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Article

Weather Affecting Macro-Moth Diversity at Khao Nan National Park, Thailand

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Abstract

Surveying on the diversity of the macro-moths was done at Khao Nan National Park, Nakhon Si Thammarat, Thailand from January 2007 to December 2008. We caught 57 species with 170 individuals of macro-moths covering nine families: Cossidae, Cyclidiidae, Eupterotidae, Geometridae, Lasiocampidae, Noctuidae, Saturniidae, Sphingidae and Uraniidae. We collected 46 species with 24 singletons and 123 individuals belonging to nine families at Headquarters and 24 species with 16 singletons and 47 individuals belonging to 6 families at Huilek Park Ranger station. Sphingidae was recorded as the most diverse family sampled in Khao Nan National Park, followed by Noctuidae, and Saturniidae. The macro-moths visited the light trap at Headquarters every month during the study period. The highest species richness was observed in June 2007 with 10 species. The number of macro-moths at Huilek Park Ranger station was highest in October and December 2007. The species composition in the Headquarters was approximately three times higher than at Huilek Park Ranger station. At Headquarters, the number of individual macro-moths was positively correlated with mean/max/min temperatures and negatively correlated with relative humidity and not associated with rainfall. On the other hand, the number of individual macro-moths at Huilek Park Ranger station was not associated with mean/max/min temperatures, relative humidity or rainfall.

Keywords: Macro-moth, diversity, rainfall, temperature, Khao Nan National Park

Introduction

Lepidoptera (butterflies and moths) is one of the most prevalent terrestrial insect groups and perform essential ecosystem services such as pollination, decomposition, and nutrient cycling, as well as providing prey for passerine birds [1]. Almost all Lepidoptera are phytophagous species feeding on specific vegetation [2] and exhibiting strong associations with vegetation structure and composition [3]. Macro-moths are one of the highly plant-dependent groups of insects and form a rich component of the rainforest fauna. They serve as major herbivores, linking primary producers and consumers in ecosystems [4], making them a suitable biological indicator group in biodiversity assessment and widely used in ecological and conservation research worldwide [5-7]. The vast majority of macro-moths are nocturnal and their response to light provides a very convenient and widely used method of sampling by using an ultraviolet light trap [8-10].

Tropical rainforests are known to house a tremendous diversity of moths. Different types of vegetation and altitude give different values of macro-moth diversity, and the diversity of macro-moths was found from the lower montane forest to an altitude of about 1,000 m [11]. Global environmental changes are among the greatest long-term threats to humans [12]. These changes, such as rising temperatures and irregular rainfall, will both directly and indirectly impact individual species and consequently lead to changes in the structure and composition of communities [13]. Higher temperatures are likely to speed up macro-moth larval development, cause more movement and more generations in a season and more synchronisation of egg hatching and bud bursting. Macro-moths show sensitivity towards environmental changes due to their vast number and diversity, habitat preference and adaptation to different environmental conditions [14]. Previous studies [15-18] noted that rainfall, relative humidity and temperature were important weather factors that are closely related to the number of moths caught.

Monitoring the population of the macro-moths, especially on protected species, is urgently needed for better understanding the current status, and implementing conservation and management. The present study had 2 main purposes: (1) to study the macro-moth diversity in a tropical rainforest at an altitude of 100 - 220 m at Khao Nan National Park, Southern Thailand and hopefully contribute to our existing knowledge on macro-moth diversity in Thailand and (2) to investigate the weather factors that are associated with the number of macro-moths in a Southern Thai tropical rainforest.

Materials and methods

Study site

This study was conducted at Khao Nan National Park on the Southern Thailand Peninsula. The geographical characteristic of Khao Nan is a high mountainous range in north-south direction which is a part of Nakhon Si Thammarat Mountain Range. The forest at Khao Nan is a tropical mountain forest and is an important watershed source for Nakhon Si Thammarat. The area of the Khao Nan is 406 km^2. The highest peak is Khao Yai which is 1,438 m above sea level.

Weather factors

We installed the Davis Vantage Pro II plus weather station to collect five weather data sets from January 2007 - December 2008 at Huilek Park Ranger station, which was 50 m away from the Huilek Park Ranger station trapping site. Weather data were composed of mean/max/min temperatures, relative humidity and rainfall.

Trapping technique

The 18 watt black light trap was set against a white cloth sheet at two study sites: the Khao Nan Headquarters (UTM X: 0969644, Y: 0588547) and Huilek Park Ranger station (UTM X: 0979723, Y: 0568732), in Khao Nan National Park, Nakhon Si Thammarat province, Southern Thailand (**Figure 1**). The forest habitat of both study sites differed. There was moderate selective logging and recovering forest at Headquarters while nearly 70 % of the area of Huilek Park Ranger station was covered by *Elateriospermum tapos* trees and no logging. Light traps were conducted daily for a total of 730 nights from January 2007 through December 2008. The light traps functioned from 18.00 - 06.00 hr. All macro-moths of a wingspan greater than 4 cm that visited the black light traps were collected twice daily at 22.00 and 06.00 hr. The dead trapped insects were recovered and transferred to the Forest Entomology and Microbiology Group, Forest and Plant Conservation Research office, Department of National Parks, Wildlife and Plant Conservation. The moth specimens were identified by using Moths of Thailand volume 1 - 5 [19-23], the Malayan Nature Journal [24] and the Moths of Borneo [25]. Cross-reference was also made with collections from the Insect Reference Collections at the Department of National Parks, Wildlife and Plant Conservation. The number of individuals for every species was also counted. Voucher specimens from this study are currently deposited at the Department of National Parks, Wildlife and Plant Conservation.

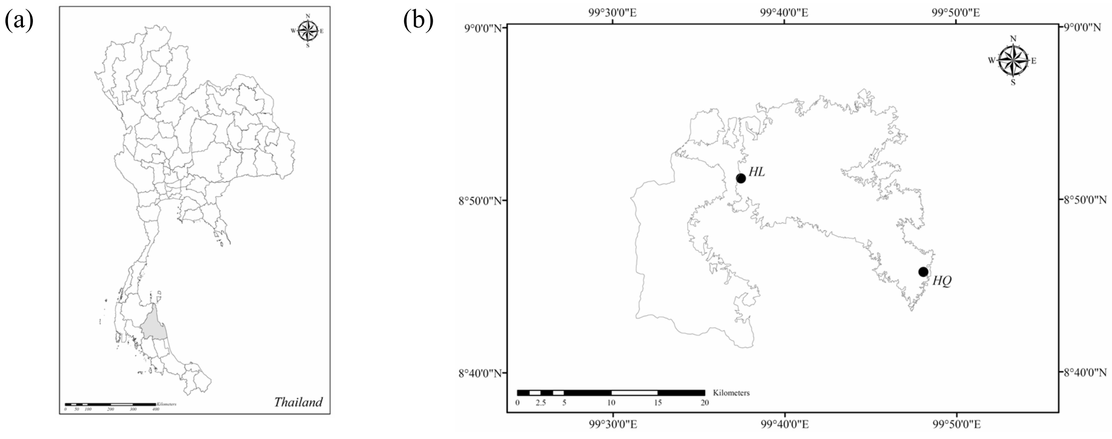

Figure 1 (a) Thailand, shaded area represents Nakhon Si Thammarat province where Khao Nan National Park is located, and (b) Two study sites. Dots represent Khao Nan Headquarters (HQ) and Huilek Park Ranger station (HL). Solid line represents Khao Nan National Park boundary.

Data analysis

The association between the number of macro-moths and monthly weather data was investigated using Pearson correlation tests. The percentage of singletons, the species for which only one individual was captured in the total sample, was calculated.

Results

Macro-moths diversity

Fifty seven species with 170 individuals of macro-moths within 9 families: Cossidae, Cyclidiidae, Eupterotidae, Geometridae, Lasiocampidae, Noctuidae, Saturniidae, Sphingidae and Uraniidae were caught by the black light traps from January 2007 to December 2008 with 1, 1, 6, 5, 3, 12, 10, 18 and 1 species, respectively. We collected 46 macro-moth species with 24 singletons and 123 individuals belonging to 9 families at Headquarters and 24 species with 16 singletons and 47 individuals belonging to 6 families at Huilek Park Ranger station (**Figure 2**, **Table 1**). Sphingidae was recorded as the most diverse family sampled in Khao Nan National Park, followed by Noctuidae and Saturniidae (**Table 1**).

Lyssa zampa, an import-export inhibition species, was found to be common at the Khao Nan National Park. There were 52.6 % of the total species collected (30 species) considered as rare species and represented by singletons (**Table 1**). These singletons were highly represented in Sphingidae (26.7 %) following by Geometridae (16.7 %), Eupterotidae (13.3 %), Noctuidae (13.3 %) and Saturniidae (13.3 %) (**Table 1**). The macro-moths visited the light trap at Headquarters every month during the study period (**Figure 3a**). The highest species richness was observed in June 2007 with 10 species. The number of macro-moths at Huilek Park Ranger station was highest in October and December 2007 (**Figure 3b**). In 2007, there were 27 species found at Headquarters, 11 species found at Huilek Park Ranger station and 5 species found at both sites. In 2008, there were 24 species found at Headquarters, 6 species found at Huilek Park Ranger station and 5 species found at both sites.

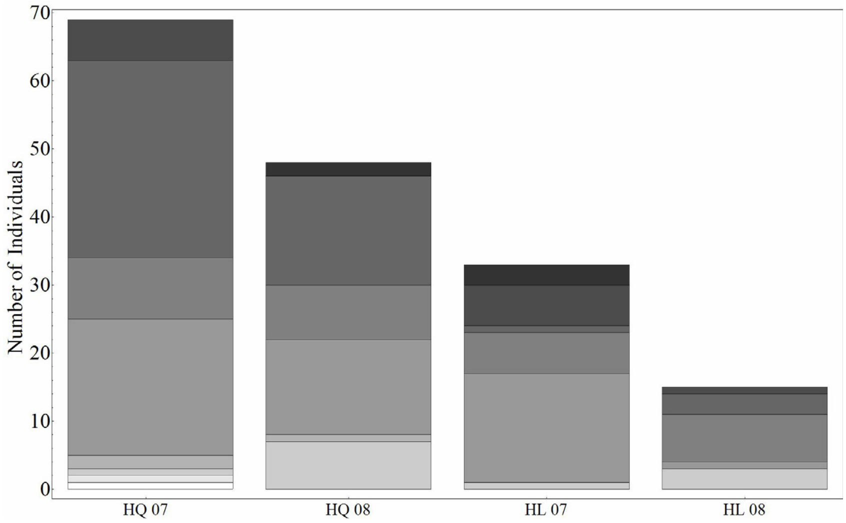

Figure 2 Number of macro-moths in 9 families at 2 trapping sites, Khao Nan National Park in 2007 - 2008. HQ and HL represent Headquarters and Huilek Park Ranger station, respectively. Nine macro-moth families from white to black colours (Cossidae, Cyclidiidae, Eupterotidae, Geometridae, Lasiocampidae, Noctuidae, Saturniidae, Sphingidae and Uraniidae).

Table 1 Macro-moth species list at Khao Nan National Park, Nakhon Si Thammarat Province. P = Protected Insects, I = Import-Export Prohibition insects and N = Non Prohibition.

No.	Species	Family	Legal Status	Abundance	
				HQ	HL
1	*Xyleutes strix*	Cossidae	N	1	0
2	*Cyclidia orciferaria*	Cyclidiidae	N	1	0
3	*Eupterote asclepiaaes*	Eupterotidae	N	0	1
4	*Eupterote muluana*	Eupterotidae	N	0	1
5	*Eupyerote* sp.	Eupterotidae	N	1	0
6	*Melanothrix nymphaliaria*	Eupterotidae	N	2	0
7	*Pseudojana sp.*	Eupterotidae	N	1	0
8	*Tagora pallida*	Eupterotidae	N	4	2
9	*Alex palparia*	Geometridae	N	0	1
10	*Amblychia hymenaria*	Geometridae	N	1	0
11	*Biston bengaliaria*	Geometridae	N	0	1
12	*Dysphania* sp.	Geometridae	N	1	0
13	*Thinopteryx crocopterata*	Geometridae	N	0	1
14	*Lebada cognata*	Lasiocampidae	N	2	0
15	*Trabala pallida*	Lasiocampidae	N	1	0
16	*Trabala viridana*	Lasiocampidae	N	1	0
17	*Eudocima homaena*	Noctuidae	N	3	0
18	*Eudocima aurantia*	Noctuidae	N	2	0
19	*Eudocima discrepans*	Noctuidae	N	2	0

20	*Eurebus caprimulgus*	Noctuidae	N	7	7
21	*Eurebus ephesperis*	Noctuidae	N	2	2
22	*Hypopyra pudens*	Noctuidae	N	0	1
23	*Ischyja hemiphaea*	Noctuidae	N	1	0
24	*Lygniodes ciliata*	Noctuidae	N	0	1
25	*Lygniodes endoleucus*	Noctuidae	N	1	1
26	*Lygniodes hypoleuca*	Noctuidae	N	2	5
27	*Phyllodes consobrina*	Noctuidae	N	1	0
28	*Phyllodes eyndhovii*	Noctuidae	N	13	0
29	*Actias maenas*	Saturniidae	P	1	3
30	*Antheraea assamensis*	Saturniidae	N	2	0
31	*Antheraea frithi*	Saturniidae	N	1	0
32	*Antheraea helferi*	Saturniidae	N	4	0
33	*Antheraea larissa*	Saturniidae	N	0	2
34	*Attacus atlas*	Saturniidae	N	7	3
35	*Lemaireia loepoides*	Saturniidae	N	0	1
36	*Loepa miranda*	Saturniidae	N	0	1
37	*Loepa sikkima*	Saturniidae	N	1	1
38	*Archaeoattacus edwardsii*	Saturniidae	N	0	1
39	*Acherontia lachesis*	Sphingidae	N	1	0
40	*Acosmeryx shervillii*	Sphingidae	N	2	1
41	*Ambulyx moorei*	Sphingidae	N	1	0
42	*Ambulyx pryeri*	Sphingidae	N	4	1
43	*Ambulyx substrigilis*	Sphingidae	N	7	1
44	*Ambulyx tattina*	Sphingidae	N	1	0
45	*Amplypterus panopus*	Sphingidae	N	7	1
46	*Callambulyx amanda*	Sphingidae	N	1	0
47	*Daphnis hypothous*	Sphingidae	N	1	0
48	*Daphnusa ocellaris*	Sphingidae	N	1	0
49	*Elibia dolichus*	Sphingidae	N	5	0
50	*Marumba cristata*	Sphingidae	N	4	0
51	*Marumba juvencus*	Sphingidae	N	1	0
52	*Meganoton nyctiphanes*	Sphingidae	N	2	0
53	*Pergesa acteus*	Sphingidae	N	1	0
54	*Poliana leucomelas*	Sphingidae	N	2	0
55	*Theretra boisduvalii*	Sphingidae	N	5	0
56	*Cechenena helops*	Sphingidae	N	1	0
57	*Lyssa zampa*	Uraniidae	I	10	7

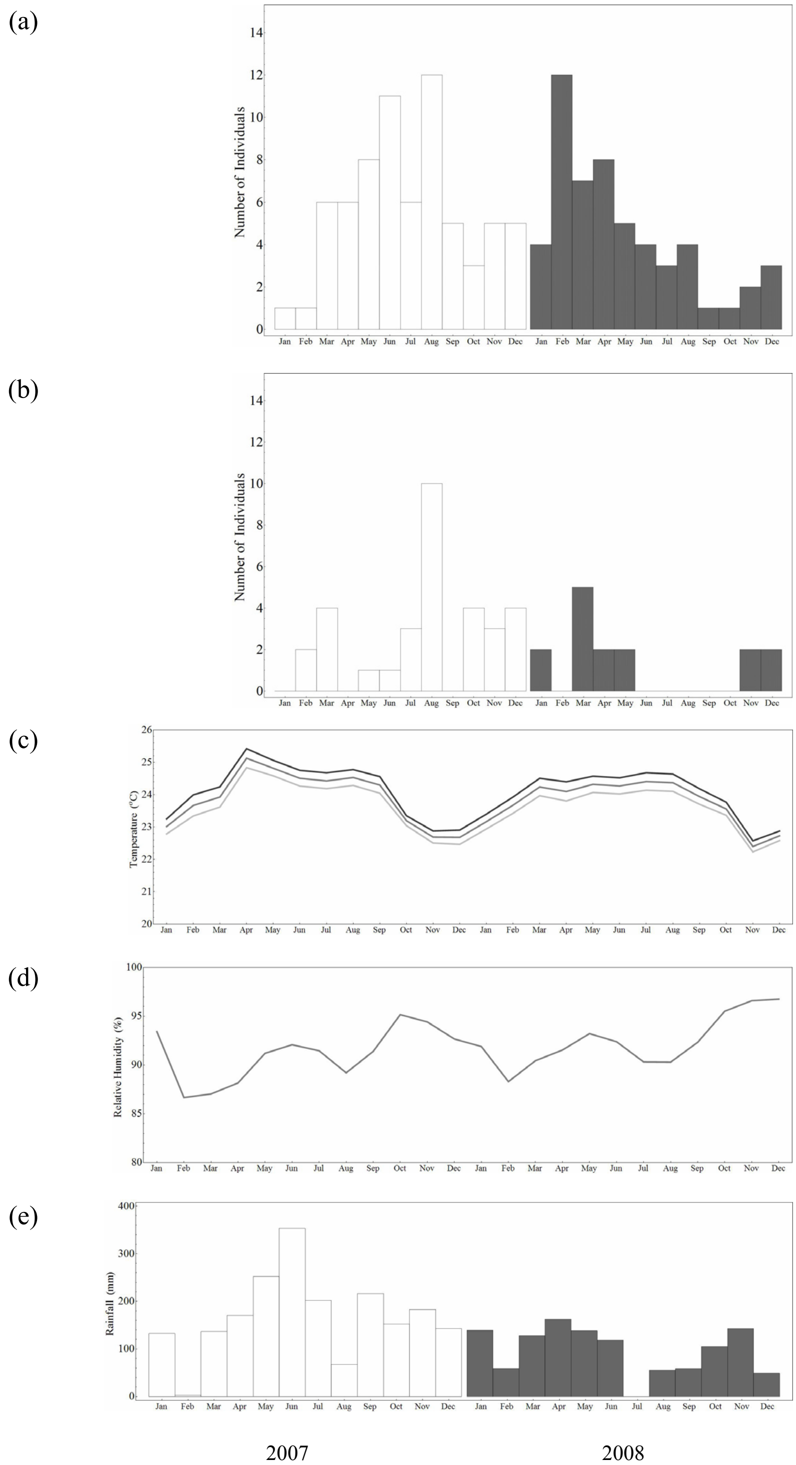

Figure 3 The number of macro-moths at Khao Nan National Park in 2007 - 2008. (a) Headquarters, (b) Huilek Park Ranger station, (c) max/mean/min temperature (°C), (d) relative humidity (%) and (e) rainfall (mm).

Macro-moth and weather factors

At Headquarters, the number of individual macro-moths was positively correlated with mean/max/min temperature and negatively correlated with relative humidity (temperature: $r_{24mean} = 0.447$, $p < 0.05$; $r_{24max} = 0.443$, $p < 0.05$; $r_{24min} = 0.449$, $p < 0.05$; relative humidity: $r_{24} = -0.411$, $p < 0.05$, **Figure 4a,c**) and not associated with rainfall (rainfall: $r_{24} = 0.384$, *ns,* **Figure 4e**).

At Huilek Park Ranger station, the number of individual macro-moths was not associated with mean/max/min temperature, relative humidity and rainfall (temperature: $r_{24mean} = -0.077$, *ns*; $r_{24max} = -0.080$, *ns*; $r_{24min} = -0.077$, *ns*; relative humidity: $r_{24} = -0.103$, *ns*, rainfall: $r_{24} = -0.030$, *ns,* **Figure 4b,d,f**).

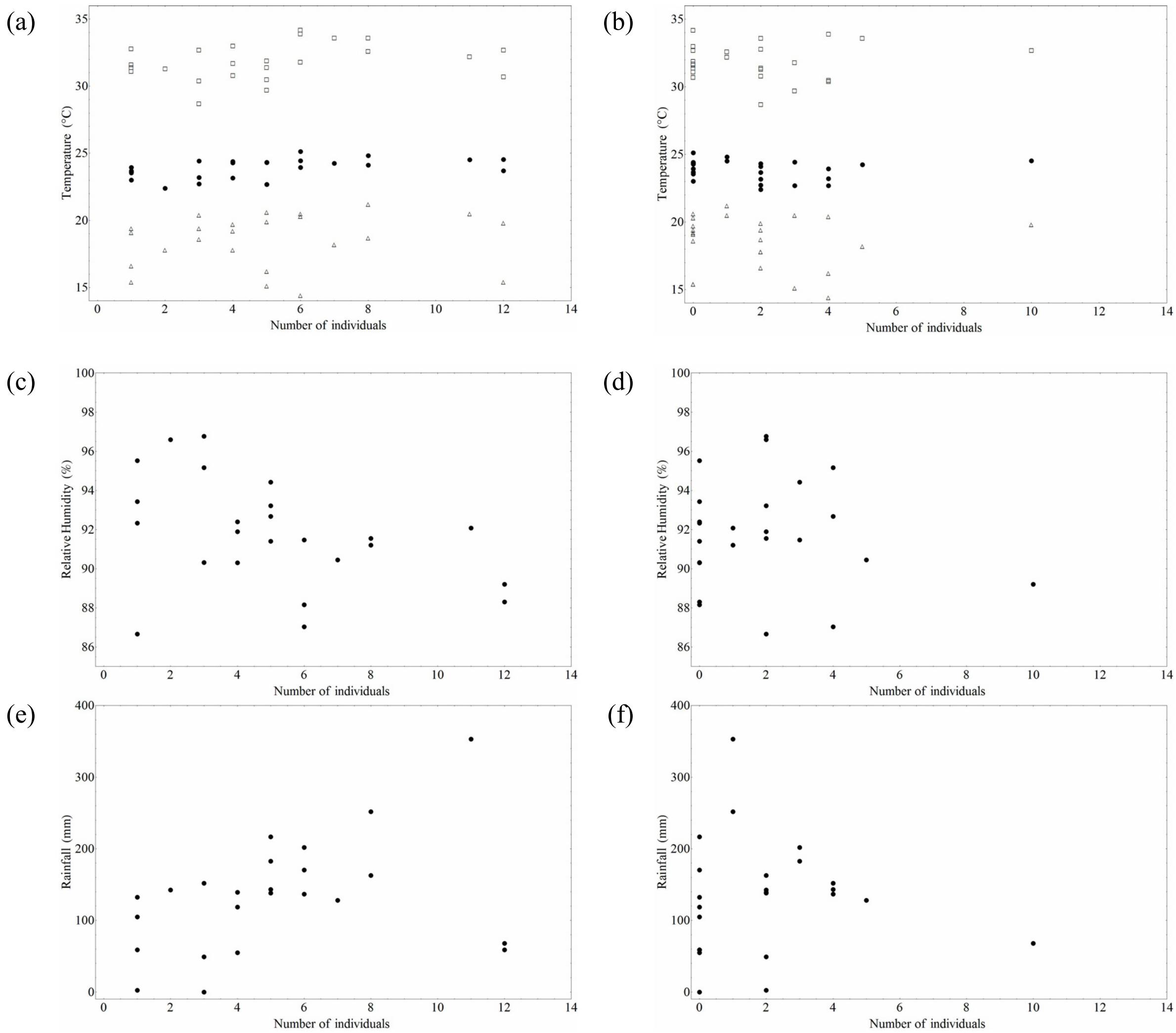

Figure 4 The number of macro-moth individuals and weather factors at Headquarters (HQ) and Huilek Park Ranger station (HL) in 2007 - 2008. (a) mean (●), max (☐) and min (△) temperature (°C) at HQ, (b) mean (●), max (☐) and min (△) temperature (°C) at HL, (c) relative humidity at HQ, (d) relative humidity at HL, (e) rainfalls at HQ and (f) rainfalls at HL.

Discussion

Our results show that Sphingidae was recorded as the most diverse family sampled at Khao Nan National Park, followed by Noctuidae and Saturniidae. However, in terms of abundance, Sphingidae and Noctuidae were found to be the most abundant, followed by Saturniidae. Sphingidae and Noctuidae were considered as highly distributed worldwide and more abundant in tropical areas [2,27]. Sphingidae and Noctuidae are highly mobile families and could be found in a wide range of habitats from lowland to montane forest, as well as undisturbed to disturbed habitats [2,28-29]. Their polyphagous larvae with a wide range of food preferences could have contributed to their high diversity and abundance [2,30]. In addition, Sphingidae are generally specialists of disturbed and open habitats.

Single individuals or singletons represented 52.6 % of the total species. These singletons were highly represented in Sphingidae (26.7 %) and followed by Geometridae (16.7 %). Among these are notably the single species of the rarely encountered species of Saturniidae, *Actias maenas* (Protected Insects). The least diverse families at Khao Nan National Park were Cossidae, Cyclidiidae and Uraniidae that are represented by one species each.

Several studies have shown that disturbance is an important mechanism maintaining species diversity (e.g. [31-33]). Species richness of moths in tropical forests may achieve peak values in old secondary forest habitats [34] or after moderate selective logging [35,36]. Indeed, we have found that both diversity and species richness of macro-moth communities were higher in moderate selective logging (at Headquarters) than in the closed forest (at Huilek Park Ranger station). This might be because the secondary forest is composed of several young trees, supplying more diverse food sources for moth larvae and more young leaves for moth larvae to eat. On the other hand, at Huilek Park Ranger station, 70 % of this site was predominately covered with *Elateriospermum tapos* trees (less diverse or nearly pure stand). The species differ in their conservation values: species with a restricted area of distribution are of the highest conservation priority [37-40] because they are vulnerable and prone to global extinction. It is interesting to note that one species of Uraniidae (*Lyssa zampa*) is highly prominent at Khao Nan National Park and recorded as an import-export prohibition insect. This suggests the presence of species in this area indicates a community that is important for conservation purposes.

Many studies have shown that weather factors such as temperature, relative humidity and rainfall are closely related to moth abundance and richness [16-18,41]. The number of moths caught in the light traps is closely related to weather conditions, with more catches on warmer nights than on windy or wet nights [15]. Our results support a previous study [15] that the number of macro-moths was positively associated with max/min/mean temperatures. Warmer conditions may speed up the physiological processes and lead to more rapid development, more generations in a season, more movement and reduced mortality from abiotic factors [18,42]. A wide variety of organisms have responded to the increase in spring temperature [13,43], including species that have advanced their timing of reproduction or growth [44-50].

Previous studies showed that in tropical forests, rainfall with a three-month lag had some effects on the abundance of moth populations [16,51-52]. In temperate forest, rainfall of current and previous months had both positive and negative effects on different moth families [18]. Studies also suggest that rainfall of the current month and rainfall of 2 previous months had negative effects on the abundance of Geometridae and Sphingidae but rainfall of the prior month had positive effects on the abundance of Sphingidae and Thyatiridae. Our results did not support these previous studies [16,18,51-52]. We found that rainfall had no effect on the total number of macro-moths at Khao Nan National Park. This disagreement could be due to 2 possible reasons: (1) rainfall might have some effects in some lag months and (2) rainfall might have some negative effects on some families and positive effects on others, but due to the small sample size in our study, we could not analyse the effect of lag month and the correlation between rainfall and the number of macro-moths at the family level.

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