Jacobus & McCafferty 2008; Ubero-Pascal & Sartori 2009), but its alate stages remained unknown up to now.

Morphologically, in considering its nymphal remarkably uniqueness of head and mouthparts, Kang & Yang (1995) established the genus *Eburella* Kang & Yang, 1995 for this species *Eburella brocha*. Sartori (2004) renamed this genus as *Kangella* to separate it from the preoccupied taxon *Eburella* Monné & Martins, 1973 (Coleoptera: Cerambycidae). Anyway, those taxonomic arrangements show this species has outstanding nymphs. In contrast, disregarding this, Jacobus & McCafferty (2008) transferred this species into the genus *Teloganopsis* Ulmer, 1939 based on the characters that match the genus characteristics (such as the absence of maxillary palpi). The validity of this change can be tested by the adults of this species.

Zhang *et al.* (2017) and Ding & Zhou (2023) have studied the diverse life styles and adaptions within the genus *Teloganopsis*. Regardless of whether the imaginal morphology of the species *brocha* remains in this present genus, the nymphal mouthparts (especially elongated mandibular incisors) show another evolutionary trend that has not been fully indicated before.

In spring 2023, more than twenty nymphs and dozens of adults of *T. brocha* were attracted in Hainan Province, southern China. They provide us a good chance not only to present its exact characteristics in both nymphal and imaginal stages, but also to confirm its generic position and possible ecological adaptation.

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Material and methods

The nymphs were collected in creeks with hand screens. A portion of the adults were obtained through light trapping, the rest were reared from mature nymphs.

All specimens were examined under a stereo microscope (Mingmei Photoelectric, MZ81, Guangzhou, China) and photographed by a digital camera (Canon EOS 6D) with a macro lens (Canon MP-E 65 mm 5×). Mouthparts, gills, claws and penis lobes were photographed under a microscope camera (Nikon Eclipse 50i, Tokyo, Japan) with temporary slides. Eggs were dissected from female imagos and photographed with a SEM (Apreo 2S, Thermo Fisher Scientific Company, Waltham, MA, USA).

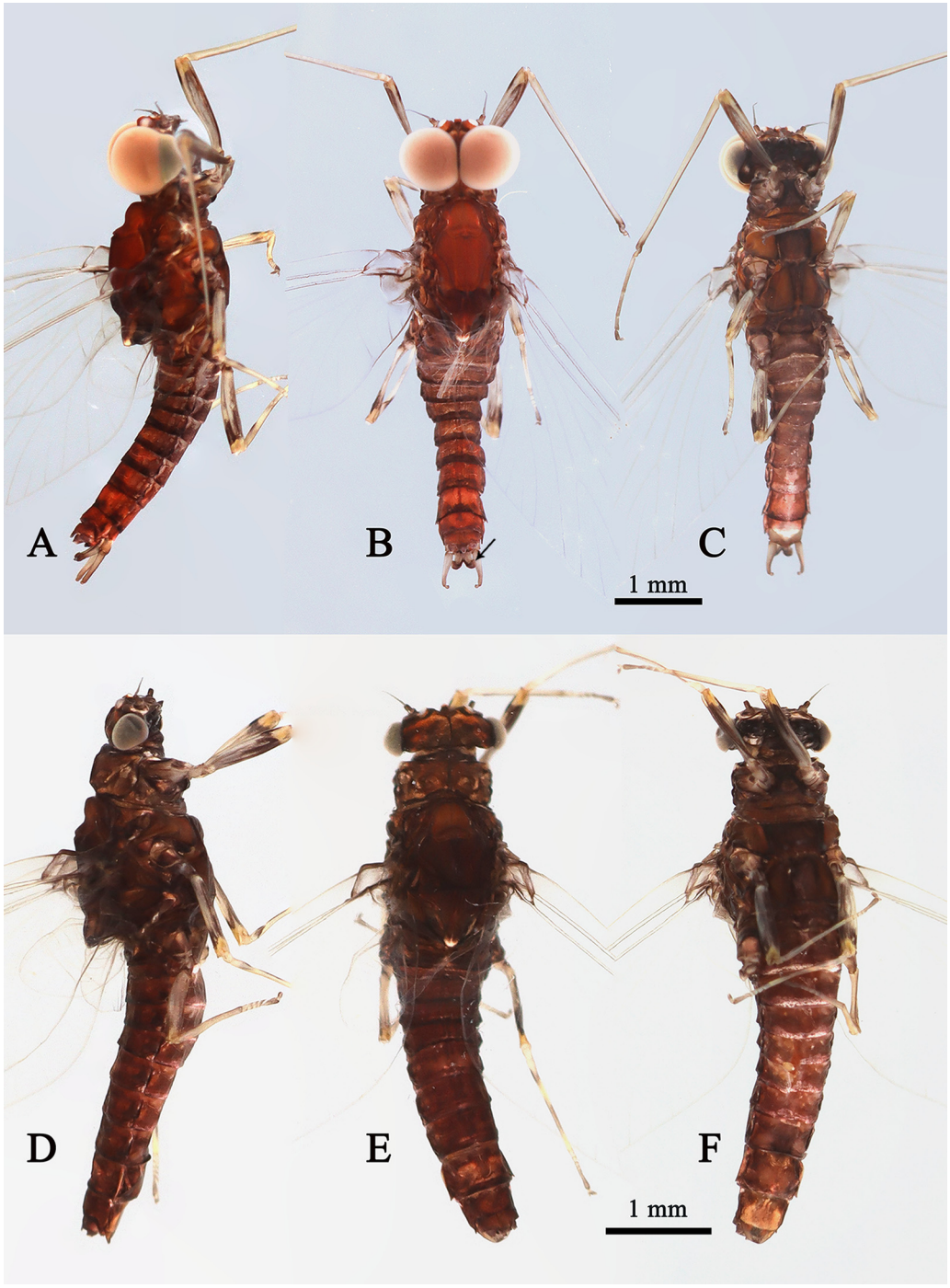

Figure 1. Imaginal habitus of *Kangella brocha*. **A, B, C,** male; **D, E, F,** female.

Result

Kangella Sartori, 2004 stat. prom.

Eburella Kang & Yang, 1995: 105
Kangella Sartori, 2004: 76
Teloganopsis (partim): Jacobus & McCafferty 2008: 240.

Male imago: Thorax distinctly wider, longer and higher than abdomen (Fig. 1A,B), width of pronotum subequal to meso- and metanotum in dorsal view (Fig. 1B); MA vein of forewing forked at distal 1/3 (Fig. 2A); hindwing costal projection at middle of leading margin (Fig. 2B); foretarsi shorter than foretibiae (Fig. 2C); segment II of forceps straight, progressively narrowed from base to apex (Fig. 3A); segment III of forceps with slightly narrowed base and apex (Fig. 3A,F); penes distinct with dorsal projections (Arrowed in Fig. 3C).

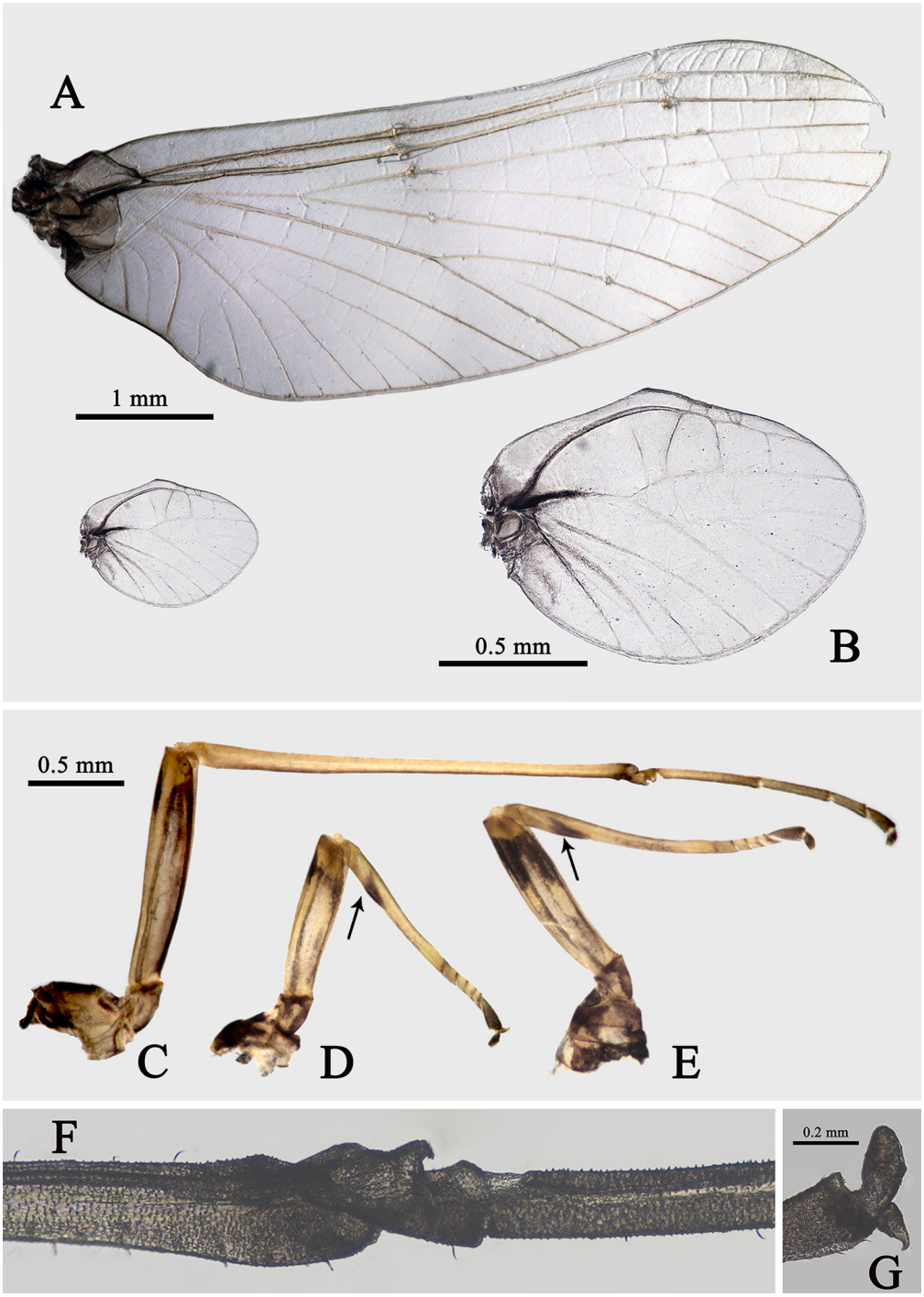

Figure 2. Male structures of *Kangella brocha*. **A,** forewing; **B,** hindwing; **C,** foreleg; **D,** midleg; **E,** hindleg; **F,** proximal hook of foreleg; **G,** claw. Arrows point to patella-tibial sutures.

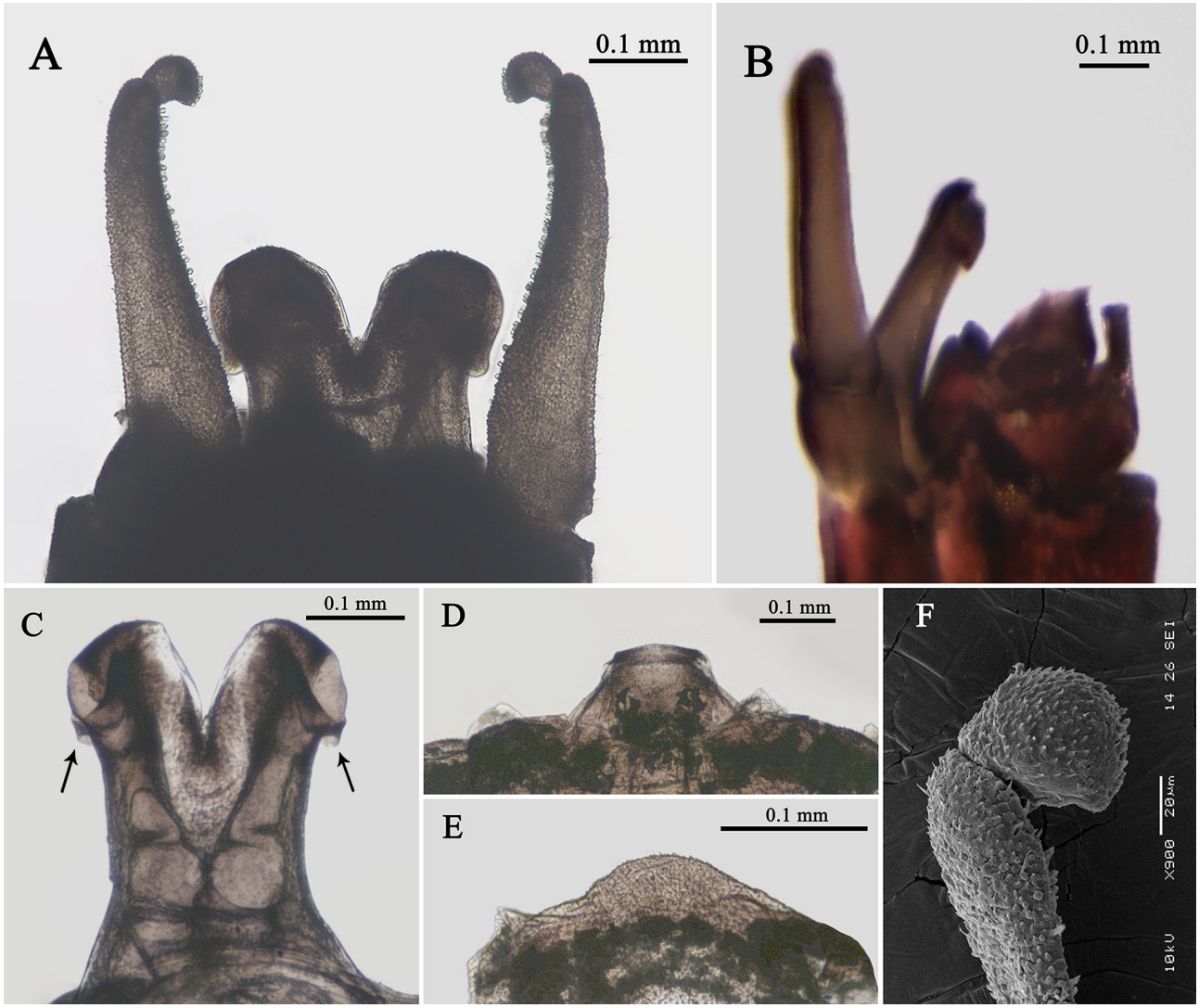

Figure 3. Genitalia of *Kangella brocha*. **A,** genitalia (ventral view); **B,** genitalia (lateral view); **C,** penis (dorsal view); **D,** posterior margin of tergum X; **E,** styliger plate; **F,** segment III of forceps. Arrows point to dorsal projections of penis.

Nymph: Prothorax distinctly wider than meso- and metathorax (Fig. 4); caudal filament ca. 0.7x body length (Fig. 4); all mouthparts elongated (Fig. 5); anterior margin of labrum widened, distinctly wider than base (Fig. 5B); superlingua much more elongated than lingua (Fig. 5C); outer margin of mandible with a row of dense hair-like setae, outer incisor elongated remarkably into tusk-like structure (Fig. 5D,G); maxilla without palpi, crown nearly flat, with dense hair-like setae (Fig. 5H); labial palpi slim, paraglossae much larger than glossae (Fig. 5I); claws with only three denticles, the basal one divided into two (Fig. 6A–C); ventral lamella of gill IV divided in two lobes (Fig. 6D).

Type species: *Kangella brocha* (Kang & Yang, 1995) **comb. nov.**

Distribution: China (Taiwan, Hainan), Thailand.

Diagnosis: The nymphs of the genus *Kangella* can be diagnosed by a long series of unique characteristics: (1) antennae about 0.5x body length, longer than other congeners (Fig. 4); (2) robust thorax and pronotum (wider than meso- and metanotum) (Fig. 4); (3) caudal filaments shorter than body, ca. 0.7x body (Fig. 4); (4) elongated and specialized mouthparts (Fig. 5); (5) all legs are similar in length and setal pattern (Fig. 6A–C); (6) claws of legs with three denticles, the basal one divided into two processes (Fig. 6A–C).

The male imago can be recognized by its genitalia (Fig. 3A), especially its forceps (shape of segments II–III) (Fig. 3A,F) and penes (with distinct dorsal projection) (Fig. 3B,C). In addition, their prothorax is almost same to meso- and metathorax in width (Fig. 1B), and whole thorax is relatively large in width, length and height.

Figure 4. Nymphal habitus of *Kangella brocha*. **A,** male; **B,** female.

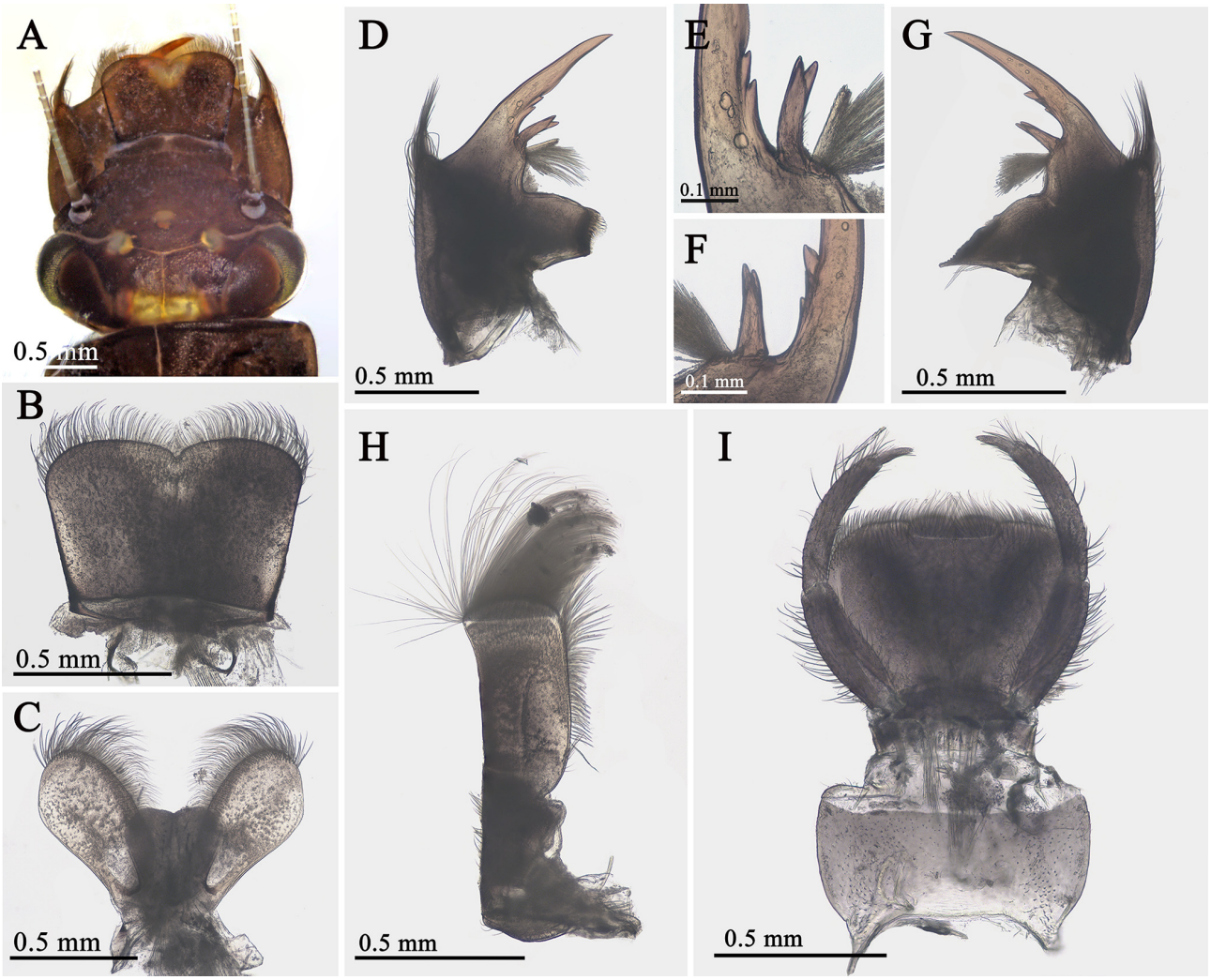

Figure 5. Head and mouthparts of *Kangella brocha*. **A,** head (dorsal view); **B,** labrum; **C,** hypopharynx; **D,** left mandible; **E,** left incisor; **F,** right incisor; **G,** right mandible; **H,** maxilla; **I,** labium.

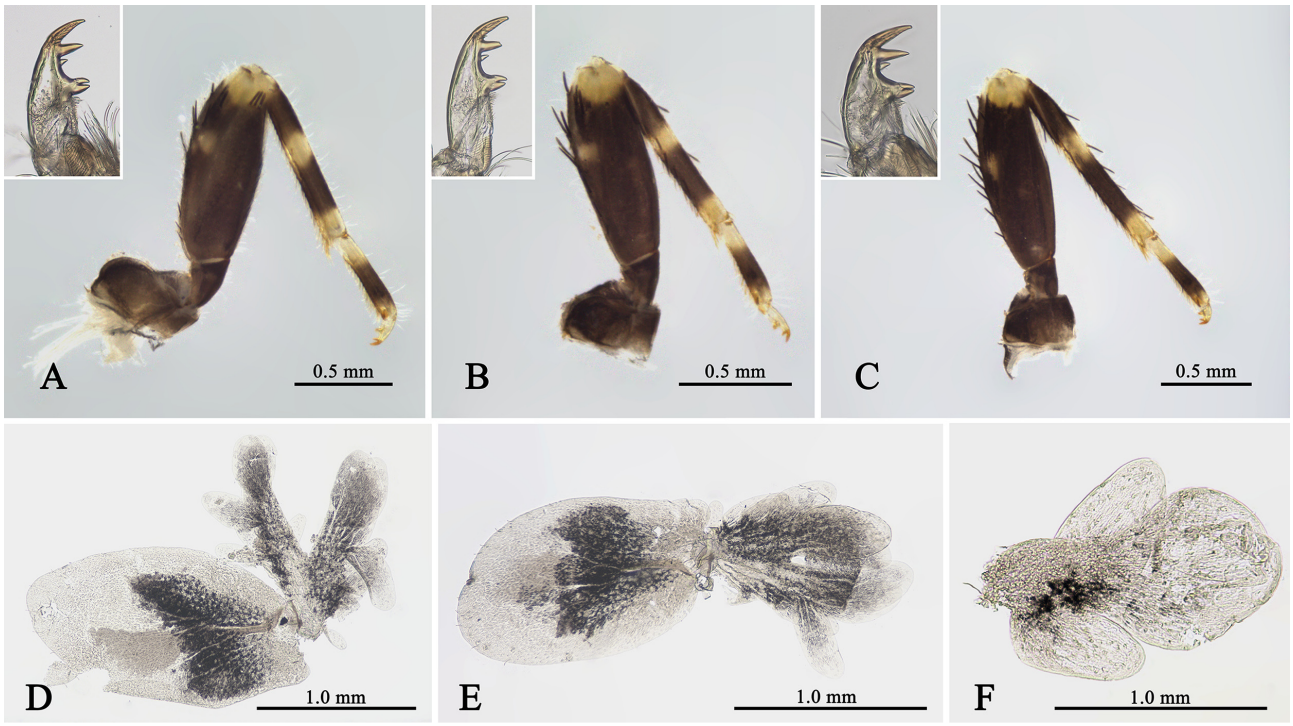

Figure 6. Legs and gills of *Kangella brocha*. **A,** foreleg and claw; **B,** midleg and claw; **C,** hindleg and claw; **D,** gill IV; **E,** gill VI; **F,** gill VII.

This genus is close to *Teloganopsis* except for the features mentioned above. Both of them have a hook-like structure of imaginal foretarsi (Fig. 2F) and an absence of maxillary palp in nymphs (Fig. 5H). Their male genitalia are similar too (Fig. 3A). However, they can be separated by the shape of thorax and penis in adults. The pronotum is subequal to meso- and metathorax in *Kangella*, but that of *Teloganopsis* is distinctly narrower than meso- and metathorax. Addition, the dorsal projections of *Kangella* penes is much larger than those of *Teloganopsis*. In nymphs, the mouthparts and thorax (especially prothorax) of them are totally different.

***Kangella brocha* (Kang & Yang, 1995) comb. nov.**

Eburella brocha Kang & Yang, 1995: 105, Figs. 5, 18, 19 (nymph, egg). Types: nymph, from China (Taiwan Province).

Kangella brocha: Sartori 2004: 76; Jacobus *et al.* 2005: 268 (Thailand); Ogden *et al.* 2009: 35.

Eburella brocha: Shieh *et al.* 2007: 614.

Teloganopsis brocha: Jacobus & McCafferty 2008: 240, Fig. 23 (nymph); Ubero-Pascal & Sartori 2009: 104, Fig. 2g–h (egg); Boonsoong 2022: 175, Fig. 5–21A (nymph, Thailand).

Description

Male imago: Body reddish brown (Fig. 1A–C), length 4.0–6.0 mm, caudal filaments ca. 4.0 mm. Compound eyes with orange upper half and gray lower half (Fig. 1A), close but not contiguous, median distance between eyes less than width of median ocellus (Fig. 1B).

Forewings 6.0–6.5 mm, transparent but with slightly pigmented base (Fig. 2A); costal brace painted deep-brown to black; pterostigma areas semitransparent, with 8–10 veinlets; MA forked at distal 1/3; MP forked at basal 1/5; CuP connected to CuA at base, but immediately forked away; bullae on Sc and Rs clearly marked (Fig. 2A). Hindwing 1.3–1.5 mm, with a shallow costal projection near midpoint, and Sc terminating close to apex; MP forked at 1/3 base (Fig. 2B).

Foreleg 4.9 mm; femora brown, foretibiae paler, both with dark apical band (Fig. 2C); foretarsi segments in decreasing order as 2, 3, 4, 5, 1, basal one with a hooked structure (Fig. 2F). Mid- and hindlegs similar, both with dark apical band on femora (Fig. 2D,E); patella-tibial sutures clearly marked, apical portion with dark pigments (Arrowed in Fig. 2D,E). Length ratio of femora: tibiae: tarsi of fore-, mid-, and hindlegs as follows: 1.0: 1.9: 1.1, 1.0: 1.0: 0.5, 1.0: 1.2: 0.5. Claws of all legs similar, one blunt, one acute (Fig. 2G).

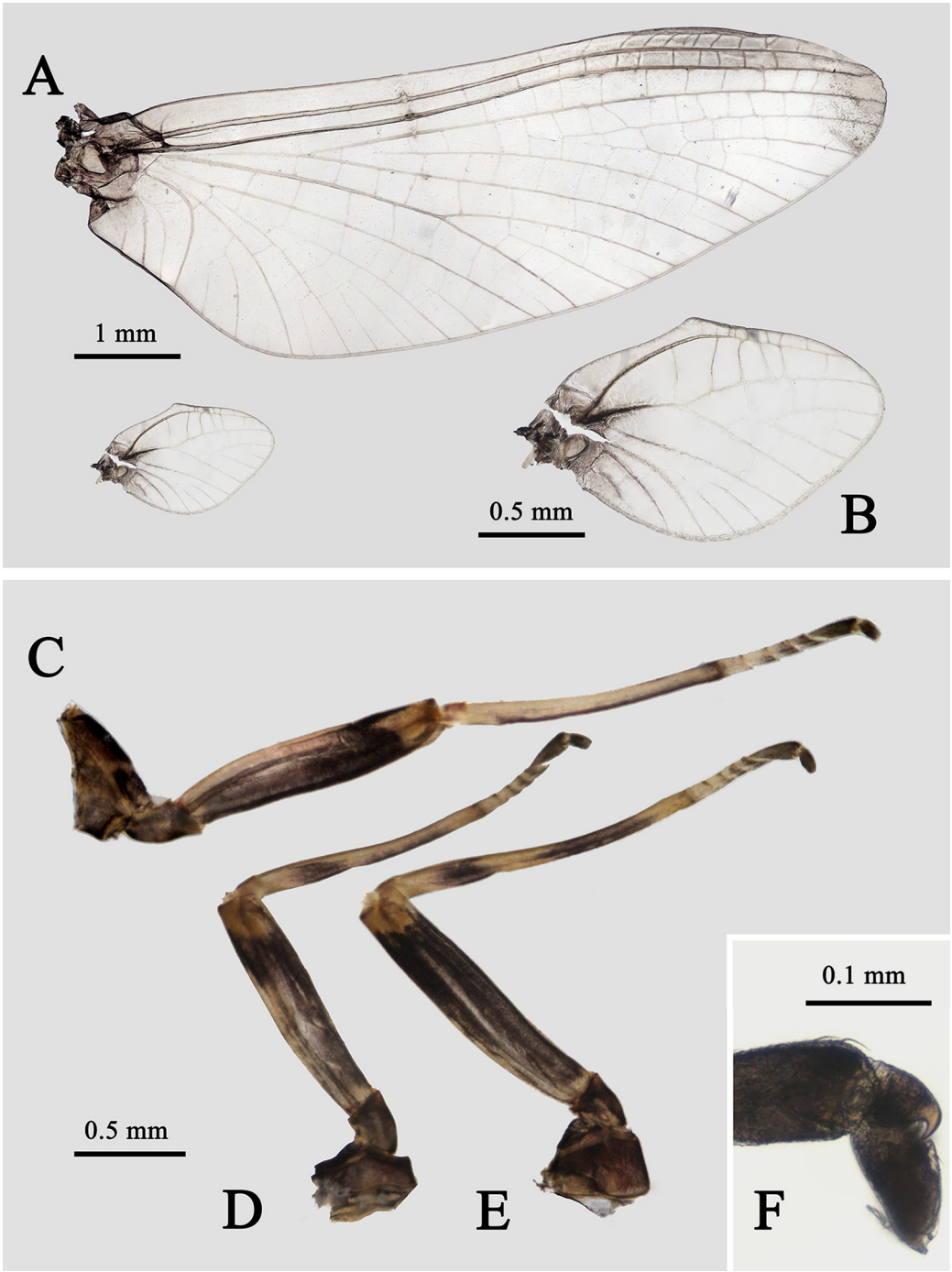

Figure 7. Female structures of *Kangella brocha*. **A,** wings; **B,** hindwing; **C,** foreleg; **D,** midleg; **E,** hindleg; **F,** claw.

Abdomen uniformly reddish brown (Fig. 1A); tergum IX with a pair of posterolateral projections; posterior margin of tergum X with a distinct median projection (Fig. 3D). Styliger plate with a round median projection (Fig. 3E). Forceps 3-segmented (Fig. 3A,B); segment II ca. 10x length of segment I, almost straight and cylindrical (Fig. 3A,B); length of segment III: width less than 2.0x, segment III almost globulous, with very slightly narrowed base and apex (Fig. 3F). two penes with a deep V-shaped cleft medially (Fig. 3C); penis slightly expended laterally, with conspicuous dorsal subapical projection, visible in both ventral and lateral views (Fig. 3A–C).

Female imago: Body red-brown, darker than male (Fig. 1D–F), length 4.5–6.0 mm. Compound eyes dark, separated widely (Fig. 1D,E). Forewings 8.0–9.0 mm, similar to male (Fig. 7A); hindwings slightly narrower than male (Fig. 7B), Sc cross-veins more numerous than in male. Femora dark (Fig. 7C–E); foreleg 3.2 mm, tarsi segments in decreasing order as 5, 2, 4, 3, 1 (Fig. 7C), that of mid- and hind-tarsi as follows: 5, 1, 2, 3, 4 (Fig. 7D) and 5, 1, 2, 4, 3 (Fig. 7E); length ratio of femora: tibiae: tarsi of three les as follows: 1.0: 1.1: 0.5, 1.0: 1.0: 0.4, 1.0: 1.1: 0.4. Claw one blunt and one acute (Fig. 7F).

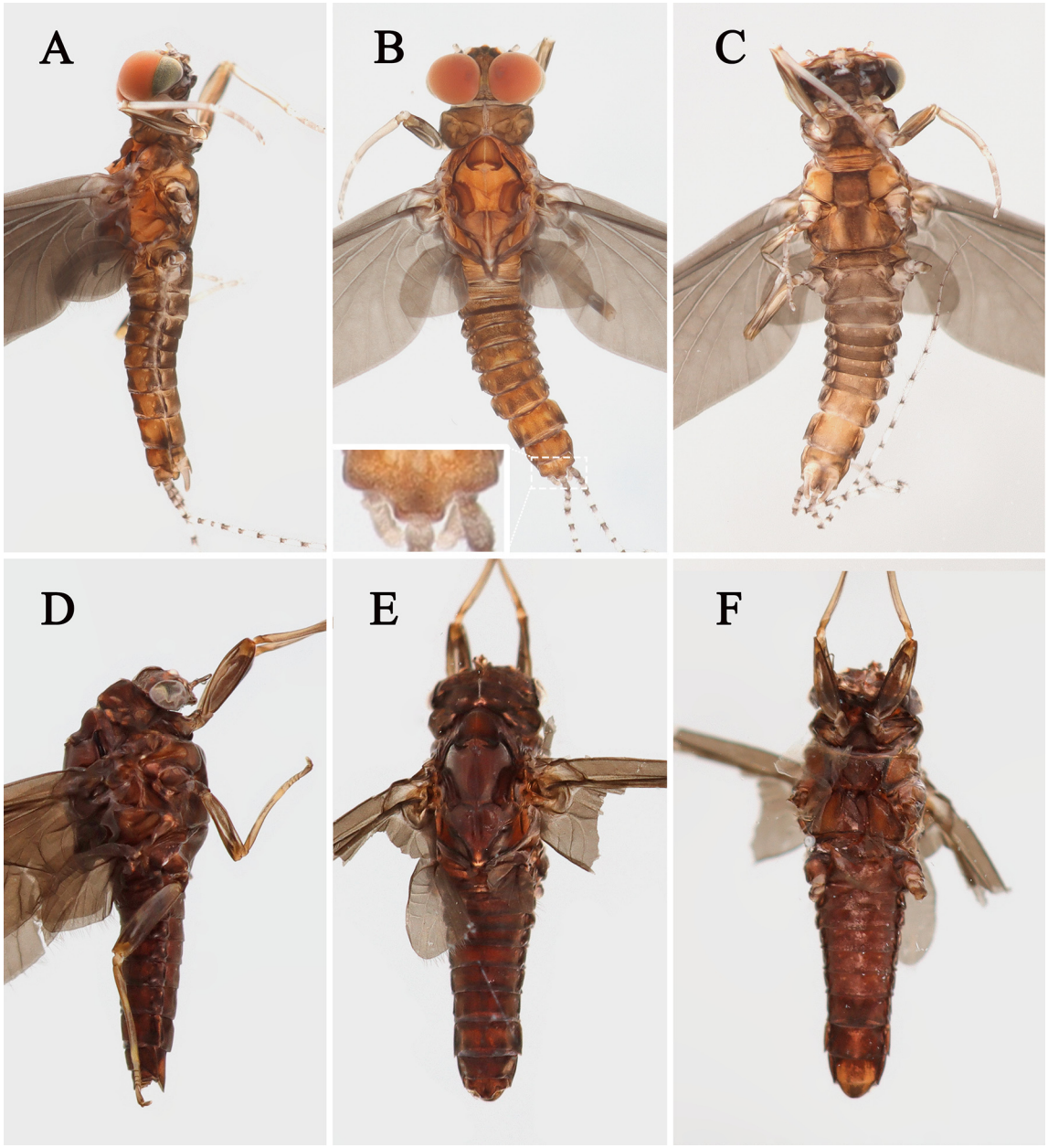

Figure 8. Subimagos of *Kangella brocha*. **A, B, C,** male; **D, E, F,** female.

Male subimago: Body orange-brown (Fig. 8A–C); compound eyes similar to imago (Fig. 8A), but clearly separated (Fig. 8B); tergum X with a posterior square projection (Fig. 8B).

Female subimago: Similar to male subimago but darker (Fig. 8D–F).

Nymph: (Details see Kang and Yang 1995 and Jacobus et al. 2008.) The remarkable characters include: antennae ca. 0.5x body length (Fig. 4); prothorax widened (Fig. 4); caudal filaments ca. 0.7x body length, with spine rings at articulations (Fig. 4); all components of mouthparts elongated and enlarged (Fig.5); Outer incisor of mandibles greatly elongated (Fig. 5D,G), ca. 3x length of inner incisors, with 2 denticles on left outer incisor and 3 on right (Fig. 5E,F); inner incisor with 3 apical canines (Fig. 5E,F); maxillae with hair-like setae only (Fig. 5H); femora of all legs without subapical spine band (Fig. 6A–C); claws with 3 denticles, the middle one smaller than other two, the basal one bifurcated (Fig. 6A–C); gills III–VI similar, with oval dorsal lobe and bifurcate ventral lobe (Fig. 6D,E); gill VII very tiny (Fig. 6F).

Egg: With a nipple-shaped polar cap, and several KCTs and micropylar devices scattered on the surface (Fig. 9).

Remarks: The nymphal characteristics of the specimens we examined are identical as the description from Chinese Taiwan island (Kang and Yang 1995) and Thailand (Jacobus and McCafferty 2005; Boongsoon 2022), especially the elongated outer incisors of mandibles (Fig. 5D,G) and the trapezoidal labrum (Fig. 5B).

Materials examined: 4 ♂♂, 6 ♀♀, 8 ♂♂ subimagos, 10 ♀♀ subimagos, 21 nymphs, Wuzhi Mountain National Nature Reserve, Hainan Province, **China**, 600m, 109.65863°E, 18.867395°N, 2023-IV-17, collected by Xu-Hong-Yi Zheng and Zhi-Teng Chen; 3 nymphs, Bawangling National Forest Park, Hainan Province, **China**, 205m, 109.104743°E, 19.105216°N, 2023-IV-22, collected by De-Wen Gong, Xiao-Fang Chen and Xin-He Qiang; 2 nymphs, Loei River, Loei Province, **Thailand**, 101.473778°E, 17.166639°N, 2017-V-27, collected by Boonsatien Boonsoong.

Distribution: China (Taiwan, Hainan), Thailand.

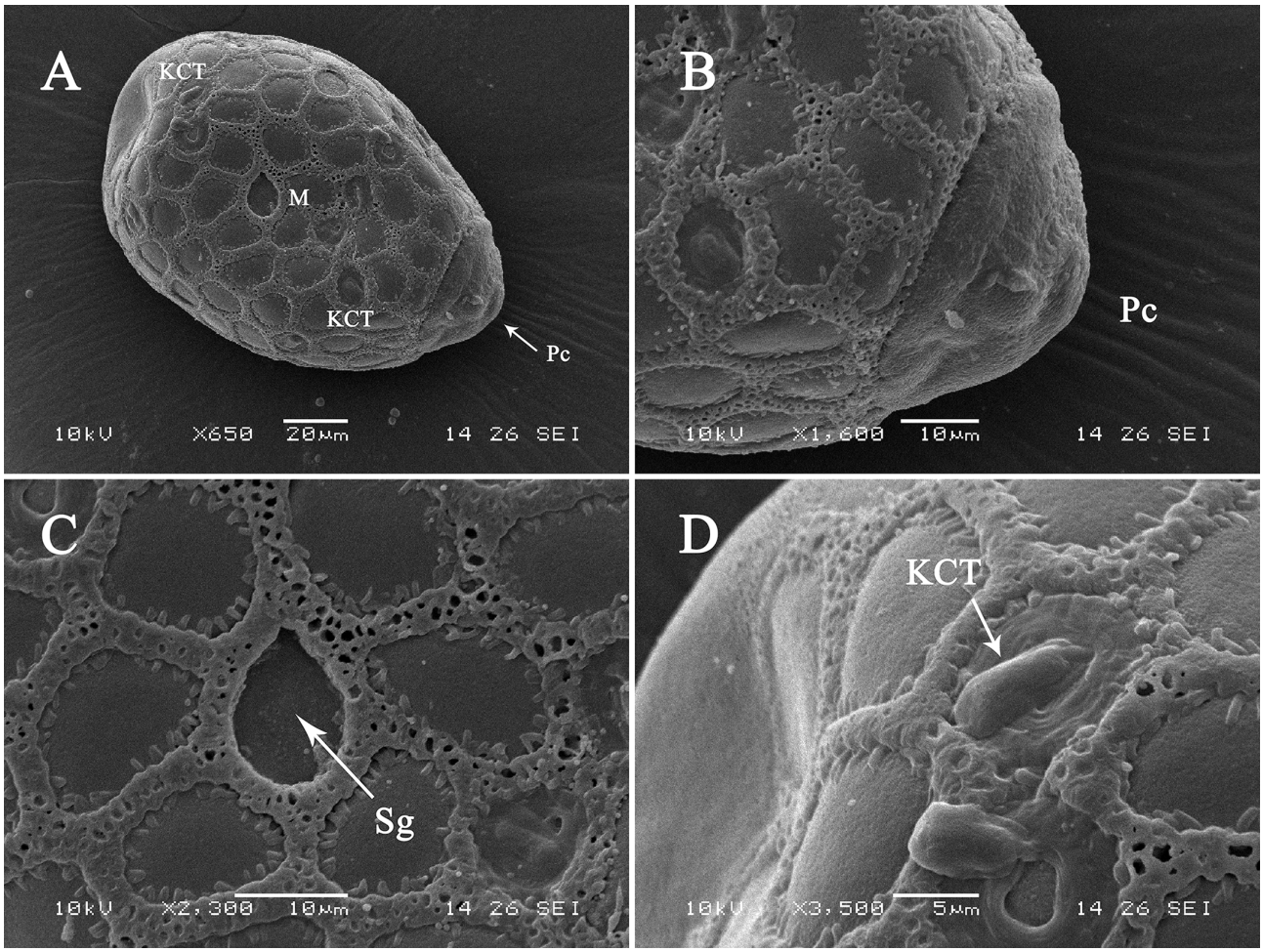

Figure 9. Egg of *Kangella brocha*. **A,** overall view; **B, C, D,** detail view. Abbreviations: KCT, knob-terminal coiled threads; Pc, polar cap; M, micropylar device; Sg, sperm guide.

Discussion

Previously, the species *Kangella brocha* was recorded from two separate places: Chinese Taiwan island and Thailand. Our new finding shows it may have a more continuous and larger distribution.

Kangella was considered to be the single endemic genus of the mayfly taxon in Chinese Taiwan island (Soldán & Yang 2003). The new finding in the Chinese mainland and the previous one in Thailand show that Taiwan has no uniqueness in the generic level of mayflies.

The ephemerellids have diverse feeding habits. Bauernfeind & Soldán (2012) reported the genus *Ephemerella* can be carnivorous, omnivorous or detritivorous by collecting or gathering. Kluge (2004) reported that *Drunella* Needham, 1905 is carnivorous and *Serratella* Edmunds, 1959 and *Teloganopsis* are filtering. Zhang *et al.* (2017) shown the species *Teloganopsis setaceous* has definitely filtering habits because of its forelegs with long filtering hairs.

The typical carnivorous mayflies have enlarged canines but diminished or lost molae, such as *Prosopistoma* Latreille, 1833 (Needham *et al.* 1935), or enlarged forelegs in *Drunella*. In contrast, the typical filter feeders have well-developed molae but shortened canines and hairy mouthparts, like *Isonychia* Eaton, 1871 (Qiang & Zhou 2023). Interestingly enough, the nymphs of *Kangella brocha* have a combination of those two kinds of features in their

mouthparts. First, all parts of their mouthparts are covered with dense hair-like setae, especially the mandibles and maxillae. Second, their mandibles have well-developed canines and molae. In addition, at least four uniqueness can be found in their body: elongated mouthparts, widened prothorax, unspecialized legs and shortened tails. That implies they use their head and mouthparts in feeding but without leg capturing prey or active swimming. So we assume one possibility is that the nymphs of *Kangella brocha* are omnivorous, using setae on mouthparts to filter debris and using enlarged outer incisors to grasp prey.

Another possibility is that the mandibular incisors are related to burrowing instead of feeding. Similar incisors can be found in some *Paraleptophlebia* species (Leptophlebiidae), such as *P. bicornuta* (McDunnough, 1926) and *P. packii* (Needham, 1927) (Needham *et al.* 1935; Bae & McCafferty 1991). Edmunds and McCafferty (1996) observed that *P. bicornuta* can move freely through interstices of stones and *P. packi* can burrow. Those pieces of evidence implied that the nymphs of *Kangella brocha* maybe use their enlarged mandibular incisors to dig burrows or move in the substrate. They may create space to facilitate their filtering. This assumption is also consistent to their smooth body and wide and enlarged head and thorax.

We examined the mouthparts of five nymphs and dissected three to observe the contents in their mouthparts and intestines. Apart from some small grains of sand, there are no other regular and shaped materials that can be recognized or identified. Remarkably, we observed that their maxillae have particle mixtures adhering to or embedded in their crown setae, including sand (Fig. 10). Based on this, we hypothesize that the nymphs of *Kangella brocha* are likely to be filter feeders.

The typical ephemerellids are clingers or crawlers in lotic substrates, like tree leaves or branches in running water or hydrophytes, like spirogyra. *Kangella brocha* may leave their original habitats and can move to open places or use their mandibles to make some, and then filter and/or hunt there.

The elongated mouthparts found in some other lineages of mayflies, such as Siphluriscidae Zhou & Peters, 2003 (Zhou 2016), may result from convergence. The pattern and shape of their mouthparts are totally different.

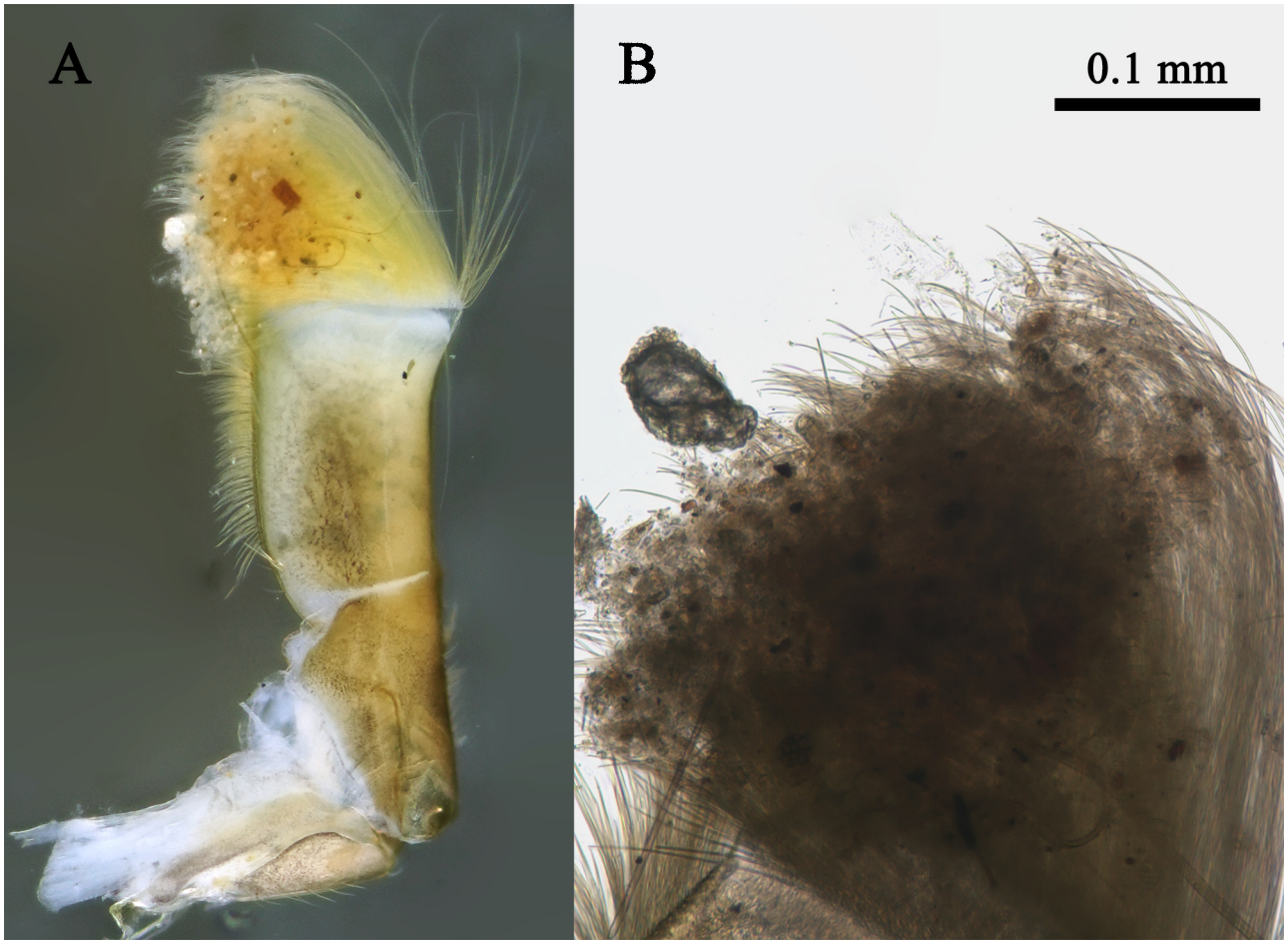

Figure 10. Maxilla of *Kangella brocha*. **A,** overall view; **B,** detail view of crown setae.

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