



Journal of
Entomology

ISSN 1812-5670



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Morphometric Description of Sandflies Belong to Genus *Sergentomyia* (*Sergentomyia*) (Diptera; Psychodidae; Phlebotominae) in Sri Lanka; Evidence for the Presence of *Sergentomyia* (*Sergentomyia*) *pondicherriensis* and *Sergentomyia* (*Sergentomyia*) *dentata* in the Country

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ABSTRACT

Leishmaniasis, mainly a zoonotic disease vectored by sand flies, emerges as major public health concern in Sri Lanka. The role of the old world sandfly genus *Sergentomyia* in the disease transmission is emphasized in recent findings. Seven species belong to the subgenus *Sergentomyia* of this genus have been reported globally. Only one (*Sergentomyia* (*Sergentomyia*) *punjabiensis*) has been recorded so far from Sri Lanka. Three species viz. *Se. (Ser.) punjabiensis*, *Se. (Ser.) pondicherriensis* and *Se. (Ser.) dentata* were identified in a collection from three Cutaneous Leishmaniasis (CL) endemic localities in Sri Lanka. This is the first record of the presence of *Se. (Ser.) pondicherriensis* and *Se. (Ser.) dentata* from the country. The detail morphology of both sexes are described along with the comparison with the existing literatures from the oriental region.

Key words: Leishmaniasis, sandflies, *Sergentomyia*, Sri Lanka, zoonotic disease

INTRODUCTION

Phlebotomine sand flies (Diptera: Psychodidae: Phlebotominae) are of human health concern. They are vectors of human diseases such as sandfly fever (Tavana, 2007) and leishmaniasis (Alexander and Maroli, 2003). The sandflies are classified, based on the geographical distribution, in to two major groups namely, old world and new world flies. Old world sandflies include three genera viz. *Phlebotomus*, *Chinius* and *Sergentomyia* while the New World includes the genera viz. *Brumptomyia*, *Lutzomyia* and *Warileya* (Lane, 1993).

Only three sandfly species were named in 1905 and since then 700 sandfly species have been identified (Ilango, 2011). Various studies have been carried out in Sri Lanka since early 1900s to record the presence of sandflies in the country (Lewis, 1978). However these studies were not conclusive and there is no catalogue of Sri Lankan sandflies.

The members of the genus *Sergentomyia* Franca and Parrot mostly prefer to feed on reptiles (Lewis, 1978; Artemiev, 1978). However, various research findings suggest that they could transmit various pathogens including *Leishmania* (Geevarghese *et al.*, 2004; Maroli *et al.*, 1988; Mukherjee *et al.*, 1997). Leishmaniasis is an emerging public health threat in Sri Lanka. The first autochthonous Cutaneous Leishmaniasis (CL) case was reported from the country in 1992

(Athukorale *et al.*, 1992). Since then, more than 2000 CL cases have been reported (Siriwardana *et al.*, 2010). The first case of Visceral Leishmaniasis (VL) was reported from North Central Province in 2006. Many CL patients have been identified in many localities in the dry zone of the country. Some of the localities that were identified, like Matara, Hambantotta, Polannaruwa, Vavuniya, Padaviya, Siripura and Anurathapura where large number of patients have been recorded for (Abeygunasekara *et al.*, 2007). The disease transmission to new localities is attributed to insufficient diagnostic facilities as well as lack of awareness (Ozbel *et al.*, 2011).

The vector for either CL or VL in Sri Lanka is yet to be identified. Sand fly taxonomy and proper identification of species is crucial. This plays a major role in vectors species identification and also in the formulation of proper control measures (Singh *et al.*, 2007). Therefore, a comprehensive taxonomic work is required to facilitate the perfect identification of sand fly species and to formulate an optimum vector control programme in Sri Lanka.

In this view, a study was carried out to record the presence of *Sergentomyia* species in the country and the results are reported with the evidence for the presence of three species of the subgenus *Sergentomyia* of which two are recorded for the first time from the country.

MATERIALS AND METHODS

The present investigation was carried out in leishmaniasis endemic localities in the districts of Vavuniya, Trincomalee and Anurathapura which are located in the dry zone of the country (Fig. 1). Sandflies were collected in and around the houses (including that of the leishmaniasis patients) by a mouth aspirator from 1700 to 0500 h from May to August 2010. Collected samples were transferred in eppendorf vials (1.5 mL) containing 70% ethyl alcohol and shifted to Zoology Department, University of Jaffna, where morphometric and meristic analysis was done. Each fly was processed and dissected following the conventional techniques (Young and Duncan, 1994; Aslamkhan and Aslamkhan, 2000). Whole specimen was temporarily mounted in distilled water to study the morphometric and meristic characteristics.

The flies were observed under a stereo microscope (Kyowa Model SE-L, Japan) and a monocular light microscope (Kyowa, Japan) equipped with a moving venire scale and an ocular micrometer. Permanent mounting of the whole specimen was done for some flies in Canada balsam after the alcohol treatment (Ko *et al.*, 2008).

Photographs of the morphometric structures were taken with the Nikon Coolpix Digital Camera fixed to the microscopes. Camera Lucida was used to draw images. The measurement of the structures such as wing, wing venation (Radial (R) 1, 2, R 3, R₂₊₃ and R₁ Overlap), halter, head, eye, labium, maxillary palp, antennal flagellomere (AF)-i,-, *S. chaetica* on AFi-v, thorax, femur, tibial, basitarsal segments of each appendages, abdomen, coxa, style (clasper), paramere, aedeagal sheath, genital pump and aedeagal filament was done with the ocular micrometer. The number of teeth found in both ventral and lateral sides of the maxillae was counted under the light microscope equipped with a camera (Olympus Model BX 51, Japan).

Identification of specimens was done with the available taxonomic keys (Lewis, 1978; Lane, 1993; Artemiev, 1978; Kakarsulemankhel, 2009; Srinivasan and Jambulingam 2010). Prepared permanent slides were deposited at the Department of Zoology, University of Jaffna.

Morphometric characters of the identified flies were compared with the available literatures from the South East Asian region (Lewis, 1978; Kakarsulemankhel, 2004a, b, 2009, Pringle, 1953; Perfiliev, 1933, 1960, 1968; Sinton, 1933) (Table 1-6) for identifying any variation in described morphometric and any new taxa.

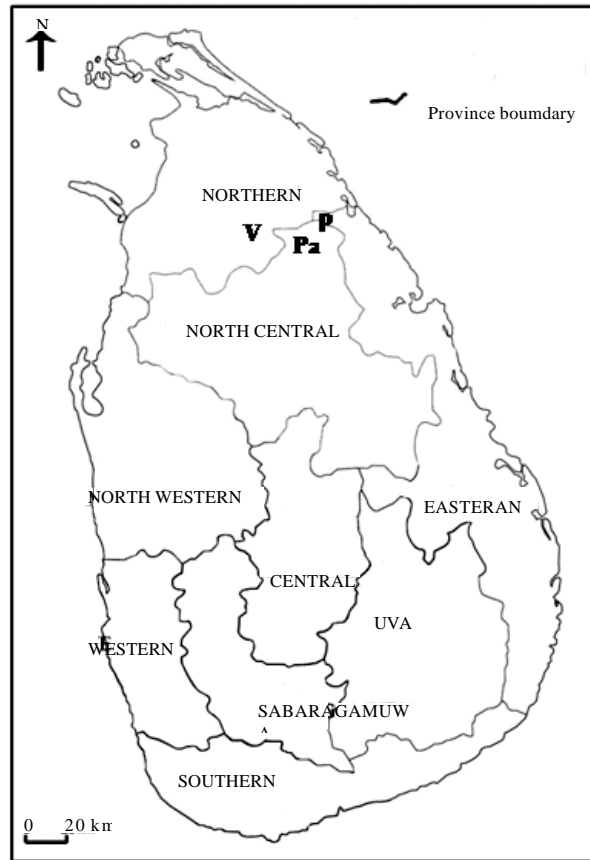


Fig. 1: The sampling localities (P- Padavi Siripura in Trincomalee district; Pa- Padaviya in Anurathapura district; V- Vavuniya)

RESULTS

Nineteen flies belonging to the genus *Sergentomyia* and subgenus *Sergentomyia* were identified. Presence of pointed wing, the small oval hair sockets in the second and subsequent abdominal tergites; the presence of four style spines and the absence of erect hairs on tergal plates were observed in all flies. All female flies had a tubular spermathecae with uniform thickness. All flies had AF_i; shorter than AF_{ii+iii} and labrum. R_2/R_{2+3} was less than 0.8.

Identified species

Sergentomyia (Sergentomyia) punjabiensis Sinton:

- *Phlebotomus minutus* var. *antennatus* Newstead (Sinton, 1924)
- *Phlebotomus antennatus* Newstead (Sinton, 1927)
- *Phlebotomus punjabiensis* (Sinton, 1933)
- *Sergentomyia (Sergentomyia) punjabiensis* (Sinton) (Theodor, 1948)
- *Phlebotomus antennatus* var. *decacanensis* (Qutubuddin, 1952)
- *Sergentomyia (Sergentomyia) punjabiensis* (Sinton) (Lewis 1978)

Specimen examined (Fig. 2; Table 1, 2)

Male: (n = 5): Abdomen length 540-640 µm; abdomen breadth 260-270 µm; thorax length 360-420 µm; thorax breadth 360-390 µm; head length 260-280 µm; head breadth 180-270 µm; eye length 130 µm; eye breadth 90-120 µm; inter ocular 100-110 µm; wing length 990-1470 µm; wing breadth 240-420 µm; halter length 100-140 µm. fore femur: fore tibia: fore basi tarsi 3.9:3.3:1.7; mid femur: mid tibia: mid basi tarsi 3.8:4.1:2.0; hind femur: hind tibia: hind basi tarsi 3.9:5.0:2.2.

Mouth parts: Labrum is chitinized; bluntly pointed broad structure with three apical sensilla. The hypopharynx is narrower compared to that of the female. Mandible is absent. Maxillary blade has very fine teeth (three). Cibarium is with a concave pigment patch with out any anterior process. Concave arrangement of teeth is found with around 27-30 pointed denticles along with 20-22 small teeth in a single row. Pharynx is broader at base and the constriction is not deep. Pointed teeth are found in the armature.

Labrum length 120-140 µm; maxillary palp length 460-490 µm; palp formula (1,2,3,4,5) with a ratio of 2.83:5.5:7.75:8.5:15.3; proboscis length 150-204 µm; cibarial length 380-400 µm; third antennal segment (Aiii) 70-190 µm; Aiv 45-105 µm; Av 48-105 µm; antennal ascoid/sensilla chaetica on third antennal segment (Aaiii) 20-45 µm; Aaiv 20 µm; Aav 20 µm; ascoid formula is 1/3-15.

Table 1: Comparison of the taxonomic characters of female *Sergentomyia (Sergentomyia) punjabiensis* Sinton (all measurements are in mm)

Characters	Lewis (1978)	Kakarsulemankhel (2004a)	Kakarsulemankhel (2009)	Present study
Wing length	1.21-1.5	1.12-1.20	1.30-1.35	0.99-1.44
Wing breadth	0.28-0.33	0.25-0.32		0.24-0.42
Wing length/breadth	---	---	4.09-4.19	3.42- 4.12
Wing index	0.40-0.9	0.6-0.62	0.6	0.45
Labrum length	0.13-0.15	0.10-0.12	0.14	0.12-0.14
Aiii	0.08-0.09	0.07-0.08	0.08	0.07-0.14
Aiii/labrum	0.6-0.7	0.66-0.07	0.571	
Aiii/Aiv+Av	Aiii<Aiv + Av	Aiii<Aiv + Av	Aiii<Aiv + Av	Aiii<Aiv + Av
Aiv	---	---	0.05	0.04-0.07
Av	---	---	0.05	0.05-0.07
Aaiii	---	---	0.78	0.01-0.02
Aaiv	0.4	0.42	0.05	0.02
Palp length	---	---	0.55	0.48
Palp formula	1, 2 (3-4), 5 or 1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5
Palp ratio	10:12:13	10:23:34:44:76	1:3:5:6:12.5	2.9:5.5:7.75:8.5:15.33
Proboscis length	---	---	0.20	0.02-0.20
Maxillary teeth (lateral + ventral)	---	---	27 + 7	22-24 + 8
Cibarium	30 Uniform teeth + 10 punctiform teeth, dark pigment patch, chitinous arch absent	28 Uniform teeth, arranged on a convex line, pigment patch broad and very dark chitinous arc absent or ill developed	Chitinous ach absent or weakly developed, a dark brown pigment patch concave row with 26-28 uniform teeth somewhat pointed outer teeth	26-27 Teeth in a concave plate with a pale pigment patch with out any anterior process, no chitinous arc
Pharynx	1.3-1.8 Long as breadth, deep median notch	1.4 Times long as breadth, sharp median notch	Broad, deep median notch, well developed teeth (at least three kinds)	Barrel shaped at base, deepconstriction. Pointed teeth, with a 0.2 length of the total pharynx
Spermathecae	Tubular with delicate ducts	Tubular with delicate ducts	Tubular with delicate ducts	

Table 2: Comparison of the taxonomic characters of male *Sergentomyia (Sergentomyia punjabiensis)* Sinton (all measurements are in mm)

Characters	Lewis (1978)	Kakarsulemankhel (2004a)	Kakarsulemankhel (2009)	Present study
Wing length	1.28-1.47	0.96-1.04	1.22-1.28	0.99-1.47
Wing breadth	0.25-0.29	0.2-0.24	---	0.24-0.42
Wing length/breadth	---	---	4.06-4.26,	3.5-4.12
Wing index	---	---	0.48	0.42
Labrum length	0.12-0.14	0.11	0.13	0.12-0.14
Aiii	0.09-0.11	0.08	0.1	0.07-0.19
Aiii/labrum	0.7-0.8	0.71	0.77	0.98
Aiii/Aiv+Av	Aiii<Aiv + Av	Aiii<Aiv + Av	Aiii<Aiv+ Av	Aiii<Aiv + Av
Aiv	---	---	0.06	0.04-0.11
Av	---	---	0.06	0.05-0.11
Aaiii	---	---	0.43	0.02-0.04
Aaiv	0.03	0.36	0.45	0.02
Palp formula	---	---	1,2,3,4,5	1,2,3,4,5
Palp ratio	---	---	1:2: 3.3: 3.3: 8.3	2.83:5.5:7.75:8.5:15.3
Maxillary palp	---	---	0.12	0.13
Cibarium	With about 20 nearly teeth, equal teeth, few punctiform variable pigment patch (short, broad), no chitinous arc	With about 18 uniform, pointed teeth, few small scattered at the base slightly brown short triangular chitinous arc absent	Sharp angular cibarial cavity, brown cylindrical median pigment patch below the ventral plates, slightly concave without anterior process, a row of about 30 dot like denticles and of about 22 uniform pointed teeth arranged on a concave line	Concave pigment patch no anterior process, concave arrangement of teeth around 27-30 pointed denticles along with 20-22 small teeth in single row
Pharynx	Faint scaly armature	Armature with Weak, faint, short, straight and curved lines	Flask shaped, faint armature of short and curved lines, 0.2 of the pharynx is with armature	Broad base with out a deep constriction, faint scale like ridges are found in the armature, 0.15 of the pharynx with armature
Style	4 apical spines and a setae (at 0.70)	4 apical spines, seta at 0.75	4 apical spines with a ventral setae at 0.7	4 apical spines with a setae at 0.75 of style
Paramere	Beak like tip	Beak like apex	Beak like tip	Hooked tip
Aedegal length	Thick with rounded end	Thick and round	Broad, slightly ventrally curved	Broad with a slight ventral curve
Genital pump/filament	3.5	3.0-3.25	2.0	2.69-3.16

Wing venation: First radial vein (R_1) 440-660 μm ; R_2 100-140 μm ; R_3 180-240 μm ; R_{2+3} 190-380 μm ; R_1 overlap 30 μm .

Genitalia: Coxa is broads at middle. Style has four spines with equal length at apex with accessory setae in middle. Paramere is hooked. Aedegal sheath is thick and slightly curved downwards.

Coxa length 170-230 μm ; coxa breadth 30-50 μm ; style length 70-90 μm ; style breadth 18-20 μm ; paramere lobe length 130-200 μm ; aedegal sheath length 100-147 μm ; genital pump length 80-100 μm ; genital filament length 180-350 μm .

Female: (n = 4): Abdomen length 540-640 μm ; abdomen breadth 260-270 μm ; thorax length 360-420 μm ; thorax breadth 360-390 μm ; head length 260-280 μm ; head breadth 180-270 μm ; eye length 120-140 μm eye breadth 100-110 μm ; inter ocular 90-120 μm ; wing length 990-1440 μm ;

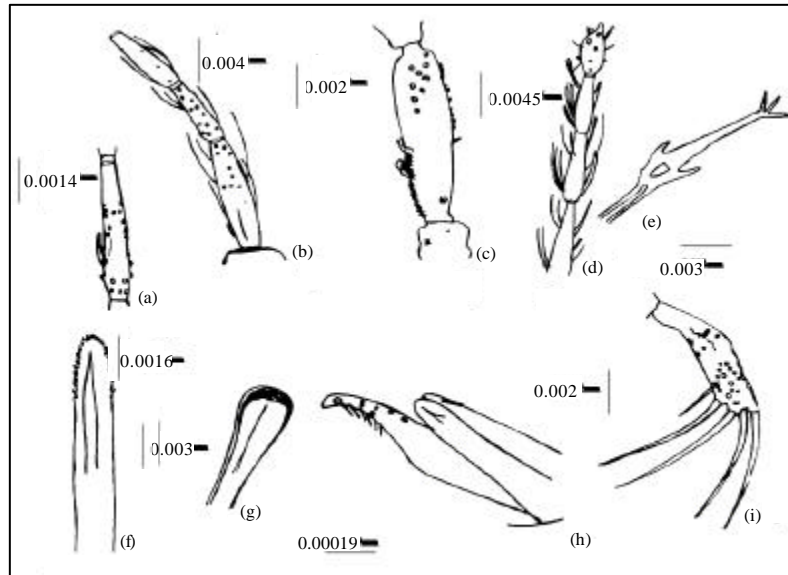


Fig. 2: Taxonomic feature of *Sergentomyia (Sergentomyia) punjabiensis* Sinton (Aiv and Aaiv (a), Aiii, Aiv and Av (b), Third palp segment with newstead organ (c), last three antennal segments (d), genital pump (e), hypopharynx (f), pharynx (g), aedeagal sheath and paramere (h) and style (i))

wing breadth 240-420 μm ; halter length 100-140 μm . fore femur: fore tibia: fore basi tarsi 30:23:11; mid femur: mid tibia: mid basi tarsi 32:31:14; hind femur: hind tibia: hind basi tarsi 33:40:18.

Mouth parts: Labrum is chitinized, bluntly pointed broad structure with three apical sensilla with 5-6 lateral groups of sensilla. The hypopharynx is broader compared to that of male with a marginal minute serration. Mandible is broad with serrated teeth found along the edge. Maxillary blade has visible teeth (lateral 22-24 and ventral 8). Cibarium is with 26-27 teeth in a concave plate with a pale pigment patch without any anterior process. Chitinous arc is absent. Pharynx is broader at base and the constriction is deep. Pointed teeth are found in the armature.

Labrum length 120-140 μm ; maxillary palp length 460-490 μm ; palp formula (1,2,3,4,5) with a ratio of 2.9:5.5:7.75:8.5:15.33; proboscis length 110-200 μm ; cibarial length 390 μm ; third antennal segment (Aiii) 70-140 μm ; Aiv 40-70 μm ; Av 50-70 μm ; antennal ascoid/ sensilla chaetica on third antennal segment (Aaiii) 15-20 μm ; Aaiv 22 μm ; Aav 21-22 μm . Pharynx length 150-200 μm ; breadth 27-42 μm ; armature length 15-60 μm .

Wing venation: First radial vein (R_1) 440-660 μm ; R_2 100-150 μm ; R_3 180-240 μm ; R_{2+3} 190-380 μm ; R_1 overlap 30 μm .

Genitalia: Tubular spermathecae with broad anterior end. The individual ducts are thick and fuse to form a short common duct and then fall in to the genital atrium. Spermathecae length is 70 μm and the breadth is 40 μm .

***Sergentomyia (Sergentomyia) pondicherriensis* (Srinivasan and Jambulingam, 2010):** This is a newly described species under the subgenus *Sergentomyia* by Srinivasan and Jambulingam (2010) from Pillaiyarkuppam village in Puduchery, South India.

Specimen examined (Fig. 3; Table 3, 4)

Male: (n = 2): Abdomen length 550-650 µm; abdomen breadth 260-280 µm; thorax length 330-410 µm; thorax breadth 360-420 µm; head length 260-270 µm; head breadth 240 µm; eye length 130 µm; eye breadth 120 µm; inter ocular 110 µm; wing length 1350-1410 µm; wing breadth 360-420 µm; halter length 140 µm. fore femur: fore tibia: fore basi tarsi 3.6:3.2:1.8; mid femur: mid tibia: mid basi tarsi 3.8:3.5:1.85; hind femur: hind tibia: hind basi tarsi 3.9:4.0:2.1.

Table 3: Comparison of the taxonomic characters of male *Sergentomyia (Sergentomyia pondicherriensis)* Srinivasan and Jambulingam (all measurements are in mm)

Characters	Srinivasan and Jambulingam (2010)	Present study
Abdomen length	1.5 (thorax + abdomen)	0.55-0.65
Abdomen breadth	---	0.26-0.28
Thorax length	---	0.33-0.41
Thorax breadth	---	0.36-0.42
Head length	0.15	0.26-0.27
Head breadth	---	0.24
Eye length	---	0.13
Eye breadth	---	0.12
Inter ocular	0.152	0.11
Wing length	1.3	1.35-1.47
Wing breadth	0.44	0.36-0.42
Wing length/breadth	2.95	3.5- 4.22
Wing index	---	0.44
Wing overlap (R1 overlap/R2)	---	0.23
Aiii	0.145	0.19
Aiv	0.180 (Aiv + Av)	0.11
Av		0.11
Aaiii	---	0.04
Aaiv	---	0.02
Aiii/Aiv+Av	0.805	0.91
Labrum	0.1875	0.14-0.16
Proboscis	---	0.20
Maxillary palp	---	0.48
Palp formula	(1, 2, 3) 4, 5	1,2,3,4,5
Palp ratio	---	2.7:5.2:7.55:8.75:16
Cibarium	2 rows of teeth, 12 (lower row) + 6 (upper row), uniform, pigment patch ill developed, no anterior process;	Pale pigment patch with out an anterior process. Concave arrangement of teeth in two rows with 11 in lowest and 8 in the upper rows
Pharynx	Barrel shaped, gradually narrowing	Barrel shaped, gradually narrowing,
Coxa	0.225 length	0.20-0.23 length
Style	4 apical spine (each 0.0775), length 0.0975	4 apical spine (each 0.07), length 0.07-0.09
Aedeagus	Dark, thick, fleshy, finger like, down ward curve	Length 0.01-0.15, dark, thick, slight ventral curve
Paramere lobe	Hooked with setae on dorsal side	Hooked
Genital pump/filament	4.0	3.65

Table 4: Comparison of the taxonomic characters of female *Sergentomyia (Sergentomyia pondicherriensis)* Srinivasan and Jambulingam (all measurements are in mm)

Characters	Srinivasan and Jambulingam (2010)	Present study
Abdomen length	2.3 (thorax + abdomen)	0.74-0.76
Abdomen breadth	---	0.25-0.27
Thorax length	---	0.34-0.38
Thorax breadth	---	0.36-0.40
Head length	0.175	0.27-0.30
Head breadth	---	0.22-0.24
Eye length	---	0.14-0.15
Eye breadth	---	0.10-0.11
Inter ocular	0.16	0.10
Wing length	1.65	1.29-1.36
Wing breadth	0.52	0.30-0.32
Wing length/breadth	3.17	4.3-4.32
Wing index	---	0.38
Wing overlap(R1 overlap/R2)	---	0.51
Aiii	0.155	0.07-0.14
Aiv	0.175 (Aiv + Av)	0.04-0.07
Av		0.05-0.07
Aaiii	---	0.02
Aaiv	---	0.02
Aiii/Aiv+Av	0.886	0.94
Labrum	0.2525	0.13-0.14
Proboscis	---	0.20
Maxillary palp	---	0.60-0.61
Palp formula	2, (1, 3), 4, 5	1, 2, 3, 4, 5
Palp ratio	---	9.8:18:21:25:48.5
Cibarium	18-22 uniform teeth in a ventral concave row; prominent hemispherical pigment patch overlaps the cibarial teeth and exposes four teeth on either margin; no anterior process, chitinous arch prominent	20-22 teeth in a concave plate with a semicircular pigment patch with out any anterior process
Pharynx	0.18 length, 0.035 breadth, barrel shaped at posterior narrow down,	Barrel shaped at base, constriction is not deep. Pointed teeth found in the armature with a straight line at posterior
Spermathecae	Wide with thin smooth walls (length 0.0725, breadth 0.0325), striated individual duct and short common duct,	Tubular, smooth walls, striated individual ducts fuse to form small common duct.

Mouth parts: Labrum is chitinized, blunt, broad structure. The hypopharynx is narrower compared to that of female. Maxillary blade has very fine teeth (2-3). Cibarium is with a pale pigment patch without an anterior process. Concave arrangement of teeth is found in two rows with around 11 in lowest and 8 in the upper rows. Pharynx is broader at base and the constriction is not deep. Pointed teeth are found in the armature.

Labrum length 140-160 μm ; maxillary palp length 480 μm ; palp formula (1,2,3,4,5) with a ratio of 2.7:5.2:7.55:8.75:16; proboscis length 200 μm ; cibarial length 400 μm ; third antennal segment (Aiii) 190 μm ; Aiv 110 μm ; Av 110 μm ; antennal ascoid/ sensilla chaetica on third antennal segment (Aaiii) 40 μm ; Aaiv 20 μm ; Aav20 μm ; ascoid formula is 1/3-15.

Wing venation: First radial vein (R_1) 440-660 μm ; R_2 960-1440 μm ; R_3 180-240 μm ; R_{2+3} 190-380 μm ; R_1 overlap 23 μm .

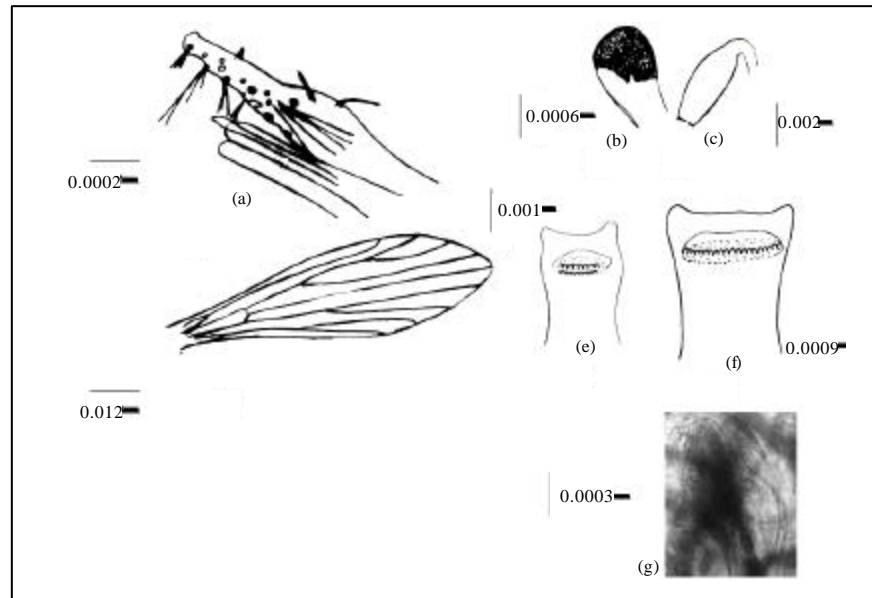


Fig. 3: Taxonomic feature of *Sergentomyia (Sergentomyia) pondicherriensis* Srinivasan and Jambulingam (aedeagal sheath and paramere (a), pharynx of female (b), spermathecae (c), wing (d), male cibarium (e), female cibarium (f) and pharynx of female (g))

Genitalia: Coxa is broad at middle. Style has four spines with equal length at apex with accessory setae in middle. Paramere is hooked. Aedeagal sheath is thick and slightly curved downwards.

Coxa length 200-230 μm ; coxa breadth 40-50 μm ; style length 70-90 μm ; style breadth 20 μm ; paramere lobe length 210 μm ; aedeagal sheath length 120-150 μm ; genital pump length 90-100 μm ; genital filament length 310-350 μm .

Female: (n = 4): Abdomen length 740-760 μm ; abdomen breadth 250-270 μm ; thorax length 340-380 μm ; thorax breadth 360-400 μm ; head length 270-300 μm ; head breadth 220-245 μm ; eye length 140-150 μm ; eye breadth 100-110 μm ; inter ocular 100 μm ; wing length 1290-1360 μm ; wing breadth 300-320 μm ; halter length 135-140 μm . fore femur: fore tibia: fore basi tarsi 3.8:4:1.8; mid femur: mid tibia: mid basi tarsi 3.9:4.3:2.0; hind femur: hind tibia: hind basi tarsi 3.4:7.0:2.1.

Mouth parts: Labrum is chitinized bluntly pointed broad structure with three apical sensilla with 5-6 lateral groups of sensilla. The hypopharynx is broader compared to that of male with a marginal minute serration. Mandible is broad with serrated teeth found along the edge. Maxillary blade has visible teeth. Cibarium is with 20-22 teeth in a concave plate with a semicircular pigment patch without any anterior process. Pharynx is broader (barrel shaped) at base and the constriction is not deep. Pointed teeth are found in the armature with a straight line at the posterior.

Labrum length 130-140 μm ; maxillary palp length 600 μm ; palp formula (1,2,3,4,5) with a ratio of 9.8:18:21:25:48.5; proboscis length 200 μm ; cibarial length 450 μm ; third antennal segment (Aiii) 70-140 μm ; Aiv 40-70 μm ; Av 50-70 μm ; antennal ascoid/sensilla chaetica on third antennal segment (Aaiii) 15-20 μm ; Aaiv 20 μm ; Aav 20 μm .

Wing venation: First radial vein (R_1) 540-550 μm ; R_2 170-200 μm ; R_3 290 μm ; R_{2+3} 250 μm ; R_1 overlap 20-70 μm .

Genitalia: Tubular spermathecae with broad anterior end and a smooth wall. The individual ducts are with striations and fuse to form a short common duct and then fall in to the genital atrium. Spermathecae length is 70 μm and the breadth is 40 μm .

***Sergentomyia (Sergentomyia) dentata* Sinton**

Specimen examined (Fig. 4; Table 5, 6)

Male: (n=2): Abdomen length 660-680 μm ; abdomen breadth 330-340 μm ; thorax length 460-500 μm ; thorax breadth 360-370 μm ; head length 290-320 μm ; head breadth 220-230 μm ; eye length 150 μm ; eye breadth 100 μm ; inter ocular 100 μm ; wing length 1150-1160 μm ; wing breadth 250 μm ; halter length 190 μm . fore femur: fore tibia: fore basi tarsi 13:10:6; mid femur: mid tibia: mid basi tarsi 13.5:13:7; hind femur: hind tibia: hind basi tarsi 15:17:9.5.

Mouth parts: Labrum is chitinized, blunt, broad structure. The hypopharynx is narrower compared to that of female with bristle like serration (soft). Maxillary blade has very fine teeth (2-3). Cibarium is with a dull pigment patch. Convex arrangement of teeth is with larger (2 μm) laterals (5-6) and smaller minute central teeth (1 μm). Pharynx is broader at base without constriction. Pharynx armature is with scales and ridges.

Labrum length 105-110 μm ; maxillary palp length 480-510 μm ; palp formula (1,2,3,4,5) with a ratio of 2:5:8:8.5:17; proboscis length 160 μm ; cibarial length 25 μm ; third antennal segment (Aiii) 75 μm ; Aiv 55 μm ; Av 55 μm ; antennal ascoid/sensilla chaetica on third antennal segment (Aaiii) 30 μm ; Aaiv 20 μm ; Aav 20 μm ; ascoid formula is 1/3-15.

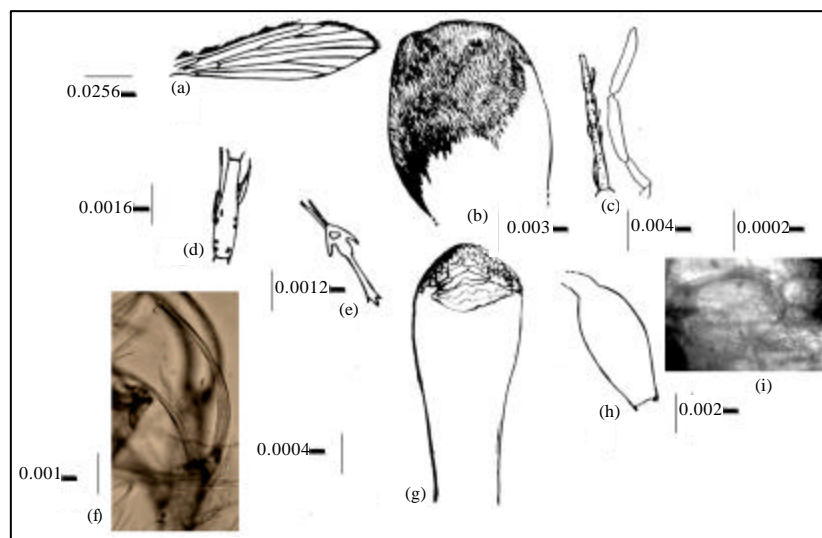


Fig. 4: Taxonomic feature of *Sergentomyia (Sergentomyia) dentata* Sinton (wing (a), female pharynx (b), Aiii, Aiv and Av, Palp segments (c), Aiv and Aaiv (d), genital pump (e), style (f), male pharynx (g), spermathecae (h) and female cibarium (i))

Table 5: Comparison of the taxonomic characters of female *Sergentomyia (Sergentomyia) dentata* Sinton (all measurements are in mm)

Characters	<i>Se. dentata var mediensis</i>		<i>Se. arpakensis</i>		<i>Se. dentata arpakensis</i>		
	Pringle (1953)	Perfiliev (1960, 1968)	Perfiliev (1933, 1968)	<i>Se. dentatus</i> Sinton (1933)	Kakarsulemankhel (2004b)	Present study	
Abdomen length	---	---	---	---	---	0.88-0.89	
Abdomen breadth	---	---	---	---	---	0.36	
Thorax length	---	---	---	---	---	0.46-0.50	
Thorax breadth	---	---	---	---	---	0.49	
Head length	---	---	---	---	---	0.25-0.27	
Head breadth	---	---	---	---	---	0.2	
Eye length	---	---	---	---	---	0.15	
Eye breadth	---	---	---	---	---	0.10-0.11	
Inter ocular	---	---	---	---	---	0.115	
Wing length	1.31-1.65	1.3-1.55	1.46-1.5	1.643-1.71	1.28	1.28-1.29	
Wing breadth	0.24-0.34	0.26-0.36	0.27-0.35	0.3-0.314	0.272	0.30-0.31	
Wing length/breadth	5.103	4.60	4.77	5.45	4.71	4.21	
Wing index	0.24-0.6	---	---	0.55-0.6	0.71	0.64	
Wing overlap	---	---	---	---	---	0.05	
(R1 overlap/R2)	---	---	---	---	---	---	
Aiii	---	---	---	---	---	0.07-0.08	
Aiv	---	---	---	---	---	0.04-0.05	
Av	---	---	---	---	---	0.05	
Aaii	---	---	---	---	---	0.020	
Aaiv	---	---	---	---	---	0.020	
Aiii/Aiv+Av	---	---	---	---	---	0.79	
Labrum	---	---	---	---	0.12	0.07	
Proboscis	---	---	---	---	0.15	0.09	
Maxillary palp	---	---	---	---	---	0.54	
Palp formula	---	---	---	---	---	1.2,3,4,5	
Palp ratio	---	---	---	---	---	14:24:29:33:80	
Cibarium	20 sharp teeth on deep arc with convex anterior, central 6-8 teeth small, laterally compressed, constant dark pigment like a piece of orange, the outer curve follow the buccal plate edge	16-22 pointed teeth, the anterior convex arc, 4-6 middle teeth smaller, dark brown oval pigment cover buccal teeth, smaller teeth of two rows near anterior main row near margin	12-16 uniform teeth on arc with anterior convexity, few irregular minute teeth at base of lateral teeth, dark brown pigment, triangle in shape, the conical part extend anteriorly	Curved armature with 4 large teeth at lateral and 6 small medians from (Fig.), No. pigment patch	5-6 large, thick, pointed lateral (0.008) and 3-4 smaller, sharp median 0.003) arranged on curved plate, the background has a dark, broad, triangle patch with out anterior process.3-4 punctiform	Sharp teeth on anteriorly curved (convex) plate, 4-5 larger laterals and smaller (5) medians (laterals twice as length as, median), pigment patch dark, overlap the medians.	

Table 5: Continued

	<i>Se. dentata var mediensis</i> Pringle (1953)	<i>Se. dentata</i> Perfiliev (1960, 1969)	<i>Se. arpaklensis</i> Perfiliev (1993, 1968)	<i>Se. dentatus</i> Sinton (1933)	<i>Se. dentata arpaklensis</i> Kakarsulemankhel (2004b)	Present study
Characters		of buccal cavity,	to form a process		teeth ill developed) At base of laterals, no (chitinous arc	Broad at base (base 0.05) length 0.1, 2.15
Pharynx	2.1-2.9 times long as breadth, armature with deeply pigmented strong blunt spines, with elongated anterior row. The posterior margin of armature is straight.	Base is 2 times wide as apex, distinct oblong pointed uniform spines with thick base, The anterior margin is convex, posterior is straight, Base with a small area of fine points	Base is 3 times wide as apex, armature well developed , posterior with small tuberoles.	Well developed armature, long numerous teeth anteriorly and small teeth posteriorly. The greatest breadth is 2 times as its anterior, length is 2.5 times long than the greater breadth	Anterior armature convex, posterior is straight, numerous long slender anterior teeth and small posterior small round denticles, pharynx 2.1 times long as its hind breadth, hind breadth is 2 times wider than the anterior	Broad at base (base 0.05) length 0.1, 2.15 times long as its greater breadth, larger pointed teeth anteriorly and smaller teeth posterior.
Spermathecae	---	---	---	---	---	Smooth walled, tubular, 0.05 long 0.03 breadth) individual duct fuse to form thick common duct

Table 6: Comparison of the taxonomic characters of male *Sergentomyia (Sergentomyia) dentata* Sinton (all measurements are in mm)

Characters	<i>Se. dentata var meddensis</i> Fringle (1953)	<i>Se. dentata</i> Perfliev (1960, 1968)	<i>Se. arpathensis</i> Perfliev (1933, 1968)	<i>Se. dentatus</i> Sinton (1933)	Kakarsulemankhel (2004b)	Present study
Abdomen length	0.66-0.68
Abdomen breadth	0.33-0.34
Thorax length	0.46-0.50
Thorax breadth	0.36-0.37
Head length	0.29- 0.32
Head breadth	0.22-0.23
Eye length	0.15
Eye breadth	0.11
Inter ocular	0.1
Wing length	1.15-1.16
Wing breadth	0.24
Wing length/breadth	4.71
Wing index	0.73
Wing overlap (R1 overlap/R2)	00
Aiii	0.145	0.12-0.18	0.13-0.16	Missing	0.11	0.08
Aiv	0.05-0.06
Av	0.074	0.06
Aaaii	0.03
Aaiv	0.016	0.02
Aiii/Aiv+Av	0.13-0.168	Aiii<Aiv + Av	Aiii<Aiv + Av	Aiii<Aiv + Av	Aiii<Aiv + Av	0.68
Aaiv/Aiv	...	<0.2	<0.25	...	0.21	0.33
Labrum	0.116	0.11
Proboscis	0.14	0.16
Maxillary palp	0.546	0.45	0.48-0.51
Palp formula	1,2,3,4,5/ 1-2,4,3,5	1,2,3-4,5/ 1,2,4,3,5	1,2,3-4,5	1,2,4,3,5	1,2,3,4,5/ 1,2,4,3,5	1,2,3,4,5
Palp ratio	1.2.5.4.4.7.7	2,7, 6,8,11, 10, 19,1.	10,30,43,3,50,90	2.5:8.8:5:17
Cibarium	20 distinct teeth, 15 moderately developed, median 4 smaller, pigment is small and pale	14-18 well defined pointed teeth arranged on line with convex anterior, median 3-6 teeth are smaller, 2 rows of smaller less numerous teeth of same from anterior to the lateral teeth of main row, oval pigment, relatively large, dark brown, cover dorsal of median teeth	10-16 small pointed uniform teeth in line with anterior convexity, 2nd row of few smaller denticles at base of major row, small pigment, dark brown, round to irregular	No. of large teeth on one side the other side was not visible, no pigment	16 small pointed uniform teeth on a row with convex, anterior few irregular small denticles at base, small pigment area, no chitinous arch	Convex arrangement of teeth is with larger (0.002mm) laterals (5-6) and smaller minute central teet 0.001mm), (few irregular maller teeth at base,pigment patch small

Table 6. Continued

Characters	<i>Se. dentata</i> var <i>mediensis</i> Pringle (1953)	<i>Se. dentata</i> Perfliev (1960, 1968)	<i>Se. arpakhtensis</i> Perfliev (1933, 1968)	<i>Se. dentatus</i> Sinton (1933)	Kakarsulemankhel (2004b)	Present study
Pharynx	More than 3 times long as broad	Small bottle shaped with poor armature	narrow region with thin wavy lines	Greatest width is around 2 times as the anterior and the length is 3.5 times long as its greater breadth, several rows of teeth, 6 in anterior row, 3 in posterior row.	Armature with series of short spines, greatest width is around 1.28 times as the anterior and the length is 3.33 times long as its greater breadth.	Armature found with rows of thick teeth not highly developed, length is around 4.5 times as its greater breadth
Coxa	0.25-0.27	0.25-0.28	0.24-0.30	---	0.21	0.18
Coxa/labrum					1.81	1.67
Coxa/style					2.62	3.0
Coxa/Aiii					1.9	2.4
Style	0.1-0.12, the longest spine is with same length as style, 2 spines are sub apical	0.11-0.13, 2 apical and 2 sub apical spines, ventral setae is short and is close to the apex	0.08-0.1, 1/3 long of the coxa, apical spines are long as or longer than style, 2 spines nearly sub apical, ventral setae is lose to apex, closer to apical spines.	4 long curved spines long as style, all apical	0.08, 2 apical and 2 sub apical spines, longer than style, ventral setae close to apex, close o sub apical spines.	0.06, 2 apical and sub apical spines, 22.9 times long as breadth, spines long as style, ventral setae near sub apical spines.
Aedeagus	0.09-0.1	Relatively thick, light rounded tip and small apical notch	Straight digit form, blunt, round apex	Blunt end	0.08, relatively thick, each half with 0.0016 breadth, slight blunt tip, distal part not narrowing	0.12 blunt ended, thick, slight curved
Paramere lobe	Slightly clubbed	Thick with rounded apex, distal part not narrowing	Thick, uniform breadth, rounded apex, ventral part of base with 4-5 hairs	Not so markedly beaked as in other species		
Sursstyle	---	0.12, rounded end 0.23-0.25	0.12, slight hook 0.16-0.118, shorter than coxa	---	.18	0.17
Genital pump/filament	---	---	---	---	3.25	4.2

Wing venation: First radial vein (R_1) 450-470 μm ; R_2 120 μm ; R_3 240-260 μm ; R_{2+3} 160-170 μm ; R_1 overlap is not found.

Genitalia: Coxa is broad from base and taper. Style has four spines with equal length, with two sub apical and two at apex with accessory setae in middle. Paramere is hooked. Aedeagal sheath is thick and slightly curved downwards.

Coxa length 180 μm ; coxa breadth 508 μm ; style length 60 μm ; style breadth 20 μm ; paramere lobe length 15 μm ; aedeagal sheath length 120-125 μm ; genital pump length 70 μm ; genital filament length 300 μm .

Female: (n = 2)

Abdomen length: 880-890 μm ; abdomen breadth 360 μm ; thorax length 460-500 μm ; thorax breadth 490 μm ; head length 250-270 μm ; head breadth 200 μm ; eye length 150 μm ; eye breadth 100-110 μm ; inter ocular 115 μm ; wing length 1280-1290 μm ; wing breadth 300-310 μm ; halter length 150 μm . fore femur: fore tibia: fore basi tarsi 4.1:4.4:1.9; mid femur: mid tibia: mid basi tarsi 4.0:4.7:2.0; hind femur: hind tibia: hind basi tarsi 4.1.4.7:2.1.

Mouth parts: Labrum is chitinized. The hypopharynx is broader compared to that of male with a marginal serration. Mandible is broad with serrated teeth found along the edge. Maxillary blade has visible teeth (16 lateral and 10 ventral). Cibarium is with sharp teeth in a convex plate with larger lateral and shorter central teeth. The pigment patch is semicircular. Pharynx is broader (barrel shaped) at base and the constriction is not deep. Pointed teeth are found in the armature with a convex at posterior.

Labrum length 700 μm ; maxillary palp length 540 μm ; palp formula (1,2,3,4,5) with a ratio of 14:24:29:33:80; proboscis length 900 μm ; cibarial length 400 μm ; third antennal segment (Aiii) 70-80 μm ; Aiv 40-50 μm ; Av 50 μm ; antennal ascoid/sensilla chaetica on third antennal segment (Aaiii) 20 μm ; Aaiv 20 μm ; Aav 25-30 μm . Newstead organ is 20 μm in length and it is found at 20 μm from the 2-3 junction of the palp.

Wing venation: First radial vein (R_1) 550 μm ; R_2 140-150 μm ; R_3 240 μm ; R_{2+3} 230 μm ; R_1 overlap 50 μm .

Genitalia: Tubular spermathecae with broad anterior end and a smooth wall. The individual ducts are with striations and fuse to form a short common duct and then fall in to the genital atrium. Spermathecae length is 50-60 μm and the breadth is 30 μm . The length of cerci 170 μm ; length of surstyle 77 μm .

DISCUSSION

Seven species have been described under the subgenus *Sergentomyia*. They are *Se. (Ser.) punjabiensis* (Sinton), *Se. (Ser.) dentata* (Sinton), *Se. (Ser.) theodori* (Parrot), *Se. (Ser.) murgabiensis* (PerPliw), *Se. (Ser.) mervynae* Pringle, *Se. (Ser.) fallax afghanica* Artemiev and *Se. (Ser.) pondicherriensis* Srinivasan and Jambulingam, 2010. This is the recent taxonomic report on *Sergentomyia* species in Sri Lanka after Lewis (1978) apart from Ozbel *et al.* (2011) where they have stated the presence of some *Sergentomyia* species with out morphological description. Among these, only *Sergentomyia (Sergentomyia) punjabiensis* (Sinton) was reported previously from Sri

Lanka (Lewis, 1978). This is the first report for the presence of *Se. (Ser.) pondicherriensis* (Srinivasan and Jambulingam, 2010) and *Se. (Ser.) dentata* Sinton from Sri Lanka.

Generally, the sandfly taxonomy is based on morphometric, either measurable or countable, characters. In the present study, taxonomic characters such as wing indices, antennal ascoid lengths, lengths of labrum and antennal segments, cibarial dimension and number of teeth along with the pharyngeal dimension and armature type were analyzed. Apart from these, all measurable characters are illustrated in tables to describe the morphology of the Sri Lankan flies precisely for future research.

The subgenus *Sergentomyia* is extensively studied in some south-east Asian region notably in Pakistan (Kakarsulemankhel, 2004a-c, 2009). The present investigation suggests that there are some minor variations in the taxonomic characters of the Sri Lankan specimens identified as *Se. (Ser.) pondicherriensis* compared to the other literatures. Males are comparatively larger than the Indian flies (Srinivasan and Jambulingam, 2010), where the females are smaller in size. Third antennal segment (Aiii) is comparatively larger in both male and female flies collected in Sri Lanka. The female flies' mouthparts and wings are comparatively smaller while the wings are larger in males. The palp formula of female varies. It is 1,2,3,4 and 5 in the present study, whereas it was 2, (1, 3), 4, 5 in Indian flies (Srinivasan and Jambulingam, 2010).

Males and females of Sri Lankan *Sergentomyia (Sergentomyia) punjabiensis* Sinton have similar taxonomic features compared to the existing literatures from Pakistan (Lewis, 1978; Kakarsulemankhel, 2004a, 2009) except having a smaller wing and larger Aiii.

Male *Sergentomyia (Sergentomyia) dentata* show similarity with the existing literatures (Kakarsulemankhel, 2004b, 2009; Pringle, 1953; Perfiliev, 1933, 1960, 1968, Sinton, 1933). But they are comparatively shorter. Females also show similarity except for smaller mouthparts. In general the morphometry of the Sri Lankan sandflies belong to this subgenus is found to be similar to previous reports from other countries.

CONCLUSION

The present study provides an evidence for the presence of a rich diversity of the subgenus *Sergentomyia* of the genus *Sergentomyia* in the CL endemic localities of Sri Lanka. As the reports from various parts of the world claim the role of this genus in disease transmission, there is a need to study the bionomics, especially the role in leishmaniasis transmission in the country. The present study suggest for an intensive sandfly survey in Sri Lanka to characterize the sandflies morphologically and molecularly as there is an urgent need to identify vectors as one can perceive a role of more than one species in the disease transmission.

ACKNOWLEDGMENTS

The authors wish to acknowledge Mr.Zudardeen, Public health Inspector of Padavi Siripura, Trincomalee. The study received financial assistance from the National Research Council of Sri Lanka (NRC/6/24) and the University Grants Commission of Sri Lanka. The approval from the Department of Wildlife Conservation of Sri Lanka for conducting the study is greatly acknowledged.

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