
Research Article

Diversity and Geographical Ranges of Insects in Crocker Range Forest Reserve, Sabah, MalaysiaArthur Y. C. Chung^{1*}, Steven Bosuang², Richard Majapun¹, Reuben Nilus¹¹Forest Research Centre, Forestry Department, P. O. Box 1407, 90715 Sandakan, Sabah²Kipandi Park, P. O. Box 12785, 88831 Kota Kinabalu, Sabah

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Abstract

An insect diversity survey was carried out in May, 2011 in the Crocker Range Forest Reserve. This is a Class VI Forest Reserve (Virgin Jungle Reserve), gazetted in 1967 and then regazetted in 1984. It comprises an area of 3,279 ha. The nocturnal insect diversity was very high, with an average of 148 insect species from 207 individuals in a square metre of the light-trapping cloth. The mean Shannon, Simpson and Fisher Alpha indices are $H' = 4.77 (>3.0)$, $D = 322.49$ and $S = 417.04$ respectively. Apart from having the highest diversity of nocturnal insects in all the 20 forest reserves surveyed within the Heart of Borneo area in Sabah, it has also recorded a number of endemic species. Some beetles are hyper-endemics, such as *Cyclommatus chewi*, *Odontolabis schenki* and *Odontolabis katsurai* (all Lucanidae beetles) which are found only in Mt. Alab of the Crocker Range F.R. At least 10 butterfly species are known to be confined to the Crocker Range, including the Kinabalu Tiger, *Parantica crowleyi*, which was sampled during the survey. A stick insect, *Orthoncrosia felix*, was recorded and it is only confined to the Crocker Range. New species are still being described. Such interesting scientific insect data from this survey and also from past records support the need to enhance biodiversity conservation in this Virgin Forest Reserve. In view of the high diversity and intriguing insect fauna, Crocker Range F.R. has potential in nature tourism for special interest tourists who contribute to Sabah's economy. A private initiative, Kipandi Park set up adjacent to the forest reserve, not only showcases the diversity of insects in Sabah but is also doing its part in studying the life cycle of rare and endemic insects which contributes towards insect conservation. The park also cooperates with government agencies in promoting conservation of biodiversity. In this paper, some of the issues pertaining to insect diversity and conservation are discussed.

Keywords: Insect, diversity, Crocker Range Forest Reserve, endemic, Heart of Borneo

Introduction

Insects are among the most diverse and abundant organisms in tropical ecosystems and they are ecologically important in the tropics (Chung, 2013). It has been estimated that some 6,000 insect species can be found in one acre of rainforest (Williams, 2012). In terms of biomass, insects are also overwhelming (Holldobler & Wilson, 1994). Insects in the Bornean rainforests are interesting, rare and many are only confined to this island. Hence, biodiversity conservation is important.

Various efforts have been taken to document the diversity of flora and fauna in Sabah, including insects. Among the key contributions towards the success of Sabah's efforts in conservation is the implementation of the Heart of Borneo (HoB) Initiative. It is the epitome of Sabah's high profile and phenomenal achievement in the management and conservation of its old world tropical rainforests. Initiated by WWF, the three countries, namely Indonesia, Malaysia and Brunei have committed through the HoB Declaration in 2007 to a common conservation vision to ensure the effective management of forest resources and the creation of protected area networks, sustainable-managed forests and land-use zones across the 22 million hectares. Following this declaration, the Sabah State Government with support from the Federal Government through the Ministry of Natural Resources and Environment, is very committed in the implementation of the HoB Initiative, with the Sabah Forestry Department taking the lead. The Sabah State Government has designated about 39,000 km² of the state's landmass, comprising mainly the important inland and highland forest ecosystems, as part of HoB (Nilus et al., 2014).

The insect diversity survey in the Crocker Range Forest Reserve was one of the programmes on biodiversity documentation under HoB. Apart from documentation, the study was also carried out to investigate issues affecting insect diversity, as well as to provide recommendations that would contribute towards biodiversity conservation of the study area.

Study Area

Crocker Range Forest Reserve is a Virgin Jungle Reserve (VJR) Class VI, located at N 05° 53' E 116° 16', at the western part of Sabah. It is conveniently situated along the right hand side of the Tambunan-Kota Kinabalu highway. This dragon-like shape reserve extends from 16 km southeast of Kota Kinabalu city to 16 km north of Tambunan town.

The forest was first gazetted in 1967 and then regazetted in 1984 (SFD 2015). It covers an area of 3,279 ha (Figure 1) which forms a small part of the Crocker Range. The bulk of the Crocker Range encompassing 139,919 ha has been gazetted as the Crocker Range Park (Taman Banjaran Crocker), managed by Sabah Parks. The Crocker Range serves as the water catchment area for the west coast and interior of Sabah. In the district forest management, Crocker Range F.R. is located mostly within the Kota Kinabalu district and only a small portion in the south is under Tambunan district.

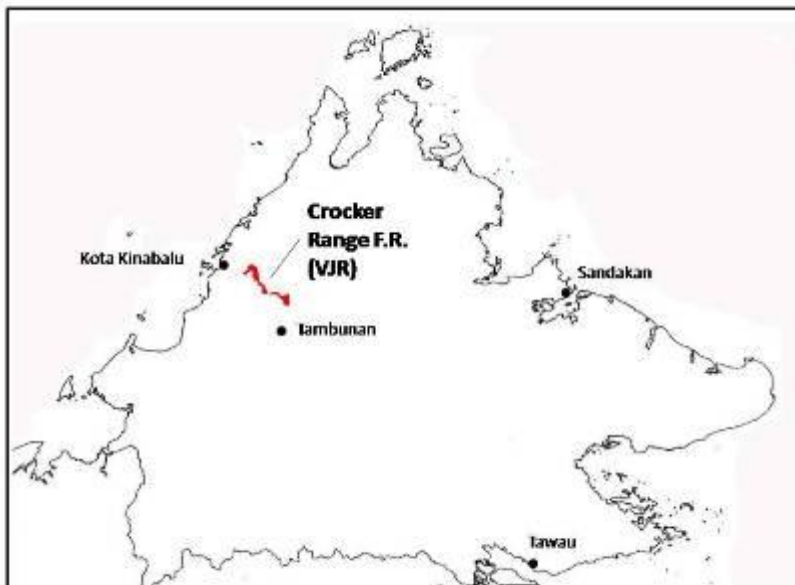


Figure 1. Location of Crocker Range Forest Reserve in Sabah.

Two major forest formations occur in the reserve, i.e. upland mixed dipterocarp forest (MDF) and lower montane forest. The differentiation of these formations is approximately at 1,000 m whereby beyond this elevation, the forest is classified as montane. Between 500 to 1,000 m, it is classified as upland MDF. However, most of the lowland and upland and some of the montane areas are degraded and overgrown by secondary plant species. The heavy clearing through nomadic agricultural practices by villagers living at the surrounding area of the forest reserve have had a major impact to the surrounding landscape (CAIMS, 2005).

This study was conducted from 11th to 21st of May, 2011. The expedition base camp was at the Rafflesia Forest Reserve (N 05° 46'25.3" E 116° 21'00.2" at 1,274 m.a.s.l.), adjacent to the Tambunan District Forestry Office and the Crocker Range F.R., located beside the Tambunan-Kota Kinabalu highway.

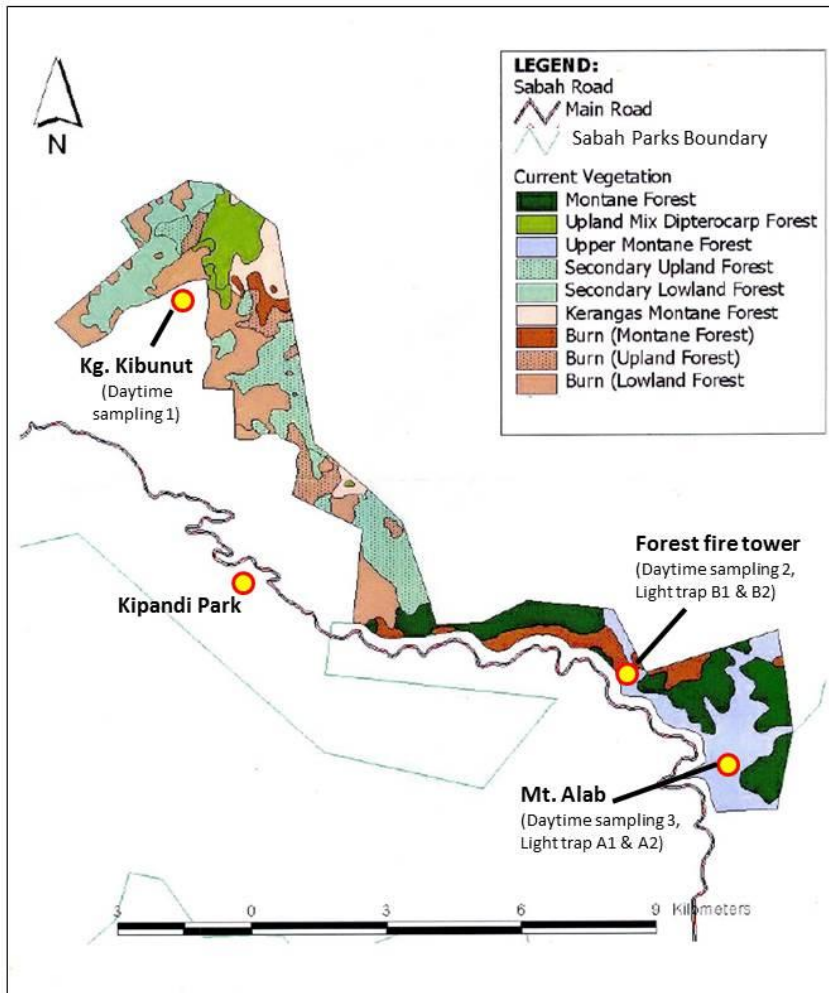


Figure 2. The forest types of Crocker Range F.R. and sampling sites during the survey.

Materials and Methods

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

Light trap

The trap consisted of a vertical white sheet (2 X 2 m) illuminated by a 250W mercury-lithium bulb. It was set up in an open area facing the forest reserve, from 7:00 to 9:00 p.m. for four nights as indicated in Table 1. Enumeration for insect species and abundance (≥ 5 mm in length) within the 1 X 1 m square was carried out from 8:30 to 9:00 pm, to evaluate diversity of the sampling area. This is a standardized enumeration for half an hour (towards the end of the two-hour light trapping) that was also applied to other samplings in the past. It is a rapid biodiversity assessment method because by the end of the sampling time, species and individual numbers could be obtained, and the data could be used to calculate diversity indices. This method is simple, fast and can be carried out by a non-insect specialist. To avoid compounding human error, the same staff was assigned to count the species and individual numbers throughout the sampling period, and also for other sampling sites. Light-trapping sites are shown in Table 1 and Figure 2. A GPS (Model: Garmin GPSMAP 60CSx) was used to determine the coordinates of each sampling site. Temperature and humidity were recorded using a digital gadget from Oregon Scientific (model no. ETHG-912).

Diversity indices

The diversity indices, namely Shannon Wiener, Simpson and Fisher Alpha were calculated through a diversity analysis software by Henderson & Seaby (1998), based on Magurran (2004) and Southwood and Henderson (2000).

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_i s 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, and the index is rarely greater than 4. 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 $-\ln D$). Since D takes on values between zero and one and approaches one in the limit of a monoculture, $(1-D)$ provides an intuitive proportional measure of diversity that is much less sensitive to species richness.

Fisher Alpha Index (S)

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

$$ax, ax^2/2, ax^3/3, \dots ax^n/n$$

Where each term gives the number of species predicted to have $1, 2, 3, \dots, n$ 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.

Table 1. Light-trapping sites in Crocker Range F.R.

Sampling site	Coordinates	Elevation (m)	Temp. (°C)	Humidity (%)	Sampling date	Remarks
A1	N 05° 49'48.2" E 116° 0'30.1"	1,957	15	85	16 May	Light trap was set up next to the TM telecommunication tower on Mt. Alab.
A2	N 05° 49'45.7" E 116° 0'29.5"	1,955	18	89	19 May	Light trap was set up next to the Digi transmission tower on Mt. Alab.
B1	N 05° 50'55.4" E 116° 9'21.9"	1,600	18	94	17 May	Light trap was set up next to the forest fire tower.
B2	N 05° 50'55.6" E 116° 9'21.7"	1,600	19	91	18 May	Same as above but facing different direction.

Sweep net and manual collection

Sweep nets were used to collect flying insects, such as butterflies and dragonflies while other insects were sampled using fine forceps. Butterflies and dragonflies were put in triangle papers while other specimens were put in vials with 75% ethanol solution. Sampling was conducted along the road, open and riverine areas within the forest, and also along trails established by the Botany and Ecology teams of the Forest Research Centre. Details of the daytime sampling sites are listed in Table 2 and Figure 2.

Table 2. Daytime sampling sites in Crocker Range F.R.

Sampling site	Starting point coordinates	Elevation (m)
1 (Kg. Kibunut)	N 05° 55'55.3" E 116° 14'20.0"	692
2 (Forest fire tower area)	N 05° 51'10.8" E 116° 19'15.1"	1,588
3 (Mt. Alab area)	N 05° 49'48.2" E 116° 20'30.1"	1,957

Insect specimens and identification

In this survey, focus was given to certain insect groups, i.e. butterflies, moths, beetles, ants and dragonflies. Only interesting and potential indicator insect species were sampled to minimize the workload at the laboratory in preparing the specimens for identification. Photographs were taken with a DSLR Nikon D300 and a compact Nikon Coolpix to facilitate identification. Common insects were not sampled but photographs were taken for record purposes.

Selected specimens were dry-mounted and sorted to family and some to the generic and species level. The specimens sampled from this study 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 Corbet & Pendlebury (1992) for butterflies; Holloway (1983, 1985, 1986, 1988, 1989, 1993, 1996a, 1997, 1998a & b, 1999, 2001, 2003, 2005, 2008 & 2009) and Robinson et al. (1994) for moths; Mizunuma & Nagai (1994), Makihara (1999) and Tung (1983) for beetles; Orr (2003) and Tang et al. (2010) for dragonflies.

Results and Discussion

Overall insect diversity

The nocturnal insect diversity was exceptionally high, compared to the diversity recorded from Gn. Lumaku F.R. in Tenom and Bukit Hampuan F.R. in Ranau and Milian Labau F.R. in Keningau (Table 3). An average of 148 insect species from 207 individuals were recorded in a square metre of the light-trapping cloth. The mean Shannon, Simpson and Fisher Alpha indices are 4.77, 322.49 and 417.04 respectively. All light-trapping sites recorded more than 130 insect species, with Site A2 recording the highest number with 170 species in one square metre. In terms of individuals, Site A2 also recorded the highest, with 310 individuals. In diversity values, however, Site A2 was the lowest among all the Crocker Range sampling sites. This is because of the high abundance of a few dominant species (see Figure 3). It is also significantly reflected in the Simpson's diversity index which is sensitive towards dominant species.

Table 3. Insect diversity within a one-square-metre, as sampled through light-trapping in Crocker Range F.R. (Sites A1, A2, B1 & B2) compared to selected sites of Milian Labau, Bukit Hampuan and Gn. Lumaku F.Rs.

No.	Sampling site	Species	Ind.	Shannon (H')	Simpson (D)	Fisher Alpha (S)
1	A1	131	146	4.81	392.04	614.91
2	A2	170	310	4.59	61.25	154.35
3	B1	159	178	5.03	716.05	717.3
4	B2	131	192	4.65	120.63	181.59
	Mean	148±20	207±72	4.77±0.2	322.49±299.3	417.04±290.8
5	Milian Labau (Site 1)	79	122	4.05	45.56	97.03
6	Bukit Hampuan (Site 2)	119	142	4.61	111.23	346.35
7	Gn. Lumaku (southern part - Site 5)	124	163	4.56	90.43	236.60

Most of the montane and upper montane forests in the light-trapping sites are still intact although certain parts were burnt or disturbed in the past before 2003 (Figure 2). Hence, the condition of the forest would have improved when the survey was carried out in 2011. Light trapping was not conducted in the more disturbed area, i.e. in Kg. Kibunut area, due to logistics difficulties at night and distance from the base camp.

The high insect diversity shows that the Crocker Range F.R. provides a conducive environment with an elevation from 1,500 to 2,000 m a.s.l. (based on light-trapping sites) and a cool atmosphere of 15-19 °C and relatively high humidity of 85-91 %, suitable for nocturnal insects. The distribution of nocturnal insect species from the light-trapping sites is reflected in the species-rank abundance curves in Figure 3.

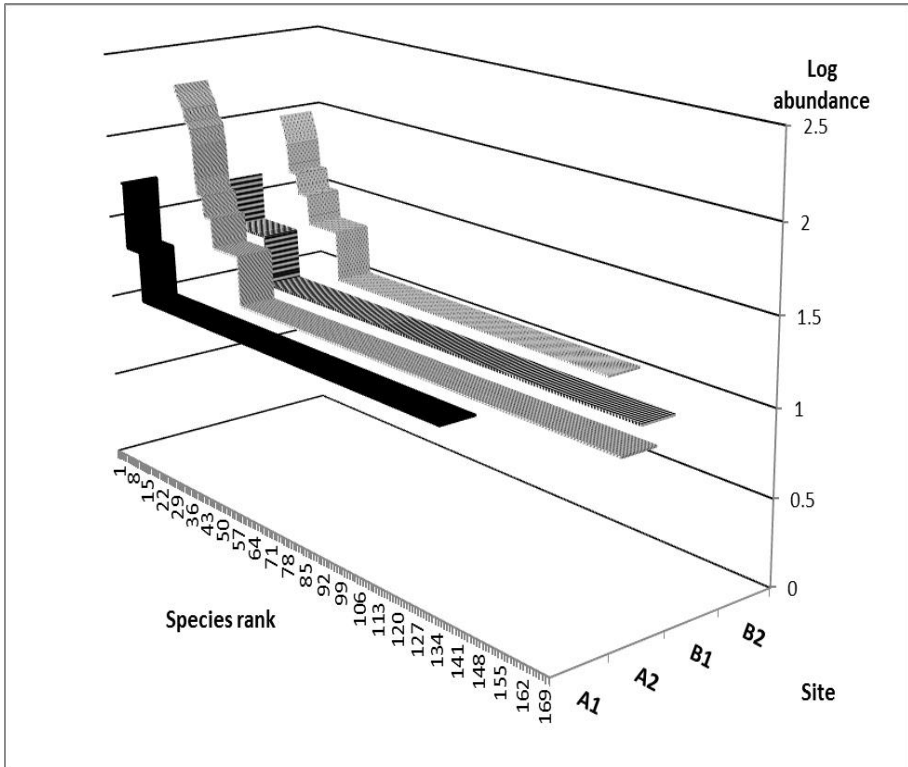


Figure 3. Species-rank abundance curves of the light-trapping sites in Crocker Range F.R.

Butterfly (Lepidoptera) diversity

Despite the high diversity of nocturnal insects, not many butterflies were sampled during the survey. Only 20 species were recorded, including the Bornean endemic Kinabalu Tiger, *Parantica crowleyi* which was frequently seen foraging at Mt. Alab area. The low butterfly number was partly due to erratic weather during the sampling period. Too much rain and the lower-than-usual temperature had adversely affected about 50 % of the butterfly population in the Kipandi Park (Steven Bosuang, pers. comm.). Some eggs were not able to hatch and some pupae could not emerge as adults due to the drastic microclimatic changes. Besides *P. crowleyi*, there are nine other species of Bornean endemic butterflies that are confined to the Crocker Range, as listed in Appendix 1.

Moth (Lepidoptera) diversity

Various moth species were attracted to the light trap set up at two locations facing the Crocker Range F.R. at 1,955 m (Sites A1 & A2) and 1,600 m a.s.l. (Sites B1 & B2) respectively. From observation, the species richness was very high, surpassing those at other forest sites sampled under the Heart of Borneo (HoB) programme in Sabah. At least 24 Bornean endemic moth species were recorded from this survey, as listed in Appendix 1.

Beetle (Coleoptera) diversity

A total of 23 species of macro-beetles were recorded. The most spectacular species was the Stag Beetle, *Cyclommatus montanellus* (Lucanidae) which is endemic to Borneo and is only confined to the Crocker Range. Measuring up to 70 mm, it is a handsome beetle with conspicuously long antler-like mandibles. There are also various variations of the mandibles. Another species which is somewhat similar to *C. montanellus* is *Cyclommatus chewi*. This hyper-endemic and rare species is only found in Mt. Alab of the Crocker Range. Other hyper-endemic species of Mt. Alab are *Odontolabis schenki* and *Odontolabis katsurai*. These species, however, were not sampled during the survey but their presence were recorded previously (Steven Bosuang, pers. comm.). A list of the Bornean endemic beetles (25 species) that are found in the Crocker Range is provided in Appendix 1.

Other interesting beetles sampled from the Crocker Range F.R. were the Giant Weevil, *Protocerius* sp. (Curculionidae) and the Trilobite Larva, *Platerodrilus* sp. (Lycidae). The elytra and pronotum of the Giant Weevil are almost entirely red. The male was larger, with a body length up to 8.5 cm while the female was about 6 cm. The forelegs of the male were longer than the mid and hind

legs. When disturbed, the weevil would raise and widely open its forelegs as a defensive posture. It looks similar to *Macrochirus praetor* Gyllenhal, found in Peninsular Malaysia (Tung, 1983). They were not attracted to the light trap but a few adult weevils were entangled on the mist nets for trapping birds and bats set up by the villagers at Kg. Kibunut, about 690 m a.s.l. The Trilobite Larva is so called because of the wingless larva-like female which resembles the extinct trilobite. It glows in the dark to attract the flying male which is smaller in size at about 8-9 mm. This sluggish insect can be seen moving slowly over the moist forest floor, feeding on rotten wood.

Other insects

The Green-banded Cicada, *Tacua speciosa*, was among the interesting montane forest insects sampled from the Crocker Range F.R. It is a magnificent cicada, measuring about 5-6 cm long. The band is sometimes yellow in colour. This species was not attracted to the light trap but was sampled in the daytime, perching on tree branches or shrubs.

Various ant species were sampled and the most common group was from the genus *Myrmecaria*. Bakhtiar et al. (2009) noted that *Myrmecaria* ants are found at high altitudes above 1,500 m where the temperature is generally low throughout the year and fluctuates during the day. Other ant species sampled were from the genera *Polyrhachis*, *Crematogaster* and *Dolichoderus*.

A pair of Stalk-eyed Flies was spotted at the forested area of Site 2 (forest fire tower) at about 1,570 m a.s.l. They belong to a very small family of peculiar flies (Diopsidae), found mainly in East Africa and South-east Asia; only seven species were recorded from Borneo. The eyes are borne on long, lateral stalks. The larvae are phytophagous or saprophagous. *Diopsis* is the most common genus found in South-east Asia (Hill & Abang, 2005).

Only a few dragonfly species were recorded from this survey. Montane forest habitats for dragonflies are confined to small streams, and the number of species restricted to the zone at 1,000-2,000 m are few (Orr, 2003). Those recorded in this study were from Kg. Kibunut area at about 700 m a.s.l. which included *Orthetrum sabina*, *O. glaucum*, *O. testaceum*, *O. pruinatum* and *Cratilla metallica*.

A colourful stick insect was sampled at Site 2 during the day, about 1,570 m a.s.l. It was identified as *Orthonectrosia felix*, and it is endemic to the Crocker Range (Francis Seow Choen, pers. comm.).

Insect geographical ranges

The Crocker Range F.R. is a haven for insects. Besides having the highest diversity of nocturnal insects in all the 20 forest reserves surveyed within HoB, it has also recorded the highest number of endemic species (Chung et al., 2015; Chung et al., 2013). More than 27 insect species were documented during the survey compared to 19 endemic species from Bukit Hampuan F.R. From previous records and references, there are a number of insect species which are confined to the Crocker Range (including Crocker Range Park and Kinabalu Park under the management of Sabah Parks). These are hyper-endemics since they do not occur in any other parts of Borneo. A few are restricted to certain areas in the Crocker Range, such as *Cyclommatus chewi*, *Odontolabis katurai* and *Odontolabis schenki* found only at Mt. Alab. At least seven endemic species of lantern bugs were recorded in the past in Crocker Range. The endemic insect species from previous records and also those from this survey are listed in Appendix 1.

Apart from endemic species, many new species have been described from the Crocker Range quite recently. For example, 14 new species of flower beetles (Scarabaeidae: Cetoniinae) have been described by Legrand & Chew (2010), and 7 new species of long-horned beetles (Cerambycidae: Callichromatini) have been described by Vives et al. (2009). All the new species are endemic to Borneo, and many are found in the Crocker Range. A long-horned beetle, *Gressittichroma sammannani* was named after Sabah Forestry Department Director, Datuk Sam Mannan while *Gressittichroma tengkuadlini* was named after former Sabah Tourism Board Chairman, Datuk Tengku Zainal Adlin. *Heudepoliana masidimanjuni* is another long-horned beetle named after the Sabah Minister of Tourism, Culture and Environment, Datuk Masidi Manjun.

Current issues on insect diversity and conservation in Crocker Range F.R.

Crocker Range is home to many rare and endemic species, and various new species have been and are still being described for this area. Although the erratic weather (too much rain and drastic change in temperature) had adversely affected some of the insect populations in the first quarter of 2011, the conducive cooling temperature and high elevation (650-2,000 m a.s.l.) are generally suitable for various insect species. This is reflected in the highest species richness and insect diversity values assessed from the nocturnal insects in this survey, surpassing all those recorded from previous HoB forest surveys. In view of the high insect diversity with many rare, endemic and interesting species, it is subjected to **illegal encroachment and collection of specimens** since the Crocker Range F.R. is conveniently located along the Tambunan-Kota

Kinabalu highway. The encroachment issue is not on insects alone but also on plants and other wildlife, such as mammals (bats) and birds. At some of the forest ridges, the vegetation was cleared to set up mist nets and light traps to collect birds, bats and insects. Under the Sabah Forest Enactment 1968, it is illegal to enter a forest reserve and to take its resources without permission from the Director of the Sabah Forestry Department. Collection for scientific purposes is allowed, with approval from the Forestry Director. The Forestry Department is monitoring the situation and warnings have been issued to suspects. Some traps, however, were set up outside the forest reserve, within villages and state land.

During the survey, it was observed that 'Forest Reserve' signages had been erected at certain locations to denote the **boundary of the forest**. It is important to have more of such signages, especially at areas adjacent to the villages which are prone to encroachment. **Public awareness and environmental education** are crucial in educating villagers and the younger generation on the importance of conservation of biodiversity and forest services to mankind. The Crocker Range is the water catchment area for the west coast and interior of Sabah. Any disturbances on the streams and riverine areas would affect the quality of the water, and this will also affect the butterfly population. Various public awareness and environmental education activities have been conducted by the Sabah Forestry Department, Sabah Parks as well as NGOs, and should be continued and further enhanced.

The high diversity of insects in Crocker Range attracts special interest tourists from all over the world to visit Sabah, and this **nature tourism** contributes to the economy of the state. The Kipandi Park located beside the Crocker Range F.R., some 40 minutes' drive from Kota Kinabalu, was set up by a Sabahan, Dr Steven Bosuang. The park showcases the diversity of insects in Sabah and also studies the life cycle of various rare and endemic insect species. Understanding the life cycle and food plants of these insects would enable **conservation of insects** to be more effective. For example, *Aristolochia* spp. which are food plants for many birdwing butterflies (including the Rajah Brooke's Birdwing, *Trogonoptera brookiana*) are not only propagated in the park but are also planted at various areas outside the park to increase the population of the birdwing butterflies. About 30% of butterflies from the park are released back to their natural habitat. These are some of the conservation efforts carried out by Kipandi Park. The Sabah Forestry Department is working with Kipandi Park on beetle diversity and conservation in Sabah, as well as plant diversity. A memorandum of understanding was signed in 2014 to

enhance such collaboration (SFD, 2014). This is a **smart partnership** between a private initiative and the State Government in the conservation of biodiversity.

Various new species of insects were discovered from Crocker Range, in collaboration with international researchers. **Discovery of new species** (which is part of biodiversity documentation) is utmost important and is a piece of hallmark information to support and enhance the need for conservation of an area, e.g. in preparation of the Forest Management Plan (FMP). This confirms the wealth of biodiversity in Sabah's rainforests and would significantly elevate their conservation status, and one such example is the Crocker Range.

Forest fire is a threat to any forest reserves and the Crocker Range F.R. is no exception, especially in areas adjacent to villages. Previously, there were slash-and-burn problems caused by villagers along the highway for agricultural purposes (see Figure 2, CAIMS 2005). For monitoring purposes, a forest fire tower was built some 10 years ago at about 1,600 m a.s.l. overlooking the Crocker Range F.R. In the recent years, the incidences of forest fires in the Crocker Range F.R. are less compared to forest reserves in the lowlands. The high humidity and rainfall in the reserve reduce the risk of forest fires.

Conclusion

From the survey, the nocturnal insect diversity in Crocker Range F.R. was very high, surpassing all those recorded from previous HoB forest surveys. In addition, there are a number of rare and endemic insect species from this forest and the surrounding areas. Various new insect species have been described. As such, these are important scientific information to support the need and effort in biodiversity conservation of the Crocker Range F.R. The diurnal insect species richness during the survey, e.g. butterflies, was below expectation. This was due to the uncondusive weather during the sampling period which had adversely affected many of the insect populations.

In view of the high diversity and interesting insect fauna, Crocker Range F.R. has potential in nature tourism for special interest tourists who contribute to the state's economy. A private initiative, Kipandi Park set up adjacent to the forest reserve not only showcases the diversity of insects in Sabah but is also doing its part in studying the life cycle of rare and endemic insects which provides salient information for insect conservation. The park also works hand-in-hand with the Sabah Forestry Department in promoting conservation of biodiversity.

Due to the interesting fauna and flora of Crocker Range, illegal encroachment and collection of specimens are among threats within this forest reserve. The Forestry Department is aware of this matter and is monitoring the situation. Based on feedback from some people staying adjacent to the Crocker Range F.R., the boundary of some parts of the reserve is still not clear. Hence, it is important to have more signboards to denote the forest reserve boundary. Public awareness and environmental education plays an important role among so that local communities understand the significance of biodiversity conservation of forest resources. Forest fires were a problem in the past. In recent years, however, the incidences of forest fires are under control.

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Appendix 1. Endemic insect species from Crocker Range (Crocker Range National Park, Crocker Range F.R. & Kinabalu Park)*.

No.	Species	Author	Family	Subfamily / Common Name	Remarks
Butterflies (source: Steven Bosuang)					
1	<i>Elymnias pelucida</i>	Fruhstorfer	Nymphalidae	Kinabalu Palm Fly	Endemic of Crocker Range
2	<i>Parantica crowleyi</i>	Jenner-Weir	Nymphalidae	Kinabalu Tiger	Endemic of Crocker Range
3	<i>Graphium procles</i>	Grose-Smith	Papilionidae	Kinabalu Bluebottle	Endemic of Crocker Range
4	<i>Graphium stratiotetes</i>	Grose-Smith	Papilionidae	Kinabalu Sword Tail	Endemic of Crocker Range
5	<i>Papilio acheron</i>	Grose-Smith	Papilionidae	Bornean Memnon	Endemic of Crocker Range
6	<i>Troides andromache andromache</i>	Staudinger	Papilionidae	Bornean Birdwing	Endemic of Crocker Range
7	<i>Delias cinerascens</i>	Mitis	Pieridae	Kinabalu Jezebel	Endemic of Crocker Range
8	<i>Delias eumolpe</i>	Grose-Smith	Pieridae	Bornean Jezebel	Endemic of Crocker Range
9	<i>Ixias undatus</i>	Butler	Pieridae	Yellow Orange Tip	Endemic of Crocker Range
10	<i>Prioneris cornelia</i>	Vollenhoeven	Pieridae	Bornean Sawtooth	Endemic of Crocker Range
Beetles (source: Steven Bosuang)					
1	<i>Chewchroma nayani</i>	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Crocker Range
2	<i>Gressittichroma sammannani</i>	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Sabah
3	<i>Gressittichroma tengkuadlini</i>	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Crocker Range
4	<i>Huedepoliana masidimanjuni</i>	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Crocker Range
5	<i>Stenochroma cheyi</i>	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Sabah
6	<i>Cyclommatus chewi</i>	Mizunuma	Lucanidae		Endemic of Mt. Alab
7	<i>Cyclommatus montanellus</i>	Mollenkamp	Lucanidae		Endemic of Crocker Range
8	<i>Hexarthrus parryi elongatus</i>	Jordan	Lucanidae		Endemic of Borneo
9	<i>Odontolabis cypri</i>	Didier et Seguy	Lucanidae		Endemic of Crocker Range
10	<i>Odontolabis hitam</i>	Nagai	Lucanidae		Endemic of Crocker Range
11	<i>Odontolabis katsurai</i>	H. Ikeda	Lucanidae		Endemic of Mt. Alab
12	<i>Odontolabis leuthneri</i>	Boileau	Lucanidae		Endemic of Crocker Range
13	<i>Odontolabis schenki</i>	Schenk	Lucanidae		Endemic of Mt. Alab
14	<i>Odontolabis vollenhoeveni</i>	Parry	Lucanidae		Endemic of Crocker Range
15	<i>Prosopocoilus tigrinus</i>	Didier	Lucanidae		Endemic of Crocker Range
16	<i>Pseudochalcothea spathulifera</i>	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
17	<i>Pseudochalcothea viridipes</i>	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range

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Appendix 1. (continued)

No.	Species	Author	Family	Subfamily / Common Name	Remarks
18	<i>Taeniodera ditissima</i>	Bates	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
19	<i>Taeniodera kinabaluana</i>	(Rothchild & Jordan)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
20	<i>Theodosia magnifica</i>	Nagai	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
21	<i>Theodosia nobuyuki</i>	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
22	<i>Theodosia telifer</i>	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
23	<i>Theodosia viriditaurata</i>	K. Sakai	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
24	<i>Xenoloba nagaii</i>	Bates	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
25	<i>Xenoloba speciosa</i>	Bates	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
Lantern Bug (source: Steven Bosuang)					
1	<i>Pyrops whiteheadi</i>	Distant	Fulgoridae		Endemic of Sabah
2	<i>Pyrops heringi</i>	Schmidt	Fulgoridae		Endemic of Crocker Range
3	<i>Pyrops sultana</i>	Adam & White	Fulgoridae		Endemic of Borneo
4	<i>Polydictya chewi</i>	Nagai & Porion	Fulgoridae		Endemic of Crocker Range
5	<i>Polydictya ornata</i>	Chew, Porion & Audibert	Fulgoridae		Endemic of Crocker Range
6	<i>Polydictya tanjiejhoi</i>	Bosuang, Audibert & Porion	Fulgoridae		Endemic of Crocker Range
7	<i>Saiva karimbujiangi</i>	Chew & Porion	Fulgoridae		Endemic of Sabah
Moths (all recorded during the survey from Crocker Range F.R.)					
1	<i>Barsine euprepia</i>	Hampson	Arctiidae	Arctiinae	Endemic of Borneo
2	<i>Lemyra bornemontana</i>	Holloway	Arctiidae	Arctiinae	Endemic of Borneo
3	<i>Nyctemera kinabaluensis</i>	Reich	Arctiidae	Arctiinae	Endemic of Crocker Range
4	<i>Spilosoma rubriventris</i>	Talbot	Arctiidae	Arctiinae	Endemic of Borneo
5	<i>Cyana cruentata</i>	Talbot	Arctiidae	Lithosiinae	Endemic of Borneo
6	<i>Garudinia simulana</i>	Walker	Arctiidae	Lithosiinae	Endemic of Borneo
7	<i>Lyclene mesilaulinea</i>	Holloway	Arctiidae	Lithosiinae	Endemic of Sabah
8	<i>Lyclene obscurilinea</i>	Holloway	Arctiidae	Lithosiinae	Endemic of Crocker Range
9	<i>Mustilia dierli</i>	Holloway	Bombycidae		Endemic of Borneo
10	<i>Ozola submontana</i>	Holloway	Geometridae	Desmobaethrinae	Endemic of Crocker Range
11	<i>Abraxas intervacuata</i>	Warren	Geometridae	Ennominae	Endemic of Borneo
12	<i>Amblychita cavimargo</i>	Prout	Geometridae	Ennominae	Endemic of Borneo

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Appendix 1. (continued)

No.	Species	Author	Family	Subfamily / Common Name	Remarks
Moths (all recorded during the survey from Crocker Range F.R.)					
13	<i>Dalima mjoeberti</i>	Prout	Geometridae	Ennominae	Endemic of Borneo
14	<i>Ourapteryx incaudata</i>	Warren	Geometridae	Ennominae	Endemic of Borneo
15	<i>Oenospita alstrix</i>	Holloway	Geometridae	Geometrinae	Endemic of Borneo
16	<i>Spaniocentra apatelloides</i>	Holloway	Geometridae	Geometrinae	Endemic of Borneo
17	<i>Problepsis borneamagna</i>	Holloway	Geometridae	Sterrhinae	Endemic of Borneo
18	<i>Rhyptoses ?maculitea</i>	Holloway	Lymantriidae		Endemic of Borneo
19	<i>Sundaroa ?transflava</i>	Holloway	Lymantriidae		Endemic of Borneo
20	<i>Asota kinabaluensis</i>	Rothschild	Noctuidae	Aganinae	Endemic of Borneo
21	<i>Hypersynoides fenella</i>	Swinhoe	Noctuidae	Catocalinae	Endemic of Borneo
22	<i>Diehitea ducais</i>	Bryk	Nolidae	Chloephorinae	Endemic of Borneo
23	<i>Tyana marina</i>	Warren	Nolidae	Chloephorinae	Endemic of Borneo
24	<i>Antheraea alteni</i>	Holloway	Saturniidae		Endemic of Borneo
Stick Insect (recorded during the survey from Crocker Range F.R.)					
1	<i>Orthonecrosia felix</i>	Redtenbacher	Heteronemiidae		Endemic of Crocker Range

*Geographically, Crocker Range includes Crocker Range National Park, Crocker Range Forest Reserve and Kinabalu Park (Tangah & Wong, 1995).