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Research Article

Diversity of Fireflies (Coleoptera: Lampyridae) of Sungai Teratak, Sabah, Malaysia

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Abstract

This study was conducted to investigate the diversity and possible factors that structure the distribution and abundance of fireflies along Sungai Teratak. Six sampling occasions were conducted from March to April 2014 where ten display trees were chosen as sampling stations. Species abundance and composition of fireflies and other insects were assessed by visual assessment and sampling with aerial net. Four *Pteroptyx* species were discovered with difference in relative abundance, namely *Pteroptyx bearni* (93.1 %), *Pteroptyx valida* (2.2 %), *Pteroptyx malaccae* (3.9 %), and *Pteroptyx tener* (0.8 %). The results of Shannon-Weiner index, H' was 0.316, and Simpson's index of diversity with the value of 0.131 indicated that the firefly at Sungai Teratak was low in diversity. Abundance of fireflies varied significantly between the six sampling occasions (Kruskal-Wallis X^2= 15.382, *d.f.*=5, $p<0.05$) but shows no difference in abundance between the ten display trees (Kruskal-Wallis X^2=14.181, *d.f.*=9, $p>0.05$). The abundance of fireflies was found to be positively correlated to the abundance of other insects (Pearson's correlation $r=0.740$, $p<0.05$). Comparison of fireflies' abundance during full moon and new moon nights showed no significant difference (Mann-Whitney *U* = 46.00, z =-0.326, $p>0.05$ and Mann-Whitney *U*=25.50, z=-1.945, $p>0.05$). Although the abundance of male (n=232) fireflies outnumbered the female (n=149), statistical analysis proved no significant difference between both groups (Mann-Whitney *U*= 8.50, z=-1.529, $p>0.05$). The mangrove trees being colonized by fireflies at Sungai Teratak was mainly from the species *Avicennia alba*.

Keywords: Firefly, Lampyridae, *Pteroptyx*, Sabah and Klias Peninsular

Introduction

Firefly belongs to the order Coleoptera, which is the largest order of insects (Mckenna & Farrell, 2009). The firefly using flashing signals produced in abdominal light organs to engage in complex male-female dialogue before mating, which makes the Lampyridae stand out from other beetles. The grandest of all flashing panoramas in the world occur in tidal swamps of mangrove and nipah palm in Southeast Asia, where species of the bent winged

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fireflies (genus *Pteroptyx*) gather by thousands on the leaves of mangrove trees. Firefly watching has become a lucrative business in Malaysia, including Sabah due to their high abundance when they congregate at mangrove trees. Places with high congregating firefly populations have become ecotourism destinations, for example the mangrove forest at Kg. Kuantan (Ballantyne & Menayah, 2000), Sungai Kinabatangan (Mahadimenakbar et al., 2004), Sungai Garama (Mahadimenakbar et al., 2007) and Sungai Paitan (Chey, 2006).

The problem with protecting insects is that it is hard to know how many species there are in the ecosystem, thus making conservation efforts almost impossible without knowledge on species richness and density. For conservation purpose and appreciation of the full biodiversity of a taxon in an area, an estimated asymptotic number of interest species is desirable. To date, there is serious lack of detailed scientific documentation that has provided sufficient information on firefly distribution, abundance and species richness in Sungai Teratak which is a growing site for ecotourism. This study was established to investigate the species richness and its abundance in a mangrove forest reserve at the coast of Sungai Teratak as well as the interaction between fireflies and their display tree.

Materials and Methods

Location of research

Padang Teratak, which is a wildlife sanctuary under the proposed new amendments to the Fauna Conservation Ordinance is about 100 hectares in size, and is located near the town of Beaufort in south-western Sabah. This current study was conducted in Sungai Teratak (05°19'38.9"N; 115°31'06.7"E) located in Padang Teratak. Sungai Teratak is surrounded by mangrove forests and has the potential to become a hotspot for firefly watching.

Field observation

Field observation was carried out from March to April 2014. Field observation and sampling were carried out according to the phase of the moon. There were 3 sampling occasions in each month which were the new moon, waxing gibbous, and during full moon. There were in total six night-time sampling occasions and two day-time vegetation profile observations. The main display trees and the vegetation near the main display trees were identified to species level. Sampling in Sungai Teratak requires a boat due to difficulty in accessing the firefly habitat on foot. Sampling time started from 8.00pm. until 10.30pm.

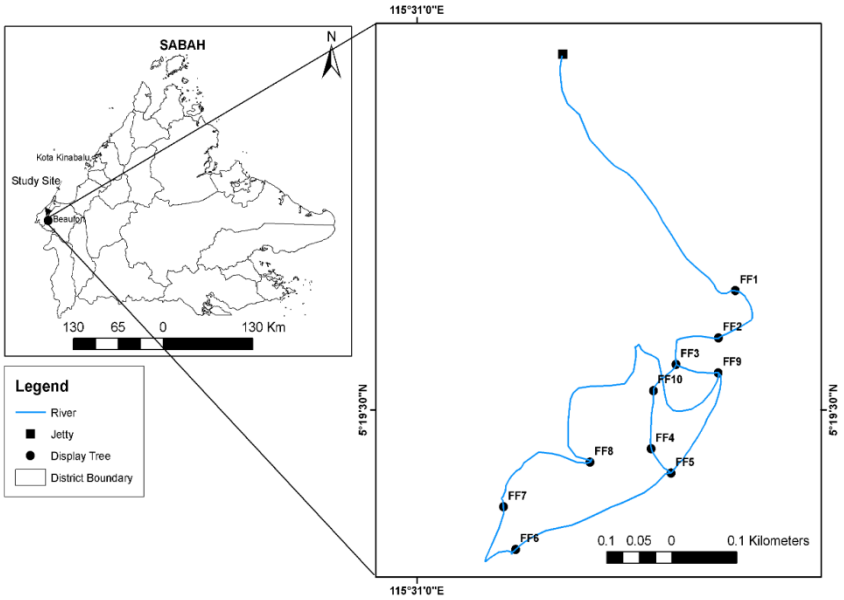

Figure 1. Map of Sungai Teratak. The blue line indicates the structure of the river. This figure shows the distribution of firefly display trees.

It was interesting to note that during the survey of fireflies at Sungai Teratak on 9th April, a natural phenomenon caused by a species of moth was witnessed by chance. *Avicennia alba* (Avicenniaceae) which is the dominant mangrove species at Sungai Teratak encountered mass defoliation by larvae of the moth, *Hyblaea puera* (Lepidoptera : Hyblaeidae).

Firefly abundance and species richness assessment

According to Wan Faridah et.al (2010b), the term "Display Section" is employed to represent continuous spread of firefly colonies. Ten display trees with the highest firefly density were selected for sampling and the proper location were recorded using a GPS receiver (Garmin GPSmap 76CSx). One display tree from each display section was selected for sampling and a ribbon about 1 metre in length was tied on the sampling tree. Firefly density was measured by using a visual comparison chart. Visual estimations of abundance percentage of fireflies on each display trees were made by using a 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". Firefly

specimens were collected by net sweeping for two minutes in each individual display tree. Species identification was done by referring to the taxonomy descriptions published by Ballantyne & Lambkin (2013).

Statistical analysis

Simpson and Shannon-Wiener indices were employed to measure the diversity of fireflies at Sungai Teratak. Pearson's correlation was used to test whether there is correlation between firefly species and non-firefly insect species on the display trees. The abundance of male and female fireflies was compared by using Mann-Whitney non-parametric *U*-test. The effect of the moon phase on the abundance of fireflies was analysed using the Mann-Whitney non-parametric *U*-test. The abundance of fireflies between stations and also between six sampling occasions was compared using the Kruskal-Wallis *H*-test. Statistical tests were performed using $SPSS^{®}$ software Version 20.0 from International Business Machines Corporation and by manual calculation to ensure the accuracy of the output.

Results

Firefly species richness and abundance

Four species of *Pteroptyx* fireflies were found in Sungai Teratak, namely *Pteroptyx bearni, Pteroptyx tener, Pteroptyx malaccae* and *Pteroptyx valida*. The most common species was *Pteroptyx bearni* (previously known as *P. similis*) which was encountered at all display trees. *Pteroptyx valida* was collected from display trees 5, 7, 9, and 10. *Pteroptyx malaccae* was recorded from display trees 4, 6, and 10. While *Pteroptyx tener* was collected from display trees 6 and 7. Results show that display trees 4, 5, 6, 7, 9, and 10 housed more than one species of firefly. A total number of 381 individuals of fireflies were sampled, the most common species was *Pteroptyx bearni*, with 216 individuals (93.1 %) followed by *Pteroptyx malaccae* with 9 individuals (3.9 %), *Pteroptyx valida* with 5 individuals (2.2 %) and *Pteroptyx tener* with 2 individuals (0.8 %).

Diversity of fireflies

From the calculation using the Shannon-Weiner Diversity index, H' was 0.316. This value shows that Sungai Teratak has low firefly diversity. To ensure the reliability of the value, Simpson's index of diversity was also used. The value of Simpson's index of diversity was 0.131, which also indicated Sungai Teratak's low firefly diversity.

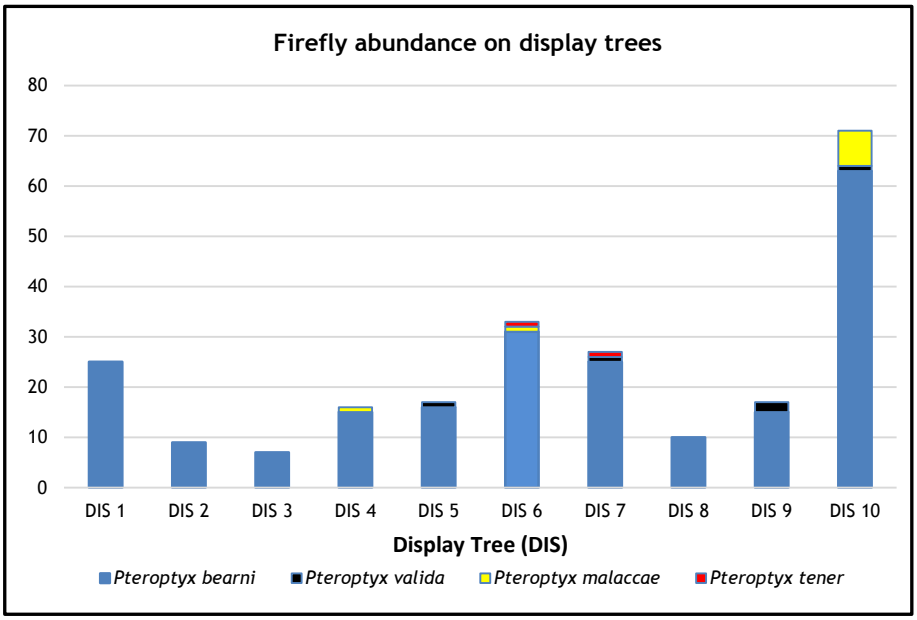

Figure 2. Species composition and abundance of fireflies in Sungai Teratak, Padang Teratak, Sabah. The X- axis indicates the number of display trees where the fireflies were collected and Y- axis indicates the abundance of fireflies.

Firefly abundance between sampling occasions and sampling stations

Overall, stations 6 and 10 showed the highest abundance of fireflies, while stations 2 and 3 showed the lowest abundance. Abundance of fireflies at night was not significantly different between stations for each sampling occasion (Kruskal-Wallis H:X^2=14.181, df=9, p>0.05). However, abundance of fireflies collected at all stations was significantly different between the six sampling occasions (Kruskal-Wallis H:X^2=11.070, df=5, p<0.05,).

Other insect diversity and correlation with fireflies

During the study, a total of 918 individuals of other insects, representing 10 orders, were collected. The majority of other insects collected were members from the order Coleoptera (non-firefly Coleoptera, n=401, 43.68 %), Hemiptera (33.01 %) and Diptera (9.37 %), while abundance of other insects is shown in Figure 3. Pearson's correlation coefficient showed firefly abundance was positively correlated with the abundance of other insects (Pearson's r=0.74, p<0.05).

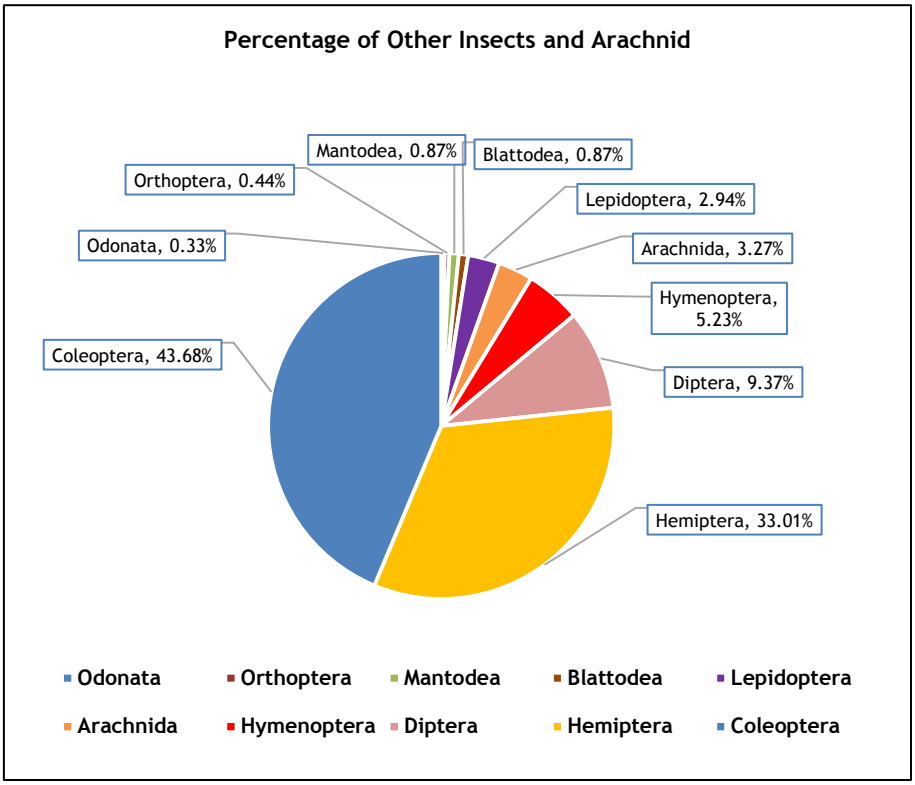

Figure 3. Percentage of other insect species abundance collected on the ten display trees in Sungai Teratak, Padang Teratak, Sabah between March to April 2014.

Male and female composition

From 381 firefly individuals collected (all species combined), 232 individuals (60.89 %) were male and 149 (39.10 %) were female. The abundance of male and female fireflies is shown in figure 4. The statistical data showed that there was no significant difference between the medians of the samples although the male fireflies were significantly more abundant (Mann-Whitney U = 8.5, z=-1.529, p>0.05).

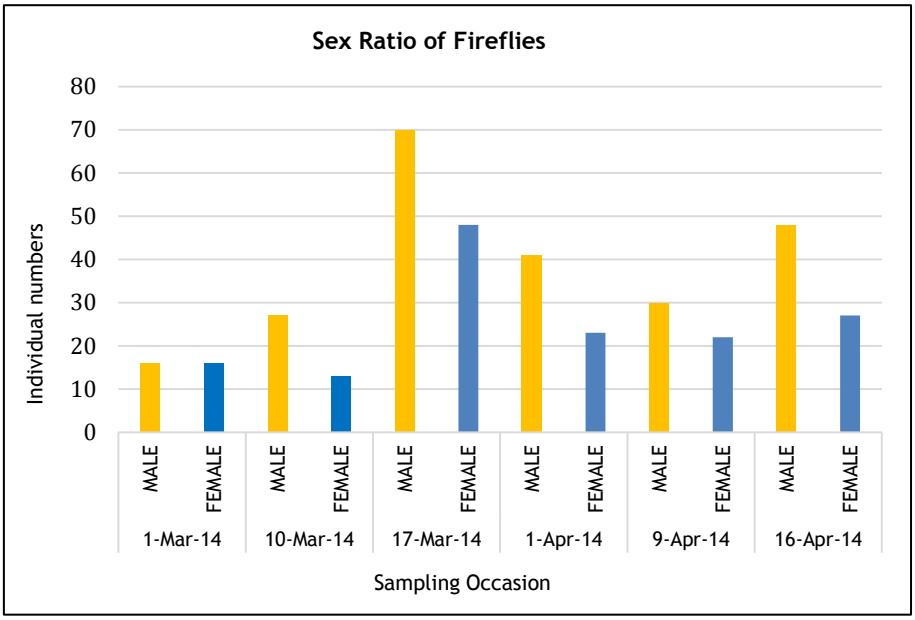

Figure 4. Sex ratio of fireflies collected at Sungai Teratak, Sabah.

Effect of moon phase on the abundance of fireflies

In order to analyse the effect of the moon phase on the abundance of fireflies, the Mann-Whitney non-parametric U-test was used. Comparison was done by using the data of visual observation of firefly abundance (percentage cover) during moonless nights (new moon) with the data recorded during full moon nights (Figure 5). The Mann-Whitney test in March indicated that there was no statistically significant difference between the medians of the samples (U=46, z=-0.326, p>0.05). Statistical tests in April also indicated that there was no statistically significant difference between the medians of the samples (U=25.5, z=-1.945, p>0.05). This showed that there was no statistical difference in abundance of fireflies on full moon and new moon nights.

Vegetation preference

A preliminary study of the vegetation profile was conducted at 10 locations along Sungai Teratak. A vegetation profile survey was done to determine what type of vegetation assemblages form the habitat of fireflies. From the day-time boat survey with GPS tagged points, the firefly colonies were observed to occur on the *Avicennia alba, Acrostichum aureum, Rhizophora*

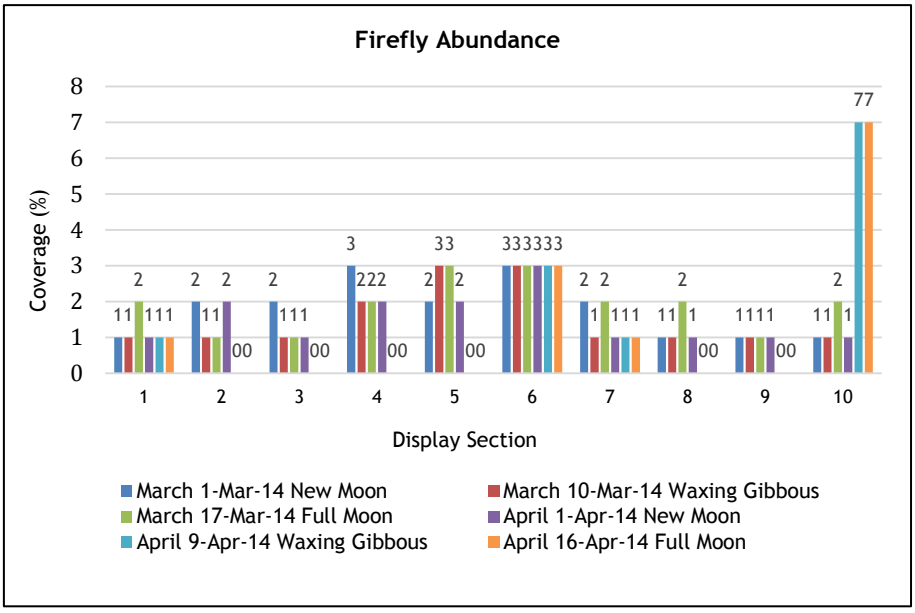

Figure 5. Abundance of fireflies in percentage cover.

apiculata, and *Nypa fructicans* assemblages. The main display tree where fireflies congregate at night was *Avicennia alba*.

Discussion

The dominant species of *Pteroptyx* fireflies in Sungai Teratak was *Pteroptyx bearni*. This was the same result as obtained by other researchers at different locations in Sabah (Chey, 2006; Mahadimenakbar et al., 2007; Chey, 2008; Chey, 2009). Statistical testing on diversity of fireflies at the study site shows that diversity is low (H'=0.316 & D=0.131). This was due to low species richness and the populations were dominated by one single species (*Pteroptyx bearni*). Several firefly species can coexist on the same display tree, while the flashing patterns of male fireflies differ in rate and duration in different species. This prevents the misinterpretation of courtship signals. By referring to Figure 4, the male fireflies outnumbered the female in a ratio of 6:4. This was because male fireflies continue to perch on the display tree after mating, while the female would fly to the muddy riverbank to oviposit.

Nocturnal behaviour varies as a function of light intensity, physiological processes and behaviour is subjected to alterations caused by circadian

rhythms, lunar cycles, as well as seasonal changes (Zimecki, 2006). Before any field observation and sampling was carried out, it was predicted that higher moon light intensity would directly affect the efficiency of firefly bioluminescence, thus reduce the overall abundance of fireflies during full moon nights. During the field observations on full moon nights, more fireflies can be seen flashing on their display trees, and together with statistical analysis, it can be concluded that moon light intensity has no influence on firefly abundance.

In this study, the correlation between abundance of fireflies and other insects was tested. Pearson's Correlation Coefficient shows strong positive correlation between abundance of fireflies and other insects. It was predicted that there are two main reasons contributed to this result. Firstly, the infestation of the main display tree (*Avicennia alba*) by larvae of *Hyblaea puera* caused mass migration of both fireflies and other insect species to certain unaffected display trees. This caused sudden increase of both firefly and other insect abundance on same display tree. The second reason which contributed to the positive correlation is believed to be related to the health of the mangrove trees. Healthier mangrove trees are known to have higher density of leaves, which increases the total surface area for insects to perch on and provide more shade that acts as refuge during the day. According to the study conducted by Wan Faridah et al. (2010), fireflies are known to select mangrove trees which are in healthy condition. A healthier display tree favour higher diversity and abundance of insects, and this could have resulted in a positive correlation between fireflies and abundance of other insects.

Most species are threatened by several factors, some of which are not known before detailed studies of their ecology. Land conversion and chemical pollution are known to cause decline in firefly abundance, while light pollution affects the distribution of fireflies and effectiveness of bioluminescence (Lloyd, 2006). The abundance of fireflies can be affected by biotic factors too, such as the snail population where the firefly larvae feed on. The snail population can be threatened by several factors, either by human activities or natural disasters. For example, the usage of fertilizer and pesticide can lead to water pollution, thus reduce the snail population. In addition, excessive nutrient level in the rivers or streams from agricultural run-off might trigger the growth of algal blooms, which in turn deplete the dissolved oxygen in the water bodies, and consequently also cause a decline in the population of snails. Further investigation is needed to determine the relationship between water quality and abundance of fireflies. Fertilizer should only be used with

care and a water quality monitoring system must be implemented to ensure the survival of the snail population that is crucial for the long-term existence of fireflies.

Conclusion

The firefly life cycle is dependent on the mangrove vegetation. There is a need to protect the many plant species that fireflies use in different life stages where they rely on different species of plants as refuge and food sources. Anthropogenic activities should be managed in a sustainable manner to reduce impacts on the firefly population. Light pollution has been considered as the most crucial factor which influences the distribution of fireflies. Artificial night lighting should be minimized in order to encourage maximum reproduction rates to ensure the long-term survival of fireflies. The elegance and beauty of fireflies should be preserved for future generations.

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References

Ballantyne LA, Lambkin CL. 2013. Systematics and phylogenetics of Indo-Pacific Luciolinae Fireflies (Coleoptera: Lampyridae) and the Description of new Genera. *Zootaxa* **3653(1):**1-162

Ballantyne LA, Menayah R. 2000. Redescription of the synchronous firefly *Pteroptyx tener* Olivier (Coleoptera: Lampyridae) of Kampong Kuantan, Selangor. *Malayan Nature Journal* **54(4):**323–328

British Columbia. Ministry of Environment, Lands, Parks, & British Columbia. Ministry of Forests. 1998. *Field Manual for Describing Terrestrial Ecosystems* (No. 25). Ministry of Environment, Lands and Parks.

Chey VK. 2006. Fireflies of Sungai Paitan. *Sepilok Bulletin* **5**:1-6

Chey VK. 2008. Fireflies of Sepilok. *Sepilok Bulletin* **9**:3-11

Chey VK. 2009. Fireflies of Tuaran. *Sepilok Bulletin* **10**:25-33

Lloyd JE. 2006. Stray light, fireflies, and fireflyers. In: Rich C, Longcore T. (Eds.). *Ecological consequences of Artificial Night Lighting*. Island Press, Washington

Mahadimenakbar MD, Hairul, HM, Mazidi AG. 2007. The Distribution and Phenology of *Pteroptyx* fireflies (Coleoptera: Lampyridae) along Garama River,Sabah, Malaysia. *Journal of Tropical Biology and Conservation*,**3**:1-9

Mahadimenakbar MD, Zulhazman H, Schilthuizen M. 2004. Conservation of fireflies (Coeloptera; Lampyridae) of the genus *Pteroptyx* in Sabah and their potential as nature tourism attraction. In: Mohamed M, Kusano T, Jensen SM (pnyt.). Biodiversity Conservation: *Forward Together*. Proceedings of the BBEC International Conference 2004, 24-26/02/2004, Kota Kinabalu: 135-136

McKenna DD, Farrell BD. 2009. Beetles (Coleoptera). In: Hedges SB, Kumar S. (Eds.). *The Timetree of Life*. Oxford University Press, Oxford.

Wan Faridah AWJ, Hashim NR, Ibrahim ZZ. 2010a. Distribution and abundances of *Pteroptyx* fireflies in Rembau-Linggi Estuary, Peninsular Malaysia. *Environment Asia:* 56-60

Wan Faridah AWJ, Hashim NR, Ibrahim ZZ. 2010b. Firefly distribution and abundance on mangrove vegetation assemblages in Sepetang estuary, Peninsular Malaysia. *Wetlands Ecology Management*,**18:**367-373

Zimecki, M. 2006. The lunar cycle: effect on human and animal behavior and physiology. *Postepy Higieny Medycyny Doswiadczalnej*. (Online), 2006; **60:** 1-7