COMPARISON OF TERMITE ASSEMBLAGES ALONG A LANDUSE GRADIENT ON PEAT AREAS IN SARAWAK, MALAYSIA

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VAESSEN T, VERWER C, DEMIES M, KALIANG H & VAN DER MEER PJ. 2011. Comparison of termite assemblages along a landuse gradient on peat areas in Sarawak, Malaysia. In this study we assessed the species density and relative abundance of termites in peat land in Sarawak, Malaysia. Termites were sampled in near-natural peat swamp forest, logged-over peat swamp forest, young oil palm plantation and a cleared and burned site. Species density and relative abundance were calculated for each site. Both species density and relative abundance differed significantly between sites. Near-natural peat swamp forest had the highest termite density, followed by logged-over peat swamp forest, young oil palm plantation and the cleared site. In contrast, the relative abundance of termites was highest in the young oil palm plantation due to the omnipresent genus *Schedorhinotermes*. Most of the species found in the cleared site and young oil palm plantation did not occur at the other sites. We conclude that ongoing forest degradation and conversion in tropical peat land result in shifting termite assemblages and declining species density. Species that originally occur at low densities in peat swamp forests are typically lost as a result of peat swamp forest conversion.

Keywords: Peat swamp forest, Borneo, Termitidae, species density, relative abundance, oil palm plantation, feeding group, nesting group

VAESSEN T, VERWER C, DEMIES M, KALIANG H & VAN DER MEER PJ. 2011. Perbandingan himpunan anai-anai di sepanjang gradien penggunaan tanah di kawasan gambut Sarawak, Malaysia . Dalam kajian ini, kami menilai ketumpatan spesies serta kelimpahan relatif anai-anai di tanah gambut Sarawak, Malaysia. Anai-anai disampel di hutan paya gambut yang hampir asli, hutan paya gambut sudah kerja, ladang kelapa sawit muda dan sebuah tapak yang telah dibersihkan dan dibakar. Ketumpatan spesies serta kelimpahan relatif dikira untuk setiap tapak. Terdapat perbezaan signifikan dalam ketumpatan spesies serta kelimpahan relatif antara keempat-empat tapak yang dikaji. Hutan paya gambut yang hampir asli mempunyai ketumpatan anai-anai yang paling tinggi diikuti oleh hutan paya gambut sudah kerja, ladang kelapa sawit muda dan tapak yang telah dibersihkan. Sebaliknya, kelimpahan relatif anai-anai paling tinggi di ladang kelapa sawit muda kerana genus *Schedorhinotermes* yang wujud secara meluas di situ. Kebanyakan spesies di tapak yang dibersihkan serta ladang kelapa sawit muda tidak dijumpai di tapak lain. Kami merumuskan bahawa degradasi dan perubahan hutan di tanah gambut tropika mengakibatkan peralihan himpunan anai-anai dan pengurangan ketumpatan spesies. Spesies yang asalnya berketumpatan rendah di hutan paya gambut kini tidak lagi wujud akibat perubahan hutan paya gambut.

INTRODUCTION

Termites (Isoptera) are important inhabitants of the tropical and subtropical regions. They are commonly known as detritivores with large impact and therefore play an important role in various forest ecosystems (Eggleton et al. 1997). Studies on the global and regional distribution of termites reveal that South-East Asian termites are relatively species-poor compared with the neotropics and Afrotropics (Gathorne-Hardy et al. 2002). These regional patterns in termite diversity may be mainly attributable to their evolutionary history and dispersive ability (Davies et al. 2003a). Nevertheless, on a local scale, the diversity of termites is strongly influenced by a variety of local environmental factors such as vegetation type (Jones 2000), habitat disturbance (e.g. Eggleton et al. 2002, Jones et al. 2003, DeBlauwe et al. 2008) and habitat fragmentation (DeSouza & Brown 1994, Davies et al. 2003b). Given their important role in decomposition and their influence on nutrient and carbon fluxes, it is crucial to understand the effects of disturbance

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and land conversion on termite communities. Termites have been used to study the effects of land conversion on biodiversity in several areas (Eggleton et al. 1996, 1997, Dibog et al. 1999), in particular because they are taxonomically tractable organisms and they are sensitive to habitat disturbance. Most studies of termite diversity in South-East Asia have been done in lowland dipterocarp forests (e.g. Eggleton et al. 1996, 1997, Gathorne-Hardy et al. 2001, Jones et al. 2010). So far, termites have not been studied in detail in tropical peat swamp forest, although there are some 26 mil ha of peat land in South-East Asia (Rieley et al. 2008), most of which was originally covered by forest. Sarawak has 1.66 mil ha of peat land, with 683 600 ha gazetted as permanent forest (Ipor 2006).

It is generally assumed that regular inundation or high water table in peat swamp forests inhibits soil-dwelling termites (Bignell DE & Jones DT, personal communication). Hydroedaphically limited forests (including mangrove, beach and riparian fringe forest, and peat swamp forest) had the lowest termite species diversity among other forest types (lowland, heath, hill and montane forests) (Salick & Tho 1984). Given the observations of higher termite diversity in acid soils (pH 3.1–4.5) compared with ultramafic soils (pH 5.0–6.1) (Jones et al. 2010), the acidity of the peat need not be a limiting factor for termites.

Currently, large areas of peat swamp forest are being converted to oil palm plantations. This has important consequences for biodiversity, including insect biodiversity (Page 2002). There are clear indications that termite diversity decreases strongly along a gradient of landuse intensification (Eggleton et al. 1995, 1997, 2002, Jones et al. 2003, Turner & Foster 2008).

This study aims to determine the effects of forest degradation and conversion on species density and relative abundance of termites in peat swamp areas in Sarawak, Malaysia. The following research questions were addressed:

(1) how were species density and relative abundance of termites affected by logging, land clearing and oil palm plantation establishment?
(2) how did the compositions of termite functional groups and nesting groups change in response to logging, land clearing and oil palm plantation establishment?

MATERIALS AND METHODS

Study sites

Data were gathered in four sites (Figure 1) on peat soil in Sarawak, Malaysia, representing a landuse gradient of increasing anthropogenic influence. Since primary peat forests are absent in the study region, we used a near-natural peat swamp forest as the relatively undisturbed reference. The following four sites were sampled:

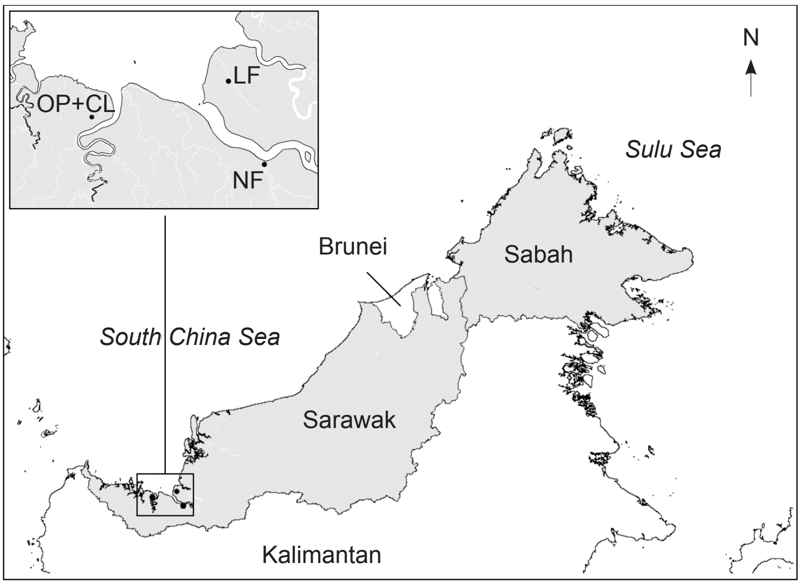

Figure 1 Census locations in Sarawak, Malaysia (black dots); NF = near-natural peat swamp forest, LF = logged-over peat swamp forest, OP = young oil palm plantation, CL = cleared site

(1) a near-natural peat swamp forest (NF) (483 ha) located in a protected water catchment area near the village of Lingga (1° 21' N, 111° 10' E). This forest was selectively logged approximately 30–40 years ago (between 5 and 10 canopy trees ha^{-1}), mainly for ramin (*Gonystylus bancanus,* Thymelaeaceae) and meranti (*Shorea albida*, Dipterocarpaceae). The forest has recovered since and has a tree density of 150 trees > 20 cm diameter at breast height (dbh) ha^{-1} (Table 1). The canopy is closed at about 20 m height (Truong 2004). Large trunks of fallen dead wood are abundant.
(2) a logged-over peat swamp forest (LF) located between the Batang Lupar and Batang Layar rivers (1° 35' N, 111° 04' E). This site lies within the Maludam National Park (43.147 ha). Commercial logging occurred until 1999, just before the area was gazetted as a national park in 2000. The density of large trees is 115 trees > 20 cm dbh ha^{-1}. Almost 80% of the trees in the area are < 20 cm dbh, resulting in a low average canopy height of 15.8 m (Tan 2004). Only limited amounts of standing and fallen dead wood have been observed at the site.
(3) a 26-month-old oil palm plantation (OP) of Sadong Jaya on peat (1° 29' N, 110° 41' E). This semi-open oil palm plantation has been treated with pesticides. Due to previous clearing of the forest, stumps and dead wood were more abundant compared with the logged-over forest.
(4) a cleared site (CL) which was logged in December 2008, burned in July 2009 and thereafter treated with pesticides.

All the study sites were previously covered by mixed swamp forest, indicating similar origin of the peat soil. The pH of the peat in both forest sites was comparable with oil palm plantation and cleared site (near-natural peat swamp forest: 3.5–3.9, Truong (2004); logged-over peat swamp forest: 3.2–3.4, Melling et al. (2007)). In the oil palm plantation and cleared and burned site the pH values were not measured but values from other plantations on similar soil range between 3.1–3.8 (ACT 2008). Both OP and CL were drained to optimum water levels for oil palm, i.e. 60–80 cm below soil surface (DID 2001).

Sampling

To examine the species density and relative abundance within sites the standardised transect method was used (Jones & Eggleton 2000, Eggleton et al. 2002). One transect was established randomly at each site (four transects in total). Each transect was 100 m long and 2 m wide and divided into 20 sections of 5 m length.

In each section, one hour was spent in search of termites. Termites were sampled in: (1) a maximum of 12 randomly chosen soil samples of about 12 × 12 cm, 10 cm deep; (2) dead wood with a diameter of more than 1 cm; (3) tree trunks and roots; and (4) nests and galleries were opened up to 2 m above ground. Where soil was

Table 1 General characteristics of the four vegetation types sampled describing the four transect sites

Site	Previous land cover	Drainage (cm below soil surface)	Tree density (no. of trees > 20 cm dbh ha^{-1})	Mean canopy height (m)	Canopy openness	Dead wood	pH
NF	Mixed swamp forest	Not drained	150	20	Closed	Abundant, large trunks fallen dead wood	3.5–3.9
LF	Mixed swamp forest	Not drained	115	15.8	Half open	Scarce, mainly small stems and few large standing dead trees	3.2–3.4
OP	Mixed swamp forest	60–80	NA	< 3	Open	Abundant, mainly large stumps, burned	3.1–3.8
CL	Mixed swamp forest	60–80	NA	NA	Absent	Abundant, large and small stumps, burned	3.1–3.8

NF = near-natural peat swamp forest, LF = logged-over peat swamp forest, OP = young oil palm plantation, CL = cleared site; NA = not available impenetrable because of a large quantity of roots, fewer soil samples were taken. Collected termites were stored in vials containing 80% ethanol. All data were gathered in July and August 2009.

Analysis

Termites were identified according to Thapa (1981). Species density was assessed for all sections and the relative abundance (α) was calculated. The relative abundance per species is defined as the sum of scores per section within a transect. Every encounter of a species within a section was used as one hit. Since there were 20 sections per transect, the maximum score per termite species was 20. For each transect we tested whether the abundance was spatially autocorrelated between sections according to $r = \Sigma\ [(n_i - z)*(n_{i+h} - z)]/2(N - h)*\sigma^2$, where r = correlation coefficient, n_i = the abundance within section i, n_{i+h} = abundance within the next section (i + h), z = average abundance per section, h = number of lags between pairs of sections, N = total the number of sections, and σ^2 = variance within the transect (Ripley 2005). As transect data were autocorrelated between sections, we could only use a limited number of sections per transect (n = 10, each lying 10 m apart) to calculate the relative abundance. Subsequently, the relative abundance was statistically compared between sites in a Kruskall–Wallis test. A Scheffe post-hoc test was used to deduce significant differences between the different sites. Additionally, species accumulation curves were calculated in EstimateS (Colwell 2005), based on the 10 non-autocorrelated sections, and the observed turnover between sites was calculated according to Jones and Eggleton (2000). Due to sample limitations species richness of termites was not assessed.

Habitat utilisation was defined according to termite feeding (Donovan et al. 2001) and nesting guilds (Homathevi & Noel 2003). Feeding guilds range from groups I to IV in which the diet of termites follows an increased humification gradient. For the analysis, groups I and II represent wood feeders and groups III and IV represent soil feeders. Nesting guilds include hypogeal nesters that build subterranean nests, epigeal nesters that build aboveground mounds, hypo-epigeal nesters that have partially subterranean and partially aboveground nests, arboreal nesters that nest on living or dead trees, and wood nesters that nest in dead wood.

RESULTS

Species density and relative abundance

Twenty species were collected in the four study sites, consisting of three families, six subfamilies and eleven genera (Table 2). The species density of termites was highest in the near-natural peat swamp forest (n = 11), with six species being recorded only in this site ('unique species'). Similar numbers of species were collected at the logged-over peat swamp forest (n = 7) and the oil palm plantation (n = 6). At the cleared and burned site only two species were found.

The relative abundance of termite species differed significantly between sites (Kruskall–Wallis: $\chi^2 = 8.95$, $p < 0.05$). The Scheffe post-hoc test revealed that the abundance of termites differed significantly between the near-natural peat swamp forest and oil palm plantation ($p < 0.05$), logged-over peat swamp forest and oil palm plantation ($p < 0.01$), and the cleared and burned site and oil palm plantation ($p < 0.01$). Figure 2 shows the species accumulation curves along the non-autocorrelated sections of transects. The slopes of both the near-natural peat swamp forest and logged-over peat swamp forest were steepest after 10 sections. This indicates that the number of species is likely to increase further if the sampled area increases. Interestingly, in the oil palm plantation many species were found on a short distance but the accumulated number of species levelled off after five independent sections. The observed turnover between sites varied between 44 and 54%. Given the isolated location of the four transects relative to each other, the amount of pseudoturnover will be limited.

The subfamily Nasutitermitinae was most common in all transects but had the highest relative abundance in the forest (Table 2). Species belonging to the Rhinotermitinae were found in all transects except for the logged-over forest (near-natural peat swamp forest, n = 5; oil palm plantation, n = 3; cleared and burned site, n = 1). Within the oil palm plantation transect these Rhinotermitinae species (all within the genus *Schedorhinotermes*) were remarkably abundant (α = 16, 4 and 7 for *S. brevialatus, S. medioobscurus* and *S. sarawakensis* respectively), compared with the near-natural forest where α = 1 for all five Rhinotermitinae species found. *Schedorhinotermes brevialatus* and *S. medioobscurus* were exclusively found at the oil palm and cleared

Table 2 Relative abundance of termite species collected in four sites on peat soil in Sarawak

Family	Subfamily	Species	Functional group	Nesting group	Site			
					NF	LF	OP	CL
Kalotermitidae	Glyptotermitinae	*Glyptotermes paracaudomunitus*	I	a	1	-	-	-
		Glyptotermes paratuberculatus	I	a	-	1	-	-
Termitidae	Nasutitermitinae	*Havilanditermes atripennis*	II	h	-	3	-	-
		Nasutitermes regularis	II	a	-	-	-	-
		Nasutitermes havilandi	II	a	2	3	-	-
		Bulbitermes borneensis	II	a	1	1	1	-
		Bulbitermes constrictus	II	a	-	-	1	-
		Bulbitermes sarawakensis	II	a	2	1	-	-
		Lacessititermes kolapisensis	II	a	1	1	-	-
		Oriensubulitermes sp. A	III	h	-	-	-	2
	Termitinae	*Prohamitermes mirabilis*	II	h/e	-	-	2	-
	Amitermitinae	*Microcerotermes sabahensis*	II	w	-	1	-	-
Rhinotermitidae	Coptotermitinae	*Coptotermes curvignathus*	I	w	4	-	-	-
	Rhinotermitinae	*Schedorhinotermes brevialatus*	I	w	-	-	16	4
		Schedorhinotermes medioobscurus	I	w	-	-	4	-
		Schedorhinotermes sarawakensis	I	w	1	-	7	-
		Schedorhinotermes tarakanensis	I	w	1	-	-	-
		Parrhinotermes microdentiformisoides	I	w	1	-	-	-
		Parrhinotermes minor	I	w	1	-	-	-
		Parrhinotermes pygmaeus	I	w	1	-	-	-
Total relative abundance					16	11	31	6

I & II = wood feeding, III = soil feeding; w = wood nesting, h = hypogeal nesting, e = epigeal nesting, h/e = hypo-epigeal nesting, a = arboreal nesting

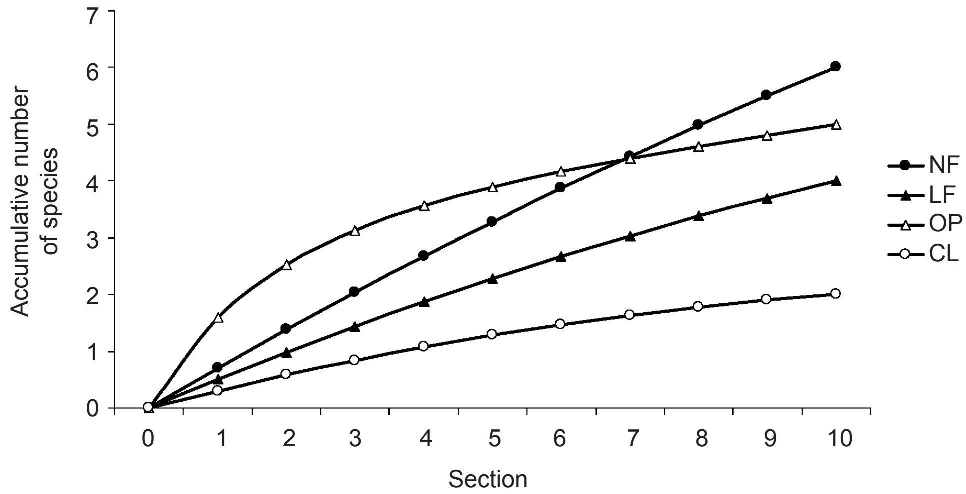

Figure 2 Species accumulation curves showing the cumulative estimated number of termite species along sampling transects in the four study sites. Only non-autocorrelated sections were used; NF = near-natural peat swamp forest, LF = logged-over peat swamp forest, OP = young oil palm plantation, CL = cleared site

site, whereas four out of the five Rhinotermitinae species found in the near-natural forest were not present in the oil palm plantation.

Feeding and nesting guilds

Wood feeding species were by far the most common in all transects, except in the cleared and burned site. A total of 19 species of the 20 found in peat area transects were wood feeding termites, all of them belonging to the wood and arboreal nesting groups. The near-natural peat swamp forest contained more wood nesters than arboreal nesters, while the logged-over peat swamp forest contained more arboreal nesters. Group III soil feeders were found at a low density exclusively in the cleared site. They were represented by *Oriensubulitermes* sp. A. Group IV soil feeders were not found in this study.

DISCUSSION

Species density of termites recorded in both forest transects of this study was relatively low compared with the density found in other non-peat forests in Borneo (e.g. Eggleton et al. 1997, Jones & Prasetyo 2002). Comparison with data from a similar transect in the undisturbed lowland dipterocarp forest at Semenggoh Nature Reserve, Sarawak (number of species = 20, α = 38, T Vaessen, unpublished data) also suggested that the near-natural peat swamp forest of this study was relatively species-poor. This could either be explained by the relatively young geological age of peat swamp forests compared with many of the dipterocarp forests in Borneo (Whitmore 1998), and hence the limited time for species to colonise and adapt to these ecosystems. Alternatively, it may be explained by the inundated soil, which does not allow or rarely allows termites to feed or nest in it (Bignell DE & Jones DT, personal communication). Consequently, termite habitat was mainly limited to trees and soil feeders were absent. Nevertheless, one hypogeal nester was found in the logged-over forest, possibly due to drier soil conditions caused by surface water evaporation under the semi-open canopy. The presence of the soil feeder *Oriensubulitermes* sp. in the cleared site may also be explained by the drier soil that results from drainage and increased exposure to sunlight. Dominance of wood feeding termites in the peat swamp forest confirms statements from Salick and Tho (1984) about peat swamp forests containing mostly arboreal species and soil-feeding termites do not inhabit the inundated peat soil.

The young oil palm plantation did not support many different termite species and was dominated by *Schedorhinotermes* (Rhinotermitinae) (Table 2). Dominance of this genus was also reported in a *Gmelina* plantation and a recently logged forest, both of which are heavily disturbed areas, in South Kalimantan, Indonesia (Jones & Prasetyo 2002). Although species density in oil palm was lower compared with near-natural peat swamp forest, the presence of non-abundant species within the Nasutitermitinae in the former might point towards a gradual transition in termite communities in response to land conversion. Possibly some remnant termite species are gradually being replaced or dominated by new species colonising the area after site preparation and oil palm planting. Comparison with termite assemblages in mature oil palm plantations is required to support this hypothesis. It is likely that the density of wood feeding and wood nesting termite species will drop as the amount of dead wood decreases over time. The oil palm plantation was logged only two years ago and, therefore, had a high density of tree stumps that attracted termites. This might also explain the lower abundance of termites in the logged-over peat swamp forest at Maludam National Park which was logged between 1960 and 1980 and where most large stems were extracted (Tan 2004).

Our results suggest that termite assemblages undergo significant changes in response to forest degradation and conversion. Nevertheless, as the treatments (i.e. landuse types) were not replicated in this study, our results merely represent the termite assemblages within the studied locations. Replication of transects would be needed to verify whether or not the observed trends are representative for the selected the landuse types.

CONCLUSIONS

This study is a first attempt to assess termite assemblages in peat areas. Results suggest that forest conversion to oil palm results in decreasing termite species density and shifting community structure. Although peat swamp forests are relatively species-poor compared with lowland dipterocarp forests, forest degradation and particularly the loss of peat swamp forest will result in significant losses of typical forest species. The abundance of termites is variable across landuse types and may be particularly high in young oil palm plantations, due to a few species becoming dominant. Results of this study suggest that peat areas are dominated by wood feeding termites and by arboreal and wood nesters. Nevertheless, these conclusions are based on a limited number of observations and more extensive research would be needed to assess the mechanisms behind shifting termite communities and declining species density of termite species on peat lands.

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