UNIVERSITI PUTRA MALAYSIA

INSECT COMPOSITION OF SUNGAI CHUKAI MANGROVE FOREST IN TERENGGANU, MALAYSIA BASED ON SELECTED SAMPLING MRTHODS

RAJA NURUL NADIA BINTI RAJA ALANG

FP 2015 56

INSECT COMPOSITION OF SUNGAI CHUKAI MANGROVE FOREST IN TERENGGANU, MALAYSIA BASED ON SELECTED SAMPLING MRTHODS

By

RAJA NURUL NADIA BINTI RAJA ALANG

Thesis Submitted to the School of Graduate Studies,Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

December 2015

COPYRIGHT

DEDICATION

This Master Research Thesis is dedicated to:

My beloved parents, Mr. Raja Alang Bin Raja Abd. Jalil and Mrs. Robaiyah Binti Muhammad. Also, to my late grandparents, you will always be in my memory.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Master of Science

INSECT COMPOSITION OF SUNGAI CHUKAI MANGROVE FOREST IN TERENGGANU, MALAYSIA BASED ON SELECTED SAMPLING METHODS

By

RAJA NURUL NADIA BINTI RAJA ALANG

December 2015

Chairman : Associate Professor Nur Azura Binti Adam, PhD
Faculty : Agriculture

Insects are one of the most abundant organisms on earth and can be found almost everywhere in any types of ecosystem. However, their abundance in mangrove forest are hardly reported. In Malaysia, the study of insect in mangrove habitat is very crucial and most of the database were recorded in other regions. Therefore, the mangrove forest in Sungai Chukai, Kemaman, Terengganu was chosen as the study site and the area also has considered threatened due to the rapid development. This study was conducted to compare the abundance of insects in different zones, to determine the functional feeding group of insects, to compare the diversity of insects and lastly to investigate the relationship of abiotic factors with the abundance of insects in Sungai Chukai mangrove. The sampling activities were done in three times and four zones of the study area along Sungai Chukai were determined according to environmental factors and accessibility to the forest floor. A Malaise trap and three yellow pan traps were installed for three days and the samples were collected on the fourth day. As a result, 7772 of individuals insects comprising of 16 orders and 123 families were identified and the most abundance was recorded from the order of Diptera with 4072 of individuals (52.39%). While, the lowest individuals were recorded in three orders, namely; Dermaptera (0.01%), Microcoryphia (0.01%) and Neuroptera (0.01%), with one individual respectively. The number of individuals between the order of insects was significantly different ($P<0.05$) where the order of Diptera had shown the differences between the order of Dermaptera, Microcoryphia, Neuroptera, Mantodea, Odonata and Isoptera. The dominant of Diptera in Sungai Chukai was due to the type of traps applied which focused on flying insect and mangrove as the habitat preferences of flies itself. Furthermore, according to zonation, the insects were most abundant in Zone 3 (37.16%), and the lowest was recorded in Zone 2 (18.99%). The abundance of insect according to zonation also had showed sigificantly different between Zone 1 and Zone 3 ($P<0.05$). The differences occured due to the compact distribution of the vegetation and high diversity of flora provides sufficient food for the insects in Zone 3 compared with the othe zones. Besides, the diversity of insects along the riverine of Sungai Chukai mangrove was quite diverse with the H' value was 3.41 and 0.71 for the evenness. For the similarity, Zone 1 was very dissimilar with the other zones due to the forest structure and also high level of disturbance which caused the difference of insect composition. However, the abiotic

factors such as temperature, humidity and rainfall are not showing strong relationship with the abundance of insects. In conclusion, the composition of insect in Sungai Chukai are quite diverse since 16 orders from overall orders were recorded within the forest. Besides, due to forest disturbances, the diversity of insects was decreased during the study periods. Therefore, further action must be taken to conserve the insects and other flora and fauna before we lost the precious biodiversity in Sungai Chukai.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KOMPOSISI SERANGGA HUTAN PAYA BAKAU SUNGAI CHUKAI DI TERENGGANU, MALAYSIA BERDASARKAN KAEDAH PERSAMPELAN TERPILIH

Oleh

RAJA NURUL NADIA BINTI RAJA ALANG

Disember 2015

Pengerusi : Professor Madya Nur Azura Binti Adam, PhD
Fakulti : Pertanian

Serangga adalah salah satu daripada organisma yang paling banyak di dunia dan boleh didapati hampir semua jenis ekosistem. Walau bagaimanapun, serangga yang terdapat di dalam hutan paya bakau tidak banyak dilaporkan. Di Malaysia, kajian mengenai serangga di habitat bakau adalah tidak banyak dan kebanyakkan pangkalan data telah direkodkan di kawasan hutan yang lain. Oleh itu, hutan bakau di Sungai Chukai, Kemaman, Terengganu telah dipilih sebagai kawasan kajian dan kawasan ini juga dianggap terancam akibat pembangunan yang pesat. Berikutan hal ini, terdapat empat objektif telah dicadangkan untuk kajian iaitu untuk membandingkan kelimpahan serangga di dalam zon yang berbeza, untuk menentukan kumpulan fungsi makanan serangga, untuk membandingkan kepelbagaian serangga dan akhir sekali untuk menyiasat hubungan antara faktor-faktor abiotik dengan kelimpahan serangga dalam hutan bakau Sungai Chukai. Aktiviti persampelan ini telah dijalankan sebanyak tiga kali dan 4 kawasan penzonan di sepanjang Sungai Chukai sebagai kawasan kajian telah ditentukan berdasarkan faktor persekitaran iaitu jenis tumbuhan dan tahap kemasinan air sungai dengan tiga plot bagi setiap zon. Pada setiap plot, satu perangkap Malaise dan tiga perangkap besen kuning telah dipasang selama tiga hari. Sebanyak 7772 individu serangga yang terdiri daripada 16 order dan 123 keluarga telah dikenal pasti dan yang paling banyak direkodkan adalah terdiri daripada order Diptera dengan 4072 individu (52.39%). Walaubagaimanapun, terdapat serangga yang dilaporkan paling rendah, iaitu; Dermaptera (0.01%), Microcoryphia (0.01%) dan Neuroptera (0.01%), dengan diwakili satu individu sahaja bagi setiap order. Bilangan individu mengikut order adalah jauh berbeza ($P<0.05$) di mana order Diptera telah menunjukkan perbezaan diantara order Dermaptera, Microcoryphia, Neuroptera, Mantodea, Odonata dan Isoptera. Perbezaan Diptera dengan order yang lain adalah disebabkan penggunaan perangkap yang lebih tertumpu kepada serangga bersayap dan hutan bakau merupakan habitat pilihan bagi serangga tersebut. Tambahan pula, berdasarkan zon, bilangan serangga yang paling banyak direkodkan adalah dalam Zon 3 (37.16%), dan yang paling rendah dari Zon 2 (18.99%). Terdapat perbezaan kelimpahan serangga antara Zon 3 dan juga Zon 1. Perbezaan yang berlaku adalah disebabkan kerana taburan tumbuhan yang lebih padat dan kepelbagain flora yang tinggi yang dapat menyediakan sumber makanan yang

mencukupi untuk serangga di Zon 3 daripada zon lain. Kepelbagaian serangga di sepanjang sungai Sungai Chukai agak tinggi dengan nilai H' adalah 3.41 dan 0.71 untuk keserataan spesis. Selain itu, Zon 1 dikenalpasti berbeza dengan zon-zon lain atas faktor lokasi, struktur hutan dan juga tahap gangguan yang telah menyebabkan perbezaan komposisi serangga. Walau bagaimanapun, faktor-faktor abiotik seperti suhu, kelembapan relatif dan hujan tidak menunjukkan hubungan yang kuat dengan bilangan serangga. Kesimpulannya, komposisi serangga di Sungai Chukai adalah pelbagai memandangkan 16 order daripada 32 keseluruhan order dicatatkan daripada hutan ini. Selain itu, disebabkan oleh pencerobohan hutan, kepelbagaian serangga telah menurun semasa tempoh kajian dijalankan. Oleh itu, tindakan lanjut perlu diambil untuk memulihara serangga serta flora dan fauna yang lain.

ACKNOWLEDGEMENTS

In the name of God, the most gracious, the most compassionate.

First of all, I am very grateful towards the God because without His blessing and the opportunity given, I will never complete my master degree and also the finalization of this thesis. The completion of this thesis would have not been possible without the supervision, guidance and valuable support from my supervisor, Associate Professor Dr Nur Azura Adam and co-supervisor, Professor Rita Muhamad Awang throughout this study.

My sincere thanks goes to Dr. Nor Rasidah Hashim and Miss Wan Faridah Akmal Wan Jusoh for the brainstorming and help prior to the study conducted.

Special thanks also will goes to all laboratory staff, Mr. Hishamuddin Zainuddin and Mr. Fadhullah Abd. Aziz, and also the Research Asisstants, Mr. Audi Jamaluddin, Mr. Neo Wei Xuan, Mr. Mustafa Jabar and Mr. Azmir from Faculty of Agriculture for their help and effort during the fields and laboratotory work.

I also would like to express my gratitude to my parents, Raja Alang Raja Abd. Jalil and Robaiyah Mohamad for supporting and inspiration throughout my hectic lifetime that contributed to the finalization of this thesis.

To my spouse, Muhd Ariffin Mansor thank you for being there when I need the advices and moral supports. Also, my friends, Ms. Marina Roseli and Mr. Mohd Amar Zaudi, thank you for your knowledges and information given. Special appreciation also means to all of my acquaintances and other family members, thanks to all of you again.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Nur Azura Binti Adam, PhD
Associate Professor
Faculty of Agriculture
University Putra Malaysia
(Chairman)

Rita Muhamad Awang, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Nor Rasidah Hashim, PhD (Resign)
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustration and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____Date:_____

Name and Matric No: Raja Nurul Nadia Binti Raja Alang, GS29044

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: Associate Professor Dr. Nur Azura Binti Adam

Signature: _____
Name of Member of Supervisory Committee: Professor Dr. Rita Muhamad Awang

Signature: _____
Name of Member of Supervisory Committee: Dr. Nor Rasidah Hashim (Resign)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHC	Agglomerative Hierarchical Clustering
FAO	Food and Agriculture Organization
GPS	Global Positioning System
MT	Malaise Trap
RH	Relative Humidity
TS	Time of Samplings
YPT	Yellow Pan Trap

CHAPTER 1

INTRODUCTION

Mangrove forest is a group of trees and shrubs that capable of growing in marine, estuarine and to a limited degree of fresh water (Stewart and Fairfull 2008). It also has been classified as a taxonomically diverse group of tropical trees which can be found in the tropical and subtropical areas and they are very important in protected the coastline against shoreline erosion, provide the source of firewood or charcoal and building materials (Latiff 2012). Not forgotten, mangroves also important for the activity of aquaculture such as shrimp and fish farming.

Ecologically, various species of organisms depend on the existence of mangrove. Even though mangrove has been neglected and classified as a less diverse ecosystem (Stewart and Fairfull 2008), the occurrences of mangrove are remarkable as its provided important breeding spot for some mammals, reptiles, crustaceans, birds and also the insects (Wan Jusoh et al. 2010, Nagelkerken et al. 2008). The saltwater surface and mudflats on mangrove forest is beneficial to supply an essential habitat for aquatic and semiaquatic insects, including species representing several families of Diptera, Hemiptera, Odonata, and Coleoptera (Gallagher 2010). Besides, the canopy of mangroves also provides a shaded area suitable with the temperature and humidity to support numerous subratidal habitats for insect herbivores (McKeon and Feller 2004).

Nowadays, there are numerous studies on insect have been conducted worldwide in many types of habitats or ecosystems. Studies in the rain forests of the tropics are rapidly conducted and has triggered interest amongst entomologists worldwide. Unfortunately, mangrove entomology has remained as a neglected field of study. The study of the insect fauna of mangroves somehow has failed to evoke sufficient interest of some entomologist and ecologist (Veenakumari et al. 1997).

Mangrove ecosystem also has been identified as one of the most threatened ecosystem in the world which suffered from deforestation and human impact (Schimtz et al. 2010). The area of mangrove forest has been decreased and the area has been tranformed into development and industrial area. Besides, many organisms also have lost their natural habitat and the quality of the surrounding environment has been altered and reduced due to the forest destruction and pollution.

In Malaysia, the total of mangrove areas are around 642,000 hectares, which only 17% cover in Peninsular Malaysia, while the remaining 57% are found in Sabah and another 26 % in Sarawak (Loo et al. 2003). However, the area of mangrove has been depleted and Malaysia had lost about 12% of its mangrove forest (Macintosh & Ashton 2002). Even though it is located within the tropical climate and also has been listed as one of the 12th mega diverse country in the world, the data on insects composition in the mangrove forest especially in the East Coast of Peninsular Malaysia are very crucial.

Most of the data of insects in mangroves are recorded outside Malaysia. Despite of the gap to fulfill the data on insect community in mangrove habitats, the studies of these invertebrates are needed.

Hence, for the purpose of this study, a mangrove habitat in the riverine of Sungai Chukai which located in Kemaman mangrove forest has been favored as the study area. The surrounding area of Kemaman district, which are quickly getting into industrial and farming activity has been seen as unitary of the threats to the mangrove forests and its community (Jusoff 2008). A complete documentation on insect composition in this mangrove ecosystem is urgent before it loses. Therefore, it is also vital for future study on insect diversity and as a baseline for bioindicator approaches. As to complete the information and database on insects composition in Kemamman mangroves forest, there are four main objectives have been proposed for this study which are:

1. To compare the abundance of insects in different zones in Sungai Chukai mangrove forest.
2. To determine the functional feeding group of insects in Sungai Chukai mangrove forest.
3. To compare the diversity of insects in Sungai Chukai mangrove forest.
4. To investigate the relationship of abiotic factors with the insects abundance in Sungai Chukai mangrove forest.

REFERENCES

Alang, R.N.N.R., Jusoh, W.F.A.W., Nur-Zati,A.M. and Hashim, N.R. (2010). Ant diversity on *Sonneratia caseolaris* trees in Rembau-Linggi mangrove forest Peninsular Malaysia. *Transylvanian Revision Systematic Ecology Resources,* 10: 55-60.

Anynomous, (2013). Jalan-jalan Kuala Kemaman, Terengganu. http://jalanja.blogspot.my/2013/06/kuala-kemaman-terengganu.html. Retrieved on 16 August 2013.

Ananthakrisnan, T.N. and Sivaramakrishnan, K.G. (2008). Ecological entomology: Insect life in odd environment. India. Scientific Publisher.

Aslam, M. (2009). Diversity, species richness and evenness of moth fauna of Peshawar. *Pakistan Entomology*, 31(2): 99-102.

Balasubramanyan, K., Srinivasan, M. and Kathiresan, K. (2005). Insects proceedings of coastal biodiversity in mangrove ecosystems: UNU–INWEH–UNESCO, International Training Course (2005), pp. 359–363

Barkati, S. and Rahman, S. (2005). Species composition and faunal diversity at three sites of Sindh mangroves. *Pakistan Journal Zoology*, 37 (1): 17-31.

Bartlett, T. (2004). Identification, images, & information for insects, spiders & their kin for the United States and Canada, Iowa State University. http://bugguide.net/node/view/3128. Retrieved on 12 November 2014.

Basset, Y. (2001). Invertebrates in the canopy of tropical rain forest; how much do we really know?. *Plant Ecology*, 153: 87-107.

Burrow, D.W. (2003). The role of leaf on the mangroves *Avicennia Marina* and *Rhizophora Stylosa*. *(*Unpublished doctoral dissertation*)*. James Cook University, Australia.

Cannicci, S., Burrows, D., Fratini, S., Smith III, T.J., Offenberg, J. and Dahdouh-Guebas, F. (2008). Faunal impact on vegetation structure and ecosystem function in mangrove forests: A review. *Aquatic Botany*, 89: 186–200.

Casanava-Torres, A.M., Goodrich-Blair, H., (2013). Immune signaling and antimicrobial peptide expression in Lepidoptera – A review. *Insects*, 320-328.

Cheng, L. (2009). Marine insects. In *Resh, V.H. and Carde, R.T.(Ed), Enpsyclopedia of insects, 2nd edition.* Academic publishers, 600-605.

Cheng, S. and Kirton, L.G. (2007). Overview of insect biodiversity research in Peninsular Malaysia: Status of biological diversity in Malaysia and threat assessmant of plant species in Malaysia, Kuala Lumpur, Forest Research Institute of Malaysia, Malaysia. p.121-128.

Child, R.E. (2007). Insect damage as a function of climate. *In* Museum Microclimates, T. Padfield and K. Borchersen (eds.) National Museum of Denmark 2007, 57-60.

Choo, P.S. (1998). Marine Biodiversity in Malaysia: Understanding the diversity, threats, and conservation strategies, Third National Congress on Genetics, 18-19 November 1998.

Cotinis, (2003). Identification, image and information for insects, spiders and their kin for the United States and Canada, Iowa State University Entomology. (Retrieved from http://bugguide.net/node/view/9594 on 19 February 2013).

Decker, T. (2006). A Comparison **of** three types **of** insect traps for collecting non-Formicidae Hymenopera on the island **of** Dominica. *Southwestern Entomologis*,31(1): 59-68

Duke, N.C., Ball, M.C. and Ellison, J.C., (1998). Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology Biogegraphy Letters*, 7: 27-47.

El-Moursy, A., El-Hawagry, M., Abdeldayem, M. and Fadh, L. (2001). Insect diversity in Zaranik Protectorate, Northern Sinai, Egypt. *Egyptian Journal of National History,* 3: 62-80.

Farahi, S., Sadeghi, H. and Wittington A.E. (2009). Lacewings (Neuroptera: Chrysopidae & Hemerobiidae) from North Eastern and East provinces of Iran, *Munis Entomology and Zoology*. 4(2): 429-437.

Farnsworth, E.J. (1998). Issue of spatial, taxonomic and temperal scale in delineating links between mangrove diversity and ecosystem function. *Global Ecology Biogegraphy Letters,* 7: 15-25.

Fazal, S., Manzoor, F, and Abdul-Sattar, A. (2012). Impact of abiotic factors on insect diversity of at lawrence Garden, Lahore. *Pakistan Journal of Science,* 64(2): 127-137.

Finn, E. M. (2003). Robber flies (family: Asilidae), University of Florida, http://entnemdept.ufl.edu/creatures/beneficial/flies/robber_flies.htm. Retrieved on 29 April 2015.

Forero, D. (2008). The systematics of the Hemiptera. *Revista Colombiana de Entomología,* 34 (1): 1-21.

Frith, D.W. (1979). A twelve month study of insect abundance and composition at various localities on Aldabra atoll. *Philosophical Transaction of The Royal Society of London, Series B, Biological Sciences*, 286(1011): 119-126.

Galagher, B. (2010). *Bugs: Discover an amazing world*. United Kingdom: Miles Kelly Publishing Limited.

Ghosh, D. (2011). Mangroves: The most fragile ecosystem. *Resonance*, 47-56.

Giesen, W., Wulffraat, S., Zieren, M. and Scholten, L. (2007). Mangrove guidebook for Southeast Asia. FAO and Wetlands International. 1-186.

Gordh, G. and Headrick, D. (2011). *A dictionary of entomology, 2nd edition.* New York: CABI Publishing.

Govrilović, B.D., and Ćurčić, S.B. (2013). The diversity of the family chrysomelidae (Insecta:Coleoptera) of the Obedska Bara Special Nature Reserve (Vojvodina Province, Serbia), with special reference to the host plants. *Acta Zoologica Bulgarica*, 65(1): 37-44.

Grampurohit, B. and Karkhanis, H. (2013). Insect biodiversity at mangrove ecosystem. National Conference on Biodiversity: Status and Challenges in Conservation - 'FAVEO' 2013, 108-115.

Haddad, N.M., Tilman, T., Haarstad, J., Ritchie, M. and Knops, J.M.H. (2001). Contrasting effects of plant richness and composition on insect communities: A field experiment. *The American Naturalist*, 158(1): 17-35.

Hagstrom, D. J. (2006). Fly predators control flies in horse facilities. University of Illinois, U.S.A. Department of Agriculture/Local Extension Councils Cooperation, July, 1-2.

Hamer, K.C., Hill, J.K., Mustaffa, N., Benedick,S., Sherratt, T.N., Chey, V.K. and Maryati, M. (2005). Temporal variation in abundance and diversity of butterflies in Bornean rain forests: Opposite impacts of logging recorded in different seasons. *Journal of Tropical Ecology*, 21:417–425. doi:10.1017/S0266467405002361.

Harrison, I., Laverty, M., & Sterling, E. (2004, July 29). Alpha, Beta, and Gamma Diversity. Retrieved from the OpenStax QA Web site: http://legacy-textbook-qa.cnx.org/content/m12147/1.2/.

Heino, J. (2009). Biodiversity of aquatic insects: spatial gradients and environmental correlates of assemblage-level measures at large scales, *Freshwater Review*, 2 : 1-29.

Hill, D.S. and Abang, F. (2005). The insects of Borneo (Including South-East and East Asia). The Sarawak Press, Malaysia, 22. 354-364.

Hogarth, P.J. (1999). The biology of mangroves. Oxford University Press, New York.

Hollier, J.A. (2008). The barklice (Psocoptera) associated with an old-field sucession in Southern Britain. *Britain Journal of Entomology and National History*, 21: 143-148.

Hopkin, S. (2002). Collembola. Encyclopedia of Soil Science, Marcel Dekker Incorporation, University of Reading, UK, 207-210.

Human, K.G., Weiss, S., Weiss, A., Sandler, B. and Gordon, D.M. (1998). Effects of abiotic factors on the distribution and activity of the invasive Argentine ant (Hymenoptera: Formicidae). *Entomological Society of America and Environmental Entomology,* 27(4): 822-833.

Hutching, P. and Saenger, P. (1987). Ecology of mangroves. University of Queensland Press, Australia.

Idris, A.B., Hanidah, J., Gonzaga, A.D. and Nur Azura, A. (2003). Diversity, abundance, species composition and similarity of genus Xantopimpla (Ichneumonidae: Pimplinae) in logged and fragmented forest of the Langat Basin in Selangor, Malaysia. *Journal of Asia-Pacific Entomology*, 6(1): 55-62.

Idris, A.B., Nor, S.M. and Rohaida R. (2002). Study on diversity of insect community at different altitudes of Gunung Nuang in Selangor, Malaysia. *Journal of Biological Sciences*, 2 (7): 505-507.

Idris, A.B., Zaneedarwaty, N.N., Gonzaga, A.D., Zaidi, M.I., Aman, S., Salmah, Y. (2001). A study on four methods of sampling of Ichneumonidae and Braconidae at two different habitats of Fraser's Hill, Malaysia. *Pakistan Journal of Biological Science,* 4912): 1515-1517.

Jaworski, T. and Hilszczanski, J. (2013). The effect of temperature and humidity changes on insect development and their impact on forest ecosystem in the context of expected climate change. *Forest Research Papers*, 74 (4): 345–355. DOI: 10.2478/frp-2013-0033.

Jiang, G., Yan, Z. and Cen, M. (2000). Insect community and its diversity in Mangrove forest at Yingluo Bay of Guangxi. *Ying Yong Sheng Tai Xue Bao*, 11 (1): 95-80.

Jusoff, K. (2008). Managing sustainable mangrove forests in Peninsular Malaysia. *Journal of Sustainable Development*, 1:1, 88-96.

Jusoff, K. The Malaysian mangrove forests and their significance to the coastal marine environment, presented at the Marine Environmental Pollution Workshop, 25th May, 2012. Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia. 2012.

Kamaruzzaman, B.Y. and Ong, M.C. (2008). Recent sedimentation and sedimentation rates of Kemaman-Chukai mangrove forest, Terengganu, Malaysia. *American Journal of Agricultural and Biological Sciences* 3 (3): 522-525.

Khadijah A. R., Azidah A. A. and Meor S. R. (2013). Diversity and abundance of insect species at Kota Damansara Community Forest Reserve, Selangor. *Academic Journals*, 8(9): 359-374.

Khaliq, A., Javed, M., Sohail, M. and Sagheer, M. (2014). Environmental effects on insects and their population dynamics. *Journal of Entomology and Zoology Studies*, 2 (2): 1-7.

Kathiresan, K. (2000). A review of studies on Pichavaram mangrove, southeast India. *Hydrobiologia,* 430: 185–205.

Kathiresan, K. and Bingham, B.L. (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology*, 40, 81-251.

Kathiresan, K. (2002). Greening the blue mud. *Review on Biology Tropical*, 50: (3/4), 869-874.

Kathiresan, K. (2003). Insect foliovory in mangrove. *Indian Journal of Marine Sciences*, 32(3): 237-239.

Kimoto, S. (2005). Systematic catalogue of Chrysomelidae (Coleoptera) from Nepal and Bhutan. *Bulletin of Kitakyushu Museum of National History and Human History, Japan*. A(3): 13-114.

Kitching, R.L., Bergelson, J.M., Lowman, M.D., McIntyre, S. and Carrutthers, G. (1993). The biodiversity of arthropods from Australian rainforest canopies: general introduction, methods, sites and ordinal results. *Australian Journal of Ecology*, 18: 181-191.

Knight, W.J. (2010). Leafhoppers (Cicadellidae) of the Pacific. An annotated systematic checklist of the leafhoppers recorded in the Pacific region

during the period 1758 – 2000. http://www.tymbal.org/publicat/KnightCatalogue.pdf.

Kraemer, M.M.S. and Wagner, R. (2009). The first psychodid (Diptera:Psychodidae:Phlebotominae) species from the lower Eocene amber of vastan, Gujarat, India. *Zootaxa,* 6152 : 63-68.

Kvifte, G.M. (2011). Biodiversity study on Afrotropical moth flies (Diptera: Psychodidae), Master thesis in Biology-Biodiversity, Evolution and Ecology, University of Bergen, Uganda.

Lassau, C.A. and Hochuli, D.F. (2007). Associations between wasp communities and forest structure: Do strong local patterns hold across landscapes?. *Austral Ecology,* 32, 656–662.

Latiff, A. (2012). Conservation strategies for endangered mangrove swamp forest in Malaysia. *Pakistan Journal of Botany*, 44:27-36.

Lewis, O.T. and Basset, Y. (2007). Insect conservation in tropical forests. Chapter 2. In Stewart, A.J.A., New T.R. and Lewis O.T. (eds). *Insect Conservation Biology*: The Royal Entomological Society 2007. 34-56.

Loo, K.K., Saberi , O., Sidik, B.J. and Misri, K. (2003). The effect of salinity on germination of *Sonneratia caseolaris* seeds. *In*: Bujang J.S, Zakaria, M.H and Kawamura,A. (eds), p.145-151. Aquatic Resource and Environmental Studies of the Straits of Malacca: Managing the Straits through Science and Technology. Malacca, Malaysia. MASDEC, Malaysia.

Macintosh, D. J. and Ashton, E. C. (2002). A Review of Mangrove Biodiversity Conservation and Management. Centre for Tropical Ecosystems Research, University of Aarhus, Denmark.

Macnae, W. (1968). A general account of the flora and fauna of the Seychelles and adjacent islands. *Transaction of the Linnean Society of London*. 19, 307-391.

Malaysian Wetland Working Group. (1987). Malaysia Wetland Directory. Department of Wildlife and National Parks, Kuala Lumpur.

Markusic, M. (2009). Measuring Biodiversity at the Species and Ecosystem Levels. In Fears, N. (Ed) http://www.brighthub.com/environment/science-environmental/articles/45716.aspx. Retrieved on 24 November 2014.

Masakatsu, K., Seiji, A. and Shin`ichi, K., (2003). The ecology of insects in mangrove forests on Iriomote Islands with special reference at three

species of Tortricidae parasitizing *Sonneratia alba*, *Rhizophora stylosa* and *Kandelia candel*. *Nendo*, 83-95.

Mastellar, M. (1997). Mangroves: The forgotten forest between land and sea. In Howes, J. and Matthew, J. (Eds). Tropical press, Malaysia. 71-74.

McGavin, G., 1997. Expedition field techniques: Insects and other terrestrial arthropods. London, *Royal Geographical Society*, 90.

Mchengga, I.,S.,S. and Ali, A.I. (2013). Macro-fauna communities in tropical mangrove forest of Zanzibar Island, Tanzania. *Global journal of Bioscience and Biotechnology*, 2(1): 260-266.

Mckee, K.L. (2002). Mangrove ecosystems: Definitions, distribution, zonation, forest structure, trophic structure, and ecological significance. In, Feller, I.C. and Sitnik, M., 2002. Mangrove ecology workshop manual. A field manual focused on the biocomplexity on mangrove ecosystem. Smithsonian Institution, Washington D.C. USA. 1-135.

Mckeon, C.S. and Feller, I.C. (2004). The supratidal fauna of Twin Cays, Belize. Atoll Reseach Bulletin No.526, National Museum of National History Smithsonian Institution, U.S.A.

Meades, L., Rodgerson, L., York, A. And French, K. (2002). Assessment of the diversity and abundance of terrestrial mangrove arthropods in southern New South Wales, Autralia. *Austral Ecology*, 27: 451-458.

Mendez, J., Mello-Patiu, C. A. and Pape,T (2008) New flesh flies (Diptera: Sarcophagidae) from coastal mangroves of Panama with taxonomic notes and keys, *Journal of Natural History*, 42:3-4, 249-257, DOI: 10.1080/00222930701850216.

Meyer, J.R. (2009). General entomology, North Carolina State University, http://www.cals.ncsu.edu/course/ent425/library/compendium/collembola.html Retrieved on 27 January 2015.

Meyer, J.R. (2013). General entomology, North Carolina State University, http://www.cals.ncsu.edu/course/ent425/library/compendium/neuroptera.html. Retrieved on 27 January 2015.

Murni, S. 2010. Fireflies sanctuary, Sungai Yak yah, Kemaman. http://terengganutravels.blogspot.my/2010/09/fireflies-sanctuary-sg-yak-yak-kemaman.html. Retrieved on 23 February 2014.

Murphy, D.H. (1990). The natural history of insect herbivory on mangrove trees in and near Singapore, *Raffles Bulletin of Zoology*, 38(2): 119-203.

Nagelkerken, I, Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.O., Pawlik, J., Penrose, H.M., Sasekumar, A. and Somerfield, P.J. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review, *Aquatic Botany*, 89:155–18.

Namaghi, H.S, Husseini, M. (2009). The effects of collection methods on species diversity of family Syrphidae (Diptera) in Neyshabur, Iran. *Journal of Agriculture Science and Technology*. 11: 521-526.

Ndenecho, E. N. (2007). Economic value and management of mangrove forests in Cameroon. *International Journal of Sustainable Development & World Ecology*. 14(6): 618-625. Doi: 10.1080/13504500709469759.

Ng, P.K.L. and Sivasothi, N. (2001) A Guide to Mangroves of Singapore. Raffles Museum of Biodiversity Research, National University of Singapore and Singapore Science Centre, Singapore.

Nielsen, M.G. (2000). Distribution of the ant (Hymenoptera: Formicidae) fauna in the canopy of the mangrove tree Sonneratia alba J.Smith in northern Australia. *Australian Journal of Entomology*, 39: 275-279.

Nielsen, M.G., Kristian, K., Henriksen, P.G. and Birkmose, D. (2005). Respiration by mangrove ants Camponotus anderseni during submersion associated with tidal inundation in Northern Australia. *Physiological Entomology*, 1-6.

Offernberg, J., Havanon, S., Aksornkoae, S., MacIntosh, D.J. and Nielsen, M.G. (2004). Observation on the ecology of weaver ants (*Oecophylla smaragdina* Fabricus) in a Thai mangrove ecosystem and their effect on herbivory on *Rhizophora mucronata* Lam. *Biotropica*, 36(3): 344-351.

Ong, S., Cheng, S., Chong, V. and Tan, Y., (2010). Pest of planted mangrove in Peninsular Malaysia. Forest Research Institute Malaysia, 5-23.

Palumbo, J.C. (2011). Weather and insects, Yuma Agricultural Center, UA Veg IPM Update, Vol 2, No. 6 - March 23.

Perner, J., Wytrykush, C., Kahmen, A., Buchmann, N., Egerer, I., Creutzburg, S., Odat, N., Audorff, V. and Weisser, W. W. (2005). Effects of plant diversity, plant productivity and habitat parameters on arthropod abundance in montane European grasslands. *Ecography*, 28: 429-442.

Prayoonrat, P. (2003). A survey of insects in the mangrove forest at the mouth of Bangpakong river in Thailand. *Asian Journal of Biology Education*, 2: 81-85.

Preisser, E., Smith, D.C. and Lowman, M.D. (1998). Canopy and ground level insect distribution in a temperate forest. *Selbyana,* 19(2): 14 1-146.

Ragaei, M. and Allam, M. (1997). Reviews and views: Insect conservation and diversity. *Journal of Islamic Academy of Sciences*, 10:1, 43-48.

Rahaman, A.A. (2002). Mangrove insect fauna of Muthupet, Tamil nadu. National Seminar on Conservation of Eastern Gharts, 24-26 March 2002, Tirupati, Andhra Pradesh.

Rosenberg, D.M. and V.H. Resh. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates, p. 1-9. *In:* D.M. Rosenberg and V.H. Resh (eds.) Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York.

Rosson, S. (2004). Abiotic and biotic factors affecting the distribution of *Solenopsis invicta buren, Brachymyrmex* sp., and *Linepithema Humile (mayr)* in East Baton Rouge Parish, Louisiana. *(*Unpublished master Thesis) Louisiana State University. United States of America.

Rotureau, B., Gaborit, P., Issaly, J., Carinci, R., Fauque, F. and Carme, B. (2006). Diversity and ecology of sandflies (Diptera: Psychodidae: Phlebotominae) in Coastal French Guiana. *American Journal of Medical and Tropical Hygiene*, 75:1, 62-9.

Sajap, A.S., Razak, R.A., Hanida, N.F., and Wahab, Y.A. (1999). Diversity of ground-dwelling insects in Ayer Hitam Forest Reserve. *Pertanika Journal of Tropical Agriculture Science*, 22(2): 207-208.

Sakchoowong, W., Jaitrong, W., Ogata, K., Nomura, S. and Chanpaisaeng, S. (2008). Diversity of Soil-Litter Insects: Comparison of the Pselaphine Beetles (Coleoptera: Staphylinidae: Pselaphinae) and the Ground Ants (Hymenoptera: Formicidae). *Thai Journal of Agricultural Science,* 41(1-2): 11-18.

Samways, M.J., (1993). Insects in biodiversity conservation: some perspectives and directives. *Biodiversity and Conservation,* 2: 258-282.

Sasekumar, A. and Chong, V.C. (1998). Faunal diversity in Malaysian mangroves. *Global Ecology and Biogeography Letters,* 7: 57-60.

Savopoulou-Soultani, M., Papadopoulos, N.T., Milonas, P. and Moyal, P. (2012). Abiotic factors and insect abundance (Edt), *Psyche: Journal of Entomology*, doi:10.1155/2012/167420, 1-2.

Schmitz, H.J., Hofmann, P.R.P. and Valente, V.L.S. (2010). Assemblages of drosophilids (Diptera, Drosophilidae) in mangrove forests: community ecology and species diversity. *Iheringia. Série Zoologia*, 100(2): 133-140.

Secretariat of the convention on biological diversity (2005). Handbook of the Convention on Biological Diversity Including its Cartagena Protocol on Biosafety, 3rd edition, Montreal, Canada.

Shetlar, D. (2009). Booklices and Psocids, Agriculture and Natural resources fact sheet, The Ohio State University Extension, HYG-2080-09.

Silberbush, A., Blaustein, L. and Margalith, Y. (2005). Influence of salinity concentration on aquatic insect community structure: a mesocosm experiment in the dead sea basin region. *Hydrobiologia*, 548: 1-10.

Singh, H.R. (2010). Mangrove of Kuala Selangor,Malaysian Nature Society, *MNS Publication Comittee*, 1-81.

Smith III, T.J. (2002). Mangrove forest structure. In, Feller, I.C. and Sitnik, M., 2002. Mangrove ecology workshop manual. A field manual focused on the biocomplexity on mangrove ecosystem. Smithsonian Institution, Washington D.C. USA. 7-135.

Speight, M.R., Hunter, M.D. and Watt, A.D. 2008. The Ecology of Insects: Concepts and Applications, 2nd edition. Blackwell Scientific, Oxford, UK.

Stanley, C. A. (2012). Booklice and their relatives (Psocoptera), Utah Pests fact-sheet, Utah State University Extension and Utah Plant Pest Diagnostic Laboratory, Entomology, 160-12.

Stewart, M. and Fairfull, S. (May 2008). Primefact: Mangroves. *New South Wales Department of Industries*, 746: 1-16.

Stork, N.E. 1988. Insect diversity: Facts, fiction and speculation. *Biogical Journal of the Linnean Society,* 35: 321-337.

Strauss, S.Y. (1988). The chrysomelidae: a useful group for investigating herbivore-herbivore interactions. Jolivet, P., Petitpierre, E., Hsio, T.H.,(eds). In: Biology of Chrysomelidae, Kluwer Academic Publisher, 91-105.

Sulong, I., Mohd-Lokman, H., Mohd-Tarmizi, K. and Ismail, A. (2002). Mangrove mapping using landsat imagery and aerial photographs: Kemaman district, Terengganu, Malaysia. *Environment, Development and Sustainability*, 4: 135-152.

Thakare, V.G. and Zade, V.S. (2011). Diversity, abundance and species composition of water beetles (Coleoptera: Dytiscidae, Hydrophilidae and Gryrinidae) in Kolkas Region of Melghat Tiger Reserve, Central India. *Academic Journal of Entomology*, 4 (2): 64-71.

Timber Malaysia, (2009). Malaysia Timber Council ,15(3):1-24.

Tipping, C. and Mizell III, R.F. (2004). Sharpshooters, Leafhoppers, Cicadellidae (Insecta: Hemiptera: Auchenorrhyncha: Cicadellidae, Department of Entomology and Nematology, University of Florida, Quincy, EENY-334.

Tomlinson, P.B. 1986. The Botany of Mangroves. Cambridge University Press, London, 413.

Triplehorn, C.A. and Johnson, N.F. (2005). Borror and Delong's Introduction to the study of insects 7th edition. Thomson Brookks. United States of America.

Uniyal, U.P. and Mathur, P.K. (1998). A study on the species diversity among selected insect groups, Wildlife Institute of India, FREEPH-GHNP, 3:13

Veenakumari, K. and Prashanth, M. (2009). A note on the entomofauna of mangrove associates in the Andaman Islands (Indian Ocean: India). *Journal of Natural History*, 43: 13-14, 807-823.

Veenakumari, K., Mohanraj, P. and Bandyopadhyay, A.K. (1997). Insect herbivores and their natural enemies in the mangals of the Andaman and Nicobar Islands. *Journal of Natural History*, 31:7, 1105-1126.

Wahizatul, A.A., Long, S.H. and Ahmad, A. (2011). Composition and distribution of aquatic insect communities in relation to water quality in two freshwater streams of Hulu Terengganu, Terengganu. *Journal of Sustainability Science and Management*, 6: 1, 148-155.

Wan Juliana, W.A., Razali, M.S., Latiff, A. (2014). Distribution and rarity of Rhizophoraceae in Peninsular Malaysia. Faridah-Hanum, I., Latiff, A., Hakeem, K.R., Ozturk, M. (eds.). *Mangrove Ecosystems of Asia,* 23-32.

Wan Jusoh, W.F.A., Hashim, N.R and Ibrahim, Z.Z. (2010). Distribution and Abundance of *Pteroptyx* Fireflies in Rembau-Linggi Estuary, Peninsular Malaysia. *Environment Asia,* 3: 56-60.

Washington, D. (2008). The concept of diversity. Washington & Company, LLC. 1-4.

Wigglesworth, V.B. (1974) The Principles of Insect Physiology. 7th Edition, Chapman and Hall, London, 827.

Wijesekara, A. and Wijesinghe, D.P. (2003). History of insect collection and a review of insect diversity in Sri Lanka. *Ceylon Journal of Science (Biological Science)*, 31: 43-59.

Williams, D,D. and Williams, N.E, (1998). Aquatic insect in an estaurine environment: densities, distribution and salinity tolerance. *Freshwater Biology*, 39: 411-421.

Wilson, E.O. (2000). Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Institute Press, Washington.

Zou Yi, Feng, J., Xue, D.,Sang, W., Axmacher, C. (2012). A comparison of terrestrial arthropod sampling methods. *Journal of Resources and Ecology,* 3(2): 174-182.