The Abundance and Biomass of Subterranean Termites (Isoptera) in a Dry Evergreen Forest of Northeast Thailand

by

T. Inoue[1], Y. Takematsu[2], F. Hyodo[1], A. Sugimoto[1], A. Yamada[1],

C. Klangkaew[3], N. Kirtibutr[3] & T. Abe[1]

ABSTRACT

The abundance and biomass of subterranean termites were assessed in the dry evergreen forest within the Sakaerat Environmental Research Station, northeast Thailand. The samplings were carried out by pit–digging in November 1998 (during rainy season) and February 1999 (during dry season). A total of 23 species of termites, comprising 17 genera were identified. Estimated abundance was 6450 termites/m^2 in November and 2526 termites/m^2 in February and biomass was 10.74g/m^2 (fresh mass) in November and 5.35g/m^2 in February, although no significant difference was detected in termite abundance and biomass between rainy and dry season. In 30cm depth pit–digging, we found more than 93% of individual termites and more than 94% of total biomass within the top 20cm of soil layer in both samplings. The termite abundance and biomass within the surficial soil layer (0–10cm layer) showed no significant difference between in November and February sampling.

INTRODUCTION

Termites are superabundant soil animals and play an important role in the process of litter decomposition in tropical terrestrial ecosystems (Lee & Wood 1971, Wood & Sands 1978). The estimates of termite abundance and biomass were regarded as an important indicator of their ecological impacts (Matsumoto 1976, Wood & Sands 1978, Abe & Matsumoto 1979, Martius 1994, Eggleton *et al.* 1996). On the other hand, termites and their symbiotic microorganisms are often referred as one of the most famous and intriguing example of mutualism. Their symbiotic systems in the gut are closely related to the decomposition process of dead plant material via various metabolisms (Breznak & Brune 1994). Physiological studies of termites, such as studies on

[1]Center for Ecological Research, Kyoto University, Otsu, Shiga, 520-2113, Japan. For correspondence: email: i-tetsu@postman.riken.go.jp.; present postal address for correspondence: JST Bio-Recycle Project, KURDI, Bangkok 10900, THAILAND
[2]Department of Applied Biology, Kyoto Institute of Technology, Matsugasaki, Kyoto 606-8585, Japan.
[3]Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok, 10900, Thailand.

cellulose digestion, methane and hydrogen production and nitrogen-fixation, have shown remarkable progress so far and confirmed important impacts of termites on terrestrial ecosystems (Slaytor 1992, Breznak & Brune 1994, Tayasu *et al.* 1994, Inoue *et al.* 1997, Sugimoto *et al.* 1998a, Sugimoto *et al.* 1998b). To assess ecological impacts of termites on ecosystems based on physiological data, it is necessary to estimate the abundance and biomass of termites with more accuracy. Recently, Eggleton *et al.* (1996) provided a relatively accurate estimation of termite abundance in the tropical forest reserve, southern Cameroon. Ideally, abundance and biomass of each species of termite should be estimated, because metabolic processes of termites are different from one another (Tayasu *et al.* 1997, Sugimoto *et al.* 1998b).

However, feeding habits of termites reflect their metabolic processes. Therefore, abundance and biomass of each feeding group provide useful information on the function of termites in an ecosystem. Three major groups, wood–feeder, fungus–grower and soil–feeder, seem to play very different roles in decomposition processes (Wood 1976, Wood & Sands 1978, Tayasu *et al.* 1997, Tayasu *et al.* 1998, Sugimoto *et al.* 1998b).

In this paper we present data on the abundance and biomass of subterranean termites in the dry evergreen forest in Sakaerat Environmental Research Station, northeast Thailand. We carried out samplings in the rainy and dry seasons and examined the fluctuation of termite abundance and biomass between seasons.

STUDY SITE AND METHODS

The study was carried out within the Sakaerat Environmental Research Station, Nakhon Ratchasima Province, northeast Thailand, about 180km northeast of Bangkok (14°30'N, 101°56'E). The station consists of 29.5km^2 of seasonal evergreen forest (dry evergreen forest) and 12.2km^2 of drought–deciduous forest (dry dipterocarp forest) (Wacharakitti *et al.* 1980). The site is located in the tropical monsoon climate zone, with annual rainfall averaging 1240mm (Sakurai *et al.* 1998). Mean annual temperature is 26.2°C and monthly rainfall is less than 50mm during the dry season, from December to February (Sakurai *et al.* 1998). The study site is in the dry evergreen forest about 500m above sea level. The most dominant plant species of the forest is *Hopea ferrea* and canopy trees attain 30–40m (Kanzaki *et al.* 1995).

In terms of sampling, subterranean termites are defined as species that use underground passages to access their food and that were active within the soil at sampling time. Therefore, termites which make epigeous nests are included in this definition. We sampled in November 1998 (the end of rainy season) and February 1999 (the end of dry season). We dug a 10 x 10 x 30 (depth) cm pit at an interval of 1m, along 50m line. Termites were extracted from every 10cm layer of soil by hand-sorting. Each soil sample was examined twice by the authors and field assistants. Fresh weight of termites was measured in the field laboratory and then termites were preserved in 80% ethanol. In a second sampling in February 1999, we positioned a line of 50m long in parallel with the first line at 3m distance, and we dug 50 pits (10 x 10 x 30cm depth) along the line. We also dug 5 pits of 25 x 25 x 20 (depth) cm at 10m interval to assess the effect of pit size.

We used log $(x+1)$ transformed data for statistical analyses. Termites were divided into four putative feeding groups, which we assigned by site of discovery, color of abdomen and known dietary requirements of the workers.

RESULTS

We collected a total of 23 termite species, comprising 17 genera from the dry evergreen forest in the Sakaerat Environmental Research Station (Table 1). Fig. 1 shows the species accumulation curves of each sampling. We found 13 species of termites from 50 pits in November 1998 (rainy season) and 21 species in February 1999 (dry season). As shown in Fig. 2, no termite was found in 18 out of 50 pits in November and less than 50 individuals of termites were collected in 21 pits. In February, no termite was found in 9 pits and the mode was the range 1–50 individuals per pit in the frequency of termite abundance (36 out of 50 pits). Arithmetic mean of termite abundance was 6450 termites/m^2 in November and 2526 termites/m^2 in February, although there was no significant difference between rainy and dry seasons by ANOVA using the transformed data. Significant difference was not detected in termite biomass between November (10.74g/m^2) and February (5.35g/m^2).

Fig. 3 shows the vertical distribution of termites in each sampling. Almost all of the termites were found within the top 20cm of soil layer in both samplings. The termite abundance in 20–30cm layer represented 5.8% of total termite abundance in November and 6.3% in February. The termite biomass in 0–10 plus 10–20cm layer represented 95% of total termite biomass in both samplings. Substantial numbers of termites were found in the 0–10cm layer in each sampling and the termite abundance in the 0–10cm layer was significantly larger than that in 10–20cm layer in both November and February. On the other hand, there was no significant difference in the termite biomass between the 0–10 and the 10–20cm layers in February, although the termite biomass in the 0–10cm layer was significantly larger than that

Table 1. Full list of termite species collected, with mean abundances and biomass. 50 pits were dug in each sampling. (Feeding groups: W=wood feeding; S=soil feeding; F=fungus growing; L=lichen feeding)

Termite species	Nov. 1998 No. of pits containing termites	Nov. 1998 Abundance (m^{-2})	Nov. 1998 Biomass (mg/m^2)	Feb. 1999 No. of pits containing termites	Feb. 1999 Abundance (m^{-2})	Feb. 1999 Biomass (mg/m^2)	Feeding group
Rhinotermitidae							
Coptotermes curvignathus				1	60	284	W
Schedorhinotermes medioobscurus				1	2	2	W
Schedorhinotermes sp.				1	2	2	W
Termitinae							
Globitermes sulphureus	1	2	4	2	24	74	W
Microcerotermes crassus	7	3048	3868	7	204	358	W
Dicuspiditermes garthwaitei	1	2	6				S
Dicuspiditermes makhamensis	1	110	348	2	474	1664	S
Mirocapritermes concaveus	5	198	258	7	492	570	S
Mirocapritermes sp. 1				1	206	562	S
Pericapritermes semarangi	1	4	6	7	146	206	S
Procapritermes prosetiger	9	1674	3760	8	348	710	S
Termes propinquus	2	136	160	10	190	232	S
Termitinae spp.				4	10	10	
Nasutitermitinae							
Bulbitermes makhamensis				1	16	24	W
Hospitalitermes bicolor				1	2	4	L
Macrotermitinae							
Hypotermes makhamensis	1	6	8	4	26	40	F
Hypotermes sp.1				2	110	106	F
Macrotermes annandalei				2	6	28	F
Macrotermes gilvus				2	12	180	F
Microtermes obesi				1	18	10	F
Microtermes pakistanicus	8	558	1046	1	4	4	F
Odontotermes feae	1	6	16				F
Odontotermes maesodensis				3	52	124	F
Macrotermitinae spp.	3	10	12	1	26	6	F
Apicotermitinae							
Euhamitermes sp. 1	6	654	1146	4	86	106	S
Speculitermes sp. 1	1	42	106	1	4	30	S
Apicotermitinae sp.				1	2	10	
Termitidae sp.				1	4	4	
Total	32	6450	10744	41	2526	5350	

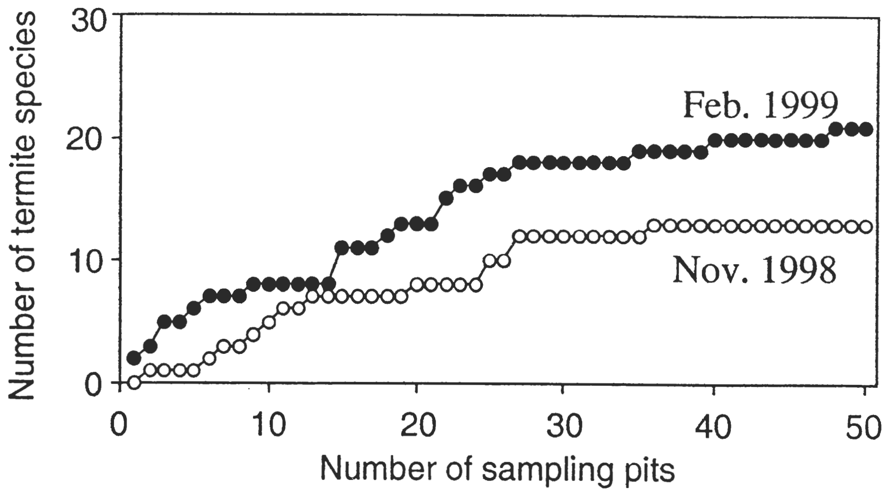

Fig. 1. Species accumulation curves for 50 pits sampling in November 1998 and February 1999.

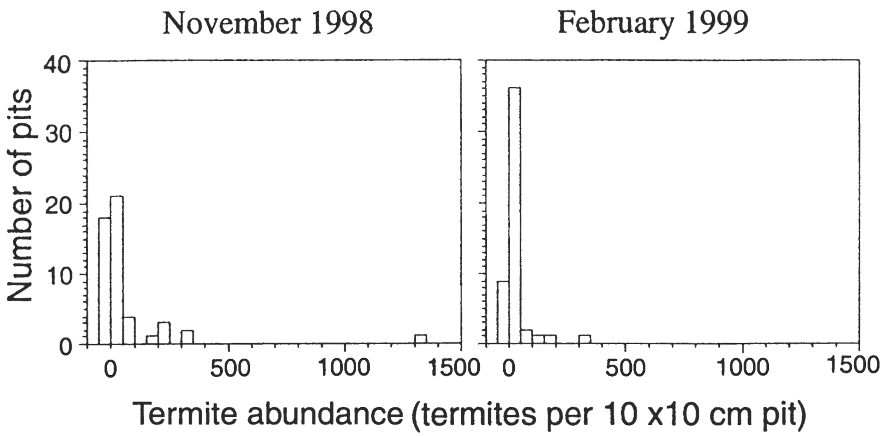

Fig. 2. Frequency distributions of termite population per pit (10 x 10cm area, 30cm in depth).

in the 10–20cm layer in November.

In relation to seasonal change in termite abundance in each layer, there was no significant difference in both termite abundance and biomass in 0–10cm layer between samplings in November and February. Furthermore, the termite abundance and biomass in 10–20cm layer did not show significant difference, although there were apparent differences in feeding group composition. We did not include data of termite abundance and biomass in 20–30cm layer for statistical analyses, because there was a large proportion of zero values.

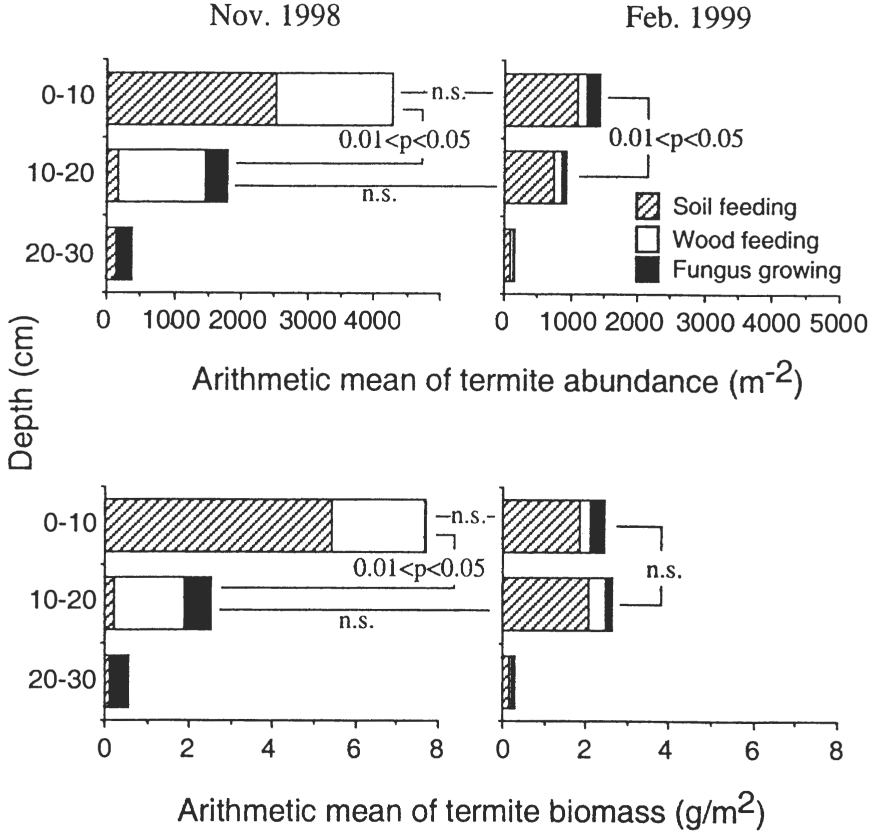

Fig. 3. Vertical distribution of soil feeding, wood feeding and fungus growing termites.
n.s. = not significant

As shown in Table 1, termites were divided into four feeding groups, namely wood feeding, soil feeding, fungus growing and lichen feeding. *Hospitalitemes bicolor* belongs to lichen feeding group. Fig. 4 shows the abundance and biomass of each feeding group except lichen feeding group. Statistical comparison of the termite abundance and biomass between November and February indicated no significant difference in each feeding group, although the arithmetic mean of termite abundance and biomass of wood feeding group apparently differed between the samplings. Number of termite species found in each layer and number of pits containing each feeding group are summarized in Table 2. Wood feeding, soil feeding and fungus growing termite species were found at 8, 22 and 11 pits out of 50 pits in November respectively, and at 12, 31 and 13 out of 50 pits in February, respectively. Frequency of

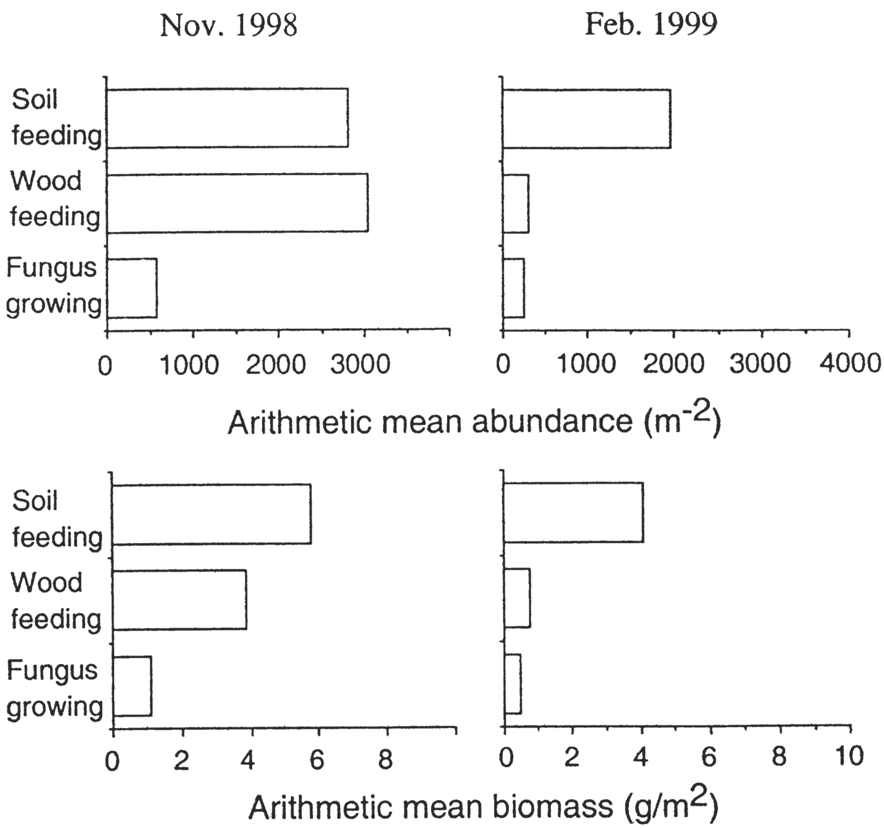

Fig. 4. Abundance (m^{-2}) and biomass (g/m^2) of each feeding group of termites.

occurrence of each feeding group was not significantly different between November and February (X^2 test of independence).

We also estimated termite abundance and biomass by digging five 25 x 25 x 20 (depth) cm pits in February 1999. We collected 8 species and 1382 individuals of termites from 5 pits. Almost all of the termites were found in 2 of the 5 pits. No termite was found in 2 pits and only 2 termite individuals were found in one pit. The arithmetic mean of termite abundance and biomass was 4422 termites/m^2 and 9.67g/m^2, respectively.

DISCUSSION

The sampling of subterranean termite is one of the most awkward problems of termite fieldwork and sampling problems and methods were reviewed by Lee & Wood (1971). The social behavior of termites

Table 2. Number of species and frequency of occurrence of each feeding group in each layer.

Depth (cm)		Number of species Nov.98	Number of species Feb.99	Number of pits Nov.98	Number of pits Feb.99
0-10	Wood feeding	1	4	7	10
	Soil feeding	7	6	16	21
	Fungus growing	2	5	5	8
10-20	Wood feeding	2	2	3	3
	Soil feeding	5	7	9	13
	Fungus growing	1	1	8	2
20-30	Wood feeding	0	2	0	2
	Soil feeding	4	6	8	11
	Fungus growing	2	5	5	5
Whole pits	Wood feeding	2	5	8	12
	Soil feeding	8	8	22	31
	Fungus growing	3	7	11	13
				n.s.(Chi square test)	

makes them more discontinuously distributed than nonsocial insects. So far, there is no general method for sampling subterranean termites. Abe & Matsumoto (1979) used a 1 x 2m pit and dug to a depth of 25cm for the estimation of subterranean termite abundance. However, a broad pit–digging requires a very large amount of labor and the whole area can not be dug quickly so termites may flee from the disturbance. Relatively few replicates due to a very large amount of labor are disadvantageous to statistical analyses. The problem of replication can be overcome by taking numerous soil cores. Ferrar (1982) used a hand-operated soil auger of 7.5cm diameter and 18cm depth and collected 30 soil cores in each sampling. However, Abbott (1984) pointed out statistical problems for the small soil core sampling, because of the large number of cores without animals. Eggleton *et al.* (1996) used a moderate size pit for the estimation of termite abundance in soil. They dug a 20 x 20 x 50 (depth) cm pit (10 pits in each hectare plot). The other method is to use a trench-digger. Abensperg-Traun & De Boer (1990) estimated the termite biomass in Western Australia using a trench–digger (100cm long, 10cm wide and 10cm deep). We could expect that the large size pit-digging might decrease the number of pits without termites. In this study, we used a 10 x 10cm pit and a 25 x 25cm pit in February 1999. Against expectation, no termite was found in 2 pits out of 5 pits and only 2 individuals of termite were found in a pit. In 25 x 25cm pit–digging, we collected 8 species of termites in the total area, 3125cm^2, while we found 18 species in 32 small pits (total 3200cm^2) in February (Fig. 1). The smaller pit–digging might reflect more species of termites in the estimation of termite abundance.

We showed the arithmetic mean number per m^2 and g/m^2 as the termite abundance and biomass, because other termite studies have used arithmetic means (Wood & Sands 1978; Abe & Matsumoto 1979; Ferrar 1982; Eggleton *et al.* 1996). The arithmetic mean of termite abundance and biomass in November were larger than those in February (Table 1), but there was no significant difference between them according to the statistical analysis using the transformed data. The log (x+ 1) transformation that we used for statistical analyses here normalizes the distribution, generally removes the correlation between the variance and the mean. We could suspect that the distribution of termites in November might show a more aggregated pattern than in February. Actually, $I\delta$ index (Morisita, 1959) which indicates the degree of aggregation was 10.1 in November and 5.7 in February. The index has a value equal to, greater than or less than 1, for random, aggregated and uniform distributions respectively. The difference in the degree of aggregation between the termite distribution in November and February explained the apparent difference in the arithmetic mean of termite abundance and biomass in spite of no significant differences in statistical analysis. Similarly, the abundance of wood feeding termites in November was much larger than in February (Fig. 4) and the $I\delta$ index that was 37.6 in November and 12.1 in February indicated that the wood feeding termites was more aggregated in November than in February. The $I\delta$ index of soil feeding termites was relatively stable, 6.4 and 8.6 in November and February, respectively.

We did not sample below 30cm, but we found more than 93% of individual termites within the top 20cm of soil layer. This is consistent with the result of Abe & Matsumoto (1979) who described that the termites were mainly distributed in 0–15cm layer in a low land rain forest of Malaysia. Wood *et al.* (1982) carried out the thorough examination for vertical distribution of termites by taking soil cores to the depth 150cm. They revealed that nearly all species were abundant in the upper 25cm.

In relation to seasonality of termite abundance, some authors reported the decrease of termite activities within the superficial soil layer in the dry season (Ferrar 1982, Wood *et al.* 1982, Abensperg-Traun & De Boer 1990). Abensperg-Traun & De Boer (1990) assessed monthly fluctuations in the biomass of termites within the superficial soil layer of the woodland and heath in Western Australia and showed that soil moisture and termite biomass within the top 10cm of soil profile were positively correlated. In this study, we consider November as the end of rainy season and February as the end of dry season. Actually, the monthly rainfall at the study site was 144.4, 124.7 and 0mm in October, November and December 1998, respectively. In 1999, 3.9mm of rainfall was recorded in January and 16.5mm in February. As shown in Fig. 3, there were no significant differences in both termite abundance and biomass in 0–10cm layer between November and February. Abensperg-Traun & De Boer (1990) suggested minimum soil moisture requirements by termites from the assessment of the fluctuations in termite activity. It was highly probable that the soil moisture in February was not below minimum soil moisture requirements due to the relatively short dry season.

ACKNOWLEDGMENTS

We thank NRCT (National Research Council of Thailand) and the people who are working at Sakaerat Environmental Research Station for their kind cooperation. This research was supported by a Grant–in–Aid for Creative Basic Research Program "An integrated study on biodiversity conservation under global change and bio-inventory management system" funded by Japan Ministry of Education, Science, Sports and Culture. The first author was supported by Research fellowships of the Japan Society for the Promotion of Science for Young Scientists.

REFERENCES

Abbott, I. 1984. Changes in the abundance and activity of certain soil and litter fauna in the jarrah forest of Western Australia after moderate intensity fire. Aust. J. Soil Res. 22:463-469.

Abe, T. & T. Matsumoto. 1979. Studies on the distribution and ecological role of termites in a lowland rain forest of West Malaysia (3) Distribution and abundance of termites in Pasoh Forest Reserve. Jap. J. Ecol. 29:337-351.

Abensperg-Traun, M. & E.S. De Boer. 1990. Species abundance and habitat differences in biomass of subterranean termites (Isoptera) in the wheatbelt of Western Australia. Aust. J. Ecol. 15:219-226.

Breznak, J.A. & A. Brune. 1994. Role of microorganisms in the digestion of lignocellulose by termites Annu. Rev. Entomol. 39:453-487.

Eggleton, P., D.E. Bignell, W.A. Sands, N.A. Mawdsley, J.H. Lawton, T.G. Wood & N.C. Bignell. 1996. The diversity, abundance and biomass of termites under differing levels of disturbance in the Mbalmayo Forest Reserve, southern Cameroom. Phil. Trans. R. Soc. Lond. B 351:51-68.

Ferrar, P. 1982. Termites of a South African savanna. IV. Subterranean populations, mass determinations and biomass estimations. Oecologia. 52:147-151.

Inoue, T., K. Murashima, J.-I. Azuma, A. Sugimoto & M. Slaytor. 1997. Cellulose and xylan utilization in the lower termite *Reticulitermes speratus*. J. Insect Physiol. 43:235-242.

Kanzaki, M., M. Kagotani, T. Kawasaki, K. Yoda, P. Sahunalu, P. Dhanmanonda, B. Prachaiyo & S. Thoranisorn. 1995. Forest structure and composition of tropical seasonal forests of Sakaerat Environmental Research Station and the effects of fire protection on a dry deciduous forest. *In:* Elucidation of the missing sink in the global carbon cycling-focusing on the dynamics of tropical seasonal forests. K. Yoda, P. Sahunalu & M. Kanzaki, eds. Osaka City University, Osaka, pp. 1-20.

Lee, K.E. & T.G. Wood. 1971. Termites and soils. Academic Press, London.

Martius, C. 1994. Diversity and ecology of termites in Amazonian forests. Pedobiologia. 38:407-428.

Matsumoto, T. 1976. The role of termites in an equatorial rain forest ecosystem of West Malaysia. I. Population density, biomass, carbon, nitrogen and calorific content and respiration rate. Oecologia. 22:153-178.

Morisita, M. 1959. Measuring of the dispersion of individuals and analysis of the distributional patterns. Mem. Fac. Sci. Kyushu University, Ser. E. 2:215-235.

Sakurai, K., S. Tanaka, S. Ishizuka & M. Kanzaki. 1998. Differences in soil properties of dry evergreen and dry deciduous forest in the Sakaerat Environmental Research Station. TROPICS. 8:61-80.

Slaytor, M. 1992. Cellulose digestion in termites and cockroaches: what role do symbionts play? Comp. Biochem. Physiol. 103B:775-784.

Sugimoto, A., T. Inoue, N. Kirtibutr & T. Abe. 1998a. Methane oxidation by termite mounds estimated by the carbon isotopic composition of methane. Global Biogeochemical Cycles. 12:595-605.

Sugimoto, A., T. Inoue, I. Tayasu, L.R. Miller, S. Takeichi & T. Abe. 1998b. Methane and hydrogen production in a termite–symbiont system. Ecological Research. 13:241-257.

Tayasu, I., T. Abe, P. Eggleton & D.E. Bignell. 1997. Nitrogen and carbon isotope ratios in termites (Isoptera): an indicator of trophic habit along the gradient from wood–feeding to soil–feeding. Ecol. Entomol. 22:343-351.

Tayasu, I., T. Inoue, L.R. Miller, A. Sugimoto, S. Takeichi & T. Abe. 1998. Confirmation of soil–feeding termites (Isoptera; Termitidae; Termitinae) in Australia using stable isotope ratios. Funct. Ecol. 12:536-542.

Tayasu, I., A. Sugimoto, E. Wada & T. Abe. 1994. Xylophagous termites depending on atmospheric nitrogen. Naturwissenshaften. 81:229-231.

Wacharakitti, S., P. Intrachanda & S. Mungkorndin. 1980. Natural resources and land use studies of Sakaerat Environmental Research Station. Forest Research Bulletin 69. Faculty of Forestry, Kasetsart University, Bangkok.

Wood, T. G. 1976. The role of termites (Isoptera) in decomposition processes. *In:* The role of terrestrial and aquatic organisms in decomposition processes.

J. M. Anderson & A. Macfadyen, eds. Blackwell Scientific Publications, Oxford, pp. 145-168.

Wood, T.G., R. A. Johnson, S. Bacchus, M.O. Shittu & J.M. Anderson. 1982. Abundance and distribution of termites (Isoptera) in a riparian forest in the Southern Guinea savanna vegetation zone of Nigeria. Biotropica.14:25-39.

Wood, T.G. & W.A. Sands. 1978. The role of termites in ecosystems. *In:* Production ecology of ants and termites. M.V. Brian, ed. Cambridge University Press, Cambridge and London, pp. 245-292.