

Short Communication

The Occurrence of *Pteroptyx tener* Olivier Firefly (Coleoptera: Lampyridae) in Malaysia

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ABSTRACT

A field survey of synchronized fireflies (*Pteroptyx tener* Olivier) was conducted in Kuala Sepetang, Perak. It involved sampling efforts for six months, from November 2021 to April 2022. A total of 10 sampling stations were selected along 5.63 km from the upstream to the downstream of the river. A sweep net was used for sampling at each station, and the net was swept for two minutes. Such sampling was replicated twice at each station. At the same time, collecting vegetation samples was done by taking the leaves, flowers, fruits, tree trunks, and roots. For species identification, collected specimens were taken to the Laboratory of the School of Biological Sciences, Universiti Sains Malaysia (USM). From this survey, a total of 111,622 individuals were recorded. This species has been observed on *Rhizophora mucronata*, *Rhizophora apiculata*, and *Sonneratia caseolaris*. The distribution and abundance of fireflies in the sampling area were undocumented prior to this study. This study is being conducted to understand *Pteroptyx tener*'s distribution in

Malaysia better and to add knowledge about the undocumented area of Kuala Sepetang. By adding an undocumented location for this species, this study can contribute to and expand the knowledge of the distribution and occurrence of fireflies in Malaysia, particularly in Perak.

Keywords: Distribution, fireflies, *Hibiscus tiliaceus* L. Engl., *Nypa fruticans*, *Pteroptyx tener* Olivier, *Rhizophora apiculata*, *Sonneratia caseolaris* Engl.

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INTRODUCTION

Fireflies are insects belonging to the Coleoptera order and Lampyridae family capable of emitting flashing bioluminescent light (Lewis et al., 2020; Shahara et al., 2017). They are also known as glow worms or lightning bugs, and their taxonomic diversity encompasses more than 2,000 species in around 100 genera and 8 subfamilies across the globe (Shahara et al., 2017). González-Oreja (2008) and Wilson (2003) report that approximately 3,000 species per year perish, or 8 per day, out of a total of 3-100 million species in the globe. In the previous 600 years, around 70 species have gone extinct (Dunn, 2005). In Malaysia, a study by Asri et al. (2021) and Jusoh et al. (2012) revealed a significant decrease in mangrove fireflies in Sungai Rembau-Linggi.

Southeast Asia, encompassing Singapore, the Philippines, Thailand, Cambodia, Indonesia, Sulawesi, Papua New Guinea, Thailand, and Malaysia, is home to the *Pteroptyx* species of bent-winged fireflies (Ballantyne, 2001; Ballantyne & Lambkin, 2001; Ballantyne & McLean, 1970; Jusoh et al., 2018; Sartsanga et al., 2018). Malaysia is home to 13 species of the *Pteroptyx*, all of which may be found congregating on the mangrove vegetation of *Sonneratia caseolaris* (Shahara et al., 2017; Sulaiman et al., 2016, 2017). Compared to other species, *Pteroptyx tener* Olivier was the most common species in Malaysia (Jusoh et al., 2011, 2018). The *Pteroptyx tener* Olivier population on Peninsular's west coast differs from those on the east

coast and in Borneo, even though there are no physical differences (Jusoh et al., 2020).

The locations of adult *Pteroptyx tener* Olivier fireflies recorded through the field surveys in Kuala Sepetang, Perak (Peninsular Malaysia), have existed for decades, but they are undocumented. Although this location is one of the most popular destinations for ecotourism, it is also one of the few places to watch fireflies where individuals can synchronize their flashing lights at night. The researchers, who studied the distribution and the occurrence of fireflies in the state of Perak, have concentrated solely on fireflies discovered in Kampung Dew, Perak. *Pteroptyx* fireflies, according to Mahadimenakbar et al. (2009), have the potential as ecotourism goods and contribute to wildlife tourism called entomotourism (Lemelin et al., 2019). Figure 1 shows the current study area for this field survey in Kuala Sepetang, Perak, compared to the previous study area in Kampung Dew, Perak. The map in Figure 1 also shows the documented and undocumented areas in Kuala Sepetang for *Pteroptyx tener* Olivier. Indirectly, this study adds information on the undocumented area for this firefly species.

The synchronized flashing light emitted by *Pteroptyx tener* Olivier makes them a valuable resource to promote ecotourism and significantly increases the local community income by creating jobs and procuring goods and services for some areas in Peninsular Malaysia (K. Nallakumar, 2003). For example, in Kuala Selangor (Khoo et al., 2012), Kuala Sepetang and Rembau-Linggi (Jusoh et al., 2010a,

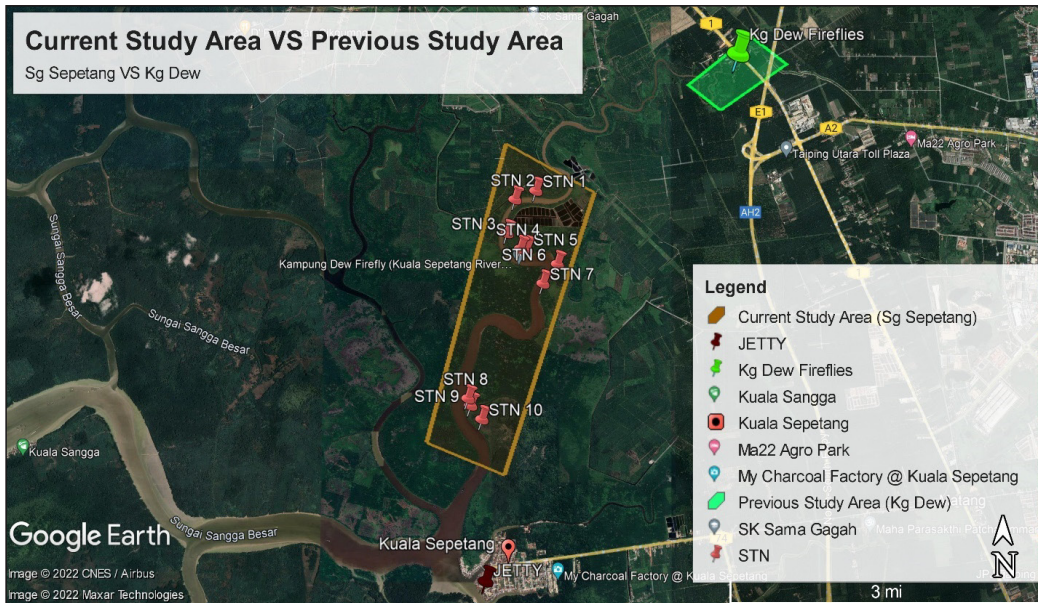


Figure 1. The current study area is in Kuala Sepetang, Perak, and the previous study area was in Kampung Dew, Perak

Note. Map was generated using Geographical Information System (GIS) software

2010b), Sungai Garama (Mahadimenakbar et al., 2007), Kg. Kuantan (Ballantyne & Menayah, 2000), Paitan River (Chey, 2006), Bernam River (Shahara et al., 2017), and Cherating River (Mohd et al., 2019). However, due to this human interference, the fireflies lost their natural habitat in mangrove forests, resulting in extinction in some places (Ballantyne et al., 2011). Hence, preserving and conserving firefly habitats is crucial (Foo & Mahadimenakbar, 2015). Furthermore, other human activities, such as speedboats operation, generate waves that erode the riverbanks, disrupting the habitat of adult fireflies by destroying the trees on which they rely. Thus, the population of fireflies is endangered (Lewis, 2016).

Therefore, this study collates records of adult *Pteroptyx tener* Olivier fireflies

reported in the Malaysian peninsular, including Sabah and Sarawak. The records used in this study are from a compilation of field surveys conducted by authors (i.e., in Kuala Sepetang, Perak, situated in Peninsular Malaysia) and from published journal articles to construct lists of the distribution of this species. Moreover, the purpose of this study is to comprehend *Pteroptyx tener*'s distribution in Malaysia. The authors discovered that it is crucial to record every location where fireflies are present to conserve them in the future. It would be challenging for the Forestry Department and other related organizations to precisely determine the number of firefly populations, the distribution, and the diversity of firefly species, particularly species that have never been discovered, if many places are undocumented. Thus, this

study attempts to bridge the knowledge gap while adding information about the undocumented area where fireflies were found.

METHODS

Study Site

This study was conducted along the Sepetang River in Kuala Sepetang, Perak. Kuala Sepetang is surrounded by mangrove swamps and is a focus for fireflies-watching activities at night; and one of the Congregating Firefly Zones (CFZs) in Malaysia, aiming to protect the river's firefly colonies, especially *Pteroptyx tener* Olivier. The main vegetation species that dominate the area are mangroves, such as *Sonneratia caseolaris*, *Rhizophora mucronata*, and *Rhizophora apiculata*. Malaysia's mangrove forests are the sixth largest in the world. In

Malaysia, mangrove forests are categorized as permanent forest reserves (PFR), which include protected forest reserves, domestic forest reserves, mangrove forest reserves (MFR), virgin forest reserves (VJR), and wildlife reserves (Tangah et al., 2022). In Kuala Sepetang, the largest mangrove forest reserve in Malaysia, with an area of about 40,000 ha, is Matang Mangrove Forest Reserve (MMFR) (Romañach et al., 2018). Figure 3 shows the distribution of mangroves in Matang, Perak, Malaysia, including Kuala Sepetang, Kuala Trong, and Kerang River.

During the initial sampling, a display tree with a large congregation of fireflies and well-synchronized *Pteroptyx tener* Olivier fireflies was used to identify ten sampling locations, as shown in Figure 2. Those ten sampling points from the upstream river to the downstream river with each sampling

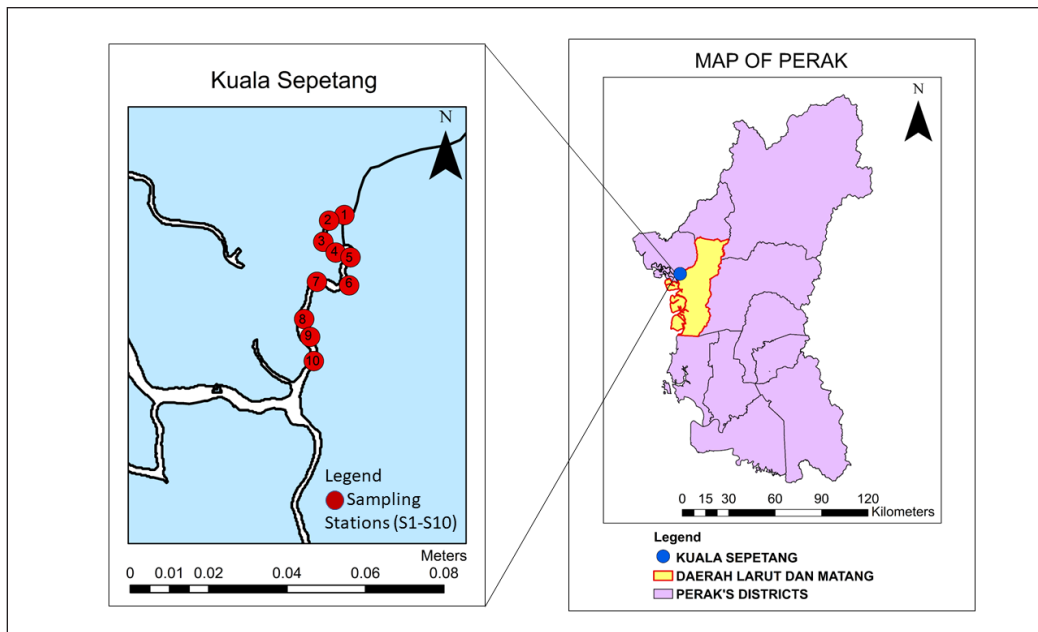


Figure 2. Sampling points located at Kuala Sepetang, Perak

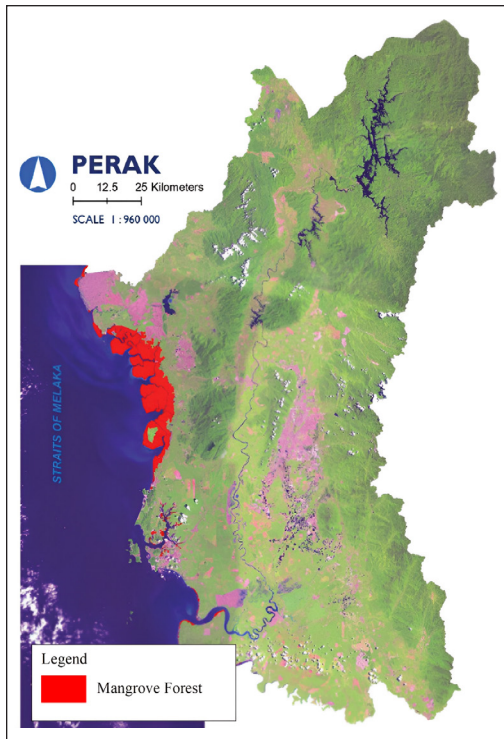


Figure 3. Distribution of mangroves in Perak (Omar et al., 2020)

point were recorded at night using a Global Positioning System (GPS) receiver (version 4.7.3) (Handheld Altimeter GPS+ via iPhone X, USA). Then, the data were analyzed using the Geographic Information System (GIS) application technique using ArcGis software (version 10.3). The coordinates for each sampling point in this study range from Station 1 to Station 10, as shown in Table 1. There had been no scientific documentation of *Pteroptyx tener* in this sampling point location before this study.

It is very relevant for this study to be conducted because the sampling point area in this study is a developing area. While conducting this study, it was found that human activities, such as ecotourism

and aquaculture (shrimp and fishponds), are increasingly carried out. It is feared that many nearby human activities would damage the mangrove firefly habitat. The fireflies' existence will be at risk if the mangroves are disrupted (please refer to the Results and Discussion section for more information). There is no documentation for fireflies in this area. Although tourism activities have been very active almost every day, especially on weekends, many boats bring local and foreign tourists to the area. The lack of documentation on the firefly population makes it challenging to know further about these fireflies from time to time. The documentation in this study is crucial to preserve and understanding the fireflies' status.

Sampling and Identification Process

The samplings were conducted for six consecutive months, from November 2021 until April 2022, from 5.30 p.m. to 9:00 p.m. Firstly, collecting vegetation samples

Table 1
Sampling points (Station 1 - Station 10) coordinates

| Sampling point | Coordinate |
|----------------|------------------------------------|
| Station 1 | 4° 53' 17.02" N, 100° 38' 03.73" E |
| Station 2 | 4° 53' 13.09" N, 100° 37' 53.02" E |
| Station 3 | 4° 52' 55.72" N, 100° 37' 48.92" E |
| Station 4 | 4° 52' 47.90" N, 100° 37' 55.77" E |
| Station 5 | 4° 52' 47.70" N, 100° 37' 58.92" E |
| Station 6 | 4° 52' 40.18" N, 100° 38' 14.73" E |
| Station 7 | 4° 52' 30.50" N, 100° 38' 07.31" E |
| Station 8 | 4° 51' 33.69" N, 100° 37' 29.31" E |
| Station 9 | 4° 51' 30.22" N, 100° 37' 30.60" E |
| Station 10 | 4° 51' 31.40" N, 100° 37' 37.75" E |

(display trees) were collected by taking the leaves, flowers, fruits, tree trunks, and roots. Further identification of the vegetation from the field survey done at the Laboratory of the School of Biological Sciences, Universiti Sains Malaysia (USM), where the description follows a book by Lee et al. (2015), which is entitled “Mangrove Guidebook for Malaysia”.

Next, the adult firefly samples were collected using the sweep method (using a sweep net). The sampling was replicated twice at each station, and the net was swept for two minutes. Then the samples were stored in bottles containing 95% ethanol and labeled according to their respective collection dates and sampling station. Finally, all the samples were taken to the Entomology Laboratory of the School of Biological Sciences, Universiti Sains Malaysia (USM), for further identification. The identification of firefly species concerning the taxonomic description was published by Ballantyne and Lambkin (2013), and the sex of fireflies followed the taxonomic description established by Jusoh et al. (2018).

RESULTS AND DISCUSSION

The Locality of *Pteroptyx tener* Olivier was Recorded

Table 2 to Table 7 list the *Pteroptyx tener* Olivier Firefly specimens examined in six states in Peninsular Malaysia, including Selangor, Johor, Negeri Sembilan, Pahang, Perak, and Terengganu. Tables 8 and 9 list the *Pteroptyx tener* Olivier Firefly samples found in East Malaysia (Sarawak and

Sabah). In addition, two digital information maps, such as in Figure 4, which show the map of the occurrence of *Pteroptyx tener* Olivier in Peninsular Malaysia, were developed using GIS software. Figure 5, meanwhile, depicts the occurrence map of *Pteroptyx tener* Olivier in East Malaysia (Sabah and Sarawak). *Pteroptyx tener* Olivier only occurs in six Peninsular Malaysia states: Terengganu, Perak, Pahang, Negeri Sembilan, Selangor, and Johor, including East Malaysia (Sabah and Sarawak). As stated by Wong and Yeap (2012), the distribution of this assemblage of firefly habitats in riverine mangroves is still primarily undocumented and unrecorded. Therefore, there is a possibility that no samples were taken or no previously published information about the distribution of this species in other states in Malaysia (Perlis, Kedah, Penang, Kelantan, Kuala Lumpur, Putrajaya, and Melaka). Another piece of evidence is the absence of records indicating the presence of fireflies in Penang, despite the presence of unknown species of fireflies in the Nibong Tebal region of the state. Therefore, future research should concentrate on documenting more firefly locations in Malaysia, particularly this species, which has the potential to boost the local economy.

Pteroptyx tener Olivier’s Dependence on Their Habitat

Pteroptyx tener Olivier fireflies are frequently seen in Malaysia along the mangrove estuary’s banks, and they are similar at the sampling points (S1–S10) in Kuala

Table 2
The samples were found in Peninsular Malaysia, Selangor

| Coordinate | Location | Data acquisition | | Other specimens | Habitat | Study period | Sources of information |
|------------------------------------|---------------------------------|--------------------|--------------------|--------------------------|------------------------------------|-------------------------------------|-------------------------------|
| | | ♂ | ♀ | | | | |
| Data not available | Kampung Kuantan | 88 | 92 | 245 newly hatched larvae | Data not available | March 2000 to June 2000 | Ballantyne and Menayah (2000) |
| 3° 14' 24.00" N, 101° 07' 12.01" E | Kuala Selangor | Data not available | Data not available | Data not available | Data not available | 25 April 1975, found by J. E. Lloyd | Jusoh et al. (2013) |
| Data not available | Selangor River, Kampung Kuantan | 40 | 40 | Data not available | Data not available | January to May 2014 | Salleh et al. (2019) |
| Data not available | Selangor River | Data not available | Data not available | Data not available | <i>Sommeratia caseolaris</i> Engl. | May 2006 to April 2009 | Khoo et al. (2012) |

Table 3
The samples were found in Peninsular Malaysia, Johor

| Coordinate | Location | Data acquisition | | | Habitat | Study period | Sources of information |
|-------------------------------------|--|--------------------|--------------------|--------------------|------------------------------------|---------------------------------------|------------------------|
| | | ♂ | ♀ | Other specimens | | | |
| Data not available | Benut | Data not available | Data not available | Data not available | Data not available | October 1965, found by J. M. Bassot | Jusoh et al. (2013) |
| 01° 22' 48.00" N, 103° 09' 00.00" E | Benut | Data not available | Data not available | Data not available | Data not available | June 1967, found by I. Polunin | Jusoh et al. (2013) |
| 1° 44' 36.10" N, 103° 54' 54.71" E; | Johor River, Kota Tinggi | 1,104 | 612 | Data not available | <i>Sommeratia caseolaris</i> Engl. | December 2007 until January 2008 | Sulaiman et al. (2016) |
| 1° 41' 31.25" N, 103° 55' 44.26" E | | | | | | | |
| 1° 25' 12.00" N, 103° 21' 00.00" E | Kota Tinggi, Kupia Labong, Endau River | Data not available | Data not available | Data not available | Data not available | 12 December 1970, found by I. Polunin | Jusoh et al. (2013) |
| 1° 31' 12.00" N, 103° 34' 12.00" E | Mawai | Data not available | Data not available | Data Not Available | Data not available | 19 December 1970, found by I. Polunin | Jusoh et al. (2013) |

Table 4
The samples were found in Peninsular Malaysia, Negeri Sembilan

| Coordinate | Location | Data acquisition | | | Habitat | Study period | Sources of information |
|---|---------------------------|--------------------|--------------------|--|--|--------------------------------|------------------------|
| | | ♂ | ♀ | Other specimens | | | |
| Data not available | Linggi River | Data not available | Data not available | Two adults (<i>Pteropyx</i> sp.). No specific species was mentioned | <i>Sonneratia caseolaris</i> | November 2008 until April 2009 | Jusoh et al. (2010a) |
| 2° 25' 08.76" N, 102° 03' 55.44" E; 2° 26' 54.24" N, 102° 03' 55.44" E | Rembau River | 835 | 313 | Data not available | <i>Sonneratia caseolaris</i> Engl., and <i>Nypa fruticans</i> | November 2017 to October 2018 | Asri et al. (2021) |
| Data not available | Rembau River | Data not available | Data not available | 658,104 adults | <i>Sonneratia caseolaris</i> , <i>Rhizophora apiculata</i> , <i>Hibiscus tiliaceus</i> , and <i>Ficus</i> sp. | November 2008 to April 2009 | Jusoh et al. (2010a) |
| 2° 25' 08.76" - 2° 26' 54.24" N, 102° 03' 55.44" E | Rembau River | Data not available | Data not available | 525 adults | Found next to the jetty, human settlement area, horticulture activity, jetty, mangrove, aquaculture activity, and oil palm plantation (specific tree species were not mentioned by the author). Data not available | January 2018 to November 2018 | Abdullah et al. (2021) |
| Data not available | Ramuan China Besar River | Data not available | Data not available | 103 adults | <i>Sonneratia caseolaris</i> and <i>Rhizophora apiculata</i> | November 2008 until April 2009 | Jusoh et al. (2010a) |
| Data not available | Ramuan China Kechil River | Data not available | Data not available | 182 adults | <i>Sonneratia caseolaris</i> and <i>Rhizophora apiculata</i> | November 2008 until April 2009 | Jusoh et al. (2010a) |

Table 5
The samples were found in Peninsular Malaysia, Pahang

| Coordinate | Location | Data acquisition | | | Habitat | Study period | Sources of information |
|--------------------|-----------------|--------------------|--------------------|-----------------|--------------------|--------------|------------------------|
| | | ♂ | ♀ | Other specimens | | | |
| Data not available | Cherating River | Data not available | Data not available | 243 adults | Data not available | March 2019 | Faudzi et al. (2021) |

Table 6
The samples were found in Peninsular Malaysia, Perak

| Coordinate | Location | Data acquisition | | Habitat | Study period | Sources of information |
|--|------------------------------|--------------------|--------------------|--|---|-------------------------|
| | | ♂ | ♀ | | | |
| Data not available | Setentang River, Kampung Dew | Data not available | Data not available | <i>Sonneratia caseolaris</i> Engl. | March 2014 to June 2014 | Hazmi and Sagaff (2017) |
| 4° 50' 27.3012" N, 100° 38' 04.92" E | Setentang estuary | Data not available | Data not available | <i>Sonneratia caseolaris</i> , <i>Nypa fruticans</i> , and <i>Rhizophora apiculata</i> | December 2006 until February 2007 | Jusoh et al. (2010b) |
| 4° 52' 13.26" N, 100° 38' 01.20" E | Setentang estuary | Data not available | Data not available | Data not available | Found by W. F. A. Jusoh (Forest Research Institute Malaysia – B. Nada, C.-K. Phon) | Jusoh et al. (2018) |
| 4° 53' 17.02" N, 100° 38' 03.73" E; 4° 51' 31.40" N, 100° 37' 37.75" E | Setentang River | Data not available | Data not available | <i>Sonneratia caseolaris</i> , <i>Rhizophora mucronata</i> , and <i>Rhizophora apiculata</i> | November 2021 to April 2022, found by N. A. Seri, A. A. Rahman, N. F. A. Kassi, and N. F. A. Fuzi | Field survey |

Table 7
The samples were found in Peninsular Malaysia, Terengganu

| Coordinate | Location | Data acquisition | | Habitat | Study period | Sources of information |
|------------------------------|------------------------|--------------------|--------------------|---|------------------------------|------------------------|
| | | ♂ | ♀ | | | |
| Data not available | Chukai River, Kemaman | Data not available | Data not available | <i>Sonneratia caseolaris</i> , <i>Hibiscus tiliaceus</i> L. Engl., <i>Nypa fruticans</i> Wurm., <i>Barringtonia</i> sp., and <i>Guilandina bonduc</i> L. | November 2017 to April 2018 | Mahmod et al. (2018) |
| 5° 33' 00" N, 102° 44' 08" E | Kampung Mangkuk, Setiu | 5 | 1 | <i>Avicennia alba</i> and <i>Sonneratia alba</i> | July 2005 until January 2006 | Azmi et al. (2015) |
| Data not available | Kerteh River | Data not available | Data not available | <i>Gluta velutina</i> Blume, <i>Hibiscus tiliaceus</i> L., <i>Xylocarpus granatum</i> J. König, <i>Avicennia alba</i> Blume, <i>Rhizophora apiculata</i> Blume, <i>Excoecaria agallocha</i> L., <i>Barringtonia racemosa</i> (L.) Spreng., <i>Ficus microcarpa</i> L.f., <i>Bruguiera gymnorhiza</i> (L.) Lam., and <i>Nypa fruticans</i> Wurm. | 18 to 20 July 2009 | Jusoh et al. (2011) |

Table 8
The samples were found in East Malaysia, Sarawak

| Coordinate | Location | Data acquisition | | | Habitat | Study period | Sources of information |
|---------------------------------------|-----------------|--------------------|--------------------|--------------------|--------------------|--|------------------------|
| | | ♂ | ♀ | Other specimens | | | |
| 2° 55' 44.82" N, 112° 32' 41.28" E | Balingian River | Data not available | Data not available | Data not available | Data not available | Found by M. Musbah | Jusoh et al. (2018) |
| 1° 19' 12.00" N, 110° 12' 00.00" E | Kuching | Data not available | Data not available | Data not available | Data not available | 26 September 1965, found by J. Buck | Jusoh et al. (2013) |
| 4° 29' 24.00" N, 115° 06' 00.00" E | Limbang | Data not available | Data not available | Data not available | Data not available | 4 October 1970, found by I. Polunin | Jusoh et al. (2013) |
| 2° 53' 48.59" N, 112° 07' 54.30" E | Mukah River | Data not available | Data not available | Data not available | Data not available | Found by T. Musa | Jusoh et al. (2018) |
| Data not available | Miri River | 23 | 11 | Data not available | Data not available | Found by M. Musbah | Jusoh et al. (2018) |
| Data not available | Kuching | Data not available | Data not available | Data not available | Data not available | 5 February 1909, found by J. E. A. Lewis | Jusoh et al. (2013) |
| 2° 15' 36.00" N, 111° 09' 36.00" E | Paya Paloh | Data not available | Data not available | Data not available | Data not available | 27 September 1965, found by J. Buck | Jusoh et al. (2013) |
| Data not available | Pending | Data not available | Data not available | Data not available | Data not available | 26 September 1965, found by J. Buck | Jusoh et al. (2013) |
| 1° 26' 24.00" N, 111° 12' 00.00" E | Saratok | Data not available | Data not available | Data not available | Data not available | 23 September 1970, found by I. Polunin | Jusoh et al. (2013) |
| 3° 31' 08.40" N, 113° 19' 43.20" E | Similajau River | Data not available | Data not available | Data not available | Data not available | Data not available | Jusoh et al. (2018) |

Table 9
The samples were found in East Malaysia, Sabah

| Coordinate | Location | Data acquisition | | | Habitat | Study period | Sources of information |
|--|--|--------------------|-----------------------|--|--|-------------------------------|------------------------|
| | | ♂ | ♀ | Other specimens | | | |
| 5° 24' 00.00" N, 118° 15' 00.00" E | Abai | Data not available | Data not available | Data not available | 21 October 1970, found by I. Polunin | Jusoh et al. (2013) | |
| 5° 31' 27" N 115°42' 03.2" E | Binsulok River | Data not available | Data not available | 5 adults | 9 September 2017 | Mahadimenakbar et al. (2018) | |
| 5° 10' 00.00" N, 115° 19' 60.00" E; 5° 30' 00.00" N, 115° 40' 00.00" E | Garama River | 261 | 158 | 316 adults | April 2004 to June | Mahadimenakbar et al. (2007) | |
| (5° 24' 37.32" N, 115° 31' 54.54" E | Garama River | 308 | 263 | Data not available | January 2015 to August 2015 | Foo and Mahadimenakbar (2017) | |
| Data not available | Garama River | Data not available | Data not available | <i>Excoecaria agallocha</i> L., <i>Rhizophora apiculata</i> , and <i>Sonneratia alba</i> | September 2009 | Chey (2010) | |
| Data not available | Klias River | Data not available | Data not available | <i>Ficus microcarpa</i> , <i>Clerodendrum inerme</i> | September 2009 | Chey (2010) | |
| Data not available | Klias River | Data not available | Data not available | <i>Glochidion littorale</i> , <i>Rhizophora apiculata</i> | April 2004 | Chey (2004) | |
| Data not available | Kudat, Kanibongan | Data not available | Data not available | <i>Sonneratia caseolaris</i> , <i>Heritiera littoralis</i> Dryand. ex Aiton), <i>Rhizophora apiculata</i> Bl., <i>Excoecaria indica</i> (Willd.) Muell. Arg. | 24 September 1965, found by K. H. Kong | Jusoh et al. (2013) | |
| Data not available | Kulamba XPDC (expedition) Sungai Terusan | 2 | 23 unassigned females | Presumed to be a species of <i>Sonneratia</i> locally known as 'Pedada') | In 2006 found by Nordin and Zaidi | Jusoh et al. (2018) | |

Table 9 (continue)

| Coordinate | Location | Data acquisition | | | Habitat | Study period | Sources of information |
|---------------------------------------|------------------------------------|--------------------|--------------------|--------------------|--|--|-------------------------------|
| | | ♂ | ♀ | Other specimens | | | |
| Data not available | Sandakan Bay, Sapagaya Lumber Camp | Data not available | Data not available | Data not available | Data not available | 7 November 1957, J. L. found by Gressitt | Jusoh et al. (2013) |
| 05° 39' 43.56" N 118° 24' 07.56" E | Kinabatangan River | Data not available | Data not available | Data not available | <i>Sonneratia caseolaris</i> , <i>Excoecaria indica</i> | 2002 | Mahadimenakbar et al. (2002) |
| 5° 04' 12.00" N, 115° 19' 48.00" E | Sipitang River | Data not available | Data not available | Data not available | Data not available | 22 October 1970, found by I. Polunin | Jusoh et al. (2013) |
| Data not available | Tawau Residency | Data not available | Data not available | Data not available | Data not available | 19 November 1958, found by L. W. Quate | Jusoh et al. (2013) |
| 5° 19' 38.9" N; 115° 31' 06.7" E | Teratak River | 656 | 104 | Data not available | <i>Excoecaria agallocha</i> L., <i>Rhizophora apiculata</i> , and <i>Sonneratia alba</i> | January 2015 to August 2015 | Foo and Mahadimenakbar (2017) |
| 5° 11' 37.82" N, 115° 34' 38.54" E | Weston River | Data not available | Data not available | Data not available | <i>Excoecaria agallocha</i> L., <i>Rhizophora apiculata</i> , and <i>Sonneratia alba</i> | January 2015 to August 2015 | Foo and Mahadimenakbar (2017) |
| 05° 19' 38.9" N, 115° 31' 06.7" E | Teratak River | Data not available | Data not available | 2 adults | <i>Avicennia alba</i> (Avicenniaceae) | March 2014 to April 2014 | Foo and Mahadimenakbar (2015) |

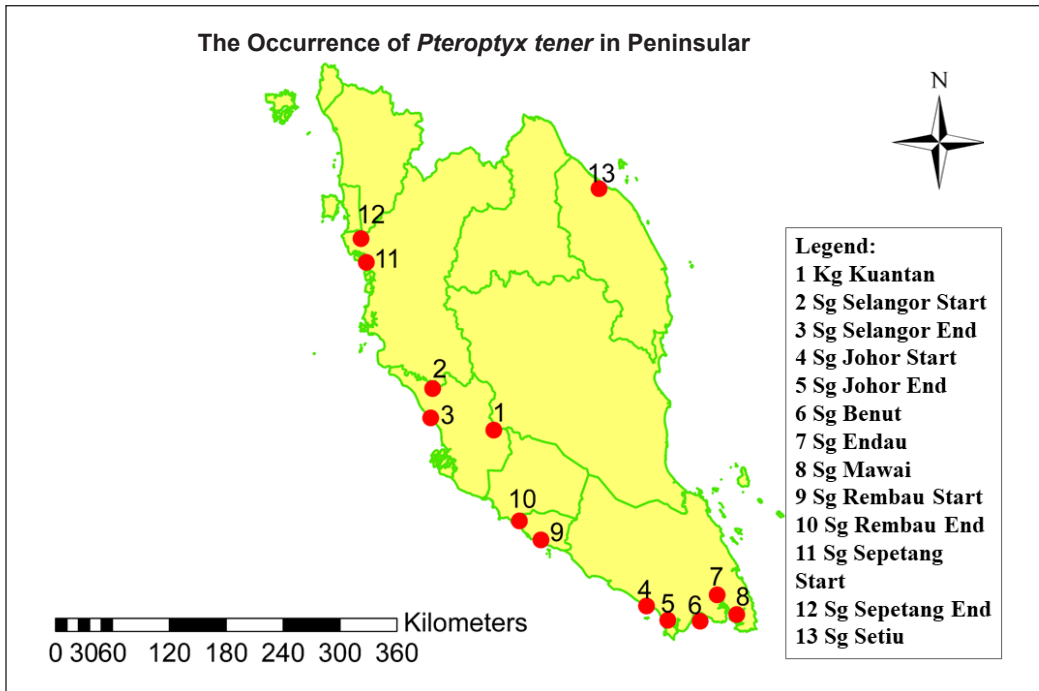


Figure 4. The occurrence of *Pteroptyx tener* Olivier in Peninsular Malaysia

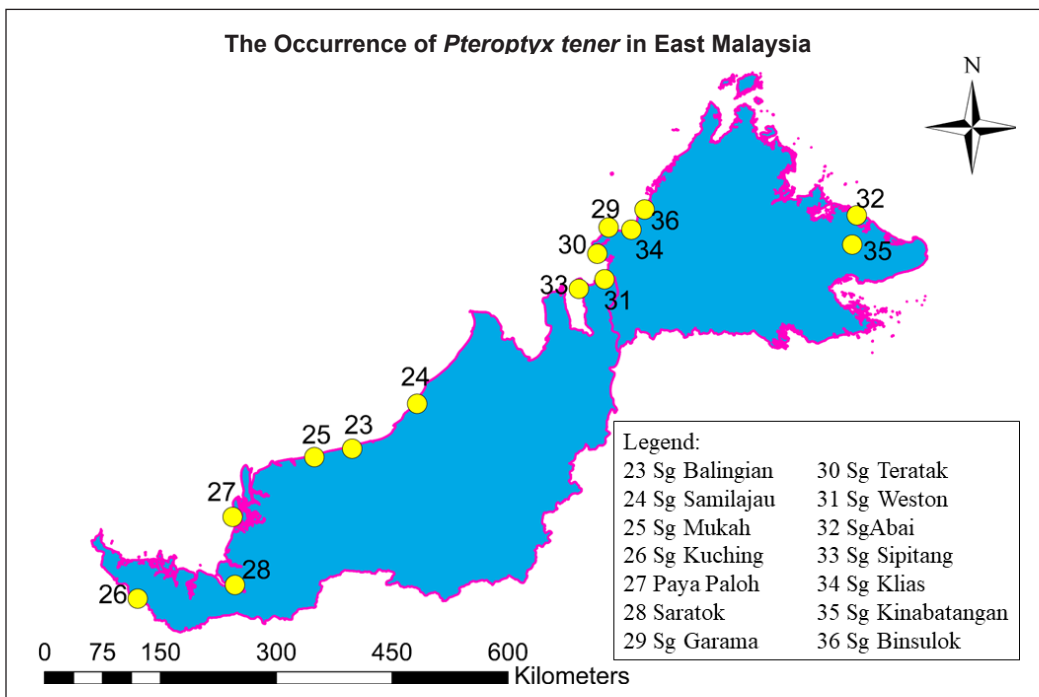


Figure 5. The occurrence of *Pteroptyx tener* Olivier in East Malaysia (Sabah and Sarawak)

Seputang, Perak. There are no other firefly species found in the area. This study found that mangrove trees, including *Sonneratia caseolaris* Engl., *Rhizophora mucronata*, and *Rhizophora apiculata*, are found along the entire river of the sampling locations. *Pteroptyx tener* uses these trees as display trees, covering them with varying densities of small, medium, and big firefly colonies on a single tree. Other than these three mangrove trees, *Hibiscus tiliaceus*, *Sapium indicum*, *Metroxylon sagu*, *Gigantochloa ligulata*, *Ficus microcarpa*, *Ficus retusa*, *Urena lobata*, *Tetracera indica*, *Avicennia* sp., *Durio* sp., and *Garcinia* sp. trees are among the mangrove trees species that has firefly species inhabiting there or nearby (Ohba & Wong, 2004).

The observations of this study also revealed that *Pteroptyx tener* favors young and low mangrove trees (*Sonneratia caseolaris* Engl.) over older trees, possibly because of the smaller, waxier leaves of this tree. More research is required to determine whether this species' adult fireflies will likely be displayed on old *Sonneratia caseolaris* Engl. The authors' observations confirm those of A. Nallakumar (2002), who discovered that some Kuala Selangor, Malaysia's *Pteroptyx* fireflies, only use young *Sonneratia caseolaris* trees as their display trees. Jusoh et al. (2010b) found that *Sonneratia caseolaris* and *Nypa fruticans* trees are the most preferred display trees. This preference may be owing to the availability of sugar in the sap of *Sonneratia caseolaris*, a food source for fireflies (A. Nallakumar, 2002; Ohba & Sim, 1994).

According to Jusoh et al. (2010b), five more criteria in tree selection by fireflies are being examined. The first is that trees must be located near the water's edge to allow firefly communication. The second criterion is that the leaf arrangement of each tree on display must be conducive to mating. Thirdly, the display tree must contain nectar or sap if the adult fireflies consume food. Next, the display tree must be close to the food plant for the larval prey. Then, the tree must be in good health. The tree's health is important because healthy mangrove trees have a higher leaf density, which increases the amount of surface area for insects to perch on and gives more protection from direct sunlight during the day (Foo & Mahadimenakbar, 2015).

In addition, the association between firefly abundance and vegetation assemblages may be related to the fact that fireflies do not mate while flying; instead, they use trees as mating locations (Buck & Buck, 1966). Adult female fireflies fly to the muddy bank behind the tree and lay their eggs near the intertidal zone of rivers (Barrows et al., 2008; Lewis et al., 2020).

The life cycle and habitat of Lampyridae (fireflies) are incredibly complex. It is because, throughout their life cycle, the surroundings and environmental circumstances play a crucial role (Salvador-Caabay, 2022). For instance, adult fireflies mainly inhabit the canopies of mangroves and other trees and will only lay their eggs in wetlands farther from their mating sites. The eggs are put on the ground or moss. When the larvae hatch, they become mobile

on the ground and feed on their prey. The pupa may remain on the ground or logs or other plants for protection until the adult firefly emerges (Salvador-Caabay, 2022). Eggs of fireflies require moist soil and shady areas, such as *Rhizophora* spp., so they are not easily harmed by heat and dryness (Jusoh et al., 2010b). In Sungai Selangor, for example, firefly larvae were found in greater abundance at the base of sago trees near the riverbank. On the other hand, areas with a high density of human activity are less suitable for larvae and snail prey. It could be owing to the soil's condition in the location, which has low humidity, high temperatures, and the prevalence of light invasion (Kirton et al., 2006).

Moreover, riverside palm trees like *Nypa fruticans* and *Metroxylon sago* provide an essential food source for snail prey that firefly larvae consume (Nada & Kirton, 2004). As a result, fireflies will make these trees their display tree. Another preferred assumption that fireflies consider when selecting a display tree as a favorable display tree is that fireflies feed exudates (sugary substances secreted by *Sonneratia caseolaris*) from leaf stipules (K. Nallakumar, 2003). This relationship between mangrove assemblage and firefly abundance (Jusoh et al., 2010) demonstrates how crucial it is to protect firefly species, as their display trees and habitat are threatened (Jusoh & Hashim, 2012). Consequently, any mangrove alterations will lead to a declining firefly population (Nallakumar, 2002; Yuma, 2007), and the loss of mangrove forests has resulted in their extinction in

some localities (Ballantyne et al., 2011). Therefore, it is crucial to take fireflies and their habitat in mangrove forests seriously as a research topic to protect these fireflies from extinction.

CONCLUSION

This study adds an undocumented location for *Pteroptyx tener* Olivier's and could contribute to the knowledge of the distribution and occurrence of fireflies in Malaysia. On the other hand, this study collected a record of the distribution and occurrence of *Pteroptyx tener* Olivier, which was then mapped using GIS software, which researchers rarely utilize to present their data visually to make it more comprehensible. However, because the records from previous researchers are limited, the mapping results indicate that there are still some locations of *Pteroptyx tener* Olivier that have been discovered that cannot be mapped; because the researcher did not record the coordinates where the species was discovered. Therefore, many locations of fireflies were found unavailable. From this study also, the literature review found that the most preferred tree for this species was *Sonneratia caseolaris* Engl. A few identified associated trees: *Rhizophora mucronata*, *Rhizophora apiculata*, *Hibiscus tilliaceus* L. Engl., and *Nypa fruticans*. In addition, the authors recommend protecting the mangrove forests along Kuala Sepetang to ensure the firefly's long-term survival. Fireflies are a keystone species in mangrove forests because maintaining the mangrove habitat will benefit both fireflies and humans.

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