

Species Diversity of Firefly (Coleoptera:Lampyridae) in the Highlands of Northern Thailand

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ABSTRACT

Diversity of firefly species have been surveyed in 83 study sites of the highland areas of Northern Thailand. A total of 19 species in 9 genera and 1 of unknown genus and species were recorded. Each habitat type contained different number of firefly species. Lower montane forests have the highest firefly diversity (at 15 species) while only 3 species occurred in coniferous forests. Firefly species *Pyrocoelia* sp.2 and *Luciola* sp. 3 had specific niche in which only found in lower montane forests and upper montane forests respectively. In addition, firefly species *Asymmetricata circumdata* can be observed in a wide altitude range from 700-1,250 msl. Seasonal variation had the effects on firefly diversity. Most species occurred in wet condition, from late summer to rainy season which resulted from availability of vegetation. But some species appear in winter with lower temperatures at high altitude, i.e. *Luciola* sp.3. The diversity of firefly species in the highlands as reported in this study suggests that these habitat types provide a suitable niche for fireflies.

Keywords: firefly, species diversity, highlands

INTRODUCTION

About 2,000 species of fireflies, in more than 80 genera in the family Lampyridae, have been reported worldwide (Branham, 2002; 2010; McDermott, 1964, 1966). They can be found in all regions, but are mostly distributed in the tropical regions of Southeast Asia and America (Branham, 2002). Even though they are mostly found in rather high humidity areas, one species of firefly, *Micropnotus ocatarthrus* even reside in desert (Usener and Cognato, 2005). Therefore, variation in habitat types may occur according to a specific group of fireflies. In Thailand, we can divide fireflies into 3 groups depending on habitat type. Firstly, the intertidal group, of which *Pteroptyx malaccae* are majority species. They are able to adapt their life style according to the sea level and are famous in their ability to synchronize flashing on a tree (Lloyd, Wing and Hongtrakul, 1989 a;b). The second group is a lowland group, which comprises fresh water fireflies, for example *Luciola aquatilis* (Thancharoen, 2007; Thancharoen *et al.*, 2007), *Luciola brahmina* (Thancharoen, 2001), *Asymmetricata circumdata* (Nak-eiam, Wattanachaiyingcharoen and Thancharoen, 2011; Theraphat, 1969). Their habitats may diverge from freshwater marshes, flooded grasslands, rice paddies, ponds and creeks. Finally, the highland group, these fireflies are mostly found at altitudes above 1,000 meters (Maxwell, 2004). The fireflies that exist in these areas are terrestrial or semi-aquatic and occupy creeks, streams or nearby wetlands. In 2001, Thancharoen reported the occurrence of some firefly species from highlands of the

central regions of Thailand i.e. *Diaphanes* spp., *Lamprigera* sp., *Asymmetricata circumdata*, *Luciola chinensis*, *Luciola* spp. and *Pyrocoelia insidiosa*, which were different from those found in the lowlands. This suggests that different niches can provide specific vegetation and an environment for firefly existence. Wijekoon, Wegiriya and Bogahawatta (2012) reported variations in firefly diversity in different topographic regions of Sri Lanka. Some species in the genus *Luciola* exhibited niche dominance. For example, *Luciola humeralis* was mostly found in the North Central area.

In Japan, a species of firefly, *Luciola cruciata* (Genji-firefly) are distributed throughout the country, but they are only found living in streams, especially in conserved agricultural areas (Satoyama). The larvae only live in running waterways while pupae and adults also reside adjacent to water. Therefore, this species needs a specific niche according to their developmental stages (Katoh, Sakai and Takahashi, 2009). Similar to other parts of the world, the accumulation of agricultural chemicals, household toxins, noise and light pollutants threaten Genji-firefly populations, causing their decline in many regions of Japan (Takeda *et al.*, 2006). As they have had a long term influence on Japanese culture, the decline of the Genji-firefly populations is of concern to the Japanese people. Conservation plans have been launched to help conserve the species. People and government agencies have cooperated to protect the Genji-firefly through the conservation of suitable and fragile habitats. Recent reports show that the Genji-firefly populations are gradually increasing in some areas (Yuma, 2007).

The firefly populations in Thailand have dramatically fallen according to the personal surveys of the researchers. The expected causes are due not only to climatic change but also to human activity. The expansion of human settlements and agricultural activities has resulted in the reduction in firefly numbers and has threatened their survival (Therapat, 1969; Hagen and Viviani, 2009; Jusoh, Hashim and Ibrahim, 2010). Apart from human activities the use of various toxic chemicals in households and in agriculture, noise and light pollutants interfere with the breeding habits of the firefly, thus causing a decline in firefly numbers (Thancharoen, 2001). Highland areas are areas that contain various forest ecosystems according to altitude resulting in different vegetation types from other ecosystems (Katoh, Sakai and Takahashi, 2009). Therefore, it can be expected that those areas may harbour various living creatures including firefly species which differ from those found in lowlands or other ecosystems. Highland areas in the lower north of Thailand seem to be famous for tourism due to favourable weather and undisturbed lands, thus, these areas will be exploited as tourist destinations. With a low standard of management in tourist industries and high levels of interference caused by human activities may lead to an accelerated reduction in flora and fauna in the highlands with no exception to fireflies. In order to provide substantial information for public concern on firefly conservation, basic knowledge of species diversity is necessary.

MATERIALS AND METHODS

Sample Collections

1. We collected firefly specimens from various highland areas in the northern region of Thailand which has an altitude of more than 700 meters. At each locality, the altitude and habitat types were recorded.

2. The observations started from sunset until midnight by observing fireflies in larval, pupal and adult stages, either by sight or searching on the ground, in the shrubbery, trees, or any possible substrates. The firefly species were distinguished by the different in flash patterns, both in those flying or resting on substrate (Yuma, 2007).

3. Adult fireflies were collected using an insect sweeping net and the samples collected were preserved in 70% ethanol for further morphological study and identification in the laboratory.

Firefly Identification

All male specimens collected were examined either on external morphology or the internal anatomy of reproductive organs, depending on identification procedures and species. Specimens are classified and identified according to generic and species levels. Classification and identification were conducted using several taxonomic references; i.e. Ballantyne (1968; 1987 a; b; 2008); Ballantyne and Lambkin (2000; 2001; 2006; 2009; 2013); Ballantyne and McLean (1970); Fu and Ballantyne (2008); Fu, Ballantyne and Lambkin (2010; 2012); Jeng, Engel and Yang (2007); Wattanachaiyingcharoen and Nak-eiam. (2012) and Thancharoen *et al.* (2007).

RESULTS AND DISCUSSION

We surveyed 83 sites of highland habitats in the north of Thailand at latitude 15 - 20 degree north and longitude 97 – 107 degree east. Highland habitats in this study are classified as areas with altitude higher than 700 meters above mean sea level (msl) which range from hill foot to hill peak (Thai Junior Encyclopedia, 1988).

Totally, 19 species of fireflies were recorded and collected for further classification and identification. According to available firefly identification references, we classified all firefly specimens into 2 subfamilies; i.e. Lampyrinae and Luciolinae. In subfamily Lampyrinae, they were classified into 3 genera, 7 species. In the study, 11 species belonging to 6 genera of the subfamily Luciolinae were collected. Several similar specimens of unknown genus species were also collected. Table 1 showed the species diversity of firefly recorded from highland habitats in the north of Thailand with vertical distribution and habitat types of each species. This result showed the diversity of firefly species in highland habitats of the north of Thailand. Thancharoen (2001) reported similar result in a highland area of north-eastern Thailand with 11 species within 7 genera.

The diversity of firefly species in the highland areas indicated that the areas are suitable for firefly existence. This is because those areas are still largely undisturbed by human activities and is less subject to pollutants. Therefore, highland areas play a role in providing adequate food resources and shelter for firefly existence. However, niche preference may vary between species. From our study, we found diverse species in different habitat types. The results show the highest number of firefly (15 species) in lower montane forest habitats (700-1,900 msl), followed by dry evergreen forests and forest parks with 9 and 8 species in each habitat type respectively. The lowest numbers of firefly species were recorded from mixed deciduous forest and coniferous plantation habitats with only 3 species in each habitat type. In higher altitude (1,300-2,500 msl), i.e. upper montane forests, 6 species of fireflies were recorded while 5 species were found in pine forest

habitats. However, due to the inaccessibility of those highlands areas, we were unable to collect and count the number of fireflies individually. Therefore, the abundance and species richness of fireflies in this area has not been assessed and reported.

Table 1. Firefly diversity, vertical distribution and habitation types in highlands of Northern Thailand.

	Vertical distribution (msl.)	Habitation						
		Upper montane forest	Lower montane forest	Pine forest	Dry evergreen forest	Mixed deciduous forest	Forest park	Coniferous plantation
Subfamily Lampyrinae								
1. <i>Diaphanes</i> sp.2	1,200	-	/	-	/	-	-	-
2. <i>Diaphanes</i> sp.3	1,300-1,600	/	/	-	/	-	/	/
3. <i>Diaphanes</i> sp.4	1,300-1,900	/	/	-	-	-	-	-
4. <i>Lamprigera yunnana</i>	1,300-1,800	/	-	-	-	-	/	-
5. <i>Pyrocoelia analis</i>	1,200	-	/	-	-	-	/	-
6. <i>Pyrocoelia</i> sp.1	1,300-1,800	/	/	-	-	-	/	/
7. <i>Pyrocoelia</i> sp.2	1,000	-	/	-	-	-	-	-
Subfamily Luciolinae								
8. <i>Abscondita anceyi</i>	1,200	-	/	-	/	-	-	-
9. <i>Abs. chinensis</i>	1,300	-	/	/	/	-	-	-
10. <i>Asymmetricata circumdata</i>	700-1,250	-	/	/	-	/	/	-
11. <i>Asy. ovalis</i>	1,200	-	/	/	/	/	/	-
12. <i>Curtos cerea</i>	1,300-1,500	-	/	-	-	/	-	-
13. <i>Luciola curtithorax</i>	1,200	-	/	-	/	-	-	-
14. <i>Luciola indica</i>	950-1,200	-	-	/	-	-	/	-
15. <i>Luciola triluvida</i>	1,200-1,300	-	/	/	/	-	-	-
16. <i>Luciola</i> sp.3	2,500	/	-	-	-	-	-	-
17. <i>Pygoluciola</i> sp.1	1,300	-	/	-	/	-	-	-
18. <i>Trisinuata</i> sp.2	1,000	-	-	-	/	-	-	/
19. Unknown genus sp.	1,850	/	/	-	-	-	/	-
Number of species		6	15	5	9	3	8	3
Total species		19						

The specific locality of fireflies has been reported in several species, for example firefly species *Luciola substriata* in China seems to have specific niche (Xinhua *et al.*, 2005). From our surveys, *Pyrocoelia* sp.2 and *Luciola* sp.3 tend to occur in specific habitats as each species occupies only 1 particular habitat type, i.e. lower montane and upper montane forests respectively. Similar to the report in Malaysia that *Pteroptyx tener* tend to live on specific plant species (Chey, 2004). However, some species of fireflies were observed to reside in wide range of diverse habitats; i.e. *Diaphanes* sp.3 and *Asymmetricata ovalis*. *Diaphanes* sp.3 appeared in coniferous plantation up to upper montane forest with the altitude range from 1,300 – 1,600 msl. Meanwhile *Asymmetricata ovalis* were observed at habitats with average altitude 1,200 msl within forest park to lower montane forest. In addition, *Asymmetricata circumdata* appeared in a wide altitude range (700-1,250 msl). This result is similar to previous report of Nak-eiam, Wattanachaiyingcharoen and

Thancharoen (2011) which found that this firefly species is distributed in varied topographical areas with a vast altitude range from 40 – 1,220 msl, consisting of 6 different habitat types. Hence, this confirmed that this firefly species may adapt to exist in various habitats in contrast with some species that may have habitat occupation preference.

Table 2. Seasonal appearance of firefly species found in highlands of Northern Thailand.

Species	Seasonal appearance
Subfamily Lampyrinae	
1. <i>Diaphanes</i> sp.2	Early Rainy (Late May)
2. <i>Diaphanes</i> sp.3	Winter (December-February)
3. <i>Diaphanes</i> sp.4	Mid - winter (January)
4. <i>Lamprigera yunnana</i>	Late Rainy - Winter (October - January)
5. <i>Pyrocoelia analis</i>	Late Summer - Rainy (Early May-September)
6. <i>Pyrocoelia</i> sp.1	Winter (December-February)
7. <i>Pyrocoelia</i> sp.2	Rainy (June-September)
Subfamily Luciolinae	
8. <i>Abscondita anceyi</i>	Summer - Early Rainy (March-May)
9. <i>Abscondita chinensis</i>	Rainy - Winter (June-December)
10. <i>Asymmetricata circumdata</i>	Summer - Rainy (March- September)
11. <i>Asymmetricata ovalis</i>	Rainy (June-September)
12. <i>Curtos cerea</i>	Rainy (June-September)
13. <i>Luciola curtithorax</i>	Rainy (June-September)
14. <i>Luciola indica</i>	Late Summer - Rainy (Early May-September)
15. <i>Luciola trilucida</i>	Rainy (June-September)
16. <i>Luciola</i> sp.3	Winter (December-February)
17. <i>Pygoluciola</i> sp.1	Early Rainy (Late May)
18. <i>Trisinuata</i> sp.2	Late Summer - Rainy (Early May-September)
19. Unknown genus species	Late Winter (January-February)

In this study, adult fireflies were observed all year round but varied in seasons (Table 2). Some species has seasonal specificity, for example, *Diaphanes* sp.3 and *Luciola* sp.3 appeared only in winter, while *Pyrocoelia* sp.2 and *Luciola trilucida* appeared only in rainy season. In contrast, some species have a wider range of adult seasonal appearance such as *Pyrocoelia analis* and *Luciola indica* which were found from summer through to rainy season. These records revealed the species preference in ambient conditions, i.e. occurrence of *Pyrocoelia* sp.2 and *Luciola trilucida* in wet conditions. Similar results were reported in Sri Lanka, where a member of *L. praeusta* complex, *Luciola chinensis* which prefers a moist habitat while *L. nicollieri* dwell in colder and higher rainfall areas. The difference in rainfall levels in Sri Lanka may play a role in the diversity of fireflies in this island (Wijekoon *et al.*, 2012). However, most species of fireflies are recorded here which appear mainly in wet conditions; i.e. summer to rainy or rainy seasons. Surprisingly, *Luciola* sp.3 was observed only in the upper montane forest with an altitude of 2,500 msl during winter, this indicated that the species is tolerant of

lower temperatures as temperatures in this area might be lower than 10 degrees Celsius in winter.

Ecological conditions have indirect effects on firefly numbers as they cause changes in vegetation. For example, during the rainy season, the abundance of fauna in those areas increases, therefore increases the amount of food resources for larval stages of fireflies. The availability of vegetation is necessary for fireflies as a copulation site and resting site as reported in Genji firefly, *Luciola cruciata*. In addition, some specific features of plant leaves, for example broader leaves, may be a crucial factor in enabling fireflies to escape the attention of predators (Yuma and Hori, 1990).

In Japan, geographical features have resulted in differences in behaviour in populations of *Luciola cruciate*. Populations have different flash patterns; slow-flash and fast-flash patterns. In each geographic area, specific flash patterns play a role in mating success. Therefore, each type of firefly mainly occurred in the area with the same flash pattern partners. Long-term separation has led to different flash patterns, and may result in speciation of these fireflies (Tamura *et al.*, 2005).

CONCLUSION

The 19 species of firefly observed in the highlands of Northern Thailand showed the diversity of this insect. Highland areas consist of several habitat types which provide diverse shelters and food resources. Therefore, some habitat types may be served as favourable firefly localities. Because of abundant varieties of vegetation, lower montane forests have been occupied by diverse species of fireflies (15 species). In contrast, the only 3 species of fireflies recorded in a monoculture coniferous plantation suggested that this habitat type is not suitable for fireflies. Furthermore, some firefly species has habitat type preference, *Pyrocoelia* sp.2 only occupies lower montane forest while *Luciola* sp.3 was found in upper montane forest. Our results indicated the influences of climate on firefly diversity as the majority of firefly species occurred in late summer through to the rainy season which resulted from the availability of vegetation in their preferred habitats. The availability of vegetation plays a major role for the survivorship of fireflies, as it not only provides food resources and shelter but also copulation and oviposition sites. Therefore, highland habitats with less interference from human activities and pollutants are important for supporting the diversity of fireflies.

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