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COMMUNICATION

The insect fauna of Tenompok Forest Reserve in Sabah, Malaysia

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Abstract: The insect fauna in Tenompok Forest Reserve, adjacent to Mount Kinabalu in Sabah was surveyed. Nocturnal insect diversity was moderately high, compared to other forest reserves surveyed earlier. Species richness, however, was moderate, with an average of 73 species from 84 individuals recorded from a 1m^2 area of the light-trapping cloth. At least 20 Bornean endemic insect species were recorded from this rapid biodiversity assessment, which include 19 moth species and one beetle species. The endemics and other insects of conservation interest recorded during the survey provide salient information to enhance the conservation effort of this forest which connects Kinabalu Park and the Crocker Range Park. Such information provides inputs towards recommendations on high conservation value (HCV) of the area that would be incorporated in the formulation of the forest management plan. Issues affecting the insect fauna and recommendations on insect diversity enhancement and conservation are highlighted in this paper.

Keywords: Biodiversity conservation, diversity, Heart of Borneo, insect fauna, Tenompok Forest Reserve.

Malay abstract: Satu tinjauan fauna serangga telah dijalankan di Hutan Simpan Tenompok, berhampiran dengan Gunung Kinabalu di Sabah. Kepelbagaian serangga malam adalah sederhana tinggi berbanding dengan hutan-hutan simpan lain yang telah dikaji sebelum ini. Walau bagaimanapun, kekayaan spesies adalah sederhana, dengan purata 73 spesies dari 84 individu yang telah direkodkan dari 1m2 kain putih perangkap cahaya. Sekurang-kurangnya 20 spesies serangga endemik kepada Borneo telah direkodkan dari penilaian kepelbagaian pantas ini, yang merangkumi 19 spesies rama-rama dan satu spesies kumbang. Spesies endemik serta serangga berkepentingan konservasi yang lain memberikan maklumat yang boleh membantu dalam mempertingkatkan usaha konservasi hutan ini, yang menghubungkan Taman Kinabalu dan Taman Banjaran Crocker. Maklumat sebegini membekalkan input terhadap rekomendasi untuk kawasan konservasi bernilai tinggi dalam penyediaan pelan pengurusan hutan. Isu-isu berkaitan dengan fauna serangga serta rekomendasi untuk konservasi dan peningkatan kepelbagaian serangga turut diketengahkan dalam penerbitan ini.

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Author details: Arthur Y.C. Chung and Steven Bosuang are entomologists based in Sabah. Arthur Y.C. Chung is a senior researcher while Viviannye Paul is a researcher at the Sabah Forestry Department.

Author contribution: AYCC and VP participated in the survey. SB is an expert on beetles and other montane insects. He contributed significantly in identification.

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INTRODUCTION

The Malaysian state of Sabah in Borneo is known for its remarkable biodiversity and iconic wildlife species (Oldfield 2014), including insects (Chung et al. 2015). These are the natural treasures that need to be protected and conserved, as stipulated in the Sabah Biodiversity Strategy 2012–2022 (Anon. 2012). This strategy is in line with the National Policy on Biological Diversity (Anon. 2016) that seeks to conserve Malaysia's biodiversity and to ensure that its components are utilised in a sustainable manner for continued progress and socio-economic development. In line with this strategy, the Sabah Forestry Department has been in the forefront in implementing biodiversity conservation programmes under the Heart of Borneo (HoB) Initiative. The HoB initiative is a 'three countries – one vision' responsibility, which is to protect and conserve the rich biodiversity within this area. It is a voluntary transboundary cooperation aimed at conserving and managing the ecologically inter-connected highlands of Borneo and parts of the adjacent foothills and lowland rainforests, which straddle the borders of three ASEAN countries, covering an area of approximately 2,00,000km^2 (Anon. 2013).

Insect numbers are declining globally (Basset & Lamarre 2019). Hence, much attention should be given to this group of living organisms. Within the HoB initiative, biodiversity documentation has been extensively carried out in Sabah, encompassing insect diversity as well, e.g., Chung et al. (2013, 2016a,b), since much is still unknown about the insect fauna compared to the large and more charismatic animals (Anon. 2012). Despite their small size in comparison with other wildlife, they are ecologically important in the functioning of the tropical ecosystems because of their high species richness and abundance (Hill & Abang 2005).

This scientific survey was carried out on 5–9 September 2016, with the base camp located at Kg. Kilimu in Ranau. The objectives of this study were to document the insect fauna of Tenompok Forest Reserve (FR) under the HoB Initiative, and to investigate issues affecting insect diversity, as well as to provide recommendations that would contribute towards biodiversity conservation of the study area. Research findings from this study would enhance this area as a Class I FR to promote the connectivity between Kinabalu Park (KP) and Crocker Range Park (CRP) under the Ecolinc Kinabalu project. This project is a connectivity conservation effort initiated by Sabah Parks to improve ecological connectivity between KP and CRP. Although KP and CRP reside on the same range, the parks are physically separated from each other; their boundaries are separated by a distance of approximately 10km at the closest point. Forest fragmentation that occurs within these two protected areas due to uncontrolled deforestation and expansion of agriculture and human activities has been an issue.

MATERIALS & METHODS

Study area

Tenompok FR (Figure 1 and Image 1) is a Class I Protection FR and is situated adjacent to Mount Kinabalu (4,095m) (Image 2), the tallest mountain in Malaysia. It is located beside the Kota Kinabalu-Ranau highway, approximately 92km east of Kota Kinabalu and 19km west of Ranau. With an area of 1,984ha the forest reserve is under the jurisdiction of the Ranau District Forestry Officer. It is surrounded by villages ('kampung' in Malay and often used as 'Kg.' before the name of the village), namely Kg. Bundu Tuhan in the east, Kg. Torolobou and Kg. Toboh in the south, Kg. Kiau in the north, and Kg. Tiong in the west.

The forest is mountainous, (1,040–1,650 m), with slope amplitudes in excess of 300m and normally greater than 25°. The soil associations in this reserve are mainly Croker and Trusmadi, based on the soil classification in Sabah (Acres et al. 1975). The reserve is a water catchment area for Kg. Bundu Tuhan and many other villages. Several rivers flow from this reserve, namely Liodan, Kenipir, Terleboh, Luminanap, Kuriau, Kipalapok and Tomis. The vegetation type of the reserve is largely lower montane forest.

Insect sampling methods

Light trap was used to sample nocturnal insects while sweep nets and forceps were used to sample diurnal insects.

Light trap

The trap consists of a vertical white sheet (2 X 2 m) illuminated by a 250W mercury-lithium bulb. It was powered by a portable Yamaha generator. The trap was set up in an open area facing the forest reserve, from 19.00 to 21.00 h. A GPS (Model: Garmin GPSMAP 60CSx) was used to determine the coordinates of each sampling site. Temperature and relative humidity were taken with a digital hygrometer from Extech Instruments (model no. 445702). The details of each trapping position are given in Table 1.

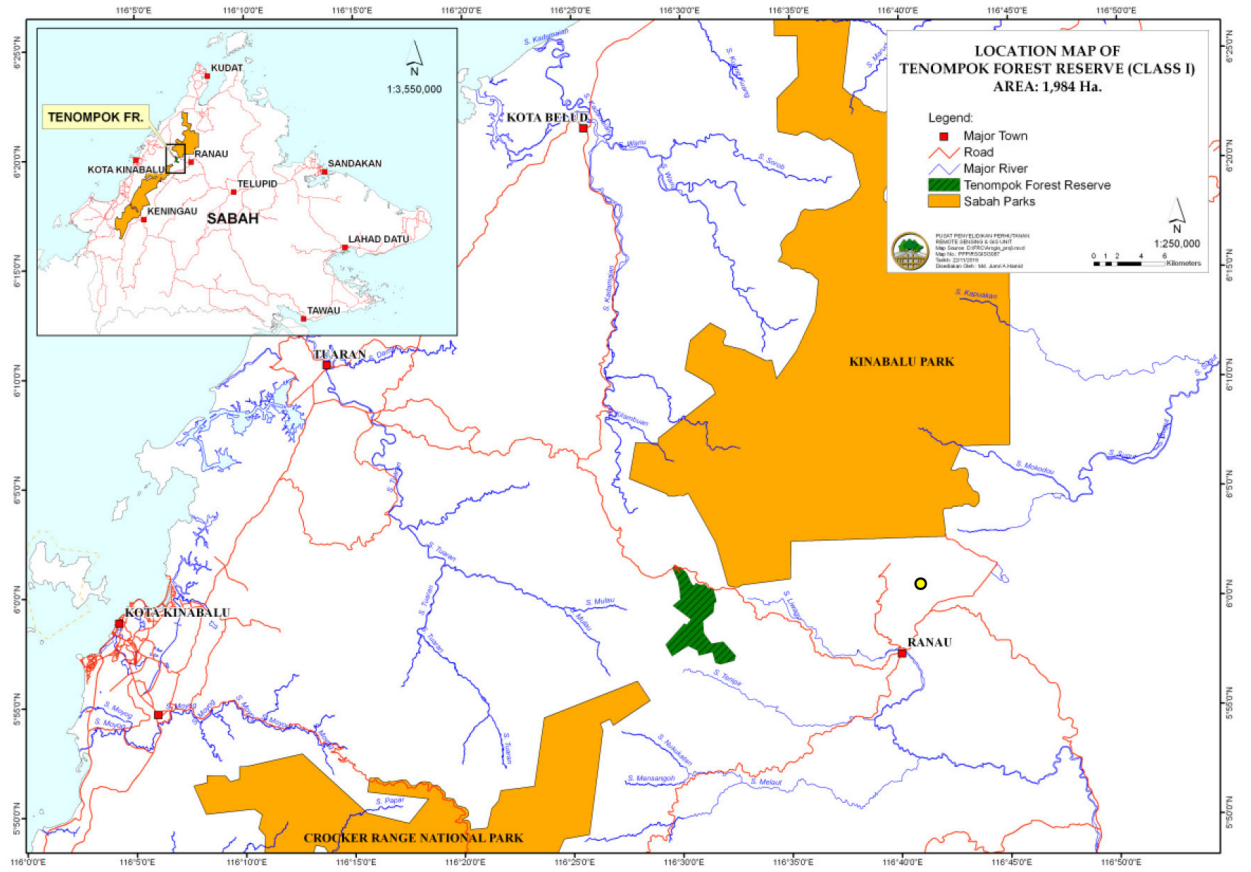


Figure 1. Location of Tenompok Forest Reserve in Sabah (inset) and the reserve (green colour) between Kinabalu Park and Crocker Range Park, and the location of the base camp (yellow dot), near Ranau.

Image 1. Tenompok FR, as viewed from Panataran at the entrance of Kinabalu Park.

To evaluate diversity of the sampling area, insect species and individuals (≥ 5mm) within the 1 X 1 m^2 at the centre of the white cloth were enumerated from 20.30 to 21.00 h. This is a rapid biodiversity assessment method because by the end of the sampling time, morphospecies and individual numbers can be obtained. The data was used to calculate diversity indices. This method is simple, fast and can be carried out by non-insect specialists. To avoid compounding human error, the same staff was assigned to count the species and individual numbers throughout the sampling period. Light trapping was conducted within the compound of the Tenompok nursery (approximately 0.5 acre) but facing different positions of the forest on different nights. The term 'position' is used here rather than site because of the limited space within the nursery and the authors acknowledge that these positions may not be independent of one another. There were no other suitable sites for setting up the light trap in other parts of the forest due to logistical difficulties and safety reasons at night.

Sweep net and manual collection

Sweep nets were used to collect flying insects while other insects were sampled using fine forceps. Butterflies were put in triangle papers while other specimens were

Image 2. Mt. Kinabalu, as viewed from Kg. Bundu Tuhan, located beside Tenompok FR.

Table 1. Light-trapping positions at the nursery of Tenompok FR.

Sampling position	Coordinates	Elevation (m)	Temp. (°C)	Humidity (%)	Sampling date	Remarks
A	6.0205°N 116.499°E	1326	17.9	88	6 Sep	Cloudy
B	6.020°N 116.499°E	1329	18.0	90	7 Sep	Cloudy
C	6.020°N 116.499°E	1334	17.9	91	8 Sep	Cloudy and misty

put in vials with 75% ethanol solution. Sampling was conducted along the trails established previously and also old skid trails. Details of the daytime sampling sites are listed in Table 2.

Table 2. Daytime sampling sites in Tenompok FR from 5 to 9 September 2016.

Sampling site	Starting point coordinates	Elevation (m)
1 -- (Along the forest trail at Tenompok nursery)	6.020°N 116.499°E	1327–1404
2 -- (Along the view point trail at Tenompok nursery)	6.020°N 116.499°E	1327–1397
3 -- (Along the trail at Kg Bundu Tuhan)	5.962°N 116.537°E	1224–1461

Insect specimens and identification

In this survey, focus was given to certain insect groups, i.e., butterflies, moths, and beetles. Other insects were recorded when encountered but without any concerted effort. Only insects with conservation interest and potential indicator insect species were sampled, so as to minimize the workload at the laboratory in preparing the specimens for identification. This is also one of the best practices adopted to minimize stress and disturbance to biodiversity, as pointed out by Costello et al. (2016) and Didham et al. (2019) on field work ethics in biological research. Photographs were taken with DSLR Nikon D800E and Nikon Coolpix cameras to facilitate identification. Common insects were not sampled but photographs were taken for record purposes. Some insect photos were not taken on the white sheet (on purpose) after the enumeration was conducted.

Selected specimens were dry-mounted and sorted to family and some to the genus and species level. The specimens sampled from this survey are deposited at the Forest Research Centre, Sepilok, Sabah. Dry-mounted specimens were identified based on the FRC Entomology Collection and various reference materials, e.g., Otsuka (1988, 2001) and Kirton (2014) for butterflies; Holloway (1983, 1985, 1986, 1987, 1988, 1989, 1993, 1996, 1997, 1998, 1999, 2001, 2003, 2005, 2008, 2009, 2011), Robinson et al. (1994), and Sutton et al. (2015) for moths; Fujita (2010), Makihara (1999), and Tung (1983) for beetles; Orr (2003) and Tang et al. (2010) for dragonflies. Some other insects were identified based on Hill & Abang (2005).

Diversity indices

The diversity indices, namely Shannon Wiener, Simpson, and Fisher Alpha were calculated through a diversity analysis software by Seaby & Henderson (2007), based on Magurran (2004) and Southwood & Henderson (2000). Merits and limitations of diversity measurements are provided by Beck & Schwanghart (2010). Knowing that biodiversity is a multifaceted phenomenon and the existence of various methods in diversity measurements, we used the same few indices that were also applied in the past insect surveys

throughout Sabah, for comparison purposes.

Shannon Wiener Index (H')

This index is calculated in the following way:

$H' = -\sum p_i \ln p_i$

where p_i is the proportion of individuals found in species i. For a well-sampled community, we can estimate this proportion as $p_i = n_i/N$, where n_i is the number of individuals in species i and N is the total number of individuals in the community. Since by definition the p_is will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why we take the inverse of the sum. Typical values are generally between 1.5 and 3.5 in most ecological studies. The Shannon index increases as both the richness and the evenness of the community increase.

Simpson Index (D)

This index is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species:

$D_s = \sum p_i^2$

where again p_i is the proportion of individuals found in species i. For a finite community, this is

$D = \sum n_i(n_i - 1)/N(N - 1)$

D is a measure of dominance, so as D increases, diversity (in the sense of evenness) decreases. Thus, Simpson's index is usually reported as its complement 1-D (or sometimes 1/D or –lnD). In Seaby & Henderson (2007), it is reported as 1/D, which is also known as Simpson's reciprocal index. It is heavily weighted towards the most abundant species in the sample while less sensitive to species richness (Magurran 1988). Hence, the value will be low if there is a very abundant species.

Fisher Alpha Index (S)

This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution:

$\alpha x, \alpha x^2/2, \alpha x^3/3, \ldots \alpha x^n/n$

where each term gives the number of species predicted to have 1,2,3,....n individuals in the sample. The index is the alpha parameter. This is a useful index, which has been widely used. It is estimated by an iterative procedure that may take an appreciable amount of time with large data sets.

Insect fauna in conservation implications

Within ecological science, there has been a large focus on whether a reduction in the diversity of the entities of organisms – biodiversity – is impacting ecological process and ecological services. Various studies have highlighted that there is indeed a positive relationship between diversity and functioning in terms of biomass production and some other functions (Balvanera et al. 2006; Cardinale et al. 2006; Isbell et al. 2011). Biodiversity conservation should focus on ecosystem function, rather than on a particular species, that could serve as a framework for addressing the current urgent conservation challenges (Peh & Lewis 2012). In this study, it is hoped that the documentation of insect fauna would provide an impetus for biodiversity conservation of Tenompok FR as insects are ecologically important in the functioning of the ecosystem.

RESULTS AND DISCUSSION

Overall insect diversity

The nocturnal insect diversity was moderately high, as shown in Table 3. The mean Shannon Index was 4.2 while Simpson index was 206.5 and Fisher alpha index was 260.2. Species number and abundance, however, were moderate, with an average of 77 species and 84 individuals recorded within a $1m^2$ light-trapping cloth.

During light-trapping, the temperature was cold, between 17°C and 18°C with relatively high humidity, between 88% and 91% (Table 1). The distribution of insect species from the light-trapping positions is reflected in the species-rank abundance curves in Figure 2. Position C recorded the most species (85), as indicated with the long tail graph, and the Shannon's index of 4.37 was the highest among the three positions. Position C also shows the steepest curve, with six specimens from one interesting moth species, *Areas galactina*. This was the most prominent species throughout the three nights of light-trapping.

When the nocturnal insect richness is compared with other forest reserves, Tenompok FR (in red) appeared to be moderate as it is ranked 8th of the 19 sites in Sabah (Figure 3a). In terms of nocturnal insect diversity, it is moderately high (ranked 5th of the 19 sites) and almost comparable to many other montane forest reserves sampled previously, such as Bukit Hampuan FR and Crocker Range FR (Figure 3b).

Many Bornean endemic species were recorded from Tenompok FR during the survey, as listed in Table 4. The endemics included 19 moth species (Image 3) and one beetle species (Image 4). This information provides input towards recommendations on High Conservation

Table 3. Insect diversity within a 1 x 1 m² of the light-trapping cloth, as sampled in Tenompok FR.

	Sampling position	Species	Ind.	Shannon	Simpson	Fisher Alpha
1	A	77	93	4.26	178.3	210.1
2	B	56	64	3.98	224	214.3
3	C	85	96	4.37	217.1	356.2
	Mean	73±15	84±18	4.2±0.2	206.5±24.6	260.2±83.2

Values (HCV) of the area, namely HCV 1 as stipulated in HCVRN (2013). From the past insect surveys under the HoB programme in Sabah, Crocker Range FR recorded the highest number of endemics with 27 species (Chung 2016a), followed by Bukit Hampuan FR with 19 species (Chung 2013). Hence, Tenompok FR recorded the second highest number of endemics. All the three forest reserves are located between 1,300 to 2,000 m within the Crocker Range, which indicate that the montane forest is a haven for endemic insect species. Merckx et al. (2015) reported that tropical mountains are hot spots of biodiversity and endemism.

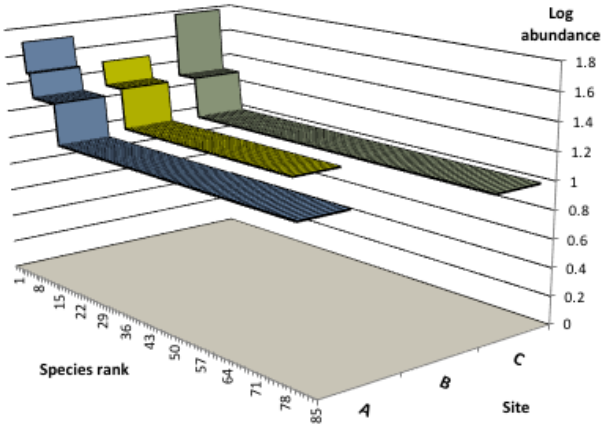


Figure 2. Species-rank abundance curves of the light-trapping in Tenompok FR.

Butterflies (Lepidoptera)

At least 13 butterfly species were recorded, as listed in Appendix 1. Most of the butterflies were recorded at Sg. Liden in Kg. Bundu Tuhan, at the fringe of the forest reserve. Among the interesting butterflies sighted were

Table 4. Bornean endemic insect species from Tenompok FR during the survey. The photographs of moth and beetle species are shown in Figures 6 and 7, respectively.

	Species	Author	Order	Family
1	*Odontolabis leuthneri*	Boileau	Coleoptera	Lucanidae
2	*Amata prepuncta*	Holloway	Lepidoptera	Erebidae
3	*Auriculoceryx pterodactyliformis*	Holloway	Lepidoptera	Erebidae
4	*Metaemene albigrisea*	Holloway	Lepidoptera	Erebidae
5	*Cyana cruentata*	Talbot	Lepidoptera	Erebidae
6	*Cyana saulia*	Swinhoe	Lepidoptera	Erebidae
7	*Garudina macrolatana*	Holloway	Lepidoptera	Erebidae
8	*Lyclene mesilaulinea*	Holloway	Lepidoptera	Erebidae
9	*Monosyntaxis trimaculata*	Hampson	Lepidoptera	Erebidae
10	*Spilosoma groganae*	Holloway	Lepidoptera	Erebidae
11	*Asota kinabaluensis*	Rothschild	Lepidoptera	Erebidae
12	*Ozola submontana*	Holloway	Lepidoptera	Geometridae
13	*Plutodes evaginata*	Holloway	Lepidoptera	Geometridae
14	*Problepsis borneamagna*	Holloway	Lepidoptera	Geometridae
15	*Spaniocentra apatelloides*	Holloway	Lepidoptera	Geometridae
16	*Buzara saikehi*	Holloway	Lepidoptera	Noctuidae
17	*Mudaria magniplaga*	Walker	Lepidoptera	Noctuidae
18	*Manoba coadei*	Holloway	Lepidoptera	Nolidae
19	*Tyana marina*	Warren	Lepidoptera	Nolidae
20	*Panacra psaltria*	Jordan	Lepidoptera	Sphingidae

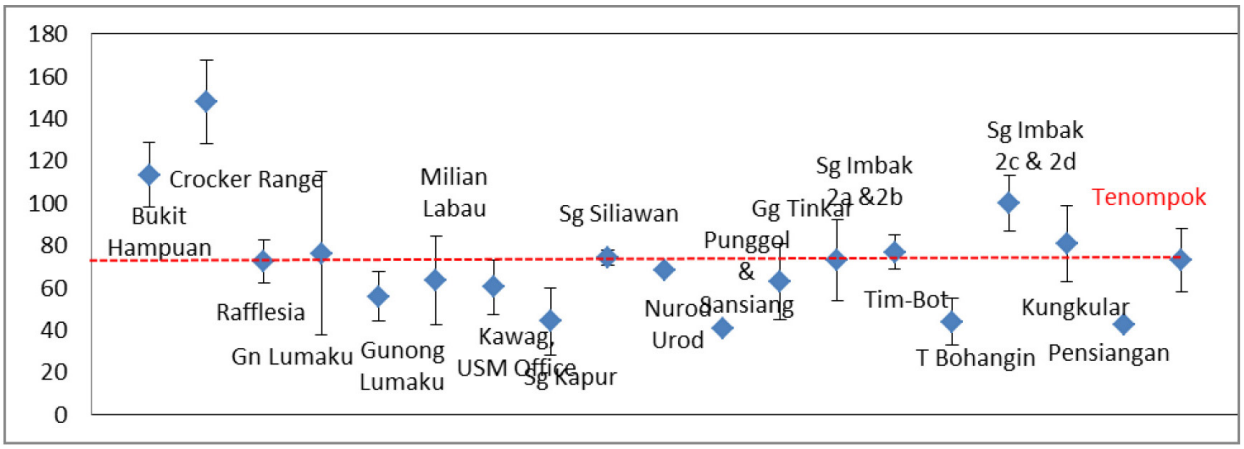


Figure 3a. Species number (±standard deviation) within one metre squared cloth as assessed through light-trapping in various forest reserves in Sabah.

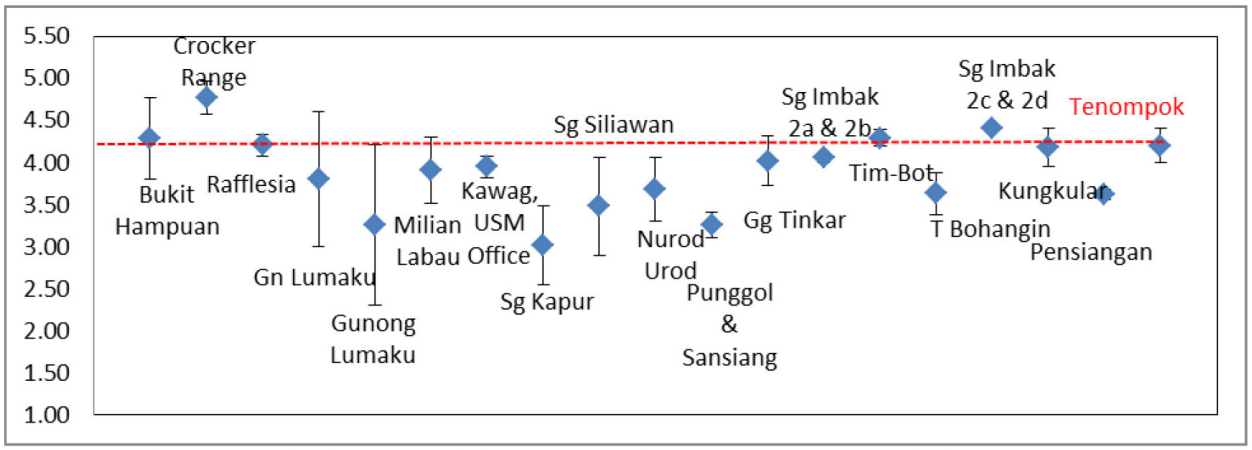


Figure 3b. Shannon index (±standard deviation) within one metre squared cloth as assessed through light-trapping in various forest reserves in Sabah.

the Rajah Brooke's Birdwing *Trogonoptera brookiana* which is the national butterfly of Malaysia and the Golden Birdwing *Troides amphrysus*, a flagship species of Sabah (Otsuka 2001).

Moths (Lepidoptera)

Some 102 moth species were recorded during this study (Appendix 2). A total of 19 endemic species were documented (Image 3), which represents 19% of the moths recorded during the survey. In terms of percentage, more endemic moths were recorded in Crocker Range FR (Chung 2016a) and Bukit Hampuan FR (Chung 2013), with 33% and 23% respectively. In this paper, all Arctiidae and Lymantriidae moths are classified under Erebidae based on DNA analyses by Zahiri et al. (2010 & 2011) and taxonomic changes highlighted by Holloway (2011).

Beetles (Coleoptera)

At least nine species of macro beetles were documented (Appendix 3). One Bornean endemic species was recorded, namely *Odontolabis leuthneri* (Image 4) of the telodonte form (Fujita 2010). This stag beetle was sighted during day time at 1,600m. A large long-horned beetle, *Batocera tigris*, (about 65mm) was attracted to the light trap at the Tenompok nursery. It is a rare beetle in Borneo although it is known to be distributed in Peninsular Malaysia, Thailand, Sumatra, Java and Borneo. Quite a number of the soldier beetles, *Mimopolemius* sp. of the family Cantharidae were sighted while trekking along the trail at Kg. Bundu Tuhan.

Other insects

At least 17 other insect species were recorded which include termites, bugs, fig wasps, honeybees, ants, night wasps, praying mantis, dragonflies, damselflies and

Amata prepuncta
(Erebidae, Arctiinae)

Auriculoceryx pterodactyliformis
(Erebidae, Arctiinae)

Cyana cruentata
(Erebidae, Arctiinae)

Cyana saulia
(Erebidae, Arctiinae)

Garudina macrolatana
(Erebidae, Arctiinae)

Lyclene mesilaulinea
(Erebidae, Arctiinae)

Monosyntaxis trimaculata
(Erebidae, Arctiinae)

Spilosoma groganae
(Erebidae, Arctiinae)

Asota kinabaluensis
(Erebidae)

Metaemene albigrisea
(Erebidae, Boletobiinae)

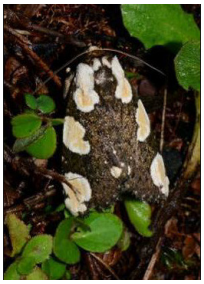
Ozola submontana
(Geometridae)

Plutodes evaginata
(Geometridae)

Problepsis borneamagna
(Geometridae)

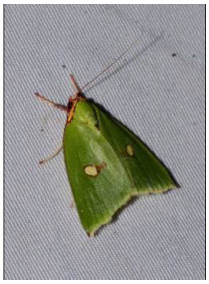
Spaniocentra apatelloides
(Geometridae)

Buzara saikehi
(Noctuidae)



Mudaria magniplaga
(Noctuidae)

Manoba coadei
(Nolidae)



Tyana marina
(Nolidae)

Panacra psaltria
(Sphingidae)

Image 3. Bornean endemic moths from Tenompok FR. © A.Y.C. Chung.

Image 4. Bornean endemic Stag Beetle *Odontolabis leuthneri* (telodonte form).

crickets. They are listed in Appendix 4.

Further pertinent observations on selected insects during the survey

Tiger Moth *Areas galactina* (Lepidoptera: Erebidae: Arctiinae)

This was the commonest moth species encountered during the three nights of light-trapping at the Tenompok FR nursery. It is a spectacular species because of its vibrant colours and interesting pattern (Image 5a & b). According to Holloway (1988), this insect cannot be confused with any other; the reticulate black markings of the forewings and the black spots on patagia and tegulae distinguish it from *Spilosoma* of the *ericsoni* group. The length of the forewings is 32–35 mm for male and 40–42 mm for female. It is distributed from northern India and southern China to Sundaland and the Philippines. Although widely distributed, it is not commonly encountered, normally found between 1,200m and 2,000m. In this survey, it was recorded from 1,300m. Although it is predominantly a montane species, it has been recorded in the lowland forest, such as Danum Valley (AYC Chung, unpublished data). There has been no information documented on the host plants.

Tiger Moth *Amerila* spp. (Lepidoptera: Erebidae: Arctiinae)

Two species of *Amerila* were recorded during the survey, namely *Amerila astreus* (Image 6a) and *Amerila omissa* (Image 6b–d). Like that of *Areas galactina*, both species are spectacular, with strikingly pink legs. Both were attracted to the light trap at the Tenompok FR nursery. They are similar externally in appearance except for the dorsal part of the abdomen. In *A. astreus*, it is entirely pink but only apically so in *A. omissa*. One of the interesting defense mechanisms that was observed

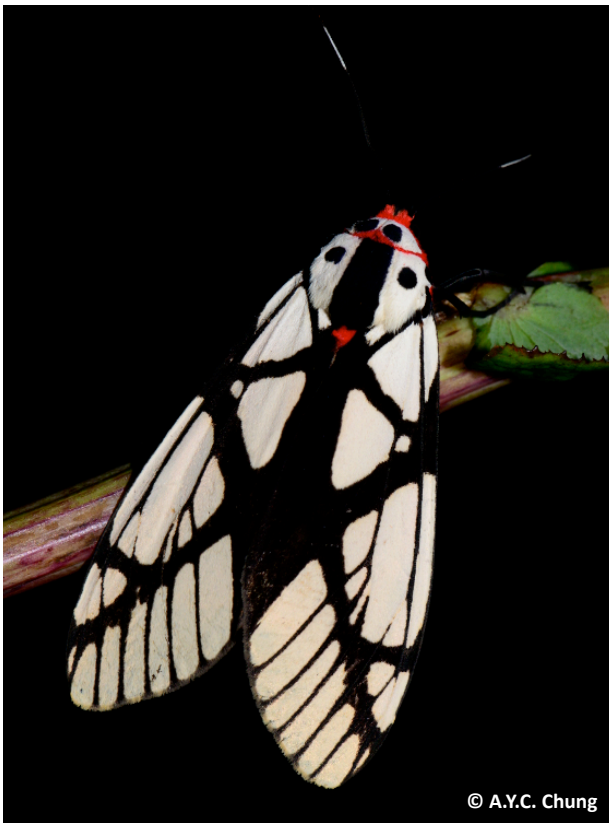


Image 5a. *Areas galactina* in resting position.

Image 5b. *Areas galactina* exposing its strikingly-coloured hind wings.

Image 6a. *Amerila astreus* with pink abdomen.

Image 6b. *Amerila omissa* with pink abdomen at the apical end.

Image 6c. The underside of *Amerila omissa*, with striking pinkish legs.

Image 6d. When alarmed, the moth produces yellow froth at the thorax.

during the survey was the secretion of acrid smelling yellow froth from the cervical glands at the anterior of the thorax when the moth was disturbed.

Carton ball-like termite nests (Termitidae: Nasutitermitinae)

While trekking along the trail (Sampling Site 3) from Kg Bundu Tuhan, at least 10 ball-like termite nests were sighted from 1,300 to 1,461 m. They were found on tree trunks (Image 7a) or hanging on tree branches (Image 7b), some of which were about the size of a football. The nests were constructed from soil and litter, mixed with termite saliva. This is interesting because it was rarely observed in previous surveys in other forest reserves, e.g., Chung et al. (2013, 2016a,b). The termites belong to the Nasutiterminae group because of their pointed-nose soldiers. They were observed carrying their food back to the nest openly in an organized manner (Image 7c).

Issues indirectly affecting insect diversity

Among many of the forest reserves in Sabah, Tenompok FR is considered one of those that is well-protected, with active participation from the local communities. The reserve is a source of water supply for many of the adjacent villages. Hence, the local communities have formed a committee to monitor and take care of the resources in the reserve. Sign boards were put up to warn trespassers into the reserve (Image 8). During the survey, a few villagers joined the researchers, indicating that they were keen to know more about the resources in the reserve.

Tenompok FR is located between Kinabalu Park and the Crocker Range Park. Hence, the reserve is important as a corridor connecting the two park areas, especially for wildlife movement. It is a stepping stone approach for movement of birds and insects, and the adverse impacts on inbreeding and decline in genetic diversity can be reduced. Staff from Sabah Parks and the Ecolinc project

Image 7a. The carton ball-like termite nest on a tree trunk in Tenompok FR.

Image 7b. The nest, hanging from a branch, could reach the size of a football.

Image 7c. The termites carrying their food back to the nest openly in an organized trail.

also participated in this survey to enhance their info on this area. The Ecolinc project was initiated some eight years ago under the EU-REDD+ programme to promote and enhance awareness to the local communities on forest connectivity and related activities on climate change and sustainable forest management. ECOLINC is the acronym for ECOlogical Linkage (conserving Sabah's heritage, empowering INdigenous Communities).

Although the forest is considered well-protected, the survey team also spotted a few animal traps in the forest. Among them was a pangolin trap at the base of a big tree (Image 9a). A few tree trunks were partly burnt previously, presumably to harvest honey from the stingless bees (Image 9b).

It is important for the local communities to work hand-in-hand with the relevant departments and agencies to tackle various issues pertaining to forest biodiversity which could indirectly affect insect population (Nilus et al. 2013). As shown in this brief study, relatively high diversity of insects and many endemic species were recorded. Hence, it is important to continue to protect the forest for its interesting biodiversity, in line with the goals of the Sabah Biodiversity Strategy (Anon. 2012), guided by the National Policy on Biodiversity.

Impediments in insect fauna study

Impediments to identification are one of the major reasons why insect data are not the prime focus in conservation, as the group is perceived too big and unwieldy to use. Misidentification potentially lead to overestimating or underestimating species richness, and these problems can extremely compromise research

Image 8. A signage put up by the villagers to warn trespassers.

involving diversity. Poor taxonomy can jeopardize the understanding of ecological patterns since they are based on richness and measurement of species turnover between sites, respectively.

For biodiversity conservation, taxonomy is important, primarily because in order to protect a taxon it is essential know it first, and secondly, because no conservation action can protect undescribed species. In this study, the enumeration on nocturnal insect diversity was based on morphospecies. Photographs of insects were taken and identification was based on various publications and the scientific reference collection at the Forest Research Centre, Sepilok. Various experts on certain insect groups also provided input in the identification of insects in this study.

CONCLUSION

From this study, the nocturnal insect diversity in Tenompok FR was moderately high when compared to other forest reserves surveyed earlier. Many endemic species were recorded in this montane forest.

The pioneer data from this rapid biodiversity assessment will serve as baseline information for other research work in future. Local university students could use these data for comparative study for long-term monitoring on the insect diversity status of Tenompok FR. The endemics and insect species with conservation interest recorded during the survey provide salient information to enhance the conservation of this forest as a Class I FR. Such information can also be used in promoting nature tourism in Tenompok which is located adjacent to the touristic Kinabalu Park and Crocker Range Park.

Issues, such as poaching and encroachment may indirectly affect the insect fauna. Relevant agencies would have to work hand-in-hand to tackle the issues with the local communities. Public awareness and environmental education would have to be enhanced among the villagers and their children who are living adjacent to the reserve to instill on them the importance of biodiversity conservation.

Image 9a. An old pangolin trap at the base of a big tree.

Image 9b. A tree trunk that had been set ablaze, presumably for the stingless bee honey.

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Appendix 1. Butterflies recorded from Tenompok FR, Sabah (5–9 September 2016).

	Species	Author	Family	Photo no. (TEN) *
1	*Graphium sarpedon sarpedon*	Linnaeus	Papilionidae	0432
2	*Trogonoptera brookiana brookiana*	Wallace	Papilionidae	Spotted
3	*Troides amphrysus flavicollis*	Druce	Papilionidae	Spotted
4	*Troides* sp.		Papilionidae	Spotted
5	*Eurema blanda blanda*	Boisduval	Pieridae	0182
6	*Cethosia hypsea hypsea*	Doubleday	Nymphalidae	0018
7	*Euploea mulciber portia*	Fruhstorfer	Nymphalidae	0180
8	*Junonia orithya metion*	Fruhstorfer	Nymphalidae	0437
9	*Mycalesis* sp.		Nymphalidae	0362
10	*Neptis duryodana duryodana*	Moore	Nymphalidae	0184
11	*Ypthima pandocus sertorius*	Fruhstorfer	Nymphalidae	0015
12	*Sinthusa* sp.		Lycaenidae	0158
13	*Potanthus* sp.		Hesperiidae	0409

Appendix 2. Selected moths recorded from Tenompok FR, Sabah (5–9 September 2016).

	Species	Author	Family	Photo no. (TEN) *	Remarks
1	*Penicillifera apicalis*	Walker	Bombycidae	0453	
2	*Arthroschista hilaralis*	Walker	Crambidae	0512	
3	*Dichocrocis zebralis*	Moore	Crambidae	0124	
4	*Fritillerynnis clathraria*	Warren	Crambidae	0255, 0107	
5	*Heortia vitessoides*	Moore	Crambidae	0469, 0473	
6	*Nevrina procopia*	Stoll	Crambidae	0463	
7	*Pitama hermesalis*	Walker	Crambidae	0095	
8	*Rhimphalea* sp.		Crambidae	0083	
9	*Syllepte iophanes*	Meyrick	Crambidae	0112	
10	*Syllepte* sp.		Crambidae	0133	
11	*Xanthomelaena* sp.		Crambidae	0261	
12	*Oreta* sp.		Drepanidae	0263	
13	*Tridrepana flava*	Moore	Drepanidae	0126	
14	*Asota heliconia*	Linnaeus	Erebidae	0488	
15	*Asota kinabaluensis*	Rothschild	Erebidae	0259	Endemic

	Species	Author	Family	Photo no. (TEN) *	Remarks
16	*Asota* nr *producta*	Butler	Erebidae	0511	
17	*Nyctemera muelleri*	Vollenhoven	Erebidae	0456, 0458	
18	*Nyctemera* sp.		Erebidae	0321	Day flying
19	*Amata prepuncta*	Holloway	Erebidae (Arctiinae)	0264	Endemic
20	*Amerila astreus*	Drury	Erebidae (Arctiinae)	0478	
21	*Amerila omissa*	Rothschild	Erebidae (Arctiinae)	0502, 0523	
22	*Areas galactina*	Hoeven	Erebidae (Arctiinae)	0052, 0065	
23	*Asura fulguritis*	Hampson	Erebidae (Arctiinae)	0125	
24	*Auriculoceryx pterodactyliformis*	Holloway	Erebidae (Arctiinae)	0243, 0256	Endemic
25	*Barsine lineatus*	Walker	Erebidae (Arctiinae)	0108	
26	*Barsine roseororatus*	Butler	Erebidae (Arctiinae)	0241	
27	*Creatonotos transiens*	Walker	Erebidae (Arctiinae)	0091	
28	*Cyana cruentata*	Talbot	Erebidae (Arctiinae)	0238	Endemic
29	*Cyana pudens*	Walker	Erebidae (Arctiinae)	0481	
30	*Cyana saulia*	Swinhoe	Erebidae (Arctiinae)	0111	Endemic
31	*Eilema* sp.		Erebidae (Arctiinae)	0480	
32	*Eugoa trifasciata*	Snellen	Erebidae (Arctiinae)	0239	
33	*Garudina macrolatana*	Holloway	Erebidae (Arctiinae)	0454	Endemic
34	*Lyclene angulifera*	Holloway	Erebidae (Arctiinae)	0240	
35	*Lyclene mesilaulinea*	Holloway	Erebidae (Arctiinae)	0092, 0265	Endemic
36	*Monosyntaxis trimaculata*	Hampson	Erebidae (Arctiinae)	0234	Endemic
37	*Padenia obliquifascia*	Rothschild	Erebidae (Arctiinae)	0484	
38	*Spilosoma groganae*	Holloway	Erebidae (Arctiinae)	0066, 0260	Endemic
39	*Metaemene albigrisea*	Holloway	Erebidae (Boletobiinae)	0125	Endemic
40	*Metaemene* sp.		Erebidae (Boletobiinae)	0250	
41	*Arctornis* sp.		Erebidae (Lymantriinae)	0075	
42	*Nygmia amplior*	Collenette	Erebidae (Lymantriinae)	0110	
43	*Nygmia* nr *atereta*	Collenette	Erebidae (Lymantriinae)	0088	
44	*Nygmia* nr *atrisignata*	Swinhoe	Erebidae (Lymantriinae)	0268	
45	*Nygmia peperites*	Collenette	Erebidae (Lymantriinae)	0081	
46	*Eupterote asclepiades*	Felder	Eupterotidae	0524	
47	*Eupterote naessigi*	Holloway	Eupterotidae	0134	
48	*Eupterote* sp.		Eupterotidae	0086	
49	*Dichomeris* sp.		Gelechiidae	0487	
50	*Chloroglyphica xeromeris*	Prout	Geometridae	0262	
51	*Cleora* sp. 1		Geometridae	0270	
52	*Cleora* sp. 2		Geometridae	0272	
53	*Comostola pyrrhogona*	Walker	Geometridae	0094	
54	*Comostola subtiliaria*	Bremer	Geometridae	0069	
55	*Dooabia plana*	Prout	Geometridae	0132	
56	*Eucyclodes* sp.		Geometridae	0076	
57	*Hypephyra brunneiplaga*	Swinhoe	Geometridae	0105	
58	*Hypochrosis hyadaria*	Guenée	Geometridae	0093	

	Species	Author	Family	Photo no. (TEN) *	Remarks
59	*Hyposidra apioleuca*	Prout	Geometridae	0507	
60	*Omiza lycoraria*	Guenée	Geometridae	0121	
61	*Ornithospila bipunctata*	Prout	Geometridae	0465, 0468	
62	*Ozola liwana*	Sommerer	Geometridae	0115	
63	*Ozola submontana*	Holloway	Geometridae	0067	Endemic
64	*Pachyodes* sp.		Geometridae	0097	
65	*Perixera* sp.		Geometridae	0116	
66	*Pingasa* sp.		Geometridae	0257	
67	*Plutodes evaginata*	Holloway	Geometridae	0489, 0129	Endemic
68	*Problepsis borneamagna*	Holloway	Geometridae	0452	Endemic
69	*Protuliocnemis biplagiata*	Moore	Geometridae	0074	
70	*Ruttellerona* sp.		Geometridae	0127	
71	*Spaniocentra apatelloides*	Holloway	Geometridae	0096	Endemic
72	*Thinopteryx crocopterata*	Kollar	Geometridae	0087	
73	*Tristeirometa* sp.		Geometridae	0119	
74	*Trabala hantu*	Roepke	Lasiocampidae	0522	
75	*Scopelodes unicolor*	Westwood	Limacodidae	0106	
76	Unidentified		Noctuidae	0123	
77	*Buzara saikehi*	Bremer	Noctuidae	0073	Endemic
78	*Catocala macula*	Hampson	Noctuidae	0118, 0131	
79	*Daddala lucilla*	Butler	Noctuidae	0251	
80	*Daddala* sp.		Noctuidae	0244	
81	*Episparis costistriga*	Walker	Noctuidae	0077	
82	*Hamodes propitia*	Guérin-Méneville	Noctuidae	0117	
83	*Hypopyra ossigeroides*	Holloway	Noctuidae	0113	
84	*Mudaria magniplaga*	Walker	Noctuidae	0128	Endemic
85	*Ochrotrigona praetextata*	Hering	Noctuidae	0476	
86	*Psimada quadripennis*	Walker	Noctuidae	0252	
87	*Rema* sp.		Noctuidae	0269	
88	*Rusicada nigritarsis*	Walker	Noctuidae	0509	
89	*Rusicada* sp.		Noctuidae	0271	
90	Unidentified		Noctuidae?	0254	
91	*Blenina* sp.		Nolidae	0090	
92	*Clethrophora angulipennis*	Prout	Nolidae	0485	
93	*Hylophilodes* nr *dubia*	Prout	Nolidae	0483	
94	*Manoba coadei*	Holloway	Nolidae	0273	Endemic
95	*Tyana marina*	Warren	Nolidae	0510	Endemic
96	*Acosmeryx shervillii*	Boisduval	Sphingidae	0089	
97	*Hippotion rosetta*	Swinhoe	Sphingidae	0245	
98	*Panacra psaltria*	Jordan	Sphingidae	0464	Endemic
99	*Theretra boisduvali*	Bugnion	Sphingidae	0508	
100	*Theretra latreillei*	MacLeay	Sphingidae	0246	
101	*Dysaethria quadricaudata*	Walker	Uraniidae	0482	
102	*Dysaethria* sp.		Uraniidae	0267	

Appendix 3. Beetles recorded from Tenompok FR, Sabah (5–9 September 2016).

	Species	Author	Family	Photo no. (TEN) *	Remarks
1	*Mimopolemius* sp. 1		Cantharidae	0104	
2	*Mimopolemius* sp. 2		Cantharidae	0304	
3	*Batocera tigris*	Voet	Cerambycidae	0175, 0174	Rare (1,400m)
4	Unidentified		Chrysomelidae	0048, 0043	
5	*Eumorphus* sp.		Endomychidae	9977	
6	*Eulichas* sp.		Eulichadidae	0275	
7	Unidentified		Lampyridae	0049	Bioluminescent larva
8	*Odontolabis leuthneri*	Boileau	Lucanidae	0209	Endemic (1,600m)
9	*Aceraius* sp.		Passalidae	0072	

Appendix 4. Other insects recorded from Tenompok FR, Sabah (5–9 September 2016).

	Species	Author	Order	Family	Photo no. (TEN)*	Remarks
1	*Bulbitermes* sp.		Blattodea	Termitidae	0343	
2	*Hospitalitermes* sp.		Blattodea	Termitidae	0336, 0365, 0373, 0386	
3	Unidentified 1		Hemiptera		9969	
4	Unidentified 2		Hemiptera		9972	
5	Unidentified 3		Hemiptera		0358	
6	*Blastophaga* sp.		Hymenoptera	Agaonidae	0324	Fig wasps
7	*Apis cerana*	Fabricius	Hymenoptera	Apidae	0156	
8	*Dolichoderus* sp.		Hymenoptera	Formicidae	9974, 9967	
9	*Myrmicaria* sp.		Hymenoptera	Formicidae	0022	
10	*Provespa anomala*	De Saussure	Hymenoptera	Vespidae	0078, 0253	
11	Unidentifed		Mantodea	Mantidae	9983	
12	*Vestalis* sp.		Odonata	Calopterygidae	0423	
13	*Euphaea* sp.		Odonata	Euphaeidae	0414	
14	*Orthetrum glaucum*	Brauer	Odonata	Libellulidae	0434	
15	*Orthetrum testaceum*	Burmeister	Odonata	Libellulidae	0433	
16	*Nisitrus vittatus*	de Haan	Orthoptera	Gryllidae	0012	
17	*Mecopoda* sp.		Orthoptera	Tettigoniidae	0417	

*Note: TEN 0000 is the photo code for Tenompok FR insects. All photographs were taken by the first author and are kept in the Forest Research Centre of the Sabah Forestry Department.

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