
Research Article

What's flashing in Kadamaian? A Note on Fireflies (Coleoptera: Lampyridae) in Kadamaian, Sabah

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Abstract

A firefly survey was conducted in Podos, Melangkap Noriou and Pinolobu in Kadamaian, Kota Belud during the Borneo Geographic Expedition Kadamaian 2019. A total of 48 fireflies were collected representing at least seven species consisting mainly of *Luciola* spp. and a single individual of *Pyrocoelia* sp. larva. Identification reveals that two samples are potentially new records to Borneo; cf. *Aquilonia* sp. and *Medeopteryx* sp., and also *Luciola niah* as a new record for Sabah. Furthermore, four samples have unique morphological characters including the potential *Aquilonia* and *Medeopteryx* samples and two *Luciola* samples. Fireflies were caught in various locations such as near rubber plantations, trails and rivers. Findings from this report expands the distributional knowledge about Lampyridae in Borneo.

Keywords: Borneo, *Luciola niah*, *Aquilonia* sp., *Medeopteryx* sp., *Pyrocoelia* sp.

Introduction

One of the ecotourism magnets, the firefly, is a bioluminescent beetle (Coleoptera) with almost 2,000 species estimated worldwide (Branham & Wenzel, 2003; Lewis et al., 2020). Currently, there are limited reports on firefly species distribution in several parts of Asia (Jusoh et al., 2018; Ballantyne et al., 2019). Fireflies in the interior of Sabah are rarely explored. Most firefly research in the Southeast Asian region is mainly focused in mangrove areas, perhaps due to its economic importance in ecotourism (Mahadimenakbar et al., 2014, 2018; Mahadimenakbar & Fiffy Hanisdah, 2016; Siti Rozziana et al., 2020; Syazlina et al., 2016) or due to ease in access compared to fireflies in forested areas.

However, these undiscovered locations may contain new lampyrid species or new geographical records for existing fireflies. For example, the new genus *Emasia* was erected in 2010 after an Otoretine firefly was found in Gunung Emas, Sabah (Bocakova & Janisova, 2010). While *Pygoluciola* was first thought

to be a rare firefly from the Bornean region (Ballantyne, 2008; Ballantyne & Lambkin, 2006), it was later found in several places transgressing biogeographic barriers such as *Pygoluciola cowleyi* from Australia (Ballantyne & Lambkin, 2013), *Pygoluciola qingyu* from China (Fu & Ballantyne, 2008) and *Pygoluciola hamulata* and *Pygoluciola satoi* from the Philippines (Ballantyne, 2008; Ballantyne & Lambkin, 2006). Recently, Nada and Ballantyne (2018) described a new species of *Pygoluciola* from the lowland dipterocarp forest as a result of an intricate sampling in Peninsular Malaysia. This shift into the inland fireflies brought a renewed look at the region's Lampyridae diversity with several new species being described recently (Ballantyne et al., 2019). Hence, we intend to build upon these efforts by exploring new areas to offer more insights on firefly distribution and diversity.

There is lack of information on the species of fireflies that reside in the interior of Sabah and Borneo at large. Via the Borneo Geographic Expedition in 2019, the authors took the opportunity to fill this knowledge gap. The specific purpose of this survey was to answer the question of what types of firefly dwell in Kadamaian, Kota Belud. The data on what firefly species and their number in certain areas served as our baseline for future scientific efforts, such as ecological study and taxonomy.

Methodology

Sampling Locations and Method

Fireflies were sampled using sweep net along the trail in Podos (basecamp), Melangkap Noriou (Noriou henceforth) and Pinolobu (Figure 1) during the Borneo Geographic Expedition from 20th to 24th October, 2019. Sampling lasted for three hours starting from 7 pm to 10 pm. Sampling locations, such as forest floor, tree, vines or river were noted. Samples were then stored in 95% ethanol and brought to the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah in Kota Kinabalu for identification.

Identification Process

Male samples were identified by morphological characters using the key provided in Ballantyne et al., (2019). Male genitalia were extracted by soaking detached abdomen in 10% KOH for approximately 10 hours (Sasso Porto et al., 2016). Female specimens were identified to species level where description is available from the key or found mating with a known male. Specimens were photographed using Leica DFC495 attached to a Leica M165C stereomicroscope

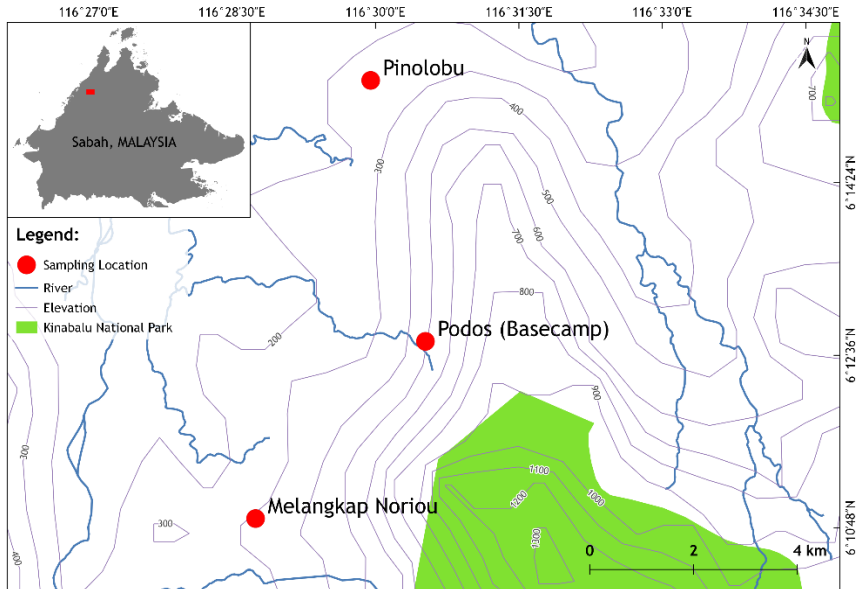


Figure 1. Sampling location. Inset: Kadamaian area marked in red in the northwest part of Sabah, Malaysia.

and inspected using the software ImageJ for measurements (Bourne et al., 2019; Mobilim & Mahadimenakbar, 2020).

Results and Discussion

After surveying three locations in Kadamaian, we found a total of 48 fireflies (Table 1) mainly dominated by *Luciola* spp. (66.66% out of total) including a single *Pyrocoelia* larva. Upon identification, we found new records of fireflies for Sabah and Borneo Island and four potentially new species. However, the suspected new species will be further investigated and will be described in detail elsewhere. Here, we only report the general descriptions of these potential new species. For the first time, the existence of cf. *Aquilonia* sp. and *Medeopteryx* sp. in Borneo Island as well as *Luciola niah* in Sabah are reported. In this survey, we observed the occurrence of cf. *Aquilonia* sp. in Pinolobu (Table 1) where the distribution was formerly recorded in Australia, New Guinea and Pacific islands (Australinea). Based on the dichotomous key by Ballantyne et al. (2019) for the identification of South East Asia and Australopacific fireflies, our sample falls into the *Atyphella* complex fireflies. This complex consists of five genera; *Atyphella*, *Aquilonia*, *Convexa*, *Lloydiella* and *Magnalata*, show emargination on the right side of their aedeagal sheath (Figure 2B and C). Interestingly, only *Aquilonia* fireflies have pale brownish or orange-yellow dorsal with dark elytral

Table 1. Fireflies caught in different areas of Kadamaian.

Species	Area			Total
	Noriou	Pinolobu	Podos	
<i>Luciola niah</i> (Jusoh 2019)	15 (6)	4 (3)	4 (2)	23 (11)
<i>Luciola pallidipes</i> (Pic 1928)	3 (1)	3	0	6 (1)
<i>Pygoluciola wittmeri</i> (Ballantyne 1968)	1	8 (3)	0	9 (3)
<i>Pyrocoelia</i> sp. larva (Gorham 1880)	0	0	1	1
cf. <i>Aquilonia</i> sp. (Ballantyne 2009)	0	1	0	1
<i>Medeopteryx</i> sp. (Ballantyne 2013)	2 (1)	1	0	3 (1)
<i>Luciola</i> sp. (Laporte 1833)	2	0	0	2
<i>Luciola</i> sp. (Laporte 1833)	1	0	0	1
Unidentified female	0	0	2	2
Total	24 (8)	17 (6)	7 (2)	48 (16)

Note: Firefly numbers indicate total individual and in brackets indicate numbers of female only.

apices (Ballantyne & Lambkin, 2009) which fit the description of our sample (Figure 2A). The other four genera have orange pronotum with either dark or dark brown elytra.

Table 2. Firefly sampling locations.

Species	Area		
	Noriou	Pinolobu	Podos
<i>Luciola niah</i> (Jusoh 2019)	Rubber estate & trail	Trail	Near Basecamp
<i>Luciola pallidipes</i> (Pic 1928)	River	River	-
<i>Pygoluciola wittmeri</i> (Ballantyne 1968)	River	River	-
<i>Pyrocoelia</i> sp. larva (Gorham 1880)	-	-	Forest Floor
cf. <i>Aquilonia</i> sp. (Ballantyne 2009)	-	Trail	-
<i>Medeopteryx</i> sp. (Ballantyne 2013)	Rubber estate	Rubber estate	-
<i>Luciola</i> sp. (Laporte 1833)	Trail	-	-
<i>Luciola</i> sp. (Laporte 1833)	Trail	-	-
Unidentified female	-	-	Vines

Earlier, we suspected that this sample belongs to the *Luciola* genus based on its size; our sample measures 5.9 mm long as opposed to the smallest *Aquilonia* to be in the range of 7.2 - 9.7 mm (Ballantyne & Lambkin, 2009), and colour. However, microscopic investigation into its genitalia proved otherwise; the aedeagal median lobe (ML) of our sample is not curved and the apices of the lateral lobe (LL) is narrower (Figure 2D) while *Luciola* possesses strongly curved

ML and expanded LL apices (shown clearly in figures 277 - 279 in Ballantyne et al., 2019, p. 94). *Aquatica* was also considered in identification, however, our sample lacks toothed aedeagal sheath sternite (figure 22 in Fu et al., 2010, p. 10).

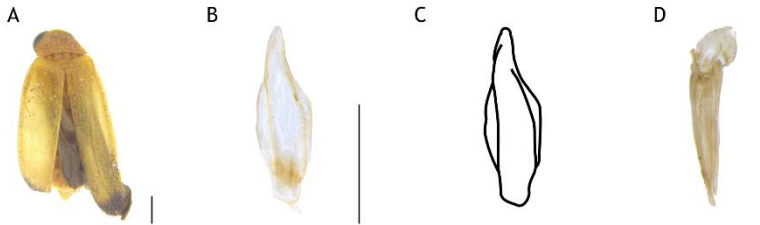


Figure 2. Dorsal part of the cf. *Aquilonia* sp. male (A); Aedeagal sheath ventral (B) with illustration (C); Aedeagus lateral (D). Scale lines are 1mm.

Although *Aquilonia* is restricted to the Australian region, they are now potentially distributed to the west of New Guinea. Additionally, a sample from Mantailang, Tenom was also collected by Mobilim in 2019 shared similar characteristics to cf. *Aquilonia similismessoria* (unpublished data). This genus has never been discovered on the west of the Wallace line, hence, *Aquilonia* existence in Borneo is unexpected. However, a growing number of literature using hyperdiverse animal shows these biogeographic lines are permeable. This explains the occurrences of the same taxonomic member in different biogeographic regions for example the *Trigonopterus* weevils (Letsch et al., 2020) and multiple genera of butterflies (Condamine et al., 2015; Toussaint et al., 2020) in Australinea, Wallacea and Sundaland. Our findings reflect this emerging data. In fact, in Lampyridae itself, current records show *Medeopteryx* fireflies have a wide distribution transgressing the biogeographic line. Ballantyne & Lambkin (2013) erected *Medeopteryx* from a bent-winged firefly that used to be in the *Pteroptyx* genus and proposed that species under *Medeopteryx* is distributed to the east of Wallace line (Australinea) (Jusoh et al., 2018). However, multiple discoveries have uncovered that member of this genus is distributed in the west of Australinea such as *Medeopteryx hongkongensis* in Hong Kong (Yiu, 2017), *Medeopteryx fraseri* in Peninsular Malaysia, *Medeopteryx timida* in Vietnam and a record from Thailand too (Ballantyne et al., 2019).

From this survey, we also reveal the wide distribution of *Luciola niah* (Figure 3A - D) in Borneo Island. In Kadamaian, *L. niah* is the most common species found in the trails of Noriou, Pinolobu and Podos. The species' first known date of collection is in 2010 from Niah National Park, Sarawak (Malaysian Borneo) and the species was only described by Ballantyne et al. (2019). The species is recognizable via its thin dark line on the base of abdominal ventrite 5 (Figure 3K) and entire light organ in ventrite 7. According to the same literature, there are only two species of *Luciola* that have dark elytral apices and yellowish dorsal; *Luciola jengai* and *Luciola niah*. Two of the other *Luciola* that we caught in Noriou have similar description but possess a unique pattern of dark colouration on their abdominal ventrites V3 to V5 which neither match *L. jengai* nor *L. niah*. Furthermore, the shape of their light organ in V7 is similar with *L. niah*; entire and longer instead of wide.

This potentially carries two conclusions; (1) the species are potentially new, or (2) phenotypic polymorphism. Deciding a taxonomical status based on minute morphological differences may be incorrect. This is because intraspecific phenotypic polymorphism may occur which is common in many species (Sánchez-Vialas et al., 2020; Yeong et al., 2018). In Lampyridae research, intraspecific variation was observed, such as the pronotum colour of *Pteroptyx bearni* from West versus East Malaysia and *Pt. tener* from different localities (Jusoh et al., 2018); multiple light spots on the body of *Phausis reticulata* females (De Cock et al., 2014) and small differences in elytral colouration of the new Brazilian *Uanauna angaporan* species (Campello-Gonçalves et al., 2019). This occurrence may be influenced by many factors during an insect development into adulthood such as sexual conflicts, food quality, temperature variations and other abiotic factors (Dillon & Lozier, 2019; Gering, 2017; Lin et al., 2018; Willink et al., 2020). Hence, to accurately arrive at any one of those two conclusions, the samples must undergo further morphological characterization coupled with DNA barcoding (Cognato et al., 2020; Lehmann et al., 2017; Sheth & Thaker, 2017).

The fireflies were found in various locations. *Luciola niah* was found flying within the rubber estate, along the trail and cleared ground of the basecamp. Previously, *L. niah* was found dwelling in the forest track of Niah National Park and several remarks indicating general locations in Kapit, Long Aton in Ulu Baram and Lambir Hill (Ballantyne et al., 2019). This list of areas presumably in forested ground shows contrast with our findings that *L. niah* may be found in disturbed areas too. This is similar with *Medeopteryx* fireflies that were caught in the rubber estate of Noriou and Pinolobu. Though our data is insufficient to conclude ecological associations of land use type with the species distribution,

this observation is similar with several findings in which Lampyridae individuals exist in various habitats including secondary forests (Viviani, 2001; Viviani et al., 2012) and plantations. For example, *Inflata indica* was collected from rubber and palm plantations as well as banana orchard (Ballantyne et al., 2015); *Luciola parvula* from the Japanese cedar plantation (Kakehashi et al., 2014); *Pyrocoelia tonkinensis* from rubber plantation (Senarat et al., 2019); and *Diaphanes* sp., *Pyrocoelia* sp. and *Trisinuata* sp. from coniferous plantation (Wattanachaiyingcharoen et al., 2016). Furthermore, our findings on the occurrence of the macropterous *Pygoluciola wittmeri* (Figure 3I - J) echoes the previous findings which was found near the river (Ballantyne & Lambkin, 2006; Kionsom River in Chey, 2008; Mobilim & Mahadimenakbar, 2020). Other than abiotic constraints (Nur Athirah et al., 2020), insect occurrence in certain locations can be influenced by several dispersal factors at different stages of their life cycle. For Lampyridae larva, such as *Pyrocoelia* sp. found in Podos leaf litter (Figure 4), food may be a factor at this phase in which they spend most of their time hunting snails on the forest floor (Jaikla et al., 2020; Kirton et al., 2006; Lewis et al., 2020) with limited dispersal range, as much as 100.7 to 245.4 cm for *Luciola parvula* flightless female in daily recapture rate of mark-release-recapture study (Kakehashi et al., 2014). As they grow into adulthood, fireflies with flight ability will be able to disperse more to find mates such as *Luciola substriata* that have the ability to fly $-0.2 - 0.4$ metres per second (Fu, 2005 found in Zhang et al., 2020). Hence, species existence in other ecotones can be expected as found in Kadamaian where the plantations are very near undisturbed forests and this potentially contributed to their dispersal capabilities.

Conclusion

From our data, Kadamaian area holds an interesting array of Lampyridae species and they are found in various landscapes. It widens our distributional knowledge of cf. *Aquilonia* sp., *Medeopteryx* sp. and *Luciola niah*. Although our data is limited to providing a checklist, the accompanying location notes reveal that an important ecological question about Lampyridae distribution in various ecosystems should axis around these diverse land use types. This is to further understand their role in the natural and converted landscape or vice versa on how these changing landscapes impact firefly species. By diversifying Lampyridae research, conservation efforts could also be properly put in place for these areas.

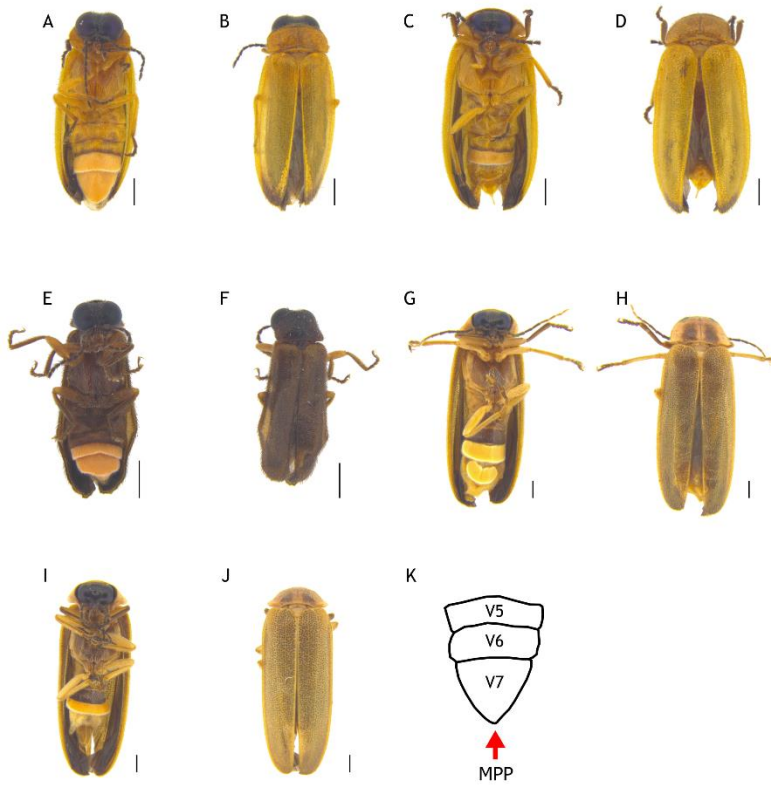


Figure 3. *Luciola niah* male (A - B), female (C - D); *Luciola pallidipes* male (E - F); *Pygoluciola wittmeri* male (G - H); female (I - J); abdomen ventral (K). MPP = median posterior projection, V5 = ventrite number 5, V6 = ventrite number 6, V7 = ventrite number 7. Scale lines are 1mm.



Figure 4. *Pyrocoelia* sp. larva found on the forest floor along the trail in Podos.

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