

Two new Species of *Simulium* (*Simulium*) (Diptera: Simuliidae) From Mount Murud, Sarawak, Malaysia

HIROYUKI TAKAOKA,¹ ZUBAIDAH YA'COB, AND MOHD SOFIAN-AZIRUN

Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur 50603, Malaysia.

J. Med. Entomol. 52(1): 38–49 (2015); DOI: 10.1093/jme/tju009

ABSTRACT Two new species of black flies, *Simulium* (*Simulium*) *murudense* and *Simulium* (*Simulium*) *cheedhangti*, are described on the basis of females, males, pupae, and larvae collected in Mount Murud, Sarawak, Malaysia. Both species belong to the *Simulium melanopus* Edwards species group. *S. (S.) murudense* sp. nov. is distinguished from most known species by a combination of the haired basal portion of the radial vein and the darkened fore coxae, and *S. (S.) cheedhangti* sp. nov. is characterized in the female by having a medium-sized claw tooth and in the pupa by six somewhat inflated gill filaments. Notes are given on the *S. melanopus* species-group in Sarawak and Sabah.

KEY WORDS *Simulium*, black fly, Malaysia, new species

Introduction

The fauna of black flies (Diptera: Simuliidae), one of the biting insects of medical and veterinary importance, has been well studied in Peninsular Malaysia, where all of the 59 species recorded are classified in the genus *Simulium* Latreille and are further placed in four subgenera: one species in *Daviesellum* Takaoka & Adler, 34 species in *Gomphostilbia* Enderlein, five species in *Nevermannia* Enderlein, and 19 species in *Simulium* Latreille s. str. (Adler and Crosskey 2014; Takaoka et al. 2014a,b,c,d; Ya'cob et al. 2014). The fauna is characterized by its richness in endemic species (46% or 27 of the 59 species) and remarkable diversity in phylogenetic lineages in terms of the number of species-groups (six in *Gomphostilbia*, three in *Nevermannia*, and nine in *Simulium* s. str.).

On the other hand, in Sarawak and Sabah, eastern regions of Malaysia, located in northern parts of Borneo Island, the black fly fauna has not been extensively explored yet. So far recorded are 33 species consisting of 17 species from Sabah, 10 species from Sarawak and 6 species from both Sabah and Sarawak, all of which are classified in the genus *Simulium* and are further placed in three subgenera: 15 species in *Gomphostilbia*, three species in *Nevermannia* and 15 species in *Simulium* s. str. (Adler and Crosskey 2014). As compared with the fauna of Peninsular Malaysia, its species endemism is much higher (82% or 27 of the 33 species), but diversity in phylogenetic lineages appears to be relatively poor, as judged by the numbers of species-groups, which are four in *Gomphostilbia*, two in *Nevermannia*, and four in *Simulium* s. str.

Morphological characters and taxonomic affinities for all the 16 but one species recorded from Sarawak are summarized by Takaoka and Leh (2009).

In 2013, we conducted surveys in several streams along the road from Bakalalan to Mount Murud in Sarawak and collected 12 species of black flies consisting of six known species [*Simulium* (*Gomphostilbia*) *auratum* Takaoka, *Simulium* (*Gomphostilbia*) *barioense* Takaoka, both described from Sarawak (Takaoka 2008a, 2009), *Simulium* (*Gomphostilbia*) *tahanense* Takaoka & Davies, originally described from Peninsular Malaysia (Takaoka and Davies 1995) and later recorded from Sarawak (Takaoka 2012), *Simulium* (*Gomphostilbia*) *terengganuense* Takaoka, Sofian-Azirun & Ya'cob, originally described from Peninsular Malaysia (Takaoka et al. 2012), *Simulium* (*Simulium*) *alberti* Takaoka, and *Simulium* (*Simulium*) *beludense* Takaoka, both from Sabah (Takaoka 1996, 2008b)], two unidentified species (one in the *Simulium feuerborni* species-group of the subgenus *Nevermannia*, and the other in the *Simulium ceylonicum* species-group of the subgenus *Gomphostilbia*), and four new species (two of the subgenus *Gomphostilbia* and the other two of the subgenus *Simulium* s. str.), of which two new *Simulium* species are described here based on females, males, pupae, and mature larvae, and the other two new species of the subgenus *Gomphostilbia* are described elsewhere.

Notes are given on the *Simulium melanopus* Edwards species-group of the subgenus *Simulium* in Sarawak and Sabah, to which the two new species of the subgenus *Simulium* are assigned.

The methods of collection, description, and illustration, and terms for morphological features used here, follow those of Takaoka (2003) and partially those of Adler et al. (2004).

The holotypes and paratypes of these new species are deposited in the Institute of Biological Sciences,

¹ Corresponding author, e-mail: takaoka@oita-u.ac.jp

Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia.

Simulium (Simulium) murudense sp. nov.

Female. Body length 2.8–2.9 mm. **Head.** Narrower than width of thorax. Frons brownish black, shiny and iridescent when illuminated at certain angles, with several dark stout hairs along lateral margins and near lower margin; frontal ratio 1.2:1.0:1.4; frons-head ratio 1.0:4.8. Fronto-ocular area triangular, directed laterally and slightly upwardly. Clypeus brownish black, shiny and iridescent when illuminated at certain angles, whitish pruinose, moderately covered with dark stout hairs except small areas near upper margin bare. Labrum 0.76 times the length of clypeus. Antenna composed of scape, pedicel and nine flagellomeres, brownish black except scape, pedicel and first flagellomere medium brown; base of first flagellomere dark yellow or light brown in some antennae. Maxillary palp light brown, composed of five segments, proportional lengths of third, fourth, and fifth segments 1.0:1.1:2.1; third segment (Fig. 1A) normal; sensory vesicle (Fig. 1A) small, globular, or ellipsoidal, 0.2–0.3 times the length of third segment, with large round opening medially. Maxillary lacinia with 11 or 12 inner and 14 outer teeth. Mandible with 23 inner and 11 outer teeth. Cibarium (Fig. 1B) with about 56 minute tubercles. **Thorax.** Scutum black, shiny, and bluish iridescent, thinly whitish pruinose peripherally when illuminated at certain angles, moderately covered with medium-brown recumbent short hairs interspersed with dark brown long upright hairs on prescutellar area. Scutellum brownish black, with dark brown long upright hairs. Postnotum dark brown, shiny, whitish pruinose when illuminated at certain angles and bare. Pleural membrane bare. Katepisternum longer than deep, brownish black to black, bare, shiny, and iridescent when illuminated at certain angles. **Legs.** Dark brown to brownish black except basal half or little more of mid-basitarsus, and little more than basal half of hind basitarsus (though base dark) yellowish white, and basal half of second hind tarsomere dark yellow or light brown. Fore tibia with whitish gray and iridescent sheen broadly on outer surface when illuminated at certain angles, mid- and hind tibiae each with similar sheen on posterior surface when illuminated at certain angles; fore tarsus with thick dorsal crest of short hairs; fore basitarsus greatly dilated, 3.4–3.7 times as long as its greatest width; hind basitarsus (Fig. 1C) nearly parallel-sided, 5.6–6.1 times as long as its greatest width, 0.7 and 0.6 times as wide as greatest widths of hind tibia and femur, respectively; calcipala 1.3 times as long as width at base, and 0.5 times as wide as greatest width of basitarsus; pedisulcus distinct; claw (Fig. 1D) with distinct subbasal tooth. **Wing.** Length 2.4–2.5 mm. Costa with dark brown spinules and hairs. Subcosta haired except apical one-fifth bare. Basal section of vein R fully haired; R₁ with dark brown spinules and hairs; R₂ with dark hairs only. Hairs at base of radial vein dark brown. Basal cell absent. **Halter.** White

except base darkened. **Abdomen.** Basal scale brownish black, with fringe of dark long hairs. Dorsal surface of abdominal segments brownish-black except segment 2 dark brown, with dark hairs; tergite 2 with pair of large whitish iridescent dorsolateral spots broadly connected to each other medially; tergites 6–9 shiny. Ventral surface of abdominal segment 7 with large sternal plate medially. **Genitalia.** Sternite 8 (Fig. 1E) well sclerotized, moderately depressed medially, with posterior margin much concave medially, and moderately covered with long stout and medium-long fine hairs on each side. Ovipositor valves (Fig. 1E and F) well demarcated from posterior margin of sternite 8, bent posteroventrally, tapered apically with transparent bare pointed apex, and covered with numerous short to long hairs on ventral surface; inner margins well sclerotized, moderately concave along basal half, moderately separated from each other. Genital fork (Fig. 1G) of inverted Y-form; stem slender, well sclerotized, with inflated apex; arms slender, each with strongly sclerotized angulate lateral ridge. Paraproct in posteroventral view (Fig. 1H) anteroventrally with dark, thin, elongate, wide, moderately sclerotized plate having round apical tip and about 30 minute setae scattered on its surface; paraproct in lateral view (Fig. 1I) much produced posteroventrally, 2.2 times as wide as its basal length, anteroventrally with dark moderately sclerotized plate, covered with several medium-long stout hairs and numerous short fine hairs on lateral surface. Cercus in lateral view (Fig. 1I) short, with posterior margin nearly straight, 3.8 times as wide as its greatest length, and covered with numerous short to medium-long hairs. Spermatheca (Fig. 1J) nearly globular, well sclerotized except duct and wide area of juncture with duct unsclerotized, without reticulate surface patterns; minute internal setae present; both accessory ducts subequal in diameter to each other, and also to that of main duct.

Male. Body length 2.7–3.2 mm. **Head.** Slightly wider than thorax. Upper eye consisting of large facets in 20 vertical columns and in 20 or 21 horizontal rows on each side. Clypeus brownish black, whitish pruinose, shiny, and iridescent when illuminated at certain angles, moderately covered with dark brown long hairs. Antenna composed of scape, pedicel and nine flagellomeres, dark brown to brownish black; first flagellomere elongate, 2.1 times length of second one. Maxillary palp light brown, composed of five segments, proportional lengths of third, fourth, and fifth segments 1.0:1.1:1.9; third segment (Fig. 2A) of normal size; sensory vesicle small, globular or ellipsoidal, 0.2 times the length of third segment, and with medium-sized opening. **Thorax.** Scutum black, with whitish gray pruinose (bluish iridescent when illuminated at certain angles) pattern composed of anterior pair of spots on shoulders, and large transverse band covering prescutellar area, which is connected to anterior pair of spots by broad band along lateral margins; anterior pair of spots about half length of scutum, directed medioposteriorly, then posteriorly, nearly parallel-sided from base to middle or little more, then tapered toward pointed apices,

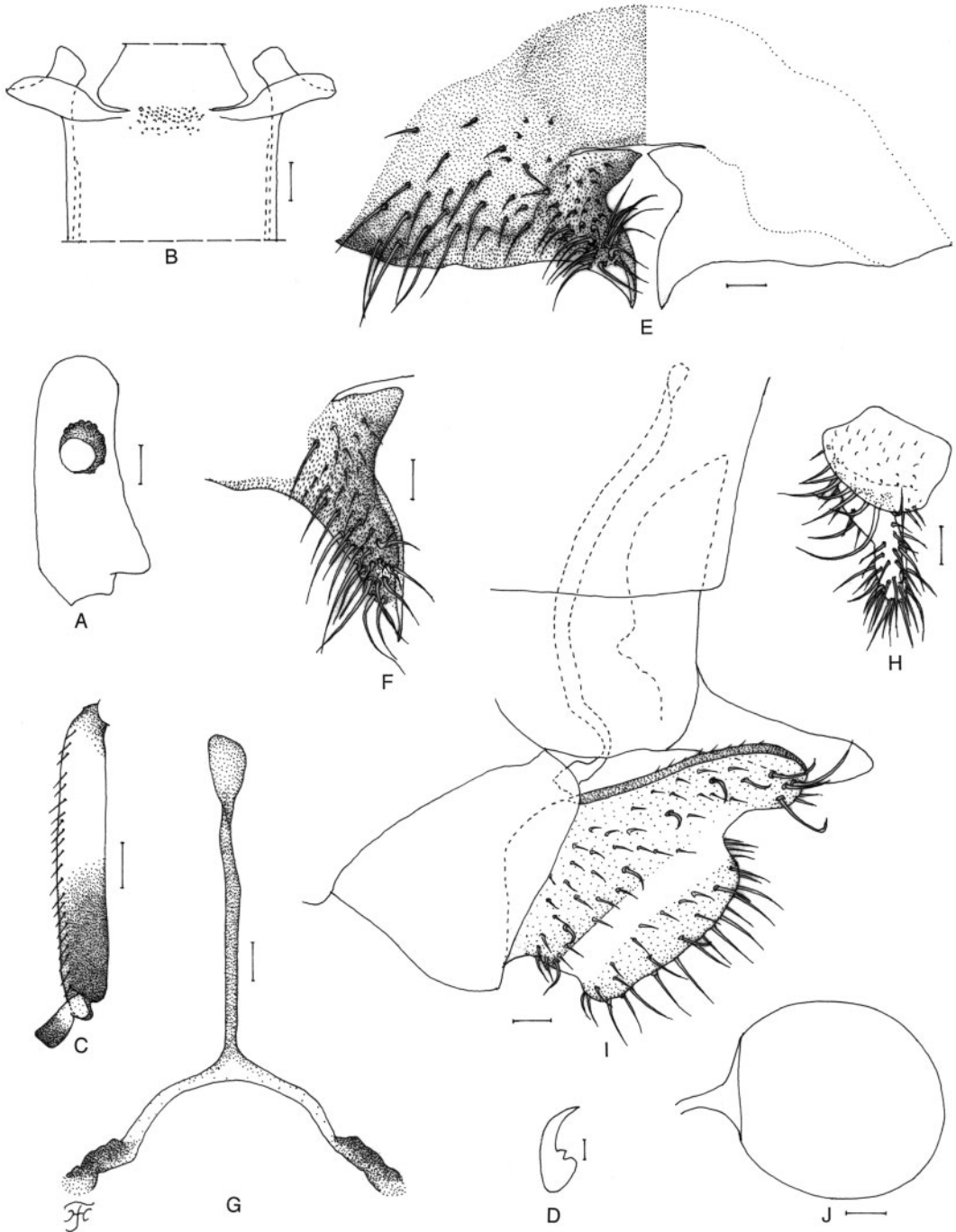


Fig. 1. Female of *Simulium* (*Simulium*) *murudense* sp. nov. (A) Third segment of maxillary palp with sensory vesicle (right side; front view). (B) Cibarium. (C) Basitarsus and second tarsomere of hind leg (left side; outer view). (D) Claw. (E) Sternite 8 and ovipositor valves (ventral view). (F) Ovipositor valve (right side; anteroventral view). (G) Genital fork (ventral view). (H) Paraproct with anteromedial plate with minute setae and cercus (right side; anteroventral view). (I) Posterior tip of abdomen showing ovipositor valve directing posteroventrally, genital fork, paraproct and cercus (right side; lateral view). (J) Spermatheca. Scale bars: 0.1 mm for C; 0.02 mm for A, B, and E-J; 0.01 mm for D.

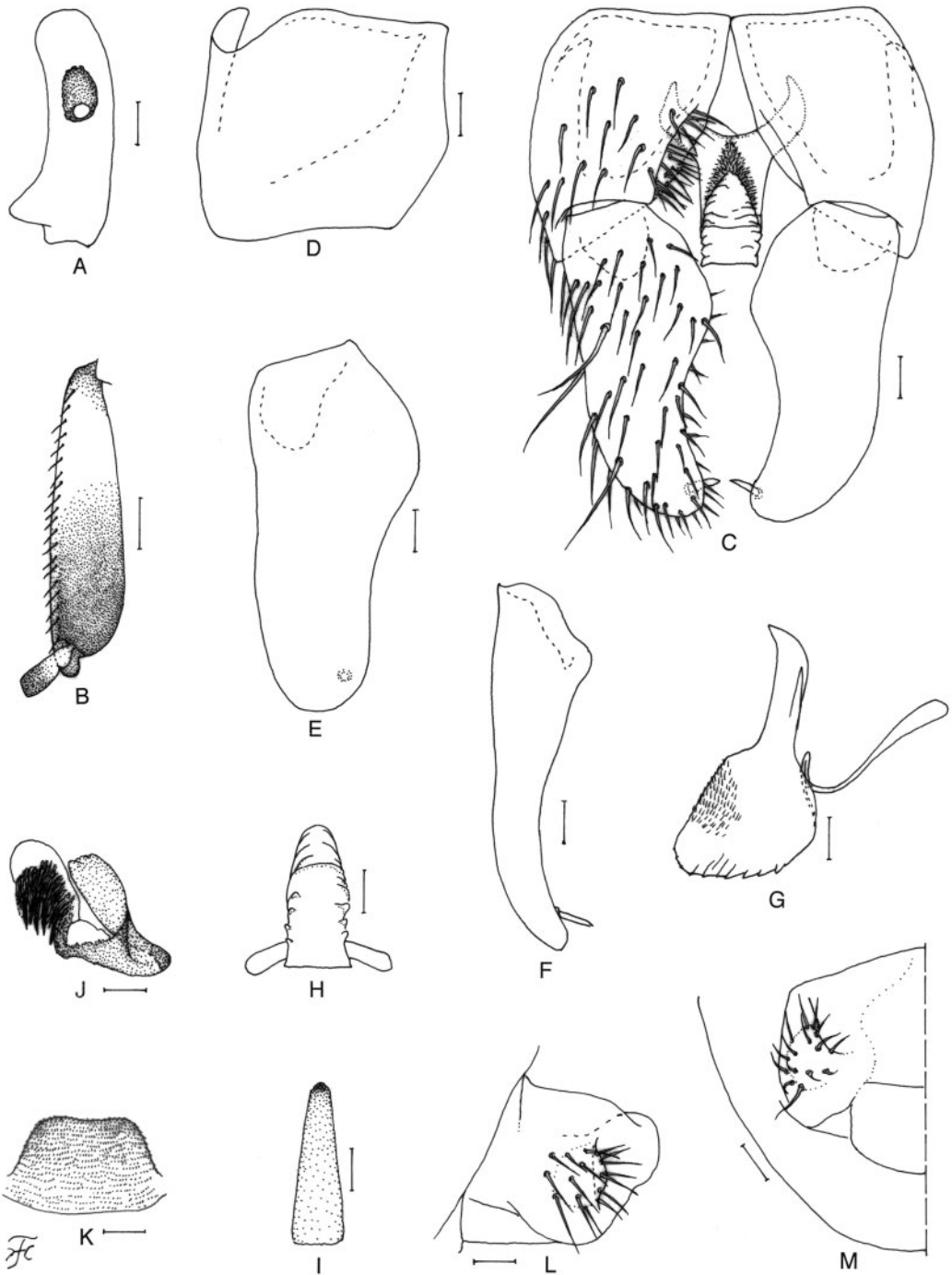


Fig. 2. Male of *Simulium* (*Simulium*) *murudense* sp. nov. (A) Third segment of maxillary palp with sensory vesicle (left side; front view). (B) Basitarsus and second tarsomere of hind leg (left side; outer view). (C) Coxites, styles and ventral plate (ventral view). (D) Coxite (right side; ventrolateral view). (E) Style (right side; ventrolateral view). (F) Style (right side; medial view). (G) Ventral plate and median sclerite (lateral view). (H) Ventral plate (caudal view). (I) Median sclerite (caudal view). (J) Paramere (left side; caudal view). (K) Aedeagal membrane (caudal view). (L) and (M) Tenth abdominal segments and cerci (right side; L, lateral view; M, caudal view). Scale bars: 0.1 mm for B; 0.02 mm for A and C–M.

widely separated from each other in middle (thus little more than middle one-third of scutum nonpruinose), and widely separated from posterior transverse spot; scutum densely covered with dark (brassy when illuminated at certain angles) fine short hairs interspersed with dark brown long upright hairs on prescutellar area. Other characters similar to those of female. **Legs.** Color pattern almost similar to that of female except hind basitarsus brownish black except basal two-fifths or little more yellowish (though base dark brown) and basal two-fifths of second hind tarsomere dark yellow to light brown; all tibiae with sheen broadly on outer or posterior surfaces, as in female. Fore tarsus with thick dorsal crest of short hairs; basitarsus greatly dilated, 4.0–4.2 times as long as its greatest width. Hind basitarsus (Fig. 2B) greatly enlarged, gradually widened toward apical one-third, nearly parallel-sided up to apical one-sixth, then roundly narrowed, 3.9–4.0 times as long as its greatest width, 0.9 and 1.0 times as wide as greatest widths of hind tibia and femur, respectively; calcipala nearly as long as its basal width, and 0.3 times as wide as greatest width of basitarsus; pedisulcus distinct. **Wing.** Length 2.0–2.4 mm; other characters as in female except subcosta and basal portion of radial vein entirely bare. **Halter.** White except base darkened. **Abdomen.** Basal scale brownish black, with fringe of dark long hairs. Dorsal surface of abdomen medium brown to brownish black, with dark hairs; segments 2 and 4–7 each with pair of silvery iridescent dorsolateral spots, broadly connected in middle on segment 2 but not on other segments; tergites of segments 8 and 9 shiny laterally, but not silvery iridescent even when illuminated at certain angles. **Genitalia.** Coxites, styles, and ventral plate in ventral view are as in Fig. 2C. Coxite in ventrolateral view (Fig. 2D) nearly quadrate, slightly wider than long. Style in ventrolateral view (Fig. 2E) elongate, 1.6 times the length of coxite, 2.2 times as long as its greatest width, widened from base to basal one-third, then narrowed toward round apex, and with stout subapical spine; style in medial view (Fig. 2F) flattened dorsoventrally, gradually narrowed toward apex, and without basal or subbasal protuberance. Ventral plate in ventral view (Fig. 2C) with body nearly rectangular having ventrally produced median process that is bare except parts of lateral and anterior surfaces covered with minute setae, and is furnished with several teeth in vertical row on each posterolateral margin; basal arms short, stout and divergent; ventral plate in lateral view (Fig. 2G) with body and its ventrally produced process with rounded ventral apex, with dentate posterior margin, and covered with minute setae anteromedially; ventral plate in end view (Fig. 2H) with body and ventrally produced median process nearly parallel-sided from base to apical one-third, then tapered apically, bare, with three or four distinct teeth in vertical row on each lateral margin of basal half and several smaller transverse ridges on apical half, of which one or two are connected medially to each other. Median sclerite in lateral view (Fig. 2G) moderately sclerotized, folded backward and then curved dorsally, and in posterior view (Fig. 2I) plate-like, slightly widened toward apex. Paramere (Fig. 2J)

wide basally and with several parameral hooks apically. Aedeagal membrane (Fig. 2K) densely covered with minute setae, without sclerotized dorsal plate. Ventral surface of tenth abdominal segment (Fig. 2L and M) without any distinct hairs. Cercus (Fig. 2L and M) rounded, with 15 or 16 distinct hairs.

Pupa. Body length (excluding gill filaments) 2.7–3.3 mm. **Head.** Integument yellow, and bare except median portion of face sparsely covered with round tubercles: frons with two unbranched slender trichomes (one short, one medium-long) (Fig. 3A) lying relatively close together on each side; face with one unbranched stout medium-long trichome (Fig. 3B) (bifid trichome on right side of one pupa) on each side, which is 1.3 times the length of medium-long trichome of frons. **Thorax.** Integument yellow, bare except dorsal surface of posterior portion and lateral surface of middle portion sparsely to moderately covered with round or cone-shaped small tubercles; thorax with two slender medium-long trichomes (one little longer than other) anterodorsally (Fig. 3C), two trichomes (one long, one medium-long) anterolaterally (Fig. 3D), one medium-long somewhat stout trichome mediolaterally (Fig. 3E), and three trichomes (two long, one medium-long) ventrolaterally (Fig. 3F) on each side; all trichomes unbranched. Gill (Fig. 3G) with six slender thread-like filaments in pairs; common basal stalk very short, with transparent basal fenestra ventrally; dorsal and ventral pairs short stalked and middle pair almost sessile or very short stalked; filaments decreasing in length and thickness from dorsal to ventral, with longest dorsal filament 1.6–1.8 cm and shortest ventral filament 0.8–1.0 mm, and relative thickness of six filaments from dorsal to ventral 1.0:0.8–0.9:0.8:0.8:0.5–0.6:0.5; all filaments light brown, nearly same thickness from base to basal one-third or little more, then gradually tapered toward apex; dorsal and ventral filaments divergent basally at angle of 90 degrees or slightly more; cuticular surface with moderately defined annular ridges and furrows throughout their length except basal portions of middle and ventral paired filaments smooth, covered with minute tubercles of same size. **Abdomen.** Dorsally, all segments unpigmented except basal portions of spine-combs on segment 8 yellow; segment 1 sparsely or moderately covered with minute tubercles in two female pupae and almost bare in other pupae, with one unbranched slender medium-long seta on each side; segment 2 bare, with one unbranched slender short seta, five unbranched short spinous setae, of which three are stout, on each side; segments 3 and 4 each with four unbranched hooked spines and one unbranched short seta on each side; segment 5 bare; segment 8 with well developed spine-combs in transverse row on each side; segments 6–9 each with comb-like groups of minute spines; segment 9 without terminal hooks. Ventrally, all segments unpigmented; segment 4 with few unbranched short setae on each side; segment 5 with pair of bifid hooks submedially and one unbranched short seta on each side; segments 6 and 7 each with pair of bifid inner and outer hooks widely spaced and one unbranched short seta on

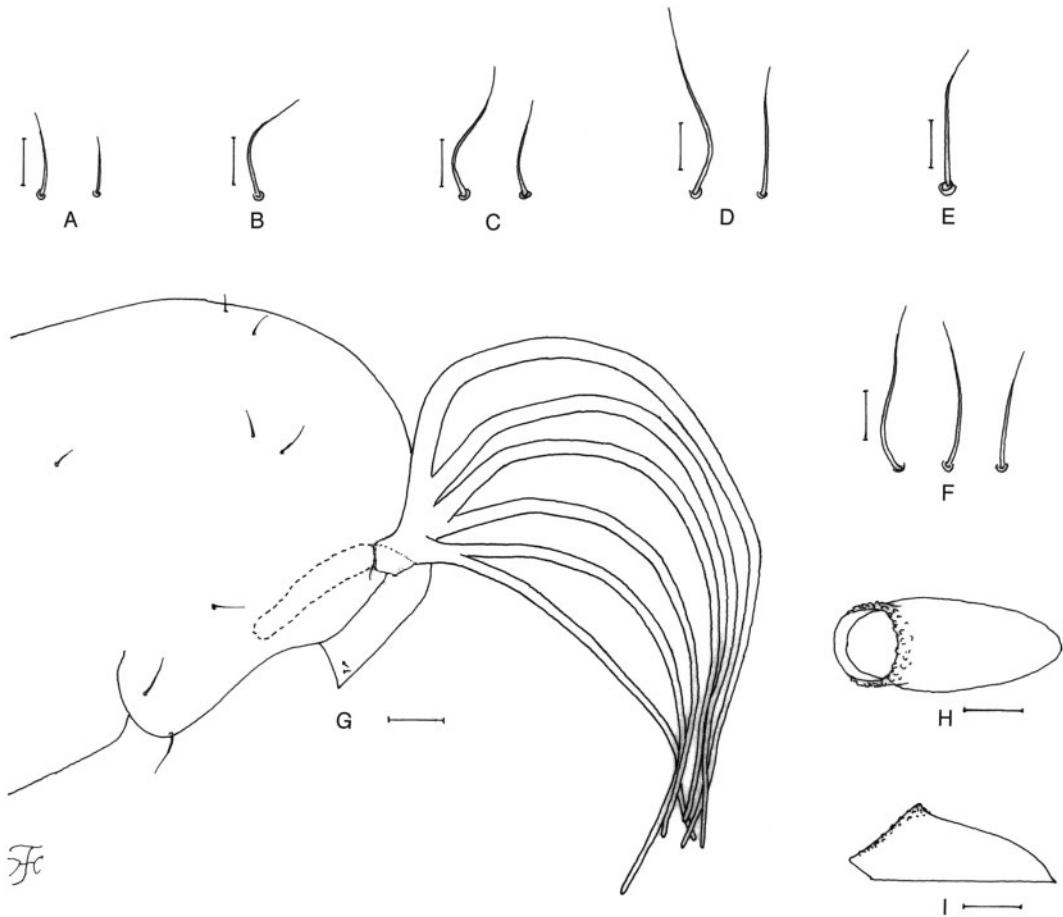


Fig. 3. Pupa of *Simulium* (*Simulium*) *murudense* sp. nov. (A) Frontal trichomes. (B) Facial trichome. (C)–(F). Thoracic trichomes (C, anterodorsal; D, anterolateral; E, mediolateral; F, ventrolateral). (G) Anterior half of thorax and gill filaments (right side; outer view). (H) and (I). Cocoons (H, dorsal view; I, lateral view). Scale bars. 1.0 mm for H and I; 0.1 mm for G; 0.02 mm for A–F.

each side; segments 4–8 each with comb-like groups of minute spines. Grapnel-like hooklets absent. **Cocoon** (Fig. 3H and I). Shoe-shaped, thickly woven, with thick rim around its opening, which is often irregularly edged with small nipple-like round projections, yellowish brown, slightly extending ventrolaterally; individual threads invisible; 3.0–3.9 mm in length by 1.5–1.8 mm in width; front collar 0.1–0.4 mm in height.

Mature Larva. Unknown.

Type Specimens. HOLOTYPE: Female (preserved with its associated pupal exuviae and cocoon in 80% ethanol), reared from a pupa collected from a stream (width 0.3–0.5 m, stream bed muddy, water temperature 14.4°C, partially shaded, altitude 2,115 m, 03° 55'36.5" N/115° 30'50.6" E) slowly flowing in a grassland, Church Camp, Bakalalan, Sarawak, Malaysia, 13–VI–2013, by Z. Ya'cob and N. Azhar. PARATYPES: Four females, three males (all reared from pupae and preserved together with their pupal exuviae and cocoons in 80% ethanol), same data as those of the holotype.

Ecological Notes. The pupae of this new species were collected from trailing grasses. Associated species were *S.* (*Nevermannia*) sp. (*S. feuerborni* species-group), *S.* (*Gomphostilbia*) sp. (*S. batoense* species-group), *S.* (*G.*) sp. (probably *S. darjeelingense* species-group) and *S.* (*S.*) *alberti* Takaoka.

Etymology. The species name *murudense* refers to the mount Murud where this new species was collected.

Discussion. *S.* (*S.*) *murudense* sp. nov. is placed in the *S. melanopus* species-group based on the ventrally produced paraprot with an anteroventral plate and elongated ovipositor valves of the female genitalia (Fig. 1E and I), and the pupal gill with six filaments (Fig. 3G).

This new species is remarkable in that the fore coxae of the female and male are darkened and the basal portion of the radial vein of the female is fully haired. A combination of these two characters is known only in *Simulium* (*Simulium*) *aquilum* Takaoka from Luzon Island, the Philippines, though the basal portion of

the female radial vein of the latter species is furnished with a few hairs on the apical one-third or one-fourth (Takaoka 2006b). *S. (S.) aquilum* differs in many characters including the shiny tergite of the female abdominal segment 5, short ovipositor valves each with a round apex, pupal head integument densely covered with tubercles, and simple wall-pocket-shaped cocoon (Takaoka 2006b).

The females of *Simulium (Simulium) crassimanum* Edwards, *Simulium (Simulium) kinabaluense* Smart & Clifford (unplaced to any species-groups), *Simulium (Simulium) laterale* Edwards and *Simulium (Simulium) lievi* Takaoka, *Simulium (Simulium) nigripilosum* Edwards, all described from Mount Kinabalu, Sabah (Edwards 1933, Takaoka 2007, Smart and Clifford 1969) have the dark fore coxae as in this new species but differ from this new species by the absence of hairs on the basal portion of the radial vein. The females of *S. (S.) crassimanum* and *S. (S.) nigripilosum* are also distinguished from this new species by the hind tibia with a yellow base (Edwards 1933). The male and pupa of *S. (S.) kinabaluense* are distinguished from those of this new species by the smaller numbers of large upper eye facets (15 or 16 vertical columns and 14–16 horizontal rows) and the cocoon with a relatively high anteroventral collar, respectively (Smart and Clifford 1969). *Simulium (S.) lievi* is also distinguished in the female by the wide frons (0.3 times the width of the head) and in the pupa by the simple wall-pocket-shaped cocoon and the gill filaments lacking definite annular ridges (Takaoka 2007). The females of *S. (S.) sp. (=S. (S.) laterale sensu Smart and Clifford, 1969)* from Sabah and *S. (S.) sp. sensu Takaoka & Leh, 2009*, from Sarawak, have the haired basal portion of the radial vein but differ from this new species by having whitish fore coxae.

Simulium (Simulium) cheedhangi sp. nov.

Female. Body length 2.9 mm. **Head.** Narrower than width of thorax. Frons brownish black, shiny and iridescent when illuminated at certain angles, with several dark stout hairs along lateral margins and near lower margin; frontal ratio 1.3:1.0:1.0; frons: head ratio 1.0:3.9. Fronto-ocular area triangular, directed laterally. Clypeus brownish black, whitish pruinose, shiny and iridescent when illuminated at certain angles, moderately covered with dark stout hairs. Labrum 0.8 times the length of clypeus. Antenna composed of scape, pedicel and nine flagellomeres, dark brown except scape, pedicel and basal one-third to two-thirds of first flagellomere yellow. Maxillary palp light brown, composed of five segments, proportional lengths of third, fourth, and fifth segments 1.0:1.0:2.1; third segment (Fig. 4A and B) normal; sensory vesicle (Fig. 4A and B) small, globular, 0.2 times the length of third segment, with medium-sized or large round opening. Maxillary lacinia with 9 or 10 inner and 14 outer teeth. Mandible with 21 inner and 9 or 10 outer teeth. Cibarium (Fig. 4C) with about 80 minute tubercles. **Thorax.** Scutum brownish-black except anterolateral calli light to medium brown, thinly whitish pruinose, shiny and

iridescent when illuminated at certain angles, moderately covered with light brown recumbent short fine hairs and dark brown short upright hairs, interspersed with dark brown longer upright hairs on prescutellar area. Scutellum brownish black, with dark brown long upright hairs. Postnotum dark brown, shiny, whitish pruinose when viewed at certain angles and bare. Pleural membrane bare. Katepisternum longer than deep, brownish black, bare, shiny and iridescent, white pruinose when illuminated at certain angles. **Legs.** Foreleg: Coxa whitish yellow; trochanter medium brown except base whitish; femur medium brown with apical cap dark brown; tibia grayish except outer surface broadly white on basal four-fifths and dark brown on apical one-fifth; outer surface of basal four-fifths with white sheen when illuminated at certain angles; tarsus brownish black; fore basitarsus greatly dilated, 4.6 times as long as its greatest width. Midleg: Coxa dark brown; trochanter dark brown except base light brown; femur medium brown except apical cap dark brown; tibia (Fig. 4D) medium brown except base whitish yellow, with white sheen broadly on posterior surface when illuminated at certain angles; basitarsus (Fig. 4E) whitish yellow with apical tip medium brown; second tarsomere (Fig. 4E) whitish yellow except apical one-third medium brown; rest of tarsus medium brown although base of third tarsomere whitish yellow. Hind leg: Coxa and trochanter medium brown; femur dark brown to brownish black; tibia (Fig. 4F) dark brown to brownish black except base yellowish white, with white or grayish sheen broadly on posterior surface when illuminated at certain angles; tarsus (Fig. 4G) medium to dark brown except basal two-thirds of basitarsus and basal half of second tarsomere yellowish white; hind basitarsus (Fig. 4G) nearly parallel-sided, 6.22 times as long as its greatest width, 0.64 and 0.55 times as wide as greatest widths of hind tibia and femur, respectively; calcipala (Fig. 4G) nearly as long as width at base, and 0.56 times as wide as greatest width of basitarsus; pedisulcus (Fig. 4G) distinct; claw (Fig. 4H) with medium-sized basal tooth 0.43 times the length of claw. **Wing.** Length 2.1 mm. Costa with dark spinules and hairs. Subcosta haired except apical one-fifth bare. Basal section of radial vein bare; R_1 with dark spinules and hairs; R_2 with dark hairs only. Hairs at base of stem vein dark brown. Basal cell absent. **Halter.** White except base darkened. **Abdomen.** Basal scale brownish black, with fringe of dark long hairs. Dorsal surface of abdominal segments medium brown, except basal half of segment 2 whitish, and covered with dark hairs; tergite 2 with pair of large whitish iridescent dorsolateral spots broadly connected to each other medially; tergites 6–9 shiny. Ventral surface of abdominal segment 7 with pair of submedial sternal plates (Fig. 4I). **Genitalia.** Sternite 8 (Fig. 4J) well sclerotized, moderately depressed medially, with middle portion of anterior margin produced forward, and covered with 15–19 long stout and medium-long fine hairs on each side. Ovipositor valves (Fig. 4J) well demarcated from posterior margin of sternite 8, somewhat bent posteroventrally, tapered apically with transparent bare pointed apex, and covered with about 30 short to long hairs on ventral surface;

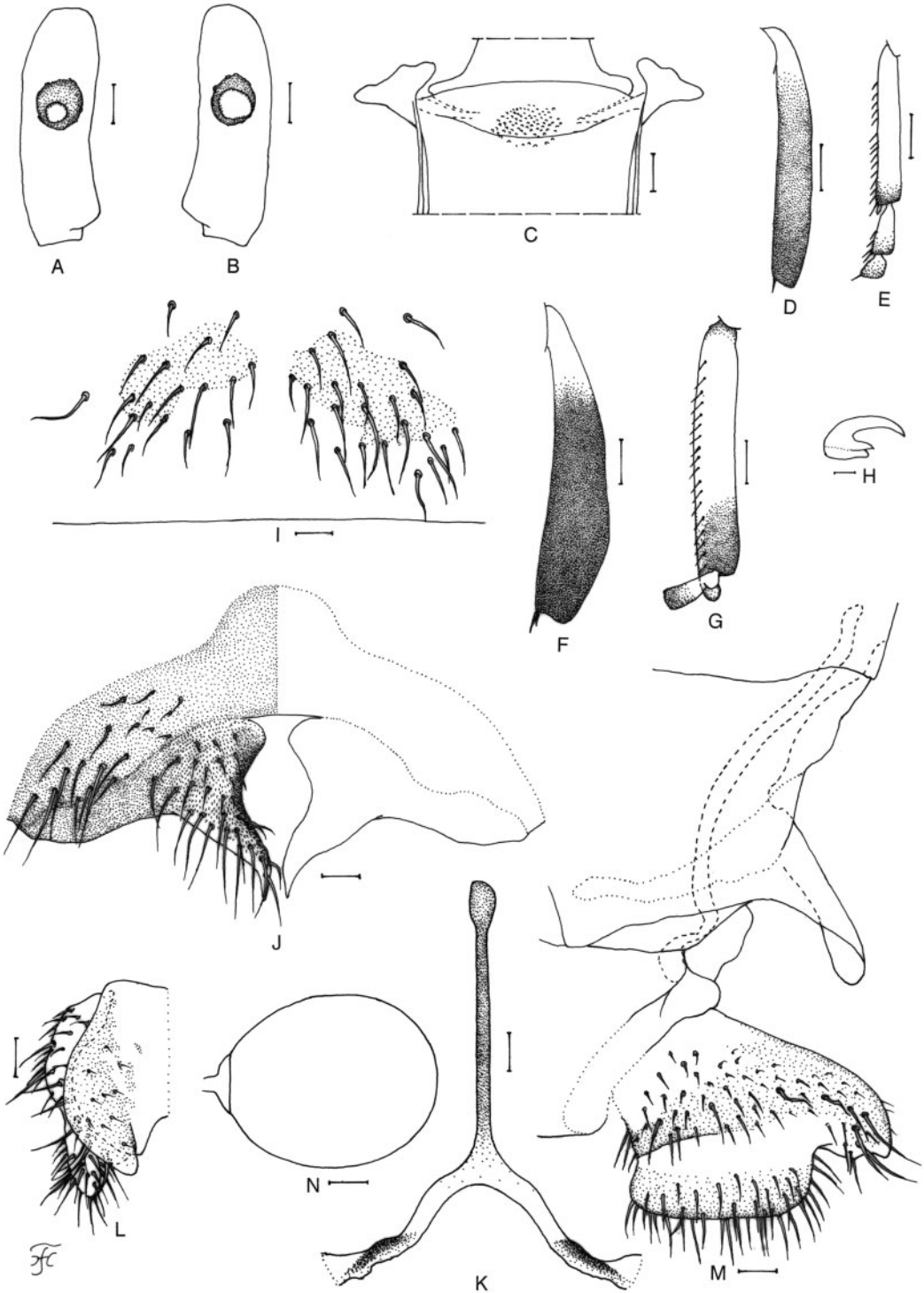


Fig. 4. Female of *Simulium* (*Simulium*) *cheedhangi* sp. nov. (A) and (B) third segments of maxillary palp with sensory vesicle (front view; A, right side; B, left side). (C) Cibarium. (D) Mid-tibia (left side; outer view). (E) Mid-tarsus (left side; outer view). (F) Hind tibia (left side, outer view). (G) Hind basitarsus with calcipala and second tarsomere with pedisulcus (left side; outer view). (H) Claw. (I) Middle portion of abdominal segment 7 with paired sternites (ventral view). (J) Sternite 8 and ovipositor valves (ventral view). (K) Genital fork (ventral view). (L) Paraproct with anteromedial plate and cercus (right side; ventral view). (M) Posterior tip of abdomen showing sternite 8, ovipositor valve somewhat bent posteroventrally, genital fork, paraproct and cercus (right side; lateral view). (N) Spermatheca. Scale bars. 0.1 mm for D–G; 0.02 mm for A–C and I–N; 0.01 mm for H.

inner margins well sclerotized, moderately concave medially, and moderately separated from each other. Genital fork (Fig. 4K) of inverted Y-form; stem slender, well sclerotized, with somewhat inflated apex; arms slender, each with strongly sclerotized lateral ridge. Paraproct in ventral view (Fig. 4L) with irregularly pigmented long plate having round apical tip and 10 minute setae scattered on its surface; paraproct in lateral view (Fig. 4M) much produced posteroventrally, 1.5 times as wide as its basal length, covered with several medium-long stout hairs and numerous short fine hairs on lateral surface. Cercus in lateral view (Fig. 4M) very short, with posterior margin nearly straight, 3.3 times as wide as its greatest length, and covered with numerous short to medium-long hairs. Spermatheca (Fig. 4N) ovoid, 1.2 times as long as wide, well sclerotized except duct and wide area of juncture with duct unsclerotized, without reticulate surface patterns; minute internal setae present; both accessory ducts subequal in diameter to each other, and also to that of main duct.

Male. Unknown.

Pupa. Body length (excluding gill filaments) about 3.0 mm. **Head.** Integument yellow except frons and antennal sheaths yellowish brown, and bare except small area near border between frons and face sparsely covered with small tubercles: frons with two unbranched slender short trichomes (Fig. 5A) arising relatively close together on each side; face with one unbranched slender medium-long trichome (Fig. 5B) on each side, which is 1.3 times the length of frontal trichomes. **Thorax.** Integument yellowish brown, bare except dorsal surface of posterior portion and lateral surface of anterior and middle portions sparsely to moderately covered with round or cone-shaped small tubercles; thorax with two slender short trichomes (one little longer than other) anterodorsally (Fig. 5C), two slender medium-long trichomes (one little longer than other) anterolaterally (Fig. 5D), one short somewhat stout trichome mediolaterally (Fig. 5E), and three trichomes (one long, two medium-long) ventrolaterally (Fig. 5F) on each side; all trichomes unbranched. Gill (Fig. 5G) with six thread-like filaments in pairs; common basal stalk very short, with transparent basal fenestra ventrally; dorsal and middle paired filaments with short stalk, and ventral paired filaments with very short stalk; filaments decreasing in length and thickness from dorsal to ventral, with longest dorsal filament including stalk 1.3 mm and shortest ventral filament including stalk 0.5 mm, relative lengths of six filaments including stalk from dorsal to ventral 1.00:0.62:0.55:0.49:0.42:0.39, and relative thickness of six filaments from dorsal to ventral 1.00:0.53:0.47:0.47:0.40:0.40; stalk of dorsal paired filaments thickest, 1.2 and 1.4 times as thick as those of middle and ventral paired filaments, respectively; all filaments light brown, gradually tapered toward apex, though some portions almost subequal in thickness; stalks of dorsal and ventral paired filaments at angle of 90 degrees; cuticular surface with moderately defined annular ridges and furrows throughout their length, forming faintly defined reticulate patterns, covered with minute tubercles of

same size. **Abdomen.** Dorsally, all segments unpigmented except segment 1 light brown, and basal portions of spine-combs and comb-like groups of minute spines on segments 7 and 8 slightly to moderately pigmented (Fig. 5 H and I); segment 1 sparsely covered with few minute tubercles medially, with one unbranched slender medium-long seta on each side; segment 2 bare, without tubercles, with one unbranched slender medium-long seta, and five unbranched short spinous setae on each side; segments 3 and 4 each with four unbranched hooked spines and one unbranched short seta on each side; segment 5 bare; segment 6 with comb-like groups of minute spines on each side; segment 7 with one distinct spine and comb-like groups of minute spines (Fig. 5H); segment 8 with spine-combs consisting of several distinct spines in transverse row on each side, and comb-like groups of minute spines (Fig. 5I); segment 9 without terminal hooks and spine-combs. Other characters on ventral surface of abdomen nearly as in *S. (S.) murudense* sp. nov. **Cocoon** (Fig. 5J and K). Shoe-shaped, thickly woven, with thick rim around its opening, yellowish brown, slightly extending ventrolaterally; anteroventral collar low; individual threads invisible; 3.0–3.6 mm in length by 1.5 mm in width; front collar 0.1 mm in height.

Mature Larva. Body length 4.5 mm. Body dark gray or grayish brown. Abdomen slightly becoming wider from segment 1 to segment 6, widest between segment 6 and segment 7. Cephalic apotome whitish yellow on anterior half and yellow on posterior half except narrow portion along posterior margin somewhat darkened medially, and head spots faintly positive in one larva, but cephalic apotome yellow, somewhat darkened near posterior margin and head spots indistinct in another larva. Lateral surface of head capsule yellow except eye-spot region whitish and spots indistinct in one larva, but somewhat darkened near posterior margin, and spots negative in another larva. Ventral surface of head capsule yellow except narrow areas on each side of postgenal cleft darkened in one larva, but somewhat darkened medially and spots on each side of postgenal cleft negative in another larva. Cervical sclerite composed of two yellow pieces (anterior one elongate with both ends pointed, posterior one elliptical) on each side, not fused to occiput, and separated medially from each other. Antenna composed of three segments and apical sensillum, slightly longer than stem of labral fan; proportional lengths of first, second, and third segments 1.00:0.95–0.98:0.50–0.54. Labral fan with 39 or 40 main rays. Mandible (Fig. 5L) with mandibular serrations composed of two teeth; major and longer tooth at obtuse angle to mandible on apical side; comb-teeth decreasing in length from first to third. Hypostoma (Fig. 5M) with nine anterior teeth, corner teeth most prominent, followed by median tooth, and middle tooth of three intermediate teeth smallest; lateral margins moderately serrate apically; six or seven hypostomal bristles lying divergent posteriorly from lateral border on each side. Postgenal cleft (Fig. 5N) large, rounded, deep, 3.0–3.2 times the length of postgenal bridge. Thoracic cuticle almost

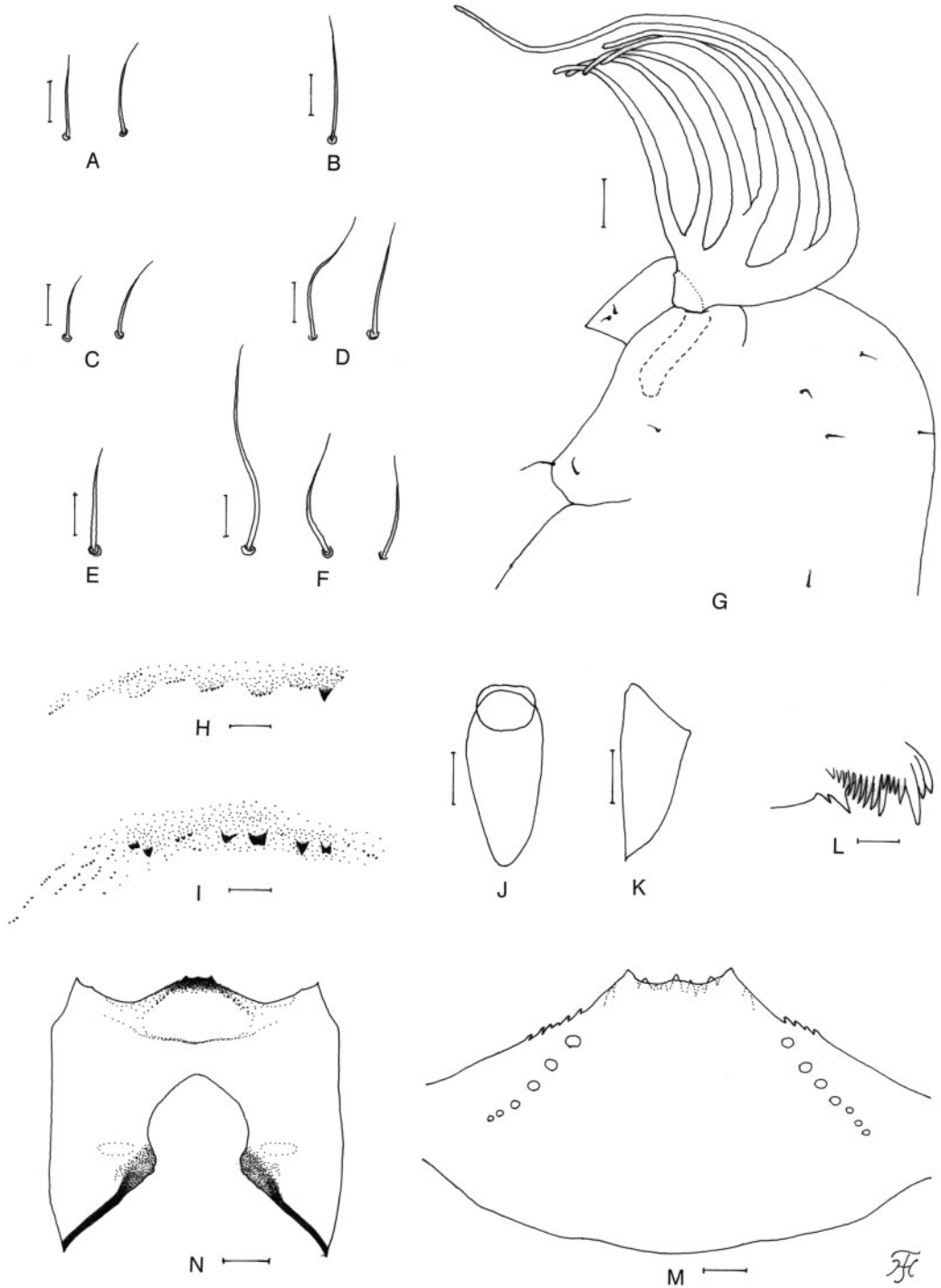


Fig. 5. Pupa and larva of *Simulium (Simulium) cheedhangi* sp. nov. (A)–(K) Pupa; (L)–(N) Larva. (A) Frontal trichomes. (B) Facial trichome. (C)–(F) Thoracic trichomes (C, anterodorsal; D, anterolateral; E, mediolateral; F, ventrolateral). (G) Anterior half of thorax and gill filaments (left side; lateral view). (H) Spine-comb and comb-like groups of minute spines on dorsal surface of abdominal segment 7 (left side; dorsal view). (I) Spine-combs and comb-like groups of minute spines on dorsal surface of abdominal segment 8 (left side; dorsal view). (J) and (K) Cocoons (J, dorsal view; K, lateral view). (L) Mandible. (M) Hypostoma. (N) Ventral surface of head capsule with postgenal cleft (ventral view). Scale bars. 1 mm for J and K; 0.1 mm for G and N; 0.02 mm for A–F, H, I, L and M.

bare. Abdominal cuticle almost bare except each side of anal sclerite moderately covered with short colorless setae. Rectal scales present. Rectal organ of compound lobes, each with 12–16 finger-like secondary lobules. Anal sclerite X-shaped, with broadened anterior arms 0.8 times the length of posterior ones, with wide thinly sclerotized extension between anterior arms; basal juncture area with deep incision opening posteriorly; two sensilla on basal juncture area and 8–13 sensilla posterior to posterior arms. Last abdominal segment somewhat bulged laterally, lacking ventral papillae. Posterior circlet with 85–92 rows of hooklets with up to 14–16 hooklets per row.

Type Specimens. HOLOTYPE: Female (preserved with its pupal exuviae and cocoon in 80% ethanol), reared from a pupa, collected from a stream (width 0.3–0.5 m, stream bed muddy, water temperature 18.6°C, partially shaded, altitude 1,544 m, 03°57'00.7" N/115°33'07.5" E), slowly flowing in natural forests, crossing the logging road from Para Rabata to Lepa Bunga, Bakalalan, Sarawak, Malaysia, 11–VI–2013, by Z. Ya'cob and N. Azhar. PARATYPES: One pupal exuviae and cocoon, and two mature larvae, same data as holotype.

Ecological Notes. The pupa, pupal exuviae, and larvae were collected from trailing grasses. Associated species were *S. (G.) auratum*, *S. (G.) barioense*, *S. (G.) tahanense*, and *S. (Simulium) sp. (S. melanopus species-group)*.

Etymology. The species name *cheedhangi* is in honor of Dr. Chee Dhang Chen, research officer, Institute of Biological Sciences, Faculty of Science, University of Malaya, who supported our studies of black flies.

Discussion. *Simulium (S.) cheedhangi* sp. nov. is assigned to the *S. melanopus* species-group based on the characteristic paraproct of the female (Fig. 4M). The female of this new species is characterized by the claw with a medium-sized tooth (Fig. 4H). Similar claws with a medium-sized tooth are reported in *Simulium (Simulium) mediodontatum* Takaoka, *Simulium (Simulium) nudifrons* Takaoka, and *Simulium (Simulium) tomophonense* Takaoka, all from Sulawesi, Indonesia, and *Simulium (Simulium) seramense* Takaoka from Seram, Indonesia (Takaoka 2003). However, all these Indonesian species differ in the female from *S. (S.) cheedhangi* sp. nov. by abdominal segment 5, of which the tergite is shiny, as are the tergites of abdominal segments 6–8, and the anteroventral plate of the paraproct, which has numerous long stout hairs in place of minute setae (Takaoka 2003). The pupa of this new species is characterized by the gill with a somewhat inflated stalk of the dorsal pair of filaments, which is 1.6 times as wide as the interspiracular trunk (Fig. 5G), and the cocoon with a low anteroventral collar (Fig. 5K).

Notes on the *S. melanopus* species-group in Sarawak and Sabah

The *S. melanopus* species-group of the subgenus *Simulium*, originally defined by Takaoka (1983) and redefined by Takaoka (2003), is characterized by

specialized female genitalia, in particular, paraproct with an anteroventral plate, and is represented by 43 species, of which 26 were recorded from the Philippines, eight from Sulawesi, four from Sabah, one from Sabah and Sarawak, one from Java, one from Java and Sumatra, one from Sumatra and Peninsular Malaysia, and one from Seram (Adler and Crosskey 2014). In this paper, we added two more species, *S. (S.) murudense* sp. nov. and *S. (S.) cheedhangi* sp. nov. from Sarawak.

Among the known species from Sarawak and Sabah, *S. (S.) laterale* recorded both from Sabah and Sarawak (Adler and Crosskey 2014) was originally described from females from Sabah (Edwards 1933) and later its female, male, pupa, and larva were described based on specimens collected in Sabah by Smart and Clifford (1969). However, an examination of the lectotype female of *S. (S.) laterale* deposited in The Natural History Museum, London, UK, shows that it differs from the female of the species thought to be *S. (S.) laterale* by Smart and Clifford (1969) by having a darkened fore coxa and bare basal portion of the radial vein (H. Takaoka, unpublished data). *S. (S.) laterale* was once recorded from Sarawak (Takaoka 2001) based on the redescription of *S. (S.) laterale* given by Smart and Clifford (1969). However, in a review of the species of black flies from Sarawak (Takaoka and Leh 2009), this species was treated as *S. (S.) sp.* because it differs from *S. (S.) laterale* sensu Smart & Clifford by the leg color. In a summary, a total of six species, i.e., *S. (S.) crassimanum*, *S. (S.) nigripilosum*, *S. (S.) laterale*, *S. (S.) liewi*, *S. (S.) maklarini* Takaoka, and one unnamed species, *S. (S.) sp. (= S. (S.) laterale* sensu Smart & Clifford), are recorded from Sabah, and three species, i.e., *S. (S.) murudense* sp. nov., *S. (S.) cheedhangi* sp. nov., and one unnamed species, *S. (S.) sp. sensu* Takaoka & Leh, are recorded from Sarawak.

Despite huge areas in Borneo Island (in particular, Kalimantan in Indonesia) remaining unexplored, it is noteworthy that the *S. melanopus* species-group is at present represented by nine species, all endemic in Sarawak and Sabah, while it is represented by one species in Peninsular Malaysia. This may suggest an occurrence of radiation in this species-group in Borneo Island, like in Sulawesi, even outside the Philippine Archipelago, a possible home region for this species-group, where it is represented by 26 species. By sharing the anteroventral plate of the female paraproct which is covered with several fine setae, all the nine species of this species-group in Sarawak and Sabah appear to be more closely related to those from the Philippines than to those from Sulawesi. All of eight species from Sulawesi bear the anteroventral plate covered with distinct medium to long hairs (Takaoka 2003). Further, all species from Sarawak and Sabah have much widened paraprocts and cerci (e.g., Fig. 1I and Fig. 4M), a most specialized form in the female genitalia of this group, while species from the Philippines show various degree of specialization in the paraprocts and cerci (Takaoka 1983, 2006a, b), suggesting a possibility of an ancestor species with most specialized paraprocts and cerci of this species-group moving

from the Philippines to Borneo Island, through Palawan passage or Sulu archipelago.

Biting habits of females and other biological aspects of this group remain unknown.

Acknowledgments

We are grateful to Prof. Peter H. Adler, Clemson University, Clemson, SC, for reading the current manuscript and providing valuable comments. Our sincere appreciation goes to Dr. Charles Leh (Sarawak Museum) and Prof. Ichiro Miyagi (Ryukyu University) for their kind invitation to conduct the surveys in Mount Murud. Thanks are due to Mr. Nor Azhar Jamil, University of Malaya, for his assistance in the field. This work was supported by the research grant from University of Malaya (RG146/11SUS and RP003A-13SUS) and also by the Fundamental Research Grant Scheme of the government of Malaysia (Project No. FP016-2012A).

References Cited

- Adler, P. H., and R. W. Crosskey. 2014.** World Blackflies (Diptera: Simuliidae): A comprehensive revision of the taxonomic and geographical inventory [2014]. <http://entweb.clemson.edu/biomia/pdfs/blackflyinventory.pdf> [accessed 1 May 2014].
- Adler, P. H., D. C. Currie, and D. M. Wood. 2004.** The black flies (Simuliidae) of North America, pp. xv+941. Cornell University Press, Ithaca, New York, NY.
- Edwards, F. W. 1933.** Diptera Nematocera from Mount Kinabalu. *J. Fed. Malay States Mus.*, 17: 223–296.
- Smart, J., and E. A. Clifford. 1969.** Simuliidae (Diptera) of Sabah (British North Borneo). *Zool. J. Linn. Soc.* 48: 9–47.
- Takaoka, H. 1983.** The blackflies (Diptera: Simuliidae) of the Philippines, pp. xi+119. Japan Society For The Promotion of Science, Tokyo, Japan.
- Takaoka, H. 1996.** Description of a new species of *Simulium* (*Simulium*) from Sabah, Malaysia (Diptera: Simuliidae). *Jpn. J. Trop. Med. Hyg.* 24: 157–161.
- Takaoka, H. 2001.** Description of two new species of black flies (Diptera: Simuliidae) from Sarawak, Malaysia. *Jpn. J. Trop. Med. Hyg.* 29: 243–252.
- Takaoka, H. 2003.** The black flies (Diptera: Simuliidae) of Sulawesi, Maluku and Irian Jaya, pp. xxii+581. Kyushu University Press, Fukuoka, Japan.
- Takaoka, H. 2006a.** Four new species of *Simulium* (*Simulium*) from Luzon Island, Philippines (Diptera: Simuliidae). *Med. Entomol. Zool.* 57: 287–307.
- Takaoka, H. 2006b.** Revised description of *Simulium* (*Simulium*) *forcipatum* Delfinado, and description of three new related species from Luzon Island, Philippines (Diptera: Simuliidae). *Med. Entomol. Zool.* 57: 309–326.
- Takaoka, H. 2007.** Two new species of *Simulium* (*Simulium*) from Sabah, Malaysia (Diptera: Simuliidae). *Med. Entomol. Zool.* 58: 291–301.
- Takaoka, H. 2008a.** Four new species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Sarawak, Malaysia. *Med. Entomol. Zool.* 59: 181–211.
- Takaoka, H. 2008b.** Taxonomic revision of *tuberosum* species-group of *Simulium* (*Simulium*) in Sabah and Sarawak, Malaysia (Diptera: Simuliidae). *Med. Entomol. Zool.* 59: 55–80.
- Takaoka, H. 2009.** Three new species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Sabah and Sarawak, Malaysia. *Med. Entomol. Zool.* 60: 97–112.
- Takaoka, H. 2012.** Morphotaxonomic revision of the subgenus *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) in the Oriental Region. *Zootaxa* 3577: 1–42.
- Takaoka, H., and D. M. Davies. 1995.** The Black Flies (Diptera: Simuliidae) of West Malaysia, pp. viii + 175. Kyushu University Press, Fukuoka, Japan.
- Takaoka, H., and C. M. Leh. 2009.** A preliminary note on the species of black flies (Diptera: Simuliidae) in Sarawak, Malaysia. *Sarawak Mus. J.* 87: 333–345.
- Takaoka, H., M. Sofian-Azirun, R. Hashim, Z. Ya'cob, and C. D. Chen. 2012.** Two new species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Peninsular Malaysia. *J. Med. Entomol.* 49: 803–812.
- Takaoka, H., M. Sofian-Azirun, and Z. Ya'cob. 2014a.** Two new species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Peninsular Malaysia, with keys to 10 Peninsular Malaysian species of the *Simulium batoense* species-group. *J. Med. Entomol.* 51: 10–26.
- Takaoka, H., M. Sofian-Azirun, Z. Ya'cob, and R. Hashim. 2014b.** Two new species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Cameron's Highlands, Peninsular Malaysia, with keys to 20 species of *Simulium asakoe* species-group. *Zootaxa* 3765: 54–68.
- Takaoka, H., M. Sofian-Azirun, and Z. Ya'cob. 2014c.** Two new species of the *Simulium batoense* species-group of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Peninsular Malaysia. *Zootaxa* 3774: 473–480.
- Takaoka, H., M. Sofian-Azirun, Z. Ya'cob, R. Hashim, and Y. Otsuka. 2014d.** A new species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Malaysia, with keys to 32 species of the *Simulium ceylonicum* species-group. *J. Med. Entomol.* 51: 517–528.
- Ya'cob, Z., H. Takaoka, and M. Sofian-Azirun. 2014.** *Simulium ledangense*, a new species of the *Simulium feuerborni* species-group of the subgenus *Nevermannia* (Diptera: Simuliidae) from Mount ledang, Peninsular Malaysia. *Zootaxa* 3881: 228–236.

Received 28 July 2014; accepted 4 October 2014.