Kasetsart J. (Nat. Sci.) 42 : 617 - 626 (2008)

Ant Diversity in Forest and Traditional Hill-Tribe Agricultural Types in Northern Thailand

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ABTRACT

This study investigated the impacts of traditional hill-tribe agricultural systems on biodiversity conservation. It compared the abundance and diversity of ants across a gradient of different types of land use in northern Thailand: tropical montane forest (MF); jungle converted to tea plantation (JT); ex forest left fallow for one year (F1); ex forest left fallow for eight years (F8 - the traditional hill-tribe agricultural system); and permanent agriculture (C -growing cabbages as an annual crop). Ants were collected from the uppermost 20 cm of the ground, covering the soil to the upper litter in eight 30 cm^2 quadrats from the different types of land use during a range of seasons at each site. A total of 12,006 ants were collected, representing 130 species from 48 genera in seven subfamilies. JT had the highest average number of species followed by MF, F8, F1 and C, respectively. There were significant differences in the number of ant species among types of land use and seasons, but no significant difference in the abundance of ants was found among land use systems. The results indicated that jungle tea land use maintained a significantly greater species-richness than any of the forest-fallow or annual-crop land uses in the highlands.

Key words: ground dwelling ants, diversity, agroforestry, land use, hill-tribe agricultural systems

INTRODUCTION

The various ethnocultural groups occupying the highlands of northern Thailand collectively are known as "hill tribes" and practice a variety of traditional agricultural techniques that vary in the severity and frequency of their habitat disturbance. The mountainous terrain from which native vegetation is removed magnifies the damage of these farm practices. Soil erosion and watershed degradation create socio-economic problems that extend beyond these traditional communities (Laongsri, 2001), but the biological ramifications of these traditional agricultural practices remain obscure.

Invertebrate communities play an integral part in the maintenance of healthy soils and in decomposition and nutrient cycling (Giller, 1996; Lavelle *et al*., 1997).

Many studies demonstrated that replacing forests with farms changes local air and soil temperatures (Anderson, 1995). These changes may impact on the abundance and diversity of terrestrial ants and other soil

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Received date: 11/07/07 Accepted date: 23/11/07

invertebrates (Andersen, 1995). Conversion of natural forests to agricultural fields in the tropics is frequently associated with a loss of species diversity in animal taxa as well as plants (Westman, 1990; Holloway and Barlow, 1992). Many insects are particularly more sensitive to ecosystem change and they have been successfully used as bio-indicators to assess the impacts of ecosystem change on biodiversity (Brown, 1991). However, comparisons of insect diversity among natural forests and various disturbed habitats by the traditional hill-tribe agricultural systems in northern Thailand are less well documented.

The variety of agricultural practices used by hill tribe people may result in significant differences in plant cover between land use types. Soil temperatures and soil invertebrates might be expected to vary in relation to the types of land use (Fittkau and Klinge, 1973). This study examined the species richness of ground-dwelling ants (Hymenoptera: Formicidae) to appraise the impacts of various traditional land use practices on ant assemblages in five different land use types in northern highland communities.

MATERIALS AND METHODS

Study sites (land use types)

Samples were collected from five land use types at Mae Chaem and Mae Tang highland districts in Chiang Mai province as follows: montane forest (MF), forest fallow for one year (F1) and eight years (F8), jungle tea (JT) and annual crop (cabbage) (C). The average daily temperature at Mae Chaem and Mae Tang is 21.6°C and 26.3°C, respectively. The average annual precipitation is between 1200 and 1400 mm. All the study sites were located at between 700 and 1120 m asl.

Montane forest (MF) sites

Montane forest sites were located in Mae Chaem district (N 18° 50', E 98° 06'). Montane forest was generally distributed in patches occurring within the traditional hill tribe agricultural land uses and contained many large trees, with a closed stratified canopy dominated by tree species such as: *Lithocarpus calathiformis, Lithocarpus elegans*, *Styrax benzoides*, *Castanopsis diversifolia*, *Castanopsis acuminatisima, Memmea siamensis*, *Lagerstroemia calyculata*, *Ternstroemia gymnanthera, Hopea odorata*, and *Memecylon geddesianum*. Five montane forest plots were established in the Mae Chaem district.

Jungle tea (JT) sites

Jungle tea (*Camellia* spp.) is known locally as "miang." The congeneric species are planted by native Austro-Asiatic hill tribe people without silvicultural management (Preechapanya, 1996). This indigenous agroforestry has been widely planted in the Mae Tang highland where it has grown in relatively small areas of two to three hectares under a variable shade canopy of the remnant forest trees near a village. Two selected jungle tea plots were established in the Mae Tang district (N 19° 07', E 98° 52').

Forest fallow for one year (F1) and eight years (F8) sites

Many Karen hill-tribe people have modified the natural landscape through a regular cycle of deforestation, agricultural use and regeneration. Forest trees are first felled and then annual crops are planted. After a certain time, the land (about one to two hectares) is then abandoned. After a number of years, the land regenerates to become secondary forest and the hill tribe people return to use this land again. Some small trees were left on the site when the land was cleared and if permanently abandoned the forest would recover, when given the opportunity (Preechapanya, 2001). This type of agroforestry has been practiced in the Mae Chaem highland forest for many decades. This study established

two plots in the Mae Chaem district that had been abandoned one year prior (N 18° 26', E 98° 08') and two plots that had been abandoned eight years prior to study (N 18° 48', E 98° 06'). The forest that had been fallow for one year was densely covered by *Imperata cylindrical*, *Eupatorium odoratum* and other pioneer annuals. The forest that had been fallow for eight years could be classified as secondary forest and was covered with young trees at the time of sampling.

Annual cabbage crop (C) sites

On this land use type, all trees were clear-cut and burnt in order to grow the vegetable crops. Crops such as cabbage or rice have continually been grown on this type of land. Since the forest is clear cut and burnt, trees are not able to recover and so it remains a permanent agricultural field. At the time of sampling, cabbage was planted as an annual crop on sites in the Mae Chaem district. Three annual crop plots located in Mae Chaem were established for this study (N 18° 25', E 98° 08').

Ant collection

Ants were collected from eight random quadrats of 30×30×20 cm in the plots representing the five different forest types. Ants were separated from the litter and soil using a sieve with a 4-mm mesh and were stored in 80% ethanol. Sampling was conducted three times in April (hot season), September (rainy season), and December (cold season) during 2000.

Ant sorting and identification

Ants were identified to the genus level using Bolton (1994). Many ants which could not be identified to the species level were identified to the genera level and grouped into morphospecies (Abbott *et al.*, 2002). All specimens were registered at the Ant Collection of the National Science Museum, Bangkok, Thailand.

Data analysis

The mean number of ant species and their abundance in each sample were analyzed using ANOVA to assess the differences in the mean number of species and individuals among the different land uses using SYSTAT version 8 software (Systat Software, 1998). Indicator species analysis (ISA) using the method of Dufrene and Legendre (1997) was carried out using PC-ORD version 4.27 software (McCune and Mefford, 1999).

RESULTS

Species richness in forest and agricultural systems on highland

A total of 12,006 individuals representing 130 species and 48 genera in seven subfamilies were collected from the forest and different agricultural land use types in the highland forest communities of Mae Chaem and Mae Tang districts. The families collected were: Myrmicinae, Ponerinae, Formicinae, Dolicoderinae, Cerapachyinae, Aenictinae, and Dorylinae. The Myrmicine genera and species were most common followed by Ponerine, Formicine, Dolichoderine, Cerapachyine and Aenictine respectively (Figure 1). The highest total number of species was found in MF (89 species), followed by F8 (51), JT (50), F1 (45) and C (42) respectively.

The mean number of species present on the different land use types and the season sampled were significantly different (Table 1). The trends in the species richness pattern showed JT had the highest mean number of species of all land use types. Annual crop land had the lowest species richness in all sampling periods. Ant species richness was higher in September (rainy season) than in April (hot season) and December (cold season). However the results showed an anomaly in F8 which had a higher number of species than any other land use type in the April sampling (Figure 2).

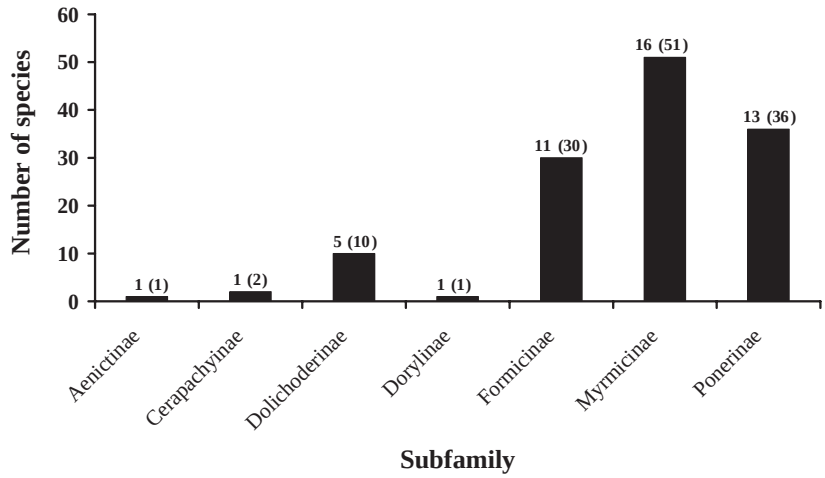

Figure 1 Numbers of species from each subfamily collected in forest and agricultural systems in the highlands, Chiang Mai; annual crop (C) jungle tea plantation (JT), forest fallow for 1 year (F1) and 8 years (F8) and montane forest (MF). The first number in each bar is the number of genera and the number in parentheses is the number of species.

Table 1 Two-way ANOVA on the mean number of species and individuals of ants in forest and agricultural land use types on highland, Chiang Mai.

Source of variation	*df*	*F* Number of species	*F* Abundance (log10)
Land use	4	5.101**	0.831ns
Season	2	4.218*	6.021**
Land use*Season	8	1.311ns	0.386ns

ANOVA, denotes significant * $p < 0.05$, ** $p < 0.01$

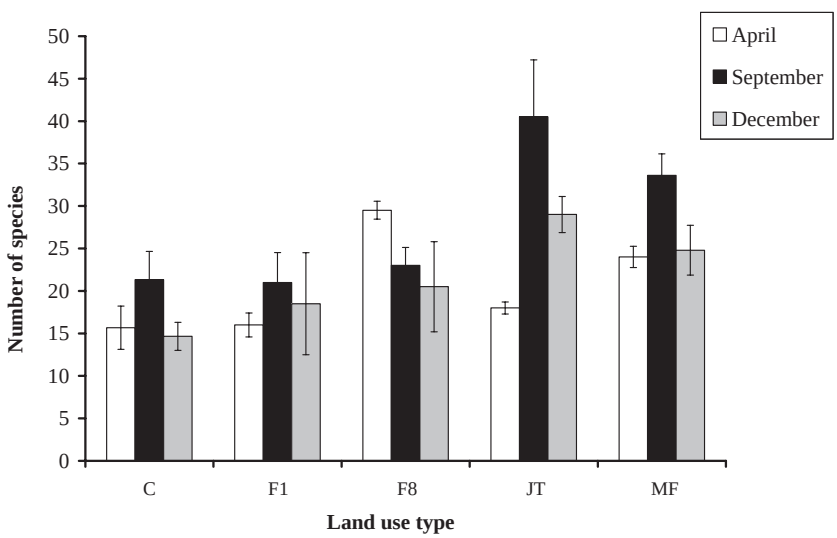

Figure 2 Mean number with standard error of ant species collected from forest and agricultural systems in the highlands, Chiang Mai; annual crop (C), jungle tea (JT), forest fallow for 1 year (F1) and 8 years (F8) and montane forest (MF).

The mean number of individuals by land use type was not significantly different, but there was a significant difference among seasons (Table 1). A greater number of ants was captured in September than in April or December (Figure 3).

Indicator species among land use types

Indicator species were identified for five land use types, ranging from one to three species per land use type. MF had three indicator species, with the major two being *Pseudolasius* sp. 1 and *Pachycondyla chinensis*. JT also had three indicator species, with the major one being ants in the subfamily Ponerinae. The highly-disturbed land use types such as C and F1 had only one indicator species each (Table 2).

Pseudolasius sp.1 was the most abundant species with 3,994 individuals or 40% of all ants sampled. It was a common species throughout the highlands, being captured at all sampling times and in all land use types. *Pheidologeton affinis* was the second most abundant species with 1,072, or 11% of all ants sampled and was in all land use types except for MF. These two species of ants contributed more than 50 % of the individuals collected.

Across all five land use types, *Pseudolasius* sp. 1 and *Lophomyrmex birmanus* were common highland species that accounted for the vast majority of ants captured. Of the ten dominant species in MF, three species, *Technomyrmex* sp. 2, *Pheidole* sp. 7 and *Polyrhachis halidayi,* were considered the most forested dependent. These species had a higher abundance only in MF and a much lower abundance in other land use types. On the other hand, *Pachycondyla luteipes* was the dominant ant in C (Table 3).

DISCUSSION

Effects of highland agricultural systems on species richness

During the period from August 1999 to July 2000, Poranee (2001) studied the biodiversity of ants in tropical montane forest at Doi Inthanon National Park, which is located in the Mae Chaem highland watershed area where part of the current study was conducted. The taxonomic diversity found in this earlier study was very similar to that

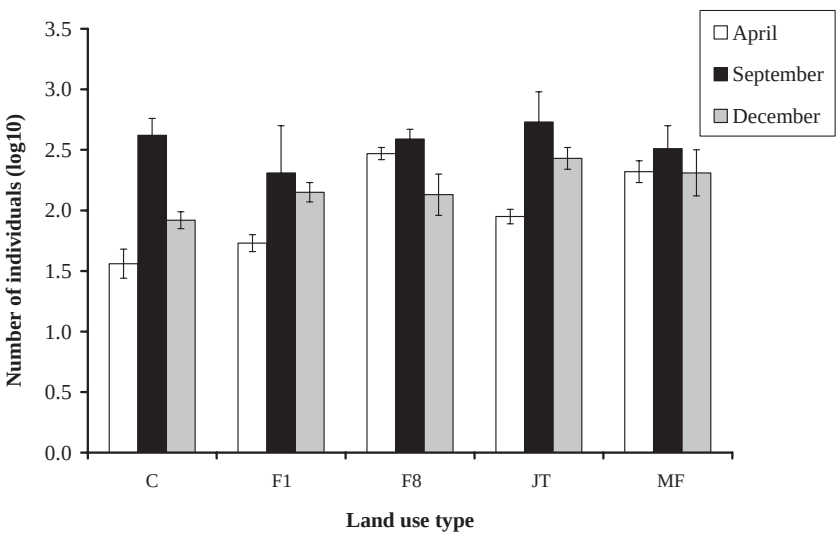

Figure 3 Mean number with standard error of ant species collected from forest and agricultural systems in the highlands, Chiang Mai; annual crop (C), jungle tea (JT), forest fallow for 1 year (F1) and 8 years (F8) and montane forest (MF).

of the current study (Figure 1).

The predominance of myrmicine ants in the current study parallels their numerical dominance within the world fauna (Holldobler and Wilson 1990; Bolton, 1994) especially the species of *Pheidole, Crematogaster, Monomorium* and other so-called generalized Myrmicinae, which are ubiquitous and abundant members of ant communities throughout the warmer regions of the world (Andersen, 2000). Species from the subfamilies Ponerinae, Formicinae, Dolichoderinae, and Cerapachyinae were well separated in the current study. Only one species was found from each of the two old-world army ant subfamilies, Aenictinae and Dorylinae. Each of these subfamilies has only one genus and comparatively few species (Bolton, 1994), hence they had less chance of being sampled.

The five land use types considered in this study represented a continuum of anthropogenic disturbance in the order: montane forest > jungle tea > land fallow eight years > land fallow one year > annual field crop (cabbage). In Indonesia, Bignell *et al*. (2000) and Watt and Zborowski (2000) found that ants in jungle rubber had the highest abundance among the different land use gradients ranging from intact forest through different silvicultural practices to intensive agricultural land uses. These studies were conducted in land use types very similar to the ones in the current study in that jungle rubber in Indonesia and jungle tea in Thailand are both practiced in semi-intact forest and both studies had very similar results. Whilst the number of species captured in MF was lower than in JT, there was no significant difference between these two land use types. This was interpreted as an indication that the environment in jungle tea plantations is indistinguishable from montane forest from the ants' perspective and the relatively small areas of jungle tea under the forest canopy may have only a small amount of disturbance impact on the ants.

Preechapanya (2001) stated that jungle tea plantations are a sustainable and environmentally tenable land use practice in the highlands of Thailand. Within such plantations,

Table 2 Indicator species of ant present in forest and agricultural types on highland, Chiang Mai; annual crop (C) jungle tea plantation (JT), forest fallow for 1 year (F1) and 8 years (F8) and montane forest (MF).

Land use type	Subfamily	Indicator value (%)	*P*
Montane forest			
Pseudolasius sp. 1	Formicinae	75	0.003
Pachycondyla chinensis	Ponerinae	53	0.05
Pheidole smythiesii	Myrmicinae	37	0.01
Jungle tea land use			
Anochetus graeffei	Ponerinae	62	0.03
Centromyrmex feae	Ponerinae	93	0.001
Odontomachus rixosus	Ponerinae	68	0.006
Forest fallow for 8 years land use			
Plagiolepis sp. 1	Formicinae	26	0.009
Crematogaster sp. 1	Myrmicinae	30	0.034
Forest fallow for 1 year land use			
Monomorium chinense	Myrmicinae	13	0.043
Annual crop (Cabbage)			
Pachycondyla luteipes	Ponerinae	65	0.001

intermingled with jungle tea plants, 91 various kinds of tree, shrub, fern, grass and parasitic shrub can be found, representing 48 families, compared with 149 species in 71 families of plant species found in undisturbed montane forest nearby. Thus the jungle tea site had retained a higher diversity of plant species than the other human-altered landscapes. Alternative land use practices, such

Table 3 Summary of the abundant species of ant in forest and agricultural types on highland, Chiang Mai; annual crop (C) jungle tea plantation (JT), forest fallow for 1 year (F1) and 8 years (F8) and montane forest (MF).

Montane forest (n = 5,255)		Forest fallow for 1 years (n = 987)	
Species	%	Species	%
Pseudolasius sp. 1	60.62	*Pheidologaton affinis*	53.56
Technomyrmex sp. 2	10.64	*Crematogaaster* sp. 1	7.59
Pheidole sp. 7	7.52	*Polyrhachis halidayi*	6.32
Polyrhachis halidayi	2.40	*Lophomyrmex birmanus*	5.75
Lophomyrmex birmanus	2.34	*Pseudolasius* sp. 1	3.91
Solenopsis sp. 1	1.76	*Anoplolepis gracilipes*	2.87
Pachycondyla chinensis	1.56	*Hypoponera* sp. 4	2.87
Myrmecina sp. 1	0.94	*Hypoponera* sp. 3	2.64
Hypoponera sp. 4	0.80	*Paratrechina* sp. 4	2.07
Crematogaaster sp. 1	0.72	*Pheidole* sp. 9	1.49
Jungle tea (n = 2,205)		Annual crop (cabbage) (n =1,935)	
Species	%	Species	%
Aenictus sp. 1	40.83	*Pseudolasius* sp. 1	32.27
Pseudolasius sp. 1	21.71	*Pachycondyla luteipes*	24.22
Pheidologaton affinis	8.98	*Lophomyrmex birmanus*	14.04
Lophomyrmex birmanus	4.72	*Pheidologaton affinis*	12.97
Paratrechina sp. 3	2.33	*Dolichoderus* sp. 1	3.66
Paratrechina sp. 5	2.07	*Technomyrmex kraepelini*	1.73
Centromyrmex feae	1.87	*Aenictus* sp. 1	1.66
Pheidologeton diversus	1.61	*Hypoponera* sp. 3	1.00
Dolichoderus thoracicus	1.49	*Paratrechina* sp. 4	0.86
Pheidole sp. 1	1.10	*Dorylus* sp.2	0.80
Forest fallow for 8 years (n = 1,624)			
Species	%		
Pheidologaton affinis	21.30		
Lophomyrmex birmanus	19.76		
Leptogenys sp. 3	11.55		
Pseudolasius sp. 1	9.15		
Plagiolepis sp. 1	8.38		
Crematogaaster sp. 1	7.19		
Pachycondyla chinensis	2.05		
Pheidole capellinii	2.05		
Pachycondyla luteipes	1.80		
Pheidole plagiaria	1.71		

as late fallow (F8) also retained a high number of plants, similar to that of JT. Forest fallow practices are a part of the traditional agricultural land use of the local hill-tribe farmers that involves a cyclical alteration of land between forest and agricultural uses and has been practiced in the northern highlands for decades.

The pattern of species decline in disturbed areas has been studied with regard to several taxa. A great number of studies have examined the responses of butterfly communities to human disturbance (Ghazoul, 2002; Stork, 2003) and some found that butterfly diversity was the highest in areas with intermediate disturbance (Connell, 1978). Species richness generally declined with increasing disturbance and this also appeared to apply to other vertebrate and invertebrate faunas (Lawton *et al*., 1998) and to soil fauna such as ants (Watt *et al*., 2002; Widodo *et al*., 2004), earthworms and termites (Jones *et al*., 2003). This general trend occurred elsewhere when forests were converted to other land uses (Jones *et al*., 2003).

CONCLUSION

Land use systems with less site disturbance and greater numbers of forest trees will contribute to habitat complexity and help mitigate against a loss of diversity. The jungle tea system, which is one type of indigenous agro-forestry practice carried out in the highlands, maintained high levels of ant species that were comparable with the diversity of natural forests and significantly greater than in other types of land use. Forest fallow land use also maintained an intermediate level of biodiversity, while annual crop field (cabbage) provided the lowest level of ant species richness. Thus, a sustainable land use system should be encouraged, involving agro-forestry practices within the forest and land uses such as longer term forest fallow, to allow the natural recovery processes to occur after the agricultural disturbance. This approach will help to conserve biodiversity in the northern highlands without significantly altering the traditional agricultural practices of the indigenous people.

ACKNOWLEDGEMENT

The authors would like to express their deep gratitude to the following: the World Agro-Forestry Centre (Thailand) which supported this project; Dr. Chaweewan Hutacharern and Dr. David Lohman for editing earlier drafts of this manuscript; Dr. Kiyoshi Nakamuta and Dr. Weerawan Amornsak for their valuable comments; Mr. Suchat Mulmuang, chief of Mae Chaem Watershed Research Station and Mr. Chalatorn Sritulanon, chief of Mae Taeng Watershed Research Station for their accommodation and provision of field work and lastly the staff of the Forest Insect Research Group, National Park, Wildlife and Plant Conservation Department for their help in the fieldwork.

LITERATURE CITED

Abbott, I., T. Burbidge, K. Strehlow, A. Mellican and A. Wills. 2002. Logging and burning impacts on cockroaches, crickets and grasshoppers and spiders in Jarrah Forest, Western Australia. **For. Ecol. Manage.** 174: 383-399.

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. **J. Biogeogr.** 20: 15-29.

Andersen, A. N. 2000. Global Ecology of Rainforest Ants: Functional Groups in Relation to Environmental Stress and Disturbance, pp. 25-34. *In* D. A. Agosti, L. E. Mejer and J.D. Schultz (eds.). **Ants: Standard Methods for Measuring and Monitoring Biodiversity.** Smithsonian

Institution Press. Washington.

Bignell, D.E., W. Widodo, F. X. Susilo and H. Suryo. 2000. Section 7: Soil Microfauna, Ground-dwelling ants, termites, other macro arthropods and earthworms, pp 91-127. *In* A. N. Gillison (ed.). **Above-ground biodiversity assessment working group summary report 1996-99.** ICRAF, PO Box 30677, Nairobi.

Bolton, B. 1994. **Identification Guide to the Ant Genera of the World.** Harvard University Press, London. 222 p.

Brown, K. S. 1991. Conservation of Neotropical Environments: Insects as Indicators, pp 349-404. *In* N. M. Collins and J. A. Thomas (eds.). **The Symposium on Conservation of Insects and Their Habitats**. 15th of the Royal Entomology Society of Landon. London.

Connell, J. H. 1978. Diversity in Tropical Rain Forests and Coral Reefs. **Science** 199: 1302-1310.

Dufrene, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. **Ecol. Monogr.** 67: 345-366.

Giller, K. E. 1996. The diversity of soil communities, the poor man's tropical rainforest. **Biodivers. Conserv.** 5: 135-168.

Fittkau, E. J. and H. Klinge. 1973. On biomass and trophic structure of the central Amazonian rain forest ecosystem. **Biotropica.** 5: 2-14.

Holldobler, B. and E. O. Wilson. 1990. **The Ants.** Harvard University Press. Cambridge, Massachusetts. 732 p.

Holloway, J. D. and H. S. Barlow. 1992. Potential for loss of biodiversity in Malaysia, illustrated by the moth fauna. pp. 293-311. *In* A. A. A. Kadir and H. S. Barlow (eds.). **Pest Management and the Environment in 2000.** CAB International.

Ghazoul, J. 2002. Impact of logging on the richness and diversity of forest butterflies in a tropical dry forest in Thailand. **Biodivers. Conserv.** 11: 521-541.

Jones, D. T., F. X. Susilo, D. E. Bignell, S. Hardiwinoto, A. N. Gillison and P. Eggleton. 2003. Termite assemblage along a land-use intensification gradient in lowland central Sumatra, Indonesia**. J. of Appl. Ecol.** 40: 380-391.

La-ongsri, S. 2001. Drug abuse control and the environment in northern Thailand. Available at: **http://www.unodc.org/unodc/en/bulletin/bulletin_1992-01-01_2_page005.html#s001** [accessed on June 13, 2005]

Lavelle, P., D. Bignell, M. Lepage, V. Wolters, P. Roger, P. Ineson, O. W. Heal and S. Dhillion. 1997. Soil function in a changing world: the role of invertebrate ecosystem engineers. **Eur. J. Soil Biol.** 33: 159-193.

Lawton, J. H., D. E. Bignell, B. Bolton, G. Bloemers, F. P. Eggleton, P. M. Hammond, M. Hodda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stork, D. S. Srivastava and A. D. Watt. 1998. Biodiversity inventories, indicator taxa and effects of the habitat modification in tropical forest. **Nature** 391: 72-75.

McCune, B. and M. J. Meffor. 1997. PC-ORD: **Multivariate Analysis of Ecological Data.** Version 3.04. MjM Software, Gleneden Beach, Oregon.

Poranee, P. 2001. **Ant diversity and Distribution in Doi Inthanon National Park, Chiang Mai Province.** MS Thesis, Chiang Mai University. Chiang Mai.

Preechapanya, P. 2001. **Folk Knowledge about Agroforestry: Ecosystems in Watershed Areas of Northern Thailand.** Thanabankarnpim, Chiang Mai. 127 p.

Stork, N. E., D. S. Srivastana, A. D. Watt and T. B. Larsen. 2003. Butterfly diversity and silvicultural practice in lowland rainforests of Cameroon. **Biodivers. Conserv.** 12: 387-410.

Systat Software. 1998. **Systat Software (computer program).** Systat Inc Richmond, California.

Watt, A. D. and P. Zborowski. 2000. Section 6: Canopy Insect, Canopy arthropods and butterfly survey: Preliminary report, pp 69-90. *In* A. N. Gillison (ed.). **Above-ground Biodiversity Assessment Working Group Summary Report 1996-99.** ICRAF, PO Box 30677, Nirobi.

Watt, A. D., N. E. Stork and B. Bolton. 2002. The diversity and abundance of ants in relation to forest disturbance and plantation establishment in southern Cameroon. **J. of Appl. Ecol.** 39: 18-30.

Westman, W. E. 1990. Managing for biodiversity. **Bioscience** 40: 26-33.

Widodo, E. S., T. Naito, M. Momamed and Y. Hashimoto. 2004. Effects of selective logging on the arboreal ants of a Bornean rainforest. **Entomol. Sci.** 7: 341-349.