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SHORT COMMUNICATION

Diversity and abundance of termites along an altitudinal gradient in Khao Kitchagoot National Park, Thailand

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Termites are dominant invertebrates in tropical soils (Wood & Sands 1978) and are important mediators of decomposition in terrestrial ecosystems (Abe & Matsumoto 1979, Lawton *et al*. 1996, Lee & Wood 1971, Matsumoto & Abe 1979, Wood & Sands 1978, Yamada *et al*. 2005). Furthermore, these processes, such as carbon mineralization and nitrogen fixation, are dependent on the species assemblage structure of the termite community (Lawton *et al*. 1996, Yamada *et al*. 2005, 2006). Feeding habits of termites reflect their metabolic processes. The three major isopteran groups – wood-feeders, fungus-growers (fungus-growing wood/litter feeders), soil-feeders – appear to play very different roles in the decomposition process (Tayasu *et al*. 1997, Wood 1976, Wood & Sands 1978, Yamada *et al*. 2005). Consequently, the relative abundance of each feeding group provides useful information on the function of the termite assemblage in an ecosystem.

Numerous studies of the effects of environmental factors on termite community structure have been undertaken. The effects of disturbances (fire or forest clearance) (Davies 1997, Eggleton *et al*. 1995, 1996) and those of forest fragmentation (Davies 2002) have been illustrated. It has also been observed that termite abundance and species density decrease with altitude (Collins 1980, Gathorne-Hardy *et al*. 2001, Kemp 1955). In addition to environmental factors, the structure of the termite community is influenced by geological history (Eggleton 2000). We can presume that termite assemblages in a continuous forest would have experienced similar geological histories. Consequently, examining the effect of altitude in continuous forest is likely to provide a more accurate evaluation of the responses of termite assemblages to environmental gradients than a comparison of termite assemblages among discrete forests. Here, we examine changes in termite assemblages along an altitudinal gradient in a continuous forest using a standardized method (Davies 1997, Eggleton *et al*. 1997, Jones & Eggleton 2000).

The study was conducted in Khao Kitchagoot National Park in Chanthaburi Province of eastern Thailand (12°49′N, 102°09′E). The area of the National Park is approximately 59 km^2 and Phabahtplaung is the highest peak, 1085 m asl. The forest in Khao Kitchagoot National Park is divided into a seasonal evergreen forest (moist evergreen forest up to approximately 800 m in altitude) and hill evergreen forest (>800 m). The moist evergreen forest (*c*. 300 m asl) was dominated by *Scaphium macropodum* Beaumee ex K. Heyne (Sterculiaceae), *Archidendron quocense* (Pierre) I. C. Nielsen (Leguminosae) and *Syzygium lineatum* (DC.) Merr. & L. M. Perry (Myrtaceae) and the canopy was at about 30 m in height with the emergent layer (36–40 m) (C. Wachrinrat unpubl. data). The hill evergreen forest (*c*. 900 m asl)

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was dominated by *Castanopsis acuminatissima* Rehder (Fagaceae), *Diospyros* sp. (Ebenaceae), *Syzygium* sp. (Myrtaceae) and *Calophyllum saigonense* Pierre (Clusiaceae), and the canopy reached about 20 m in height (C. Wachrinrat, unpubl. data). The annual litterfalls excluding large branches and trees were 7.9 and 4.9 t ha^{-1} y^{-1} in the moist evergreen forest and the hill evergreen forest in 2001, respectively (C. Wachrinrat, unpubl. data). The average annual rainfall and temperature for the period 1998 to 2000 were 3230 mm and 27.5 °C, respectively at Chanthaburi Weather Station (12°37′N, 102°07′E, 2.8 m asl) (Meteorological Department, Thailand) and rainy season is from May to November. Termite sampling was carried out in the dry season (April and December 2000 and February 2001), because the sites at high altitudes were accessible by car only within the dry season.

The method for sampling species density followed that of Davies (1997) and Eggleton *et al.* (1997). Belt transects measuring 2 m × 100 m divided into 20 contiguous 5-m sections were randomly positioned. We spent one man-hour searching for termites in each of the 5 × 2-m sections (30 min in each of 5 × 1-m section) and searched all potentially suitable microhabitat types for termite populations. This included the lower 2-m sections of tree trunks; stumps, logs and twigs; termite mounds and soil beneath logs, fallen branches, surface rocks and the bases of tree buttresses. Soil microhabitats were also sampled with a maximum of a dozen soil scrapes (each approximately 5 cm ×10 cm by 5 cm deep, spaced apart so as to sample all parts of the section) taken in each section. A total of five transects were positioned such that a range of altitudes (100, 300, 500, 700 and 850 m) were sampled. A sample specimen of each termite population was placed in a separate vial of 80% ethanol. The number of encounters with termites (hits) along a transect was used as an indicator of the relative abundance of species within that transect. An encounter was defined as the presence of a species in one section (5 m × 1 m). Termites were divided into three putative feeding groups based on the site of discovery, the colour of the abdomen and known dietary requirements of the workers.

We collected 30 termite species, comprising 18 genera from the moist and hill evergreen forests in Khao Kitchagoot National Park (Table 1). Species density (number of species per transect) peaked at an altitude of 100 m, followed by sites at altitudes of 300 and 700 m. There was no significant correlation between species density and altitude (Spearman's rank test, $r_s = -0.62$, $P > 0.05$).

The species density of fungus-growing termites (subfamily Macrotermitinae) was greatest in the lowest transect and generally declined with increasing altitude. Conversely, species density of wood-feeding termites was nearly constant along the altitudinal gradient.

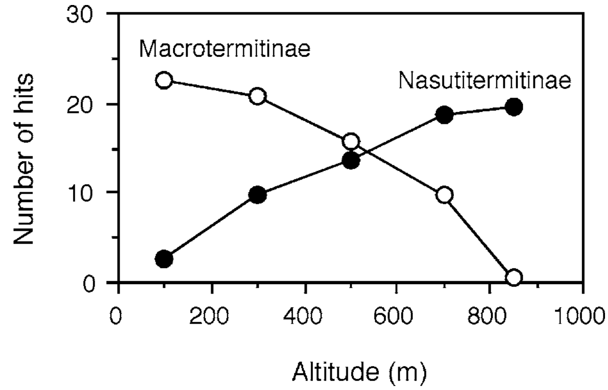

Figure 1. Relative abundance (hits) of Macrotermitinae and Nasutitermitinae species along an elevation gradient.

Although there was no significant correlation between the abundance of termites (number of hits in a transect) and altitude (Spearman's rank test, $r_s = -0.600$, $P > 0.05$), the abundance of Macrotermitinae and Nasutitermitinae species was significantly correlated with altitude (Spearman's rank test, $r_s = 1.00$ and -1.00, $P < 0.05$). As altitude increased, the abundance of Macrotermitinae species decreased, whereas the abundance of Nasutitermitinae species increased (Figure 1).

Not all the species of Macrotermitinae and Nasutitermitinae showed the same tendency with increasing altitude. The most abundant species of Macrotermitinae, *Ancistrotermes pakistanicus* (Ahmad), was dominant at low altitudes and disappeared as altitude increased. In contrast, *Odontotermes proformosanus* Ahmad increased gradually in number with altitude, peaking at middle altitudes (at 500 m), before decreasing once more as altitude increased. Nasutitermitinae species, *Bulbitermes prabhae* Krishna also peaked at middle altitudes, although *Bulbitermes parapusillus* Ahmad and *Nasutitermes matangensis* (Haviland) were dominant at high altitudes and were not found at low altitudes.

In contrast to the fungus-growing group, the abundance of wood-feeders was relatively constant along the altitudinal gradient. However, the species composition of the wood-feeding group varied as altitude increased. *Microcerotermes crassus* Snyder and *B. parapusillus* belong to the wood-feeding group, but their distribution patterns are mutually exclusive.

The remaining feeding group, soil-feeders were distributed almost constantly in species density and abundance along the altitudinal gradient, although they were insufficiently abundant to show any clear tendencies.

With respect to responses of termite feeding groups to altitudinal gradients, Gathorne-Hardy *et al.* (2001) clearly demonstrated that species density of wood-, litter- and grass-feeding higher termites (feeding group II) decrease significantly with increasing altitude in Sumatra. Our results suggest that the decrease of

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Table 1. Full list of termite species found in five transects at Khao Kitchagoot National Park. Numbers refer to encounters per species per transect (number of hits). (Feeding groups: w = wood-feeder; s = soil-feeder; f = fungus-grower).

		Altitude (m)				
Species	Feeding group	100	300	500	700	850
Kalotermitidae						
Kalotermitidae sp. 1	w					1
Rhinotermitidae						
Schedorhinotermes medioobscurus (Holmgren)	w	3	3		1	5
Schedorhinotermes rectangularis Ahmad	w	2	1	2	1	1
Termitidae						
Macrotermitinae						
Ancistrotermes pakistanicus (Ahmad)	f	12	8	2	3	
Hypotermes makhamensis Ahmad	f	4	5			
Macrotermes annandalei (Silvestri)	f	2	1	6	1	1
Microtermes obesi Holmgren	f	1	2			
Odontotermes feae (Wasmann)	f	1	1		1	
Odontotermes proformosanus Ahmad	f	3	4	8	5	
Nasutitermitinae						
Bulbitermes laticephalus Ahmad	w			1		5
Bulbitermes parapusillus Ahmad	w					11
Bulbitermes prabhae Krishna	w	1	4	7	1	
Bulbitermes sp. 1	w				3	
Lacessititermes sp. 1	w				2	1
Nasutitermes johoricus (John)	w	1	4	3	2	
Nasutitermes matangensis (Haviland)	w			1	11	
Nasutitermes sp. 1	w	1	2	2		
Nasutitermes sp. 2	w					3
Apicotermitinae						
Euhamitermes sp.1	s	2				
Euhamitermes sp.2	s		1			
Termitinae						
Dicuspiditermes spinitibialis Krishna	s				1	1
Globitermes sp. 1	w	1				
Microcerotermes crassus Snyder	w	9	6			
Mirocapritermes concaveus Ahmad	s	1	4		3	
Mirocapritermes sp. 1	s					2
Pericapritermes latignathus (Holmgren)	s					1
Pericapritermes semarangi (Holmgren)	s	1				
Procapritermes parasilvaticus (Ahmad)	s				1	3
Procapritermes prosetiger Ahmad	s		2		1	
Termes comis Haviland	s	1				
Total no. of species		17	15	9	15	12
Total no. of hits		46	48	32	37	35

wood/litter feeders observed in Sumatra could be explained by the decrease in fungus-growing termites (Macrotermitinae). Additionally it is also suggested that species density of wood/litter feeders other than Macrotermitinae might show the mid-altitude peak as described by Donovan *et al.* (2002). Likewise, the increase in the abundance of Nasutitermitinae found in our study may exhibit an increasing side of the mid-altitude peak.

In relation to the environmental factors that affect distribution of fungus-growing termites, Pomeroy (1978) reported a significant correlation between the distribution of two species of *Macrotermes* and environmental temperature. Korb & Linsenmair (1998) also investigated the importance of temperature and found that maintenance of a constant nest temperature (*c.* 30 °C) was important for the survival of termite colonies because this was the optimal temperature for fungus-cultivation and growth and development of the termites (Lüscher 1961). This was in good agreement with another demonstration that Macrotermitinae were confined to lower altitudes (<1100 m) in South-East Asia (Collins 1980, Gathorne-Hardy *et al.* 2001, Jones 2000), although two Macrotermitinae species were found at a much higher altitude (2140 m) in Africa (Donovan *et al.* 2002).

Both Macrotermitinae and Nasutitermitinae species utilize wood or/and litter as a food source, but the ecological impact of each group was significantly different. The fungus-growers cultivate symbiotic fungi on fungus-gardens (fungus combs), which are made from litter consumed by termites. The termites utilize the fungal nodules and the fungus combs are degraded by the fungi. The termite population and fungus combs mineralized

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11.2% of carbon (C) in the annual above-ground litterfall (AAL) by their respiration in the dry evergreen forest of north-eastern Thailand (Yamada *et al.* 2005). Fungus combs were responsible for a significant proportion of this contribution (7.2% of the AAL) toward C mineralization. These results suggest that a decrease in abundance of fungus-growers may result in drastic decrease in amount of carbon mineralization mediated by termites (Yamada *et al.* 2005).

The present study can offer only tentative conclusions, because of the insufficient altitudinal range at our study site to fully assess termite distribution limits and the lack of replicate transects for each site. Nevertheless, our results illustrate opposing responses of Macrotermitinae and Nasutitermitinae to increasing altitude in their abundance and indicate possible avenues for further study.

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