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Research Article

Termite assemblages across an anthropogenic disturbance gradient at the Sakaerat Biospher Reserve, Nakhon Ratchasima Province, Thailand

Suksawat Ponpinij[1] and Sasitorn Hasin[2*]

[1]Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand.
[2]College of Innovative Management, Valaya Alongkorn Rajabhat University Under the Royal Patronage, Pathum Thani, Thailand.
*Correspondence: sasitorn.ha@vru.ac.th

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Abstract: Termite communities serve as environmental indicators of the effects of agricultural practices and forest trees. A little knowledge is required to report termite assemblages across an anthropogenic disturbance gradient in Thailand. This study aimed to investigate the distribution pattern of termites across an anthropogenic disturbance gradient from natural forest areas to adjacent agricultural areas. Termites were sampled using a subterranean trap baited with baits and direct sampling along three transects of 50 m x 2 m^2 in three continuous habitats: an agricultural area (AA), a forest area (FA), and an ecotone (ET). In total, 16 termite species in 12 genera belonging to 4 subfamilies were found at the study sites. There were no significant differences in termite richness among the study sites during either the wet or dry season ($p > 0.05$). *Microcerotermes crassus* was the dominant termite species, as indicated by a larger value in frequency of occurrence with 100% in ET and FA, and 89% in AA. Principal component analysis revealed that the presence of *Globitermes sulphureus* and *M. crassus* was associated with increased soil moisture content. Our findings suggest that all mound-building termites and most of the fungus-growing termite species do not persist in areas of relatively high human disturbance (AA, ET). These distribution patterns of termites could reduce ecosystem services at AA and ET, particularly by decreasing enhanced nutrient availability for soil ecosystems.

Keywords: Diversity; Land-use; Subterranean bait; Termite; Direct sampling

1. Introduction

The effects of land-use intensity on arthropod diversity and community structure are fundamental knowledge for assessing soil health [1, 2,3]. Soil organisms are able to adapt quickly to agricultural activities; however, any disturbance of the soil surface may indirectly affect the diversity and abundance of soil organisms. For example, ground-dwelling arthropod communities vary in abundance and species richness according to changes in vegetation and soil conditions [4, 5,6]. Changes in agricultural activities may alter environmental conditions suitable for soil insects, whose diversity and abundance are strongly dependent on their sensitivity to environmental conditions [7, 8, 9, 10,5]. For example, current research has reported that insect diversity is highly tolerant of environmental changes induced by agricultural practices, particularly among ground beetles, rove beetles, and ants [7, 11, 9,3]. Anderson (1988) and Batary et al. (2012) documented that intensified agricultural activities and land use have led to changes, particularly in soil physical and chemical properties, as well as in food, habitats, and biodiversity of soil fauna such as ants and termites. Thus, various groups of soil insects are currently used as indicators when assessing the environmental risks associated with soil use [1,4, 12,11, 13, 2].

In Thailand, the most common consequence of converting forest area for agricultural use is changes in vegetation structure, which are managed differently in land management practices.

Changes in insect species numbers and composition may be associated with the intensification of natural forest habitats, particularly for soil insects such as termites [1, 7, 14, 9]. Thus, understanding the effects of environmental factors on each type of land-management practice can inform the use of termites as bioindicators of soil health, particularly through changes in the habitat of soil insects and their food. However, there is very little data on the diversity of subterranean termites inhabiting agricultural and forest soils, and the interactions between environmental factors and termite diversity remain relatively unknown.

This study aimed to (1) investigate the distribution pattern of termites across an anthropogenic disturbance gradient from natural forest areas to adjacent agricultural areas, and (2) evaluate the relationship of environmental factors on the termite community. Finally, based on the composition of subterranean termites, we focused on the impact of anthropogenic disturbance on the ecosystem services they provide.

2. Methodology

2.1 Study sites

This study was conducted in an agricultural landscape adjacent to a natural forest within the Sakaerat Biosphere Reserve (SERS) (14°30′ N, 101°06′ E), Nakhon Ratchasima Province, northeastern Thailand. The study area is situated at an average elevation of approximately 500 m above mean sea level. The regional climate is characterised by a dry season from November to April and a wet season from May to October. According to records from the meteorological station located within SERS, annual air temperatures range from 4 to 35 °C, with a mean relative humidity of 23.5–90.5% (SE) and a mean air temperature of 22–27.4 °C (SE).

Based on vegetation characteristics and land-use management, three distinct study sites were identified: agricultural area (AA), forest area (FA), and the ecotone (ET) between them. The agricultural area (AA) comprised land cultivated primarily for cassava production, on which chemical fertilisers and pesticides were regularly applied. This area has been used for crop cultivation during the wet season for at least 10 years before the study. The ecotone (ET) was defined as the transitional zone between the agricultural and forest areas. The forest area (FA) was classified as a dry dipterocarp forest, characterised by natural tree vegetation, with the ground layer dominated by *Vietnamosasa pusilla*.

At each study site, three sampling plots of approximately 1 ha were randomly selected to assess termite abundance and associated environmental variables. Within each plot, three line transects measuring 50 m × 2 m were established for systematic termite sampling and ecological data collection.

2.2 Termite sampling

At each sampling plot, termites were collected using a combination of subterranean baiting and direct hand-searching methods. Subterranean bait stations consisted of a PVC tube measuring 8 cm in diameter and 15 cm in height, which served as a bait container. The tube was covered with a gypsum sheet to facilitate air exchange and maintain suitable microclimatic conditions. Rubberwood baits measuring 7.5 × 14 cm were used as bait (Fig. 1a). Bait stations were buried in the soil along line transects at 2 m intervals (Fig. 1b, c), resulting in 10 baits per transect and 20 baits per study area. All subterranean termite baits were left in the ground for 30 days before collection to allow termite colonisation.

In addition to baiting, termites were sampled by direct hand searching across all available ground-level microhabitats, including logs, leaf litter, stumps, twigs, nests, runways, sheeting, fallen branches, and areas between grass tufts. Collected specimens were preserved in 80% ethanol and properly labelled for subsequent taxonomic identification.

Sampling was conducted on six occasions to account for seasonal variation, comprising three sampling events during the dry season (November 2016–April 2017) and three during the wet season (June 2017–October 2017).

Figure 1. Subterranean termite baits were made by using (a) a PVC tube, rubber wood of dimensions 7.5 cm × 14 cm and a gypsum sheet. (b) Subterranean termite baits were buried in the soil and covered by a gypsum sheet, and (c) it was set up in the ground for 30 days.

2.3 Identification of Termites

Termite specimens collected from each bait station were identified to the lowest possible taxonomic level using standard morphological characters and authoritative identification keys for Thai termites [15, 16, 17]. Species determinations were verified through consultation with experienced termite taxonomists to ensure accuracy and consistency. Representative voucher specimens were preserved and deposited in the Thailand Natural History Museum, where they are available for future reference and verification.

2.4 Data Analysis

Species richness was determined as the total number of termite species recorded from both subterranean termite baiting and direct sampling methods. The frequency of occurrence (F) of each termite species in each study area was calculated based on the proportion of sampling units (subterranean termite baits) in which the species was detected. Based on frequency of occurrence values, termite species were classified into three categories:

(i) Uncommon species (F=0–35%),
(ii) Common species (F = 36–70%), and
(iii) Dominant species (F = 71–100%).

A univariate analysis of variance (ANOVA) was used to compare termite species richness, frequency of occurrence, and soil environmental variables among study areas and between seasons. The study area and season were treated as explanatory variables. When significant effects were detected, pairwise comparisons were performed using the least significant difference (LSD) test, with $p < 0.05$ as the significance threshold. Before analysis, data were examined for compliance with the assumptions of normality and homogeneity of variance using the Shapiro–Wilk test and Levene's test, respectively. Where necessary, data were appropriately transformed to reduce heteroscedasticity and meet model assumptions. All univariate statistical analyses were conducted using SPSS software, version 20.0.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results

3.1 The diversity of Termites and their occurrence

In total, 16 termite species were identified in 12 genera belonging to 4 subfamilies (Table 1). The mean richness of termite was higher in the FA with 14 ± 0.5SD than the ET (5 ± 1.5) and the AA (3 ± 0.5) ($F_{1, 54} = 0.68$; $p < 0.05$). A univariate ANOVA indicated no significant difference in termite richness between the wet and dry seasons ($p > 0.05$). No statistically significant interaction among the three study sites was found in either the wet or dry seasons ($p > 0.05$).

Table 1. List of subfamilies and species of termites collected in each study area, including agricultural area (AA), a forest area (FA) and the ecotone (ET). The table shows the frequency of occurrence (%), collected by subterranean baited (BT) and presence (P) or absence (A) of termites from direct sampling (DS), and is abbreviated.

subfamily/species	Termite sampling technique	Study areas [1]		
		AA	ET	FA
Macrotermitinae				
Ancistrotermes pakistanicus (Ahmad, 1955)	BT	0	50%	50%
Hypotermes makhamensis Ahmad, 1965	DS	A	A	P
Microtermes obesi Holmgren, 1912	BT	100%	56%	100%
Odontotermes feae (Wasmann, 1896)	DS	A	A	P
Odontotermes takensis Ahmad, 1965	DS	A	A	P
Macrotermes annandalei (Silvestri, 1914)	DS	A	A	p
Macrotermes carbonarius (Hagen, 1858)	DS	A	A	P
Macrotermes gilvus (Hagen, 1858)	DS	A	A	P
Coptotermitinae				
Coptotermes gestroi (Wasmann, 1896)	BT	0	0	17%

	Coptotermes curvignathus (Holmgren, 1913)	DS	A	P	P
Termitinae					
	Globitermes sulphureus (Haviland, 1898)	BT	22%	22%	50%
	Microcerotermes crassus (Snyder, 1934)	BT	89%	100%	100%
	Dicuspiditermes sp.	BT	0	17%	0
	*Termes comis (*Haviland, 1898)	DS	A	A	P
Nasutitermitinae					
	*Hospitalitermes ataramensis (*Prashad & Sen-Sarm 1960)	DS	A	A	P
	Nasutitermes matangensis (Haviland, 1898)	DS	P	P	P

The frequency of occurrence (F) was higher for *Microcerotermes crassus*, ranging from 89–100% (Table 1). In the FAs, a relatively large value of 100% was found for *M. crassus* and *Microtermes obesi,* followed by *Globitermes sulphureus* (50%), *Ancistrotermes pakistanicus* (50%) and *Coptotermes gestroi* (17%). In the AAs, a higher value of the F was found for *M. obesi* with 100%, followed by *M. crassus* (89%) and *G. sulphureus* (22%). In the ecotone, higher values were observed for *M. crassus* (100% of the F), followed by *M. obesi* (56%), *A. pakistanicus* (50%), *G. sulphureus* (22%), and *Dicuspiditermes sp.* (17%).

4. Discussion

This pilot study examined the relationships between habitat characteristics and the occurrence of subterranean termite species, to identify factors underlying observed distribution patterns. Comparisons of species richness revealed that termite richness was significantly higher in forest habitats than in ET and AA plots at the study site. These findings are consistent with previous studies demonstrating that insect species richness, including termites and other ground-dwelling insects, varies across land-use types and spatial scales in response to land-use intensity [5, 8, 10, 11, 13, 18, 19, 20].

The reduced termite richness observed in agricultural areas is likely attributable to human-induced land-use changes, particularly the conversion of forest to agricultural land, which has resulted in measurable declines in native insect biodiversity. Soil-dwelling insects appear especially sensitive to such changes in vegetation structure and habitat continuity in Nakhon Ratchasima Province. These results support the potential use of termite diversity as a bioindicator of land-use intensity and soil ecosystem condition, consistent with previous studies identifying ground-dwelling arthropods as indicators of ecosystem health in forests, grasslands, and agricultural systems [3, 6, 21,].

A higher frequency of *Macrotermes* spp. Mound occurrence was observed in forest areas. This pattern may be explained by several factors, including (1) destruction of termite mounds by agricultural machinery, (2) reduced availability of leaf litter due to farming activities, which limits a key food resource for *Macrotermes* spp., and (3) harvesting of termites and mound soil for food and medicinal purposes. These findings indicate that mound-building, fungus-growing termites are unable to persist in areas subjected to high levels of human disturbance (AA and ET). Such changes may reduce ecosystem services, including nutrient cycling and the availability of termite-associated mushrooms as a food resource.

Termite diversity was consistently higher in forest plots than in agricultural plots, likely reflecting the negative effects of pesticide use and indigenous pest control practices, which target termites perceived as crop pests [22]. Overall, this study highlights the value of termites as bioindicators for assessing soil ecosystem health and provides a foundation for future research on termite diversity, abundance, and frequency of occurrence across land-use gradients [18, 19, 23].

5. Patents

Author Contributions: S.P. and S.H. conceptualized and conducted the study, performed data curation, formal analysis, and prepared the original draft. All authors have read and agreed to the published version of the manuscript.

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