A New Species of *Simulium* (*Simulium*) (Diptera: Simuliidae) from Langkawi Island, Peninsular Malaysia

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The *Simulium* (*Simulium*) *multistriatum* species-group, which consists of 30 species, is mainly distributed in the Oriental Region and extends its distribution northwest into Central Asia of the Palearctic Region (Adler and Crosskey 2012). In Peninsular Malaysia, where 46 species of black flies are recorded (Crosskey 1973; Edwards 1928; Takaoka 2000, 2008; Takaoka and Adler 1997; Takaoka and Davies 1995, 1997; Takaoka et al. 2010, 2011a, b, 2012a, b), this species-group is represented by two species, *S.* (*S.*) *hirtinervis* Edwards, 1928, and *S.* (*S.*) *malayense* Takaoka and Davies, both from Peninsular Malaysia, and several other known species from Bhutan, India, Nepal, and Thailand.

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In this article, this species is described as new, based on adult female, male, pupal, and larval specimens, and taxonomic notes are given to separate it from *S.* (*S.*) *hirtinervis* and *S.* (*S.*) *malayense*, both reported from Peninsular Malaysia, and several other species from Bhutan, India, Nepal, and Thailand.

The methods of collection, description, and illustration, as well as terms for morphological features used here, follow those of Takaoka (2003). The holotype and paratypes will be deposited at the Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia.
viewed dorsally, scutum thickly white pruinose, with five longitudinal nonpruinose vittae (one narrow median vitta, two wider submedian vittae, and two wider sublateral vittae though sublateral vittae somewhat wider than submedian ones), all vittae united with broad transverse band on prescutellar area; when illuminated from behind, scutum having reversed color pattern. Scutellum (not yet pigmented), covered with dark brown upright long hairs as well as golden-yellow short hairs. Postnotum dark brown, bare. Pleural membrane bare. Katepisternum dark brown, longer than deep, bare.

Leg. Color appearing to be essentially similar to that of male except hind tibia, which is white on basal two-thirds and light to dark brown on rest; fore basitarsus greatly dilated, 4.91 times as long as its greatest width; hind basitarsus nearly parallel-sided; calcipala moderately developed, nearly as long as basal width; pedisulcus well developed at basal one-third of second tarsomere; all tarsal claws simple.

Wing. Costa with dark spinules and hairs; subcosta haired except near apex bare; basal section of radial vein bare; R₁ with dark spinules and hairs; R₂ with hairs; hair tuft on stem vein dark brown; basal cell absent.

Abdomen. Basal scale medium brown, with fringe of long hairs. Dorsal surface of abdomen dark brown to brownish-black except basal half of second segment

Fig. 1. Female of *Simulium (Simulium) kisapense* sp. nov. (A) Third segment of right maxillary palp with sensory vesicle (front view); (B) upper portion of cibarium (front view); (C) sternite eight and ovipositor valve (only right half shown) (ventral view); (D, E) genital forks (D, ventral view; E, lateral view); (F, G) right paraprocts and cerci (F, ventral view; G, lateral view); (H) spermatheca. Scale bars. 0.02 mm for A–H.
yellowish-white, with short dark hairs; tergite two shiny, white iridescent when illuminated, and tergites 6–8 shiny.

**Genitalia.** Sternite eight (Fig. 1C) bare medially, with 23–26 dark medium-long to long stout hairs on each lateral surface. Ovipositor valves (Fig. 1C) rounded, membranous, each moderately covered with microsetae and two or three dark medium-long hairs, except portion along inner margin widely bare, so thin and transparent that it is difficult to discern inner margins. Genital fork (Fig. 1D, E) of inverted-Y form, with narrow well sclerotized stem; arms of moderate width, each with distinct short and wide projection having pointed apex directed anterodorsally. Paraproct in ventral view (Fig. 1F) nearly quadrate, with narrow tip medially, strongly sclerotized on outer and medial surfaces but unsclerotized on anterior surface, densely covered with minute setae and with 17–25 short to medium-long hairs on lateral and ventral surfaces; medial surface with 7–11 short sensilla; paraproct in lateral view (Fig. 1G) moderately protruded ventrally beyond ventral margin of cercus. Cercus in lateral view (Fig. 1G) short, rounded posteriorly, 0.45 times as long as wide, and with numerous short to medium-long hairs. Spermatheca (Fig. 1H) large, nearly ovoid, 1.32 times as long as wide, well sclerotized except portion of juncture with duct unsclerotized, with no defined surface patterns, and with internal setae: accessory ducts subequal in thickness to each other, and slightly thicker than major duct.

**Male.** Body length 2.5–2.7 mm.

**Head.** Width subequal to that of thorax. Upper eye medium brown, consisting of large facets in 17 or 18 vertical columns and in 17 or 18 horizontal rows. Clypeus black, thickly white pruinose, silvery or bluish, shiny when illuminated at certain angle of light, covered with dark brown hairs along and near lateral margins (most of central portion bare). Antenna composed of scape, pedicel and nine flagellomeres, medium to dark brown except scape, pedicel, and base of first flagellomere yellow though apical portion of pedicel dark yellow; first flagellomere elongate, 2.11 times as long as second one. Maxillary palp grayish to dark brown, composed of five segments with proportional lengths of third, fourth, and fifth segments 1:0.25:2.38: third segment (Fig. 2A) of normal size; sensory vesicle (Fig. 2A) small (0.21–0.23 times as long as third segment), ellipsoidal, and with opening of moderate size.

**Thorax.** Scutum brownish-black to black, with white pruinose pattern, that is, anterior pair of rectangular spots on shoulders extending posteriorly along lateral margins and connected to large transverse spot entirely covering prescutellar area; these pruinose areas somewhat shiny when illuminated at certain angles of light; scutum uniformly and densely covered with golden-yellow recumbent short hairs interspersed with dark brown long upright hairs on prescutellar area. Scutellum brownish-black, with several dark long upright hairs as well as golden-yellow short hairs. Postnotum brownish-black, white pruinose, bare. Pleural membrane bare. Katepisternum longer than deep, brownish-black, bare.

**Legs.** Foreleg: coxa whitish-yellow; trochanter light brown though base of posterior surface yellowish; femur light brown with apical cap dark brown; tibia medium to dark brown except outer surface widely white medially, and with white sheen when illuminated at certain angle of light; tarsus brownish-black, with moderate dorsal hair crest; basitarsus greatly dilated, 5.05–5.30 times as long as its greatest width. Midleg: coxa brownish-black; trochanter medium brown except base of outer surface light brown; femur medium brown with apical cap dark brown; tibia whitish to yellowish-white on basal three-fourths or little more, and dark brown on apical cap; tibia with white sheen on posterior surface of basal three-fourths or little more when illuminated at certain angle of light; tarsus dark brown except basal half or little more of basitarsus yellowish. Hind leg: coxa brownish-black; trochanter whitish-yellow; femur dark brown except base whitish-yellow and apical cap brownish-black; tibia brownish-black except basal tip whitish-yellow; tarsus (Fig. 2B) dark brown to brownish-black except little more than basal half of basitarsus and basal half of second tarsomere whitish-yellow; basitarsus (Fig. 2B) much enlarged, wedge-shaped, gradually widened from base to basal one-third, then nearly parallel-sided up to near apex, 3.80–3.81 times as long as its greatest width, and 0.82–0.88 and 0.83–0.84 times as wide as greatest widths of hind tibia and femur, respectively; calcipala (Fig. 2B) small, slightly shorter than width at base, 0.26 times as wide as greatest width of basitarsus; pedisculus (Fig. 2B) well marked.

**Wing.** Length 1.7–1.9 mm; costa with dark spinules and hairs; subcosta bare; basal section of radial vein bare; R₁ with dark spinules and hairs; R₉ with hairs; hair tuft on stem vein dark brown; basal cell absent.

**Abdomen.** Basal scale brownish-black, with fringe of dark long hairs. Dorsal surface of abdomen brownish-black to black, with dark short hairs; segments 2 and 5–7 each with pair of silvery or bluish iridescent spots dorsolaterally, those on segment 2 connected broadly to each other in middle.

**Genitalia.** Coxite in ventral view (Fig. 2C) nearly quadrate, covered with many stout hairs on posterior half. Style in ventral view (Fig. 2C) elongate, gradually tapered to apical one-third and slightly widened apically, with apical spine (two spines in left style of one male; Fig. 2C): style in ventrolateral view (Fig. 2D) elongate, 2.79 times as long as its greatest width at basal one-fourth, with outer margin slightly sinuous, slightly tapered from basal one-fourth to middle, then nearly parallel-sided toward apex; style in medial view (Fig. 2E) spatulate dorsoventrally, 1.47 times as long as coxite, with long horn-like basal protuberance pointed dorsally that has several small cone-like spines on anterior surface. Ventral plate in ventral view (Fig. 2C) well sclerotized and black, with body nearly rectangular (though somewhat narrowed basally, and rounded on each posteroventral corner), with many minute setae on each anteroventral surface; arms directed forward and diverging outward from each oth-
er; ventral plate in lateral view (Fig. 2F) having body triangular, with ventral process at about right angle against dorsal margin of body, and with serrated posterior margin; ventral plate in end view (Fig. 2G) having body ventrally narrowed on basal two-fifths, then nearly parallel-sided on middle two-fifths, and gently convergent on apical one-fifth forming round apex, and having several ridges in two irregular vertical rows on posterior surface except near ventral apex without ridges. Median sclerite (Fig. 2F, H) plate-like, widened from base toward near apex, with round apex, brown basally, but not so well sclerotized apically. Paramere (Fig. 2I) with several distinct hooks. Aedeagal membrane (Fig. 2J) short, moderately covered with minute setae, and with moderately sclerotized dorsal plate in form of horizontal bar (Fig.

Fig. 2. Male of Simulium (Simulium) kisapense sp. nov. (A) Third segment of right maxillary palp with sensory vesicle (front view); (B) basitarsus and second tarsomere of left hind leg showing calcipala and pedisulcus (outer view); (C) coxites, styles and ventral plate (ventral view); (D, E) right styles (D, ventrolateral view; E, medial view); (F) ventral plate and median sclerite (lateral view); (G) ventral plate (caudal view); (H) median sclerite (caudal view); (I) left paramere (caudal view); (J) aedeagal membrane (caudal view); (K) dorsal plate (caudal view); (L, M) 10th 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.
2K). Abdominal segment 10 (Fig. 2L, M) without any distinct hair on ventral and lateral surface. Cercus (Fig. 2L, M) small, rounded, with 11 or 12 distinct hairs.

**Pupa.** Body length 2.7–3.0 mm.

**Head.** Integument including antennal sheaths dark yellow, densely and elaborately covered with small round tubercles; frons with two pairs of simple slender short trichomes; face with pair of simple medium-long trichomes.

**Thorax.** Integument dark yellow except posterior one-third of dorsal surface and medial portion on each side of longitudinal suture dark greyish, densely and elaborately covered with small round tubercles; thorax on each side with three medium-long or long trichomes (one simple, two bifid, or two simple, one bifid) mediodorsally (Fig. 3A), two simple trichomes (one very long, one short) anterolaterally (Fig. 3A), one simple medium-long trichome posterolaterally, and three simple trichomes (two medium-long, one short) ventrolaterally. Gill (Fig. 3A) with eight slender thread-like short filaments in four pairs (one dorsal, two middle, and one ventral) arising from very short common basal stalk; all pairs short-stalked, and stalks of dorsal and ventral pairs widely divergent, forming an obtuse angle of 90–120 degrees when viewed laterally; upper filament of dorsal pair longest (≈1.5 mm long), gradually shortened from dorsal to ventral, and lower filament of ventral pair shortest (≈0.8 mm long); relative thickness of eight filaments from dorsal to ventral when basal portions were compared 1.58:1.37:1.33:1.17:1.33:1.17:1.17:1.00; all filaments light yellow to light yellow-brown, tapered toward apex, with distinct annular ridges and furrows forming definite reticulate surface patterns, and densely covered with minute tubercles.

**Abdomen.** Dorsally, segment 1 weakly sclerotized, dark greyish, with one simple slender short seta on each side; segment 2 transparent, with one simple slender short seta and five spinous short setae, of which three are much stouter than two others, on each side; segments 3 and 4 transparent, each with four distinct simple hooks and one simple spinous short seta on each side; segments 5, 6, 7, and 9 transparent and lacking spine-combs; segment 8 with distinct spine-combs in transverse row; segments 6–9 with comb-like groups of minute spines on each side; segment 9 without terminal hooks. Ventrally, segments 3–9 transparent, each (except segment 9) with comb-like groups of minute spines; segment 4 with few slender minute setae on each side; segment 5 with pair of bifid stout hooks submedially and few simple short setae on each side; segment 5 with pair of bifid stout hooks submedially and few simple short setae on each side; segments 6 and 7 each with pair of bifid inner and simple outer stout hooks somewhat separated from each other, and few simple short setae on each side. Grapnel-shaped hooklets absent on each side of segment 9.

**Cocoon** (Fig. 3B, C). Shoe-shaped with narrow anteroventral collar, tightly and thickly woven, light to dark brown, with small elliptical or slit-like anterolateral window often accompanied with few very small open spaces (exceptionally, neither anterolateral window nor open spaces present on right side of one
coconut), and not extended ventrolaterally; individual threads invisible; 3.0–3.4 mm long × 1.1–1.3 mm wide.

**Mature Larva.** Body length 4.8–5.3 mm. Body light brown, except thorax often dark greyish. Cephalic apotome variable in color, pale yellow to dark yellow on anterior two-fifths, dark yellow to medium-brown on posterior three-fifths, and narrow area along posterior margin medium to dark brown, with median dark portion slightly extended forward; head spots almost indistinct or faintly negative. Lateral surface of head capsule dark yellow to dark yellowish-brown except eye-spot region whitish-yellow; eye color distinct; one spot below eye-spot region obscure or positive, and large spots before posterior margin faintly negative. Ventral surface of head capsule (Fig. 3E) dark yellow to medium brown though area near posterior margin of hypostoma often yellowish narrowly, and each side of basal portion of postgenal cleft dark brown. Antenna composed of three segments and apical sensillum, slightly longer than stem of labral fan; length ratio of three segments (from base to tip) 1.00: 1.09–1.16:0.69–0.70. Labral fan with 34–41 main rays. Mandible with mandibular serrations composed of two teeth (one medium-sized and one small); main tooth at obtuse angle against mandible on apical side; supernumerary serrations absent; comb-teeth decreasing in length from first to third. Hypostoma (Fig. 3D) with nine anterior teeth, of which corner teeth most prominent, longer than median tooth; three intermediate teeth on each side small, subequal in length to one another; lateral margins weakly serrate apically; five hypostomial bristles divergent posteriorly from lateral border on each side. Postgenal cleft (Fig. 3E) large, rounded, 3.7 times as long as postgenal bridge; subesophageal ganglion not pigmented. Histoblast of pharate pupal gill with eight short filaments. Thoracic and abdominal cuticle almost bare except last segment of abdomen moderately covered with short colorless setae on each side of anal sclerite; abdominal segments 5 and 6 each with pair of small round dorsolateral protuberances in one of three larvae examined. Rectal scales absent. Rectal organ compound, each lobe with six or seven finger-like secondary lobules. Anal sclerite X-shaped, with short broad anterior arms about half as long as posterior ones and with forked apices. Last abdominal segment lacking ventral papillae. Posterior circllet with 96–90 rows of hooklets with up to 16 or 17 hooklets per row.

**Type Materials.** **HOLOTYPE:** Male (with its associated pupal exuviae and cocoon) (preserved in 50% ethanol), reared from pupa collected from the river Kisap (width =10 m, flow moderate, bed of pebbles, water temperature 24.0°C, exposed to the sun, altitude 42 m, 06° 22′33.9″ N, 99° 51′92.4″ E), MALAYSIA: Kedah State, Langkawi Island, 27-X-2011, H. Takaoka, M. Sofian–Azirun, and Z. Ya’cob. Paratypes: two pharate females and one male, with their associated pupal exuviae and cocoons, and three mature larvae (all preserved in 50% ethanol), same data and date as those of the holotype.

**Distribution.** Peninsular Malaysia (Langkawi Island).

**Etymology.** The specific name kisapense refers to the name of the river, where this new species was collected.

**Biology.** The pupae and larvae of S. (S.) kisapense sp. nov. were collected from twigs of a fallen tree trailing in the water. Associated species was Simulium (Gomphostilbia) duolongum Takaoka and Davies, 1995.

**Discussion.** S. (S.) kisapense sp. nov. is the third Peninsular Malaysian species assigned to the multistriatum species-group of the subgenus Simulium. This new species is distinguished from the two other known species of this species-group recorded from Peninsular Malaysia, S. (S.) hirtinervis and S. (S.) malayense, by the following characteristics (characteristics of the known species in parentheses): from S. (S.) hirtinervis in the female by lacking hairs on the basal portion of the radial vein; in the male by the number of the enlarged upper-eye facets in 17 or 18 vertical columns and 17 or 18 horizontal rows (in 14 or 15 vertical columns and 15 horizontal rows), subcosta bare (with 3–6 hairs in the males of S. (S.) hirtinervis collected from Cameron’s Highlands), the hind tibia white only on the basal tip (white on the basal one-third or slightly less), the basal protuberance of the style with spines on the anterior surface (Fig. 3E) (without such spines), the ventral plate in lateral view having its body triangular, with a ventral process at about right angle against the dorsal margin of the body (Fig. 2F) (with a ventral process somewhat inclined posteriorly) and the ventral plate in end view with its body ventrally narrowed on the basol-two-fifths, then nearly parallel-sided on the middle two-fifths, and gently convergent on the apical one-fifth forming a round apex (Fig. 2G) (with its body ventrally narrowed on the basal half, then divergent on the middle one-fourth, and convergent on the apical one-fourth forming a round apex); in the pupa by the cocoon with small anterolateral windows (Fig. 3B, C) (with large windows); and in the larva by lacking protuberances on the dorsal surface of the abdomen, though rarely present on segments 5 and 6 (present on abdominal segments 1–8), and rectal organ with six or seven secondary lobules per lobe (with 12–14 secondary lobules per lobe); and from S. (S.) malayense in the female by the inner margin of the ovipositor valve transparent (Fig. 1C) (darkened at least medially), the genital fork with arms twice as thick as its stem (Fig. 1D) (arms slightly thinner than its stem), the spermatheca enlarged and ovoid (Fig. 1H) (medium-sized and globular), and the paraproct in lateral view ventrally rounded, appearing as semicircular (Fig. 1G) (ventrally tapered, with a nipple-like apex); in the male by the mid tibia that is white on the basal three-fourths (white on the basal half or slightly more) and the hind basitarsus that is white on the basal half or slightly more (Fig. 2B) (yellow on the basal two-fifths or slightly less) (the male of S. (S.) malayense remains undescribed, its characteristics noted here are based on adult male specimens reared from the pupae newly collected from Perak State, Peninsular Malaysia); in the pupa by the integument of the frons densely covered with tubercles (bare), the integument of the
thorax densely covered with tubercles (bare on the anterior one-third of the thorax), spine-combs present on abdominal segment eight (on abdominal segments 7 and 8), and the cocoon shoe-shaped, with anterolateral windows (Fig. 3B, C) (wall-pocket shaped, without anterolateral windows); and in the larva by the head capsule darkened on the posterior two-thirds (entirely yellowish white), and the postgenal cleft of round shape (Fig. 3E) (of bullet shape).

The pupal gill with eight filaments divergent at an angle of >90 degrees (Fig. 3A) seems to relate this new species to S. (S.) barraudi Puri, S. (S.) dentatum Puri, S. (S.) digitatum Puri, and S. (S.) novolineatum Puri, all originally described from India (Puri 1932, 1933), S. (S.) deothangense Takaoka and Somboon from Bhutan (Takaoka and Somboon 2008), S. (S.) hillycum Maskey from Nepal (Maskey 1989), and S. (S.) lampangense Takaoka and Choochote from Thailand (Takaoka and Choochote 2005). However, this new species is distinguished from S. (S.) novolineatum by the ventral plate with setae (Fig. 2F); from the three other Indian species by the difference in the shape of the ventral plate; from S. (S.) deothangense by the basal protuberance of the style with several small cone-like spines on the anterior surface (Fig. 2E); from S. (S.) hillycum by the female mid tibia that is whitish to yellowish-white on the basal three-fourths or a little more, and dark brown on the apical cap (entirely black in S. (S.) hillycum according to the figure in the original description); and from S. (S.) lampangense by the male hind basitarsus dark brown to brownish-black except slightly more than the basal half whitish-yellow (Fig. 2B) (dark brown to brownish-black except slightly more than the basal one-third or a little less dark yellow in S. (S.) lampangense).

The geographical distribution of the multistriatum species-group in the Oriental Region covers most of the Southeast Asian areas of the Eurasian Continent including Peninsular Malaysia, but its southward extension is limited up to Sumatra (one of the so-called continental islands, which were parts of the Greater Sundaland formed by decreasing sea levels at the glacial epochs [Takaoka 1996]), and no record of this species-group has been present on three other major continental islands (Borneo, Java, and Palawan) (Adler and Crosskey 2012). It is not surprising that this species-group was also found on Langkawi Island, one of the continental islands, located 31 km west from the nearest coastline of the northwestern region of the mainland of Peninsular Malaysia. The coastal areas of Langkawi Island consist of flat, alluvial plains pocked with limestone ridges but almost two-thirds of the island are dominated by mountains (the highest 850 m above sea level) and hills covered with natural forests, supporting a number of fast-flowing permanent streams suitable for habitats of the immature stages of black flies. Given the dispersal capabilities of black flies over open waters (maximum flight range 116 km in still air) (Hocking 1953) and colonization of near-mainland islands (within 100 km from the nearest source) by the resident species of the nearest mainland (Adler et al. 2005), the presence of a new species of the multistriatum species-group on Langkawi Island is unexpected because this island is only 31 km from the nearest mainland of Peninsular Malaysia. Out of 14 species of black flies collected from Langkawi Island, 12 were common on the mainland of Peninsular Malaysia, and two (S. (S.) kisapense sp. nov. and another sp. of the subgenus Gomphostilbia) were new species (unpublished data). This high species-sharing rate may suggest the very low possibility that S. (S.) kisapense sp. nov. is an endemic species on Langkawi Island. However, whether this new species is breeding also in the mainland of Peninsular Malaysia, and whether two mainland species, S. (S.) hirtinervis and S. (S.) malayense, are living on Langkawi Island could be solved by future extensive investigations.

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