

REVISION OF THE MADAGASCAN GENUS *PARAFLATA* (HEMIPTERA: FULGOROMORPHA: FLATIDAE), WITH NOTES ON PLANTHOPPER HOSTS PARASITIZED BY EPIPYROPIDAE MOTHS

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Abstract.— The Malagasy planthopper genus *Paraflata* is revised. To the three previously known species (*P. seminigra*, *P. kingdomi* and *P. dewalschei*) two new ones are added and described: *P. masoalae* **sp. nov.** and *P. unispinosa* **sp. nov.** Their distribution is discussed and a bipolar distribution (from mountain and coastal biotopes) is reported for *P. dewalschei*. During morphological investigations, several dead pupae of unidentified Lepidoptera Epipyropidae specimens were discovered attached to the planthopper abdomens. This is the first report for the genus *Paraflata* of these planthopper parasitic moths, which might be considered, in this particular interspecific interaction, rather as ectoparasites than as parasitoids.



Key words.— taxonomy, Fulgoroidea, ectoparasites, Afrotropical region

INTRODUCTION

Madagascar is located in the south-western Indian Ocean, in a significant distance from Africa, India, Indonesia and Australia. Its long geographical isolation (approximately 80 Ma) from the previously mentioned landmasses (Storey *et al.* 1995) has contributed to the evolution of exceptional biota with high overall diversity and unparalleled levels of endemism (e.g., Kamiński and Raś 2012, Kamiński 2015), and places the island in a group of the world's top 12 “mega-diversity” hotspots (Myers *et al.* 2000, Mittermeier *et al.* 2005). Most of

this biodiversity occurs in the humid and sub-humid, evergreen forests that occupy the windward, eastern part of the island. However, due to human impact, many of Madagascar's primary ecosystems have been reduced in size and degraded beyond the point of recovery. Damage to the environment has not been arrested and the island continues to suffer further losses of biodiversity, a situation which can only be addressed by stricter conservation programmes (Ganzhorn *et al.* 2001).

Flatidae constitutes the 4th largest family of planthoppers (Fulgoromorpha) distributed worldwide,

consisting of 298 genera and 1,422 species grouped in 2 subfamilies: Flatinae Spinola, 1839 with 13 tribes and Flatoidinae Melichar, 1901 without tribal classification (Bourgoin 2016). With respect to morphology, flatids are characterized by the presence of wax bearing pustules and a 'submarginal vein', parallel to the wing margin, which defines a series of marginal cells in the apical and leading portion of the front wings (Bartlett *et al.* 2014). Adult and immature flatids live on the above-ground parts of a wide variety of woody and semi-woody plants, which provide them not only with food, but also oviposition and communication substrate and, therefore, a place to develop.

Currently, the Flatidae fauna of Madagascar includes, in total, 21 genera with 47 species of Flatinae and 11 genera with 37 species of Flatoidinae (Świerczewski and Stroiński 2013, Małkol *et al.* 2014, Stroiński and Świerczewski 2014a–b, Świerczewski and Stroiński 2015). The family shows a firm association with particular vegetation formations on the island and thus may serve as an appropriate tool to assess the biodiversity of rare and endangered ecosystems e.g., *Phleboterum tapiae* Świerczewski *et al.* Stroiński, 2012 for tapia woodlands (Świerczewski and Stroiński 2012a) or *Latois nigrolineata* Świerczewski *et al.* Stroiński, 2012 for littoral forests (Świerczewski and Stroiński 2012b). With respect to mountain vegetation, the models are species of *Urana* Melichar, 1902 (Stroiński and Świerczewski 2012) allied to high mountain rainforest and *Peyrierasus philippiae* Stroiński *et al.* Świerczewski, 2013 known from montane (*Philippia*) scrubland of Chaînes Anosyennes (Stroiński and Świerczewski 2013a). However, Flatidae like other planthopper families inhabiting Madagascar or other adjacent islands such as Socotra and the Seychelles are still poorly known and need much further research (Świerczewski *et al.* 2014, Gnezdilov and Bourgoin 2015).

The genus *Paraflata* was established by Melichar (1901) for Malagasy *Phromnia seminigra* Stål, 1866. Later, two additional species were described from the island: *P. kingdomi* Distant, 1910 and *P. dewalschei* Lallemand, 1933. Melichar (1923) placed *Paraflata* within the tribe Phromniini and this interpretation was later accepted by subsequent authors (e.g., Metcalf 1957). During a recent taxonomic investigation two new species of this genus were described and on the basis of the newly studied material the taxonomical concept of *Paraflata* was tested. Additionally, dead pupae of the planthopper parasite moths (Lepidoptera: Epipyropidae) were discovered on the body surface of several of the studied *Paraflata* specimens. Because this is the first report on lepidopteran ectoparasites of *Paraflata*, the information concerning the biology of planthopper parasite moths is also summarized.

MATERIAL AND METHODS

Preparations and illustration. The abdomens of the specimens examined were removed and cleared for 30 min in warm (50°C) 10% KOH solution with a few drops of black chlorazol (CAS No. 1937–37–7) for dyeing 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. All color images were taken using a stereomicroscope Leica MZ 16 with digital camera IC 3D; final images were produced using Helicon Focus and Adobe Photoshop software. The SEM photographs of uncoated specimens were taken in the Laboratory of Scanning Microscopy, MIZ PAS (Warsaw), using a scanning electron microscope HITACHI S-3400N under low vacuum conditions.

Measurements and abbreviations. The following measurements made with an ocular micrometer, ratios and abbreviations were 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 measured 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.

Vein nomenclature follows the interpretation proposed by Bourgoin *et al.* (2015). Antennal structures are named in accordance with Stroiński *et al.* (2011). The terminology of the genitalia follows Bourgoin (1988) and Bourgoin and Huang (1990) for the male, and Bourgoin (1993) for the female.

Material. The studied material is deposited in the entomological collections of the following museums:

- CAS – California Academy of Sciences, San Francisco, USA;
- HNHM – Hungarian Natural History Museum, Budapest, Hungary;
- IRSNB – Institut royal des Sciences naturelles de Belgique, Brussels, Belgium;

MIZ – Museum and Institute of Zoology PAS, Warsaw, Poland;

MMBC – Moravske Muzeum, Brno, Czech Republic;

MNHN – Muséum national d'Histoire naturelle, Paris, France;

NHML – Natural History Museum, London, UK;

NHMW – Naturhistorisches Museum, Wien, Austria;

NHRS – Naturhistoriska riksmuseet, Stockholm, Sweden;

NMPC – National Museum, Prague, Czech Republic;

RMCA – Musée Royal de l'Afrique Centrale, Tervuren, Belgium;

ZMHB – Museum für Naturkunde der Humboldt-Universität, Berlin, Germany;

ZMUH – Universität Hamburg, Zoologisches Institut, Hamburg, Germany.

Label information of all examined species are provided verbatim with each label, separated with square brackets.

TAXONOMY

Order Hemiptera Linnaeus, 1758

Suborder Fulgoromorpha Evans, 1946

Family Flatidae Spinola, 1839

Subfamily Flatinae Spinola, 1839

Tribe Phromniini Melichar, 1923

Paraflata Melichar, 1901
(Figs 1–72)

Type species. *Phromnia seminigra* Stål, 1866.

Designated by monotypy.

Etymology. The name indicates that *Paraflata* resembles the genus *Flata* Fabricius, 1798. Gender feminine.

Diagnosis. The Malagasy genus *Paraflata* Melichar, 1901 is related to *Flatida* White, 1846 but differs from its representatives by the following characters: frons wide, almost rectangular, with median carina in *Paraflata* (narrow, without median carina in *Flatida*), pronotum and mesonotum without carinae in *Paraflata* (with three carinae in *Flatida*), antenna with pedicel relatively short, club-like in *Paraflata* (pedicel much elongated, cylindrical in *Flatida*), hind tibia with 1 lateral spine in *Paraflata* (with 2 lateral spines in *Flatida*).

Redescription. **Head.** Head with compound eyes in dorsal view distinctly narrower than thorax (Figs 4, 8). Vertex (Figs 4, 7) wider than long at midline. Anterior and posterior margins placed at the same level, not carinate, anterior margin in form of ridge; lateral margins carinate only in anterior part. Disc of vertex with

median gibbosity (Fig. 7). Frons (Figs 4–5) just longer than wide, widest at level of antennae (Fig. 4); lateral margins carinate and distinctly elevated; disc of frons with median carina, in some specimens with median portion obsolete; lateral carinae absent. Frontoclypeal suture slightly arquate. Clypeus (Fig. 4) narrower than frons, convex, without median carina. Rostrum with apical segment shorter than subapical, its apex reaching hind coxae.

Compound eyes (Figs 5, 10) rounded, with small callus at posterior and ventral margins; lateral ocelli as remnants. Antennae (Figs 10–15) located antero-ventral in respect to eye; scapus a bit shorter than eye diameter, cylindrical, covered with short setae; pedicel longer than eye diameter and length of scapus, club-like, apical part concave, functional area at the top and on dorsal and ventral sides, sensilla placodea of the clover leaf-like type.

Thorax. Pronotum (Figs 5–7) distinctly longer than vertex at midline, with smooth surface; anterior and posterior margins slightly arcuate; anterior margin placed below the level of posterior one, medially pointy produced; disc of pronotum with or without median groove; postocular eminences absent.

Mesonotum (Figs 6, 8–9) deltoid, a bit wider than long, much longer than cumulative length of vertex and pronotum; disc of mesonotum strongly convex medially, without carinae; scutellum triangular, large and elevated.

Tegmen (Figs 1–3, 16–19) membranous, elongately-oval and weakly convex, with distinct venation. Costal margin arcuate, costal angle widely rounded, apical margin arcuate with breaking point about midlength, sutural angle rounded, postclaval sutural margin long and straight. Costal area about the same width as its length, with dense, transverse veinlets, terminating about the level of end of clavus. Postcostal cell tapering apicad, narrower than costal area, with irregular net of veinlets. ScP+RA and RP veins leaving basal cell at a single point; basal part of ScP+RA crossing the top of bulla, first fork after end of costal area, ScP+RA ending with 3–10 terminals; RP forked a bit before end of bulla ending with 13–20 terminals. Longitudinal vein MP leaving basal cell as long common stem, with first fork before RP fork, MP₁₊₂ ending with 18–27 terminals, MP₃₊₄ ending with 24–33 terminals; CuA leaving basal cell with long common stem, with first fork after MP fork, CuA ending with 3–5 terminals. Claval veins Pcu and A₁ fused almost anterior to clavus apex, Pcu and A₁ veins elevated; transverse veinlets absent. Apical and subapical lines present, apical and subapical cells distinctly longer than wide; transverse veinlets forming dense irregular net except the basal part, *icu* veinlet present. Tubercles present on basal half of costal area, between basal part of RP and MP veins and between Pcu and A₂ veins on clavus.

Femora shorter than tibiae; hind tibiae almost straight, triangular in cross section, with 1 lateral spine placed in posterior half, apically with row of 5–6 well-developed teeth; basitarsomeres as long as cumulative length of 2nd and 3rd tarsomeres, with row of 6–8 apical spines and thick setae; second tarsomere with 2 lateral spines and median pad with thick setae. Metatibiotarsal formula: 1+5-6/6-8/2.

Male terminalia (Figs 20–25). Anal tube, in lateral view (Figs 20–21, 44, 59, 64), elongate and curved, ventroapical part with or without lobe; anus placed after midlength; anal tube, in dorsal view (Figs 22–23, 45, 65), elongate with apical median incision; basal part narrower than apical part.

Pygofer, in lateral view (Figs 20–21, 44), taller than wide, dorsal part narrower than ventral part; posterior-dorsal angle with triangular lobe oriented dorsad, anterior and posterior margins arcuate. Genital styles, in lateral view (Figs 20–21, 44), longer than wide and bearing distinct, dorsocaudal capitulum with bluntly rounded apex.

Phallic complex. Perianthrium (Figs 24–25, 46–47, 60–62, 66–67, 70–71) stout, more or less upcurved, shorter than aedeagus, apically divided by lateral split into dorsal and ventral part; lateral split reaching about midlength. Dorsal part longer than ventral part, apically with distinct appendage divided into membranous base and well sclerotized process with one or two arms; ventral margin with or without spiniferous microsculpture. Ventral part, in ventral view, unilobate, tapering apicad; lateral margins serrate. Dorsobasal part of perianthrium with or without lobe.

Aedeagus s.s. (Figs 24–25, 48–49, 68–69) with apical, well-developed and sclerotized appendages; deep median split reaching basal part; shaft of aedeagus almost straight or curved; ventral side of apical appendage denticulate, dorsal side with or without microsculpture.

Female terminalia (Figs 26–43, 50–55, 56–58, 63). Pregenital sternite with lateral lobes distinctly separated (Figs 30–31, 50, 56). Anal tube, in lateral view (Figs 26–27), elongately oval, distinctly surpassing end of gonoplac; anus placed dorsally after midlength; anal tube, in dorsal view (Figs 28–29, 51), oval, apically with deep and narrow median incision, surface wrinkled with scarce setae.

Gonoplac (Figs 30–37, 52, 57, 63) with triangular or irregular ventral lobe. Gonapophysis VIII laterally flattened (Figs 33–37, 52, 57, 63), tapering apicad, with sharp apex and spiniferous microsculpture. Gonapophyses IX and gonospiculum bridge as in Figs 38–43, 53. Bursa copulatrix forming single, oval, huge pouch with or without cell imprints (Fig. 54). Spermatheca well-developed; *ductus receptaculi* ribbed, about the same length or longer than *diverticulum ductus* (Figs 55, 58).

Distribution. Madagascar. Provinces: Antsiranana, Toamasina, Fianarantsoa, Toliara, Antananarivo (Fig. 72).

Key to adults of *Paraflata*

The identification key placed below only summarizes current knowledge concerning diagnostic characters for certain *Paraflata* species. Because of the scarcity of material, the data on the morphology of males (*P. kingdomi*) and females (*P. masoalae* sp. nov., *P. unispinosa* sp. nov.) is unavailable or incomplete for some species.

1. Black coloration of tegmen only at basal part, not exceeding its half *P. dewalschei*
- . Black coloration of tegmen exceeding its half 2
2. Males 3
- . Females 5
3. Apical part of anal tube, in lateral view, widely rounded, with triangular lobe oriented ventrad *P. masoalae* sp. nov.
- . Apical part of anal tube, in lateral view, narrow, without lobe 4
4. Perianthrium apical appendage with 2 arms *P. seminigra*
- . Perianthrium apical appendage with 1 arm *P. unispinosa* sp. nov.
5. Posterior margin of pregenital sternite almost straight with median incision, bursa copulatrix with cell imprints, *ductus receptaculi* the same length as *diverticulum ductus* *P. seminigra*
- . Posterior margin of pregenital sternite sinuate, bursa copulatrix without visible cell imprints, *ductus receptaculi* much longer than *diverticulum ductus* *P. kingdomi*

Paraflata seminigra (Stål, 1866) (Figs 1, 4–25, 44–55, 72)

Phromnia seminigra Stål, 1866: 240.

Phromnia seminigra: Dallas (1867).

Paraflata seminigra: Melichar (1901), Distant (1910), Jacobi (1917), Melichar (1923), Synave (1956), Metcalf (1957).

Etymology. The specific epithet comes from the combination of Latin words: *semi* – half and *nigrus* – black and reflects the coloration of tegmina.

Diagnosis. The species can be distinguished from other species of the genus by the following characters: male perianthrium appendage process with 2 arms: dorsal arm short, ventral arm long, curved, surpassing lateral split; female pregenital sternite with posterior margin almost straight with median incision, bursa copulatrix with cells, *ductus receptaculi* the same length as *diverticulum ductus*.

Redescription. Total length 12.70–15.30 mm.

Head. Vertex: ratio A/B = 6.00–8.75. Frons: ratio C/E = 0.53–0.60; D/E = 0.55–0.65.

Thorax. Pronotum: ratio F/B = 3.60–5.25. Mesonotum: ratio G/F = 4.89–5.94, G/B+F = 4.04–4.75, G/H = 0.81–1.03. Tegmina: ratio I/J = 1.44–1.77.

Male terminalia. Anal tube, in lateral view, with apical part rounded (Figs 20–21, 44). Anal tube, in dorsal view, with apical part elongate and oval, with median rectangular incision (Figs 22–23, 45).

Periandrium (Figs 24–25, 46–47): upper margin of periandrium smooth, surface of dorsal periandrium without denticulate microsculpture, base of appendage rectangular oriented ventro-posteriorly, process of appendage with 2 arms: dorsal arm short, ventral arm long, curved, surpassing lateral split, ventral part with delicately denticulate margins and long sharp apex, dorso-basal part of periandrium without lobe. Aedeagus (Figs 25, 48–49): shaft of aedeagus curved, dorsal margin smooth; apical appendage tapering apicad; ventral side of apical appendage straight.

Female terminalia. Pregenital sternite with well separated lateral lobes, anterior margin almost straight with median small triangular appendage, posterior margin with median small incision (Fig. 50). Gonoplac in form of irregular lobe, gonapophysis VIII bipartite (Fig. 52). Gonapophyses IX and gonospiculum bridge with sac-like appendages covered with setae (Fig. 53). Bursa copulatrix huge and oval, with cell imprints and sclerites (Fig. 54); *ductus receptaculi* about the same length as *diverticulum ductus*, ribbed, widening apicad; *diverticulum ductus* smooth, with long distal, narrow part and apical bulb (Fig. 55).

Coloration. Head, thorax and legs dark brown to black with yellow discolourations, tegmina generally in half black, in half milky white but in some specimens the black part is larger, abdomen ochraceous to light brown (Fig. 1).

Type material. Holotype, ♀: [Madagasc.], [Type], [Paraflata Mel. 1901 *seminigra Stål, 1866], [Paraflata seminigra Stål samica Edm. Schmidt determ. 1911.], [Mus. Zool. Polonicum Warszawa 12/45], [MIZ 212530] – (MIZ)

Additional material. Unpublished material determinate as *Paraflata seminigra*: [Madagascar Sambirano, Nosy-Be, foret de Lokobe, I-60, Andria Robinson], [Institut Scientifique MADAGASCAR], [R. I. Sc. N. B. I. G. 22.889] – 1 ♂ (IRSNB); [Madagascar Sambirano Nosy-Be foret de Lokobe I-60 Andria Robinson], [Institut Scientifique MADAGASCAR], [Coll. Mus. Tervuren], [R.I.Sc.N.B.I.G. 22.889], [H. Synave det., 195 Paraflata seminigra Stål] – 1 ♂ (RMCA); [Madagascar Sambirano Nosy-Be foret de Lokobe I-60 Andria Robinson], [Coll. Mus. Tervuren], [H. Synave det., 195 Paraflata seminigra Stål] – 1 ♀ (RMCA); [Loucoubé,

auf Nossi-Bé, Carl Bosse leg., ded.4.I.1892], [L. Melichar, determ. 1901], [Paraflata seminigra] – 1 ♂ (ZMUH); [Madagascar, Rumena Val], [Coll. R.I.Sc. N.B.], [Paraflata seminigra], [Déterm. Melichar], [Paraflata seminigra (Stål), Det. Medler, 1987], [383] – 1 ♀ (parasitized) (IRSNB); [Madagascar, Rumena Val], [Coll. R.I.Sc.N.B.], [Paraflata seminigra], [Déterm. Melichar], [Paraflata seminigra (Stål), Det. Medler, 1987], [382] – 1 ♂ (parasitized) (IRSNB); [Maroantsetra, Madagascar], [Paraflata irritans Melichar cotype], [381], [Paraflata seminigra (Stål), Det. Medler, 1987] – 1 ♂ (parasitized) (IRSNB); [Madagascar, Rumena Val], [Paraflata seminigra Brussel] – 1 ♀ (parasitized) (NHMW); [Madag.], [Boucard.], [78], [NHRS-GULI 000001937] – 1 ♀ (parasitized) (NHRS); [Madagascar l. č. 3744], [Paraflata seminigra Stal.] – 7 exx (NMPC); [13115], [Madagascar Brenn J.], [Paraflata seminigra Melichar det.], [Naturkundemuseum Berlin Germany] – 1 ♀ (ZMHB).

Indeterminate material assigned here to *Paraflata seminigra*: [Museum Paris, Madagascar S.-E., Prov. de Farafangana, Midongy du Sud. 600 a 1000, R. Decary 1926], [AOUT] – 1 ♂ (MNHN); [Tamatave, Dr Martin] – 1 ♀ (MNHN); [Madagascar, Vohilava 60 m, Faraony], [Museum Paris, 1934, R. Catala] – 1 ♂ (MNHN); [20/XI/2005, region lac Alaotra, route Didy à Ambatondrazaka], [Bosquet, végét. Secondaire, fauchage], [Museum Paris, Madagascar 2005, Bourgoin, Ouvrard, Attié, Soulier-Perkins] – 1 ♂ 1 ♀ (MNHN); [MADAGASCAR: Province Fianarantsoa, Parc National Ranomafana, Vohiparara, at broken bridge, el. 1110 m 4–12 February 2002], [21°13.57'S, 47°22.19'E collector: R. Harin'Hala California Acad of Sciences malaise trap in high altitude rainforest, MA-02-09A-15], [Paraflata seminigra (Stal) det. J.T.Medler 2002] – 1 ♂ (CAS); [Museum Paris, Madagascar S.-E., R. Decary 1926], [Hansenia Kirk] – 1 ♂ (MNHN)

Remark. The type from MIZ labelled by Schmidt as *Paraflata seminigra* originally belonged to C.A. Dohrn collection (Stettiner Entomologische Verein) and was the specimen used by Stål for the species description as stated in his paper.

Distribution. Madagascar. Provinces: Antsiranana, Toamasina, Fianarantsoa (Fig. 72).

Associated taxa. Parasitized by Epipyropidae Dyar, 1903 moths – 2 ♂ ♂ and 3 ♀ ♀ (Figs 78–83).

Paraflata kingdomi Distant, 1910
(Figs 56–58, 72)

Paraflata kingdomi Distant, 1910: 302.

Paraflata kingdomi: Jacobi (1917), Melichar (1923), Synave (1956), Metcalf (1957), Medler (1990).

Etymology. The species was named to honour Dr. Kingdom.

Diagnosis. The species can be distinguished from *P. seminigra* (females) by the following characters: posterior margin of pregenital sternite sinuate, bursa copulatrix without visible cells, *ductus receptaculi* much longer than *diverticulum ductus*.

Redescription. Total length 16.3 mm.

Head. Vertex: ratio A/B = 5.60. Frons: ratio C/E = 0.56; D/E = 0.62.

Thorax. Pronotum: ratio F/B = 4.00. Mesonotum: ratio G/F = 4.50, G/B+F = 3.60, G/H = 0.75. Tegmina: ratio I/J = 1.79.

Male terminalia. Male unknown.

Female terminalia. Similar to *P. seminigra* but with the following differences: pregenital sternite with anterior margin straight and posterior margin sinuate (Fig. 56). Gonoploc with triangular lobe, gonapophysis VIII unipartite (Fig. 57). Bursa copulatrix without visible cell imprints; *ductus receptaculi* much longer than *diverticulum ductus*, ribbed, widening apicad; *diverticulum ductus* with distal, narrow part short and ribbed, apically with smooth bulb (Fig. 58).

Coloration. Similar to *P. seminigra*.

Type material. Holotype, ♀: [Type], [Parafleta kingdomi Dist. Type], [Madag. 19.31] – (NHML).

Additional material. [Madagascar: Ankeramadinika, M.E.Fontaine. B.M. 1934-267], [Ankeramadinika Madagascar.] – 1 ♀ (NHML) (pinned in the drawer as *Paraflata kongdomi*).

Remark. Specimens listed above were wrongly interpreted by Medler (1990) as syntypes. Actually, his “lectotype” is Distant’s (1910) holotype. Moreover, according to the original publication, the second specimen does not belong to type material. Therefore, in light of the ICZN (1999) Article 74.2. Medler’s designation of a lectotype is invalid.

Distribution. Madagascar. Province Antananarivo (Fig. 72).

Paraflata dewalschei Lallemand, 1933
(Figs 3, 26–43, 59–63, 72)

Paraflata dewalschei Lallemand, 1933: 198.

Paraflata dewalschei: Synave (1956), Metcalf (1957), Synave (1980).

Etymology. The species was named to honour Dr. Dewalsch.

Diagnosis. The species can be distinguished from other species of the genus by coloration of tegmina and characters of male genitalia – perianthrium appendage process with 2 arms: dorsal and ventral arms almost the same length, shorter than lateral split.

Description. Total length 13.00–15.50 mm.

Head. Vertex: ratio A/B = 5.40–7.50. Frons: ratio C/E = 0.54–0.64; D/E = 0.60–0.71.

Thorax. Pronotum: ratio F/B = 3.50–5.50. Mesonotum: ratio G/F = 4.50–6.20, G/B+F = 3.60–4.89, G/H = 0.74–0.92. Tegmina: ratio I/J = 1.62–1.86.

Male terminalia. Anal tube, in lateral view, with basal part prolonged in form of lobe (Fig. 59). Perianthrium (Figs 60–62): upper margin of perianthrium denticulate, surface of dorsal perianthrium with denticulate microsculpture present on ventro-basal part, base of appendage obovate oriented ventro-posteriorly, process of appendage with 2 arms: dorsal and ventral arms almost the same length, shorter than lateral split, down-curved, dorsal arm massive, ventral arm lanceolate (in specimens from Morondava both arms upcurved as in Fig. 61); ventral part with strongly denticulate margins and long sharp apex, dorso-basal part of perianthrium with narrow lobe. Aedeagus: shaft of aedeagus curved, dorsal margin smooth, apical appendage tapering apicad; ventral side of apical appendage straight.

Female terminalia. Similar to *P. seminigra* but with the following differences: gonoploc with triangular, rolled up lobe (Figs 32–34, 63), gonapophysis VIII unipartite (Figs 35–36, 63).

Coloration. Head, thorax and legs dark brown to black, with yellow discolourations; tegmen mostly milky white with only small black portion at base, abdomen ochraceous (Fig. 3).

Type material. Holotype, ♀: [Environs de Tananarive, Madagascar], [Paraflata Dewalschei Lallemand, V. Lallemand det.], [R. I. Sc. N. B., I. G. 18.380], [Type], [Holotype], [Paraflata dewalschei. Lallemand.] – (IRSNB).

Paratypes: 5 ♂♂, 11 ♀♀ (6 parasitized), [Environs de Tananarive, Madagascar], [Paratype] [R. I. Sc. N. B., I. G. 18.380] – (IRSNB).

Additional material. [Morondava forêt sud de Befasy 1-56 R.P.], [Institut Scientifique Madagascar], [R.I.Sc.N.B. I.G. 22.889] – 3 ♂♂ (1 parasitized) 3 ♀♀ (1 parasitized) (IRSNB); [Morondava forêt sud de Befasy 1-56 R.P.], [Institut Scientifique Madagascar], [Coll. Mus. Tervueren], [Paraflata dewalschei Lall H. Synave det., 195] – 1 ♀ (RMCA); [Ambatolaona, Madagascar], [Collectio Dr. L. Melichar, Moravské museum Brno], [Transcriptio Paraflata seminigra Stål L. Melichar det.] – 1 ♀ (MMBC); [Ambatolaona, Madagascar], [16], [irritans Paraflata], [Collectio Dr. L. Melichar, Moravské museum Brno], [Transcriptio Paraflata seminigra Stål L. Melichar det.] – 1 ♀ (parasitized) (MMBC); [Madagascar: Province Antananarivo. 46 km NE of Ankazobe: Ambohitantaly 18°11.88’S, 47°16.89’E, 1–12 February 2004], [California Acad of Sciences, coll: M. Irwin, R. Harin’Hala, malaise trap – in sclerophyl forest elev 700m, MA-27-15], [CASENT 8107345] – 1 ♀ (CAS).

Distribution. Madagascar. Provinces: Toliara, Antananarivo (Fig. 72).

Associated taxa. Parasitized by Epipyropidae moths – 1 ♂ and 8 ♀♀ (Figs 73–77).

Paraflata masoalae sp. nov.
(Figs 2, 64–69, 72)

Etymology. The specific epithet comes from the name of the Masoala peninsula – *terra typica* of the species.

Diagnosis. The species can be distinguished from other species of the genus by the following characters: male apical part of anal tube, in lateral view, widely rounded, with triangular lobe oriented ventrad; perianthrium appendage process with 1 massive, laterally flattened curved arm distinctly surpassing lateral split, apex oriented dorsad.

Description. Total length 15.50–15.70 mm.

Head. Vertex: ratio A/B = 4.29. Frons: ratio C/E = 0.47; D/E = 0.50–0.53.

Thorax. Pronotum: ratio F/B = 2.29–2.86, disc of pronotum without median groove. Mesonotum: ratio G/F = 5.50–5.94, G/B+F = 4.07–4.13, G/H = 0.85–0.96. Tegmina: sutural angle acute and slightly produced, ratio I/J = 1.63–1.68.

Male terminalia. Anal tube, in lateral view, with apical part widely rounded, with triangular lobe oriented ventrad, basal part prolonged (Fig. 64). Anal tube, in dorsal view, broadly widening apicad, with median shallow incision (Fig. 65).

Perianthrium (Figs 66–67): upper margin of perianthrium smooth, surface of dorsal perianthrium with denticulate microsculpture along ventral margin, base of appendage triangular oriented dorsad, process of appendage with 1 massive, laterally flattened curved arm distinctly surpassing lateral split, apex oriented dorsad; ventral part with delicately denticulate margins and blunt apex with median incision, dorso-basal part of perianthrium without lobe. Aedeagus (Figs 69–69): shaft of aedeagus almost straight, dorsal margin denticulate; apical appendage tapering dorsad; ventral side of apical appendage curved.

Female terminalia. Female unknown.

Coloration. Coloration similar to *P. seminigra*.

Type material. Holotype, ♂: [Madagascar Est presqu'île Masoala Hiaraka XII. 1968 Vadon et Peyrieras], [Museum Paris] – (MNHN).

Paratypes: 2♂♂, [Madagascar Est presqu'île Masoala Hiaraka XII. 1968 Vadon et Peyrieras], [Museum Paris] – (MNHN).

Distribution. Madagascar. Province Antsiranana (Fig. 72).

Paraflata unispinosa sp. nov.
(Figs 70–72)

Etymology. The specific epithet comes from the unique character: single process of aedeagus.

Diagnosis. The species can be distinguished from other species of the genus by the following characters: male perianthrium appendage process with single, almost straight arm, with curved apex oriented basad; arm reaching end of lateral split.

Description. Total length 14.00–14.20 mm.

Head. Vertex: ratio A/B = 4.00–4.17. Frons: ratio C/E = 0.46–0.50; D/E = 0.52–0.58.

Thorax. Pronotum: ratio F/B = 2.86–3.33. Mesonotum: ratio G/F = 4.00–4.50, G/B+F = 3.08–3.46, G/H = 0.82–0.94. Tegmina: ratio I/J = 1.65–1.73.

Male terminalia. Perianthrium (Figs 70–71): upper margin of perianthrium smooth, surface of dorsal perianthrium with denticulate microsculptures, base of appendage elongate with rounded apex oriented ventro-posteriorly, process of appendage with 1 arm almost straight, with curved apex oriented basad, arm reaching end of lateral split; ventral part with denticulate margins and short sharp apex, dorso-basal part of perianthrium with narrow and elongate lobe.

Female terminalia. Unknown as the abdomen of the only available female is damaged.

Coloration. Coloration similar to *P. seminigra*.

Type material. Holotype, ♂: [Madagascar Antongil B. Mocquerys], [seminigra det. Melichar.], [Hung. Nat. Hist. Mus. Budapest coll. Hemiptera] – (HNHM).

Paratypes: 1♂, [Madagascar Antongil B. Mocquerys], [seminigra det. Melichar.], [collection Dr. L. Melichar Moravské museum Brno], [Transcriptio *Paraflata seminigra* Stål L. Melichar det.] – (MMBC); 1♀, [Madagascar Antongil B. Mocquerys], [seminigra det. Melichar.], [Hung. Nat. Hist. Mus. Budapest coll. Hemiptera] – (HNHM).

Remark. All specimens belonging to the type material were examined by Melichar and published as *Paraflata seminigra* in his monograph (Melichar 1901: 218).

Distribution. Madagascar. Province Toamasina (Fig. 72).

Associated taxa. Parasitized by Epipyropidae moths – 1♀.

DISCUSSION

The genus *Paraflata* is mainly distributed in the eastern and central part of Madagascar (Fig. 72): *P. seminigra* on Nosy-Be island and in the eastern lowlands of Madagascar, *P. kingdomi* on the eastern escarpment of the Ankaratra massif, *P. dewalschei* on the northern slope of the Ankaratra massif and an isolated locality on the west coast, *P. masoalae* in the Masoala peninsula and *P. unispinosa* in Antongil Bay (the northern end of the east coast). The dipolar distribution (mountain and coastal) reported here for

P. dewalschei is surprising but it has already been recorded for other flatids such as *Madoxychara unicornis* Stroiński et Świerczewski, 2013 (Stroiński and Świerczewski 2013b) and *Perinetella flavomarginata* Świerczewski et Stroiński, 2015 (Świerczewski and Stroiński 2015) as well as other groups of insects (e.g., Iwan and Kamiński 2012). However, all the mentioned cases have still not been satisfactory explained.

What is also interesting is that a close examination of *Paraflata* specimens revealed several individuals of different species hosting pupae of ectoparasitic moths of the family Epipyropidae Dyar, 1903 (planthopper parasite moths).

Epipyropidae represent a small Lepidoptera family, whose species are well known as a parasite of various hemipteran taxa, mainly planthoppers, in their larval stages. The family comprises about 40 species separated into two subfamilies, Epipyropinae Dyar, 1903 and Heteropsychinae Perkins, 1905 distributed in tropical and warm temperate areas, mainly in Australia and on the Indian subcontinent (Heppner 2008). In the Afro-tropical area, 6 species have been recorded, including 3 known in eastern and central Madagascar (De Prins and De Prins 2015).

Adult epipyropids are minute insects (4,00–35,00 mm wingspan), characterized by a robust body, with head scaling mostly roughened, and quadratic, broadly rounded wings (Heppner 2008). Their activity is crepuscular and nocturnal; males are active, in contrast to females, which are sedentary, laying eggs on various plants. Epipyropid larvae are hypermetamorphic, with a campodeiform first instar which seeks a host that predominantly belongs to planthoppers (Pierce 1995), while later instars are eruciform and fixed on the dorsal area of the host abdomen, where they are generally located (Quartau *et al.* 1998).

The biology of planthopper parasite moths is precisely known only for a few species, but particularly for *Fulgoraecia melanoleuca* (Fletcher, 1939). This species is an ectoparasitoid on nymphs and adults of the lophopid planthopper *Pyrilla perpusilla* (Walker, 1851) and has been extensively used for biocontrol programs against this pest in India (Gangwar *et al.* 2008). Females of *F. melanoleuca* lay up to 450 eggs and the newly hatched larvae have been observed in an erect position, clinging to the margins of leaves with their pro-legs and waving their thorax back and forth, ready to grasp a host when it passes. After catching a host, the larva attaches itself by hooked claws to one side of the abdomen with its head directed posteriorly. In this position, the larva penetrates the host cuticle with sharp mandibles and sucks on the host's body fluids. However, in some other species such as *F. cerolestes* Tams, 1947 no signs that the tegument was punctured were observed (Kirkpatrick 1947) and the larvae are supposed to feed on the waxy secretions of adult

planthoppers. The larva passes through three instars on the host. During this period it develops a waxy covering over the body, making it conspicuous. In *F. melanoleuca* the fully-grown larva leaves the host, pupates on the surface of the leaf and spends 4–11 days as pupa. The host *P. perpusilla* often dies after it has been released by the epipyropid parasitoid (Kumarsinghe and Wratten 1996, Kumar *et al.* 2015). At the contrary, in *Paraflata* the parasitic larva don't leave the host for a plant, but pupates into a silk cocoon attached to the abdomen of the planthopper, which itself remains alive and continue to carry the non-feeding pupa. These suggest that the moth act here rather as an ectoparasite than as a parasitoid.

Although only three species of epipyropids are known from Madagascar (Figs 84–87): *Fulgoraecia grandidieri* (Viette, 1960), *F. malagassica* (Jordan, 1928) and *F. radama* (Viette, 1960), we were unable to identify the species parasitizing the *Paraflata* specimens with the only pupa stage. However, *P. seminigra*, *P. dewalschei*, and *P. unispinosa* interestingly expand the list of flatid hosts known for being parasitized by Epipyropidae, including: *Ityrea patricia* (Melichar, 1901), *Mesophantia kanganica* Dlabola, 1983, *Metcalfa pruinosa* (Say, 1830), *Sanurus indecora* (Jacobi, 1941) and *Sanurus flavovenosus* Bierman, 1910 (Pierce 1995).

Many aspects of the interaction between Hemiptera and the parasitic moths are still enigmatic and further studies and observations are needed to better understand this interesting phenomenon. For instance, one of the issues already noted is the higher ectoparasitism reported for female hosts (over 80%) than for males in two Indonesian flatid species (Supeno 2011): *S. indecora* and *S. flavovenosus*, infested by larvae of *Epieurybrachys* Kato, 1940. This differential ratio was also observed here for the *Paraflata* species: *P. seminigra* (2♂♂ and 3♀♀), *P. dewalschei* (1♂ and 8♀♀) and *P. unispinosa* (1♀). Whether this observation is a real preference (attraction/recognition) of the parasites for the female hosts or it only reflects some biased sampling connected with the probable longer life of the female lying their eggs, remains to be further investigated.

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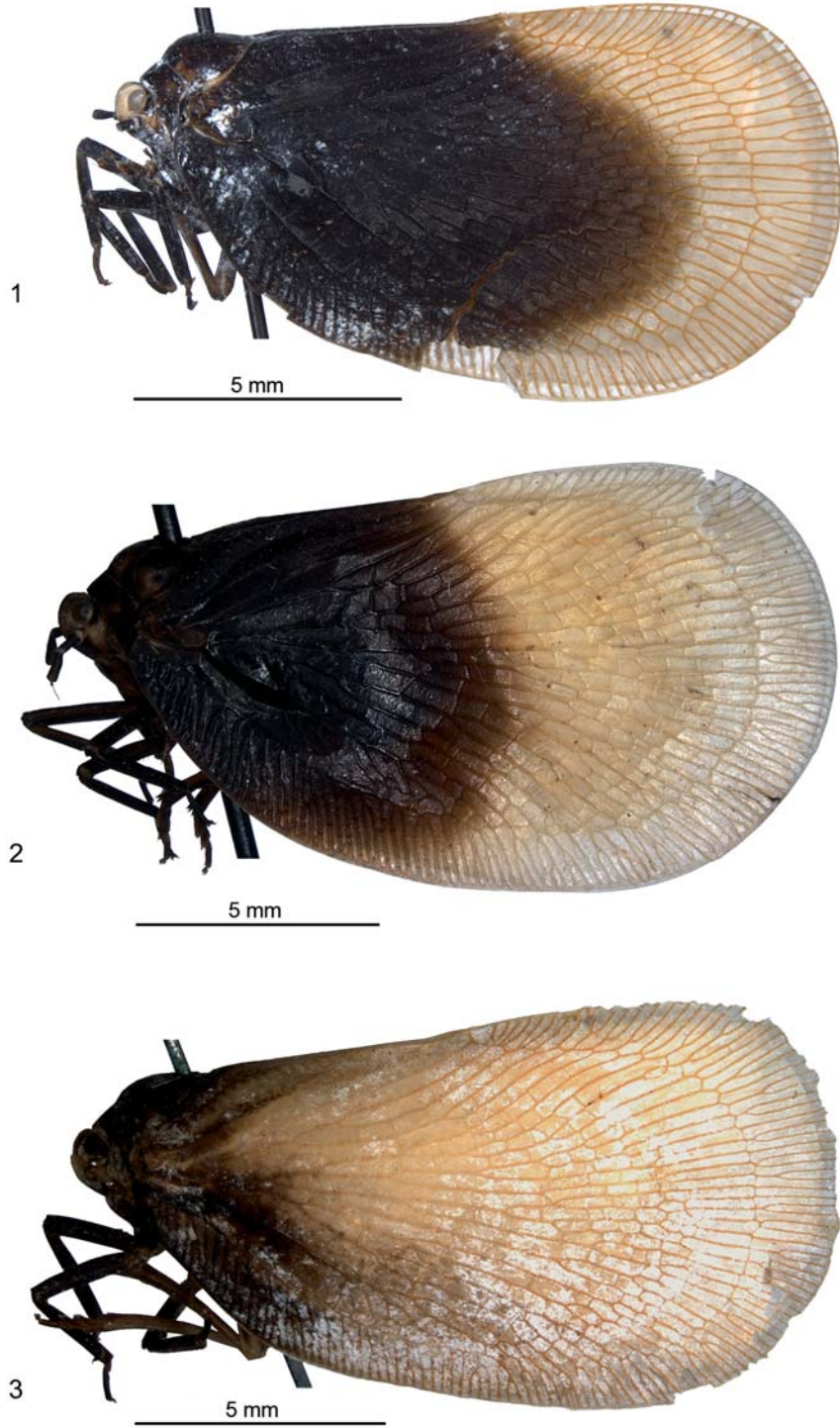
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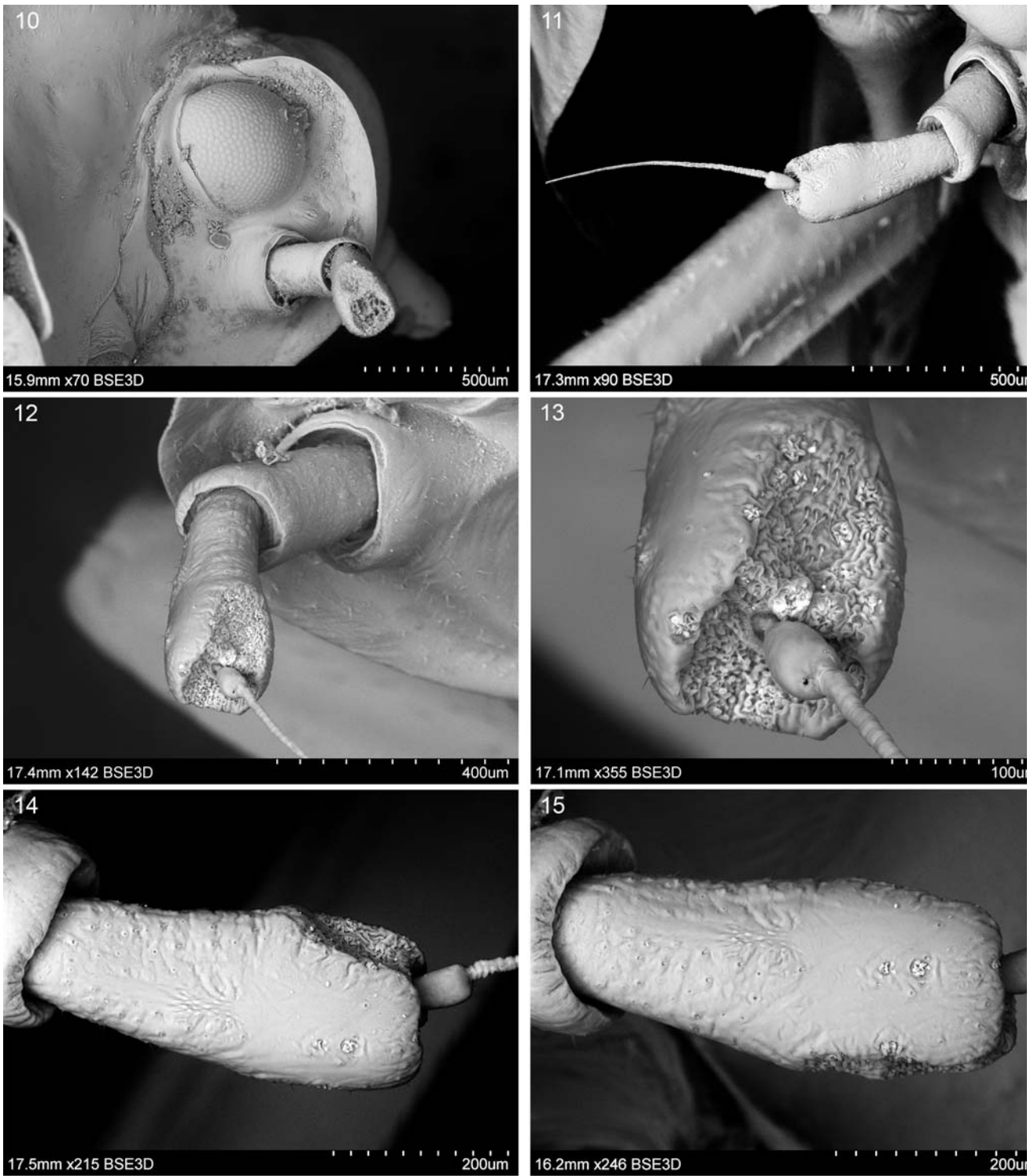
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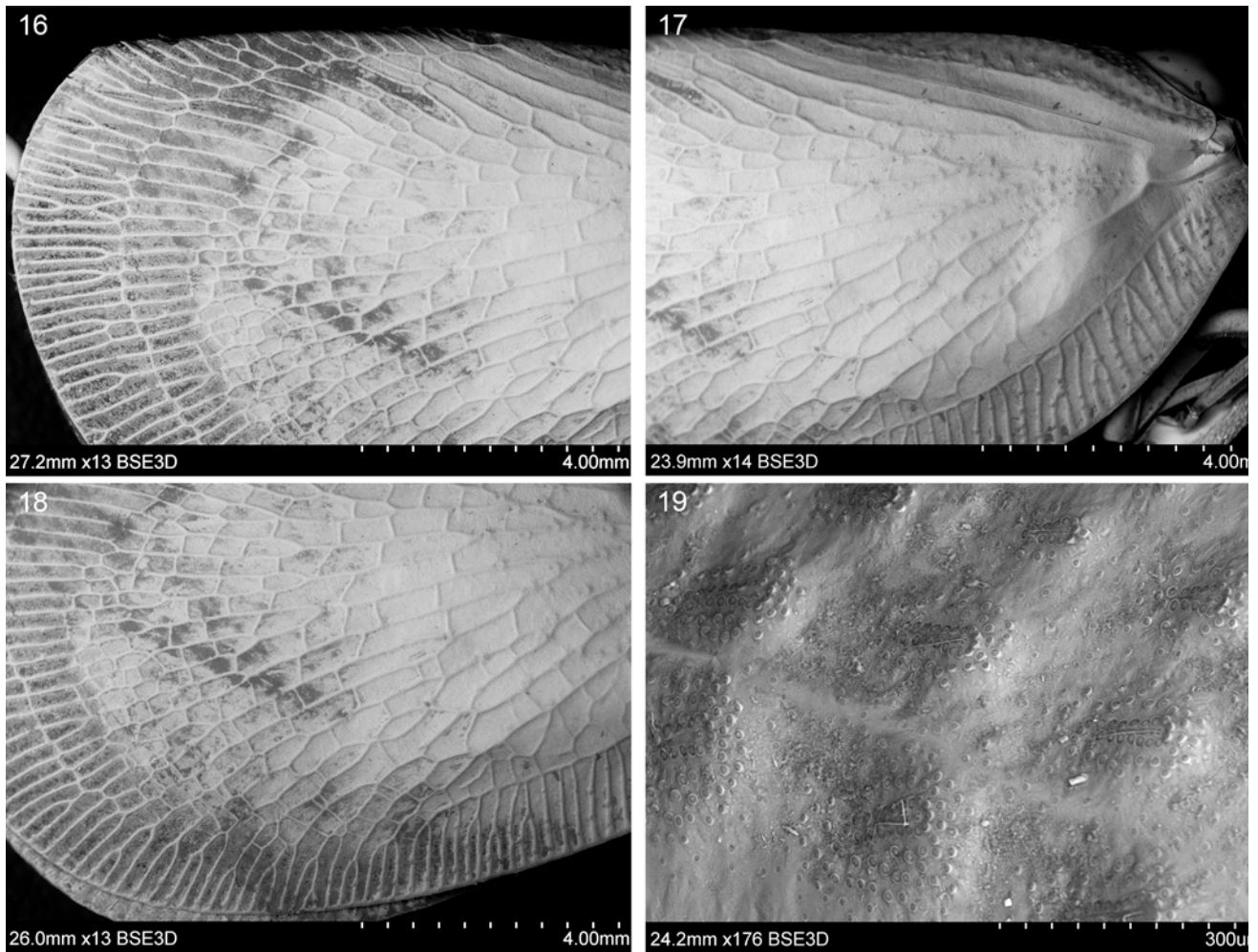
Figures 1–3. *Parafлата* spp., habitus, lateral view. (1) *P. seminigra*, male from Vohilava/Faraony; (2) *P. masoalae* sp. nov., male – paratype; (3) *P. dewalschei*, female – paratype.



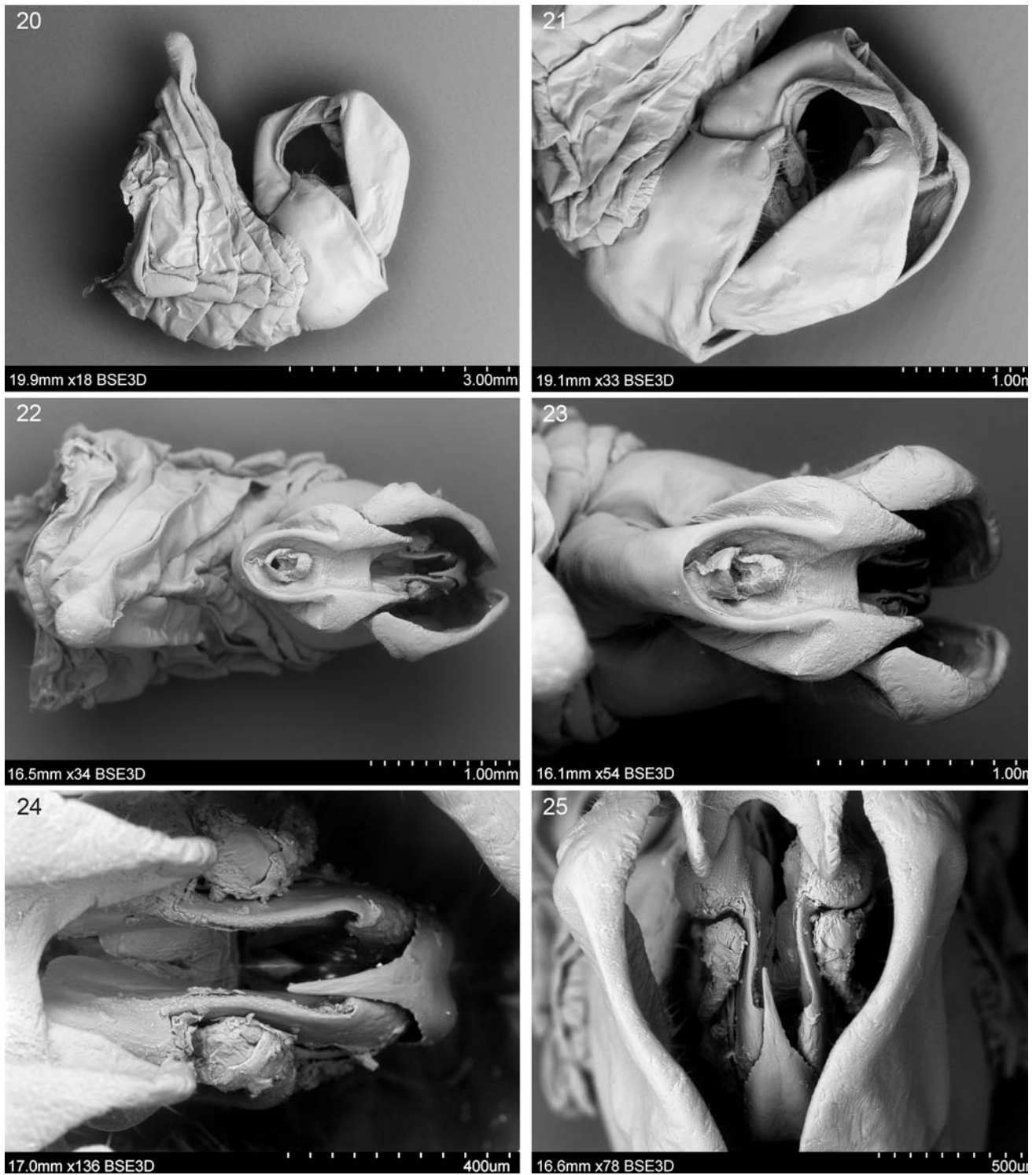
Figures 4–9. *Parafлата seminigra*, male from lac Alaotra, SEM photos. (4) Anterior part of body, frontal view; (5) anterior part of body, ventro-lateral view; (6) anterior part of body, dorso-lateral view; (7) vertex and pronotum, dorso-lateral view; (8) anterior part of body, lateral view; (9) mesonotum; dorsal view.



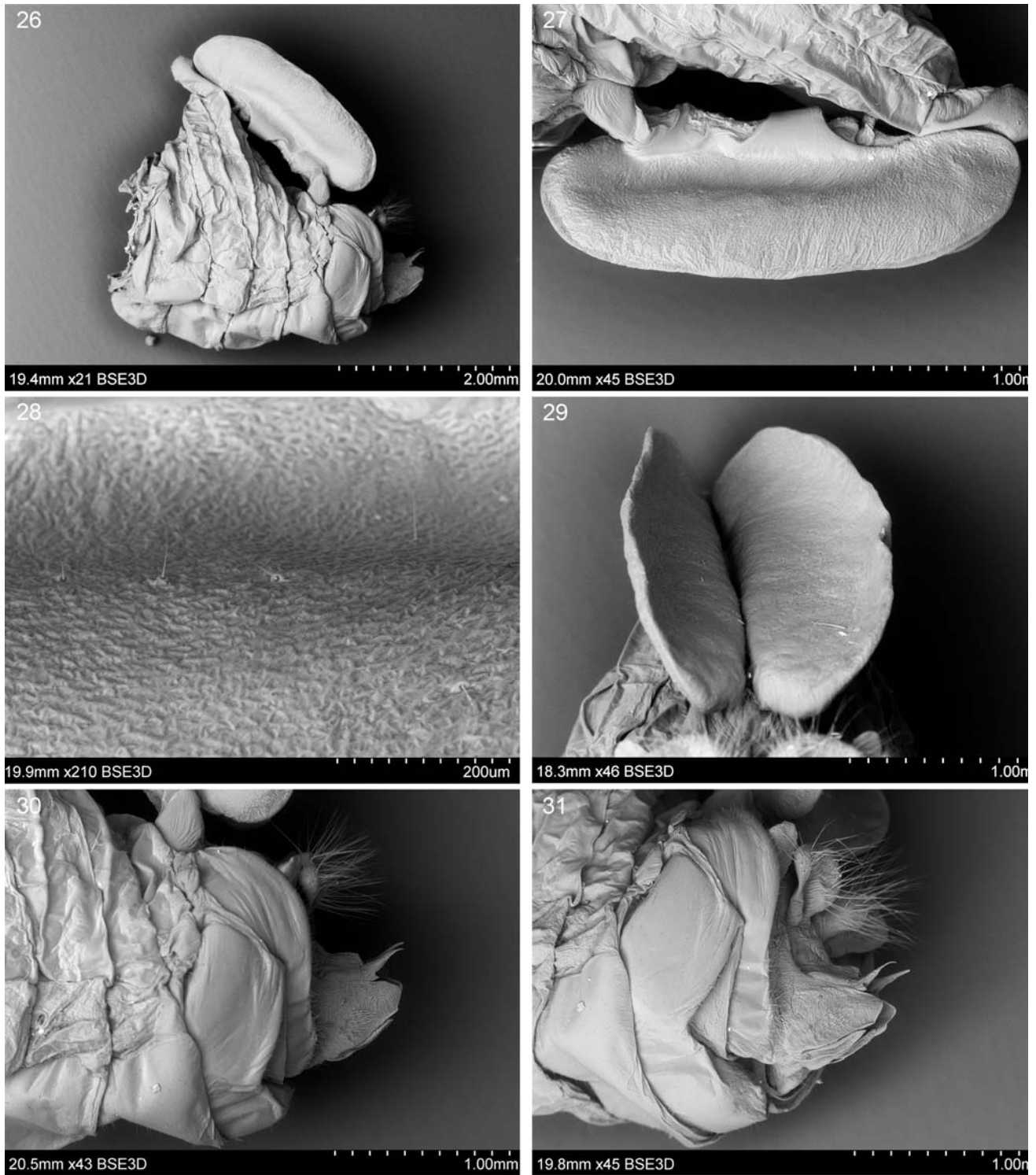
Figures 10–15. *Paraflata seminigra*, male from lac Alaotra, antenna, SEM photos. (10–11) General view; (12–13) apical part; (14–15) lateral view.



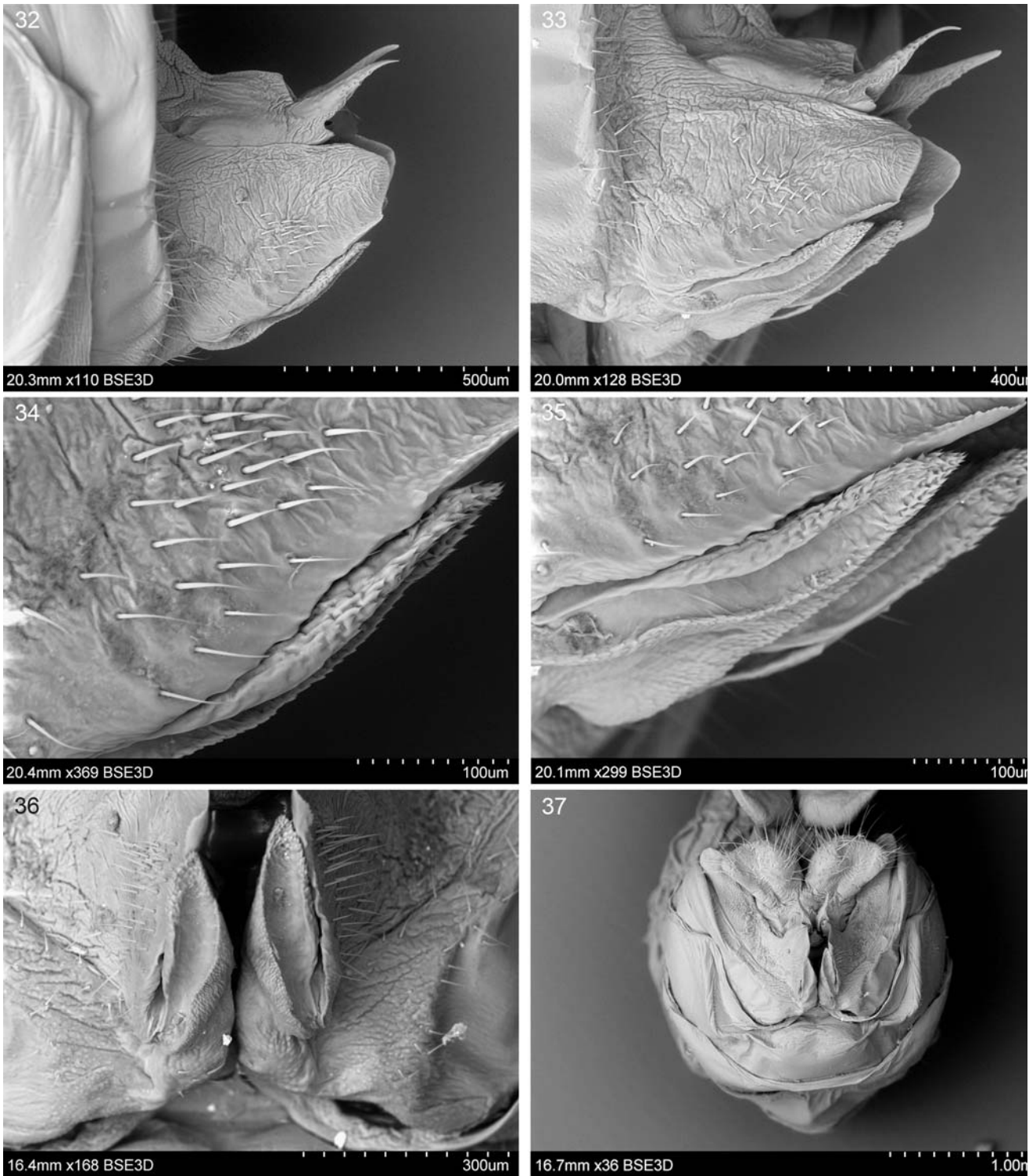
Figures 16–19. *Parafлата seminigra*, male from lac Alaotra, tegmen, SEM photos. (16) Dorso-apical part; (17) basal part; (18) ventro-apical part; (19) sensory and secretory structures.



Figures 20–25. *Paraflata seminigra*, male from Ranomafana, terminalia, SEM photos. (20–21) Lateral view; (22–23) dorsal view; (24–25) frontal view.



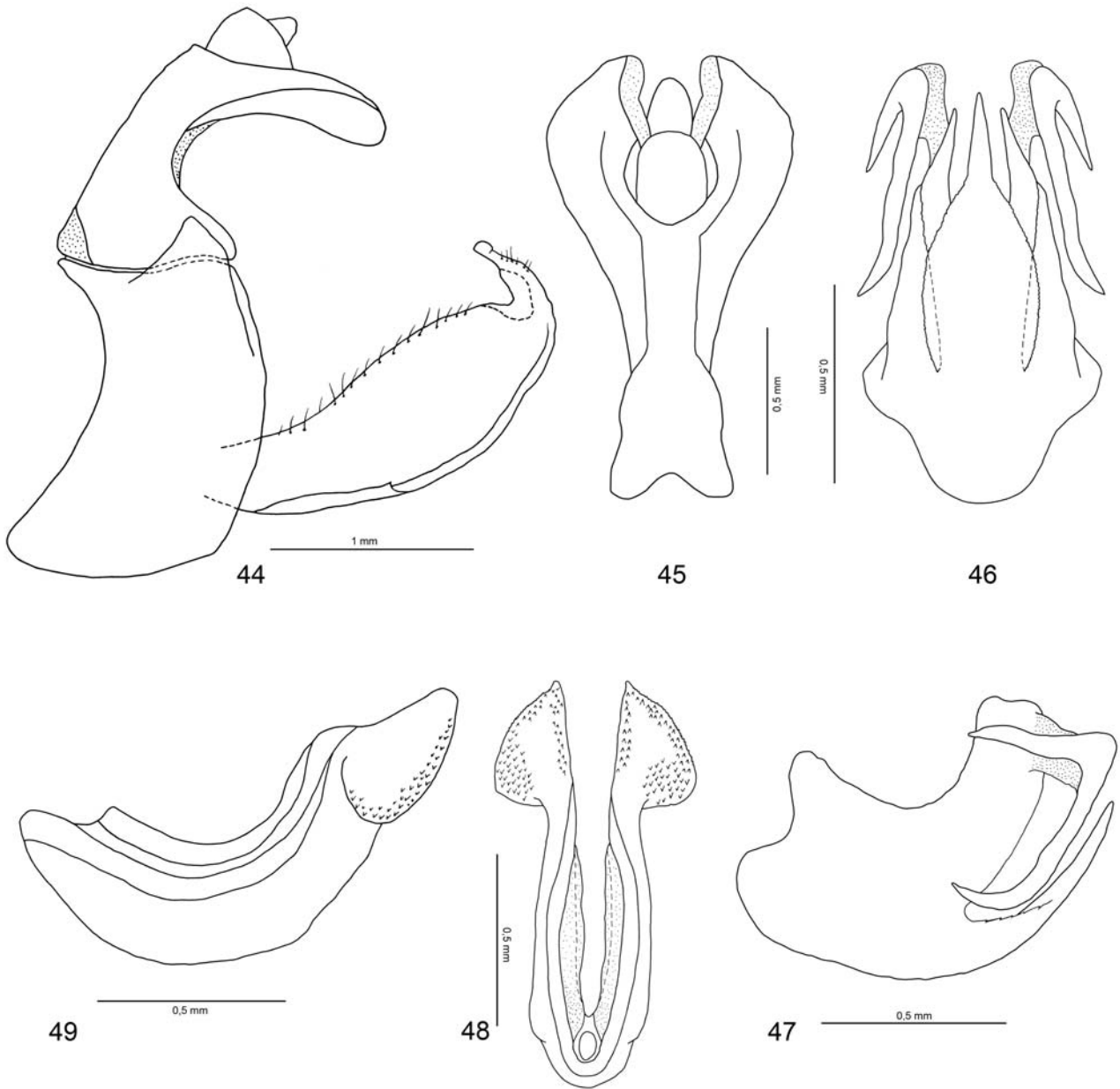
Figures 26–31. *Parafleta dewalschei*, female from Ankazobe, SEM photos. (26) terminalia, lateral view; (27) anal tube, lateral view; (28) same, surface structure; (29) same, dorsal view; (30–31) genitalia, lateral view.



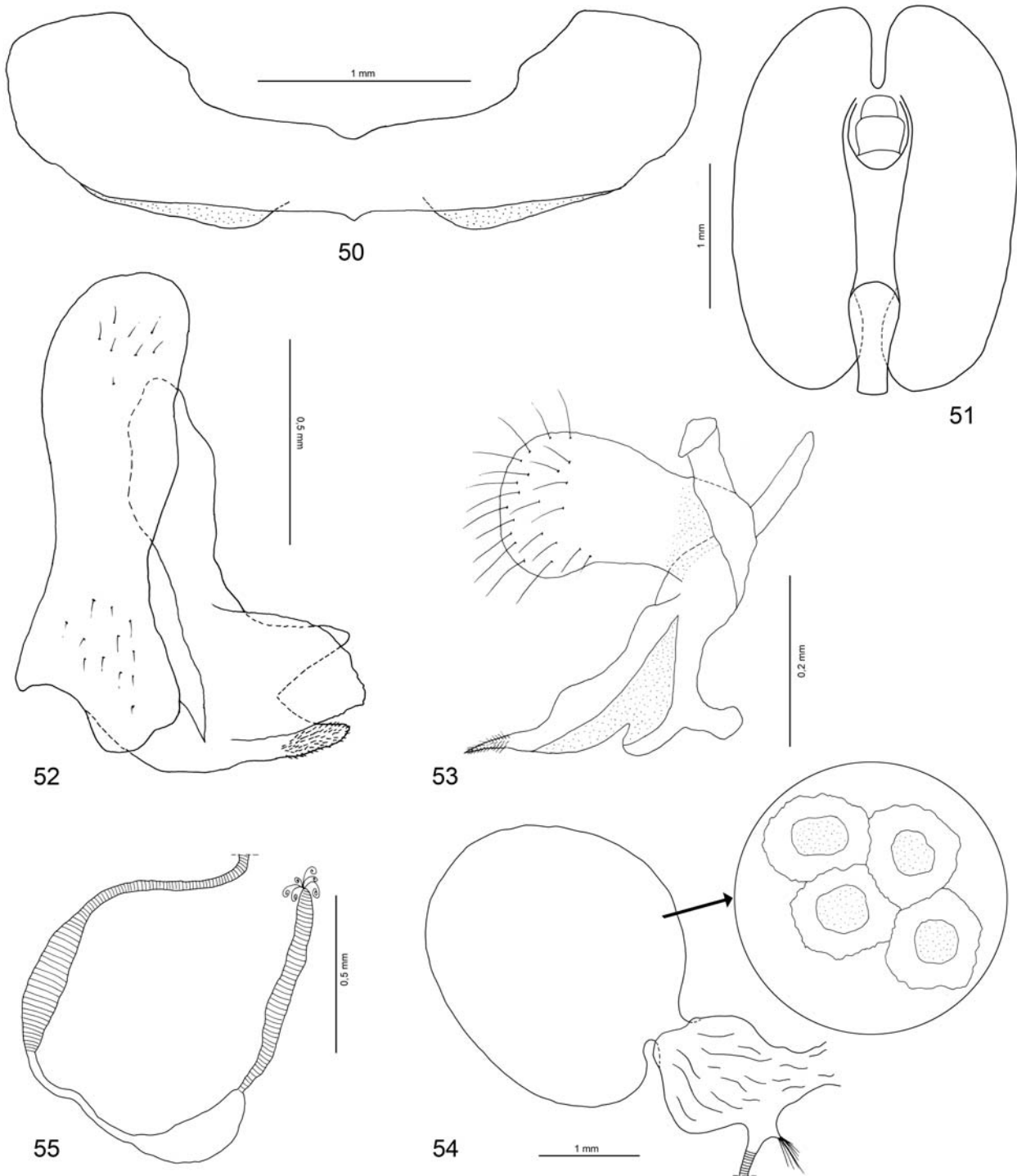
Figures 32–37. *Paraflata dewalschei*, female from Ankazobe, SEM photos. (32–33) gonoplac, lateral view; (34–35) gonapophysis VIII, lateral view; (36) gonoplac and gonapophyses VIII, frontal view; (37) genitalia, frontal view.



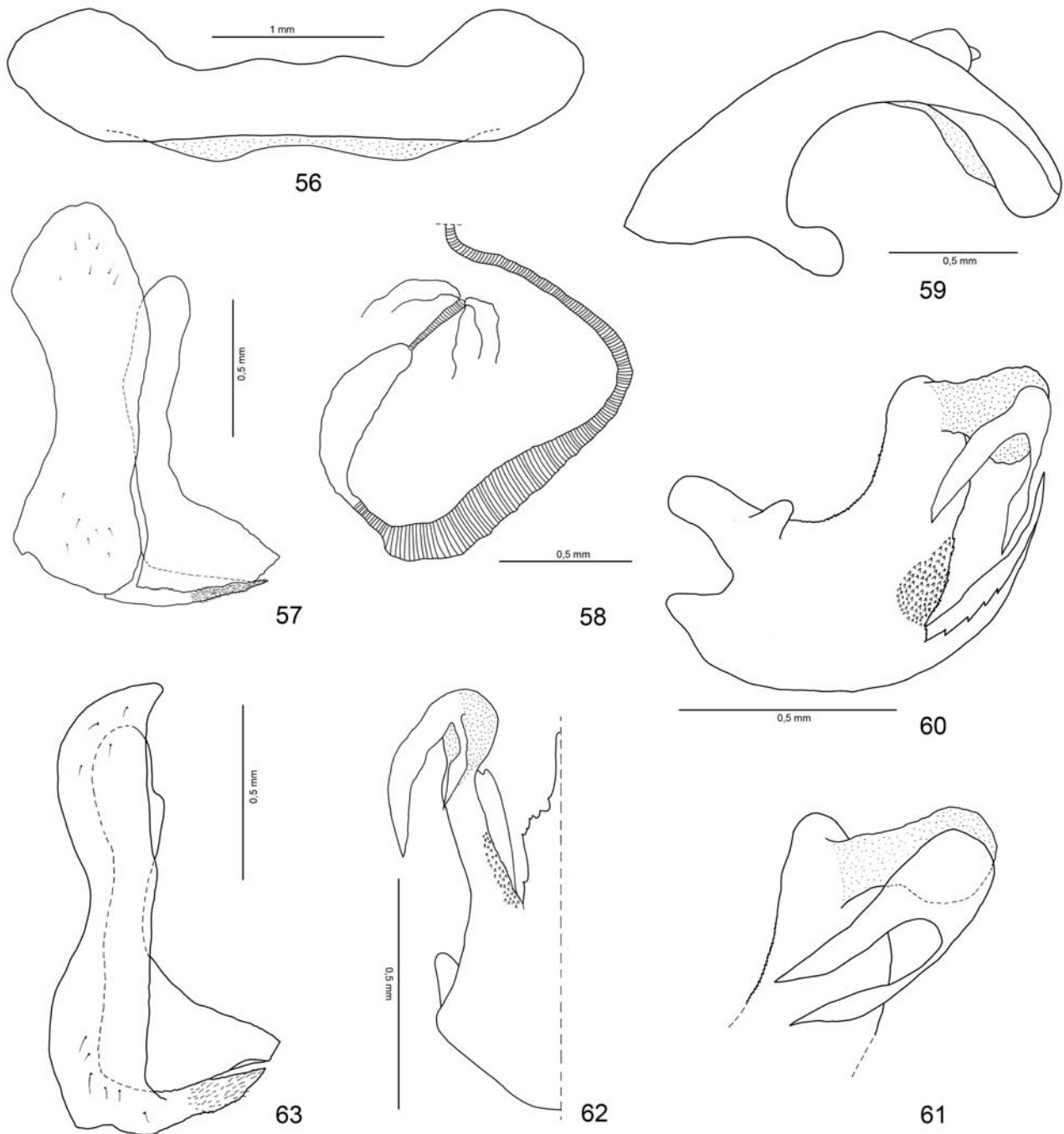
Figures 38–43. *Parafhlata dewalschei*, female from Ankazobe, SEM photos. (38–39) gonospiculum, frontal view; (40–42) gonospiculum, lateral view; (43) genitalia, frontal view.



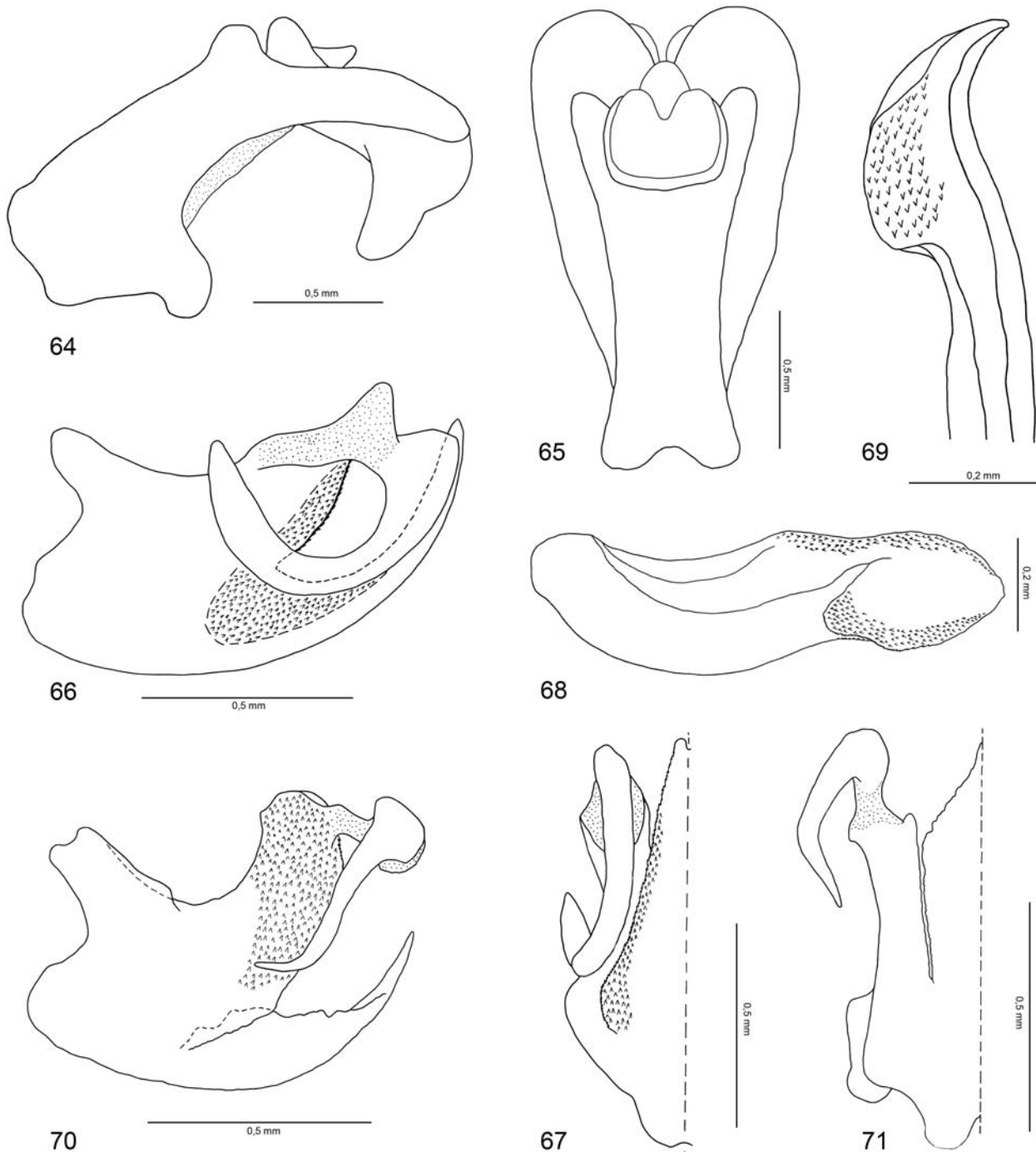
Figures 44–49. *Paraflata seminigra*, male. (44) Terminalia, lateral view; (45) anal tube, dorsal view; (46) periandrium, ventral view; (47) same, lateral view; (48) aedeagus, ventral view; (49) aedeagus, lateral view.



Figures 50–55. *Parafllata seminigra*, female – holotype. (50) Pregenital sternite, depressed; (51) anal tube, dorsal view; (52) gonoplac, external view; (53) gonospiculum and gonospiculum bridge, lateral view; (54) bursa copulatrix and cells (female from lac Alaotra); (55) spermatheca (female from lac Alaotra).



Figures 56–63. 56–58. *Parafлата kingdomi*, female from Ankeramadinika. (56) Pregenital sternite, flattened; (57) gonoplac, external view; (58) spermatheca; 59–63. *Parafлата dewalschei*, (59–62) male, (63) female – holotype. (59) Anal tube, lateral view; (60) perianthrium, lateral view; (61) perianthrium, apical part (specimen from Morondava); (62) perianthrium, ventral view; (63) gonoplac, external view.



Figures 64–71. (64–69) *Parafleta masoalae* sp. nov., male – holotype. (70–71) *Parafleta unispinosa* sp. nov., male – holotype. (64) Anal tube, lateral view. (65) same, dorsal view; (66) perianthium, lateral view; (67) same, ventral view; (68) aedeagus, lateral view; (69) aedeagus, apical part, ventral view; (70) perianthium, lateral view; (71) same, ventral view.

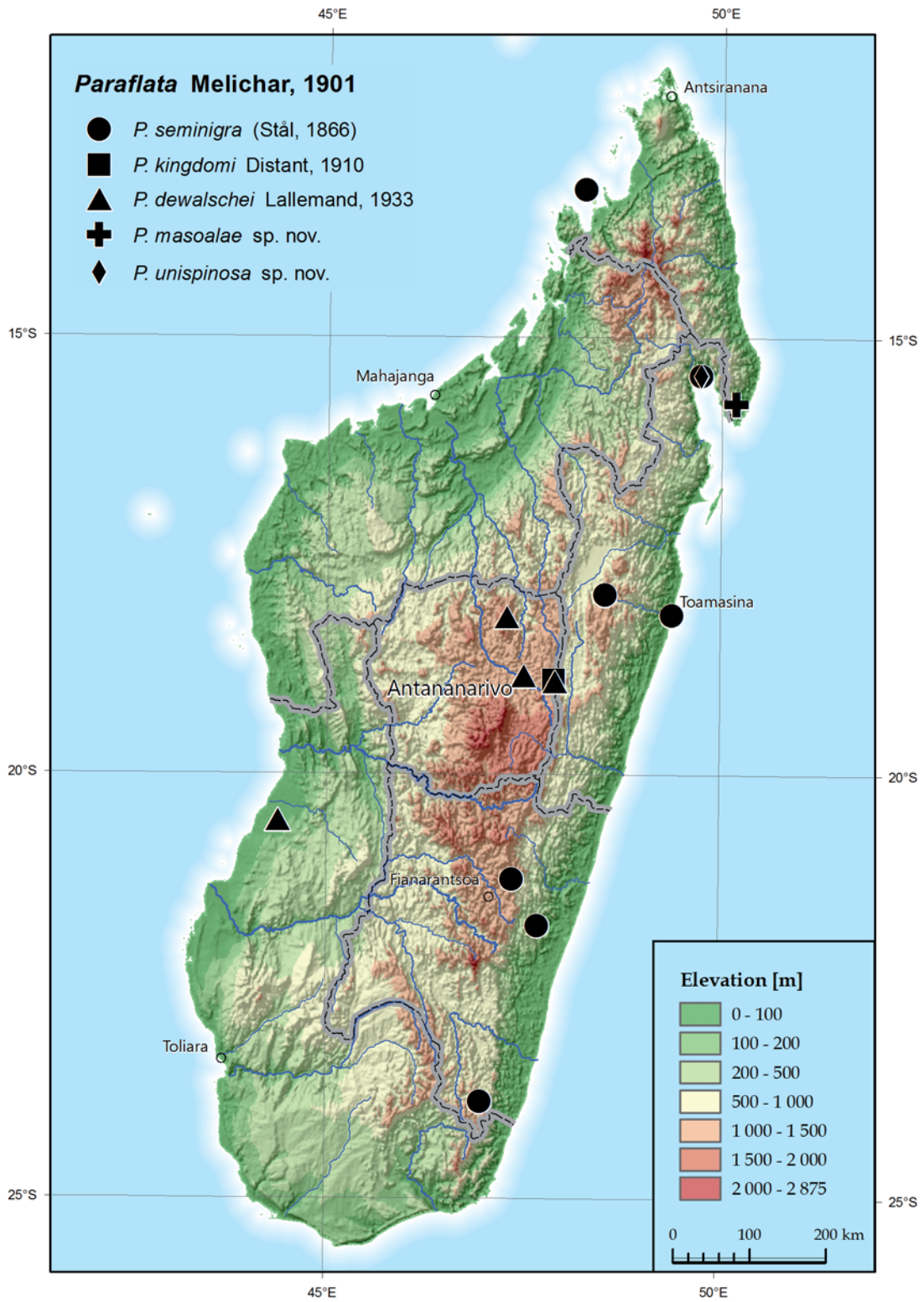
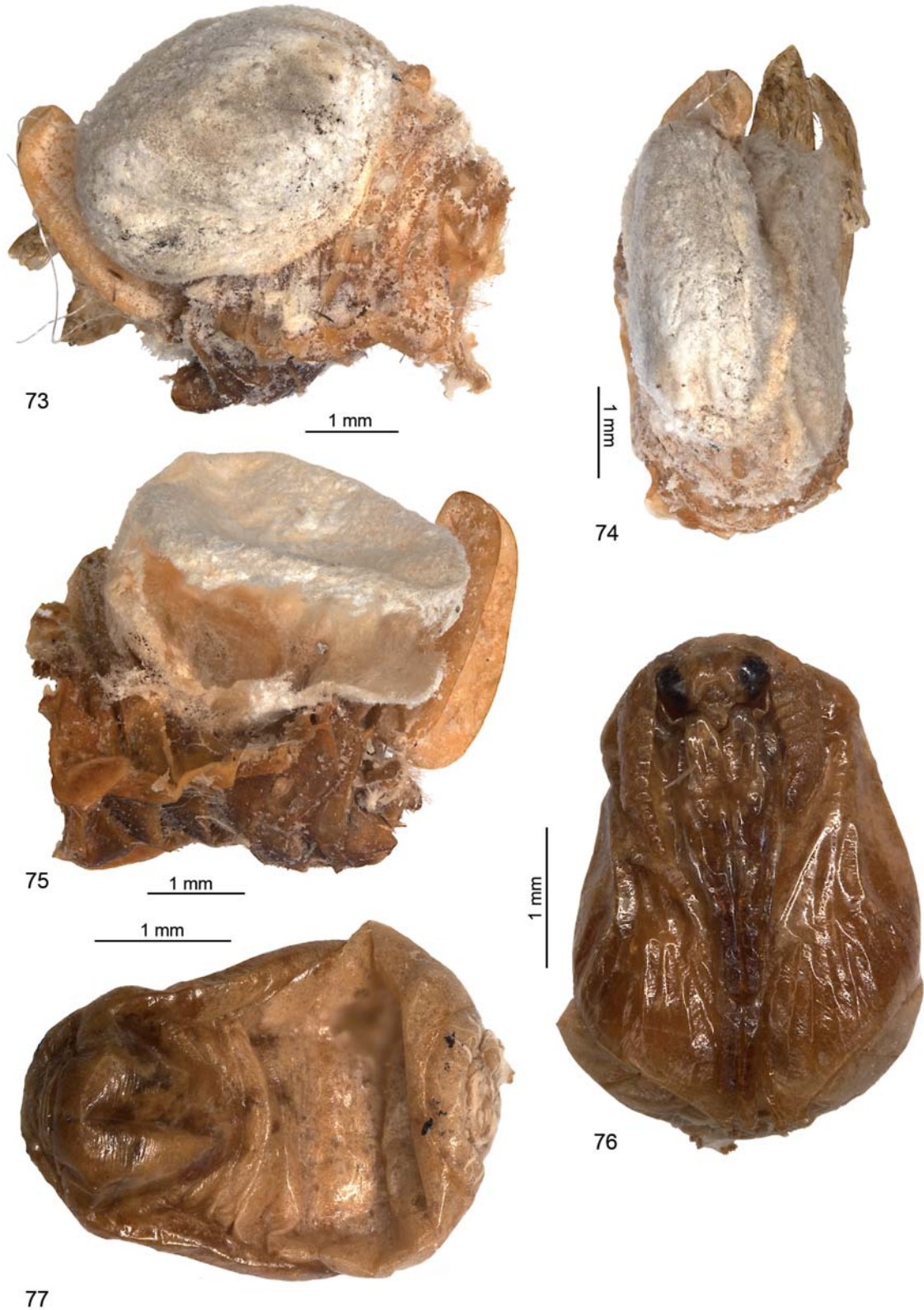
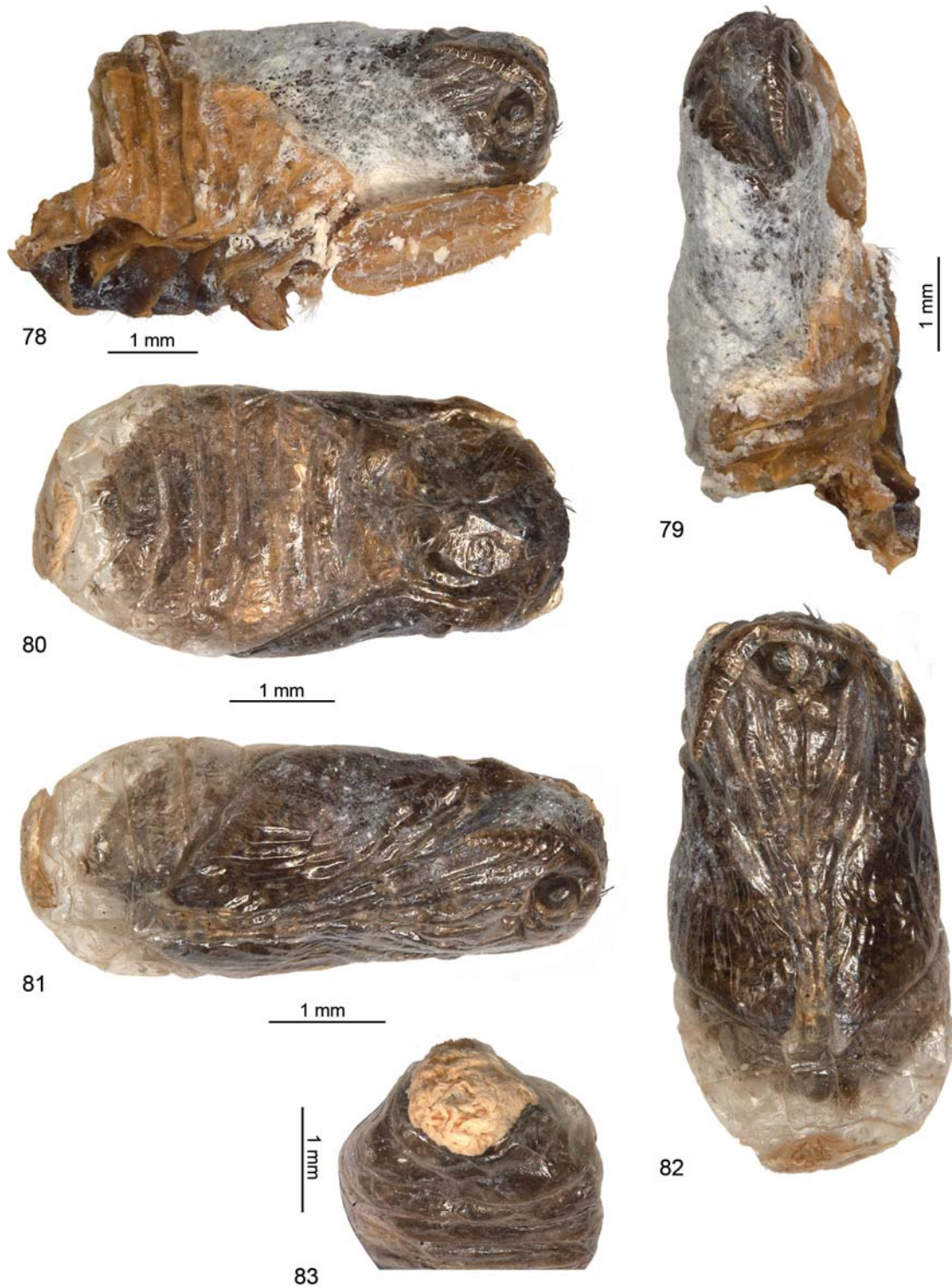


Figure 72. Distribution of the genus *Paraflata*.



Figures 73–77. Epipyropidae moths parasitizing female of *Parafлата dewalschei* (paratype). (73–75) Cocoon with chrysalid attached to abdomen: (73) lateral view, (74) dorsal view, (75) lateral view with open cocoon; (76) chrysalid dissected from the cocoon, ventral view; (77) – same, dorsal view.



Figures 78–83. Epipyropidae moths parasitizing female of *Paraflata seminigra* (specimen from Nossi-Be, Rumena Val., collection of NHMW). (78–79) Chrysalid partly released from the cocoon: (78) lateral view, (79) dorsal view; (80) chrysalid dissected from the cocoon, dorsal view; (81) – same, dorso-lateral view; (82) – same, frontal view; (83) – same, apical part of abdomen.



Figures 84–87. Epipyropidae moths from Madagascar, specimens from MNHN. (84–85) *Fulgoraecia radama* (Viette, 1960), holotype: (84) habitus, (85) labels; (86) *Fulgoraecia malagassica* (Jordan, 1928) labelled: [Andobo 190 m, forêt Antsingy, det Antsalovo, -II-57 Griv.], [Institute Scientifique Madagascar]; (87) *Fulgoraecia grandidieri* (Viette, 1960), paratype.