FEATURES OF A POPULATION OF THE FORMOSAN SUBTERRANEAN TERMITE, *COPTOTERMES FORMOSANUS*, ESTABLISHED IN SOUTHERN CALIFORNIA

DONALD A. REIERSON, M. K. RUST, T. H. ATKINSON, K. A. HAAGSMA, AND D. KELLUM[1]

Department of Entomology, University of California, Riverside, CA 92521, USA
[1]Dept. of Agriculture, County of San Diego, CA 92123

Abstract—A population of the Formosan subterranean termite, Coptotermes formosanus Shiraki, detected in February 1992, was determined to be well established within a limited residential area of La Mesa, San Diego County, California, U.S.A. The large size of workers and soldiers, and annual swarms of reproductives in the La Mesa population (LMP) indicate at least one mature colony. The LMP have been found in soil, trees, and structures. Apparently introduced in wooden articles transported from Hawaii approximately 10 years ago, worker caste of the LMP have only been detected within 75 metres of the suspected point of introduction. No significant structural damage attributable to *C. formosanus* has been found. Less than 4% of 700 ground monitor stakes in the LMP area have reflected termite activity. Maximum activity at any ground trap has been 892 workers, and 13.9 g wood consumed per month, significantly less than reported for most other *C. formosanus* sites. In dye-release-recapture studies of the LMP, no dyed individuals released at a monitor site were recaptured, suggesting at least two possibilities: a.) foraging may be affected by population size or environmental stress, or b.) the LMP may be an exceptionally large population in which the relatively few released dyed termites were assimilated into a large number of foragers. La Mesa may be drier than is optimal for this species, and may retard the rapid spread of the LMP. Conventional termiticide is being used to protect structures while plans for eradicating the LMP are being developed.

INTRODUCTION

The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, is one of the most economically important and potentially destructive termites in the world. Native to mainland China, *C. formosanus,* presently occurs in many coastal subtropical areas, having generally thought to have been transported via commerce. In the United States *C. formosanus* has been documented from Hawaii and at least seven southeastern states but, until it was found in San Diego, the reported population closest to California was in Houston, Texas, nearly 1450 km away.

C. formosanus was discovered in a residential area of La Mesa, near San Diego in southern California in February, 1992 (Atkinson et al., 1993). La Mesa is a suburban town approximately 15 miles southeast of downtown San Diego. After several attempts to control a chronic recurring termite problem at one residence, a local pest control operator collected specimens and sent them to us for identification. Confirmation of our identification of *C. formosanus* was made by Dr. Scheffrahn at the University of Florida.

Under ideal conditions introduced *C. formosanus* may develop to significant pest status within a few years, as has apparently been the case in some localities in Florida (Su and Scheffrahn, 1991). As reported by Su and Scheffrahn (1988b), matured colonies may contain 2 to 3 million termites and forage over expansive areas (Lai, 1977), can cause significant damage within six months, and can almost destroy a home within two years (Tamashiro, 1984). Structures may be protected from Coptotermes attack by pretreatment with sand, wire mesh, or termiticide barriers, and fumigant may be used to eliminate aerial colonies, but there is presently no consistently effective area-wide remedial treatment for Coptotermes available for commercial use in the United States.

Keeping in mind the destructive capability of *C. formosanus* elsewhere, and similarities and differences of environmental condition between Hawaii, coastal Florida and southern California, a study was undertaken to assess the extent of the Formosan subterranean termite population discovered in San Diego County and to develop potential strategies to eradicate it.

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METHODS AND MATERIALS

Ground monitoring

A thorough visual inspection was made of homes and the properties where *C. formosanus* was suspected, maps of the properties were prepared, and an intensive wooden stake monitoring system similar to that used by Su and Scheffrahn (1986, 1988a) was installed throughout the affected area. Oven-dried Douglas-fir foundation form board stakes (4 x 2 x 45 cm) were driven into the ground, leaving about 10 cm exposed. Stakes were placed every 5 or 6 feet in areas next to trees and shrubs, in flower and ivy beds, along the edges of lawns, along walkways and driveways, and within about two feet of building foundations. More than 900 stakes were installed on 16 properties. The entire monitoring system was in place by May. All stakes were removed and examined for termite activity monthly since July 1992. Broken or rotten stakes were replaced.

Permanent monitoring stations

Permanent stations (i.e. traps) were installed wherever subterranean termites were found at a monitor stake. The purpose of traps was to provide numbers of termites for laboratory and population estimate study. The termites were identified and a piece of PVC pipe (10.5 cm diam. x 13 cm) was slipped over the stake and tamped into the ground. The stake was removed and cut so that when replaced it protruded only slightly above ground level inside the pipe. A dampened pre-weighed wooden wafer block made of five pieces of Douglas-fir (7.5 x 9.0 x 0.6 cm) held apart with dabs of hot glue was placed inside the pipe. The wafers (about 130 g) could be removed later to determine feeding activity. The exposed end of the pipe was covered with a protective plastic cap sealed in place with plumber's putty.

The wooden wafer blocks were oven-dried at 200°C for 24 hours and weighed. Each block was numbered and rehydrated for use. Each trap was examined monthly when the monitor stakes were assessed. When termite activity was noted during an inspection time, the blocks were removed, placed in sealed plastic bags, and returned to the laboratory where the termites in them were extracted and counted. The wafers were pulled apart, cleaned, dried again for 24 hours, and weighed. The difference between the final and initial weight was presumed to be attributable to termite feeding.

Estimation of the size of the colony feeding within an area has been done by using a mark-release-recapture technique (Begon, 1979; Su and Scheffrahn, 1986, 1988a). Our most prolific permanent trap site was to be used to estimate colony size. Approximately 500 worker termites captured at the most active site were returned to the laboratory where they were allowed to feed 4 days on filter paper impregnated with 0.1% (wt/wt) Nile Blue stain. All the termites dyed noticeable blue. Except for a few individuals retained for a mortality check, all the dyed termites were released at the site of collection, and attempts were made to recapture them at that and surrounding traps one and two weeks later.

Alate traps

Major swarms of *C. formosanus* reportedly occur at night in May and June (Sponsler and Appel, 1990; Su and Scheffrahn, 1988b). The presence of reproductives indicates a mature colony.

Swarming alates were monitored in La Mesa in 1992 with yellow plastic sticky traps suspended from hanger wire near outdoor lights. Saturn yellow aphid traps made from 3-lb can lids lightly coated with Stick-em^{tm} were used as traps. Traps were placed near porchlights and other outdoor lighting of every home in the affected area, and at homes as far as 1000 ft (305 m) away. Up to three traps were used on each property. The alate traps were installed April 1 and were monitored by us or the property owners on a regular basis. Records were kept of visual sightings of swarms and these were eventually related to trap catch. Traps were replaced once Coptotermes were found on them.

Size and cuticular permeability

The mass of selected collected aliquots of live LMP were determined on a electrobalance. For comparative purposes, worker caste LMP and western subterranean termites, Reticulitermes

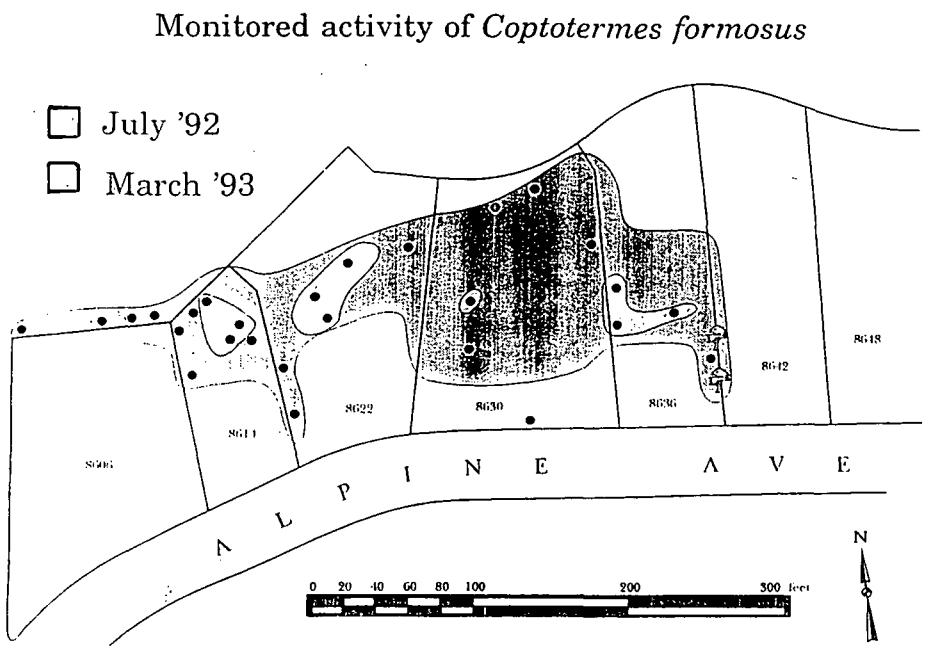

Fig. 1. Area of *C. formosanus* foraging in La Mesa, CA (LMP) in 1992 and through March 1993. Based on ground stake monitoring. Lightly shaded area indicates areas to which population(s) have receded over last several months.

hesperus Banks, collected from permanent monitoring stations at the La Mesa site were weighed, and cuticular permeability (CP) calculated from the rate of mass lost while the termites were held in still air at 0-2% relative humidity in an 11 litre desiccator. It was presumed that weight loss was due only to water lost.

The head capsule size of soldier caste LMP Coptotermes was measured at 25X with a calibrated ocular micrometer. Severed head capsules were measured from the dorsal aspect. Width was determined as the widest expanse across the head; length was determined along the midline as the distance from the apex of the most posterior margin of the head to the rim of the fontanelle.

RESULTS

Inspection and ground monitoring

We first visited and inspected the LMP site on 5 March 1992. The affected area lies in a gently sloping east-west canyon, about 100 feet highest at the eastern end and with an elevated ridge along the northern borders of the properties. A prevailing daily afternoon onshore breeze is from the west, but dry winds (< 10% relative humidity; Santa Ana condition) from the east occur periodically in spring and fall. The properties are irrigated with a combination of drip and sprinkler irrigation, and are planted with lush vegetation, ornamentals, and an abundance of fruit trees.

Live Coptotermes were found in wood that was buried or in contact with the ground, and termite damage was prevalent. Tree stumps, raised borders of flower beds, fences, wooden planter boxes, and a wooden deck were infested. Live *C. formosanus* and carton were found extending at least 12 feet high in a aged pepper tree and an adjacent alderberry tree at the property line between 8636 and 8642. Termite activity in the trees has persisted to this date.

The only *C. formosanus* inside a home were found at 8630. This is the home where several attempts to eliminate termites had failed. Before identification of Coptotermes has been made, the soil at the perimeter of the home had been treated with termiticide and bendiocarb dust blown into wall voids where termites were seen. More than 200 dead Coptotermes workers and soldiers were found under the edge of the carpet along the exterior west wall of one room, and numerous cadavers and shed Coptotermes wings were found in the attic above that room. No live specimens were found inside the home on 5 March, and inspection with a fibre optic scope revealed no termites, soil

Table 1. Activity of LMP at permanent monitor traps, beginning in 1992.

Month	No. traps	*C. formosanus*		Feeding (g)
		Total	% Soldiers	
August	13	—	—	—
September	5	—	—	—
October	7	1153	33.5	50.8
November	6	1031	16.6	24.2
December	3	35	17.1	8.4
January	5	1286	13.7	35.4
February	6	397	13.9	38.4
March	11	3416	8.9	90.8

— indicates no data collected

or carton in wall voids near where the specimens were found. Live termites were found 3 weeks later and necessitated another treatment to soil along the west wall of the structure, after which termite activity in the home ceased immediately. After several months with no observed activity, live Coptotermes soldiers began appearing on the inside surface of that wall in January 1993, indicating the likely presence of a nearby colony and breached barrier. However, no colony could be located.

Ground stake monitoring of the LMP has been done for only nine months. In July 1992 LMP *C. formosanus* were found at 13 of approximately 700 buried wooden monitor stakes (1.9%). By February 1993 the total number of stake sites which had ever been positive for Coptotermes totalled 27 (3.9%), but no more than 13 were ever positive at one time. The specific sites where termites were found and the general area encompassed by the LMP are depicted in Fig. 1. The shaded area for July '92 actually includes all positive sites to date. Except for one stake on 8630, no Coptotermes have been found at buried stakes outside the area indicated by shading on Fig. 1. Although monitored continuously, no worker Coptotermes have been found on the south side of Alpine Ave. nor on properties north and west of the July 1992 LMP area.

Based on the history of the occupants, *C. formosanus* was probably introduced at 8622 Alpine Avenue, where a total of 6 of 125 stakes (4.8%) have shown Coptotermes activity at one time or another. There have been 12 positive sites (12.1%) at neighbouring 8614 and 6 positive (5.9%) at 8630.

Permanent monitoring stations

Permanent monitoring station traps were installed at stake sites where active termite foraging was noted. Most traps with termites in July became inactive by August and remained inactive during the fall and winter. For example, of 13 traps active in July, termites could subsequently be found at 4 in November and at only one between August and December. However, the decline in activity at the initial stake sites was compensated for by activity at other stakes during the cooler months. Twelve (12) stake sites with no activity in July became active in August, 2 in November, 1 in January, and 1 in February. This ebb and flow seasonal pattern of foraging is consistent with the concept of a slowly developing, well-established population in a marginally favorable area.

The number of worker and soldier LMP Coptotermes collected at ground traps is shown in Table 1. Because of the limited time trapping has been done, it is not yet possible to draw definite conclusions from the numbers. There was a reduction during the cooler months in the number of traps at which termites were found, and an apparent simultaneous reduction in total trap catch and feeding. Although the total g of wood consumed per month are shown in the table, feeding at any given trap was variable and considerably less. For example, greatest feeding done at one site (16.0 g of a total of 50.8 g) was in October 1992, whereas the greatest amount of feeding at a trap in March 1993 was only 10.4 g (of a total of 90.8 g).

Alate traps

Several hundred reproductives were caught in alate traps in the LMP and surrounding areas. Distinct swarms were observed and alates captured in 1992 on 25-27 April, 1-3 June, and 21-24

June. Swarming occurred between 19.30 and 20.30 hrs (PDST) on very warm, calm evenings. Alates were captured on traps more than 200 m beyond the ground stake LMP area. Homeowners reported similar swarming in previous years.

Size and cuticular permeability

Average worker LMP *C. formosanus* collected in March 1992 weighed 4.27 ± 0.09 mg. Workers collected in January and February 1993 were significantly lighter, weighing 3.58 mg and 3.81 mg, respectively. The heavier termites were noticeably larger.

The average size of head capsules of LMP soldiers collected in March 1992 measured 1.27 x 1.52 mm (width x length). Most monitored Coptotermes from Florida are smaller, being 0.98-1.18 mm x 1.13-1.42 mm (Scheffrahn, pers. comm.). Head capsules of LMP soldiers collected in March 1993, regardless of the site from which they were collected, averaged 1.25 x 1.30 mm.

The average % total body water of worker LMP was 70.0 - 73.9% and cuticular permeability (CP) measured at 2 h was 33.7 ± 2.7 micrograms cm^{-2} h^{-1} $mmHg^{-1}$.

DISCUSSION

Inspection and monitoring indicate a remarkably restricted area of infestation of LMP at the present time. Worker Coptotermes have only been found within an area measuring approximately 50 x 150 m, involving five contiguous residential properties. A countywide survey has revealed no other incidence of this species. Because of the relation between population age and the history of where the owners have lived, and the apparent epicentre of the population, it is likely that the LMP was introduced in wooden belongings transported from Hawaii.

As shown in Fig. 1, the area of LMP foraging declined during the cooler months of 1992. Since activity increased in March 1993, it is likely that Coptotermes will forage over at least as wide an area this year as they did last year. The smallest areas to which foraging was restricted in the winter may represent epicentres of separate colonies. The three swarm flights that took place over two months also supports the idea of multiple LMP colonies. A single colony is likely to swarm within a shorter period of time.

Ground stakes adjacent to the termite infested trees at 8636-8642 have not shown termite activity even though live termites have been seen in the trees monthly since last March. The lack of activity at nearby monitor stakes suggests that the trees were infested from alates from nearby colonies rather than from termites moving through soil. These trees may serve as an important source of swarmers in 1993 if they are not treated or destroyed.

Because we were unable to recapture any of approximately 500 dyed termites released at one permanent ground trap, we have been unable to estimate the size and foraging range of the LMP. Dyed termites kept in the laboratory survived well, living 6 to 8 weeks. Larger numbers of termites may need to be released in order to obtain good estimates.

The small amount of feeding per month on trap wafer blocks suggests that baiting LMP for eradication may be ineffectual unless many sites are baited. Not only has there been limited termite feeding at any given trap, but there is significant distance between some sites where feeding occurs. Ground stake monitoring and permanent traps may be useful for determining the ultimate success of any eradication strategy.

Based on soldier head capsule measurements and reports of previous swarms of alates, the LMP Coptotermes is probably at least 10+ years old (Scheffrahn, pers. comm.). Supposedly, soldiers from older colonies are larger. There was no statistical difference in head capsule size of soldiers collected from different parts of the LMP area. Soldier uniformity suggests that the LMP may be one large colony or that nearby colonies began at approximately the same time as the initial colony. That swarmers were captured well beyond the ground stake LMP area suggests the potential for expansion of the LMP beyond Alpine Ave. It is surprising that worker Coptotermes have not been found south of Alpine Ave. or in nearby properties that appear to be maintained under similar conditions. The area for monitoring alates is presently being expanded to include all properties within a 1/4 mile (0.4 km) radius of 8622. Termites that have swarmed from the LMP area may

have begun colonies in adjacent areas, but there is no evidence or reports of that yet occurring. Insipient colonies may have begun that will not be evident for years.

The percent body water and cuticular permeability (CP) of worker LMP was similar to the corresponding values of worker Coptotermes from Florida and Alabama (Sponsler and Appel, 1990). However, during desiccation experiments the average LT-50 of worker LMP Coptotermes at 31°C was 3.5 - 4.8 h (90.8 - 100% by 6 h). LMP time for death was significantly shorter than the 7.1 h for worker Coptotermes at 30°C reported by Sponsler and Appel (1990). Perhaps the populations have physiological differences attributable to size or acclimation. In any event, Coptotermes cannot tolerate extended periods of dryness and high temperature. Their restricted area of infestation in La Mesa may be at least partly attributable to dry air and soil during parts of the year.

Vigilance being maintained to assure the limits of the LMP include a countywide survey and awareness program among pest control operators; ground stakes, permanent ground traps, and alate traps in and beyond the LMP area; and an awareness program among homeowners in the surrounding area. Besides specific standard remedial treatment for affected property, plans are presently being made to use a proprietary bait product to eradicate Coptotermes from the LMP area in 1993. If initially successful, such a program must be monitored over a period of several years to insure that insipient colonies have not begun from the LMP.

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