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A NEW SPECIES OF *PHLEBOPTERUM* STÅL, 1854 (HEMIPTERA: FULGOROMORPHA: FLATIDAE) FROM THE TAPIA WOODLANDS OF MADAGASCAR

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Abstract.— A new species of the family Flatidae (Sisciini) *Phlebopterum tapiae* **sp. nov.** from Madagascar is described and illustrated. Additionally, environmental affinities of newly described species are discussed. A key to all Madagascan *Phlebopterum* Stål species is also provided.

Key words.— Entomology, taxonomy, Hemiptera, Fulgoromorpha, Flatidae, *Phlebopterum*, new species, Madagascar.

INTRODUCTION

The family Flatidae is one of the largest families of planthoppers (Fulgoromorpha, Hemiptera) with 1446 described species in 299 genera and 12 tribes, which are worldwide in distribution (Bourgoin 2012). In Afrotropic the family is represented by 231 species in 74 genera. These phytophagous insects are highly diverse in terms of their colour and size (from 4.5 up to 32 mm), found on all continents, but especially common and abundant in the tropics (O'Brien 2002). They are divided into two subfamilies – Flatinae and Flatoidinae, which can be easily distinguished from each other by the shape of the body. Flatinae are flattened laterally, in contrast to Flatoidinae which held their wings horizontally (O'Brien and Wilson 1985).

The state of knowledge on Madagascan flatids is deeply unsatisfactory, taking into account that the last comprehensive monograph was published at the beginning of 20th century (Melichar 1901, 1902) and a few short papers were released after years (Synave 1956, 1966). Madagascan Flatidae consists presently of 17 genera with 39 species of Flatinae and 11 genera with 37 species of Flatoidinae, however, it is estimated that the total number of species might be quadrupled (Metcalf 1957, Stroiński and Świerczewski 2011, Stroiński and Świerczewski 2012a). The tribe Sisciini Melichar, 1923 is a small flatid tribe covering four genera restricted to Afrotropic: *Latois* Stål, 1866, *Euryprosthius* Karsch, 1890, *Phlebopterum* Stål, 1854 and *Aulophorina* Strand, 1928 and one genus *Siscia* Stål, 1870 from Oriental Region (Philippines).

The flatid planthopper genus *Phlebopterum* was established by Stål (1854) for *Phlebopterum praemorsum* Stål, 1854 from Sierra Leone in Western Africa. Later, Melichar (1902) added a further three species: *Phlebopterum angulatum* Melichar, 1902 from Madagascar, Nossi-Be and Sainte Marie islands, *Phlebopterum viridis* Melichar, 1902 confined exclusively to Madagascar and *Phlebopterum maculatum* Melichar, 1902 from northern Celebes (Indonesia: Sulawesi). Moreover, Schmidt (1912) described *Phlebopterum angulinum* Schmidt, 1912 from Nyasaland and Tanganyika (presently Malawi and Tanzania, respectively). Later, Medler (1990) established *Poeciloptera solita* Walker, 1851 described from Ghana as 'a senior synonym of *Phlebopterum praemorsum* Stål, thereby becoming the type-species of *Phlebopterum* Stål'.

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He transferred to this genus also *Leptoflata seydeli* Lallemand, 1931, described from Congo, resulting in *Phlebopterum seydeli* (Lallemand, 1931) (Medler 1993). Finally, the previously mentioned *Phlebopterum maculatum* Mel. was placed by Metcalf (1957) in the genus *Sephena* Melichar, 1902 and by Medler (1991) in the genus *Miniscia* Medler, 1991.

Below a new species of the genus *Phlebopterum* Stål from south-central Madagascar is described. A key to the species known from Madagascar is also given.

Material and methods

Preparations and illustrations

The abdomens of the specimens examined were removed and cleared for 30 min. in warm (50°C) 10% KOH with a few drops of chlorazol black to stain the ectodermic genital ducts based on the method introduced by Carayon (1969) and Bourgoin (1993). Dissections and cleaning of genital structures were performed in distilled water. Final observations and drawings were done in glycerin using a camera lucida attached to a light microscope. The photos of the habitus and male and female genital structures were taken using a stereomicroscope Leica MZ 16 with digital camera IC 3D; final images were produced using Synoptics Automontage software. The SEM photographs of uncoated specimens were taken in the Laboratory of Scanning Microscopy, MIZ PAS (Warsaw), using a scanning microscope HITACHI S-3400N under low vacuum conditions. The nomenclature of the male genitalia follows Bourgoin (1988) and Bourgoin and Huang (1990), and for the female genitalia Bourgoin (1993).

Measurements and abbreviations

The following proportions of measurements made with an ocular micrometer and abbreviations were used in this study:

Total length – measured (in dorsal view) from the apex of head protrusion to the apex of tegmina,
A/B – width of vertex measured at anterior margin/length of vertex measured at midline,
C/E – width of frons between eyes/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.

Vein nomenclature after interpretation proposed by Szwedo and Żyła (2009).

Material

The material studied comes from the collection of the California Academy of Sciences in San Francisco, USA (Dr N. Penny). Depositories of material are abbreviated as follows:

CAS – California Academy of Sciences, Department of Entomology, San Francisco (USA);
MIZ – Museum and Institute of Zoology PAS, Warszawa (Poland).

Taxonomy

Phlebopterum tapiae sp. nov.
(Figs 1–59)

Etymology. The specific epithet comes from the name of the forest formation in which the species occurs.

Diagnosis. *Phlebopterum tapiae* differs from other species belonging to the genus by the pattern of coloration (dark brown band along dorsal part of head, thorax and clavus) and the structure of the male genitalia: genital style deeply incised (V-shaped), dorsal part of periandrium with well sclerotised, bifurcated process oriented ventro-basad.

Description. Total length 8.00–10.20 mm.

Head with compound eyes (in dorsal view) a little narrower than thorax (Figs 1–3, 6–7).

Vertex transverse, separated from frons, distinctly wider than long at midline, proportion A/B = 4.00–4.75; posterior part partly covered by pronotum (Figs 2–3, 6, 12, 13); anterior margin as suture deeply incised medially, posterior margin almost straight, lateral margins straight and parallel; disc of vertex in median portion convex, without carinae (Fig. 6).

Frons (Figs 8–13) the same length as width, the widest between compound eyes, proportion C/E = 0.98–1.13, proportion D/E = 0.98–1.13; frons with sharp and wide protrusion in the upper part of head – between anterior margin of vertex and lateral carinae; lateral carinae in the form of semicircle, a bit surpassing the upper margin of compound eyes; protrusion with lateral ridges, apex of protrusion (in lateral view) above level of vertex; disc of frons without median carina; lateral margins of frons carinate and elevated,

in frontal and lateral view arcuate (Figs 8–10); disc of frons depressed, irregularly rugose in upper part, with sensory and excretory organs (Figs 10–11).

Antennal segment II (pedicel) a bit longer than wide, wider at apex, sensory organs located at the top of pedicel, in shallow depression, and partly at upper surface (Figs 14–17). Compound eyes oval with very small callus at lower posterior margin, lateral ocelli present.

Frontoclypeal suture arcuate; clypeus without carinae, median portion convex (Figs 5, 8). Rostrum reaching hind coxae; apical part a bit shorter than the basal one.

Thorax. Pronotum (Figs 2–3, 6–7) longer at midline than vertex (proportion F/B = 1.45–1.80); anterior margin in lateral view a bit lower than posterior margin; anterior margin carinate, in dorsal view shallowly incised medially, partly covering posterior margin of vertex; posterior margin concave; disc depressed medially, irregulary rugose, without carinae; lateral parts of pronotum elongate-triangular with conical postocular eminences.

Mesonotum (Figs 2, 7) deltoid, proportion G/F = 4.56–5.00, G/B+F = 2.57–3.26, G/H = 0.96–1.08; in lateral view at the same level as posterior margin of pronotum; lateral angles placed about 1/3 of the length of mesonotum at midline; median part strongly elevated, separated from lateral parts by two longitudinal carinae reaching posterior margin.

Tegmen (Figs 1, 18–23) subrectangular, membranous, flat, surface smooth, proportion I/J = 1.81–2.11; costal margin – 2/3 arcuate, posterior part almost straight; costal angle rounded; apical margin straight; sutural angle right; postclaval sutural margin straight; costal area narrower than costal cell at midline, about the same width at its length, with numerous transverse veinlets, end placed before end of clavus; costal cell tapering apicad, with sparse net of veinlets; basal cell about twice as long as wide.

Longitudinal vein Sc+R arises as extremely short common stem from basal cell, Sc+RA strong and basally elevated. M leaving basal cell with a long stalk, but shorter than CuA stalk. First fork of Sc+RA after end of costal area; first fork of RP before end of costal area. Location of M_{1+2} fork variable: before, at the same level or a bit after RP fork; M_{3+4} fork after M_{1+2}. CuA diverging far after the level of M fork. Sc+RA ending with 5–6 terminals, RP with 8–9 terminals, M_{1+2} with 12–13 terminals, M_{3+4} with 8 terminals, CuA with 7–10 terminals ending at postclaval margin.

Irregular net of numerous transverse veinlets starting from basal part of tegmen; nodal line absent; one apical line present, apical cells elongated, 3–4 times longer than wide; tubercles present mainly on costal area, between Sc+RA, RP and M veins and on clavus. Claval veins slightly elevated, connected a little before end of clavus; transverse veinlets present.

Femora shorter than tibiae (Fig. 24); fore and middle tibiae rectangular in cross section with carinate margins; hind tibia arcuate with 2 lateral spines after half of length, row of 6–7 apical teeth in formula 2 (longer) + 5–6 (shorter); basitarsomere (Fig. 25) as long as cumulative length of second and hind tarsomeres, with arcuate line of 8–9 apical teeth, lateral teeth larger than internal.

Male genitalia (Figs 26–41). Anal tube (in lateral view, Figs 26–27, 36) elongated and 'broken' about middle point; basal part same width as apical; ventral and dorsal margin of basal part subparallel; of apical part arcuate. Anus placed about midlength. Anal tube (in dorsal view, Fig. 28) elongated; basal part distinctly narrower than widened apical part.

Pygofer (in lateral view, Figs 26–27, 36) higher than wide; dorsal part distinctly narrower than the ventral one, posterior margin arcuate. Posterior-dorsal angle without process, bluntly rounded.

Genital style (in lateral view, in direct observation, Figs 26–27, 36) deeply incised (V-shaped); dorsal and ventral parts tapering apicad, dorsal part with distinct and short capitulum; genital styles (in ventral view) connected basally.

Phallic complex (Figs 30–35). Periandrium (Figs 37–39) elongated, basal part the same width as apical part; lateral split reaching about midlength; dorsal part a bit longer than ventral, divided into two lateral and two dorsal lobes; lateral lobes well-sclerotized and widened, apically bluntly rounded, dorsal lobes membranous with spiniferous microsculpture; dorsal part with well sclerotised process oriented ventro-basad, bifurcated close to base; internal arm distinctly shorter than external; ventral part with medially placed, elongated and narrow keel.

Aedeagus s.s. (Figs 40–41) with shaft as long as dorsal part of periandrium, weakly arcuate, open dorsally; lateral parts well-sclerotised with posterior-ventrad bulb-like appendage near the apex; ventral parts membranous with short split.

Female genitalia (Figs 42–56). Pregenital sternite (Figs 42, 48) with narrow and well sclerotised median portion; lateral lobes wide and well developed; anterior margin in median portion weakly arcuate, posterior margin deeply concave.

Anal tube (in lateral view, Figs 44, 50) elongately oval, massive, completely covering gonoplac, twice as long as gonoplac; ventral margin strongly arcuate, posterior part bluntly rounded; anus placed at about midlength.

Anal tube (in dorsal view, Figs 43, 49) oval; anterior margin weakly concave, posterior margin in median portion with deep, narrow incision; anus placed at about midlength.

Gonoplac unilobate, triangular, oriented ventrad (Figs 45–47, 51); posterior margin with row of big teeth; upper part to the level of teeth limit well sclerotised, lower part membranous without hairs.

Gonapophysis VIII (Figs 57–58) triangular, laterally flattened, slightly oblique in respect to longitudinal body axis; apical teeth on both margins; 3 parallel, short, vertical, serrated keels near the lower margin; endogonocoxal process about as long as gonaphophysis, distinctly tapering apicad, membranous with spiniferous microsculpture.

Gonospiculum as in Figs 52–54.

Bursa copulatrix (Fig. 55) with single pouch, elongately oval with distal hollow; cells absent, sclerotised plates in groups on the whole surface. Spermatheca (Fig. 56) well developed; *ductus receptaculi* the same length as *diverticulum ductus*, with smooth, narrow and elongated basal part, widened and ribbed after midlength, tapering apicad; *diverticulum ductus* with smooth, short basal part and elongately widened apical part.

Coloration (specimens after the storage in EtOH, Figs 1–5). General coloration yellowish; tegmina milky-white, ochraceous; dark brown band along dorsal part of head, thorax and posterior margin of tegmina to the end of clavus.

Type material. Holotype, ♂: [MADAGASCAR: Province Fianarantsoa, Italaviana, 35 km SSE of Antsirabe 20°10.40'S, 47°05.16'E], [3–15 January California Acad of Sciences coll: M. Irwin, R. Harin'Hala malaise trap – in Uapacca forest elev 1360 m MA-24-65], [CASLOT 044488]

Paratypes (19♂♂, 13♀♀). **1** – same locality as holotype (contents of labels pinned under the specimen in square brackets): [3–15 January 2005], [MA-24-65], [CASLOT 044488] – (1♂, CAS); [16–28 January 2003], [MA-24-05], [CASLOT 044455] – (1♂, CAS); [22 Jan – 4 Feb 2004], [MA-24-41], [CASLOT 044457] – (4♂♂, 1♀ CAS; 1♂, 1♀ MIZ); [28 Jan – 7 Feb 2003], [MA-24-06], [CASLOT 044434] – (1♂, CAS); [10–20 March 2003], [MA-24-10], [CASLOT 044521] – (1♂, CAS); [24 March – 8 April 2004], [MA-24-44], [CASLOT 044460] – (3♂♂, CAS); [30 March – 9 April 2003], [MA-24-12], [CASLOT 044525] – (1♀, CAS); [8–15 May 2005], [MA-24-72], [CASLOT 044481] – (1♂, 1♀, MIZ); [27 June – 11 July 2004], [MA-24-50], [CASLOT 044487] – (1♀, CAS); [27 Sept – 5 Oct 2003], [MA-24-30], [CASLOT 044433] – (1♀, CAS); [2–14 October 2004], [MA-24-57], [CASLOT 044485] – (1♂, MIZ); [16–26 October 2003], [MA-24-32], [CASLOT 044596] – (1♂, CAS); [6–16 November 2003], [MA-24-34], [CASLOT 044456] – (1♀, CAS); [27 Nov – 7 Dec 2003], [MA-24-36], [CASLOT 044459] – (1♂, 1 without abdomen, CAS); [30 Nov – 9 Dec 2002], [MA-24-01], [CASLOT 044506] – (1♀, CAS); [9–19 December 2002], [MA-24-02], [CASLOT 044446] – (1♂, 1♀, CAS); [30 Dec 2002 – 3 Jan 2003], [MA-24-04], [CASLOT 044442] – (1♀, CAS). **2** – [MADAGASCAR: Province Fianarantsoa, 7 km W of Sandrisoa, N of Andringitra National Park, elev 1465 m 30 Nov – 21 Dec 2001], [21°57.96'S, 46°55.95'E, coll: M. Irwin, R. Harin'Hala California Acad of Sciences malaise trap – in vegetation near river MA-02-10-03], [CASLOT 044752] – (1♀, CAS). **3** – [MADAGASCAR: Province Fianarantsoa, near Isalo National Park, in dry wash south of Interpretive Center 7–22 September 2002], [22°37.60'S, 45°21.49'E, collector: R. Harin'Hala California Acad of Sciences malaise trap in open area elev 825 m, MA-02-11B-39], [CASENT 3007220] – (1♀, CAS). **4** – [MADAGASCAR: Province Fianarantsoa, radio tower 22 km SW of Ilakaka, near Fianarantsoa/Tulear border 24 Dec 2001 – 16 Jan 2002], [22°46.75'S, 45°1.50'E coll: M. Irwin, R. Harin'Hala California Acad of Sciences malaise in Uapacca forest elev 1100 m, MA-02-12-05], [CASLOT 044707] – (1♀, CAS); [16–26 Jan 2002], [MA-02-12-06], [CASLOT 044711] – (1♀, CAS); [5-16 February 2002], [MA-02-12-08], [CASLOT 044749] – (1♂, CAS); [27 Feb – 6 March 2002], [MA-02-12-10] – (1♂, CAS).

Distribution. Madagascar: Province Fianarantsoa (Fig. 59).

Environmental note. So far the species occurs mainly in two tapia forest clusters – 'Col des Tapia zone' located between Antsirabe and Ambositra in the central part of the island and 'Isalo zone' in the south (Fig. 60).

Key to the *Phlebopterum* species known from Madagascar

1. Costal and apical margins of tegmen strongly arcuate forming semicircle; tegmen yellowish green with 7–8 small dark brown dots. Male: apical part of anal tube strongly produced, tapering apicad; periandrium process single . . . . . ***P. angulatum*** Melichar, 1902
–. Costal margin of tegmen slightly arcuate, apical margin almost straight; tegmen without dots. Male: apical part of anal tube not strongly produced, widened apically; periandrium process bifurcated **2**
2. Tegmen light green, claval and sutural margin dark brown punctuate. Male: apical part of anal tube curved; genital style without incision, rectangular . . . . . ***P. viridis*** Melichar, 1902
–. Dark brown band along dorsal part of head, thorax and clavus. Male: apical part of anal tube almost straight; genital style deeply incised, V-shaped . . . . . ***P. tapiae*** sp. nov.

Discussion

The genus *Phlebopterum* Stål covers 3 species restricted to continental Africa, 2 species known

exclusively from Madagascar and 1 restricted to Madagascar, Nossi-Be and Sainte Marie islands.

Our preliminary morphological studies suggest that African and Madagascan species might belong to different genera indicating that the genus *Phlebopterum* needs revision in the nearest future.

The relations between Flatidae as phytophagous insects and vegetational formations they inhabit have been poorly documented so far. However, our previous studies indicate that there are strong relations of Flatinae with particular Madagascar floral communities, such as characteristic species for littoral forests – *Flatopsis medleri* (Świerczewski and Stroiński 2011) and *Latois nigrofasciata* (Świerczewski and Stroiński 2012) and for high altitude mountain rainforest – *Urana paradoxa* and *Urana unica* (Stroiński and Świerczewski 2012b). In this paper we associate another species *Phlebopterum tapiae* with tapia woodlands of Madagascar.

The tapia woodlands are a short, endemic, sclerophyllous forest formation, which can be found in four zones (Imamo, Col des Tapia, Itremo and Isalo) located in the central and southern part of the island (Fig. 60), covering approximately 2600 km^2 (Kull 2002). They usually occur on the western slopes of the central plateau, from 800 to 1.600 m above sea level. The dominant canopy tree species is *Uapaca bojeri* Baillon, 1874 (or tapia in Malagasy) belonging to Phyllanthaceae (Euphorbiaceae s.l.) – one of 8 endemic *Uapaca* species recognized in Madagascar and additional 40 recorded from mainland Africa (McPherson 2011, Schatz 2001). The understory is predominantly formed by immature trees, shrubs, herbs and grasses.

Tapia woodlands reveal strong adaptations to fire and are specifically human-shaped through controlled burning and selective cutting as they serve as a source of non-timber forest products for local residents (Kull 2003). These are mainly marketable fruit, wild silk and firewood. Moreover, tapia woodlands benefit from protection by local traditions and government rules. The only threat is the invasion by exotic species from private woodlots, such as pines (*Pinus khasya* and *P. patula*) and *Eucalyptus* spp.

There has been much discussion about the type of primary vegetation occurring on the central plateau of Madagascar prior to human arrival: essentially continuous, dense, climax forest (Gade 1996) *versus* vegetation composed of forest, shrubland and thicket (Lowry *et al*. 1997). The answer might be partly provided by the study of ant assemblages (Fisher and Robertson 2002) which revealed high levels of species endemism. This suggests that a comparable habitat i.e. lacking a closed canopy and with open areas existed on Madagascar long before humans developed the secondary grasslands. Endemic ants now found in the secondary grasslands were originally native to this habitat.

Summarizing, to understand the complex historical factors that have shaped the unique wildlife of Madagascar, we need thorough studies on the insect fauna of the island including poorly known ecosystems such as the tapia woodlands described above. Such a biodiversity map may give the possibility for more effective conservation practice in respect to current levels of habitat degradation and continued high rates of deforestation.

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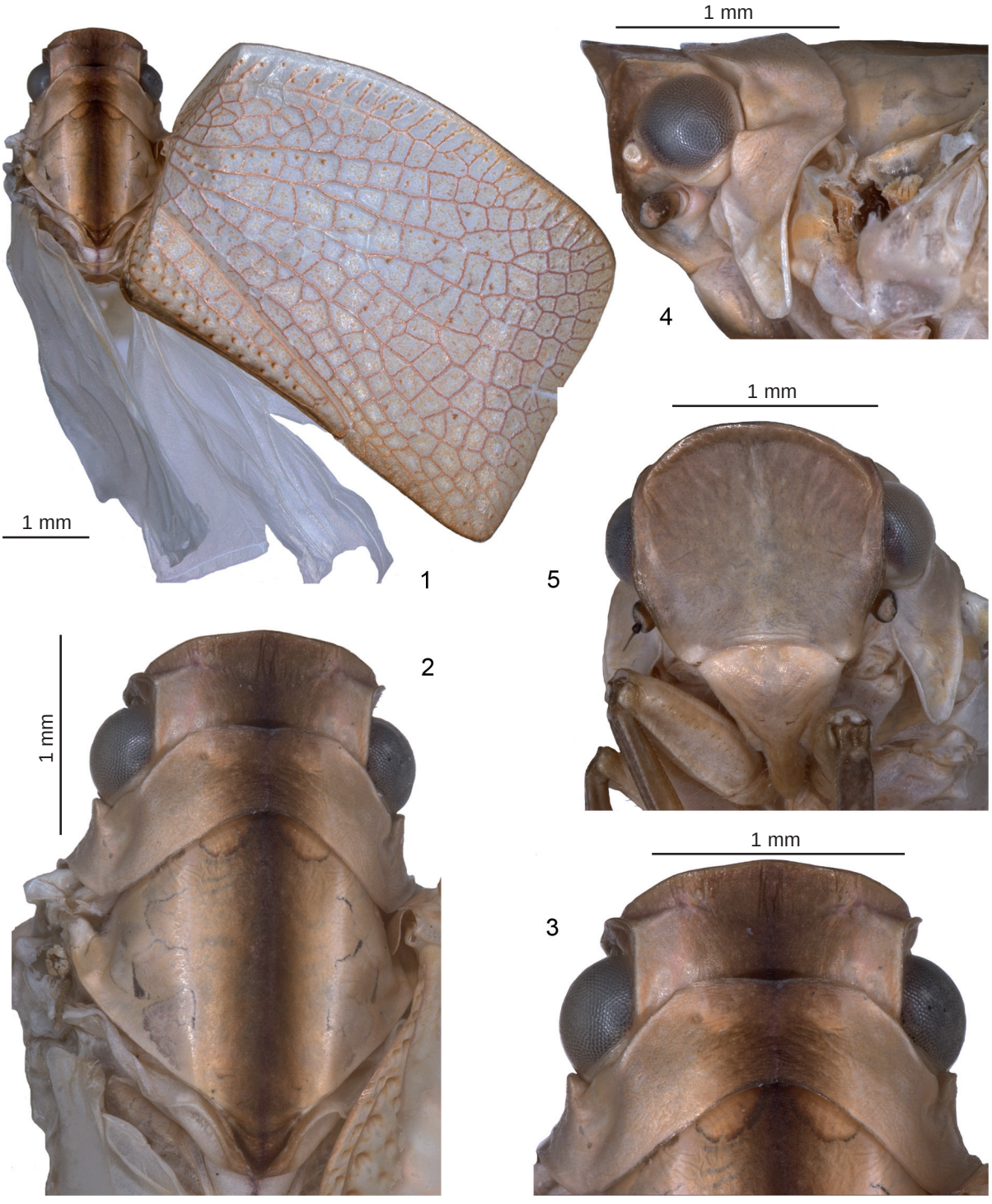
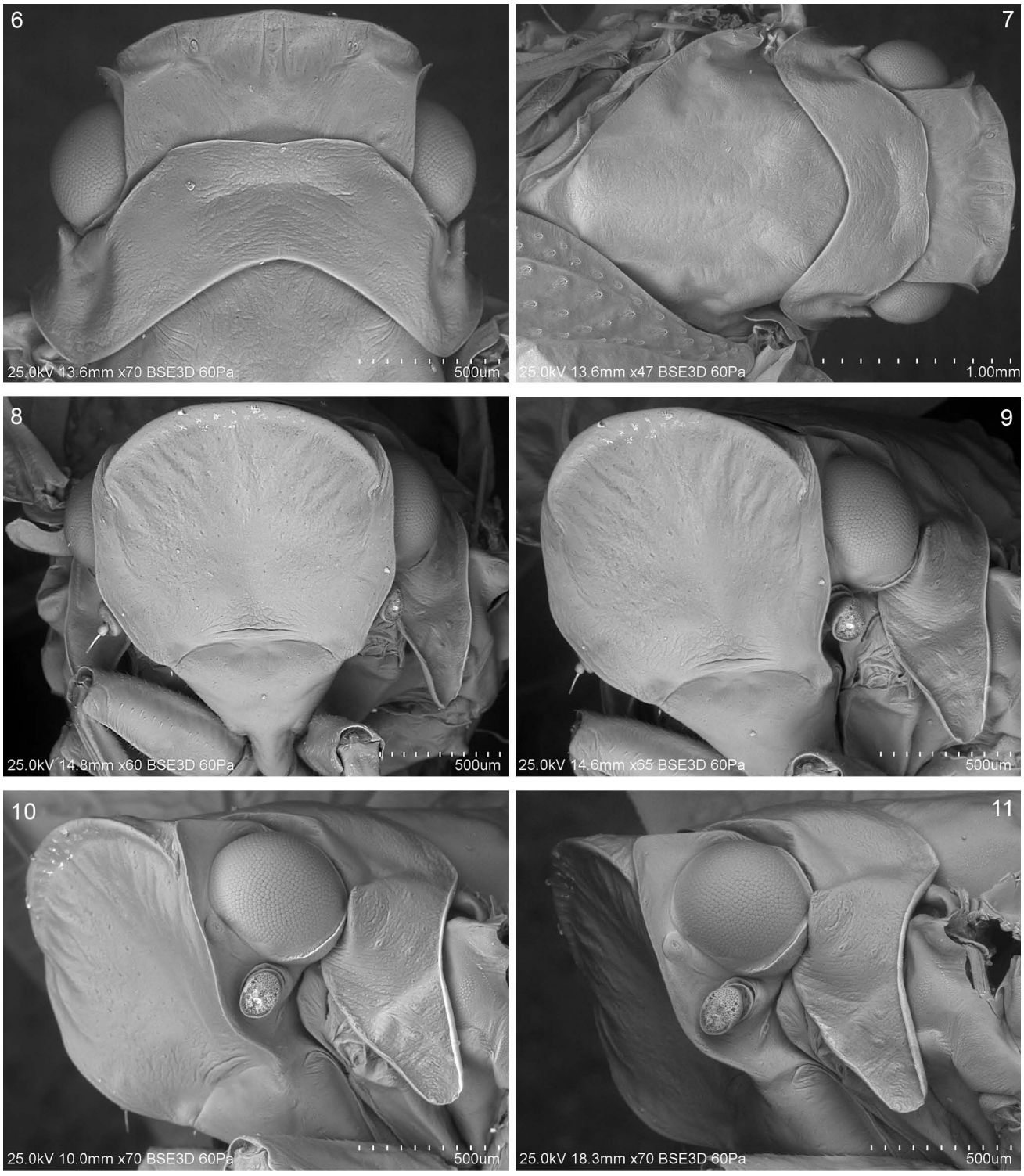
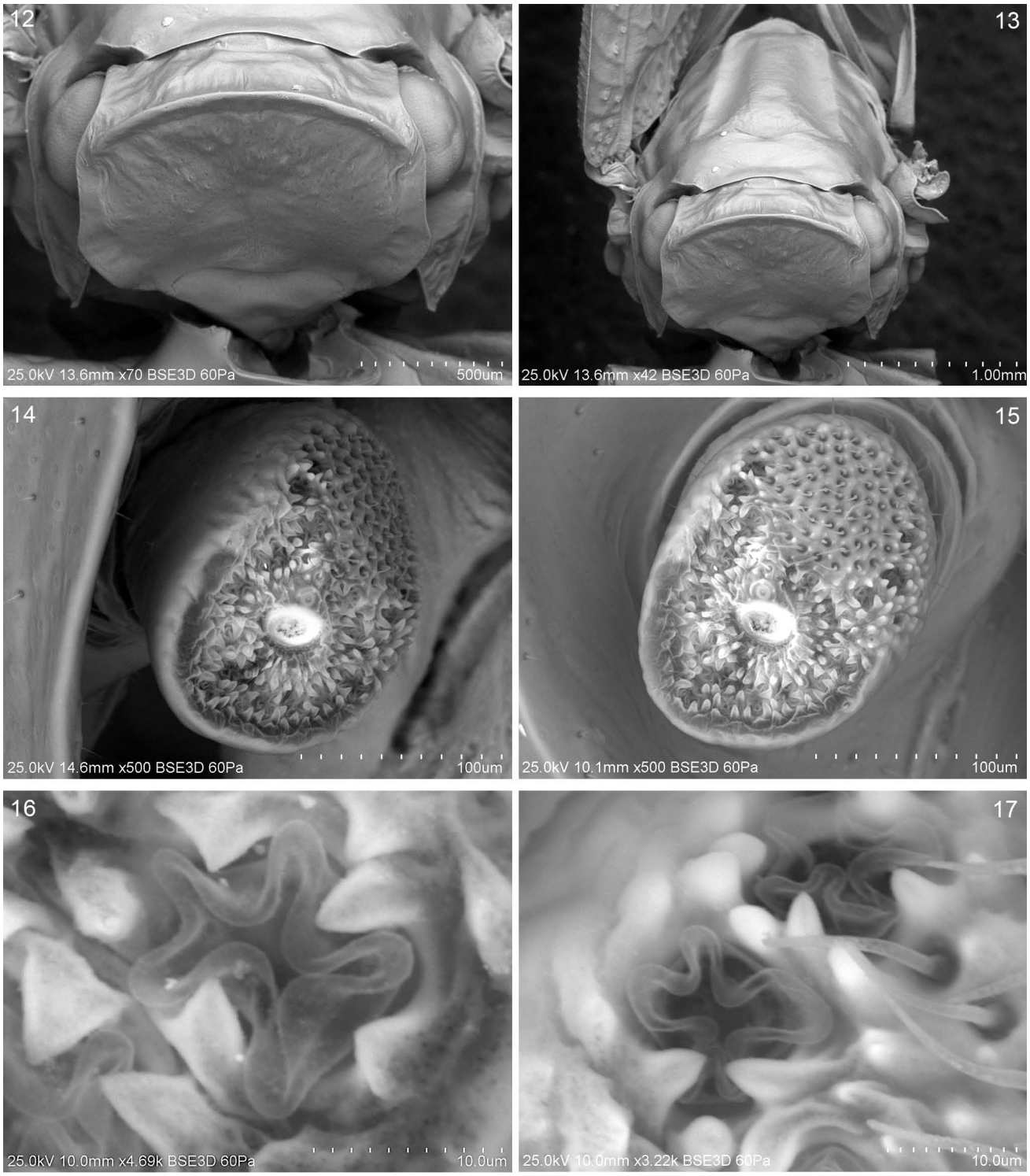


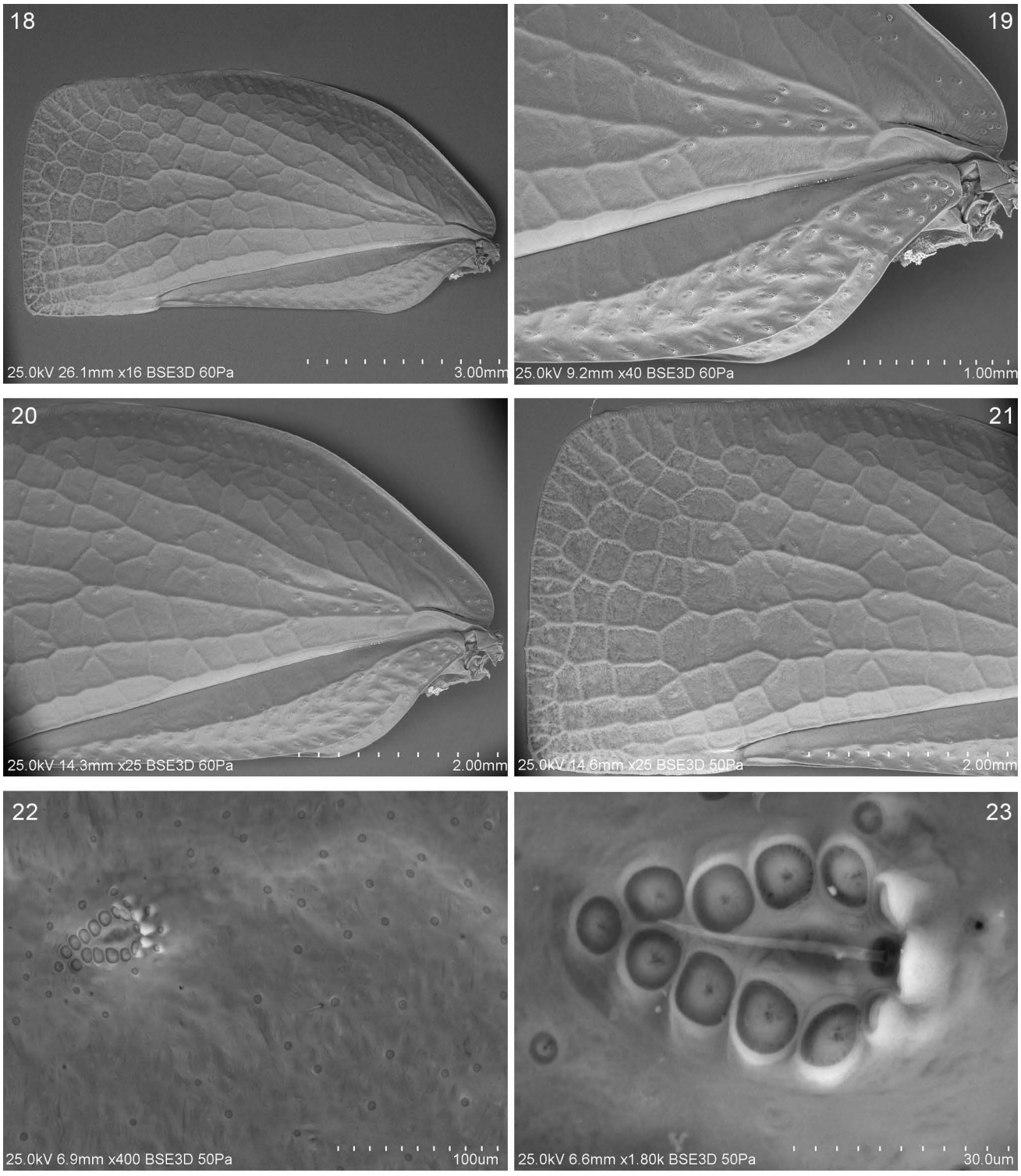
Figures 1–5. *Phlebopterum tapiae* sp. nov. (1) Habitus, dorsal view; (2–3) anterior part of body, dorsal view; (4) same, lateral view; (5) same, frontal view.



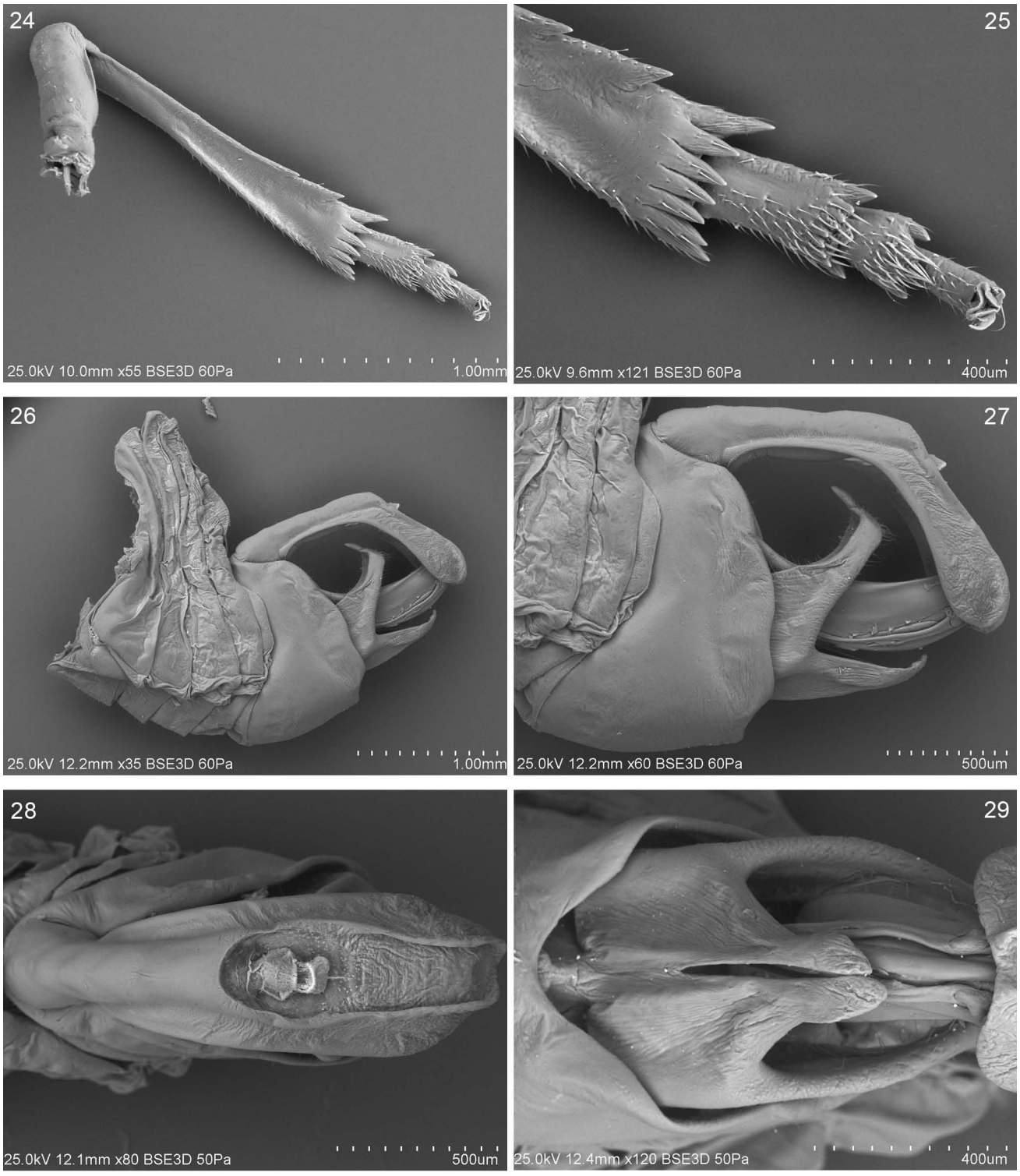
Figures 6–11. *Phlebopterum tapiae* sp. nov, SEM photos. (6–7) Anterior part of body, dorsal view; (8–9) same, frontal view; (10–11) same, fronto-lateral view.



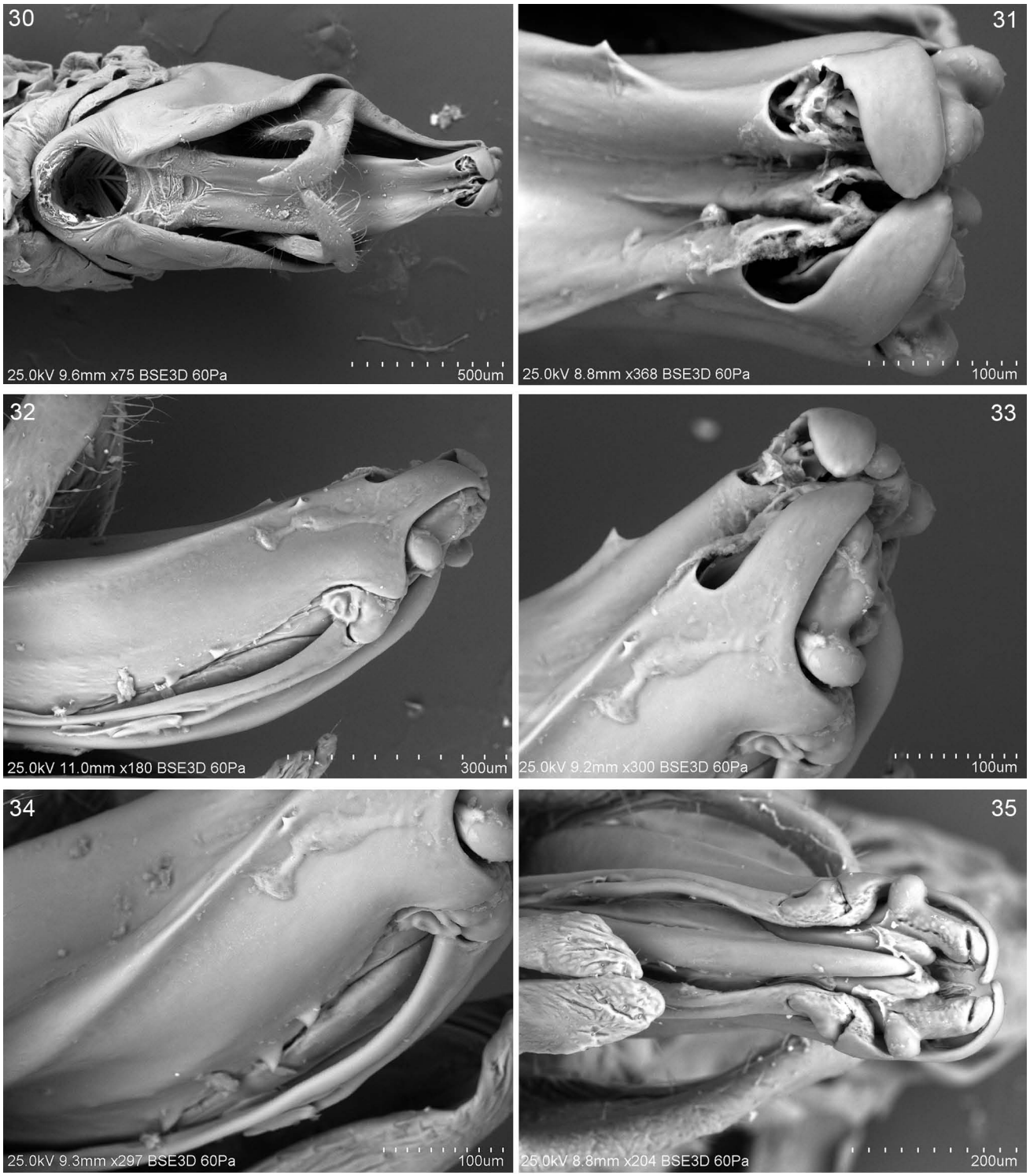
Figures 12–17. *Phlebopterum tapiae* sp. nov., SEM photos. (12–13) Anterior part of body, fronto-dorsal view; (14–15) antenna, antero-dorsal view; (16–17) same, antennal plate organs.



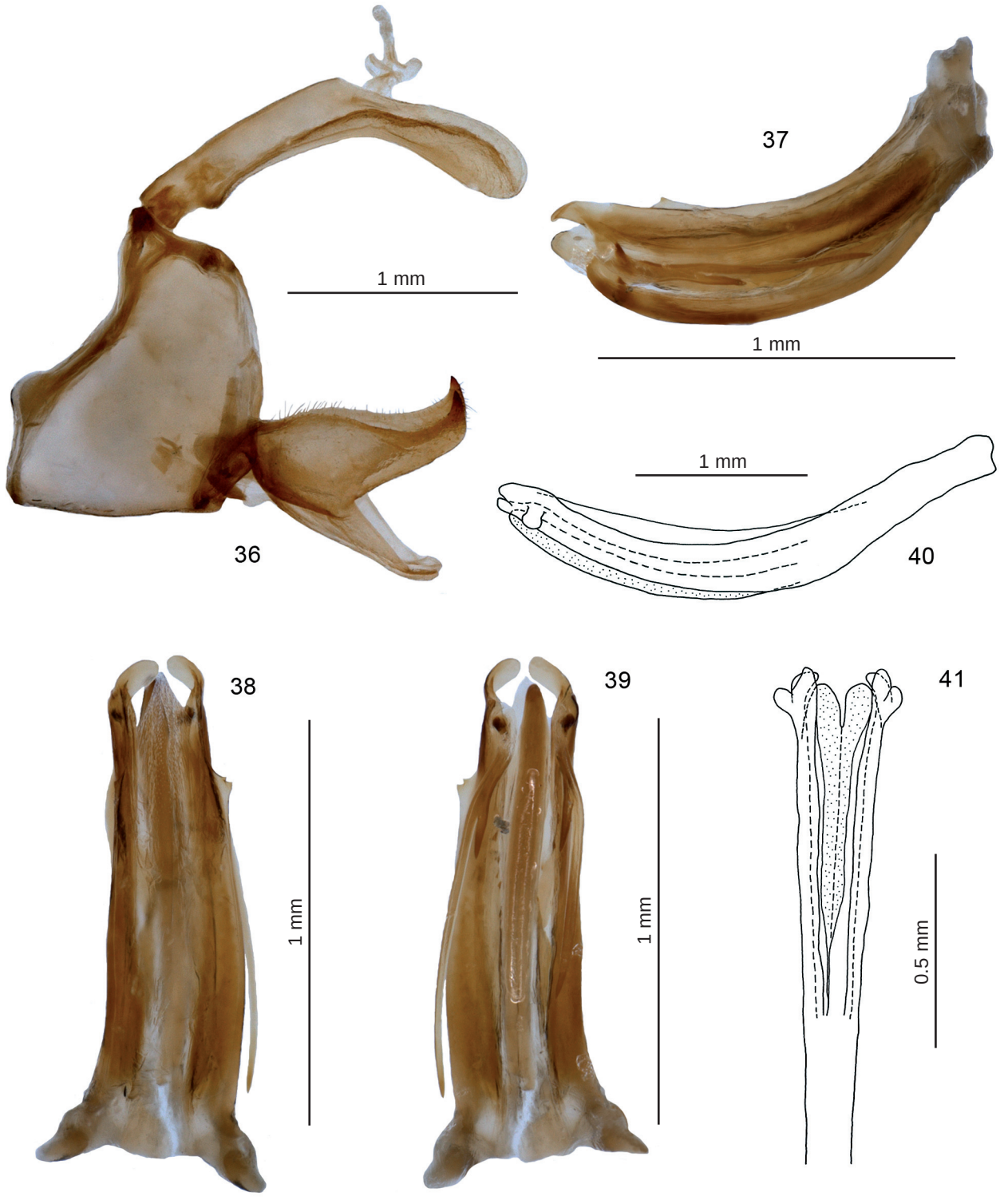
Figs 18–23. *Phlebopterum tapiae* sp. nov., SEM photos. (18) Tegmen, general view; (19–20) same, basal part; (21) same, apical part; (22–23) same, single pore with ring-shaped area.



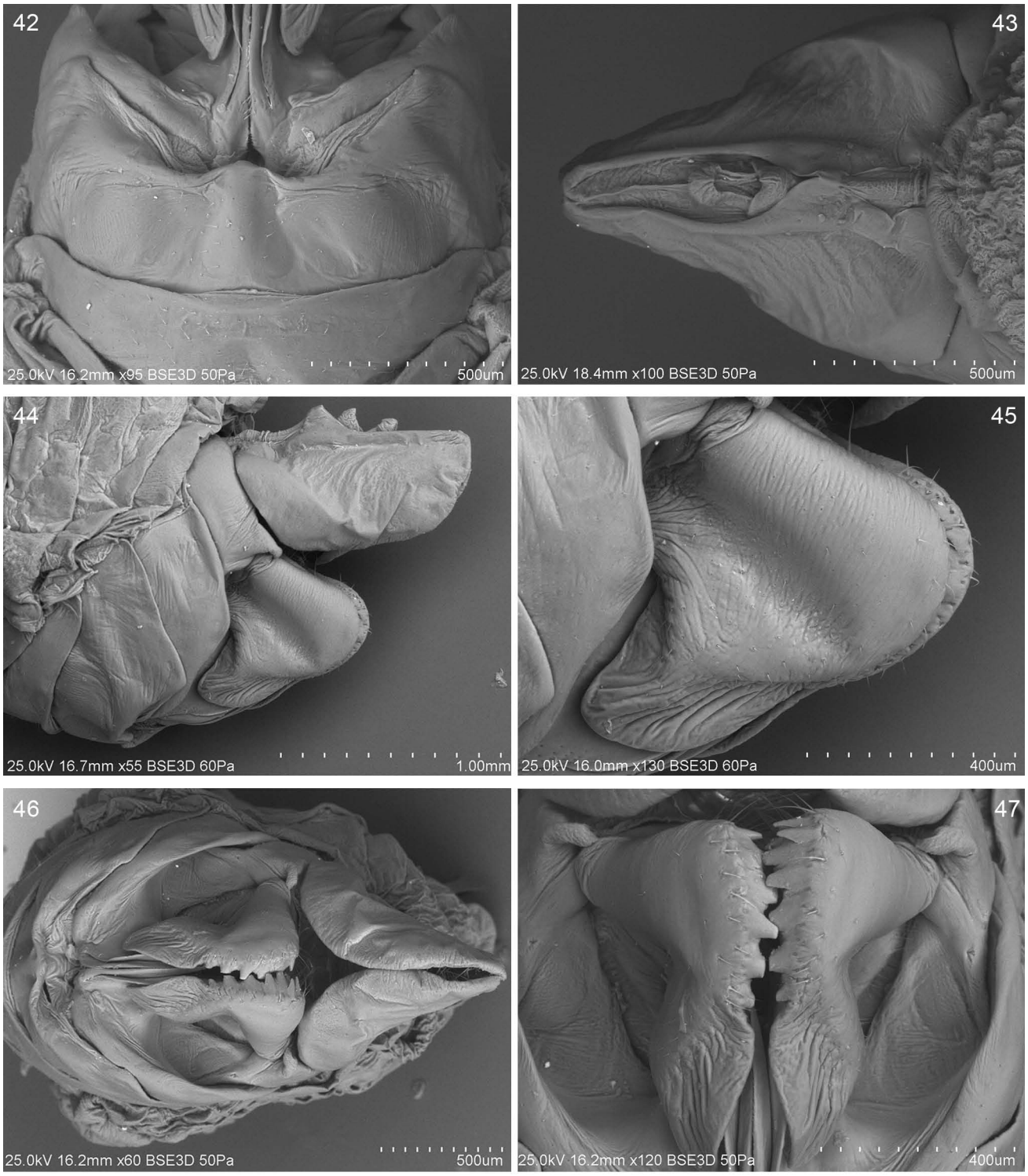
Figs 24–29. *Phlebopterum tapiae* sp. nov., SEM photos. (24) Hind leg; (25) apex of hind tibia and tarsomeres; (26–27) male genital capsule, lateral view; (28) same, dorsal view; (29) same, ventral view.



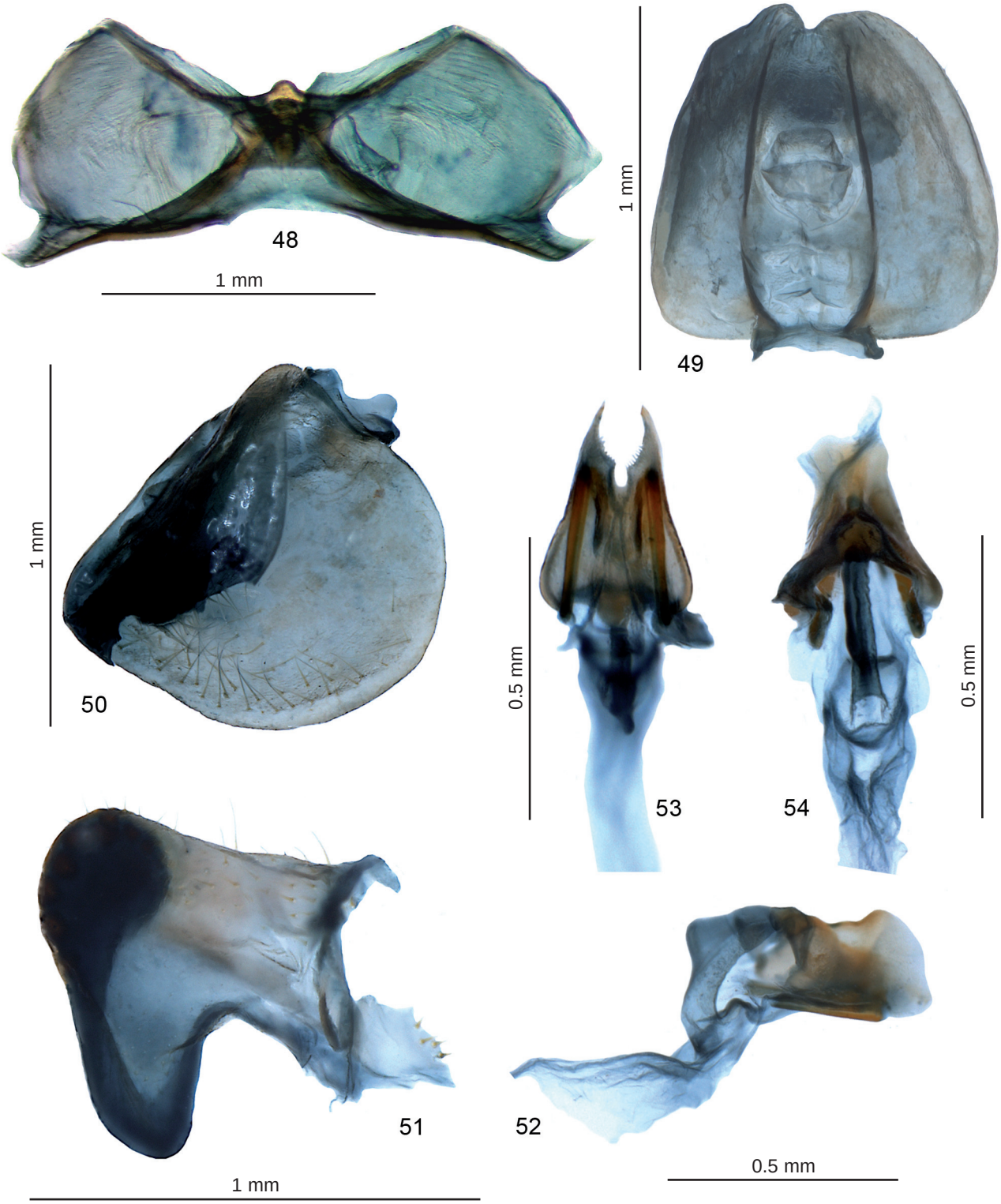
Figs 30–35. *Phlebopterum tapiae* sp. nov., male, SEM photos. (30–31) Phallic complex, dorsal view; (32–34) same, lateral view; (35) same, ventral view.



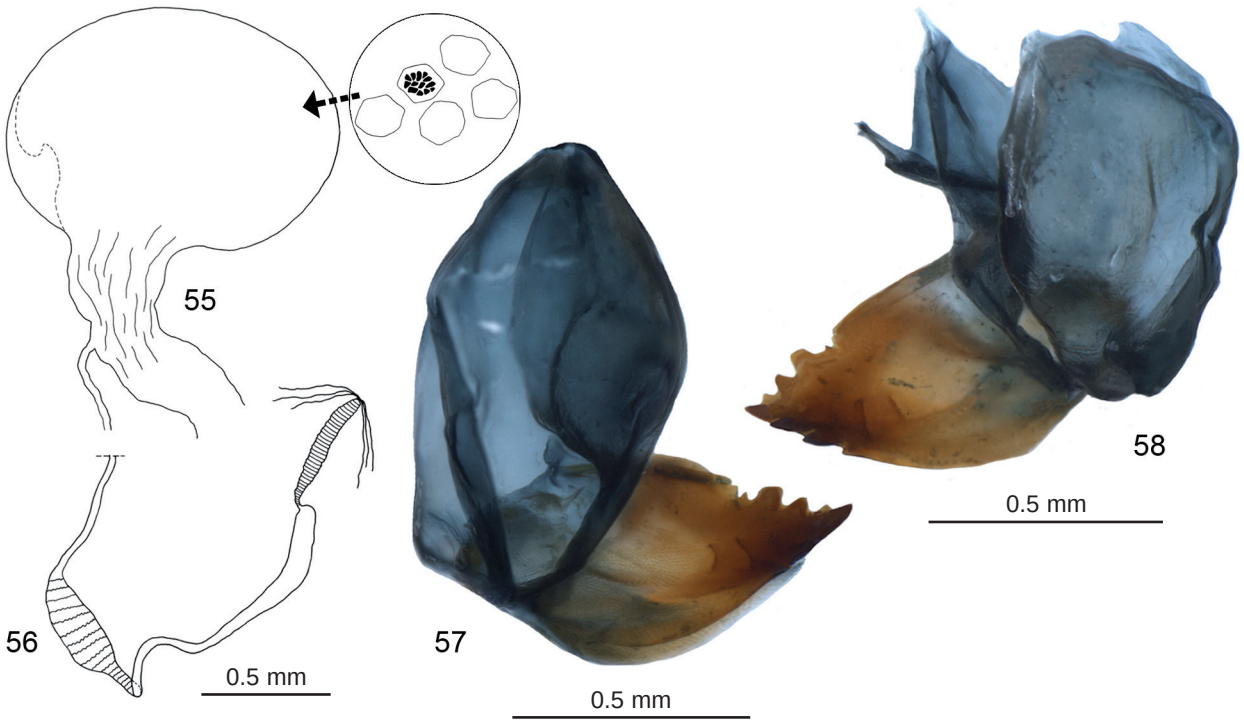
Figs 36–41. *Phlebopterum tapiae* sp. nov., male. (36) Genital capsule, lateral view; (37) periandrium, lateral view; (38) same, dorsal view; (39) same, ventral view; (40) aeadagus, lateral view; (41) same, dorsal view.

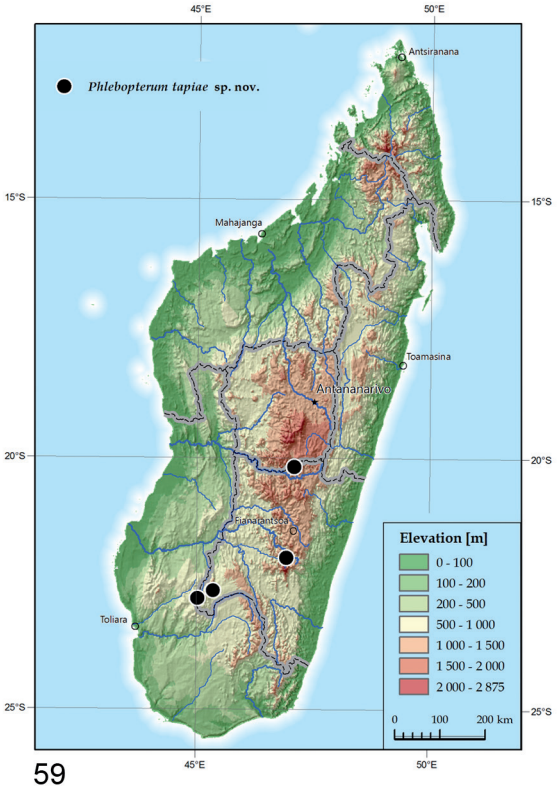


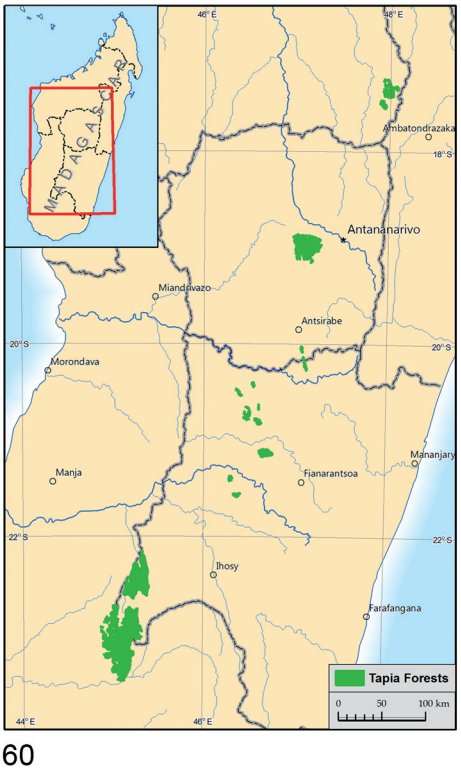
Figs 42–47. *Phlebopterum tapiae* sp. nov., female, SEM photos. (42) Pregenital sternite, ventral view; (43) anal tube, dorsal view; (44) genital capsule, lateral view; (45) gonoplac, lateral view; (46) genital capsule, frontal view; (47) gonoplacs, frontal view.



Figs 48–54. *Phlebopterum tapiae* sp. nov., female. (48) Pregenital sternite, flattened; (49) anal tube, dorsal view; (50) same, lateral view; (51) gonoplac, external view; (52) gonapophyses IX and gonospiculum bridge, lateral view; (53) same, dorsal view; (54) same, ventral view.







Figs 55–60. *Phlebopterum tapiae* sp. nov. (55) Female, bursa copulatrix, lateral view (56) female, spermatheca (57) female, gonaphophysis VIII, lateral view; (58) female, same, dorso-lateral view; (59) distribution map; (60) locations of tapia woodlands in Madagascar after Moat and Smith (2007).