Research article

A Preliminary Study on the Parasitic Wasps of Langkawi Islands with Special Emphasis on the Ichneumonidae and Braconidae

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ABSTRACT: A preliminary study was conducted on parasitic wasps using Malaise traps and yellow pan traps at four sites in Langkawi, Malaysia. A total of 316 individuals consisting of 131 morphospecies of parasitic wasps were collected (79, 20, 31 and 9 for ichneumonids, braconids, chalcids and evaniids respectively). The ichneumonids were found to be significantly ($p < 0.05$) more abundant, speciose and diverse than the braconids in all study sites. Surprisingly, the braconids were found to be significantly ($p < 0.05$) less abundant and diverse than the evaniids, the relatively smaller group of parasitic wasps compared to braconids. An interesting result was that the diversity of ichneumonids at Langkawi was somewhat similar to that of the bigger size and undisturbed Kuala Lompat Forest Reserve in the state of Pahang. Although the genus *Goryphus* (Ichneumonidae: Cryptinae) was the only taxon identified up to species level, we had identified one species that is potentially new to science. This suggests that Langkawi Island is still rich in parasitic wasps despite its small size and some disturbances that had occurred. However, if land development activities continue without considering their effect on the island's natural heritage, the biological diversity of flora and fauna including the parasitic wasps might not be able to sustain their populations and existence.

Keywords: Parasitic wasps, Ichneumonidae, Braconidae, diversity, Langkawi, Malaysia

INTRODUCTION

While some groups of organisms such as mammals, birds, butterflies, and even the social Hymenoptera have consistently attracted a lot of attention among conservationists, environmentalists as well as academicians, the parasitic wasps have been greatly underworked and have gained very few converts among the ranks of amateur entomologists. This is in spite of the fact that they are not only ubiquitous but also perhaps the most diverse group of insects, rivaling even the beetles in terms of number of extant species, and that, as a whole, they are of enormous ecological and economic importance (LaSalle & Gauld, 1993; Janzen, 1981).

The 'Parasitica' (parasitic wasps) are a huge group of generally small insects, which mostly

are parasites or hyperparasites of other insects. They make up the bulk of the Hymenoptera, both in number of species and number of individuals, though because of their small size they may not constitute the bulk of the Hymenopteran biomass. They are distinguished from the 'Aculeata' (bee group) by the presence of an ovipositor rather than a sting. The ovipositor is an instrument of the parasitic wasps for oviposition while the sting in bees is an instrument for defense. Many of the Parasitica, which have 11 superfamilies and 47 families are gardener's friends as they destroy millions of pests every year and many of them are commercially reared and sold as biological control agents of economically important insect pests. Two important superfamilies are the Chalcidoidea and Ichneumonoidea (Goulet & Huber, 1993; Quicke, 1997).

The superfamily Ichneumonoidea comprises two main families namely Ichneumonidae (Ichneumons) and Braconidae. Most Ichneumons are parasites of Lepidoptera (butterflies and moths), while the genus *Pezomachus* in which the female is wingless, parasitizes spiders. Though some Ichneumons have short ovipositors such as *Ophion luteus*, some have extremely long ones such as *Rhyssa persuasoria* which preys on the larvae of the Wood Wasp that drill through several centimeters of living wood with its ovipositor in order to lay its eggs. The braconids are generally smaller than ichneumonids and often have darkened or partially darkened wings. A female braconid will often lay more than one egg in a given prey item, thus many braconids can emerge from one victim to pupate immediately outside the shriveled remains of the caterpillar (Gauld & Bolton, 1996).

Locally, parasitic wasps have been studied by Gonzaga & Idris (2003), Idris *et al.* (2003), Idris *et al.* (2002), Idris and Hainidah (2003), Nor Zaneedarwaty (2002 & 2003), Hainidah (2002), Idris *et al.* (2001), Idris (2000) and Nur Azura (2000). Most of these studies revealed that parasitic wasps, especially the braconids and ichneumonids, were highly diverse even in the highly disturbed forests (Gonzaga, 2003; Idris *et al.*, 2003; Wharton, 1993; Lewis & Whitfield, 1999). However, none of their studies were conducted in an island fauna. The rapid increase in land development that have occurred in Langkawi is fascinating and its effect on biological diversity is unimaginable considering the size of the islands as compared to Peninsular Malaysia. This is because a small and isolated area like Langkawi would have limited space and carrying capacity for insects to be speciose and abundant (Ng, 2005; Price, 1984). Therefore, our hypothesis was that the ichneumonid, braconid, chalcid and evaniid wasps diversity in different forest sites of Langkawi Main Islands were not different despite of some disturbances from land development. However, we expected that the diversity of these wasps would be different compared with most sites of Peninsular Malaysia. It was hoped that the study could provide an initial indication of wasp diversity as well as making an inventory of parasitic wasps of Langkawi Islands.

MATERIALS AND METHODS

Study sites

The study was conducted in four different forests on the main island of Langkawi, an area of 939 square kilometers. The four forests were Gunung Raya (» 881 m a.s.l) and Lubuk Semilang (lower part of Gunung Raya, 100 m a.s.l) in the southeast, and Datai and Lenggara (both at » 50 m a.s.l) in the northwest of the main island (Fig. 1).

Experimental lay out

A total of 16 Townes's malaise traps (MTs) (Townes, 1972) and 20 yellow pan traps were used in the study (Noyes, 1989b). Four malaise traps (representing four replicates) with a collecting bottle half filled with 80% ethanol and five yellow pan traps (YPTs) half filled with 10% soap solution were installed along a transect line at each study site started from 100 m from the forest edge (first sampling point) to 500 m inside the forest (Idris & Kee, 2002). At each sampling point the distance between malaise traps was 100 m apart while for the yellow pan traps it was 50 m. Malaise traps were left for six to seven days before insects were collected and brought back to the laboratory. However, insects from the yellow pan traps were collected every two days until the six days of sampling period were over. Only four parasitic wasp families (Ichneumonidae, Braconidae, Chalcididae and Evaniidae) were sorted and studied. Sorted insects were pinned and dried in an oven at 40°C for seven to ten days and identified to subfamily level and sorted to morphospecies (Achterberg, 1993; Idris, 2000, 1999; Wahl & Sharkey, 1993). Because of experiences and references limitation, only subfamily Microgastrinae (Braconidae) was identified down to genus while genera *Goryphus Cryptinae*) and *Xanthopimpla* (Pimplinae), both ichneumonids, were identified to the species level (Gauld, 1984; Townes *et al.*, 1961; Townes & Chiu, 1970; Townes, 1969; Jonathan & Gupta, 1973). Numbers of individuals per family, genus or species were recorded.

Data collection and analysis

Data from both methods of collection (MTs and YPTs) were pooled before analysis. Differences in individual abundance of parasitic wasps among sampling sites were analyzed by two-way analysis of variance (ANOVA) (sites and subfamily as independent variables, while the number of insect individuals per subfamily as dependent variable) using MINITAB statistical package Version 12.1 (MINITAB Version 13, 1996). The wasp species diversity, richness and evenness were determined by running the number of individuals per morphospecies per family on the GW Basic statistical program (Robinson, 1991). The numbers of morphospecies were considered to be a sufficiently reliable and conservative approach for Parataxonomy in ecological biodiversity studies or conservation biology as it is time-saving especially to find out patterns in taxonomically neglected groups (Krell, 2004).

RESULTS AND DISCUSSION

Abundance

A total of 316 individuals consisting of 131 morphospecies were collected from all four sampling sites. Among morphospecies collected, 71, 20, 31 and 9 were ichneumonid, braconid, chalcid and evaniid respectively. Ten ichneumonid subfamilies were recorded. These are Metopiinae, Orthocentrinae, Cryptinae, Campopleginae, Anomaloninae, Ichneumoninae, Labeninae, Tersilochinae, Pimplinae and Acaenitinae, which is 31.3% of the recorded subfamilies of ichneumonid worldwide (Goulet & Huber, 1993). The cryptines seemed to be most abundant in Langkawi, which is 36.7% (46) of the total 126 ichneumonid individuals collected. This is not surprising as the cryptines are reported to be highly abundant throughout the world (Wahl & Sharkey, 1993; Idris & Kee, 2002). Thirteen genera of *Cryptinae* were identified (Mansa, Etha, Goryphus, Coesula, Apsilops, Bozakifs, Friona, Skeatia, Charitopes, Nematopodius, Microstenus, Platymystax and Fitasia) consisting of 20 species. Interestingly, one species from the genus *Goryphus* is potentially new to science (Fig. 2), but a detailed description will be published in an

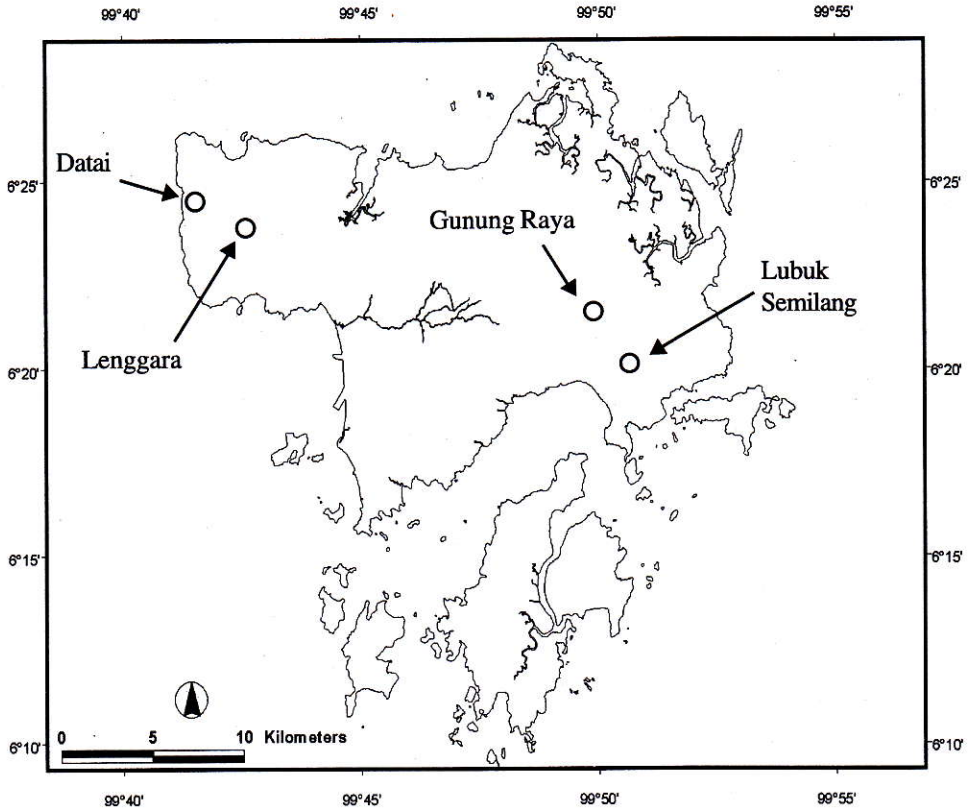

Figure 1. Map of Langkawi Island with the four sampling sites – Datai, Lenggara, Gunung Raya and Lubuk Semilang.

appropriate journal. There was only one species of the genus *Xanthopimpla* (Fig. 3) recorded in this study.

Although braconids were the least abundant parasitic wasps collected in this study, they were represented by 14 subfamilies, namely the Microgastrinae (genera *Hypomicrogaster* and *Parapanteles*), Alysiinae, Cheloninae, Cardiochilinae, Braconinae, Euphorinae, Helconinae, Miracinae, Rogadinae, Meteorinae, Origilinae, Agathidinae, Opiinae, and Dorytinae, and these constitute 46.7% of the total subfamilies of Braconidae recorded throughout the world (Goulet & Huber, 1993). Studies conducted by Idris and his students at various forests and non-forest habitats of Peninsular Malaysia from 1996 until today have recorded 22 and 20 ichneumonid and braconid subfamilies, respectively (Nur Azura, 2000; Azneza Ayu, 2001; Idris & Hasmawati, 2002; Nor Zaneedarwati, 2000; 2003; Hasnah, 1999; Idris, 1997). Only one braconid (Microgastrinae) was collected in Datai forest. There was a significant difference ($F = 43.4$, $df = 3$ & 32, $p < 0.05$) in number of individuals collected per subfamily among forests. The number of ichneumonid individuals collected was significantly higher ($p < 0.05$) in Gunung Raya and Lenggara than in Lubuk Semilang

Figure 2. *Goryphus* sp. (potentially new species). Scale = 1mm

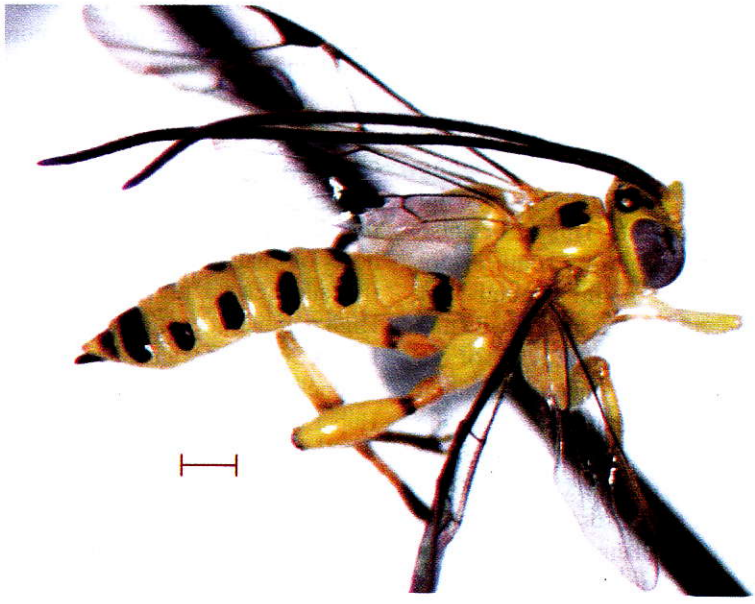

Figure 3. *Xanthopimpla minuta minuta* Townes & Chiu. Scale = 1 mm

and Datai (Table 1). The number of braconid individuals collected in Gunung Raya and Lubuk Semilang was not significantly different ($p > 0.05$). The chalcids, however, were significantly ($p < 0.05$) more abundant in Lenggara than in other forests. As for the evaniids, in Gunung Raya they were significantly ($p < 0.05$) more abundant than in Datai. Data also indicated that ichneumonids and evaniids were more abundant in Gunung Raya, Lenggara and Lubuk Semilang, while chalcids were more abundant in Lenggara than in other forests. Braconids, however, were the least abundant in all forests studied. Except for evaniids, the mean number of morphospecies per family among forests indicated a similar trend as for the mean number of individuals collected per family (Tables 1 & 2). There was a significant interaction ($F = 11.6$, $df = 9$ & 32, $p < 0.05$) between parasitic wasps family and sampling sites (forests) in influencing the number of individuals collected. This suggests that the changes in forest environment, especially the temperature and relative humidity may change the number of wasps' subfamilies and species present.

Based on the number of ichneumonid individuals and species collected among forests, we believe that locations (forests) did not influence the results. This is because Gunung Raya, situated in the southeastern part of the island had a similar number of ichneumonid individuals and species with that of Lenggara in the northwestern part of the island (Tables 1 & 2). The differences might be due to some sort of disturbances to the landscape and habitats and their floristic/ faunistic composition (Smith & Smith, 2001) that had happened to the forests, especially to Datai and Lubuk Semilang forests compared to Gunung Raya and Lenggara forests, as the ichneumonids are more speciose and abundant (Table 1). The presence of only one *Xanthopimpla* species, *X. minuta minuta* (Townes & Chiu 1970) at Gunung Raya suggests the forest was not or less disturbed (Gonzaga & Idris, 2006). Additionally, ichneumonids prefer to thrive at the middle altitudes (Rohaida, 2001; Sutton & Collin, 1991; Price, 1991; Fernandes & Price, 1988; Gauld, 1987; Lawton *et al.*, 1987; Janzen, 1981,1976), such as on the peak of Gunung Raya (881 m a.s.l). Similar trend showed by the number of morphospecies per ichneumonid subfamilies among forests (Table 2).

The braconids were less abundant and speciose (Tables 1 and 2) at Datai Forest than at the other forests because it is the most disturbed forests, which might have less host and food available for braconids compared to the other forests (Jervis *et al.*, 1993). Higher number of ichneumonids species and individuals than the braconids in all forests of Langkawi supported the reports of previous studies conducted in Peninsular Malaysia by Nur Azura (2000), Idris *et al.* (2001; 2002), Hasnah (1999) and Idris (1997), and rejecting the idea that the braconids are more speciose and abundant than ichneumonids in the tropics compared with the temperate regions (Goulet & Huber, 1993; Noyes, 1989a). In contrast, the chalcids were abundant and diverse at Lenggara Forest (Tables 1 & 2). This suggests that Lenggara forest supports more insect hosts of chalcids compared to other forests (LaSalle & Gauld, 1993; Goulet & Huber, 1993). High number of evaniid at Gunung Raya and Lubuk Semilang is an indication of abundance of cockroaches in these forests (Gaulet & Huber 1993).

Diversity

The value of Shannon Diversity Index (H') for parasitic wasp species (morphospecies) was significantly lower ($t = 6.65$, $df = 98$, $p < 0.05$) in Datai than in the three other forests (Fig. 4). This might have contributed to the higher

Table 1. Mean number of Ichneumonid, Braconid, Chalcid and Evaniid individuals per forest collected in one week sampling on the main island of Langkawi.

Family	Forests			
	Gunung Raya	Lenggara	Datai	Lubuk Semilang
Ichneumonidae	46.6 ± 10.3a	44.0 ± 8.7a	6.8 ± 2.4c	29.0 + 7.5b
Braconidae	9.0 ± 3.2a	10.8 ± 3.5a	0.3 ± 0.1b	12.8 + 4.4a
Chalcididae	12.7 ± 5.3c	46.7 ± 11.3a	3.3 ± 1.4d	35.8 ± 7.9b
Evaniidae	20.4 ± 5.7a	10.3 ± 3.5c	6.8 ± 2.4c	16.8 + 5.4ab

In row, means having the same letter are not significantly different (Protected Fisher's LSD, $p < 0.05$)

Table 2. Mean number of morphospecies per family per forest collected in one week sampling period on the main island of Langkawi.

Family	Forests			
	Gunung Raya	Lenggara	Datai	Lubuk Semilang
Ichneumonidae	32.4 ± 6.5a	24.7 + 7.3ab	6.8 ± 2.4c	22.5 ± 5.8b
Braconidae	3.3 ± 1.2b	9.9 ± 3.5a	0.3 ± 0.1b	10.8 + 3.4a
Chalcididae	10.1 ± 4.3b	16.2 ± 3.2a	3.3 ± 1.8c	12.3 ± 3.9ab
Evaniidae	3.4 ± 1.7a	3.3 ± 1.5a	2.8 ± 1.4a	5.8 + 0.8a

In row, means having the same letter are not significantly different (Protected Fisher's LSD, $p < 0.05$)

values of Margalef's Index of Richness (R') in Gunung Raya, Lenggara and Lubuk Semilang than in Datai as the Shannon Evenness Index (E') values were somewhat similar among forests. The E' and R' are two important components that determine the H' values (Magurran, 1988; Pielou, 1975).

The diversity of ichneumonids showed a similar trend with the diversity of parasitic wasps as a whole (Fig. 4 & 5). Although Gunung Raya had the highest value of R', the diversity of ichneumonids was not significantly different ($p > 0.05$) between forests. This is probably due to the dominance effect of one species (morphospecies 52) recorded in Gunung Raya, which had 10 individuals compared to other species having at most four individuals per morphospecies. Because only one species is dominant (more individuals collected) over the others, we decided to use Shannon rather than Simpson Diversity Index in the data analysis (Magurran, 1983; Pielou, 1975).

The braconid diversity in Gunung Raya was significantly lower ($p > 0.05$) than in Lenggara and Lubuk Semilang (Fig. 6). This is probably

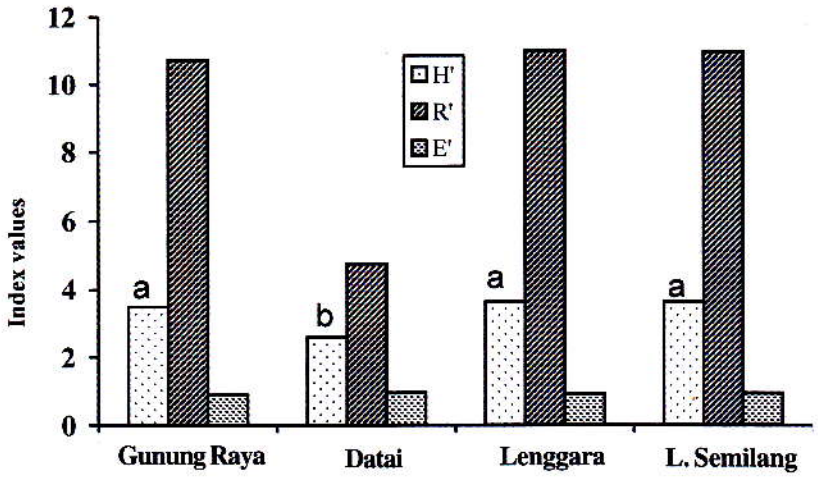

Figure 4. Values of Shannon Weiner Index of diversity (H'), Shannon evenness index (E') and Margalef's index of richness (R') for parasitic wasps species at four sites of the main Langkawi Island. H' values with same letter are not different (t-test, $p < 0.05$)

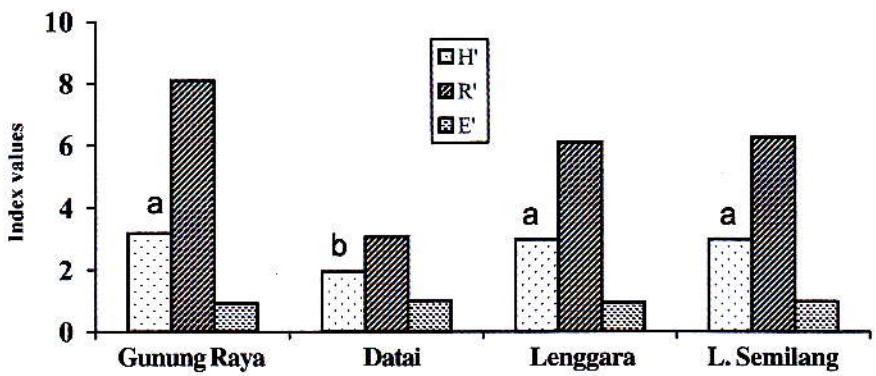

Figure 5. Values of Shannon Weiner Index of diversity (H'), Shannon evenness index (E') and Margalef's index of richness (R') for Ichneumonidae species at four sites of the main Langkawi Island.H' values with same letter are not different (t - test, $p < 0.05$)

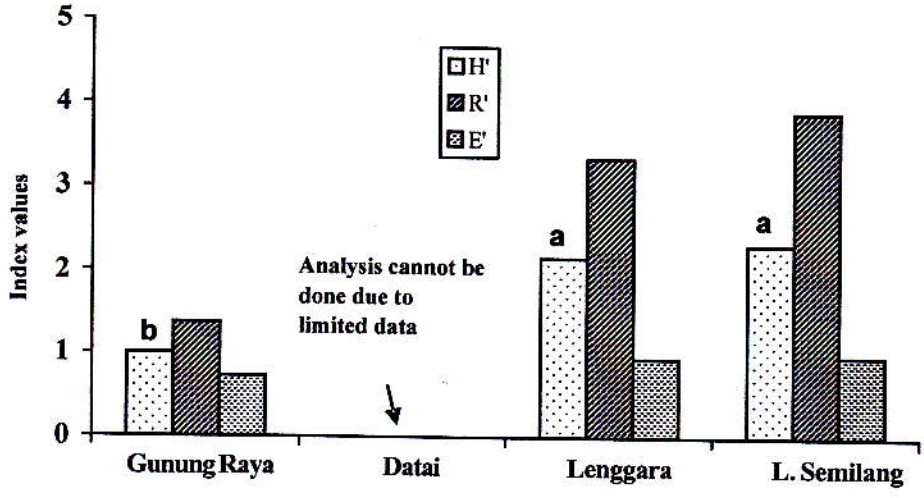

Figure 6. Values of Shannon Weiner Index of diversity (H'), Shannon evenness index (E') and Margalef's index of richness (R') for Braconidae species at four sites of the main Langkawi Island.H' values with same letter are not different (t- test, $P < 0.05$)

Table 3. Comparison for values of Shannon Diversity Index (H') for Ichneumonidae and Braconidae species between Langkawi Island and other forests in Malaysia Peninsular main Land.

Family	Forests[a]					
	TNM	HP	HKLU	HKL	HSUKM	LANGKAWI[b]
Ichneumonidae	4.32	4.28	3.81	3.28	1.67	3.18
Braconidae	4.12	4.19	4.11	4.14	3.94	2.31

Sources: Idris & Hainidah 2003; Hasnah (1999), Nor Zaneedarwaty (2003)

[a]TNM, National Park at Merapoh; HP, Pasoh Forest Reserve; HKLU, North Kuala Langat Forest Reserve; HKL, Kuala Lompat Wildlife Forest Reserve; HSUKM, Universiti Kebangsaan Malaysia Forest Reserve

[b]Selected the highest H' from Tables 1 or 2.

due to the behavior of braconids that favor hot and wet environment in the lower altitudes (Wahl & Sharkey, 1993). Nevertheless, the H' values of braconids in Lenggara and Lubuk Semilang were somewhat lower than the H' values of ichneumonids species (Fig. 5 & 6). This suggests that braconids are less diverse than ichneumonids in Langkawi even though braconids are ubiquitous throughout the world (Goulet & Huber, 1993). No H' value was calculated for braconids in Datai forest because there was only one individual collected in Datai.

Although preliminary, the sampling revealed that the diversity of ichneumonids in Langkawi (Gunung Raya) is as diverse as in Kuala Lompat Forest Reserve and higher than the UKM forest Reserve (HSUKM, 80 ha isolated forest) (Table 3) (Asneza Ayu, 2001). Low value of H' for ichneumonids in Langkawi might be attributed to the small size of the island as compared to the TNM. Diversity of braconids (2.31) in Langkawi seemed to be very low even with that of the isolated, fragmented, highly disturbed and small size (100 ha) HSUKM forest (3.94). This suggests that the Langkawi Island may have less available resources (plants for their insect hosts as well as food plant) for the braconids to survive and reproduce (Jervis *et al.*, 1993; Idris *et al.*, 2003; Idris & Grafius, 1996; Noyes, 1989a).

CONCLUSION

Although Langkawi Island has recently been developed into a tourist paradise causing many disturbances to its landscape, the abundance and diversity of parasitic wasps seemed to be considerably high. There are at least three interesting findings in this short study. First, the diversity of ichneumonids is somewhat similar to that of the bigger size and undisturbed Kuala Lompat Forest Reserve in the state of Pahang. Secondly, the braconids had surprisingly low abundance and diversity compared to other parasitic wasps. This phenomenon has not been reported elsewhere and further studies need to be conducted. Finally, we discovered one species under the genus *Goryphus* that is potentially new to science, based on available references and specimens that closely related to it, and needs description. This suggests that a sustainable development of the Langkawi Island is necessary to ensure no loss on species that are still out there waiting to be collected and described.

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