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

By

NURUL AIN BINTI SHA'ARI

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

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2017

DECLARATION

I declare that this thesis entitled "Diversity of Beetles (Order: Coleoptera) 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 : ______________________________

Name : ______________________________

Date : ______________________________

ACKNOWLEDGEMENT

In the name of Allah, the Beneficent, the Merciful. First praise is to Allah, the Almighty, on whom ultimately we depend for sustenance and guidance. Secondly, my sincerest appreciation goes to my parents, Mr. Sha'ari bin Abdul Manaf and Mrs. Nor Mizah binti Ibrahim Tan for their constant support throughout my life.

By all means, I extend my deepest gratitude for my supervisor Miss Nivaarani A/P Arumugam for her full commitment that she has pulled herself in giving the extensive guidance without endless patience in facilitating me through this whole semester especially regarding in completing this thesis until reached its final form. May Allah bestow her with blessing and sustained prosperity in her teaching career. I am also indebted to both my examiners, Madam Aainaa Syazwani bt Mohd Amir Hamzah and Dr Kamarul Ariffin bin Hambali for their invaluable advice and supervision aiding me to complete this study. Not to forget, Dr Norashikin bt Mohd Fauzi for helping me in identifying all the Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

I also wish to thank the Committee Members of R.E.A.C.H Biodiversity Centre, Cameron Highland especially its president, Mr Ramasamy A/L Ramakrishnan for their knowledgeable experience and assistance during my research being conducted there. Credit also goes to my friends for their help, knowledge and time. Special thanks, tribute and appreciation to all those their names do not appear here who have contributed to the successful completion of this study.

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

ABSTRACT

R.E.A.C.H Biodiversity Centre Forest, Cameron Highland is a 16 years old rehabilitated forest that was cleared for agricultural activities. This forest is managed by Regional Environmental Awareness Cameron Highland (R.E.A.C.H). This study was conducted at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland from July 2016 until August 2016. Coleopterans were sampled using four methods which are sheet light trap, yellow pan trap, pitfall trap and manual collection. A total of 34 specimens of Coleopterans comprising 16 species from eight families were assembled in this study. Light trap was the most efficient method in collecting all the sampled specimens. The diversity of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland was high with H'=2.51 (Shannon-Wiener Diversity Index) and the species richness recorded also high with D_{Mg}=4.25 (Margalef's Index). The most diverse beetles collected was the scarab beetles (family Scarabaeidae) followed by family Carabidae. Only one species of Coleopteran is diurnal which is *Thaumastopeus pugnator*, known as green flower beetle. Pictorial identification key was constructed to differentiate the family and genera of Order Coleoptera. Coleopterans diversity and species richness at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland are influenced by habitat changes, forest modification and fragmentations. As a conclusion, the diversity and species richness of Coleopterans species were high for a new rehabilitated forest such as R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. Future scientific studies are strongly encouraged to study the diversity of ecosystem at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

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

ABSTRAK

Hutan R.E.A.C.H Pusat Kepelbagaian Biologi, Tanah Tinggi Cameron adalah pusat penanaman semula hutan yang telah berusia 16 tahun dimana dahulunya telah ditebang untuk aktiviti pertanian. Hutan ini telah dikendalikan oleh Persatuan Kesedaran Alam Sekitar Cameron Highland (R.E.A.C.H). Kajian ini telah dijalankan di Hutan R.E.A.C.H Pusat Kepelbagaian Biologi, Tanah Tinggi Cameron dari Julai hingga Ogos 2016. Kumbang telah disampel menggunakan empat kaedah iaitu perangkap cahaya, perangkap pan kuning, perangkap *pitfal* dan kutipan secara manual. Sebanyak 34 spesimen Coleopterans yang terdiri daripada 16 spesies dan lapan keluarga telah disampel dalam kajian ini. Perangkap cahaya adalah kaedah yang paling berkesan dalam mengumpul semua spesimen. Kepelbagaian kumbang di Hutan R.E.A.C.H Pusat Kepelbagaian Biologi, Tanah Tinggi Cameron adalah tinggi dengan nilai H'=2,51 (Indeks Kepelbagaian Shannon-Wiener) dan kekayaan spesies direkodkan juga tinggi dengan nilai D_{MG}=4.25 (Indeks Margalef). Kumbang yang mempunyai kepelbagaian paling tinggi adalah kumbang scarab (famili Scarabaeidae) diikuti dengan kumbang dari famili Carabidae. Hanya satu spesies Coleoptera yang merupakan diurnal iaitu *Thaumastopeus pugnator*, yang dikenali sebagai kumbang bunga hijau. Kekunci bergambar telah dilakar untuk mengenalpasti perbezaan famili dan genera bagi Order Coleoptera. Kepelbagaian dan kekayaan spesies kumbang dipengaruhi oleh perubahan habitat, pengubahsuaian hutan dan fragmentasi. Kesimpulannya, hutan baru yang ditanam semula seperti Hutan R.E.A.C.H Pusat Kepelbagaian Biologi, Tanah Tinggi Cameron mempunyai kepelbagaian spesies dan kekayaan spesies kumbang yang tinggi. Kajian saintifik pada masa hadapan amat digalakkan untuk mengkaji kepelbagaian ekosistem di Hutan R.E.A.C.H Pusat Kepelbagaian Biologi, Tanah Tinggi Cameron.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

Mm	Millimetre
SHB	Small hive beetle
R.E.A.C.H	Regional Environmental Awareness Cameron Highland
sq	Square
mi	Miles
N	North
E	East
ft	Feat

LIST OF SYMBOLS

%	Percentage
^oC	Degree celcius
^oF	Fahrenheit
°	Degree
’	Minutes
”	Seconds
H’	Shannon-Wiener Diversity Index
D_{Mg}	Margalef’s Diversity Index
J’	Pielou’s Evennes Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Beetle is classified under order Coleoptera, which derived from the Greek words *"koleos"*, means cover and *"ptera"*, means wing. It refers to the front wings of the beetles that are modified into elytra (hardened wings) to protect the membranous hind wings (Meyer, 2009). Species in Coleopterans often characterize by its hard exoskeleton and hard forewings (elytra). The species of Coleopterans are vast than any other order of animals, range in size from 1-100 mm constituting by most 25% of all forms of animal life in the world (Rosenzweig, 1995).

Coleopterans representing about 40% of all known insects and consist about 450,000 species (Hammond, 1992). Beetles consist of small to very large insects of variable colour and shape and they are compact, mostly strongly sclerotized and more or less flattened (Arnett, 1973). Coleopterans can be found in all natural habitats, including aquatic habitats, freshwater, vegetation, from trees and their bark to leaves, flowers, in all plant tissue, including decaying plant (Foottit & Adler, 2009).

Coleopterans have a total four suborders which are Polyphaga, Adephaga, Archostemata and Myxophaga. Polyphaga is the largest suborder, followed by Adephaga, Archostemata and Myxophaga (Benisch & Christoph, 2010). Coleopterans are very wide-ranging and are distributed all over the continent. Ecologist had discovered two factors that defined the species diversity which are species richness and species evenness. Species richness defines the number of species in an ecosystem. The ecosystem is said to be rich when many species presence in the ecosystem. Species evenness defines the relative richness of difference species which make up the abundance of an ecosystem (Magurran & McGill, 2011). Even at the family level, there are total of 166 families worldwide and more than half were recorded in Malaysia (Chung, 2005).

The diversity of beetles may vary due to the differences in agro-ecosystem. Previous research studies in Tropical Africa showed that the highest diversity of beetles, family Chrysomelidae was found numerous in the mixed-crop fields followed by secondary forests (Dagobert et al., 2008). Besides, beetles abundance and diversity are affected by the latitude and altitude of their habitat (La Salle & Gauld, 1993). Williams et al (2008) found that different elevation influenced the community structure and flight periodicity of bark beetles (family Scolytidae) in ponderosa pine forest of Arizona. Insects are found abundantly diverse in the tropics, and Coleopterans are among the well-known orders in the class Insecta.

Coleopterans are exceedingly variable both biologically and ecologically. Coleopterans are majority terrestrial herbivores but they are highly specialized host ranges or life cycles that make them well known as a predator. Although the activity and identity of a few forest beetles are well known, excluding the major pests, most of those have been little studied (Scudder et al., 2005). Coleopterans play important roles in ecological system. Examples is the small hive beetles (SHB), they are scavengers of honey bee and other social native sub-Saharan Africa bee colonies and also known as parasites where they are usually considered as a minor pest only (Lundie, 1940; Neumann & Ellis, 2008). Even though they are known as pests, they can also be beneficial, especially in controlling the populations of pests. For example, Ground beetles (family Carabidae) are mutual predators of many different insects and other arthropods, such as wireworms, caterpillars, fly eggs, and others (Kromp, 1999).

1.2 Problem Statement

Research on diversity of Coleopterans has been conducted in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. R.E.A.C.H Biodiversity Centre Forest was established in 2012 in order to conduct research on flora and fauna around the biodiversity centre. It has been 16 years since the forest around the biodiversity centre have been rehabilitated. Previously, the forest was cleared for agricultural activity by local farmers. Regional Environmental Awareness Cameron Highland (R.E.A.C.H) was established in 2001 by local people to bring back the endemic species and replanted the plants in the forest. Lack of information about the diversity of Coleopterans in Malaysia especially in Cameron Highland lead this study to be conducted in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

In addition, there is no scientific studies have been conducted here (Regional Environmental Awareness Cameron Highland, 2016). The collected data will support the forest conservation effort by R.E.A.C.H in Cameron Highland.

Besides, pictorial identification key for non-taxonomic and non-entomologist to identify the species of Coleopterans is not available for R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. Thus, pictorial identification key was constructed to identify the species of Coleopterans collected for R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. It is very helpful for future scientific studies at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

1.3 Objectives

The objectives of this study are:

a) To identify the diversity of Coleopterans species at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

b) To construct a pictorial identification key of Coleopterans in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

1.4 Scope of Study

All the species of Coleopterans have been collected using light trap, pitfall trap, yellow pan trap and manual collection at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. Construction of pictorial identification key was focused for only collected Coleopterans species in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

1.5 Significance of Study

From this study:

a) Acquired the essential information about the species diversity of Coleopterans in R.E.A.C.H Biodiversity Centre, Cameron Highland.

b) Provide the pictorial identification key of the species diversity of Coleopterans to R.E.A.C.H Biodiversity Centre, Cameron Highland.

CHAPTER 2

LITERATURE REVIEW

2.1 Morphology of Coleoptera

The morphology of the Coleopterans has a uniform scheme. The Coleopterans body is segmented into three major fragments which are head, thorax and abdomen as shown in Figure 2.1. Coleopterans are often characterized by a predominantly rigid exoskeleton and rigid forewings (elytra) that act as protective covers to protect the membranous hind wings (Benisch & Christoph, 2007). Numerous plates which made up the Coleopterans exoskeletons which are called sclerites, were separated by thin sutures and the elytra will covered the abdomen. Both elytra will meet laterally in the central of the back and formed a straight line when the Coleopterans are at rest, making it most likely the most distinguishing characteristics of the order. On the other hand, the elytra are seized out to the sides of the body when the Coleopterans flight, where they provide a definite amount of aerodynamic stability (Meyer, 2009). The elytra play an important role in beetle identification, as they often display characteristic maculation or shapes.

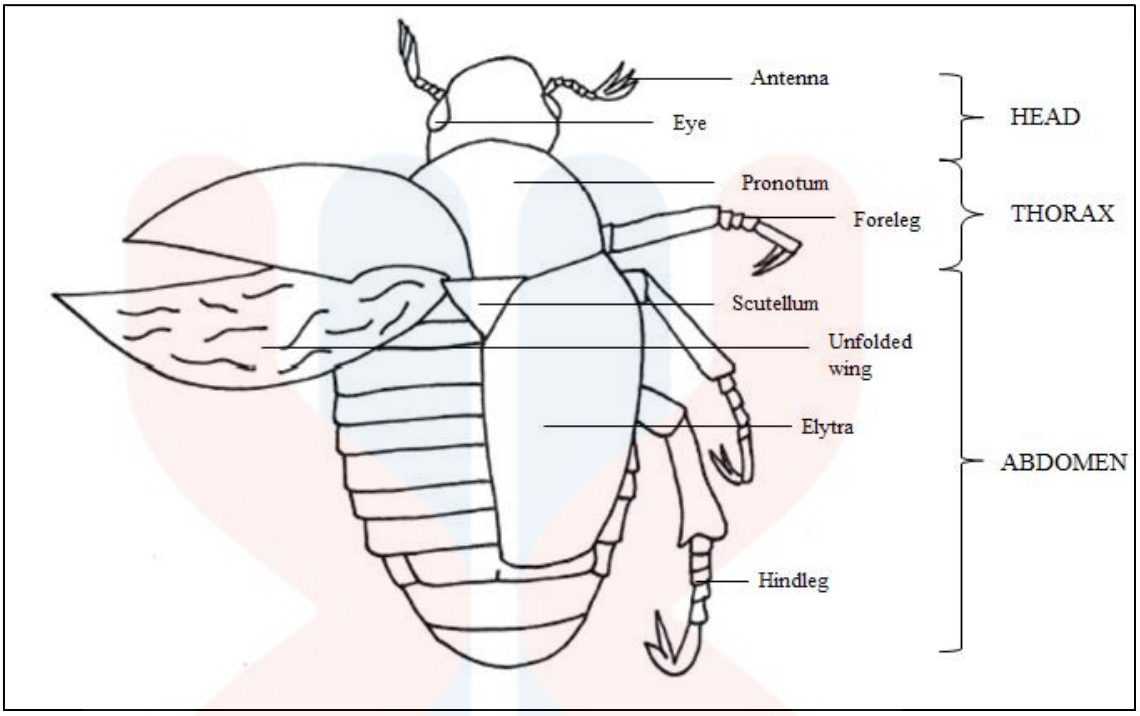


Figure 2.1: The Morphology of Beetle

(source: modified from Ratcliffe, 1991)

2.1.1 Head

The head that attached to the thorax by the cervix is likely more or less flexible. The head consist of a rigid capsule which contains the eyes (oculi), mouthparts and antennae (Benisch & Christoph, 2007). The mouthparts sticking out forward or sometimes downturned the head, is usually varies in size and profoundly sclerotized. Some whirligig beetles (family Gyrinidae) and longhorn beetle (family Cerambycidae) have divided and split eyes to allow a view of above and below the waterline (Gillott, 1995). Both larvae and adults of Coleopterans have strong mandibulate mouthparts (Meyer, 2009). The sense organ of Coleopterans, antennae is a primarily organ of smell, used to sense a physically beetle's environment, during mating and also for defence. Males and females may have altered forms of antennae. Antennae could be moniliform, filiform, geniculate, clavate (lamellate and flabellate are subforms of clavate), serrate or pectinate (Gillott, 1995). Coleopterans also have similarity to those of grasshoppers which is mouthparts where the mandibles are possibly most commonly known, which look as if large forceps on the front of particular Coleopterans. The mandibles are a pair of rigid and having tooth-like structures that move horizontally to grip, crush, or cut food and enemies. The mandibles are sexually dimorphic in many species of Coleopterans, with the males enlarged massively compared to females of the same species (Gillott, 1995). Herbivorous species use their mandibles to bite into and crush their food, while predator species have pointy and edged mandibles to seizure and hold their prey. In particular species, for example is the male of the stag beetles, *Lucanus cervus*, their mandibles are not functional for food intake. Instead, they are used for fights between male opponents as their mandibles are formed like antlers (Benisch & Christoph, 2007).

2.1.2 Thorax

The thorax consists of three sections which are prothorax, mesothorax and metathorax. The front pair of Coleopterans legs abides by the prothorax and always clearly separated. The episternum separated the articulation from the thorax and the thorax segment which is located directly behind the articulation is called epimerum. Mesothorax is attached to the prothorax which abides the middle pair of the Coleopterans legs. The last section of the thorax is the metathorax which abides the rear pair of Coleopterans legs (Benisch & Christoph, 2007).

2.1.3 Abdomen

The third main fragment of the body is the abdomen. The elytra covered the upper side of the body and the venter formed in the lower side. The abdomen comprises of 89 segments. The abdomen is the segment located behind the metathorax, made up of a sequence of rings. They are comprised with a hole for each ring for respiration and breathing, so-called a spiracle and constituting three different segmented sclerites which are the tergum, pleura, and the sternum. The tergum is soft and membranous in almost all species and usually covered by the elytra and wings when the Coleopterans are not flying. In some species, a small or hidden pleura usually have a single spiracle in each pleuron. The sternum, which being a more or less sclerotized is the most widely observable part of the abdomen. The abdomen itself does not have any attachments (Ivie & Michael, 2002). The elytra are strongly and rigid sclerotized forewings of the Coleopterans. The elytra functioned as a protective cover of the rear part of the body and protect the second pair of wings (alae) when at rest and does not used for flight. To move the hind flight wings, the elytra must be raised (Carpenter & Herbert, 1899). In most cases, the abdomen was covered by elytra. However Coleoptera species such as rove beetles (family Staphylinidae) have shortened elytra in which the tergites are at least partially visible. Some "true weevils" (family Curculionidae) and round beetles (family Carabidae) have their elytra attached together and form a closed covering. Thus, the membranous wings (alae) are reduced or completely missing and these are flightless (Benisch & Christoph, 2007).

2.2 Taxonomy and Identification

Coleoptera is divided into four suborders which are Polyphaga, Adephaga, Archostemata and Myxophaga. The largest suborder which is Polyphaga, comprises beyond 300,000 defined species in more than 170 families, including blister beetles (Meloidae), scarab beetles (Scarabaeidae), rove beetles (Staphylinidae), true weevils

(Curculionidae) and stag beetles (Lucanidae) (Benisch & Christoph, 2010). The existence of the cervical sclerites (hardened parts of the head used as points of attachment for muscles) is the main character of beetles in the Polyphaga suborder which is absent in the other suborders. Largely predatory beetles comprised about 10 families in Adephaga suborder, includes whirligig beetles (Gyrinidae), ground beetles (Carabidae), and Dytiscidae. The characteristics that are necessary to identify these beetles are the first abdominal sternum (a plate of the exoskeleton) is separated by the rear coxae (the basal joints of the beetle's legs) and the testes are tubular. Archostemata comprises four families of predominantly wood-eating beetles, including the telephone-pole beetle and reticulated beetles (Cupedidae). Myxophaga comprises four families of 100 species and they are mostly very tiny, including Sphaerius and Hydroscaphidae (Benisch & Christoph, 2010).

Fireflies (family Lampyridae) and glow-worms (family Phengodidae) are the two families of Coleoptera which are bioluminescent (able to produce light). Their organs in the abdomen can function as a light-producing. In some species, the females larviform and wingless. The fringed ant beetle, *Nanosella fungi* (family Ptiliidae) was classified as the smallest beetles species as shown in Figure 2.2. It has length of 0.25 mm and it is approximately 16 million times slighter in size than the largest beetle, *Goliathus giganteus* (family Scarabaeidae), which body length may increase up to 10 cm (Meyer, 2009).

Figure 2.2: Fringed ant beetles under microscope (the smallest beetles)

(source: Meyer, 2009)

2.3 Diversity and Distribution

The most often targeted level is the species diversity. However, if the species rich and their taxa to be involved are difficult to identify, like many invertebrate taxa, it is practically impossible to conduct a species level survey (Stork, 1994; Baldi, 1999). Advanced trapping, handling and identification skills might be required (Nielsen & West, 1994). Coleopterans are the largest order of insects, range in size from one to 100 mm with 350,000 to 400,000 species in four suborders (Adephaga, Archostemata, Myxophaga, and Polyphaga), assemble more or less of 40% of all insect species, and approximately 30% of all animals life forms (Gillott, 1995; Bouchard et al., 2011). The overall amount of Coleoptera species on the world is first assessed based on field data and probably as many as 12 million species was analysed then it was reviewed with 850,000 to 4,000,000 species proposed was estimated.

The Coleopterans is not correspondingly well acknowledged in all parts of the world. For example, 23,000 species in 3265 classes and 121 families of known Coleopterans diversity of Australia was estimated. To some extent, it is lower than North America, which has 25,160 species in 3526 classes and 129 families with a terrestrial mass of similar size (Foottit & Adler, 2009).

There are 166 families of Coleopteran species worldwide and more than half have been recorded in Malaysia where the common families founds are Scarabaeidae and Cerambycidae (Chung, 2005). However, there is a great void of information on Coleopterans in Malaysia. Although some groups have been relatively well-studied, example is family Chrysomelidae, on the whole there is very little documentation of the taxonomy of most groups of Coleopterans especially in Peninsular Malaysia (Cheng & Laurence, 2007).

Based on research studies that have been conducted by Abdullah et al., (2012), total of 348 beetle specimens comprising 113 species from 34 families were collected at Gunung Benom, Pahang. Meanwhile, according to Abdullah et al., (2001), total of 98 specimens of beetles from 16 family beetles compromising of 68 species were collected which the most abundance beetles were found in Gunung Brinchang compared to Tanah Rata at Cameron Highland. The most abundant and diverse beetle collected in Gunung Brinchang was the leaf beetles (family Chrysomelidae) while the least diverse family caught was from family Scolytidae (Abdullah et al., 2001).

The diversity of beetles also may vary due to the different in ecosystem. Previous research studies in Tropical Africa indicated that the highest diversity of beetles was found in the mixed-crop fields followed by secondary forests and it is found that the family Chrysomelidae was most numerous and better represented in primary and secondary forests (Dagobert et al., 2008). Besides, in comparison between deciduous forest and reforested forest in determining the diversity of ground beetles, beetles are found most abundance in deciduous forest (Magura et al., 2002). In recent times where the plantation established, species distinctive of open habitats, small and winged Coleoptera were found abundantly and they declined or disappeared in density after closure of the canopy layer suggesting the process of the secondary succession after reforestation and the colonization of new habitats (Magura et al., 2002). The overall diversity of Coleopterans in different habitat type in Sabah was particularly high, with 1711 species recorded from only 81 families and 8028 individuals (115 family and subfamily groups) where the most abundance species of beetles found in primary forest compared to logged forest and oil palm plantation (Chung et al., 2000).

Beetles abundance and diversity also are affected by the latitude and altitude of their habitat (La Salle & Gauld, 1993). Williams et al., (2008) found that different elevation influenced the community structure and flight periodicity of bark beetles (family Scolytidae) in ponderosa pine forest of Arizona.

2.4 Ecological Importances of Coleoptera

Beetles not only play critical roles as herbivore, predator, fungiform and detritivore of ecosystems in the web food structure and the flow of energy, but also used as source of food for mammals, birds, reptiles and amphibians (Holland, 2002; Triplehorn & Johnson, 2004). Moreover, beetles are used as biological indicator species to evaluate forest management, the segmentation of mountain forest, deforestation, and forest fire (Werner & Raffa, 2000). Approximately, 75% of Coleopteran species are phytophagous in both the larval and adult stages, and live in or on plants, fungi, wood and a variation of stored products, including dried fruits, cereals, and tobacco.

Coleopterans can be considered pests as a lot of these plants are significant for forestry, agriculture and the household. For example, other pests include the coconut hispine beetle, *Brontispa longissima*, which forages on damages seedlings, young leaves and mature coconut palms. Philippines' Metro Manila and 26 provinces were set apart on 27 September 2007, to save the $800million Philippine coconut industry as they have been infected with this pest (Remo & Amy, 2007). Invasive species are a major threat to biodiversity and agriculture globally (Nentwig, 2007). It is not surprising that this is true for apiculture as well. For example, small hive beetles (SHB) known to be a threat to beekeeping. They are scavengers of honey bee and other social native sub-Saharan Africa bee colonies and also known as parasites where they are usually considered as a minor pest only (Lundie, 1940; Neumann & Ellis, 2008).

Although they are known as pests, they can also be beneficial, especially in controlling the populations of pests. Ground beetles (family Carabidae) are mutual predators of many different insects and other arthropods, including wireworms, caterpillars, fly eggs, and others (Kromp, 1999). Although these beetles were beneficial to agriculture, human activities such as insecticide usage at the plantation may affect abundance and diversity of beetles especially the leaf beetles (Abdullah et al., 2001).

2.5 Identification Key

There are various types of identification keys in order to classify the living organism. The most traditional biological identification keys are dichotomous (every choice has two options) or polytomous (two or more options at each choice) forms. The structure of these keys normally comprises of a series of alternative statements, called “leads”. All leads that need to be evaluated for a single decision form a “couplet” (Hagedorn et al., 2010). Besides, a “single-access key” that consists of a combination of simple polytomous and complex dichotomous elections could be used (Winston, 1999). Dichotomous key is said to be useful and simple than any other keys because it used only two alternative choices of characters in identifying the type of species thus make it easy to characterize the species of an organism (Hagedorn et al., 2010). Meanwhile, the pictorial identification key will be constructed and used to assist the dichotomous key to give a clear view on determining the characteristic of species identified also to ease the non-taxonomic and non-entomologist to identify the species of Coleopteran collected in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

The free-access key (also known as matrix key, multi-access key or synoptic key) is a substitute to a single-access key. Although printable free-access keys exist, they are utmost fit for computer-aided identification tools. A single key access can be printed in various styles such as linked style, nestled style and graphical style (Pankhurst, 1991). A reticulated key used in lead styles where couplets may comprise of a question, with the leads providing different answers. The case will often simply be handled by true duplication, multiple references to whole branches of a decision tree turn a “tree” structure into a directed reticulated identification key (Hagedorn, 2007).

Serious consequences in both pure and applied disciplines, including ecology, pest control, forensics and medical diagnosis may happen due to the error in identification key (Bland & Jaques, 2010). Therefore in order to reduce the incidence of such errors, identification keys must be assembled with prodigious attention. The identification acquired from a key should be regarded as only a suggestion of the species real identity. The specimens that need to be compared with some authoritative source, such as a complete and precise description of the species, will be required for full identification preferably in a monograph. Brief descriptions are mostly required in many keys to allow more certain identification, but these should not be assumed sufficient for authentication (Bland & Jaques, 2010).

There is very lack of information on research studies of Coleopterans in Malaysia and very little documentation of the taxonomy of most groups of Coleopterans especially in Peninsular Malaysia (Cheng & Laurence, 2007). Despite of the lack of studies on Coleopterans in Malaysia, therefore there is less identification key were recorded for species of Coleopterans in Malaysia. Thus, the identification key from other sources as shown in Table 2.1 can be made as references to identified species of Coleopterans in Malaysian.

Adult Coleopterans identification can be subject to certain features of external morphology and their terminology. Many keys use the “tarsal formula”. It refers to the expression of the number of tarsal segments on each of the legs. For example, a formula of 4-5-5 designates 4 segments in the front tarsi, 5 in the middle tarsi, and 5 in the hind tarsi. The tarsal formula sometimes differs in the sexes of the same species, in which case it is almost always the male which has the lower formula (Crowson, 1956). Antennal morphology is also convenient and a familiarity with the various types of antennae is vigorous to keying numerous species of the

Coleopterans (Bland & Jaques, 2010). Any other morphological characteristics to identify Coleopterans includes mouthparts (labial and maxillary palpi), antennal shapes, ventral characters (sterna, pleura, coxae) and tarsi (shapes of segments) (Choate, 1999). The number of taxa in biology is very huge. For example, 900,000 insect taxa alone are currently recognized (Hagedorn et al., 2010).

Table 2.1: List of Sources on Identification of Beetles worldwide

No	Title	Description	Sources
1.	An Introduction to The Study of Insects	Identification key of all insects in the world	Borror & DeLong (1971)
2.	Introduction to The Identification of Beetles (Coleoptera)	Identification key of beetles	Choate (1999)
3.	Borror and Delong's introduction to the study of insects	Identification key of insects refer to Borror and Delong's study	Triplehorn & Johnson (2004)
4.	Beetle Morphology	The morphology of beetles	Benisch & Christoph (2007)
5.	How to Know The Insects	The morphology and identification key of all insects	Bland & Jaques (2010)
6.	Key to Families of Coleoptera	Identification key to families of Coleoptera	Key to Families of Coleoptera (n.d.)

2.6 Cameron Highland

Cameron Highland is the smallest district in Pahang and was first discovered by Sir William Cameron in 1885. Cameron Highland was named after Sir William Cameron’s name (Moore & Khadijah, 2004). It is one of Malaysia’s most wide-ranging hill station located at 4°31’45’’ N 101°20’20” E and inhabits an area of 712 square kilometres (275 sq mi) as shown in Figure 2.3. The settlement consists of three regions, Ulu Telom (63,981 hectares), Ringlet (5,165 hectares) and Tanah Rata (2,081 hectares) (De Souza & Roy, 2010). All the three regions are burrowed at elevations ranging from 1,100 metres (3,600 ft) to 1,600 metres (5,200 ft) above sea level. The humidity is high with no patent dry seasons. Its wettest months are from October to November whereas it’s “driest” period is from January to February. The mean annual temperature is about 18°C (64°F). During the day, the temperature occasionally rises over 25°C (77°F) and it hardly ever drops to as low as 9°C whereas at night (48°F) (De Souza & Roy, 2010).

Figure 2.3: Map of Cameron Highland in Malaysia

(source: modified from De Souza & Roy, 2010)

The Cameron Highlands is different from any other constituency in Malaysia. Cameron Highland is one of the few places in Malaysia that assists as a habitat for a wide diversity of flora and fauna. There are more than 700 species of plants that grow here. As the mountain ascend, the vegetation altered in each level. The district is known for its flower nurseries, vegetable farms and tea growing. Its forests form the fundamental natural ecosystem within and all over the area. It is a home for hundreds of tropical rare floral species, and it is also an area with a markedly different ecosystem. In 1958, the settlement was acknowledged as a reserve for deer. Four years later, it became a place giving protection to animals and birds (Rodrigo & Jennifer, 1996). From year 1957 to 1973, during the Post-Independence Period, massive regions of land were cleared for agriculture and infrastructure development. After 1974, more land was cleared for agriculture, logging activities, livestock farming, hotel construction, housing projects, human resettlement, power plants, small-scale industries, and road building (De Souza & Roy, 2010).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Site

This research has been conducted in month of July to August 2016 (24 days) at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. The biodiversity centre is located on an edge of Gunung Brinchang at an elevation of 1781 metres above sea level (N 04°31'12.1", E 101°23'40.1") as shown in Figure 3.1. R.E.A.C.H Biodiversity Centre Forest was established in 2012 in order to reforest the flora and fauna around the biodiversity centre (Regional Environmental Awareness Cameron Highland, 2016). R.E.A.C.H is a community founded organisation formed in 2001 by a group of Cameron Highland's residents. It was illegally cleared in 2000 by the local farmers for agricultural activities. An official permission was given to R.E.A.C.H in 2002 to reforest it and it has been 16 years since the forest around this biodiversity centre have been rehabilitated centre. The total area of this place is 50 hectares and the area has two trails with 380 metres and 350 metres length of each trail (Regional Environmental Awareness Cameron Highland, 2016).

Considered to rapidly declining environment especially the declining forests and water quality, R.E.A.C.H with the help of volunteers managed to cover about 80% of the site by planting some local plants. Since then, more than 9200 trees were planted and they are all from endemic species such as Gerok, *Eugenia*, Rhododendrons and *Nepenthes*. Birds, insects and small mammals has been started to move into the area. This is one of the first reforestation sites at such a high elevation. (Regional Environmental Awareness Cameron Highland, 2016). A group of volunteers is now running the organisation with fund from membership, reforestation activities, small grants, donations and sales of souvenirs.

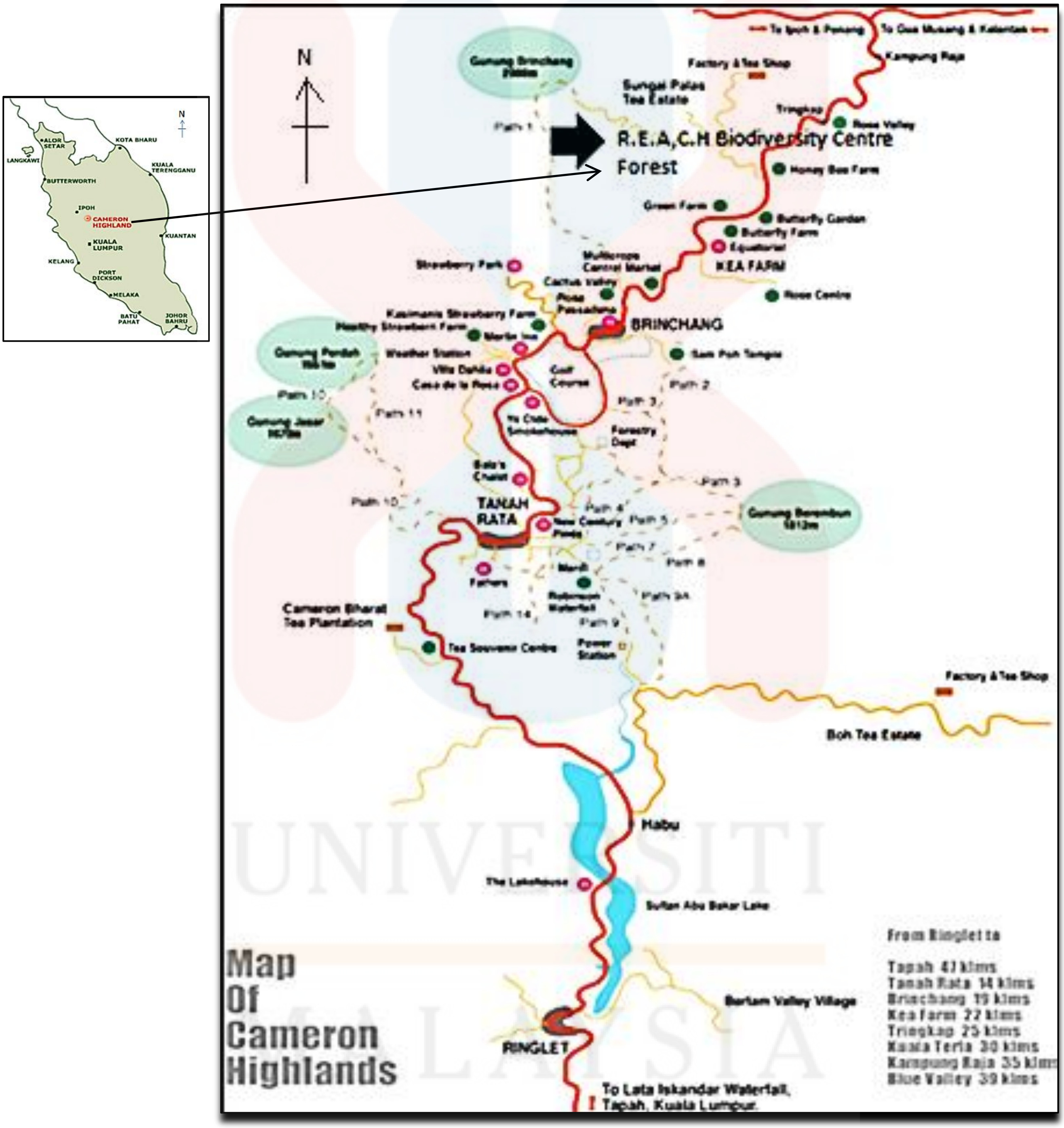


Figure 3.1: Map of Gunung Brinchang in Cameron Highland

(source: modified from De Souza & Roy, 2010)

3.2 Materials

Table 3.1 below shows list of materials for collecting, preservation and mounting of beetles specimens.

Table 3.1: List of materials for collecting and preservation of beetles specimens

NO.	MATERIAL	DESCRIPTION
1.	Light trap, pitfall trap & yellow pan trap	To attract beetle species
2.	Falcon tube	To immobilize collected insects
3.	Ethyl Acetate	Killing agent that produce a toxic atmosphere that make the insects cannot breathe
4.	Small jar	Placing specimens for dry preservation method
5.	Insect pin	To pin the insects
6.	Insect label	Information or data about the insects to be pinned together with the insects specimens

3.3 Methods

3.3.1 Data Collection

a) Light Sheet Trap

All samples of Coleopterans in the study area have been collected by using light traps (Figure 3.2 and 3.3). Insects are positively phototrophic and use of light traps for insect catches produces valuable faunistic data. Ramamurthy et al., (2010) used Mercury, Black and Ultra-violet light traps for insect capture and found that Coleopterans dominate the catches followed by Hemipterans, Hymenopterans and Lepidopterans. Lamps rich in their output of ultraviolet light is the most efficient light traps (Steiner & Hauser, 1991).

The main advantage of light-trapping is the large number of species which can be recorded during a relatively short period. In this research study, two light sheet traps has been used where it were installed in Trail 1 and Trail 2 at R.E.A.C.H. The lamp was placed in front of a vertical white sheet which serves as a good reflector and also allows insects to settle near the lamp. As Steiner & Hauser (1991) said, this method is the simplest among the other light traps. A cloth sheet, usually a white bed sheet, was hung outdoors at night with a proper light source. During this experiment, spiral bulbs and fluorescent lamp were used as a light source and it were connected to car battery as an electrical source. Then the sheet was pinned to a rope tied between two trees, with the bottom edge of the sheet will be spread out on the ground below the light.

Figure 3.2: Light sheet trap (Trail 1)

Figure 3.3: Light sheet trap (Trail 2)

The light traps have been set up on the trail before the experiment was conducted. The light traps were installed in the evening and the time range for this experiment being conducted was from 6.30pm to 11.30pm. The light traps were installed at Trail 1 and Trail 2 and they were installed for 12 days at each of the trail. The moon phase condition had been taken into account as the moon phase may effects the attraction of insects to the artificial light (Barr, 1963). The light source will compete with the bright moon which may results in a reduced catch. The most suitable time for collecting insects for each month is from the fifth night after the full moon until about a week before the next full moon occur (Barr, 1963). The samples collected were kept in a falcon tube which has been poured with ethyl acetate to immobilize the beetles. The samples collected were carried back safely to Natural Resources Museum, Universiti Malaysia Kelantan, Jeli Campus for preservation.

b) Pitfall Trap

All samples of Coleopterans in the study area were collected by using Pitfall trap (Figure 3.4 and 3.5). It is another simple and effective yet a useful type of interception trap consists of a can, jar, or dish sunk in ground. A cover must be placed over the open top of the jar to prevent raindrop and small vertebrate enter the jar while allowing insects to enter it (Briggs, 1971; Clark & Blom, 1992). Pitfall traps may be lured with various substances. In this research, soaps water has been used to trap beetle specimens. Even though the specimens that fall into the trap will remain there, it should be checked daily and desired specimens will be relocated and placed in a killing bottle or alcohol while they are in their best state (Clark & Blom, 1992).

Pitfall traps which made up from plastic bottles have been set up along the Trail 1 and Trail 2 in the research areas before the experiment was conducted. A total of 15 pitfall traps were used in this experiment. Each trail was installed with pitfall traps and the distance between each trap is 20 meters. The pitfall trap has been installed for 24 days at both trails. The pitfall traps were checked every day in the morning and the evening. The samples collected were kept in a falcon tube which has been poured with ethyl acetate to immobilize the beetles. The samples collected were carried back safely to Natural Resources Museum, Universiti Malaysia Kelantan, Jeli Campus for preservation.

Figure 3.4: Pitfall trap

c) Yellow Pan Trap

Coleopterans specimens were also collected by using yellow pan trap at the research area. Yellow pan trap are used broadly by some collectors. A plastic or an aluminium pan is painted yellow and placed on the ground and filled with some non-toxic fluid (Granger, 1970). In this research, yellow pan trap was made up from plastic container and soaps water has been used as the substance filled in the trap. The yellow pan traps have been set up along the Trail 1 and Trail 2 before the experiment was conducted as each distance between the trap is 20 metres. A total of 15 yellow pan traps were used in this experiment. The installation of yellow pan trap also took 24 days at each trail. The yellow pan traps were checked every day in the morning and the evening like pitfall traps. The samples collected were kept in a falcon tube which has been poured with ethyl acetate to immobilize the beetles. The samples collected were carried back safely to Natural Resources Museum, Universiti Malaysia Kelantan, Jeli Campus.

Figure 3.6: Yellow pan trap

d) Manual Collection

Several Coleopterans were manually collected on the ground during the research study conducted at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. The Coleopterans were collected using forceps and the collection time was in the morning and night. The samples collected were kept in a falcon tube which has been poured with ethyl acetate to immobilize the beetles. The samples collected were carried back safely to Natural Resources Museum, Universiti Malaysia Kelantan, Jeli Campus for preservation method.

3.3.2 Identification and Preservation

The samples have been identified through the identification key by following Borror & DeLong (1971). The existing identification key of Coleopterans was used to identify the species of Coleopterans collected in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. In need for identification of beetles collected in R.E.A.C.H Biodiversity Centre Forest, Cameron Highland, prior knowledge towards certain features of external morphology and their terminology is needed such as the antennal shape, mouthparts, tarsal and other characters (Lane, 1965). After the Coleopterans specimens have been identified according to their suborders, families and species, they will be mounted on spreading board. Before dry insects need to be pinned, they need to be relaxed, that is, remoistened enough so that it will not halt when the pin is inserted or the specimens be rearranged or repositioned (Lane, 1965).

The samples were preserved using dry preservation method. In this research, a manual dry preservation method has been applied where all the samples collected were dried under sunlight in the morning till evening about two to four days based on size of organism. The preserved specimens were labelled with complete collection data (Tindale, 1962). Then, Coleopterans specimens were kept in Natural Resources Museum of Universiti Malaysia Kelantan, Jeli Campus.

3.3.3 Construction of Pictorial Identification Key

Coleopteran species identification requires prior knowledge to become acquainted with tarsi (shapes of segments), mouthparts (labial and maxillary palpi), antennal shapes, ventral characters (sterna, pleura, coxae), and other morphological characters (Bland & Jaques, 2010). Many keys use the "tarsal formula". Antennal morphology is also useful and understanding with the various types of antennae is vital to keying many of the Coleopteran species (Bland & Jaques, 2010). The characters that will take into account in order to identify the type of Coleoptera species collected at R.E.A.C.H Biodiversity Forest are the by looking at their protothorax, antenna, abdominal segment and their coxae (Crowson, 1956).

The type of identification key that has been constructed is dichotomous, meaning that each couplet has 2 paragraphs of characters from which the best match was picked. Through process of elimination of the unneeded characteristic, a reasonable identification choice has been made through this key. If it is found that if every couplet seems to be a problematic choice, an error is probably have been made or the specimen that are tried to be identify belongs in a family which are not encompassed in the key (Choate, 1999).

Pictures of specific morphological characters of identified Coleopterans were drawn under the dichotomous key identification. It is to ease the non-entomologist and non-taxonomist at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland in order to identify and differentiate the species of Coleopteras collected in further research studies.

3.3.4 Statistical Analysis

a) Species Accumulation Curve

The species accumulation curve was used to find out how many species characterizing an assemblage, which means the specimens will be sampled to a greater extent until no new species are found and the species accumulation curve will reaches an asymptote (Choate et al, 2009).

b) Rarefaction Curve

After the species accumulation curve was constructed, a rarefaction curve also was constructed to compensate for sample-size differences in the measurement of richness in ecological studies. The rarefaction curve consists of the number of species as a function of the number of a sample (Sanders, 1968). Generally, as the most common species are found, rarefaction curve grow promptly at first, but as only the rarest species remain to be sampled, the curve will become plateau (Gotelli & Colwell, 2001).

c) Shannon-Wiener Diversity Index

The data collected was analysed using Shannon-Wiener Diversity Index (H) to determine the diversity of the Coleopterans. This data analysis was chosen because it is believed to emphasize the richness component of diversity. According to Magurran (2004), this index assumed that each species was represented in each sample and that there was random sampling of individuals from an infinitely large population. Diversity increases with the increase in the value of the index. Shannon-Wiener Index has a maximum value of 5 (Magurran, 2004). This index also can be used to calculate diversity of families among the Coleopterans (Abdullah et al., 2001; Abdullah et al., 2012). In other words, the Shannon–Wiener Index (Shannon & Weaver, 1948) is defined as in Equation 3.1:

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

where the range is between 0 – $H'_{max'}$,

$$\mathbf{H'_{max} = \ln S} \qquad \text{……Equation 3.2}$$

Where;

H' = Shannon-Wiener Index

N = Total individual in a population

$\mathbf{n_i}$ = Total individual for n_i species

S = Number of species

d) Pielou's Evenness Index

According to Mulder et al., (2004), the evenness of a community also can be calculated by Pielou's evenness index.

$$\mathbf{J' = H'/H'max} \qquad \text{……Equation 3.3}$$

Where:

J' = value inhibited between 0 and 1, the less variation in communities between the species (similar proportion of species), the higher J' is.

H' = Shannon-Wiener Index

H'_{max} = Maximum possible value of H'(calculated using Equation 3.2)

e) Margalef's Diversity Index

Besides using Shannon-Wiener Index to calculate species richness, Margalef's Diversity Index (Margalef, 1951) also was used. This index is simply scale the number of species to calculate diversity and how the closely related species does not take into account. Abundance increased proportionally with the value of Margalef's Diversity Index. Margalef's Diversity Index is defined as in Equation 3.4:

$$D_{Mg} = (S-1) / \ln N \quad \text{......Equation 3.4}$$

where:

S = Number of species

N = Number of individuals (of all species)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Coleopterans Assemblage

A total of 34 Coleopterans specimens that comprised of 16 species (Appendix A) were collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland (R.E.A.C.H B.C.F). Recorded Coleopterans were comprised of eight families which are Silphidae, Cerambycidae, Scarabaeidae, Cetoniidae, Carabidae, Curculionidae, Lucanidae and Colydiidae. The study at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland have been carried out for 24 days and species accumulation curve was used to make sure the data is reliable and significant for species collected at R.E.A.C.H B.C.F as shown in Figure 4.1 below:

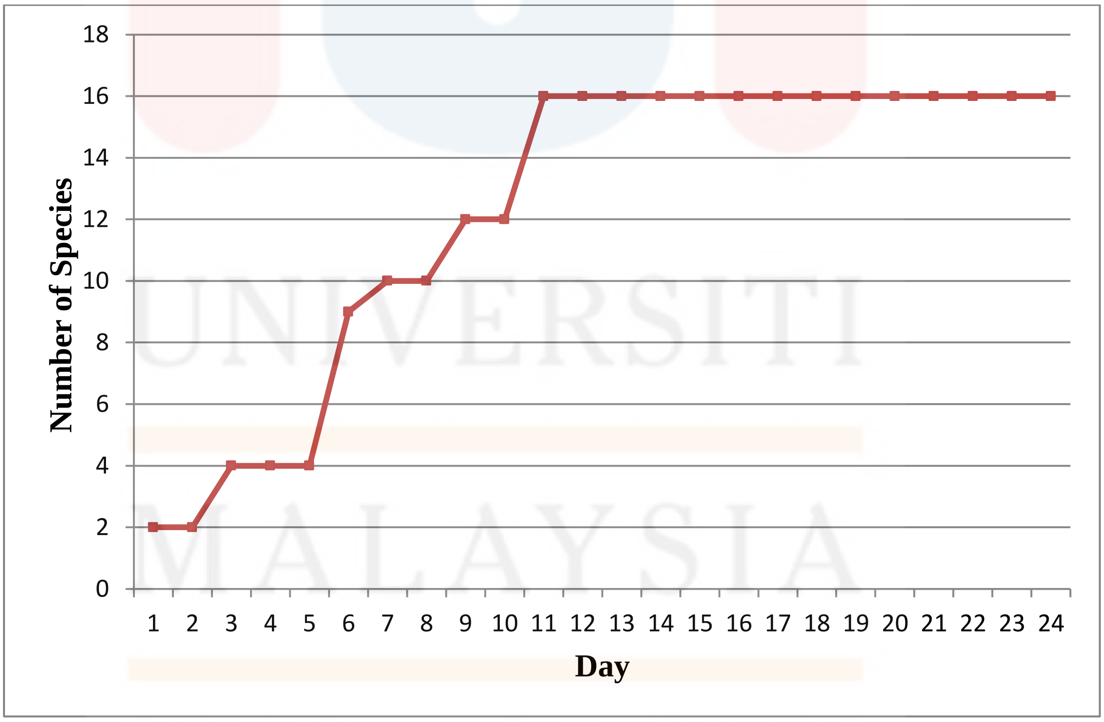


Figure 4.1: Graph of species accumulation curve of species of Coleopterans collected

Rarefaction curve also was constructed to give the general view of the number of species and the number of individuals of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. The rarefaction curve grows promptly as there are most common species of Coleopterans found. Figure 4.2 showed the rarefaction curve of the Coleopterans collected.

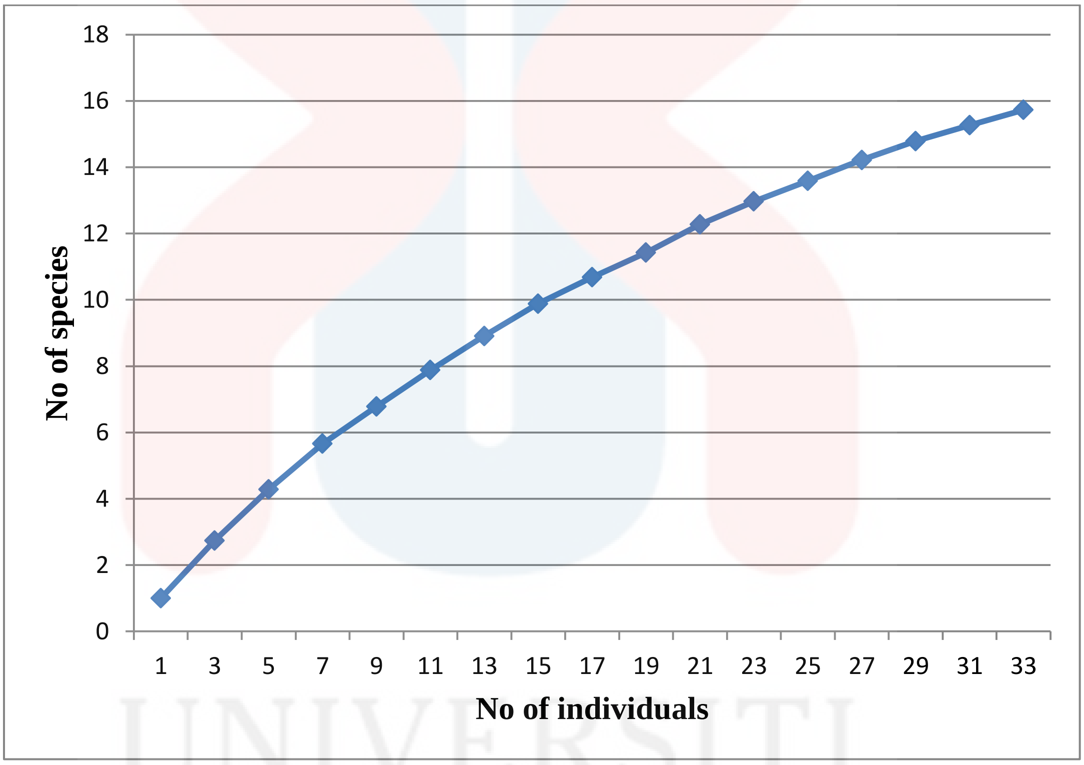


Figure 4.2: Rarefaction curve of Coleopterans collected

From Table 4.1, it has been found that family Scarabaeidae has the largest population at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland where it contains of eight species which are, *Anomala* sp. 1, *Anomala* sp. 2, *Adorefus* sp. 1, *Phyllopertha* sp., *Blitopertha* sp., *Apogonia* sp. 1, *Apogonia* sp. 2 and *Ectinohoplia* sp. The second largest population at R.E.A.C.H B.C.F is family Carabidae, where there are two species found which are *Pterostichus* sp. and *Amara* sp. There is one species that have been recognized in family Silphidae which is *Nicrophorus nepalensis*. It is also known as burying beetle. One species from family Cetoniidae was collected which is *Thaumastopeus pugnator*, known as green flower beetle. There is also one species of longhorn beetle found in family Cerambycidae which is *Sciades* sp. There is only one species of weevil beetle found in family Curculionidae which is *Telephae* sp. One species of family Colydiidae was found which is *Ascetoderes* sp. Stag beetle also was found in that area, *Macrodorcas* sp. which classified in family Lucanidae.

Table 4.1: List of Coleopterans species in R.E.A.C.H Biodiversity Centre, Forest Cameron Highland.

No.	Family	Species	Common name
1.	Carabidae	*Amara* sp.	Ground beetle
2.		*Pterostichus* sp.	
3.	Cerambycidae	*Sciades* sp.	Longhorn beetle
4.	Cetoniidae	*Thaumastopeus pugnator*	Green flower beetle
5.	Colydiidae	*Ascetoderes* sp.	Bark beetle
6.	Curculionidae	*Telephae* sp.	Weevil beetle
7.	Lucanidae	*Macrodorcas* sp.	Stag beetle
8.	Scarabaeidae	*Adorefus* sp. 1	Dung beetle
9.		*Anomala* sp. 1	
10.		*Anomala* sp. 2	
11.		*Phyllopertha* sp.	
12.		*Blitopertha* sp.	
13.		*Apogonia* sp. 1	
14.		*Apogonia* sp. 2	
15.		*Ectinohoplia* sp.	
16.	Silphidae	*Nicrophorus nepalansis*	Burrying beetle
TOTAL	8	16	

4.2 Diversity of Coleopterans

In this study, nine specimens of beetles were identified to species levels which are *Thaumastopeus pugnator* from family Cetoniidae and *Nicrophorus nepalansis* from family Silphidae. There were 29 specimens of beetles were identified to genus level only. There is only one species of Coleopterans collected which is diurnal that is *Thaumastopeus pugnator*, green flower beetle. All the species in this study are new published records of R.E.A.C.H Biodiversity Centre Forest, Cameron Highland since no study has been conducted at R.E.A.C.H B.C.F before. Besides, the collected Coleopterans species were not recorded under International Union for Conservation Nature (IUCN) Red List (IUCN Red List, 2016).

Coleopterans in family Scarabaeidae, Carabidae, Cetoniidae, Curculionidae, Cerambycidae and Silphidae are commonly found in Malaysia (Abdullah et al., 2001; Abdullah et al., 2012). The distributions of these Coleopterans families are mostly in Southeast Asia (Malaysia, Indochinese Peninsular, Philipine, and Thailand). They also can be found in Australia, Japan and China (Maeto et al., 2002; Dalgleish & Elgar, 2005; Kojima & Morimoto, 2011). The other families of Coleopterans, Lucanidae was merely found in Myanmar and Thailand which is the neighboring country to Malaysia (Nagai, 2000). They also can be found in Indochinese Peninsular and in East Asia (Taiwan, China and Japan) (Nagai, 2000). Only family Colydiidae was distributed in continent Australia, East Asia (Taiwan and Japan) and Southeast Asia (Philipines) (Pope, 1961; Fauna Europaea, 2011).

Figure 4.3 showed the number of species sampled from each family of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

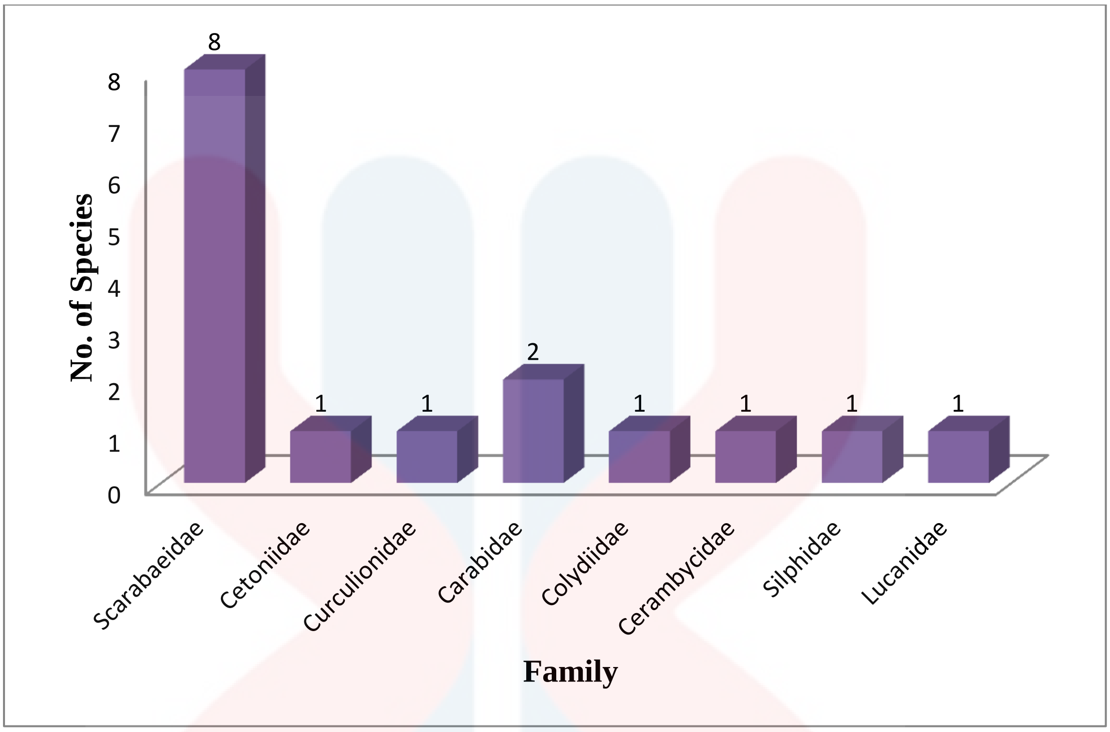


Figure 4.3: Number of Species Sampled from Each Family of Beetles sampled at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Based on Figure 4.3, the most number of species collected were from family Scarabaeidae (s=8) followed by Carabidae (s=2). The least number of species were collected from family Cetoniidae, Curculionidae, Colydiidae, Cerambycidae, Silphidae and Lucanidae which only one species collected from each of the family.

Two ecological indices were used which are Shannon-Wiener Diversity Index and Margalef's Diversity Index. Shannon-Wiener Diversity Index was used to determine the diversity of the Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. All the Coleopterans species that have been collected were counted and being calculated in the Shannon-Wiener Diversity Index (Appendix B) and the result was shown in Table 4.2.

Table 4.2: Shannon-Wiener Diversity Index

SYMBOL	RESULT
H’	2.51
H'_{MAX}	3.53

Based on the table above, the Shannon-Wiener Diversity Index (H’) value is 2.51 while value of H'_{max} is 3.53. The range of Shannon-Wiener Diversity Index (H’) should be in between 0 and H'_{max}. Through the calculation above, the value of Shannon-Wiener Diversity Index showed a high diversity of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Margalef’s Diversity Index was also used to estimate the species richness of Coleopterans in the research areas. The value of species richness was presented as in the Table 4.3 below:

Table 4.3: Margalef’s Diversity Index

SYMBOLS	RESULT
D_{Mg}	4.25

The calculated value of D_{Mg} of Coleopterans at R.E.A.C.H. Biodiversity Centre Forest, Cameron Highland is 4.25.

Using ecological indices, the diversity of beetles collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland is better presented. Significantly, result from Shannon-Wiener Diversity Index showed the diversity of the

Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland was high. The results showed a positive and successful succession of Coleopterans in a new rehabilitated forest which only aged 16 years since it is reforesting in year 2000. The insects were able to migrate and reoccupy the new ecosystem at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Table 4.4 gives the ecological indices for different families of Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. The family of Coleopterans that most diverse and high in species richness was Scarabaeidae (Shannon-Wiener Index, 0.35; Margalef's Index, 2.52) and followed by Carabidae (Shannon-Wiener Index, 0.26; Margalef's Index, 0.36).

Table 4.4: Summary of ecological indices according to beetle family at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Family	Shannon-Wiener Index	Margalef Index
Scarabaeidae	0.35	2.52
Carabidae	0.26	0.36
Cetoniidae	0.17	0
Curculionidae	0.17	0
Colydiidae	0.17	0
Cerambycidae	0.17	0
Silphidae	0.17	0
Lucanidae	0.17	0

4.2.1 Evenness of Coleopterans

The evenness of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland was calculated using Pielou's Evenness Index. The result shown in the Table 4.5 below:

Table 4.5: Pielou's Evenness Index

SYMBOL	RESULT
J'	0.71

The value of the species evenness (J') of Coleopterans at R.E.A.C.H. Biodiversity Centre Forest, Cameron Highland obtained was 0.71. Value of J' should be in the range between 0 and 1 and the much higher the value of J' is, the similar the proportion of species of Coleopterans at R.E.A.C.H B.C.F. Thus, based on the value of species evenness obtained using Pielou's Evenness Index, the Coleopterans are evenly distributed in abundance among them at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

4.3 Abundance of Coleopterans

Abundance is measured as the number of individuals found per sample (Bartelt et al., 2001). R.E.A.C.H Biodiversity Centre Forest, Cameron Highland has high diversity of Coleopterans. Unfortunately, the Coleopterans were least abundance in individuals. Figure 4.4 showed numbers of individuals of Coleopterans sampled at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland which showed the least abundance of Coleopterans.

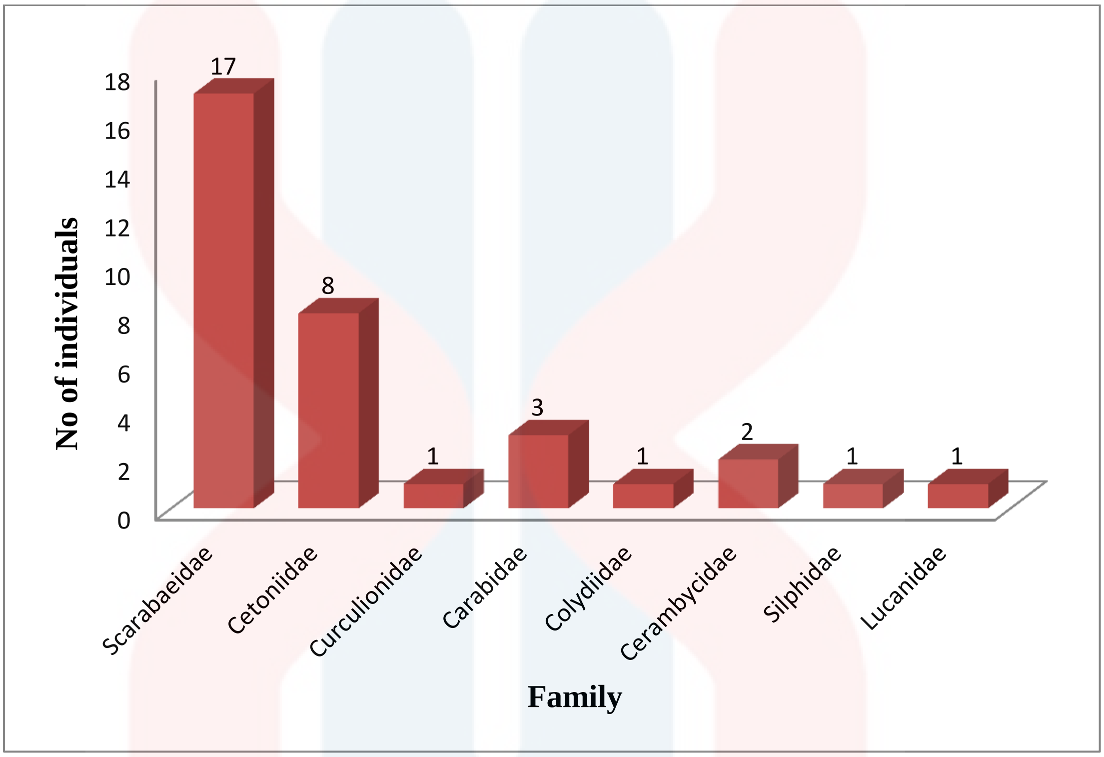


Figure 4.4: Number of Individuals of Each Family of Beetles Sampled at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Based on Figure 4.4, the most number of Coleopterans specimens collected belongs to family Scarabaeidae (n=17), followed by Cetoniidae (n=8), Carabidae (n=3) and Cerambycidae (n=2). The least number of Coleopterans specimens collected belongs to family Curculionidae, Colydiidae, Silphidae and Lucanidae with each of the family consist only one specimen.

There are several factors that may contribute in least abundance of Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. Rainfall interference during the experiment being conducted may affect the abundance of beetles in R.E.A.C.H B.C.F. William & Liebhold (2002) reported that warmer temperature and climate change may not only increase the period of flight activity and increase the number of generation per year, but also protracted the range of abundance of lower elevation beetles to higher elevation beetles. Besides, beetle scavenging season was peak in the mid-August to mid-September (Bai et al., 2008). This factor may cause a bias result in abundance of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

Cameron Highland is one of the last refugees for several of Asia's large characteristic species. Unfortunately, due to its popularity with tourist and visitors, plentiful harm has been done to the forest over the year and the mountain is still reeling from the effects of land clearing and over pollution (Abdullah et al., 2001). There are parts of Cameron Highland comprised of tea plantations, flower nurseries, vegetable farms and orchards. Human activities such as pesticides usage at the plantation may affect abundance and diversity of beetle (Abdullah et al., 2001).

4.4 Comparison with Previous Study

Apart from this research study, there is previous study on Coleopterans at Gunung Brinchang where it is the nearest location to R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. The recent study can be used to compare with Coleopterans at R.E.A.C.H Biodiversity Centre Forest in term of its diversity, species richness and their abundance. It is also to investigate whether R.E.A.C.H Biodiversity Centre Forest, Cameron Highland as it is a rehabilitated forest success or not in bringing backs the ecosystem of the Coleopterans back in the forest.

In comparison with recent study that has been done at Gunung Brinchang by Abdullah et al (2001), it is favourable to compare with R.E.A.C.H Biodiversity

Centre Forest, Cameron Highland as this study site located near Gunung Brinchang. The study found that the beetle abundance and diversity at different elevation was different at Cameron Highland. R.E.A.C.H Biodiversity Centre Forest, Cameron Highland which is located on the edge of Gunung Brinchang has elevation of 1781 metres above sea level while elevation of Gunung Brinchang is 2032 metres above sea level (Abdullah et al., 2001). Thus, Gunung Brinchang which has higher elevation showed high abundance and species richness of Coleopterans where 73 of beetle specimens collected comprised of 54 species from 15 different families (Abdullah et al., 2001) while species of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland that managed to be sampled only contains of 34 beetles comprised of 16 species from 8 families.

From perspective of ecological indices calculation, the value of Shannon-Wiener Index of Coleopterans collected at Gunung Brinchang was 3.81 and the value of Margalef Index was 12.35 (Abdullah et al., 2001) while the values of Shannon-Wiener Index and Margalef's Diversity Index of R.E.A.C.H Biodiversity Centre Forest, Cameron Highland were 2.51 and 4.25 respectively. The greatest difference in both values of Shannon-Wiener Diversity Index and Margalef's Diversity Index showed that Gunung Brinchang has the most diverse and abundance in species richness of Coleopterans. Nevertheless, factor such as size of areas for both of Gunung Brinchang and R.E.A.C.H Biodiversity Centre Forest should be taken into account as both areas have different sizes. As for R.E.A.C.H Biodiversity Centre Forest which has smaller area compared to Gunung Brinchang, thus the value for diversity of Coleopterans at R.E.A.C.H B.C.F showed rather high result for Coleopterans collected there. Since R.E.A.C.H Biodiversity Centre Forest was a rehabilitation forest, it is natural that the number of beetles found is less than the number of beetles found in primary forest. This is because they are influenced by habitat changes, synergistic effect of forest modification and fragmentation.

Previously, Coleopterans loss their habitat in the original forest at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland due to deforestation for agricultural activities and Coleopterans in that site were declined in numbers decades ago. After the biodiversity centre was reforest back, the Coleopterans were starting to increase in numbers as they migrate into the forest and adapt to the new surroundings ecosystem. This explains why the beetles specimens collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland were less than beetles collected at Gunung Brinchang.

This result may happen due to several factors such as the forest modification, elevation of their habitat, habitat changes and environmental changes. The alteration of natural landscape by humans is the main cause of global biodiversity loss through all major taxonomy groups (Coleman & Hendrix, 2000). The higher diversity and abundance values were related with the highest habitat diversity, with more abundant of ecological functions supporting insect development and their trophic desires. Cultivated landscapes are vastly diverse and provide numerous kinds of habitats suitable for a countless number of species (Jeanner et al., 2003).

Different gradations of environmental changes had varying effects on the beetle species richness and abundance such as number of leaf litter, plant species, ground cover and soil pH (Chung et al., 2000). Leaf litter associated with abundance, species richness and composition of underground beetles. Plant species richness, tree and sapling densities interconnected with abundance and species richness of understory beetles while ground cover interrelated only with the species richness and abundance of these beetles (underground & understory beetle). Canopy covers associated only with arboreal beetles (Chung et al., 2000). The Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland were mostly underground and understory beetle such as Scarabaeidae, Carabidae, Cerambycidae and Lucanidae.

R.E.AC.H Biodiveristy Centre Forest, Cameron Highland is the rehabilitation forest aged 16 years after the forest has been cleared for agriculture purpose. The endemic species of plants such as Gerok, *Eugenia*, Rhododendrons and *Nepenthes* were replanted in the forest to attract back all the animals include insects and create a new environmental ecosystem. Assemblage distribution of Coleopterans was mainly influenced by the position of sites, aged of ecosystem and spatial heterogeneity.

However, the various ecosystems in Gunung Brinchang and R.E.A.C.H Biodiversity Centre Forest, Cameron Highland may have some families and species in common. These similarities may be due to the species of beetles that favour disturbed habitats were advance compounded by the capability to fly and therefore migrate to neighbouring habitats in search for shelter, foods and mates (Coleman & Hendrix, 2000). For example, there are four similar families of Coleopterans found at both sites which are Scarabaeidae, Carabidae, Cerambycidae and Curculionidae. Significantly, R.E.A.C.H Biodiversity Centre Forest, Cameron Highland managed to attract some of the Coleopterans species in the neighbouring areas and create a new environmentally ecosystem for the Coleopterans.

4.5 Identification Key of Coleopterans

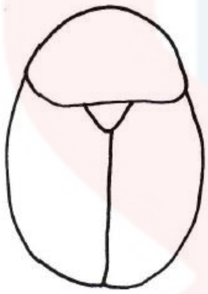
All the species of Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland were identified using ‘An Introduction to The Study of Insects’ by Borror & DeLong (1971). This key was constructed as no pictorial key available for beetle of Cameron Highland as can be seen in journal of Beetle Fauna of Cameron Highland Montane Forest by Abdullah et al. (2001). Key to families and genera levels of Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, were constructed. For Scarabaeidae and Carabidae, the key was constructed to genus level as other families of Coleopterans collected at R.E.A.C.H B.C.F consist only one genera per family. The pictures of morphological characteristics of Coleopterans were modified and redrawn manually using 0.8 Artline Drawing System pen.

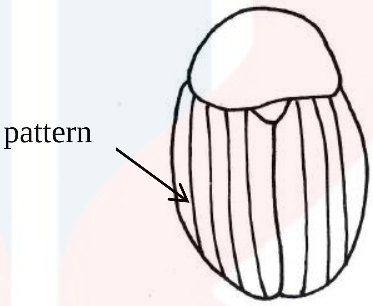
Common and visible morphological characteristics were used to differentiate all the Coleopterans collected at R.E.A.C.H B.C.F, therefore is used to construct pictorial identification key. Characters that are being used are body shape and size, head, antenna, mouth, scutellum and pattern on elytra. Current available identification key (Borror & DeLong, 1971) which used specific and more detail characteristics to identify the Coleopterans were used as a guide in the construction of this pictorial identification key. The pictorial identification key was constructed based on common characteristic that can be easily observed on Coleopterans collected at R.E.A.C.H Biodiversity Centre. Thus it can be easily recognized and identified by common people at Cameron Highland and this pictorial identification key will be helpful for future studies.

4.5.1 Key to Families Level of Coleopterans

1. a) The elytra have a smooth surface and does not have emerging pattern (i)…….. 2

b) The elytra have a rough surface and have an emerging pattern (ii)……….….. 5

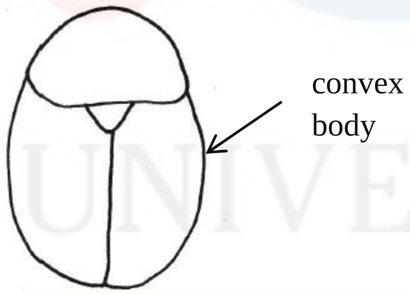


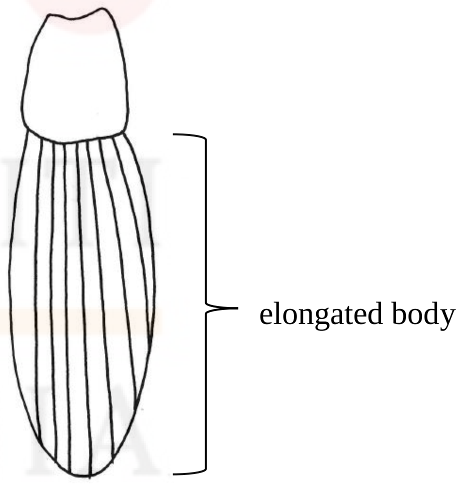


(i) (ii)

2. a) Body size is convex (i)…………………………………….….. Scarabaeidae

b) Body size is elongated (ii)…………………………………………………..3



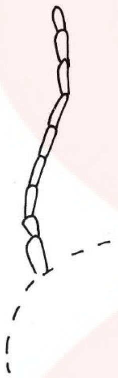


(i) (ii)

3. a) The antenna not clubbed and most species are shiny dark in color (i)..................

……………………………………………………………………….. Carabidae

b) The antenna is clubbed and it usually has bright colors (ii)………………..….. 4



(i)

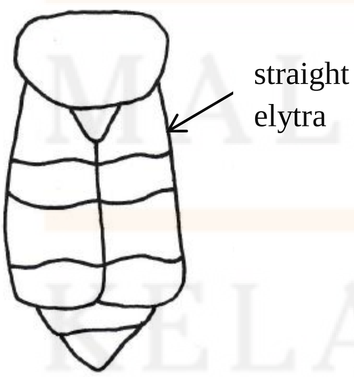
(ii)

4. a) The elytra is straight along the body and the color is orange-black (i)…………...

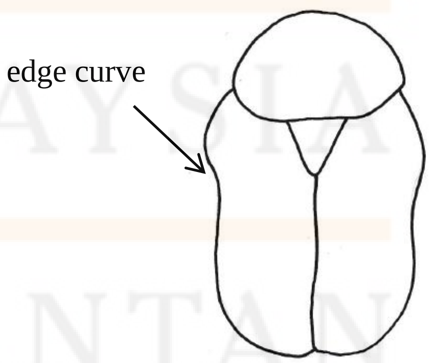
………………………………………………………………………… Silphidae

b) The elytra is curve at the edge of the body and the color is green (ii)…………...

……………………………………………………………………….. Cetoniidae



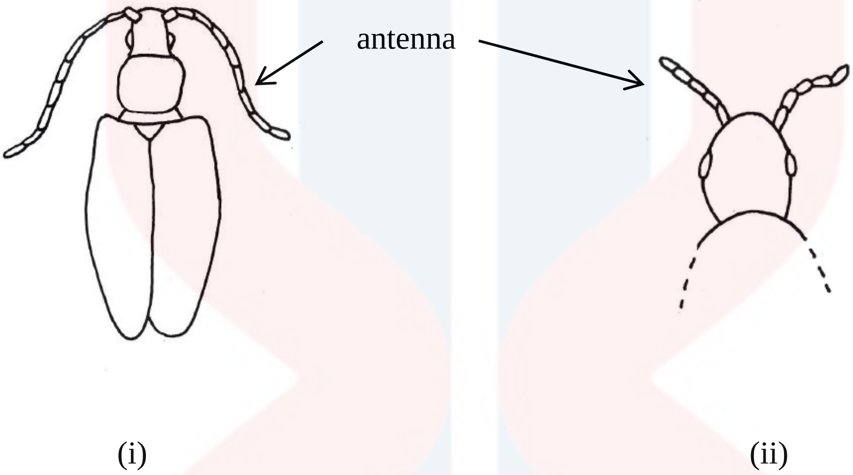
(i)



(ii)

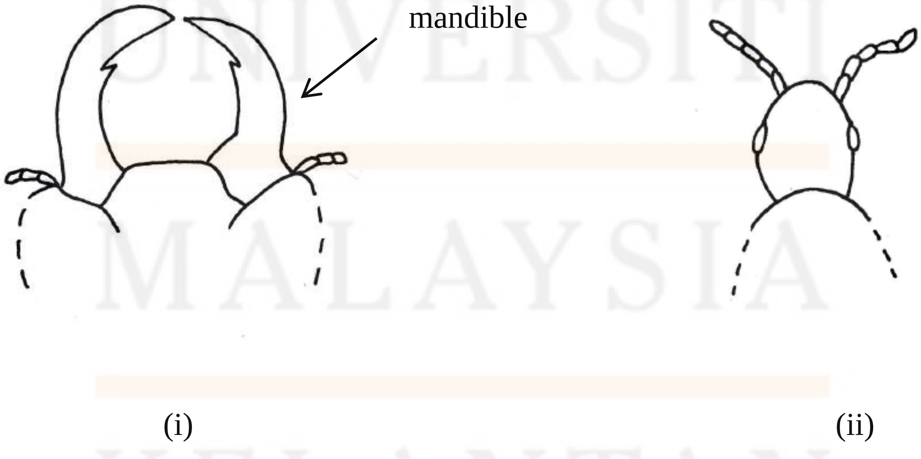
5. a) Antenna usually longer than one half length of body (i)……..….. Cerambycidae

b) Antenna is short than the body size (ii)……………………………………..….. 6



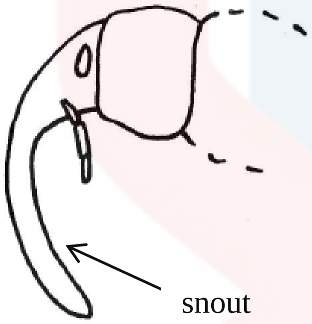
6. a) It has mandible like the antlers of the stag (i)………………………..….. Lucanidae

b) It does not have mandible (ii)………………………………………………….. 7



7. a) The head is more or less prolonged forward into snout (i)…………….. Lucanidae

b) The head absence of snout (ii)…………………………………...….. Colydiidae



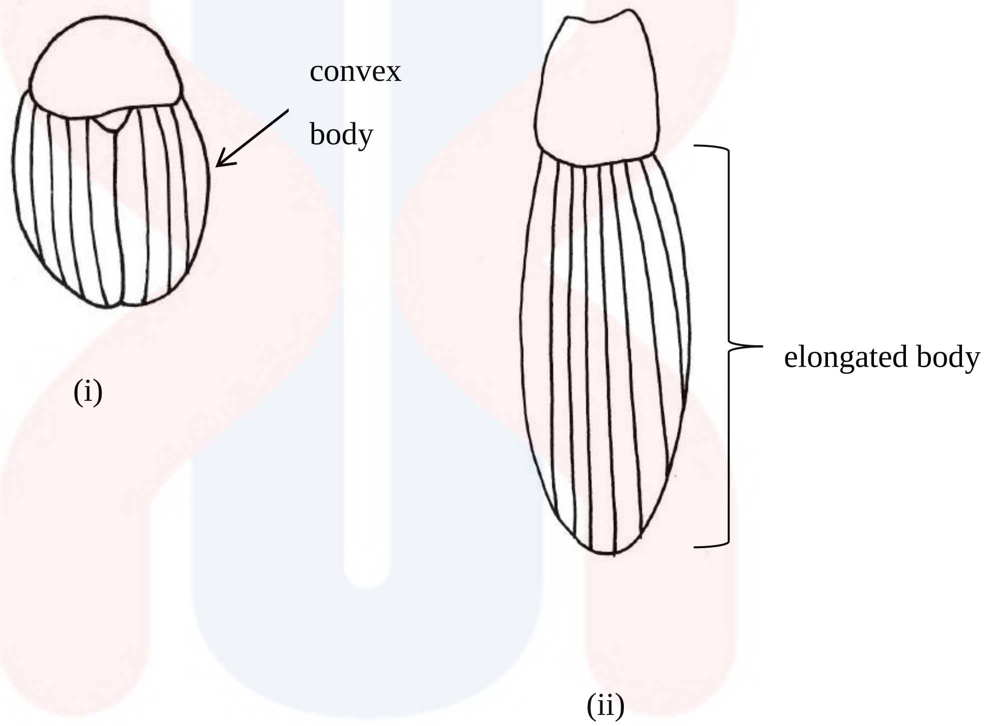
(i)

(ii)

4.5.2 Key to Genus of Family Carabidae

1. a) It has convex body size (i)……………………………………………….. *Amara*

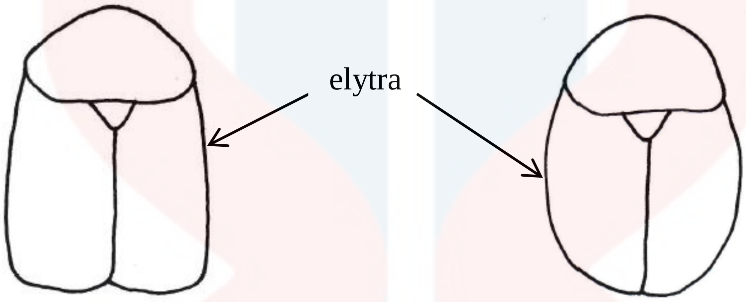
b) It has elongated body size (ii)…………………………………….….. *Pterostichus*



4.5.3 Key to Genus of Family Scarabidae

1. a) It has square shape elytra and rough surface (i)……………….…….. *Ectinohoplia*

b) It has oval shape elytra and smooth surface (ii)……………………………….. 2



(i) (ii)

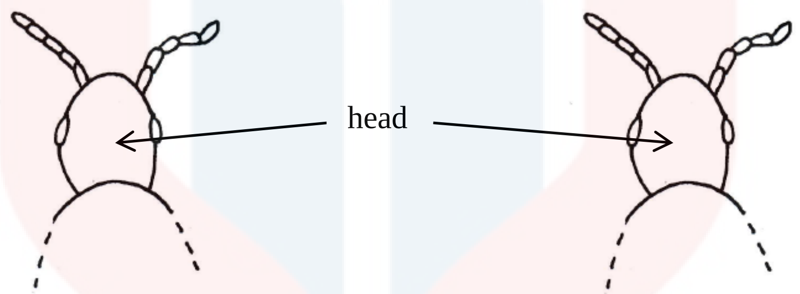
2. a) Pronotum and elytra have black spots (i)……………………..…….. *Blitopertha*

b) Pronotum and elytra do not have black spots (ii)…………………………..….. 3

(i) (ii)

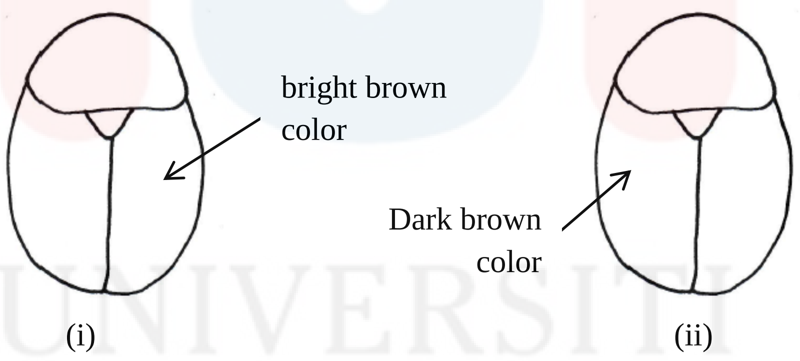
3 a) The head colour is dark green (i)…………..…………..…………. *Phyllopertha*

b) The head is absent of dark green colour (ii)……………………………………. 4



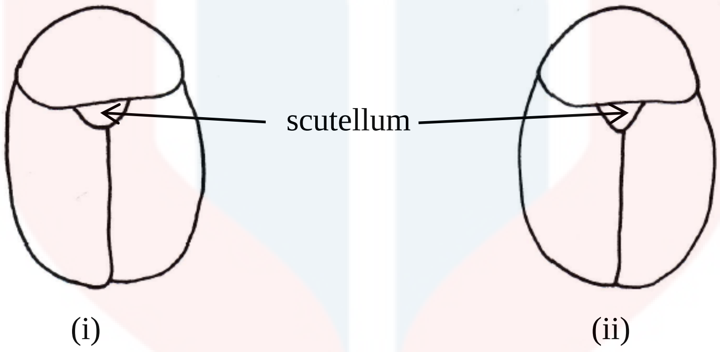
4 a) The body color is bright brown (i)……………..………………………. *Adorefus*

b) The body color is dark brown and dull (ii)……….……………………………. 4



5 a) The scutellum shape is roundish (i)……………...………...…………… *Anomala*

b) The scutellum shape is triangle (ii)………..………………………….. *Apogonia*



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A total of 34 specimens of Coleopterans comprising 16 species from eight families were assembled in this study. R.E.A.C.H Biodiversity Centre Forest, Cameron Highland which is a rehabilitated forest was managed to attract back Coleopterans diversity to the forest and some common Coleopterans from neighbouring area, Gunung Brinchang also can be found at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland. This shows that reforestation at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland was a success.

5.2 Recommendations

Further study of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland should have entails a combination of different type of trapping methods on sampling Coleopterans because restraint of a type of traps will compliment other type of traps. This combination of trapping method will ensure a better estimation of abundance, diversity and species richness of Coleopterans in different land use type (Dagobert et al., 2010). Furthermore, the future research should be conducted with detail physical parameter reading, location and altitude. Noyes (1989) reported that in tropical lowland areas, insects was greater in number at elevation of 1300 m to 1700 m as compared lower and high elevation. Besides, the future studies should be conducted during wet and dry season as to compare the diversity and abundance of Coleopterans at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

REFERENCES

Abdullah, F., Shamsulaman, K., Isa, S. M., & Sina, I. (2001). Beetle Fauna Of Cameron Highland Montane Forest. *Siri Kepelbagaian Biologi Hutan*, Jabatan Perhutanan Semenanjung Malaysia. 244-256.

Abdullah, F., Sina, I., & M. Sabri, M. S. (2012). Diversity of Beetles (Coleoptera) at Gunung Benom, Pahang, Malaysia. *The Asian International Journal of Life Sciences.* Asia Life Science. 265-285.

Arnett R. H. Jr. (1973). Beetles of the U.S.A. Manual for identification, American Entomological Institute, *Ann Arbar MI*. 11-12.

Bai Y., Wu J., Xing Q., Pan Q., Huang J., Yang D. & Han X. (2008). Primary production and rain use efficiency across a precipitation gradient on the Mongolia Plateau. *Ecology.* 89(8):2140-53.

Baldi, A. (1999). Biodiversity in Hungary: advantages and limits of taxonomically complete faunal inventories. *Natural Areas Journal 19*, 73-78.

Barr, A. R. (1963). Evaluation of some factors affecting the efficiency of light traps in collecting mosquitoes. *Journal Economy Entomology. 56*:123-127.

Bartelt, G. A., Rolley, R. E., Vine, L. E. (2001). Evaluation of abundance indices for striped skunks, common raccoons and Virginia opossums in southern Wisconsin. Madison, Wisconsin: Wisconsin Dept. of Natural Resources, Bureau of Integrated Science Services. Retrieved 2006-12-15.

Benisch & Christoph. (2007). Beetle of Morphology. Retrieved April 18, 2016, from http://www.kerbtier.de/Pages/Themenseiten/enKoerperbau.html.

Benisch & Christoph. (2010). "Phylogeny of the beetles". Retrieved February 18, 2016, from The beetle fauna of Germany.

Bland, R. G., & Jaques, H. E. (2010). *How to Know The Insects,3rd ed.* Germany.

Borror, D. J., & DeLong, D. M. (1971). *An* Introduction *to The Study of Insects*. 3rd ed. Holt, Rinehart and Winston. New York.

Bouchard, P., Bousquet, Y., Davies, A., AlonsoZarazaga, M., Lawrence, J., Lyal, C., Newton, A., Reid, C., Schmitt, M., Ślipiński, A., & Smith, A. (2011). "Familygroup names in Coleoptera (Insecta)". *ZooKeys* 88: 1– 972.

Briggs, J., B. (1971). A comparison of pitfall trapping and soil sampling in assessing populations of two species of ground beetles (Col.: Carabidae). *Rep. E. Mailing Res. Stn.* 1970:108-112.

Carpenter & Herbert, G. (1899). *Insects: their structure and life*. Harvard University: J.M. Dent. pp.1-404.

Cheng, S., & Laurence, G. K. (2007). Overview of Insect Biodiversity Research in Peninsular Malaysia. *Status of Biological Diversity in Malaysia & Threat Assessment of Plant Species in Malaysia.* 121-128.

Choate, P. M. (1999). The Identification of Beetles (Coleoptera). *Dichotomous Keys to Some Families of Florida Coleoptera*. pp.23-32.

Choate, A., Colwell, R. K., Lin, C., & Gotelli, N. J. (2009). Sufficient sampling for asymptotic minimum species richness estimators. *Ecological of America*. 1125-1133.

Chung, A. Y., Eggleton, P., Speight, M. R, Hammond, P. M, & Chey, V. K. (2000). The diversity of beetle assemblages in different habitat types in Sabah, Malaysia. *Bulletin of Entomological Research.* Cambridge University Press 90(6):475-496.

Chung, A.Y.C. (2005). An overview of beetle diversity and taxonomy research in Malaysia. Paper presented at the Seminar on the Status of Biological Diversity in Malaysia, at FRIM, Kepong. 28-30 June, 2005.

Clark, W., H. & Blom P., E. (1992). An efficient and inexpensive pitfall trap system. *Entomology News 103(2)*:55-59.

Coleman, D. C., & Hendrix, P. F. (2000). *Invertebrates as Webmasters in Ecosystem*. CABI Publishing, Wallingford.

Crowson, R. A. (1956). *Coleoptera Introduction and Keys to Families.* London: Society and Sold.

Dagobert, K. K., Klimaszewski, J., Mamadou, D., Daouda, A., & Mamadou. D. (2008). Comparing Beetle Abundance and Diversity Values along a Land Use Gradient in Tropical Africa (Oumé, Ivory Coast). Retrieved March 22, 2016, from http://zoolstud.sinica.edu.tw/Journals/47.4/xxx.pdf.

Dagobert, K. K., Mamadou, D., & Klimaszewski, J. (2010). Assessment of Beetle Abundance and Diversity by Four Methods of Capture in the West-central part of Oume, Ivory Coast. *Journal of Animal and Plant Species* 6: 579-588.

Dalgleish, E. A. & Elgar, M. A. (2005). Breeding ecology of the rainforest dung beetle Cephalodesmius armiger (Scarabaeidae) in Tooloom National Park. *Australian Journal of Zoology* 53(2) 95-102.

De Souza & Roy, E. (2010). SOLVED! The "Mysterious". *Disappearance of Jim Thompson, the Legendary Thai Silk King (2nd ed).* Word Association Publishers. p. 19. ISBN 9781595715050. LCCN 2009944204.

Fauna Europaea (2011): Colydiinae. Version 2.4, 2011-JAN-24. Retrieved November 29, 2016 from www.faunaeur.org/.

Foottit, G. R. & Adler, P. H. (2009). Insect biodiversity: science and society. John Wiley and Sons.

Gillott, C. (1995). In *Entomology (2 ed.)* (p. 96). Verlag New York, LCC: Springer.

Gotelli, N. J. & Colwell, R. K. (2001). “Quatifying Biodiversity:Procedures and pitfalls in the measurement and comparison of species richness”. *Ecology Letters 4 (4):*379-391.

Granger, C., A. (1970). Trap design and color as factor in trapping the salt marsh greenhead fly. *Journal Economy Entomology. 63:*1670-1672.

Hagedorn, G. (2007). Structuring Descriptive Data of Organisms. *Requirement Analysis and Information Models*. Ph. D. Thesis, Universität Bayreuth.

Hagedorn, G., Rambold, G., & Martellos, S. (2010). Types of identification keys. *In Tools for Identifying Biodiversity: Progress and Problems* (pp. 59-64). P. L. Nimis and B. Press.

Hammond, P. (1992). "Species inventory". *In Global Biodiversity, Status of the Earth's Living Resources: a Report (1st ed.)* (pp. 17-39). London: Chapman & Hall.

Holland J. M. (2002). *The agroecology of carabid beetles*. Andover, UK: Intercept Limited.

IUCN Red List. (2016). Retrived November 29, 2016 from http://www.iucnredlist.org/.

Ivie, & Michael A. (2002). Ross H. Arnett & Michael Charles Thomas, ed. *American Beetles: Polyphaga: Scarabaeoidea through Curculionoidea*. American Beetles 2. CRC Press. ISBN 9780849309540.

Jeanner, P. H., Schupbach, B., & Luka, H. (2003). Quantifying the impact of landscape and habitat features on biodiversity in cultivated landscapes. *Agriculture Ecosystem Environment.* 98: 311-320.

Key to Families of Coleoptera. (n.d.). Retrieved April 18, 2016, from http://www.zoology.ubc.ca/bcbeetles/Text%20files/coleoptera%20keys.html.

Kojima, H & Morimoto, K. (2011). Curculionine weevils of the genus Ergania Pascoe (Coleoptera, Curculionidae) from Thailand. *Japanese Journal of Systematic Entomology* 17: 105-107.

Kromp, B. (1999). "Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation aspects and enhancement". *Agriculture, Ecosystems and Environment 74 (1–3)*, 187-228.

La Salle, J., & Gauld, I. D. (1993). *Hymenoptera and Biodiversity*. C.A.B International, pp: 384.

Lane, J. (1965). The preservation and mounting of insects of medical importance. WHO/Vector Control 152.65, pp.27. Mimeographed.

Lundie, A. (1940). The small hive beetle Aethina tumida. *Science Bulletin 220.* Pretoria, South Africa: Department of Agriculture and Forestry, Government Printer.

Maeto, K., Sato, S. & Miyata, H. (2002). Species diversity of longicorn beetles in humid warm-temperate forests: the impact of forest management practices on old-growth forest species in southwestern Japan. *Biodiversity and Conservation* 11: 1919. doi:10.1023/A:1020849012649.

Magura, T., Elek, Z., & Tóthmérész, B. (2002). Impacts of non-native spruce reforestation on ground beetles. *In European Journal of Soil Biology*. Volume 38, Issues 3-4 (pp. 291-295). Éditions scientifiques et médicales Elsevier SAS.

Magurran, A. E. (2004). *Measuring Biological Diversity*. Oxford: Blackwell Publishing. ISBN 0-632-05633-9.

Magurran, A. E. & McGill, B. J. (2011). *Biological Diversity*. New York: Oxford University Press Inc.

Margalef, R. (1951). Role des entomostraces dans la régéneration des phosphates. *Verh. Internat. Verein. Limnol*. 11: 246-247.

Meyer, J. R. (2009). *ENT 425 General Entomology Resource Library Compendium [coleoptera]*. Retrieved February 18, 2016, from https://www.cals.ncsu.edu/course/ent425/library/compendium/coleoptera.html.

Moore, & Khadijah, W. (2004). Malaysia: A Pictorial History 1400–2004. Archipelago Press. p. 182. ISBN 981-4068-77-2.

Mulder, C. P. H., Bazeley-White, E., Dimitrakopoulos, P. G., Hector, A., Scherer-Lorenzon, M., & Schmid, B. (2004). "Species evenness and productivity in experimental plant communities".*Oikos* 107: 50-63.

Nagai, S. (2000). Notes on some SE Asian stag-beetle (Coleoptera, Lucanidae) with description of several new taxa. *Gekkan-Mushi* 356:2-9.

Nentwig, W. (2007) *Biological invasions*. Springer Verlag; Berlin, Germany.

Neumann, P., & Ellis, J. (2008). The small hive beetle (Aethina tumida Murray, Coleoptera: Nitidulidae): distribution, biology and control of an invasive species. *Journal of Apicultural Research 47(3)*, 180-183.

Nielsen, E., & West, J. (1994). Biodiversity research and biological collections: transfer of information. *In Forey PL, Humphries CJ, Vane-Wright RI (eds) Systematics and conservation evaluation* (pp. 101-120). Oxford: Clarendon Press.

Noyes, J. S. (1989). A study of five methods of sampling Hymenoptera in a tropical rainforest with special reference to the Parasitica. *Journal Natural History*. 13: 285-298.

Ramamurthy, V. V., Akhtar, M. S., Patankar, N., Menon, P., Kumar, R., & Singh, S. K. (2010) Efficiency of different light sources in light traps in monitoring insect diversity. *Entomology Zoology 2010; 5(1)*:109-114.

Pankhurst, R. J., (1991). *Practical Taxonomic Computing*. Cambridge,UK: Cambridge University Press.

Pope. (1961). Insectoid.Info. Retrieved November 2, 2016, from http://insectoid.info/insecta/coleoptera/.

Ratcliffe, B. C. 1991. The Passalidae and Lucanidae (Insecta: Coleoptera) of Nebraska. Great Plains Research 1: 249–282.

Regional Environmental Awareness Cameron Highland, (R.E.A.C.H). (2016). Retrieved Friday 20, 2016 from http://reach.org.my/2014/?cat=29.

Remo, & Amy, R. (2007). Beetles infest coconuts in Manila, 26 provinces. *Philippine Daily Inquirer*.

Rosenzweig, M. (1995). *Species Diversity in Space and Time*. Cambridge: Cambridge University Press.

Rodrigo, & Jennifer (1996). *Malaysia: The Beautiful*. New Holland (Publishers) Ltd. p. 19. ISBN 1853687448.

Sanders, H. L. (1968). Marine Benthic Diversity: A Comparative Study. *American Naturalist 102*:243-282.

Scudder, Geoffrey G. E, Cannings, & Robert A, (2005)**.** Project Report; Beetle Families of British Columbia, Project Number: Y051001). Forest Investment Account (FIA) - Forest Science Program.

Shannon, C. E., & Weaver, W. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, 27, 379–423 and 623–656.

Steiner, A., & Hauser, C. L. (1991). Recording insects by light-traps. pp.400-422.

Stork, N. (1994). Inventories of biodiversity: more than a question of number. *In: Forey PL, Humphries CJ, Vane-Wright RI (eds) Systematic and conservation evaluation* (pp. 81-100). Oxford: Clarendon Press.

Tindale, N. B. (1962). The chlorocresol method for field collecting. *Journal Lepidoptera Society*. 15:195-197.

Triplehorn C. A, & Johnson N. F. (2004). *Borror and Delong's introduction to the study of insects.* Belmont, CA: Thomson Brooks/Cole.

Werner S. M, & Raffa K. F. (2000). Effects of forest management practices on the diversity of ground-occurring beetles in mixed northern hardwood forests of the Great Lakes Region. *Forest Ecology and Management* 139:135e155.

William, D. W. & Liebhold, A. M. (2002). Climate change and the outbreak of two North American bark beetle. *Agricultural Forest Entomology*. 4: 87-99.

William, K. K., Mcmillin, J. D., DeGomez, T. E., Clancy, K. M. & Miller, A. (2008). Influence of elevation on bark beetle (Coleoptera: Scolytidae) community structure and flight periodicity in ponderosa forest of Arizona. *Environmental Entomology*. 37(1): 94-109.

Winston, J. (1999) *Describing Species*. New York: Columbia University Press.

APPENDIX A

This is the list figures of Coleopterans collected at R.E.A.C.H Biodiversity Centre Forest, Cameron Highland.

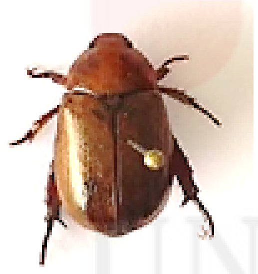
Family: Scarabaeidae

Species: *Adorefus* sp. 1

Family: Scarabaeidae

Species: *Anomala* sp. 1

Common name: Shining leaf chafer



Family: Scarabaeidae

Species: *Anomala* sp. 2

Common name: Shining leaf chafer

Family: Scarabaeidae

Species: *Phyllopertha* sp.

Family: Scarabaeidae

Species: *Blitopertha* sp.

Family: Scarabaeidae

Species: *Apogonia* sp. 1

Family: Scarabaeidae

Species: *Apogonia* sp. 2

Family: Scarabaeidae

Species: *Ectinohoplia* sp.

Common name: Monkey beetle

Family: Cetoniidae

Species: *Thaumastopeus pugnator*

Common name: Green flower beetle

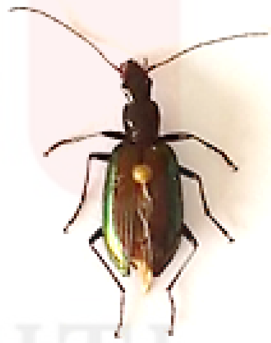
Family: Curculionidae

Species: *Telephae* sp.

Common name: Weevil bettle

Family: Carabidae

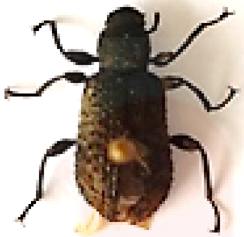
Species: *Amara* sp.



Family: Carabidae

Species: *Pterostichus* sp.

Common name: Ground beetle



Family: Colydiidae

Species: *Ascetoderes* sp.

Family: Cerambycidae

Species: *Sciades* sp.

Common name: Longhorn beetle

Family: Silphidae

Species: *Nicrophorus nepalansis*

Common name: Burrying beetle

Family: Lucanidae

Species: *Macrodorcas* sp.

Common name: Stag beetle

APPENDIX B

Table 1: Shannon-Wiener Diversity Index calculation table

Species	n_i	n_i/N	$\ln(n_i/N)$	$(n_i/N)\ln(n_i/N)$
Adorefus sp. 1	4	0.1176	-2.1405	-0.2517
Anomala sp. 1	4	0.1176	-2.1405	-0.2517
Anomala sp. 2	2	0.0588	-2.8336	-0.1666
Phyllopertha sp.	2	0.0588	-2.8336	-0.1666
Blitopertha sp.	1	0.0294	-3.5268	-0.1037
Apogonia sp. 1	1	0.0294	-3.5268	-0.1037
Apogonia sp. 2	2	0.0588	-2.8336	-0.1666
Ectinohoplia sp.	1	0.0294	-3.5268	-0.1037
Thaumastopeus pugnator	8	0.2353	-1.4469	-0.3405
Telephae sp.	1	0.0294	-3.5268	-0.1037
Amara sp.	1	0.0294	-3.5268	-0.1037
Pterostichus sp.	2	0.0588	-2.8336	-0.1666
Ascetoderes sp.	1	0.0294	-3.5268	-0.1037
Sciades sp.	2	0.0588	-2.8336	-0.1666
Nicrophorus nepalensis	1	0.0294	-3.5268	-0.1037
Macrodorcas sp.	1	0.0294	-3.5268	-0.1037
TOTAL(N)	34			-2.5065