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A Survey of Termites in the Singapore Botanic Gardens Rain Forest

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Abstract

A survey on termites in the Singapore Botanic Gardens Rain Forest included termite collection and quantitative assessment of vegetation, dead trees and wood litter in 15 random sample plots, which covered 7.5% area of the forest. Termite infestation was high in the northern zone, moderate in the central and light in the southern zones. The abundance of termite-infested microhabitats shows a positive relationship with the number of big trees, dead standing trees and ground timber, and a negative relationship with the number of herbs. A total of 22 termite species were found. Three genera of gallery-forming termites identified were *Bulbitermes, Nasutitermes* and *Microcerotermes.* The major fungus-growing genera were *Macrotermes, Odontotermes* and *Microtermes.* The ground-nesting genera included *Termes, Dicuspiditermes, Hospitalitermes* and *Prohamitermes.* The other genera found were *Coptotermes*, *Schedorhinotermes*, *Subulitermes* and *Procapritermes*. Three new records for Singapore are *Bulbitermes borneensis*, *B. constrictus* and *Microcerotermes crassus*. *Microcerotermes* and *Nasutitermes* are involved in the self-pruning of trees. The *Bulbitermes*, *Macrotermes* and *Odontotermes* are dominant in ground timber. The different species richness and uneven distribution of termites in different parts of the forest is attributed, not only to the differences in forest structure and flora, but also the degree to which the forest floor space has been depleted for visitor and horticultural activities.

Introduction

The Singapore Botanic Gardens (SBG) includes a 6.3-ha plot of forest, which according to Corlett (1992), no longer resembles primary rain forest in structure or flora. The insect fauna is similarly depleted as exemplified by the ants (Murphy, 1973). There are few publications on the vegetation in the early years although Corner (1935) did make an interesting study of higher fungi. Turner *et al.* (1996) surveyed the vegetation and compared it with historical records of herbarium collections made since 1893 and revealed that the forest has suffered a significant loss of species. They attributed this to the rampant growth of climbers, dense undergrowth of exotic and clonal herbs and a loss of animal disposal agents, which have led to a low density of saplings and seedlings and hence no recruitment of the high forest species. *Calophyllum ferrugineum* (Guttiferae) is an exception being numerically the dominant species making up 26.2% of the trees. The death of trees, caused either by lightning strike, disease or other factors, has given rise to a great variety of fallen and standing dead timber in all stages of decay. The aim of the survey of the termite fauna in this disturbed rain forest was to record termite species diversity and their distribution and also the roles the different species play in the decomposition of the dead timber, as well as the effects the different vegetation life forms have on termite distribution.

Methods of Study

Sampling methods

A map of SBG rain forest by the Nature Conservation Branch was used for the selection of sampling points. The map has grid lines spaced 40 m apart, which give rise to 45 points evenly spaced over the entire area. Using a random table (Snedicor & Cochran, 1969), one third of these intersection points, i.e. 15, were picked as the sample points for the termite survey. These sample points, i.e. points 5, 6, 8, 15, 16, 17, 20, 24, 28, 31, 34, 40, 41, 42, 45, were located and pegged on site (Fig.1). Around each point, a sample plot of radius 10 m was cordoned off for the survey. The 15 sample plots covered a total area of 7.5% of the 6.3-ha rain forest. The sampling of termites and the quantitative assessment of the vegetation and wood litter were conducted once to three times a week from end May to end August 1998.

Termite Collection and Identification

Within each sample plot, the following microhabitats were searched: ground nests, inside of dead logs, fallen branches, leaf litter under rotten logs and galleries on logs and tree trunks up to a height of 2 m above ground level. Termites in soil, high canopy, tree stumps and fallen macro-timber equal or greater than 30 cm diameter were not surveyed. From each infested microhabitat, one series of termites comprising soldiers and workers was collected for each species found. The soldiers were identified to species level as far as possible using taxonomic keys (Thapa, 1977; Tho, 1992; Holmgren, 1913). The location of each infested microhabitat was mapped.

Quantitative assessment of vegetation and wood litter

Each sample plot was divided into quarters and a systematic count of vegetation categorised into trees, shrubs, herbs and climbers was made. To correctly categorise the plants, especially the seedlings, to their life forms, the identity of the plants was confirmed with assistance of SBG Herbarium

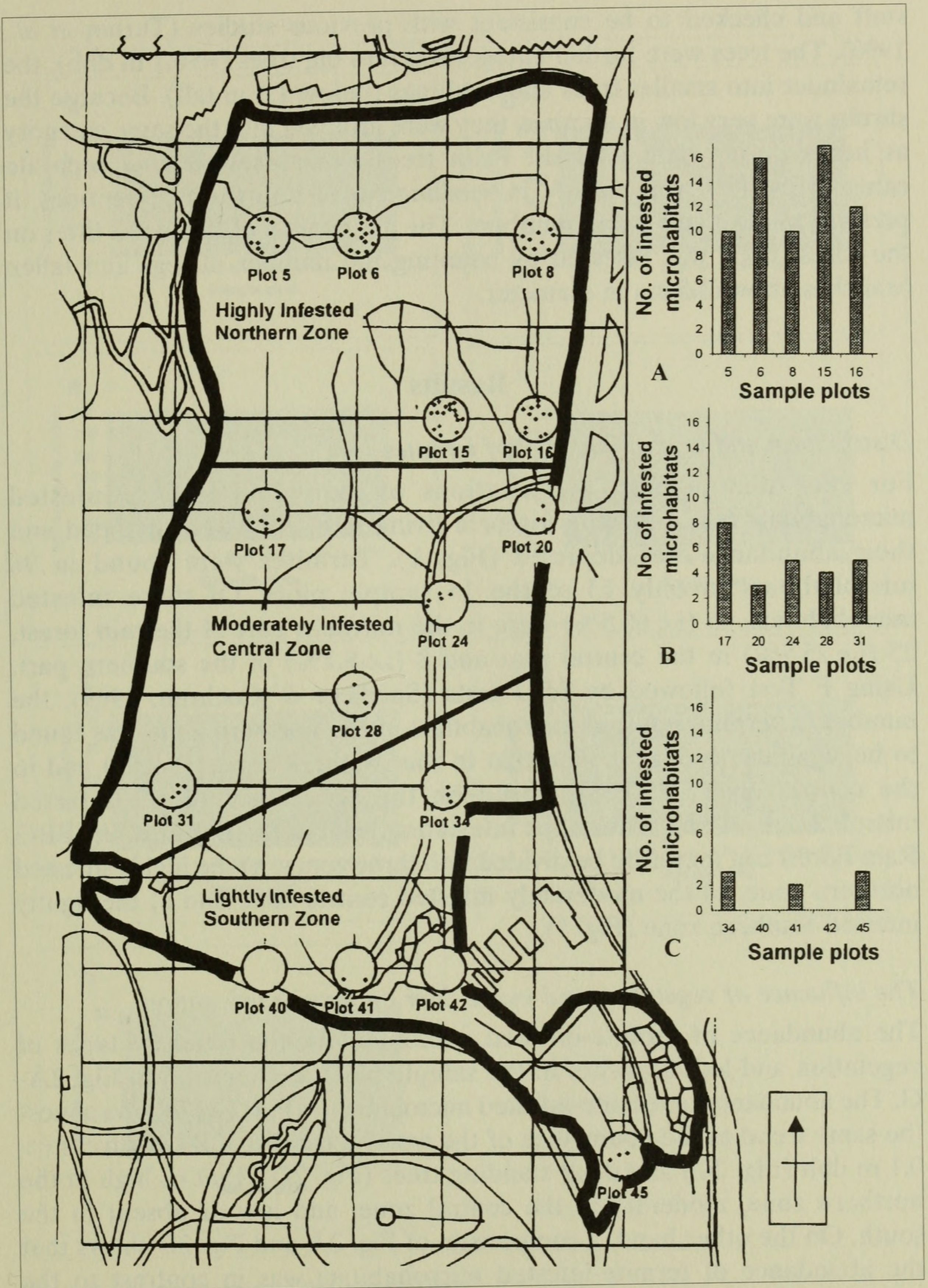

Figure 1. The three zones of SBG Rain Forest with different termite infestation levels. The locations of the termite infested microhabitats within the sample plots are marked by black dots, while their abundance is depicted by the histograms for A. northern zone, B. central zone and C. southern zone.

staff and checked to be consistent with previous studies (Turner *et al.*, 1996). The trees were further categorised into big trees (=>0.1 m dbh), the remainder into smaller trees and seedlings (below 1.5 m tall). Because the shrubs were very low in number, they were grouped into the same category as herbs during data analysis. Palm trees were assessed as a separate category as they were mostly in seedling stages and the mature ones, if present, were in very small numbers. The abundance of the wood litter on the forest floor was assessed by counting the number of logs and fallen branches above 1.5 cm in diameter.

Results

Distribution and infestation level of termites

For each sample plot, the locations of individual termite-infested microhabitats (e.g. a nest, a log or a living tree, etc.) were mapped and their abundance was depicted (Fig. 1). Termites were found in 98 microhabitats in only 13 of the 15 sample plots. Of these infested microhabitats, 65 (i.e.66.5%) were in the northern part of the rain forest, 25 (i.e.25.5%) in the central part and 8 (i.e.8.2%) in the southern part. Using F Test followed by LSD tests (Snedicor & Cochran, 1969), the number of termite infested microhabitats in the northern zone was found to be significantly higher than that in the southern zone (P=0.01) and in the central zone (P=0.05). Based on the abundance of the infested microhabitats, which reflects the infestation level of the termites, the SBG Rain Forest can therefore be divided into three zones: a) the highly infested northern zone, b) the moderately infested central zone and c) the lightly infested southern zone (Fig. 1).

The influence of vegetation and wood litter on termite infestation

The abundance of termite-infested microhabitats, the different types of vegetation and logs/branches in the sample plots are depicted in Fig. 2A-G. The abundance of termite-infested microhabitats (Fig. 2A) follows almost the same trend as the abundance of the wood litter (Fig. 2B), big trees => 0.1 m dbh (Fig. 2C) and dead standing trees (Fig. 2D), that is, high in the northern zone, moderate in the central zone, and low or absent in the south. On the other hand, a comparison of Fig. 2A and Fig. 2E shows that the abundance of termite-infested microhabitats was in contrast to the abundance of herbs and shrubs in the sample plots. Fig. 2F and 2G show that the abundance of palm trees and climbers in the sample plots do not have any influence on the abundance of the termite-infested microhabitats.

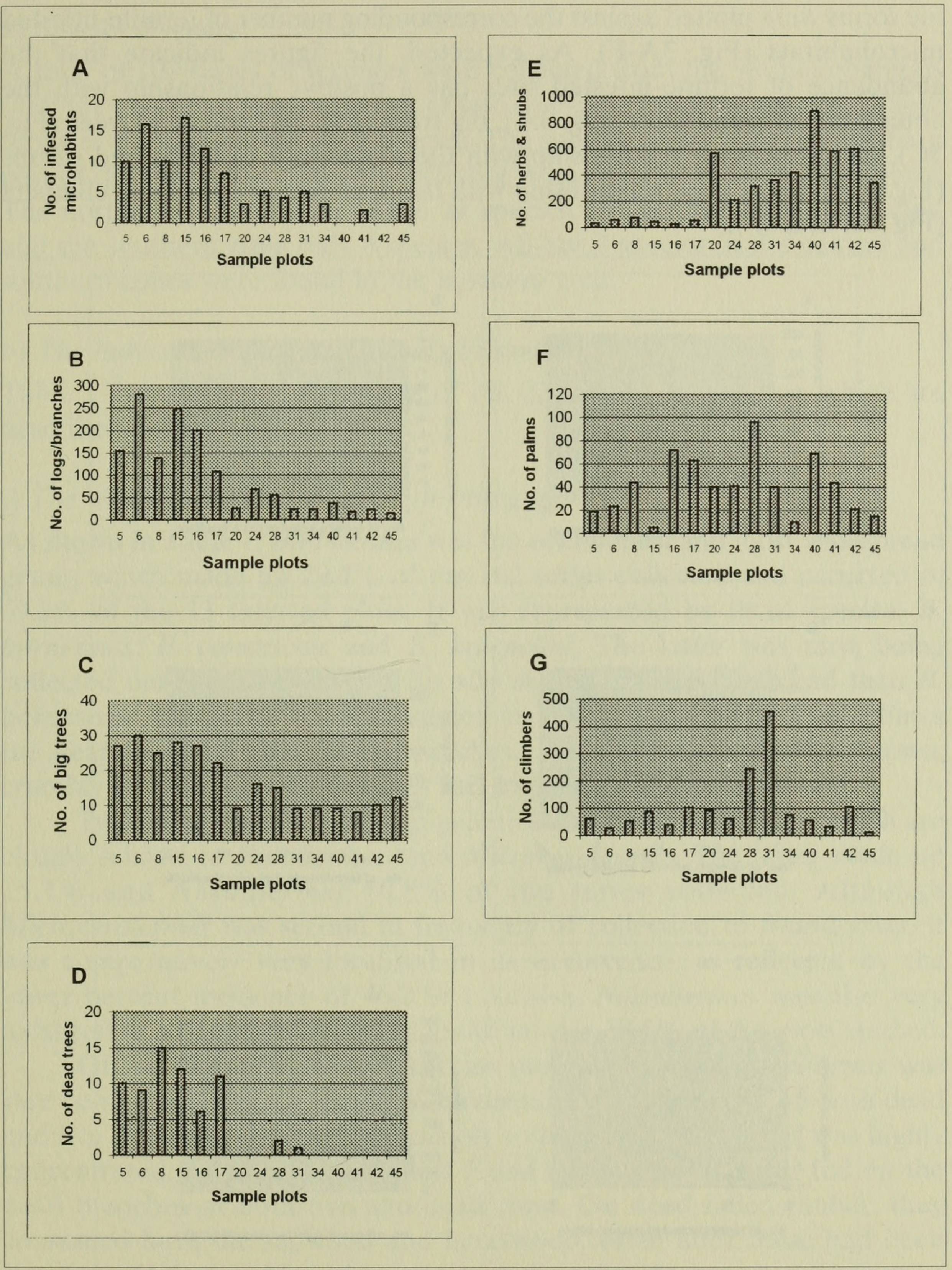

Figure 2. Characteristics of the sample plots
A. No. of infested microhabitats; B. No. of logs and fallen branches; C. No. of mature trees (=> 0.1 m dbh); D. No. of dead trees; E. No. of herbs and shrubs; F. No. of palm trees; G. No. of climbers.

The number of logs and fallen branches and the various vegetation life forms were plotted against the corresponding number of termite-infested microhabitats (Fig. 3A-F). As expected, the figures indicate that the abundance of termite-infested sites has a positive relationship with the abundance of wood litter (Fig. 3A), big trees (Fig. 3B) and dead trees (Fig. 3C), and a negative relationship with the abundance of herbs and shrubs (Fig. 3D). There is no relationship with the presence of palms and climbers (Fig. 3E and 3F).

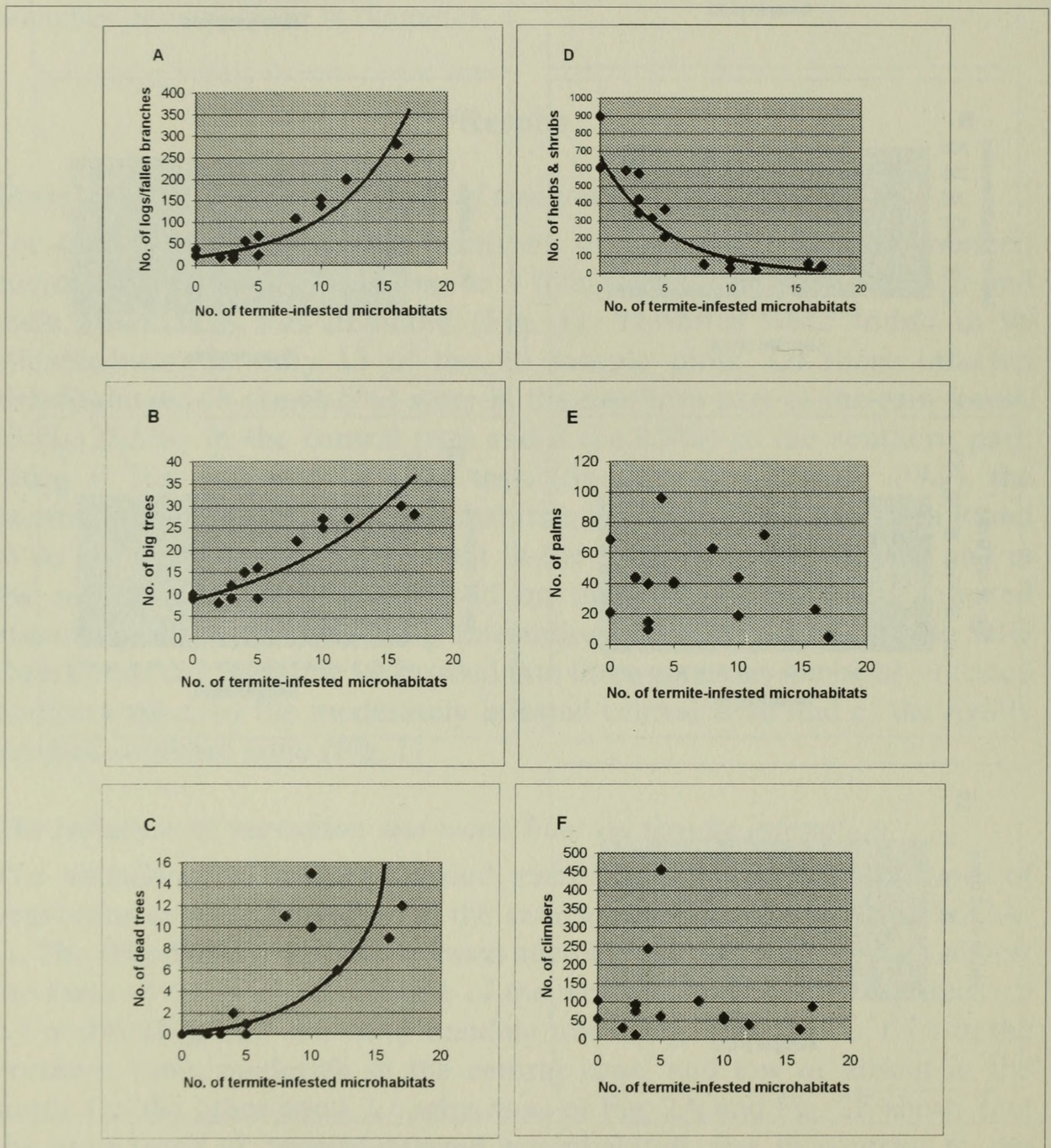

Figure 3. The relationship between the abundance of termite-infested microhabitats and the various types of vegetation and wood litter.
A. Logs and fallen branches; B. Big trees =>0.1 m dbh; C. Dead trees; D. Herbs and shrubs; E. Palms; F. Climbers.

The termite fauna

a) *Species diversity*

A total of 102 series of termites were collected from the 98 microhabitats (4 of the microhabitats had series of two co-existing termite species). These termites were identified to 22 species. The species diversity of the northern part of the forest was distinctly different from those of the other two parts. The northern zone had 20 of the 22 species, the central zone 10 species, and the southern zone only 6 species. All but 2 species in the central and southern zones were found in the northern zone.

b) *The habitats, feeding and nesting behaviour*

Table 1 indicates the occurrence of the 22 species of termites, which are described below:

i) *The wood-feeding cum gallery-forming termites*

As shown in Table 1, *Bulbitermes* was the commonest and most widespread genus, which made up 29.4% of the 102 series collected and occurred in 69.2% of the 13 infested plots. It was represented by three species: *B. borneensis*, *B. constrictus* and *B. kraepelini*. The latter was rare, being collected only once. *B. constrictus* was slightly more widespread than *B. borneensis*. The *Bulbitermes* consumed mainly the sapwood and sometimes the heartwood of dead fallen branches. They frequently formed brown, crumbly galleries on the branches and logs where they were found.

Two other genera that form galleries are the *Nasutitermes*, which are closely related to *Bulbitermes*, and *Microcerotermes*. The latter made up 15.7% and *Nasutitermes* 10.8% of the series collected. Although *Microcerotermes* was second in frequency of collection to *Bulbitermes*, it was comparatively very localized in its occurrence, as reflected by the lower percent incidence of 46.2%. Likewise, *Nasutitermes* was also very localized in its occurrence, being found in only 38.5% of the plots studied.

Of the two *Nasutitermes* species present, *N. matangensiformis* was rare being only collected once. *N. havilandi* formed galleries on both dead and live trees and was confined mainly to the northern zone. It was highly concentrated south of sample plots 5 and 6. The *Nasutitermes* fed on the dead branches of both live and dead trees. On dead fallen timber, they consumed both the sapwood and heartwood, often after these had been invaded and deserted by other species such as the *Macrotermes*. They were found mainly inside small stems or branches as small as 1.5 cm diameter.

Microcerotermes was represented by three species: *M. serrula*, *M. havilandi* and *M. crassus*. *M. serrula* was found once, in a nest at the base of a live tree. *M. havilandi* formed galleries at two plots. *M. crassus*, the most common species, was collected from many different infested microhabitats including seven around a ground nest in plot 15. It formed characteristic small and hard galleries on both live and dead trees as well as fallen branches. It attacked the sapwood of dead branches as small as 1.5 cm diameter.

Table 1. Termite species collected from the Singapore Botanic Gardens Rain Forest

Species	No. of series collected	% of series collected	No. of plots with termites	% of plots with termites	Sample plots where termites are found
Bulbitermes	30	29.4	9	69.2	
borneensis					5,6,8,15,28,31
constrictus					5,6,8,15,16,17,24,28,45
kraepelini					16
Microcerotermes	16	15.7	6	46.2	
havilandi					6,8
crassus					15,41,45
serrula					6
Nasutitermes	11	10.8	5	38.5	
havilandi					5,6,8,16,34
matangensiformis					8
Macrotermes	13	12.7	8	61.5	
gilvus					6,15,20
malaccensis					8,15,16,17,31,34
Odontotermes	12	11.8	7	53.8	
denticulates					5,15
oblongatus					5,6,15,17,20,24,28,45
Termes	8	7.8	5	38.5	
comis					6,16
rostratus					6,8,15,31
Dicuspiditermes	2	2.0	2	15.4	
nemorosus					5,28
Hospitalitermes	2	2.0	2	15.4	
umbrinus					5,41
Microtermes	2	2.0	2	15.4	
pallidus					24
Schedorhinotermes	2	2.0	2	15.4	
medio-obscurus					5,17
Coptotermes	1	1.0	1	7.7	
travians					20
Procapritermes	1	1.0	1	7.7	
augustignathus					6
Prohamitermes	1	1.0	1	7.7	
mirabilis					6
Subulitermes	1	1.0	1	7.7	
unidentified sp.					15
Total	102	100	13		

ii) *The wood-feeding cum leaf-litter feeding termites*

The two common and widespread genera found belong to *Macrotermes* and *Odontotermes* (Macrotermitinae). These are capable of growing fungi in their underground nests (Collins *et al.* 1983; Collins, 1981). Typical signs of their presence are the clayey soil refill inside the burrowed dead branches or stems. They were found inside branches or in the soil among leaf litter just beneath the branches. It was observed that both genera burrowed into the sapwood and sometimes heartwood under the bark of branches greater than 4 cm diameter.

Of the two *Macrotermes* species, *M. malaccensis* and *M. gilvus*, *M. malaccensis* was more widespread (Table 1). A nest of *M. gilvus* contained fungus gardens. Of the two *Odontotermes*, *O. denticulatus* was collected from only two northern plots, and *O. oblongatus* was present in eight plots all over the rain forest.

Microtermes was the other Macrotermitine found, with only two collections of *M. pallidus* from one plot.

iii) *The ground-nesting termites*

Species of *Termes* were most prevalent with eight series collected from five plots. Two series of *T. comis* were found but no nest could be located. On the other hand, *T. rostratus* was found inside two hard ground nests and in another nest freshly made with black soil refills inside a piece of rotted log. The nests were fairly easily broken into soil crumbs.

The three other species, *Dicuspiditermes nemorosus*, *Hospitalitermes umbrinus* and *Prohamitermes mirabilis,* formed prominent ground nests. Their percent incidence was comparatively low, especially for *P. mirabilis*. *Dicuspiditermes* made raised, ball-like nests. Two *Hospitalitermes* nests were found, one being free-standing while the other leaned against the base of a large tree.

iv) *Other soil and wood-feeding termites*

The other species made up only 1-2% of the series collected and included *Coptotermes travians* and *Schedorhinotermes medio-obscurus* of the Rhinotermitidae, an unidentified species of the *Subulitermes* complex and *Procapritermes augustignathus* of Termitidae.

Discussion

The distribution and infestation levels of termites in the SBG Rain Forest, as in other ecosystems, are dependent on the availability of their food sources. These include the wood and leaf litter on the forest floor, the standing dead trees and the dead branches of live trees. The northern part of the forest has a higher population of live trees than the central and southern parts and larger amounts of ground and standing dead timber as evidenced by our quantitative assessments. Having greater amounts of food for termites explains why the northern part of the rain forest is significantly more heavily infested than the central and southern parts.

In the central and southern parts, where herbaceous undergrowth thrives, there is a lower density of trees and saplings. The abundance of herbaceous plants, which are often accompanied by the presence of ants, has a negative relationship with the presence of termites. Ants have often been considered as enemies of termites (Eisner *et al.*, 1976) and strong negative associations between ants and termites had been attributed to competition between the two groups (Fowler *et al.*, 1980).

The total of 102 series of 22 termite species collected within three months is high when compared with the 70 species collected over several years from the much larger Bukit Timah and Central Catchment Nature Reserves (Murphy, 1997). Due to the short time frame of the study, the collection though fairly intensive is by no means exhaustive. There was probably under-collection of the fungus-growing Macrotermitinae, which reportedly consumed over 75% of total organic matter taken by termites in Peninsular Malaysian rain forests (Collins *et al.*, 1983) and 95% of leaf litter in Nigerian savanna (Collins, 1981). Other than Macrotermitinae, the termite species inhabiting the soil and the macro-timber are probably also under-represented. According to the lists of termite species compiled for Singapore's nature reserves (Murphy, 1997) and Malaysia's Pasoh Forest Reserve (Jones & Brendell, 1998), the soil-inhabiting species and the wood-feeding Rhinotermitidae together constitute about 40% to 50% of all species recorded. Further studies need to focus on these soil and wood-feeding termites to cover the entire termite fauna in the rain forest.

Of the species collected, three are of particular interest because they have not been reported by earlier collectors and are not in the most recent list of termites species reported from Singapore (Murphy, 1997). These are the *Bulbitermes borneensis*, *B. constrictus* and *Microcerotermes crassus*.

The northern zone of the rain forest contains some species that are common in the actively regenerating secondary forests of the Central Catchment Nature Reserves (Murphy, 1997). These include the gallery-forming *Microcerotermes* and *Nasutitermes,* which are actively involved in the self-pruning of younger trees, and the wood-feeding *Bulbitermes*. However, unlike the nature reserves, the nest of *Bulbitermes* was not found. Murphy (1997) reported the widespread occurrence of *Macrotermes* and *Odontotermes* in the more established secondary forests and the primary forests. This holds true for both genera in the northern and central zones but not in the southern zone, which has very little ground timber. Separate studies have been initiated to check whether the fallen timber in the northern zone are attacked by Kalotermitidae (dry wood termites) including species of *Cryptotermes, Glyptotermes* and *Neotermes*, which reportedly had a high incidence of attack in the nature reserves' secondary forests.

Eggleton *et al.* (1995) found that species diversity of termites was greatly reduced in severely disturbed plots of forests, but increased marginally in slightly disturbed regenerating plots. The different termite species diversity of the three zones of the rain forest reflects to a certain extent the different degrees to which the forest has been disturbed. The study of the forest vegetation also reveals that different parts of the forests differ in their structure and regeneration. For instance, much of the northern zone of the forest has high forest species of *Calophyllum* and *Garcinia* (Guttiferae) and *Syzygium* (Myrtaceae), which are common in established secondary forests (Wong *et al.*, 1994). Other than having a large gap caused by trees struck by lightning, and an adjacent patch with a large number of small trees and rapid turnover of saplings, the northern zone is not much disturbed in most parts. This could account for its relatively high termite diversity. In contrast, the central and southern parts of the forest which have lower mature tree populations but contain more specimens of the larger sized trees e.g. dipterocarps, are much more disturbed. Here the faunal diversity, forest structure and tree regeneration are clearly affected by the rampant growth of climbers, dense undergrowth of herbs and ornamentals, and large spaces created by paved roads criss-crossing the forest, the encroachment of buildings and horticultural facilities and the proximity of the forest to public roads. The three zones were markedly different in the amount of space utilised for human activities. Assuming that plots of radius 10 m are drawn around each of the 15 or so transect points within each zone, the northern zone would have 7 plots trespassed mainly by 1.3m wide paths; whereas the central zone would have 9 plots trespassed by 2 m, 4 m and 6 m wide roads, while the southern zone would have 12 out of 14 plots depleted of floor space by 2 m, 4 m, 5.5 m and 6 m wide roads, as well as by a gazebo and potting yard.

In conclusion, the reduction of space depletion of this rain forest and removal of the herbaceous undergrowth and the tree-smothering climbers will do much to minimise the loss of its termite species.

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