

CHANGES IN DISTRIBUTION OF SUBTERRANEAN TERMITE COLONIES (ISOPTERA: RHINOTERMITIDAE) IN A NEW ORLEANS, LOUISIANA CITY PARK AFTER HURRICANE KATRINA

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Abstract Termite activity had been continuously monitored in four sections of City Park since 2002. Between 2002 and 2005, 12 distinct Formosan subterranean termite, *Coptotermes formosanus* Shiraki, colonies had been delineated using mark-release-recapture techniques. This study examines how the distribution of subterranean termites has changed in City Park two years after Hurricane Katrina by using mark-release-recapture techniques to delineate distinct *C. formosanus* colonies post-Katrina. Pre-Katrina, there were nine monitoring stations occupied by *Reticulitermes* sp. Of the nine stations that were occupied by *Reticulitermes* sp. pre-Katrina, 5 are unoccupied, 2 are occupied by *C. formosanus*, and 2 stations are missing due to downed trees. Boundaries for Formosan subterranean termite colonies were relatively stable between 2003 and 2005. Mark-release-recapture methods have determined that there have been more changes in the foraging ranges of *C. formosanus* colonies after Hurricane Katrina than in the two year period before the storm. The temporary vacancy of gallery systems due to flooding may have provided the opportunity for a new colony to move into parts of a gallery system previously occupied by another colony without encountering members of the other colony.

Key Words *Coptotermes formosanus*, *Reticulitermes*, foraging ranges, monitoring

INTRODUCTION

The distribution of subterranean termites in City Park has been monitored continuously between 2002 and 2007. Mark-release-recapture methods were used to delineate the foraging ranges of colonies of the Formosan subterranean termite, *Coptotermes formosanus*. Mark-release-recapture techniques have frequently been used to delineate foraging ranges of subterranean termite colonies in the field (Su and Scheffrahn, 1988; Grace et al., 1989; Su et al., 1993; Messenger and Su, 2005). Detailed studies of termite colonies in Louis Armstrong Park, New Orleans demonstrated that colony identities derived from mark-release-recapture techniques corresponded with colony identities determined using DNA fingerprinting techniques (Husseneder et al., 2003).

City Park was inundated with water in the aftermath of Hurricane Katrina. After the initial surge of floodwater, water levels dropped slightly and standing water remained for 2-3 weeks. The water marks on many of the trees where monitoring stations were located ranged between approximately 1-2 meters in height. In the immediate aftermath of Hurricane Katrina, the impact of flooding on the distribution of subterranean termites in City Park, New Orleans, LA was determined in four sections of the park where termite activity had been continuously monitored since 2002. Monitoring stations were checked for the first time after Hurricane Katrina in October of 2005. There was no significant difference in the percentage of active to inactive monitoring stations in August 2005 pre-Katrina, October 2005 post-Katrina, or October 2006 (Cornelius et al., 2007).

This study examines how the distribution of subterranean termites has changed in City Park two years after Hurricane Katrina by using mark-release-recapture techniques to delineate foraging ranges of subterranean termite colonies.

MATERIALS AND METHODS

Subterranean termite populations were monitored in clusters of trees along the fairways and greens of the golf courses in four sections of City Park, New Orleans, LA (Cornelius et al., 2007). In each section, a wooden pine (*Pinus* sp.) stake was placed in the ground at the base of every tree. Stakes were checked monthly and monitoring stations were installed at the base of each tree when stakes became infested by subterranean termites. Therefore, monitoring stations were only installed at locations where there was evidence of subterranean termite activity. Monitoring stations consisted of cylindrical irrigation valve boxes (NDS, Inc, Lindsay, CA) that were buried in the ground and filled with blocks of wood (spruce, *Picea* sp. or yellow pine, *Pinus* sp.). Monitoring stations were checked on a monthly basis. The installation of new monitoring stations continued periodically between October 2002 and August 2005. GPS data was taken for each monitoring station and information on termite activity was applied to aerial photographs of City Park using ArcGIS (ESRI, Redlands, CA). The post-Katrina aerial photographs of City Park were taken in 2005. Pre-Katrina, there were a total of 125 monitoring stations in four sections of City Park. In the immediate aftermath of Hurricane Katrina, 112 monitoring stations were checked for termite activity and 13 stations were missing. By September 2007, five more stations had been eliminated when dead trees were removed, and one station was added for a total of 108 monitoring stations: Section 1 (28 stations); Section 2 (28 stations); Section 3 (28 stations); Section 4 (24 stations).

Foraging ranges of *C. formosanus* colonies were delineated using a mark-release-recapture technique where termites were collected from particular stations in the field, fed Whatman #4 filter paper dyed with either Nile blue A or neutral red (Sigma-Aldrich, St. Louis, MO) (0.05 % wt/wt) in the laboratory, and then released into the same station from which they were collected. After approximately two weeks, termites from active stations in the surrounding area were collected. All termites from these collections were examined in the lab. Any stations containing dyed termites were considered to be part of the same colony as the station from which the dyed termites were released. The delineation of colonies in City Park was a long-term, on-going project initiated in 2003 that was abruptly halted due to Hurricane Katrina. There were 125 monitoring stations in City Park in August of 2005. Twelve distinct *C. formosanus* colonies were identified: Section 1 (4), Section 2 (1), Section 3 (3), Section 4 (4). Between October 2006 and October 2007, mark-release-recapture techniques were employed to determine if there had been changes in the distribution of *C. formosanus* colonies in the aftermath of the flooding due to Hurricane Katrina.

Data Analysis

The percentage of active monitoring stations in the four sections were compared pre-Katrina (August 2005), immediately post-Katrina (October 2005), a year after Katrina (October 2006), and two years after Katrina (September 2007) using a one-way ANOVA (SPSS, 1996). Means were separated using Tukey's honestly significant difference (HSD) test (SPSS, 1996).

RESULTS AND DISCUSSION

Pre-Katrina, there were nine monitoring stations occupied by *Reticulitermes* sp.: Section 1 (1), Section 2 (2), Section 3 (4), Section 4 (2) (Cornelius et al., 2007). Since Hurricane Katrina, only a single station has been briefly occupied by *Reticulitermes* sp. Station 145 had been occupied by *C. formosanus* until December 2005, and was unoccupied until August 2006. In August and September 2006, the station was occupied by *Reticulitermes* sp. The station was unoccupied from October 2006 until December 2006, at which point the station was reoccupied by *C. formosanus*. No other stations have been occupied by *Reticulitermes* sp. since Hurricane Katrina. Of the nine stations that were occupied by *Reticulitermes* sp. pre-Katrina, 5 are unoccupied, 2 are occupied by *C. formosanus*, and 2 stations are missing due to downed trees. It is possible that colonies of *Reticulitermes* sp were more adversely affected by the flood than colonies of *C. formosanus*. Alternatively, colonies of *Reticulitermes* sp may still be present in the study sites, but foragers of *Reticulitermes* sp. were less likely to recolonize stations after a disturbance than foragers of *C. formosanus*.

The foraging ranges of most of the *C. formosanus* colonies have remained relatively unchanged two years after the flood. Mark-release-recapture techniques have confirmed that there have been some changes in the distribution of *C. formosanus* colonies since Hurricane Katrina. Pre-Katrina, there were

seven distinct *C. formosanus* colonies in sections 1 and 3. Post-Katrina, eight *C. formosanus* colonies have been identified. In section 1 pre-Katrina, there were four distinct *C. formosanus* colonies and an additional cluster of unconnected stations that were generally unoccupied by termites. This cluster of stations may have been part of another colony or may have been within the foraging range of Colony 1 (Fig. 1). Post-Katrina, stations that were formerly part of two distinct colonies, Colony 1 and Colony 2, were connected by mark-release-recapture techniques. Currently a single colony occupies the former foraging ranges of Colony 1 and Colony 2. Post-Katrina, the new foraging range has been designated Colony 1, although it is not known which of the two pre-Katrina colonies invaded the other colony's range. Three stations in the cluster of formerly unconnected stations have now been connected and these newly connected stations have been designated Colony 2 (Fig. 1). Pre-Katrina, termites collected from stations in Colonies 1 and 2 were highly aggressive toward each other and these two colonies had maintained stable colony borders for at least two years. It is possible that the temporary vacancy of the gallery systems due to the flooding enabled one colony to invade the vacant gallery system of the other colony.

Pre-Katrina, Colony 3 had been found in a single station in section 1 (station 2) and a single station in section 3 (station 118). Although marked termites had not yet been found in these stations, stations 1 and 119 were located within the foraging range of Colony 3. Post-Katrina, station 2 is at the base of the only remaining tree within the colony borders of Colony 3. Stations 118 and 119 were lost immediately after the storm because they were located at the base of fallen trees and within a few months, the large oak trees were removed and the stumps were ground up. Station 2 was active immediately after the storm, and continued to be active until June 2006. The large oak tree where station 1 was located was cut down and removed in January 2007. There has been no activity in station 2 since June 2006.

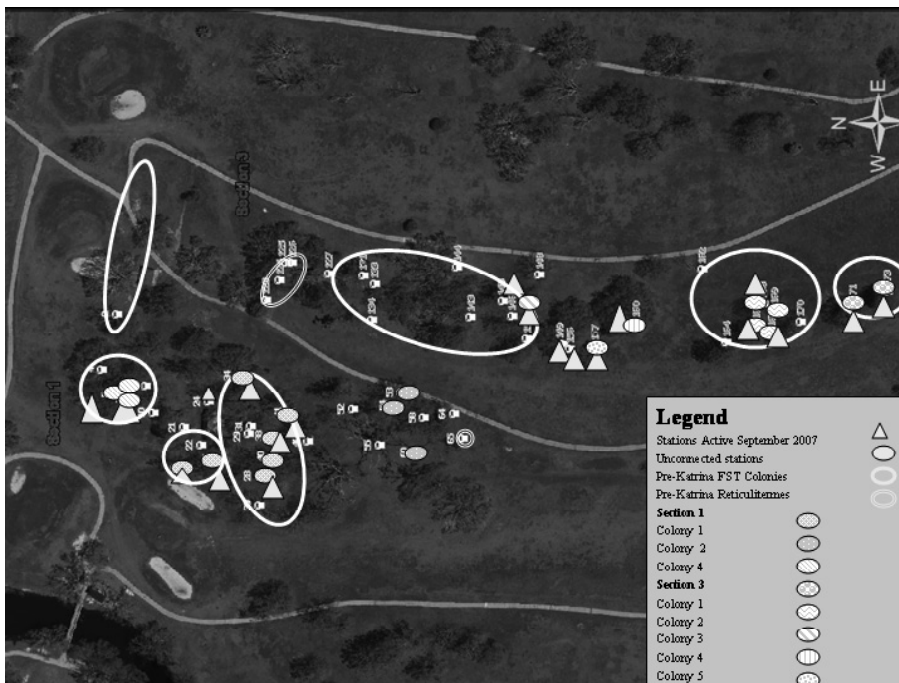


Figure 1. Aerial photograph of Sections 1 and 3 in City Park 2005 post-Katrina. Approximate foraging ranges of *C. formosanus* designated with single band open circles and stations occupied by *Reticulitermes* sp. pre-Katrina designated with double band open circles. Closed circles are stations occupied by *C. formosanus* that have been connected post-Katrina using mark-release-recapture techniques. Triangles are stations active in September 2007.

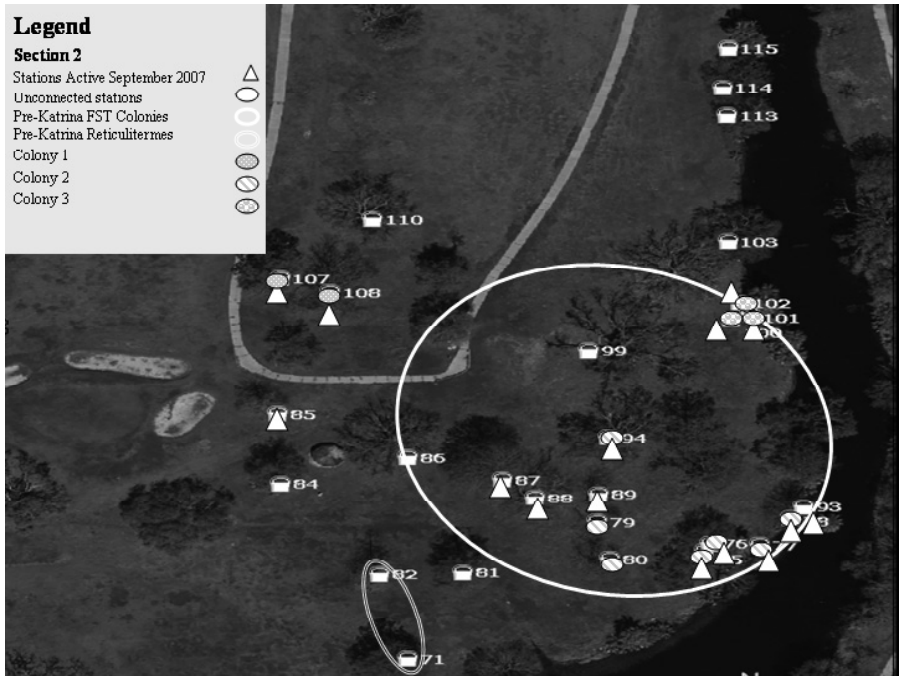


Figure 2. Aerial photograph of Section 2 in City Park 2005 post-Katrina. Approximate foraging ranges of *C. formosanus* designated with single band open circles, stations occupied by *Reticulitermes* sp. pre-Katrina designated with double band open circles. Closed circles are stations occupied by *C. formosanus* that have been connected post-Katrina using mark-release-recapture techniques. Triangles are stations active in September 2007.



Figure 3. Aerial photograph of Section 4 in City Park 2005 post-Katrina. Approximate foraging ranges of *C. formosanus* designated with single band open circles, stations occupied by *Reticulitermes* sp. pre-Katrina designated with double band open circles. Closed circles are stations occupied by *C. formosanus* that have been connected post-Katrina using mark-release-recapture.

In section 3 there were three distinct *C. formosanus* colonies pre-Katrina (Fig 1). Post-Katrina, there do not appear to be any changes in the foraging ranges of colonies 1 and 2. However, only one of the stations formerly connected to Colony 3 remains active. In section 3, nine neighboring stations (127, 130-135, 145, 146) were very active pre-Katrina. Although only five of these stations (127, 131-133, 146) had been connected using mark-release-recapture methods, the other four stations were located within the foraging range of Colony 3 (Fig. 1.). In the immediate aftermath of Hurricane Katrina, five of these stations (127, 132, 133, 145, and 146) were still active and station 135 was missing. By August 2006, only two stations (132, 145) were still active. By January 2007, stations 130 and 132 were lost after dead trees were removed. By September 2007, only two stations (145, 146) located at the periphery of the foraging range of Colony 3, were still active. The lack of activity in stations 127, 131, 133, 134 may be related to the removal of large dead trees nearby (stations 130, 132, 135).

Two new colonies have appeared in Section 3 (Fig. 1). Despite marking and releasing large numbers of termites in these two stations (neutral red in 160 and Nile blue in 157); no marked termites have been found in any other stations. Based on average body weights (2.5 ± 0.04 mg), it is likely that an incipient colony has moved into three stations (149, 156, 157). However, these stations have not been connected yet using mark-release-recapture techniques.

Pre-Katrina, only a single *C. formosanus* colony had been delineated in Section 2 (Fig. 2). Post-Katrina, three *C. formosanus* colonies have been identified using mark-release-recapture techniques (Fig. 2). Colony 2 colonized stations 107 and 108 just before the storm. Stations 107 and 108 had been occupied by *Reticulitermes* sp. until July 2005, but these two stations were occupied by *C. formosanus* in August 2005 pre-Katrina. However, Colony 3 has only appeared post-Katrina. Station 101 was previously connected to Colony 1. Post-Katrina, stations 100, 101 and 102 have been connected to each other. Repeated releases of dyed termites have confirmed that these three stations are now a separate colony from Colony 1 and are now identified as Colony 3.

In Section 4, there were four *C. formosanus* colonies pre-Katrina. One colony was only identified from a single station (Fig. 3). Since Hurricane Katrina, there has not been any termite activity in station 153 previously identified as Colony 4. Monitoring stations from the other three *C. formosanus* colonies are active. Two monitoring stations that were connected to Colony 1 are missing due to downed trees. However, termite activity in the remaining two stations has been very high. Only one of the two stations connected to Colony 2 has remained active post-Katrina. Four of the six stations that were previously connected to colony 3 have been reconnected post-Katrina. Although termites have been found in all six stations post-Katrina, activity in stations 202 and 207 has been sporadic. Therefore, marked termites have not been found in these two stations. In Section 4, five stations (265, 268-271) were active pre-Katrina. In the immediate aftermath of the storm, four of these stations (265, 269, 271, 272) were still active and one was missing due to a downed tree (270). By October 2006, station 265 was lost due to the removal of a dead tree. None of the remaining stations were active. Currently, station 272 has been consistently active, but termite activity has not returned to the three remaining stations (268, 269, or 271). Two large oak trees were removed and the stumps were ground up near these stations. In addition, several large trees that were located directly across the street from this group of stations were also removed and the stumps were ground up.

The percentage of active monitoring stations were compared pre-Katrina (August 2005), immediately post-Katrina (October 2005), a year after Katrina (October 2006), and two years after Katrina (September 2007) (ANOVA: $F = 3.5$; $df = 4, 15$; $P = 0.03$). Percent active stations were only significantly different in August 2005 and August 2006. Percent active stations were not significantly different immediately after the storm or in October 2006 or September 2007. There has been a decline in the percentage of active stations in September 2007 (42%) compared with pre-Katrina August 2005 (59%). Termite activity was not significantly reduced in the immediate aftermath of the flooding due to Hurricane Katrina. Although the percentage of active stations in September 2007 was not significantly different than the percentage of active stations in August 2005 pre-Katrina, there are several clusters of stations that were very active pre-Katrina and are no longer active. In most cases, these stations are located within a few meters of areas where large trees were removed and formerly active stations were lost. It is not known whether or not carton nests containing the royal chamber and large numbers of termites were removed along with the dead trees or whether

termites merely moved away from the area due to the disruption caused by the removal of the dead trees or the loss of a major food source. In any case, the complete cessation of termite activity in these areas did not occur immediately after the flooding. Termite activity in nearby stations gradually disappeared after the removal of large dead trees.

Boundaries for Formosan subterranean termite colonies were relatively stable between 2003 and 2005. Mark-release-recapture methods have determined that there have been more changes in the foraging ranges of *C. formosanus* colonies in the aftermath of Hurricane Katrina than in the two year period before the storm. The temporary vacancy of gallery systems due to flooding may have provided the opportunity for a new colony to move into parts of a gallery system previously occupied by another colony without encountering members of the other colony. When colonies were eliminated from Armstrong Park through baiting programs, neighboring colonies invaded the vacated foraging ranges of eliminated colonies within a few months (Messenger et al., 2005). However, 54% of stations in City Park were active within a month of the flood (Cornelius et al., 2007). Gallery systems were probably only vacant for a very brief period of time. Therefore, the foraging ranges of most of the *C. formosanus* colonies have remained relatively unchanged two years after the flood.

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