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Diversity of Moth (Order: Lepidoptera) at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resources Science) with Honours

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DECLARATION

I declare that this thesis entitled "Diversity of Moth (Order: Lepidoptera) at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

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Diversity of Moth (Order: Lepidoptera) at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland

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ABSTRACT

R.E.A.C.H Biodiversity Centre Forest is a 16 years old rehabilated forest. Local farmers have cleared the site for agricultural and vegetation activities. The site is currently managed by Regional Environmental Awareness Cameron Highland (R.E.A.C.H), a NGO with the help of volunteers through reforestation programme in order to attract back the old diversity of animals. A study of moth fauna was conducted at R.E.A.C.H Biodiversity Centre Forest in Cameron Highland from July to August in 2016 aimed to determine the diversity of the moth fauna and to construct a pictorial identification key to the families of moth species recorded at the centre for usage of general and non-taxonomist. A total of 89 individuals of moths comprising of 53 species belonging to 10 families were recorded in 24 day of sampling by using light traps. Families Arctiidae (3 species), Bombycidae (1 species), Drepanidae (1 species), Erebidae (2 species), Geometridae (21 species), Noctuiidae (13 species), Nolidae (1 species), Saturniidae (2 species), Sphingidae (1 species) and Uraniidae (1 species) were identified in this study. The most dominant family recorded here is Geometridae and Noctuiidae among the other families. The overall Shannon-Wiener index (H') value for 24 days sampling is 3.38 (stable environmental condition) while (H'max) is 3.97, Pielou's Evennes index (J) is 0.85 and Margalef index (D_{Mg}) is 11.58. The values of H', J and D_{Mg} indices show that R.E.A.C.H Biodiversity Centre Forest, Cameron Highland has moderately large diversity of moth species with uniform distribution. A pictorial identification key was constructed for 10 families species of moth by referring their morphology characteristics. Moth plays an important role in determining ecosystem of Cameron Highland. Further studies should be conducted on the secondary forests to study about diversity of habitat before and after disturbing forest as it is still deficit especially in Peninsular Malaysia.

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Kepelbagaian Rama-Rama (Order: Lepidoptera) di Hutan Pusat Kepelbagaian Biologi R.E.A.C.H, Tanah Tinggi Cameron

ABSTRAK

Hutan Pusat Kepelbagaian Biologi R.E.A.C.H merupakan kawasan pemulihan hutan dari 16 tahun yang lalu. Petani tempatan telah membersihkan kawasan ini untuk dijadikan sebagai tapak aktiviti pertanian dan sayuran. Kawasan ini telah berjaya dilindungi oleh Regional Environmental Awareness Cameron Highland (R.E.A.C.H) yang merupakan sebuah NGO dengan bantuan daripada sukarelawan melalui program penanaman semula hutan yang bertujuan untuk menarik semula kepelbagaian haiwan yang mendiami di kawasan ini sebelum ini. Satu kajian rama-rama telah dijalankan di Hutan Pusat Kepelbagaian Biologi R.E.A.C.H di Tanah Tinggi Cameron dari Julai hingga Ogos pada 2016 bertujuan untuk 1) menetukan kepelbagaian rama-rama dan 2) membina kekunci bergambar spesies famili rama-rama di kawasan ini untuk kegunaan umum dan bukan ahli taksonomi. Sebanyak 89 individu rama-rama yang terdiri daripada 53 spesies daripada 10 famili telah dicatatkan dalam 24 hari persampelan dengan menggunakan perangkap cahaya. Spesies ini terdiri daripada famili Arctiidae (3 spesies), Bombycidae (1 spesies), Drepanidae (1 spesies), Erebidae (2 spesies), Geometridae (21 spesies), Noctuiidae (13 spesies), Nolidae (1 spesies), Saturniidae (2 spesies), Sphingidae (1 spesies) dan Uraniidae (1 spesies). Famili Geometridae dan Noctuiidae merupakan famili yang paling dominan di kawasan ini berbanding famili lain. Secara keseluruhannya, nilai indeks Shannon-Wiener (H') bagi 24 hari persampelan ialah 3.38 (keadaan alam sekitar stabil) manakala (H'max) ialah 3.97, indeks Pielou's Evenness (J) ialah 0.85 dan indeks Margalef (D_{Mg}) ialah 11.58. Nilai H', J dan D_{Mg} yang tinggi menunjukkan bahawa Hutan Pusat Kepelbagaian Biologi R.E.A.C.H mempunyai kepelbagaian sederhana besar spesies rama-rama dengan taburan yang seragam. Kekunci bergambar rama-rama telah dihasilkan bagi 10 famili rama-rama dengan merujuk ciri-ciri morfologi. Rama-rama memainkan peranan penting dalam menentukan ekosistem di Tanah Tinggi Cameron. Oleh hal yang demikian, kajian lanjut perlu dijalankan di hutan sekunder untuk mengkaji kepelbagaian habitat sebelum dan selepas kemusnahan hutan disebabkan kurang kajian berkenaan hal ini di Semenanjung Malaysia.

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LIST OF ABBREVIATION

a.s.l	-	above sea level
IUCN	-	International Union for Conservation of Nature
p.m.	-	Post Meridiem
R.E.A.C.H	-	Regional Environmental Awareness Cameron Highland

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LIST OF SYMBOLS

%	-	percentages
°	-	Degree
C	-	Celcius
D_{Mg}	-	Margalef Index
E	-	East
J	-	Pielou’s Evenness
F	-	Fahrenheit
H’	-	Shannon-Wiener Index
m	-	meter
N	-	North

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

1.1.1 Moths

Lepidoptera (butterflies and moths) is one of the most prevalent terrestrial insect order and performs essential ecosystem services such as pollination, decomposition and nutrient cycling, as well as providing prey for passerine birds (Jaroensutasinee et al., 2011). The order comprises of 157,424 described species with a total of 130,623 of moths species in the world (Iwasaki, 2010). Moths are best known for their popularity among the insecta, entomologist, amateur and geographic distribution of lepidopterans (Wahlberg et al., 2013). Their smaller size and short life cycle which can produce more generation per year make them successful and most diverse group.

Moth larvae feeding on plant tissues while adult moth feeding on liquid called nectar where they are mostly phytophagous. The existence of suitable food plants can determined its habitat choice as most moths are monophagous or oligophagous (Majerus, 2002). This trait can be useful in assessing plant diversity in an area (Ricketts et al., 2001). The distribution and ecology of moths are well known in comparison to many other invertebrates such as beetle, dragonfly and centipede (Jonason et al., 2014).

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Moths are highly plant dependent group of insect as they are a good biological indicator for environment. They shows sensitivity towards environmental changes due to their habitat that fulfill most of the requirement as effective biological indicator group in biodiversity (Abang & Karim, 2002). The distribution of moths will decrease when there is disturbance in environment. There are many researchers used Lepidoptera as a model of organism to assess the impacts of human and pollution disturbance and management practices of the forest ecosystem (Elanchezhian et al., 2014). They have attracted the attention of a variety of non-professional lepidopterists where identification is primarily visual as these insects lend themselves to colour and pattern-based identification. This professionals would do well to encourage this broader engagement and help the other research group to become the flagship taxon of the invertebrates for inventorying biodiversity (Kristensen et al., 2007).

Regional Environmental Awareness Cameron Highland or R.E.A.C.H was created by local residents when the water disaster hit Cameron Highlands in 1990. Deeply concerned with the forest around Cameron Highlands that are being cleared by local farmer, the reforestation project in 2001 was conducted with the support of Forestry Department and thus, a biodiversity centre was build in 2012 for research purpose and provide scientific value for education (Melati, 2009).

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1.1.2 Light trapping

Light traps, either with or without ultraviolet light, can attract certain insects. It is widely used to survey nocturnal moths and design according to the behavior of the insects being studied. Thomson (1991) stated that many species of moths can be found at night as they are fly readily towards a light sources. However, there is no effective method to date at catching night-flying moths in such a broad diversity and huge number.

Entomologist believed that moths often use the moon to orient themselves during night flight. Hsiao (1973) suggests that physiological structure of moth’s compound eyes that the moth ommatidia within the eye were face the light directly causes optical inhibition in the surrounding ommatidia and thus, make them to captivate to the light. Unfortunately, the theories about a phenomena of moths attracted towards the light is remain unknown as they do not have any proof or solid reason that support their theory. Different light sources might impact species composition and sample size when the trap is operated at night. Factors such as weather, lunar light and vegetation causes the abundance of moth species to attract toward the light (Linsenmair & Beck, 2006).

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1.2 Problem Statement

As the biodiversity centre, R.E.A.C.H is established in 2012 and there has been no scientific studies and previous record to date about Lepidoptera (moths) in forest surrounded area. Hence, this study was conducted to collect the preliminary data of moth that inhibit in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. This data are important to support the conservation effort by R.E.A.C.H in Cameron Highland.

There is also lacking of pictorial identification key to ease non-taxonomic and non-entomologist to identify moth species of R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. Hence, a pictorial identification key was constructed for the identified moth species at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

1.3 Objectives

The objectives of this study are:

i. To determine the diversity of the moth fauna at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.
ii. To construct a pictorial identification key of collected moth family at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

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1.4 Scope of Study

The focus of this study is to access the composition of moths species and gather the information of moths diversity in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. The pictorial identification key was constructed according to the morphological characteristics of identified moth species of R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

1.5 Significant of study

This research produce a list of moth species in R.E.A.C.H Biodiversity Centre Forest and update species of moth in Cameron Highland. This study contribute to the insect collection of Natural Resources Museum, Universiti Malaysia Kelantan, Jeli Campus and R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Other than that, construction of pictorial identification key can ease non-entomologist and taxonomic to identify moth species. This data will support the conservation effort by R.E.A.C.H at Cameron Highland.

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CHAPTER 2

LITERATURE REVIEW

2.1 Morphology of Moths

In the order Lepidoptera, Moths and butterflies are grouped together according to the presence of scaly wings. Moths can be divided into three section of bodies which are head, thorax and abdomen (Figure 2.1). Moths also known as an ordinary insects that have two antennae, four wings and six legs. The wings and legs are usually attached to the thorax (Rauner, 2012). Sense organs on the legs have greater sensitivity than human tongue.

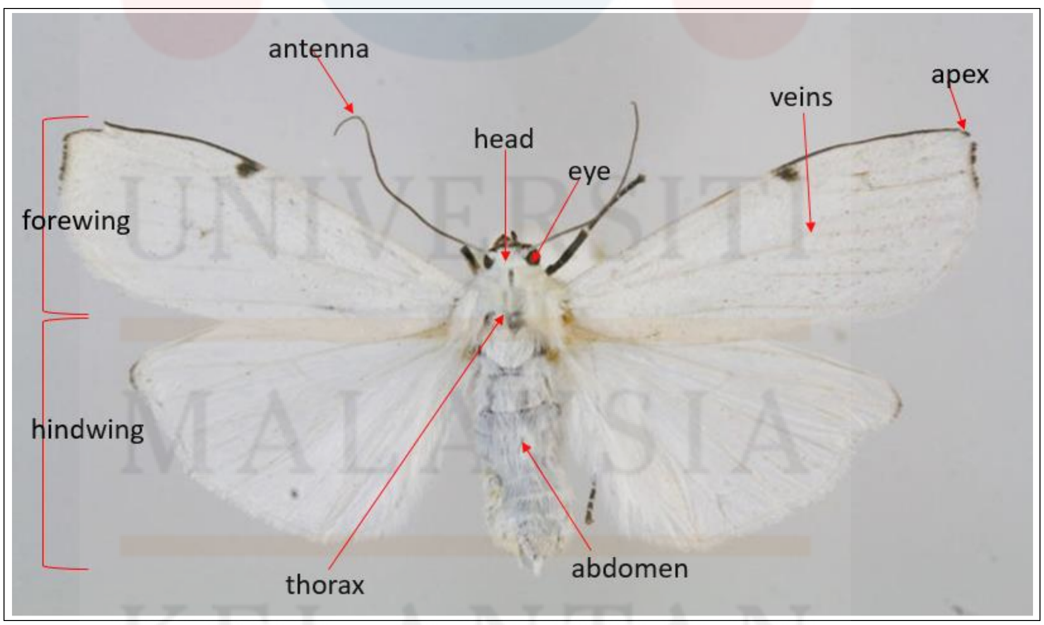

Figure 2.1: Structure of moths

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2.1.1 Head

The head is typically consisted of large compound eyes that is composed of many ommatidia. Moths also usually have superposition eyes and one ocelli presented above each eyes as adaptations for low light environments suiting the nocturnal moths (Lepidoptera: moths and butterflies, 2015). Ocelli are small but it can apparently bigger in a some lepidopteran family (Wigney, 2006).

Male moths generally own feathery or comb-like antennae while female's moths antennae are long and slender (Moth vs. Butterflies, 2016) without club-shaped ends (Figure 2.2) (Lepidoptera: moths and butterflies, 2015) but some moths, like Astniidae have clubbed antenna. Flagellum in moths are variable in structure and often complexes in males than females. Most of them feed on leaves or other plant material and have chewing mouthparts and (Moth, 2016). Mouthparts are formed into a sucking tube known as haustellum. A proboscis formed from the grooved galae of the maxillae and elongate usually present to hold together by minutes interlocking spines. When it is not in used, the feeding tube will coiled under the head and it is usually long (Lepidoptera: moths and butterflies, 2015).

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(a) (b)

Figure 2.2: Structure of clubbed antennae between male (a) and female (b) moths (Wigney, 2006).

2.1.2 Thorax

The thorax can be divided into three parts which are metathorax, mesothorax and prothorax in which each have a pair of legs and the last two have a pair of wings each (Bartlett, 2004). They have frenulum which is a filament arising from the hindwing and coupling with barbs on the forewing (Moth vs. Butterflies, 2016) to ensure they work together during the flight (Lepidoptera: moths and butterflies, 2015). The wings supported by a system of hollow veins which consisted of an upper and lower membrane. Hindwings are usually smaller than forewings, both entirely covered with a scale that usually conceals their transparency and venation. The scales usually arranged in innumerable patterns and coloured to the bright and showy from the subtle and cryptic. Some moths have jugum which helps in coupling with the hindwing and located at a lobe on the forewing. When they are not active, moths spread their wings in a tent-like manner (Lepidoptera: moths and butterflies, 2015). Each leg of moth composed by a coxa which is rest next to the thorax.

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2.1.3 Abdomen

The abdomen usually soft and consisted of eight segments and terminal genitalia. The dorsal plates of the abdomen are termed tergites and ventral plates sternites. At the end of the abdomen, female’s moths often have hairy lobes. When the scales male have a pair of claspers that is associated with the genitalia are brushed off at the tip of the abdomen, it can be visible without dissection (Bartlett, 2004).

Moths are usually gray, plain brown, white or black without permanent markings on the wings so that it make them difficult to see in shadows and blend with the bark of branches as they tend to have a risk being spotted in daylight in order to match the places they rest in (Lepidoptera: moths and butterflies, 2015). When they rest during the day, their obscuring patterns like zigzags or swirls can help them in camouflage. On the other hands, many day-flying moths are brightly-coloured which particularly if they are toxic this is because they evolved to locate their mates visually and not primarily by pheromones as their drab nocturnal cousins (Gauri et al., n.d.). Moths have stout and hairy or furry-looking bodies as they conserve heat during the cooler nights. They look more dense and fluffy by their larger scales on their wings (Moth vs. Butterfly, 2016).

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2.1.4 Larvae

Fully grown larvae of moths or called as caterpillar, produce a cocoon made of silk which they metamorphose into the pupal stage (Gauri et al., n.d.). Moth larvae are wormlike and wingless (Figure 2.3), with a row of simple eyes on either side of the body (Moth, 2016). The head is hardened with chewing mouthpart or mandible (always vestigial or lacking). They have well developed a finger-like structure (maxillary palpi) for food handling and spinnerets which is tubes from the silk glands that use for releasing silk.

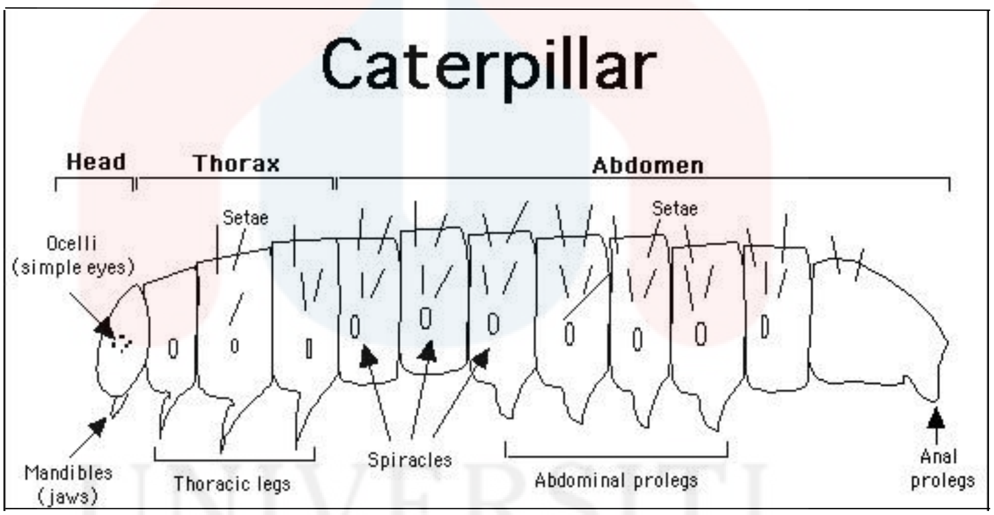

Figure 2.3: Structure of larvae or caterpillar (Snodgrass, 1985).

Their thorax has one pair of leg on each of its three segments. For breathing they use spiracles that can be found on the thorax (one pair) and the abdomen (one pair on each segment) (Gauri et al., n.d.).

Larvae mostly have a soft bodies. Abdominal segments three to ten have prolegs (fleshy legs without joints). Little hooks or crochets in prolegs, let the caterpillar cling to stems or leaves of the plants. They also have spines, hairs or bumps in the body. Colour

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range from camouflage to bright waning. Swallowtail larvae in some species give off a disagreeable odor (Rauner, 2012).

2.2 Life Cycle of Moth

They are dull or drab in colour and not captivating compared to the butterflies (Holloway et al., 2001). Moth's life-cycle is similar with butterflies as they go through a complete metamorphosis (Figure 2.4). The larva (caterpillar) hatches from the egg and turn into a pupa or chrysalis and finally adult moth emerges (Pohl et al., 2015). For reproduction, adult moth is the stages of the life cycle, in order to do so, males and females need to find each other or mates. Female moths produces a chemical scent called a pheromone and at the same time the male will detects it by using its antennae. The antennae should be feathered to be more sensitive for the scent (Rauner, 2012). The eggs are laid singly or in clusters on or either singularly or in groups near host plant. Only a few or ten thousands eggs may lay by female moth depending on the species (Moth, 2016).

Caterpillar usually develop over a period of weeks and few months after hatching through four to seven instars depends on the species before they go to pupa stages (Kristensen et al., 2007). The larvae of moths will spin a cocoon in which to pupate in order to transform into adult stage and it is usually on or near their host plant, some in the leaf litters, soil or inside the wood they have been tunneling in (Pohl et al., 2015).

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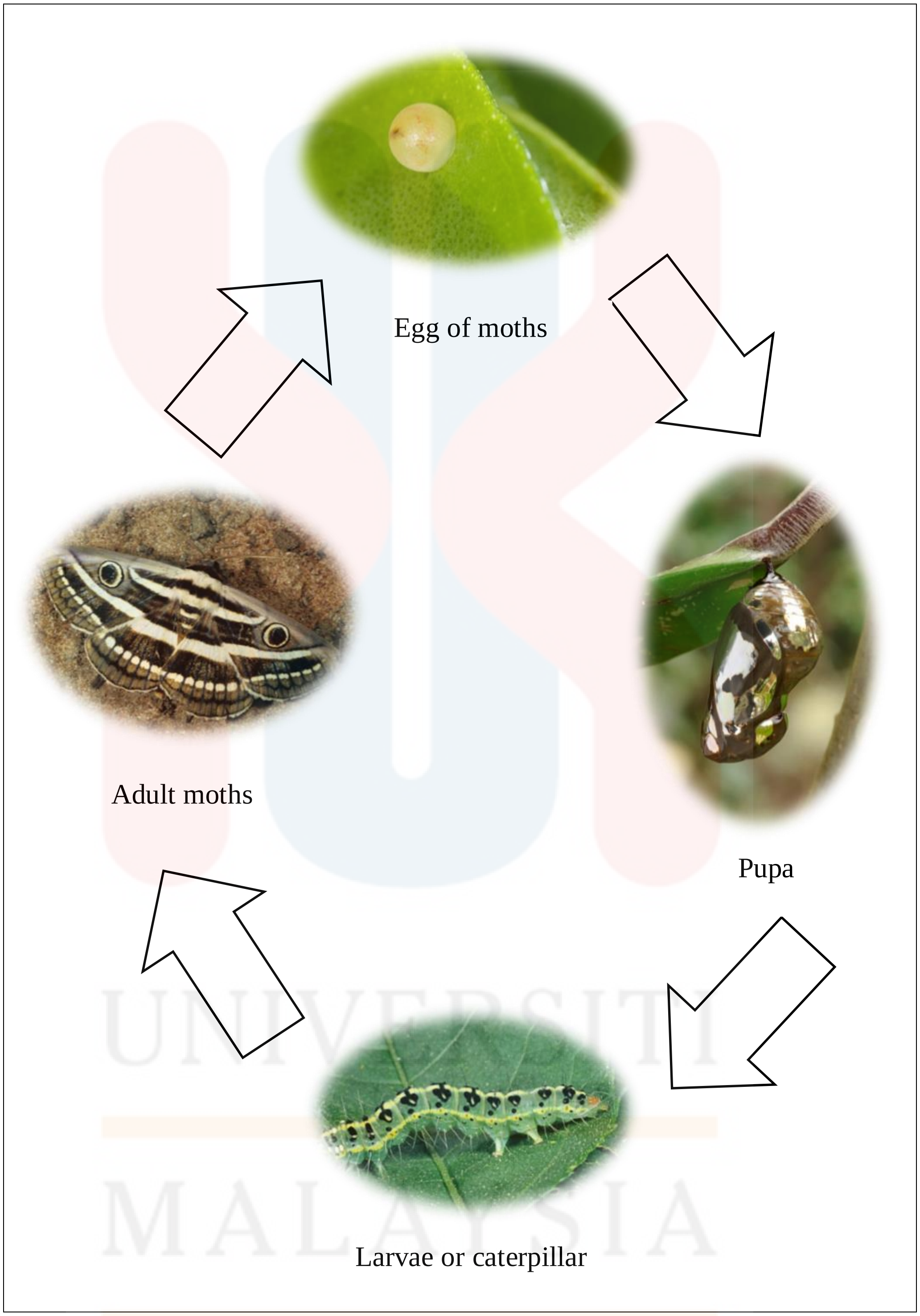

Figure 2.4: Life cycle of moth (Lotts et al., n.d.).

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The cocoon can be the source of commercial silk by the domesticated silkworm moths. Some moths pupate underground and some of them make a cocoon of bits of leaf or wood, glued together with silk and some of them (Moth, 2016). Instars where it is a caterpillar grow stages by splitting and shedding the old skin for each time to allow its body to expand. Depending on the species, it may take a few weeks or a few years to reach full size (Anders et al., n.d.).

Some species may pupate in a sheltered area such as leaf litter or in the soil. Next, pupal skin will splits apart and soft adult emerged in the newly formed. The adults mostly live only about two weeks, during which they mate and lay eggs (Rauner, 2012). Large wood-boring Cossidae may take up to five years to evolve (Kristensen et al., 2007).

2.3 Classification of Lepidoptera

Moths belongs to the distinctive order of insects known as Lepidoptera (Holloway et al., 2001). Butterflies and moths are grouped together because they are very closely related to one another. From the Greek word *lepidos* which means scale and *ptera* which means wings, Lepidoptera is gain from one of their major features, namely having wings covered in tiny scales (scale wings). Butterflies and skippers are monophyletic groups but moths are paraphyletic groups within the Lepidoptera (Bartlett, 2004).

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More than 32 families of moth can be identified around the world with a different size, colour and wings. Moth can be divided into two suborders which are Macrolepidoptera (larger moths) and Microlepidoptera (small moths). Smaller moths are in facts larger than some of the macrolepidoptera and they prefer to be more primordial in evolutionary terms (Barlow et al., 1982).

Twigs, galls, fallen material, leaves, buds, roots, fruits, seeds, trunk, bark, branches and flowers which are parts of the plant usually utilize by the Lepidoptera species. In concealed situation, the larvae feed casebearers, leaf tiers and leaf rollers, leaf and bark miners and wood borers. This larvae mostly belong to primordial families (Holloway et al., 2001). Others larvae are carnivorous where they eat egg masses of other spiders (Oecophoridae) or Lepidoptera (Pyralidae). A few of them kill scale insects (Oecophoridae, Noctuidae, Batrachedridae) or ant larvae (Lycaenidae). Besides that, family Epipyropidae are ectoparasites on plant and leaf and family Tineidae feed wool and keratin from material of animal origin (Rauner, 2012).

Noctuids are the largest family of moths with just over 400 members. They are powerful, usually need to refuel with nectar, agile flight and active at night (Bartlett, 2004). When viewed from the above, they look like a narrow triangle or letter ‘A’ as their wings are held overlapping across the back making a tent-like shape. Most of Noctuiidae tend to be subtly coloured like a mixture of grays and browns. Moreover, Pink-barred Sallow is an illustration of moth with more colourful structure of bodies (Anders et al., n.d.).

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After Noctuids, Geometrids are the second largest family with more than 300 species around the word. They had thin structure bodies and hold their wings flat like a butterfly shape at rest (Bartlett 2004). Most of them fly during dusk or dawn and sometime during day time as they have weak fluttering flight (Anders et al., n.d.).

Arctiidae or known as a tiger moth have a spotted forewings or striped with white or cream. On the other hands, to warn the predators, most of their bodies are a yellow, orange or vivid red (Bartlett, 2004). Small slender footman moths with structure like pumpkin seeds while White Ermine and Buff Ermine resemble fur when at rest (Anders et al., n.d.).

Another family that are easy to recognize is hawk-moth family. They had big, swept-back wings for past powerful flight, narrow and fat bodies. Besides, due to fat furry bodies and transparent wings, Bee Hawk-moths have a look just like bumble bees and they sometimes may not recognized as moths at all. Their features help them to avoid being eaten by predators. Clearwings family also used the same trick by pretending to be a wasp (Anders et al., n.d.).

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2.4 Diversity of Moths

Over 157,000 described species around the world, Lepidoptera is known as the most diverse groups of insects (An & Choi, 2013). Repeated sampling of indicators within the overall assemblage proving that Lepidoptera are very useful taxon for the rapid categorization and monitoring of change in habitats (Holloway, 1993). Moths are grouped under order Lepidoptera, with over 160,000 described species in more than 120 families around the world (Choi, 2008). They are known as the most recognizable insects in the world because of their striking wing patterns together with butterflies. The larvae are often host-specific to one species or family of plants and are mainly plant feeders (Iwasaki, 2010).

Habitat diversity is the place where moths live and breeding for instance like lowlands forest, grasslands, salt marshes, mountain zones, sand dunes, wetlands, and mangroves (Patrick, 2012). Higher abundance of nectar-feeding which is moths can be found in the canopy than in the understory (Linsenmair et al., 1998). This is proved by Kato et al. (1995) who found the abundance for the guild of nectar collectors to occur at the canopy level. High availability of the food plants could be one of the contributing factors for the richness of diversity of moths, as most of its larvae prefer trees or shrubs as their food-plants (Abang & Karim, 2002).

Low diversity value of moths can be found in the sites of the mixed dipterocarp forest. High content of alkaloids in their foliage is believe as the main factors that contribute to the lower moth diversity in lowland areas (Holloway, 1984).

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Vegetation layer or often described as canopies of tropical forest contains a lot of arthropods diversity like beetles, moth and other insects in that ecosystem (Patrick, 2012). Limited number of suitable vegetation at highlands area is the main reason for the lack of community to react in it where the ground mostly bare rock for moths species to inhibit at this area (Chen et al., 2009). Moth (2016) stated that temperature below -8˚C (18˚F) can killed moths larvae. According to Chen et al. (2009), highlands area will become most crucial refugia for low elevation species if surrounding lowlands forest and other natural habitats are maintained. Endemic montane species is support by tropical mountain, if they are pushed to higher elevations when the increasing of elevation were constrained by a limited number of vegetation and succession is reduced on bare rock at high altitude as it can result with the extinction (Brehm & Fiedler, 2005).

Most families of Lepidoptera among the insects have been recorded as the largest habitat diversity at medium elevations between 600 and 1000m a.s.l. (Holloway et al., 1987). However, the general decreasing diversity at altitudes more than 1000m had been recorded for anthropods. The decreasing in the number of ectothermic insect species that able to cope in this obstacles happen due to the environmental conditions within and above cloud forest zone of tropical mountains (Brehm et al., 2003).

The Malaysian moths can be found in the lowlands and highlands area with a variety of size, tiny and big (Khen, 2010). The highest diversity of moths was found from the lower montane or lowlands area at the altitude of 1000 m (Jonason et al., 2014) compared to highlands area. Diversity of moth that had been found in rainforest of Borneo and Peninsular Malaysia was highest at elevation between 200m and 700m with 127 and 128 species of moth were found (Barlow & Woiwod, 1989).

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Borneo is a well-known island including Sabah, Sarawak and Kalimantan which consisted the number of an extraordinary species richness of moth than in Peninsular Malaysia. In Borneo, Robinson et al., (1994) stated more than 8628 species richness of moths can be found in macromoths and micromoths with the ratio of 1:1.39. The higher number of diversity of moths in Borneo is believe due to the eastern connections to Papua and Australian regions which likely add to its richness (Holloway, 1976).

The macromoth species diversity and distribution within rainforest is still rather inadequately known in term of knowledge in Peninsular Malaysia. To date, the macromoth studies in Peninsular still less compared to Borneo. According to Norashikin et al., (2014) the greatest challenges in striking a balance between development and conservation because of threats such as deforestation, land degradation, inappropriate agriculture and depletion of natural resources for local people is crucial to document the diversity of moths.

Based on the research by Barlow & Woiwod (1989), the high diversity of moth can be found in the secondary hill dipterocarp forest at altitude of 600m at Genting Sempah, Pahang. Meanwhile 83 species under 13 families with total of 114 individuals are recorded at Gunung Tebu Forest Reserve in Terengganu with Geometridae and Noctuidae represent most diverse family here (Norela et al., 2010; Norela et al., 2014). The peak height of this forest reserve at 1097 metres above sea level make it very suitable for the lepidopterans inhibit in this places (Norela et al., 2014). Besides that, a total of 637 individuals representing 161 species from 12 families were collected in Gunung Stong Tengah State Park, Jeli Permanent Forest Reserve and Gemang, Jeli, Kelantan (Norashikin et al., 2014). Two major families of moths among the 12 families

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were recorded. The family Noctuidae and Geometridae are the most diverse families with 28 and 44 species respectively. High diversity of moth can be found at Gemang followed by Jeli Permanent Forest Reserve and Gunung Stong Tengah State Park as most of this species collected were lowland macroheterocerous (macrolepidoptera) moth (Norashikin et al., 2014).

However, after several studies had been conducted in Peninsular, it is indicate that two major families of macromoths namely Noctuidae and Geometridae recorded as the most abundance family here (Norashikin et al., 2014; Norela et al., 2014).

2.5 Factor Affecting Lepidopterans Diversity

Changes in number of Lepidopterans phenology, abundance, diversity, assemblage and distribution prompt by climate changes towards higher temperatures and lower summer precipitation can impact species interactions ecosystem function and services for example like insect infestation and pestilence can disturbed structure of plant communities and economic losses (Ferro et al., 2014). Recently, a large number of moth species is declining, including many familiar moths in the countryside and gardens and their survival being treated. According to the State of Britain's Larger Moths report in 2006, the total abundance of moths reduced by a three percent since 1968. The impacts of their decline on the other wildlife is become troublesome as it is very sensitive to change it as they had been found in such large variety of habitat that had been widespread across the country (Choi, 2008).

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Climatic variables are driving changes in species range and numbers as they do not clarify in detail the decreasing in both of their frequency and the numbers of species (Pollard, 1988). For instances, improvement of tree bud-burst in tree phenology changes in plant or vegetation show that larvae hatching synchrony when there is available of their food source. To sum up, phenological changes caused the moths failing to respond and emerge behind the time (Burton & Sparks, 2002). However, extinction and local decline due to moth defoliators is being transplant away can affects the associated of moths as it may be indicative of a shift in range. Inhibiting effects of resource competition caused immigrant and unknown species to inhibit in this abandon habitats (Karim & Abang, 2005).

The result of climatic variation was prove probably because it indicate broad inter-specific variation in phenology which is feature of Lepidopterans as there is no apparent life-cycle event in the analysis of life-event tables (Snodgrass, 1985). Higher nitrogen content and weak in chemical defences in young leaves caused the herbivores prefer young leaves than old leaves for food (Coley & Barone, 1996).

On the other hands, continuous fragmentation of habitat, urbanization and manufacture development, altering in agriculture and forestry practices, drainage, pollution and unsympathetic management is the main reason that contributed in the declining of moths species with the variation between other species (Anders et al., n.d.). According to Aslam (2013), it was proved that vegetation plays an important role for the existence of insects fauna in a community as it provides the main sources of food, for example like insects.

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Disturbance is an important mechanism maintaining species diversity according to previous study by Brehm et al. (2003). Old secondary forest habitats or after moderate selective logging can achieve peak value of species richness of moths in tropical forests (Jaroensutasinee et al., 2011). Both diversity and species richness of macromoth communities were higher in moderate selective logging than in closed forest as this may happen due to the secondary forest is composed of several young trees, by supplying more food sources for moth larvae and more young leaves for moths larvae to eat (Ashton et al., 2014).

The abundance of herbivores may increase with a high production of flowers by flower-feeding larvae (Intachat et al., 2001). Thus, high flowering may increase the number of moths species. Dunn (2004) in his previous studies found that there is a correlation between logging intensity and species richness. This is because lepidopteran species richness is not reduce by logging compared to mature forest (Pollard, 1988). Differences in nutrient availability, light regime and microlimatic conditions through the host can reflect in the larval community as they are closely linked to these factors (Karim & Abang, 2005).

The composition of the vegetation and environmental factors show it is closely related to the assemblage of moths with changes in altitude (Axmacher et al., 2004). More action is needed to conserve the moths, but they also can react via preservation efforts in order to improve the environment (Anders et al., n.d.). The entry level enviro-agricultural stewardship schemes provided potential solution to stop moth's decline (Miller, 2013). Johns (2004) suggested that by concerning maximum gap size or density and the size of the seed trees through logging intensity to ensure successful regeneration

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should be guided by regeneration processes in the area. Besides, regenerating secondary and logged forests can prevent large scale of species extinction and filling the gap that is leaves by the lost from primary forest (Chey, 2010). According to Intachat et al. (2001), high degree of habitat specialization is influences by habitat diversity of Lepidopterans species.

2.6 Identification Key of Moths

Identification key is a tool to assist a user identify an organism to a specific order. The process of identifying insects is largely based on simple observation as it is involved the observer going about collecting and reviewing the information and delivering a verdict (Writer, 2015).

There are several type of identification key such as single access key which is most common type of key but tabular key and multi access are often useful. Single access key or branching key is the sequences or structure in identification steps that have been fixed by the author of the key (Hagedorn et al., 2010). The majority of single-access key are dichotomous but sometimes it is described as polytomous. This key may be printed in various style such as graphical style, linked style and nested style. Multi access key allow the user to enter the key at any point. The user can adapt the key to the circumstances of identification and organism that is being identified. These keys is printed in variety way such as in formula, tabular and matrix style. Tabular keys can be divided into a lot of specific character and small subkeys by combining properties of

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branching and multi access key to the differentiation of certain taxa as it can presented in natural language description form than in separate form (Hagedom, 2010).

Dichotomous key are developed to help non-entomologist and non-taxonomic to identify insects order. This key is widely used by researcher as it is systematic, reliable and ease in identification. This key include information such as characteristics of the wings, antennae and body structure of moth and together with the figures.

Pictorial identification key is very important as it help non-taxonomic and non-entomologist to identify moth species and at the same time this key can support the conservation effort by R.E.A.C.H in Cameron Highland. This key provide vivid images of moth species to ease them recognize and draw feature of moth that is not easily viewed by human eyes.

For identification and classification for the current key of moth species, standard references in Table 2.1 was used.

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Table 2.1: Moths Identification References

	Title	Description	Source
1.	An Introduction to the Study of Insects	This book combines the study of insects with current insects identification within United States and Canada	Borror & Delong (1971)
2.	An Introduction of the Moths of Southeast Asia	This book review on adult moth, life history, distribution and identification of Lepidoptera in South-East Asia	Barlow et al. (1982)
3.	Eyewitness Handbooks: Butterflies and Moths	Packed with detailed information on characteristic, distinguish features with cleared identification guide to butterflies and moths	Carter (1992)
4.	Lepidoptera	This book provides a detailed information on the diversity, and key to families of moth and butterflies	Holloway et al. (1987)
5.	Butterflies and Moths (Lepidoptera)	Review on identification, pictures and information of moth and butterflies for the United States and Canada	Bartlett (2004)
6.	A Field Guide to the Smaller Moths of South-East Asia	This book review on identification and information of moth species in South-East Asia and	Robinson et al. (1994)
7.	Moths of Thailand 3: Noctuidae Part 2: An illustrated catalogue of Erebidae, Nolidae, Euteliidae and Noctuidae in Thailand	Packed with detailed information on species, distribution, bionomy and include a checklist of moths in Thailand	Kononenko & Pinratana (2013)
8	A Preliminary Guide to the Pyralid Moths of Borneo, Part 1: Thyridoidea and Pyraloidea: Pyralidae	This book explain on current moths identification guide, distribution within Borneo	Barlow et al. (2015)

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2.7 Cameron Highland

Cameron Highland is one of Malaysia's vast mount stations located at 4˚31'45" N 101˚20'20"E that covers 712 square kilometres of area (Cameron Highlands District, n.d.). The temperature seldom soars above 25˚C, during the day and drop as low as 12˚C sometimes at night. It is not only home to wide variety of floral species that are unfamiliar to the tropics but it is a place for different ecosystem to inhibit in this area such as flora and fauna with over 700 species of plant can be found here. Other than that, its woodland form the prevailing natural ecosystem within and around the prefecture. Cameron Highlands is unlike any other constituency in Malaysia because this place is known as a home for variety of habitat and species living inside it (Worthington, 2012).

Cameron Highland is one of the last refuges for several Asia's large characteristics species. Because of its popularity among tourists and visitors, much damage has been done towards the forest over the year and the mountain is still reeling from the effects of over collection and pollution (Melati, 2009).

Located at an elevation of 1800 m above sea level, R.E.A.C.H had set up a biodiversity centre at the reforestation site on a ridge in Gunung Brinchang, Cameron Highland for research and education in 2012 (Regional Environmental Awareness Cameron Highlands (R.E.A.C.H), 2016). Ramakrishnan Ramasamy, who is the president of R.E.A.C.H and also a local citizen of Cameron Highlands has been inside this community since the organization establish in 1998 (Melati, 2009).

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Before this biodiversity centre was established, local farmers have cleared the site for agricultural and vegetation activities and it was a part of forest reserve of Ulu Bertam 16 years ago. It consists of wide variety of flora and fauna where the water catchment area for the Sungai Burung water treatment is a part of this forest. R.E.A.C.H convincing the Department of Forestry to have smart-partnership and technical assistance to reforest the illegal cleared site in 2001 that include 17 hectares of area in Gunung Brinchang, in order to prevent this scenario from worst. About 60% of the cleared site managed to cover by R.E.A.C.H with the help of volunteers (Melati, 2009).

More than 9200 trees were planted (Regional Environmental Awareness Cameron Highlands (R.E.A.C.H), 2016) and some of local species such as *Swietenia penagiana* (merapuh daun runcing), *Shorea platyclados* (meranti bukit), *Lauraceae* spp. (medang) and *Podocarpus neriifolia* (podo bukit) (Melati, 2009). Some of them come from all endemic species such as *Eugenia*, *Rhododendrons* and *Nepenthes*. The trees have grown to more than 15 feet with ground covered with rich humus in some areas. Thus, attract variety of birds, insects and small mammals to live in this area (Regional Environmental Awareness Cameron Highlands (R.E.A.C.H), 2016). REACH collaborating with local universities and environmental NGOs to have more research done at this site and this included documentation of ferns, mosses, insects, amphibians and orchids (Regional Environmental Awareness Cameron Highlands (R.E.A.C.H), 2016).

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CHAPTER 3

MATERIALS AND METHODS

3.1 Study Site

Moths sampling at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland was conducted from July to August 2016 (Figure 3.1). Light traps were set up at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland (N 04˚31'12.1", E 101˚23'40.1") with elevation at 1781m. The study site is a rehabilitated forest which is 16 years old with total area about 50 hectare. It was formerly covered by montane forest which is consists of various flora and fauna and lies in the water catchment area for Brinchang.

Endemic trees such as *Gerok*, *Eugenia*, *Rhododendrons*, *Nepenthes*, tree ferns, *Arundina*, *Baeckea* and *Laurel* are planted at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. This study site have two short trails with 380 m and 350 m lengths from the base camp.

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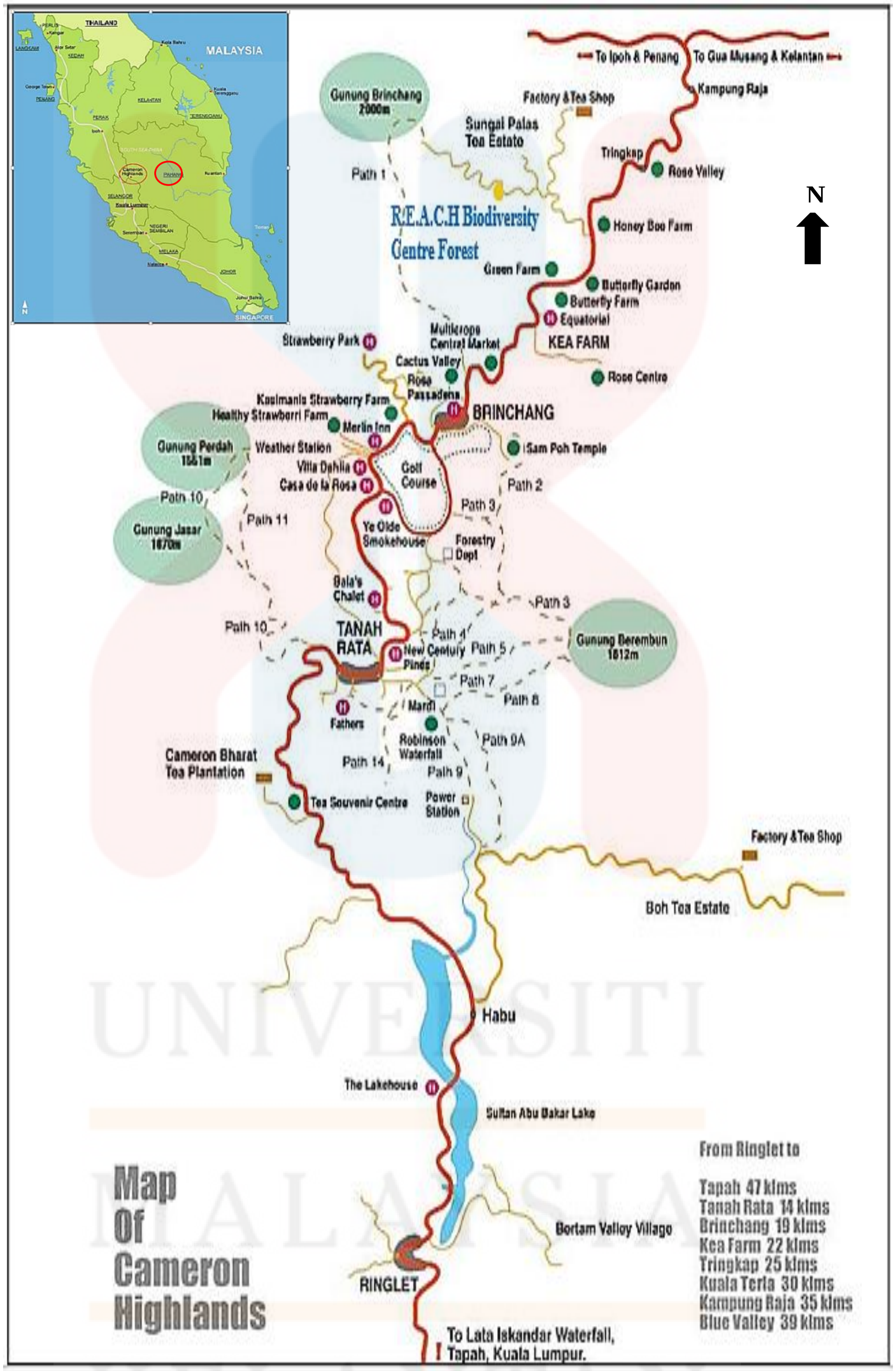

Figure 3.1: Maps of REACH Biodiversity Centre Forest, Cameron Highland (Modified from: De Souza & Roy, 2010; Zu, 2013).

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3.2 Material

Table 3.1 indicated the material and apparatus that were used to capture the moth species and preparation for preservation and construction of pictorial identification key of moths.

Table 3.1: Material and apparatus

Material	Description
Light Trap	To attract moth species
Triangle Paper	To keep the insects
Dry Oven	Removing the moisture from the specimen and chamber
Insect Pin	Pinning the insects
Spreading Board	Mounting insects
Insects Label	Information or data about the insects

3.3 Methods

3.3.1 Data Collection

Light trap (Figure 3.2) was used to sample moths at R.E.A.C.H Biodiversity Centre Forest. This is the most commonly used method for sampling Lepidoptera and captures a very wide range of moth species. A strong light bulb with 8watt power are hung in front of a vertical white sheet near bushland can yield a great range of moths. This light trap was chosen because it is easy to move from one location to another location and relatively portable.

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Two light trap were set up with 500m interval at two different locations along trails at the forest. The attraction of light traps decreased with distance and is low at the distance exceeding 20m. The trap will not be set on nights when it is raining, cold or clear moonlit nights because trap catch is known to be significantly lower under these condition. Light trap was conducted during the peak of moth activity at dusk between 7.00pm and 11.00pm local time and collected manually. Field works was conducted for 24 days where, 12 days in each site.

Figure 3.2: Light trap

Moths that are attracted to the light trap and lied at the white screen were collected and placed into triangle paper. Identification of species was done in the Natural Resources Museum, Universiti Malaysia Kelantan Jeli Campus using available moth identification key.

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3.3.2 Specimen Preservation

The preservation of specimen was conducted at the Natural Resources Museum Universiti Malaysia Kelantan, Jeli Campus. Mounting moth is a special technique that required a spreading board to do an attractive job. Their wings are spread and then dried up under the sunlight for 2-3 days (dried preservation), depends on the condition of the specimen (Holloway et al., 1987). All moths specimen were labelled and taxonomically identified using available identification key. For identification and classification of the moth species, standard references such as Barlow et al. (1982), Carter (1992) and Holloway et al. (1987) are used.

3.3.3 Construction of Identification Key

Pictorial identification key are constructed according to the morphological characteristics of identified moth species. Pictures were drawn for each stated character in the key. Example of morphological characteristics are mostly based on the shape, colour pattern and venation of the wings.

3.3.4 Statistical Analysis

a) Species Accumulation Curve

Species accumulation curve can be extrapolated to indicate the adequacy of faunal surveys in representing the fauna in a particular area and indicates the rate at which new species are found within a community. Species accumulation curves were used to predict species richness and number of species in study area. As more

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individuals are sampled, the total number of species recorded in the sample increases and a species accumulation curve is generated. (Thomson, 1991).

b) Rarefaction

Rarefaction is a technique to assess species richness from the results of sampling. Based on the construction of rarefaction curves, it allows the calculation of species richness for a given number of individual samples. As a function of the number of samples, this curves is a plot of the number of species (Ashton et al., 2014). Rarefaction curve was extrapolated by using software EcoSim700.

c) Shannon-Wiener Diversity Index

This index is one measure that was used to draw information from samples in the field. Shannon-Wiener Diversity Index measure based on information theory and the order observed within the particular system. The index are widely used because it does not take into account habitat specific parameters required by specific species (Javaid & Pandit, 2013). This index can also be used to measure family species level (Aslam, 2013) In other words, the Shannon-Wiener Diversity Index is defined as in Equation 3.1.

$$H' = -\sum [\, (n_i/N) \ln(n_i/N) \,] \qquad \text{.... Equation 3.1}$$

where the range is between 0 – H'_{max}, $H'_{max} = \ln s$

H' = Shannon-Wiener Index

N = Total individual in a population

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n_i = Total individual for n_i species

s = Number of species

d) Pielou's Evenness Index

Pielou's Evenness Index was used for calculating the evenness of species as shown in Equation 3.2 (Aslam, 2013).

$$J = \frac{H'}{\ln S} \quad \text{.... Equation 3.2}$$

Where the range is 0 to 1

H' = Shannon-Wiener Diversity

S = Total number of species in sample

e) Margalef Index

Margalef Index was used as a simple measure of species richness, as shown in Equation 3.3 (Aslam, 2013).

$$D_{Mg} = \frac{(S-1)}{\ln N} \quad \text{.... Equation 3.3}$$

S = Number of species

N = Total number of individuals in the sample

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Moth Assemblage

In this study, a total of 89 specimens of moths, representing 53 species and 10 families were collected at Biodiversity centre forest area using light traps (Table 4.1) (Appendix A). Five species of moth (8 individuals) were unidentified due to loss of their colour on the wings and poor condition of the body. This happened because moth scale are easily to loss and broken when touched by hands. Thus, some species cannot be distinguished as it is hard to identified and figure the character of moth species due to that factors.

IUCN Red List website http://www.iucnredlist.org/ is used as a references in order to know the conservation status of current collected moth species at this Biodiversity centre forest. However, there is no record of moth species at this study site recorded in IUCN Red List status.

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Table 4.1: Distribution of moth species encountered according to family in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Family	Scientific name
Arctiidae	*Nyctemera adversata*
	Nyctemera tripunctaria
	Vamuna remelana
Bombycidae	*Comparmustilia semiravida*
Drepanidae	*Callidrepana albiceris*
Erebidae	*Orvasca subnotata*
	Tamba lala
Geometridae	*Alcis maculate*
	Cleora determinata
	Cleora pendleburyi
	Fascellina meligerys
	Fascellina castanea
	Hypomecis separata
	Lassaba acribomena
	Lomographa luciferata
	Luxiaria hyalodela
	Mesotrophe curtisi
	Myrioblephara simplaria
	Organopoda acmaea
	Ornithospila bipunctata
	Ornithospila succincta
	Ornithospila sundaensis
	Orothalassodes hypocrites
	Ourapteryx claretta
	Plutodes costatus
	Pogonopygia nigralbata
	Pogonopygia pavida xanthura
	Racotis inconclusa
	Tristeirometa curvistriga
	Xenoplia contrasqualida
Noctuiidae	*Artena dotata*
	Callopistria sp.
	Elusa ceneusalis
	Ercheia pulchrivenula
	Erygia sp.
	Lignispalta incertissima
	Ophiusa trapezium
	Parallelia calefaciens
	Sasunaga interrupta
	Spodoptera pecten
	Thyas coronata
	Thyas javanica
	Trachea auriplena

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Nolidae	*Tyana marina*
Saturniidae	*Cricula trifenestrata*
	Samia cynthia
Sphingidae	*Cechenena lineosa*
Uraniidae	*Lyssa menoetius*

Species accumulation curve was used to indicate the adequacy of faunal surveys in representing the fauna in a particular area and also indicate the rate at which new species are found within a community (Brehm & Fiedler, 2005). As more individuals are sampled, the total number of species recorded in the sample increases and a species accumulation curve is generated and the graph showed stable line at the end of the day which indicate there is enough sampling at the study site and no new species were collected at study site (Figure 4.1).

The species accumulation curved (Figure 4.1) indicates that the estimated species richness at the study sites was asymptotic, which is suggesting that a 24 days faunal survey at R.E.A.C.H Biodiversity Centre was sufficient for determining species richness with 53 total species collected.

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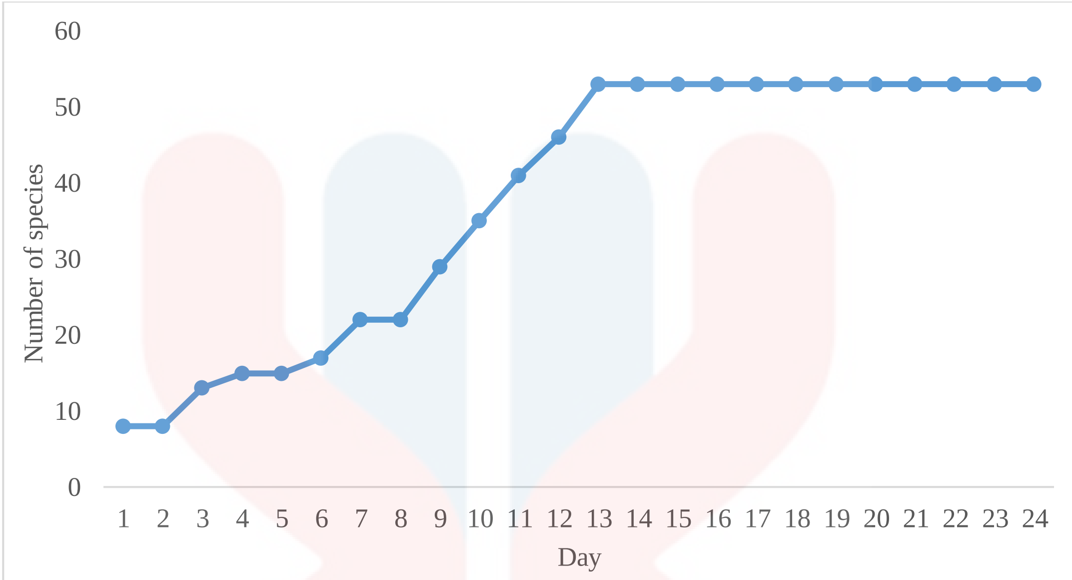

Figure 4.1: Species accumulation curve for moth species collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Rarefaction curve (Figure 4.2) were extrapolated based on number of individuals in each species of moth and number of species richness collected at the study site. The graph reach asymptote at the end of the graph which indicate there is high number of species richness at the biodiversity centre.

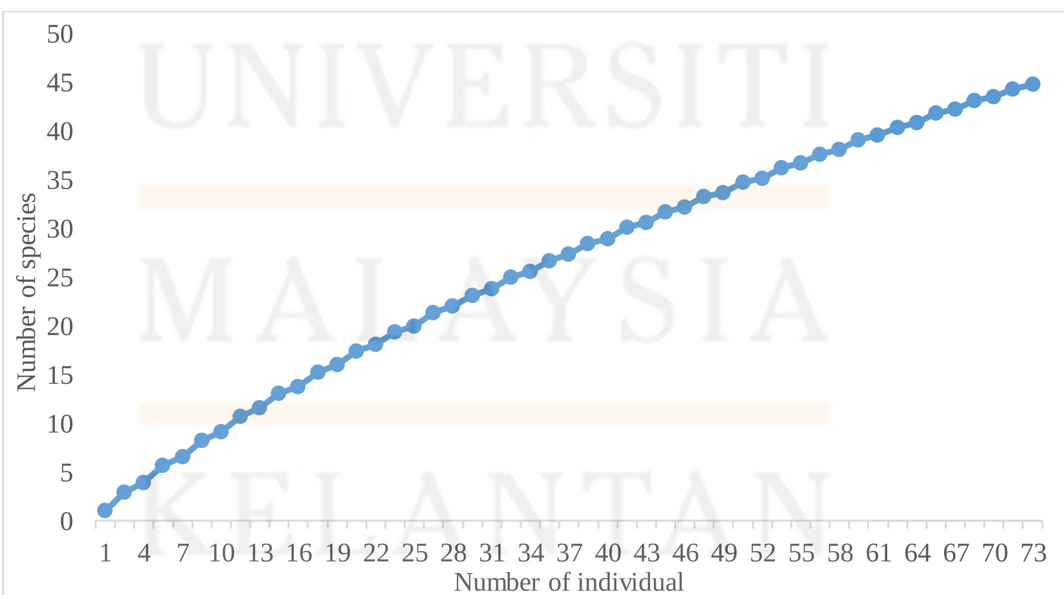

Figure 4.2: Rarefaction curves for moth species

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4.2 Diversity

Diversity of moth can be used as the measure of monitoring the health of forest ecosystems. By studying the concerned insect species or community in degraded areas, it can indicates which parts of the ecosystem had been degraded and the rehabilitation at such parts can be monitored (Holloway, 1984). Factors like degradation, forest fires, clear-cutting and the aliens species of animals and plants who arrived and inhibited the area due to changing climate and environment has led to changes in populations of moth species and in communities. This happened because of moth sensitivity towards the changes in their environment and that conversely, these changes can be monitored by monitoring moth communities. (Choudhury & Choudhury, 2013).

This study showed that the structure of moth community in the area changed when degradation occur in their habitat due to clear-cutting forest for agriculture or other purposes that destroyed their habitat particularly for species that are restricted in range as it can cause a decline in forest species abundance and diversity. Although high number of species shown in the transition area but those species represent a small number of families (Sutrisno, 2010).

Family Geometridae and Noctuiidae is the most dominant family in the study area with 21 species and 13 species and proved by numerous researchers reported that family Geometridae and Noctuiidae have the most dominant family around the world. This followed by family Arctiidae (three species), Erebidae and Saturniidae (each with two species), and Bombycidae, Drepanidae, Nolidae, Sphingidae and Uraniidae (each with one species) (Figure 4.3) (Appendix B & Appendix C).

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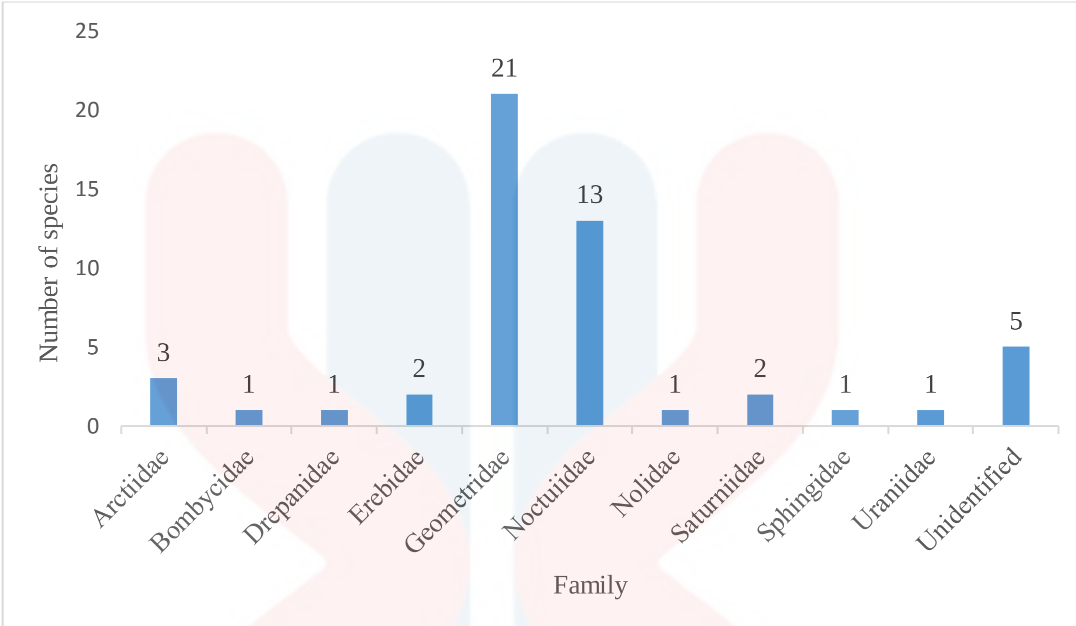

Figure 4.3: Number of species of each family of moth collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Table 4.2: Shannon-Wiener Diversity Index

Symbol	Total
H’	3.38
H’max	3.97

Shannon-Wiener diversity index varies from 0 to 5. In this study, Shannon-Wiener index are H’ = 3.38 which considered as stable environmental condition for diversity index and achieve maximum number at H’max = 3.97.

In Figure 4.4, family Geometridae had the highest diversity index with 0.36 while family Bombycidae, Drepanidae, Nolidae and Sphingidae showed the lowest value with 0.05 diversity index (Appendix B).

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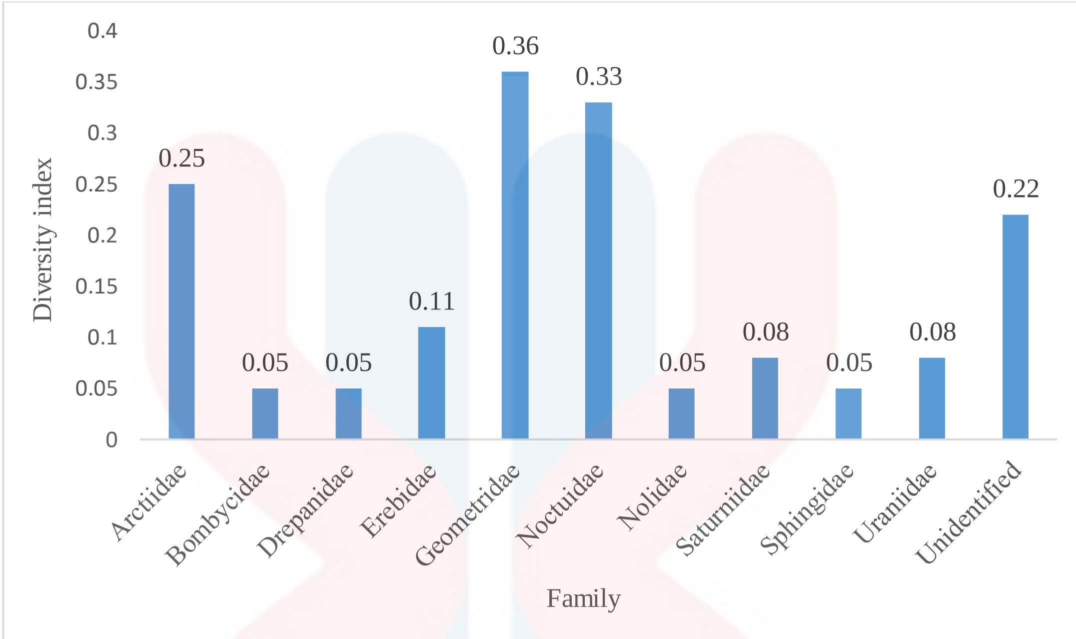

Figure 4.4: Diversity index of each family of moths

Table 4.3: Margalef Index

Symbol	Total
D_{Mg}	11.58

Margalef index has no limit value and shows a variation depends on the number of species. Thus, it reflecting sensitivity to sample size as it takes only one component of diversity which is a species richness (Javaid & Pandit, 2013). In the present investigation, the values of Margalef Index were D_{Mg} = 11.58 which represent the number of species richness at the biodiversity centre.

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Species richness of moth may achieve peak values after moderate selective logging or in old secondary forest habitats (Ashton et al., 2014). This could happen because the secondary forests especially in this biodiversity centre forest is composed mainly young trees and at the same time supplying more diverse food such as young leaves for moth larvae to eat.

It can be explained that the diversity of moths found at the disturbed sites might be due to the role of immigrating species from adjacent intact forest and the suitability of secondary forest remnants as habitats (Chey et al., 1997). The composition and diversity of moths can be determine through floral diversity at the disturbed sites because of their larvae often shows a great specificity to hostplants eventhough their adults can use many kind of flowers as sources of their nutrition. The majority of larvae are defoliator, but some of them are also leaf miners (Gracillaridae and Nepticulidae), timber borers (Cossidae and Hepialidae), stem borers (Noctuidae and Pyralidae) and flower feeders (Noctuidae and Geometridae) (Chaundy, 1999).

The overall structure of vegetation community explains much moth diversity, abundance and evenness in this landscape. We also found that irregular rainfall had slightly effect on the total number of moths at Biodiversity centre forest. This is because, these changes impact individual species of moth and lead to changes in the composition and structure of communities directly or indirectly.

Besides that, other environmental conditions such as microclimatic can also influence the distribution of moth species in this Biodiversity centre forest. Since the area is vastly mountainous, the flowering season usually delay resulting in a relatively lower temperature in these habitat. The adults of many Lepidoptera species occur most

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frequently in June as the green vegetative begins to appear in the late April. The moths begins to disappear as the temperature drops by the end of August due to the shortage of food and cool temperature (Okyar et al., 2009).

Higher temperature can speed up the larval development and causes more generations and movement in a season and synchronization of bud bursting, egg hatching and at the same time can reduced mortality from abiotic factors (Khen, 2010).

There are certain group of moth able to adapt at low temperature which is at high altitudes such as Noctuidae and Geometridae due to their dense scales. They are able to survive at the high altitude (>2000 m) with temperature vary from 15˚C to 20˚C (Chen et al., 2009). As the peak height of this forest is almost 1097 metres above sea level, it provides a very suitable habitat for the lepidopteran. This proved by Choi (2008) as he stated that rainfall, temperature and relative humidity are important weather factors that are closely related to the number of moth caught.

4.3 Abundance

A species abundance is a number of individuals observed for each different species encountered within a community (Iwasaki, 2010). The abundance is calculated based on number of individuals sample in each species.

Family Geometridae shows the highest number of moth specimens with total 40 number of individual while the least number of moth specimens belonged to family Bombycidae, Drepanidae, Nolidae and Sphingidae (each with one number of individual) (Figure 4.5).

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In general, the most abundant species here is *Pogonopygia pavida xanthura* (Geometridae) with 7 individuals recorded here compared to other species with one individuals, while the common species here is *Lyssa menoetius* (Uraniidae).

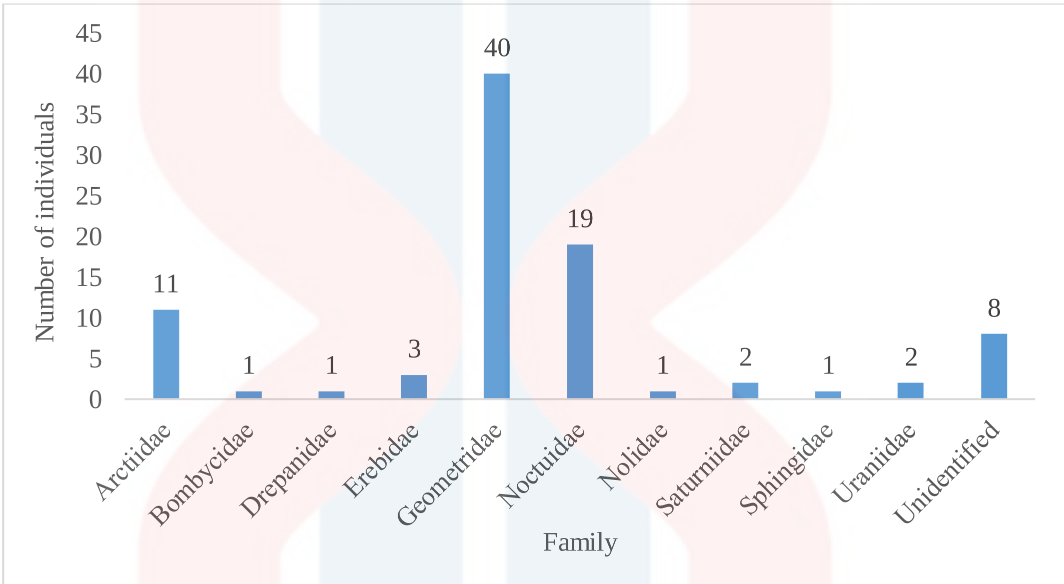

Figure 4.5: Number of individuals of each family of moths

In terms of abundance, the moths were found to be low abundance because most of the species here consists of least number of individuals. This is because some species of moth apparently restricted to particular forest types correlated with a climatic regime and some others may be constricted by geographical boundaries and may reflect as well as distribution of their hostplants (Barlow & Woiwod, 1989).

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4.3.1 Evenness

Table 4.4: Pielou's Evenness Index

Symbol	Total
J	0.85

Evenness index varies from 0 to 1. In this study, Pielou's Evenness Index are J = 0.85. This indicates that the individuals in the communities of moth are evenly distributed over the different species. The reason may be because of disturbed sites in this study area provide appropriate habitats for a number of species using plants of early successional stages as larval food resources and attract other new species from neighbor forest to live in this area.

4.4 Comparison with previous studies

In comparison, the total number of moths species recorded at the R.E.A.C.H Biodiversity Centre Forest is the lowest compared to other site in Malaysia with similar elevation and sampling method such as Gunung Tebu Forest Reserve (Norela et al., 2014) and Lojing Highland (Norela et al., 2008) (Table 4.2).

Limited duration of sampling period and area covered compared to the previous studies locations in order to have a good picture of diversity of moth fauna as they cover much more time of sampling and area probably the reason why this study have low number of moth species.

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On the other hand, R.E.A.C.H Biodiversity Centre Forest is a rehabilated forest which is 16 years old from clear cutting land for agriculture activities. Thus, this comparison is made to know whether this forest is successful in attracting old habitat or new habitat of fauna especially moth to live inside this forest and compare with the other research at the similar elevation.

Table 4.5: Comparison with previous study site in Malaysia

Site	Number of species	Number of individual	Elevation (m)
Gunung Tebu Forest Reserve	83	114	1097
Lojing Highland	29	60	1800

Table 4.2 show that Lojing highland has the least number of moth species compared to R.E.A.C.H Biodiversity Centre Forest and Gunung Tebu. This is because the sampling only took for three days while R.E.A.C.H Biodiversity Centre Forest and Gunung Tebu conducted sampling for a month. R.E.A.C.H Biodiversity Centre Forest and Gunung Tebu have quiet similar number of moth species with 53 and 83 species number with a similar sampling period. This indicate that R.E.A.C.H Biodiversity Centre Forest has started to attract back the old and new species of moth to inhibit at this biodiversity centre forest. Thus, the reforestation here is successful as it attract a lot of species to inhibit here.

Moth are most diverse at an elevation of 600m to 1000m a.s.l (highland) and less diverse at an elevation of <600m (lowland) due to near to disturbance by human being. Higher elevation are often situated on ground based sampling and steeper slope which

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likely attract moths flying in higher forest strata (Chen et al., 2009). At this elevation, which is nonforested clearings are ecologically important parts of the landscape although it have lower moth abundance but they do have high number of evenness and richness when summed over many years and indicates as an important habitat for rare species. The moth communities at high elevation are generally coupled to the habitats that containing high elevation shrubs, herbs and grasses (Highland et al., 2013).

Previous studies showed that family Geometridae and Noctuiidae is the most dominant family in all sites at Malaysia (Barlow & Woiwod, 1989; Chey, 2010; Norela et al., 2010 and Norashikin et al., 2014). Most larvae of Geometridae known as phytophagus which has no specific host plant while Noctuiidae have specific host plant for example *Heliothis virescens,* it is a pest of tobacco, cotton and vegetables as they used it as hosts. Most of geometrid and noctuid moth are flower feeders mainly young broadleaf plant such as *Oemleria cerasiformis* (Coley & Barone, 1996). This biodiversity centre site is dominated by *Eugania*, *Gerok*, tree fern, *Rhododhendrons* and etc. Thus, the more varies vegetations resulted more divers on moth fauna as this type of plant play such important bio-indicator for moth in order to inhibit in the certain place as indicated by the results of the study. However, according to Romoser and Stoffolano (1998), moth diversity are shaped by environmental parameters such as habitat disturbance, elevation and temperature factors.

Besides that, the methodology difference of sampling can give severe impacts to the moth collecting. Thus, the method use in this study are similar with all the compared site except for the date of sampling. It has been known that light collecting will be best conducted during high temperature and no rainy season as this can effect the moth

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composition directly or indirectly. During those periods, the irregular rainfall in this study site are moderate which cause the temperature to slightly drop (17˚C to 15˚C) and cause the light trap less attractive to attract the moth due to low temperature as there are certain family of moth such as Geometridae and Noctuiidae can adapt with low temperature.

To conclude, the study of diversity of moth in R.E.A.C.H Biodiversity Forest was considered moderately large diversity of moth species with uniform distribution although limited sampling period and area covered compared to similar research studies from other part of Malaysia. The collection data from this study may be change when there is other researcher do another sampling at this biodiversity centre and at the same time can update the data as the number of moths species might be increase.

4.5 Identification Key to Family Level

Pictorial identification key for family of collected moth species was constructed according to the morphological characteristics as following Borror and Delong (1971), Dugdale (1988) and Holloway (1976) to ease non-entomologist and non-taxonomic to identify moth species.

Key to family level was constructed based on the wing morphological structure characteristics of moth. The picture was modified from Borror and Delong (1971) and Dugdale (1988). The key to 10 family level were drawn by using black pen (07) PILOT drawing pen based on collected family of moth species at R.E.A.C.H Biodiversity Centre Forest.

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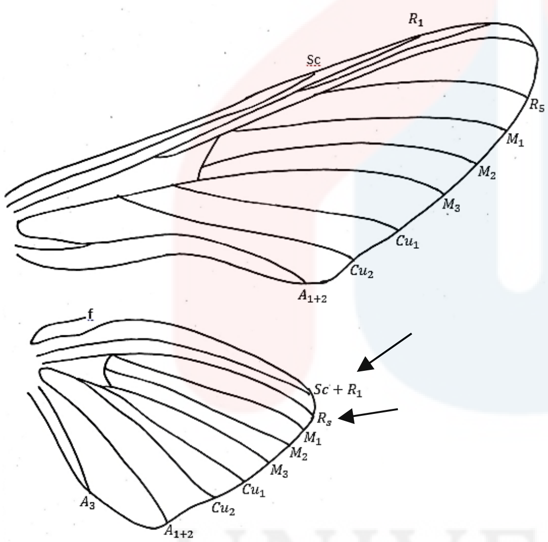
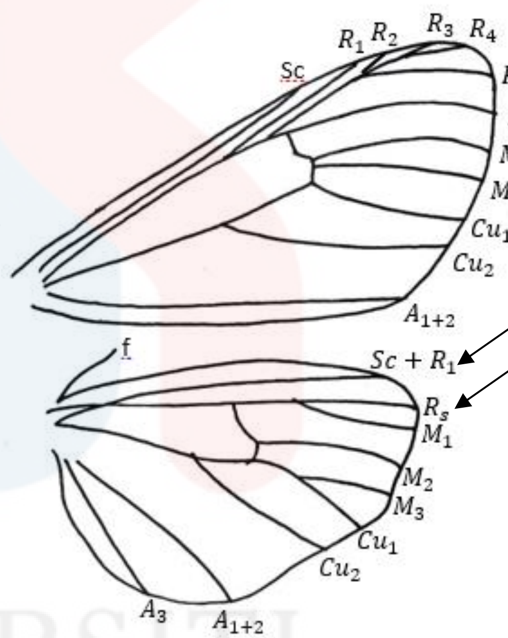
1. Antennae thickened, spindle-shaped; Sc and Rs in hind wing connected by a crossvein near middle of discal cell, the 2 veins parallel to end of discal cell and beyond; heavy-bodied with narrow and small wings (i)………...**Sphingidae**

- Antennae variable, not spindle shaped; Sc and Rs in hindwing not connected by crossvein or if such a crossvein is present then 2 veins strongly divergent beyond crossvein (ii)……………………..……………………………………**2**



(i)



(ii)

2 M_2 in front wing arising about midway between M_1 and M_3, cubitus appearing 3-branched, cubitus appearing to have fewer than 3 branches (i)........................….**3**

- M_2 in font wing arising closer to M_3 than to M_1, cubitus appearing 4-branched (ii)...…………………………..…………………………………………………...…..**8**

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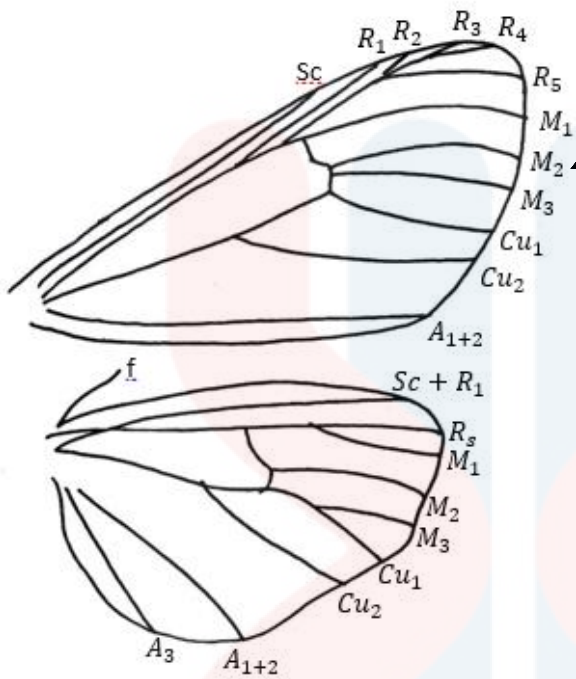
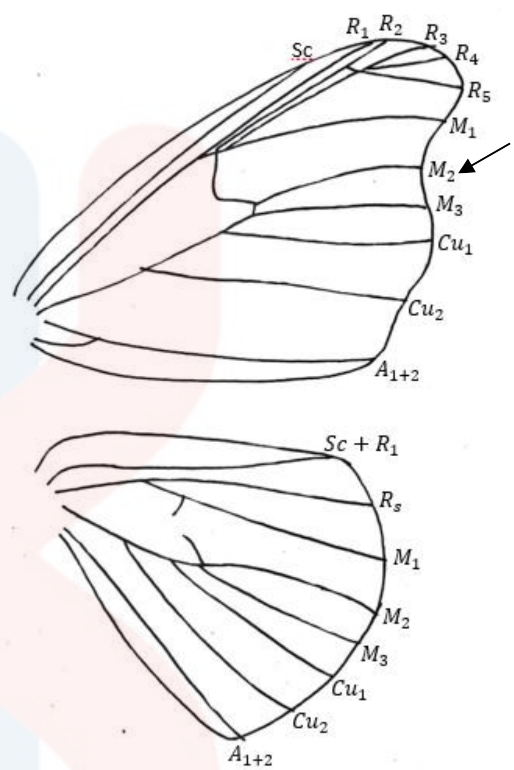


(i)



(ii)

3 Sc and Rs in hindwing swollen at base, fused to middle of discal cell, then diverging; M_2 and M_3 in front wing sometimes absent (i)…………......**Arctiidae**

\- Sc and Rs in hind wing not fused at base, although they may be fused farther distad or connected by a crossvein (ii)…..……………………….……………….**4**

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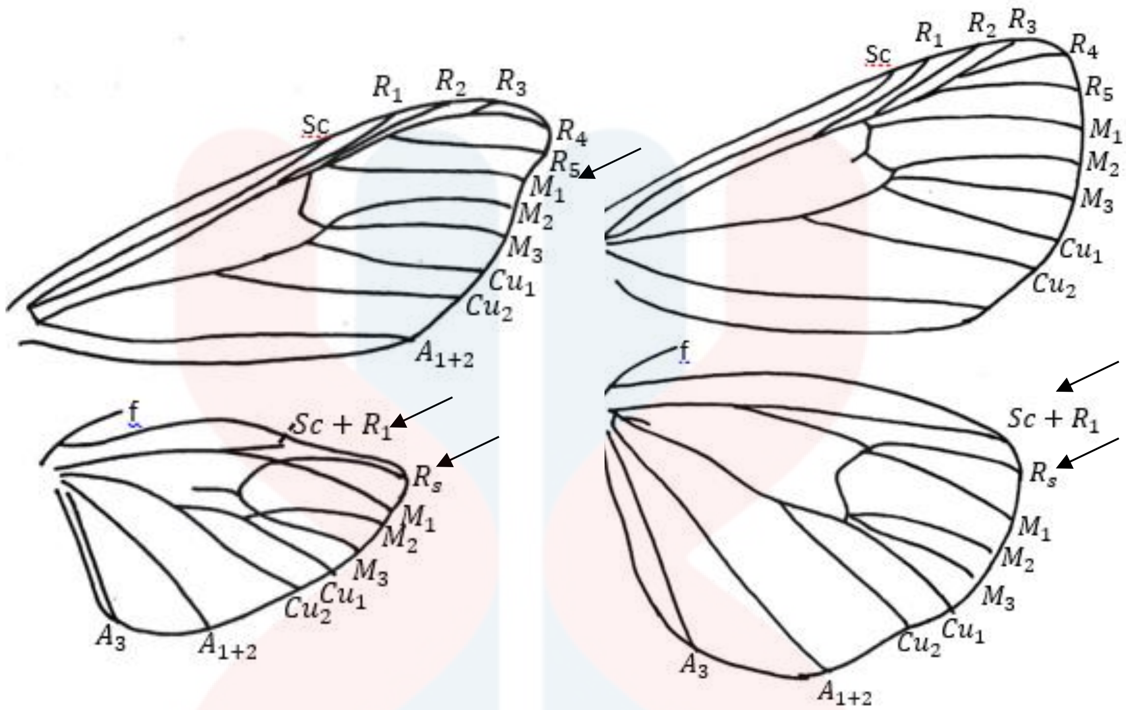
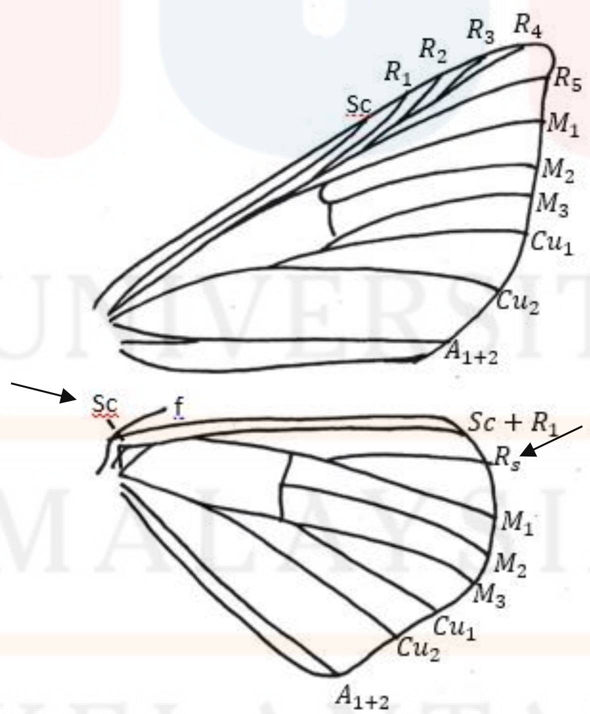


(i)



(ii)

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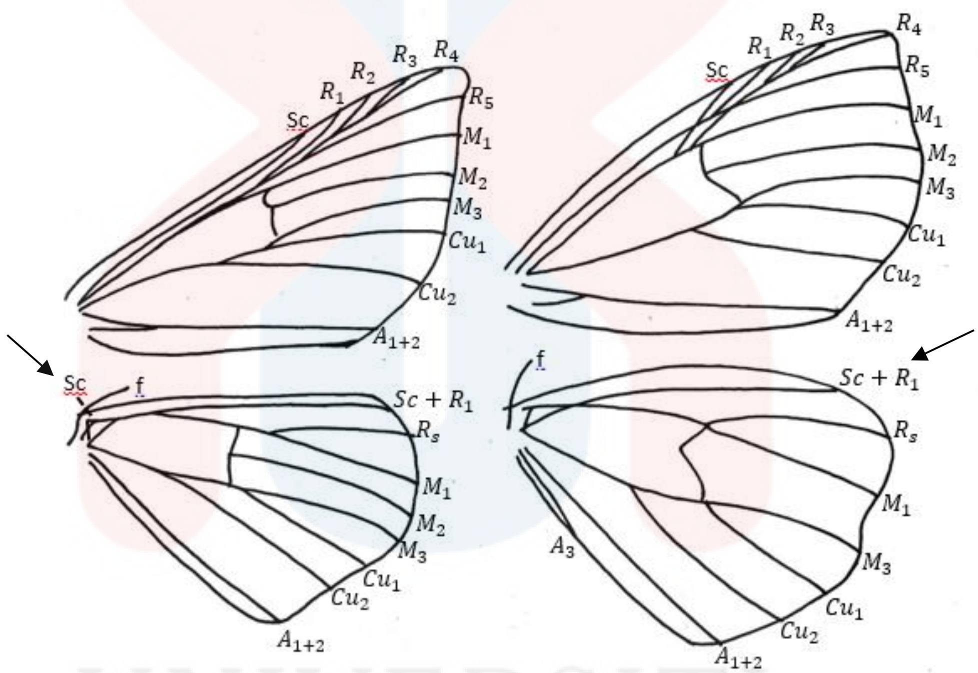
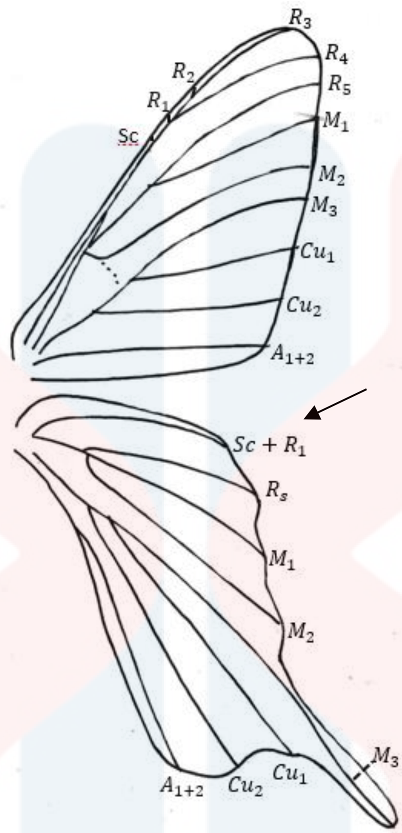
4 Sc in hind wing strongly angled at base, abruptly bent into humeral angle of wing and connected by strong brace vein; (i)………..………..……**Geometridae**

\- Sc in hind wing staright or slightly curving at base, not of the configuration in preceding entry (ii)……………..……………………..…..……………………**5**



(i)



(ii)

5 Frenulum well developed; Sc and Rs in hind wing variable (i)……………...…..**6**

\- Frenulum vestigial or absent; Sc and Rs in hind wing never fused but sometimes touching at a point beyond base or connected by a crossvein (ii).……...……..…**7**

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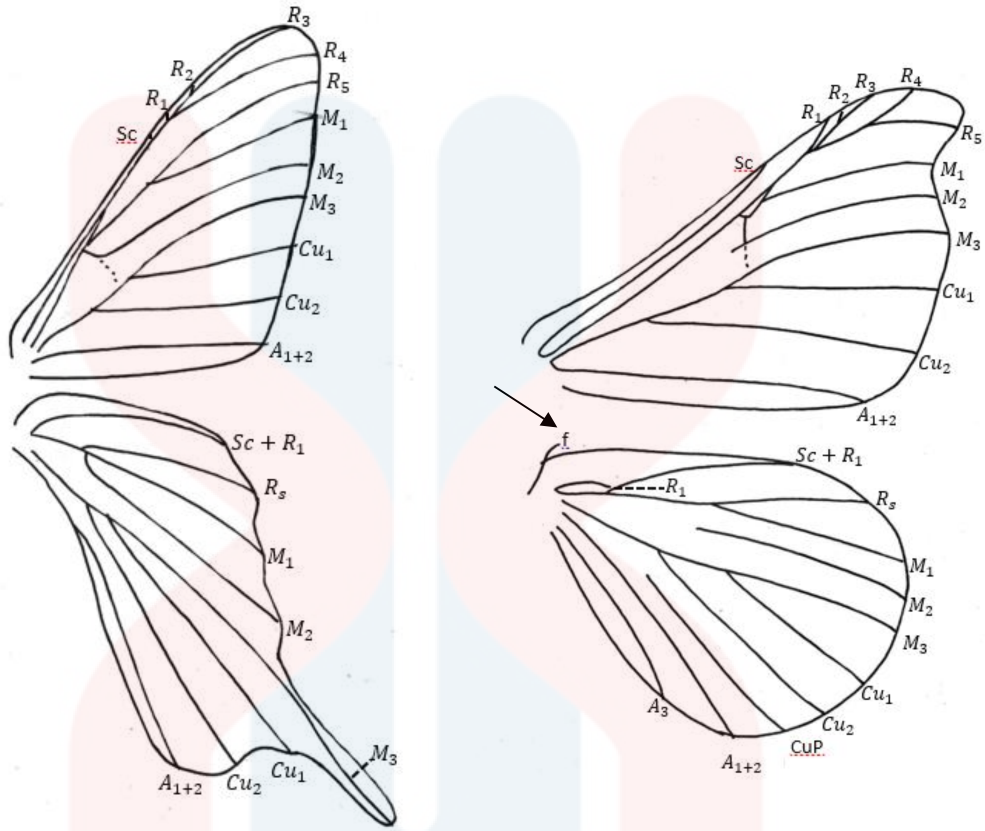

(i) (ii)

6 Sc in hind wing widely separated from Rs from near base of wing; M_1 in front wing stalked with R_5, which is well separated from R_4 (i)…….…….…...**Uraniidae**

- Sc in hind wing fused with Rs at least to middle of discal cell; frontwings with tufts of raised scales (ii)...…………………....…...…………………....…..**Nolidae**

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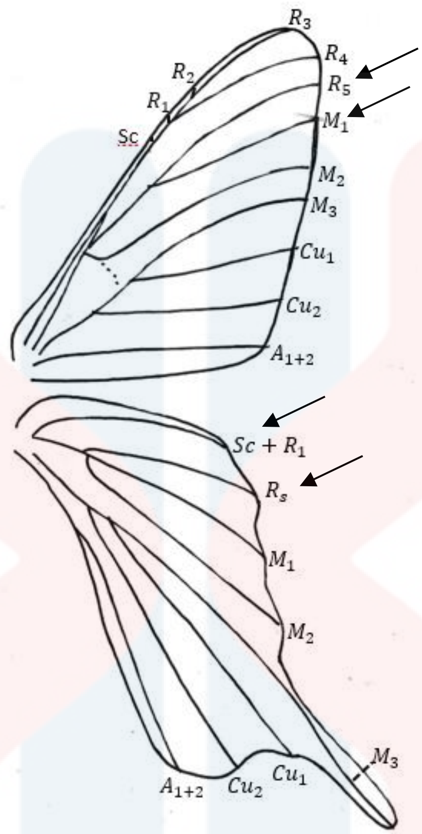

(i)

7 Rs and M_1 in hindwing stalked beyond discal cell; Sc and Rs in hindwing connected by a crossvein (i)…………….………………………….…**Bombycidae**

- Rs and M_1 not stalked beyond discal cell; M_2 in hindwing arising closer to M_1 than to M_3; frenulum small or vestigial (ii)..………….…………….….**Saturniidae**

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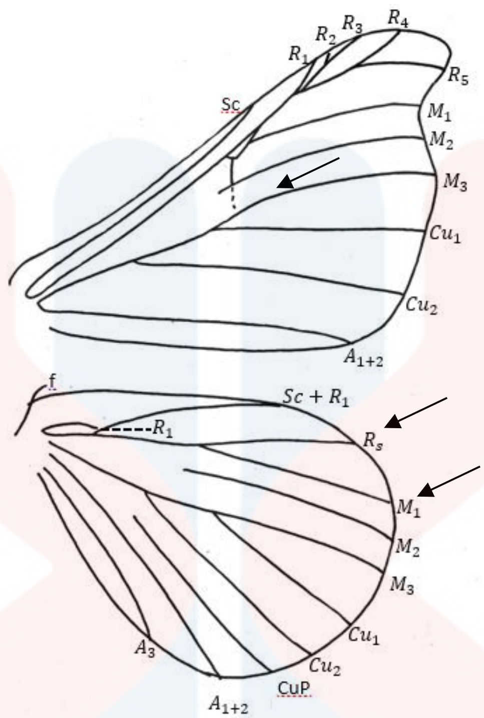
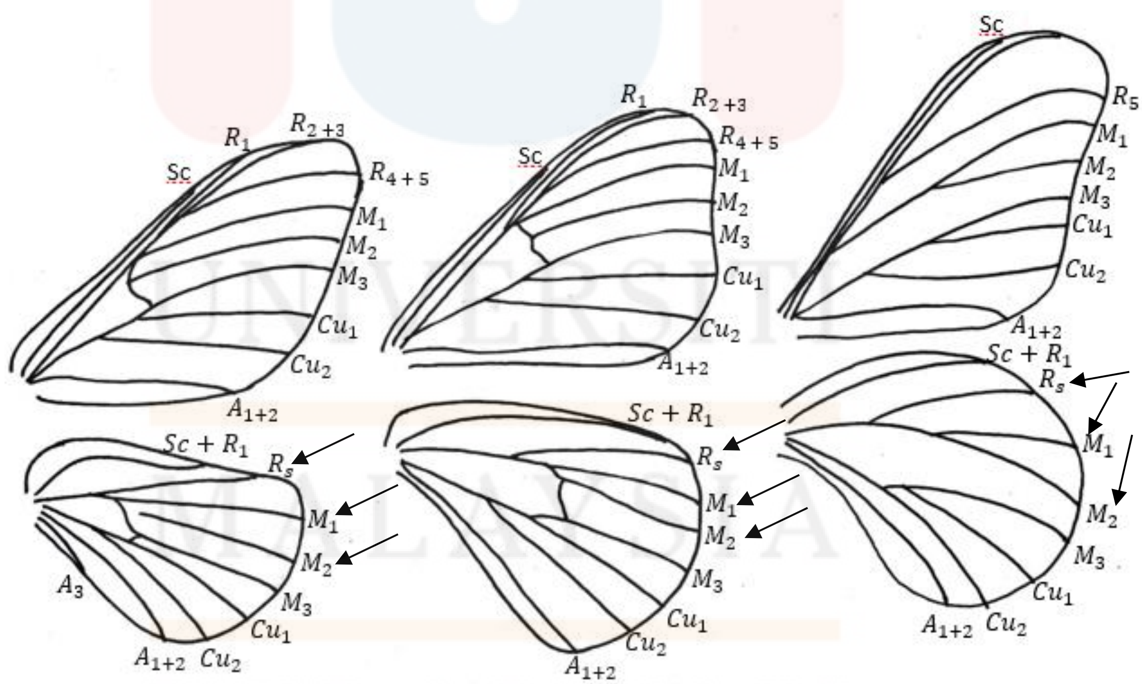


(i)



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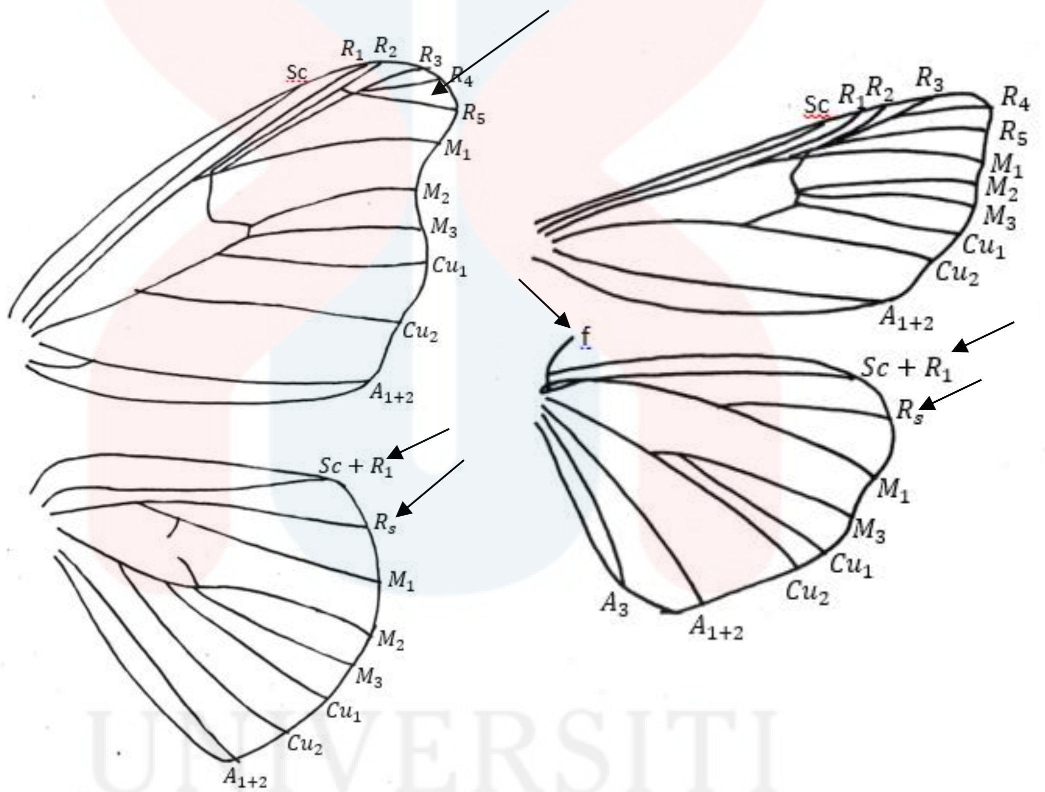
(ii)

8 Frenulum absent or vestigial; Sc and Rs in hindwing approximated, parallel along discal cell; sickle-shaped apex of frontwings (i)……...**Drepanidae**

\- Frenulum well developed; Sc and Rs in hindwing not as in preceding entry; apex of front wings usually not sickle shaped (ii)…………...………………………..**9**



(i) (ii)

9 Antennae swollen apically; Sc in hindwing fused with Rs for only a short distance at base of wing; Ocelli present (i)…………………………..……**Noctuidae**

\- Antennae usually not swollen apically; Sc in hindwing variable, M_2 not connect to cubital veins; ocelli present or absent (ii).……………………………**Erebidae**

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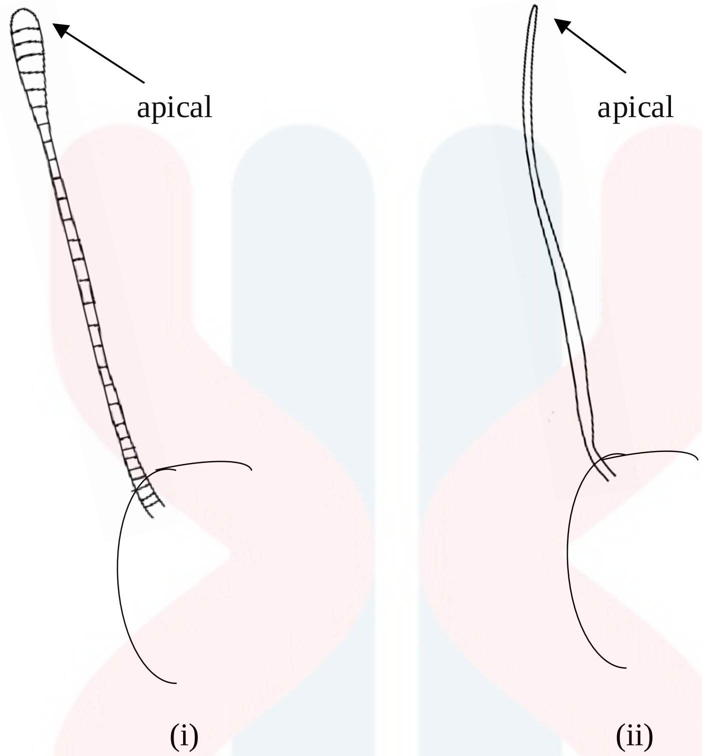

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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

To conclude, the study of moths diversity at R.E.A.C.H Biodiversity Centre Forest indicates that this montane area has moderately large diversity of moth species with uniform distribution. Results from this study indicates that secondary forest also characterized by a large proportion of family Geometridae and Noctuiidae which are the most abundance family of moth in Malaysia as this family feed mainly on broadleaf plants. In general, the highly abundant species here is *Pogonopygia pavida xanthura* (Geometridae), while the common species is *Lyssa menoetius* (Uraniidae). It was reported that moth are most diverse between 600 m to 1,500 m above sea level. This indicates that the secondary forest is successful here and in relatively healthy conditions as it is containing a substantial variety of flora and fauna of conservation interest and arthropods species such as the moths, butterflies and beetle that live inside the forest.

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5.1 Recommendations

The reforestation programmes are important and should be taken by many third world countries as it can attract various fauna by the presence of a richer and diverse understorey with numerous undoubtedly arthropods, including moths. It is essential for the conservation of the natural habitats for the existence of many species of lepidopterans (Brehm & Fiedler, 2005).

Further research can be conducted in R.E.A.C.H Biodiversity Centre Forest especially in studies of species such as birds, dragonfly and plants in order to investigate the diversity of such species after reforestation. On the other hand, further studies should be conducted on the secondary forests to study about diversity of habitat before and after disturbing forest as it is still deficit especially in Peninsular Malaysia. The ongoing destruction on Cameron Highland rainforests could give a severe impacts on the diversity of moths. There is obviously reason for concern from a conservation viewpoint as it is noted that Cameron Highland rainforests could be hotspot for diversity of moth especially family Geometridae and Noctuiidae and also for a range of other organism. In order to protect the remaining pristine and secondary habitats, strong measures should be taken by Malaysian people to handle this problem such as awareness campaign and fix new law and regulation.

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APPENDIX A

Images of selected moths collected from the R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Family Saturniidae

Cricula trifenestrata

Family Arctiidae

Nyctemera tripunctaria

Family Bombycidae

Comparmustilia semiravida

Family Nolidae

Tyana marina

Family Sphingidae

Cechenena lineosa

Family Uraniidae

Lyssa menoetius

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Family Erebidae

Tamba lala

Family Noctuiidae

Thyas javanica

Family Geometridae

Ourapteryx claretta

Family Drepanidae

Callidrepana albiceris

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APPENDIX B

Number of family species, individual and diversity index of moth species collected at R.E.A.C.H Biodiversity Forest, Cameron Highland

Family	Number of species	Number of individuals	Diversity index
Arctiidae	3	11	0.25
Bombycidae	1	1	0.05
Drepanidae	1	1	0.05
Erebidae	2	3	0.11
Geometridae	21	40	0.36
Noctuiidae	13	19	0.33
Nolidae	1	1	0.05
Saturniidae	2	2	0.08
Sphingidae	1	1	0.05
Uraniidae	1	2	0.08
Unidentified	5	8	0.22
Total	53	89	1.63

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APPENDIX C

Number of species, individual and diversity index of moth species collected at R.E.A.C.H Biodiversity Forest, Cameron Highland

Scientific name	Number of individuals	Diversity Index
Nyctemera adversata	1	0.05
Nyctemera tripunctaria	6	0.19
Vamuna remelana	4	0.13
Comparmustilia semiravida	1	0.05
Callidrepana albiceris	1	0.05
Orvasca subnotata	2	0.08
Tamba lala	1	0.05
Alcis maculata	1	0.05
Cleora determinata	1	0.05
Cleora pendleburyi	2	0.08
Fascellina meligerys	1	0.05
Fascellina castanea	1	0.05
Hypomecis separata	5	0.19
Lassaba acribomena	2	0.08
Lomographa luciferata	1	0.05
Luxiaria hyalodela	2	0.08
Mesotrophe curtisi	1	0.05
Myrioblephara simplaria	1	0.05
Organopoda acmaea	1	0.05
Ornithospila bipunctata	2	0.08
Ornithospila succincta	1	0.05
Ornithospila sundaensis	1	0.05
Orothalassodes hypocrites	1	0.05
Ourapteryx claretta	2	0.08
Plutodes costatus	1	0.05
Pogonopygia nigralbata	2	0.08
Pogonopygia pavida xanthura	7	0.20
Racotis inconclusa	1	0.05
Tristeirometa curvistriga	1	0.05
Xenoplia contrasqualida	1	0.05
Artena dotata	1	0.05
Callopistria sp.	6	0.19
Elusa ceneusalis	1	0.05
Ercheia pulchrivenula	1	0.05
Erygia sp.	1	0.05
Lignispalta incertissima	1	0.05
Ophiusa trapezium	1	0.05
Parallelia calefaciens	1	0.05

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Sasunaga interrupta	2	0.08
Spodoptera pecten	1	0.05
Thyas coronata	1	0.05
Thyas javanica	2	0.08
Trachea auriplena	1	0.05
Tyana marina	1	0.05
Cricula trifenestrata	1	0.05
Samia cynthia	1	0.05
Cechenena lineosa	1	0.05
Lyssa menoetius	2	0.08
Unidentified	8	0.22
Total	89	3.38

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