

**THE EFFECTS OF TRAMPLING TO THE
ABUNDANCE AND DIVERSITY OF LITTER
ANTS IN STABILITY OF ALTERED
FOREST ECOSYSTEM (SAFE)
KALABAKAN, SABAH**



HASRIN BIN ROSSLEYKHO

UMS
UNIVERSITI MALAYSIA SABAH

**INSTITUTE FOR TROPICAL BIOLOGY AND
CONSERVATION
UNIVERSITI MALAYSIA SABAH
2016**

**THE EFFECTS OF TRAMPLING TO THE
ABUNDANCE AND DIVERSITY OF LITTER
ANTS IN STABILITY OF ALTERED
FOREST ECOSYSTEM (SAFE)
KALABAKAN, SABAH**

HASRIN BIN ROSSLEYKHO



UMS

**THESIS SUBMITTED IN FULFILLMENT FOR
THE DEGREE OF MASTER OF SCIENCE**

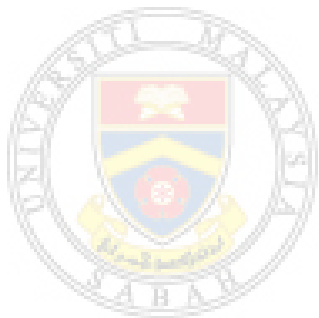
**INSTITUTE FOR TROPICAL BIOLOGY AND
CONSERVATION
UNIVERSITI MALAYSIA SABAH
2016**

DECLARATION

I hereby declare that the work in this thesis is my own except for the citation which has been fully acknowledged.

1 December 2015

Hasrin bin Rossleykho
MX1211008T



UMS
UNIVERSITI MALAYSIA SABAH

TABLE OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
<i>ABSTRAK</i>	vi
TABLE OF CONTENT	vii
LIST OF TABLE	x
LIST OF FIGURE	xi
LIST OF ABBREVIATION	xii
LIST OF APPENDICES	
CHAPTER 1: INTRODUCTION	1
1.1 Disturbance	1
1.2 Litter Ants	2
1.3 Effects of disturbance on ecosystem	3
1.4 Justification	3
1.5 Objectives	4
1.6 Hypothesis	4
CHAPTER 2: LITERATURE REVIEW	5
2.1 Systematics of ants	5
2.1.1 Ant diversity in different habitat type	6
2.1.2 Composition of Borneo ants	8
2.2 Trampling	9
2.2.1 Trampling effect on soil properties	9
2.2.2 Trampling effect on understory vegetation	10
2.2.3 Trampling effect toward arthropods diversity	10
2.3 Ant as bio indicator	11
2.3.1 Functional group of ants	12
2.4 Stability of Altered Forest Ecosystems	13

CHAPTER 3: METHODOLOGY	
3.1	Study sites 15
3.2	Experimental design and data analysis 16
3.2.1	Effect of trampling on the diversity of litter ants 16
3.2.2	Effect of environment variables to ant diversity 17
3.2.3	Ants identification and curation 20
3.2.4	Indicator species for different habitat types 20
3.2.5	Differences of ant communities in different habitat types 21
CHAPTER 4: RESULTS	23
4.1	General findings 23
4.2	Effect of trampling on the diversity of litter ants 26
4.2.1	Effects of associated parameters to ants and variables in different sampling distances 30
4.2.2	Comparison of environmental variables in different distances on the trails 34
4.3	Indicators species for different habitat type 34
4.4	Diversity of ants in different habitat types 38
CHAPTER 5: DISCUSSION	43
5.1	General finding 43
5.2	Effect of trampling on the diversity of litter ants 44
5.2.1	Effects of associated parameters to ants and variables 46
5.3	Indicator species for different habitat types 49
5.4	Diversity of ants in different habitat types 50
CHAPTER 6: CONCLUSION	
REFERENCES	53

LIST OF TABLE

	Page	
Table 2.1	The distribution of ant species	6
Table 2.2	Composition of Borneo ants up to 2011	8
Table 2.3	Functional group of Australian Ants	12
Table 2.4	Experimental plot in SAFE project area	14
Table 3.1	Environmental variables taken, method of recording and data output	18
Table 4.1	Total number of species and individual number of each ant genera	24
Table 4.2	Total number of species and individual number of each ant genera	27
Table 4.3	Post hoc result of (a) species abundance, (b) individual Abundance, (c) Shannon diversity index, and (d) Simpson diversity index	29
Table 4.4	Axis summary statistic	30
Table 4.5	Species-Environment correlation based on randomization by Monte Carl (999) randomization	31
Table 4.6	Intra-set correlations and Bi-plot scores for 11 environmental variables	31
Table 4.7	The Indicator and significance p-values for indicator species (with 999 Monte Carlo permutations) where RA= relative abundance and RF= relative frequency	35
Table 4.8	Value of diversity indices, species richness, and individual Abundances for each habitat	38
Table 4.9	ANOVA result of p values amongst habitat	39
Table 4.10	Post hoc result of (a) species richness, (b) individual abundance, (c) Shannon diversity index, and (d) Simpson diversity index between sampling site	40

LIST OF FIGURE

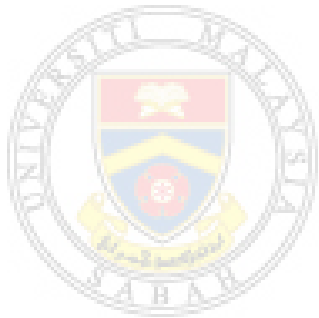
		Page
Figure 3.1	Map of Stability of Altered Forest Ecosystem (SAFE) and respective sampling site, Old Growth 2 (OG2), Oil Palm 3(OP3), B, C, D, and LFE	16
Figure 3.2	Experimental designs on the effect of the trampling toward litter ant diversity	17
Figure 4.1	Genera composition of ant subfamilies	23
Figure 4.2	Species accumulation curve of ant collected at each distance on the transect in all sampling sites	26
Figure 4.3	Mean of species and individual abundance of ants across sampling distances	27
Figure 4.4	Bi-plotted CCA ordinations using environmental scores to structuring different habitat and ants assemblages. Axis explains linear variation of the environmental scores. The coloured polygons represent sampling points in each habitat. OP3 (Oil palm 3), OG2 (Old Growth 2), LFE (Log Fragmented Edge), B (Block B), C (Block C), and D (Block D)	32
Figure 4.5	Bi-plotted CCA ordinations showing distribution pattern of the ants in relation to the environments	33
Figure 4.6	Figure 4.8: Distribution of (a) <i>Lophomyrmex</i> sp. 2, (b) <i>Prionopelta</i> sp. 1, (c) <i>Ponera</i> sp. 1, (d) <i>Mesoponera</i> sp. 1, (e) <i>Mesoponera</i> sp. 2, (f) <i>Paratrechina</i> sp. 2, (g) <i>Cardiocondyla</i> sp. 1, (h) <i>Mesoponera</i> sp. 3, and (i) <i>Lophomyrmex</i> sp. 1 using CCA ordinations. Coloured polygons represent sampling points where the species were captured. Heavy coloured polygons represent high number of individuals	37
Figure 4.7	Species accumulation curve in all sampling sites	39
Figure 4.8	Ants genera composition in all sampling habitat	42

LIST OF ABBREVIATION

%	-	Percent
H₀	-	H null
H₁	-	H alternative
ha	-	Hectares
SAFE	-	Stability of Altered Forest Ecosystem
OP3	-	Oil Palm 3
OG2	-	Old Growth 2
m	-	Meters
ln	-	natural log
H'	-	Shannon index
D	-	Simpson index
SPSS	-	Statistical Package for the Social Sciences
cm	-	Centimeters
CCA	-	Canonical Coordination Analysis
Spp-Envt	-	Species environment correlation
Litter D	-	Litter depth
ATemp	-	Air temperature
Humid	-	Humidity
STemp	-	Soil temperature
Litter C	-	Litter coverage
Compact	-	Compaction
RF	-	Relative frequency
RA	-	Relative abundance
GM	-	Generalise Myrmicinae
CS	-	Cryptic species
O	-	Opportunist

LIST OF APPENDICES

		Page
Appendix A	Total number of species for each ants genera	60
Appendix B	ANOVA test of species richness (Spr2), individuals (In2) and diversity indices between habitats	61
Appendix C	List of ant genera and subfamily based on their individual abundances and species (in bracket)	66
Appendix D	ANOVA test for species richness (Spr2), individuals abundance (In2) and diversity indices between sampling distances	68
Appendix E	Full list of potential indicators species	73



UMS
UNIVERSITI MALAYSIA SABAH

CERTIFICATION

NAME : **HASRIN BIN ROSSLEYKHO**
MATRIC NO. : **MX1211008T**
TITLE : **THE EFFECTS OF TRAMPLING TO THE
ABUNDANCE AND DIVERSITY OF LITTER
ANTS IN THE STABILITY OF ALTERED
FOREST ECOSYSTEM (SAFE) KALABAKAN,
SABAH**
DEGREE : **MASTER OF SCIENCE
(ECOLOGICAL PROCESS)**
VIVA DATE : **5 FEBRUARY 2015**



DECLARED BY

1. MAIN SUPERVISOR

Assoc. Prof. Dr. Bakhtiar Effendi Yahya

Signature

UMS
UNIVERSITI MALAYSIA SABAH

2. CO-SUPERVISOR

Dr. Mahadimenakbar Mohd Dawood

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim, finally the thesis were finished after my two years of study and this would not have been made possible without the support from numerous party. Before I say my gratitude to all parties that involved either directly or indirectly in completing this research, I want to say thanks to Allah because with His blessing, I can finish writing my Master thesis with ease and without major complication.

First and foremost, I want to deliver my greatest gratitude to Dr. Bakhtiar Effendi Yahya for his loving and never ending guidance that allow me to go through the ever so challenging journey till finally I am able to finish my research and presented it in this thesis. There are times that problems drag me down but thanks to his unwavering support, I push myself to be able to finish this work on time. Also I want to share thanks to my co-supervisor Dr Mahadimenakbar M Dawood for his contribution in terms of ideas to make this research better.

Next, I am greatly thankful to MyBrain as well as research grant FRG0302 for providing fund to me to conduct all the fieldwork for the past 2 years. Without it, all the fieldwork would not be successful.

Next I want to say my sincere thanks to all my friends especially, Mohd Afif Zakaria, Musa bin Muchtar, Mohd Afifi Ahmad Hamdan, and Anati Sawang for their brilliant ideas and encouragement during my research. Also, I want to share this success to SAFE staff as especially to Mus and Siun for their help during fieldwork. Also to all ITBC staff who help me in finishing this research successfully.

Last but not least, my beloved family. This work is dedicated especially for them because of their never ending support and loving advices to me. They were always right behind me whenever I needed and without them I am surely cannot finish this research.

Again, thanks to all..

Sincerely,

Hasrin bin Rossleykho
1 December 2015

ABSTRACT

This study was conducted at the Stability of Altered Forest Ecosystem (SAFE) between March 2013 to July 2013. The main objective of this study was to investigate the effect of human disturbance towards the litter ant. Winkler extraction method was used to collect litter samples from six blocks namely blocks B, C, D, LFE, Old Growth 2 (OG2), and Oil Palm 3 (OP3). Six random points were chosen in each block. Each point located exactly on the centre of the trails to represent the first point (0m). Then a 50 m line transect was set up starting from the first point and stretched to the interior part of the forest. Litter samples were collected from 0 m, 2 m, 10 m, 20 m, 30 m and 50 m point respectively. Sampling from each marks represent the impact of human disturbance where the first point (0 m) yielded a greater impact than the sixth point (50 m). A total of 5,932 individuals (55 genera, 8 subfamilies, and 163 species) were collected. OG2 recorded the most species (91) followed by block D (70), LFE (57), B (55), OP3 (44), and C (40). In terms of individual abundance, block D recorded the highest numbers (1,767) followed by OG2 (1,665), B (704), LFE (775), C (523) and OP3 (498). ANOVA test showed that there were a significant differences of species richness (d.f=5, $F=19.635$, $p<0.05$) between habitat and between distance (d.f=5, $F=14.712$, $P=<0.05$). Post Hoc test (Tukey) showed that there were a significant differences between 0m-10m, 0m-20m, 0-30m, 0m-50m, 2m-20m, 2m-30m, and 2m-50m ($p<0.05$). Nine ants were considered good indicator for habitat type that is *Mesoponera* sp 1, *Ponera* sp 1, *Paratrechina* sp 2, *Mesoponera* sp 2, *Cardiocondyla* sp 1, *Lophomyrmex* sp 1, *Lophomyrmex* sp 2 and *Prionopelta* sp 1 indicated by their high observation indicator values.

Key words: Disturbance, litter ants, SAFE,.

ABSTRAK

KESAN PIJAKAN SARAP KEPADA KEPELBAGAIAN DAN KELIMPAHAN SEMUT SARAP DI SAFE KALABAKAN, SABAH

*Kajian ini dijalankan di sepanjang bulan Mac 2013 hingga July 2013 di Stability of Altered Forest Ecosystem (SAFE). Objektif utama kajian ini adalah untuk mengkaji kesan gangguan manusia terhadap semut sarap hutan. Kaedah yang digunakan adalah perangkap Winkler di mana sampel sarap diambil di enam blok iaitu B, C, D, LFE, OG2, dan OP3. Enam lokasi telah dipilih secara rawak disetiap blok. Lokasi pertama terletak tepat pada laluan kaki (0m). Kemudiannya, transek sepanjang 50m dibuat menuju kearah hutan bermula pada setiap titik 0m tersebut. Sampel sarap akan diambil disetiap 0m, 2m, 10m, 20m, 30m, dan 50m. Jarak-jarak ini mewakili tahap gangguan di mana 0m merupakan lokasi yang paling terdedah kepada aktiviti manusia dan jarak 50m pula adalah yang sebaliknya. Sejumlah 5,932 individu (55 genera, 7 subfamili, dan 163 spesies) telah berjaya ditangkap. Blok OG2 merekodkan jumlah spesies terbanyak (91) diikuti oleh blok D (70), LFE (57), B (55), OP (44), dan C (40). Dari segi kelimpahan individu, blok D merekodkan jumlah tertinggi (1,767) diikuti oleh OG (1,665), B (704), LFE (775), C (523) dan OP (498). Analisis statistik ANOVA menunjukkan terdapat perbezaan signifikan diantara kekayaan spesies diantara habitat ($d.f=5$, $F=19.6355$, $p<0.05$) dan diantara jarak persampelan ($d.f=5$, $F=14.712$, $p<0.05$). Keputusan Post Hoc (Tukey) menunjukkan bahawa terdapat perbezaan signifikan diantara 0m-10m, 0m-20m, 0m-30m, 0m-50m, 2m-20m, 2m-30m, dan 2m-50m ($p<0.05$). Terdapat sembilan semut yang boleh digunakan sebagai petunjuk kepada jenis habitat iaitu *Mesoponera sp 1*, *Ponera sp 1*, *Paratrechina sp 2*, *Mesoponera sp 2*, *Cardiocondyla sp 1*, *Lophomyrmex sp 1*, *Lophomyrmex sp 2* dan *Prionopelta sp 1* kerana mempunyai nilai pemerhatian yang lebih tinggi berbanding spesies lain.*

Kata kunci: Gangguan, semut, SAFE

CHAPTER 1

INTRODUCTION

1.1 Disturbance

Disturbance means any events that disrupted environment that cause changes in their structure (Yadav and Gupta, 2006). Disturbance such clear cutting of forest can lead to the change of vegetation distribution, thus will give major impact towards the surrounding ecosystems (Yorks and Dabydeen, 1999).

Anthropogenic disturbance are those caused by human who seek valuable natural resources or exploiting the forest area for conversion to something else such as construction or monoculture plantation. Landscape changes are considered as one of the major factors regarding the loss of flora and fauna (Carreno-Rocabado *et al.*, 2012). Deterioration of forest ecosystem has caused many forest areas to suffer from fragmentation and edge effects (Broadbent *et al.*, 2008). Afraid of biodiversity loss, effort such as sustainable forest management was introduced in order to reduce the impact of human activity towards ecosystem (Carreno-Rocabado *et al.*, 2012). However, such practice often cannot meet with human demands, thus it is hard to balance the ecological, economic and social needs (Carreno-Rocabado *et al.*, 2012).

There are many types of human disturbances ranging from low level to the higher form of disturbance. Trampling by humans can be considered less severe than trampling by heavy machinery or more severe types of disturbance such as a total conversion of forest habitat. However, it is expected that the changes to the soil communities can be seen even when low level of disturbance was introduced.

1.2 Litter Ants

Litter ants are basically ants that were found in the litter layer. They were highly diverse and occupied large range of habitat but usually clustered heavily in tropical ecosystem (Hashimoto, 2006). Due to their function in ecosystem and it is easy to catch and cost-effective (Majer, Orabi, and Bisevac, 2007), they provided more data compared to other organism such as birds, plants and butterflies (Hashimoto, 2006).

All litter ants rely mostly on leaf litter because it provides them with a habitat as well as a feeding ground. Litter usually consists of fallen leaves, branches, dead tree, fruit, and flower. On top of that, animal carcasses and their feces also considered as litter (Perry *et al.*, 2008). The litter mass differs through time and place. This is due to the rate of litter is affected by biotic factor such as seasonality and topography (Bastos and Harada, 2011). Hence, the abundance of litter ants differs from each place and varied according to season since density of litter ants is tend to be higher at higher litter mass (Bastos and Harada, 2011).

Litter arthropod is sensitive to the changes in the ecosystem, making them an important indicator (Yi and Moldenke, 2008). It is because of their rapid reproductive rates, short generation times, and able to occupy small pores in the soil (Marra and Edmonds, 2004).

Thus, trampling from human activity can affect the litter ants community as they rely mostly on the litter layer. Thinning of litter layer will eventually cause the ant abundance to decrease due to the removal of their habitat. Other changes such soil pH, soil temperature and diversity of understory vegetation also proven to affect the litter inhabitants (Kotze *et al.*, 2012). With growing interest on the effect of low level of disturbance such as trampling, many researchers try to use ants in order to quantify the effect of disturbance towards the biodiversity level on the tramped sites. A possible indicator for quantifying such disturbance is usually ants and beetles because of their abundance in leaf litter and can be easily accessed. Kotze *et al.* (2012) for example, use carabid beetles as bio-indicator to find out the impact of human trampling.

1.3 Effects of Disturbance on Ecosystem

The impact of human trampling itself may not seem to be so severe if compared to the clear cutting of forest. The reduction of litter layer will remove material and places for the ants to live in and since ants play a significant role in the ecosystem as a predator, food web will be affected (Philpott, Perfecto, and Vandermeer, 2008). Secondly, the quality of soil may decrease (Littlemore and Barker, 2001). It is proven that feeding activity of litter ants or their nesting behavior has an indirect effect toward litter decomposition (Guzman and Sanchez, 2003). Carbon and nitrogen were produced through decomposition of leaf litter (Perry *et al.*, 2008) which is essential for the growth of vegetation. If decomposition relies mostly on fungi and bacteria, the cycle still be completed, but will be much slower. This is because, when large litter was broken into small pieces, the increase in surface area will help with the chemical reaction secreted by fungi and bacteria, thus increasing the rate of decomposition (Guzman and Sanchez, 2003).

1.4 Justification

SAFE Project is a new project established in Sabah that aim in studying the effect of habitat conversion towards the biodiversity. This research could help in providing extra data regarding the effect of human disturbance towards biodiversity. Also, this research can contribute to a better management of forest reserve especially on the trail management as there were very few research conducted in Sabah that were focusing on the effect of human trampling on the litter ants. Thus, the data can be used in the future for reference or as an idea to conduct more detailed research.

1.5 Objectives

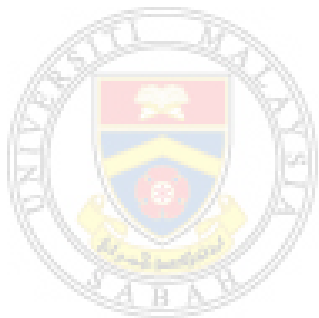
The objectives of this study are:

1. To investigate the trampling effects on the diversity of litter ants.
2. To identify potential indicator species in different habitat types.
3. To determine the differences of litter ants in different habitat types.

1.6 Hypothesis

H_0 = There was significant different of the effect of trampling towards litter ants.

H_1 = There was significant different of the effect of trampling towards litter ants.



UMS
UNIVERSITI MALAYSIA SABAH

CHAPTER 2

LITERATURE REVIEW

2.1 Systematics of Ants

Ants are metropolitan species where they are dominant in nature and play significant roles in ecosystem (Guenard, Weiser, and Dunn, 2010). Due to their importance, ants can give more output regarding biodiversity compared to other organism (Hashimoto, 2006).

Basic classification of ants is that they are from single family only known as Formicidae (Folgarait, 1998). Based on Bolton (1994) on his book identification guide to the ant genera of the world, a total of 16 subfamilies, 296 genera and 15,000 species and only 10,000 were described recorded. The distribution of the ants is the highest in the Indo-Australian followed by Neotropical, Oriental, Australian, African, Palearctic, Nearctic, and Malaysia (Bolton, 1994). The highest endemic species were found in the Neotropical and African and the least is Nearctic and Oriental (Bolton, 1994) (Table 2.1).

However, recent taxonomic work often alters the species and the subfamily of the ants where new names will arise or older genus to be resurrected thus the number can be different from time to time. The most recent is revision of ants in *Pachycondyla* groups in the Ponerinae subfamily. *Pachycondyla* group were divided into 19 genera : *Bothroponera*, *Brachyponera*, *Ectomomyrmex*, *Euponera*, *Hagensia*, *Megaponera*, *Mesoponera*, *Neoponera*, *Ophthalmopone*, *Pachycondyla*, *Palothyreus*, *Pseudoneopopone*, *Mayaponera*, *Parvaponera*, *Rasoponera*, *Wadeura*, *Termitopone*, *Syntermitopone*, and *Iroponera* (Schmidt and Shattuck, 2014).

Table 2.1: The distribution of ant species

Region	Number of species
African (Sub-saharan)	2500
West Indies, Mexico, Central and South America	2233
Asia (parts of this region)	2080
Australia	1100
North America, North of Mexico	585
Europe	429
USA	400
New Guinea, New Britain, and New Ireland	275
Polynesia	42
New Zealand	23

Source: Forgarait (1998)

Another example is the reclassification of genus *Cerapachys* to the subfamily Dorylinae instead of Cerapachyinae (Brady, Fisher, Schultz, and Ward, 2014). Dorylomorphs consist of six different subfamilies namely Aenictinae, Dorylinae, Ecitoninae, Aenictogitoninae, Leptanilloidinae and Cerapachyinae. However, all the five subfamilies were nested within Cerapachyinae and since it is hard to deal with Cerapachyinae monophyly, all six of them were grouped together in one subfamily and the name Dorylinae were chosen since it is the oldest name (Brady *et al.*, 2014).

2.1.1 Ant Diversity in Different Habitat Types

Ants can be found almost everywhere in this world such as tropical rainforest, desert, and mountain. Although they are metropolitan species, certain places have higher ant distribution than others. Based on the research by Silva, Feitosa, and Eberhardt (2007), they found out that the diversity of ants was significantly higher in the primary forest compared to disturbed forest.

Ants prefer foraging in the primary forest because of the availability and the variety of food compared to the secondary forest (McGee and Eaton, 2013). Other than that, deeper litter layer and more heterogeneity of the plant species at the primary forest provide ants with more places for foraging activity (Bastor and

Harada, 2011). Higher diversity of leaf morphotypes at the primary forest also proved to have positive effect to the diversity of the litter ants (Silva, Bieber, Correa, and Leal, 2011).

On the other hand, ants diversity are higher in secondary forest than in the plantation area. Secondary forest has higher tree diversity, better place for nesting, more source of food, and suitable climatic condition (Pacheho, Silva, Morini, and Brandao, 2009). Pacheho *et al.* (2009), also mentioned that the understory plant composition in monoculture plantation is poor and homogeneous litter may support fewer species than heterogeneous litter due to the limited foraging places.

Agricultural area causes the most severe impact on the diversity of litter ants and worst, the conversion of tropical forest to monoculture plantation is expanding at an alarming rate (Fayle, Turner, Snaddon, Chey, Chung, Eggleton, Foster, 2010). Loss of more than 50% species of ants due to conversion of forest to oil palm plantation was recorded by Fayle *et al.* (2010). Pacheho *et al.* (2009) also stated that the diversity of ants in secondary forest were higher because of the availability of better foraging area compared to the monoculture plantation. Even though a monoculture plantation has the ability to support a new succession of invertebrate communities, it is more likely to have less diversity compared to the secondary forest (Suguituru, Silva, Souza, Munhae, and Morini, 2011).

Fragmentation of forest habitat is another factor affecting the diversity of ants. Fragmentation is a landscape-level disturbance which results in the rearrangement of the landscape matrix (Hobbs and Huenneke, 1992). Fragmentation will lead to formation of mosaic structure of remaining primary forest, secondary forest and other land uses (Yamada, Hyodo, Matsuoka, Hashimoto, Kon, Ochi, Yamane, Ishii, Itioka, 2013). Yamada *et al.* (2013) in their paper stated that smaller fragmented forest will influence the species diversity of ants and those larger remnants will affect the species composition of ants. Bruhl, Eltz and Linsenmair (2003), found that the number of species collected in contiguous forest was higher than the isolated fragmented forest area.

2.1.2 Composition of Borneo Ants

Borneo is the world's third largest island and considered one of the major hotspot in the Sundaland sub region along with Malay Peninsula, Sumatra and Java (Pfeiffer, Mezger, Hosoiishi, Yahya, Kohout, 2011). Based on the preliminary checklist by Pfeiffer *et al.* (2011), a total of 97 genera with 717 valid species and 52 additional subspecies of ants from 12 subfamilies were recorded (Table 2.2).

However, there was a change in the classification of the ants as mentioned before where Cerapachyinae and Aenictinae were included in Dorylinae (Brady *et al.*, 2014).

The genus *Pachyconcylla* were also divided into 19 separate species (Schmidt and Shattuck, 2014).

Table 2.2: Composition of Borneo ants up to 2011

Subfamily	Genera	Species	Subspecies	Species subspecies	Percentage of taxa
Myrmicinae	42	315	17	332	43.2
Formicinae	19	213	21	234	30.4
Ponerinae	14	59	10	69	9.0
Dolichoderinae	6	49	4	53	6.9
Ectatommatinae	2	22	0	22	2.9
Pseudomyrmecinae	1	16	0	16	2.1
Aenictinae	1	14	0	14	1.8
Proceratiinae	3	12	0	12	1.6
Cerapachyinae	1	10	0	10	1.3
Amblyoponinae	4	3	0	3	0.4
Leptanillinae	1	2	0	2	0.3
Dorylinae	3	2	0	2	0.3
All	97	717	52	769	100

source: Pfeiffer *et al.* (2011)

2.2 Trampling

Trampling can be defined as an object repeatedly going through the same path over and over again. The object can be human, animal and also machine and each of these resulting in different degree of destruction where the trampling cause by hordes of horses gives greater impact than a group of hikers (Weaver and Dale, 1978).

Trampling by human in forest interior can cause visible path on the ground where prolonged exposure will lead to the destruction of understory vegetation, changing the properties of the soil, and ultimately disturbing the communities of soil organisms (Littlemore and Barker, 2001).

Worse of all is trampling by heavy machinery for example conversion of forest to oil palm plantation. Trampling by heavy machinery were obviously much more severe as proven by a research by Weaver and Dale (1978) that showed that motorcycles give more damage to the soil than hikers and animals.

Different level of trampling causes different effects on the grounds. Mostly is the wear and tear of the trails. The widths of the trail become wider as the number of users, duration, and repetition increased and also due to the human nature to find a better footing ground (Bayfield, 1973; Weaver and Dale, 1978).

2.2.1 Trampling Effect on Soil Properties

Reduced vegetation cover due to trampling eventually causes the soil to be exposed to rain and wind (Grieve, 2001). Soil tolerances toward compaction are affected by the structure, density and the texture of the soils (Dumitrascu *et al.*, 2010).

The major impact of trampling is compaction, reduction in soil volume and soil bulk density (Gouvenain, 1996). Compaction of the soil causes the porosity and the aeration of the soil to change (Dumitrascu *et al.*, 2010). This can indirectly affect the soil arthropods. Burrowing arthropods usually take advantage of the soil porosity in term of laying their eggs or as a temporary niche. When the soil is compacted, the soil become bulky and become harder to penetrate (Cole, 1988;

Littlemore, 1998; Littlemore and Barker, 2001). It also loses the ability to absorb water, thus the soil temperature and moisture can be variable. The changes of physical and chemical properties of the soil eventually reshape the surrounding habitat where ground-dwelling fauna such as soil invertebrates were found (Littlemore and Barker, 2001).

2.2.2 Trampling Effect on Understory Vegetation

Vegetation is very important because it can indicate the intensity of the trampling and has been used by many researchers because of its effectiveness (Atik *et al.*, 2009). Changes in vegetation cover, vegetation height, bare ground, and species cover has been recorded by Cole and Bayfield (1993). Trampling can disturb soil development due to the loss of protective vegetation cover, thus the soil will be exposed by natural disturbance such as rain and wind (Grieve, 2001). The degree of trampling usually influenced by the type of recreational activities, the number and size of the visitor groups and the physical characteristics of sites for example, topography, climate, and soil type (Dumitrascu *et al.*, 2010). Experiment by Cole (1995) shows that plant morphology also influences the impact of trampling as some of the plant is resistant to trampling.

2.2.3 Trampling Effect Toward Arthropods Diversity

The impact of trampling can be seen from the wear and tear on the ground, which is visible as a path where the understory vegetation is reduced and the soil is eroded (Lehvavirta *et al.*, 2006). Trampling by human also affects the soil in terms of soil compaction, loss of soil structure and reducing the number of soil organism (Ayres *et al.*, 2008). Therefore, soil and litter arthropods can be used as a bio-indicator to check the effects of forest management on the quality of the soil as well as the productivity of the site (Bird *et al.*, 2004).

Another negative impact of trampling is the reduction of the litter layer. Litter is essential because it provides habitat and feeding ground for the litter inhabitant (Adams *et al.*, 2006). Litter inhabitant, mostly arthropods is very important because they play a major role in the decomposition process which is necessary in maintaining the quality of the soil in order for the plant to grow (Perry *et al.*, 2008). However, litter arthropods are very susceptible to disturbance, thus

often used as the indicator for soil quality. A study by Lee *et al.* (2009) shows that the total number of litter arthropods is decreased when the litter layer is removed. Another study by Oke and Chokor (2009), shows that the species diversity decreases when a disturbance occurred. Even in the most pristine area that is in the Antarctica where disturbance by human is at the lowest, the total percentage of soil nematode was found decreasing dramatically when sampled at the trampled area (Ayres *et al.*, 2008).

2.3 Ant as Bioindicator

The term bioindicator can be explained as a species, groups of species or other animals used to evaluate the status of the environment (Majer *et al.*, 2007). Insect was known to be effective tools to detect a wide range of environmental condition because of their abundance, short life cycle and sensitive towards the changes in the environment (Peck *et al.*, 1998). Arguably, aquatic insect was the most famous indicator group that has been used for years because of their effectiveness in detecting the changes in water quality (Ellison, 2012).

However, in the past few years other groups of arthropods especially insect started to rise as a potential biological indicator, especially for assessing the quality of terrestrial ecosystems (Ellison, 2012). A research by Majer *et al.* (2007), showed the potential of ants as an indicator because of their function in the environment and it is easy to do a field sampling and cost-effective.

The use of ants as indicators was widely used by many researchers. Read and Andersen (2000) use ants as an indicator to see the responses of ants towards cattle grazing. Ant is a good choice due to their high abundances (Andersen, 1995) and has significant roles in the soil ecosystem (Read and Andersen, 2000). One major breakthrough is the usage of functional groups in explaining the roles of ants as an indicator.