Abundance, Distribution, and Colony Size Estimates for *Reticulitermes* spp. (Isoptera: Rhinotermitidae) in Southern Mississippi[1]

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ABSTRACT

Environ. Entomol. 11: 1290–1293 (1982)

A census of 24 1-ha plots indicated an average abundance per ha of 4.42 colonies of *Reticulitermes flavipes* (Kollar) and 2.38 colonies of *R. virginicus* (Banks). Nearest neighbor analysis indicated the mean distance between colonies of *R. flavipes* to be 22.48 m, between colonies of *R. virginicus* to be 26.19 m, and between colonies, irrespective of species, to be 16.80 m. Six *R. flavipes* colonies were selected by a ranked-set sampling method, and the mean colony size was estimated to be 244,445 termites.

Reticulitermes flavipes (Kollar) and *R. virginicus* (Banks) are important economic pests, yet little pertinent research of an ecological nature has been conducted. This perhaps reflects the long-standing availability of highly effective termiticidal soil treatments which place a chemical barrier between the wooden commodity (home) and the termite colony. Newer control techniques now being developed, however, are designed to treat specific, individual colonies; consequently, better knowledge of termite ecology is needed.

We recently initiated research on the biology, demography, and field ecology of *Reticulitermes* spp. in southern Mississippi. We have described the abundance of soldiers and reproductives, sex ratio of reproductives, association of soldiers with reproductives in *R. flavipes* (Howard and Haverty 1980), and seasonal variation in caste proportions of *R. flavipes* field colonies (Howard and Haverty 1981). Here we report on the abundance and distribution of *R. flavipes* and *R. virginicus* colonies, and on the mean number of termites in mature colonies of *R. flavipes*, i.e., colonies in the reproductive stage of their life cycle (Oster and Wilson 1978).

Materials and Methods

Estimation of Colony Abundance and Distribution

In August 1980, a total of 104 contiguous plots (100 by 100 m; 1 ha) in the Desoto National Forest, ca. 20 km north of Gulfport, Miss., was surveyed, and their boundaries were marked. The site consists of gently rolling hills (ca. 15- to 30-m elevation) covered with a stand of predominately 50- to 60-year-old naturally regenerated longleaf pine (*Pinus palustris* Mill.) with some slash pine (*P. elliottii* Engelm. var. *Elliottii*) at the lower elevations. The dominant understory consists of gallberry (*Ilex glabra* L.), Yaupon (*I. vomitoria* Ait.) and dogwood (*Cornus florida* L.). The area was control burned ca. 3 years before this study.

In November 1980, four representative blocks of six 1-ha plots were selected and exhaustively examined for dead logs, standing or lying on the ground, which measured 10 cm or more in diameter at their greatest breadth. The locations and dimensions of these logs were plotted on a topographical map. With a hand axe as a sampling tool, the presence or absence of termites, by species, was noted for all logs. All logs were disturbed as nearly alike as possible. Logs containing conspecific termites and separated by at least 15 m were assumed to represent separate termite colonies. These data were analyzed to estimate mean number of termite colonies, by species, and nearest-neighboring logs containing termites, by species. Summary statistics were calculated by plot, as well as the dispersion coefficient "a," using the formula of Wood and Lee (1971): $a = m\bar{r}^2$, where m = density of logs with termites per m^2, and $\bar{r}$ = mean distance (m) between pairs of nearest neighbor logs containing termites. Distance measurements were made from midpoint of log 1 to the midpoint of log 2.

Estimation of Number of Termites in a Mature R. flavipes Colony

In March 1981, four 10-m-wide transects 100 m apart along the north-south axis of the study site and four along the east-west axis were examined for logs exceeding 10 cm in diameter. Logs containing mature *R. flavipes* colonies (as evidenced by large numbers of either long wing-pad nymphs or callow alates) were noted and given an identification number. A total of 18 such colonies was identified. Six were selected for sampling by a ranked-set sampling method (Dell and Clutter 1972). This involved randomly choosing six sets, each containing three colonies, and ranking the colonies within each set by estimated size as small, medium, or large. The ranking of each of the three colonies within a set was done on the same day, to facilitate visual comparisons of termite numbers. The estimated largest colonies in two sets then were designated as sampling units. The medium sized colonies in a second two sets were designated as sampling units, and in the remaining two sets the smallest colonies were designated as sampling units.

Each colony was sampled as follows. A trench (30 cm wide by 122 cm deep) was dug with a tractor-mounted backhoe at a radius of ca. 20 m completely around the colony site to constrain both emigration of the colony's foraging population and immigration of termites from other colonies. The log and associated stump were assumed to constitute the epicenter of the colony. Any logs or other large cellulose debris without termites were

[1]Received for publication 19 March 1982.

placed outside the trench. As the trench was dug, the log portion of the colony was sawed into ca. 25-cm lengths, and each was examined for termites. Segments containing termites were placed in sequence into garbage cans and taken to the laboratory. Segments without termites were removed from the site. The stump and taproot associated with the log then were extracted from the soil by severing lateral roots with an axe and digging out the stump/taproot with the tractor-mounted backhoe. This wood was sawed into ca. 25-cm segments and processed as above.

To sample termites remaining in the soil, a double layer of corrugated cardboard, 60 cm wide by 2 cm deep, was laid on the ground covering the previous site of the log and stump. The cardboard then was moistened and covered with black polyethylene plastic and held in place with small amounts of soil at the edges. One to 3 weeks later, the cardboard was examined for termites, and penetration sites were noted. The cardboard from each penetration site was taken to the laboratory. Uninfested cardboard was discarded. Fresh sections of cardboard, 60 cm wide by 5 cm thick, were placed over only the active infestation sites, covered with black plastic, and completely buried with soil. This cardboard was examined weekly and replaced with new cardboard until termite infestation either ceased or declined to negligible levels (500 or fewer termites). The logs and stump/taproots were sampled from 23 March to 12 April 1981; the cardboard was sampled from 16 April to 12 June.

Termites were exhaustively extracted by splitting the wood along growth rings or by pulling layers of cardboard apart. Extraneous debris was removed and the termites from each garbage can were weighed. Representative subsamples (n = 3 to 16) from each colony then were reweighed and counted. The resulting average numbers of termites per gram were used to estimate the numbers of termites in each colony. Summary statistics were computed for the six colonies.

Results

A general overview of the topography and subdivision of the study site is shown in Fig. 1. The mean number of logs containing *R. flavipes* and *R. virginicus* per ha was 4.42 ± 0.43 ($\bar{x}$ ± SE) and 2.38 ± 0.29, respectively. The mean nearest neighbor distance for *R. flavipes* colonies was 22.48 ± 3.09 m, for *R. virginicus* colonies 26.19 ± 6.51 m, and for *Reticulitermes* spp. 16.73 ± 1.05 m. The mean dispersion coefficient was 0.19. An average mature *R. flavipes* colony was found to contain 244,445 ± 53,156 termites (Table 1). All colonies examined contained numerous neotenic reproductives either in the log or stump/taproot. No primary reproductive was found. In four colonies, alates flew before the colonies were sampled. The remaining two colonies contained alates in the log or stump/taproot at the time of sampling. In one colony, the alates represented ca. 8% of the colony's population. In the other colony, alates began flying in the laboratory before they could be extracted and an accurate assessment of their numbers therefore was not possible. Workers, small wingpad nymphs, and soldiers were the only castes recovered from the cardboard baits. The logs and stump/taproots contained eggs, larvae, workers, nymphs, soldiers, alates, and neotenic reproductives.

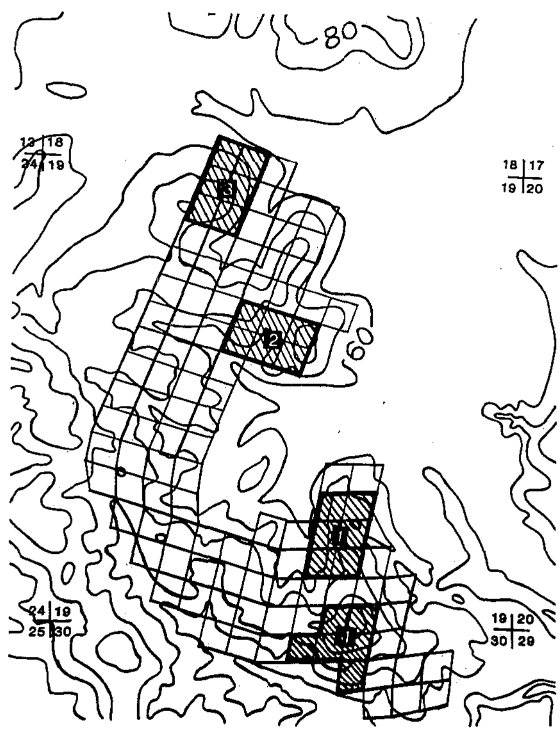

FIG. 1.—Aerial photograph of surveyed study site with topographical overlay. The four outlined and shaded blocks each contain six 1-ha plots.

Discussion

Understanding the role of subterranean termites in forest ecosystems requires accurate information on their density and spatial distribution. Unfortunately, *Reticulitermes* spp., like other subterranean termites, are cryptic. Rather than building well-defined nests, they inhabit diffuse, multicompartmental "nests" distributed between the soil and a substantial mass of wood (Howard and Haverty 1981). In this study we assume that the log/stump/taproot complex constitutes the epicenter of a termite colony. Prior experience indicates that the actual proportion of termites to be found in the wood, rather than in the soil, is a function of a complex of variables. Temperature, soil type, moisture, and season apparently are the most important. Our sampling times (early fall and midspring) were chosen to maximize the probability of finding the bulk of the colony in the wood rather than in the soil.

Slightly more *R. flavipes* than *R. virginicus* colonies occurred within each of the four blocks (a range of 3.67–5.67 for *R. flavipes* and 1.67–3.00 for *R. virginicus*), and their number within any given ha was rather variable. To test the hypothesis that the colonies were nonrandomly distributed, we calculated the coefficient of

Table 1.—Estimated number of termites in mature *R. flavipes* colonies

Colony	Rating[a]	Estimated No. of termites in[b]: Log	Stump/taproot	Soil[c]	Total
18	Large	348,785	13,801	926	363,512
21	Medium	61,412	220,381	1,025	282,818
39	Small	46,580	4,925	0	51,505
45	Large	211,995	13,693	107,477	333,165
46	Small	244,617	47,233	32,295	324,145
49	Medium	107,274	3,975	278	111,527
Mean ± SEM					244,445 ± 53,156

[a]Qualitative estimate of colony size used for ranked-set sampling assignments.
[b]Representative subsamples were weighed and counted, and estimated numbers then based on total weights of termites from each colony.
[c]Numbers of termites in the cardboard traps.

dispersion, "a" (Clark and Evans 1954, Lee and Wood 1971). The value of this coefficient can range from a theoretical minimum of zero if all colonies are aggregated into a single mass to a maximum of 1.158 if all colonies are situated at the corners of a network of regular hexagons. A completely random distribution of colonies would result in a coefficient of dispersion of 0.25. Thus, values less than 0.25 suggest an aggregation of colonies, and values greater than 0.25 suggest an overdispersion of colonies. Clearly, our data (a = 0.14 to a = 0.22) support the hypothesis of a nonrandom aggregating of the *Reticulitermes* spp. colonies. *R. flavipes* appears to be more prevalent at the higher sites, whereas *R. virginicus* is more prevalent at the lower sites. This distribution is perhaps related to the higher moisture requirements of *R. virginicus* (Collins 1969). The soil at lower sites in the study area usually contains more moisture than soil at the higher elevations. Other site factors also may influence the distribution of these termite species.

Reliable estimates of the number of termites in a colony are difficult to obtain (Baroni-Urbani et al. 1978, Lee and Wood 1971), even for the conspicuous mound-building species. Basically, two approaches have been tried: total colony sampling and mark-recapture estimation (Baroni-Urbani et al. 1978). Both present serious problems but have been widely used because better alternatives are not available.

We initially have chosen to address the question of the number of termites in a mature *R. flavipes* colony by a total colony-sampling protocol. Ranked-set sampling provides a relatively unbiased sample of colony sizes. Thus, the resulting mean population estimate for an "average" colony also should be relatively unbiased. Clearly, it would be desirable to sample additional colonies. Money, time, and labor constraints on this type of sampling, however, preclude such an approach. Although the range of values obtained for the smallest to the largest colony (Table 1) covers a factor of 7, the SE of the mean for all six colonies is fairly low (ca. 20%).

Variation occurred in the number of termites recovered from the cardboard traps (Table 1). However, *Reticulitermes* spp. are known for their mobility with changing environmental and seasonal parameters. Colonies 18, 21, and 39 were initially sampled during the last half of March when the daily mean air temperatures were moderate (11.7 to 24.5°C) and the soil surface was moist. Also, alate flights occurred during this time period. These factors combine to maximize the proportion of the colony expected to be in the log and stump/taproot rather than in the soil. Accordingly, small numbers of termites in these colonies were recovered from the soil. The remaining three colonies (45, 46, and 49) were sampled in late April to early May after the alate flights had occurred and during a period of increasing daily mean air temperature (15.7–31.3°C) and decreasing surface soil moisture. The combination of these factors should lessen the proportion of the colony in the wood and increase that in the soil (Howard and Haverty 1981), the substantial numbers of termites were recovered in the cardboard traps of colonies 45 and 46. Furthermore, the number of termites trapped each week in all colonies increased to a maximum and then declined to negligible quantities by the last 3 weeks of sampling.

About 1 month after the log and stump/taproot were removed from each site, we inspected the walls of the trench for evidence of termite shelter tubes. Colonies 18, 39, 45, and 46 had a few shelter tubes evident ca. 10 to 20 cm below the top of the trench, extending at most 5 to 10 cm along the inside face of the trench. No tube ever crossed the bottom of the trench, nor did any shelter tube from the outside face of the trench cross the bottom. This suggests that the trench served as an effective barrier to termite immigration and emigration, although termite galleries below the trench would remain undetected. Colonies 21 and 49 contained no tubes on the surface walls of their trenches. All trenches contained numerous shelter tubes of *Solenopsis* spp. ("fire ants") that extended down and across both faces of the trenches. None of these shelter tubes, however, intersected the shelter tubes of termites.

Our quantitative findings of this study support our qualitative impressions of prior years: *R. flavipes* is the dominant species (at least in number of colonies per ha) in this area and tends to occupy the higher, more arid sites. A rough estimate of total population can be made with the data from this study. Given that *R. flavipes* colonies occur at a density of ca. 4.42 colonies per ha with an average colony size of ca. 244,445 termites, then our plots contain ca. 108 termites per m^2. This value may be compared with Lee and Wood's (1971) estimate of subterranean termite abundances in arid and semi-arid habitats in Australia (12–2,000 termites per m^2) and their summary of subterranean termite abundance estimates in various forest habitats (12–4,450 termites per m^2) (see p. 70 and Table 6 in Lee and Wood [1971]). Whitford and Gentry (personal communication) recently estimated the density of *Reticulitermes* spp. on four habitats in South Carolina. A recently control-burned pine habitat had 1,300 termites per m^2, an unburned pine plantation and lowland hardwood had 260 and 220 termites per m^2, respectively, and a turkey oak woodland had 6 termites per m^2. All estimates were obtained using different sampling techniques. Esenther (1980) recently estimated the population size of colonies of *R. flavipes* in Janesville, Wis., using a simple Lincoln index mark-recapture technique. He estimated the populations of two colonies to be 325,600 ± 153,100 and 1,135,600 ± 736,400 ($\bar{x}$ ± SD). He reported that five additional colonies constituted a single multicolonial complex whose members freely intermingled, and estimated that it contained 9,516,300 ± 4,255,800 termites. As noted by Brian (1965) and Baroni-Urbani et al. (1978), however, social insect populations seldom, if ever, fulfill the basic assumptions of the mark-recapture method, thus rendering Esenther's population estimates suspect.

We have no quantitative estimates of the number of termites in a mature *R. virginicus* colony. It is our impression, however, after collecting this species for several years, that its colonies are somewhat large than those of *R. flavipes*. Future experiments will be required to test this impression, and to confirm the other estimates and underlying assumptions made in this paper.

REFERENCES CITED

Baroni-Urbani, C., G. Josens, and G. J. Peakin. 1978. Empirical data and demographic parameters, pp. 5–44. *In* M. V. Brian, [ed.], Production ecology of ants and termites. Cambridge University Press, Cambridge. 409 pp.

Brian, M. V. 1965. Social insect populations. Academic Press, Inc., New York. 135 pp.

Clark, P. J., and F. C. Evans. 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35: 445–453.

Collins, M. S. 1969. Water relations in termites, pp. 433–458. *In* K. Krishna and F. M. Weesner, [eds.], Biology of termites. Vol. 1. Academic Press, Inc., New York. 598 pp.

Dell, T. R., and J. L. Clutter. 1972. Ranked-set sampling theory with order statistics background. Biometrics 28: 545–555.

Esenther, G. R. 1980. Estimating the size of subterranean termite colonies by a release-recapture technique. Proc. 11th Annu. Meet. Int. Res. Group Wood Preserv. Working Group I: Biol. Problems, Document No. IRG/WP/1112. Raleigh, N.C. 4 pp.

Howard, R. W., and M. I. Haverty. 1980. Reproductives in mature colonies of *Reticulitermes flavipes*: abundance, sex-ratio, and association with soldiers. Environ. Entomol. 9: 458–460.

1981. Seasonal variation in caste proportions of field colonies of *Reticulitermes flavipes* (Kollar). Ibid. 10: 546–549.

Lee, K. E., and T. G. Wood. 1971. Termites and soils. Academic Press, Inc., New York. 251 pp.

Oster, G. F., and E. O. Wilson. 1978. Caste and ecology in the social insects. Princeton University Press, Princeton. 352 pp.

Wood, T. G., and K. E. Lee. 1971. Abundance of mounds and competition among colonies of some Australian termite species. Pedobiologia 11: 341–366.