EASTERN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE) FORAGING TERRITORIES AND POPULATIONS IN TORONTO

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Abstract

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A mark–release–recapture study was conducted with dye-marked eastern subterranean termites, *Reticulitermes flavipes* (Kollar), at two sites in metropolitan Toronto. Interconnected termite galleries were found to extend up to 79 m and to cover areas of 266 and 1091 m^2. Colony foraging populations at the two sites were estimated at 2.1 and 3.2 million termites. These foraging distances and population estimates exceed those reported for *R. flavipes* in other regions.

Résumé

Nous avons mené une étude basée sur la technique de marquage–relâchement–reprise, à l'aide de termites souterraines de l'est, *Reticulitermes flavipes* (Kollar), teints en rouge, à deux sites dans la métropole de Toronto. Des galeries communicantes de termites fut découvertes, pouvant s'étendre jusqu'à 79 m et pouvant couvrir des surfaces de 266 et de 1091 m^2. Les populations de colonies de fouragement des deux sites fut estimés à 2,1 et 3,2 millions de termites. Les évaluations de distances de fouragement et de populations surpassent celles rapportées pour *R. flavipes* dans d'autre régiones.

Introduction

The eastern subterranean termite, *Reticulitermes flavipes* (Kollar) (Isoptera: Rhinotermitidae), is an economically damaging species with a broad North American distribution. This species is found throughout the southeastern United States, north along the Atlantic coast into the state of Maine, and west along the southern shores of the Great Lakes (Weesner 1970). *Reticulitermes flavipes* was first reported in Ontario from Point Pelee (41°57′N, 82°31′W) in 1929 (Kirby 1965), and was found infesting a building in Toronto (43°42′N, 79°25′W) in 1938 (Urquhart 1953). To date, termite infestations have been reported in 28 southern Ontario municipalities (Cutten 1988), with Kincardine (44°11′N, 81°38′W) representing the northernmost site of established infestation.

The galleries of *Reticulitermes* spp. do not incorporate mounds or other nest structures that are separable from the surrounding soil matrix. This cryptic habit presents difficulties in studying demographics and foraging dynamics. Howard *et al.* (1982) used excavation to census *R. flavipes* colonies in rural Mississippi. However, destructive sampling precludes further study at the disturbed site, is not practical in most urban settings, and may lead to underestimation of colony populations due to the fragility of the insects and their gallery system (Darlington 1984; Su and Scheffrahn 1988). As an alternative to destructive sampling of termite colonies, Su *et al.* (1984) and Su and Scheffrahn (1988) combined wood baits with the use of a dietary dye to trace movements and estimate populations of foraging *Coptotermes formosanus* Shiraki. Esenther (1980) used a similar mark–recapture technique to estimate the population of several *R. flavipes* colonies in Wisconsin. We report here the results of a mark–release–recapture study to determine the foraging territories and estimate the forager populations of *R. flavipes* colonies at two urban sites in metropolitan Toronto.

Materials and Methods

In May and June 1988, white pine (*Pinus strobus* L.) stakes (ca. 1.5 by 4 by 15 cm) were installed at two sites to monitor feeding by *R. flavipes*. Each stake was sheathed in a single layer of single-faced corrugated paper (Dominion Corrugated Paper Inc., Toronto, Ont.) to provide harborage and increase the surface area available to foragers. Stakes were

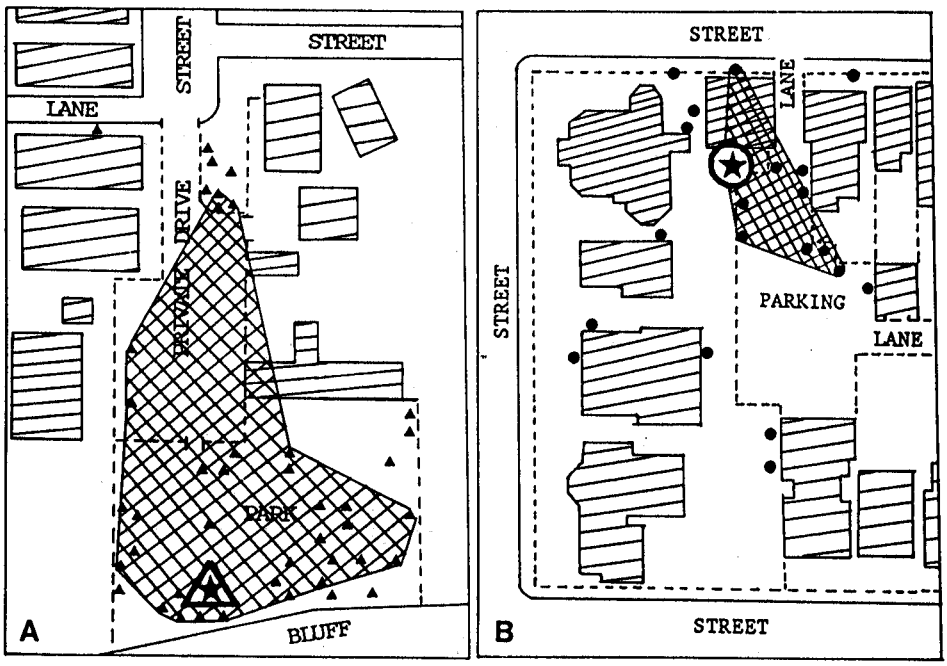

FIG. 1. *Reticulitermes flavipes* foraging territories (cross-hatched) at two sites (A and B) in metropolitan Toronto. Shaded objects are residential buildings. Solid triangles (site A) and circles (site B) indicate trap locations, and a star indicates the trap at each site where marked termites were released.

examined at 1- to 2-week intervals. Once termites were detected, the stake was replaced with a trap modified after Su and Scheffrahn (1986). The trap consisted of two 15-cm lengths of 4-cm-ID plastic (ABS) pipe, each containing a roll of single-faced corrugated paper moistened with deionized water. The pipes were placed side by side vertically within a 15-cm length of 10-cm-ID plastic pipe. The larger pipe was topped with a plastic pipe cap and buried vertically just below the soil surface. This formed a permanent trap installation, from which the inner pipes could be easily removed and replaced.

The mark–release–recapture study was conducted at two sites (Fig. 1). Site A was located on the Scarborough bluffs (43°44′N, 79°16′W) at the eastern end of metropolitan Toronto. This site had a gravel private drive and parking area, with a low-maintenance garden area at the north end. The drive led to a maple-canopied (*Acer negundo* L. and *A. platanoides* L.) unimproved park overlooking Lake Ontario. Stakes (1158) were spaced at 1-m intervals in grid patterns throughout the park and garden and a portion of the parking area. Where termite activity was observed, a total of 44 traps were installed. Traps were at least 2 m apart.

The second site (site B) was located centrally in the City of Toronto. This one-half block of semi-detached homes and small apartment buildings has a well-maintained lawn and was bisected by a paved laneway and parking area. As it was not practical to install a grid of stakes at this site, 461 stakes were placed at 2- to 3-m intervals along all fences, and around buildings, stumps, trees, and the edge of the parking area. Observed termite activity led to the installation of 21 traps. Residents and gardening staff at both sites were cooperative, and no traps were disturbed.

In the last week of July (site B) and first week of August (site A), termites were collected from all traps at both sites. The inner pipes, labeled by trap number, were removed from each trap and both ends sealed with plastic caps. In the laboratory, termites were

gently removed from the pipes and corrugated paper within 24 h, placed in plastic containers, and manually counted using a hand-held aspirator attached to a small vacuum pump. Each trap was assessed separately. The termites from the single trap at each site found to contain the largest number of termites were placed in separate plastic boxes in a dark cabinet at 27 ± 0.5°C and 90 ± 5% RH. These termites were fed filter paper impregnated with a 2% (weight/weight) concentration of the oil-soluble dye Fat Red 7B (Sigma Chemical Co., St. Louis, MO) for a period of 5 days. Under these conditions, the dye is clearly visible through the cuticle for 15 days and difficult to detect by 30 days. It is not passed in high enough concentration by either trophallaxis or cannibalism to be visible through the cuticle (Grace and Abdallay 1989).

Marked workers (90–92% of each group) and nymphs with short wing pads (8–10%) were then returned to the single trap at each site from which they had been collected. Because more termites were collected in the trap at site A than at site B, a larger number were released at site A (5000) than at site B (1800). Over the next 18 (site A) to 22 (site B) days, four successive collections were made from all traps at each site. The termites in each trap were counted, weighed, and examined visually for dye marking.

Foraging territories were mapped by the trap locations from which dyed termites were recovered. Forager populations were estimated by the Lincoln index method (Baroni-Urbani *et al.* 1978), which assumes that the proportion of marked individuals recovered is equivalent to the proportion of marked individuals released in the general population. Collections from the traps containing marked termites were summed and the foraging population estimated for each collection date, adjusting for marked individuals removed in earlier collections.

Results and Discussion

Dye-marked termites were recaptured up to 75 m from the trap where they were released at site A (Fig. 1). Trap locations from which marked individuals were recovered at this site indicated that *R. flavipes* foraging galleries extended over an area of 1091 m^2 (Table 1). At site B, traps were interconnected beneath the paved laneway and parking area and extended over an area of 266 m^2. The greater number of buildings (i.e. food resources) in close proximity at site B may reduce the need for lengthy foraging trails, or the spatial arrangement of concrete, pipes, and compacted soil at this more urbanized site may constrain termite excavation. Because marked termites were recovered at the margins of both sites, the actual termite foraging territories may exceed the measured areas.

Seven days elapsed between the release of dye-marked termites and the first recapture samples. However, most of the paper provided as food in the traps was completely consumed by this time, resulting in high inter-trap variability and a relatively small number of termites collected at either site. Subsequently, the interval between collections was reduced to 3–6 days, and 2- to 6-fold greater numbers of termites were recovered. Each trap contained between 318 and 5786 termites. In the course of the study, a total of 185 901 (site A) and 20 761 (site B) termites were collected from traps containing marked individuals.

Foraging *R. flavipes* populations were estimated from the last three recapture samples to be 3.2 ± 0.6 million at site A and 2.1 ± 0.3 million at site B (Table 1). These estimates are in the same range as those of Esenther (1980) in Wisconsin (0.3–9.5 million), but greatly exceed those of Howard *et al.* (1982) in Mississippi (0.05–0.4 million). By destructive sampling of termite-infested logs and excavation of the surrounding soil, these latter authors estimated the mean *R. flavipes* colony size to be 244 445 termites. However, their census was based on an assumption that logs separated by at least 15 m constituted separate termite colonies. In collecting *R. flavipes* for genetic analysis, Reilly (1987) assumed similarly that logs separated by 20 m represented separate colonies. These assumptions, and the estimate by Howard *et al.* (1982) of a 22.48-m mean distance between *R. flavipes*

Table 1. Foraging territories and populations of *Reticulitermes flavipes* colonies at two sites in metropolitan Toronto

Site	No. of traps	Foraging area (m^2)*	Maximum foraging distance (m)†	Foraging population (mean ± SE)‡	Individual weight (mg) (mean ± SE)§	Foraging biomass (kg)	Density of foragers (per m^2)
A	44	1091	79	3 187 538 ± 606 341	3.22 ± 0.05	10.26	2922
B	21	266	48	2 084 219 ± 323 049	3.14 ± 0.06	6.54	7835

*Area delimited by interconnected traps.
†Maximum linear distance between two connected traps.
‡Mean of Lincoln index estimations from last three collections at each site, adjusting for prior removal of marked individuals.
§Mean from weighing 20 groups of 10 workers per site.

colonies, were not valid at our study sites, where we found 48-m and 79-m linear foraging distances (Table 1).

Homogeneous distribution of marked individuals in the population is a critical assumption of mark–recapture methodology (Andrewartha 1961) that is difficult to confirm with cryptic social insects (Baroni-Urbani *et al.* 1978). As was observed by Su and Scheffrahn (1988), we can only draw conclusions concerning the *foraging* termite populations at our study sites, rather than total colony populations. In laboratory studies (Grace and Abdallay 1989), we have not observed any segregation of dye-marked termites that would lead us to suspect uneven mixing. Although Esenther (1980) based his mark–recapture estimates on one to five traps per site, we recovered marked termites from a larger number of broadly distributed traps at each site (Fig. 1). For example, 25–27 active traps were collected at site A on each sample date and 15–18 of these contained marked termites, suggesting that even mixing did occur.

Because of the labor-intensive nature of our sampling regime and the short period of warm weather and peak termite activity in Ontario in comparison with the southeastern United States, we used the "positive" method (Andrewartha 1961; Jackson 1939) of multiple recaptures from a single release rather than multiple releases of marked individuals. The 15% and 19% standard errors of our population estimates slightly exceeded those of Su and Scheffrahn (1988) using the latter methodology with *C. formosanus*. We are currently applying the multiple recapture method at other Ontario sites, and also are evaluating alternative dye markers suitable for simultaneous multiple releases of different-colored groups.

The southeastern United States, where *R. flavipes* and other *Reticulitermes* spp. are endemic, may be characterized by a high density of small termite colonies. Our results indicate that, at the northern limits of *R. flavipes* distribution, individual colonies, or "colony complexes" (Esenther 1980), can grow substantially larger and forage over greater areas. Limited introductions, possibly leading to a high degree of relatedness within Ontario termite populations, and suppression of alate flights in northern regions (Esenther 1969) may be contributing factors. Foraging behavior unique to northern *R. flavipes* such as the construction of shelter tubing on the exterior of trees also has been documented (Cooper and Grace 1987).

In terms of termite biomass and spatial density of foragers (Table 1), the impact on a given site of many small termite colonies and that of a few large colonies are probably equivalent. However, foraging by *R. flavipes* colonies over large territories has important implications for termite control. In an urban area such as metropolitan Toronto, more structures in the vicinity of discovered infestations are potentially at risk than was previously thought. Although municipal records indicated that buildings at both of our study sites had undergone perimeter termiticide treatments, large termite populations persisted in the surrounding soil. With respect to the possibility of using baits to eradicate termite colonies (cf. Ostaff and Gray 1975), our results suggest that a small number of baits might be sufficient to distribute a toxic agent throughout a large *R. flavipes* foraging population. As bait methodology would rely upon the foragers to introduce the toxicant to the termite colony, this technique would be more difficult to implement at a site containing numerous unconnected foraging groups.

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