



A new lophopid genus as another piece in the biogeographical history puzzle of the family in the Sunda Shelf (Hemiptera: Fulgoromorpha: Lophopidae)

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Abstract

A new Lophopidae genus *Binaluana* **gen. nov.** and species *B. emarginata* **sp. nov.** from Palawan are described. Characters are given in order to distinguish this new genus from *Bisma* and *Zejeja* that share general figure with it. The morphological characters are coded for the genus and a new phylogenetic analysis using parsimony is performed. The Lophopidae remain monophyletic and *Binaluana* is placed as sister group of the genus *Bisma*. (*Zejeja* (*Binaluana*+*Bisma*)) is monophyletic and emerges at the base of the *Zejeja*⁺ group. The place of *Binaluana* within the Lophopidae is discussed along with its historical biogeographic origin.

Key words: Auchenorrhyncha, Fulgoroidea, planthopper, new genus, new species, taxonomy, Southeast Asia, island biogeography

Introduction

Actually, 44 genera representing 146 species are described for the Lophopidae, 4 of which are fossils (Bourgoin 2015). Phylogenetic analysis showed that four main monophyletic lineages can be recognised, Carriona⁺ group with its only representative *Carriona* Muir, 1931, Makota⁺, Sarebasa⁺ and Bisma⁺ (Soulier-Perkins 2001). The Bisma⁺ group contains 17 genera and its distribution goes from Sri Lanka to Papua New Guinea and from South China to Australia. *Bisma* Distant, 1906 is found in Sri Lanka, South India and Hainan but the 8 other basal taxa of this lineage are noticeably present in the Malay-Indonesian regions, with *Aluma* Distant, 1909 and *Zejeja* Melichar, 1915 both present in Borneo, *Lapithasa* Melichar, 1914, *Asantorga* Melichar, 1915, *Pseudotyxis* Soulier-Perkins, 1998 and *Pseudocorethrura* Melichar, 1915 respectively endemic to Philippines, Ambon, Java and Sulawesi. *Apia* Distant, 1909 is found in the Malay Peninsula and on the islands Siberut and Sipora and finally *Menosca* Stål, 1870 is more largely distributed to the Philippines, Borneo and Myanmar. The 8 most apical Bisma⁺ taxa are grouped in a clade that extends its geographic distribution in New Guinea and a few adjacent islands with one genus found in Australia (Soulier-Perkins & Stroiński 2013). At a first look, the new genus described here seems to show some resemblances to the genera *Zejeja* and *Bisma*. It was found in Palawan, which is congruent with the general distribution of those basal taxa.

Material and methods

Material. The studied specimen comes from the entomological collection of the Moravian museum in Brno (MZM). Labels reported verbatim with square brackets “[]” indicating individual labels separated by commas.

Preparation and observation. The abdomen of the specimen examined was cut off and cleared for 20 minutes in warm (50°C) 10% KOH with a few drops of chlorazol black (CAS No. 1937-37-7) for dyeing the ectodermic genital ducts based on the method introduced by Carayon (1969). Dissections and cleaning of genital structures were performed in distilled water. Final observations were done in glycerine using a camera lucida attached to a

Olympus microscopes (SZH10). The photos of the habitus were taken using a stereomicroscope Leica MZ 16 with IC3D digital camera; final images were produced using Helicon 5.0 software. The SEM photographs of uncoated specimen were taken in the Laboratory of Scanning Microscopy, MIZ PAS (Warsaw), using a scanning microscope HITACHI S-3400N under Low Vacuum conditions.

Measurements and abbreviations. The following proportions of measurements and abbreviations were made and used in this study:

Total length—measured (in dorsal view) from the apex of head to the apex of tegmina;

A/B—width of vertex measured at posterior margin/length of vertex at midline;

C/E—width of frons at upper margin/length of frons at midline;

D/E—maximum width of frons/length of frons at midline;

F/B—length of pronotum at midline/length of vertex at midline;

G/F—length of mesonotum/length of pronotum at midline;

G/B+F—length of mesonotum/cumulative length of vertex and pronotum at midline;

G/H—length of mesonotum at midline/width of mesonotum between lateral angles;

I/J—length of tegmen measured from the base to the apical margin in median portion/width of tegmen measured from the apex of clavus to the anterior margin.

Terms used for the female genitalia are those of Bourgoïn (1993) and Soulier-Perkins & Bourgoïn (1998). The nomenclature for the tegmina follows Bourgoïn *et al.* (2015).

Morphological phylogeny. The encoding of the characters for *Binaluana*, and the phylogenetic methodology, used to test the place of this genus within the Lophopidae, followed Soulier-Perkins (2001) and Stroiński & Soulier-Perkins (2015). The phylogeny is based on a total of 74 morphological characters, 73 described in Soulier-Perkins (2001) plus 1 character for which the state present is shared by *Binaluana* and *Bisma*. This 74th character is a small keel absent (0) or present (1) on the frons just bellow the vertex margin. Forty three taxa are included in this analysis, 7 outgroups (2 Eurybrachidae, 3 Ricaniidae, 1 Tettigometridae and the genus *Hesticus* Walker, 1862), 35 ingroups as in Stroiński & Soulier-Perkins (2015) plus *Binaluana* gen. nov. The encoding sequence of *Binaluana*'s 74 characters is the following:

0,0,0,0,1,-,1,0,0,1,0,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,1,2,2,0,1,0,-,-,1,0,1,1,2,-,1,1,1,1,0,1,1,?,?,?,?,?,?,?,?,?,?,?,?,?,?,?,?,1.

The cladistic analysis using parsimony was performed using the same software packages as in Soulier-Perkins (2001), PAUP version 3.1.1 (Swofford 1993) and MacClade version 3.07 (Maddison and Maddison 1992). The Bremer support (Bremer 1994) was calculated using the program AutoDecay version 4.0.2 (Eriksson 1999).

Taxonomy. The placement of the genus and species are given at minima in order to place them directly in the family that we expect to be a monophyletic lineage. Since the tribe and sub-family (Emeljanov 2013), they may have belonged, are paraphyletic or polyphyletic, we prefer not to pronounce ourselves.

Taxonomy

Binaluana gen. nov.

(Figs 1–60)

Type species: *Binaluana emarginata* sp. nov., here designated.

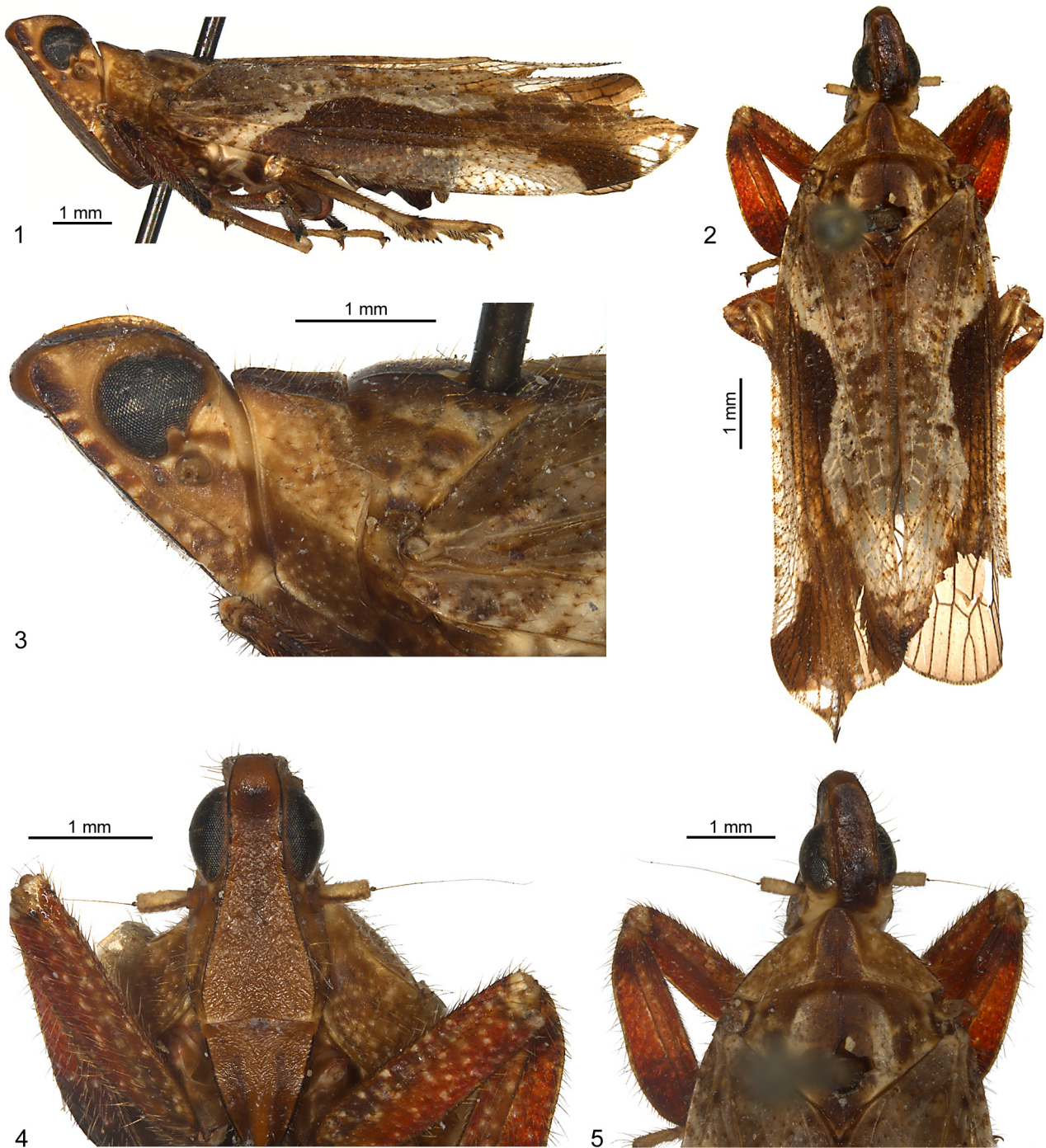
Etymology. Melichar intended to name this genus after the location where it was found, Binaluan. We kept his name *Binaluana*. Gender: feminine.

Diagnosis. *Binaluana* gen. nov. similar to *Zezeja* and *Bisma*, but *Bisma* presents some carinae on the frons, when frons in *Binaluana* and *Zezeja* presents none. *Binaluana* and *Bisma* have a shorter prothorax than mesothorax, with a clear produced disc, when *Zezeja* has a pro- and mesothorax equal in length.

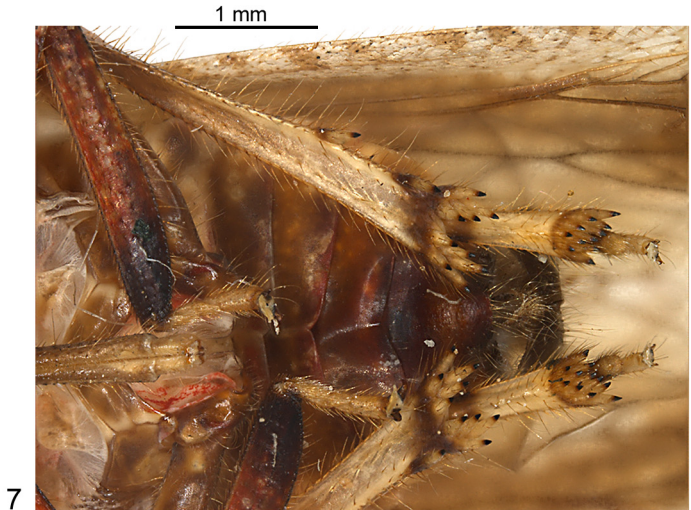
Description. Body elongate and narrow (Figs. 1–2).

HEAD. Head with compound eyes narrower than prothorax (Figs 2, 5 & 12). Vertex longer than wide, flat, without median carina, lateral margins carinate, parallel and elevated, anterior margin obsolete (Figs 4, 15–17). Frons generally flat with the exception of the protuberance just bellow the upper margin, no carinae, lateral margins carinate and continuous from the vertex to the frontoclypeal margin. Frons bottle-shape, with widest part along the

frontoclypeal suture. In lateral view, top of the head higher than the surface of pro- and mesothorax, compound eyes rounded, flattened postero-ventrally, with margin cut out ventrally; ocelli present; foramen of antenna not touching the compound eyes; ocellar and genal carina absent (Figs 1, 3, 13, 18–22). Carinated line starting at the edge of frontoclypeal suture and lateral frontal margin, running toward the ocellar and disappearing (Figs 1–2, 18–22). Pedicel of antenna twice longer than wide (Figs 4–5, 24–27). Sensory plate organs multi-petals shaped, surrounded by strong denticules, present on whole pedicel, arranged in lines (Figs 24–29); trichoid sensilla present (type 1 and 2). Clypeus strongly carinate laterally without median carina (Figs 4, 6 & 15). Rostrum reaching metacoxa, apical segment distinctly shorter than subapical one (Figs 6 & 41).



FIGURES 1–5. *Binaluana emarginata* gen. et sp. nov., female. (1) Habitus, lateral view; (2) same, dorsal view; (3) anterior part of body, lateral view; (4) anterior part, frontal view; (5) anterior part of body, dorsal view.



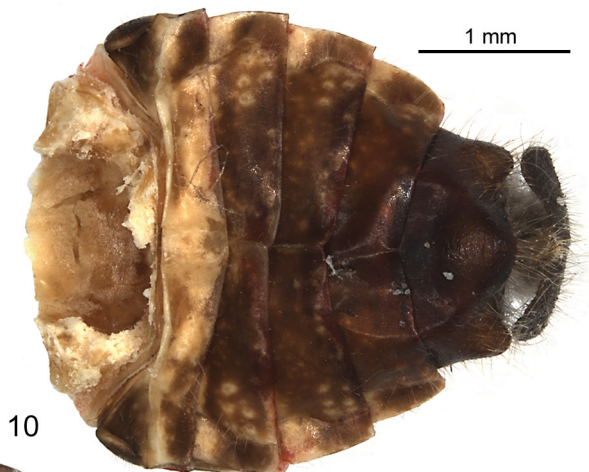
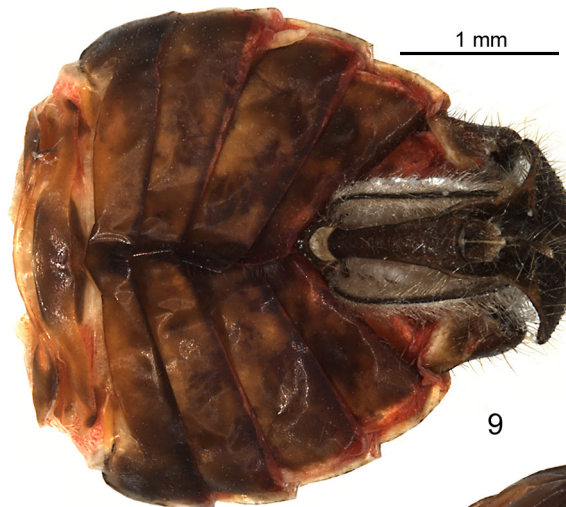
N. Palawan
Binaluan
Nov.-Dec. 1913
leg. G. Roethcher

Binaluana ♀
emarginata
n. sp.

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Nomen invalidum
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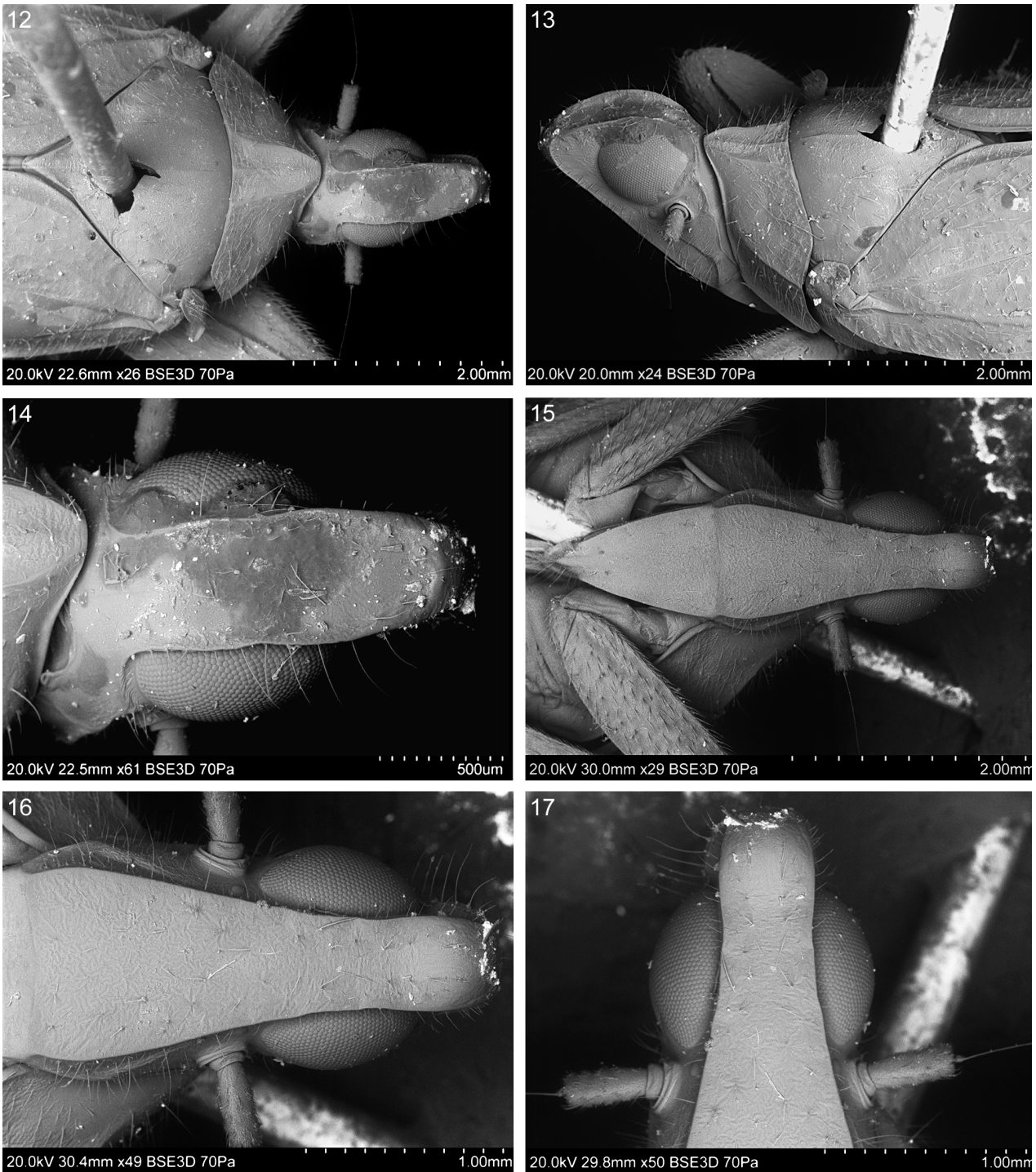
Collectio
Dr. L. Melichar
Moravské museum Brno

1 cm

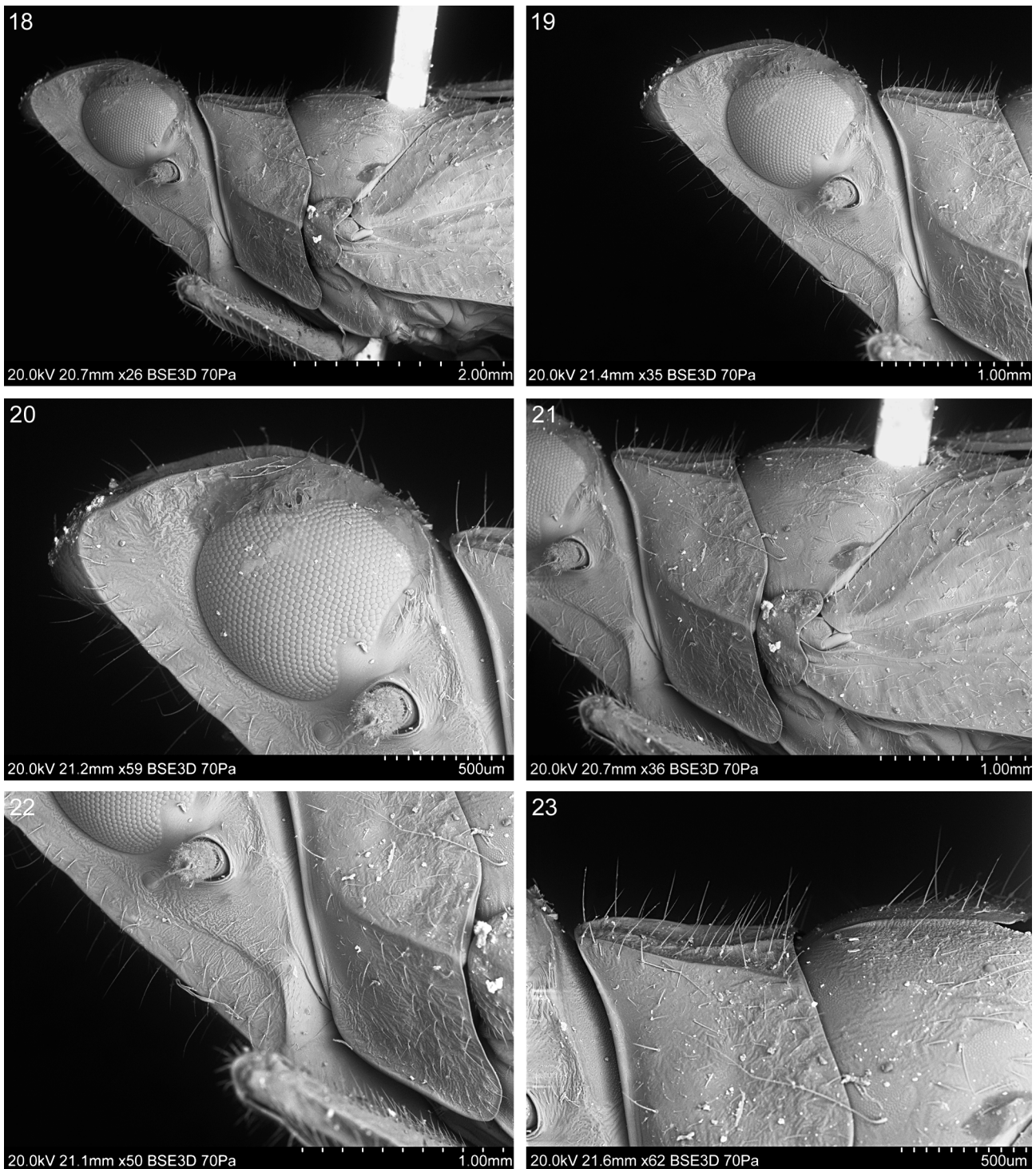


FIGURES 6–11. *Binaluana emarginata* gen. et sp. nov., female. (6) Head, rostrum and legs, ventral view; (7) abdomen and hind legs, ventral view; (8) labels; (9–11) abdomen: (9) dorsal view, (10) ventral view, (11) posterior view.

THORAX. Pronotum anteriorly rounded, median disc tricarinate, carinae connected anteriorly and reaching posterior margin (Figs 2, 5, 12–13). Median disc elevated and flattened, slightly protruding anteriorly. Strong carina present on lateral part of pronotum (Figs 18–19, 21–22). Posterior margin widely rounded. Mesothorax with a single median carina starting on the anterior margin but not reaching the scutelum. Pro- and mesothoracic legs flattened, but not foliaceous, with femur and tibia of the same length, prothoracic leg more flattened than mesothoracic one (Figs 6, 36). Metathoracic leg with tibia longer than femur. Tibia with 2 lateral spines on the lower half, row of large apical teeth present, with median diastemma. First tarsal segment bearing apical spines organised in a triangular area, second tarsal segment without any spine reduced into a small rounded lobe (Figs 7, 37–41).



FIGURES 12–17. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (12–13) Anterior part of body: (12) dorsal view, (13) dorso-lateral view; (14) vertex, dorsal view; (15) head, frontal view; (16–17) frons, frontal view.



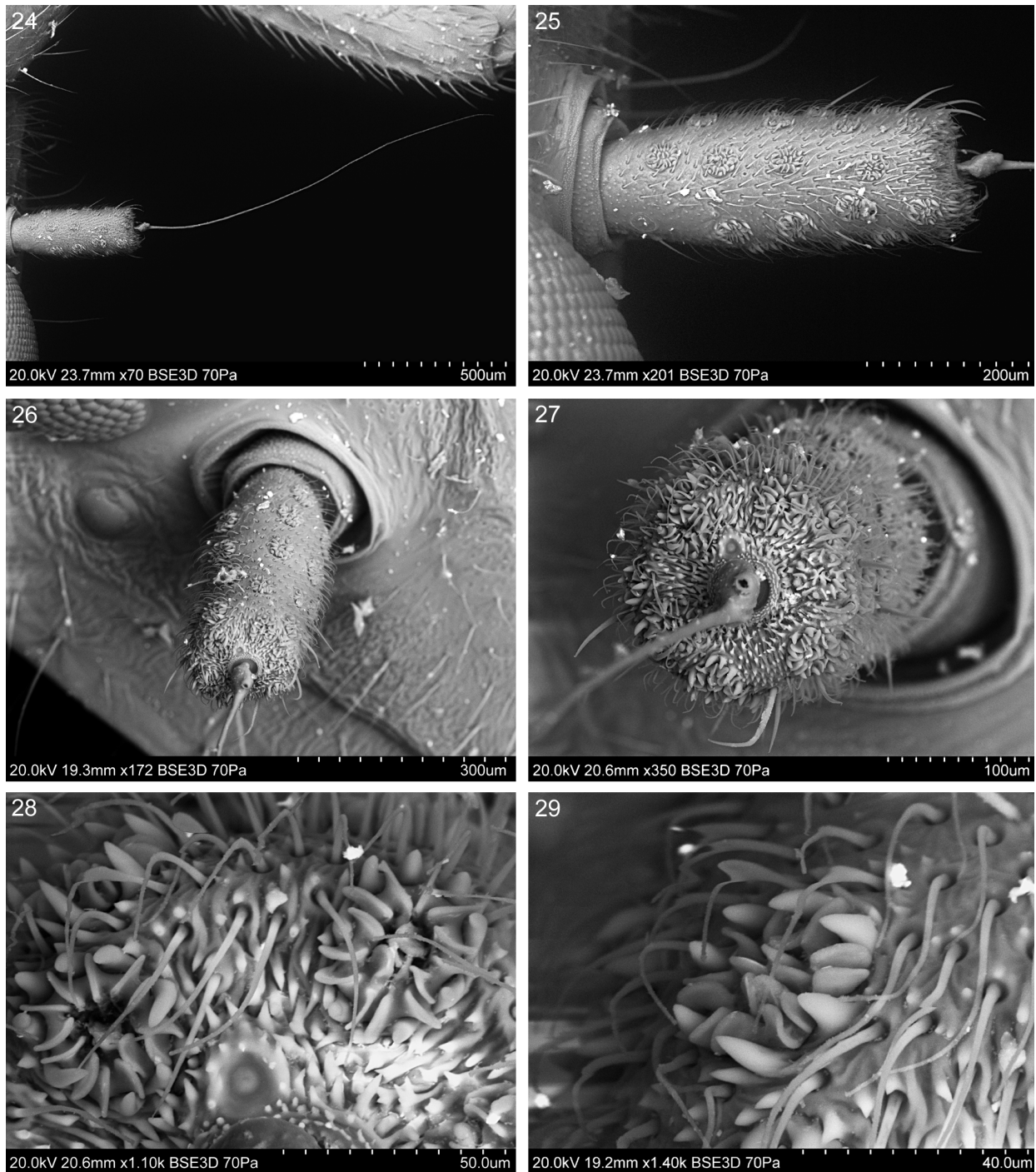
FIGURES 18–23. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (18) Anterior part of body, lateral view; (19) head and pronotum, lateral view; (20) upper part of head, lateral view; (21) pronotum and mesonotum, lateral view; (22) lower part of head and pronotum, lateral view; (23) upper part of pronotum and mesonotum, lateral view.

TEGMINA (Figs 1–2, 30–35). Tegmen elongate, flattened, membranous, completely covered with setae, on and between veins. Costal margin almost parallel to postclaval margin. Costal area narrow at the base and getting wider toward the apex, reaching the level of claval apex, transversal veinlets present all along it. Postcostal cell with veinlets. Basal cell much narrower than long. ScP+R+MA leaving basal cell by a long common stem. Forking of the veins, leaving the basal cell, is done in the following order: ScP+RA, CuA and MP. ScP+RA forking almost at same level than secondary forking of RP and both a little before the end of costal area. MP forking before ScP+RA

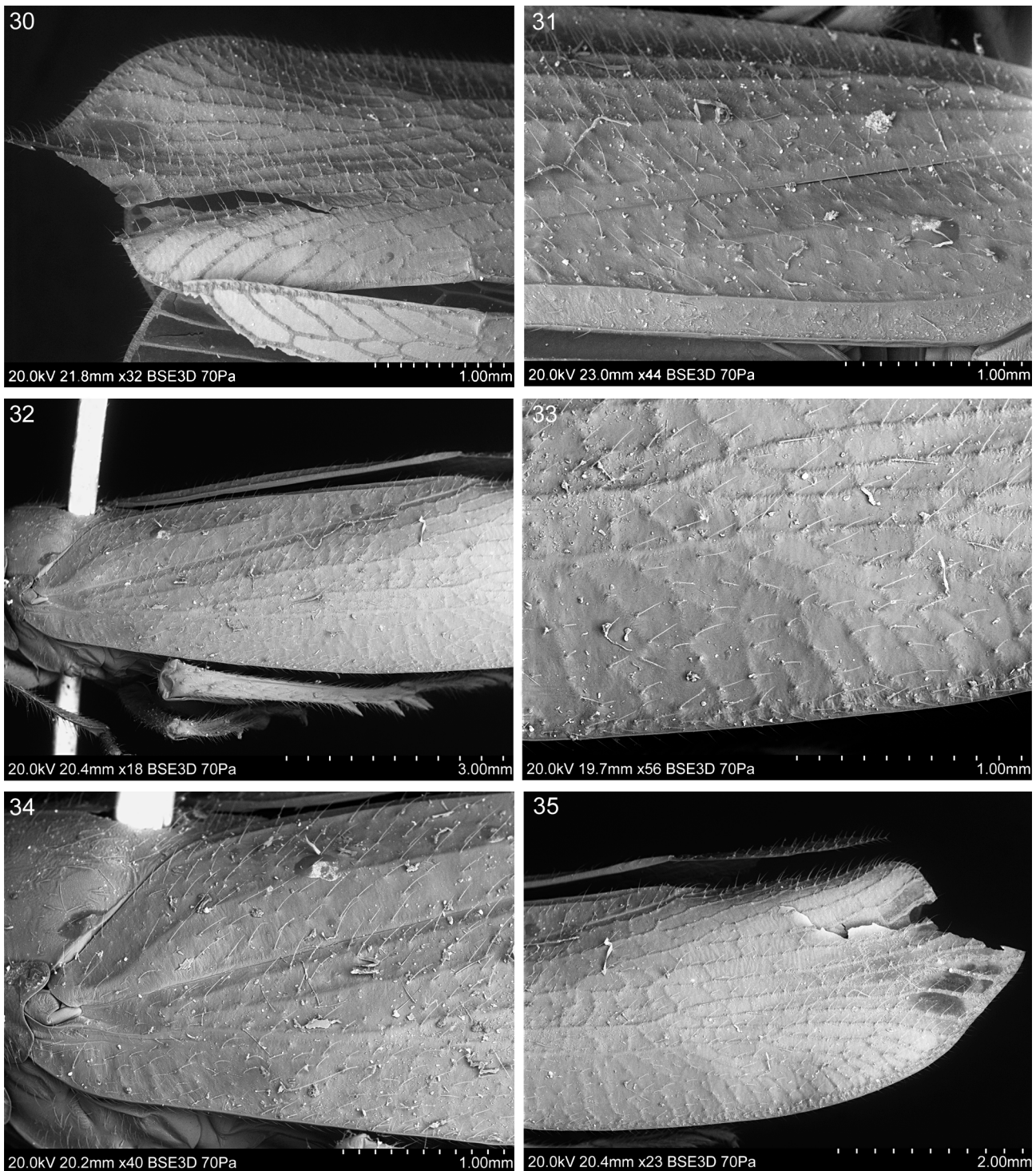
forking. MP_{1+2} forking before MP_{3+4} and not forking any further. CuA forking a little later than fusion of $Pcu+A_1$, all CuA terminals reaching postclaval margin. Transverse veinlets present in radial and median cells, but weakly visible. Few transverse veinlets present in apex of cubital cell. Transverse veinlets between CuP and Pcu and $Pcu+A_1$.

MALE. Unknown.

FEMALE TERMINALIA. Seventh abdominal sternite bearing a protuberance ventrally (Figs 7, 10, 44–45, 48–50, 53–55), anterior margin convex anteriorly and posterior margin with lateral corners protruding. Medio-ventral extension at the apex of the anal tube absent. Anal tube bearing two large lobes apically, oriented postero-ventrally and covering the gonoplags (Figs 9–11, 42–47, 56). Small longitudinal carina along the ventral part of anal tube. Dense and long setae covering the anal tube.



FIGURES 24–29. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (24–27) Antenna: (24–25) dorsal view, (26) dorso-lateral view, (27) apical view; (28–29) plate organs.



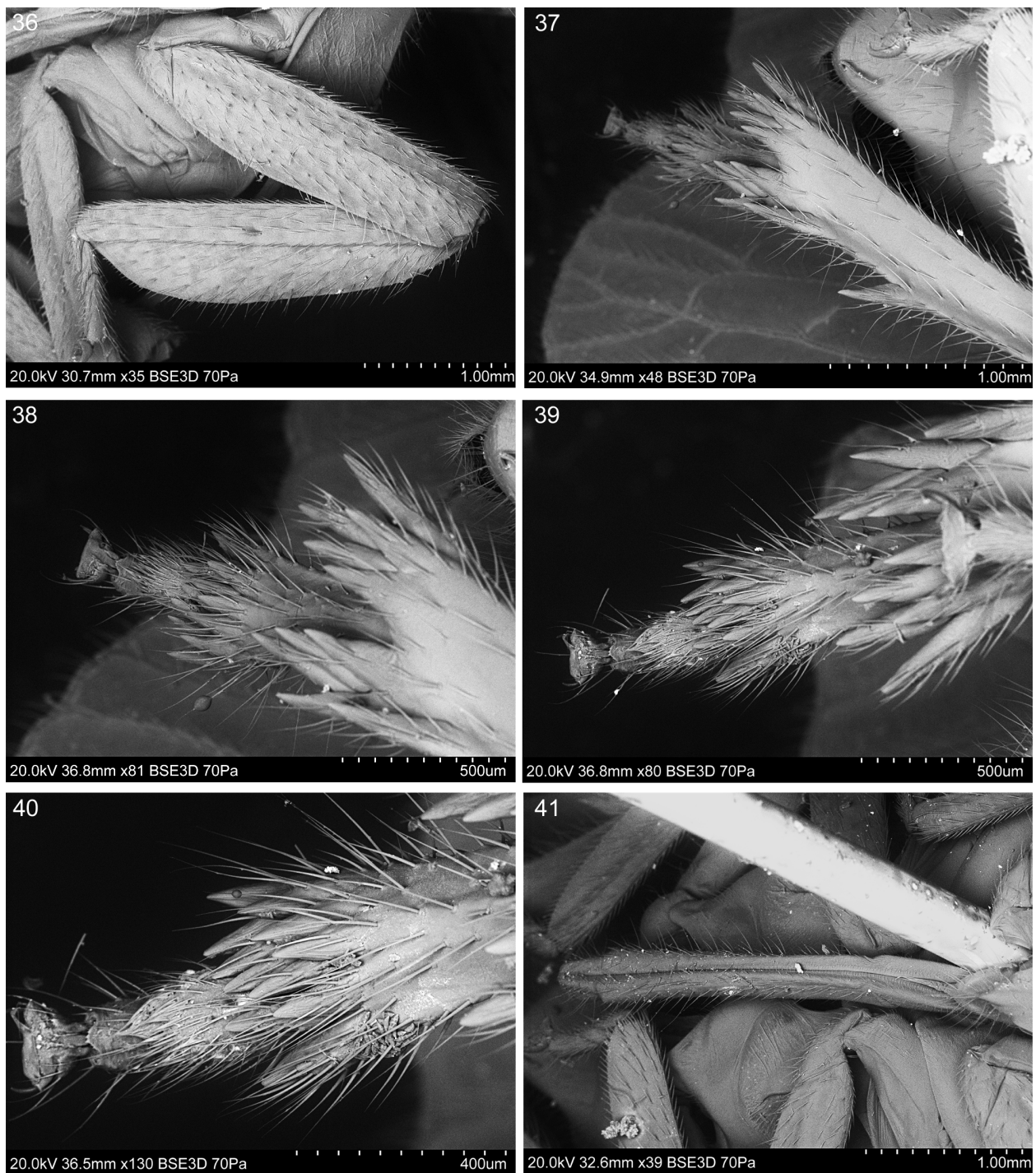
FIGURES 30–35. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (30–35) Tegmina.

Gonoplasts, unilobate elongate-rounded and bearing dense setae internally and externally (Figs 42–45, 52, 57). Gonocoxae IX present, gonapophysis IX clearly visible when for the other Lophopid genera they are strongly reduced and hardly observable sometime (Fig. 57). *Bursa copulatrix* with a single pouch with visible cells (Fig. 58).

Spermatheca well developed, *ductus receptaculi* distinctly longer than *diverticulum ductus*, ribbed. *Diverticulum ductus* smooth, bulbous (Figs 59–60).

As for all Lophopidae, gonospiculum absent.

Distribution. Palawan (The Philippines).



FIGURES 36–41. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (36) Fore femur and tibia, ventral view; (37–40) hind tibia and tarsal segments; (41) rostrum, ventral view.

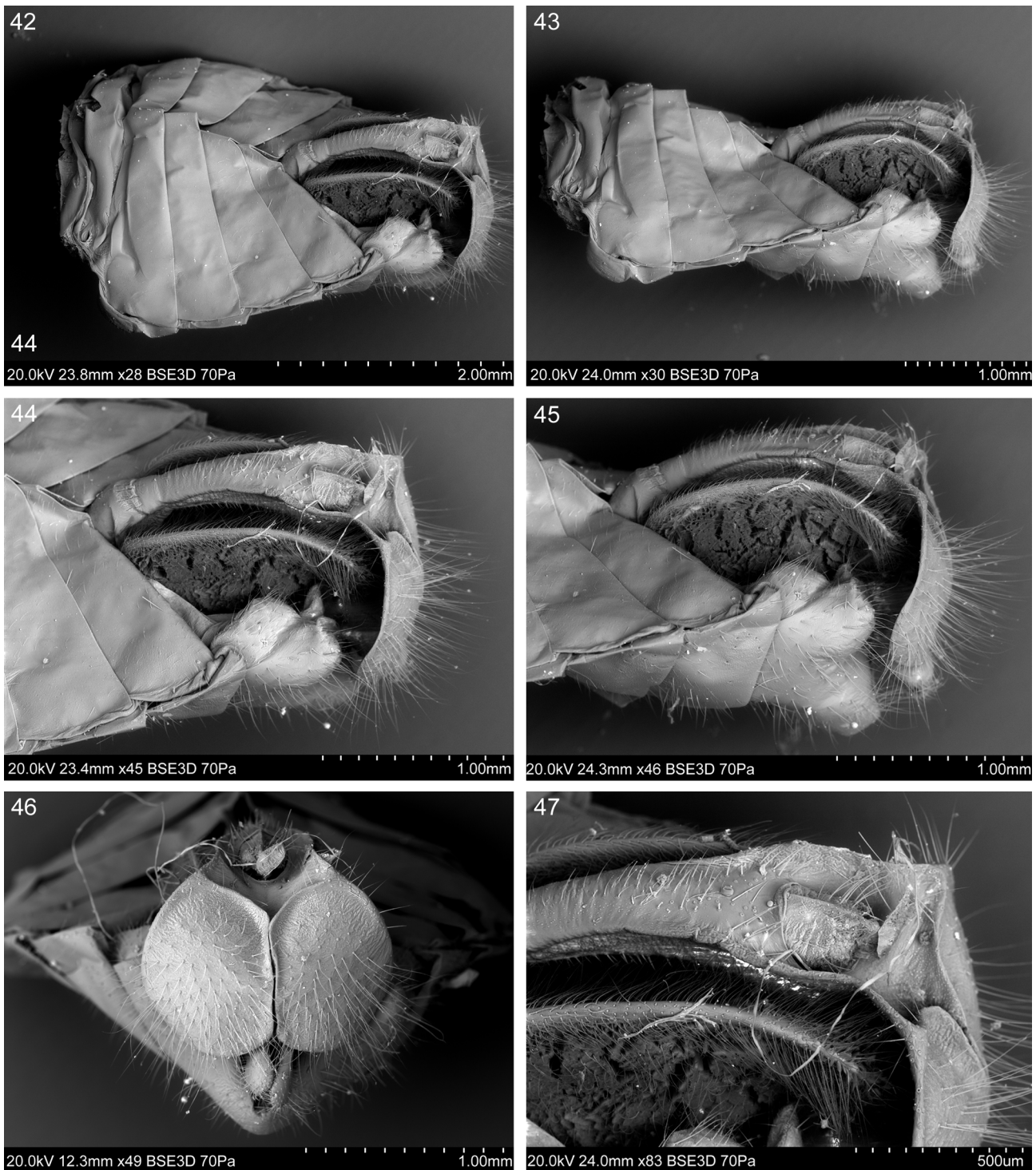
***Binaluana emarginata* sp. nov.**

(Figs 1–60)

Etymology. Melichar intended to name this species “emarginata”, as written on the label and refers to the characters of frons (without carinae). We kept the name he had chosen.

Diagnosis. Coloration and pattern on dorsal view on the tegmina draw a whitish hastate leaf shaped figure.

Description. Total length 1.24 cm.



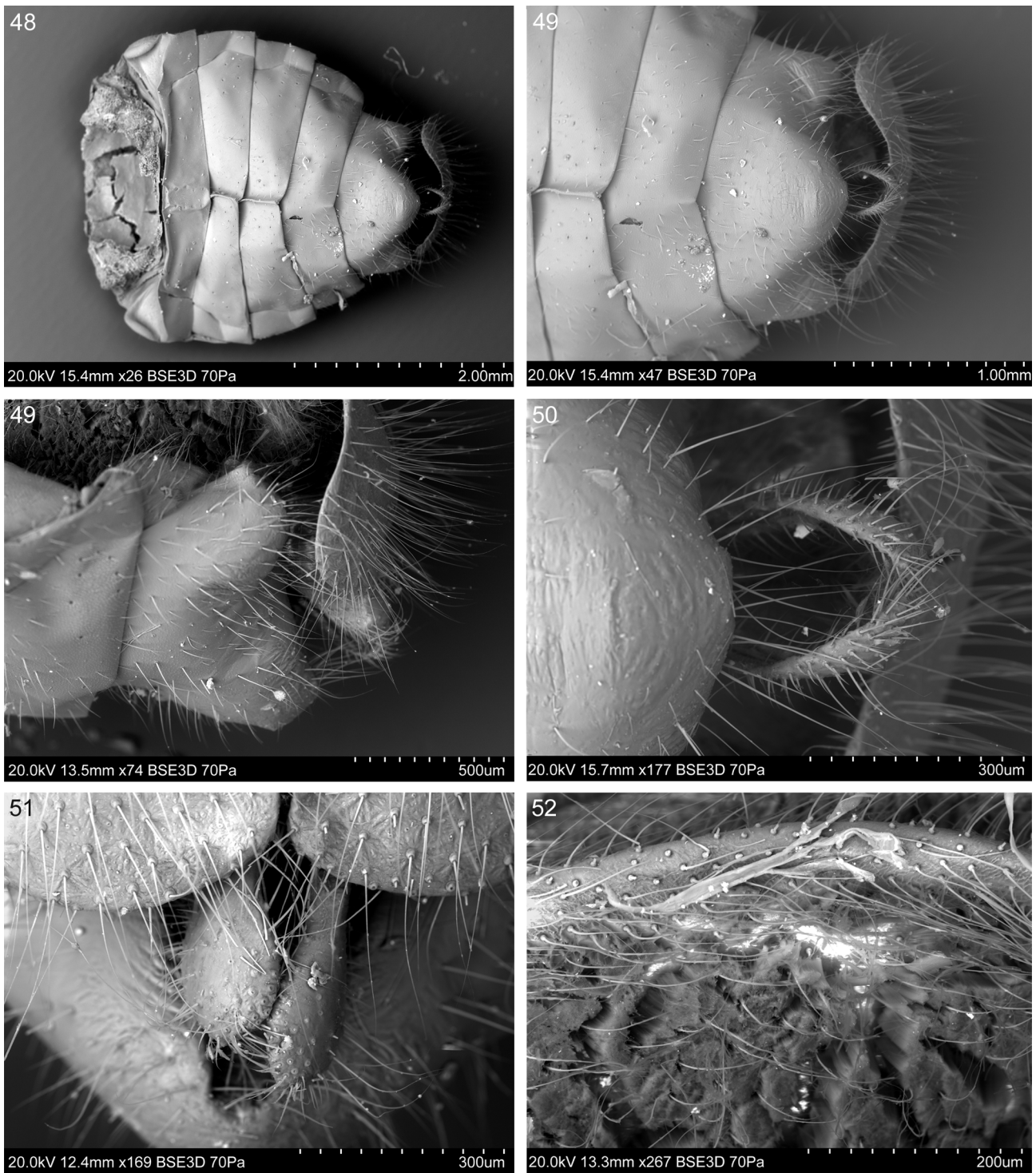
FIGURES 42–47. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (42–43) Abdomen: (42) dorso-lateral view, (43) lateral view; (44–45) terminalia: (44) dorso-lateral view, (45) lateral view; (46) anal tube, posterior view; (47) median part of anal tube, dorso-lateral view.

HEAD. Vertex with anterior margin rounded anteriorly. Vertex: proportion A/B = 0.33. Frons: proportion C/E = 0.15; proportion D/E = 0.39.

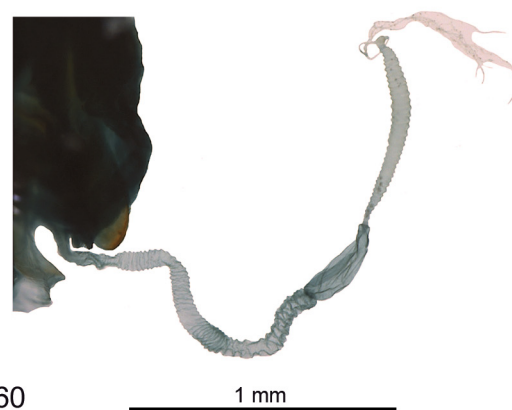
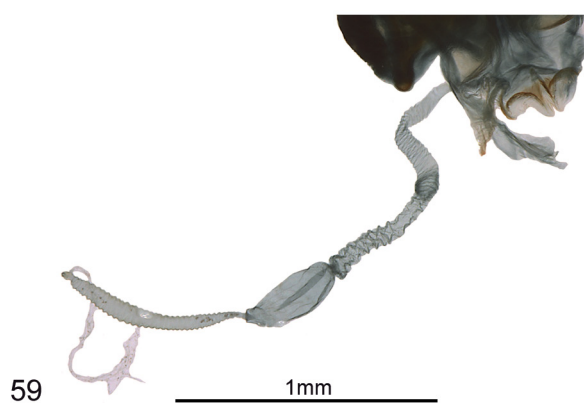
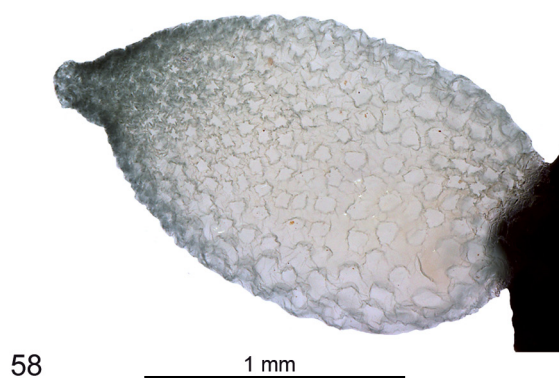
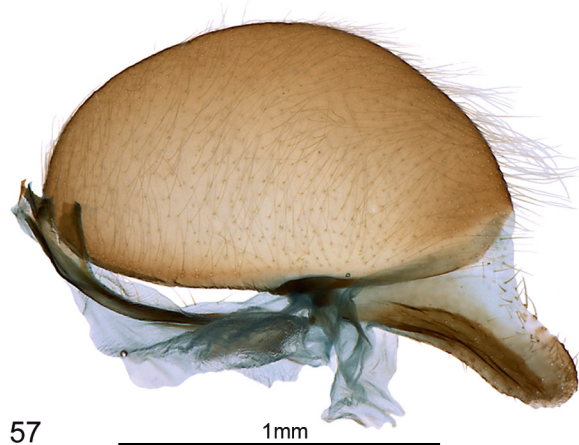
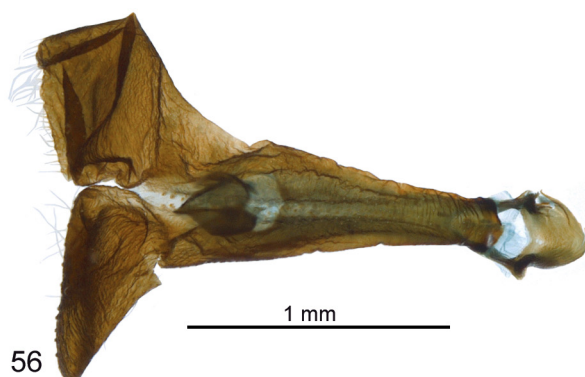
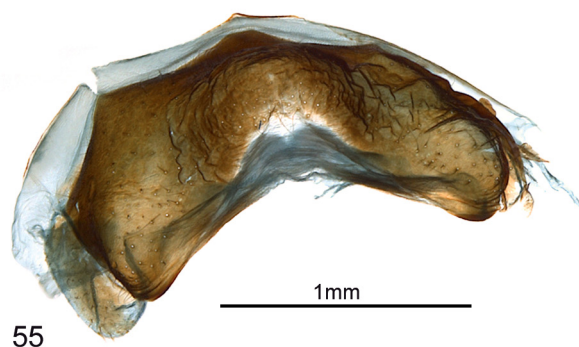
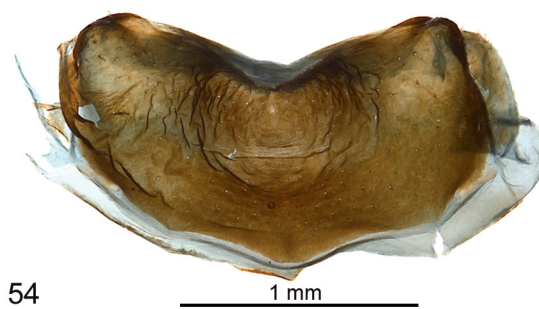
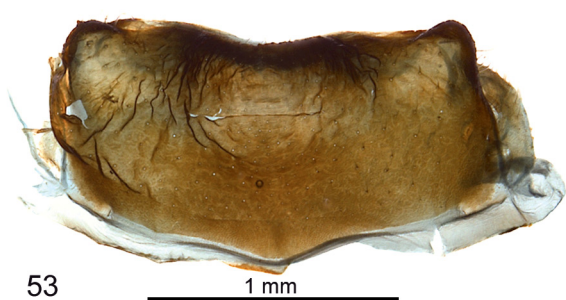
THORAX. Pronotum: proportion F/B = 0.53. Mesonotum: proportion G/F = 2.12, proportion G/B+F = 0.73, proportion G/H = 0.68. Tegmina: proportion I/J = 3.51.

MALE. Unknown.

FEMALE TERMINALIA. Seventh abdominal sternite almost rectangular when seen from below. The protuberance observed on the middle of the sternite is large and rounded with an important concavity visible above when viewed from behind.



FIGURES 48–52. *Binaluana emarginata* gen. et sp. nov., female, SEM images. (48) Abdomen, ventral view; (50) terminalia, ventral view; (49) same, lateral view; (50–51) gonapophysis VIII: (50) ventral view, (51) posterior view; (52) gonoplac with wax secretion, lateral view.



FIGURES 53–60. *Binaluana emarginata* gen. et sp. nov., female. (53–55) Pregenital sternite: (53) ventral view, (54) ventro-posterior view, (55) posterior view; (56) anal tube, dorsal view; (57) gonoplac and gonapophysis VIII, external view (lateral); (58) bursa copulatrix, lateral view; (59–60) spermatheca.

Discussion

Placement in the phylogeny. With the description of a new genus, we were tempted to include it in the matrix in order to get an idea of its place within the phylogeny of the group. It is what we already done with the genus *Venisiella* (Stroiński & Soulier-Perkins 2015). Here, we described *Binaluana* and proceed to its inclusion into analysis and phylogeny scheme as for the previous genus. However, here it was not possible to provide the male characters since only a female specimen was available for the description of the new genus. Characters can be optimised but loss of resolution in the phylogeny could be expected. When making a cladistic analysis, it is generally said that the number of morphological characters used in the matrix should be at least 2 times plus 1 higher than the number of taxa included in the analysis. In order to get close to this situation we tried to find some new characters to include in the matrix. We described a 74th character, its presence was observed on *Binaluana* when before it was known only for *Bisma*. Since it was autapomorphic for this genus, it was not included in the original matrix. (*Zeleja* (*Bisma* + *Binaluana*)) is a monophyletic lineage emerging as the sister group of the rest of *Zeleja*⁺ group, *Lapithasa*⁺, which is a monophyletic lineage containing 15 genera.

About India and Sundaland throughout time. Even if Palawan is part of the Philippines, it is often said that it shares more affinities with Borneo and the Sundaland than with most of the Philippines islands (Huxley 1868). However some recent studies document that: populations on Palawan to be closely related to taxa from the oceanic Philippines (Esselstyn *et al.* 2010). The biologic affinities of fauna between this composite island: Palawan and the Sunda Shelf and/or the Philippines is more complex than expected and depending of the age of the studied lineages (Lohman *et al.* 2011, De Bruyn *et al.* 2014) it is to be expected that they have crossed or not the Huxley line.

North Palawan block seems to have undergone the same geological events than Mindoro (McCabe *et al.* 1987; Almasco *et al.* 2000), both were part of a landmass, finding their origins on the southern border of China and brought southward by the opening of the South China sea (e.g. Holloway 1982). At one point they must have collided with the actual remainders of the Philippines Archipelago (Almasco *et al.* 2000). South Palawan seems to find its origin more south from its actual latitude like North Sabah. Both have experienced a counter clockwise rotation and a northward migration (Almasco *et al.* 2000). According to Hall (2013), it is reasonable to suppose that most Sundaland was an emergent region from the late Cretaceous to middle Eocene.

From 80 Mya, the Indian plate moved north. It collided at about 55 Mya, west of Sumatra (Hall 2013), which may have provided an exchange route between the Sundaland and India in the Paleocene (Ali & Aitchison, 2008). India continued to move north and collided with Asia in the Eocene (Hall 2012), which allowed exchanges of fauna and flora with Southeast Asia as early as 55 Mya, or later on from 35 Mya, depending on the authors (Hall 2013).

Biogeographic scenario for (*Zeleja* (*Bisma* + *Binaluana*)). Spread across the Sundaland with *Zeleja* in Borneo and *Binaluana* in Palawan; this group reach, on the west, Sri Lanka with the genus *Bisma*. The lophopids found their origins in Southeast Asia (Soulier-Perkins 2000). From this territory it is likely that the ancestor of the group moved and colonised the Malay Peninsula and get to the Sundaland using this road of migration. From the Sundaland the group diversified and when India became reachable throughout the west of Sumatra the ancestor of *Bisma* emigrated on it. At this point of knowledge of the group, this hypothesis is the most parsimonious for the lineage considered.

Acknowledgment

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