Serangga 22(1): 33-64
ISSN 1394-5130 © 2017, Centre for Insects Systematic, Universiti Kebangsaan Malaysia

CANOPY VERSUS EPIGEAL BEETLE SPECIES DIFFERENTIAL DIVERSITY AND FEEDING ECOLOGICAL CHARACTERITICS EMPLOYING LIGHT-BASED TRAPPING METHODS ACROSS DIFFERENT OIL PALM AGE STAND TYPES

Ahmad Bukhary Ahmad Khair[1], Mohd Fauzi Mohd Muzamil[1], Ruslan Md Yusop[1], Noor Hisham Hamid[2], Mohd Yusri Mohd. Naser[3], Izfa Riza Hazmi[1], Abu Hassan Ahmad[4], Idris Abdul Ghani[1]

[1]Center of Insect Systematics, School of Environmental Sciences and Natural Resources, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.
[2]Tun Razak Agricultural Research Centre (PPPTR), Felda Sungai Tekam, 27000 Jerantut, Pahang, Malaysia.
[3]Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan, Locked Bag 01, 16300 Bachok, Kelantan, Malaysia.
[4]School of Biological Sciences, Universiti Sains Malaysia, 11800 USM Gelugor, Penang, Malaysia.
Corresponding author: prince_bukhary87@yahoo.com

ABSTRACT

Suitability of canopy-height light trap tailored from both primary and secondary tropical forests was compared with the newly modified pit-light trap within the context of oil palm plantation of various age stand types and across different seasons. Beetle species were chosen as the representative of other insects within oil palm plantations as to evaluate the effectiveness of both trapping methods. Results showed that the canopy-height light trap employed over the canopy stratum of the selected oil palm age stands produced unstable and unreliable data, with characteristics of overlapping beetle species communities along significant ordination gradients. Modified pit-light trap, on the other hand, showed clear separations of beetle species community structures between younger-older oil palm age stands along significant ordination gradients, as well as accurate divisions of beetle species ecological feeding groups corresponded to different oil palm age stand types and seasons, and acceptable diversity levels. The modified pit-light trap, employed on the epigeal stratum of selected oil palm plantations, paralleled with most anthropogenic and naturally occurring microhabitats, could reduce the risks of attracting unintended beetle species from unrelated oil palm age stand types, as well as possible surrounding secondary tropical forests. It is proposed that the modified pit-light trap to be applied officially for improved evaluations of insect species' diversity and ecological attributes within oil palm agro-ecosystems.

Keywords: canopy-height light trap, modified pit-light trap, oil palm age stands, beetle, canopy, epigeal, sampling.

ABSTRAK

Kesesuaian perangkap cahaya-ketinggian kanopi berpandukan kepada kedua – dua kawasan hutan tropika primer dan sekunder dibandingkan dengan perangkap lubang-cahaya yang baru diubahsuai dalam konteks kawasan perladangan kelapa sawit melibatkan peringkat umur ladang kelapa sawit dan musim yang berbeza. Spesies kumbang dipilih sebagai wakil spesies serangga yang lain dalam kawasan perladangan kelapa sawit dalam menghuraikan keberkesanan bagi kedua – dua jenis kaedah perangkap. Keputusan menunjukkan bahawa perangkap cahaya-ketinggian kanopi yang dipasangkan merentasi stratum kanopi dalam ladang kelapa sawit yang dipilih menghasilkan data yang tidak stabil dan tidak sahih, dengan pencirian pertindihan komuniti spesies kumbang sepanjang paksi – paksi ordinasi yang signifikan. Perangkap lubang-cahaya, sebaliknya, menunjukkan pengasingan yang jelas bagi komuniti spesies kumbang di antara ladang kelapa sawit muda-ladang kelapa sawit tua sepanjang paksi – paksi ordinasi yang signifikan, serta pembahagian yang jitu terhadap kumpulan pemakanan ekologi yang selari dengan peringkat umur ladang kelapa sawit dan musim yang berbeza, dan taraf kepelbagaian yang lebih rasional. Perangkap lubang-cahaya, yang dipasangkan pada stratum epigeal bagi ladang kelapa sawit yang dipilih, adalah selari dengan hampir kesemua mikrohabitat yang bercirikan antropogenik atau secara semulajadi, mampu mengurangkan risiko terhadap pemerangkapan spesies kumbang yang tidak berkenaan berasal dari ladang kelapa sawit yang tidak berkaitan, termasuk kawasan hutan sekunder yang merangkumi kawasan pinggir ladang kelapa sawit. Ia adalah diusulkan bahawa perangkap lubang-cahaya untuk diaplikasi secara rasmi bagi penerangan terhadap nilai kepelbagaian spesies serangga dan ciri – ciri ekologi spesies serangga yang lebih bermutu dalam kawasan perladangan kelapa sawit.

Kata kunci: perangkap cahaya-ketinggian kanopi, perangkap lubang-cahaya yang baru diubahsuai, peringkat umur ladang kelapa sawit, kumbang, kanopi, epigeal, persampelan.

INTRODUCTION

The conversion of undisturbed primary and secondary tropical forests into large scale, continuously developing oil palm agro-ecosystems has tremendously altered the complex structural stratifications (Fitzherbert et al. 2008; McNeely et al. 1995; Sodhi et al. 2010), severely simplified the intermediate stratum, resulting in direct connections between the canopy and epigeal strata, affecting insect species diversity (Koh & Wilcove 2008; Liow et al. 2001; Rosenberg et al. 1986). Since insects are essentially the primary resources that fundamentally bolstering complex food-webs for higher level vertebrates, similarly within primary and secondary tropical forest ecosystems, the conservation of insects can be perceived as equally as important (Turner & Foster 2009). Reductions of complex structural stratifications has directly affected the structural diversity in the form of microhabitats (Hristovski et al. 2016; Stenbacka et al. 2010), which becoming the important element in sustaining natural resources and increasing fitness of insect species incorporated directly within newly developed food webs of oil palm agro-ecosystems (McCann 2000). Revising the diversity and ecological statuses of insect species within oil palm plantations required extensive systematic field sampling (Chung 2004; Koh 2008). Sampling of insect species within oil palm plantations employing standard and established entomological sampling methods tailored from the primary and secondary tropical forest ecosystems are demanding modifications as the oil palm agro-ecosystems are structurally dissimilar, with highly possible ambiguous sampling results, producing imprecise diversity and ecological interpretations. One of the commonly implemented entomological sampling methods, involved the light-based trapping methods or light trapping, had been proved by many studies to achieve excellent results pertained to diversity and ecological studies within primary and secondary tropical forest ecosystems (Farrow 1974; Jonason et al. 2014; Robinson 1952).

However, light-based entomological sampling methods have not yet extensively tested to be of equally effective when implemented within oil palm agro-ecosystems. Since light-based trapping are much more attractive to insect species compared to the non-light-based trapping methods, there are probabilities that the light-based trapping methods might have certain degree of imperfections when directly, without specific modifications, implemented within oil palm agro-ecosystems. Fundamentally, the oil palm plantations comprised of adjacently arranged, 'island-resembled' various age stand types, with varying physical characteristics of oil palm stands' heights and sizes, overall canopy coverages in the form of fronds' overlapping, as well as the number of naturally occurred and anthropogenic-formed microhabitats, producing varying degrees of obstructions and hindrances to the progress of light electromagnetic wavelengths across the studied oil palm plantations. These factors will eventually affect the consistency, effectiveness, and reliability of light-based trapping methods within oil palm plantations.

Sampling pertained to any existing microhabitats for quantifying insect species diversity statuses has been stressed to be significant by Mehrabi et al. (2014), and since the purposes of sampling insect species within oil palm plantations are solely not only focused on identifying diversity statuses, but also related to discern insect species' ecological functions within oil palm plantations, stable light-based entomological sampling methods must be urgently necessary for accurate interpretations. This is very important, corresponding to the increasing arguments of insect species diversity statuses within oil palm plantations over the decades, and debated by many researches (Badrul et al. 2015; Yaap et al. 2010; Yue et al. 2015) that most studies showed critical reductions of insect species diversity statuses. Furthermore, elucidating insect species statuses based on existing microhabitats within oil palm plantations can be observed to be critical as most microhabitats were occupied by insects (Fayle et al. 2010). Implementing modified and corrected entomological sampling tools and methods are very crucial as this can essentially result in accurate assessments of insect species diversity statuses within oil palm agro-ecosystems. Pertained to the elaborated problems related to our oil palm plantations, especially to the statuses of insect species diversity and ecological attributes, this study attempted on testing the reliability and stability of light-based trapping methods at the existing canopy and epigeal strata, respectively implementing the canopy-height light traps and the newly modified pit-light traps, initially designed and proposed by both Hébert et al. (2000) and Heap (1988). Beetle species were chosen in this study as representative of other the insect species within oil palm plantations since beetle species have diverse and complex feeding ecological groups, paralleled to the existing structural diversity on the epigeal stratum as microhabitats, becoming the medium for consistency testing of light-based trapping methods (Chung et al. 2000).

MATERIALS AND METHODS

Field samplings were done in Sungai Tekam Felda Oil Palm Plantations, Jerantut, Pahang, from February 2013 to Februari 2014. Five different oil palm age stand types were chosen based on gradual oil palm developmental stages, viz., less than one-year old (N03°54’592” E102°31’502”), 3 years old (N03°54’052” E102°32’062”), 6 years old (N03°54’253” E102°32’184”), 18 years old (N03°53’592” E102°31’482”), and 23 years old (N03°55’024” E102°30’482”). Each of the chosen oil palm age stand types have four separated plot replicates. One plot replicate to another plot replicate of similar age stand type was separated by one kilometre between each other. A total of 40 plot replicates were employed in this study. 20 plot replicates were specific for canopy-height light traps evaluation on the canopy stratum (Figure 1), and the remaining 20 plot replicates were specific for modified pit-light traps evaluation on the epigeal stratum (Figure 2). One unit of canopy-height light trap was placed at the centre of each selected plot replicates per oil palm age stand types, powered by charged 12V car battery. Canopy-height light traps' collection containers were prepared with tissue cloth dipped within 70% liquid alcohol and 50% liquid acetyl acetate to kill and partially preserve collected beetle species. Four units of modified pit-light traps were set per plot replicate and per oil palm age stand types, arranged 50 meters between each other, powered by the charged 6V lead-acid battery. The modified pit-light traps' collection containers were prepared with liquid detergent, 70% liquid alcohol, and 50% liquid acetyl acetate to kill and partially preserved collected beetle species. Both types of traps were tested from 1900 hours to 0600 hours on the next day. Samplings were done for 10 nights per sampling month, with 2-days gaps between sampling days reserved for recharging batteries and trap technical maintenances. Sampling was not performed during the full moon phase since this can reduce the catchability effectiveness of both trap types (Bowden & Church 1973; Nowinszky et al. 2012). Beetle species collected from each trap types were sorted to the morpho-species level, based on the corresponded families and subfamilies. Beetle families and subfamilies were identified based on Borror and White (1970) and Triplehorn and Johnson (2005), respectively.

Figure 1. Canopy-height Light Trap.

Figure 2. Modified Pit-light Trap.

RESULTS

A total of 13254 beetle individuals representing 119 species from 24 families were successfully captured using the canopy-height light traps from all selected oil palm age stands, with 7016 beetle individuals captured during dry-hot season, and 6238 beetle individuals captured during wet-rainy season. A total of 10356 beetle individuals representing 28 species from 13 families were successfully captured using the modified pit-light traps from all selected oil palm age stands, with 4396 beetle individuals captured during dry-hot season, and 5960 beetle individuals captured during wet and rainy season. Comparatively, these findings showed that the canopy-height light traps captured 4.25 times more beetle species compared to the modified pit-light traps from all selected oil palm age stands. The number of beetle families captured by the canopy-height light traps were also two times higher than that of the modified pit-light traps. The beetle species abundances with correspondence number of species were simplified in Table 1 and Table 2 for the canopy-height light traps respectively for dry-hot and wet-rainy seasons, and Table 3 and Table 4 for the modified pit-light traps for dry-hot and wet-rainy seasons respectively.

Table 1. Total numbers (first number) and number of species (second number, after /) of Coleoptera from different families captured in the canopy-height light traps during the dry-hot season and across different oil palm age stand types.

Families	Hot-Dry Season				
Oil Palm Plots	**< 1 yr**	**3 yrs**	**6 yrs**	**18 yrs**	**23 yrs**
Aderidae	3/1	3/2	4/2	5/2	14/2
Anthicidae	60/2	40/2	6/2	21/2	14/2
Anthribidae	13/2	7/2	15/2	9/2	21/2
Cantharidae	33/3	20/3	6/3	11/3	32/3
Carabidae	132/17	151/17	100/17	137/17	219/17
Chrysomelidae	38/8	51/8	49/8	47/8	53/8
Cicindelidae	18/2	42/2	18/2	31/2	47/2
Cleridae	3/1	2/1	1/1	11/1	4/1
Coccinellidae	20/3	12/3	21/3	51/3	62/3
Curculionidae	81/10	87/10	97/10	135/10	174/10
Dytiscidae	62/8	46/8	858	89/8	123/8
Elateridae	12/4	8/4	40/4	31/4	43/4
Endomychidae	8/1	4/1	3/1	4/1	4/1
Erotylidae	63/5	66/5	61/5	92/5	97/5
Hydrophilidae	55/4	50/4	43/4	61/4	82/4
Lycidae	0/1	2/1	1/1	9/1	5/1
Mordellidae	28/2	21/2	49/2	51/2	40/2
Nitidulidae	107/12	184/12	214/12	267/12	483/12
Passandridae	7/1	14/2	4/2	14/2	9/2
Lucanidae	12/1	5/1	1/1	4/1	3/1
Scarabaeidae	38/8	29/8	20/8	55/8	39/8
Staphylinidae	106/11	133/11	127/12	210/12	224/12
Tenebrionidae	135/6	147/4	158/6	177/6	352/6
Zopheridae	17/3	10/3	7/3	20/3	14/3

Table 2. Total numbers (first number) and number of species (second number, after /) of Coleoptera from different families captured in the canopy-height light traps during the wet-rainy season and across different oil palm age stand types.

Families	**Wet-Rainy Season**				
Oil Palm Plots	**< 1 yr**	**3 yrs**	**6 yrs**	**18 yrs**	**23 yrs**
Aderidae	4/2	7/2	6/2	2/2	0/0
Anthicidae	14/2	20/2	9/2	28/2	10/2
Anthribidae	11/2	16/2	9/2	12/2	15/2
Cantharidae	8/3	12/3	9/3	36/3	12/3
Carabidae	95/17	107/17	83/17	83/14	100/15
Chrysomelidae	42/8	37/8	28/8	33/4	25/5
Cicindelidae	37/2	14/2	42/2	9/2	25/1
Cleridae	2/1	1/1	2/1	4/1	1/1
Coccinellidae	26/3	22/3	34/3	22/3	13/3
Curculionidae	139/10	34/10	131/10	105/7	70/7
Dytiscidae	112/8	53/8	101/8	28/7	61/8
Elateridae	28/4	23/4	28/4	16/4	21/3
Endomychidae	4/1	5/1	3/1	4/1	0/0
Erotylidae	53/5	47/5	51/5	77/5	54/5
Hydrophilidae	56/4	53/4	65/4	11/4	78/4
Lycidae	2/1	2/1	2/1	1/1	0/0
Mordellidae	19/2	22/2	34/2	5/2	10/1
Nitidulidae	261/12	265/12	279/12	120/12	175/12
Passandridae	10/2	11/2	6/2	3/2	0/0
Lucanidae	2/1	1/1	3/1	1/1	0/0
Scarabaeidae	29/8	38/7	27/8	24/6	13/5
Staphylinidae	169/12	239/12	263/12	115/12	96/10
Tenebrionidae	470/5	175/6	199/6	212/6	202/5
Zopheridae	26/3	13/3	40/3	9/3	7/3

Table 3. Total numbers (first number) and number of species (second number, after /) of Coleoptera from different families captured in the modified pit-light traps during the dry-hot season and across different oil palm age stand types.

Families	Hot-Dry Season				
Oil Palm Plots	**< 1 yr**	**3 yrs**	**6 yrs**	**18 yrs**	**23 yrs**
Aderidae	8/1	2/1	0/0	0/0	1/1
Anthribidae	2/1	2/1	10/1	7/1	9/1
Carabidae	7/3	0/3	95/2	13/2	7/3
Cicindelidae	5/1	6/1	13/1	6/1	2/1
Cucujidae	0/0	0/0	13/1	5/1	5/1
Curculionidae	27/4	6/2	133/5	199/4	193/5
Endomychidae	3/1	4/1	21/1	5/1	10/1
Erotylidae	11/1	4/1	144/1	55/1	43/1
Histeridae	0/0	2/1	0/0	2/1	3/1
Mordellidae	0/0	1/1	41/1	65/1	11/1
Nitidulidae	13/2	19/2	847/3	1088/4	916/4
Scarabaeidae	4/1	6/2	74/3	11/2	50/3
Staphylinidae	19/3	15/3	39/3	42/5	52/5

Table 4. Total numbers (first number) and number of species (second number, after /) of Coleoptera from different families captured in the modified pit-light traps during the wet-rainy season and across different oil palm age stand types.

Families	Wet-Rainy Season				
Oil Palm Plots	**< 1 yr**	**3 yrs**	**6 yrs**	**18 yrs**	**23 yrs**
Anthribidae	0/0	49/1	8/1	12/1	7/1
Carabidae	9/1	22/2	106/2	12/2	11/3
Cicindelidae	9/1	16/1	11/1	4/1	2/1
Cucujidae	11/1	3/1	13/1	8/1	3/1
Curculionidae	58/3	119/2	149/2	168/1	252/3
Endomychidae	0/0	5/1	23/1	6/1	10/1
Erotylidae	15/1	18/1	182/1	51/1	49/1
Histeridae	0/0	0/0	0/0	2/1	0/0
Nitidulidae	226/3	479/4	649/2	1407/3	1301/3
Scarabaeidae	71/2	46/2	57/2	41/2	49/3
Staphylinidae	62/5	40/3	60/3	29/3	22/3

In terms of beetle species communities' structures elucidated by the gradient-based Non-metric Multi-Dimensional Scaling Ordination (NMS) method, canopy-height light traps showed no clear difference for beetle species communities' structures across different seasons and oil palm age stands (Figure 3 and Figure 4), with all beetle species communities from younger (less than one year old and 3 years old) and older oil palm age stands (6 years old, 18 years old, and 23 years old) overlapped together. Modified pit-light traps showed clear difference of beetle species communities across different seasons and oil palm age stands (Figure 5 and Figure 6), with beetle species communities within the older oil palm age stands (6 years, 18 years, and 23 years old) were separated from the beetle species communities within younger oil palm age stands (less than one year old and 3 years old) during the dry-hot season. The wet-rainy season did not show any beetle species communities' difference for the case of modified pit-light traps.

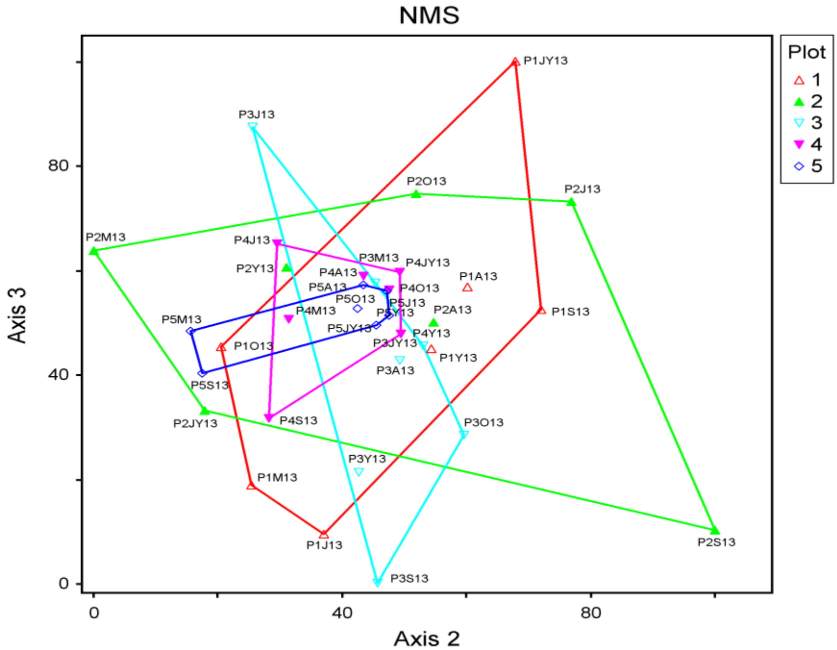

Figure 3. Non-Metric Multi-Dimensional Scaling (NMS) simple scatterplot of beetle species communities captured by the canopy-height light traps during the dry-hot season. P1 = Less than one year old; P2 = 3 years old; P3 = 6 years old; P4 = 18 years old; P5 = 23 years old. M = March; A = April; Y = May; J = June; JY = July; O = August; S = September. 13 = Year 2013.

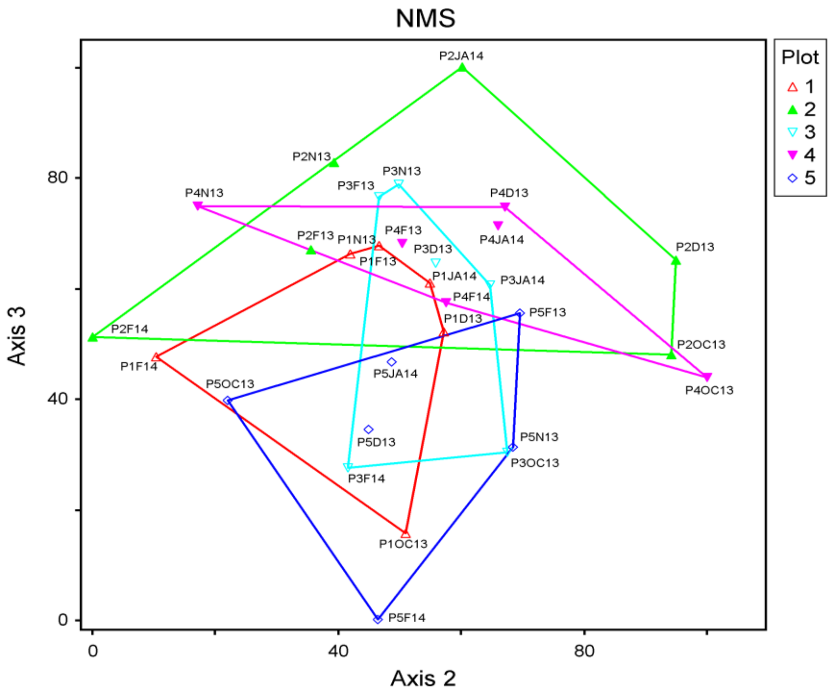

Figure 4. Non-Metric Multi-Dimensional Scaling (NMS) simple scatterplot of beetle species communities captured by the canopy-height light traps during the wet-rainy season. P1 = Less than one year old; P2 = 3 years old; P3 = 6 years old; P4 = 18 years old; P5 = 23 years old. F = February; OC = October; N = November; D = December; JA = January. 13 = Year 2013; 14 = Year 2014.

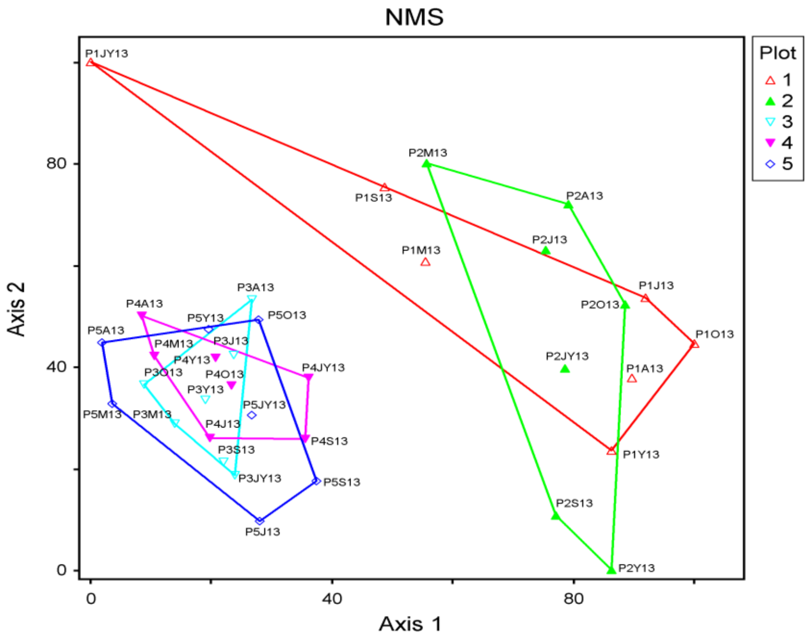

Figure 5. Non-Metric Multi-Dimensional Scaling (NMS) simple scatterplot of beetle species communities captured by the modified pit-light traps during the dry-hot season. P1 = Less than one year old; P2 = 3 years old; P3 = 6 years old; P4 = 18 years old; P5 = 23 years old. M = March; A = April; Y = May; J = June; JY = July; O = August; S = September. 13 = Year 2013.

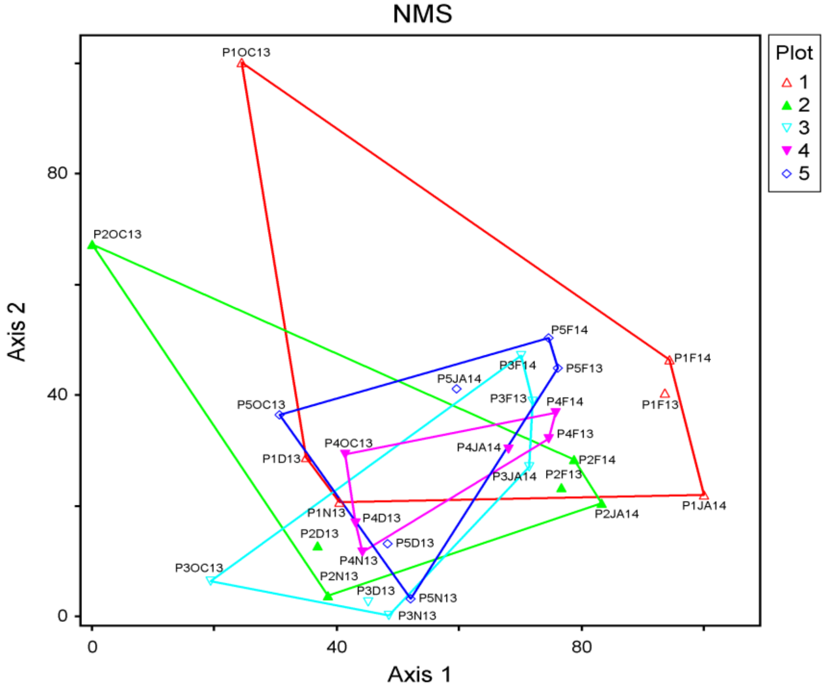

Figure 6. Non-Metric Multi-Dimensional Scaling (NMS) simple scatterplot of beetle species communities captured by the modified pit-light traps during the wet-rainy season. P1 = Less than one year old; P2 = 3 years old; P3 = 6 years old; P4 = 18 years old; P5 = 23 years old. F = February; OC = October; N = November; D = December; JA = January. 13 = Year 2013; 14 = Year 2014.

Comparing beetle species diversity between different trapping methods and across different oil palm age stands showed that the canopy-height light traps recorded higher beetle species diversity during the dry-hot season, based on Shannon Diversity Index (H'), within the range of H' = 4.079 to 4.366, compared with the modified pit-light traps within the range of

H’ = 1.233 to 2.688 (Table 5). Nearly similar patterns were observed for wet-rainy season, with the Shannon Diversity Index (H’) for the canopy-height light traps recorded higher values, within the range of H’ = 3.812 to 4.419, while the modified pit-light traps recorded lower values, within the range of H’ = 0.965 to 2.036 (Table 6). Overall, these records of Shannon Diversity Index (H’) showed that the canopy-height light traps had increased the beetle species diversity values and statuses across different oil palm age stands for up to a maximum of four times and a minimum of two times compared with the modified pit-light traps with moderate beetle species diversity values and statuses. Pielou’s Evenness Index (E’) between the canopy-height light traps and the modified pit-light traps did not show wide-ranging differences, except for the older oil palm age stands of the age 6 years, 18 years, and 23 years old, which showed wider differences in overall beetle species evenness for both seasons. The modified pit-light traps showed lower overall beetle species evenness within the older oil palm age stands compared with the canopy-height light traps.

Table 5. Diversity Indices, species number, and abundances of beetle species communities between canopy-height light traps (C-HL) and modified pit-light traps (M-PL) across different oil palm age stands around the dry-hot season.

Oil Palm Plots	**CH-L**				**M-PL**			
Diversity Indices	**H'**	**E'**	**S**	**N**	**H'**	**E'**	**S**	**N**
< 1 year old	4.366	0.922	114	1050	2.688	0.949	17	99
3 years old	4.286	0.902	116	1134	2.487	0.897	16	67
6 years old	4.246	0.888	119	1130	1.629	0.527	22	1430
18 years old	4.360	0.912	119	1542	1.233	0.388	24	1498
23 years old	4.079	0.854	119	2158	1.396	0.419	28	1302

Descriptions: CH-L: Canopy-height Light Trap; M-PL: Modified Pit-light Trap. H': Shannon Species Diversity Index; E': Pielou's Species Evenness Index, S: Total species numbers; N: Total species abundances.

Table 6. Diversity Indices, species number, and abundances of beetle species communities between canopy-height light traps (C-HL) and modified pit-light traps (M-PL) across different oil palm age stands around the wet-rainy season.

Oil Palm Plots	**CH-L**				**M-PL**			
Diversity Indices	**H'**	**E'**	**S**	**N**	**H'**	**E'**	**S**	**N**
< 1 year old	3.812	0.799	118	1619	2.036	0.719	17	463
3 years old	4.068	0.853	118	1217	1.818	0.629	18	797
6 years old	4.149	0.868	119	1454	1.706	0.615	16	1257
18 years old	3.902	0.842	103	960	0.965	0.340	17	1738
23 years old	3.912	0.859	95	988	1.038	0.347	20	1706

Descriptions: CH-L: Canopy-height Light Trap; M-PL: Modified Pit-light Trap. H': Shannon Species Diversity Index; E': Pielou's Species Evenness Index, S: Total species numbers; N: Total species abundances.

Feeding ecological groups' compositions interpreted in percentages and constructed by both the canopy-height light traps and modified pit-light traps also showed several differences, in which the canopy-height light traps showed high consistent percentages of predators, herbivores, and saproxylics across different seasons, plus with the presence of omnivores in the smallest percentages. The modified pit-light traps, on the other hand, showed no presence of omnivores, plus with the higher percentages of fungivores during the dry-hot season, compared with the canopy-height light traps (Table 7). Furthermore, during the wet-rainy season, the modified pit-light traps also showed lower percentages of predators, to be slightly similar to the percentages of herbivores, and significantly lower than that of the saproxylics (Table 8). This was different for the case of the canopy-height light traps, in which both the predators and saproxylics showed nearly comparable percentages between each other for both seasons. The variations of fungivores' percentages can be observed clearly between different seasons related to the modified pit-light traps, in which higher percentages of fungivores to be observed within younger oil palm age stands (less than one year old and 3 years old) during the dry-hot season, while higher percentages of fungivores to be observed higher within the older oil palm age stands (6 years, 18 years, and 23 years old) during the wet-rainy season the canopy-height light traps did not show clear differences of fungivores' percentages between different seasons and across different oil palm age stand types.

Table 7. Percentages of beetle species feeding ecological groups based on the canopy-height light traps (CH-L) and modified pit-light traps (M-PL) across different oil palm age stands during the dry-hot season.

Oil Palm Plots			**CH-L**					**M-PL**		
Feeding Groups (%)	**P**	**H**	**S**	**F**	**O**	**P**	**H**	**S**	**F**	**O**
< 1 year old	37.17	16.44	32.22	8.37	5.70	31.31	22.22	30.30	16.16	0.00
3 years old	37.92	15.96	35.54	7.05	3.53	34.33	14.93	35.82	14.93	0.00
6 years old	34.60	19.56	39.03	6.28	0.53	11.19	8.32	68.25	12.24	0.00
18 years old	38.06	17.70	35.52	7.38	1.34	4.54	5.14	85.85	4.47	0.00
23 years old	34.71	15.06	44.25	5.33	0.65	5.30	4.92	85.02	4.76	0.00

Descriptions: CH-L: Canopy-height Light Trap; M-PL: Modified Pit-light Trap. P: Predators; H: Herbivores; S: Saproxylics; F: Fungivores; O: Omnivores.

Table 8. Percentages of beetle species feeding ecological groups based on the canopy-height light traps (CH-L) and modified pit-light traps (M-PL) across different oil palm age stands during the wet-rainy season.

Oil Palm Plots			**CH-L**					**M-PL**		
Feeding Groups (%)	**P**	**H**	**S**	**F**	**O**	**P**	**H**	**S**	**F**	**O**
< 1 year old	30.45	13.03	50.53	5.13	0.86	19.87	16.41	60.69	3.24	0.00
3 years old	39.69	12.90	40.43	5.34	1.64	10.15	6.52	74.31	9.02	0.00
6 years old	40.37	13.07	39.48	6.46	0.62	15.06	4.54	63.51	16.89	0.00
18 years old	27.50	18.23	41.98	9.38	2.92	3.11	2.36	90.56	3.97	0.00
23 years old	36.74	13.16	42.91	6.17	1.01	2.23	2.93	91.03	3.81	0.00

Descriptions: CH-L: Canopy-height Light Trap; M-PL: Modified Pit-light Trap P: Predators; H: Herbivores; S: Saproxylics; F: Fungivores; O: Omnivores.

DISCUSSIONS

The beetle species diversity levels captured by the canopy-height light traps across different oil palm age stand types and seasons in most cases showed high diversity levels (H’ > 4.00). According to Prakash and Amita (2012), if the range of H’ is 1.00 to 2.40, it indicates the site has low species diversity, if the range is 2.50 to 3.50, it has moderate range of species diversity, and the range of 4.00 and above indicates high level of species diversity. It can also be observed that the level of beetle species diversity based on the modified pit-light traps in most cases showed low species diversity levels (H’ = 1.00 - 2.40), and only a few cases showed moderate diversity levels (H’ = 2.50 - 2.70). The wide and significant differences of beetle species diversity levels between canopy-height light traps and modified pit-light traps showed that there were different consistency levels for both type of trapping methods when applied within the context of oil palm plantations and across different age stand types. It can be observed that, during dry-hot season, the diversity levels across all selected oil palm age stands for the case of canopy-height light traps showed consistently high levels of beetle species diversity, as well as the overall beetle species evenness, while the modified pit-light trap clearly showed differential levels of beetle species diversity and species evenness according to different oil palm age stand types. The older oil palm age stand types had lower beetle species diversity levels and species evenness, different from the younger oil palm age stands that showed moderate levels of beetle species diversity and higher species evenness. Lower beetle species diversity and species evenness within older oil palm age stands during the dry-hot season showed the possible impacts of structural diversity reductions, which in turn directly affecting the levels of beetle species diversity, since the simplifications of intermediate stratum in all oil palm age stand types generated higher pressure to most beetle species to locate suitable and viable epigeal-related microhabitats for maintenance of their fitness (Miñarro & Dapena 2003; Nadeau et al. 2015; Peltonen et al. 1998).

It is also can be deduced that the distance between both the canopy and epigeal strata could directly impact on the diversity levels of beetle species overall, with lower distances produce higher probabilities for most beetle species to locate feeding materials and breeding grounds with ease, and less energy expenditure for movement between different strata, hence increasing fitness (Didham et al. 1998; Southwood et al. 1979; Wermelinger et al. 2007). Since older oil palm age stand types had farther distances between the canopy and epigeal strata, this condition will give disadvantages on most beetle species to freely locate feeding resources and breeding grounds, reducing their fitness and levels of diversity over time. Canopy-level light trapping failed to discern such differential qualities of canopy-epigeal distance factor on beetle species diversity, hence further showing the importance of corrected light-based trapping methods within oil palm plantations. The modified pit-light traps were close to the epigeal-located microhabitats, hence producing stable and reliable results on the true levels of beetle species diversity. The application of modified pit-light traps is not to prove that the levels of beetle species diversity within oil palm plantations to be lower compared with the results from canopy-height light traps, but to produce improved and stable results regarding the true levels of beetle species diversity, as well as appropriately spearheading conservational efforts, guided by the notions on the significance of microhabitats (Mehrabi et al. 2014; Chung et al. 2000).

Canopy-height light traps can be observed to be unsuccessful in differentiating both levels of beetle species diversity and species evenness during the dry-hot season across different oil palm age stands, showing ineffectiveness of discerning small differences between younger and older oil palm age stands, hence neglecting the importance of microhabitats as a factor in elucidating beetle species diversity and species evenness differences. Another possible factor of reduced beetle species diversity and species evenness across older oil palm age stand types based on the modified pit-light traps was the intensified oil palm management system activities, which indirectly affecting the beetle species that possibly employing the available microhabitats around the older oil palm age stands. Similar cases can be observed during the wet-rainy season, where the canopy-height light traps also failed to discern different beetle species diversity levels and species evenness across both younger and older oil palm age stands, where most of the oil palm age stands showed high level of beetle species diversity, and the same time nearly equal levels of species evenness. The modified pit-light traps clearly showed lower species evenness levels around the older oil palm age stands, especially of the age 18 years and 23 years old. Possibly both of these older oil palm age stands were heavily intensified from the oil palm management system activities, hence have reduced remnants of viable microhabitats for beetle species survival and maintenance of natural resources. This can be supported by the overall beetle species community structures generated by the Non-Metric Multi-Dimensional Scaling (NMS) ordination to be overlapped between different oil palm age stand types involving the canopy-height light traps, while clear differences between different seasons and between younger-older oil palm age stand types involving the modified pit-light traps (McCune et al. 2002; Peck 2010).

Although it can be argued that the beetle species community structures based on the modified pit-light traps should be separated during the wet-rainy season and overlapped during the dry-hot season, it can be explained that most saproxylic beetle species required certain levels of ambient relative humidity to effectively utilized the rotting microhabitat structures, either for procuring food materials in the form of rotting oil palm sap, or for breeding (Speight 1989). Since wet-rainy season showed highest percentages attained by the saproxylic beetle species groups, this supported the perception that saproxylic beetle species within oil palm plantations had altered their innate behaviours and the ways these saproxylic beetle species manipulating rotting oil palm microhabitats. Furthermore, the reductions in the presence of most predatory beetle species during the wet-rainy season also gave the clear advantage to most saproxylic beetle species, creating better and risk-free opportunities in utilizing the rotting oil palm microhabitats (Hjältén et al. 2012; Mawdsley 1994). Canopy-height light traps failed to elucidate the presence-absence alternating factor for the utilization of microhabitats by most saproxylic beetle species in relation to predatory beetle species, as for both seasons it can be observed that the percentage of presence for both saproxylic and predatory beetle species were at nearly equal levels.

Variations of herbivores, as for most herbivores to have higher diversity levels within the younger oil palm age stands, and lower diversity levels within the older oil palm age stands, failed to be discern by the canopy-height light traps. Canopy-height light traps had produce vague results in the status of most herbivore beetle species across different oil palm age stand types. This is very risky and crucial since when based on the results from canopy-height light traps, it can be concluded that conservational efforts need not to be done within older oil palm age stands. Imprecise light-based trapping methods can deviate the correct path of conservational efforts within different oil palm age stand types. Although it can be reasoned that all oil palm age stands must apply urgent conservational efforts, but discerning which oil palm age stand type and setting improved priorities is very important as to minimize conservational costs over longer periods of time (Didham et al. 1998; Koh & Wilcove 2007; Myers et al. 2000). This is paralleled to the concept that high quality and effective conservation efforts must be done by stages and consumed much more time to be successful. Varying the oil palm management systems' intensifications in retaining any rotting microhabitats with the presence of fungal bodies can be clearly observed when based on the results of modified pit-light traps, with less intensifications of management systems within the older oil palm age stands during both seasons. The canopy-height light traps showed no clear difference in terms of fungivores' presence around all oil palm age stands, making specific decisions on conservational efforts for most fungivores to be in uncertainty.

The canopy-height light traps can be observed to incorporate many beetle species across different oil palm age stand types together, evident by most beetle species feeding ecological groups to have nearly equal percentages across different oil palm age stand types and seasons. Since the canopy levels of most oil palm age stand types are not obstructed by any forms of obstacles, the light electromagnetic wavelengths can further cleanly emitted throughout the canopy levels of all oil palm age stand types, attracting almost all beetle species within different oil palm age stand types. This can be proved by the results of the beetle species community structure generated by NMS ordination across both seasons. It is also possible that the light from the canopy-height light traps also affecting beetle species from any closest surrounding secondary forests, making interpretations pertained to true beetle species dwelled within oil palm plantations to be erroneous. Modified pit-light traps applied at the epigeal levels of most oil palm age stand types however can be seen much more effective in attracting and trapping true beetle species dwelled within oil palm plantations, and in addition to be specific around any closest epigeal-related microhabitats. The light from modified pit-light traps is mostly directed towards any closest epigeal-related microhabitats, not dispersed widely and continuously obstructed by any surrounding microhabitats, unlike the light emitted from the canopy-height light traps. Consequently, any other forms of light-based trapping implemented within oil palm plantations established either parallel to the canopy, near the canopy, above the canopy, below the canopy, or between the canopy-intermediate strata have higher probability to generate unreliable and unstable data. It is highly suggested that light-based trapping must be implemented around the epigeal stratum within the context of oil palm plantations to produce reliable results.

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. Noor Hisham Hamid, by providing the appropriate oil palm study plots, located in Felda Sungai Tekam, Pahang, under Tun Razak Agricultural Research Centre (PPPTR) Unit. We would also want to wish our appreciation to Dr. Izfa Riza Hazmi, as the Head for Centre of Insects Systematic (CIS), Universiti Kebangsaan Malaysia (UKM), by providing suitable and the best quality insect laboratory for Coleoptera species identification and setting processes. Finally, we want to recognize Mr. Mohd. Yusri Mohd. Naser from the Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan (UMK), for supporting this project pertaining to the counsels given for the fundamental technical designs and efficiencies, as well as on electronic arrangements of the modified pit-light trap.

REFERENCES

Badrul, A., Norzanalia, S., Puan, C. L., Norizah, K., Najjib, A., Siti, N. and Fischer, J. 2015. Promoting landscape heterogeneity to improve the biodiversity benefits of certified palm oil production: evidence from Peninsular Malaysia. *Global Ecology and Conservation* 3: 553-561.

Borror, D. J. and White, R. E. 1970. *Peterson Field Guide – Insects of North America*. New York: Houghton Mifflin Company, pp 404.

Bowden, J. and Church, B. M. 1973. The influence of moonlight on catches of insects in light-traps in Africa. Part II. The effect of moon phase on light-trap catches. *Bulletin of Entomological Research* 63(1): 129-142.

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.

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.

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: 437–451.

Farrow, R. A. 1974. A modified light-trap for obtaining large samples of night-flying locusts and grasshoppers. *Australian Journal of Entomology* 13(4): 357–360.

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* 11: 337– 345.

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.

Heap, M. A. 1988. The pit-light: a new trap for soil-dwelling insects. *J. Aust. Entomol. Soc* 27: 239-240.

Hébert, C., Jobin, L., Fréchette, M., Pelletier, G., Coulombe, C., Germain, C. and Auger, M. 2000. An efficient pit-light trap to study beetle diversity. *Journal of Insect Conservation* 4(3): 189–200.

Hjältén, J., Stenbacka, F., Pettersson, R. B., Gibb, H., Johansson, T., Danell, K., Ball, J. P. and Hilszczánski, J. 2012. Micro- and macro-habitat associations in saproxylic beetles: implications for biodiversity management. *PloS One* 7(7): e41100.

Hristovski, S., Cvetkovska-Gjorgievska, A. and Mitev, T. 2016. Microhabitats and fragmentation effects on a ground beetle community (Coleoptera: Carabidae) in a mountainous Beech forest landscape. *Turkish Journal of Zoology* 40: 402-410.

Jonason, D., Franzén, M., and Ranius, T. 2014. Surveying Moths Using Light Traps: Effects of Weather and Time of Year. *Plos One* 9: e92453.

Koh, L. P. and Wilcove, D. S. 2008. Is oil palm agriculture really destroying Tropical biodiversity? *Conservation Letters* DOI: 10.1111/j.1755-263X.2008.00011.x.

Koh, L. P. 2008. Can oil palm plantations be made more hospitable for forest butterflies and birds? *Journal of Applied Ecology* 45: 1002-1009.

Koh, L. P. and Wilcove, D. S. 2007. Cashing in palm oil for conservation. *Nature* 448: 993-994.

Liow, L. H., Sodhi, N. S. and Elmqvist, T. 2001. Bee diversity along a disturbance gradient in Tropical lowland forests of South-East Asia. *Journal of Applied Ecology* 38: 180-192.

Mawdsley, N. A. 1994. Community structure of Coleoptera assemblage in a Bornean tropical forest. PhD Thesis. University of London.

McCann, K. S. 2000. The diversity-stability debate. *Nature* 405: 228-233.

McCune, B., Grace, J. B. and Urban, D. L. 2002. *Analysis of Ecological Communities*. Oregon: MjM Software Design, pp 304.

McNeely, J. A., Gadgil, M., Leveque, C., Padoch, C. and Redford, K. 1995. Human influences on biodiversity. In *Global Biodiversity Assessment*, ed. V. H. Heywood, and R. T. Watson. UNEP. Cambridge: Cambridge University Press, pp. 711 – 822.

Mehrabi, Z., Slade, E. M., Solis, A. and Mann, D. J. 2014. The importance of microhabitat for biodiversity sampling. *PLoS One* 9(12): e114015.

Miñarro, M. and Dapena, E. 2003. Effects of groundcover management on ground beetles (Coleoptera: Carabidae) in an apple orchard. *Applied Soil Ecology* 23: 111-117.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., de Fonseca, G. A. B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853-858.

Nadeau, P., Majka, G. C. and Moreau, G. 2015. Short-term response of coleopteran assemblages to thinning-induced differences in dead wood volumes. *Forest Ecology and Management* 336: 44-51.

Nowinszky, L. and Puskás, J. 2012. Light-Trap Catch of the Harmful Moths Depending of Moonlight in North Carolina and Nebraska States of USA. *ISRN Zoology* DOI: 10.5402/2012/238591.

Peck, J. E. 2010. *Multivariate Analysis for Communities Ecologists: Step by Step Using PC-ORD.* Gleneden Beach: MjM Software Design, pp 170.

Peltonen, M., Heliovaara, K., Vaisanen, R. and Keronen, J. 1998. Bark beetle diversity at different spatial scales. *Ecography* 21: 510-517.

Prakash, M. M. and Amita, D. 2012. Study of diversity indices (zooplankton) at Munj Sagar Talab, Dhar Madya Pradesh, India. *International Journal of Fisheries and Aquaculture Sciences* 2(1): 1-7.

Robinson, H. S. 1952. On the behaviour of night-flying insects in the neighbourhood of a bright source of light. *Proceedings of the Royal Entomological Society of London. Series A, General Entomology* 27(1-3): 13–21.

Rosenberg, D. M., Danks, H. V. and Lehmkuhl, D. M. 1986. Importance of insects in impact assessment environmental. *Environmental Management* 10(6): 773-783.

Speight, M.C.D. 1989. *Saproxylic Invertebrates and Their Conservation*. Strasbourg: Council of Europe.

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* 143: 2375-2384.

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.

Stenbacka, F., Hjältén, J., Hilszczański, J. and Dynesius, M., 2010. Saproxylic and non-saproxylic beetle assemblages in Boreal Spruce forests of different age and forestry intensity. *Ecol. Appl* 20: 2310–2321.

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.

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.

Wermelinger, B., Flückiger, 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 – 114.

Yaap, B., Struebig, M. J., Paoli, G. and Koh, L. P. 2010. Mitigating the biodiversity impacts of oil palm development. CAB Reviews: *Perspectives in Agriculture, Veterinary Science, Nutrition, and Natural Resources* 5: 11.

Yue, S., Brodie, J. F., Zipkin, E. F. and Bernard, H. 2015. Oil palm plantations fail to support mammal diversity. *Ecological Applications* 25(8): 2285-2292.