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

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ABTRACT

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, *Mesaponera* 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 jumlas 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) diiukti oleh OG (1,665), B (704), LFE (775), C (523) dan OP (498). Analisi statistic 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, Mesaponera 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

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LIST OF ABBREVIATION

%	-	Percent
H_0	-	H null
H_1	-	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

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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 literal 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.

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 examples 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 hard to deal with Cerapachyinae monophyly, all six of them were group 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 place has higher ant's distribution than the other. Based on the research by Silva, Feitosa, and Eberhardt (2007), they found out that the diversity of ants were 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 plants 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, Hosoishi, 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 *Pachyconcyla* 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.

REFERENCES

Andersen A. N. (1995). A classification of Australian ant communities based on functional groups which parallel plant life-forms in relation to stress and disturbance. *Journal of biogeography* **22**(1): 15-29

Atik M., Sayan S., and Karaguzel O. (2009). Trampling effects on understory vegetation. *Tarim Bilimleri Dergisi* **15**(3) : 249-258

Ayres E., Nkem J. N., Wall D. H., Adams B. J., Barrett J. E., Broos E. J., Parsons A. N., Powers L. E., Simmons B. L., and Virginia R. A. (2008). Effects of human trampling on population of soil fauna in the McMurdo Dry Valleys, Antarctica. *Conservation Biology* **22**(6): 1544-1551

Bastos A. H. d.S. and Harada A. Y. (2011). Leaf-litter amount as a factor in the structure of a ponerinae ants community (Hymenoptera, Formicidae, Ponerianea) in an eastern Amazonian rainforest, Brazil. *Entomologia* **55** (4): 589-596.

Bayfield N. G. and Cole D. N. (1993) Recreational trampling of vegetation: standard experimental procedures. *Biologial Conservation* **63**: 209-215

Bharti H. and Sharma Y. P. (2009). Diversity and abundance of ants along an elevational gradient in Jammukashir Himalaya. *Halteres* **1** (1).

Bibi F. and Ali Z. (2013). Measurement of diversity indicices of avian communities at Taunsa Barrage Wildlife Sanctuary, Pakistan. *The Journal of Animal and Plant Sciences.* **23**(2): 469-474

Birda S. B., Coulson R. N., and Fisher R. F. (2004). Changes in soil and litter arthropods abundance following tree harvesting and site preparation in loblolly pine (Pinus taeda L.) plantation. *Forest ecology and management* **202**: 195-208

Bolton B. (1994). *Identification guide to the ant genera of the world.* Harvad University Press

Brady S. G., Fisher B. L., Schultz, and Ward P. S. (2014). The rise of army ants and their relaties: diversification of specialized predatory doryline ants. *Evolutionay Biology* **14**: 93

Broadbent E. N., Asner G. P., Keller M., Knapp D. E., Oliveira P. J. C., and Silva J. N. (2008). Forest fragmentation and edge effects from deforestation and selective logging in the Brazilian Amazon. *Biological conservation* **141**: 1745-1757

Bruhl C. A., Eltz T., and Linsenmair K. E. (2003). Size does matter-effects of tropical rainforest fragmentation on the leaf litter ant community in Sabah, Malaysia. *Biodiversity and Conservation* **12**: 1371-1389

Cole D.N. (1988). Disturbance and recovery of trampled montane grasslands and forests in Montana. *USDAForest Service Intermountain Research Station Paper* **389** : 1-37

Castillo M. P. G., Ontiveros G. H., and Noya D. R. (2014). Contribution to the current knowledge of ant communities (Hymenoptera: Formicidae) in a xerophitic scrubland of southeast Durango, Durango. *American journal of applied sciences* **11**(5): 740-747

Claver S., Silnik S., L., and Campon F. F. (2014). Response of ants to grazing disturbance at the central monte desert of Argentina: community descriptors and functional group scheme. *J Arid Land* **6**(1): 117-127

Cole D. N. (1995) Experimental trampling of vegetation. II. Predictors of resistance and resilience. *Applied ecology* **32** : 215-224

Dumitrascu M., Marin A., Preda E., Tibirnac M., and Vadineanu A. (2010). Trampling effects on plant species morphology. *Plant biol* **55** : 89-96

Ellison A. M. (2012). Out of Oz: opportunities and challenges for using ants (Hymenoptera: Formicidae) as biological indicators in north-temperate cold biomes. *Myrmecological News* **17**: 105-119

Eltz T. and Bruhl C. (2001). Ecological evaluation of forest management using leaf-litter ants and stingless bees as indicators. *Deutsche Gessellschaft Fur Technische Zusammenarbeit* (GTZ).

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-litter. *Basic and Applied Ecology* **11** : 337-345.

Figueras G. S. and Nuneza O. M. (2013). Species diversity of ants in karst limestone habitats in Bukidnon and davao oriental, Mindanao, Philippines. *AES Bioflux* **5**(3)

Folgarait P. J. (1998). Ant biodiversity and its relationship to ecosystem functioning: a review. *Biodiversity and conservation* **7**: 1221-1244

General D. M. and Alpert G. D. (2012). A synoptic review of the ant genera (Hymenoptera, Formicidae) of the Philipines. *ZooKeys* **200**: 1-111

Gouvenain R. C. D. (1996). Indirect impacts of soil trampling on tree growth and plant succession in the north cascade mountain of Washington. *Biological conservation* **75**: 279-287

Grieve I. C. (2001). Human impacts on soil properties and their implications for the sensitivity of soil systems in Scotland. *Catena* **42**: 361-374

Guenard B., Weiser M. D., and Dunn R. R. (2010). Global generic richness and distribution: new maos of the world of ants with examples of their use in the context of Asia. *Asian Myrmecology* **3**: 21-28

Guzman, G. B. and Sanchez J. A. (2003). The Relationship Between Litter Fauna and Rates of Litter Decomposition In A Tropical Rain Forest. *Applied Soil Ecology* **24**: 91-100.

Hashimoto Y. (2006). *Inventory and Collection : Total protocol for understanding of biodiversity 2nd edtion.* BBEC publication **56**: 136-154

Hobbs R. J. and Huenneke L. F. (1992). Disturbance, Diversity, and Invasion: Implications for conservation. *Conservation biology* **6**(3): 324-337

http://www.safeproject.net/concept/forest-modification-gradient/ (2014).

www.safeproject.net/concept/maps

Johnson E. A. and Catley K. M. (2002). *Life in the leaf litter.* American Museum of Natural History

Khot K., Quadros G., and Somani V (2013). Ant diversity in an urban garden at Mumbai, Maharashtra. Nationa conference on biodiversity: Status and challenges in conservation (FAVEO): 121-125

King J. R., Andersen A. N., and Cutter A. D. (1998). Ants as bioindicators of habitat disturbance: validation of the functional group model for Australia's humid tropics. *Biodiversity and Conservation* **7**: 1627-1638.

Kotze D. J., Lehvarvita S., Koivula M., O'hara R. B., and Spence J. R. (2012). Effects of habitat edges and trampling on the distribution of ground beetles (Coleoptera, Carabidae) in urban forests. *Insect conserve* **16**: 883-897

Lamsa, M. M., Hamberg L., Haapamaki E., Liski J., Kotze D. J., Lehvavirta S., and Fritze H. (2008). Edge effects an trampling in boreal urban forest fragments- impacts on the soil microbial community. *Soil biology & Biochemistry* **40**: 1612-1621

Lavelle P., Deacens T., Aubert M., Barot S., Blouin M., Bureau F., Margerie P., Mora P., and Rossi J. P. (2006). Soil invertebrates and ecosystem services. *European journal of Soil Biology* **42**

Lee Y. F., Kuo Y. M., Lu S. S., Chen D. Y., Jean H. J., and Chao J. T. (2009). Trampling, litter removal, and variations in the composition and relative abundance of soil arthropods in subtropical hardwood forest. *Zoological studies* **48**(2): 162-173

Lehvavirta S., Kotze D. J., Niemela J., Mantysaari M., and O'hara B. (2006). Effects of fragmentation and trampling on carabid beetle assemblages in urban woodlands in Helsinki, Finland. *Urban Ecosyst* **9**: 13-26

Li X., Hu Y., Han S., Liu Y., and Zhang Y. (2009). Litterfall and litter chemistry change over time in an old-growth temperate forest, northeastern China. *Ann. For. Sci* **67**: 206

Littlemore J. (1998). The ecological impact of recreation in British temperate woodlands. Unpublished pH.D. thesis, University of Warwick

Littlemore J. and Barker S. (2001). The ecological response of forest ground flora and soils to experimental trampling in British urban woodlands. *Urban Ecosytem* **5** : 257-276

Longino J. and Cox D. J. (2009). *Pheidole bilineki* reconsidered (Hymenoptera: Formicidae). *Zootaxa* **1985**: 34-42

Luke S. (2010*). Ant and termite assemblages along a tropical forest disturbance gradient in Sabah, Malaysia: A study of co-variation and trophic interactions.* P.H.D Dissertation. University of East Anglia.

Magurran A. E. (2004). *Measuring biological diversity.* Blackwell Science

Majer J. D., Orabi G., and Bisevac L. (2007). Ants (Hymenoptera: Formicidae) pass the bioindicator scorecard. *Myrmecological News* **10**: 69-76

Marra J. L. and Edmonds R. L. (2004). Soil arthropods responses to different patch types in a mixed-conifer forest of the Sierra Nevada. *Forest science* **51**(3) : 255-265

McCune B. and Mefford M. J. (2011). Multivariate Analysis of ecological data version 5.33. Mjm software, U.S.A.

Mcdonald C., Smith R., Scott M., and Dick J. (2010). Using indices to measure biodiversity change through time. International Workshop on Spatio-Temporal Modeling.

McGee K. M. and Eaton W. (2013). The effects of the conversion of a primary to a secondary tropical lowland forest on Bullet ant (*Paraponera clavata)* foraging behavior in Costa Rica: A possible indicator of ecosystem condition. *J Insect Behav* **26** (5)

Mustafa N-Z. A., Salim H. M. W., Fletcher C., Kassim A. R., and Potts M. D. (2011). Taxonomic and functional diversity of ants (Hymenoptera:Formicidae) in an upper hill dipterocarp forest in Peninsular Malaysia. *Raffels Bulletin of Zooloy* **59**(2): 181-194

Ober H. K. and DeGroote L. W. (2011). Effects of litter removal on arthropod communities in pine plantations. *Biodives Conserv* **20**: 1273-1286

Oke O. C. and Chokor J. U. (2009). The effect of land use on snail species richness and diversity in the tropical rainforest of South-Western Africa. *African Scientisti* **10**(2)

Pacheho R., Silva R. R., Morini M. S.d. C., and Brandao C. R. F. (2009). A comparison of the leaf-litter ant fauna in a secondary Atlantic forest with an adjacent pine plantation in southeastern Brazil. *Neotropical Entomology* **38**(1): 055-065

Pechenik, J. A. (2010). *Biology of the Invertebrates.* McGraw-Hill Higher Education, New York.

Peck S. L., Mcquaid B., and Campbell L. (1998). Using ant species (Hymenoptera: Formicidae) as a biological indicator of agroecosystem condition. *Envrion. Entomol* **27**(5): 1102-1110

Pfeiffer M., Mezger D., Hosoishi S., Yahya. B. E., and Kohout R. J. (2011). The Formicidae of Borneo(Insecta: Hymenoptera): a preliminary list. *Asian Myrmecology* **4**: 9-58

Philpott S. M., Perfecto I., and Vandermeer J. (2008). Effects of predatory ants on lower trophic levels across a gradient of coffe management complexity. *Journal of Animal Ecology* **77**: 505-511

Perry D. A., Oren R., and Hart S. C. (2008) *Forest ecosytem, second edition.* The Johns Hopkins University Press.

Read J. L. and Andersen A. N. (2000). The value of ants as early warning bioindicators: responses to pulsed cattle grazing at an Australian arid zone locality. *Journal of Arid Environment* **45**: 231-251

Ribas C. R., Campos R. B. F., Schmidt F. A., and Solar R. R. C. (2012). Ants as indicators in Brazil: a review with suggestions to improve the use of ants in environmental monitoring programs. *Psyche* **2012**: 1-23

Rigato F. (1994). Revision of the myrmicine ant genus *Lophomyrmex,* with a review of its taxonomic position (Hymenoptera: Formicidae). *Systematic Entomology* **19**: 47-60.

Rocabado G. C., Claros M. P., Bongers F., Alarcon A., Licona J. C., and Poorter L. (2012). Effects of disturbance intensity on species and functional diversity in a tropical forest. *Journal of ecology* **10** : 1365-2745

Rousseau G. X., Silva P. R. D. S., and Carvalho C. J. R.D. (2010). Earthworms, ants and other arthropods as soil health indicators in traditional and no-fire agro-ecosystems from eastern Brazilian Amazonia. *Acta Zoological Mexicana* **2**: 117-134

Sakchoowong W., Jaitrong W., and Ogata (2009). Comparison of ground ant diversity between natural forest and disturbed forest along a natural gas pipeline transect in Thong Pha Phum National Park, Kanchanaburi province. *Kasetsart J (Nat. Sci.)* **43**: 64-73

Schmidt C. A. and Shattuck S. O. (2014). The higher classification of the ants subfamily Ponerinae (Hymenoptera: Formicidae), with a review of Ponerinae ecoloy and behavior. *Zootaxa* **3817** (1): 001-242

Seifert B. (2003). The ant genus *Cardiocondyla* (Insecta : Hymenoptera: Formicidae) a taxonomic revision of the C. *elegans, C. bulgarica, C. batesii, C. nuda, C. shuckardi, C. stambuloffii, C. wroughtonii, C. emeryi,* and *C. minutior* species groups. *Ann. Naturhist. Mus. Wein* **104**B: 203-338

Sekyere E. o., Cobbina J., and Wakatsuki T. (2006). Nutrient cycling in primary, secondaru forest and cocoa plantation in the Ashanti region, Ghana. *West Africa Journal of Applied Ecology* (WAJAE) **9**

Sharafatmandrad, Bahremand, Mesdaghi, and Barani (2010). The role of rainfall and light interception by litter on maintenance of surface soil water content in an arid rangeland (Khabr National Park, southeast of Iran). *DESERT* **15**: 53-60

Shattuck S. O. (2008). Revision of the ant genus Prionopelta (Hymenoptera: Formicidae) in the Indo-Pacific region. *Zootaxa* **1846**: 21-34

Silva R. R., Feitosa R. S. M., and Eberhardt F. (2007). Reduced ant diversity along a habitat regeneration gradient in the southern Brazilian Atlantic forest. *Forest ecology and management* **240**: 61-69

Silva P. S. D., Bieber A. G. D., Correa M. M., and Leal I. R. (2011). Do leaf-litter attributes affect the richness of leaf-litter ants? *Neotrop Entomol* **40**(5):542-547

Sitthicharoenchai D. and Chantarasawat N. (2006). Ant species diversity in the Establishing Area for Advanced Technology Institute at Lai-Nan sub district, Wiang Sa District, Nan province, Thailand. *The Natural History Journal of Chulalongkorn University* **6**(2): 67-74

Stork N. E. and Eggleton P. (1992). Invertebrates as determinants and indicators of soil quality. *American Journal of alternative Agriculture* (7).

Suguituru S. S., Silva R. R., Souza D. R.d., Munhae C.d. B. and Morini M. S.d. C. (2011). Ant community richness and composition across a gradient from Eucalyptus plantations to secondary Atlantic Forest. *Biota Neotrop* **11**(1).

Tschinkel W. R. (1998). Distribution of the fire ants Solenopsis invicta and S. geminate (Hymenoptera: Formicidae) in relation to habitat and disturbance. *Ann. Entomol. Soc. Am* **81**(1): 76-81

Turner E. C., Abidin Y. Z., Barlow H., Fayle T. M., Jaafar M. H. HJ., Khen C. V., Larenus J., Nainar A., Reynolds G., Yusof b. Y., Khoo M. S., and Ewers R. M. (2012). The stability of Altered Forest Ecosystem project: Investigating the design of human-modified landscapes for productivity and conservation. *The planter* **88** (1036): 453-468

Watanasit S. and Nhu-eard T. (2011). Diversity of ants (Hymenootera: Formicidae) in two rubber plantations un Songkhla Province, southern Thailand. *Songklanakarin J. Sci. Technol.* **33**(2), 151-161.

Weaver T. and Dale D. (1978). Trampling effects of hikers, motorcycles and horses in meadows and forests. *Applied Ecology* **15**: 451-457

Wetterer J. K. (2011). Worldwide spread of the tropical fire ant, Solenopsis geminata (Hymenoptera: Formicidae). *Myrmecological news* **14**: 21-35

Whalen, J. K. and Sampedro, L. (2010). *Soil Ecology and Management.* McGill University. CABI Pub.

Wilkie K. T. R., Mertl A. L., and Traniello J. F. A. (2010). Species diversity and distribution pattern of the ants of Amazonian Ecuador. *Plos one* **5**(10)

Yadav A. S. and Gupta S. K. (2006). Effect of microenvironment and human disturbance on the diversity of woody species in the Sariska Tiger Project in India. *Forest Ecology and Management* **225**: 178-189

Yamada K. K., Hyodo F., Matsuoka M., Hashimoto Y., Kon M., Ochi T., Yamane S., Ishii R., and Itioka T. (2013). Effects of remnant primary forest on ant and dung beetle species diversity in a secondary forest in Sarawak, Malaysia. *J Insec Conserv* **17**: 591-605

Yamane S, Itinp T., and Nona Abd. R. (1996). Ground an founa in a borneon dipterocarp forest. *The raffles bulletin of zoology* **44**(1): 253-262

Yamane S. (2009). Odontoponera denticulate (F. Smith) (Formicidae: Ponerinae) , a distinct species inhabiting disturbed areas. *ARI* 32

Yi H. and Moldenke A. (2008). Responses of litter-dwelling arthropods to four different thinning intensities in douglas-fir forest of the Pacific Northwest, USA. *Ann. Zool. Fennici* **45**: 229-240

Yorks, T. E. and Dabydeen S. (1999). Seasonal and successionalo understory vascular plant diversity in second-growth hardwood clearcuts of western Maryland, USA. *Forest Ecology and Management* **119** :217-230.