DIVERSITY OF COCKROACH (ORDER: BLATTODEA) AT HUTAN LIPUR BUKIT BAKAR, MACHANG, KELANTAN

by

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DECLARATION

I declare that this thesis entitled "Diversity of Cockroach (Order: Blattodea) at Hutan Lipur Bukit Bakar, Machang, Kelantan" 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.

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APPROVAL

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Natural Resources Science) with Honors"

Signature :

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Diversity of Cockroach (Order: Blattodea) at Hutan Lipur Bukit Bakar, Machang, Kelantan

ABSTRACT

Hutan Lipur, Bukit Bakar is conserved under Kelantan Forestry Department since 1975 and was opened as a recreational area for local people in Machang Kelantan with some facilities like playground, public toilet and resting hut. A study of forest cockroach was conducted at Hutan Lipur Bukit Bakar located in Machang, Kelantan from July to August 2018 with the objective to determine the diversity of forest cockroach in that study area. The method applied in cockroach sampling was light trap, baited trap, pitfall trap, and manual collection. Faunal sampling was conducted for 21 days in Hutan Lipur Bukit Bakar. A total of 60 individual of cockroach consists of 12 species belonging to three families which are Blaberidae, Blattelidae and Blattidae. Families Blaberidae (seven species), Blattellidae (three species) and lastly Blattidae (two species) were identified in this study. The most dominant families with the highest species recorded are Blaberidae. The overall Shannon-Wiener Diversity Index (H') values for 21 days of sampling are 2.13 that indicate, this value had achieved stable environment condition while H'_{max} is 2.48, Pielou's Evenness Index is 0.86 and Margalef Index is 85.84. The value of H', J and D_{mg} indices show that Hutan Lipur Bukit Bakar has a moderately large diversity of cockroach species with uniform distribution. Cockroach plays a crucial role as leaf decomposers in this study area. Further studies regarding the diversity of cockroach in Malaysia should be studied extensively.

Kepelbagaian Lipas (Order: Blattodea) di Hutan Lipur Bukit Bakar, Machang, Kelantan

ABSTRAK

Hutan Lipur Bukit Bakar dipelihara di bawah Jabatan Perhutanan Negeri Kelantan dari tahun 1975 dan dibuka sebagai kawasan rekreasi untuk penduduk tempatan di Machang Kelantan. Beberapa kemudahan disediakan seperti taman permainan, tandas awam dan pondok istirehat. Kajian terhadap lipas hutan dijalankan di Hutan Lipur Bukit Bakar yang terletak di Machang, Kelantan bermula dari Julai sehingga Ogos 2018. Objektif kajian ini adalah untuk menentukan kepelbagaian lipas hutan di Hutan Lipur Bukit Bakar. Kaedah yang digunakan dalam menjalankan persampelan lipas hutan adalah dengan menggunakan perangkap cahaya, perangkap umpan, perangkap pitfall dan koleksi secara manual. Persampelan lipas hutan dijalankan selama 21 hari di Hutan Lipur Bukit Bakar. Sebanyak 60 individu lipas terdiri daripada 12 spesies daripada tiga famili iaitu Blaberidae (tujuh spesies), Blattellidae (tiga spesies) dan Blattidae (dua spesies). Blaberidae merupakan spesies dominan dengan spesies paling tinggi yang telah dicatatkan. Secara keseluruhannya, nilai indeks Shannon-Wiener (H') bagi 21 hari persampelan ialah 2.13 menandakan keadaan persekitaran yang stabil manakala H'_{max} ialah 2.48, indeks Pielou's Evenness (J) ialah 0.86 dan indeks Margalef (D_{mg}) ialah 85.84. Nilai H', J dan D_{mg} yang tinggi menunjukkan bahawa Hutan Lipur Bukit Bakar mempunyai kepelbagaian sederhana besar spesies lipas dengan taburan yang seragam. Lipas memainkan peranan penting sebagai pengurai daun di kawasan kajian. Oleh itu, kajian lanjut, mengenai kepelbagaian lipas hutan di Malaysia perlulah dikaji dengan lebih meluas.

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LIST OF SYMBOLS

° - Deg

D_{mg} - Margalef Index

S - Southree

N - North

J' - Pielous's Evenness

H' - Shannon-Wiener Index

M - Meter

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The term 'insects' is well known as a vast group of animals with wide variation in structure and behavior that belongs to over 30 different orders. Besides, insects have three pairs of legs in some point of their life-cycle, although some of the insects missing, reduced or altered in their morphological structure (Gibbons, 1995). Other than that, insects are characterized by their feature which is hard, jointed exoskeleton and arthropods that are common are the segmental plans. Exoskeletons are formed by the cuticle (external surface of the insect that completely covered by extracellular layer), consists series of hard plates and the sclerites (component section of exoskeleton) joined to each other with the flexible membrane which also cuticular and covered the whole body (Chapman, 1998).

Gibbons (2011) described that three main parts of the insect's body are head, thorax, and abdomen. Some various basic part of the insect's segment may be greatly modified or lost (Chapman, 1998). Furthermore, the insect is also classified as a successful animal and can affect many aspects of human life. The simple and unifying body plan has become modified and adapted to produce a variety of species. Generally, insects basically exploit terrestrial and freshwater environment on this earth. The "success" of insects can be measured by their long-term persistence and stability of their basic patterns (Foottit & Adler, 2009).

The cockroach was the first group of flying insects that have been on earth for almost 400 million of years. Within the class Insecta, the cockroach belongs to superorder Dictyoptera and the order Blattodea (Barnard & Royal Entomological Society of London., 2011). The cockroach is known as a cursorial insect with 5-segmented tarsi and none of the legs were altered for grasping and digging. Stridulating organ which refers to the hearing organ in insect and tympana usually absent. In general, wings are present in certain species, although some species do not have wings (Triplehorn et al., 2005).

Blattodea is an order that consists of cockroaches and termites. Recent research has shown that termites are the lineage of cockroach which came from the same ancestor and not a separate insect order (Inward et al., 2007). Living cockroach similar to Arthropod that dominated the insect communities on this earth since Carboniferous era. A modern cockroach that living on the earth now evolving from them by the middle of Mesozoic (William et al., 2007).

The order Blattodea consists between 3500 to 4000 species around the world (Resh, 2009), found mostly in all part of this world which has its own indigenous species in every continent. The cockroach is divided into six families which are Blaberidae, Nocticolidae, Corydiidae, Blattidae, Tryonicidae, and Blatellidae (Rentz, 2014). Cockroaches are mainly found among leaf litter, crevices, cavities beneath bark, also a rotting log or wood and some debris. Some cockroaches are arboreal that lives in trees and some species adapt to aquatic and caves area (William et al., 2007). A small number of species are living in a residential area with humans, building and are regarded as pests.

Cockroaches are commonly known as nocturnal creatures that hide during the day and forage at night (Gerozisis et al., 2008). The cockroach is hemimetabolous, where it does not have a pupal stage, the stage where transformation between immature and mature stage. Nymph of the cockroach is identically the adults apart from their size and the absence of wings because it undergoes incomplete metamorphosis process (William et al., 2007). Egg sac which is known as ootheca produced by a female cockroach. The female cockroach was able to carry the egg sac everywhere up to 25 eggs depending on the species. Duration of the nymph stage may be affected due to the number of nutrients received in a diet and the differences of seasonal (Park et al., 2002).

In Malaysia, the most dominant species of cockroach reported by Oothuman (1984) is American Cockroach (*Periplaneta americana*). By referring to the research Oothuman (1984) from School of Biological Science in Malaysia has found 10 species from 3,289 individual in the residential premises which are *Periplaneta americana, Periplaneta brunnea, Periplaneta australasiae, Neostylopyga rhombifolia, Nauphoeta cinerea, Supella longipalpa, Blatella germanica, Blatella vaga, Symploce pallens,* and *Pycnoscelus surinamensis* (Lee et al., 1993).

Cockroaches are found in nearly all habitats, from the forest canopy to the soil, within burrows and caves, within logs and detritus, and in a nest of social insects, rodents, reptiles, and birds. They are most abundant in the hot, humid tropics, between N and S. They are also more common at sea level where temperatures are warmer rather than at high altitudes (Capinera, 2008).

1.2 Problem Statement

Basic studies in Malaysia about the diversity of forest cockroach are still lacking especially in Kelantan. Ecology and bionomics on species composition in Malaysia are insufficient. Actually, there is much research regarding cockroach has been done in Malaysia, but most studies that have been conducted are not related to the distribution and diversity of cockroach especially forest cockroach. The research that has been done in Malaysia entitled Diarrhoeal diseases, that analyze the important role of cockroach in Malaysia as a pathogen that was published in Jun 1984 (Oothuman et al) Secondly, a researcher from USM has done studies of American cockroach entitled Population Ecology of the American Cockroach, *Periplaneta americana,* and its Potential Control Using Arasitoid *Aprostecetus hagenowii* (ratzebug) (Tee et al., 2011)

Other than that, studies on the species of cockroach in Malaysia have been published, investigating the situation in Kelang and in Penang. Studies have been carried out to determine the species composition of cockroaches in Klang and in Penang (Oothuman et al, 1991; Lee et al, 1993). Most of the research carried out previously was confined to the infestation and relative abundance in different localities in housing estates (Vythilingam et al., 1997). This research wants to update data about the cockroach in Hutan Lipur Bukit Bakar, Machang, Kelantan.

1.3 Objective

This study aims to identify the diversity of cockroach in Hutan Lipur, Bukit Bakar, Machang Kelantan.

1.4 Scope of Study

The main focus of this study is the diversity of cockroach in Hutan Lipur Bukit Bakar, Machang, Kelantan. The cockroach that has been caught was collected and analyzed by comparing their morphological structure among the individual such as wing pattern and color. Besides, this research focusing on abundance and species richness of cockroach in the forest area at Bukit Bakar.

1.5 Significance of Study

The significance of this study is focusing on the species of forest cockroach especially in Kelantan updated. Other than that, data from Hutan Lipur Bukit Bakar, can promote that area and potentially to be insect tourism places, besides being able to give benefit and general knowledge about insect to local people. Other than that, the collected data was used for the management of insect resources in Natural Resources Museum of Universiti Malaysia Kelantan Jeli Campus (UMKKJ) and help in rising data collection of insect in Kelantan.

Other than that, information on this research can contribute to the development in Hutan Lipur, Bukit Bakar area and the management of the park was helpful to the Department of Wildlife and National Park (PERHILITAN). Lastly, it also contributes to increasing insect data in Kelantan.

CHAPTER 2

LITERATURE REVIEW

2.1 Morphological Characteristic of Cockroach

Cockroach usually has a dorso-ventrally flattened body, elongated and segmented with head directed downwards and bearing chewing mouthpart that allows them to cut and bite solid foods (Figure 2.1). Roaches have two long and thin antennae that function in smell and touch. The small hair, along with the antenna, helps the roaches to smell and feel the object.

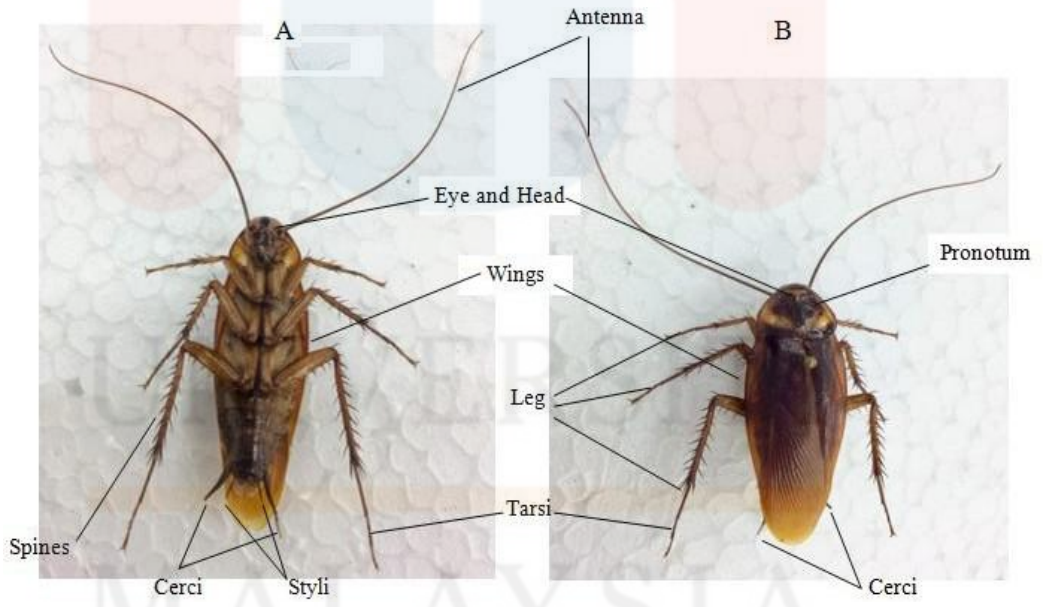

Figure 2.1: Morphological characteristic of American Cockroach (*Periplaneta americana*). (A) Female ventral view and (B) Male dorsal view.

External morphology of cockroach includes its shape, size, and color. The adult of cockroach measure from 28-44 mm in length and the width about 8 to 10

mm. The shinning reddish-brown with a paler yellow area around the edge of pronotum and it has two dark patches over it (Gupta, 2004). Cockroach consists of three body parts which are head, thorax, and abdomen. The six legs of cockroach attached to the thorax.

The abdomen protects most of the cockroach's organ. Integument of cockroach or its body wall and exoskeleton consist of cuticle, hypodermis and basement membrane. Cuticle or exoskeletons are entire bodies including appendages which covered externally by a thick, brown-colored, non- living hard and chitinous cuticle which is the structure of insect's exoskeleton (Kotpal, 2012).

The head varies in shape from one insect to another. The tough capsule is formed from the six structural segments that are welded together. Usually, the segmental divisions are not visible. The head bears with antennae, the mouthparts which widely different in structure and the eyes. Virtually, all insects possess antennae from their younger stage that function as smell organ and touch (Gibbons, 1995).

Most of the insect can live without food and stand for a long day. However, the absence of water may lead to dehydration and slowly kill them. Cuticle plays an important role in their great success. Cuticle provides protection, rigidity, and support to the cockroach. Besides, waxy layer o n the surface of cuticle prevent and protect the insect from loss of water and enabling cockroach to live in the relatively dry environment. Other than that, the cuticular lining of fore and hindguts protect their epidermis from abrasions by passage food (Kotpal,2012).

The cockroach is a hemimetabolous insect. The cockroach nymphs ordinarily look like adults except for the absence of wings and tegmina. Its structures

sometimes indicated by non-articulated, lobe-like extensions of the meso and metanotum in later developmental stages. Both sexes at the early instars have styles on the subgenital plate these are usually lost in older female instars and absent in adult females (William et al., 2008)

The cockroach has small hair, called cerci on the abdomen's underside that helps them to detect and sense thing around it. The cerci are too sensitive as they can pick up on the tiniest movement air which easier to this insect to protect themselves from the enemy and at the same time their six legs help them to run away in a speed movement (Wilson, 2008).

The excretory system in cockroach involves four main structures which are malpighian tubules, fat body cells, uriscose glands, and cuticle. Malphigian tubules are attached to the alimentary canal at the end of the hindgut. Meanwhile, granular cells of distal extract nitrogenous waste in form of salts of uric acids. Moreover, water from blood or hemolymph forming a solution called urine. Last but not least, fat body cells are a lobed white tissue known as a fat body that filling up the greater part of hemocoel (Kotpal, 2012).

2.2 Classification of cockroach and their habitat

Cockroaches are an insect that belongs to order Blattodea, family Blattidae and under suborder Dictyoptera. About 3500 to 4000 species of cockroach have been identified and classified and dividing into five families which are Cryptocercidae, Blattidae, Blattellidae, Blaberidae, and Polyphagidae (Resh, 2009). Blaberidae is the largest family of cockroach about 2000 species can be found and consists of dozen genera. Cryptoceridae is the most primitive family that consists of one genus with

less than 10 species. These families are large in body shape with reddish brown color and wingless when adult.

Cockroach mainly found in all over the world. Most of all the species easily to adapt and live in damp and warm places example tropical forests. Other species of cockroach live in the mountain, grassland, desert, and swamps. Some species of cockroach- like German cockroach (*Blatella germanica*) and American Cockroach (*Periplaneta americana*) live with human environment and known as a pest.

Forest cockroaches are commonly depicted as insects from a wet tropical zone which are diverse and abundant; nevertheless, a cockroach can be found in parched or arid climate and semiarid areas. In the drier environment cockroach survive itself by dependant on its relationship with local plant or native plant species (Schapheer et al., 2017).

2.3 Lifecycle of cockroach

The cockroach is known as hemimetabolous. The immature of cockroach usually have same appearances as the adult. However, the immature cockroach is not fully developed of their wing and sexual organs. Typically, reproductions of cockroaches are sexual, but certain species undergo parthenogenesis. Parthenogenesis is a reproduction of cockroach from an ovum without fertilization (Lloyd et al., 2002). Figure (2.2) showed lifecycle of cockroach (*Blatella germanica*).

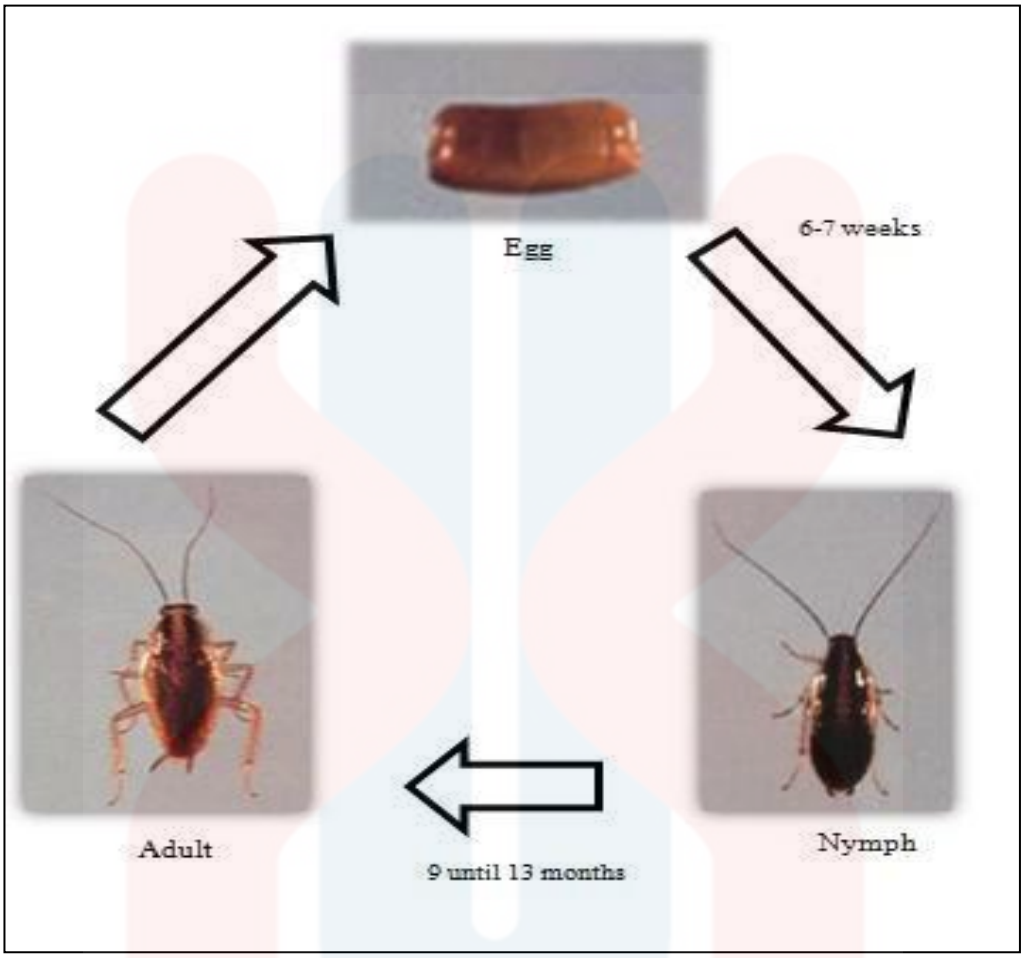

Figure 2.2: Lifecycle of cockroach (*Blatella germanica*) (Resh, 2009).

Usually, cockroach reproduction is characterized by the development of an ootheca which is the egg delivered from the ovaries and moves down oviducts are arranged into two rows by the ovipositor valves, then encompassed by a defensive covering (William et al., 2007).

Cockroaches usually have short lifecycles and undergo slowly metamorphosis. Mostly, male and female cockroaches of many species are dissimilar (Rentz, 2014). Besides, the cockroach is hemimetabolous insect which means that this insect undergoes an incomplete metamorphosis that grows through a series of molts, have egg and nymph (Resh, 2009).

2.4 Ecological importance

According to the Encyclopedia of Entomology in the year 2008, cockroach plays significance roles and function in the ecosystem which contributes to releasing nutrients by decomposing organic matter. Besides, the cockroach is also classified as a major component of leaf- litter fauna which plays vital roles in the return of the litter to the soil. Forest cockroaches play vital ecological roles as detritivores (Tarli et al., 2014), florivores which refer to floral herbivore (Ball et al., 1942), xylophagous and also function as a pollinator (Nagamitsu & Inoue, 1997; Vlasáková et al., 2008).

2.5 Cockroach Diversity and Distribution

There are about 4000 species of cockroach around the world (Mullen & Durden, 2009) and on the other studies stated about 4500 species worldwide (Rasplus & Roques, 2010). Forest cockroaches are commonly depicted as insects from a wet tropical zone which are diverse and abundant; nevertheless, a cockroach can be found in parched or arid climate and semiarid areas. In the drier environment cockroach survive itself by dependant on its relationship with local plant or native plant species (Schapheer et al., 2017).

Besides, cockroaches are popularly recognized as a household pest. Domestic or pest cockroaches are a capable competent human environment and become a health concern when it is additionally an urban disturbance (Rivault et al., 1993; Schapheer et al., 2017). Perversely, the remaining known cockroach species is generally not related with urbanization condition, as they lived in the assorted common biological community, where cockroach also has its own key ecological roles (Roth & Willis, 1960; Schapheer et al, 2017).

The distribution of forest cockroach or wild cockroach is mainly live in natural areas in most tropical regions around the world. Example, the most record of forest or wild species in South America, are from Brazil (Pellens & Grandcolas, 2008; Schapheer et al., 2017). Distribution of cockroach is mainly adapted in an area with low temperature and low humidity which restricts the tropical rainforest climate as the potential habitat for the cockroach (William et al., 2007).

CHAPTER 3

METHODOLOGY

3.1 Study Area

Cockroach sampling was conducted at Hutan Lipur Bukit Bakar, located in Machang Kelantan, east coast Malaysia with coordinate 5 43”22.1”N 102 15’27.8”E (Abas et al., 2018). The estimated area of Bukit Bakar (Figure 3.1) is about 3.14 hectare within the Ulu Sat forest reserve and it is classified as lowland dipterocarp forest that consists of tall hardwood tropical trees which have been dominated by dipterocarp species. The elevation of Bukit Bakar was estimated about 585 meters above the sea level. Hutan Lipur, Bukit Bakar was opened in 1975 as a recreational forest for visitors as it has complete facilities and waterfall beside the greenery of tropical rainforest (Nadia, 2013). Bukit Bakar is managing by Kelantan Forestry Department. Cockroach sampling was conducted in Hutan Lipur Bukit Bakar starting from July 2018 until August 2018 for 21 days. Table 3.1 shows the geographical coordinate and elevation of every sampling point.

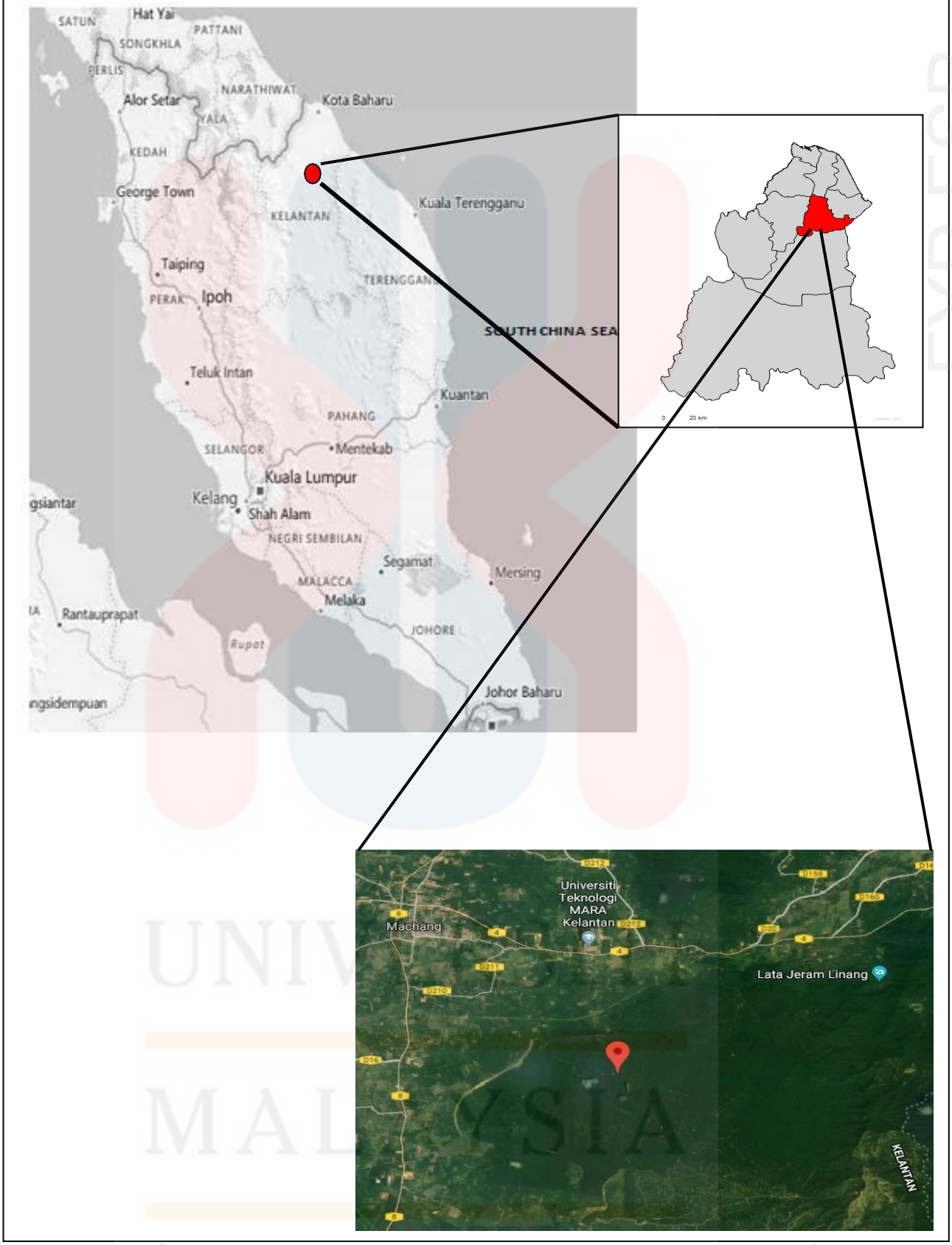

Figure 3.1 Maps of Hutan Lipur Bukit Bakar, Machang Kelantan (Source: Google (2018) maps of Hutan Lipur Bukit Bakar, Machang Kelantan, Malaysia).

Table 3.1: Geographical Coordinates and Elevation of every sampling point.

Sampling Point	Interval/m	Geographical Coordinate	Elevation/m
1 (Trail 1)	00	N 05 44’42.8”E 101 51’52.5”	55.5
	50	N 05 43’12.2”E 102 15’37.7”	77.6
	100	N 05 43’12.1”E 102 15’38.8”	97.5
	150	N 05 43’12.2”E 102 15’40.9”	99.0
	200	N 05 43’12.2”E 102 15’41.9”	119.3
2 (Trail 2)	00	N 05 43’03.7”E 102 15’36.6”	123.6
	50	N 05 43’04.2”E 102 15’37.8”	123.6
	100	N 05 43’08.3”E 102 15’44.9”	165.2
	150	N 08 02’51.3”E 101 48’00.0”	163.0
	200	N 07 32’54.4”E 101 48’00.0”	164.0
3 (Trail 3)	00	N 05 43’01.6”E 102 15’41.9”	159.6
	50	N 05 43’22.7”E 102 15’43.3”	112.3
	100	N 05 43’03.3”E 102 15’44.2”	125.6
	150	N 06 39’40.6”E 101 48’12.8”	116.3
	200	N 05 44’42.8”E 101 51’52.5”	113.4

3.2 Materials

Table 3.2 indicates the important materials that were used during the collection of a cockroach.

Table 3.2: Materials and method

Method	Materials	Description
Transect Sampling	• Rope • Measuring Tape	200m of raffia rope has been measured by using a measuring tape and tied between trees before the installation of baited and pitfall trap.
Baited Trap	• Reusable Cockroach Trap/plastic bottle • Vaseline	The plastic bottle was cut into two parts as a body trap and Vaseline was rub around the mouth of the bottle.
Pitfall Trap	• Plastic Container • Soap Fluid	The container was sunk under the ground and the fluid was filled in the container.
Light Trap	• Light Source (Lamp) • White bed sheet	The white bed sheet was tied between pillars and the lamps are connected with the power plug.

3.3 Methods

3.3.1 Cockroach Sampling

Transect method was set up by using a string as a guide in a sampling method to measure the distribution of cockroach. Before installing pitfall and baited trap, 200m of transect line have been measured and tied between trees and every 50m interval was marked as cockroach sampling area with some information (Figure 3.2). After that, pitfall and baited trap were installed every 50m interval at the left and right side, one meter away from the transect line. Three transect sampling was set up around the study area. The method that has been used in transect sampling is a baited trap and pitfall trap.

Figure 3.2: Sampling point that has been marked (Picture was taken by Nurul Nasuha)

a. Baited Trap

Cockroaches are classified as omnivores because these insects ate sweet food, meats and also attract to decaying matter like dead logs. A cockroach can live up to seven days without consuming any food but it can die in a few days without water. Trapping cockroach with dry food can make cockroach dehydrated and become weak (William, 2007).

The baited trap (Figure 3.3) was placed on the leaf litter where the habitat of cockroach lives. The baited trap was set up by using a tin or bottle can trap many cockroaches at one time. Vaseline was applied to the mouth of the bottle and the roaches' food was put in the trap that can attract the cockroach to enter the trap. Vaseline prevented the cockroach from crawling out. The cockroach trap was left for four days in every trail and was checked every morning to collect the trapped cockroach.

Figure 3.3: Baited trap **(**Picture was taken by Nurul Nasuha **)**

b. Pitfall Trap

Pitfall trap is a placement of an open container sunk under the ground and it is containing fluid (Figure 3.4). Pitfall trap is one of the methods to sample terrestrial arthropod communities. This trap captures both diurnal and nocturnal species. About six traps were installed for every 50- meter interval.

Figure 3.4: Pitfall Trap with soap liquid **(**Picture was taken by Nurul Nasuha)

c. Light Trap

The light trap is commonly used to trap flying insect at night. As state by Southwood and Henderson in the year 2000, diversity of insects active at night and the collection through light trap provide a significant clue (Ramamurthy et al., 2010). The light trap (Figure 3.5) has been done at three different points which are point 1 (trail 1), point 2 (trail 2) and point 3 (trail 3).

Figure 3.5: Light Trap **(**Picture was taken by Nuru l Nasuha)

A great specimen in a better condition should be collected by waiting at the trap by observing the white bed sheet and directly get the desired insect into a killing jar once they perch on the white sheet (Triplehorn et al., 2005). By using a traditional light trap, the white bed sheet was tied between two pillars and the light source (12V 5W DC LED white bulb) was installed under the white bed sheet connecting to the battery (12V 7.2AH Sealed Lead Acid Batteries). The data of the insect was collected in every five minutes because the flying insect may escape in a short time.

The killing jar was prepared with hard tissue paper and chloroform to ensure the toxic agent does not evaporate easily. The insect must be killed in the way not injured or broken the specimen. Light trap was conducted for seven hours starting from 1900 until 0200. The light trap was not conducted on a full moon and rainy day.

d. Manual Collection

The night is often the best time to collect cockroach because the insect is nocturnal creatures and mainly forage at night. The cockroach can be found under the bark or by searching in leaf litter (Triplehorn et al., 2005). The equipment used in

collecting insect should be assembled by preparing empty container or killing jar that contains chloroform. Hand picking and insect net are an effective method in collecting cockroach. The cockroach is picked up by hand and placed in the killing jar. Handpicking was applied for the small and medium size of a cockroach while the big size of cockroach was collected by using the aerial net. Hand picking method needs extra precaution to avoid any damage to the cockroach specimen (Prakash, 2001).

3.3.2 Cockroach Preservation

The cockroach was killed by using a killing jar that contains toxic agent like chloroform which causes the insects immobilized. Cockroach preservation involves pinning and spreading process. Nymph cockroach is too small and needs to pin on a card (Appendix A) or point or need to be preserved in liquid (Triplehorn et al., 2005). Insects are glued to the tip of the point on the triangle paper that has been cut. After collecting and pinning it on the mounting board, the big size of cockroach was dried in the oven under the temperature of 40℃ for two days while the nymph was preserved for one day under the same temperature to avoid the specimen broke. The specimen was handled carefully to avoid any damage to its morphologicalstructures.

Forceps and pin were used in pinning the specimen on the polystyrene or spreading board. The function of forceps is spreading every body part of the cockroach without directly touching it. Large size cockroach that was damaged is preserved in 90% ethanol to ensure its component features are in a good condition for identification purpose.

3.3.3 Cockroach Identification

A cockroach was identified with the help of standard identification key (Table 3.2) as a reference. Nymph cockroach was observed under the microscope due to the small structure of its morphology like antenna, mouthpart, and eyes of different species. The different structure and color of cockroach indicated the different species.

Table 3.3: References of Cockroach Identification

	Title	Description	Sources
1.	Encyclopedia of Insects	This book covers all aspects of insect's anatomy, physiology, evolution, behavior, reproduction, ecology, and diseases.	Resh (2009)
2.	A Guide to the Cockroach of Australia	This book explains about hundreds of species of cockroach that have been found in Australia.	Rentz (2014)
3.	Encyclopedia of Entomology	This book provided a detailed about insect and they are closed relative including taxonomy, ecology behavior, history, and management.	Capinera (2008)
4.	Invertebrates of Central Texas Wetland	This book explains the examination of invertebrate's example crustacean, insects, molluscs, and others that inhabit the ottine waters, wetlands, and woodlands.	Taber et al. (2005)
5.	Cockroach Species File Online	This website provides the latest profile of cockroach species that have been updated.	http://cockroach.speciesfile.org (Version 5.0/5.0)
6.	Introduction of the Study of Insects 7th Edition	This book explains the diversity of insect and its evolution. Besides, it also explains the identification key of Blattodea.	Borror and Delong (2005)

3.3.4 Data Analysis

The important components of diversity indices are evenness that measures the relative abundance of different species that making up the richness in that area. Species diversity which increases the complexity of the habitat is called as species evenness and richness (Hill, 1973; Turchi et al., 1995; Leinster & Cobbold, 2012). The data that have been collected was analyzed by using Shannon-Wiener Diversity Index and Species Accumulation Curve.

a) Species Accumulation Curve

A species accumulation curves are also a graph plotting of the cumulative number of species discovered within an area (Hawksworth, 1995). In this study, Species Accumulation Curve was used to estimate the species richness of the cockroach. Species accumulation curve recorded the rate of newly species that have been added with continue trapping effort. The total number of species present which refers to species richness is equal to the asymptote value of a species accumulation curve (Thompson & Withers, 2003). The shape of a species accumulation curve is influenced by the pattern of relative abundance among the species sampled (Colwell & Coddington, 1994).

b) Shannon-Wiener Diversity Index

Shannon-Wiener Index is an index that used to calculate species evenness, richness, and diversity indices (Shannon & Weaver, 1949). The various habitat of diversity is comparing using the Shannon-Weiner Index (Clarke & Warwick, 2001).

The basic assumptions that must be met is that the sample of organisms used in calculation is representative of the entire community of organism (Little, 1998). Besides, the Shannon-Wiener Index also used in the calculation to know the diversity of a species in a different habitat (Hutcheson, 1970) based on the following formula that counted the abundance of the species:

$H' = -[\sum Pi \ln Pi]$ ---------- Equation (3.1)

Based on the Shannon-Wiener Index

equation (3.1) H'= Index Diversity

Pi= The sample of the proportion of individuals of the total sample belonging to its species.

lnPi= Proportion of this natural logarithm (Bibi & Ali,

2013). Range= 0 until H'max, where H'max= ln s.

S= Number of species.

c) Margalef Diversity Index

Widely used index in calculation large sample size (Van Dyke, 2008).

$D_{mg} = \frac{(S-1)}{\ln(N)}$ ---------- Equation (3.1)

Where,

S = Number of species recorded

N= Total individual of all S species

d) Pielou's Index of Evenness

As indicated by Pielou (1966), Pielou Evenness Index is derived from Shannon-Wiener Diversity Index. Evenness of species in a community can be represented by Pielou Evenness Index and expressed as

$$J' = \frac{H'}{\ln(s)}$$ ---------- Equation (3.1)

Where,

H'= Shannon- Wiener diversity

S = Total number of species that have been observed

Range = 0 to 1

CHAPTER 4

RESULTS AND DISCUSSION

4.1 The Assemblage of Cockroach

In this research, a total of 60 individual, representing 12 species from three families of cockroach were collected (Table 4.1) at Hutan Lipur Bukit Bakar, Machang Kelantan by using four methods which are baited trap, pitfall trap, light trap, and manual collection during daylight and night. This study shows that Blaberidae's family is the highest with the collection of seven species followed by Blatellidae (three species) and lastly Blattidae which consists of two species.

Table 4.1 showed that *Parcoblatta* sp. was the highest compared to other species which are mainly found in sampling point 2. *Parcoblatta* sp. or is known as a wood cockroach that has been found are commonly small in size and light brown in color. Secondly, 11 individuals of *Calolampra* sp. were recorded from sampling point 1 and 3. This species are wingless and mainly found under the leaf litter. The characteristic of *Calolampra* sp. like a leaf-notching make it difficult to see. Other than that, forest cockroach that is commonly found is *Rhabdoblatta* sp. which are active and forage at night and more attracted to light. A total of three individuals of *Panchlora* sp. were recorded from sampling point 2. *Panchlora* sp. is green and greyish in color is a nocturnal insect and attracted to a light trap.

Periplaneta americana recorded only an individual that was found on sampling point 3. The American cockroach is classified as an urban cockroach that can easily be found in the residential and building area. In this study, the reason maybe American cockroach was brought into Hutan Lipur Bukit Bakar by a car that passing by into the forest area. A total of 7 individuals of *Periplaneta fuliginosa* was collected. This species also known as a Smoky-Brown cockroach were collected by using a baited trap. *Periplaneta fuliginosa* is classified as cockroach pest that carries pathogen in their body which can contaminate food with a harmful microorganism (Roth & Willis, 1960).

Table 4.1: Distribution of cockroach species encountered.

Family	**Taxon**	**Sampling Point**			**Total Individual**
		S1	S2	S3	
Blaberidae	*Calolampra* sp.	6	0	5	11
	Panchlora sp.	0	3	0	3
	Rhabdoblatta sp. 1	0	3	0	3
	Rhabdoblatta sp. 2	1	3	0	4
	Rhabdoblatta sp. 3	0	3	0	3
	Rhabdoblatta sp. 4	1	2	0	3
	Pycnoscelus sp.	0	1	0	1
Blatellidae	*Blatella* sp.	1	0	1	2
	Parcoblatta sp.	6	9	3	18
	Pseudophyllodromia sp.	3	1	0	4
Blattidae	*Periplaneta americana*	0	0	1	1
	Periplaneta fuliginosa	0	7	0	7
	Total	18	32	10	60

Species accumulation curve (SAC) was used to indicate the adequacy of data sampling and to estimate species richness, where the number of species that have been encountered is plotted as a function (MacKenzie, 2006) and also representing the new species collection within the community. Every new species that have been collected will increase the number of new species in the graph until it reaches asymptote which is a stable line when there are no new species recorded at the end of the sampling day.

The species accumulation curve (Figure 4.1) showed that the estimated total species of cockroach reaches asymptote line on the 18th-day of sampling from the total of 21 days which are sufficient in determining species richness.

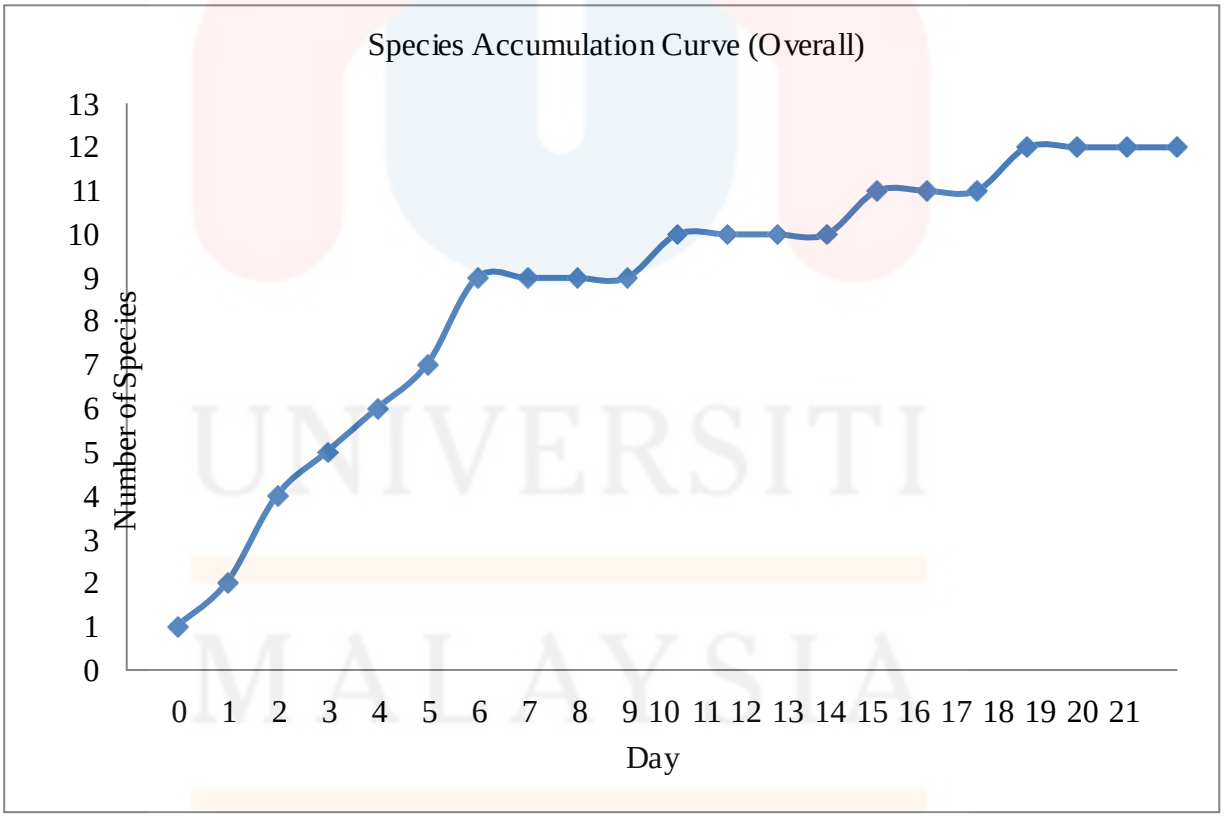

Figure 4.1: Species Accumulation Curve for cockroach species that have been collected at Hutan Lipur Bukit Bakar using a light trap, baited trap, pit fall trap, and manual collection.

Sampling methods play an important role in all studies on the behavior and ecology of insects in the field. The used of the light trap to sampling night-flying insects by using white bed sheet is classified as a traditional technique (Britain, 1986). In these studies, one of the methods to collect cockroach fauna is by using a light trap. The light trap was set up for seven hours from dusk until 0200 to attract cockroach and other nocturnal insects. Light trap was conducted for 21 days on a three different point around the study site.

Based on the graph (Figure 4.2), it showed that the graph keeps rising in the first week of the cockroach sampling due to the increasing number of species that were collected. The graph approaching constant value on the 7th day of sampling and reach constant value on the 8th day until the 15th day and slightly increase on the 16th day and lastly reach the asymptotic line at the end of the day.

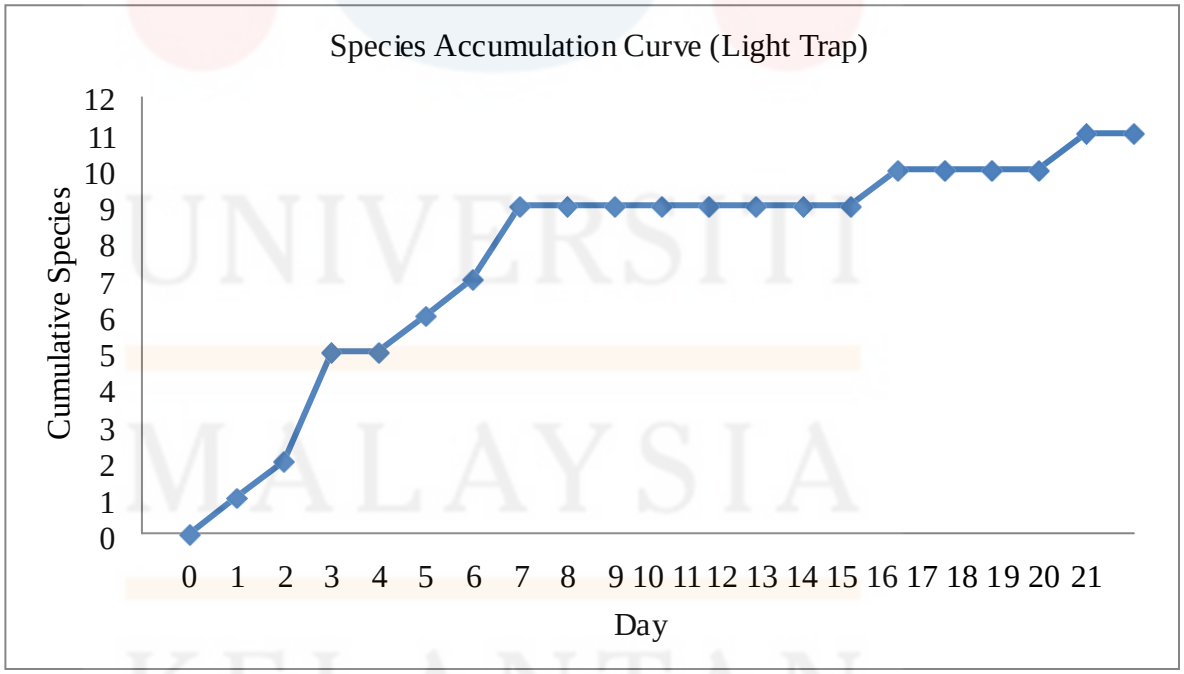

Figure 4.2: Species Accumulation Curve of cockroach that has been collected using a light trap method.

In this study, the baited trap is not an effective method that can be used to trap forest cockroach compared to the urban cockroach. Sweet biscuit was used as the bait to attract the cockroach. Based on the graph (Figure 4.3), there are no data was collected from the first day of sampling until the 11th day. On the 12th day, the value of the graph rising due to two species of cockroach was collected. The graph increases on the 17th day and reaches asymptote line because no new species are added until the last day of sampling.

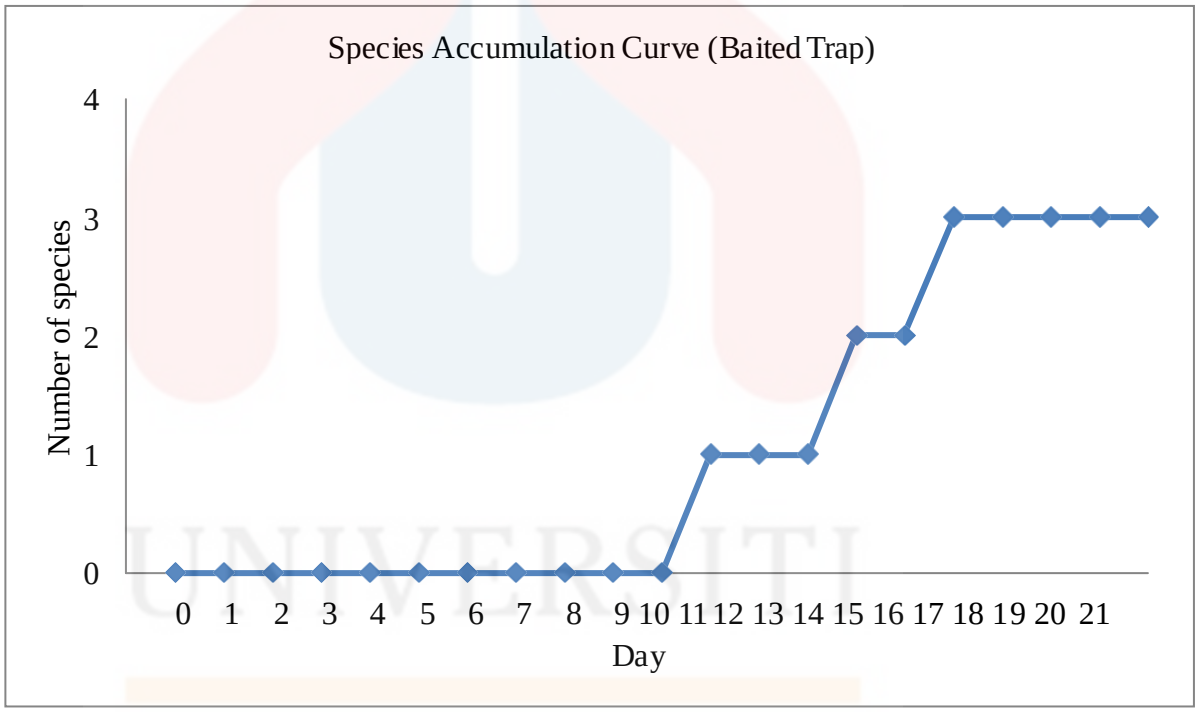

Figure 4.3: Species Accumulation Curve of cockroach using baited t rap method.

Pitfall trap is the most frequently used as a method to trap passive insects because it does not need higher cost and time effective. It is commonly used to monitor the movement or biodiversity of the ground-dwelling organism. Pitfall trap is a simple method that needs a container filled with fluid that was buried up to the rim of the soil (Paulson, 2005). In this study, a pitfall trap is ineffective in cockroach sampling due to its location that was placed at the hilly surface. Other than that, a certain factor that may affect pitfall trap is the trap fluid type and trap surface texture (Topping & Luff, 1995).

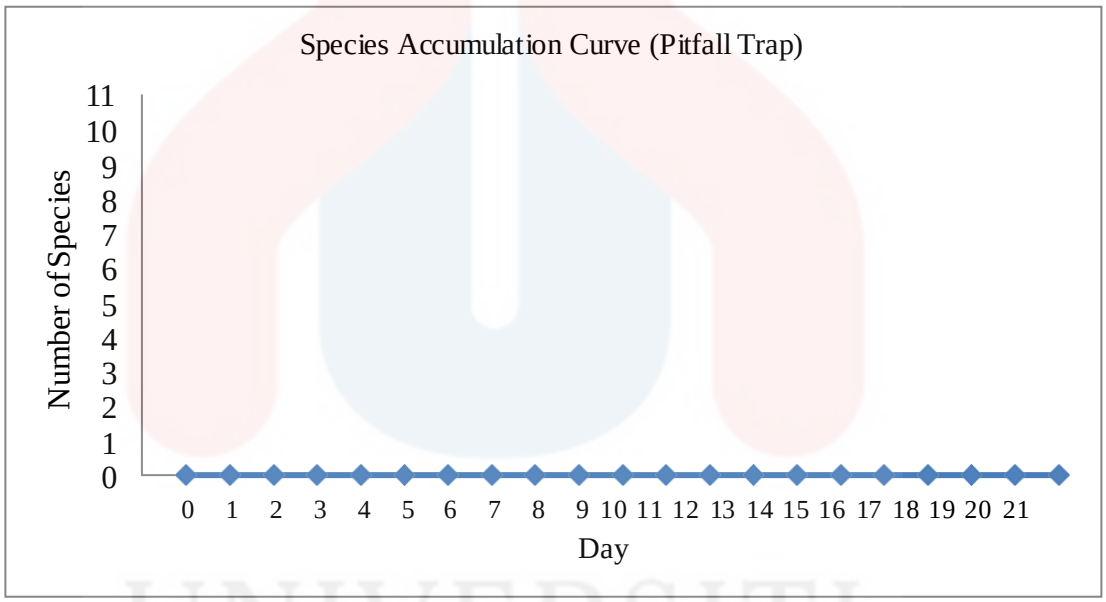

Figure 4.4: Species Accumulation Curve of cockroach using a pitfall trap

The manual collection has been done around the study site for 26 days during day and night. On the first week of faunal sampling, the graph (Figure 4.5) showed that no data collected on the 1st until the 3rd day. The graph starts to increase on the 4th day because the new species was collected and stop on day 9. It showed a constant value until the new species was collected on the 16th day and reach asymptote line on the 20th day indicating there are enough collected data.

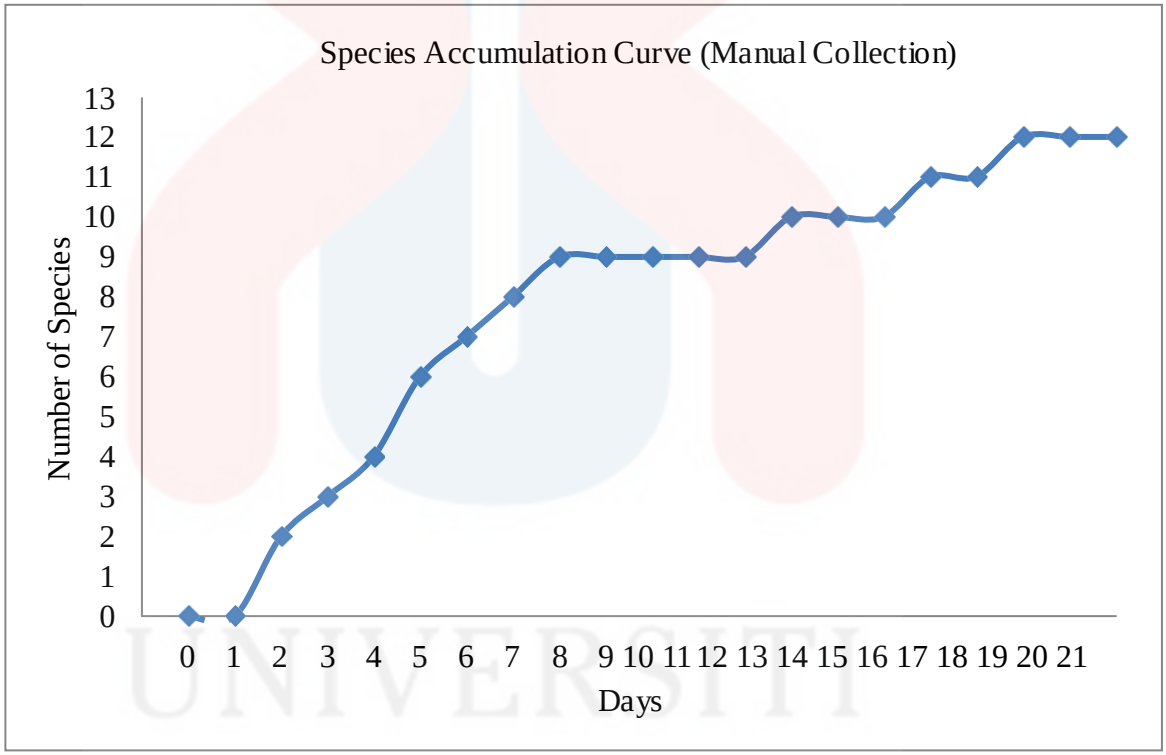

Figure 4.5: Species Accumulation Curve of a cockroach by manual collection along the selected trail.

4.2 Species Richness of Cockroach

Cockroach plays an important role in ecology that function in the microbial breakdown of organic matter by transporting microbes known as locomotion (Foottit & Adler, 2009). Forest cockroach or wild cockroaches are mainly described as an abundant and diverse insect from wet tropical zones. The distribution of forest cockroach is mainly limited to the natural areas in the tropical region (Schapheer et al., 2017).

Table 4.2: Species Richness Diversity Index

Index	Symbol	Total
Shannon-Wiener	H’	2.13
	H'_{max}	2.48
Margalef	D_{mg}	85.84
Pielou’s Evenness	J’	0.86

Shannon-Wiener diversity index range from zero in communities consists of one single species to a maximum ln(S) or H'_{max} (Lindenmayer & Burgman, 2005). Based on the table (Table 4.2) Shannon-Wiener Index shows the value of 2.13 where H'_{max} is equal to 2.48 indicate the stable environment condition for index diversity and H’ value approaching H'_{max} show that species richness at Hutan Lipur Bukit Bakar is slightly high (Appendix B). Species richness of cockroach is mainly due to the rich of vegetation in Hutan Lipur Bukit Bakar as vegetation plays an important

role in the existence of insect fauna because it provides food (Aslam, 2009).

In Figure 4.6, Blaberidae shows the highest species richness with the total of seven species compared to families Blattellidae and Blattidae (three species). Based on the graph, Blattidae's family show the lowest species richness with only two species (*Periplaneta americana* and *Periplaneta fuliginosa*) were recorded.

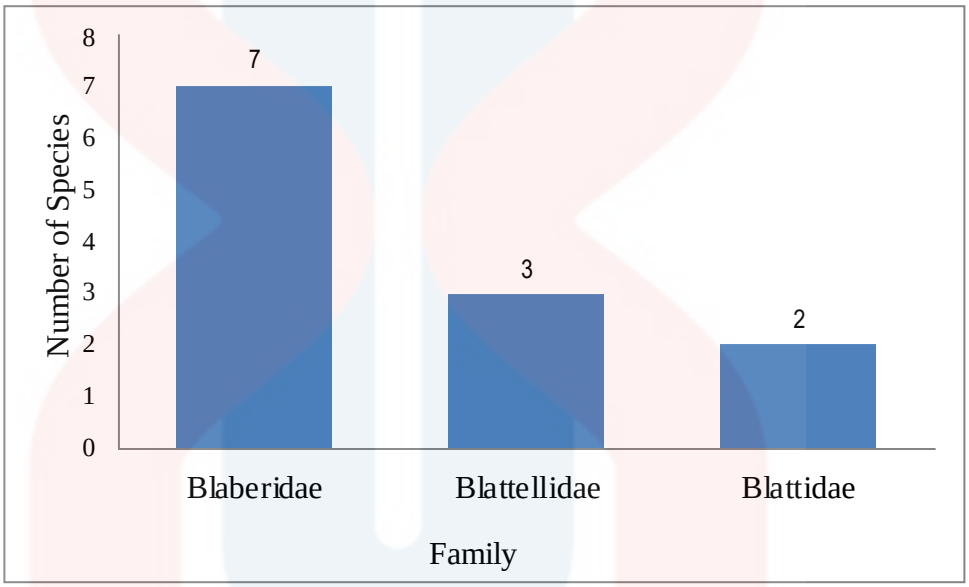

Figure 4.6: Number of Species of each family of a cockroach at Hutan Lipur Bukit Bakar

Margalef index is one of the mathematical calculations in calculating species richness to show how much the different species covered the study area. The lowest richness values (zero) are *Pycnoscelus* sp. and *Periplaneta americana*. The highest richness value was contributed by *Blatella* sp. (two individual) with the value 15.87 (Appendix E). This result is supported by the study Šímová, Li, and Storch (2013) mention that the least number of individuals contributed to the high number of richness. Thus, the result that was obtained which is 85.84 (Table 4.2) represents species richness at Hutan Lipur Bukit Bakar.

4.3 Abundance of Cockroach

Species abundance refers to the number of the individual within a region. The abundance is counted base on the number of individuals in each species (Krishnamurthy, 2003). Family Blaberidae is the most dominant species in this study (Figure 4.7) with a total of 28 individual comprising seven species followed by family Blattellidae and Blattidae.

The result shows (Figure 4.7) the most abundant species that have been collected is *Parcobllata* sp. with 18 individuals was recorded. The least abundant species is *Periplaneta americana* which is only one individual was recorded. The reason that the lowest number of *Periplaneta americana* recorded is that the forest is not typically a habitat for urban cockroach. The transportation by workers that passing through the road at night is the proof that American cockroach was brought into that area. *Panchlora* sp. and *Rabdoblatta* sp. show the same number of individual (three) while *Periplaneta fuliginosa* is the third higher compared to *Pseudophyllodromia* sp. (seven).

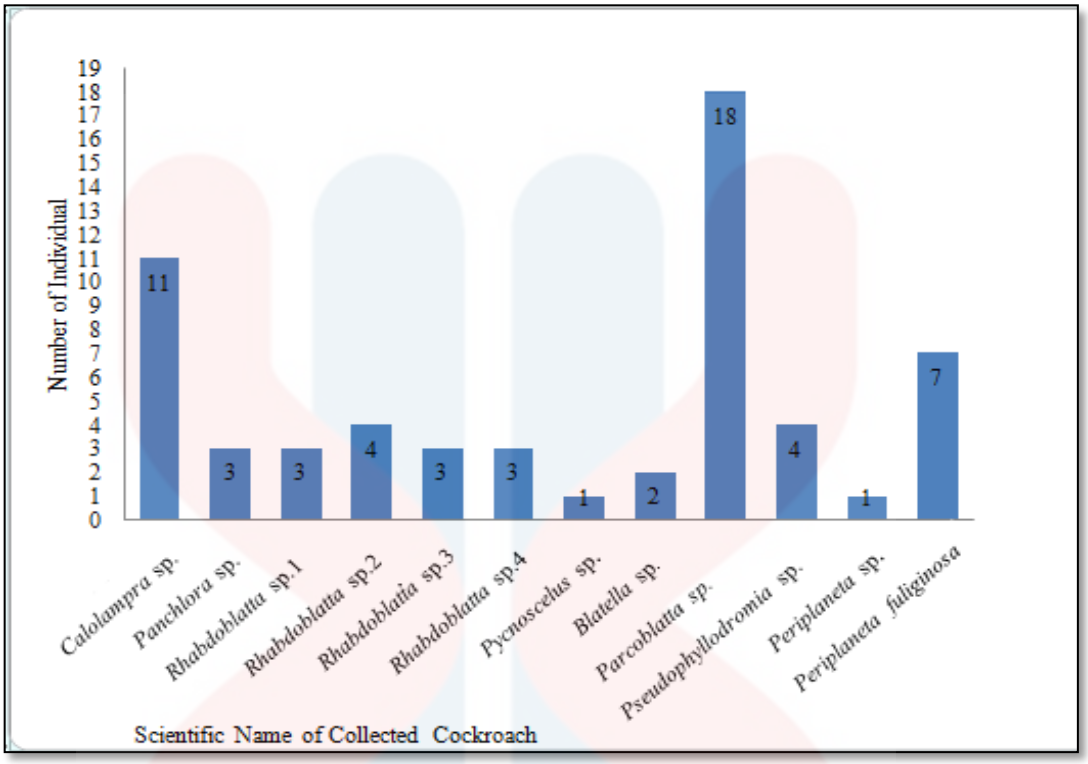

Figure 4.7: Number of Individuals of each Species

4.3.1 Evenness

Species evenness refers to the close in a number of the species in the study area which mathematically defined it as a diversity index (Krishnamurthy, 2003). In this study, the calculation of the evenness index is referring to the value of the Shannon-Wiener Index (H'). *Parcoblatta* sp. shows the high number of evenness (0.15) and followed by *Calolampra* sp. which is 0.13 (Appendix D).

By referring to Table 4.3, the higher value of evenness influenced by the higher number of diversity (H'). Guntenspergen (2014) indicated that, evenness range from 0 to 1. Maximally unevenness is approaching 0 value and perfectly evenness equal to 1. The results that have been obtained from Table 4.2 show that evenness index equal to 0.86 which approaches 1. This indicates that the number of

Individuals in a community of a cockroach are almost reached total evenness in the study area. The reason may be, Hutan Lipur Bukit Bakar is one of undisturbed forest which means no logging activities at the forest area. The forest that full of leaf litter may be one of the reasons which are the suitable habitat of forest cockroach that lives under a dead leaf (William, 2007).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The faunal survey revealed moderate levels of cockroach diversity at Hutan Lipur Bukit Bakar with three families belonging to 12 species was recorded. The highest families were Blaberidae with total numbers of 28 individuals compared to Blattellidae and Blattidae. The method in cockroach sampling play an important role in collecting data which is the type of baited and fluid that was used in baited trap and pitfall trap to attract cockroach. The value of H' (2.13), H'_{max} (2.48), Pielou's Evenness (0.86) and Margalef index (85.84) show that the study area is a moderately large diversity of cockroach species with uniform distribution. Generally, the most abundant species that was recorded is *Parcoblatta* sp. or wood cockroach belonging to family Blaberidae with a total of 18 individuals and followed by *Rhabdoblatta* sp. with 13 individuals. Species richness of cockroach with the value of 2.13 indicates the stable environment in that study area. The presence of another insect like leafhopper, moth, and butterfly showed that this forest is in a healthy condition.

5.2 Recommendations

Forest was classified as one of the major components of earth vegetation. Forest and insects play a crucial role in maintaining the effectiveness of their process that largely depends on insects as pollinators, parasitoid, seed predators and decomposer (New, 2018). The urban cockroach is usually related to domiciliary pest which brought pathogen that can cause sickness and also the role as intermediate host for the parasite (Russell, Otranto, & Wall, 2013).

Further study should be done regarding the diversity of forest cockroach in Malaysia to compare the distribution of forest cockroach from many tropical forests. The variety of cockroach with beautiful color and pattern can attract people and tourist to learn and appreciate our nature. Other than that, the researcher should apply other effective technique in cockroach sampling like using the right technique of pitfall trap and accurate timing to conduct light trap. Besides, Hutan Lipur Bukit Bakar has high potential in other studies regarding species study like a bird, macaque, damselflies, dragonflies, butterfly, moth and other plant species. After that, feeding behavior of forest cockroach should be study deeply to know the different behavior of every species. The wide area of Hutan Lipur Bukit Bakar is potential to get more species of flora and fauna for further research in creating herbs and medicine. Besides, the waterfall and undisturbed forest have high potential value as a recreational and ecotourism places.

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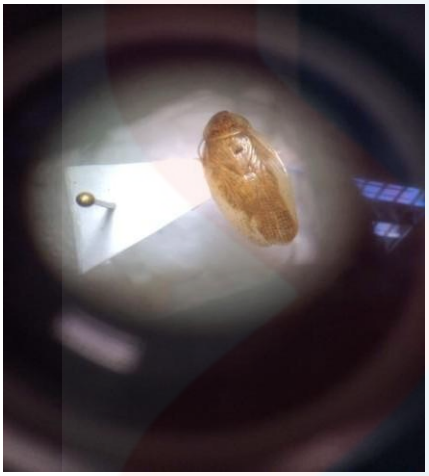
APPENDIX A

Images of selected cockroach collected from Hutan Lipur Bukit Bakar, Machang Kelantan



Family Blattellidae

Parcoblatta sp.

Family Blaberidae

Panchlora sp.

Family Blatellidae

Female *Blatella* sp. with ootheca

Small cockroach were pin on the card point on the polystyrene board.

APPENDIX B

Images of trapped cockroach in a baited trap

Family Blattidae

Periplaneta fuliginosa

APPENDIX C

A number of species, individual and Shannon-Wiener diversity index of a cockroach at Hutan Lipur Bukit Bakar, Machang Kelantan.

Taxon	Ni	Pi	ln Pi	(Pi*lnPi)
Calolampra sp.	11	0.18	1.70	0.31
Panchlora sp.	3	0.05	3.00	0.15
Rhabdoblatta sp.1	3	0.05	3.00	0.15
Rhabdoblatta sp.2	4	0.07	2.71	0.18
Rhabdoblatta sp.3	3	0.05	3.00	0.15
Rhabdoblatta sp.4	3	0.05	3.00	0.15
Pycnoscelus sp.	1	0.02	4.09	0.07
Blatella sp.	2	0.03	3.40	0.11
Parcoblatta sp.	18	0.30	1.20	0.36
Pseudophyllodromia sp.	4	0.07	2.71	0.18
Periplaneta americana	1	0.02	4.09	0.07
Periplaneta fuliginosa	7	0.12	2.15	0.25
Total	60	1.00	34.04	2.13

APPENDIX D

Number of species, individual and Pielou evenness Index (J')

Taxon	**No. Of species (S)**	**H'**	**ln (S)**	**J'**
Calolampra sp.	1	0.31	2.48	0.13
Panchlora sp.	2	0.15	2.48	0.06
Rhabdoblatta sp.*1*	3	0.15	2.48	0.06
Rhabdoblatta sp.*2*	4	0.18	2.48	0.07
Rhabdoblatta sp.*3*	5	0.15	2.48	0.06
Rhabdoblatta sp.*4*	6	0.15	2.48	0.06
Pycnoscelus sp.	7	0.07	2.48	0.03
Blatella sp.	8	0.11	2.48	0.05
Parcoblatta sp.	9	0.36	2.48	0.15
Pseudophyllodromia sp.	10	0.18	2.48	0.07
Periplaneta americana	11	0.07	2.48	0.03
Periplaneta fuliginosa	12	0.25	2.48	0.1
Total	12	2.13	2.48	0.86

APPENDIX E

Number of species, individual and Margalef index D_{mg}

Species	No. Of species (S)	S-1	ln(N)	D_{mg}
Calolampra sp.	1	11	2.4	4.59
Panchlora sp.	2	11	1.1	10.01
Rhabdoblatta sp.1	3	11	1.1	10.01
Rhabdoblatta sp.2	4	11	1.39	7.93
Rhabdoblatta sp.3	5	11	1.1	10.01
Rhabdoblatta sp.4	6	11	1.1	10.01
Pycnoscelus sp.	7	11	0	0
Blatella sp.	8	11	0.69	15.87
Parcoblatta sp.	9	11	2.89	3.81
Pseudophyllodromia sp.	10	11	1.39	7.93
Periplaneta americana	11	11	0	0
Periplaneta fuliginosa	12	11	1.95	5.65
Total	12	11	15.09	85.84

MILESTONE

Final Year Project I	
15th February- 24th April 2018	Completing Chapter 1 - Introduction
	Completing Chapter 2 - Literature Review
	Completing Chapter 3 – Material and Method
25 April 2018	Proposal Defense
5th July 2018	Submission Report of FYP I
Final Year Project II	
4 July 2018	Preparation of 90% ethanol
6 July 2018	Preparation of light trap, baited trap, and pitfall trap
8 July 2018 – 8 August 2018	Sample collection at point 1 (Trail 1)
	Sample collection at point 2 (Trail 2)
	Sample collection at point 3 (Trail 3)
10 August 2018	Submission of Thesis