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Diversity and abundance of hymenopteran parasitoids at two different elevations in Redang Island, Terengganu, Malaysia

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A study was conducted to determine the diversity and abundance of hymenopteran parasitoids in two different elevations of the coastal and inland forest of Redang Island, Terengganu. Three Malaise traps were installed at each three sampling points in both plots, respectively. The insect samples were collected after seven days and brought to the laboratory for sorting, enumeration, and identification process up to family level. The abundance of parasitoids between two plots was compared using T-test analysis while the comparison of hymenopteran parasitoids abundance between different families was analysed using one-way Analysis of Variance (ANOVA). The insect diversity was analysed using the Shannon-Weiner Diversity Index (H'). Overall, there were 48 individuals of parasitoids from 13 families were collected and no significant difference (P>0.05) of parasitoids abundance between both plots. However, the parasitods population in inland forest was more diverse (H'=1.58) compared to the coastal forest (H'=1.42). Thus, there was a significant difference (P<0.05) of parasitoids abundance among the 13 different hymenopteran families. The most abundant family was Braconidae with 24 individuals followed by Ichneumonidae with six individuals whilst the least abundant families were Elasmidae, Mutillidae, Diapriidae, Chalcididae, Eulophidae, Pompilidae, Chrysididae, and Platygastridae with only one individual, respectively. In conclusion, the diversity of hymenopteran parasitoids in the inland forest was higher than coastal forest although the abundance was not significantly different. Other parameters such as vegetation species and distribution, and abiotic factors should be considered in future studies in order to describe more on the diversity and abundance of hymenopteran parasitoids in the Redang Island forest.

Keywords: Hymenoptera, insect diversity, island, parasitoids

INTRODUCTION

Parasitoid is important as a regulator of other insect populations and it's covered about 20% of all insect species (LaSalle and Gauld, 1991). The parasitoid species are mostly from order Hymenoptera (75% from total species) and considered as major insect components in terrestrial ecosystems (Belshaw et al. 2003). Sheikh et al. (2019) reported that the order Hymenoptera composed of more than 153,000 species which grouped into 132 families and 8,432 genera throughout the world. Most of the hymenopteran parasitoids particularly from family Ichneumonidae and Braconidae. They frequently can be found in the middle of the forest than the edge of the forest (Sajap et al. 2001). This is probably due to a large number of host insects and food sources can be found at the interior forest.

Redang Island is an island of Peninsular Malaysia located in the Terengganu territory and is endowed with a high diversity of flora and fauna. It is part of a Marine Park archipelago of corals and thousands of fish and invertebrates (Fisher et al. 2008). As one of the most popular islands in Malaysia, Redang Island is being gazetted as one of the Malaysia Marine Parks which currently managed by the Ministry of Natural Resources and Environment (NRE) (Khairil et al. 2012). The island consists of lowland, coastal and mangrove forest. However, the tourism industry has expanded on Redang Island and the tourism industry may be putting a strain on natural resources. Hence, habitat degradation vastly occurred and affecting the habitat loss of the fauna including hymenopteran parasitoids. According to Salmah et al. (2019), the study of diversity and abundance of parasitoids in certain habitats such as rainforest will indicate the stability of the forest ecosystem due to the existence of parasitoids depends on the existence of their hosts in the forest. Moreover, Sodhi et al. (2004) reported that the diversity of habitat types in Southeast Asia is another major challenge for the conservation of its biodiversity and there are numerous habitats that neglected to study such as island forest.

Therefore, the research on the diversity and abundance of hymenopteran parasitoids at Redang Island is important as the data obtained will contribute to the increase of baseline information indicating the diversity of hymenopteran parasitoids in Redang Island. Thus, the aim of this study was to investigate the diversity and abundance of hymenopteran parasitoids in two different elevations which are the coastal and inland forest of Redang Island, Terengganu, Malaysia.

MATERIALS AND METHODS

Experimental Site and Sampling Methods

The research was conducted in two types of Redang Island forest (latitudes 5°45'59.7"N to 5°46'05.0"N and longitude 103°01'41.3"E to 103°01'35.1"E) which were the coastal forest (Plot A) and the inland forest (Plot B). Plot A was located near the coastal with elevation range from 20 m to 66 m in height above sea level (a.s.l.) while Plot B elevation range from 75 m to 105 m in height a.s.l. Three Malaise traps were installed in three points randomly at two plot areas, respectively with 20 m intervals between each trap point. On the seventh days, the samples were collected and preserved in the white container containing 70% ethanol then brought to the laboratory for further identification process.

Parasitoids Identification

Insect identification was conducted by sorting, identifying and enumerating up to family level. All specimens were identified under a stereomicroscope (Olympus SZ51) based on Goulet and Huber (1993). This process was held in the Entomology Laboratory at Faculty of Bioresources and Food Industry, UniSZA Besut Campus, Besut, Terengganu.

Data Analysis

The Statistical Package for the Social Sciences (SPSS) software was used to conduct T-test analysis in comparing the abundance of hymenopteran parasitoids between two different elevations (i.e. coastal and inland forest) and one-way Analysis of Variance (ANOVA) was used to analyse the comparison of the abundance of hymenopteran parasitoids between different families. Shannon-Weiner Index, H' (Robinson, 1991) was used to analyse species diversity (H'), richness (R') and evenness (E') which performed by PAST 4.0 software.

RESULTS

The Abundance of Hymenopteran Parasitoids at Two Elevations of Redang Island

A total of 26 individuals (54.0%) of hymenopteran parasitoids was obtained from the coastal forest while 22 individuals (46.0%) from the inland forest of Redang Island (Table 1). However, there was no significant difference ($P>0.05$) of hymenopteran parasitoids abundance between both plots although the lower elevation of coastal forest has recorded a higher number of individuals compared to the higher elevation of inland forest.

Table 1: Total abundance of hymenopteran parasitoids at different plots of Redang Island.

Plot	Average Insect (±SE)	Total Insect	%
Coastal Forest	8.67±6.11[a]	26	54.0
Inland Forest	7.33±7.77[a]	22	46.0
	Total insect	48	100

Means with the same letters in different rows are not significantly different at $P>0.05$

The Abundance of Hymenopteran Parasitoids of Different Families at Redang Island

A total of 48 individuals composed of 13 families of hymenopteran parasitoid was collected at Redang Island from both coastal and inland forest (Table 2). Overall, there was a significant difference ($P<0.05$) of hymenopteran parasitoids abundance between different families. The results showed that the family of Braconidae was the most significantly abundant family consisted of the highest number of individuals collected which was 24 individuals, representing 50.0% of the total individuals collected, followed by Ichneumonidae (6 individuals, 12.5%), Sphecidae (5 individuals, 10.4%), Tanaostigmatidae (3 individuals, 6.3%), and Apidae (2 individuals, 4.2%). Whilst the Elasmidae, Mutillidae, Diapriidae, Chalcididae, Eulophidae, Pompilidae, Chrysididae, and Platygastridae were the least abundant families recorded with only one individual (2.1%), respectively.

Table 2: Total abundance of hymenopteran parasitoids of different families in both plots of Redang Island.

Family	Average Insect (±SE)	Total Insect	%
Braconidae	4.00 ± 2.19^{a}	24	50.0
Ichneumonidae	1.00 ± 0.68^{b}	6	12.5
Sphecidae	0.83 ± 1.60^{b}	5	10.4
Tanaostigmatidae	0.50 ± 1.23^{b}	3	6.3
Apidae	0.33 ± 0.82^{bc}	2	4.2
Elasmidae	0.17 ± 0.41^{cd}	1	2.1
Muitillidae	0.17 ± 0.41^{cd}	1	2.1
Diapriidae	0.17 ± 0.41^{cd}	1	2.1
Chalcididae	0.17 ± 0.41^{cd}	1	2.1
Eulophidae	0.17 ± 0.41^{cd}	1	2.1
Pompilidae	0.17 ± 0.41^{cd}	1	2.1
Chrysididae	0.17 ± 0.41^{cd}	1	2.1
Platygastridae	0.17 ± 0.41^{cd}	1	2.1
	Total insect	48	100

Means with the same letters in different rows are not significantly different at $P>0.05$

The Hymenopteran Parasitoids Diversity, Richness and Evenness

Table 3 showed that the hymenopteran parasitoids diversity in inland forest (i.e. 105 m elevation) which was at H'=1.58 was higher compared to the coastal forest at H'=1.42 (i.e. 20 m elevation). As for evenness, the coastal forest recorded lower value (E'=0.52) than the inland forest (E'=0.69). But the richness of the parasitoids for the coastal forest (R'=2.15) was higher compared to the inland forest (R'=1.94).

Table 3: Shannon-Weiner Index (Diversity, Richness, and Evenness) of hymenopteran parasitoids at different plots of Redang Island.

Index	Coastal Forest	Inland Forest
Diversity (H')	1.42	1.58
Richness (R')	2.15	1.94
Evenness (E')	0.52	0.69

DISCUSSION

The findings of this study showed that the abundance of hymenopteran parasitoids at two elevations of Redang Island was not significantly difference ($P>0.05$) (Table 1). This might be due to the altitude of the sampling area was only within 105 m a.s.l. It is due the fact that the distribution of insects varies with every 100 m increase in elevation (Abdelmutalab et al. 2018). Although the two plots located at different elevations and insect's abundance and diversity were affected by both altitude and latitude (Rohner et al. 2015), but due to the total elevation of Redang Island forests only within 100 m range thus, the abundance of hymenopteran parasitoids between the coastal and inland forest was not affected.

Generally, the lower altitude caters more abundance of insect species groups (Lessard et al. 2011; Nufio et al. 2010; Sanders and Rahbek, 2012) due to the denser and more varied vegetation (Adam et al. 2011; Barbieri Junior and Dias, 2012). A greater diversity of host plants and hymenopteran parasitoids occurs at lower altitude is due to the occurrence of high number of small plants such as shrubs and herbs which deplete as altitude increases (Khairiyah et al. 2013). Furthermore, various host insects of hymenopteran parasitoids are more attracted to heavy vegetation covers for accumulation process (Campan and Benrey, 2004; Sperber et al. 2004). The availability of hosts influences the parasitoids survival (Eitam et al. 2004). Parasitoids can utilize available hosts in a various way to support the development of their progeny (Rohner et al. 2015).

On the contrary, the higher altitude environment of the inland forest has low productivity rates of wasp (Mani, 2013). Insect's

species richness decreases as the altitude increases due to the deficiency of food sources and limitation in host plants that less adaptive and specific plant (Lomolino, 2001; McCain and Grytnes, 2010). Besides, weather conditions can influence the inland forest and play an important role in soil characteristics, plants composition, population structure and invertebrate composition (Willig et al. 2011). Thus, environmental changes can decrease the host population and negatively affect the wasps' population (Idris and Hasmawati, 2002).

Our results demonstrated that the family of Braconidae, known as braconid wasp was the most abundant family compared to other hymenopteran families found in Redang Island (Table 2) and this finding is in line with Salmah et al. (2019). The braconid wasp is a large group of hymenopteran parasitoids with more than 15,000 species distributed throughout the world (Hanson and Gauld, 2006; Quicke, 2014). The family occurs around the world and is diverse in all areas, particularly in tropical and temperate regions (Achterberg, 1993; LaSalle and Gauld, 1993). Their diversity and population were higher in lower altitude is mainly due to the availability of food sources and hosts. The presence of hosts directly invites the wasps to parasitize and continue their life cycle (Rabibah et al. 2018). Moreover, different altitude tended to have a different specific plant that strongly associated with insect accumulation, thus offer various host insects to the wasps (Campan and Benrey, 2004). The most common insect hosts for Braconidae are the larvae of Lepidoptera, Coleoptera and Diptera (Triplehorn and Johnson, 2005).

On the other hand, braconid wasps are highly adaptive to environment (Rabibah et al. 2018) while the inland forest has limited plant variation and tourist conveniences construction that has produced low braconid abundance and diversity compared to coastal forest. According to Shaw and Hochberg (2001), less adaptive braconid species will not survive at higher altitudes. They also very sensitive to environmental disturbances that made them good indicators of diversity and environmental stability (Shaw and Hochberg, 2001).

Meanwhile, the higher diversity of hymenopteran parasitoids at inland forest as shown in Table 3 probably means that elevation of Redang Island has a complex environment in which a high degree of species interaction. In contrast, Salmah et al. (2019) stated that the higher diversity of hymenopteran insects in coastal forest compared to inland forest of Perhentian Island is expected due to the higher availability of life support resources such as insect hosts and food/nectar sources. Moreover, the communities with higher diversities commonly have higher levels of competition, limited niche availability and high number of predations due to limited food sources and larger size of animals (Manuel, 2008). It might also be influenced by the availability of certain plant species that provide shelter to insect hosts and this result might be due to the type and distribution of vegetation (Nurul et al. 2015). In addition, hymenopteran parasitoids can travel several kilometres, and sometimes even further than their host (Godfray, 1994).

The E' value of inland forest (0.69) was higher than coastal forest (0.52) is due to the number of individuals in the inland forest was quite evenly distributed between the hymenopteran parasitoid families. As Thukral (2017) stated that the range of evenness values was $0 < E < 1$. Moreover, the high elevation of inland forest recorded lower richness value (R= 1.94) compared to lower elevation (R= 2.15). This can be related to the species richness decline with the increase in elevation (McCoy, 1990). According to Lawton et al. (1987), the decline of Margaleff R' values might be due to reduced habitat area and resource diversity, increasingly unfavourably environments and reduced primary productivity at high elevation. These results were supported by Evans (2008), who stated that if the value of both E' and R' are high so do the number of species presence.

However, the diversity value is considered low as the value of H' is below 2.4 (H'=1.58). Magurran (2004) stated that low species diversity has H' value within 1.0 to 2.4. Thus, the overall diversity of hymenopteran parasitoids in Redang Island that was obtained in this study is considered low. It might be due to the disturbance to the natural habitat especially tourism activities and construction of infrastructure that become a threat to the insects. Moreover, some parts of forest of Redang Island have been cleared for tourism infrastructures and agriculture practices such as coconut, clove and rubber plantations (Khairil et al. 2012).

CONCLUSION

A total of 48 individuals of hymenopteran parasitoids from 13 families were successfully collected and identified from two study plots which were coastal forest at low elevation and at high elevation of the inland forest at Redang Island.

The results showed that the abundance of hymenopteran parasitoids was not significantly difference between coastal and inland forest due to the elevation of both plots is considered low. However, the diversity index of hymenopteran parasitoids indicated that inland forest was more diverse than the coastal forest. Among the 13 families of hymenopteran parasitoids recorded for both plots, the Braconidae was the most dominant hymenopteran parasitoids family. In future study, it is suggested to consider the vegetation species, distribution and abiotic factors (i.e. temperature, relative humidity, and rainfall) in order to describe more on the abundance and diversity of hymenopteran parasitoids. The diversity and abundance of the insects must be preserved to prevent them against a threat of extinction from the ecosystem as hymenopteran parasitoids are important in stabilizing the nature and ecosystem.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

MAFH, SM, MR and KM involved in the insect sampling. MAFH and SM involved in experimental designed, data analysis and manuscript writing. MR and KM help with the experimental designed, data analysis, and reviewed the manuscript. SM is the project leader. All authors read and approved the final version.

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