Foraging Populations and Territories of the Eastern Subterranean Termite (Isoptera: Rhinotermitidae) in Southeastern Florida

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ABSTRACT Foraging populations of colonies of the eastern subterranean termite, *Reticulitermes flavipes* (Kollar), were surveyed in residential and undeveloped environments of southeastern Florida. A triple mark–recapture program using the dye marker Nile Blue A indicated foraging populations of *R. flavipes* contain ≈0.2–5.0 million termites per colony, and the foraging territories encompass an area of up to 2,361 m^2 and a linear foraging distance of 71 m. Habitat type was not correlated with foraging population size.

KEY WORDS *Reticulitermes flavipes*, foraging, territories

IN MANY NATIVE forests of North America, the subterranean termites, *Reticulitermes* spp., are important decomposers of fallen trees and other dead, woody accumulations (La Fage & Nutting 1978). When this cellulosic debris is cleared from the soil surface for commercial development, the subterranean termites continue to seek cellulosic resources, including those supplied by man. The eastern subterranean termite, *Reticulitermes flavipes* (Kollar), is known to forage in soil of both undeveloped lands and residential areas. Howard et al. (1982) excavated logs infested by *R. flavipes* in forest land and indicated that the foraging populations consisted of ≈100,000 individuals per colony. Although the direct excavation method has been employed to study foraging territories of subterranean termites (Ratcliffe & Greaves 1940, King & Spink 1969, Howard et al. 1982), it is not suitable for studying *Reticulitermes* spp. in densely populated urban environments.

A mark–recapture method using dye markers can delineate foraging territories only where termites can be collected or observed. Because only portions of a colony population actively forage, the mark–recapture results provide an estimate of the numbers of foraging individuals rather than of the entire colony (Ayre 1962). Despite these shortcomings, the mark–recapture method remains the only viable approach in many circumstances (Baroni-Urbani et al. 1978), including studies of the cryptic populations of subterranean termites.

Lai et al. (1983) first suggested that the oil-soluble dye Sudan Red 7B was a suitable marker for population studies of the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. Sudan Red 7B has been used to estimate foraging populations and to study the cryptic foraging territories of *C. formosanus* in southeastern Florida (Su & Scheffrahn 1988), *R. flavipes* in metropolitan Toronto (Grace et al. 1989, Grace 1990), and *Heterotermes aureus* (Snyder) in Arizona (Jones 1990).

Sudan Red 7B caused unacceptably high mortality of *R. flavipes* at high concentrations and was visibly retained for <2 wk when sublethal doses were used (Su et al. 1988). Because of the large standard errors inherent in the Lincoln index estimate, a weighted mean model with a multiple mark–recapture procedure (Begon 1979) was adopted to improve the accuracy of the estimates of foraging populations (Su & Scheffrahn 1988). The procedure requires a marker that exhibits minimum lethal effects yet is visibly retained by termites long enough (ideally 4–8 wk) to complete several (≥3) mark–recapture cycles. A dye, Nile Blue A, was found to possess these characteristics for both *R. flavipes* and *C. formosanus* based on a laboratory screening study (Su et al. 1991).

In previous reports, the direct count of excavated colonies of *R. flavipes* in forest land in Mississippi (Howard et al. 1982) was approximately one-tenth the mark–recapture estimate reported by Grace et al. (1989) in a residential area in Toronto. Although this discrepancy may be attributed to the methodology used in these studies, a recent mark–recapture study conducted in undeveloped land in northern Florida suggested smaller (≈100,000 termites per colony) *Reticulitermes* colonies (F. H. Oi & N.-Y.S., unpublished data). These results suggested that habitats may influence the population sizes of these subterranean termites. We initiated this study to survey the populations of *R. flavipes* in undeveloped lands and residential areas of southeastern Florida.

Materials and Methods

Surveys were done in three sites each of undeveloped lands and residential areas. Colonies of undeveloped sites were located in recreational forest lands in Broward County, FL. These habitats were characterized as tropical hardwood hammocks, dominated primarily by live oak, *Quercus virginiana* Michaux, with scattered ficus, *Ficus laevigata* Vahl., and royal palm, *Roystonea elata* Harper, grading into swamp associations in the wetter areas dominated by red maple, *Acer rubrum* L., and bald cypress, *Taxodium distichum* (L.) Rich. The lands were subjected to occasional flooding. Subterranean termites, *Reticulitermes* spp., were often found feeding on dead standing trees or on logs and branches on the ground.

Three residential sites near buildings with previous histories of *R. flavipes* infestations were also chosen for this study. Activity by colony IV was first noticed in 1988 when a door of a nearby building was damaged. Termites of colony V have infested a high-rise since 1989 despite numerous soil termiticide treatments. Both colonies IV and V were located in Broward County. Foragers of colony VI were observed near a structure in Palm Beach County, FL. The townhouse complex was built in 1987 and has been treated at least twice (1990 and 1991) with soil termiticide by a pest control firm. Spring-swarming alates from colony VI have been reported by residents annually from 1988 to 1991.

Wooden stake surveys (Su & Scheffrahn 1988) were conducted in all field sites. Monitoring stakes (*Picea* sp., 2.5 by 4.0 by 28 cm) were driven into soil adjacent to fallen logs (undeveloped sites) or among buildings (residential sites) with *R. flavipes* activity and were examined monthly. Infested stakes were replaced by underground monitoring stations that included wooden (*Picea* sp.) blocks surrounded by a plastic collar (17 cm outside diameter, 15 cm high) as described by Su & Scheffrahn (1986). These blocks were composed of 10 wooden boards (four boards [2.0 by 6.0 by 12.5 cm] encircling six boards [0.5 by 6.0 by 12.5 cm] nailed together). The six thinner boards were separated by wooden applicator sticks (2 mm diameter) as spacers to maximize the surface area available to foraging termites.

After the establishment of ≥5 monitoring stations for each colony, a triple mark–recapture program (Su & Scheffrahn 1988) was used to estimate the foraging territory and population size. For each termite collection, mean body weight of termite workers was determined by weighing five groups of 10 individuals each. Numbers of collected workers were determined by the total weight of collected workers and the mean worker weight. *R. flavipes* workers collected from a station with heavy activity (>2,000 termites collected) were stained with 0.05% (wt/wt) Nile Blue A (Su et al. 1991) by a no-choice feeding of stained filter paper disks (Whatman No. 1, 9.0 cm diameter) for 3 d before being released back to the same station. During the 3-d staining period, ≈1% of *R. flavipes* workers did not stain, possibly because of pre-ecdysis fasting. Monitoring stations at each site were collected 1 wk after the release. Numbers of termites collected from stations containing marked termites were determined and again stained and released into their respective stations. The mark–release–recapture cycle was repeated three times at each colony. The numbers of marked and unmarked workers were recorded for each cycle. A weighted mean model (Begon 1979) was used to estimate the foraging populations (N) and associated standard error (SE):

$$N = (\Sigma M_i n_i)/[(\Sigma m_i)+1];$$

$$SE = N\sqrt{[1/(\Sigma m_i+1)]+[2/(\Sigma m_i+1)^2]+[6/(\Sigma m_i+1)^3]};$$

where for each ith cycle, ni is the number captured, mi is the number of marked individuals among captured termites, and Mi is the total number of marked individuals up to the ith cycle. Foraging territories of colonies, defined as the areas encompassed by interconnected stations, were determined by the presence of marked termites. Colonies I, II, and IV were surveyed in 1990; colonies III, V, and VI were surveyed in 1991.

Results and Discussion

Approximately 100–200 survey stakes were used for each site (denoted by × in Fig. 1). The stake survey extended beyond the areas illustrated in Fig. 1. Stakes that were not infested by termites and were not near the colony foraging territory were excluded from the figure. Of the 100–200 stakes placed in the ground, typically only 5–14 were infested by termites and were replaced with the underground monitoring stations (denoted by solid circles with identification numbers in Fig. 1).

The number of marked termites released, termites recaptured, and marked termites among recaptured termites during the triple mark–recapture procedure are listed in Table 1. One wk after the release, the initially marked termites were recaptured from most of the interconnected monitoring stations (Table 1; Fig. 1). Estimated foraging populations of three *R. flavipes* colonies in undeveloped lands ranged from ≈0.7 to 5.0 million termites per colony (Table 2). Population sizes of colonies I and III were virtually identi-

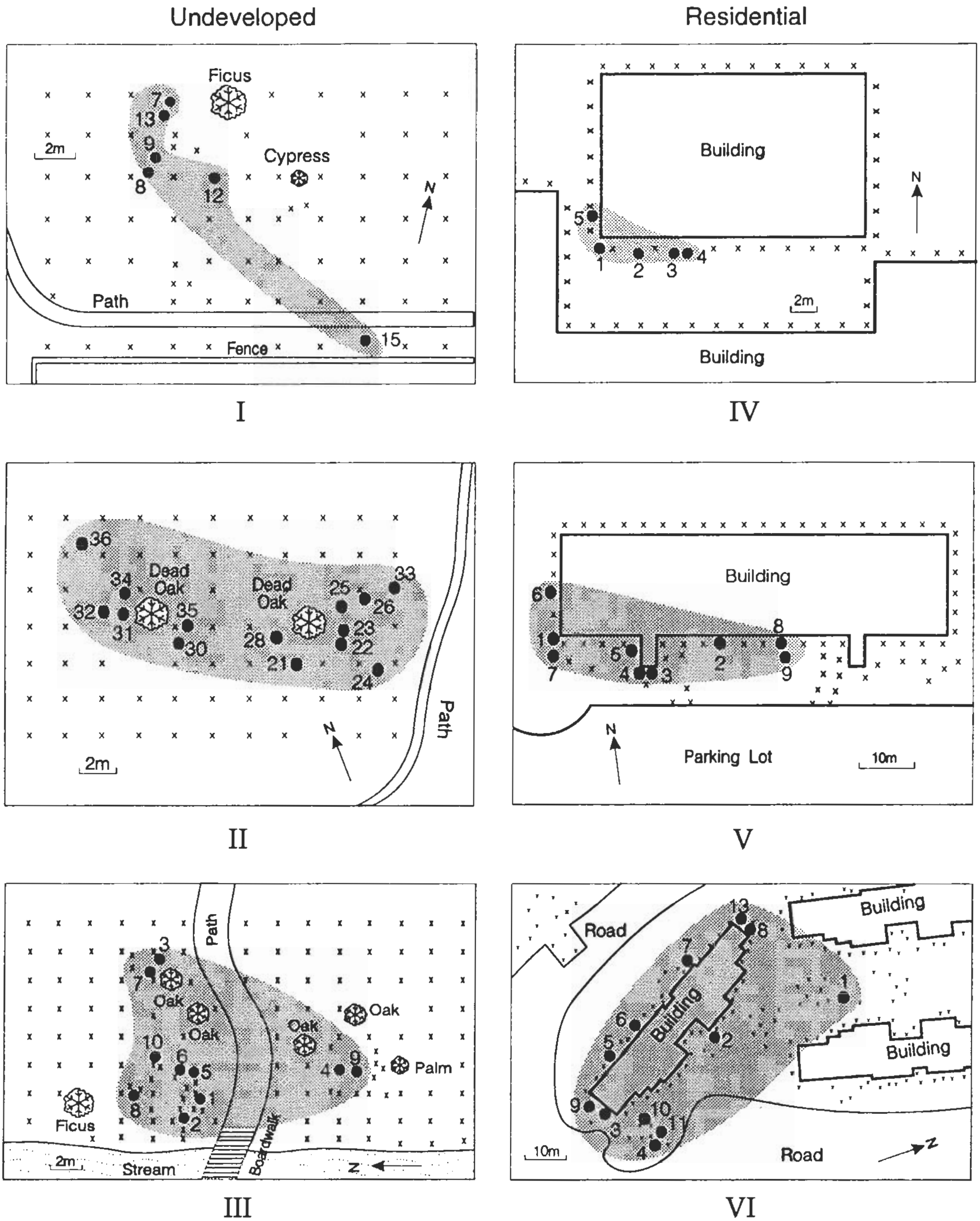

Fig. 1. Foraging territories (shaded areas) of *R. flavipes* colonies in undeveloped (I, II, and III) and residential (IV, V, and VI) areas. X denotes a survey stake; solid circle (with identification number) denotes an underground monitoring station with termite activity. Survey stakes without termite activity and not near the colony territory are not shown in the figure.

cal to those reported by Grace (1990), whereas that of colony VI was comparable to the estimates of Grace et al. (1989) in Toronto. Our data on colonies IV and V were within the range reported by Howard et al. (1982) in a Mississippi pine forest. The foraging population of colony II

Table 1. Number of marked termites released (*ri*), number of termites captured (*ni*), and number of marked termites among those captured (*mi*) during a triple mark–recapture program

Colony	*i*th mark–recapture	*ri*	*ni*	*mi*
I	1	12,687	8,666	250
		(9)	(8, 9, 12, 13)	
	2	8,646	16,893	203
		(8, 9, 12, 13)	(7, 8, 12, 13, 15)	
	3	14,292	21,505	1,222
		(7, 8, 12, 13, 15)	(7, 8, 9, 12, 13, 15)	
II	1	6,587	40,714	74
		(21)	(21, 22, 23, 24, 26, 30, 32, 33, 34)	
	2	40,027	76,572	885
		(21, 22, 23, 24, 26, 30, 32, 33, 34)	(21, 22, 23, 24, 25, 26, 28, 30, 31, 32, 33, 34, 35, 36)	
	3	74,550	61,309	1,276
		(21, 22, 23, 24, 25, 26, 28, 30, 31, 32, 33, 34, 35, 36)	(21, 22, 23, 25, 26, 28, 30, 32, 33, 34, 35, 36)	
III	1	14,264	52,190	636
		(2)	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)	
	2	48,037	8,949	1,084
		(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)	
	3	7,823	17,530	1,059
		(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)	
IV	1	10,216	43,397	1,079
		(3)	(1, 2, 3, 4, 5)	
	2	35,668	48,011	4,418
		(1, 2, 3, 4, 5)	(1, 2, 3, 4, 5)	
	3	44,249	33,211	5,846
		(1, 2, 3, 4, 5)	(1, 2, 3, 4, 5)	
V	1	2,338	19,289	239
		(5)	(1, 2, 3, 4, 5, 6, 7, 8, 9)	
	2	18,393	2,698	693
		(1, 2, 3, 4, 5, 6, 7, 8, 9)	(1, 2, 3, 4, 5, 6, 7, 8, 9)	
	3	2,381	10,886	1,068
		(1, 2, 3, 4, 5, 6, 7, 8, 9)	(1, 2, 3, 4, 5, 6, 7, 8, 9)	
VI	1	10,886	19,963	96
		(4)	(2, 3, 4, 5, 6, 8, 9, 10, 11)	
	2	19,853	38,578	529
		(2, 3, 4, 5, 6, 8, 9, 10, 11)	(1, 2, 3, 4, 5, 6, 7, 8, 9, 11)	
	3	34,539	49,998	1,000
		(1, 2, 3, 4, 5, 6, 7, 8, 9, 11)	(1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 13)	

Identification number of monitoring stations (see Fig. 1 for location) from which marked termites were captured and released are listed in parentheses.

(5.0 million) exceeded all previous estimates of *Reticulitermes* spp. colonies except those of Esenther (1980). Although the foraging territory of colony II was relatively small (108.5 m^2), two dead oak trees probably provided food and harborages to sustain the large population (Fig. 1). On several occasions when the land was flooded, termites of colony II were found above waterline in these standing dead oaks.

Table 2. Foraging populations, territory areas, and linear foraging distances of the eastern subterranean termite, in undeveloped or residential areas

Colony	Habitat	Foraging population ± SE	Foraging territory, m^2	Linear distance, m
I	Undeveloped	729,400 ± 17,827	28.7	15.1
II	Undeveloped	5,009,612 ± 105,989	108.5	17.6
III	Undeveloped	897,626 ± 17,030	147.7	14.5
IV	Residential	476,492 ± 4,474	18.0	7.3
V	Residential	170,832 ± 3,821	441.4	42.1
VI	Residential	2,848,698 ± 7,068	2,361.0	70.6

Foraging populations of three *R. flavipes* colonies surveyed in residential areas ranged from ≈0.2 to 2.9 million termites per colony (Table 2). Reinfestation by colony IV did not occur after 1988 when an infested door was removed and the door frame was spot-treated with insecticides. Termites from colony IV, however, continued foraging in soil adjacent to the nearby building (Fig. 1). Since 1989, repeated soil termiticide treatments (subslab injection, trenching, and rodding) have been performed to exclude infestations by populations of colony V. This population of ≈170,000 estimated foragers remained active at the southwest corner of the building in 1991 (Fig. 1). The foraging population of colony VI (≈2.8 million termites) covered an extensive territory (2,361 m^2) beneath and surrounding the two-story townhouse building (Fig. 1). The foraging population and territory size of colony VI were comparable to *R. flavipes* population estimates in metropolitan Toronto as reported by Grace et al. (1989).

The results indicated that colonies of *R. flavipes* may contain several hundred thousand to several million foragers in both undeveloped and residential environments. The magnitude of the *R. flavipes* populations from our results encompassed both those reported by Howard et al. (1982) in undisturbed forests (several hundred thousand per colony) and those reported by Grace et al. (1989) in urban residential areas (several million per colony). Although we surveyed only three colonies each from two distinctly different habitats, there was no apparent correlation of habitat type and foraging population size of *R. flavipes* (Table 2).

It should be noted, however, that the undeveloped land in southeastern Florida may not represent a true "undisturbed" habitat, because lands in this area were mostly reclaimed from the Everglades wetlands at the end of the last century. Foraging populations of *R. flavipes* in such a modified environment may differ from those in stable climax communities. Moreover, results of this study may represent only those of mature or large colonies because colonies of smaller population size (because of environmental constraints or colony age) may not be readily monitored by our survey method. Further studies are needed to compare foraging dynamics of subterranean termites in various environments. This information will enable us to understand pestiferous foraging behavior of subterranean termites in or near structures.

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