Foraging Territories of the Black-winged Subterranean Termite *Odontotermes formosanus* (Isoptera: Termitidae) in Southern China

by

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ABSTRACT

A mark-recapture study was conducted to characterize foraging distances and territories of four *O. formosanus* colonies located in Guangzhou, China. During the test period, the maximum foraging distances were 7.3 m, 35.0 m, 23.9 m and 4.2 m, while the foraging territories were 15.7 m^2, 367.9 m^2, 148.9 m^2 and 13.0 m^2. The maximum foraging distances for single observation days were 7.0 m, 26.6 m, 22.8 m and 4.0 m, while the territories were 14.1 m^2, 194.8 m^2, 137.2 m^2 and 6.8 m^2. These results could help to determine optimal monitoring station intervals and to formulate a management strategy against *O. formosanus*.

Keywords: *Odontotermes formosanus*, Mark-recapture, Foraging territories, Foraging distances.

INTRODUCTION

The black-winged subterranean termite, *Odontotermes formosanus* (Shiraki), is an important pest in China of agricultural crops, plantations, and forestry, and it endangers earthen dikes and dams (Huang *et al.* 2000). This species can build large subterranean cavities at a depth of 1-3m inside earthen dikes and dams, and its tunnel systems can cause water infiltration and even the collapse of dikes and dams (Liu *et al.* 1998). According to an investigation in 14 provinces in southern China, over 90% of river dikes and reservoir dams more than 15 years old have been damaged by this termite. There is a saying that "a small leak will destroy a great dam" to describe the impact of this termite (Li 1989; Hu *et al.* 2006). Information on the size of foraging territories of this

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subterranean termite, i.e. its 'foot print', is important to better understand its impact and to determine the effectiveness of control tactics.

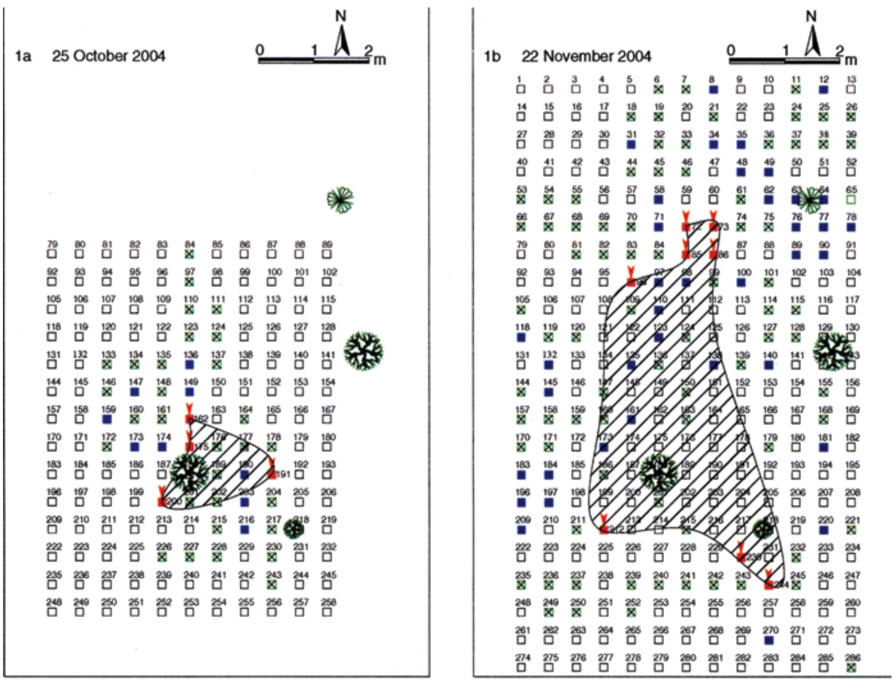
Previous studies based on radio isotopic tracing of the foraging territory of one *O. formosanus* colony showed that it encompassed an area of 238 m^2 (Li *et al.* 1981). However, this method has several limitations: (1) The label does not last long; (2) The termite has many natural enemies outside of the nest (e. g. *O. formosanus* has more than 30 species of predators which belong to 21 families [Zhang & Li 1982]), so it is difficult to distinguish between the radioactive markers of termites and natural enemies; (3) Radioisotope pollution.

An alternative method, the mark-release-recapture method, has been widely used to assess foraging population sizes and territories of subterranean termites, such as *Coptotermes* (Lai 1977; Su *et al.* 1984; Su & Scheffrahn 1988), *Reticulitermes* (Grace *et al.* 1989; Grace 1990; Su *et al.* 1993; Tsunoda *et al.* 1998), *Heterotermes* (Jones, 1990), *Microtermes* (Lee *et al.* 2003a) and *Globitermes* (Ngee & Lee 2002; Lee *et al*. 2003b). Although the mark-release-recapture method has its limitations in estimating foraging population sizes (Thorne *et al.* 1996; Forschler & Townsend 1996; Curtis & Waller 1997; Evans *et al.* 1998, 1999), this method is useful in determining foraging territories by linking stations with marked termites (Tsunoda *et al.* 1999; Zhong *et al.* 2005). It is hard to keep *O. formosanus* workers in the laboratory even for several days, hence marking termites first in the laboratory and then releasing them back into the field for estimating the colony foraging population sizes is difficult to impossible. Therefore, the objective of this study is to delineate foraging distances and territories of *O. formosanus* using a solely field-based mark-recapture method.

MATERIALS AND METHODS

Test colonies A, B, C were located on the campus of Sun Yat-Sen University (23°6" N, 113°17"E), and test colony D was located in South China Botanical Garden (23°11"N, 113°21"E), Guangzhou, China. Colony A was selected after a preliminary survey on 16 September 2004. Termites of *O. formosanus* were baited with pieces of eucalypt bark (*Eucalyptus exserta* F. V. Mull.) (20×5 cm) simply laid out on the soil surface. The point of highest termite activity was chosen as the initial marking station. On 20 September

2004 termites were offered eucalypt bark treated with 0.1% (wt: wt) of neutral red (SSS, Shanghai, China) water solution (Su *et al.* 1991). At the initial marking station (201, Fig. 1a) workers were visibly marked 7 – 10 days after feeding on dyed bark. Neutral red, a fat-stain marker, can be maintained in the field by workers for 15 – 30 days. Termite activity was monitored by using untreated eucalyptus bark as monitoring stations at which to collect marked termite workers. One end of the bark was pressed into the ground, the other end exposed on the ground to allow easy detection. Termites could be easily detected by the presence of shelter mud on the bark (Zhong & Liu 2003). 77 bait stations consisting of slices of eucalyptus bark were set at 0.5 m intervals on 23 October 2004, radiating out from the initial marking point to attract termites. We checked the stations once every 3 – 4 days, added 3 pieces of dyed bark to stations once marked workers were detected, and withdrew dyed bark if marked termites could not be detected again. This ensured that the study colonies were marked red continuously during the test period. The



Figs. 1a & 1b. Survey of monitoring stations for the estimation of foraging territories of *Odontotermes formosanus* (colony A) on the campus of Sun Yat-Sen University by a mark-recapture program in 2004-2005. Fig. 1a. 4 stations had marked termites on 25 October 2004. Fig. 1b. 8 stations had marked termites on 22 November 2004. Marking details shown on next page.

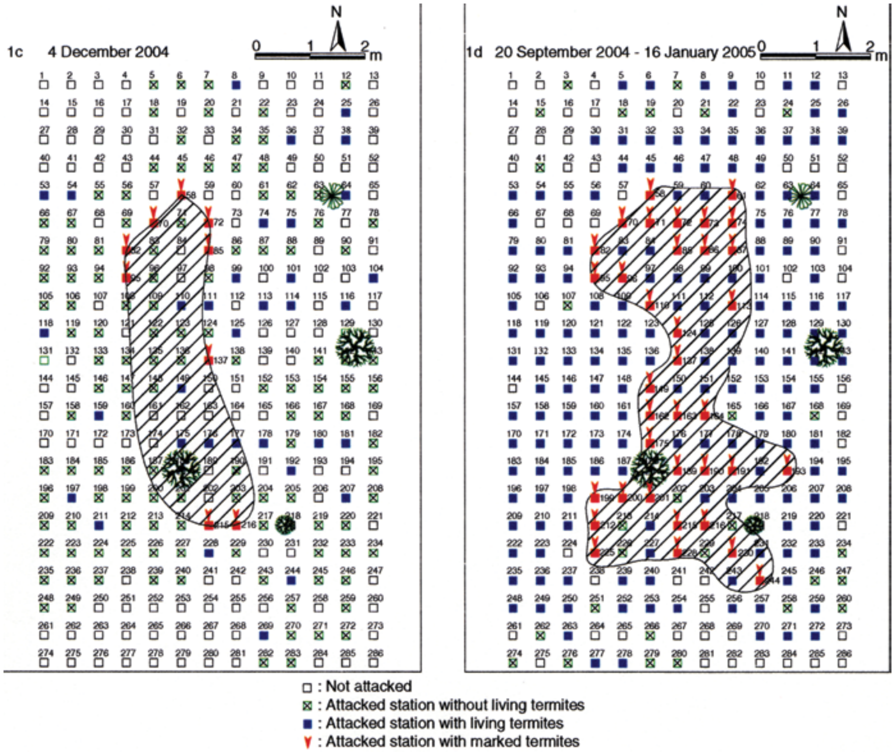


Fig. 1c . 9 stations had marked termites on 4 December 2004. Fig. 1d. Foraging territory of colony A (15.7 m^2) during the period from 20 September 2004 to 16 January 2005.

monitoring program of colony A ceased on 16 January 2005 because low temperatures depressed termite activity.

The colony B territory test program was conducted from 8 April to 13 July 2005 with the initial marking station (483, Fig. 2). Although location B was close to that of A, they were different colonies as worker body sizes differed greatly between the two colonies. Colony C was 510 m distant from colony A. The colony C territory test program was carried out from 20 April to 16 August 2005 (166, Fig. 3). Colony D was in a forest field more than 8 km away from colony A. The experiment with this colony was conducted from 19 April to 12 October 2005 (157, Fig. 4). For all colonies the same protocol was followed, except that for colonies B, C and D the monitoring station interval was 1 m.

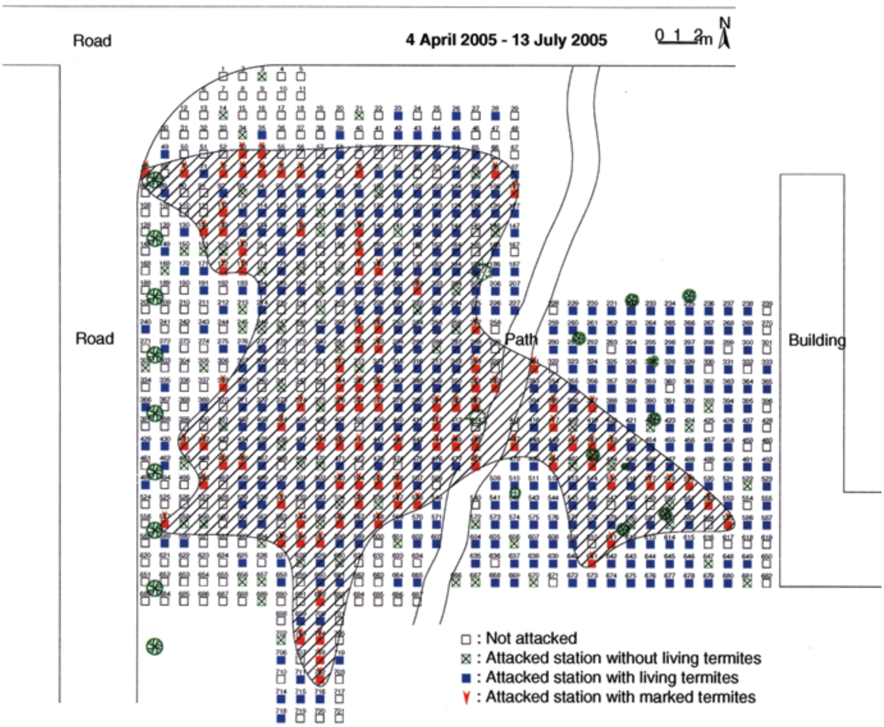


Fig. 2. Foraging territory of *Odontotermes formosanus* (colony B) (367.9 m^2) during the period from 8 April to 13 July 2005

RESULTS AND DISCUSSION

Colony A - Marked *O. formosanus* workers were detected in 4 stations on 25 October, 8 stations on 22 November and 9 stations on 4 December 2004. As the marked territories were shown to grow larger over time, more monitoring stations (n = 286) were placed from 20 November 2004 onwards (Fig. 1. a-d). Final results indicated that the foraging territory occupied an area of 15.7 m^2 (based on contact with 36 monitoring stations; Fig. 1). The maximum foraging distance was 7.3 m (between station 58 and 244) and the maximum foraging distance for single observation days was 7.0 m (between stations 61 and 244). The perimeter of area over which termites foraged was 23.6 m (Table 1).

Colony B - The foraging territory covered 67.9 m^2 (based on contact with

Table 1. Inspection results of four field colonies of *Odontotermes formosanus*

Colony	Date	No. of stations with marked termites	Maximum foraging distance, m	Foraging territory, m^2
A	20 Sep. 2004 – 16 Jan. 2005	36 (58, 61, 70, 71, 72, 73, 82, 85, 86, 87, 95, 96, 110, 113, 124, 137, 149, 162, 163, 164, 175, 189, 190, 191, 193, 199, 200, 201, 212, 215, 216, 217, 225, 228, 230, 244)	7.3 (between 58 and 244)	15.7
B	8 Apr. –13 Jul. 2005	97 (53, 54, 68, 70, 72, 73, 74, 75, 76, 79, 86, 107, 112, 131, 132, 136, 139, 153, 159, 172, 173, 179, 180, 202, 251, 252, 257, 282, 283, 312, 319, 321, 338, 344, 345, 346, 351, 352, 374, 376, 377, 378, 381, 382, 383, 385, 387, 404, 412, 417, 431, 432, 438, 439,440, 442, 444, 445, 446, 447, 450, 451, 452, 465, 466, 478, 481, 483, 496, 503, 504, 505, 506, 515, 517, 518, 519, 531, 535, 537, 538, 552, 557, 564, 566, 568, 585, 595, 596, 597, 611, 641, 672, 683, 684, 688, 692)	35.0 (between 68 and 585)	367.9
C	20 Apr. – 16 Aug. 2005	42 (41, 42, 47, 59, 100, 101, 103, 110, 111, 112, 115, 116, 133, 137, 147, 151, 153, 157, 158, 163, 166, 168, 169, 170, 171, 172, 181, 184, 185, 186, 208, 237, 238, 247, 255, 269, 298, 300, 304, 308, 314, 318)	23.9 (between 269 and 298)	148.9
D	19 Apr. – 12 Oct. 2005	10 (126, 141, 143, 144, 155, 156, 157, 170, 173, 174)	4.2 (between 126 and 174)	13.0
		Average	17.6	102.9
maxima for single observation days				
A	14 Nov. 2004	8 (61,73, 85, 86, 87, 212, 230, 244)	7.0 (between 61 and 244)	14.1
B	11 Jul. 2005	26 (68, 70, 72, 76, 79,112, 131,132, 173, 338, 377, 431, 432, 440, 465, 478, 496, 503, 531,535, 537, 538, 557, 568, 683, 688)	26.6 (between 68 and 688)	194.8
C	11 Jul. 2005	14 (41, 42, 59, 103, 110, 116, 159, 184, 185, 238, 247, 269, 304, 308)	22.8 (between 269 and 298)	137.2
D	25 Aug. 2005	5 (141, 156, 157, 170, 174)	4.2 (between 170 and 174)	6.8

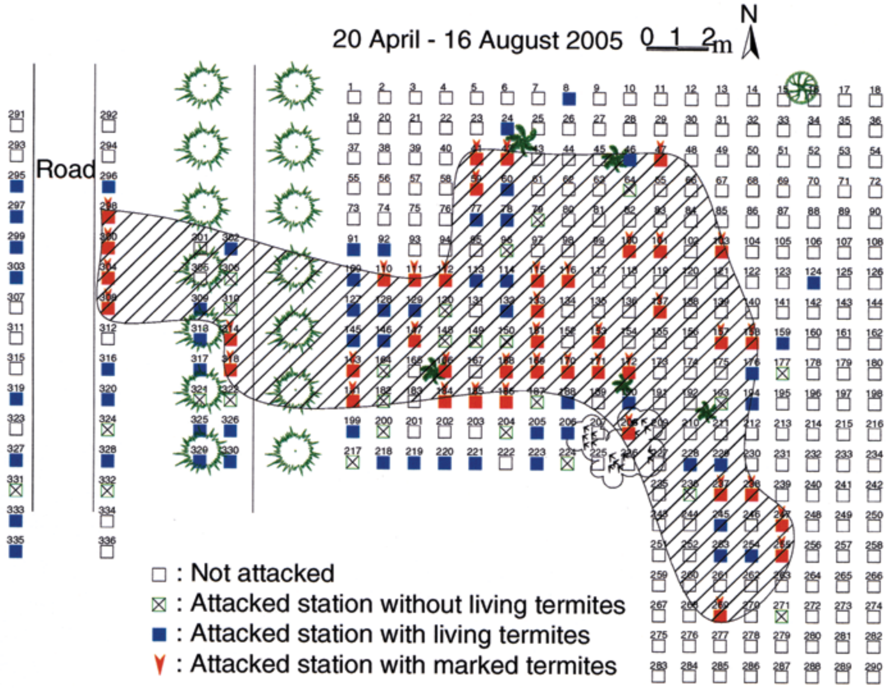


Fig. 3. Foraging terrirory of *Odontotermes formosanus* (colony C) (148.9 m^2) during the period from 20 April to 16 August 2005.

97 monitoring stations; Fig. 2). The maximum foraging distance was 35.0 m (between station 68 and 585) and the maximum foraging distance for single observation days was 26.6 m (between station 68 and 688, 11 July 2005). The perimeter of the foraging area amounted to 116.2 m (Fig. 2, Table. 1).

Colony C - The foraging territory encompassed an area of 148.9 m^2 (based on contact with 42 monitoring stations; Fig. 3). The maximum foraging distance was 23.9 m (between station 58 and 244) and the maximum foraging distance for single observation days was 22.8 m (between station 269 and 298, 11 July 2005). The perimeter of the foraging area was 70.1 m (Fig. 3, Table. 1).

Colony D - Foragers occupied a territory of 13.0 m^2 (based on contact with 10 monitoring stations; Fig. 4). The maximum foraging distance was 4.2 m (between station 126 and 174) and the maximum foraging distances

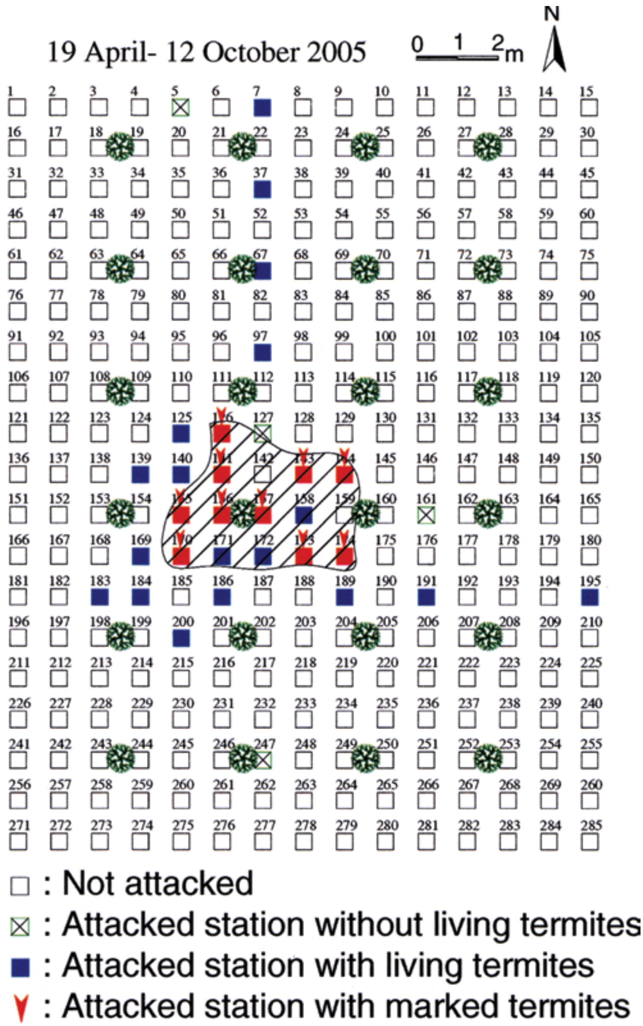


Fig. 3. Foraging terrirory of *Odontotermes formosanus* (colony D) (13.0 m^2) during the period from 19 April to 12 October 2005.

for single observation days was 4.0 m (between station 170 and 174). The perimeter of foraging movement was 14.8 m (Fig. 4, Table. 1).

The changes in foraging distances and territory sizes over time within the observation periods indicated the dynamic nature of foraging activity. It would appear that the foraging territory of an *O. formosanus* colony varies with seasons, having the farthest foraging distance and the largest territory in summer, but contracting in autumn, and decreasing to a minimum in the winter season, and expanding again in spring. Soil temperature (as a reflection of ambient temperature) has an important effect on subterranean termite activity.

Foraging territory size for different colonies depends on many factors, such as colony age and size, food resources, season and other environmental variables. We suggest that territories are mainly affected by colony age (size), as our observations showed that larger territories correlated with larger worker body size. The age of a colony can be roughly estimated by worker size.

In contrast to estimating foraging territories using radioisotopes, the mark-recapture method provided the furthest foraging distance of 35.0 m and the largest foraging territory of 368 m^2 of a single colony, which exceed the estimate of 16.0 m and 238 m^2 by Li et al (1981). Compared to other termite species, *O. formosanus* at our study sites foraged over moderate distances and had territory size of moderate proportions. For example, the distance was 10 m for *R. speratus* (Tsunoda *et al.* 1999), 10.5 m for *Microtermes pakistanicus* Ahmad (Lee *et al.* 2003a), 16 m for *G. sulphureus* (Ngee & Lee 2002; Lee *et al.* 2003b), 71 m for *R. flavipes* (Su *et al.* 1993), 100 m for *C. formosanus* (Lai, 1977), 120 m for *H. aureus* (Jones, 1990). Reported territories for other species are 31 – 54 m^2 for *M. pakistanicus* (Lee *et al.* 2003a), 43 – 62 m^2 for *G. sulphures* (Ngee & Lee 2002; Lee *et al.* 2003b), 57 m^2 for *R. speratus* (Tsunoda *et al.* 1999), 2,367 m^2 for *R. flavipes* (Su *et al.* 1993), 3,571 m^2 for *C. formosanus* (Su & Scheffrahn. 1988) and 3,762 m^2 for *H. aureus* (Jones, 1990). Generally, the greater the foraging distance, the larger is the foraging territory.

The large *O. formosanus* subterranean nests at a depth of 1 – 3 m endanger dikes and dams by allowing water influx when the water level is high. This softens the foundations and creates instability in dikes and dams. *O. formosanus* is the most serious pest among all dam-occupying termite species in Southern China. Annually, governments of China are spending hundreds of millions of dollars to control this species. Above all, the estimates of foraging territories are important in determining the spacing of termite monitor stations on dikes and dams. If the intervals are too large, termite activity can only be partially monitored. If the intervals are too small, the installation and monitoring cost will increase. The number of stations relates to the square of decreasing station intervals. In other words, if the station interval decreases by half, the number of monitoring stations required would increase fourfold.

The standard spacing of monitoring stations is based on the size of foraging territories. According to our results, the average territory of *O. formosanus* colonies was 103 m^2. We suggest that the spacing between *O. formosanus* monitoring stations should be 10 m. This could detect most termite colonies in dikes and dams, and hopefully improve the efficacy of control measures. This result would assist in termite management in Southeast Asian countries where dikes and dams suffer from *O. formosanus* infestation, although further research, such as finding means of estimating forager populations and the factors that influence the dynamics of foraging territories is required.

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