
Research Article

Diversity of *Pteroptyx* Fireflies (Coleoptera: Lampyridae) and Their Display Trees at Klias Peninsula, Sabah, Malaysia.

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Abstract

Congregating fireflies are among the most marvellous organisms that fill the mangrove forests with “living fireworks”. These dainty creatures emit bioluminescence to attract mates by nightfall. Fireflies from the genus *Pteroptyx* aggregate on mangrove trees lighting up the riverine of several places in Malaysia, and this natural phenomenon provides local communities with lucrative business opportunity. Unsustainable management can bring disastrous consequences to the natural population of these graceful beetles. Without information on the current status of *Pteroptyx* fireflies in Klias Peninsula, any variation of this population in the future would be untraceable. This study was carried out to document the diversity of *Pteroptyx* fireflies and to identify their display trees in Klias Peninsula which is known as a firefly watching hotspot in Sabah. A total of four firefly species are found in Klias Peninsula, namely *Pteroptyx tener* Olivier, *Pteroptyx malacca* Gorham, *Pteroptyx valida* Olivier, and *Pteroptyx bearni* Ballantyne. *Pteroptyx tener* is the dominant species in both Weston and Garama rivers while *Pteroptyx bearni* is the dominant species in Teratak River. The overall sex ratio on the display trees in Klias Peninsula was significantly biased towards the male. Seven mangrove species were selected as display trees by the congregating fireflies, particularly *Excoecaria indica* L. (Family Euphorbiaceae), *Hibiscus tiliaceus*, *Nypa fruticans*, *Rhizophora apiculata*, *Avicennia alba*, *Excoecaria agallocha* L., and *Sonneratia alba* J. Smith (Family Lythraceae)-IUCN Red List. Information on the display tree species provides indispensable information for conservation and rehabilitation purposes while information on the *Pteroptyx* firefly species composition and abundance can be used as reference to track the spatial and temporal variation of firefly communities.

Keywords: Congregating fireflies, Klias Peninsula, Ecotourism, *Pteroptyx tener*, *Pteroptyx malacca*, *Pteroptyx valida*, *Pteroptyx bearni*, Display trees

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Introduction

Congregating fireflies from the genus *Pteroptyx* are primarily associated with the aquatic-terrestrial ecotone at the edge of mangrove forests. Their bioluminescence ability and aggregative behaviour that light up mangrove trees never fail to fascinate whoever has the opportunity to see this natural phenomenon. These congregating fireflies also provide benefit to local communities involved in ecotourism activities. At the same time, contemporary anthropogenic activities and global climate change are expected to result in various unprecedented ecological impacts on mangrove ecosystems as well as the survival of these fireflies. There is a remarkable decline in the abundance of the congregating firefly observed in Kampung Kuantan, Selangor (Nallakumar, 2003). The observation in Peninsular Malaysia warns us to prepare for rapid decline of this natural capital if it is not managed in a sustainable manner. Despite their economic importance for ecotourism purposes, there is inadequate research carried out to document the current status of *Pteroptyx* fireflies in Klias Peninsula which is one of the firefly watching hotspots in Sabah. Furthermore, it is unclear how the congregating fireflies' population might respond to the current ecotourism practices in Klias Peninsula. The knowledge gained from this study might potentially act as a reference for future comparisons to determine spatial-temporal variations of the firefly communities in this area. In order to sustain and conserve the congregating firefly population in their natural habitat, their diversity and ecological information must be acquired. For these reasons, this study was carried out to determine the diversity of *Pteroptyx* fireflies and their display trees in Klias Peninsula.

Method and Materials

Study site and identification of display tree

Three rivers that are known to have high population of *Pteroptyx* fireflies were selected as sampling sites, namely Garama River, Teratak River and Weston River (Figure 1). Garama River lies within the centre of the Klias Peninsula. The river is 5.4 km long (N 05°24'37.32", E 115°31'54.54"), located in the Padas Damit Forest Reserve while parts of the river flows outside the forest reserve. Teratak River (N 05°19'38.9"; E 115°31'06.7"), located within the Padang Teratak wildlife sanctuary was also selected as one of the three sampling sites. Weston River (N 05°11'37.82", E 115°34'38.54") flows towards a wide estuary and the riverine is surrounded by mangrove vegetation and nypa palms. Field sampling was carried out from January 2015 to August 2015. There were five sampling occasions in each river.

A total of 15 display trees were selected in each river for sampling purposes (selected display trees were indicated by red dots on Figure 1). The display trees where the congregating fireflies perched on were identified to species level.

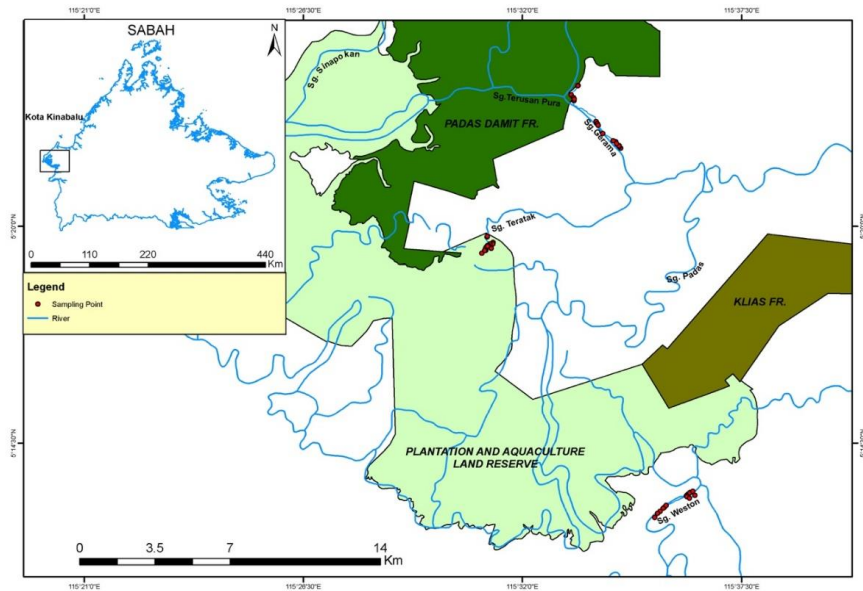


Figure 1. Map presenting three sampling sites, namely Sg. Garama, Sg. Teratak and Sg. Weston. The blue line indicates the river structure and red spots indicate the sampling sites in different rivers.

Firefly diversity assessment and statistical analysis

Visual estimation technique was utilized to determine the firefly density on each display tree by referring to modified percentage cover comparison chart employed from “Field Manual for Describing Terrestrial Ecosystems: Land Management Handbook number 25, 1998, from British Columbia Ministry of Environment, Lands, and Parks” (Province of British Columbia, 1998). Firefly specimens were collected through net sweeping technique for two minutes on each individual display tree. Firefly species identification was done by referring to the taxonomy description published by Ballantyne & Lambkin (2013). Temporal variation on the abundance of fireflies between sampling occasions was compared by Kruskal-Wallis *H*-test (Mahadimenakbar et al., 2007). The abundance of male and female fireflies was analysed using the Mann-Whitney non-parametric *U*-test.

Results

Firefly diversity and abundance

Approximately 1,750 individuals representing four species were recorded from the three sampling rivers (Garama River, Teratak River and Weston River). Weston River exhibited the highest abundance while Garama River had the lowest (Figure 2). Kruskal-Wallis test showed the abundance of fireflies collected at all stations of Weston River were significantly different among the five sampling occasions ($H = 11.88$, $d.f. = 4$, $p < 0.05$). However, there were no significant variations ($p > 0.05$) observed in Garama River and Teratak River.

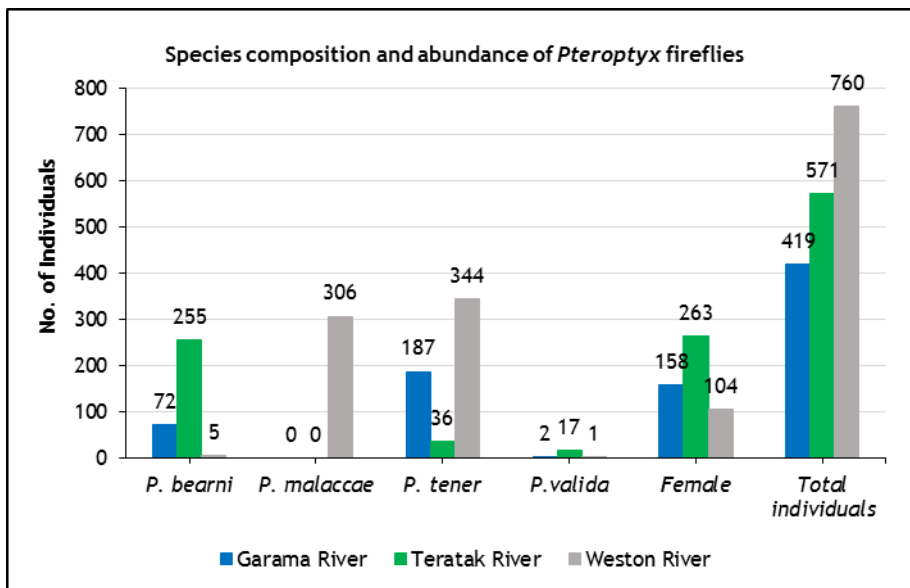


Figure 2. Species composition and abundance of *Pteroptyx* fireflies in Garama River, Teratak River and Weston River.

Male-female composition

Of the 1,750 firefly individuals collected (all species combined), 1,225 individuals (70.0 %) were male while 525 (30.0 %) were female. Results from the Mann-Whitney U -test showed that abundance of males was significantly higher than females in all samples (Mann-Whitney $U = 6162.0$, $Z = -7.814$, $p < 0.05$). Except for Teratak River that had almost a 1: 1 sex ratio, both Garama and Weston rivers showed that the male abundance was significantly higher than that of the female ($p < 0.05$) (Table 2).

Table 1: Sex composition and Mann - Whitney *U* test result from Garama River, Teratak River and Weston River.

	Overall	Garama River	Teratak River	Weston River
Male	1225 (70.0 %)	261 (62.3 %)	308 (53.9 %)	656 (86.3 %)
Female	525 (30.0 %)	158 (37.7 %)	263 (46.1 %)	104 (13.7 %)
Male-Female Ratio	2.33 : 1	1.65 : 1	1.17 : 1	6.31 : 1
Mann - Whitney <i>U</i>	6162.0	449.5	1126.5	492.5
Z-score	-7.814	-2.845	-1.169	-8.103
Sig. <i>P</i>	0.000	0.004	0.242	0.000

Coverage on display trees

Fifteen display trees with high flashing visibility were selected in Garama River, Teratak River and Weston River. The percentage cover of fireflies on selected display trees in Garama River was within the range of 0.5 to 5 %, Teratak River within the range of 0 to 3 %, and Weston River ranged between 0 to 5 %. It was found that fireflies in Weston River displayed their light on a single mangrove species, *Sonneratia alba*, with an average firefly coverage of 1.66 %. Interestingly, this plant species was not selected as a display tree by firefly communities at the Garama River and Teratak River. Both Garama River and Teratak River had a higher coverage of fireflies on plant species of *Excoecaria* (-2.1 %), and lower coverage on *Rhizophora apiculata* (<1 %).

Table 2. Percentage covers of fireflies (mean ± standard deviation) on main display mangrove plant species in Garama River, Teratak River, and Weston River

Plant Species	Garama River	Teratak River	Weston River
<i>Avicennia alba</i>		1.06 ± 0.64	
<i>Excoecaria agallocha</i>		2.13 ± 1.18	
<i>Excoecaria indica</i>	2.15 ± 0.89		
<i>Hibiscus tiliaceus</i>	1.88 ± 1.39		
<i>Nypa fruticans</i>	1.89 ± 1.40		
<i>Sonneratia alba</i>			1.66 ± 1.26
<i>Rhizophora apiculata</i>	0.75 ± 0.29	0.5 ± 0.71	

Discussion

Among the three sampling rivers, the highest species richness was recorded from Weston River. Four *Pteroptyx* firefly's species were found in Weston, namely *Pteroptyx bearni* Ballantyne, *Pteroptyx malacca* Gorham, *Pteroptyx tener* Olivier, and *Pteroptyx valida* Olivier. The dominant species in Weston River was *Pteroptyx tener* ($n = 344$, 52.4 %) but *Pteroptyx malacca* was just slightly lower in abundance compared to *P. tener* ($n = 306$, 46.6 %). On the

other hand, *Pteroptyx tener* was also the dominant species in Garama River ($n = 187$, 71.6 %). Studies carried out in Peninsular Malaysia show that *Pteroptyx tener* was the dominant species in several localities, namely Rembau-Linggi Estuary (Wan Jusoh et al., 2010a), Sepetang Estuary (Wan Jusoh et al., 2010b), Kampung Kuantan (Ballantyne and Menayah, 2000) and Sungai Johor (Norela et al., 2015; Sahara et al., 2017 (in press)). Interestingly, the dominant species in Teratak River was *Pteroptyx bearni* ($n = 255$, 82.8 %). Previous documentation suggested that *Pteroptyx bearni* was the dominant species across the mangrove forests of Sabah, especially in Paitan (Chey, 2006), Garama River (Mahadimenakbar et al., 2007), Sepilok (Chey, 2008), Tuaran (Chey, 2009), Pulau Sakar (Chey, 2011). In addition, *P. bearni* was also recorded in Kerteh River at Terengganu (Wan Jusoh et al., 2011). Hence, *P. bearni* is not endemic to Sabah. This indicates that Klias Peninsula harbours an interesting species composition of *Pteroptyx* fireflies.

Combining the result from current study with findings from Mahadimenakbar et al. (2007), the data indicated that the *Pteroptyx valida* is comparatively rare in Klias Peninsula. Surprisingly, *Pteroptyx malacca* that was previously documented in Garama and Teratak Rivers (Mahadimenakbar et al., 2007; Foo & Mahadimenakbar, 2015) is not recorded in this study. This could not be due to seasonal emergence because a large population of this species was found in Weston River around the same period. The temporal fluctuation of *Pteroptyx* fireflies was tested by Kruskal-Wallis H -test and statistical analysis determined significant temporal variations of firefly abundance in Weston River ($H = 11.88$, $d.f. = 4$, $p < 0.05$), but no significant ($p > 0.05$) temporal variations were observed in other sampling rivers. This result leads us to assume that the firefly population at the sampling sites is considerably stable in terms of abundance. In addition, this suggests that ecotourism that utilizes congregating fireflies as an attraction can operate throughout the year without worrying about a sudden sharp decline of the firefly population.

In terms of abundance, the male fireflies (70 %) outnumber the female fireflies (30 %) on the display trees (Table 1). However, this number does not emphasize the sex ratio within the entire mangrove habitat. The Mann-Whitney U -test revealed that the abundance of males was significantly higher than females in the entire sample (Mann-Whitney $U = 6162.0$, $Z = -7.814$, $p < 0.05$). Combining the findings from the current study and sex ratio results published by Koji et al. (2012), we suggest that the males are most probably the primary signaler that are retained on the display tree after mating, subsequently resulting in significantly higher male abundance on the display tree. Identifying

display trees species that are utilized by congregating fireflies is essential for the purpose of rehabilitation. In Garama River, four mangrove tree species were selected as display trees, such as *Excoecaria indica*, *Hibiscus tiliaceus*, *Nypa fruticans*, and *Rhizophora apiculata*. For Teratak River, three mangrove species were selected as display trees, namely *Avicennia alba*, *Excoecaria agallocha*, and *Rhizophora apiculata*. The display tree species selected by fireflies as their perching tree during the night are different between sites except for *Rhizophora apiculata* that was selected as the display tree in both Garama and Teratak rivers (Table 2). There is only one mangrove species selected as the display tree by *Pteroptyx* fireflies in Weston, that is the *Sonneratia alba*. The exact reason behind the selection of specific mangrove species at different localities remains unclear. We suspect the antimicrobial chemical secreted by certain mangrove species might act as a factor that governs the selection of display trees, for example the *Sonneratia alba* was proven to exhibit antimicrobial activities (Saad et al., 2012). The highest firefly coverage was identified on *Excoecaria indica* (2.15 ± 0.89 %) and *Excoecaria agallocha* (2.13 ± 1.18 %). We suspect that the leaf arrangement and large surface area that is suitable for mating are the main factors influencing the selection of these display trees.

Collectively, the findings from this study on the diversity of *Pteroptyx* fireflies can be used as a reference for future studies to determine the spatial-temporal variation of these congregating firefly communities in Klias Peninsula. The information on the display tree species in different rivers provides input for rehabilitation projects.

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