

## A PRELIMINARY CHECKLIST OF FIREFLIES (COLEOPTERA: LAMPYRIDAE) WITH TWO NEW DISTRIBUTION RECORDS FROM SARAWAK

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### ABSTRACT

The remarkable ability of fireflies for bioluminescence makes them one of the most charismatic species of beetles. Despite the increasing development and urbanisation especially in mangrove areas, the current status of fireflies in Sarawak is not well documented. Hence, this study aims to provide an updated preliminary checklist focusing on the firefly species from Sarawak, Malaysia to contribute to the scientific knowledge of Lampyridae. Twenty localities in Sarawak were selected as the sampling sites based on firefly sightings. Field surveys were carried out from October 2022 to February 2023 with additional samples obtained from the UNIMAS Insect Reference Collection (UIRC). The present study recorded a total of 372 individuals of fireflies representing five genera, namely *Pteroptyx* (with five species and two morphospecies), *Pyrocoelia* (with one species and one morphospecies), *Luciola* (with two species), *Colophotia* (with one species) and *Abscondita* (with one species). The first record of two species *Colophotia brevis* (Luciolinae) and *Pyrocoelia opaca* (Lampyrinae) in Sarawak was documented in this study. Thus, it is suggested that a more comprehensive study, especially in the central region of Sarawak alongside its preferred host trees should be conducted. This information will provide a better understanding of firefly habitats in Sarawak and assist to identify areas with significant conservation value.

**Keywords:** Fireflies, Lampyridae, bioluminescence, Coleoptera, Sarawak

### ABSTRAK

Keupayaan luar biasa kelip-kelip untuk biopendarcahaya menjadikannya salah satu spesies kumbang yang sangat unik. Walaupun pembangunan dan pambandaran semakin meningkat terutamanya di kawasan bakau, dokumentasi status semasa kelip-kelip di Sarawak, Malaysia masih kurang. Oleh itu, kajian ini bertujuan untuk menyediakan senarai semak awal yang memfokuskan kepada spesies kelip-kelip dari Sarawak bagi menyumbang kepada pengetahuan saintifik Lampyridae. Dua puluh lokaliti di Sarawak telah dipilih sebagai tapak persampelan berdasarkan pencerapan kelip-kelip. Kerja lapangan telah dijalankan dari Oktober 2022 hingga Februari 2023 dengan sampel tambahan diperolehi daripada *UNIMAS Insect Reference Collection* (UIRC). Kajian ini telah merekodkan sebanyak 372 individu kelip-kelip daripada

lima genus, iaitu *Pteroptyx* (lima spesies dan dua morfospesies), *Pyrocoelia* (satu spesies dan satu morfospesies), *Luciola* (dua spesies), *Colophotia* (satu spesies) dan *Abcondita* (satu spesies). Dua spesies iaitu *Colophotia brevis* (Luciolinae) dan *Pyrocoelia opaca* (Lampyrinae) telah pertama kali direkodkan di Sarawak melalui kajian ini. Oleh itu, adalah dicadangkan bahawa kajian yang lebih komprehensif, terutamanya di wilayah tengah Sarawak bersama pokok perumah perlu dijalankan. Data ini bakal memberikan pemahaman yang lebih baik tentang habitat kelip-kelip di Sarawak dan mengenal pasti kawasan yang mempunyai nilai pemuliharaan yang signifikan.

**Kata kunci:** Kelip-kelip, Lampyridae, biopendarcahaya, Coleoptera, Sarawak

## INTRODUCTION

Fireflies from the family Lampyridae are a very diversified taxon with over 2,000 species worldwide (Lewis et al. 2020). In Malaysia, Seri and Rahman (2022) have documented a total of 56 firefly species belonging to 16 genera, with 26 of these species located in East Malaysia. Fireflies can be found in temperate and tropical climates, concentrated in the mangrove, swamp and riparian habitats where congregating fireflies thrive (Wong 2022). Their preferred habitat is commonly situated near water sources, particularly in mangroves as the females will oviposit in sand or soil on the open ground adjacent to mangroves or the edge of forests (Hill & Abang 2010) and their larvae primarily feed on tiny river snails and insects (Hazmi & Sagaff 2017).

The behaviour of fireflies can be distinguished into two categories: congregating and solitary. Congregating fireflies display synchronised flashing displays and are commonly found in large groups, while solitary fireflies do not display synchronised flashes and are typically found alone or in small groups (Buck & Buck 1976; Mobilim & Dawood 2020). In Malaysia, the common local *Pteroptyx* spp. have been recorded in wetlands, estuaries and brackish water environments and are often seen congregating on a wide variety of riparian and mangrove trees, especially *Sonneratia caseolaris* (Jusoh et al. 2010; Wong & Yeap 2012). The two predominant species of fireflies in Malaysia are *Pteroptyx tener* Olivier and *Pteroptyx bearni* Olivier, as noted by Jusoh et al. (2018). In contrast, solitary fireflies are not known to congregate in large numbers and do not engage in synchronised flashing displays like their congregating counterparts. Although less documented and studied compared to congregating fireflies, recent studies have revealed that there are several genera of solitary fireflies in Malaysia, including *Abcondita*, *Colophotia*, *Luciola*, *Pygoluciola*, *Pyrocoelia*, and *Medeopteryx* (Jusoh et al. 2018; Mobilim & Dawood 2020; Seri & Rahman 2022).

A compilation of records from various works of literature reports the occurrence of at least 15 firefly species from four genera, namely *Abcondita*, *Colophotia*, *Luciola*, and *Pteroptyx*, in Sarawak (Abdullah et al. 2021; Ballantyne et al. 2015; Ballantyne et al. 2019; Jusoh et al. 2018; Seri & Rahman 2022; Wan Nurainie et al. 2020; Wong 2022). Among these, the most speciose genus in Sarawak is *Pteroptyx*, which comprises eight species. However, Wong (2022) cautious that the firefly occurrence of *P. tener* in Kuching, Sarawak was said to be “possibly extinct”. Jusoh and Hashim (2012) reported that the decline in congregations of *P. tener* in Malaysia is mainly due to the conversion of riverbank mangroves for agriculture, aquaculture, and urbanisation. Likewise, the study conducted by Hazmi and Sagaff (2017) and Faudzil et al. (2021) proved that the release of pollutants leads to the deterioration of river quality, causing a decline in firefly abundance. On a wider scale, this was supported by Lewis et al. (2020) who stated that habitat loss, artificial light, and pesticides are perceived as the three most serious threats to fireflies globally.

Fireflies' unique characteristics of large congregations and synchronous flashing make them a potential flagship group for ecotourism in Sarawak that can provide both economic and conservation benefits (Lewis et al. 2021). However, firefly habitats are under threat from coastal development, land-use change, pollution, and other anthropogenic activities. One of the most significant efforts to conserve fireflies in Malaysia is the establishment of the Kuala Selangor Firefly Park in Selangor. The park was created in 1995 as a protected area to conserve the mangrove forest and the fireflies' habitats, and it has become a popular ecotourism destination. Other firefly sanctuaries have also been established such as Kampung Kuantan Firefly Park in Selangor and Cherating Firefly Sanctuary in Pahang.

Although much has been recorded and researched about fireflies in Peninsular Malaysia and Sabah (Abdullah et al. 2021; 2023), the firefly population in Sarawak, the largest state in Malaysia, remain inadequately studied despite their significant economic, aesthetic, and ecological values in ecotourism and environmental monitoring (Syed & Anderson 2021; Wong 2022). To support this, other researchers also have recommended that more studies should be conducted in relation to specific aspects such as the diversity and distribution of fireflies (Abdullah et al. 2021; Jusoh & Hashim 2012; Lewis et al. 2020).

Therefore, it is important to identify areas with significant conservation value to ensure appropriate conservation actions and management practices can be adopted to preserve firefly habitats in Sarawak. The objective of this study is to obtain a checklist of fireflies species from Sarawak. The findings could contribute to the scientific knowledge of family Lampyridae as a whole and provide a more comprehensive understanding of the current distribution of fireflies, allowing the monitoring of changes in species composition and distribution over time in Sarawak. Finally, such related information can be fully utilised to promote and support the sustainable development of ecotourism in Sarawak, in line with the State's development agenda within the framework of Post COVID-19 Development Strategy (PCDS) 2030 (Sarawak Economic Planning Unit 2021).

## **MATERIALS AND METHODS**

### **Study Area**

Sarawak is the largest state in Malaysia, located in the northwestern of Borneo Island known for its diverse forest types and rich biodiversity. Twenty localities (Table 1) within the state of Sarawak were selected as the sampling sites based on firefly sightings (Figure 1). The sites were selected through information provided by villagers around the area or by observing the presence of mangrove forests. The field surveys were carried out from October 2022 to February 2023.

### **Sampling Method**

The field surveys were conducted in the morning and the fireflies were collected in the evening (7:00 pm) with a modified aerial net using the active method. Sampling hours vary from one to two hours depending on the presence of fireflies. All the samples were immediately transferred into vials containing ethanol (99.8%).

Table 1. The twenty localities selected in Sarawak

No	Localities	GPS Coordinates	Habitat Type	Display Tree
1	Academia Lane, Samarahan	1°28'16.5"N 110°25'15.9"E	Mangrove	-
2	Gua Raya. Kampung Chupak, Padawan	1°14'17.6"N 110°25'50.2"E	Limestone, artificial wetlands (near cave and paddy fields)	Jackfruit, tall grass
3	Jalan Layang-Layang, Long Lama, Marudi	3°45'58.4"N 114°24'15.1"E	Mangrove	Tall grass/shrubs
4	Kampung Kuhom, Serian	1°6'35.1"N 110°23'53.1"E	Mixed dipterocarop forests	Grass
5	Kampung Pulau Seduku, Lingga, Sri Aman	1°21'00.2"N 111°16'23.9"E	Mangrove	Mangrove apple
6	Kampung Seberang, Maludam	1°39'11.7"N 111°02'13.6"E	Mangrove	Mangrove apple
7	Kampung Semarang, Maludam	1°40'40.4"N 111°06'02.2"E	Mangrove	Mangrove apple
8	Kampung Senau, Oya, Mukah	2°51'42.6"N 111°52'5.05"E	Peat swamp forest	-
9	Kem Belia Mukah, Mukah	2°53'34.7"N 112°1'22.09"E	Mangrove	Grass
10	Niah National Park, Miri	3°48'02.2"N 113°47'03.4"E	Lowland dipterocarp forest	-
11	Pekan Simunjan, Simunjan	1°23'54.3"N 110°44'55.4"E	Mangrove	Mangrove apple
12	SJKC Su Lee, Sarikei	2°7'16.8"N 111°30'24.02"E	Mangrove	-
13	SK Pangkalan Sorah, Kpg Sorah Melayu, Serian	1°7'39.6"N 110°32' 38.62"E	Mangrove	Grass
14	Sungai Jaie, Sadong Jaya, Asajaya	1°15'41.7"N 110°39'06.7"E	Mangrove	Mangrove apple
15	Sungai Pendam Batu, Lingga, Sri Aman	1°22'29.6"N 111°12'13.6"E	Mangrove	Mangrove apple
16	Sungai Seblak, Sessang, Kabong	1°53'18.1"N 111°11'06.5"E	Mangrove	Mangrove apple
17	Sungai Sempadi, Lundu	1°41'30.9"N 110°05'28.9"E	Mangrove	Mangrove apple
18	Sungai Susur, Lingga, Sri Aman	1°21'01.5"N 111°16'19.6"E	Mangrove	Mangrove apple
19	Teluk Serabang, Sematan	1°58'57.3"N 109°39'03.7"E	Mangrove	Mangrove apple
20	Trombol, Telaga Air	1°40'16.8"N 110°11'26.30"E	Mangrove	Mangrove apple, Api-api

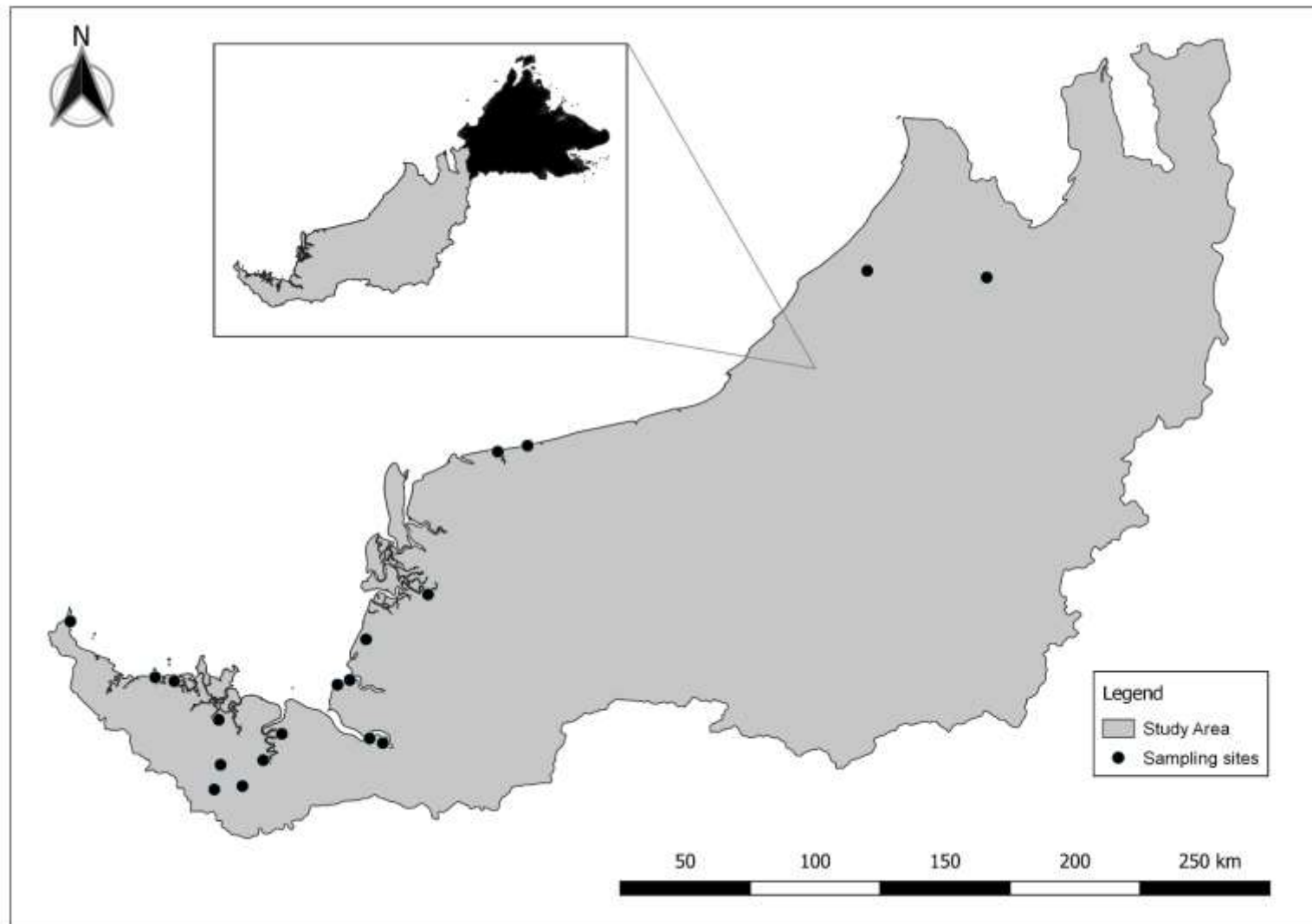


Figure 1. Firefly sampling sites in Sarawak

### Species Identification

The collected samples were brought back to UIRC for identification by referring to available identification keys (Ballantyne & Lambkin 2013; Ballantyne et al. 2015; Ballantyne et al. 2019; Jusoh & Ballantyne 2015; Jusoh et al. 2018) with the aid of a NIKON SMZ445 stereomicroscope. Similarly, the museum specimens from UIRC collected included in this study were also identified to species level. Male fireflies are identified through their colouration (e.g., pronotum, elytra, abdomen and legs), the structure of the light organ, and the morphology of their antennae. Females, on the other hand, are identified by their association with males or by their colouration. Additionally, the identification of one unidentified species was made possible with the expertise and assistance of Dr Wan Faridah Akmal Jusoh, the co-chair of the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) Firefly Specialist Group, and a Senior Lecturer in Biodiversity and Conservation at Monash University Malaysia's School of Science.

## RESULTS AND DISCUSSION

This study has documented 372 individuals of fireflies comprising 13 species, with 10 confirmed species and three morphospecies, from five genera and two subfamilies, namely Luciolinae (*Abscondita*, *Colophotia*, *Luciola* and *Pteroptyx*) and Lampyrinae (*Pyrocoelia*) (Table 2). Amongst the five genera, *Pteroptyx* is the most speciose with seven species (*P. bearni*, *P. malacca*, *P. tener*, *P. testacea*, *P. valida*, *Pteroptyx* sp. 1 & *Pteroptyx* sp. 2), followed by the genus *Luciola* with two species (*L. niah* & *L. pallidipes*). Additionally, *Colophotia* is represented by one species (*C. brevis*), *Abscondita* by one species (*Abs. pallescens*) and *Pyrocoelia* by two species (*Pyr. opaca*, *Pyrocoelia* sp.) (Figure 2).

Table 2. Checklist of Lampyridae species documented from field sampling and the UNIMAS Insect Reference Collection (UIRC)

Family	Subfamily	Genus	Species	Individual(s)
Lampyridae	Luciolinae	<i>Abscondita</i>	<i>Abscondita pallescens</i>	5
			<i>Colophotia brevis</i>	20
		<i>Luciola</i>	<i>Luciola niah</i>	2
			<i>Luciola pallidipes</i>	3
		<i>Pteroptyx</i>	<i>Pteroptyx bearni</i>	67
			<i>Pteroptyx malacca</i>	32
			<i>Pteroptyx tener</i>	60
			<i>Pteroptyx testacea</i>	72
			<i>Pteroptyx valida</i>	102
				<i>Pteroptyx</i> sp. 1
			<i>Pteroptyx</i> sp. 2	2
	Lampyrinae	<i>Pyrocoelia</i>	<i>Pyrocoelia opaca</i>	2
			<i>Pyrocoelia</i> sp.	2
				<b>372</b>

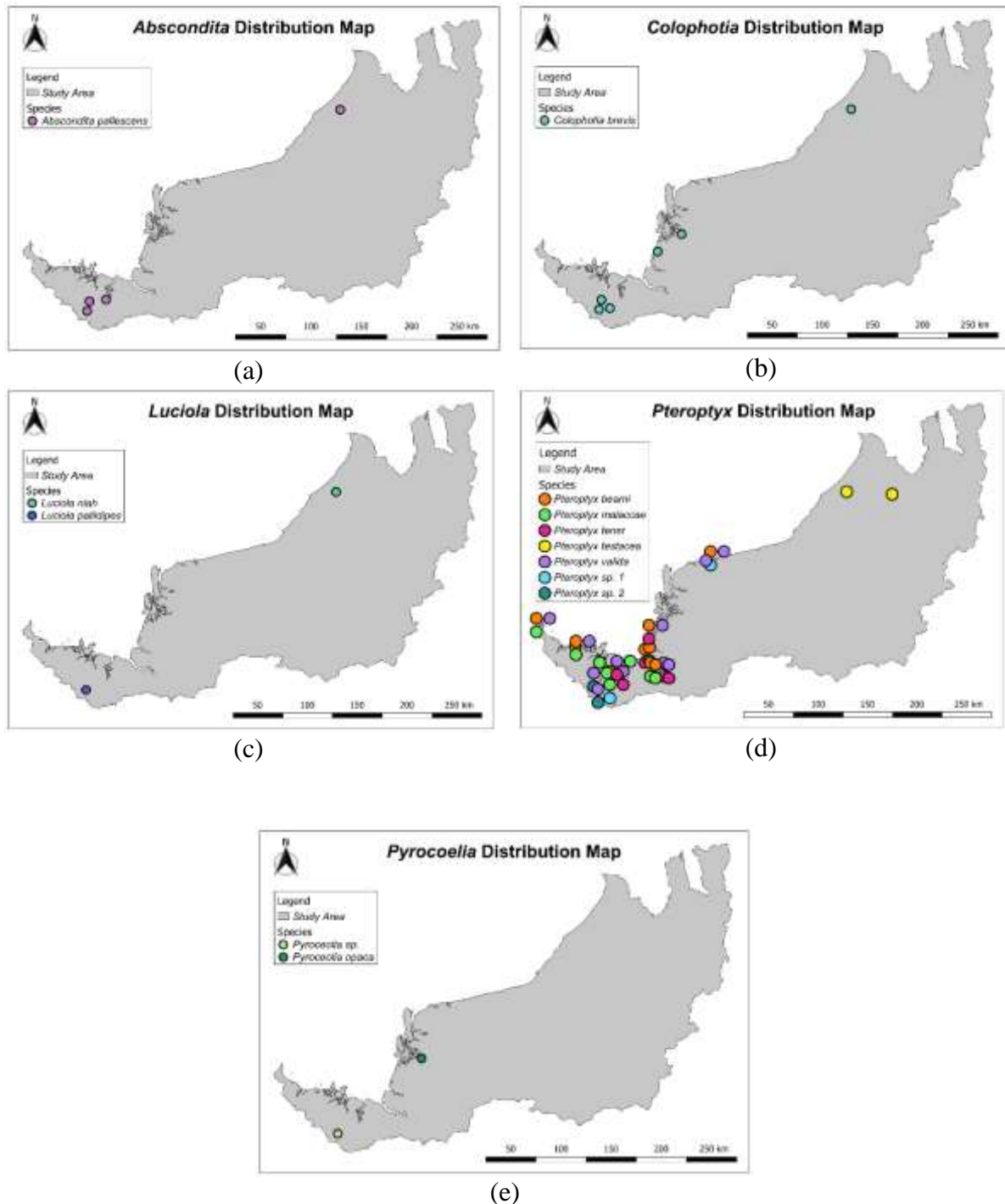


Figure 2. Distribution map of fireflies by genus in Sarawak. (a) *Abscondita*, (b) *Colophotia*, (c) *Luciola*, (d) *Pteroptyx*, (e) *Pyrocoelia*

This study has successfully documented the first distribution record of two solitary firefly species in Sarawak, namely, *Colophotia brevis* Olivier from Padawan, Serian, Sarikei, Niah and Kabong, and *Pyrocoelia opaca* (Olivier 1885) from Sarikei, respectively (Table 3). Previously, *C. brevis* was only recorded in Peninsular Malaysia (Pahang, Negeri Sembilan, Selangor and Terengganu) as reported by Ballantyne et al. (2019). Meanwhile, the genus *Pyrocoelia*, with one species (*Pyr. analis*) recorded in Peninsular Malaysia (location not specified) (Seri & Rahman 2022).

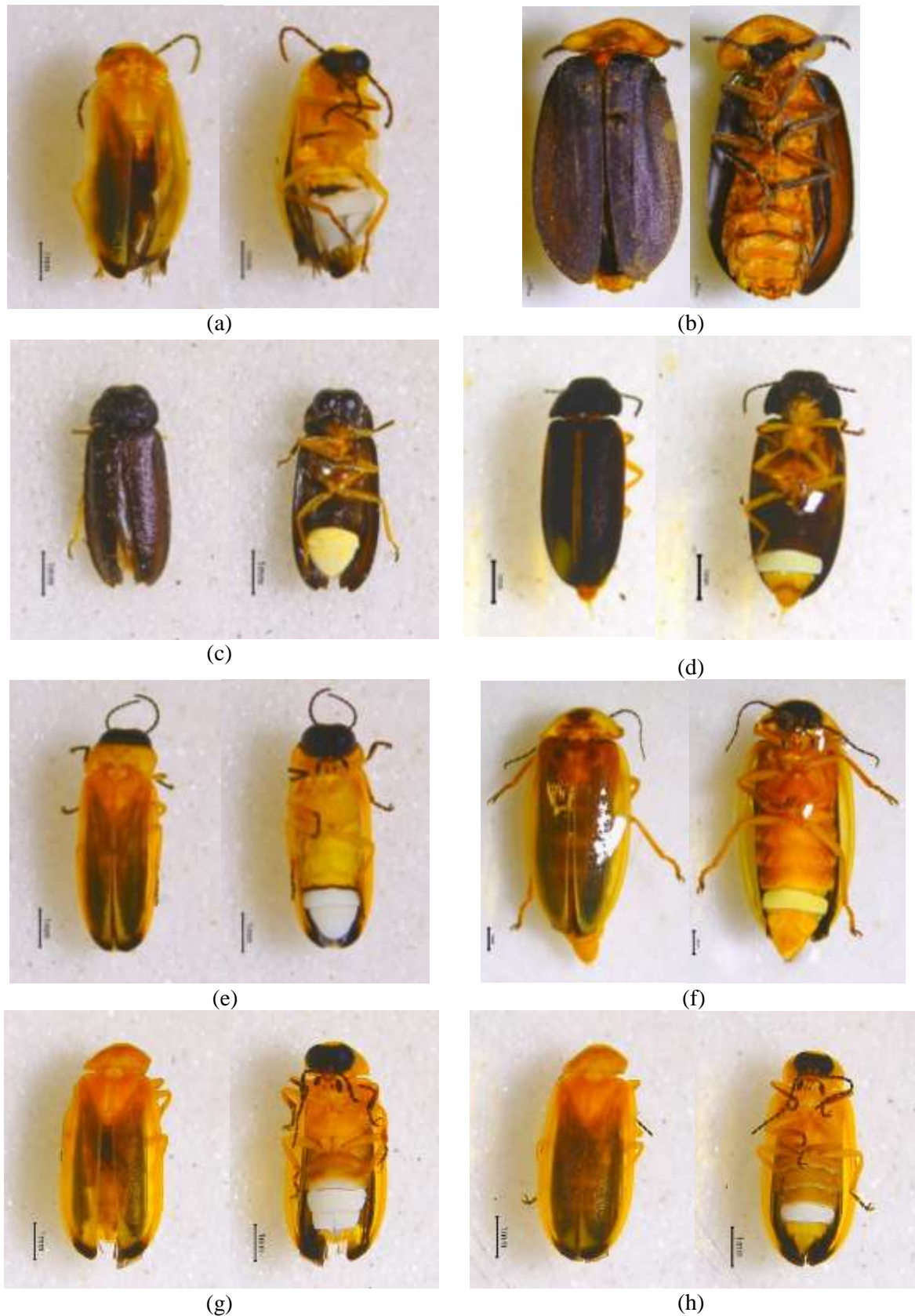


Figure 3. Habitus images of firefly species in Sarawak. (a) *Colophotia brevis* male, (b) *Pyrocoelia opaca* male, (c) *Luciola pallidipes* male, (d) *Luciola pallidipes* female (e) *Luciola niah* male, (f) *Abscondita pallescens* female, (g) *Pteroptyx testacea* male, and (h) *Pteroptyx testacea* female



Furthermore, this study revealed that Kampung Kuhom, Serian is the location with the highest number of firefly species with at least six species (*Abs. pallescens*, *C. brevis*, *L. pallidipes*, *P. valida*, *Pteroptyx* sp. 2, and *Pyrocoelia* sp.). The high species richness in Kampung Kuhom could be possibly due to the nature of its mixed dipterocarp forest habitat and the area is not susceptible to anthropogenic activities. In contrast, several locations were dominated by a single species, such as *P. testacea* in Jalan Layang-layang, *P. valida* in Kampung Senau, *P. bearni* in Sungai Sempadi, *C. brevis* in SJK Su Lee and SK Pangkalan Sorah, respectively. It is assumed that their presence might be affected by other abiotic factors such as precipitation, humidity, and wind speed during the sampling.

Additionally, *P. valida* Olivier previously only recorded in Mukah River and Sadong Jaya (Table 4), were also found in 17 other localities within Sarawak (Gua Raya, Kampung Kuhom, Kampung Senau, Kem Belia Mukah, Pekan Simunjan, Pulau Seduku, Sungai Jaie, Sungai Pendam Batu, Sungai Seblak, Sungai Susur, Teluk Serabang, Trombol, Adis Buan, Fairy Cave, Kampung Serpan Laut, Kampung Trusan Jaya and Mount Serumbu) (Figure 2). Since this study employed the use of a modified aerial net which is extendable up to three to five meters, high numbers (more than five individuals) of *P. valida* were obtained as they prefer to perch on the top section of trees, as reported by Jusoh et al. (2018). Notably, the presence of *P. valida* is considered uncommon in Peninsular Malaysia and Sabah (Foo & Dawood 2017; Mahmud et al. 2018), whereas it is regarded as one of the most common species in Thailand (Jaikla et al. 2020; Sartsanga et al. 2018). This difference in distribution may likely be associated with the role of palaeorivers in the dispersal ability of fireflies throughout Southeast Asia (Cheng et al. 2023).

Uniquely, the fireflies in Gua Raya were seen congregating in a jackfruit tree (*Artocarpus* sp.) which has never been recognised as a firefly display tree in Malaysia (Seri & Rahman 2021). This finding suggests that fireflies may utilise a wider range of tree species for their displays highlighting the need for further studies on firefly display trees in Sarawak. Furthermore, as reported by Abdullah et al. (2021) the display trees of the fireflies in Miri Sarawak were found to be different compared to those of Peninsular Malaysia. Specifically, *P. tener* has been observed to prefer congregating on *Sonneratia caseolaris* trees in Peninsular Malaysia, while *P. bearni* is commonly found congregating on two dominant mangrove species, namely *Rhizophora apiculata* and *Bruguiera parviflora*, in Miri. In contrast, *P. valida* displays on *Sonneratia* and *Nypa* trees in Sungai Mukah (Wong 2022). Similarly, other researchers (Jaikla et al. 2020; Ohba & Wong 2004) have suggested that the selection of mangrove trees for *Pteroptyx* congregations is not dependent on a specific type of plant, but rather on factors such as the size, density, arrangement of leaves, and location of the tree. Apart from that, an additional noteworthy observation was that large numbers of *P. testacea* were sighted among tall grasses and shrubs along Jalan Layang-layang, Long Lama highlighting their habitat preferences. This finding is particularly significant considering the limited knowledge available regarding the habitat of *P. testacea* (Jusoh et al. 2018).

Table 3. Record of firefly species based on localities from field sampling and UIRC collection

Species/ Localities	Field Sampling (October 2022 – February 2023)																UIRC Collection																				
	Academia Lane, Samarahan	Gua Raya, Padawan	Jln Layang-layang, Long Lama	Kampung Kuhom, Serian	Kampung Seberang, Maludam	Kampung Semarang, Maludam	Kampung Senau, Oya, Mukah	Kem Belta Mukah, Mukah	Niah National Park, Miri	Pekan Simunjan, Simunjan	SJKC Su Lee, Sarikei	SK Pangkalan Sorah, Serian	Pulau Seduku, Lingga	Sungai Jaie, Sadong Jaya	Sungai Pendam Batu, Lingga	Sungai Seblak, Sessang	Sungai Sempadi, Lundu	Sungai Susur, Lingga	Teluk Serabang, Sematan	Trombol, Telaga Air	Adis Buan Resort, Bau	Fairy Cave, Bau	Gua Raya, Padawan	Gumpey, Gedong	Kampung Serpan Laut, Asajaya	Kampung Temurung, Padawan	Kampung Trusan Jaya, Sematan	Pekan Sarikei, Sarikei	Mount Serumbu, Bau	Sebangkoi, Sarikei	Taman Tasik, Sarikei						
<i>Abscondita pallescens</i>		*		*				*					*																								
<i>Colophotia brevis</i>		*		*				*		*	*				*																						
<i>Luciola niah</i>								*																									*				
<i>Luciola pallidipes</i>				*																					*												
<i>Pteroptyx bearni</i>					*	*	*					*	*	*	*	*	*	*	*	*																	
<i>Pteroptyx malaccae</i>	*	*				*			*			*	*	*	*	*	*	*	*	*																	
<i>Pteroptyx tener</i>					*				*			*	*	*	*		*	*	*				*														
<i>Pteroptyx testacea</i>			*					*				*	*	*	*		*	*	*																		
<i>Pteroptyx valida</i>		*		*			*	*	*			*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Pteroptyx sp. 1</i>							*						*																								
<i>Pteroptyx sp. 2</i>		*		*																																	
<i>Pyrocoelia opaca</i>																																				*	
<i>Pyrocoelia sp.</i>				*																																*	

Table 4. A compilation record of firefly species in Sarawak from various literatures

Species/ Localities	Published Articles																		References													
	Bako National Park	Balingian, Mukah	Balingian River	Kadulit	Kapit	Kuching	Lambir Hill, Miri	Limbang	Long Aton, Baram	Matang, Kuching	Miri River	Mount Dulit, Miri	Mount Merinjak	Mount Mulu National Park	Mukah River	Niah, Miri	Niah National Park	Niah River		Nyalau, Bintulu	Paya Paloh, Kota	Quop, Padawan	Rejang-Sibu, Sarikei	Sadong Jaya	Santubong	Saratok, Betong	Sibuti River	Similajau River	Suai, Miri	Raan River	Ulu Baram, Baram	
<i>Abscondita pallescens</i>									*		*	*	*								*											Ballantyne et al. 2019
<i>Colophotia miranda</i> **									*																							Ballantyne et al. 2019
<i>Luciola lata</i>									*												*											Ballantyne et al. 2019
<i>Luciola niah</i>					*		*		*								*													*		Ballantyne et al. 2015; Ballantyne et al. 2019
<i>Luciola pallidipes</i> **																																Ballantyne et al. 2019
<i>Pteroptyx balingiana</i>		*																														Jusoh et al. 2018
<i>Pteroptyx asymmetria</i>																							*									Wan Nurainie et al. 2020
<i>Pteroptyx bearni</i>				*													*	*	*			*		*		*		*	*			Abdullah et al. 2021; Jusoh et al. 2018; Wan Nurainie et al. 2020; Wong 2022
<i>Pteroptyx decolor</i>	*					*													*					*								Jusoh et al. 2018; Wong 2022
<i>Pteroptyx galbina</i>																*														*		Ballantyne et al. 2015
<i>Pteroptyx gelasina</i> **																																Wong 2022
<i>Pteroptyx malacca</i>							*										*		*		*	*	*	*								Abdullah et al. 2021; Jusoh et al. 2018; Wan Nurainie et al. 2020; Wong 2022
<i>Pteroptyx tener</i>			*			*					*				*				*					*			*					Jusoh et al. 2018; Wong 2022
<i>Pteroptyx testacea</i> **																																Wong 2022
<i>Pteroptyx valida</i>														*									*									Jusoh et al. 2018; Wan Nurainie et al. 2020

\*\*location not specified

The identification and revision of firefly (Lampyridae) species have been traditionally performed using male morphological characters (Ballantyne & Lambkin 2013) due to the distinct morphological characteristics, especially the light organ which occupies both ventrites 6 and 7 (V6 & V7) as opposed to the females with their light organ only occupying V6 (Figure 3 & 4). Therefore, the identification of females relied on association with the males and colour patterns. The morphological characteristics used to identify each species (based on male unless specified) are described following the morphological terms used by Ballantyne et al. (2019): *Colophotia brevis* (Figure 3(a)) was identified by its brownish yellow dorsal surface and black elytral apices with light organ separated by a narrow median carina. Additionally, the presence of short hooks at the end of the median posterior projection on V7. *Pyrocoelia opaca* (Figure 3(b)) was distinguished by its large size, black dorsal surface with an orange pronotum, serrated antennae and tergites (6, 7 & 8) protruding from the sides when viewed from below. *Luciola pallidipes* (Figure 3(c)) by its dark brown dorsal surface and pronotum, with paler metathorax and legs. *Luciola niah* (Figure 3(e)) by its yellowish legs with dark brown tibiae and tarsi as well as a thin dark marking on ventrite 5 just above the light organ. *Abcondita pallescens* (female) (Figure 3(f)) was recognized by its large size, pale brownish yellow dorsal surface with brown markings on the pronotum and V7 protruding beyond elytral apices. All five *Pteroptyx* species (*P. bearni*, *P. malaccae*, *P. tener*, *P. testacea* & *P. valida*) have bipartite light organs on V7 and deflexed elytral apices except *P. testacea* (Figure 3(g)). *P. tener* (Figure 4(e)) is differentiated from *P. bearni* (Figure 4(a)) by the right-angled posterolateral projections on V7. As for *P. malaccae* (Figure 4(c)), identified by the presence of a semicircle shape separating their light organ on V7 and the enlarged hind tibiae. Whereas *P. valida* (Figure 4(g)) by its pale-yellow colouration and light organ fills most of V7 with short and wide median posterior projection on V7.



(a)



(b)



(c)



(d)



Figure 4. Habitus images of *Pteroptyx* species from Sarawak. (a) *Pteroptyx bearni* male, (b) *Pteroptyx bearni* female, (c) *Pteroptyx malacca* male, (d) *Pteroptyx malacca* female, (e) *Pteroptyx tener* male, (f) *Pteroptyx tener* female, (g) *Pteroptyx valida* male and (h) *Pteroptyx valida* female

Although recent studies (see Ballantyne & Lambkin 2013; Ballantyne et al. 2015; Ballantyne et al. 2019; Jusoh 2018) have provided a thorough description of the morphological features of both male and female fireflies which greatly facilitates the identification process in this study, the presence of unidentified firefly morphospecies is attributed to the lack of studies on fireflies in Sarawak thereby hampering the identification process. Among the unidentifiable morphospecies, there might be species that are new to science, but this can only be ascertained by conducting further studies (morphometrics or DNA barcoding) or only when the specimens are compared against museum specimens with a more extensive firefly collection.

## CONCLUSION

This study has successfully provided a recent species checklist for fireflies in Sarawak with a total of 372 individuals of Lampyridae representing 13 species from five genera, namely *Abcondita*, *Colophotia*, *Luciola*, *Pteroptyx* and *Pyrocoelia*, belonging to two subfamilies, Luciolinae and Lampyrinae. In addition, the first record of two species (*Colophotia brevis* and *Pyrocoelia opaca*) in Sarawak was documented. However, it is strongly recommended that a more comprehensive study on fireflies, especially in the central region of Sarawak (e.g., Betong, Sarikei, Bintulu) alongside the preferred host trees should be conducted to provide a better understanding of firefly habitat in Sarawak and promote conservation by identifying the areas with significant conservation value. The list from this study can hopefully serve as an initial reference for future inventories and research on fireflies. Related information can also be

utilised to promote and support the development of ecotourism in Sarawak and more importantly for the conservation of fireflies.

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### **AUTHORS DECLARATIONS**

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#### **Conflict of Interest**

The authors declare that they have no conflict of interest.

#### **Ethics Declarations**

No ethical issue required for this research

#### **Data Availability Statement**

Not relevant

#### **Authors' Contributions**

NAZ and SNS conceived this research and designed experiments; NAZ and SNS participated in the design and interpretation of the data; NAZ and SNS performed experiments and analysis; NAZ and SNS wrote the paper and participated in the revisions of it. All authors read and approved the final manuscript.

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