



Micro-habitats' Utilization, Feeding Niche Overlapping, and Plantation Management Systems: Impacts on the Hymenopteran Community Tolerances Within Oil Palm Plantations

Ahmad Bukhary, A.K.^{1*}, Ruslan, M.Y.¹, Mohd. Fauzi, M.M.¹, Noorhisham, H.², Muhamad Fahmi, M.H.¹, Nicholas, S.¹, Izfa Riza, H.¹, Idris, A.B.¹

¹Universiti Kebangsaan Malaysia, Center for Insect Systematics, School of Environmental Sciences and Natural Resources, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia.

prince_bukhary87@yahoo.com, ruslanmdyusop@gmail.com, fauzi_muzamil@yahoo.com, mfahmi85@yahoo.com, nickolas_ukm09@hotmail.com, izfariza.hazmi@gmail.com, idrisyatie@yahoo.com.my

²Tun Razak Agricultural Research Center (PPPTR), Felda Sungai Tekam, 27000 Jerantut, Pahang, Malaysia. nhisham.h@feldaglobal.com

ABSTRACT

A study on micro-habitats utilizations, feeding *niche* overlapping, and management systems impacts pertaining to hymenopteran community were evaluated at five chosen oil palm age stands within FELDA Sungai Tekam oil palm plantations, Pahang. Samplings were done within the duration of one year, employing the standard Malaise traps, starting from February 2013 till February 2014, involving both hot and wet seasons. 60 species, from 17 families and 35 subfamilies were successfully collected during the sampling periods. Eight defined micro-habitats were elaborated, with the subdivisions of major, minor, stable, and risky micro-habitat types. Management systems impacts were associated with the applications of chemical herbicides and fertilizers. Species groups were formed using Two-Way Hierarchical Cluster Dendrogram, following 75% of information remaining. Three species groups were formed for hot and wet seasons respectively, with the first group involved nearly half of the overall hymenopteran community. Beneficial *nectariferous* plants, heaps of chipped rotting oil palm trunks, and remnants of rotting forest logs were all the prominent micro-habitats associated with all cases of hymenopteran species groups, for both cases of major and minor micro-habitat types. Application of BASTA, Glyphosate-Type-A and Type-B herbicides, as well as NK-Mix, Borax, and GML chemical fertilizers were all highly correlated with hymenopteran species groups, showing the high tolerance of most hymenopteran species towards the employed management systems, with reference to minor micro-habitats. Strong feeding ecological *niches* and *plexus* values between species of similar species groups formed were specifically associated with discrete but connected minor micro-habitats with weaker food chains, collectively forming larger stable food webs within major micro-habitats. Suggestions on maintaining minor micro-habitats for the survival of most hymenopteran community, as well as the sustenance of their food sources were also discussed.

Indexing terms/Keywords

Micro-habitats, *Niche* Overlapping, Management Systems, Community, Oil Palm Plantations, Wasps.

Academic Discipline And Sub-Disciplines

Entomology, Ecology, Agriculture, Biodiversity.

SUBJECT CLASSIFICATION

Original Research Work. Correlating wasps (Hymenoptera) communities within oil palm plantations with various oil palm plantations' management systems, in accordance to the suitability of several defined and measured micro-habitats. Altered niche overlapping of several hymenopteran species within specified species groups in relation to these factors were also focused.

INTRODUCTION

Malaysia has become one of the primary oil palm producers in Southeast Asia after Indonesia, with oil palm industries ranked as second most important revenue sources after oil and gas sectors (MPOB 2007). However, the alleged oil palm plantation activities have a substantial impact on the environment, particularly endangered species of flora and fauna (Koh and Wilcove 2007). Southeast Asia experienced one of the highest rates of deforestation in tropical areas as a result of involving the urbanization process, which is estimated to result in the reduction and extinction of natural forest stands, continually worsen where there are additional increasing trending in world demand for food, bio-fuel sources, and other types of productions or generate savings to the rapid development of industries – oil palm industry having such impacts on the lowland dipterocarp forest, thus affecting biological status of Southeast Asian forests (Sodhi et al. 2010). Oil palm is one of the few plants that are growing very rapidly in the world. Oil palm plantations support a small number of species of insects from the primary forests as well as compared with other crops (Fitzherbert et al., 2008). There have been considerable researches and records on the diversity-ecological studies of arthropods and insect species within oil palm plantations, heavily focused on beetle and ant species in most cases, resulted from feasible sampling efforts (Chung et al. (2000), Fayle et al. (2010), Turner and Foster (2009)), but very few specifically focused on other types of insect orders, as

well as the more important context of oil palm-specific micro-habitats that can eventually affecting the diversity status of all insect species currently existing within oil palm plantations. Previous studies had pinpointed and stressed on the importance of micro-habitats in managing insect species within oil palm plantations, but solely referred to forest-specific micro-habitats, which in most cases were considered impractical for any oil palm plantations of various age stand types, especially whether involved the initial replanting stands, or even for the older, advanced age stands (McNeely et al. 1995). Insects are the basis of many terrestrial-related food webs (Southwood et al. 1979), and so far the most studied insect species within oil palm plantations, besides beetle and ant species, are mostly of pest-related (Mohd Hanysyam et al. (2013); Chong et al. (1991); Wood (1982); Turner and Gillbanks (2003); Salmah (2005); Faszly et al. (2003); Norman & Basri (2003)). Changes and fluctuations of the harsh environment within oil palm plantations could direct to a significant impact on the diversity and ecology of insects within oil palm plantations (Ulyshen et al. (2004); Didham et al. (1998); Purvis and Fadl (2002)) as because most of the insect species are specific to the host plant species assemblages and also most of the time, are limited to one type of habitat only and showing such a strong endemism. In addition, farming activities can elaborate further clear and profound impact on the changes, successions, and displacements to land and soil structures, the natural vegetational characteristics, and on the related temporal scale as well as in terms of spatial factors (Jepsen et al. 2005). There are several researches exploring the diversity status, taxonomy, abundances, and host insects' preferences of beneficial insects within oil palm plantations, such as parasitoid hymenopterans, however, there is no clear research has been done thoroughly, specifying on the resource utilizations (feeding and micro-habitat resources utilizations) of these parasitoids with the incorporations of implemented oil palm plantations' management systems, and to the eventual effect on the overall diversity and ecological attributes changes of such parasitoids, and the continual sustenance for their fitness as viable biological control agents in naturally controlling pest species within oil palm plantations. Hence, this study attempted to fundamentally study the utilizations of various oil palm-specific micro-habitats types existing within different oil palm age stands by various parasitoid species, in relation to the existing feeding ecological niches and with the incorporations of external factor involving oil palm plantations' management systems.

MATERIALS AND METHODS

Sampling was carried out for 13 months, starting from February 2013 till February 2014, involving the oil palm plantation plots provided within FELDA Sungai Tekam, Jerantut, Pahang. Oil palm age stand types, geo-co-ordinates for replicate plots, trap numbers employed, trapping efforts, and all micro-habitat types complete names are summarized in Table 1. In each chosen oil palm age stand, the Malaise traps were placed at the centre for each oil palm replicate plots, to maximize their effectiveness, following Townes (1972) and Hutcheson (1991). The temporal interval for collecting all trapped insect samples and refilling of 70% alcohol solutions within Malaise traps collecting bottle is one month. All of the trapped hymenopteran samples within the collection bottle were brought to the entomological laboratory for further sorting from other unrelated insect species and pinning processes. Identification was made to the level of subfamilies and related suitable morphospecies or forms of Recognizable Taxonomic Units (RTUs) (Chung et al. 2000), based on Triplehorn and Johnson (2005), Borror and White (1970), and Goulet and Huber (1993). Voucher species and the original data are stored at the Centre of Insect Systematics (CIS), Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM). The experiment covered an overall area of 2 ha for all the five chosen oil palm age stands. All of the defined micro-habitats were chosen in terms of visual-physical variability. Ambient temperature and relative humidity for each defined micro-habitats were recorded using soil surface located-HOBO probes for each sampling month. Recorded ambient temperature and relative humidity raw data were summed and averaged per sampling month, according to different micro-habitat types, suited for advanced statistical ecology analyses. Morphospecies data were arranged for ecological analyses using PC-ORD V.6 statistical package (McCune and Mefford 1997), with the first matrix specifying on constructing the Two-Way Hierarchical Cluster Dendrogram (TWHCA), used for choosing significant species groups following 75% of information remaining and 25% variances between species groups formed, while both the first and second matrix specifying on iteration of CCA and NMS ordinations, including the Chi-Square Species *Plexus* values, and the ordination scores (r , r^2 , and τ) for the impacts of both applied management systems and micro-habitats, will all related values chosen for ≥ 0.300 . Species groups formed referring to the Two-Way Hierarchical Cluster Dendrogram were further tested within Ecosim Professional statistical package, specifying on Pianka's Pairwise Niche Overlapping analysis (Acquired Intelligence 2005). Simplified, coloured figures depicting the micro-habitats' utilizations of hymenopteran species based on CCA and NMS ordination scores were constructed using Microsoft Excel 2013.

Table 1. Study sites, geographical coordinates, number of traps, trapping efforts, and micro-habitats complete names.

Oil Palm Age Stands	Geographical Coordinates	No. of Malaise Traps	Sampling Efforts	Micro-habitats (Complete Names)
< 1 year old				
Replicate 1	N 03°54'592" E 102°31'502"	1	393	CT Chipped Trunks
Replicate 2	N 03°54'474" E 102°31'413"	1	393	
Replicate 3	N 03°54'492" E 102°31'573"	1	393	EFB Empty Fruit Bunches
Replicate 4	N 03°54'382" E 102°32'023"	1	393	RFL Rotting Forest Logs

**3 years old**

Replicate 1	N 03°54'052" E 102°32'062" N 03°54'133"	1	393	LCC Legume Cover Crops
Replicate 2	E 102°32'143" N 03°53'582"	1	393	
Replicate 3	E 102°32'153" N 03°53'493"	1	393	BNP Beneficial Plants
Replicate 4	E 102°32'242"	1	393	

NWV Natural Weeds and Vines**6 years old**

Replicate 1	N 03°54'253" E 102°32'184" N 03°54'234"	1	393	BEC Bryophytes Cover
Replicate 2	E 102°32'071" N 03°54'252"	1	393	
Replicate 3	E 102°31'532" N 03°54'163"	1	393	ROF Rotting Old Fronds
Replicate 4	E 102°31'581"	1	393	

T Ambient Temperature**18 years old**

Replicate 1	N 03°53'592" E 102°31'482" N 03°54'113"	1	393	RH Relative Humidity
Replicate 2	E 102°31'441" N 03°54'062"	1	393	
Replicate 3	E 102°31'561" N 03°53'482"	1	393	
Replicate 4	E 102°31'401"	1	393	

23 years old

Replicate 1	N 03°55'024" E 102°30'482" N 03°55'001"	1	393	
Replicate 2	E 102°31'002" N 03°54'532"	1	393	
Replicate 3	E 102°31'074" N 03°55'042"	1	393	
Replicate 4	E 102°31'203"	1	393	

RESULT

A total of 19516 hymenopteran individuals, from 60 species, 17 families, and 35 subfamilies were successfully collected throughout the year 2013, and based on the Two-Way Hierarchical Cluster Dendrogram Analysis (TWHCDA) constructed, (Figure 1 and Figure 2, for both hot and wet seasons, respectively), six hymenopteran significant main species groups were attained, following 75% of information remaining and 25% of variances between formed species groups. Defined species groups (containing two or three species elements per group) reaching Chi-square *Plexus* and Pianka's *Niche* Overlapping Pairwise values of more than 0.00 were further chosen and characterized into several distinctive micro-habitat attributes. The Chi-Square *Plexus* values were based on CCA and NMS ordination scores, for both management system and micro-habitat factors, as each ordination methods were related with major and minor micro-habitat types, respectively. Three significant micro-habitats-based groups were successfully erected for each cases of tropical annual season (hot and wet seasons), with the total formed of six groups. For each group, species elements were further associated with both the stable and risky micro-habitats. Significant associated of stable and risky micro-habitats were calculated based on comparison and by percentages, with reference to classified major and minor micro-habitats. Figure 3-5 separately showed the figural representations of all the associated major, minor, stable, and risky micro-habitats for hot season, and Figure 6-8 for wet season. For the case pertaining to species groups tolerance levels with the associated management systems factor implemented, these findings were summarized in Table 1 to 3 for hot season, while Table 4 to 6 for wet season, both supplied with the related Pianka's *Niche* Overlapping Pairwise values.

During the hot season, for Group 1, the utilization percentages of both major and minor stable micro-habitats were significantly high, with 60.00% and 75.00% respectively, compared with the utilizations of both major and minor risky micro-habitats, with 40.00% and 25.00% respectively. There were no record on any concentrated community on both stable and risky micro-habitats. These findings were correlated with the high parallel impacts between the species within similar species groups, with 81.82%, compared with only 18.18% that showed cases of disparity impacts between species within similar species groups. All of the species groups showing parallel impacts were highly correlated with the employment of BASTA and Glyphosate-Type-B herbicides, as well as the application of NK-Mix fertilizer. Heaps of chipped, old, oil palm trunks, remnants of old forest logs, and beneficial nectariferous plants were all become the stable

major and minor micro-habitats for most species within Group 1 during the hot season, related with 37.00% from total hymenopteran community. The oil palm of the age less than a year, as well as 3 years old all equally important in providing all these micro-habitats for nearly half the hymenopteran community during the hot season. High parallel impacts between the species within similar species groups showed high species tolerance despite of the application of various herbicides and chemical fertilizer, with significantly high overlapping between the defined micro-habitats and feeding resources. There are high possibilities that most of the host insects' larvae or pupae developing stages are highly abundant within the related micro-habitats of less than a year and 3 years old of oil palm age stands, giving out the higher chances for tolerance pertained to feeding resources for all species within the Group 1 species groups (with reference that most of these hymenopteran species are parasitoids and the rest are predators). For Group 2, the utilization percentages of both major and minor stable micro-habitats were significantly high, similar

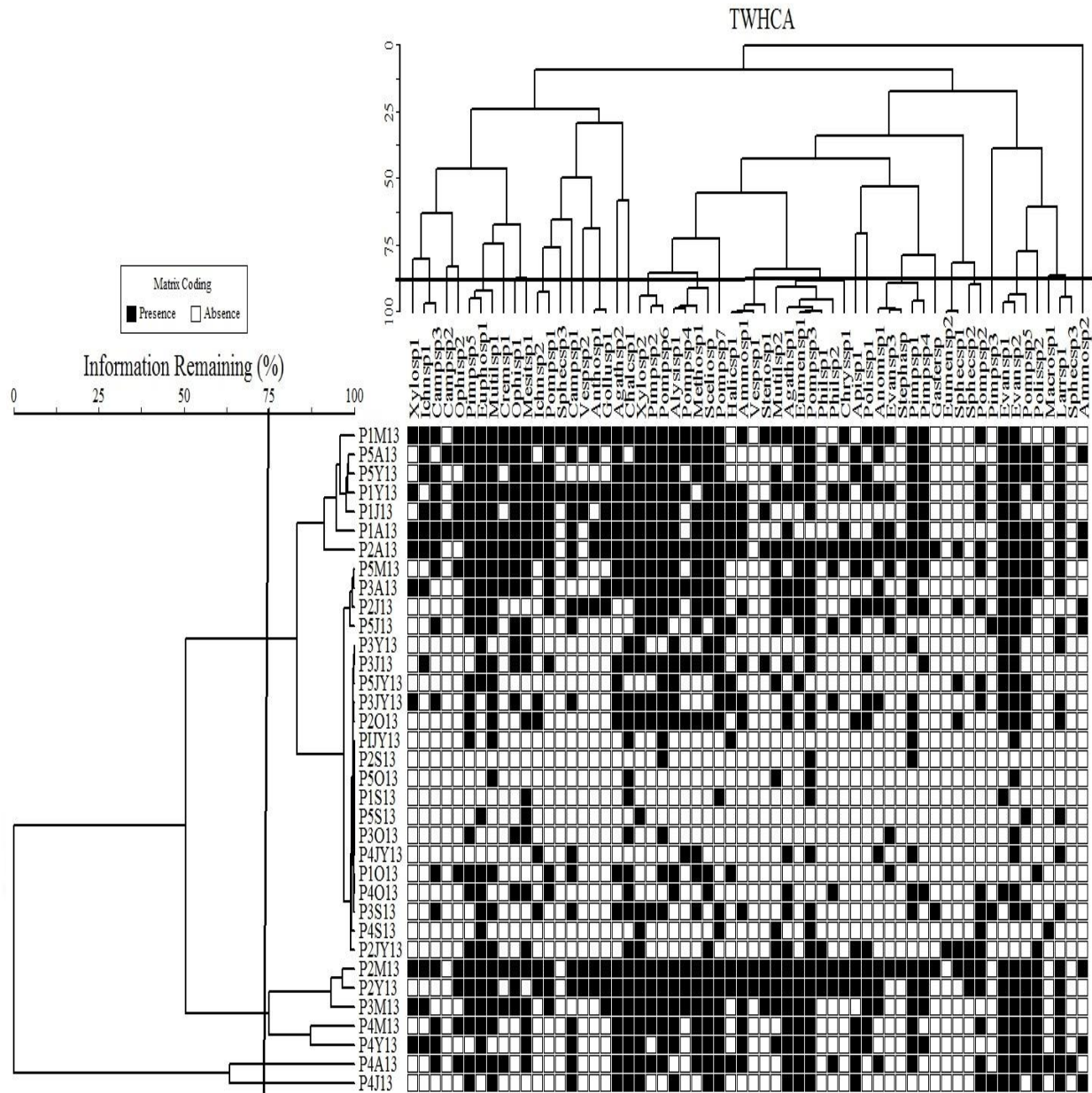


Figure 1: Species groups formed by constructed Two-Way Hierarchical Cluster Analysis (TWHCA), following 75% of information remaining across hot season.

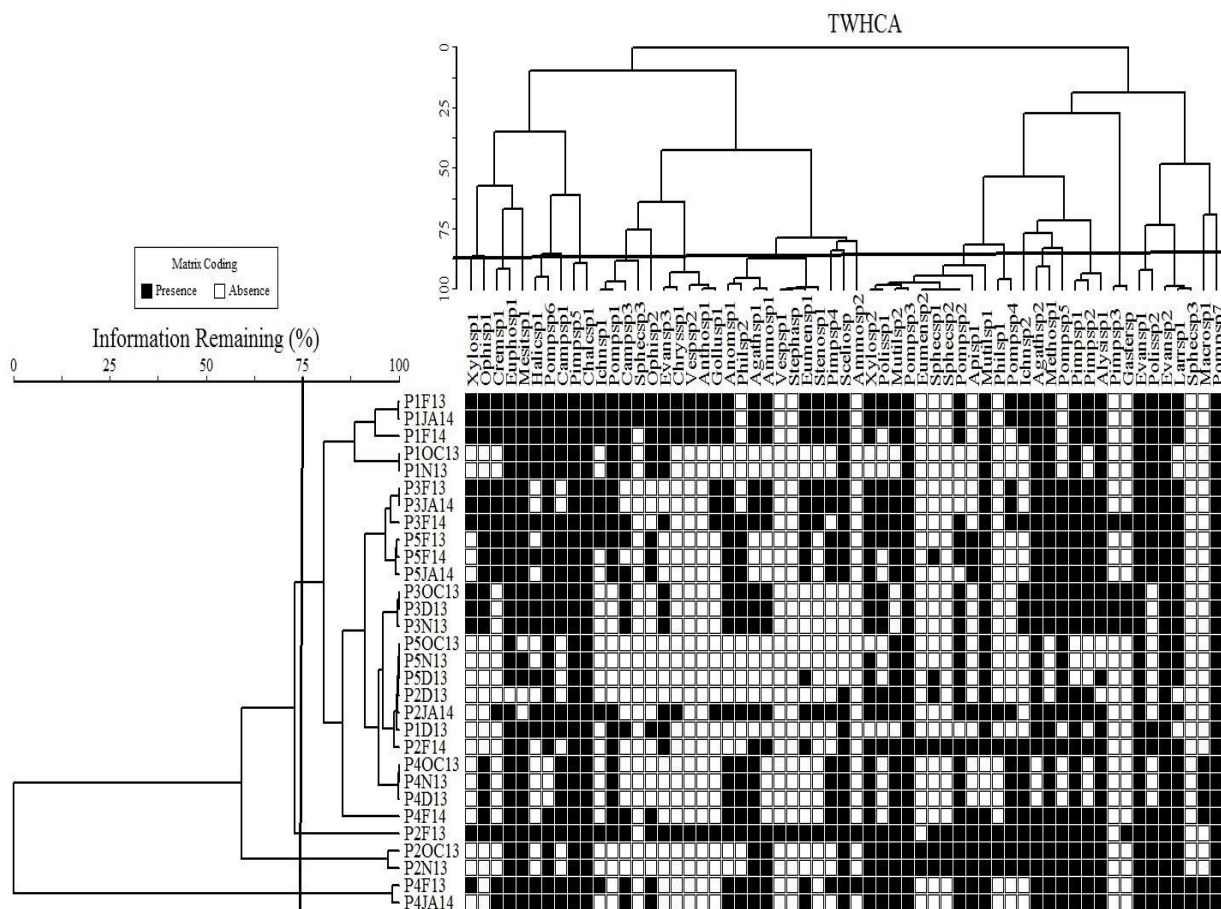
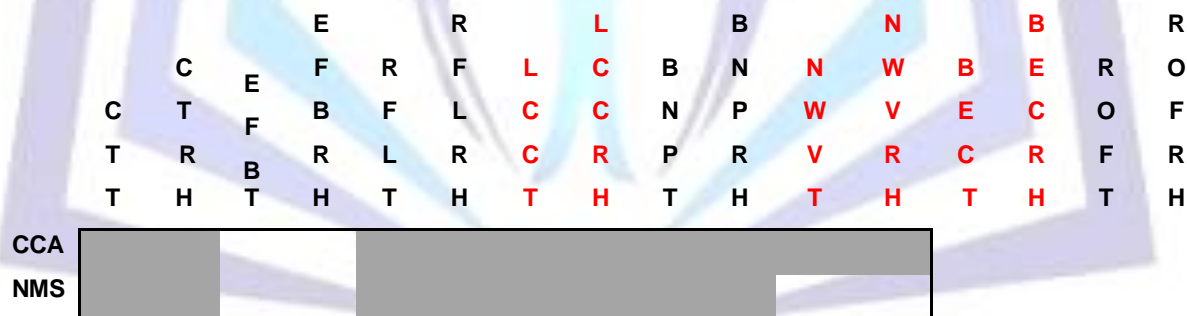


Figure 2: Species groups formed by constructed Two-Way Hierarchical Cluster Analysis (TWHCA), following 75% of information remaining across wet season.



Percentages of major stable micro-habitats: 60.00%

Percentages of minor stable micro-habitats: 75.00%

Percentages of major risky micro-habitats: 40.00%

Percentages of minor risky micro-habitats: 25.00%

Percentages of major stable micro-habitats with concentrated community: 0.00%

Percentages of minor stable micro-habitats with concentrated community: 0.00%

Percentages of major risky micro-habitats with concentrated community: 0.00%

Percentages of minor risky micro-habitats with concentrated community: 0.00%

Figure 3: Major, minor, stable, and risky micro-habitats utilization percentages of Group 1 hymenopteran species groups across hot season.

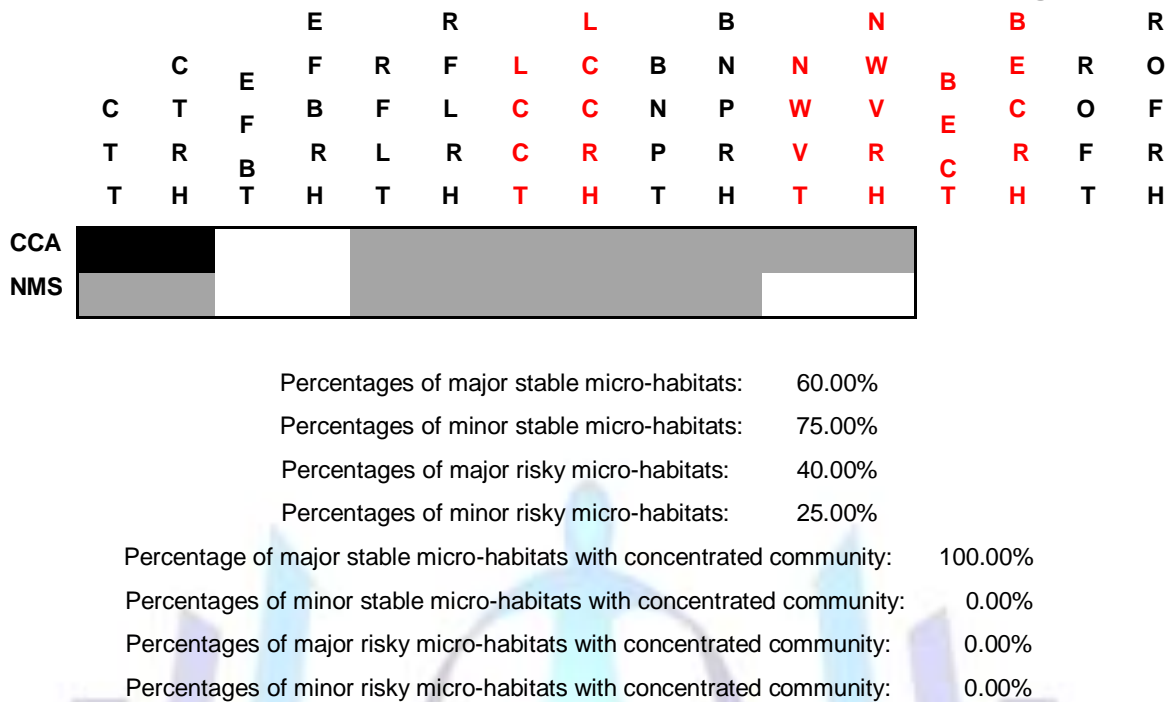


Figure 4: Major, minor, stable, and risky micro-habitats utilization percentages of Group 2 hymenopteran species groups across hot season.

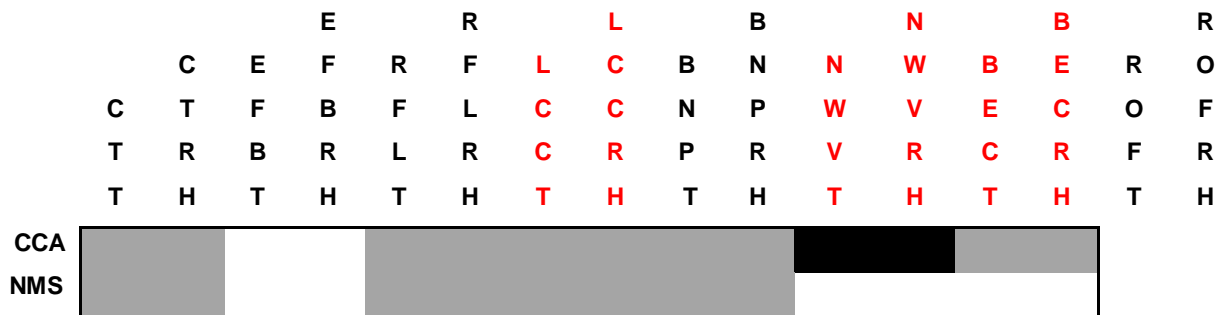
of Group 1, with 60.00% and 75.00% respectively, and also showing similar utilization percentages for major and minor risky micro-habitats, with 40.00% and 25.00% respectively. However, there was a record on the utilization of one major micro-habitats, which was the heaps of chipped, old oil palm trunks, harbouring concentrated hymenopteran community with the level of 100.00%. Group 2 only contained two species groups, compared with Group 1 with 11 species groups. Furthermore, the parallel impacts were of equal with the disparity impacts for Group 2, with both recorded 50.00% of tolerance levels, showing that the heavy dependency on one major micro-habitat significantly affecting species tolerances. The addition impacts of the herbicide Ally/Garlon application, as well as the Borax fertilizer, which is known to give indirect entomo-repellent effects, can also be the possible factors of much reduced species groups within Group 2, even though all other micro-habitat types utilizations were at similar percentages with Group 1. Group 3, similar with Group 2, have two species groups, although the utilization percentages of major stable micro-habitats were slightly lower (50.00%), but at equal percentages of the case for minor stable micro-habitats (75.00%). The utilization on major risky micro-habitats were also slightly higher compared with Group 1 and Group 2 (50.00%), but keeping similar utilizations on minor risky micro-habitats (25.00%).

The most notable difference between Group 1 and Group 2 with Group 3 is the total concentration of community on one single major risky micro-habitat, involving the natural weeds, shrubs, and vines. The tolerance levels were at equal, similar of Group 2, with 50.00% showing parallel impacts, and another 50.00% showing cases of disparity impacts of species within similar species groups. The additional impacts of the Ally/Garlon herbicide application, as well as the entomo-repellent Borax fertilizer, might become the factors of reduced species groups in Group 3, similar with Group 2. Overall, during hot season, comparing all three main groups, Group 1 showed the highest tolerance, despite no community concentration but with many species groups interacting together within the defined micro-habitats and higher Chi-Square *Plexus* and Pianka's *Niche* Overlapping values, followed by Group 3, which also showed moderate tolerance compared with Group 2, which showed the least tolerance, considering the concentrated community on the major risky micro-habitat for Group 3, and maintaining comparable species group numbers as Group 2, which also had concentrated community, but involved major and stable micro-habitat. Comparing Group 2 and Group 3 in terms of Chi-Square *Plexus* and Pianka's *Niche* Overlapping values, showed that Group 2 having higher values compared with Group 3, but because Group 2 were much more related with community concentration on stable micro-habitat, this condition can eventually buffer the management system effects, hence making Group 3 to have slightly higher tolerance levels compared with Group 2.

During the wet season, for Group 1, the utilization percentages of both major and minor stable micro-habitats were significantly high, with both recording at 75.00%, compared with the lower utilizations of both major and minor risky micro-habitats, both at 25.00% respectively. Different from Group 1 during the hot season, there were considerable record on community concentration for Group 1 during wet season, with all cases of major, minor, stable, and risky micro-habitats showing similar percentages of concentrations (50.00%). Unexpectedly, the incidence of parallel impacts for species within similar species groups were slightly higher (83.33%), compared during the hot season. At the same time, the

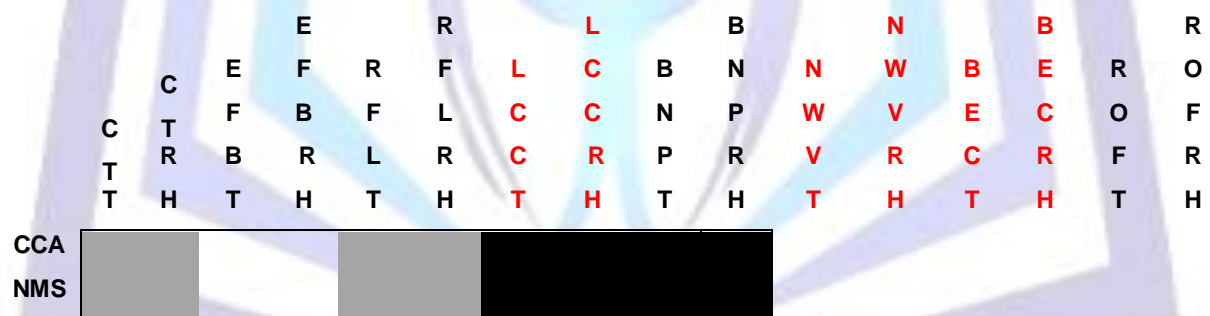


occurrences of disparity impacts of species within similar species groups were also slightly lower (16.67%), proving that community concentration within certain micro-habitats with the support of minor micro-habitats can eventually buffer species intolerances,



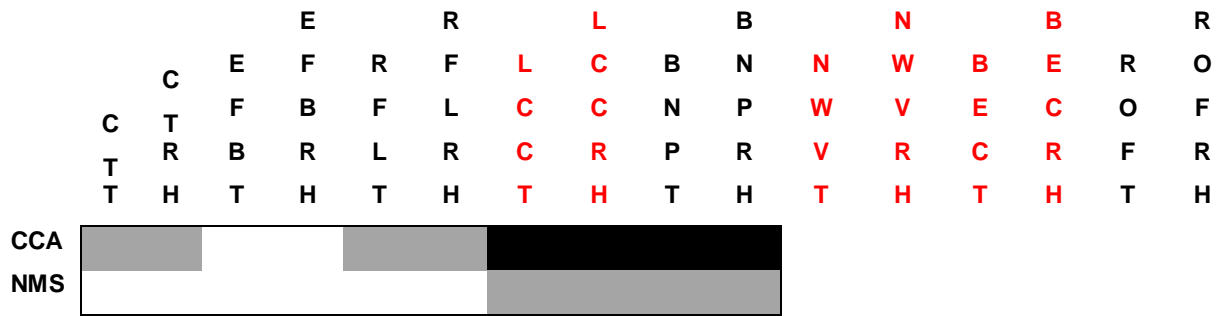
Percentages of major stable micro-habitats: 50.00%
 Percentages of minor stable micro-habitats: 75.00%
 Percentages of major risky micro-habitats: 50.00%
 Percentages of minor risky micro-habitats: 25.00%
 Percentage of major stable micro-habitats with concentrated community: 0.00%
 Percentages of minor stable micro-habitats with concentrated community: 0.00%
 Percentages of major risky micro-habitats with concentrated community: 100.00%
 Percentages of minor risky micro-habitats with concentrated community: 0.00%

Figure 5: Major, minor, stable, and risky micro-habitats utilization percentages of Group 3 hymenopteran species groups across hot season.



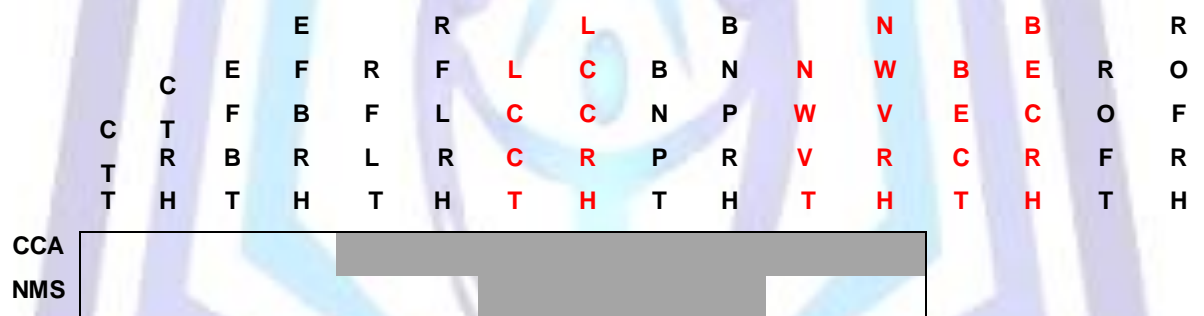
Percentages of major stable micro-habitats: 75.00%
 Percentages of minor stable micro-habitats: 75.00%
 Percentages of major risky micro-habitats: 25.00%
 Percentages of minor risky micro-habitats: 25.00%
 Percentage of major stable micro-habitats with concentrated community: 50.00%
 Percentages of minor stable micro-habitats with concentrated community: 50.00%
 Percentages of major risky micro-habitats with concentrated community: 50.00%
 Percentages of minor risky micro-habitats with concentrated community: 50.00%

Figure 6: Major, minor, stable, and risky micro-habitats utilization percentages of Group 1 hymenopteran species groups across wet season.



Percentages of major stable micro-habitats: 75.00%
 Percentages of minor stable micro-habitats: 50.00%
 Percentages of major risky micro-habitats: 25.00%
 Percentages of minor risky micro-habitats: 50.00%
 Percentage of major stable micro-habitats with concentrated community: 50.00%
 Percentages of minor stable micro-habitats with concentrated community: 0.00%
 Percentages of major risky micro-habitats with concentrated community: 50.00%
 Percentages of minor risky micro-habitats with concentrated community: 0.00%

Figure 7: Major, minor, stable, and risky micro-habitats utilization percentages of Group 2 hymenopteran species groups across wet season.



Percentages of major stable micro-habitats: 50.00%
 Percentages of minor stable micro-habitats: 50.00%
 Percentages of major risky micro-habitats: 50.00%
 Percentages of minor risky micro-habitats: 50.00%
 Percentage of major stable micro-habitats with concentrated community: 0.00%
 Percentages of minor stable micro-habitats with concentrated community: 0.00%
 Percentages of major risky micro-habitats with concentrated community: 0.00%
 Percentages of minor risky micro-habitats with concentrated community: 0.00%

Figure 8: Major, minor, stable, and risky micro-habitats utilization percentages of Group 3 hymenopteran species groups across wet season.

compared with cases where community concentrations (as in Group 1 during hot season) solely dependent on major micro-habitats. The existence of minor micro-habitats, although less physically prominent in terms of volume and surface area within the oil palm plantations, act as an environmental buffer, able to alleviate any subcases of species intolerance between species members of similar species groups, and eventually result in overall stability over time. All of the species groups showing parallel impacts were highly correlated with the employment of BASTA herbicide, and also GML fertilizer. Heaps of chipped, old, oil palm trunks, remnants of old forest logs, and beneficial nectariferous plants were all become the



stable major and minor micro-habitats for most species within Group 1 during the wet season, at similar trend during the hot season, with the difference of further community concentrations within the mentioned micro-habitats. This were related with 23.00% from total hymenopteran community, although to be much lower compared during the hot season, further showing that nearly a quarter of hymenopteran community were dependent on minor micro-habitats during the wet season for survival and buffering any adverse management system impacts. The oil palm of the age less than a year was important in providing all these micro-habitats for nearly a quarter of the hymenopteran community during the wet season. Although observed as having lower percentages of community accumulation compared during the hot season, additional and unpredictable adverse effects coming along during the wet season can be buffered by the support and dependent behaviour on the minor micro-habitats.

Furthermore, high parallel impacts between the species within similar species groups, even higher than during the hot season, showed high species tolerance despite of the application of herbicide and chemical fertilizer, evidencing the sustenance provided by the minor micro-habitats, despite of heavy community concentrations of similar, major micro-habitats. Community concentration within the minor micro-habitats eventually benefit in lessening the impacts of species competitions over similar host insect species (in the form of larvae or pupae) for parasitoids, and partially for predatory hymenopterans, as most other prey insect species may concentrated on the major micro-habitats. For Group 2 during the wet season, the utilizations percentages for major stable micro-habitats were similar of Group 1 (75.00%), but with lower utilization percentages for minor stable micro-habitats (50.00%). Additionally, the utilization percentages of major risky micro-habitats were similar to Group 1, but eventually higher for the case of minor risky micro-habitats (50.00%). There were also cases of community concentration on only major micro-habitats, both involved the stable and risky types. This resulted in lesser species groups compared with Group 1, with only three species groups. However, the parallel impacts for the species within similar species groups were considerably high (66.67%), but at the same time with higher disparity impacts for one species group (33.33%). Similar to Group 1, both BASTA herbicide and GML fertilizer implementations were the main management system factors affecting the species groups with parallel impacts, with additional Glyphosate-Type-A impact on the single species group with disparity impacts. Group 2 was another example of how community concentrations within only major micro-habitats, either stable or risky, that can lead to species groups instability and higher intolerances, finally resulted in lesser number of species groups with parallel impacts. Finally, for Group 3, which showed to have all equal utilization percentages on all cases of major and minor micro-habitats, both stable and risky (50.00%). However, the disparity impacts cases were the highest recorded, compared with other groups and also among different seasons (75.00%), and only 25.00% involving one species group showing parallel impacts. The parallel impacts showing BASTA herbicide and GML fertilizer employments, while for all three other disparity impacts showed Glyphosate-Type-A as additional management system impacts. Overall, comparing both tropical annual seasons on micro-habitat utilizations of hymenopteran communities, any adverse management system impacts implemented by oil palm plantations managers were not adversely affecting them, as long as there are support from any existing minor micro-habitats of either cases of stable and risky. In cases where there were community concentrations only on major micro-habitats, resulted in reductions in species groups formations, hence affecting lesser hymenopteran communities, which in turn will ensure negative intolerances between any existing species foraging for host or prey insect species, and causing species displacements, reductions, and food webs disintegrations over time in the long run. As mentioned earlier, minor micro-habitats acted as environmental buffer, slowing the rate of species interacting with negative or adverse management system impacts, as well as providing additional spaces for parasitoids and predatory hymenopteran species to search for their host or prey insect species, as well as subduing any possible risks of intolerances between species that simultaneous high levels of Chi-Square *Plexus* and Pianka's *Niche* Overlapping values at the same time. This notion can be depicted by Group 1 within both seasons, showing many of the species groups that showed parallel impacts, at the same time also having simultaneous Chi-Square *Plexus* and Pianka's *Niche* Overlapping values that were considerably high, as these species groups related equally among both the major and minor micro-habitats and very seldom involved only the major micro-habitats alone. In addition, most of the species groups within Group 1 were most probably inhabiting many minor micro-habitat patches (evident by the high Chi-Square *Plexus* and Pianka's *Niche* Overlapping values), and these conditions creating 'small-scale ecosystem island', where most of the species have specific feeding preferences over their own patchy territories, including resting sites and places for procuring extra energy in the form of nectar, as well as avoiding any damaging management system impacts on physically dominant major micro-habitats, and at the same time restricting other species to occupy spaces for foraging and finding host insects within specified minor micro-habitat patches. Minor micro-habitats are indeed urgently important as confirmed in this study, hence, it is important that oil palm plantation managers to conserve and not to disturb the less physically prominent, patchy, but collectively large in surface-area of minor micro-habitats for the survival of important parasitoid and predatory hymenopteran species within oil palm plantations of various age stand types, and in a long run, can eventually promoting and sustaining the natural propagation of natural biological control agents for controlling any foliar or fresh-bunch related pests species.

Table 2. Pianka's *Niche* Overlapping values, Chi-Square *Plexus* values, Tolerance levels and Management System Impacts for Group 1 hymenopteran species group across hot season.

Group 1	<i>Plexus</i>	Pianka's <i>Niche</i> Overlapping	Tolerance levels	Tolerance Ranking	Management System Impacts
<i>Antho-sp1</i>	0.710	0.990	Paralleled Impacts	1	BASTA, Gly-B, NK-Mix
<i>Gollu-sp1</i>					



<i>Xylo-sp2</i>	0.537*	0.948*	Paralleled Impacts	2	BASTA, Gly-B, NK-Mix
<i>Pimp-sp2</i>					
<i>Pomp-sp6</i>					
<i>Scelio-sp1</i>	0.516	0.954	Parallel Impacts	3	BASTA, Gly-B, NK-Mix
<i>Metho-sp1</i>					
<i>Ophi-sp1</i>	0.502	0.860	Parallel Impacts	6	BASTA, Ally/Garlon
<i>Mesit-sp1</i>					
<i>Vespid-sp1</i>	0.492	0.900	Parallel Impacts	5	BASTA, Gly-B, NK-Mix
<i>Steno-sp1</i>					
<i>Pimp-sp1</i>	0.462	0.925	Parallel Impacts	4	BASTA, Gly-B, NK-Mix
<i>Pimp-sp4</i>					
<i>Alysi-sp1</i>	0.359	0.956	Parallel Impacts	7	BASTA, Gly-B, NK-Mix
<i>Pomp-sp4</i>					
<i>Anom-sp1</i>	0.336*	0.928*	Disparity Impacts	10	<i>Evan-sp3</i> – BASTA, <i>Anom-sp1, Stepha-sp1</i> - Gly-B, NK-Mix
<i>Evan-sp3</i>					
<i>Stepha-sp1</i>					
<i>Ichn-sp2</i>	0.304	0.969	Disparity Impacts	11	<i>Ichn-sp2</i> – Ally/Garlon <i>Pomp-sp1</i> – BASTA
<i>Pomp-sp1</i>					
<i>Ichn-sp1</i>	0.284	0.940	Parallel Impacts	8	BASTA, Gly-B, NK-Mix
<i>Camp-sp3</i>					
<i>Eumen-sp1</i>	0.238*	0.983*	Parallel Impacts	9	BASTA, Gly-B, NK-Mix
<i>Pomp-sp3</i>					
<i>Phil-sp1</i>					

*Averaged Chi-Square *Plexus* and Pianka's *Niche* Overlapping Pairwise Values for three species elements.

*Percentages of Parallel Impacts from all species groups: 81.82%

*Percentages of Disparity Impacts from all species groups: 18.18%

Table 3. Pianka's *Niche* Overlapping values, Chi-Square *Plexus* values, Tolerance levels and Management System Impacts for Group 2 hymenopteran species group across hot season.

Group 1	<i>Plexus</i>	Pianka's <i>Niche</i> Overlapping	Tolerance levels	Tolerance Ranking	Management System Impacts
<i>Pimp-sp5</i>	0.367*	0.957*	Disparity Impacts	2	<i>Pimp-sp5, Eupho-sp1</i> – BASTA <i>Mutil-sp1</i> – Gly-B, NK-Mix
<i>Eupho-sp1</i>					
<i>Mutil-sp1</i>					
<i>Halic-sp1</i>	0.304	0.990	Parallel Impacts	1	Ally/Garlon, BASTA, Gly-B, NK-Mix, Borax
<i>Ammo-sp1</i>					

*Averaged Chi-Square *Plexus* and Pianka's *Niche* Overlapping Pairwise Values for three species elements.

*Percentages of Parallel Impacts from all species groups: 50.00%

*Percentages of Disparity Impacts from all species groups: 50.00%

Table 4. Pianka's Niche Overlapping values, Chi-Square Plexus values, Tolerance levels and Management System Impacts for Group 3 hymenopteran species group across hot season.

Group 1	Plexus	Pianka's Niche Overlapping	Tolerance levels	Tolerance Ranking	Management System Impacts
<i>Sphec-sp2</i>	0.298	0.916	Disparity Impacts	2	<i>Sphec-sp2</i> – Ally/Garlon, BASTA
<i>Pomp-sp2</i>					<i>Pomp-sp2</i> – Gly-B, NK-Mix, Borax
<i>Xylo-sp2</i>	0.148*	0.948*	Paralleled Impacts	1	Ally/Garlon, BASTA, Gly-B, NK-Mix, Borax
<i>Pimp-sp2</i>					
<i>Pomp-sp6</i>					

*Averaged Chi-Square Plexus and Pianka's Niche Overlapping Pairwise Values for three species elements.

*Percentages of Parallel Impacts from all species groups: 50.00%

*Percentages of Disparity Impacts from all species groups: 50.00%

Table 5. Pianka's Niche Overlapping values, Chi-Square Plexus values, Tolerance levels and Management System Impacts for Group 1 hymenopteran species group across wet season.

Group 1	Plexus	Pianka's Niche Overlapping	Tolerance levels	Tolerance Ranking	Management System Impacts
<i>Vesp-sp2</i>	1.000	0.990	Paralleled Impacts	1	BASTA, GML
<i>Antho-sp1</i>					
<i>Chrys-sp1</i>	0.742	0.947	Paralleled Impacts	2	BASTA, GML
<i>Gollu-sp1</i>					
<i>Xylo-sp1</i>	0.526	0.967	Paralleled Impacts	3	BASTA, GML
<i>Ophi-sp1</i>					
<i>Halic-sp1</i>	0.356	0.980	Paralleled Impacts	4	BASTA, GML
<i>Pomp-sp6</i>					
<i>Ichn-sp1</i>	0.249*	0.984*	Paralleled Impacts	5	BASTA, GML
<i>Camp-sp3</i>					
<i>Pomp-sp1</i>					
<i>Crem-sp1</i>	0.162	0.959	Disparity Impacts	6	<i>Crem-sp1</i> – Gly-A
<i>Eupho-sp1</i>					<i>Eupho-sp1</i> – BASTA

*Averaged Chi-Square Plexus and Pianka's Niche Overlapping Pairwise Values for three species elements.

*Percentages of Parallel Impacts from all species groups: 83.33%

*Percentages of Disparity Impacts from all species groups: 16.67%

Table 6. Pianka's Niche Overlapping values, Chi-Square Plexus values, Tolerance levels and Management System



Impacts for Group 2 hymenopteran species group across wet season.

Group 1	Plexus	Pianka's Niche Overlapping	Tolerance levels	Tolerance Ranking	Management System Impacts
<i>Vesp-sp1</i>	1.000	1.000	Paralleled Impacts	1	BASTA, GML
<i>Stepha-sp1</i>					
<i>Ammo-sp1</i>	0.756	0.943	Disparity Impacts	3	<i>Ammo-sp1</i> – BASTA
<i>Agath-sp1</i>					<i>Agath-sp1</i> – Gly-A
<i>Eumen-sp1</i>	0.603	0.935	Paralleled Impacts	2	BASTA, GML
<i>Steno-sp1</i>					

*Percentages of Parallel Impacts from all species groups: 66.67%

*Percentages of Disparity Impacts from all species groups: 33.33%

Table 7. Pianka's Niche Overlapping values, Chi-Square Plexus values, Tolerance levels and Management System Impacts for Group 3 hymenopteran species group across wet season.

Group 1	Plexus	Pianka's Niche Overlapping	Tolerance levels	Tolerance Ranking	Management System Impacts
<i>Eumen-sp2</i>	0.604	0.999	Paralleled Impacts	1	BASTA, GML
<i>Sphec-sp1</i>					
<i>Phil-sp1</i>	0.478	0.914	Disparity Impacts	4	<i>Phil-sp1</i> –BASTA, GML
<i>Pomp-sp4</i>					<i>Pomp-sp4</i> –Gly-A
<i>Xylo-sp2</i>	0.449	0.988	Disparity Impacts	2	<i>Xylo-sp2</i> –Gly-A
<i>Polis-sp1</i>					<i>Polis-sp1</i> – BASTA, GML
<i>Pomp-sp2</i>	0.257	0.988	Disparity Impacts	3	<i>Pomp-sp2</i> – Gly-A
<i>Sphec-sp2</i>					<i>Sphec-sp2</i> –BASTA, GML

*Percentages of Parallel Impacts from all species groups: 25.00%

*Percentages of Disparity Impacts from all species groups: 75.00%

DISCUSSION

Deciphering the functions of micro-habitats in buffering community tolerances over adverse environmental impacts and conditions in natural ecosystems, or management systems-related in agro-ecosystems can be mirrored by the Diversity-Stability debate (McCann 2000), which showed how assemblages of minor species and related smaller-scale food webs can eventually buffered overall major and important food webs disintegrations as well as key-stone species extinctions. In this study, it can be concluded that the existence of similar but patchy, minor forms of micro-habitats (based on the NMS ordination scores) can have great importance in increasing the tolerance between species groups, even in larger groups sharing resources together without any displacement effect takes place, hence indirectly and inherently slowing down the rates of hymenopteran species extinctions and disappearances within the already degraded oil palm plantations. Applying similar concept that parallel with this study, the existence of patchy, physically less prominent, but collectively large surface-area of minor micro-habitats within the oil palm plantations bolstered many hymenopteran species, providing partially-isolated, small-scale 'islands' for different species to forage for specific host or prey insect species, including spaces for escaping any implemented hazardous plantation management system activities, as well as minimally reducing the elevating overall *niche* overlapping within major micro-habitats, and becoming small-scale, spatially-wide *niche*



resource partitioning platforms. This study has emphasized and realized the concept by Dudley et al. (2004), which was related with vegetative structural residues abandoned after the opening of any previously undisturbed terrestrial ecosystems, persistently becoming crucial micro-habitats and structural diversity for many beneficial arthropods, including parasitoids and predators, naturally controlling the rapid abundance escalation of many herbivorous insect pest species after high intensity of agricultural activities began. The importance of micro-habitats, had been stressed by Chung et al. (2000), which argued that insect species within oil palm plantations can be much more diverse by increasing habitat heterogeneity via rehabilitations of forest-related micro-habitats. Other researchers, including Turner and Foster (2009), as well as Fayle et al. (2010) had also studied extensively pertaining to any forest-specialist arthropods and ant species, respectively, specifying on forest-specific micro-habitats within oil palm plantations, and found that there were indeed considerable reductions in terms of both species richness and abundances. Chung (2004) also stressed that oil palm plantations have been severely degraded, that, sampling has to focus on the *epigeal* layer for maximum sampling efforts, and the reconstructions of forest-related complex multiple-stratifications need to be urgently done within oil palm plantations by repairing any existing forest-related micro-habitats. Each stratifications-complex can have great consequences on the overall stability of an ecosystem. In this study, we had stresses the importance of any available and existing oil palm-specific micro-habitats, which can still prove to be stable in managing hymenopteran species tolerance and resource utilizations. Oil palm-specific micro-habitats are still showing promising results in sustaining insect species richness, abundances, and stability, proved in this study.

The different species within patchy minor micro-habitats, ecologically can act as physically separated but ecologically connected micro-habitats, providing as many as small-scale food chains, and collectively becoming the basis for larger food webs. In other words, the minor micro-habitats are becoming the basic foundations for the more complex food webs within the oil palm plantations, as all of the separated species coming from different minor micro-habitat types interact together within the major micro-habitats, creating larger food webs. Heavy dependent on only major micro-habitats without the support of a more patchy, minor micro-habitats, can eventually lead to greater risks of extinctions for the hymenopteran species, as there are no other micro-habitats left for emergency dispersal after the gradual intolerable increment of *niche* overlapping, as well as the repetitive implementation of hazardous plantation management systems, which also in time, degrading the major micro-habitats' physical and biological qualities. This is also evident by the research done on scale insects (Kozár 2008), where there were no full utilizations of scale insects on specified deciduous trees, showing clear intense competition-riddance behaviour, and only focused on several small-scale part of the trees. Even if there are arguments that most hymenopterans are active fliers, in which they can eventually escape to the upper part or the canopy *strata* of the oil palm plantations that are unaffected by any hazardous plantation management systems, however, most other prey or host insect species, important for the long term sustenance survival of the hymenopterans are still within the major and minor micro-habitats, escaping activities through active flight are not fully functional to maintain the survival of these hymenopterans. The minor micro-habitats are not specifically focused on the survival of the hymenopteran species, but also giving higher chances of survival for any prey or host insect species, and in return, will benefit the hymenopterans in a long run without feeding deprivations and confirming species continual, even saving flight activities' energy expenditures. Davis (1993) and Philips et al. (1999) both suggested that many ground-dwelling arthropods, including insects, will spread across different micro-habitats after the main or major micro-habitat types have been saturated with dominant species. It is a gradual dispersal processes in that, over time, insect species will inhabited different, spatially segregated minor micro-habitats to reduce the effects of intense competition for resources. This is also supported by Stenbacka et al. (2010), Hjältén et al. (2012), and Sodhi et al. (2010), that stated the ecology of ground-dwelling beetle species that dependent on any ground-related micro-habitats and resources will disperse actively after the main micro-habitats which have the most resources have been depleted and concentrated with intense competitions. From this, possibly that, most of the ground-dwelling prey or host insect species were already in the advanced spreading or dispersed states, after the major micro-habitats have been saturated with intense competition levels, which in turn benefiting the hymenopteran species passively, as most of them focused on the minor micro-habitats for resting sites and searching for any specific prey or host insects. Indirectly, as mentioned, hymenopteran species had eventually procured dual quality of escaping from the adverse management system impacts and at the same time, reducing any possible accumulations of inter-species competitions within specific and spatially and physically segregated minor micro-habitats, but collectively were important for overall ecological food webs. As many species were collectively sharing the similar micro-habitat patterns as in Group 1, this condition showed that, the existences of minor micro-habitats eventually becoming the factor that connecting and tying different species together, as heavy and sole dependent on any major micro-habitats will eventually leads to increasing and intolerable *niche* overlapping for both feeding and micro-habitat resources, and bring species groups to disappearance and displacements over time.

The role of micro-habitats, besides becoming buffers for any adverse environmental conditions, which also functioning as micro-scale adaptations for any new species entering a new agro-ecosystems, as proposed by Gardner (2010), which suggested that suitable and hospitable agro-landscapes compositions and spatial configurations of landscape elements will give the higher ability for any possible visiting forest-specialist species to dwell over the disturbed, inhospitable habitats of the plantations, and temporally stabilized by the successions of species. Essential for this study, the existence of less populated, lower inter-species competitions, and fewer incidences of implementations of any direct- or indirectly-hazardous plantation management systems, credited to the minor micro-habitats will ensure for future possibilities of any forest-related hymenopteran species to passively enter the agro-ecosystems of oil palm plantations without any pressure or risks of repellence and disturbances. This is also supported by Lucey and Hill (2011), proving the spill-over of forest-specialist species into the oil palm plantations as a positive indicator that oil palm plantations can be diversity-reservoir plantations with the recommendations for having any forest-related structures that can enhance the diversity levels better. So far, the heaps of oil palm old chipped trunks, beneficial nectariferous plants, and the remnants of



old forest logs are all the possible micro-habitats that can be enhanced to be much more forest-related, for future recommendations in attracting more forest-specialist hymenopteran species into the oil palm plantations.

Another interesting finding in this study is that, besides becoming ecological or environmental buffers for hymenopteran species against adverse plantation management effects, as well as alleviating intense competitions for the processes of procuring feeding and micro-habitat-related resources, the existences of several different types of micro-habitats, adjacent and some others inter-mixing to each other, with the patchy minor micro-habitats seemed to have reflected the ecotones, but with a smaller context, enabling most hymenopteran species to interact to each other. Results in this study showed that, for both season, and between defined species groups formed, the differences between utilized micro-habitats were showing small difference, further depicting the narrow micro-ecotones bordering between different types of minor micro-habitats utilized by each different species groups. For the species groups that contained the highest number of hymenopteran species, changes pertaining to the utilizations of major and minor micro-habitats over different seasons were not significant, meaning that most of the hymenopteran species had attained species-micro-habitat specific stability, not easily altered even after the significant successions and environmental fluctuations between different seasons occurred. Oil palm plantations have both anthropogenic and human-made major and minor micro-habitats, and hymenopteran species seemed to have utilize each types of minor micro-habitats effectively and alternately, to achieve species stability over time without depending on only one type of minor micro-habitat. The micro-ecotone bordering zones, between different minor micro-habitats with patchy but wide in surface area of spatial distributions, observed as having very narrow separations because most hymenopteran species have chosen the minor micro-habitats for their survival. If however the hymenopterans exhibited focus on the major micro-habitats, there will be wider micro-ecotones bordering between the utilized micro-habitats, and this will produce wider gaps between major and minor micro-habitats, as well as between major micro-habitats, hence risking for a more unstable food webs constructed with no interlinking.

The heaps of old chipped oil palm trunks, the beneficial nectariferous plants, the remnants of old forest logs, as well other types of riskier minor micro-habitats, such as natural weeds, shrubs, and vines, as well as the less prominently utilized legume cover crops and bryophytes *epigeal* covers, are all inter-mixing to each other and having narrow borders, showing the hymenopteran utilized every minor micro-habitats that meets to their biological and physiological needs and at the same time providing small-scale food chains that will further collectively supported larger, more prominent food webs among all mixed minor micro-habitats. Didham et al. (1998), Duelli and Obrist (1998), Hamer et al. (2003), Myers (1984), Myers et al. (2000), Southwood et al. (1979), Wermelinger et al. (2007), and Virkkala et al. (2004) all suggested that micro-habitats within any types of ecosystems, especially more concerns on degraded agro-ecosystems such as oil palm plantations, required support from both dominant and minor species assemblages, which in turn reflected by the existence of any major and minor micro-habitats, that will ensure the formed food webs to be stable and not easily ruptured under least or minimal adverse environmental effects, and that of differential micro-habitats varieties and sustaining heterogeneities between micro-habitat patches and stratifications are crucial for the continual survival of insect species without prolonged resources depletions. Oil palm plantations are indeed mostly have concentrated *epigeal*-related micro-habitats, with severely reduced intermediate and canopy-levels micro-habitats, different from the complex forest ecosystems which have complex and stable micro-habitats over all stratifications. Eventually, although all major and minor micro-habitats in this study are concentrated specifically on *epigeal* strata, most hymenopteran species, at least nearly half of the successfully collected or trapped species assemblages for both tropical annual seasons, showing excellent adaptations on the newly developed *epigeal*-related of naturally occurring and anthropogenic-related major and minor micro-habitats.

CONCLUSION

Minor micro-habitats have been discovered in this study as the crucial buffering factor for many hymenopteran species, particularly shielding them from many adverse implemented oil palm plantations' management systems, as well as producing various, separated minor-scale food chains, that collectively support the larger food webs existing within the more prominent, major micro-habitats, and in the long run, alleviating the rupturing of larger food webs after repetitive implementations of management systems factors. As mentioned, although most of hymenopteran species have the active flight capability to escape such employed adverse oil palm plantations' management systems, specifically to the intermediate and canopy strata, most of the prey or host insect species were dependent on the *epigeal* micro-habitats, hence, the existence of minor micro-habitats will indirectly ensuring the survival and sustaining the fitness of hymenopteran species by providing residual sites for most prey or host insect species to escape, maintain the small-scale food chains to persists cyclically within the minor micro-habitats, synchronously with the implementations of oil palm plantations' management systems. The narrow micro-ecotones gaps between different major and minor micro-habitat types altogether promote hymenopteran species dispersal, and although in the long run, this condition can increase the risk of parallel micro-habitat-related food webs degradations following the implementations of any adverse plantations' management systems, it indirectly allows the rapid synchronous reorganization of smaller scale food chains and hence altered into new level of larger food webs, sustaining the species diversity through flexible ecological attributes. In the future, farmers and oil palm plantations' managers require to reserve as many as minor micro-habitats as possible, excluding these minor micro-habitats from the applications of chemical herbicides, and focused only on any physically prominent micro-habitats, as well as increasing the abundance and surface area covered by beneficial nectariferous plants.

ACKNOWLEDGEMENTS

We are particularly grateful to the Ministry of Education (MOE), Malaysia, for funding this project, under the Exploratory Research Grant Scheme (ERGS/1/2013/STWN03/UKM/03/1). We also deeply want to thank FELDA (Federal Land



Development Authority) Malaysia, particularly to Mr. Noorhisham Hamid, by providing the best oil palm study plots, located in Felda Sungai Tekam, Pahang, under Tun Razak Agricultural Research Centre (PPPTR) Unit. Finally, we would also want to wish our appreciation to Dr. Izfa Riza Hazmi, as the Head for Centre of Insect Systematics (CIS), Universiti Kebangsaan Malaysia (UKM), by providing suitable and the best quality insect laboratory for hymenopteran species identification and setting processes.

REFERENCES

1. Acquired Intelligence Inc. & Kelsey-Bear. (2005) *EcoSim*. Copyright 1997-2005. <http://homepage.together.net/~gentsmin/ecosim.htm>.
2. Borror, D.J. and White, R.E. (1970) Peterson Field Guide – Insects of North America. New York: Houghton Mifflin Company pp 404.
3. Chong, K.K., Peter, A.C. and Ho, C.T. (1991) *Crop pest and their management in Malaysia*. Kuala Lumpur. Tropical Press.
4. Chung, A.Y.C., Eggleton, P., Speight, M.R., Hammond, P.M. and Chey, V.K. (2000) The Diversity Of Beetle Assemblages in different Habitat types in Sabah, Malaysia. *Bulletin of Entomological Research* **90**, 475 – 496.
5. Chung, A.Y.C. (2004) Vertical stratification of Beetles (Coleoptera) Using Flight Intercept Traps in a Lowland Rainforest of Sabah, Malaysia. *Sepilok Bulletin* **1**, 29-41.
6. Davis, A.J. (1993) The Ecology and Behavior of Rainforest Dung Beetles in Northern Borneo. Unpublished Ph.D. Thesis. University Of Leeds, U.K.
7. Didham, R.K., Lawton, J.H., Hammond, P.M. and Eggleton, P. (1998) Trophic structure stability and extinction dynamics of beetles (Coleoptera) in tropical forest fragments. *Philosophical Transactions of the Royal Society, Series B* **353**. pp 437 – 451.
8. Dudley N. and Vallauri, D. (2004) The importance of veteran trees and deadwood to biodiversity. *World Wild Fund for Nature*. Gland. Switzerland.
9. Duelli P. and Obrist M.K. (1998) In search of the best correlates for local organismal biodiversity in cultivated areas. *Biodiversity and Conservation* **7**, 297-309.
10. Faszly, R. Idris, A.B., Sajap, A.S., Norman, K. and Mohd. Basri, W. (2003) The pattern of infestation by subterranean termite *Coptotermes curvignathus* Holmgren (Isoptera: Rhinotermitidae) on young oil palm peat. AP-37 in *Proceedings Of Agricultural Conference, International Palm Oil Congress 2003*. Putrajaya, Malaysia: 24-28.
11. Fayle, T.M., Turner, E.C., Snaddon, J.L., Chey, V.K., Chung, A.Y.C., Eggleton, P. and Foster, W.A. (2010) Oil Palm Expansion into Rain Forest greatly reduces Ant Biodiversity in Canopy, Epiphytes, and Leaf-litters. *Basic and Applied Ecology* pp 337 – 345.
12. Fitzherbert, E.B., Struebig, M.J., Morel, A., Danielsen, F., Brühl, C.A., Donald, P.F. and Phalan, B. (2008) How Will Oil Palm Expansion Affect Biodiversity?. *Trends in Ecology & Evolution* **23**(10), 538 – 545.
13. Gardner, T. (2010) Monitoring Forest Biodiversity: Improving Conservation through Ecologically-Responsible Management. Earthscan Ltd. United Kingdom, U.K. pp 351.
14. Goulet, H. and Huber, J.T. (1993) Hymenoptera of the World: An Identification Guide to Families. Centre for Land and Biological Resource Research. Agricultural Canada Publication. pp 680.
15. Hamer, K.C., Hill, J.K. and Benedick, S. (2003) Ecology of butterflies in natural and selectively logged forests of northern Borneo: the importance of habitat heterogeneity. *J Appl Ecol.* **40**, 150–162.
16. Hjältén, J., Stenbacka, F., Pettersson, R.B., Gibb, H., Johansson, T., Danell, K., Ball, J.P. and Hilszczanski, J. (2012) Micro- and Macro-habitat Associations in Saproxyllic Beetles: Implications for Biodiversity Management. *PLoS One Journals.* **7**(7). e41100. doi:10.1371/journal.pone.0041100.
17. Hutcheson, J.A. (1991) Malaise trap collection jar: A cheap simple modification. *New Zealand Entomologist* **14**, 48-49.
18. Jepsen, J.U., Topping, C.J., Odderskaer, P. and Andersen, P.N. (2005) Evaluating Consequences of Land-Use Strategies on Wildlife Populations using Multiple-species Predictive Scenarios. *Agriculture, Ecosystem, And Environment* **105**, 581-594.
19. Koh, L.P. and Wilcove, D.S. (2007) Cashing in palm oil for conservation. *Nature* **448**, 993 – 994.
20. Kozár, F. (2008) Microhabitat specialization and similarity of scale-insect assemblages on different fruit trees and in different countries. *Ecological Entomology* **14**(2), 175 – 180.



21. Lucey, J.M. and Hill, J.K. (2011) Spillover of Insects from Rain Forest into Adjacent Oil Palm Plantations. *Biotropica* **44**(3), 368 – 377.
22. McCann, K.S. (2000) The Diversity-Stability Debate. *Nature* **405**, 228-233.
23. McCune, B. and Mefford, M.J. (1997) PC-ORD. Multivariate analysis of ecological data, Version 3.0. MjM software design, Gleneden Beach, Oregon, USA.
24. McNeely, J.A., Gadgil, M., Leveque, C., Padoch, C. and Redford, K. (1995) Human influences on biodiversity in Heywood, V. H. & Watson, R. T. (Eds) *Global biodiversity assessment*. UNEP, Cambridge, Cambridge University Press. pp 711 – 822.
25. Mohd Hanysyam, M.N., Fauziah, I., Siti Khairiyah, M.H., Fairuz, K., Mohd. Rasdi, Z., Nurul Zfarina, M.Z., Ismail, R. and Norazliza, R. (2013) Assessment on the Diversity of Parasitoids of Bagworms (Lepidoptera: Psychidae) in FELDA Gunung Besout 6, Sungkai, Perak. IEEE Symposium on Humanities, Science, and Engineering Research (SHUSER) pp 130 – 135.
26. MPOB. (2007) *Review of the Malaysia Oil Palm Industry 2006*.
27. Myers, N. (1984) *The primary source: Tropical forests and our future*. W. W. Norton, New York.
28. Myers N., Mittermeier R.A., Mittermeier C. G., d. Fonseca G.A.B. and Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature* **403**, 853-858.
29. Norman, K. and Basri, M.W. (2003) *Handbook of Oil Palm Pests*. Bandar Baru Bangi: Malaysian Palm Oil Board.
30. Philips, A., Simon, G., Muirhead, A., Bashford, D., Yee, M., Ramsden, N. and Taylor, R. (1999) Long-term monitoring of beetle succession in decaying *Eucalyptus obliqua* logs. *Long Term Ecological Research* pp 72.
31. Purvis, G. and Fadl, A. (2002). The Influence of Cropping Rotations and Soil Cultivation Practice on the Population Ecology of Carabids (Coleoptera: Carabidae) in Arable land. *Pedobiologia* **46**, 452-474.
32. Salmah, M. (2005) Study on taxonomy and effect of host larval stages and diets on development, parasitism behavior, longevity and fecundity of *Apanteles metesae* Nixon. UKM.
33. Sodhi, N.S., Koh, L.P., Clement, R., Wanger, T.C., Hill, J.K., Hamer, K.C., Clough, Y., Tscharntke, T.C., Posa, M.R. and Lee, T.M. (2010) Conserving Southeast Asian forest biodiversity in human-modified landscapes *Biological Conservation*.
34. Southwood, T.R.E., Brown, V.K. and Reader, P.M. (1979) The relationship of plant and insect diversities in succession. *Biol. J. Linn. Soc.* **12**, 327-348.
35. Stenbacka, F., Hjältén, J. and Andersson, J. (2010) Saproxylic Beetle Assemblages on Low Stumps, High Stumps and Logs: Implications for Environmental Effects of Stump Harvesting. *Forest Ecology and Management* **260**(7), 1149-1155.
36. Triplehorn, C. A. and Johnson, N.F. (2005) Borror and DeLong's Introduction to the Study of Insects *7th Edition*. United States Of America: Thomson Brooks/Cole pp 864.
- Townes, H. (1972) A lightweight Malaise trap. *Entomological News* **83**, 239-247.
37. Turner, E.C. and Foster, W.A. (2009) The Impact of Forest Conversion to Oil Palm on Arthropod Abundance and Biomass in Sabah. *Journal of Tropical Ecology* **25**, 23 – 30.
38. Turner, P.D. and Gillbanks, R.A. (2003) *Oil Palm cultivation and management 2nd ed*. Kuala Lumpur: Integrated Society of Planters. pp 915.
39. Ulyshen, M.D., Hanula, J.L., Horn, S., Kilgo, J.C. and Moorman, C.E. (2004) Spatial and Temporal Patterns of Beetles Associated with Coarse Woody Debris in Managed Bottomland Hardwood Forests. *Forest Ecology and Management* **199**(2-3), 259-272.
40. Virkkala, R., Luoto, M. and Rainio, K. (2004) Effects of landscape composition on farmland and red-listed birds in boreal agricultural-forest mosaics, *Ecography* **27**, 273–284.
41. Wermelinger, B., Fluč̈kiger, P.F., Obrist, M.K. and Duelli, P. (2007) Horizontal and vertical distribution of saproxylic beetles (Col., Buprestidae, Cerambycidae, Scolytinae) across sections of forest edges. *J. Appl. Entomol.* **131**(2), 104 – 11
42. Wood. B. J. (1982) The present status of pests of oil palm estates in South-East Asia. In: Pushparajah, E. & Chew, P.S. (eds.). *The Oil Palm in agriculture in the eighties*. Vol II pp. 499 – 518. Kuala Lumpur. Incorporated Society of Planters.



Author's biography with Photo



Ahmad Bukhary bin Ahmad Khair is a Full-time Researcher and PhD student of the Center of Insect Systematics, Faculty of Science and Technology, University Kebangsaan Malaysia, Malaysia. His research interests include ecological, environmental, and agricultural entomology. He is also has other research interests including invertebrate biology and entomological community ecology. He had attended and presented at various international symposiums and conferences pertained to the field of entomology.

