



Systematics and biology of male, female and larvae of *Diaphanes lutescens* (Walker) (Coleoptera: Lampyridae: Lampyrinae) in Sri Lanka

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ABSTRACT. *Diaphanes lutescens* was originally described by Walker, 1858, using specimens from Sri Lanka. The systematics and biology of this species has been unexplored since it was first described in the early eighteenth century. This paper provides a detailed description of systematics and biology of the identified male, female and larvae of *D. lutescens* with their areas of incidence and habitat types in Sri Lanka. Females and larvae were identified when they were associating with males in the same habitat. Remarks of their flashing patterns and flying behaviour are addressed.

Key words: *Diaphanes lutescens*, Lampyrinae firefly, Sri Lanka

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Introduction

Sri Lanka has rich biodiversity consisting with large number of insect species (Wijesekara & Wijesinghe 2003). Fireflies or lampyrids are one of the insect groups, which have been recorded by numerous researchers in Sri Lanka since the eighteenth century. However, most of their information was scattered in the taxonomic literature. Hence, there is a gap on the diversity and taxonomy of Sri Lankan fireflies since they have been unexplored after their original description. The genus *Diaphanes* Motschulsky, 1853 was described based on *D. luniger* Motschulsky from Northern India. It is the fourth most diverse genus of Lampyridae after *Luciola* (Laporte, 1833), *Lucidota* (Laporte, 1833) and *Photinus* (Laporte, 1833). Over 90 species of *Diaphanes* have been recorded from the Oriental and the Ethiopian realms (Olivier 1907, 1910; McDermott 1964, 1966). Males of the genus *Diaphanes* bear modified mandibles and elongated clypeus (Green, 1959; McDermott, 1964). Females of *Diaphanes* are apterous or possess short elytral rudiments in all known species (Olivier, 1910; Chen, 1999). Both sexes emit green light: females glow intermittently, while males flash continuously or intermittently in a very high frequency during flight. Both males and females of *Diaphanes* species are nocturnal. Jeng et al. (2001) indicated some taxonomic issues on *Diaphanes* species while several undescribed species have been found in recent years. The systematic knowledge of female *Diaphanes* is still dearth

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because they have been described in brief in previous taxonomic publications (Olivier, 1911; McDermott 1964, 1966; Ho, 1997; Chen, 1999). Jeng et al. (2001) re-described the genus *Diaphanes* using the characters of Taiwan species. *Diaphanes* species are distributed in the East and South-east Asian countries and Russia (Pacific side) (Jeng, 2008). However, there are no detailed descriptions or documented taxonomic records of Sri Lankan *Diaphanes* species up to date. General morphology of male *Diaphanes* is similar to that of the genera *Lampyrus* Motschulsky, 1853 and *Nyctophyla* Motschulsky, 1853. *Lampyrus* and *Nyctophyla* fireflies have obscure pronotal areolet areas, rudimentary photogenic organs and a projecting apex of the last abdominal ventrite (V7). In contrast, *Diaphanes* males always have clear pronotal areolet areas, well-developed photogenic organs on abdominal ventrites 5–6 and an emarginated apex of the last abdominal ventrite. Species of the genus *Pyrocoelia* Gorham, 1880 are also very similar to *Diaphanes*, whereas the comparative size of the head to pronotum and eyes to head of *Pyrocoelia* are smaller than those of *Diaphanes*.

Males of *Diaphanes* have wings and their body size is larger than the Luciolinae Lacordaire, 1857 fireflies. Usually, they have pale elytra varying from pale yellow to pale brown. Eight visible abdominal segments can be seen and abdominal spiracles are present on ventral side of the abdomen. Male has strip like two light segments. *Diaphanes* females are either smaller or larger than conspecific male. Usually they are apterous form. Body is brownish yellow or milky white. Elytra are either totally absent or present as small bud-like rudiments. Photogenic organs are presence on abdominal sternites. Abdominal spiracles can be seen on sub lateral margins of pleurites of segments 1–8 (Jeng et al., 2001).

The Sri Lankan fireflies have been originally described by European naturalists during the colonial era. Thereafter the taxonomy or ecology of Sri Lankan firefly fauna has not been explored to any extent due to the lack of studies in the past several decades. Hence, we started a long-term survey to fill the gap on taxonomy, biology and ecology of Sri Lankan fireflies. *Diaphanes lutescens* was recorded as one of the Lampyrinae fireflies during this study. In this paper, we describe the systematics and biology of male, female and larvae of *D. lutescens* recorded in Sri Lanka.

Material and methods

The survey was carried out from January 2010 to January in 2012. All nine Provinces of Sri Lanka, Uva, Sabaragamuwa, Southern, Western, Central, Eastern, Northern, North-Western and North-Central were selected for the study. Three sub-sampling sites indicating three types of habitats (terrestrial grassland, cultivated and fresh water associated) in each Province were selected for collecting the fireflies (Table 1). Locations of sub-sampling sites are indicated in the map (Fig. 1). Data collection was carried out from 17.00 p.m. to 22.00 p.m. in each sampling day. The 100 m² area was selected in each habitat and adult fireflies (males) were collected using the standard size (30.5 cm/ 12 inch) insect hand net. Females and larvae were collected using a fine forcep when they were associating with males in the same habitat.

Two sampling occasions were carried out within each six-month period and a total of eight samplings were done during the study. Total individual number of male, female & larvae in each sampling occasions at each habitat was recorded. All adults (flying males & apterous females) and larvae observed in the selected area were collected. Collected individuals were temporarily put in to the transparent polythene bags in the field. Captured individuals were generally identified in the field using relevant morphological characters such as dorsal and ventral colour, shape of light organ and the number of light segments. A number of samples including both male

and females as well as the larvae were collected and preserved in plastic containers with 70% ethanol medium for subsequent identification. Collected males, females and larvae were taxonomically identified in the laboratory using available keys and published information of Lampyrids in South East Asia (Motschulsky, 1845, 1853; Olivier, 1907, 1910; McDermott, 1964; 1966; Jeng et al., 1998, 1999, 2000, 2001, 2003; Jeng, 2010; Ho, 1997; Chen, 1999).

In addition, the repository specimens stored in National Museum, Colombo, Sri Lanka were used to confirm the species. Furthermore, male specimens were confirmed using a genital dissection (Ballantyne & Lambkin, 2009; Ballantyne et al., 2019). Genitalia of five males were dissected and both male genitalia and aedeagal sheaths were examined. Females and larvae were confirmed after examine their taxonomic characters. The Light microscope (Nikon-ECLIPSE-E100) (10×4) (with a ruler- micrometer calibration) was used to observe several special body features (pronotal areolet, elytra, legs, antennae, pronotum, light organ) of recorded fireflies. The Dino-lite camera (AM7515MT4A - Digital Microscope, 2592 x 1944/5 MPixel, 415 -470x, USB 2.0) was used to take photographs of firefly specimens.

Table 1. The selected sampling locations and habitats in nine Provinces of Sri Lanka.

Province	Sub-sampling sites/ Locality	Latitude & Longitude	Habitat/ Vegetation type
Uva	Welimada	6°54'04" N, 80°55'22" E	Fresh water associated
	Bandarawela	6°50'00" N, 80°59'00" E	Paddy cultivation
	Wellawaya	6°44'00" N, 81°06'00" E	Terrestrial grassland
Sabaragamuwa	Balangoda	6°39'00" N, 80°41'00" E	Fresh water associated
	Ratnapura	6°40'00" N, 80°24'00" E	Paddy cultivation
	Embilipitiya	6°20'38" N, 80°50'56" E	Terrestrial grassland
Southern	Matara	5°57'00" N, 80°33'00" E	Terrestrial grassland
	Galle	6°03'00" N, 80°13'00" E	Fresh water associated
	Hambanthota	6°07'28" N, 81°07'21" E	Paddy cultivation
Central	Peradeniya	7°16'00" N, 80°36'00" E	Terrestrial grassland
	Kandy	7°17'47" N, 80°38'06" E	Paddy cultivation
	Nuwaraeliya	6°58'00" N, 80°46'00" E	Fresh water associated
Western	Maharagama	6°51'00" N, 79°59'00" E	Fresh water associated
	Panadura	6°42'48" N, 79°54'15" E	Paddy cultivation
	Gampaha	7°05'30" N, 79°59'59" E	Terrestrial grassland
North Western	Kurunegala	7°29'00" N, 80°22'00" E	Terrestrial grassland
	Kuliyapitiya	7°28'14" N, 80°02'44" E	Paddy cultivation
	Narammala	7°26'04" N, 80°13'17" E	Fresh water associated
Northern	Point Pedro	9°49'00" N, 80°14'00" E	Terrestrial grassland
	Jaffna	9°40'00" N, 80°00'00" E	Paddy cultivation
	Kilinochchi	9°23'00" N, 80°24'00" E	Fresh water associated
Eastern	Arugam bay	6°51'00" N, 81°50'00" E	Terrestrial grassland
	Ampara	7°05'00" N, 81°45'00" E	Paddy cultivation
	Trincomalee	8°34'00" N, 81°14'00" E	Fresh water associated
North Central	Anuradhapura	8°21'00" N, 80°23'00" E	Paddy cultivation
	Kekirawa	8°02'00" N, 80°36'00" E	Fresh water associated
	Polonnaruwa	7°56'00" N, 81°00'00" E	Terrestrial grassland

- | | |
|-------------------|-----------------|
| 1. Peradeniya | 21. Hambantota |
| 2. Kandy | 22. Welimada |
| 3. Nuwaraeliya | 23. Bandarawela |
| 4. Arugam bay | 24. Wellawaya |
| 5. Ampara | 25. Maharagama |
| 6. Trincomalee | 26. Panadura |
| 7. Point Pedro | 27. Gampaha |
| 8. Jaffna | |
| 9. Killinochchi | |
| 10. Anuradhapura | |
| 11. Kekirawa | |
| 12. Polonnaruwa | |
| 13. Kurunegala | |
| 14. Kuliyaipitiya | |
| 15. Narammala | |
| 16. Balargoda | |
| 17. Ratnapura | |
| 18. Embilipitiya | |
| 19. Matara | |
| 20. Galle | |

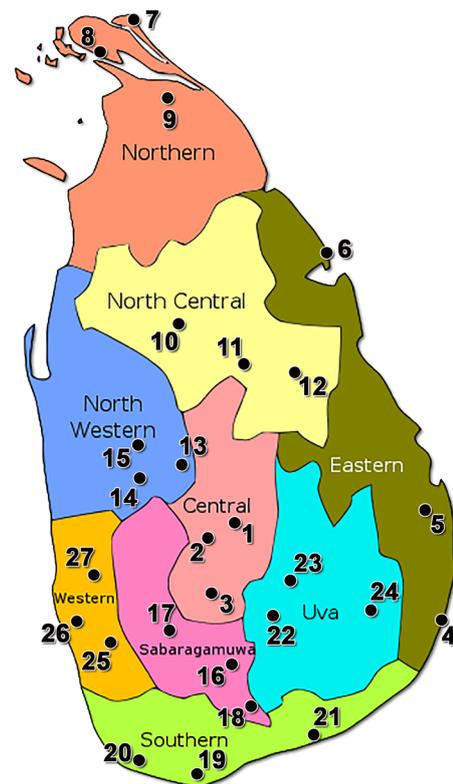


Figure 1. Sub-sampling sites of nine Provinces of Sri Lanka.

Twenty male, 10 female & 10 larvae were measured. Specimens were air dried for 5-10 minutes. Then, each specimen was placed on the stage of Light microscope (Nikon-ECLIPSE-E100) (10×4) (with a ruler-micrometer calibration). Length and width of the whole body, pronotum, elytra, male light organ and antenna of the male specimens were measured. All measurements were converted to the millimetre units. In addition, type of antenna and colour patterns of dorsal and ventral sides of the body were observed and compared. Similarly, two morpho-metric measurements including length and width of the whole body were measured in each female and larvae because firefly modern taxonomy is based on their male characters. Abundance of *D. lutescens* among three habitats (terrestrial grassland, cultivated and fresh water associated) in each Province was also compared throughout the study. In addition, the flashing differences among the sexes were observed.

The following abbreviations were used for the taxonomic characters and Depositories: TBL: Total body length; EW: Elytral width; TBW: Total body width; MLOL: Male light organ length; PL: Pronotum length; MLOW: Male light organ width; PW: Pronotum width; AL: Antenna length; EL: Elytral length; DOZUORSL: Department of Zoology, University of Ruhuna, Sri Lanka, NHMUK: National History Museum, UK

Results

Family: Lampyridae Linnaeus, 1758

Subfamily: Lampyrinae Olivier, 1907

Genus: *Diaphanes* Motschulsky, 1853

Diagnosis – Pronotal areolet areas clear, male has pale colour elytra and it varies from pale yellow to pale brown, semi-circular shaped pronotum with lateral expansions.

Description of *Diaphanes lutescens* (Male)

Diaphanes lutescens; Walker, 1858, [Motschulsky, 1853:36; 1853:51](#) (by general description). [Olivier, 1907:55; 1910:47](#) (distribution). [McDermott, 1964:47; 1966:118](#) (checklist). [Jeng et al., 1998, 1999, 2000, 2001, 2003; Jeng, 2010](#) (taxonomy and distribution). *Diaphanes lutescens* originally described as *Lampyrus lutescens* (Tennent, 1849).

Materials examined: Holotype, 1♂ (NHMUK), 4♂♂ Sabaragamuwa Province; Rathnapura (collector unknown) (1941), deposited at National Museum SL, Colombo. 6♂♂, 3♀♀, 1 larva, Sri Lanka, Uva Province, Welimada (6°54'04" N, 80°55'22" E, 1133.85 m) (080.III.2010, 11.IX.2010, 09.XII.2010, 09.III.2011, 13.IX.2012); 12♂♂, 2♀♀, 2 larvae, Uva Province, Bandarawela (6°50'0" N, 80°59'0" E, 1219.2 m) (09.III.2010, 06.X.2010, 10.III.2011, 14.IX.2011, 16.I.2012); 8♂♂, 4♀♀, 2 larvae, Sabaragamuwa Province, Rathnapura (6°40'0" N, 80°24'0" E, 131.06 m) (16.II.2010, 20.XI.2010, 18.II.2011, 23.VIII.2011, 21.XI.2011); 7♂♂, 5♀♀, 1 larva, Sabaragamuwa Province, Balangoda (6°39'0" N, 80°41'0" E, 751.94 m) (17.II.2010, 22.VIII.2010, 20.XI.2010, 19.II.2011, 24.VIII.2011, 17.V.2012); 8♂♂, 4♀♀, 2 larvae, North Western Province, Kuliapitiya (7°28'14" N, 80°2'44" E, 33 m) (17.V.2010, 15.XI.2010, 09.II.2011, 09.VIII.2011, 12.XI.2011, 19.VI.2012); coll.: Wijekoon. Deposited in DOZUORSL.

Measurements: 20 males (10- paddy field and 05- fresh water associated land), 10 females (05- paddy field and 05- fresh water associated land) and 10 larvae (05- paddy field and 05- fresh water associated land) ([Table 2; Table 3](#)).

Diagnosis

Diaphanes lutescens: the black abdominal sternites, light brown body and transparent semi-circular central disk milky white & strip like light organs in males, emit green colour light. Very slow fliers, in the environment. All morphological characters of the genus and species described by [Walker \(1858\)](#), [McDermott \(1964:47, 1966:118\)](#) and [Jeng et al. \(2001\)](#) are matched with our identifications of *D. lutescens*. In addition, the morphology of repository specimens stored in the National Museum, Colombo, Sri Lanka are compatible with the identified specimens of *D. lutescens* in the study.

Table 2. Measurements of male *Diaphanes lutescens* (in mm).

Species	Number measured	TBL	TBW	PL	PW	EL	EW	MLOL	MLOW	AL
<i>Diaphanes lutescens</i>	20	15-17	7-8	4-6	6-7	10-13	7-8	1-2	1-2	3-4

Table 3. Measurements for adult female and larvae of *Diaphanes lutescens* (in mm).

Species	Number measured	TBL	TBW
Adult female	10	10-12	3-4
Larvae	10	30-34	5-6

Description - Male (Figs 2 & 3)

General morphology - Body dorsal colour light brown, TBL: 15-17 mm, TBW: 7-8 mm. entire elytra light brown with three intestinal lines and smooth surface, no punctures, EL: 10-13 mm, EW: 7-8 mm. Pronotum with lateral expansions and with medial semicircular transparent central disc, semielliptical pronotum, slightly broader than long, mesocutellum light brown, no punctures, PL: 4-6 mm, PW: 6-7 mm.

Head: Head is totally concealed by pronotum dorsally, mouthparts well developed, Antenna with 11-segments, nearly filiform, relatively short, AL: 3-4 mm.

Thorax: Thorax light brown ventrally. Femur light brown, entire tibia, tarsus and claws black, two claws at the apex.

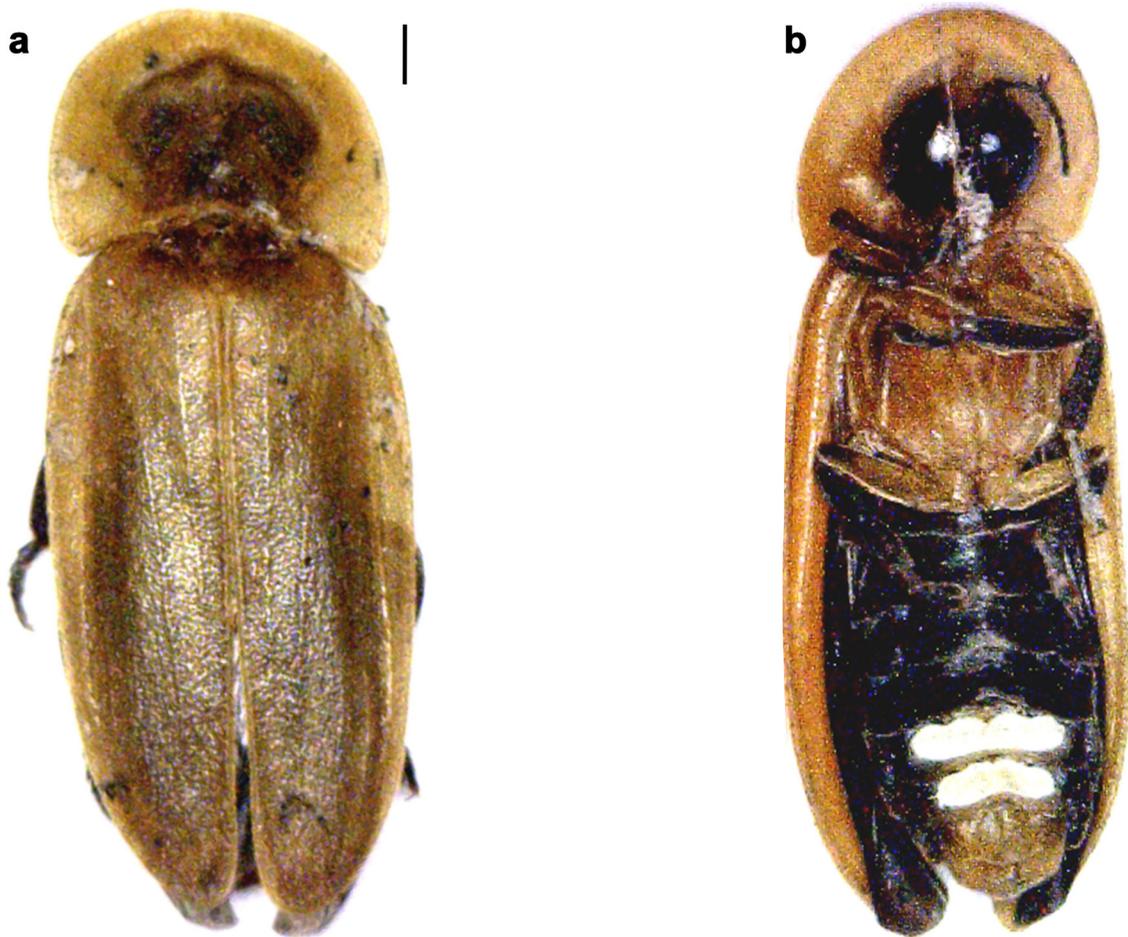


Figure 2. *Diaphanes lutescens* (Male); **a.** Dorsal view; **b.** Ventral view (Scale bar = 1mm).

Abdomen: Eight visible abdominal sternites, abdominal spiracles on the ventral side of abdomen, abdominal sternite 1-4 black, both 5th and 6th sternites with medial flattened light organs (strip like), milky white light organs in the black background, 7th sternite light brown and narrowed posterior, tergite VIII curls around the apex of sternite VII creating wide lobe, light organ in sternite V (MLOL: 1-2 mm, MLOW: 2-3 mm) wider than in that in sternite VI (MLOL: 1-2 mm, MLOW: 1-2 mm). Aedeagus (Fig. 4); trilobed structure, single median lobes and two lateral lobes present, median lobe narrowed and lateral lobes have wider part and narrowed tip at the end, lateral lobes fused dorsally and enfolds to ventral side, Length 0.8 mm, width 0.35 mm. Aedeagal sheath; enfolds the aedeagus, Length 0.8 mm, width 0.3 mm. There were no morphological variations of genitalia recorded in dissected males.

Female (Fig. 5)

General morphology - Whitish brown, body surface granulate, TBL: 10-12 mm, TBW: 3-4 mm, smaller than male. Apterous form, very short elytral rudiments (TBL: 0.5-0.7 mm).

Head: Head completely covered with pronotum dorsally, antenna moniliform, 11-segmented, longer as pronotum (AL: 2-3 mm).

Thorax: Pronotum semi-elliptic, broader than long (PL: 2-3 mm), areolet area more or less obscure on apical half of pronotum. Legs are robust, femora and tibia flat.

Abdomen: usually pink markings on posterior margin of abdominal segments, thoracic terga pink appearance, first abdominal tergite slightly broader than metanosturm, very weakly broadened toward third tergite, then gradually but insignificantly diminishing toward tergite VI each with lateroapical angles and sub rectangular, sternite VII is roundly emerginated apically, light organs are transversed and located as two strips in sternite VII.

Larva (Fig. 6)

General morphology - Body dorsally dark brown colour with distinct pale yellow vertical spotted lines, pink colour spots presence on posterior margin of each segments, mid saggital line prominent in pale yellow color, TBL: 30-34 mm, TBW: 5-6 mm.

Head & Thorax: Dorsally 12 segments distinct as three thoracic and nine abdominal, prothorax wider as long; anterior margin bluntly rounded, narrowed at anterior and containing retracted head beneath, retractable mouth parts distinct, pro, meso and meta thorax covering plates larger and distinct than rest, base of legs dark brown and rest milky white.

Abdomen: First abdominal segment less longer than others and pale yellow two marks in sides of segment, usually abdominal segments slightly narrowed posterior and sub equal, dorsal surface of body roughened but projections absent, abdominal segments ventrally brown in mid region with milky white vertical strips in sides, each segments have pink colour spots in posterior margin of abdominal segments, one to eight of abdominal segments have single laterotergites at each side ; dark brown strip like light organ present at abdominal segment VIII, final plate slightly divided making fin structure and abdomen terminated by series of filaments or holdfast organ and their function is locomotion and cleaning.

Remarks: This species is nocturnal. Adult males are always active in uppermost layers of vegetation and suddenly come to the ground. They emit green colour light when they fly. Female emit weak green light.

Distribution: Globally distributed in the Oriental region (Jeng, 2010). This species recorded from three Provinces of Sri Lanka such as, Uva, Sabaragamuwa and North western during the study period. They were prominently found in paddy fields and fresh water associated habitats from locations in Sri Lanka.

Phenology: February to June of the year.

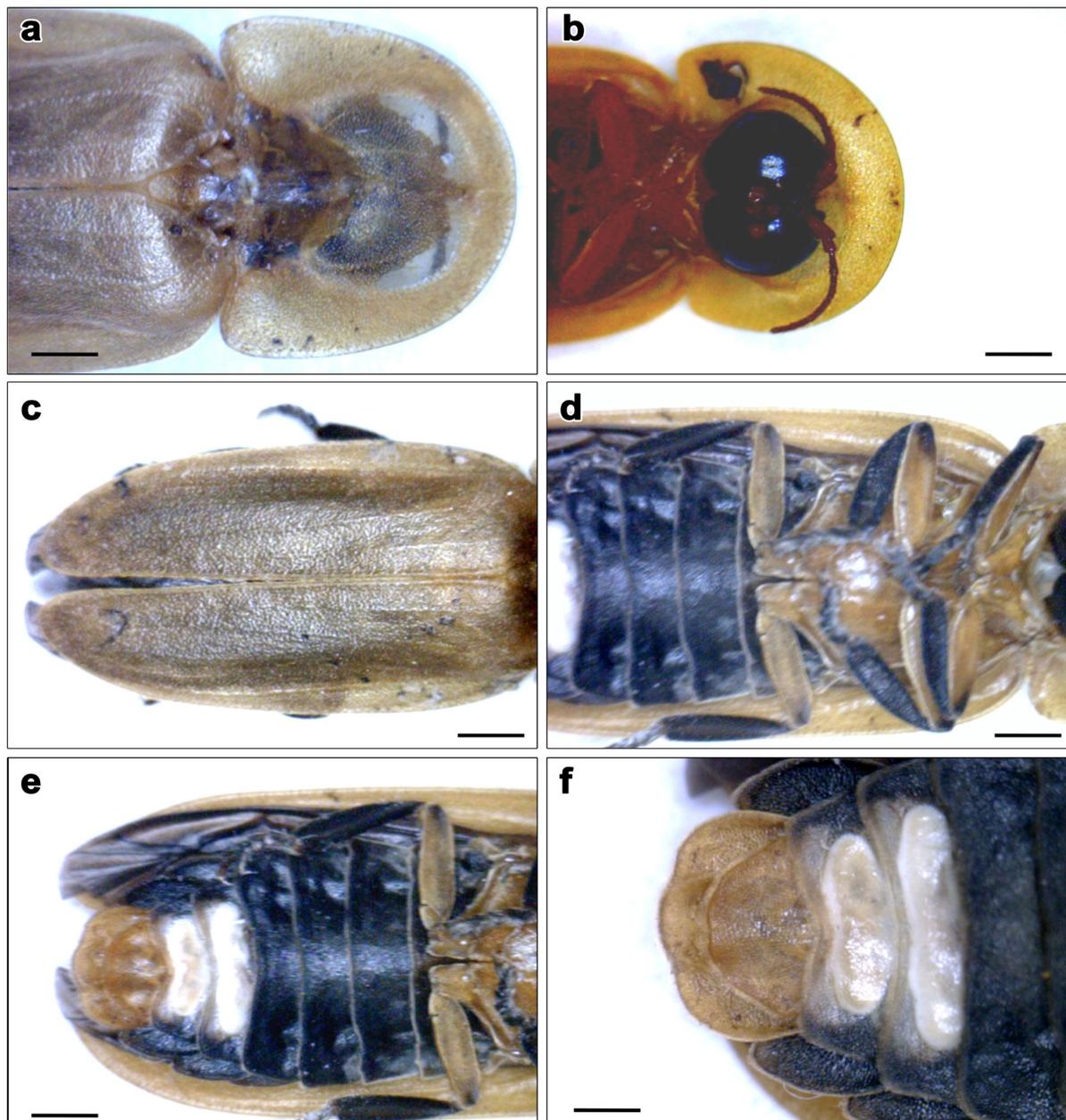


Figure 3. Taxonomic characters of *D. lutescens* (Male); **a.** Pronotum and mesocutelum; **b.** Antennae and head; **c.** Elytra; **d.** Thorax and legs; **e.** Eighth abdominal sternites; **f.** Light organ strips (Scale bar = 1mm).

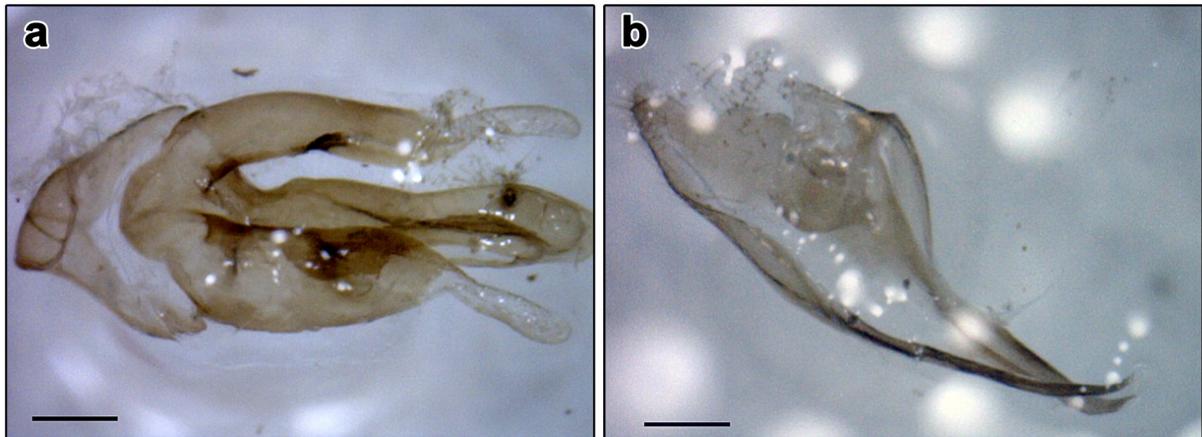


Figure 4. Genitalia of *Diaphanes lutescens* (Male); **a.** Aedeagus; **b.** Aedeagal sheath (Scale bar = 0.1mm).

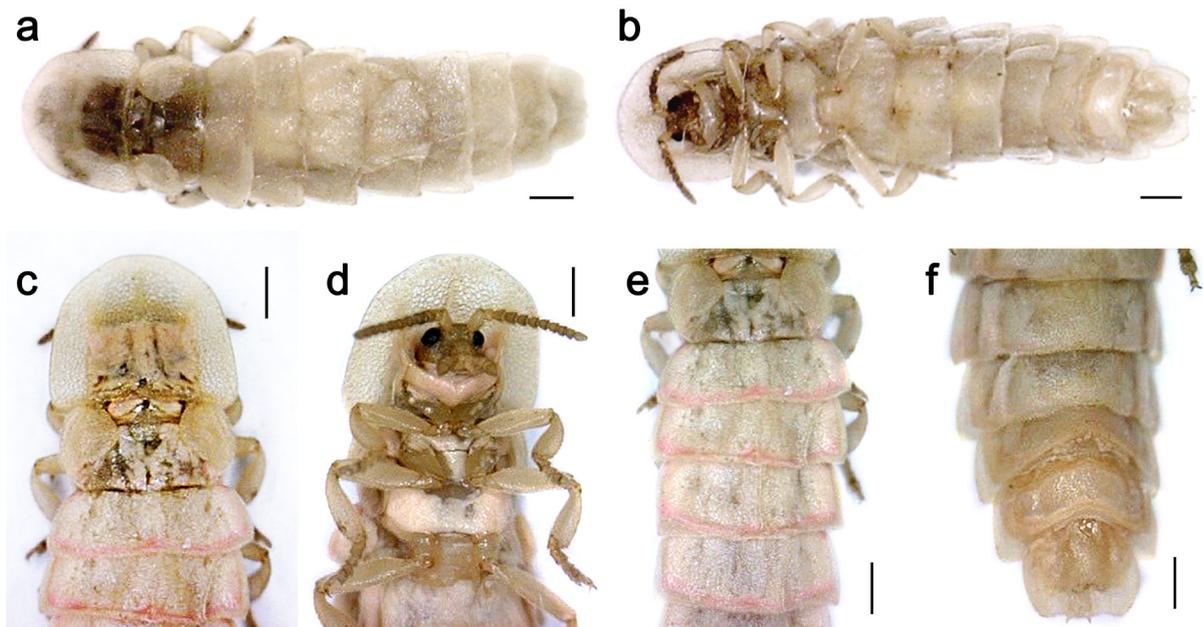


Figure 5. Female of *Diaphanes lutescens*; **a.** Dorsal view; **b.** Ventral view; **c.** Pronotum and elytral rudiments; **d.** Antennae and head region; **e.** Abdominal segments with pink posterior margin-dorsal; **f.** Last abdominal segments with light organ spots (Scale bar = 1mm).

Discussion

The study provides a detail systematic description of life forms such as male, female and larvae of *D. lutescens* recorded from Sri Lanka, and which is the first comprehensive account of *D. lutescens* since their original concise description. The female and larvae of *D. lutescens* have not been previously described because their original description was based on their male's taxonomy. This paper describes the first systematic description of the female and larvae of *D. lutescens* in addition to the detailed systematic account of their male.

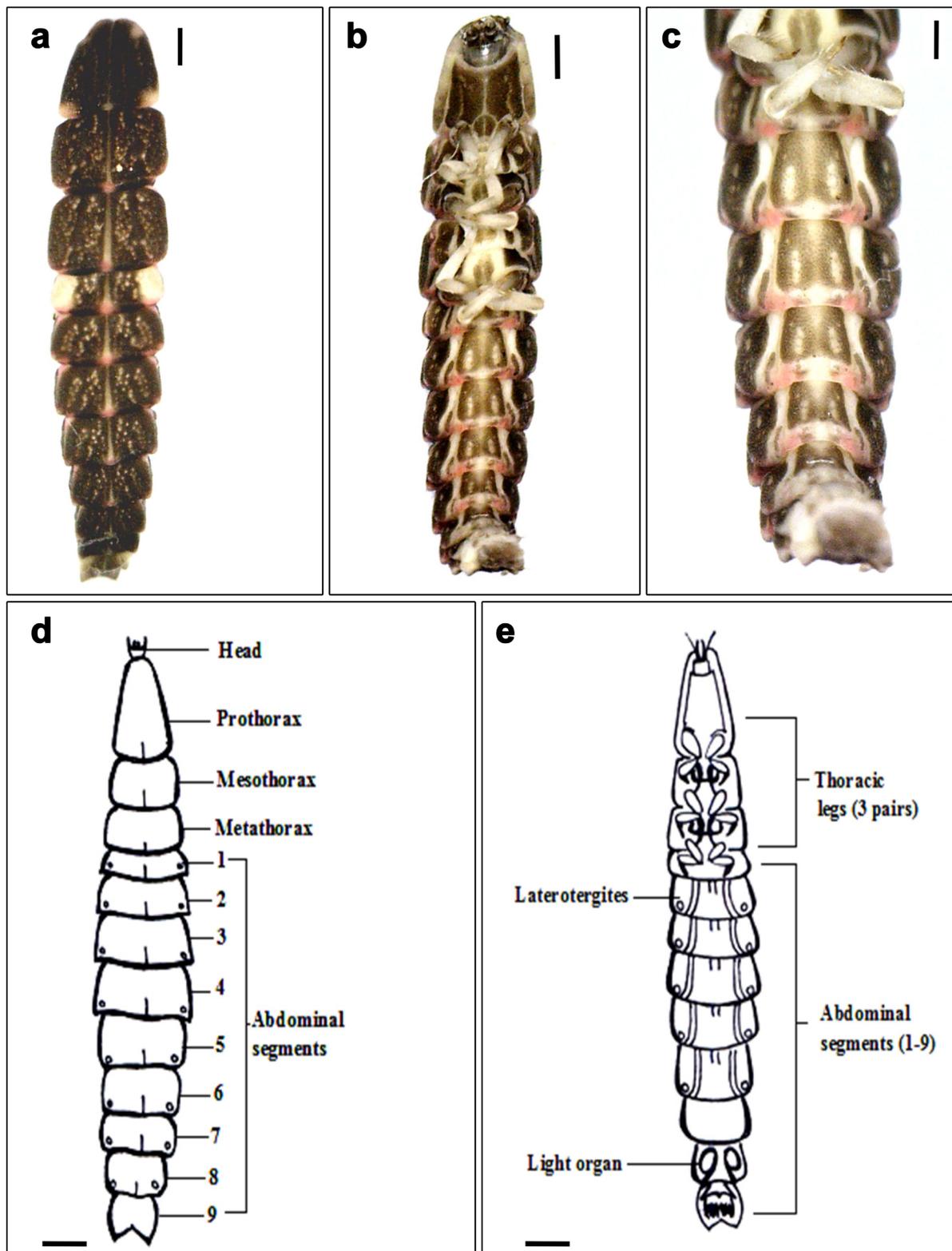


Figure 6. Larvae of *Diaphanes lutescens*; **a.** Dorsal view; **b.** Ventral view; **c.** Abdominal segments- ventral side; **d.** Line diagram-dorsal; **e.** Line diagram-ventral (Scale bar = 1mm).

The recorded males of *D. lutescens* during the study were taxonomically identified using the original description of Walker, 1858 which has been addressed in the McDermott (1964, 1966). In addition, the collected male specimens were morphologically fit with the specimens of *D. lutescens* stored in the Department of National Museums, Colombo, Sri Lanka (Wijekoon et al., 2016). There were no previous records of female and larvae of *D. lutescens* reported in Sri Lanka. The recorded females of *D. lutescens* from Sri Lanka were flightless. Jeng et al. (2001) mentioned that most of the females of genus *Diaphanes* are wingless.

The female and larvae were collected when they were associating in the same habitat with males. We identified their females when they were showing the mating behaviour with males. Both larvae and female of *D. lutescens* in Sri Lanka share few morphological features with *D. citrinus* in Taiwan; pink markings on the posterior margin of the abdominal segments. Any of other taxonomic features of female and larvae of *D. citrinus* is not compatible with *D. lutescens* in Sri Lanka. Male *D. lutescens* do not show any morphological similarity with *D. citrinus* in Taiwan. When comparing the taxonomic features of *D. lutescens* in Sri Lanka with the description of *D. citrinus* described by Jeng et al. (2001), it indicates the body size of *D. citrinus* is small (TBL: 12.4–15.6 mm, TBW: 5.1–6.3 mm, than *D. lutescens* and the dorsal and ventral body colour of *D. citrinus*; orange elytra, pronotum central disk red, abdominal sternites 1–4 dark brown, 5–7 yellowish brown and antenna; nearly moniliform are different than the *D. lutescens*.

There are no records of *D. lutescens* from other regions in the world. During the study, *D. lutescens* was recorded from Uva, Sabaragamuwa and North-Western Provinces of Sri Lanka. They were commonly recorded in two types of habitats; fresh water associated lands and paddy cultivated lands than terrestrial habitats in the present study. In 2001, Jeng et al. mentioned, the most of larvae of genus *Diaphanes* are terrestrial. The description of systematics and biology of the male, female and larvae of *D. lutescens* will be helpful to fill the void of the present taxonomic dearth of the Sri Lankan fireflies in some extent because their systematics has not been explained to any extent after since they were first described by Walker over 100 years ago.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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رده‌بندی و زیست‌شناسی حشرات نر، ماده و لاروهای *Diaphanes lutescens* (Walker) در سریلانکا (Coleoptera: Lampyridae: Lampyrinae)

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چکیده: توصیف اصلی گونه *Diaphanes lutescens* براساس نمونه‌های جمع‌آوری شده از سریلانکا توسط Walker, 1858 انجام شد. رده‌بندی و زیست‌شناسی این گونه از زمانی که اولین بار در اوایل قرن هجدهم توصیف شد، ناشناخته مانده است. این مقاله توضیحات کاملی در مورد رده‌بندی و زیست‌شناسی حشرات نر، ماده و لاروهای سوسک *D. lutescens* با مناطق انتشار و نوع زیستگاه آنها در سریلانکا ارائه می‌دهد. ماده‌ها و لاروها همراه با حشرات نر از یک زیستگاه جمع‌آوری و شناسایی شدند. الگوهای تولید نور و رفتار پرواز این گونه نیز تشریح شد.

واژگان کلیدی: گونه *Diaphanes lutescens*، کرم شب‌تاب Lampyrinae، سریلانکا