OnLine Journal of Biological Sciences 3 (2): 259-270, 2003
ISSN 1608-4217

Diversity of Ichneumonid Wasps in the Logged over Forests of Langat Basin in Selangor, Malaysia

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Abstract: The present study was carried out to observe the differential effect of logged over forests of the Langat Basin in Selangor, Malaysia on diversity of Ichneumonid wasps. A total of 732 ichneumonid individuals comprising 16 subfamilies (45.7% of the world recorded ichneumonid subfamily) and 136 morphospecies were successfully collected. Of this 10 subfamilies were recorded in HSUKM while HSKLU and HSKLS had 12 and 14 subfamilies respectively. However, the HSUKM had the less number of ichneumonid species (73) as compared to HSKLU (84) and HSKLS (78). There were nine subfamilies recorded in all forest with the Cryptinae members was the most abundance representing 62.4% of the ichneumonid individuals collected. There was a significantly different ($P < 0.05$) in the mean number of ichneumonid individuals collected among forests with the HSUKM had HSKLS had the highest and lowest respectively. This result showed that the small, fragmented and isolated HSUKM capable of acting as refuge for the certain ichneumonid species. Ichneumonid diversity was significantly higher at HSKLS and HSKLU than at HSUKM. The Jaccard's Coefficient Index (percent species similarity) among forests was 36.1, 36.5 and 38.5% between HSKLU and HSKLS, HSKLU and HSUKM, HSUKM and HSKLS respectively. Based on Jaccard's Coefficient Index there seemed to be two community assemblages exist between these three forests. First is between HSKLS and HSUKM and another one is between HSKLU and HSKLS and HSUKM. In general, distances from forest's edge into the forest seemed to have no influence on abundant and species composition, diversity and similarity of ichneumonid.

Key words: Ichneumonid, logged forest, disturbance, parasitoid, diversity

Introduction

Ichneumonidae is one of the biggest families in Hymenoptera comprising 39 subfamilies with estimated 60,000 species worldwide (Wahl and Sharkey, 1993). Ichneumonid represent one of the most diverse and abundant of the parasitoid groups (Wharton, 1993; LaSalle and Gauld, 1993;

Gauld, 1987). As for other parasitic hymenopterans, the ichneumonids also play an important role as a natural agent for stabilizing the insect pest population in any habitat (Gauld, 1988). This is because they are typically parasitoids of other insects, parasitizing and ultimately killing their hosts. Their most common hosts are the larvae of Lepidoptera, Coleoptera and Diptera (Wahl and Sharkey, 1993). Presently, several species are being used as biological control agents of insect pests of an economic importance crops (Quicke, 1997; Ooi, 1992).

The role and population abundance of ichneumonid could be influenced by the habitat character and environment (Kim, 1993). The size of fragmented forest, distance between fragmented forest and corridor connecting the new and original forests determine biological diversity (Forman, 1995). Although the abundance of certain plant species may be higher in the fragmented than in the virgin forests, it could only provides food source for certain ichneumonid and their insect host species (Price, 1993). On the other hand, as the forest being fragmented and isolated their size will drastically reduced. This change would only fit to ichneumonid species that have bigger host ranges (generalists) but not to those species that have smaller host ranges (specialists) (Hawkin and Sheehan, 1994; Price, 1993). The specialist ichneumonids are highly mobile to find their scattered host in heterogeneous landscape (Idris and Grafius, 2001; Hawkin and Sheehan, 1994), as such fragmented forest and small size forests are likely to affect much on it survival. Furthermore, most specialist parasitoids are able to recognize hosts that have been previously parasitized either by her or other female parasitoids (Price, 1971). So, if the habitat is small enough to house large number of host then it has to travel out of that habitat to find host. This would make them become less effective biological control agents as well as exposing them to the mortality factors (predators) during host finding bout. This proves the importance of spatial relationship between populations dynamic of insect like ichneumonid and their habitat size (Price, 1993).

Insects such as ichneumonids are well suited to monitoring landscape changes because they are abundant, species rich and ubiquitous in occurrence (Rossenberg ***et al.***, 1986). Among the insect, the Hymenoptera and in particular the ichneumonid parasitoid wasps are among the most species rich and biologically diverse taxa (LaSalle and Gauld, 1993). The objectives of this study were to investigate the effect of different logged over forests on abundance and diversity of ichneumonid wasps and to prove the ichneumonid wasps have characteristics that make them useful biological indicators of habitat disturbance. Results of this study are expected to serve as useful information for the policy makers and land development managers for future land development program.

Materials and Methods

Study was conducted at three different logged and fragmented forests of the Langat Basin located between longitude 101°17’ and 101°58’E and latitude between 2°44’ and 03°16’N covering an area of 231,521 ha. The forests selected were the Hutan Simpan UKM Forest Reserve (HSUKM), Northern Kuala Langat Forest Reserve (HSKLU) and Southern Kuala Langat Forest Reserve (HSKLS) of Langat Basin, Selangor, Malaysia. The HSUKM is a lowland dipterocarp forest with 50 - 200 m altitude and total area of 105 ha. It was logged twice, first between 1941 and 1945 and second in 1969 (Noraini, 1990; Latiff, 1990). The HSKLU and HSKLS are peat swamp forests with total area of 1107 and 7198 ha respectively. The HSKLU was logged in 1945, 1949 and 1993 and dominated by early succession plants while the HSKLS was logged in 1954 and 1976. The Dipterocarpaceae and Euphorbiaceae are the dominant plants in old and recently logged forests, respectively (Bakri and Latiff, 2000). The climate of the study area is equatorial with high but uniform annual temperature, humidity and rainfall throughout the year. Dry and wet seasons are not particularly well marked. The distances were approximately 20, 35 and 75 km between HSKLU and HSKLS,0 HSKLU and HSUKM and HSUKM and HSKLS. The villages and the scattered small agricultural areas, oil palm plantation, housing estates, airport and industrial areas are main features surrounding these forests.

Experimental layout

Nine transects (three per forest = three replicates), each with 500 m from the forest edge were randomly made per forest (Idris and Soon, 2002). The distance between transects was 600-700 m depending on the accessibility of installing the traps in each forest. Malaise traps were installed along each transect line namely at 5, 250 and 500 m from the forest edge, respectively. Insects were collected from the traps 7 - 8 days later. The samplings were done for a week per month from July to October 2001 with sampling interval between four to five weeks. Samples were brought to laboratory, put in vials filled up with 70% ethanol and temporary kept in freezer before sorted out. The specimens were identified based on Gauld (1984), Townes (1969) and Townes and Chiu (1970).

Data Analysis

Data of four samplings (four weeks in months) were pooled before analysis to reduce error related to sampling time effect. A two-way analysis of variance (ANOVA) was used to analyze differences in the number of individual per species collected among forests and/or distances of trap from forest edge (MINITAB Version 13.0) while one-way ANOVA was used to analyze the difference in number of individuals among forests (monthly data and the data for all distances from forest edge per transect were pooled before analysis). When ANOVA was significant means were separated using Tukey's test at P = 0.05. A multi-variate analysis (Anonymous, 1999) was used to find out percent species similarity among species within forest and among forests. GW Basic programme (Robinson, 1991) was used to analyze species diversity, richness and evenness.

Results and Discussion

Abundance and Species Composition

A total of 732 ichneumonid individuals comprising 16 subfamilies and 136 species (= morphospecies) were successfully collected. Of this 10 subfamilies were recorded in HSUKM while HKSKLU and HSKLS had 12 and 14 subfamilies respectively (Table 1). The HSUKM had relatively more number of individuals collected (287) than that of HSKLS (226) and HSKLU (219). However, the HSUKM had the less number of ichneumonid species (73) as compared to HSKLU (84) and HSKLS (78). The distribution pattern of total individuals collected per habitat was significantly different among subfamilies (χ^2, df = 15, $P < 0.05$), indicating that certain subfamily are less or more abundant than the others. For example, the Cryptinae and Orthocentrinae had the most individual while the last six subfamilies had the least individuals collected in each forest (Table 1). In fact in all forests the cryptines and orthocentrines had a total of 310 and 147 individuals respectively, representing 62.4% of the total ichneumonid individuals collected in this study.

The total number of subfamilies recorded in this study (16) is 45.7% of the total ichneumonid subfamilies recorded worldwide (35) (Goulet and Huber, 1993). Two of the 16 subfamilies were new record for Peninsular Malaysia and as such the number of ichneumonid subfamily has increased from 18 (Idris, 2000) to 20 which is 57.1% of the world record. There were only nine subfamilies recorded in all forests (Cryptinae, Pimplinae, Ichneumonidae, Anomaloninae, Metopiinae, Acaenitinae, Orthocentrinae, Cremastinae and Campopleginae). These subfamilies are commonly found in the tropical area (Goulet and Huber, 1993; LaSalle and Gauld, 1993). There were significantly different (χ^2 = 295.0, df = 15, $P < 0.05$) in the total number of individuals collected among subfamilies. The cryptines seem to be the most abundant ichneumonid collected I all forests. Members of this subfamily are highly diverse and widely distributed throughout the world (Wahl and Sharkey, 1993; Hasnah, 1999; Idris, 2000). This is not surprise as the majority of cryptines are generalist idiobiont ectoparasitoid parasitizing wide range of hosts (Spradbery, 1968) and that might the reason they were well represented in all forests. Intriguingly, the cryptine individuals recorded were highest at the HSUKM and lowest at HSKLS (Table 1). This indicates that size and age of the regeneration forests were not the factors influencing the abundance of cryptines as HSKLU and HSLS were the youngest and biggest regeneration forests, respectively. The HSUKM may be a refuge habitat for this parasitoid as it is a really isolated forest surrounded by housing estates, oil palm plantation, villages, government buildings and Universities campus. Although the most abundant animal species are normally used for monitoring habitat changes (Smith and Smith, 2001), the cryptines seemed to be not suitable for this purpose as their population abundance are influenced by complex of factors that need further study.

Table 1: Number of Ichneumonid individuals collected from three different forest of Langat Basin from July to November 2001

Subfamilies	Morphospecies	HSKLU	HSKLS	HSUKM	Total
Cryptinae	46	81	66	163	310
Pimplinae	28	37	22	25	84
Ichneumoninae	11	6	3	16	25
Anomaloninae	9	2	20	18	40
Metopiinae	7	20	16	20	57
Ophioninae	6	11	6	0	17
Acaenitinae	5	4	2	2	8
Orthocentrinae	5	41	73	33	147
Cremastinae	6	9	3	4	16
Banchinae	4	2	5	0	7
Campopleginae	4	4	7	5	16
Diplazontinae	1	0	1	0	1
Labeninae	1	1	0	0	1
Tersilochinae	1	0	0	1	1
Eucerotinae	1	0	1	0	1
Lycorininae	1	0	1	0	1
Number of individuals	-	219	226	287	732
Number subfamily	-	12	14	10	-
No. Species	136	84	78	73	-
Chi-square values	-	213.6	208.9	295.7	-
df	-	15	15	15	-

HSKLU, Northern Kuala Langat Forest Reserve; HSKLS, Southern Kuala Langat Forest Reserve; HSUKM, Universiti Kebangsaan Malaysia Forest Reserve

On the other hand, the Diplazontinae, Labeninae, Tersilochinae, Eucerotinae and Lycorininae were the rare subfamilies as only one individual was collected throughout the study (Table 1). As such they might not be good candidate to be used as biological indicator of habitat disturbance (Idris, 2000). Members of these subfamilies are abundant in the Holarctic region (especially in temperate Europe)(Diplazontinae, Tersilochinae, Eucerotinae and Lycorininae), Australia and South America (Labeninae) (Goulet and Huber, 1993; Wahl and Sharkey, 1993).

Significant differences ($F = 6.7$; df = 2 & 15, $P = 0.013$) in the mean number of ichneumonid individuals collected among forests was observed. The mean number of ichneumonid collected was significantly higher ($P < 0.05$) at HSUKM (95.7) than at the HSKLS (75.5) and HSKLU (73.0) (Fig. 1).

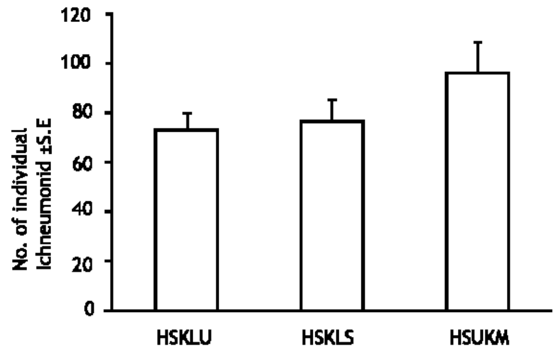

Fig. 1: Mean number of ichneumonid individuals collected from three different forest of Langat Basin from July to October 2001

This suggests that the small fragmented and isolated HSUKM capable of acting as refuge for the ichneumonid communities within the landscape of UKM campus and its surrounding area. We anticipated a higher individuals collection in HSKLU than in the forests, as this recently logged forest had diverse of plant species (Bakri and Latiff 2000) that could serve as food source for ichneumonid and its insect hosts (Idris and Soon 2002; Thomas and Mallorie, 1985). However, result indicated that it is not the case for ichneumonids. This probably due to many ichneumonids preferred the older regeneration forests (less disturbed) than the younger regeneration forest (more disturbed). Shahabuddin (2000) reported that 75% of butterfly species, mostly are host of many parasitoids, in the fragmented forests have low population density than the same butterfly species in less or undisturbed forests of the Veneuzuela. However, Daily and Ehrlich (1995) found that the number of butterfly species increases or no change in small isolated, disturbed and fragmented rainforests.

Result s of two-way analysis of variance (ANOVA) indicated that only subfamily had significant effect ($F = 24.9$, $df = 4, 30$; $P < 0.05$) on the number of ichneumonid individual collected but not the forests. However, the interaction of both subfamily and forest resulted in significant ($F = 4.7$, $df = 8, 30$; $P = 0.001$) effects on the number of ichneumonid individual collected.

There was a no significant difference ($F = 1.85$, $df = 2$ & 18, $P = 0.73$) in the mean number of ichneumonid individual collected per distance from forest's edge among forests (Fig. 2). There was also no significant interaction between forests and distances of traps installed in influencing the number of ichneumonid individuals collected. This indicates that the number of individuals (abundance) per family is not a better parameter to test the effect of forest's edge to insect population among forests. The abundance of ichneumonids was not significantly influenced by the distances from forest's edge except at HSKLU. There was significantly more ichneumonid individual collected at 5 m from the edge of HSKLU than at the

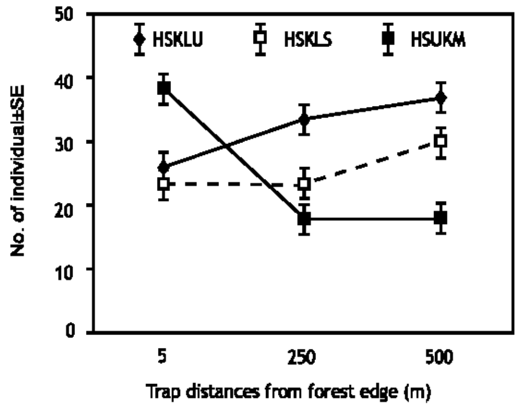

Fig. 2: Mean number of ichneumonid individual collected at 5,250 and 500 m from forest edges of three different forests from July to October 2001.

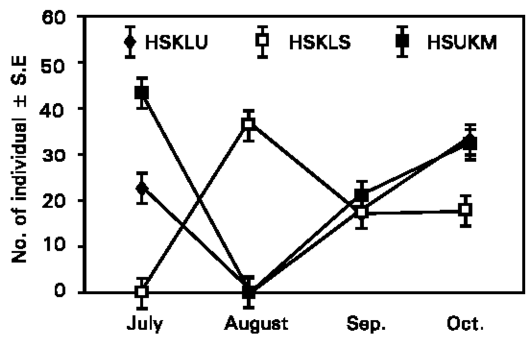

Fig. 3: Mean No. of ichneumonid individual collected in four counsequtive months of three different forests of Langat Basin

250 and 500 m from the edge of this forest. This is probably due to the abundance of shrubs and flowering plants at the edge of HSKLU that provide food sources for the parasitoids (Jervis ***et al.***, 1993; Ayers ***et al.***, 1987) and it insect hosts (Idris, 2000).

There was no significant interaction ($P > 0.05$) between time of samplings (months) and forests in influencing the number of ichneumonid collected (Fig. 3). However, the main effect (months or forests) significantly influenced ($P < 0.05$) the number of insect collected. Similar result was reported in Georgia, USA (Christine and Pickering, 1994). They suggested that certain ichneumonid species might have different activities (base on hosts development stages or food availability) in different months and that in certain months they can be more abundant than the other months. Except in August, the mean number of ichneumonid individuals collected at HSKLS was significantly lower ($P < 0.05$) than that of HSKLU and HSUKM. This could be due to wet condition at the HSKLS as there was a significantly more ($P < 0.05$) rain in the HSKLS than at the other forests.

Diversity

The H' (Shannon diversity index) values for ichneumonid in HSUKM were significantly lower than that of HSKLU and HSKLS (Table 2). This may be attributed to the higher values of E' (evenness) and R' (richness) in HSKLU and HSKLS than the E' and R' values in HSUKM (Pielou, 1975; Magurran, 1988). The HSUKM is smaller in size than the other forests and that it might have lower diversity of plants species and insect hosts of ichneumonid than the HSKLU and HSKLS. Although the HSKLU is more disturbed compared to HSUKM, the ichneumonid species in HSKLU as rich as in the HSKLS. This is seemed to be due to the abundance of food plants as a results of higher plant diversity in HSKLU than HSUKM - provided food for parasitoid's insect hosts such as butterfly larva (Thomas and Mallorie, 1985). Aside from this, many parasitoid females are sensitive to dense situation that lead to intraspecific competition for hosts or food (Price, 1993). Because of this the parasitoid may either perish or migrated out of small habitat like HSUKM.

Table 2: The Shannon Diversity Index (H') and Evenness Index (E'), and Margalef's Index (Richness Index, R') of Ichneumonidae in three different logged and fragmented forests of the Langat Basin in Selangor Malaysia[1]

Forests	H'	E'	R'
HSKLS	4.04a	0.91	15.40
HSKLU	3.81a	0.88	14.21
HSUKM	3.39c	0.79	12.72

[1]The value of H' with similar letter were not significantly different (paired t-test, $P > 0.05$).

The ichneumonid diversity (H') was significantly higher (t test, $P < 0.05$) at 5 m (3.76) distances than at 250 (3.24) and 500 m (3.43) from the edges of HSKLU. In contrast, diversity was significantly higher at 500 m (3.62) into the forests than at the 5 m (3.23) and 250 m (3.27) from the edge of HSKLS while there was no significant difference in diversity among distances from the edge of HSUKM; the H' values were 3.11, 3.23 and 2.89 at 5, 250 and 500 m respectively. HSKLU is a recently logged forest having wider forest edge full of young vegetations favorable for parasitoid development and reproduction compared to HSKLS and HSUKM. According to Magurran (1988) the number of species and number of individual per species among habitats are the most important factors in determining the value of H'. Result also showed that at any distance from the forest edges the H' of Ichneumonidae species in HSUKM was not significantly different, suggesting the HSUKM forests is very small in size and isolated. However, H' seemed to increase with the distances from the edge of HSKLS. This indicates that although HSKLS is about the same stages of regeneration forest as of the HSUKM, it larger in size than that of HSUKM contributed to the relatively higher diversity of ichneumonidae at all distances from forest edge. Overall, there is a possibility of using the H' to determine size or comparing the stage (age) of regeneration among forests.

Table 3: The Jaccard's Similarity Index for Ichneumonid in three different logged and fragmented forests of Langat Basin in Selangor, Malaysia

Forest	HSKLU	HSKLS	HSUKM
HSKLU	1.000	0.361	0.365
HSKLS	0.361	1.000	0.385
HSUKM	0.365	0.385	1.000

Species Similarity

The Jaccard's Coefficient Index (percent species similarity) among forests was between 0.385 (38.5%) and 0.361 (36.1%) (Table 3); similarity was 36.1, 36.5 and 38.5% between HSKLU and HSKLS, HSKLU and HSUKM and HSUKM and HSKLS respectively. This indicates that the ichneumonid species at the HSKLU comprising 36.1 and 36.5% of the HSKLS and HSUKM species assemblages respectively, while only 38.5% species in HSUKM are somewhat similar with that of HSKLS. The higher percent similarity between HSUKM and HSKLS is probably due to HSUKM and HSKLS are much older regeneration forests than that of HSKLU. Many species shared by HSUKM and HSKLS are probably specialist ichneumonid that are highly sensitive to habitat disturbance as compared to species inhabit the HSKLU (Hawkin and Sheehan, 1994). Similarly, 53.3% of the braconid species was shared by the HSUKM and KSKLS (Idris ***et al.***, 2002). The size and distances between these fragmented forests seemed to have no influence on the species similarity. For example, although HSKLS is much bigger in size than the HSUKM and HSKLU and HSUKM are only 25 km apart, the percent species shared between HSUKM and HSKLS and HSKLU and HSUKM were only 38.5 and 36.5%, respectively. Based on Jaccard's Coefficient Index there seemed to exist two community assemblages between these three forests. First is between HSKLS and HSUKM and another one is between HSKLU and HSKLS and HSUKM. This suggests that younger regeneration forest (HSKLU) had somewhat different community assemblages than that of older regeneration logged over forests (HSKLS and HSUKM).

Results of this study indicated that ichneumonid diversity, abundance and species composition influenced by the age of forest after it was last logged. The older regeneration forests had low ichneumonid individuals (abundance) than the younger one. However, the older one had higher ichneumonid diversity than the younger one if their size is relatively similar. The diversity of ichneumonid from the forest's edge into 500 m is also dependent on age of regeneration forest as well as their size. The study should be prolonged and compared with other forests of the same nature so that the result could be generalized. High population densities caused rapid changes in land-use patterns in the Langat Basin (LB) area have increased pressure on natural and environmental resources within it ecosystem besides threatening the existence of the remaining forests. Therefore, result of this study could be extended to the policy makers and forest managers of LB for their references in future land development program, but there should be a balance between development and nature conservation.

Acknowledgment

This project was funded by IRPA grant 08-02-02-0047, 09-02-02-0170 and 09-02-02-0017-EA072 of the Ministry of Sciences, Technology and Environment (MOSTE) of Malaysia.

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