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Research article

The Distribution and Phenology of *Pteroptyx* fireflies (Coleoptera; Lampyridae) along Garama River, Sabah, Malaysia

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ABSTRACT. An ecological study of fireflies of the genus *Pteroptyx* was conducted along the Garama River, Klias Peninsula from April to June 2004. Fourteen stands of relatively good display trees were selected from the riverine vegetation along Garama River, about 8.4 km long. Sampling was conducted using an areal net at each tree (station) for two minutes in two consecutive nights for every two weeks. Altogether there were six sampling occasions. We found four *Pteroptyx* fireflies, namely *P. similis* Ballantyne, *P.tener* Olivier, *P. malaccae* Gorham and *P. valida* Olivier. Abundance of fireflies varied significantly from one station to another on each sampling occasion (Kruskal-Wallis $\chi^2 = 69.180$, d.f. = 13, $p<0.05$) but did not differ between the six sampling occasions (Kruskal-Wallis $\chi^2 = 1.607$, d.f. = 5, $p>0.05$). The cycle of the moon was found to have no significant influence on fireflies abundance (Mann-Whitney U = 3346.00, Z = -0.579, $p>0.05$). Males fireflies were significantly more abundant than females in the ratio of 60% / 40% (Mann-Whitney U = 12307.5, Z = -2.036, $p<0.05$) for the entire samples.

Key words: firefly, *Pteroptyx*, Klias Peninsula, Borneo.
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INTRODUCTION

Fireflies belong to the order Coleoptera under the family Lampyridae (Atkins, 1979). This family consists of 1,891 species in 100 genera (Lloyd, 1978) including 4 fossil species (Suzuki, 1997). Fireflies are commonly being categorized as nocturnal insects, but some are diurnal and others have both nocturnal and diurnal characteristics (Suzuki, 1997). Fireflies are also well-known as luminescent insects for their capability to emit light (Harvey, 2000). Many firefly taxonomists place the genus *Pteroptyx* in the subfamily Luciolinae (e.g. Ballantyne, 2001). Fireflies of this genus have caught the attention of researchers because these fireflies are diverse in term of their morphology and behaviour.

In terms of distributions, the *Pteroptyx* populations can be found in Southern Asia and west Pacific from east India to Thailand, Malaysia, Indonesia and the Philippines (Mastellar, 1997) and also around Australasian countries such as Papua New Guinea (Ballantyne, 1987) and Australia (Ballantyne & Lambkin, 2000). In the region of South East Asia, more that 20 species of fireflies from this genus have been recorded so far (Azhar, 1994).

Populations of fireflies are not restricted to riverine forest only but can also be found in other forested areas (Ballantyne & Lambkin, 2000) and open areas such as natural grassland (Ballantyne & Buck, 1979). There are two common types of firefly display behaviour; those that fly and flash solitarily, and those that congregate in mass to form colonies on display trees. Some colonies can even flash synchronously. Solitary fireflies usually can be found in forested areas and open areas (Viviani, 2001) while grouping fireflies generally can be found on trees which grow on the banks of rivers (Buck & Buck, 1978). In tropical areas, studies on habitats of fireflies are more concentrated on species that congregate on display trees (Buck & Buck, 1978; Azhar, 1994).

At present, only fireflies from the genus *Pteroptyx* are known for their species number in Malaysia. Ballantyne (2001) has recorded eight species from this genus to occur in Malaysia namely *Pteroptyx tener*, *P. malaccae*, *P. valida*, *P. bearni*, *P. decolor*, *P. asymmetria*, *P. gelasina* and *P. similis*. There is very little information about other genus in Malaysia due to the lack of studies. Nevertheless, distributions of few genera like *Luciola*, *Lychnuris* and *Colophotia* have been recorded in Peninsular Malaysia.

In Sabah (Northern part of Malaysian Borneo), five species of fireflies of the genus *Pteroptyx* have been recorded so far. On the west coast, *Pteroptyx tener*, *P. malaccae* and *P. gelasina* were found along the Sipitang River, in Sipitang (Ballantyne, 2001). While populations of *P. valida* were found along the Garama River in Beaufort and *P. gelasina* in Kudat (Ballantyne, 2001). On the east coast, only populations of *P. tener* have been recorded i.e., along Kinabatangan River in Sandakan (Mahadimenakbar *et al.*, 2003).

This paper is focused on *Pteroptyx* fireflies along the Garama River in Sabah. The objectives are; (1) to study the species composition of fireflies, (2) to see if there are any changes in their abundance from month to month, and (3) to investigate the influence of moon cycle on firefly abundance.

Materials and methods

Study site

The Garama River (5°10'-5 °30'N, 115°20'-115°40'E) is located in the district of Beaufort on the west coast of Sabah (Fig. 1). Garama is a tributary of the Klias River, with a length of approximately 8.4 km. The river runs through two villages i.e., Kampung Gimba and Kampung Garama. The main vegetations that grow along the riverbanks on the upper part of the river are riverine forests dominated by *Ficus* sp. and *Excoecaria indica*. The lower part is dominated by *Rhizophora* and *Bruigera* species. The forest in the surrounding area is very scenic and has a diverse hence, making this area a popular nature tourism site on the west coast of Sabah. Bernard (1997) found that the riverine forests on the riverbanks are habitat to several species of primate i.e., proboscis monkey (*Nasalis larvatus*), long-tailed macaque (*Macaca fascicularis*) and silver leaf monkey (*Presbytis cristata*).

Fourteen display trees were chosen along the riverbanks (Fig. 2). These trees were used as sampling stations throughout the sampling periods. Only trees with high densities of fireflies were selected as sampling stations. List of the species and vernacular names of each tree are shown in Table 1.

Samplings were carried out from April until June 2004 in two consecutive nights in every two weeks interval. There were altogether 6 sampling occasions. Samplings on the first night of every sampling occasion were done

going up-stream from station 1 up to station 14. On the following night, sampling was conducted in the reverse order. In each sampling month, the first sampling was done during moonless nights while the second sampling was done during full moon nights. The sampling was done from 7:00pm until 11:00pm *via* boat ride along the riverbanks. An areal net was used to collect as many as possible specimens at every station for 2 minutes. Specimens for each station were kept in separate plastic bags. These were kept in a refrigerator until all of the collected specimens were killed.

Statistical analysis

To analyse the effect of moon cycle on the distribution of fireflies, Mann-Whitney non-parametric *U*-test was use i.e., by comparing samples collected during moonless nights with samples collected during full moon nights. To compare abundance of fireflies between stations and also between the six sampling occasions, Kruskal-Wallis test was used. Mann-Whitney non-parametric *U*-test was used to compare the abundance of male and female fireflies.

RESULTS

Species of fireflies

Four species of fireflies were found in Garama River, namely *Pteroptyx similis*, *P. tener*, P. *malaccae* and *P. valida*. *P. similis* was the most common species and was found at all stations. *P. tener* was collected from station 3, 4, 5, 6, 7, 8, 10, 11, 13 and 14. *P. malaccae* was collected from station 5, 6, 7, 8 and 11 while *P. valida* was only collected from station 11 and 12. Different species of fireflies can be found on the same display tree. In stations 4, 5, 6, 7, 8, 11, 12, and 14, more than one species of fireflies were recorded. Four species of fireflies were recorded from station 11, three species from station 5, 6 and 7, and two species from station 4, 13 and 14. For the other stations (1, 2, 3, 9, and 10), only one species of firefly was recorded.

Firefly abundance

From this study, 2,216 firefly individuals were collected during the six sampling occasions. *P. similis* has the highest abundance with *1,776 individ*uals. This was followed by

Table 1: Number of sampling stations, scientific and vernacular names of each tree observed at the study area in Garama

Station	Species	Vernacular name
1	*Rhizophora apiculata*	Bakau Tunjang
2	*Rhizophora apiculata*	Bakau Tunjang
3	*Rhizophora apiculata*	Bakau Tunjang
4	*Rhizophora apiculata*	Bakau Tunjang
5	*Rhizophora apiculata*	Bakau Tunjang
6	*Rhizophora apiculata*	Bakau Tunjang
7	*Rhizophora apiculata*	Bakau Tunjang
8	*Ficus binjamina*	Ara Pokok
9	*Nypa fruticans*	Nipah
10	*Acrostrichum aureum*	Piai
11	*Glochidion* sp.	Sesaka
12	*Hibiscus tiliaceous*	Pokok Baru
13	*Excoecaria indica*	Gurah
14	*Excoecaria indica*	Gurah

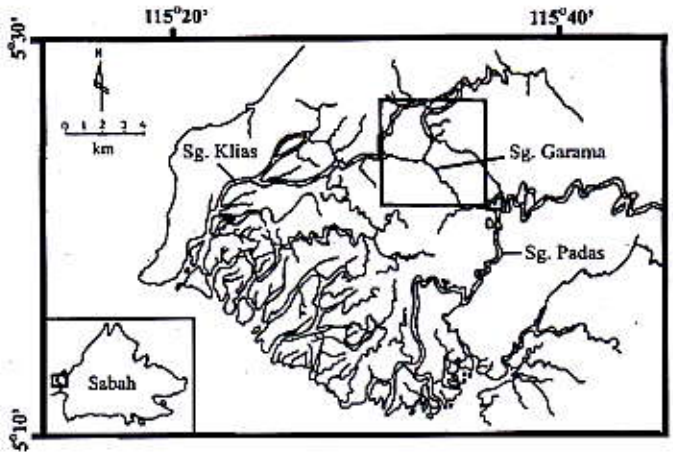

Figure 1: Map of Garama River on the west coast of Sabah

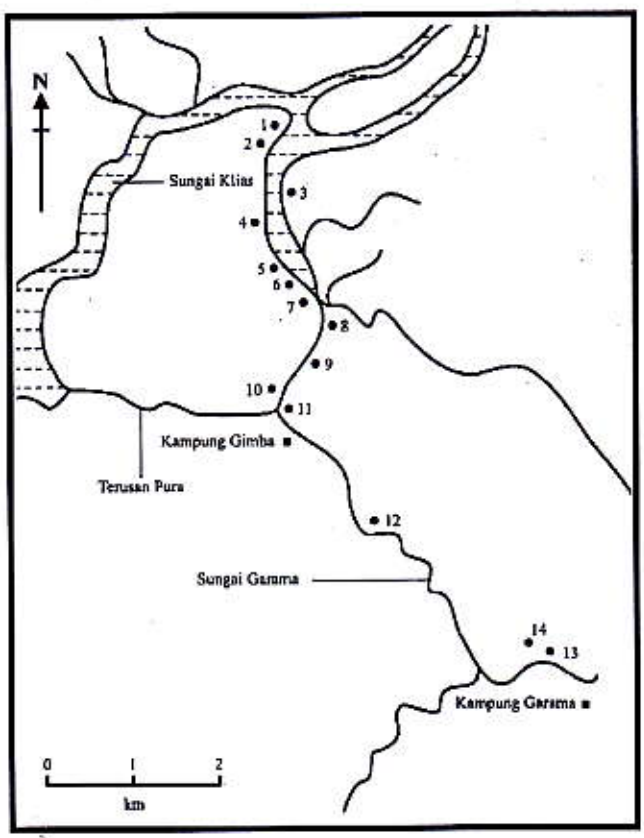

Figure 2: Locations of sampling stations (• #) along Sungai Garama

P. tener (376 individuals), *P. malaccae* (57 individuals) and *P. valida* (7 individuals). Stations 11 and 13 showed the highest abundance of fireflies for every sampling while stations 9 and 14 showed the lowest abundance for every sampling throughout the sampling period. Kruskal-Wallis test showed that abundance of fireflies at night was significantly different between stations for each sampling occasion ($\chi^2 = 69.180$, d.f. = 13, $p<0.05$). However, abundance of fireflies collected at all stations were not significantly differ between the six sampling occasions (Kruskal-Wallis $\chi^2 = 1.607$, d.f. = 5, $p>0.05$).

Generally, abundance of fireflies was relatively highest at station 13, located at the upper part of the river and followed by station 11 which was located halfway up the river. However, the result from Mann-Whitney *U*-test did not show any differences in terms of individual numbers between station 11 and 13 and also between station 6 and 7 ($p>0.05$). Conversely, individual numbers of fireflies at stations 11 and 13 were significantly higher compared to station 1 to 5 (lower part), station 8 to 10 (middle part) and station 12 and 14 (upper part) ($p<0.05$). Abundance at station 6 and 7 were also relatively higher. Individual number at station 6 was significantly higher than at station 3, 9, 10 and 14, while individual numbers at station 7 was significantly higher than station 14 ($p<0.05$). However, individual numbers of fireflies from station 6 and 7 were not significantly different from each other ($p>0.05$).

Effect of moon cycle on the abundance of fireflies

Sampling was made on six moonless nights and six nights during full moon. In general, abundance of fireflies was higher during moonless nights (1,220 individuals) compared with nights with full moon (996 individuals). However, results from the Mann-Whitney *U*-test showed that there was no significant difference in terms of abundance of fireflies between samplings made on moonless nights (84 nights) with nights with full moon (84 nights) (Mann-Whitney $U = 3346.00$, $Z = -0.579$, $p>0.05$).

Male-female composition

From 2,216 firefly individuals collected (all species combined), 1,332 individuals (60.1%) were males while 884 (39.9%) were females. Result from Mann-Whitney *U* test showed that abundance of males were significantly higher than females in the entire samples (Mann-Whitney $U = 12307.5$, $Z = -2.036$, $p<0.05$).

DISCUSSION

Firefly, populations can be found almost all along the Garama River. They were not only found on tall trees, but also on shrubs that grow on the riverbanks. The formation of firefly colonies on the riverine vegetations would meet their communication and copulation needs (Buck & Buck, 1966) because this would broaden the visibility of their light signals, compared to if the colonies were formed inside thick bushes. Furthermore, the reflections from the river would help to intensify their light signals.

Generally, *Pteroptyx* populations could be found on riparian (partially submerged) vegetations (Buck & Buck, 1966). This not only serves as their communication and copulation purposes but to some extent it also act as refuge from predators (Ohba & Wong, 2004). During a survey prior to the sampling period, we found that fireflies along Garama River formed clustered populations. Each cluster may be up to four colonies. The existence of such colonies was also recorded by Zaidi *et al.* (2004) along Sepetang River in Perak, Peninsular Malaysia. However, unlike in Sepetang River where colonies were only formed on *Sonneratia caseolaris* stands,

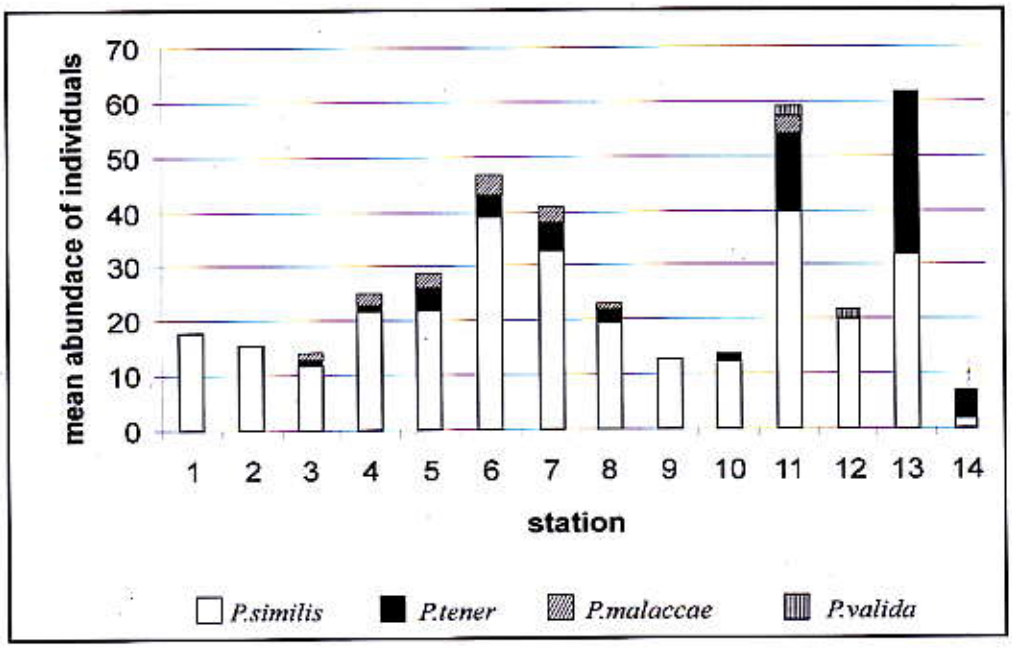

Figure 3: Mean abundance of individuals of each species of fireflies collected at 14 study stations for the entire sampling.

fireflies in Garama River also formed their colonies on other trees such as *Rhizophora apiculata*, *Excoecaria indica* and *Nypha fruticans*.

Populations of fireflies stayed on the same display trees. There were only some occasions where fireflies switched to trees that were not occupied before. Ohba and Wong (2004) suggested that this may be due to the difference in density and intensity of light signals emitted by neighbouring populations or due to environmental factors. However, we did not study the change of temperature and humidity during the short study period.

In Garama River, colonies of fireflies can be found on different tree species. At the lower part of the river where mangrove vegetations were found, colonies of fireflies can be seen on *Rhizophora apiculata*, *Bruguiera parvifolia* and *Nypa fruticans*. Conversely, at the upper part of the river where riverine forests were found, colonies can be seen on riparian vegetations such as *Excoecaria indica*, *Ficus binjamina* and *Hibiscus tiliaceous*.

According to Azhar (1994), the height of trees would influence the formation and density of the colonies. Usually, more individuals will concentrate at the middle part of the tree, about three metres high from water level. In Garama River, colonies were usually seen on trees of which the height was less than 10 m. The middle part of a tree is the best position for fireflies to aggregate since this part is free from emerging tide and not severely interrupted by wind (Azhar, 1994).

Another factor that could influence the formation of firefly colonies is the density of leaves on the trees (Ohba & Sim, 1994). In this study, colonies were commonly found on trees

with thick leaves such as *Rhizophora apiculata*, *Exoecaria indica* and *Ficus binjamina*. Trees with thick leaves provide more perching spaces and this allows more fireflies to perch on a single tree, thus intensifying the light signal (Ohba & Wong, 2004).

From the present study, there were no differences in terms of fireflies' abundance throughout the sampling occasions. This could be due to the short sampling period (April-June 2004). Although, Buck and Buck (1978) reported that population of fireflies could fluctuate due to seasonal changes, this factor could not be studied since the study period was only three months.

In general, stations with high abundance of fireflies will always maintain their condition. On the other hand, stations with low abundance will continuously have low populations. In this case, stations with high firefly abundance were able to sustain their populations. The survival of a population is greatly dependent on the ability of its habitat to support its life cycle (Ohba & Sim, 1994).

In this study, stations 6, 7, 11, and 13 were the stations which had high mean abundance of fireflies. These stations had relatively open environment and were close to natural grassland. Open environment would allow fireflies to expand their light communication while tall grass serve as an important refuge for the larvae and adult fireflies during daytime. Additionally, grassland is an important place for females to lay their eggs after copulating with males (Ohba & Sim, 1994). Thus indirectly, open areas with natural grassland are important for sustaining firefly populations.

Abundances of fireflies at each station were not significantly different from station 1 until 10, but, the last four stations showed that abundances were significantly different from one station to another. This is an indication that the continuous population from station 1 to 10 was one of the factors that made no difference of abundance from one station to the other. Trees that grew side by side may have allowed colonies to spread continuously and not only concentrating on certain trees (see Buck & Buck, 1978).

The conditions were a bit different from station 11 until 14 where colonies were far apart. These stations were located in Kampung Garama, where human disturbances on the natural vegetation were obvious. Disturbance of riverine environment would considerably reduce firefly populations (Ohba & Wong, 2004). When colonies were far apart, fireflies would tend to concentrate in certain colonies. This is why the abundances were significantly different from one station to another station. Stations 11 and 13 were located in relatively undisturbed areas and that would explain why populations were high here.

Records also showed that in a colony of fireflies, male individuals tend to be more abundant than females. For example, populations of *P. cribellata* and *Luciola pupilla* in Papua New Guinea had 60-70% males, and in Thailand, 70% of *P. malaccae* collected were males (Buck & Buck, 1968). Since the flashing behaviour on display trees is actually initiated by the males (Buck & Buck, 1978), this can be a factor why more males were caught during this study. However, for stations 1, 2 and 8, the abundances of females were higher than of males. This could be due to the males having moved to a more crowded colony or the females being the ones that did not leave the display tree from the previous night (Ohba & Wong, 2004).

CONCLUSIONS

Garama River has four of the five species of *Pteroptyx* recorded from Sabah. Only *P. gelasina*, which was collected in Sipitang River

in 1970, has not been recorded so far in this area (Ballantyne, 2001). In term of conservation, this area should be conserved as it serves as a natural habitat for these fireflies. At present time in Sabah, there are very few places where we can see large population density of congregations of fireflies flashing and some even show mass synchrony among them like in Klias Peninsula. Almost all other natural habitats have been wiped out for development, such as in Likas area. There is a great potential in terms of nature tourism in Klias Peninsular where firefly watching can be added as night activity for tourists who come to the place to watch the nature in the daytime.

Although less fireflies can be seen during full moon, the occurence of moon actually has no effect in terms of firelies abundance. This simply means that fireflies were still exist on the display tree during full moon, only that their lights were less visible then. Most fireflies that were seen flashing were males attracting the females. The composition of males-females were 60% / 40%. There were also no signs of seasonal effects as the abundances of fireflies collected were not different from one sampling occasion to the other.

More studies should be carried out to investigate the life cycle of fireflies, their habitat preferences and disturbances that may lead to the extinction of this wonderful group of insects.

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