INSECT DIVERSITY OF UiTM MUKAH: A RESORT CAMPUS, SARAWAK, MALAYSIA

Yahutazi Chik[1,4*],
[1]*Faculty of Plantation & Agrotechnology,*
Universiti Teknologi MARA (UiTM) Cawangan Sarawak,
Mukah Campus, 96400 Mukah , Sarawak, Malaysia
[4]*Natural Products and Research Development Centre (NPRDC),*
Universiti Teknologi MARA (UiTM), 94600 Kota Samarahan, Sarawak, Malaysia
**yahutazi@sarawak.uitm.edu.my*

Suffina Long[2]
[2]*Faculty of Computer and Mathematical Science,*
Universiti Teknologi MARA (UiTM) Cawangan Sarawak,
Mukah Campus, 96400 Mukah, Sarawak, Malaysia

Siti Sahmsiah Sahmat [3,4]
[3]*Faculty of Plantation & Agrotechnology,*
Universiti Teknologi MARA Cawangan Sarawak,
Samarahan Campus, 94600 Kota Samarahan, Sarawak, Malaysia
[4]*Natural Products and Research Development Centre (NPRDC),*
Universiti Teknologi MARA (UiTM), 94600 Kota Samarahan, Sarawak, Malaysia

ABSTRACT

Malaysia is recognised as one of the 17 mega-diverse countries in the world with diverse recorded species of flora and fauna. However, the deforestation of lowland dipterocarp forest due to demand for oil palm plantation and other economic crops and rapid urbanisation possess risk to ecosystem's health. Therefore, species identification is needed as a first step to be taken for the development of comprehensive database of Malaysian tropical rainforest insect species. However, the identification of insect species has never been done systematically at UiTM Sarawak Branch, Mukah Campus – a resort campus, even though it possesses a beautiful, naturally green vegetation ecosystem and surrounded by freshwater aquatic ecosystem. Without a standard insects' inventory, it will result to incomplete and inaccurate insect's identification. Therefore, this study is an initial stage for documenting and recording the present natural fauna especially insects' species thus providing a more standard inventory for the insect species within this campus. The main objectives of this research were to collect the insect species from both terrestrial and aquatic insects and subsequently providing an inventory and explorations of the overall insect species in UiTM Mukah. The different trapping methods were employed in this study which consists of sweeping net for diurnal flying insect, while light traps were used to capture nocturnal insect. Additional trapping with pit-fall traps were employed for crawling types of terrestrial insect together with aspirators for minutes insect. Assessment of species' diversity of the insects in UiTM Mukah was based on Shannon and Weaver Index where it focuses on species' richness and evenness. There were 13 important orders of insect found in UiTM Mukah namely Lepidoptera, Coleoptera, Homoptera, Orthoptera, Hemiptera, Hymenoptera, Odonata, Mantodae, Diptera, Blatodae, Neuroptera, Phasmatodae and Dermaptera. The highest percentage of insects was found from order Lepidoptera (26.06%), followed by Coleoptera (17.82%), Homoptera (17.76%), Orthoptera (12.59%), Hemiptera (6.79%), Hymenoptera (5.63%), and Odonata (5.46%) respectively. The Lowest percentage of insect's order were found belong to Mantodae (3.48%), Diptera (1.51%), Blatodae (1.45%), Neuroptera (0.81%), Phasmatodae (0.52%) and Dermaptera (0.12%). Shannon and Weaver diversity index is (H') =2.045 while the evenness index is = 0.797. With this tremendous number of insect's orders, it can be concluded that the ecosystem's health of UiTM Mukah is at its optimum level thus providing a prominent level of insects' biodiversity.

Keywords: Insect, biodiversity, tropical rainforest, diversity index, Mukah

INTRODUCTION

Tropical rainforests are often thought of as an extremely diversified plant population; indeed, it has a range of species richness that far outstretches the range found in temperate region due to extremely greater number of phytophagous insect species and plant species (Novotny *et al.* 2014; Norton & Didham 2007; Gaston, 2000; Becerra, 2015; Moreira *et. al* 2016; Zhang *et.al* 2016). It was first recognised by Wallace (1869) in his expedition to the Malay Archipelago where he never enjoyed collecting so much insect samples during his twelve years expedition in the western and eastern tropics except in Borneo Island. In modern world, Malaysia has been recognized as the 17 mega-diverse countries in the world along with Madagascar, India, Peru, Ecuador, Venezuela, Mexico, China, Indonesia, Australia, The Democratic Republic of Congo, Papua New Guinea, Philippines, South Africa, United States, Colombia and Brazil (White and Martin, 2002). Despite being declared as one of the 17 mega-diverse countries in the world, there are still some areas which have not been explored yet. Therefore, with the previous records on higher diversity of insect in Borneo (Kato *et al.,* 1995; Nagamitsu and Inoue, 1997) it will be a fascinating experience to explore it further especially in UiTM Sarawak Branch, Mukah Campus – a resort campus which coincidently located in the middle of a tropical forest and surrounded by lowland dipterocarp forest. In addition, the topographical aspect which is the aquatic ecosystem constitutes one third of UiTM Mukah which will provide a comprehensive inventory of both terrestrial and aquatic insects thus providing overall insect diversity's assessment.

Diversity is often defined as the variety of all forms of life from the level of genes to species through broad scale of ecosystem (Purvis & Hector, 2000; Rasmann & Mooney, 2016). Diversity is a contraction of "Biological Diversity", coined in 1985, with the new term as "Biodiversity". In fact, biodiversity used to mean "life" or "wilderness" or other "conservation" value which is linked with "variation" and "value" (Hamilton, 2005). Biodiversity study of insect is focused directly on the variations at the species of insects. Employing different methods of sampling is crucial to provide a comprehensive data on insect diversity where insecticides fogging types of sampling, information on insect host-plant relationship as well as food web studies in the ecosystem will justify the degree of species diversity in one area (Godfray *et al.,* 1999). Shannon and Wiener Index of species diversity are commonly used to ascertain the species diversity (Izsák & Papp, 2000). Assessment of species diversity should focus on species richness, species abundance and species evenness (Spellerberg & Fedor, 2003).

There are numerous records on insect species research conducted in university campus (Stoll, 1995) but it focuses specifically on one order of species such as Lepidopera (butterfly and moth) (Tiple *et al.,* 2005; Tiple *et al.,* 2007; Tiple *et al.,* 2009; Ramesh *et al.,* 2010), hymenoptera (Alves-dos-Santos, 2003;) and diptera (Senthamarai & Jebanesan, 2014) thus providing lack on overall assessment of insect species. Overall ecosystem assessment is vital to determine species diversity since every insect species is related to each other whether directly or indirectly, whether as pollinator agents, natural enemies or pest species (Price *et al.,* 1980). The differences of insects' roles in ecosystem is because of the vegetational diversity (Letourneau, 1983) and variation in landscape whether the areas are in the urban, forest or farmland sites (Baldock *et al.,* 2015).

Significant efforts should be done to preserve natural flora and fauna of an ecosystem in the university thus offering extraordinary opportunities for student learning (Eagan, 1992). University contributed a lot in insect studies where farmers and university researchers cooperated actively in determining control strategies for insect pest outbreak (Stoll, 1995). However, the identification of insect species should be done initially before efficient decision-making in control strategies can be made especially when the invasion of alien species happens without warning (Kenis *et al.,* 2007; Neumann *et al.,* 2016). There are still many insect groups that were poorly studied in Malaysia with exceptions for attractive species such as butterflies, moth and stick insects, agricultural important insects as well as forestry-important groups of insects (Cheng & Kirton, 2005). Therefore, research on insect diversity should consider to include the overall assessment of insect groups because each insect species contributed either directly or indirectly in the ecosystem such as effective pollinators of diverse plants species and valuable biological indicator to monitor ecosystem disturbance and habitat fragmentations. Therefore, a standardised insect inventories and catalogues from this study are useful not only to the management and the students, but also to the public who have vast interest in the fascinating world of insect.

METHODOLOGY

Sampling sites

This research was carried out in UiTM Sarawak Branch, Mukah Campus which is located at 2°51'43" N and 112°1'40" E respectively. This campus is a resort campus where it covers 500 acres of land including an area which has not yet established with a diversified ecosystem. Insects' species were collected randomly in three different areas within UiTM Sarawak consisting of college residential area, aquatic ecosystem and aqua and agrotech park.

Figure 1: UiTM Sarawak Branch, Mukah Campus surrounded with lowland dipterocarp forest. Source: RECODA (2016)

Insect sampling

Insects sampling were carried out with four distinct types of trapping techniques such as yellow pan water trap, pitfall trap, insect light traps-fitted with mercury vapour 160w bulb, aspirators and sweeping net. Insects' trapping was carried out from December 2015 – March 2016, June 2016 – October 2016 and December 2016 – April 2017 where it took into considerations the variation of weather patterns during the study period to reduce the bias of the samplings. The selection of trapping points in each sampling point is done randomly, considering the different habitats of insect such as near to aquatic ecosystem, next to residential areas and adjacent to forest area.

Insect preservation and handling

The insect specimens collected were deposited in Entomology Laboratory, Faculty of Plantation and Agrotechnology UiTM Sarawak Branch, Mukah Campus for sorting out and morphological observation to identify the orders. Secondary sorting process was done by separating the specimens into different orders and taxonomic levels. The insect samples were dried and pinned with different pin sizes according to different insects' order. All dried insect samples then stored systematically according to the Orders of insect in the insect collection box for future references.

Analysis of Data

Insect identification

Morphological identification technique was done by determining its taxon level such as its Order, Family, Genus and finally its species with the aids of Dichotomous Key as well as with various references materials such as Hill & Abang (2010), McGavin (2010), Tang *et al.* (2010), Abang (2006), Chung (2006), Braack (1997) and many more references. Furthermore, each insect specimen was photographed for record purposes and future references.

Shannon-Wiener Index of Diversity (H')

There are numerous diversity indexes developed by ecologist and mathematicians to measure the diversity in a particular habitat and ecosystem. There are three measurements of diversity- species diversity, species richness and species evenness. Species diversity refers to different number of species and the number of individual of each of them in one community while species richness refers to the present of distinct species in one area. The richness of an area is positively correlated with the present of species where the more species present, the richer the area is. However, 99.9% of similar species is not considered as an overall indicator for the species diversity. The species richness alone is not comprehensive in determining the diversity of area. Therefore, it should be complemented together with the evaluation of species evenness. Species evenness is referring to the uniformity of the distinct species distribution. (Purvis & Hector, 2000). In addition, assessment of species diversity should focus on species richness, species abundance and species evenness (Spellerberg & Fedor, 2003). Shannon and Wiener Index of species diversity is commonly used to ascertain the species diversity (Izsák & Papp, 2000). According to Spellerberg & Fedor (2003), Shannon and Wiener Index can be calculated with the following formula;

where:

Shannon-Wiener Index of Diversity (H’) $\mathbf{H} = \sum_{i=1}^{S} p_i\,(1\mathrm{n})\,p_i$

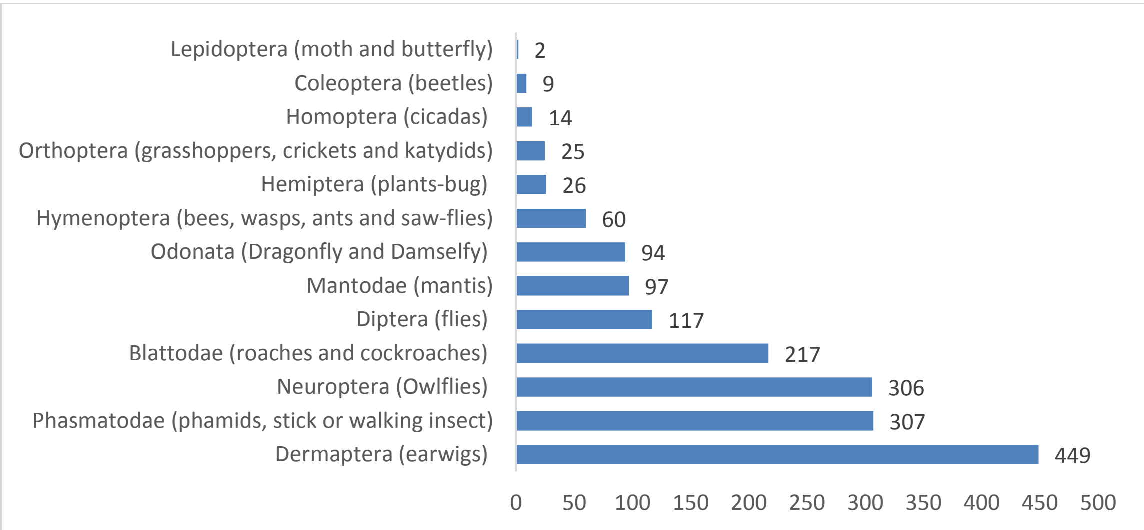
H = the Shannon-Wiener Index of Diversity
$\boldsymbol{P_i}$ = fraction of the entire population made up of species i
S = numbers of species
$\sum$ = sum from species 1 to species S

RESULT AND DISCUSSION

Major Insect Orders in UiTM Mukah

A total of 13 different orders of insects were collected and identified during the period of study. The following orders and number of insects for each insect orders were observed: Lepidoptera (moth and butterfly): 449, Coleoptera (beetles): 307, Homoptera (Cicadas and Planthoppers): 306, Orthoptera (grasshoppers, crickets and katydids): 217, Hemiptera (plants-bug): 117, Hymenoptera (bees, wasps, ants and saw-flies): 97, Odonata (Dragonfly and Damselfly): 94, Mantodae (mantis): 60, Diptera (flies): 26, Blatodae (roaches and cockroaches): 25, Neuroptera (Owlflies): 14, Phasmatodae (phamsids, stick insect or walking insects): 9 and Dermaptera (earwigs): 2. The total number of insects recorded in this study are illustrated in Figure 2 below.

Figure 2: The Total Number of Insects Trapped based on Insect Order in UiTM Mukah



Percentage of Insect’s Orders in UiTM Mukah

The following percentages of insect’s orders were recorded in UiTM Mukah. The highest percentage of insect’s orders was recorded from order of Lepidoptera (moth, butterfly and skippers): 26.06%, Coleoptera (beetles): 17.82%, Homoptera (cicadas and planthoppers): 17.76%, Orthoptera (grasshoppers, crickets and katydids): 12.59%, Hemiptera (plants-bug): 6.79%, Hymenoptera (bees, wasps, ants and saw-flies): 5.63%, Odonata (dragonfly and damselfly): 5.46% respectively. Lowest percentages of insect’s order were found belong to Mantodae (mantis): 3.48%, Diptera (flies): 1.51%, Blatodae (roaches and cockroaches): 1.45%, Neuroptera (owlflies): 0.81%, Phasmatodae (phamsids, stick insect or walking insects): 0.52% and Dermaptera (earwigs): 0.12%. Total percentages of these insect orders are presented in Table 1 below.

Table 1: Total number of insects and the percentage of insect order in UiTM Mukah

No.	Insect Order	Total	Percentage
1.	Lepidoptera (moth and butterfly)	449	26.06%
2.	Coleoptera (beetles)	307	17.82%
3.	Homoptera (cicadas)	306	17.76%
4.	Orthoptera (grasshoppers, crickets and katydids)	217	12.59%
5.	Hemiptera (plants-bug)	117	6.79%
6.	Hymenoptera (bees, wasps, ants and saw-flies)	97	5.63%
7.	Odonata (Dragonfly and Damselfy)	94	5.46%

8.	Mantodae (mantis)	60	3.48%
9.	Diptera (flies)	26	1.51%
10.	Blattodae (roaches and cockroaches)	25	1.45%
11.	Neuroptera (Owlflies)	14	0.81%
12.	Phasmatodae (phamids, stick or walking insect)	9	0.52%
13.	Dermaptera (earwigs)	2	0.12%
	Overall insects recorded	**1723**	**100%**

Shannon-Wiener Index of Diversity (H') and Species Evenness

Overall insects' numbers in the study area showed moderate result in diversity index value as shown in Table 2 where Shannon-Wiener Index of Diversity (H') = 2.045. General diversity index value is in the range of 1.5 – 3.50 where the values is increasing as it is positively related to the richness and evenness index of the community (Chung *et al.*, 2016)**.** Despite the moderateness in diversity index (H), the species evenness calculated showed also showed moderate value as indicated with 0.797. The diversity index recorded in UiTM Mukah was lower than other areas in Borneo such as those recorded by Chung *et al.*, (2016) and other part of the world as compared to Perry *et al.,* (2016).

Table 2: Shannon-Wiener Index of Diversity (H') and Species Evenness in UiTM Mukah

No.	**Insect Order**	**(n)**	**n/N (Relative abundance)**	**ln(n/N)**	**n/N*ln(n/N**
1	Lepidoptera	449	0.261	-1.345	-0.350
2	Coleoptera	307	0.178	-1.725	-0.307
3	Homoptera	306	0.178	-1.728	-0.307
4	Orthoptera	217	0.126	-2.072	-0.261
5	Hemiptera	117	0.068	-2.690	-0.183
6	Hymenoptera	97	0.056	-2.877	-0.162
7	Odonata	94	0.055	-2.909	-0.159
8	Mantodae	60	0.035	-3.357	-0.117
9	Diptera	26	0.015	-4.194	-0.063
10	Blattodae	25	0.015	-4.233	-0.061
11	Neuroptera	14	0.008	-4.813	-0.039
12	Phasmatodae	9	0.005	-5.255	-0.027
13	Dermaptera	2	0.001	-6.759	-0.008
	N	1723			
	Species Richness (S):	13			
	Number of Individuals (N):	1723			
	Shannon-Wiener Index of Diversity (H'):	2.045			
	Species Evenness (H'/ln(S)):	0.797			

Insect diversity and ecosystem services

Lepidoptera was found to be the dominant insect's order in UiTM Mukah with more than 26% of overall insect. Oil palm and sago plantation and lowland dipterocarp tropical forest surrounded UiTM Mukah is identified as the key factors for high number of lepidoptera recorded. Most of the lepidoptera is regarded as insect pest especially during larval stages. In addition, the number of moth species was recorded higher than butterflies in the study area. The presence of Coleoptera as the second highest insect orders with more than 17% of overall insect is also related to the oil palm plantation and lowland dipeterocarp tropical forest. UiTM Mukah is developed from peat swamp area. Apart from regarded as insect pest, Coleoptera also important in decomposition process and nutrient cycling. With tremendous amount of organic material in peat soil, it becomes the source of breeding place for most of coleopteran species. Insect diversity is positively related to the diversity of plants and vegetation area. The variation of habitat in UiTM Mukah which is surrounded by lowland dipterocarp tropical forest and aquatic ecosystem offers high diversity of insects. Furthermore, the presence of agropark with cultivated area of economic crops such as oil palm and ornamental plants also contributed to the prominent level of insect diversity in UiTM Mukah. The higher the insect diversity index shows, the better the functioning of the ecosystem health and services. The ecosystem services including nutrient cycling

(Coleoptera and Diptera), pollination (Lepidoptera and Hymenoptera), pest control (the natural enemies of predators: Mantodae and parasitoid: Hymenoptera) and environmental monitoring such as aquatic biological indicators with Odonata species. Even though the diversity index recorded in UiTM Mukah was moderate, all the important orders in ecosystem services were present in the study showing balanced coexistence of pollinator agents, decomposers and nutrient cycling, and the relationship of prey and predators in food chain. Current land used, habitat fragmentation and disturbance greatly affected number of insect species in UiTM Mukah and its surrounding area. Thus, environmental conservation is required for future sustainability in biodiversity.

CONCLUSION

This study successfully recorded a total of 13 important orders of insects found in UiTM Mukah with 1723 insects' inventory. The insect orders were Lepidoptera, Coleoptera, Homoptera, Orthoptera, Hemiptera, Hymenoptera, Odonata, Mantodae, Diptera, Blatodae, Neuroptera, Phasmatodae and Dermaptera. The presence of countless number of insects' orders with balanced coexistence of pollinators' agent, decomposers, prey and predators both terrestrial and aquatic insect orders showed healthy ecosystem services. In addition, Shannon and Weaver diversity index value is considered moderate with (H)=2.045 while the evenness index = 0.797. The presence of distinctive number of insects is influenced by the abiotic and biotic factors of surrounding area as well as within the study area such as the species of lowland dipeterocarp forest, economics crop and plantation area and other types of vegetation which supplied food and shelter for the insects. With this tremendous number of insect orders, it can be concluded that, the Universiti Teknologi MARA, Sarawak Branch, Mukah Campus is a house for insect diversity therefore shows that the ecosystem's health of UiTM Mukah is at its optimum level and provides prominent level of insect biodiversity. With the limitation of expertise in taxonomist in this study and the time constraint especially in the species identification, further efforts will be needed to increase the sampling areas. It is hoped that, this study provided the data needed for the conservation and improvement of the environment in the future. For future studies, identification of overall species is important for conservation purposes to determine the endemic species and endangered species in the study area in line with the Malaysian Convention on Biological Diversity (CBD).

ACKNOWLEDGEMENT

This research was funded with *Dana Kecemerlangan* / Excellence Fund 2016 with Reference No. 600-RMU/DANA5/3 (4) (2016). The authors would like to acknowledge Research Management Unit (RMU) of Universiti Teknologi MARA Cawangan Sarawak for the opportunities given.

REFERENCES

Abang, F. (2006). *Butterflies of Malaysian Borneo: A Pocket Guide*. Universiti Malaysia Sarawak.

Alves-dos-Santos, I. (2003). Trap-nesting bees and wasps on the university campus in Sao Paulo, southeastern Brazil (Hymenoptera: Aculeata). *Journal of the Kansas Entomological Society*, 328-334.

Baldock, K. C., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M., & Vaughan, I. P. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society of London B: Biological Sciences*, *282* (1803), 20142849.

Becerra, J. X. (2015). On the factors that promote the diversity of herbivorous insects and plants in tropical forests. *Proceedings of the National Academy of Sciences*, *112*(19), 6098-6103.

Braack, L. E. O. (1997). *Fascinating Insects of Southeast Asia.* Times Editions.

Cheng, S., & Kirton, L. G. (2005). Overview of insect biodiversity research in Peninsular Malaysia. In Status of biological diversity in Malaysia and threat assessment of plant species in Malaysia. *Proceedings of the Seminar & Workshop* (pp. 28-30).

Chung, A. Y. (2006). *Biodiversity and conservation of the Meliau Range: a rain forest in Sabah's ultramafic belt*. Natural History Publ.

Chung, A. Y. C., Chew, S. K. F., Majapun, R., & Nilus, R. (2013). Insect diversity of Bukit Hampuan Forest Reserve, Sabah, Malaysia. Journal of Threatened Taxa, 5(10), 4461-4473.

Chung, A. Y., Bosuang, S., Majapun, R., & Nilus, R. (2016). Diversity and Geographical Ranges of Insects in Crocker Range Forest Reserve, Sabah, Malaysia. *Journal of Tropical Biology & Conservation (JTBC)*, *13*.

Eagan, D. J. (1992). Campus environmental stewardship. New Directions for Higher Education, 1992(77), 65-76.

Gaston, K. J. (2000). Global patterns in biodiversity. *Nature,* 405(6783), 220-227.

Godfray, H. C. J., Lewis, O. T., & Memmott, J. (1999). Studying insect diversity in the tropics. Philosophical Transactions of the Royal Society B: *Biological Sciences*, 354(1391), 1811-1824.

Hamilton, A. J. (2005). Species diversity or biodiversity? *Journal of Environmental Management*, 75(1), 89-92.

Hill, D. S., & Abang, F. (2010). *The insects of Borneo (including South-east Asia).* Universiti Malaysia Sarawak.

Izsák, J., & Papp, L. (2000). A link between ecological diversity indices and measures of biodiversity. *Ecological Modelling*, 130(1), 151-156.

Kato, M., Inoue, T., Hamid, A. A., Nagamitsu, T., Merdek, M. B., Nona, A. R., ... & Yumoto, T. (1995). Seasonality and vertical structure of light-attracted insect communities in a dipterocarp forest in Sarawak. *Researches on Population Ecology*, 37(1), 59-79.

Kenis, M., Rabitsch, W., Auger-Rozenberg, M. A., & Roques, A. (2007). How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of entomological research*, 97(05), 489-502.

Letourneau, D. K. (1983). *The effects of vegetational diversity on herbivorous insects and associated natural enemies: Examples from tropical and temperate agroecosystems*. University of California, Berkeley.

McGavin, G. C. (2010). Insects. Dorling Kindersley Ltd.

Moreira, X., Abdala-Roberts, L., Rasmann, S., Castagneyrol, B., & Mooney, K. A. (2016). Plant diversity effects on insect herbivores and their natural enemies: current thinking, recent findings, and future directions. Current Opinion in Insect Science, 14, 1-7.

Nagamitsu, T., & Inoue, T. (1997). Cockroach pollination and breeding system of Uvaria elmeri (Annonaceae) in a lowland mixed-dipterocarp forest in Sarawak. *American Journal of Botany*, 84(2), 208-208.

Neumann, G., O'Dowd, D. J., Gullan, P. J., & Green, P. T. (2016). Diversity, endemism and origins of scale insects on a tropical oceanic island: Implications for management of an invasive ant. *Journal of Asia-Pacific Entomology*.

Norton, D. A., & Didham, R. K. (2007). Comment on" Why Are There So Many Species of Herbivorous Insects in Tropical Rainforests?". *Science*, 315(5819), 1666-1666.

Novotny, V., Drozd, P., Miller, S. E., Kulfan, M., Janda, M., Basset, Y., & Weiblen, G. D. (2006). Why are there so many species of herbivorous insects in tropical rainforests? *Science*, 313(5790), 1115-1118.

Perry, J., Lojka, B., Quinones Ruiz, L. G., Van Damme, P., Houška, J., & Fernandez Cusimamani, E. (2016). How natural Forest Conversion Affects Insect Biodiversity in the Peruvian Amazon: Can Agroforestry Help? *Forests*, 7(4), 82.

Price W.T., (1997). *Insect Ecology* (3rd ed.). New York: A John Wiley & Sons, Ltd., Publication

Price, P. W., Bouton, C. E., Gross, P., McPheron, B. A., Thompson, J. N., & Weis, A. E. (1980). Interactions among three trophic levels: Influence of plants on interactions between insect herbivores and natural enemies. *Annual Review of Ecology and systematics*, 41-65.

Purvis, A., & Hector, A. (2000). Getting the measure of biodiversity. *Nature*, 405(6783), 212-219.

Ramesh, T., Hussain, K. J., Selvanayagam, M., Satpathy, K. K., & Prasad, M. V. R. (2010). Patterns of diversity, abundance and habitat associations of butterfly communities in heterogeneous landscapes of the department of atomic energy (DAE) campus at Kalpakkam, South India. *International Journal of Biodiversity and Conservation*, 2(4), 75-85

Rasmann, S., & Mooney, K. A. (2016). Editorial overview: Ecology: The studies of plant–insect interaction—approaches spanning genes to ecosystems. *Current Opinion in Insect Science*.

RECODA. (2017). Sarawak SCORE Mukah Smart City. Retrieved May 30, 2017, from http://www.recoda.com.my/dev/recoda-2016/score-areas/sarawak-score-mukah/

Senthamarai Selvan, P., & Jebanesan, A. (2014). Survey and epidemiology of tree hole breeding mosquitoes in Annamalai University campus, Tamilnadu, India. *Int J Curr Res*, 6(5), 6462-5.

Spellerberg, I. F., & Fedor, P. J. (2003). A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon–Wiener'Index. *Global ecology and biogeography,* 12(3), 177-179.

Stoll, S. (1995). Insects and institutions: University science and the fruit business in California. *Agricultural History,* 216-239.

Tang HB, Wang LK, Hamalainen M. (2010). *A photographic guide to the dragonflies of Singapore*. The Raffles Museum of Biodiversity Research, Singapore

Tiple, A. D., & Khurad, A. M. (2009). Butterfly species diversity, habitats and seasonal distribution in and around Nagpur City, central India. *World Journal of Zoology*, 4(3), 153-162.

Tiple, A. D., Deshmukh, V. P., & Dennis, R. L. (2005). Factors influencing nectar plant resource visits by butterflies on a university campus: implications for conservation. *Nota lepidopterologica,* 28(3/4), 213.

Tiple, A., Khurad, A. M., & Dennis, R. L. (2007). Butterfly diversity in relation to a human-impact gradient on an Indian university campus. *Nota lepidopterologica,* (30), 81-90.

Wallace, A. R. (1869). *The Malay Archipelago: The Land of the Oranguatan, and the Bird of Paradise. A Narrative of Travel, with Studies of Man and Nature*. Harper & Brothers.

White, A., & Martin, A. (2002). Who owns the world's forests? *Forest Trends*, Washington, DC.

Zhang, K., Lin, S., Ji, Y., Yang, C., Wang, X., Yang, C., & Douglas, W. Y. (2016). Plant diversity accurately predicts insect diversity in two tropical landscapes. bioRxiv, 040105.