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THE GENUS *PROCORDULIA* MARTIN IN WESTERN MALESIA (ODONATA, CORDULIIDAE)

Descriptions and records of Malesian Odonata, 4 *)

Tol, J. van, 1997. The genus *Procordulia* Martin in western Malesia (Odonata, Corduliidae). Descriptions and records of Malesian Odonata, 4. – Tijdschrift voor Entomologie 140: 133-146, figs. 1-27. [ISSN 0040-7496]. Published 31 October 1997.
The species of the genus *Procordulia* occurring in Malaysia, the Philippines and Indonesia, excl. New Guinea, are discussed and a key to the species is provided. *P. papandayanensis* is described from Java, and *P. lompobatang* and *P. rantemario* from SW Sulawesi. These new species all belong to the *P. sambawana* group of species.
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Key words. – *Procordulia*; Malesia; Java; Sulawesi; new species.

*) Part 3: Tijdschrift voor Entomologie 138: 131-141.

All species of *Procordulia* Martin of the western part of Malesia are assigned to an apparently monophyletic group, the so-called '*sambawana*' group. *P. sambawana* Foerster was formerly considered a widespread, although rather variable species (e.g. Lieftinck 1930) in which possibly several geographical races could be distinguished. Later, Lieftinck (1977: 165) provisionally split off the Javan specimens for which the name *P. karnyi* Fraser was available. Although this observation was cryptically published without comment, this opinion was followed in the recent checklist by Davies & Tobin (1985), but not by Tsuda (1991). Lieftinck also mentioned the existence of two undescribed species on Sulawesi (Celebes) (Lieftinck 1977: 167). All further studies on Corduliidae by Lieftinck remained, however, unfinished and unpublished.

In the present paper descriptions or diagnoses of eight species from the Lesser Sunda Islands, Java, Sumatra, Borneo, Sulawesi (Celebes) and Mindanao, are provided. Three species are described as new to science. This paper focuses on the species of western Malesia, although also new species from New Guinea are available in various collections. Also, a first attempt is made to understand the relationships of the Malesian Corduliidae at a higher level. A more detailed analysis of the species groups now united in *Procordulia*, and a general discussion of the Indo-Australian genera of Corduliidae, has to await the descriptions of new Papuan representatives of *Procordulia* and *Hemicordulia*. Finally, the biogeography of the western Malesian species is briefly discussed.

Abbreviations for museums and institutions follow the 'codens' in Arnett & Samuelson (1986).

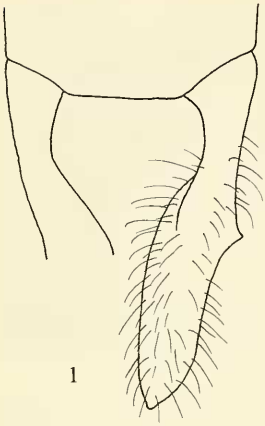
Systematic part

Procordulia Martin, 1907 [1906]

Type species. – *Cordulia affinis* Selys, 1871 [selected Ris 1910: 437].

The closely related genera *Hemicordulia* Selys and *Procordulia* can be distinguished (Martin 1907) by (a) the presence of auriculae in *Procordulia* (absent in *Hemicordulia*), (b) the presence of a cross-vein in the anal triangle of *Procordulia* (absent in *Hemicordulia*), and (c) a distinct anal angle in the hind wing of *Procordulia* (rounded in *Hemicordulia*).

The distinguishing characters of both genera are, however, not so clear (e.g. Watson et al 1991: 218) anymore, especially since the discovery of several intermediate forms in the Pacific. The status of both genera is further evaluated in the discussion section of this paper.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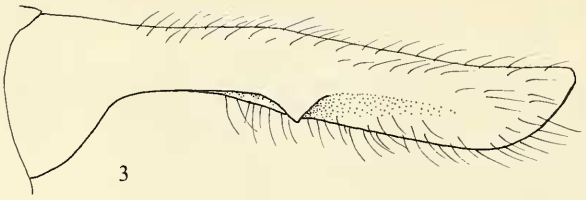
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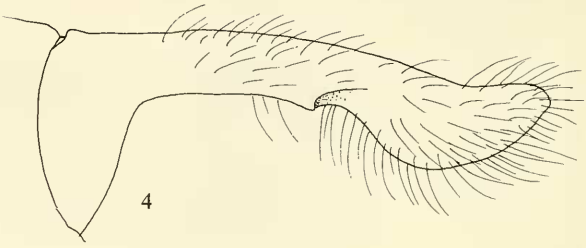
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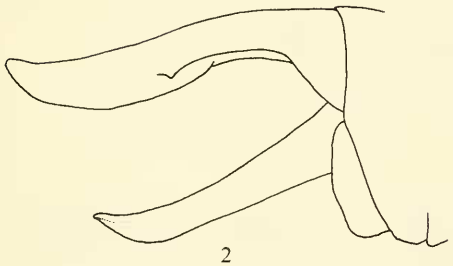
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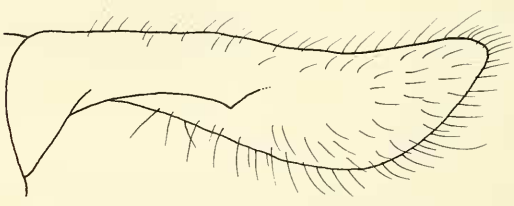
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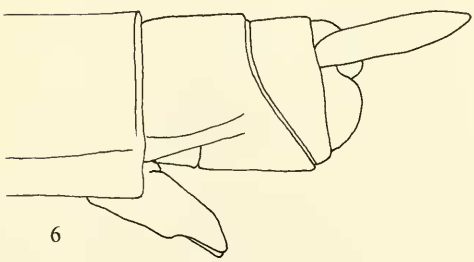
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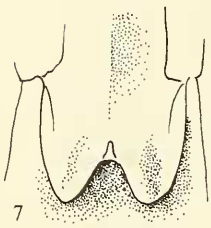
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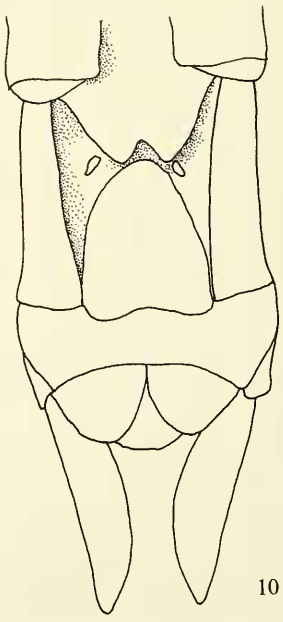
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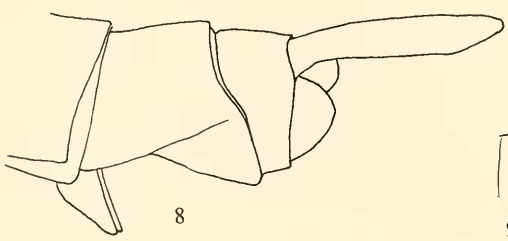
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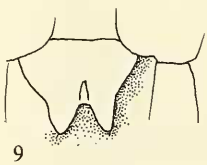
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Key to the males of western Malesian species of *Procordulia*

1. Base of male superior appendage in lateral view distinctly separated from the main stem (figs. 3-4). Usually 6 Ax in hind wing 2
– Base of male superior appendage in lateral view smoothly continuing into the main stem. Characteristically 5 Ax in hind wing 6
2. Males with two Cux in hind wing, the distal Cux forming an infratriangle (fig. 24). Superior appendage with sharp lateral tubercle. Lesser Sunda Islands, Mindanao and ? Sulawesi 3
– Males with one Cux in hind wing. Superior appendage with or without lateral tubercle. Java and Sulawesi 4
3. Superior appendage very long and slender, c. 2.8 mm (fig. 3). Hind wing 35-37 mm. Lesser Sunda Islands . . . . . *P. sambawana* (Foerster)
– Superior appendage more robustly built with tip club-shaped. Hind wing 40 mm. Mindanao . . . . . *P. moroensis* Lieftinck
4. Lateral tubercle on superior appendage approximately in the middle and sharp (fig. 4). Hind wing characteristically with 5 Ax and 7 Px. Sulawesi 5
– Superior appendage without lateral tubercle (fig. 12). Hind wing characteristically with 6 Ax and 8 Px . . . . . *P. karnyi* Fraser
5. Superior appendage in lateral view slender (fig. 4), with lateral tubercle hardly visible in dorsal view (fig. 17) . . . . . *P. lompobatang* sp. n.
– Superior appendage in lateral view relatively robust (fig. 5), with lateral tubercle conspicuous in dorsal view (fig. 18) . . . . . *P. rantemario* sp. n.
6. Superior appendage with a subterminal, bluntly shaped tubercle (fig. 14). Java . . . . . *P. papandayanensis* sp. n.
– Superior appendage straight, with a lateral carina, but without a tubercle (figs. 15-16) 7
7. Abdomen fusiform, relatively short. Hind wing 32-33 mm. N Borneo . . . *P. fusiformis* Lieftinck
– Abdomen only somewhat constricted at segment 3. Hind wing 34-35 mm. Java . . . . . *P. artemis* Lieftinck

Procordulia artemis Lieftinck
(figs. 15, 19, 28)

Procordulia artemis Lieftinck, 1930: 159-162, figs. 23-25 [original description, habitat]. Lectotype: Kawah Kamodjan. 19.iv.1930. Lft. in RMNH [examined]. – Lieftinck 1933: 399-429 [biology, descriptions]; Lieftinck 1934: 431-432 [material, habitat, habits, oviposition]; Lieftinck 1971: 75 [lectotype designation]; Lieftinck 1977: 164 [compared with *P. fusiformis*].

Diagnosis. – Small and slender species. Male with superior appendage slender, in lateral view in the middle hardly wider that at base; base not conspicuously heavier, tip not club-shaped (figs. 15, 19). Arculus in forewing approximately midway between Ax1 and Ax2. One Cux. Female with cylindrical abdomen without swollen basal segments. Appendages c. 1.8 mm. Genital valve short, projecting caudad from sternite 8, c. 1/4 of the length of segment 9, shorter than wide, margin with V-shaped excision with a depth of c. 1/4 of length of valve.

Apparently closely allied to *P. fusiformis*, which, however, has a conspicuous spindle-shaped abdomen. Superior appendages of both species very slender, without lateral tubercle; those of artemis c. 7-8 times as long as width in middle, and with acute tip in dorsal view (fig. 19), those of *fusiformis* c. 6 times as long as width in the middle, with a sharp tip (fig. 22).

Ecology. – Lieftinck (1933) provides an interesting account of the ecology of this species. Larvae were found in swamps and crater lakes.

Remark. – Locality data of the lectotype as given by Lieftinck (1971) are a free interpretation of the data actually available with the specimen. This method was also followed for many species.

Material examined. – Long series from Java (RMNH).

Distribution. – Java, South Sumatra.

Procordulia fusiformis Lieftinck
(figs. 16, 22, 28)

Procordulia fusiformis Lieftinck, 1977: 162-164, fig. 3 [original description, distribution].

Diagnosis. – Small size and spindle-shaped abdomen distinguish this species from other *Procordulia*

Figs. 1-10. *Procordulia* species. 1-3, *P. sambawana*, 4, *P. lompobatang*, 5-10, *P.* cf. *lompobatang*. – 1, anal appendages of male holotype, dorsal view; 2, idem, right lateral view; 3, superior appendage male, left lateral view; 4, superior appendage male, left lateral view; 5-7, female Bulluballija, abdomen left lateral view, dorsal view, and valvula vulvae in ventral view; 8-10, female Loka, abdomen left lateral view, dorsal view and valvula vulvae in ventral view.

species (Lieftinck 1977).

Male with superior appendage (figs. 16, 22) slender, but not as straight as in *P. artemis*; base somewhat heavier, top straight, not club-shaped, without lateral tubercle. Arculus in forewing about midway between Ax1 and Ax2. One Cux in hind wing. Apparently most closely related to *P. artemis* (see under that species).

Material examined. – N. Borneo. Mt. Kinabalu. Mesilau Camp. 4.iv.1964. 5000 ft. Coll. S. Kueh, 1 ♂ paratype (in RMNH, ex BMNH).

Distribution. – Northern Borneo (Sabah, ? Sarawak).

Procordulia karnyi Fraser
(figs. 11-13, 21, 26, 28)

Procordulia karnyi Fraser, 1926: 472-473 [original description, ♂ ♀ Java, Mt Tengger]. – Lieftinck 1930: 162-164 [type discussed]; Lieftinck 1971: 95 [lectotype designated: Mts. Tengger, 1200 m, 8 Dec 1920, H. Docters van Leeuwen]; Davies & Tobin 1985: 65 [specific status]; Tsuda 1991: 225 [as synonym of *P. sambawana*].

Procordulia sambawana [pro parte]. – Lieftinck 1953: figs. 58-59 (and ? 60) [♂ anal appendages, genitalia, # last abdominal segments].

Description

Male adult. – A relatively large and robust Procordulia. Head densely setose, darkbrown at upperparts. Labrum pale yellowish white, mandibles and labrum pale brown; clypeus olive-brown with pale coloured transversal depression against labrum. Frons brownish with bilobed upper parts with blue-green metallic shine, coarsely punctate. Depressions between frons and vertex deep; vertex high, truncated, punctulate, metallic green; occiput dark brown, slightly convex behind, shining. Eyes brown in dried specimens.

Synthorax rather robust, brilliant metallic green, areas against sutures more brownish without metallic shine, synthorax covered with long, slender, creamish white setae; ventral side of thorax and spaces between wings light brown. Legs long and slender; trochanters, fore femur and posterior side of middle and hind femur brown, legs otherwise dark brown. Wings almost hyaline with a very slight yellowish tint covering the whole surface, colouring somewhat more conspicuous at wing tip and wing base; veins dark brown. Neuration rather similar to that in *P. sambawana*; pterostigma oblique, in fore and hind wing 2.0 mm wide; membranula brownish grey, paler part at wing base intermediate between that of *P. sambawana* and of *papandayanensis* (fig. 26). Nodal index in forewing 6.8 | 9.6 or 6.9 | 8.7, in hind wing 8.5 | 6.8 or 8.6 | 6.7. Forewing with one cross-vein in triangle, subtriangle three-celled; one Cux. Hind wing without cross-veins in triangle; one Cux, no subtriangle. Both wings without cross-vein in supratriangle, no supplementary bridge cross-vein at subnodus. Arculus oblique, in hind wing situated midway between Ax1 and Ax2. Anal angle of hind wing with distinct edge, anal triangle with a short vein in its apical third.

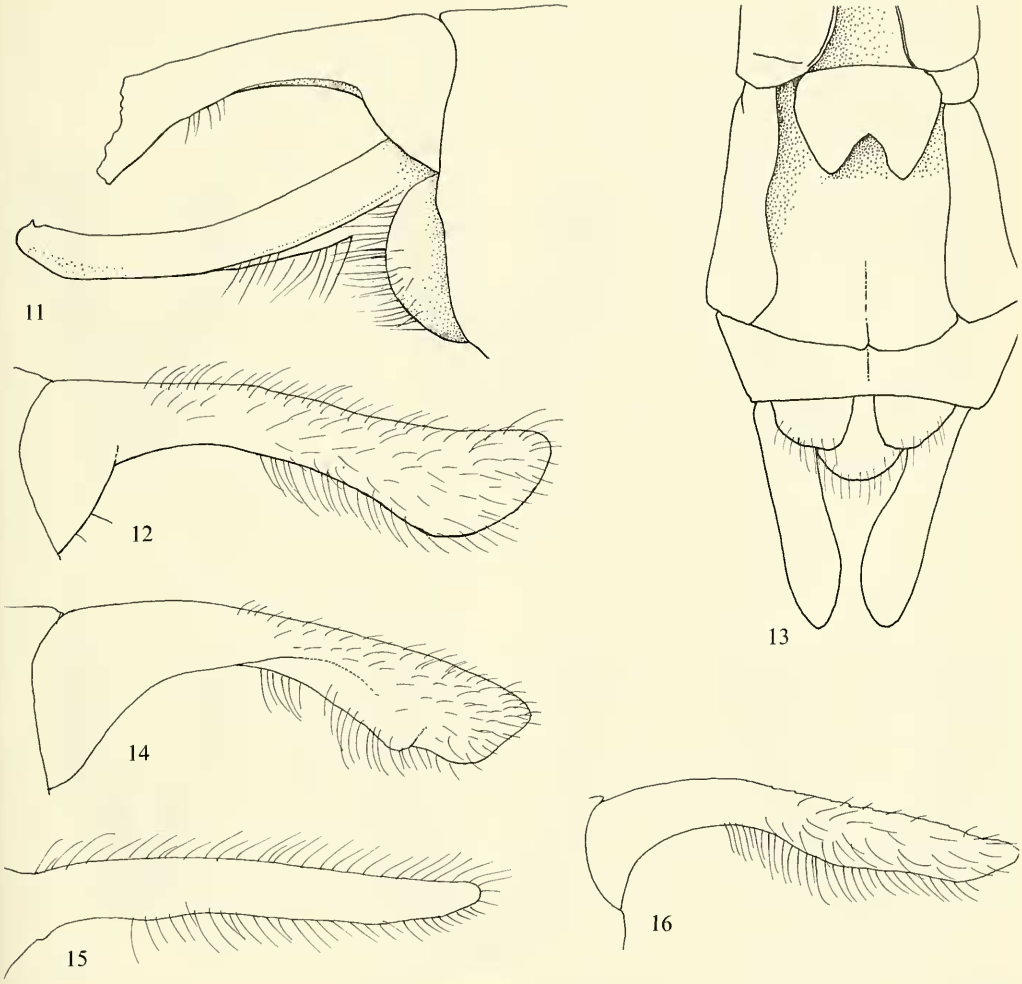
Abdomen slender, slightly constricted in the middle of segment 3, then gradually enlarged towards the end of segment 6, where it is broadest. Basal segments slightly swollen, much higher than wide, greatest width 3 mm. Segment 3-5 rounded above, then subtriangular in diameter, from about the middle of segment 6 to the middle of segment 9 with an indistinct median longitudinal crest. Venter flattened. Segment 10 with crest on dorsum. Auriculae small, knob-like, brown. Coloration dark bronzed-black, first three segments with distinct metallic green or coppery-red shine; middle segments with slight coppery-red reflex and segment 9-10 almost black. Dorsum of segment 1-2 covered with long setae. Sides of segment 1-2 and basal half of 3 very shining. Ventral sides of tergites dull brownish, their terminal fifth darkened. Accessory genitalia on segment 2 not very prominent, dark brown. Genital lobe subtriangular in general outline, with acute tip; posterior hamuli somewhat shorter than the lobe, thick at base, then constricted and considerably narrowed, strongly curved inwards, then outwards, straight in the median plane.

Anal appendages with superiors 2.75 mm long, in dorsal view (fig. 21) relatively slender at base, distal part club-shaped; base rather heavy, with a sudden transition between the base and the main stem; on stem no or hardly any trace of a lateral tubercle (figs. 11-12).

Female. – Similar to the male, but head more brownish, vertex brown without metallic shine. Wings generally with more conspicuous yellowish shine than male; nodal index forewing 5.9 | 9.6, hind wing 8.6 | 7.7. Hind wing with one Cux. Abdomen more robust than male, with purple shine. Basal segments slightly swollen; appendages c. 2.3 mm; genital valve projecting caudad from sternite 8, c. 1/3 the length of segment 9, somewhat shorter than wide with V-shaped excision c. 2/5 the length of the valve.

Differential diagnosis. – Males of *Procordulia* of Java can be distinguished by the shape of the superior appendage (figs. 11-12, 14-15). For distinguishing characters with *P. papandayanensis*, see under that species.

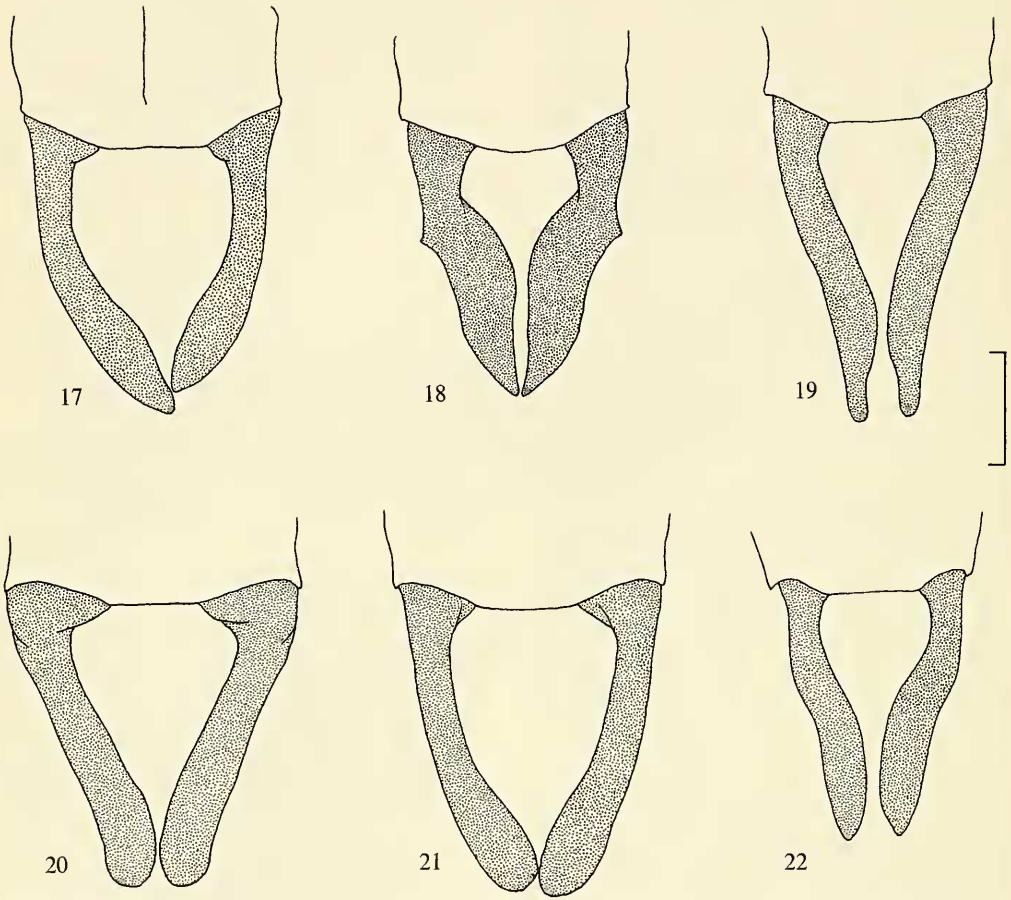
Ecology. – Possibly a species inhabiting running waters. The data of Lieftinck (1933, sub nom. *P. sumbawana*) may or may not include material of *P. karnyi*. In the light of the records of adults taken in 1961 (see below), I presume that at least the ultimate larva from E Java (Mt. Lawoe, little fall near Serangan above Madioen, ca. 1300 m, 29 Sep 1927, leg. A.



Figs. 11-16. *Procordulia* species. 11-12, 14-16, superior appendage of male in lateral view, 13, last abdominal segments of female. – 11, *P. karnyi*, holotype, right lateral view; 12-13, *P. karnyi*, Java, Baturraden; 14, *P. papandayanensis*, Java, Mt. Papandajan; 15, *P. artemis*, Java; 16, *P. fusiformis*.

Vorstman) can be attributed to *P. karnyi*.

Other material examined. – Java: E Java, Tengger Mts, 8 Dec 1920, H. D. v. L., 1♂ [lectotype] (RMNH); E Java, Tengger Mts, 6 Dec 1920, H. Docters van Leeuwen, 1♀ (BMNH) [not seen]; W Java, Preanger, Sitoe Lembang, 1600 m, Dec 1936, F. C. Drescher, 1♂ (BMNH); S Java, Mt. Tangkuban Prahu, 1300-1400 m, 1♂ (BMNH, ex coll. Lieftinck); Batoerraden, Mt. Slamat, ca. 2500 ft, F. C. Drescher, 27 Dec 1927, 19 Apr 1929, 2 Apr 1930, 3♂ 1♀ (BMNH, ex coll. Lieftinck); Java occ., H. Fruhstorfer, 3♂ 1♀ (Museum Berlin) [not seen]; W Java, Situ Lembang, 1600 m, Dec 1936, F. C. Drescher, 5$ (RMNH); W Java, slopes of Mt Gedeh and Pangrango, series of both sexes (RMNH); Mt. Patuha, Patuhawattee, 1750 m, 3 Jun 1935, J. van Marle, 1♀ (RMNH); E Java, Mt. Ardjuno, Djunggo, 1600 m, Jan 1936, M. E. Walsh, 1♂ (RMNH); E. Java, Mt. Lawu, 2000 m, Tjemorosewu, 24 Feb 1961, 'Vole en forêt vierge très près du sol, vol rapide, capture difficile,



Figs. 17-22. Superior anal appendages of male *Procordulia*. – 17, *P. lompobatang*; 18, *P. sambawana*; 19, *P. artemis*; 20, *P. papandayanensis*; 21, *P. karnyi*; 22, *P. fusiformis*. Scale bar 1 mm.

semble ici assex commune', P. Jauffret, 1♂ 1♀ (RMNH, ex coll. A. Heymer). – Sumatra. W Sumatra, Lebong Tandai, 1920-23, C. J. Brooks, 1♂ (headless) (BMNH); Central W Sumatra, Mt. Dempo, Gunung Agung Estate, 1500-2000 m, 11 Sep 1941, W. C. Verboom, 1♂ (bred from larva, emerged Bogor 2 Jan 1942) (RMNH).

Distribution. – Java, Sumatra.

Procordulia lompobatang sp. n.
(figs. 4-10, 17, 23, 28)

Procordulia irregularis Martin, 1907 [1906]: 16-17 [original description] [partim, male Celebes only].

? *Procordulia sumbawana*. – Martin 1907 [1906]: 17 [partim].

Procordulia sambawana. – Lieftinck 1953: figs. 63-64 [♂ anal appendages].

Procordulia celebensis Lieftinck, ms name.

Type material. – Holotype ♂: 'H. Fruhstorf. Celebes mer.' [white, round, handwritten], '*Neonyx nitens*' [white, handwritten in unknown hand], '*Procordulia sumbawana* (Frst) / det vdW[eele]' [white with black margin, handwritten], 'det MA Lieftinck 75 / *Procordulia celebensis* Lieft. / holotype' [white, partly in print], 'RMNH Leiden / *Procordulia lompobatang* Van Tol / det. J. van Tol, 1988' [white, partly in print], 'Holotype' [red, in print] in RMNH. – Paratypes: Lansbg Celebes ?, 1♂ in IRSN [this specimen is also a paralectotype of *Procordulia irregularis* Martin]; Celebes mer, 1♂ (Fruhstorfer) in RMNH; S Celebes, Lompa Battau, 3000', Mar 1896, 4♂ (Fruhstorfer) in MNHN; SW Celebes, Mt Lompobatang, Parasalawaki, 1600-1650 m, 3, 4 and 8 Jul 1936, 3♂ (L. J. Toxopeus) in RMNH; S Celebes, Kanrapia, 3 km E of Bulubalija, 2000 m, 30 Oct 1965, 2♂ (R. Straatman) in RMNH; SW Celebes, Lompobatang complex, 1100 m, Malino resthouse, 2 Jun 1982, 1♂ (M. A. Lieftinck) in RMNH.

Other material. – Celebes mer, 1♀ (Fruhstorfer) in rmnh; S Celebes, Lompa Battau, 3000', Mar 1896, 1♀ (Fruhstorfer) in MNHN; S Celebes, Loka, Mt Lompobatang, 1200 m, May 1949, 1♀ (C. Franssen) in RMNH; S Celebes, 82 km ESE of Makassar, Bulubalija, 1700 m, 12 Oct 1965, R. Straatman, 1♀(R. Straatman) in RMNH.

I have also examined in SMFD Frankfurt 11♂ and 2♀, with various labels (nos. O-37065 to O-37075, 37104 and 37100, ex collection Ris), but probably all belonging to the series collected by H. Fruhstorfer on the Lompobatang in March 1896. I have not examined these specimens since 1986, and thus did not include them in the type series. I have not included any females in the paratype series, since at least two types of females can be distinguished (see below). It is not clear whether one or more species are involved.

Description

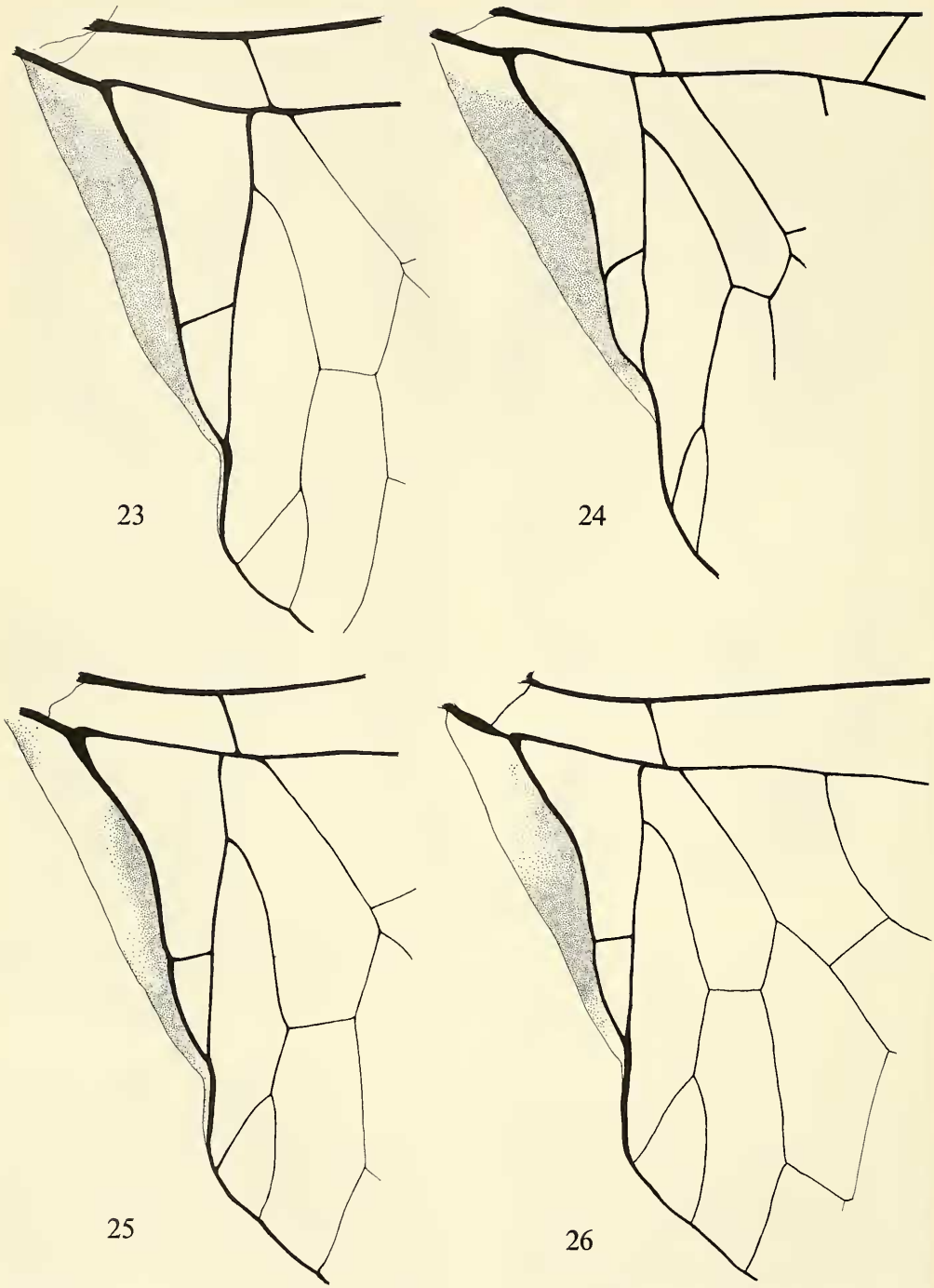
Male adult, holotype. – A relatively large and robust *Procordulia*. Head densely setose, dark brown at upper parts. Labium pale yellowish white, mandibles and labrum yellowish, labrum with subtriangular, olive-brown basal marking; clypeus olive-brown. Frons yellowish with the bilobed upperparts with blue-green metallic shine, coarsely punctate. Depressions between frons and vertex deep; vertex high, truncate, punctulate, metallic green; occiput dark brown, slightly convex behind, very shining. Eyes brown in dried specimens.

Synthorax rather robust, brilliant metallic green, covered with long, slender, creamish white setae; ventral side of thorax and spaces between wings light brown. Legs long and slender, trochanters and anterior side of fore and middle legsbrown; legs otherwise darkbrown. Wings almost hyaline with a very slight yellowish tint covering the whole surface, although somewhat more conspicuous towards the wing base. Neuration very similar to that in *P. sambawana*; neuration dark brown; pterostigma oblique, in fore and hind wing 1.85 mm wide; membranula brownish grey, somewhat lighter at extreme base. Nodal index of holotype fore wing 6.8 | 8.6, hind wing 7.5 | 5.7. Fore wing with one cross-vein in triangle, subtriangle three-celled; one Cux. Hind wing without cross-veins in triangle; one Cux (no subtriangle). Arculus oblique, in hind wing in all specimens situated midway between Ax1 and Ax2. Anal angle (fig. 23) in hind wing with distinct edge, triangle with a short vein in its apical third. Membranula dark-grey, only somewhat paler at its very base.

Abdomen slender, slightly constricted in the middle of segment 3, then gradually enlarged towards the end of segment 6, where it is broadest. Basal segments slightly swollen, much higher than wide, greatest width 3.25 mm. Segment 3-5 rounded above, then subtriangular in diameter, from about the middle of segment 6 to the middle of segment 9 with an indistinct median longitudinal crest. Venter flattened. Segment 10 with crest on dorsum. Auriculae small, knob-like, brown. Coloration dark bronzed-black, first three segments with distinct metallic green shine; middle segments with slight coppery-red reflex and segment 9-10 almost black. Dorsum of segment 1-2 covered with long setae; sides of segment 1-2 and basal half of 3 very shining. Ventral sides of tergites dull brownish, their terminal fifth darkened. Accessory genitalia on segment 2 not very prominent, dark brown. Genital lobe subtriangular in general outline, with acute tip; posterior hamuli of about equal length as the lobe, thick at base, then constricted and considerably narrowed, strongly curved inwards, then outwards, straight in the median plane.

Anal appendages with superiors 2.9 mm long, in dorsal view (fig. 17) relatively slender at base, distal part more knob-like; a small tubercle just visible about halfway in lateral view (fig. 4), the distal part beyond the tubercle somewhat widened, especially at ventral side.

Female. – Generally as male. Head as male, but vertex with metallic shine; occiput castaneous. Synthorax as male; hind wings in teneral specimens with yellow tint, adult female wings brownish yellow, especially against the wings. Neuration very similar to *P. sambawana*, including two Cux in the hind wing (only one female with one Cux in left hind wing); frontal side of pterostigma 2.5 mm (Loka) or 2.0 mm (Bulubalija); arculus oblique, in hind wing midway between Ax1 and Ax2. Abdomen stoutly built, hardly constricted. Genital valve and appendages with much variation between the specimens. Loka specimen (figs. 8-10) with genital valve protruded from



Figs. 23-26. Base of hind wing of male *Procordulia*. – 23, *P. lompobatang*; 24, *P. sambawana*; 25, *P. papandayanensis*; 26, *P. karnyi*.

abdomen with angle of 60°, length c. 1/2 of segment 9, V-shaped excision c. 1/3 of valve; anal appendages long and slender, 2.7 mm. Buluballija specimen (figs. 5-7) with much larger valve, 2/3 the length of segment 9, V-shaped excision less deep; anal appendages straight and shorter, 1.8 mm long.

Ecology. – A species of mountainous areas.

Distribution. – SW Sulawesi (Celebes) (fig. 28).

Procordulia moroensis Lieftinck
fig. 28

Procordulia moroensis Lieftinck, 1977: 164-167, figs. 4-5 [original description, distribution Mindanao]. Holotype ♂, Mindanao I., Upper Eden, 1000 m, 2.xi.1965 (in USNM) [not examined].

Diagnosis. – Adequately described by Lieftinck (1977).

Remarks. – In the original description, Lieftinck (1977) notes that 'this stout species approaches the two *Procordulia* occurring in Celebes, both of the *P. sambawana* group, ...'. In the characters used here it stands apart from the Sulawesi species by the 6 Ax veins in the hind wing. The superior anal appendages are indeed very similar to the Sulawesi taxa. Remarkably, it seems to be especially close to *P. rantemario*, which was unknown to Lieftinck. In lateral view, however, the superiors are quite different, in *P. moroensis* more or less club-shaped, and *P. rantemario* smoothly widening nearly from the base. *P. rantemario* is also c. ten percent smaller than *P. moroensis*.

Procordulia papandayanensis sp. n.
figs. 14, 20, 25, 28

? *Procordulia sumbawana*; Lieftinck 1933: 429 [larvae] [at least part of the material was collected on sites where the present species has been found].

Type material. – Holotype ♂: 'W Java, 2250 m / Mt. Papandajan / pondok, 9.vii.1934 / M. A. Lieftinck', with on reverse side '*P. sambawana* / dt. Lieftinck' [white label, both texts in Lieftinck's hand], 'Museum Leiden / ex verz. M. A. Lieftinck' [printed], 'Holotype' [red, printed], 'RMNH Leiden holotype / *Procordulia papandayanensis* Van Tol / det J. van Tol, 1996' [partly printed, partly handwritten] [JvT 6787]. – Paratypes: All specimens from W Java. Gunung Gedeh, c. 2000-2600 m, 11♂; Gunung Papandajan, 2300-2600 m, 7♂; Gunung Tangkuban Prahu, 1400 m, 1♂ (all RMNH); W Java, Mt. Papandajan, 5000 ft, 23 Nov 1929, 1♂ (C. Longfield) in BMNH (det. *P. sumbawana* by C. Longfield).

Description

Male. – A relatively large and robust species of *Procordulia*, stouter than *P. sambawana*, although with some variation. Head densely setose, darkbrown at upperparts, paler otherwise. Labium and mandibles pale yellowish white, labrum more brownish. Clypeus olive-brown with a rectangular, paler depression along labrum. Frons light to olive-brown, or dark yellowish, with the bilobed upperparts with blue-green metallic shine, coarsely punctate. Depression between frons and vertex deep; vertex high, truncated, punctulate, with only inconspicuous metallic green shine, less than in other species; occiput chestnut brown, slightly convex posteriorly, very shining, densely setose, rear side with a dense fringe of long setae. Eyes brown in dried specimens.

Synthorax robust, metallic green lees brilliant than related species, covered with long, slender, creamish white setae; ventral side of thorax and spaces between wings light brown. Legs long and slender, trochanters brown, legs otherwise dark brown. Wings almost hyaline with a yellowish tint covering the whole surface, especially near the wing base. Neuration dark brown; pterostigma oblique, in fore and hind wing c. 2.0 mm wide; membranula off-white, darker posteriorly. Nodal index fore wing 6.8 | 8.6, in hind wing 7.5 | 5.7 in nearly all specimens. Fore wing with one cross-vein in triangle, supratriangle without cross-veins, subtriangle three-celled, one Cux. Hind wing without cross-veins in triangle and supra-triangle; one Cux. Arculus oblique, in hind wing in all specimens situated midway between Ax1 and Ax2. Anal angle (hind wing) with distinct edge; anal triangle with a short vein in its apical third. Supplementary bridge cross-vein at subnodus.

Abdomen more robust than in *P. sambawana*, slightly constricted in the middle of segment 3, then gradually somewhat enlarged toward the end of segment 6, where it is broadest. Basal segments slightly swollen, much higher than wide, greatest width 3.2 mm. Segment 3-5 rounded above, then subtriangular in diameter, from about the middle of segment 6 to the middle of segment 9 with an indistinct median longitudinal crest. Venter flattened. Segment 10 with crest on dorsum. Auriculae small, knob-like, brown. Coloration dark bronzed-black, first three segments with metallic shine greenish or coppery-red; middle segments with slight coppery-red reflex and segment 9-10 almost black. Dorsum of segment 1-2 sparsely covered with long setae. Sides of segment 1-2 and basal half of 3 very shining. Ventral sides of tergites dull brownish, their terminal fifth darkened.

Accessory genitalia on segment 2 not very prominent, dark brown. Genital lobe subtriangular in general outline, with acute tip; posterior hamuli somewhat shorter than the lobe, thick at base, then

constricted and considerably narrowed, strongly curved inwards, then outwards, straight in the median plane.

Anal appendages with superiors 2.5 mm long in dorsal view; in dorsal view (fig. 20) relatively slender at base, slightly widening from base to apex, the tips somewhat curved outwards; in lateral (fig. 14) view transition of base to stem smooth without distinct angle, at c. 1/4 from the top a bluntly shaped ventral tubercle; top club-shaped.

Female. – Unknown.

Differential diagnosis. – The males of *Procordulia* species of Java can be distinguished by the shape of the superior appendage. In *P. papandayanensis* the top is more or less club-shaped with a sub-terminal ventral blunt tubercle, which is absent in the other species. In *P. karnyi* the appendage is rather robust, while the transition of the base to the stem is characteristically distinct as in *P. sambawana*. The appendage of *P. artemis* is much more slender and tubiform.

Distribution. – Java, where is seems to be confined to higher altitudes.

Procordulia rantemario sp. n.
(figs. 5,10, 18, 28)

Type material. - Holotype ♂: Indonesia. SW Sulawesi. 30 km NE of Enrekang. SW slope of Gn Rantemario. Sg. Gowa Sarumpa'pa at Gowa camp (Pos 2). Fast flowing stream, rapids, ponded sites. Primary rain forest. Shade; w=3-5 m, d=10-30 cm. Altitude 1800 m. 3°24'15"S 120°00'30"E. 6-9 Nov 1993. Leg. J. van Tol [JvT no 1730] (in RMNH). – Paratypes 1♂ 3♀, same data [JvT 1731-1734] (1♂ 1♀ in MBBJ, other specimens in RMNH).

Description

A relatively small and slender representative of the *P. sambawana* group.

Male. – [JvT 1730]. Head and thorax densely setose. Head: Labium yellowish white, mandibles and labrum yellowish, labrum with subcircular brown base, rest orange-yellow; frons olive-brown with bilobed dorsal parts brownish black with blue-green metallic shine, coarsely punctate; depression between frons and vertex deep; vertex brown with hardly detectable metallic shine, high, truncate, punculate; occiput brown, slightly convex, finely punctulate. Eyes in dried specimens dark green below and brown above.

Synthorax slender, greenish with blue metallic shine; ventral side of thorax pale brown. Legs long and slender; trochanter of fore and middle leg and anterior side of tranchanter of hind leg middle brown; anterior side of femora middle brown (in hind leg reduced to longitudinal stripe); remaining parts of legs brownish black. Wings hyaline with very slight yellowish tint; anal triangle and cubital space of hind wing with dark yellow tint; neuration similar to P. sambawana, nervature dark brown, pterostigma oblique, in fore and hind wing anteriorly approximately 1.9 mm wide; membranula isabel coloured at base, more brownish near apex; nodal index fore wing 6.8 | 9.5, hind wing 7.5 | 5.6; triangle of fore wing with one cross-vein, subtriangle three-celled, one Cux; triangle of hind wing without cross-vein, one Cux (no subtriangle); Arculus oblique, in fore wing closer to Ax2 than to Ax1; anal angle in hind wing with distinct edge, anal triangle with short vein in its apical third.

Abdomen slender, slightly constricted at the middle of segment 3, then gradually enlarged towards the end of segment 6, where it is broadest. Segments 2-9 with conspicuous green metallic shine; basal segments slightly swollen, higher than wide; from segment 4-9 with lateral carina, making segments triangular in diameter; from middle of segment 4 to middle of segment 10 with (especially rostrally rather inconspicuous) dorsal carina, base of segment 10 with conspicuous crest; auriculae small, knob-like, brown; coloration segments 1-9 bronzed black with green metallic shine on all segments, but segment 10 rather dull and hardly metallic; dorsum of segment 1-2 with long setae; dorsal sites of tergites with brownish yellow markings against lateral carina, more or less central on segment 4, covering anterior three-quarters of segments 5-7, basal half of segment 8 and basal quarter of segment 9; ventrum most light brown. Accessory genitalia on segment 2 not very prominent, dark brown; genital lobe elongate subtriangular, more straight than in *P. lompobatang*, tip acute; posterior hamuli in ventral view of about the same length as the lobe, solid at base, then constricted and considerably narrowed, curved inwards, the tip curved outwards as well as towards the body. Anal appendages with superior approximately 2.5 mm long, in dorsal view (fig. 18) much more robust than in sambawana or lompobatang, basal half more or less straight up to a conspicuous extero-lateral tooth; the distal half curved inwards, only somewhat widening with distal one-third approximately parallel; in lateral view (fig. 5) with conspicuous edge at base (as in *lompobatang*), side margin running distally in lateral tooth, knob-like distal part conspicuously widening, starting proximally to lateral tubercle; inferior appendage rather short.

Measurements: Hind wing 36 mm; abdomen incl. appendages 36 mm.

Variation: Male paratype has wing formula forewing 5.8 | 8.5, hindwing 7.5 | 5.7. Other characters similar as in holotype.

Female. – Generally as the male, but much more robust. Head as male, but labium rather pale, yellowish white; wings hyaline without conspicuous yellow tint; neuration similar to male, also one Cux in hind wing (compare *P. lompobatang*); frontal side of pterostigma ca. 2.0 mm; Arculus oblique, in hind wing halfway between Ax1 and Ax2. Abdomen rather stout, only somewhat constricted at posterior half of segment 3 and base of segment 4. Genital valve rather short, covering approximately two-fifths of entral side of segment 9, emarginate with emargination approximately one-third of length of valve; anal appendages straight, ca. 2 mm.

Etymology. – Rantemario, name of the mountain of the type locality; a noun in apposition.

Distribution. – Only known from the type locality, Gn. Rantemario, one of the tops in the Latimojong mountains.

Procordulia sambawana (Foerster)
figs. 1-3, 18, 24, 28

Somatochlora sambawana Foerster, 1899: 64-65 [holotype ♂, Insel Sumbawa / zwischen Floris / u. Sumba / d. Pagenstecher don. 1898] [UMMZ, examined].

Procordulia sambawana (Foerster). – Lieftinck 1936: 148-149 [material Lombok and Sumba only]; Lieftinck 1953: 191-193, figs. 61-62 [partim, only records Lesser Sunda Islands] [references, material Sumbawa, geographical variation]; Lieftinck 1954: 122 [partim, only specimens Lesser Sunda Islands] [synonymy, range, ecology].

Procordulia sumbawana (Foerster) [incorrect emendation]; Martin 1907: 17 [partim, only records Lesser Sunda Islands]; Lieftinck 1930: 162-164 [partim, only records Lesser Sunda Islands] [comparison with *P. artemis*].

Other material examined. – Lesser Sunda Islands, W Flores, Rana Mese, 1300 m, 5-8 Apr 1958, A. M. R. Wegner, 9♂ (RMNH); Soemba, Fruhstorfer, 1♂ (IRSN); Insel Sumbawa bei Flores, 1898, Dr. A. Pagenstecher, 1♀ (UMMZ) [with Cux 2 | 1]; Lombok, Sambalun, 4000', Apr 1896, H. Fruhstorfer, 1♀(RMNH). – [Doubtful record]: Celebes, Bua Kraeng, 5000 ft, Feb 96, Fruhstorfer, 1♂ (BMNH) [with Lieftinck's label 'P. spec. nov. Celebes'].

Lieftinck examined: Lombok, Sapit 2000', Apr 1896, H. Fruhstorfer, 2♂ 1♀ (ZMHB).

Description

Male. – A relatively large and robust *Procordulia*, although with some variation. Head densely setose, dark brown at upperparts, paler otherwise. Labium and mandibles pale yellowish white, labrum more brownish. Clypeus olive-brown with a rectangular, paler depression along labrum. Frons light brown or dark yellowish with the bilobed upperparts with blue-green metallic shine, coarsely punctate, Depressions between frons and vertex deep; vertex high, truncated, punctulate and hardly shining, metallic green; occiput chestnut-brown, slightly convex posteriorly, very shining, rear side with a dense fringe of long setae. Eyes brown in dried specimens.

Synthorax relatively slender, brilliant metallic green, covered with long, slender, creamish white setae; ventral side of thorax and spaces between wings light brown. Legs long and slender; trochanters and anterior side of fore and middle legs brown; legs otherwise dark brown. Wings almost hyaline with a very slight yellowish tint covering the whole surface. Neuration with nervature darkbrown; pterostigma oblique, in fore and hind wing c. 2.0 mm wide; membranula brownish grey, off-white in basal 1/6th. Nodal index in fore wing 6.9 | 9.6, in hind wing 9.6 | 5.8 or 8.6 | 6.8. Fore wing with one cross-vein in triangle, supratriangle without cross-veins, subtriangle three-celled, one Cux. Hind wing without cross-veins in triangle and supra-triangle; characteristically with two Cux. Arculus oblique, in hind wing in all specimens situated in the middle between Ax1 and Ax2. Anal angle (hind wing) with distinct edge; triangle with a short vein in its apical third. Supplementary bridge cross-vein at subnodus.

Abdomen slender, slightly constricted in the middle of segment 3, then gradually somewhat enlarged towards the end of segment 6, where it is broadest. Basal segments slightly swollen, much higher than wide, greatest width 2.75 mm. Segment 3-5 rounded above, then subtriangular in diameter, from about the middle of segment 6 to the middle of segment 9 with an indistinct median longitudinal crest. Venter flattened. Segment 10 with crest on dorsum. Auriculae small, knob-like, brown. Coloration dark bronzed-black, first three segments with distinct metallic green shine; middle segments with slight coppery-red reflex and segment 9-10 almost black. Dorsum of segment 1-2 sparsely covered with long setae. Sides of segment 1-2 and basal half of 3 very shining. Ventral sides of tergites dull brownish, their terminal fifth darkened. Accessory genitalia on segment 2 not very prominent, dark brown. Genital lobe subtriangular in general outline, with acute tip; posterior hamulus shorter than the lobe, thick at base, then constricted and considerably narrowed, strongly curved inwards, then outwards, straight in the median plane.

Anal appendages with superiors 3.5 mm long, in dorsal view relatively slender at base, widening at c. 1/5 from the base and distal 4/5th more or less straight; a sharp, tooth-like tubercle at about midway in lateral view.

Distribution. – Lombok, ? Sumba, Sumbawa, Flores, ? Sulawesi.

Differential diagnosis. – Can be distinguished from other species in this group by the virtually straight su-

perior anal appendage with a sharp lateral tubercle approximately midway, and the presence of two Cux in the hindwing.

Remarks. – The present data are insufficient to decide whether *P. sambawana* is indigenous to Sulawesi. It is not unlikely that the Sulawesi male mentioned above was mislabelled. Mislabelling of Indonesian material collected by Fruhstorfer is, unfortunately, common (see Van Tol 1987: 163). On the other hand, the collections of apparently genuine Sulawesi females of *Procordulia* are heterogeneous. All specimens have two Cux in the hind wing, a character occurring otherwise only in the males of *Procordulia sambawana*. Lieftinck considered the Sulawesi specimen distinct from *P. sambawana*, but I can not distinguish this specimen from material from the Lesser Sunda Islands.

Discussion

Affinities of genera

Several efforts have been made in the past (e. g. Martin 1907, Lieftinck 1953, 1977) to understand the systematics of the genus *Procordulia* Martin and related genera, or the Corduliidae in general (Needham 1908, Williamson 1908). Nevertheless, the relationships of the corduliine genera, and those of the species included in *Procordulia* plus *Hemicordulia*, remain poorly understood (e.g. Watson 1981: 1148).

It is also unclear which character or characters are diagnostic for each genus. In the Pacific islands, the easternmost part of their ranges, both genera cannot be kept apart based on the characters used so far. Lieftinck (1977) also notes that females are difficult to assign to any of both genera. Besides, the species of the Australian region, particularly several included in *Procordulia* so far, differ from their Malesian congenerics in many ways. Especially the position of the New Zealand *Procordulia grayi* (Selys, 1871), originally described in the genus *Cordulia*, subgenus *Epitheca* and later included in *Somatochlora* by Martin (1907), has been questioned already several times (see Rowe 1987). The *Procordulia* species of Malesia, on the other hand, are quite uniform and presumably form a monophyletic group. Their pattern of speciation may contribute to our understanding of the biogeographical history of this region. Although a more detailed systematic and biogeographical analysis has to wait for the future when also the species of New Guinea, Australia and the islands in the Pacific have been included, a few notes may summarize our present state of understanding.

Most indo-australian Corduliinae are united in *Procordulia* and *Hemicordulia*. A few oriental species with obvious Palaearctic relationships are attributed to *Cordulia* Leach, while several aberrant Malesian species are arranged in monospecific genera as *Antipodochlora* Fraser, *Guadalca* Kimmins, *Heteronaias* Needham & Gyger and *Pentathemis* Karsch (see Watson 1969). The relationships of these genera are unknown, since they have been characterized by autapomorphies only. As noted above, the difference between the two genera that mainly concern us here is less distinct in the eastern parts of their ranges. *Hemicordulia mumfordi* Needham from the Marquesas Islands is remarkable in this respect, since it has a cross-vein in the anal triangle. Based on a preliminary cladistic analysis, it appears that this cross-vein, also being more oblique, is not homologous to that in *Procordulia*. For this analysis the South-American genus *Rialla* was used as outgroup. The choice of a remotely related outgroup in phylogenetic analysis is certainly not without problems, and the results of this cladogram have to be used with care.

The genus *Hemicordulia* is aberrant within the Corduliidae for two characters, viz. it lacks an angulated base of the male hind wing, as well as auricles (oreillets). The characters should be interpreted as autapomorphies. *Hemicordulia* is not restricted to Australia and Southeast Asia. *H. virens* (Rambur) occurs on Mauritius, *H. similis* (Rambur) on Madagascar and the Seychelles, while *H. asiatica* is widespread and known from Uganda, South India, Ceylon and Assam (Pinhey 1962). Fraser (1949) attributed the occurrence of *Hemicordulia* on the Mascarene islands and Madagascar to the strong migratory tendencies of some species. He also states that 'there is good evidence to show that they [*H. virens* and *H. similis*] are lineal descendents of *H. asiatica*'. Both remarks would be in support of an Indo-Australian origin of the genus, with westward migration in a later phase. The preliminary analysis seems to indicate that *Procordulia grayi* and *P. jacksoniensis* are not closely allied to *Procordulia* + *Hemicordulia* (as defined by their type species).

Biogeographical notes

The distribution of the western Malesian species of *Procordulia* is illustrated in fig. 27. The genus is known from the southern tip of Sumatra, Java, Lombok, Sumba, Sumbawa and Flores, the southwestern peninsula of Sulawesi, the northern part of Borneo and the island of Mindanao. This distribution pattern may be compared with the comments on the biogeographical relationships between the Philippines and Sulawesi as summarized by Vane-Wright (1990) and of the relationship of microcontinents in this region by Michaux (1991, 1994, 1996). Relationship between Sulawesi and the Philippines have been proposed earlier by Wallace and by Croizat (1958), who suggested a relation between Sulawesi

Fig. 27. Distribution of western Malesian *Procordulia* species.

and the Philippines via Halmahera. Vane-Wright demonstrates the faunal regions of the Philippines, and postulates that the Philippines, rather than Sulawesi, will provide the key to our understanding of the evolution of Southeast Asia. His conclusion is that the Philippines have a derived Sunda Shelf fauna. Due to recent geological uplift the land area of the islands is considerably larger now than before. These conditions may have induced exchanges between faunal elements from the Philippines to Sulawesi and from Sulawesi to the Moluccas.

Studies of McCabe & Cole (1989), on the other hand, indicate that the Banda, Sulu and Celebes Sea are composed of old oceanic crust surrounded by younger, actively spreading oceanic crust. Michaux' conclusion of these data is, that western Sulawesi, eastern Borneo and parts of Mindano formed a single tectonic unit and share a common history. This microcontinent would be of Gondwanic origin, and have a collision age of (possibly) late Cretaceous.

Thirdly, also more recent climatic changes may have influenced the possibilities for dispersal of mountainous species. It is largely unknown what kind of vegetation dominated during the Pleistocene glaciations, but lower sea levels may have opened corridors for species now confined to higher altitudes.

The relative close relationships of the species of the *P. sambawana* group, as based on morphological characters, suggest a Pleistocene rather than a Cretaceous time of splitting of the lineages.

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