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Altitudinal Diversity of Braconid Wasps (Hymenoptera: Braconidae) at Fraser's Hill, Pahang, Malaysia

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ABSTRACT

A diversity study of the subfamilies of Braconidae was conducted at Fraser's Hill, Pahang, Malaysia. Sampling took place at three different altitudes using Malaise traps: lower altitude (<500m), intermediate altitude (501-1000m) and higher altitude (>1000m). A total of 572 individuals of braconids were collected from the three altitudes and comprised 15 subfamilies: Agathidinae, Alysiinae, Blacinae, Braconinae, Cheloninae, Doryctinae, Euphorinae, Helconinae, Lysiterminae, Microgastrinae, Miracinae, Opiinae, Orgilinae, Pambolinae and Rogadinae. There were 435 individuals and 55 species, 84 individuals and 30 species, and 53 individuals and 26 species, with a diversity index of H'= 3.75, 2.91 and 3.01, representing the lower, intermediate and higher altitudes, respectively. The diversity index of the lower altitude (H'=3.75) was significantly different from the intermediate (p=0.00, <0.05) and higher altitudes (p=0.00, <0.05). There was no significant difference between the intermediate and higher altitudes (p=0.86, >0.05). This is probably due to the variability of host and food availability i in lowlands compared with highlands.

Keywords: Altitude, braconid, diversity, abundance

INTRODUCTION

Braconid wasps (Hymenoptera: Braconidae) is a large group of insects with more than 15,000 species distributed throughout the world (Hanson & Gauld, 2006; Quicke, 2014) and occupying different ecological habitats (LaSalle & Gauld, 1993; Shaw & Huddleston, 1991). Braconids are insects that have been proven to be of economic

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and ecological interest (Billah et al., 2008; Whitfield, 2003). Most braconid species have the potential to be used as biological control agents due to their nature of parasitizing other insects (Gillott, 2005; Kimani-Njogu et al., 2001). They tend to have a specific range of hosts specialized by biological and behavioural adaptation (Janzen et al., 2003). The most common hosts for braconids are the larvae of Lepidoptera, Coleoptera and Diptera (Tripplehorn & Johnson, 2005). Braconids are also very sensitive to environmental disturbances which makes them good indicators of diversity and environmental stability (Shaw & Hochberg, 2001). However, in Malaysia, studies on this subfamily is remains undeveloped (Yaakop & Aman, 2013; Yaakop et al., 2009).

Insects usually occupy different niches in a certain habitat and play a functional role in maintaining the dynamics of the ecosystem (Goldstein, 1999). According to Rohner et al. (2015), insect abundance and diversity are affected by both altitude and latitude. For parasitoids, the geographic distribution depends on the plant communities and on their faunal history (Wiens & Donoghue, 2004). This is because of the difference in environmental conditions in lowlands and highlands (Lomolino, 2001).

Abiotic (e.g., temperature, humidity, etc.) and biotic (e.g., competition, migration, etc.) factors can affect the distribution of any species (Eitam et al., 2004). Temperature is a crucial factor that limits distribution especially when altitude becomes a physical factor (Logan, 2001; Parmesan, 2006). Furthermore, wasp diversity is also closely influenced by altitude and latitude (Tan et al., 1990; van der Ent & Shaw, 1998), such that if any change in these factors may affect their diversity. Vegetation covers are strongly associated with insect accumulation, thus attracting various host insects to the wasps (Campan & Benrey, 2004; Sperber et al., 2004). The abilities of parasitoids differ in their surviving period based on the availability of hosts (Eitam et al., 2004). Fraser's Hill is one of the areas known for ecotourism, but there are some activities that can affect the biodiversity of insects. The objective of this study is to compare and measure the differences in braconid diversity and abundance between different altitudes at Fraser's Hill.

METHODS

Study Site

Sampling was conducted at Fraser's Hill in the state of Pahang, Peninsular Malaysia. A few areas have been developed into tourism destinations, but most of the hill forests are still protected and conserved. Three altitudes were selected for this study: lower (<500m), intermediate (501-1000m) and higher (>1000m). The lower altitude is composed of lowland dipterocarp forest, intermediate altitude of hill dipterocarp forest, and higher altitude of montane forest (WWF, 2001).

Braconid Collection

Sampling was carried out by using Malaise traps, which are known for the best ways to capture flying insects passively (Mazon & Bordera, 2008). During the sampling, a total of nine Malaise traps were set up and placed at three different altitudes faced towards the sunlight. For each selected altitude three traps were set up for 30 days before the samples were collected. Sampled insects were then kept in 70% ethanol for further identification in the laboratory.

Species Identification

Identification of braconids was carried out using morphological characters based on taxonomic keys by Achterberg up to subfamily level and to genus and species where possible (Achterberg, 1993; Li et al., 2012; Li et al., 2013). The identification process utilized a stereo microscope, and a photograph of each specimen was taken with a Canon EOS 1000D attached to the stereo microscope (Carl Zeiss Stemi DV4).

Data Analysis

Samples from different altitudes were analysed using PAST software to compare the diversity indices. Diversity Indices viz. Shannon diversity index (H'), Evenness (E) and Richness (R') were analysed to measure the braconids' diversity and species richness at each altitude. The diversity of braconids at the three altitudes was then compared using t-test with p=0.05. Two-way clustering was conducted using computer software PCORD 6 to observe the similarities and differences between the species and altitudes.

RESULTS

A total of 572 individuals were successfully collected throughout the sampling period. They represented 15 subfamilies from all altitudes: Agathidinae, Alysiinae, Blacinae, Braconinae, Cheloninae, Doryctinae, Euphorinae, Helconinae, Lysiterminae, Microgastrinae, Miracinae, Opiinae, Orgilinae, Pambolinae and Rogadinae (Table 1). The lower altitude (<500m) showed the highest number with 435 individuals and 55 species, followed by the intermediate altitude (501-1000m) with 84 individuals and 30 species. The higher altitude (>1000m) showed the lowest number with 53 individuals and 26 species (Table 1). The 15 subfamilies that were found at Fraser's Hill represent 32% of the 46 subfamilies recorded all over the world. Seven of the subfamilies were found in all three altitudes: Alysiinae, Braconinae, Cheloninae, Doryctinae, Microgastrinae, Opiinae and Orgilinae.

Table 1
Subfamilies and genera collected in three different altitudes in Fraser's Hill, Pahang, Malaysia

Subfamily	Genus	Altitude		
		<500m	501-1000m	>1000m
Agathidinae	*Aneurobracon* sp.	0	5	0
	Therophilus sp.	0	0	7
Alysiinae	*Dinotrema* sp.	0	5	1
	Dacnusa sp.	5	0	0
	Heratemis sp.1	4	2	0
	Heratemis malayensis	0	0	1
Blacinae	*Blacus* sp.1	1	1	0
	Blacus sp.2	3	3	0
	Blacus sp.3	6	2	0
Braconinae	*Bracon* sp.1	3	0	1
	Bracon sp.2	5	1	0
	Bracon sp.3	23	0	0
	Braconinae sp.	5	0	1
	Gammabracon sp.	0	1	0
	Habrobracon sp.	10	0	1
	Vipio sp.	6	0	1
Cheloninae	*Ascogaster* sp.	12	1	1
	Chelonus sp.	10	1	0
	Phaneretoma sp.	7	1	0
Doryctinae	*Rhoptrocentrus* sp.	6	0	1
	Spathius sp.1	7	0	1
	Spathius sp.2	10	0	0
	Spathius sp.3	8	0	0
	Spathius sp.4	3	1	0
	Spathius sp.5	9	0	0
Euphorinae	*Centistes* sp.	1	1	0
	*Peristenu*s sp.	8	0	0
Helconinae	*Triaspis* sp.	5	2	0
Lysitermiinae	*Acanthormius* sp.	6	0	0
Microgastrinae	*Alloplitis* sp.	23	4	0
	Apanteles sp.1	2	21	5
	Apanteles sp.2	16	4	2
	Choeras sp.	4	4	4
	Cotesia sp.1	18	1	2
	Cotesia sp.2	4	0	1
	Diolcogaster sp.1	9	1	0
	Diolcogaster sp.2	21	0	0
	Fornicia sp.	7	0	2

Table 1 *(continue)*

Subfamily	Genus	Altitude		
		<500m	501-1000m	>1000m
	Glyptapanteles sp.	7	1	1
	Microgaster sp.	9	0	2
	Parapanteles sp.	39	4	5
	Pholetesor sp.	7	1	1
	Wilkinsonellus sp.	15	7	3
Miracinae	*Centistidae* sp.	5	0	1
Opiinae	*Apodesmia* sp1	8	0	0
	Biosteres sp.	0	1	2
	Bitomoides sp.	7	2	0
	Opiinae sp.1	7	0	0
	Opiinae sp.2	6	0	0
	Opiinae sp.3	9	0	0
	Opius sp.1	5	0	0
	Opius sp.2	9	0	0
	Opius sp.3	4	0	0
	Orientopius sp.	4	2	4
	Psyttalia sp.	7	1	0
Orgilinae	*Orgilus* sp.	5	1	0
	Stantonia sp.	3	0	1
Pambolinae	*Pambolus* sp.	0	0	1
Rogadinae	*Aleiodes* sp.	1	0	0
	Canalirogas sp.	6	2	0
	Rogas sp.1	1	0	0
	Rogas sp.2	4	0	0
	Total	435	84	53

Table 2
Number of individuals, species and diversity indexes sampled from Fraser's Hill, Pahang, Malaysia. Small letter a and b indicates significant difference at p = 0.05

	<500m	501-1000m	>1000m
No. of Individuals	435	84	53
No. of genus	55	30	26
Shannon (H')	3.75^{a}	2.91^{b}	3.01^{b}
Richness (R')	8.89	6.55	6.30
Evenness (E)	0.77	0.61	0.78

This study shows that Microgastrinae has the highest abundance in both species (14) and individuals (257), and can be found in all altitudes. The most dominant genus is also from the same subfamily, *Apantales,* with 50 individuals. In terms of the Shannon diversity index, the lower altitude has the highest H' of 3.75, compared to the intermediate ($p=0.00$, < 0.05) and higher ($p=0.00$, <0.05) altitudes, while there is no significant difference between the intermediate and higher altitudes ($p=0.86$, >0.05) (Table 2).

Based on the two-way cluster analysis, there are three groups that represent more than 75% similarities (Group 1, 2, 3) (Figure 1). Group 1 has the highest number of species (50) which are mostly found in the lower altitude even though some of them can also be accommodated in intermediate and higher altitudes. Group 2 has three species, *Aneurobracon* sp.1, *Gammabracon* sp.1 and *Dinotrema* sp.1 which appear in the intermediate altitude. *Dinotrema* sp.1 also occurs in the higher altitude but at weak probability. Meanwhile, Group 3 has four species, *Biosteres* sp.1, *Heratemis malayensis*, *Pambolus* sp.1 and *Therophilus* sp.1, concentrated in the higher altitude, but there is one, *Biosteres* sp.1, that was also found in the intermediate altitude.

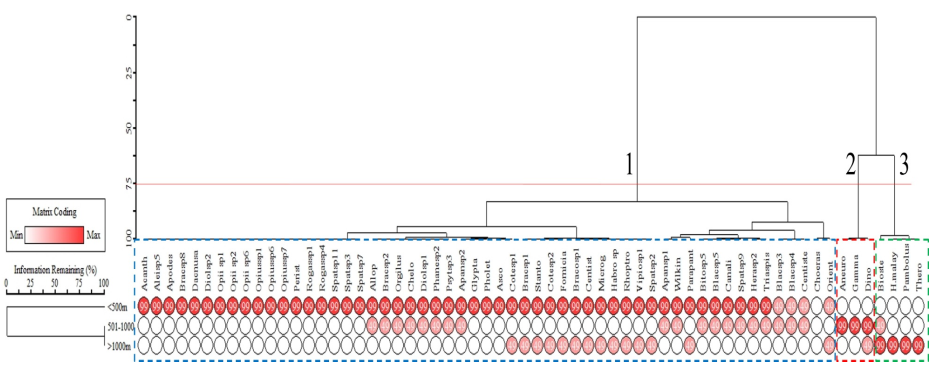

Figure 1. Two-way cluster analysis (dendrogram) of the braconid species collected from different altitudes in Fraser's Hill

DISCUSSION

In this study, 15 braconid subfamilies were found in Fraser's Hill, Malaysia based on Yu et al. (2012). Previous studies from Sivinski et al. (2000) in Mexico, Fernandez-Triana et al. (2013) in New Zealand and Fernandez-Triana et al. (2016) in Costa Rica also discovered some subfamilies in highland areas, such as Alysiinae, Doryctinae, Microgastrinae, and Opiinae, that were similar to this study. A few species from subfamily Opiinae, such as *Fopius arisanus*, are thought to be limited in low temperatures (Snowball & Lukins, 1964), while subfamily *Doryctinae Doryctobracon* crawfordi is sensitive to higher temperatures than the host, *Anastrepha ludens* (Sivinski et al., 2000). However, there is no solid proof to support that subfamilies Alysiinae, Doryctinae, Microgastrinae, and Opiinae found in this study have been recorded in highlands, because most of the previous studies found them only in lowlands (Abu El-Ghiet et al., 2014; Gadelha et al., 2012; Jimenez-Peydro & Peris Felipo, 2011). This may be a new record for diversity of braconid wasps in highlands in Malaysia, especially for Fraser's Hill.

For overall diversity, the lower altitude (<500m) showed the highest number of braconid individuals compared to both intermediate and higher altitudes (>501m). The lower altitude is said to have denser and more varied vegetation (Adam et al., 2011; Barbieri Junior & Dias, 2012) and generally more abundant insect species groups (Lessard et al., 2011; Nufio et al., 2010; Sanders & Rahbek, 2012). In addition, the altitudinal study of Janzen et al. (1976) shows that species richness of parasitic Hymenoptera was high at 200m is congruent with our study in lower altitudes below <500m is because in most habitats, plant communities determine the physical structure of the environment and hence the distribution and species interactions (Saaksjarvi et al., 2004). The number of small plants such as shrubs and herbs declines as altitude increases, which is another reason lower altitudes has greater diversity of host plants and wasps (Khairiyah et al., 2013).

Higher altitude tends to have more adaptive and specific plants compared to the lower altitude. According to this study, *Apanteles* sp. Were found in all three altitudes. This may be due to its high adaptive character. Besides limited plant variation at higher altitudes, and the construction of tourist conveniences contribute to less braconid abundance and diversity compared to lower ground. Less adaptive braconid species will not survive at higher altitudes (Shaw & Hochberg, 2001), leaving the area less sensitive and adaptive groups. Environmental changes will diminish the host population negatively affecting the braconid population as the habitat area becomes undersized and more disturbed (Bobo et al., 2006; Malmivaara et al., 2002; Roy et al., 2001).

An urbanized forest area that experiences destruction will lead to habitat and species loss (Blair & Launer, 1997; Brown et al., 1996). Poor adaptive species are fragile and cannot survive such disturbances, which will be forced to either leave for other favourable areas, or die (Lien, 2013). The environment at higher altitudes are also influenced by weather conditions and can play an important role in soil characteristics, the composition of plants, population structure and invertebrate composition (Willig et al., 2011). In addition, high altitude environments have low productivity rates (Mani, 2013; Stevens, 1989). Environmental changes can shrink the host population and negatively affect the wasps' population (Idris & Hasmawati, 2002).

Microgastrinae are known for its vast diversity and distribution besides being the most conspicuous group attacking caterpillars. As exclusive caterpillar parasitoids, the Microgastrinae are one of the most economically important natural enemies of Lepidoptera. This is proved by the utilization of more than 100 species of Microgastrinae in the biological control of lepidopteran pests in industries (Whitfield, 1997). According to Kahuthia-Gathu (2013), the genera *Apanteles* are found to be the common parasitoid for the larvae of *Plutella xylostella*, diamondback moth, the most destructive insect of cruciferous plants throughout the world (Talekar & Shelton, 1993). In Malaysia, these caterpillars are non-native pests of cruciferous crops that were frequently found to be parasitized by a braconid wasp in the genus *Apanteles* (Furlong et al., 2013). Cruciferous plants are economically important being the most common diet in various cultures (Shelton, 2001). The genera *Apanteles* is one of the dominant species with the highest parasitism recorded in reducing the *P. xylostella* population. Besides that, *Heratemis malayensis* has been discovered in highland altitudes corresponding to the taxonomic study by Yaakop et al., (2009) who found the species in the highlands of Bukit Larut, Perak, Malaysia.

Based on the two-way cluster analysis, Group 1 is mostly concentrated at lower altitudes. This is due to the availability of food, temperature and humidity conditions, found in the lowlands (Sanders & Rahbek, 2012). Their numbers could be higher during the rainy season as young new leaves grow, and provide more food for insects (Barbieri Junior & Dias, 2012; Young, 2012). Compared with the lowlands, Groups 2 and 3 are more likely to have a similar habitat which increases in altitude. Species of insects are less rich as the altitude increases because higher altitudes have lower habitat niches, limitation in host plants, and deficiency of food sources (Lomolino, 2001; McCain & Grytnes, 2010). In addition, the good flying ability of braconids makes them capable of finding a suitable habitat for their development (Araujo et al., 2004). From our study, although we can still find a few species of braconid in the higher altitudes, their diversity and abundance tell us that the lowlands are a preferable habitat for the braconid.

CONCLUSION

The braconid wasp's diversity and population were higher in lower altitude mainly because of the availability of food sources. The presence of hosts directly invite the wasps to parasitize and continue their life cycle. Microgastrinae is the most abundant subfamily as the species is widely distributed. As the altitude increases wasp diversity decreases due to less productive vegetation.

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REFERENCES

Abu El-Ghiet, M. U., Edmardash, A. E. Y., & Gadallah, S. N. (2014). Braconidae Diversity (Hymenoptera: Ichneumonoidea) in Alfalfa, *Medicago sativa* L., Fields of Some Western Desert Oases in Egypt. *Journal of Crop Protection, 3*(4), 543-556.

Adam, J. H., Ming, L. K., Juhari, M. A. A., Jalaludin, M. A., Idris, W. M. R., Othman, A. R., & Tarmidzi, S. N. A. (2011). Cluster Analysis of Submontane Forest Along Western Slope of Frasers' Hill Research Centre in Raub District, Malaysia. *Bangladesh Journal of Botany, 40*(2), 121-132.

Araujo, E. D., Costa, M., Chaud-Netto, J., & Fowler, H. G. (2004). Body Size and Flight Distance in Stingless Bees (Hymenoptera: Meliponini): Inference of Flight Range and Possible Ecological Implications. *Brazilian Journal of Biology, 64*(3B), 563-568.

Barbieri Junior, C. A., & Dias, A. M. P. (2012). Braconidae (Hymenoptera) Fauna in Native, Degraded and Restoration Areas of the Vale Do Paraiba, Sao Paulo State, Brazil. *Brazilian Journal of Biology, 72*(2), 305-310.

Billah, M. K., Kimani-Njogu, S. W., Wharton, R. A., Woolley, J. B., & Masiga, D. (2008). Comparison of Five Allopatric Fruit Fly Parasitoid Populations (*Psyttalia* Species) (Hymenoptera: Braconidae) from Coffee Fields Using Morphometric and Molecular Methods. *Bulletin of Entomological Research, 98*(1), 63-75.

Blair, R. B., & Launer, A. E. (1997). Butterfly Diversity and Human Land Use: Species Assemblages Along an Urban Grandient. *Biological Conservation, 80*(1), 113-125.

Bobo, K. S., Waltert, M., Fermon, H., Njokagbor, J., & Mühlenberg, M. (2006). From Forest to Farmland: Butterfly Diversity and Habitat Associations Along a Gradient of Forest Conversion in Southwestern Cameroon. *Journal of Insect Conservation, 10*(1), 29-42.

Brown Jr, K. S., Ae, S. A., Hirowatari, T., Ishii, M., & Brower, L. P. (1996). The Use of Insects in the Study, Inventory, Conservation and Monitoring of Biological Diversity in Neotropical Habitats, in Relation to Traditional Land Use Systems. *Lepidopterological Society of Japan, 3*, 128-149.

Campan, E., & Benrey, B. (2004). Behavior and Performance of a Specialist and a Generalist Parasitoid of Bruchids on Wild and Cultivated Beans. *Biological Control, 30*(2), 220-228.

Eitam, A., Sivinski, J., Holler, T. & Aluja, M. (2004). Biogeography of Braconid Parasitoids of the Caribbean Fruit Fly (Diptera: Tephritidae) in Florida. *Annals of the Entomological Society of America, 97*(5), 928-939.

Fernandez-Triana, J., Boudreault, C., Dapkey, T., Smith, M. A., Rodriguez, J., Hallwachs, W., & Janzen, D. H. (2016). Revision of the Genus *Promicrogaster* (Hymenoptera, Braconidae, Microgastrinae) from Area De Conservacion Guanacaste, Costa Rica, with a Key to All Species Previously Described from Mesoamerica. *Journal of Hymenoptera Research, 50*, 25-79.

Fernandez-Triana, J., Ward, D., Cardinal, S., & Achterberg, C. (2013). A Review of Paroplitis (Braconidae, Microgastrinae), and Description of a New Genus from New Zealand, *Shireplitis*, with Convergent Morphological Traits. *Zootaxa, 3722*(4), 549-568.

Furlong, M. J., Wright, D. J., & Dosdall, L. M. (2013). Diamondback Moth Ecology and Management: Problems, Progress, and Prospects. *Annual Review of Entomology, 58*, 517-541.

Gadelha, S. D. S., Penteado-Dias, A. M., & Silva, A. D. A. (2012). Diversity of Braconidae (Insecta, Hymenoptera) of the Parque Natural Municipal De Porto Velho, Rondonia, Brazil. *Revista Brasileira de Entomologia, 56*(4), 468-472.

Gillott, C. (2005). *Entomology* (pp. 755-757). Germany: Springer Science and Business Media.

Goldstein, P. Z. (1999). Functional Ecosystems and Biodiversity Buzzwords. *Conservation Biology, 13*(2), 247-255.

Hanson, P. E., & Gauld, I. D. (2006). *Hymenoptera De La Region Neotropical*. USA: American Entomological Institute.

Hortal, J., Triantis, K. A., Meiri, S., Thébault, E., & Sfenthourakis, S. (2009). Island Species Richness Increases with Habitat Diversity. *The American Naturalist, 174*(6), 205-217.

Idris, A. B., & Hasmawati, Z. (2002). Ecological Study of Braconid Wasps in Different Logged over Forests with Special Emphasis on the Microgastrines (Hymenoptera: Braconidae). *Pakistan Journal of Biological Sciences, 5*(11), 1255-1258.

Janzen, D. H., Ataroff, M., Farinas, M., Reyes, S., Rincon, N., Soler, A., Soriano, P., & Vera, M. (1976). Changes in the Arthropod Community Along an Elevational Transect in the Venezuelan Andes. *Biotropica, 8*(3), 193-203.

Janzen, D. H., Walker, A., Whitfield, J. B., Delvare, G., & Gauld, I. D. (2003). Host-Specificity and Hyperparasitoids of Three New Costa Rican Species of *Microplitis* Foerster (Hymenoptera: Braconidae: Microgastrinae), Parasitoids of Sphingid Caterpillars. *Journal of Hymenoptera Research, 12*(1), 42-76.

Jimenez-Peydro, R., & Peris-Felipo, F. J. (2011). Diversity and Community Structure of Opiinae (Hymenoptera: Braconidae) in the Forest Estate of Artikutza (Spain). *Florida Entomologist, 94*(3), 472-479.

Kahuthia-Gathu, R. (2013). Seasonal Incidence of *Plutella xylostella* (Lepidoptera: Plutellidae) and Its Associated Natural Enemies in Major Crucifer Growing Areas of Kenya. *Journal of Plant Breeding and Crop Science, 5*(5), 73-79.

Khairiyah, M. H. S., Usman, S., Suzita, Y., Florinsiah, L., & Nur Shahirah, N. (2013). The Effect of Elevations on Diversity and Abundance of Class Insecta at Taman Negara Gunung Ledang, Johor. In *Business Engineering and Industrial Applications Colloquium (BEIAC), 2013 IEEE*, (pp. 246-250). IEEE.

Kimani-Njogu, S. W., Trostle, M. K., Wharton, R. A., Woolley, J. B., & Raspi, A. (2001). Biosystematics of the *Psyttalia concolor* Species Complex (Hymenoptera: Braconidae: Opiinae): The Identity of Populations Attacking *Ceratitis capitata* (Diptera: Tephritidae) in Coffee in Kenya. *Biological Control, 20*(2), 167-174.

Lasalle, J., & Gauld, I. D. (1993). *Hymenoptera and Biodiversity* (pp. 197-215). Wallingford, UK: CAB International.

Lessard, J. P., Sackett, T. E., Reynolds, W. N., Fowler, D. A., & Sanders, N. J. (2011). Determinants of the Detrital Arthropod Community Structure: The Effects of Temperature and Resources Along an Environmental Gradient. *Oikos, 120*(3), 333-343.

Li, X. Y., Achterberg, C. V., & Tan, J. C. (2012). *Psyttoma* Gen. N.(Hymenoptera, Braconidae, Opiinae) from Shandong and Hubei (China), with a Key to the Species. *Journal of Hymenoptera Research, 29*, 73-81.

Li, X. Y., Achterberg, C. V., & Tan, J. C. (2013). Revision of the Subfamily Opiinae (Hymenoptera, Braconidae) from Hunan (China), Including Thirty-Six New Species and Two New Genera. *ZooKeys, 268*, 1-186.

Lien, V. V. (2013). The Effect of Habitat Disturbance and Altitudes on the Diversity of Butterflies (Lepidoptera: Rhopalocera) in a Tropical Forest of Vietnam: Results of a Long-Term and Large-Scale Study. *Russian Entomological Journal, 22*(1), 51-65.

Logan, J. A., & Powell, J. A. (2001). Ghost Forests, Global Warming, and the Mountain Pine Beetle (Coleoptera: Scolytidae). *American Entomologist, 47*(3), 160.

Lomolino, M. (2001). Elevation Gradients of Species-Density: Historical and Prospective Views. *Global Ecology and Biogeography, 10*(1), 3-13.

Malmivaara, M., Lofstrom, I., & Vanha-Majamaa, I. (2002). Anthropogenic Effects on Understorey Vegetation in *Myrtillus* Type Urban Forests in Southern Finland. *Growth, 36*(1), 367-381.

Mani, M. S. (2013). *Ecology and Biogeography of High Altitude Insects* (pp. 81-84). Germany: Springer Science & Business Media.

Mazon, M., & Bordera, S. (2008). Effectiveness of Two Sampling Methods Used for Collecting Ichneumonidae (Hymenoptera) in the Cabaneros National Park (Spain). *European Journal of Entomology, 105*(5), 879.

McCain, C. M,. & Grytnes, J. A. (2010). *Elevational Gradients in Species Richness*. Chichester, UK: John Wiley & Sons, Inc. doi: 10.1002/9780470015902.a0022548.

Nufio, C. R., Mcguire, C. R., Bowers, M. D., & Guralnick, R. P. (2010). Grasshopper Community Response to Climatic Change: Variation Along an Elevational Gradient. *PLoS One, 5*(9), e12977.

Parmesan, C. (2006). Ecological and Evolutionary Responses to Recent Climate Change. *Annual Review of Ecology, Evolution, and Systematics, 37*, 637-669.

Quicke, D. L. J. (2014). *The Braconid and Ichneumonid Parasitoid Wasps: Biology, Systematics* (pp. 453-461). New York: John Wiley & Sons.

Rohner, P. T., Bächli, G., Pollini Paltrinieri, L., Duelli, P., Obrist, M. K., Jochmann, R., & Blanckenhorn, W. U. (2015). Distribution, Diversity Gradients and Rapoport's Elevational Rule in the Black Scavenger Flies of the Swiss Alps (Diptera: Sepsidae). *Insect Conservation and Diversity, 8*(4), 367-376.

Roy, D. B., Rothery, P., Moss, D., Pollard, E., & Thomas, J. (2001). Butterfly Numbers and Weather: Predicting Historical Trends in Abundance and the Future Effects of Climate Change. *Journal of Animal Ecology, 70*(2), 201-217.

Saaksjarvi, I. E., Haataja, S., Neuvonen, S., Gauld, I. D., Jussila, R., Salo, J., & Burgos, A. M. (2004). High Local Species Richness of Parasitic Wasps (Hymenoptera: Ichneumonidae; Pimplinae and Rhyssinae) from the Lowland Rainforests of Peruvian Amazonia. *Ecological Entomology, 29*(6), 735-743.

Sanders, N. J., & Rahbek, C. (2012). The Patterns and Causes of Elevational Diversity Gradients. *Ecography, 35*(1), 1.

Shaw, M. R., & Hochberg, M. E. (2001). The Neglect of Parasitic Hymenoptera in Insect Conservation Strategies: The British Fauna as a Prime Example. *Journal of Insect Conservation, 5*(4), 253-263.

Shaw, M. R., & Huddleston, T. (1991). Classification and Biology of Braconid Wasps. *Handbooks for the Identification of British Insects, 7*(11), 126.

Shelton, A. M. (2001). Management of the Diamondback Moth: Deja Vu All over Again? In *Proceedings of the 4th International Workshop onThe Management of Diamondback Moth and Other Crucifer Pests* (pp. 26-29). Melbourne, Australia.

Sivinski, J., Pinero, J., & Aluja, M. (2000). The Distributions of Parasitoids (Hymenoptera) of *Anastrepha* Fruit Flies (Diptera: Tephritidae) Along an Altitudinal Gradient in Veracruz, Mexico. *Biological Control, 18*(3), 258-269.

Snowball, G., & Lukins, R. (1964). Status of Introduced Parasites of Queensland Fruit Fly (*Strumeta tryoni*), 1960–1962. *Crop and Pasture Science, 15*(4), 586-608.

Sperber, C. F., Nakayama, K., Valverde, M. J., & De Siqueira Neves, F. (2004). Tree Species Richness and Density Affect Parasitoid Diversity in Cacao Agroforestry. *Basic and Applied Ecology, 5*(3), 241-251.

Stevens, G. C. (1989). The Latitudinal Gradient in Geographical Range: How So Many Species Coexist in the Tropics. *American Naturalist, 133*(2), 240-256.

Talekar, N. S., & Shelton, A. M. (1993). Biology, Ecology, and Management of the Diamondback Moth. *Annual Review of Entomology, 38*(1), 275-301.

Tan, C. L., Khashiyah, M. H., Aminah, I., & Jayprakash, P. (1990). Hymenopteran Abundance and Diversity from Three Altitudes at Gunung Janing Barat, Endau-Rompin, Malaysia. In *Proceedings of the International Conference on Tropical Biodiversity* (pp. 225-229). Malaysia.

Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M. C., Schwager, M., & Jeltsch, F. (2004). Animal Species Diversity Driven by Habitat Heterogeneity/Diversity: The Importance of Keystone Structures. J*ournal of Biogeography, 31*(1), 79-92.

Tripplehorn, C. A., & Johnson, N. F. (2005). *Borror and Delong's Introduction to the Study of Insects* (pp. 52-57). Belmont, California.

van Achterberg, C. (1993). Illustrated Key to the Subfamilies of the Braconidae (Hymenoptera: Ichneumonoidea). *Zoologische Verhandelingen, 283*(1), 1-189.

van Der Ent, L. J., & Shaw, S. R. (1998). Species Richness of Costa Rican Cenocoeliini (Hymenoptera: Braconidae): Anomalous Diversity. *Journal of Hymenoptera Research, 7*(1), 15-24.

Whitfield, J. B. (1997). Subfamily Microgastrinae. In R. A., M., M. P. Wharton & M. J. Sharkey (Ed.), *Identification Manual to the New World Genera of Braconidae* (pp 333-364). Special Publication of the International Society of Hymenopterists.

Whitfield, J. B. (2003). Phylogenetic Insights into the Evolution of Parasitism in Hymenoptera. *Advances in Parasitology, 54,* 69-100.

Wiens, J. J., & Donoghue, M. J. 2004. Historical Biogeography, Ecology and Species Richness. *Trends in Ecology and Evolution, 19*(12), 639-644.

Willig, M. R., Presley, S. J., Bloch, C. P., Castro-Arellano, I., Cisneros, L. M., Higgins, C. L. & Klingbeil, B. T. (2011). Tropical Metacommunities Along Elevational Gradients: Effects of Forest Type and Other Environmental Factors. *Oikos, 120*(10), 1497-1508.

WWF. (2001). *Fraser's Hill: A Lush Highland Hideaway. World Wildlife Fund for Nature* Retrieved from http://awsassets.wwf.org.my/downloads/fraser_s_hill_guidebook_2013.pdf

Yaakop, S., & Aman, A. Z. (2013). Does the Fragmented and Logged-over Forest Show a Real Hyperdynamism on Braconid Species? *Malaysian Applied Biology, 42*(2), 65-69.

Yaakop, S., Van Achterberg, C., & Idris, A. (2009). Heratemis Walker (Hymenoptera: Braconidae: Alysiinae: Alysiini): Revision and Reconstruction of the Phylogeny Combining Molecular Data and Morphology. *Tijdschrift voor Entomologie, 152*(1), 3-64.

Young, A. M. (2012). *Population Biology of Tropical Insects* (pp. 277-281). Germany: Springer Science & Business Media.

Yu, D. S., Achterberg, C. V., & Horstmann, K. (2012). *World Ichneumonoidea 2011*. Taxonomy, Biology, Morphology and Distribution.