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Results of Operation Full Stop: Terminix Service Co. Inc., control of Formosan Subterranean Termites (Coptotermes Formosanus) in the French Quarter of New Orleans

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RESULTS OF OPERATION FULL STOP: TERMINIX SERVICE CO. INC., CONTROL OF FORMOSAN SUBTERRANEAN TERMITES (COPTOTERMES FORMOSANUS) IN THE FRENCH QUARTER OF NEW ORLEANS

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ABSTRACT

In New Orleans alone, the Formosan subterranean termite, *Coptotermes formosanus*, causes $300 million in damages annually. Formosan subterranean termites are the most destructive subterranean termite in the world wherever they occur. From 1998- 2011 Operation Full Stop was implemented in five phases. Basic parameters were set up through the LSU AgCenter. French Quarter Residents were allowed to select their own licensed pest control operator for approved termite treatments. The United States Department of Agriculture in New Orleans provided funds to Operation Full Stop to pay the pest control operator for initial treatment and yearly renewal of termite contracts. Terminix Service Co. Inc. in New Orleans participated fully in the program from 1998 to 2011 in New Orleans. Terminix Service Co. Inc. (Metairie, LA) had 404 Sentricon® baiting accounts in Operation Full Stop (Pest Control Solutions, Jackson Mississippi). From this list every 7th account was selected until one hundred accounts was achieved. From the master list each account was looked up on Dox Serve Software (Abita Spring, LA) where route sheets were stored. Each account had its own file stored in the Dox Serve system. Account information and route sheets were then individually analyzed and the information was manually implemented in an Excel spreadsheet, sorted by JMP statistical software by SAS and analyzed by SAS PROC MIXED. Termite activity was calculated based on an Attack Rate. Attack Rate was defined as the number stations with active termites/ number of stations divided by number of inspections and then multiplied by 100. Attack Rate average was calculated for each account per year. Our study measured termite activity based on sampled Terminix Sentricon® baiting accounts from 1998 to 2011 only. The main objective of this study was to determine if Terminix Service Co. Inc. decreased termite activity in sampled baiting accounts during Operation Full Stop. There was a significant decrease in Attack Rate from 1998 to 2011. The slope of this decreasing trend of Attack Rate observed from 1998 to 2011 was also

significant. Our results suggest that termite baiting in Terminix Service Co. Inc. decreased Formosan subterranean termite activity in Operation Full Stop.

CHAPTER 1. INTRODUCTION

1.1 Background

In nature, subterranean termites live in the ground and are beneficial to the ecosystem as they help recycle cellulose to usable energy for other organisms (Vail et al. 2000). However, subterranean termites can be a major pest of humans due to the destruction they can cause to wooden structures (Gold et al. 2005). Subterranean termites forage on structures inhabited by humans (Vail et al. 2000). Subterranean termites come from the ground through wood, piers, foundation walls, expansion joints, and utility sewer openings or directly from the soil (Vail et al. 2000). In the United States, it was noted that *Reticulitermes* and *Coptotermes* are the most economically important (Henderson and Fei 2002). For example, *Reticulitermes* in nine southern states caused $435 million dollars in losses to property and costs for control 30 years ago (Su and Scheffrahn 1986). In New Orleans alone, the Formosan subterranean termite, *Coptotermes formosanus* causes $300 million in damages annually (Suszkiw 1998). Formosan subterranean termites are the most destructive subterranean termite in the world wherever they occur (Osbrink et al. 1999).

The Formosan subterranean termite was first introduced to New Orleans after World War II by infesting cargo returning from Asia (La Fage 1987). Due to the New Orleans active port after WWII, Formosan subterranean termites have spread throughout the New Orleans metropolitan area (La Fage 1987). Formosan termites have likely displaced most native subterranean termites, and have caused damage to buildings, trees, boats, and railroad ties throughout the New Orleans metropolitan area (Messenger and Mullins 2005). In New Orleans, people dread the Formosan subterranean termite because it has the ability to build above ground carton nests and below ground colonies forage over an area the size of a football field harboring millions of individuals (Henderson 2008). Formosan subterranean termites can exist aerially

without ground contact if they are supplied with suitable conditions: food, shelter, and water (Hu et al. 2001, Su and Scheffrahn 2013). For example, flat roofs of buildings are sometimes suitable areas for Formosan termites because they are notorious for poor drainage and constantly collect rainwater which supplies the termites with a constant water source (Su and Scheffrahn 2013). This above ground nesting behavior is believed to be a survival adaption due to the Formosan subterranean termite's life history of living in areas that are known to flood such as in their place of origin of Southern China (Henderson and Forshler 1995). In New Orleans, Formosan termites have been implicated in causing the floodwalls to fail during Hurricane Katrina (Henderson 2008) and have even caused New Orleans school board officials to ask that students be removed from a New Orleans public school because of severe termite damage throughout the building (Kari 2013). New Orleans is estimated to have the heaviest Formosan subterranean termite population in North America and possibly the world (Lax and Osbrink 2003). This is part of the reason that New Orleans control and repair cost of Formosan termites is estimated at $300 million (Suszkiw 1998).

It was not until the early 1990's after Hurricane Andrew that the public and the press became fully aware of the serious termite problem (Henderson 2001). Hurricane Andrew downed 350 trees and New Orleans Mosquito Control Board and LSU AgCenter researchers estimated 30–50% of downed trees were termite infested (Henderson 2001). After Hurricane Andrew, press on Formosan subterranean termites grew with front-page news stories about their damage to the French Quarter and New Orleans' famed oak trees (Henderson 2001). Out of all the New Orleans neighborhoods, the French Quarter is the hardest hit area (Laurence and Waits 2004). So, in 1998, with vocal support for action by the French Quarter Residents Association, Congressman Bob Livingston secured funding for Formosan subterranean termite control

(Henderson 2001). The continual and costly infestations of Formosan subterranean termites that threatened to destroy historical buildings in the French Quarter was the reason a federally funded program, Operation Full Stop, was implemented (Husseneder and Guillot 2010). Operation Full Stop was implemented to apply newly-developed area-wide treatments to reduce the Formosan subterranean termite populations and limit further damage to the French Quarter (Husseneder and Guillot 2010). The program called for a cooperative effort among the LSU AgCenter, United States Department of Agriculture and the New Orleans Mosquito and Termite Control Board (Husseneder and Guillot 2010). The program began in 1998 when 15 blocks of the French Quarter were chosen to test non-repellent termiticides and baits (Spillman 2002). Private pest control companies were subcontracted to treat the buildings in the French Quarter (Morgan et al. 2005). The LSU Agricultural Center had two goals of the program: the first goal was to reduce termite pressure in the French Quarter and to prove that area-wide management could be successful if the program was implemented correctly (Morgan et al. 2005). The second goal was to educate New Orleans residents, particularly French Quarter residents, on Formosan subterranean termites and the procedures necessary to achieve effective control (Morgan et al. 2005). Operation Full Stop was "an unusual urban scientific experiment asking the question: if every building in a major neighborhood was treated and maintained termite free, could the program put a dent in the $300 million paid for damage in treatments in New Orleans?'' (Schleifstein 2013).

From 1998- 2011 Operation Full Stop was implemented in five phases: I 1998; II 2002; III 2004; IV 2006; V 2009. Basic parameters were set up through the LSU AgCenter. French Quarter residents were allowed to select their own licensed pest control operator for approved termite treatments. The United States Department of Agriculture in New Orleans provided funds

to Operation Full Stop to pay the pest control operator for initial treatment and yearly renewal of termite contracts (Appendix A). Local pest control operators adhered to LSU AgCenter guidelines on treatment. Only baits and non-repellent liquids approved by the Louisiana Structural Pest Control Commission and LSU AgCenter were to be used in the program (Appendix A). Pest control operators (PCO) offered both methods of treatment: bait or non-repellent (Appendix A). The PCO would engage in a written agreement with the consumer (Appendix A). Terms for the customer included but were not limited to agreement of the property owner to reduce conducive conditions and to allow LSU, Agriculture Research Service (ARS) and New Orleans Mosquito and Termite Control Board (NOMTCB) to inspect the property and collect data (Appendix A). The PCO, which acted as an independent contractor, also agreed to terms that included, but were not limited to a signed contract, detailed diagram of the property, allowance for LSU, ARS, or NOMTCB to accompany them during treatment and supply proper paperwork to the LSU AgCenter (Appendix A).

Under Operation Full Stop, PCOs had a treatment choice between non-repellent termiticides and baits (Appendix A). The conventional method of treatment for control of subterranean termites is a liquid termiticide treatment (Meiracker et al. 2000). In the French Quarter, conventional treatments mostly consist of drilling holes through adjacent cement and injecting termiticide under the foundation (Su and Scheffrahn 2013 and Martin 2015). In instances of concrete block, brick, foundations, or brick piers a termiticide is pressure injected into drill holes (Gold et al. 2005). Non-repellent termiticides are slow acting termiticides that are not detected by foraging termites (Henderson 2003). These insecticides are transferred through termites grooming and incidental contact; therefore, they can kill termites when they tunnel through treated soil (Chan et al. 2000). Baits can be used to reduce the population size of

subterranean termites not directly feeding on the bait through trophallaxis of ingested toxicant (Henderson and Fei 2002). Bait stations are normally placed below ground every 10 to 20 feet around a structure (Meriracker et al. 2000).

According to Terminix corporate history, Terminix began in 1925 in Memphis, Tennessee, by E. L. Bruce, an owner of a floor company. Mr. Bruce was having problems with 'worms' in his hardwood flooring products; he soon discovered that these 'worms' were termites infesting his hardwood floor products. In 1927, Bruce founded the Terminix Research Laboratory to find a solution for his constant problem with termites in his floors. The name, 'Terminix' was originated from E.L Bruce wanting to "nix' the termites (Stahls 2004. In 1932, Terminix employee Frank Lyons patented the first United States approved termite chemical (Stahls 2004). The first Terminix franchise in Louisiana was in East Baton Rouge in 1941 (Stahls 2004). Bill Brothers bought the franchise for Southern Louisiana and opened the New Orleans office in 1947 (Stahls 2004). In 1960, Mr. Brothers hired my grandfather Eddie Martin Jr., an entomologist, and recent graduate of Louisiana State University in Baton Rouge to develop both commercial and residential pest control (Stahls 2004). At the time, Terminix only offered termite control; therefore, Martin's assignment was to expand Terminix's service to include treatment for household insects and rodents (Stahls 2004). Two years later, Mr. Brothers was set to retire and offered my grandfather to buy the Southern Louisiana territory of Terminix (Martin, Personal Communication 2015) Then, in 1962, with a loan co-signed by his father Mr. Martin acquired the Southern Louisiana territory that at the time had one office in New Orleans with five employees (Martin, Personal Communication 2015). Today, Terminix Service Co. Inc. operates four branches, with over 135 Employees and over 90 trucks (Terminix New Orleans). When Mr. Martin took over he still had not found a Formosan subterranean termite (Martin,

Personal Communication 2015). Over fifty years later, Martin called New Orleans the "Buckle of the termite belt" commonly referred to as the Southeastern United States (Harbison 2000). Terminix has been at the forefront in Formosan subterranean termite treatments and research since the late 1960s (Harbison 2000). In the 1970's, Terminix developed control procedures for secondary Formosan subterranean termite carton nests in buildings (Stahls 2004). Also at this time, Terminix implemented a ground treatment and fumigation treatment to eliminate Formosan subterranean termites from building (Harbison 2000). This research was critical for the current labeling for Formosan subterranean termite fumigations (Harbison 2000). Since the 1970's nearly every available termiticide has been evaluated by Terminix (Harbison 2000). The growth of Terminix New Orleans can be credited to a growing renewal base, acquiring new territories and through mergers and acquisitions (Stahls 2004). Today, Terminix provides residential and commercial pest control, termite control, and fumigation.

My employment at Terminix Service Co. Inc., started in 2012. I am presently a graduate student in the LSU Department of Entomology, having started the spring of 2014. This thesis is my contribution to the pest control industry, and researchers who spent an extraordinary amount of time looking into answers of Operation Full Stop. Since the start of Operation Full Stop it was questioned if a report would ever be produced (Mcquaid and Schleifstein 1998). Scientists worried that the size, corporate involvement, and public relations message would hinder scientific goals of unbiased data gathering and analysis (Mcquaid and Schleifstein 1998). Professor Roger Gold, an urban entomologist at Texas AandM, stated that his "greatest fear is that the public may have been promised something we can't deliver on" (Mcquaid and Schleifstein 1998). Fifteen years later in 2013, the Times Picayune contacted USDA officials for scientific evidence of their one-sentence report that Operation Full Stop resulted in a 50%

reduction of termites and saved New Orleans residents $150 million dollars (Schleifstein 2013). USDA officials were unable to provide any scientific evidence of these estimates, directing the reporters to summaries in recent studies and a USDA website (Schleifstein 2013). Until now there has not been a scientific evaluation or report of the 13 year attempt to curb termite numbers in the French Quarter. Professor Gregg Henderson, an urban entomologist at LSU AgCenter, stated "The public deserves some sort of report coming out of this major effort" (Schleifstein 2013). Therefore, I am happy to present this thesis on behalf of the pest control industry and LSU AgCenter.

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CHAPTER 2. TERMINIX'S BATTLE IN THE FRENCH QUARTER

2.1 Introduction

Terminix battled with Formosan subterranean termites in the French Quarter long before Operation Full Stop. Formosan subterranean termite control is a major problem in the French Quarter because the buildings are extremely vulnerable to termites due its construction: common walls, floating slabs and flat roofs that hold water (Morgan et al. 2005). Some pest control companies reportedly stopped attempting to control Formosan subterranean termites in the French Quarter because management had become too complex (Ring et al. 2010). French Quarter buildings were not built to prevent termites from entering the foundations of the structures having been constructed in the 1700's by the French (Morgan et al. 2005). The architecture creates a thriving environment for Formosan subterranean termites to survive due the buildings sandstone and wood framing, which helps provide food and moisture to termites (Mcquaid and Schleifstein 1998).

The biggest challenge Terminix had in treating Formosan subterranean termites before Operation Full Stop was the large nature isolated colonies in common walls (Martin, personal communication 2015). This made treatment difficult because access to neighboring buildings to properly treat was often not available. The second major challenge was performing adequate liquid treatment because the foundation brick walls go deep underground (Martin, personal communication 2015). Meanwhile, the chemicals being used were repellents. The third biggest challenge was roofs and walls holding moisture accessible Formosan subterranean termites (Martin, personal communication 2015). Terminix's chosen method of treatment during Operation Full Stop was to use Hexaflumuron available from Dow AgroSciences (Indianapolis, Indiana) Baiting was the only approved method of Operation Full Stop in its beginning demonstrations in 1997. Non-repellent liquid termiticides entered the program in 1998 and 2001.

(Henderson, personal communication 2015). Baiting was chosen by Terminix over liquid non repellent termiticides as the premier treatment during Operation Full Stop. The company believed it was an advanced technique to go on the offensive against termites looking for food (Martin, personal communication 2015). Liquid repellent termiticides were used prior Operation Full Stop and Terminix still had above ground breakouts in common walls (Martin, personal communication 2015). Martin explained that repellent insecticides were effective as a defensive measure but had minimal effects on colonies inside of buildings (Harbison 2000) Terry Bruno, General Manager of Terminix New Orleans, stated that before Operation Full Stop, Terminix would consistently have reinfestations of Formosan subterranean termites in buildings. Terminix agreed with USDA-ARS official Dr. John Patrick who stated: ‘historically we have protected against a building or a tree, now we are shifting to the offensive, we have to attack’ (Mcquaid and Schleifstein 1998). Terminix believed baiting was also a useful option because a PCO could not properly treat even with the newer non- repellent liquids in a French Quarter building since it was not practical to adhere to Louisiana Department of Agriculture and Forestry specifications (LDAF) (Martin, personal communication 2015).

Termite baits are primarily placed in the ground where subterranean termites are searching for additional food sources (Henderson and Fei 2002). Termite baits use cellulose-based materials mixed with small amounts of insecticide to reduce populations of foraging termites in and around structures which are used to lure termites to feed (Vail et al. 2000). The toxicant used in baiting systems are insect growth regulators (Hu et al. 2001). This ‘inceptive baiting’ approach is defined as the beginning of an action. Stations are installed around a structure to detect the presence of an active colony (Chan et al. 2000). These stations are placed below ground every ten to twenty feet around a structure (Meiracker et al. 2000). Once a station

is confirmed to contain live termites the station is replaced with toxicant-laced bait (Chan et al. 2000). Termite baiting systems can be advantageous on a structure where soil treatment methods are impractical, due to hard-to-treat construction, chronic retreatment histories, inaccessible crawl spaces or where termites are isolated (Chan et al. 2000). Baiting was also the more expensive option to the customer and more lucrative to the PCO. A study conducted by the LSU AgCenter stated that New Orleans residents preferred the more expensive baiting treatment due to Operation Full Stop paying for treatments and the fear of potentially discovering Formosan subterranean termites (Paudel et al. 2010). A liquid treatment cost for a 2000 square foot building was around \$750 with a \$113 renewal (contract maintained with inspection) each subsequent year (Paudel et al. 2010). A baiting treatment was around \$2000 with a \$450 renewal (Paudel et al. 2010).

Hurricane Katrina struck New Orleans August 29, 2005 and company headquarters in Metairie took in some flood water. However, the building did not sustain any significant damage. Terminix employees were back to work at the Metairie office in early October 2005. The majority of the French Quarter did not flood, with 9% within the French Quarter boundaries experiencing only minor flooding (Campanella 2015). Terminix was able to resume normal operations in Operation Full Stop in January 2006.

2.2 Materials and Methods

For this thesis one hundred baiting Operation Full Stop accounts were chosen from our files master list which was printed from Pest Control Solutions (Jackson, Mississippi). Account is defined as a property location within Operation Full Stop under contract with Terminix New Orleans. Terminix Service Co. Inc,. (Metairie, LA) had 404 Sentricon® baiting accounts in Operation Full Stop. In this study, from this list every 7th account was selected until one hundred

accounts were achieved from the master list. Each of the 100 accounts was examined using Dox Serve Software (Abita Spring, LA) where route sheets were stored. Each account had its own file stored in the Dox Serve system. Account and route sheet information were then individually analyzed regarding bait attacks by termites. Termite activity was calculated based on an Attack Rate for each account per year. Attack Rate is defined as the sum of termite hits divided by number of stations / number of inspections multiplied by

100.

$$Attack\ Rate = \left(\frac{\frac{Number\ of\ hits}{Number\ of\ stations}}{Number\ of\ inspections} \right) \times 100\% \tag{1}$$

The average of each accounts' Attack Rate per year was used for analysis. The information was manually implemented in an Excel spreadsheet, sorted by JMP statistical software by SAS and analyzed by SAS PROC MIXED.

2.2.1 Baiting procedures

Sentricon®, developed by Dow AgroSciences, is a termite baiting colony elimination system that kills termites using a slow acting toxicant that inhibits the molting process resulting in death (Potter 2004). The bait contained hexaflumuron, an insect growth regulator which disrupts the molting process and development of subterranean termites which results in effective control (Dow AgroSciences Label). Bait stations installed by Terminix were placed 10 feet apart in the French Quarter during Full Stop whenever possible (Bruno, personal interview 2015). Stations are put in soil via augered hole with a top cover flush with the surface of the soil (Potter 2004). If it was not possible to put stations every 10 feet due to obstructions, Sentricon® stations were not to exceed 20 feet if soil was available (Dow AgroSciences Label). If soil was not available a core hole drilled through the concrete was often done to properly install the stations

(Sentricon Technical Manual 2013). When core drills had to be performed Terminix would contact Louisiana Dial One (Baton Rouge, Louisiana). Louisiana Dial One would locate utility and pipe lines and mark them accordingly before Terminix would perform the core drilling. When termite activity was found in a station the untreated pieces of wood in the station was replaced with a plastic tube containing the toxic bait. When this bait was placed in the station the ‘recruiting technique’ was used to transfer termites from the untreated wood monitoring devices onto the top of bait tube (Sentricon Technical Manual 2013). Terminix technicians were instructed to add water to slightly moisten the bait tube before the transfer of the termites. This was performed to increase bait attractiveness.

2.2.2 Terminix’s data processing

Terminix implemented a specific process to sign up customers and effectively collect and store data for the USDA and LSU AgCenter. A customer in the approved Operation Full Stop area would call the office and request a free termite inspection and treatment proposal. The cost of the treatment and the yearly renewal of the contract was paid for by USDA-ARS New Orleans. During the inspection the field inspector would draw a graph of the property. This graph would include the linear footage, location of any termite activity, and an estimate on how many stations would be needed for the installment. The field inspector, at the time of the sale would also fill out a questionnaire sheet. This questionnaire sheet provided Terminix with information about the building such as: residential or commercial, linear footage, if the house chemically treated within the last five years, type of slab or pier, and would this be a preventative treatment or the one that has active termites (‘Known’). ‘Treated within or over five years’ was defined as: where the homeowner thought the property was chemically treated within or over five years. ‘Preventative’ treatment was defined as no known termites were present at the time of sale. After the sale, when the customer agreed to the terms of the contract, the company would send out an

installation crew to install the stations and fill out a completion form for Terminix. This completion form included: insect type, construction type, treatment type, date/time of completion, linear footage of the building, and number of stations installed. Insect type for these accounts was defined ‘subterranean termites’ and did not specify species of subterranean termite. Construction type was defined as a ‘slab’ or ‘pier’ house. Treatment type used was as ‘baiting’. This information was stored in the assigned accounts property’s folder with the information from the field inspector and any other paperwork needed such as payment information, tenant contact number, owner’s number, etc. After the installation was complete and all necessary paperwork submitted the information was manually entered into Pest Control Solutions (PCS). In PCS, the customer’s name, mailing address, billing address, tenant information, start date, contract, type, and customer type (termite baiting) were manually inserted. In this system, Operation Full Stop accounts were specifically coded so they could be retrieved digitally from 1998 to 2000. After completion of the installation, the completed folder was filed. In 2001, Terminix implemented the Dox Serve Software System (Abita Springs, Louisiana.). This was a paperless software system which allowed the files to be scanned into the system and searched for by name, address, or account number. In PCS, Operation Full Stop accounts were also specifically coded to ensure the bait stations were checked monthly by Terminix technicians. Every month all baiting accounts for the month were printed by PCS and distributed to the technicians in the area. This would create a ‘route’ for the month for the technician to check his/hers accounts for the month. The first time the technician would check the stations around the structure was approximately one month after its installation. At this time, the technician would number each station while inspecting the stations for termites. After the initial inspection the labeled station numbers were permanent for all future inspections. When live termites were found in a station the technician

would mark the station number as a ‘hit’. If live termites were found in a station and/or inside a structure the technician would bait the station and install an above-ground bait station (AG) on the live termites inside the structure. AGs were installed on known areas of termite activity in or on a structure. Each technician monitoring Operation Full Stop accounts would carry an individual account sheet in a binder. This sheet contained the date of the stations inspection, and whether the stations were hit, baited, with termites, or without termites. ‘Hit’ and ‘with termites’ are defined as live termites were found in a station, if this occurred the technician would note that the station was ‘baited’. If no live termites were present, technicians most commonly wrote ‘N/A’. If an above ground station was installed the technician would number the station and mark ‘AG’ on the sheet. The above ground station would then be monitored monthly with the ground stations. When a station did have active termites the technician would mark the station number with 1) baited 2) hit, 3) with termites. If on a check, no active termites were found but with some bait eaten, and the bait was to remain the technician would mark: 1) baited, 2) hit, and 3) without termites. For the purpose of this research I recorded stations that were 1) baited, 2) hit 3) with termites and 4) without termites. The information was also submitted to the LSU AgCenter according to Operation Full Stop requirements. In the Excel spreadsheet, the address, start date, linear feet of house, slab or pier, treated within or over five years, and known or preventative treatment treated also were categorized. Thus, each account was individually sorted based on its year in the program, number of hits, and number of inspections performed.

The average of the individual Attack Rates was calculated for each of the 100 accounts and recorded in Excel. The account addresses were converted to latitude and longitude coordinates using www.gps-coordinates.net on Google Maps. Longitudinal and latitudinal data were plotted using Geocoding Place Names Add-In in JMP Statistical Discovery Software 11.0 from SAS.

2.2.3 Percentage of baits attacked in calendar year

We analyzed the Attack Rate from 1998 to 2011. The overall average Attack Rate of the 100 accounts was sorted into Excel for each calendar year for each account. Number of accounts, inspections, stations present, stations inspected, and hits was recorded from each accounts file in Dox Serve Software and manually implemented into Excel. Attack Rates were calculated in excel and statistically analyzed by ANOVA in SAS PROC MIXED.

2.2.4 Percentage of baits attacked after installation by year

To determine termite activity per year after installment of bait installation we analyzed termite activity by year. Attack Rate was manually implemented into Excel. Attack Rates were calculated in Excel and statistically analyzed by ANOVA in SAS PROC MIXED. Percentage of baits attacked by year of bait installation was categorized by the first year data was available to the last year of data availability. These categories were Year 1–14, Year 2–14, Year 3–14, Year 4–14, Year 5–14, and Year 6–14. Number of accounts, stations present, of stations, and stations inspected were recorded from the Dox Serve Software System and inserted in tables for each category.

To determine termite activity in calendar months we analyzed Attack Rate by month from 1999 to 2011. Attack Rate were calculated for each month for each account out of the 100 accounts and sorted in Excel by calendar year. Number of accounts and hits were recorded from each accounts file in Dox Serve Software that was manually implemented into Excel. Attack Rates were calculated in excel and statistically analyzed by ANOVA in SAS PROC MIXED.

2.2.5 Timeline between termite activities

To determine if termite activity was more likely than not to continue on a station after it had previously been attacked we analyzed for the likelihood of a second attack on a station. Termite hits were sorted for each account by station number in Excel. Stations on that were ‘hit’

twice or more times were manually marked. Number of hits and numbered stations was gathered from Dox Serve Software files and manually implemented into Excel. Number of hits was analyzed by a Chi Square test in SAS PROC MIXED.

2.2.6 Slab versus pier

To determine termite activity difference between slab and pier houses we analyzed Attack Rates between slab and pier structures from 1998 to 2011. Slab and pier structures were sorted in Excel and JMP statistical discovery by SAS. Number of accounts, inspections, stations present, stations inspected and hits for each month in Dox Serve Software that was manually implemented into Excel. The overall Attack Rates were analyzed in a T-Test SAS PROC MIXED.

2.2.7 Preventative versus known infestation

'Preventative' and 'Known' accounts were sorted in Excel and JMP statistical discovery by SAS and the overall Attack Rates were analyzed. Number of hits, stations inspected, and number of inspections was recorded from each accounts file from Dox Serve Software. Overall Attack Rate was analyzed in a T-Test by SAS PROC MIXED.

2.2.8 Treated over/under five years

Attack Rates were used to determine termite activity on structures which had been stated by homeowner as chemically treated over or under five years. 'Over' and 'Under' account overall Attack Rate was sorted in Excel and JMP statistical software by SAS. Number of accounts, inspections, stations present, stations inspected, and hits was recorded from each accounts file in Dox Serve Software that was inserted manually into Excel. Overall Attack Rate was analyzed in a T-Test by SAS PROC MIXED.

2.2.9 Linear footage

To determine termite activity affects related to linear footage of a structure's bait stations in Operation Full Stop were put approximately ten feet apart unless obstruction occurred. Accounts consisting of the following linear footages were sorted: 0–199, 200–299, 300–399, and 400+ linear ft. Attack Rates were manually implemented, sorted in Excel and JMP statistical discovery by SAS. Number of accounts, inspections, stations present, stations inspected, and hits was recorded from each accounts file in Dox Serve Software that was inserted manually into Excel. Overall Attack Rate was analyzed by ANOVA by SAS PROC MIXED.

2.2.10 Number of stations

To determine termite activity on structures based on the number of stations around a structure overall Attack Rate was calculated for each account. The average Attack Rate was then calculated for 100 accounts in divided into four categories by number of stations: 1–15, 16–30, 31–45, 45+. Number of accounts, inspections, stations present, stations inspected, and hits was recorded from each accounts file in Dox Serve Software that was inserted manually into Excel. Overall Attack Rate was analyzed by ANOVA by SAS PROC MIXED.

2.2.11 Statistical analysis

PROC MIXED repeated ANOVA was used to analyze Attack Rates by year, month, linear footage, and number of stations using SAS 9.4 (SAS Institute, Cary, NC, 2013). T-tests were used to compare: slab versus pier, known versus preventative, over or under five years, with or without AGs. Chi-square tests were used to for timeline of repeated hits and termites present or absent. This was analyzed by SAS PROC MIXED. Means were compared at $\alpha<0.05$ using Tukey's Honestly Significant Difference.

2.3 Results

2.3.1 Percentage of baits attacked from 1998 to 2011

There was a significant difference in Attack Rate from 1998 to 2011. (F=2.41; DF=13; P=0.034) (Figure 1). The decreasing trend of Attack Rate observed from 1998 to 2011 had a slope of (Y=-0.077x+1.411) (Figure 1). The highest Attack Rate was in 1999. The number of hits was highest in 2002 and decreased to 2011 (Table 1).

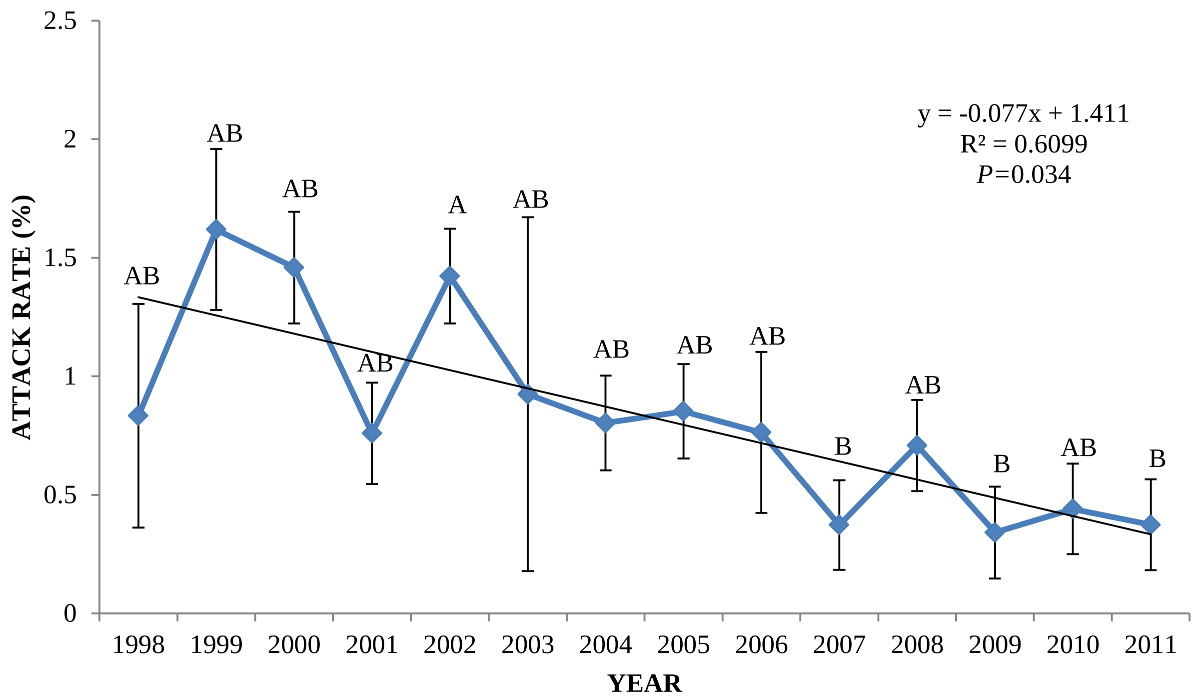

Figure 1. Changes in Attack Rate (±SEM) of Termites in 1998–2011 in Operation Full Stop.

2.3.2 Percentage of baits attacked in years 1–14

There was no significant difference in Attack Rate in years 1–14 (F=1.4; DF=49; P=0.1544) (Figure. 2). There was a decreasing trend of Attack Rate observed in years 1–14. The correlation had a slope of (Y=-.0289x+0.752) (Figure 2). Stations inspected, hits, and inspections observed decreased over time up to Year 9. Attack Rate then slowly decreased until Year 14 where it was the highest of all years (Table 2).

Table 1. Attack Rate and Number of Hits, Stations Inspected, and Inspections 1998–2011 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
1998	39	95	766	3
1999	135	229	1982	24
2000	249	440	3789	53
2001	348	440	5280	48
2002	566	963	8996	115
2003	787	1144	12559	91
2004	956	1385	15552	104
2005	693	1384	16560	85
2006	1004	1385	16560	93
2007	1007	1538	16865	64
2008	1070	1643	18946	73
2009	1079	1636	19310	60
2010	1078	1620	19400	70
2011	1005	1602	18333	73

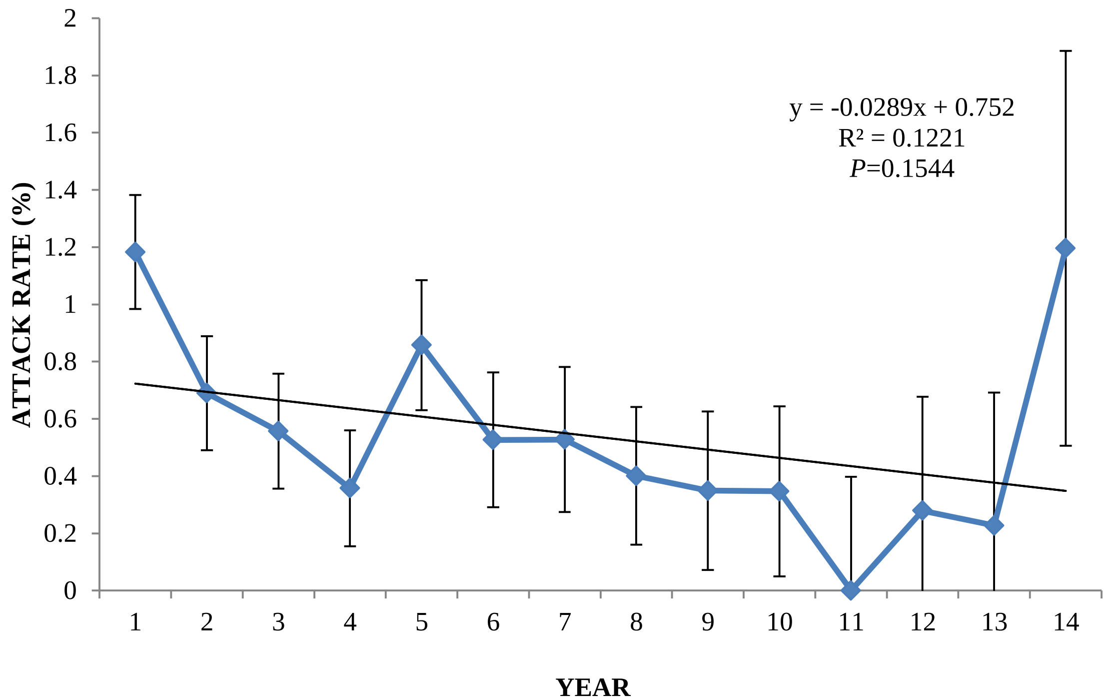

Figure 2. Changes in Attack Rate (±SEM) of Termites in Years 1–14 in Operation Full Stop.

Table 2. Attack Rate and Number of Termite Hits Years 1–14 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
1	394	1156	7963	81
2	684	1156	13056	65
3	696	1134	13476	54
4	643	1102	12242	45
5	599	929	10962	68
6	491	758	8677	43
7	470	735	8340	24
8	469	717	8183	36
9	362	492	5834	23
10	305	452	5173	15
11	180	228	2736	0
12	180	228	2736	7
13	131	165	1962	4
14	60	77	924	12

2.3.3 Percentage of baits attacked in years 2–14

There was no significant difference in Attack Rate in years 2–14 (F=1.06; DF=12; P=0.4124) (Figure 3). The decreasing trend of Attack Rate observed in years 2–14 had a slope (Y=-0.1861x+2.3963) (Figure 3). Hits recorded were variable over time (Table 3). Stations and inspections slightly decreased over time (Table 3).

2.3.4 Percentage of baits attacked in years 3–14

There was no significant difference in Attack Rate in years 3–14 (F=1.09; DF=11; P=0.383) (Figure 4). However, a decreasing trend was observed in Attack Rate in year 3–14 with a slope of (Y-0.0969x+1.5414) (Figure 4). Hits and number of inspections were variable over time (Table 4). Stations inspected decreased slightly in Year 13 and Year 14 (Table 4).

2.3.5 Percentage of baits attacked in years 4–11

No analysis was performed on this category since only one account was present (see Figure 5 and Table 5).

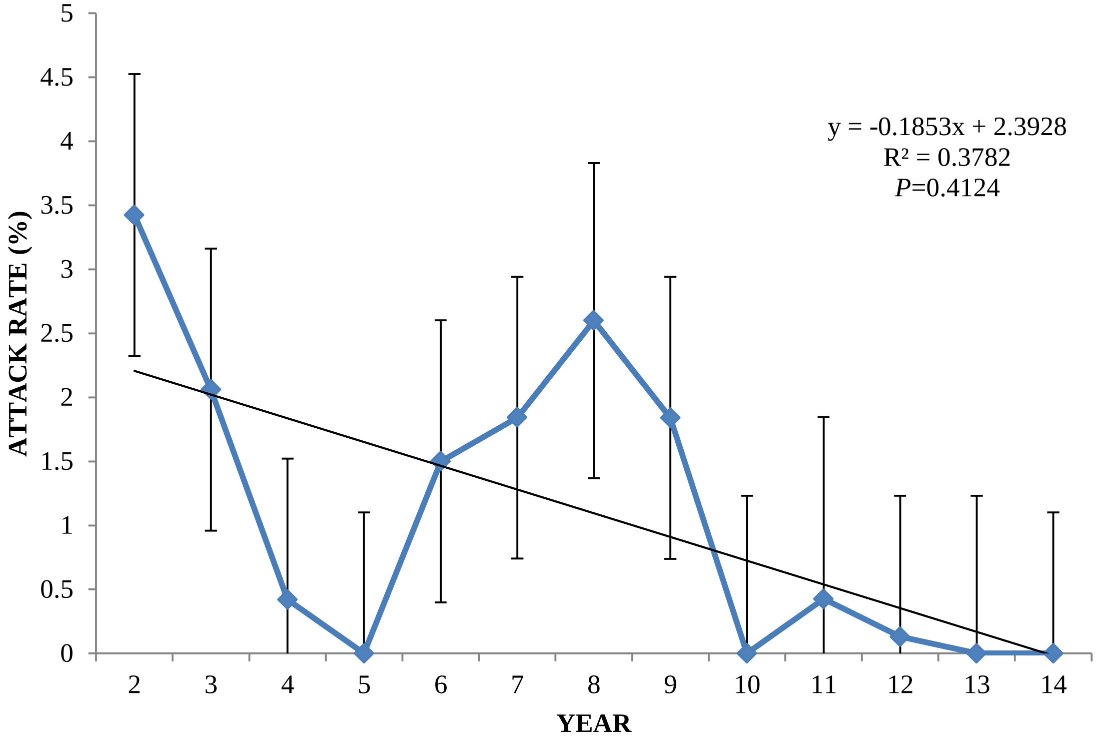

Figure 3. Changes in Attack Rate (±SEM) of Termites in Years 2–13 in Operation Full Stop.

Table 3. Attack Rate and Number of Hits, Stations, Inspections Years 2–13 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
2	34	69	2346	15
3	60	69	828	21
4	60	69	828	8
5	60	69	828	0
6	60	69	828	13
7	56	69	808	7
8	44	69	564	10
9	60	69	828	16
10	49	69	652	0
11	48	53	636	1
12	48	53	636	2
13	48	53	636	0
14	35	48	567	0

Note. Y1 data N/A.

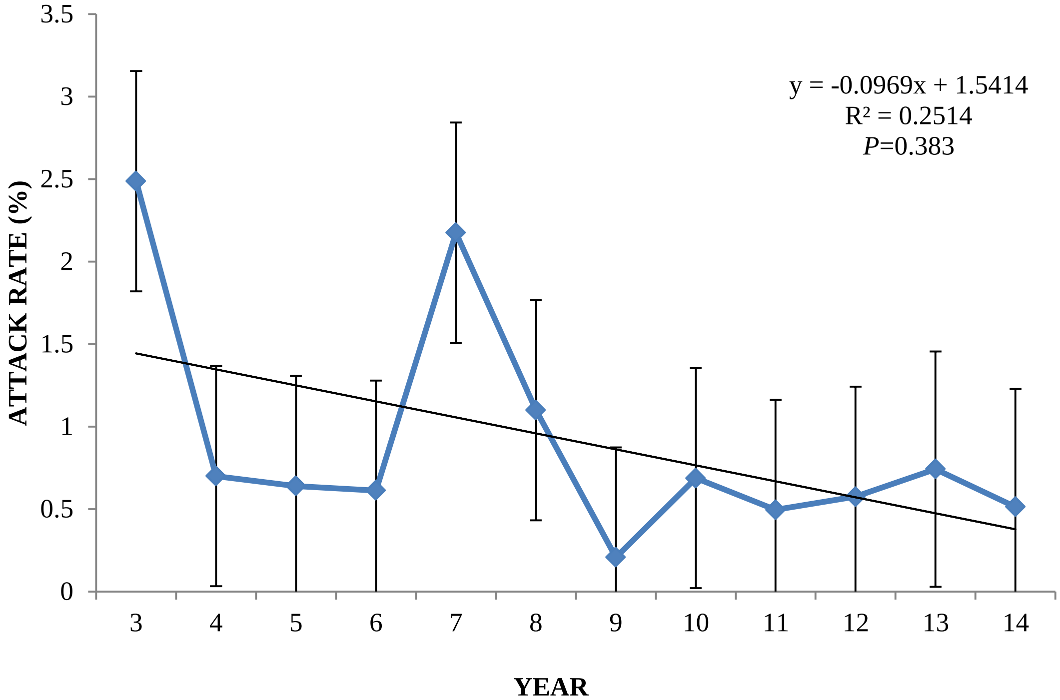

Figure 4. Changes in Attack Rate (±SEM) of Termites in Years 3–14 in Operation Full Stop. Y1 and Y2 data N/A.

Table 4. Attack Rate and Number of Hits, Stations, and Inspections Years 3–14 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
3	36	122	550	12
4	96	122	1464	17
5	96	122	2016	12
6	92	122	1404	7
7	96	122	1464	30
8	68	122	1036	11
9	96	122	1464	4
10	96	122	1464	11
11	96	122	1464	7
12	92	122	1404	8
13	84	107	1284	10
14	80	107	1228	7

Note. Y1 and Y2 data N/A.

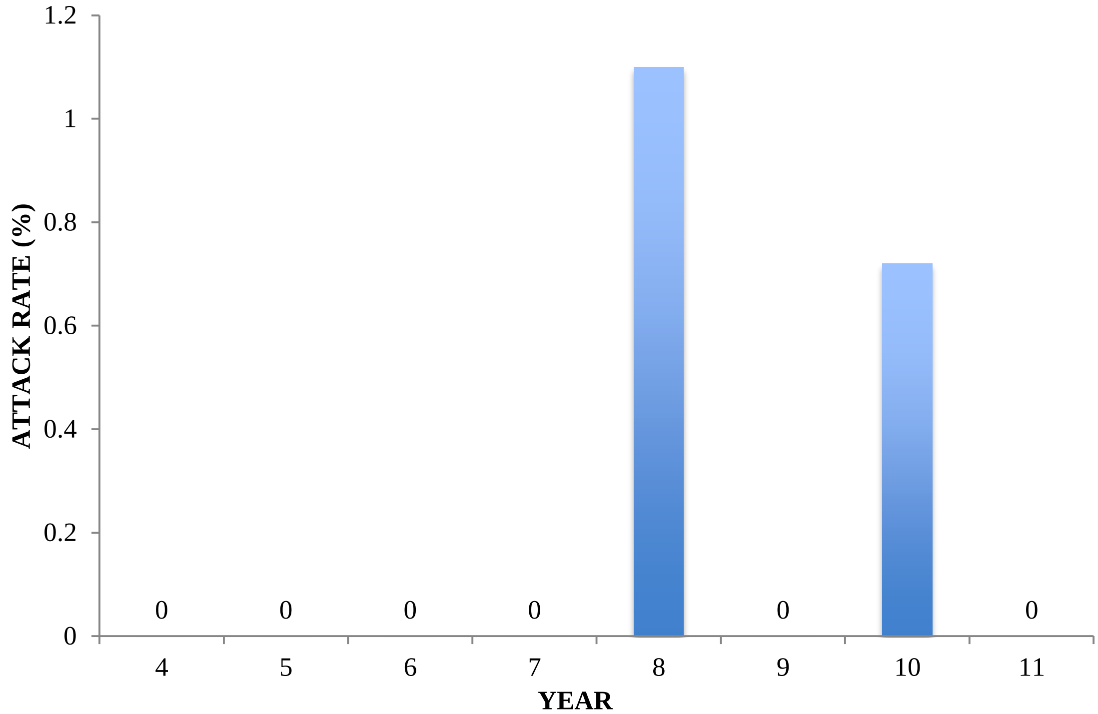

Figure 5. Changes in Attack Rate (±SEM) of Termites in Years 4–14 in Operation Full Stop. Y1–Y3 data N/A.

Table 5. Attack Rate and Number of Hits, Stations and Inspections Years 4–11 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
4	10	23	230	0
5	8	23	184	0
6	12	23	276	0
7	12	23	276	0
8	12	23	276	3
9	12	23	276	0
10	12	23	276	2
11	12	23	276	0

Note. Y1–Y3 data N/A.

2.3.6 Percentage of baits attacked in years 5–14

There was no significant difference in Attack Rate observed in year 5–14 (F=0.74; DF=9; P=0.06737) (Figure 6). The decreasing trend of Attack Rate was observed in Year 5–14 had a slope of (Y=-0.0942x+1.384) (Figure 6). Number of hits decreased over time (Table 6).

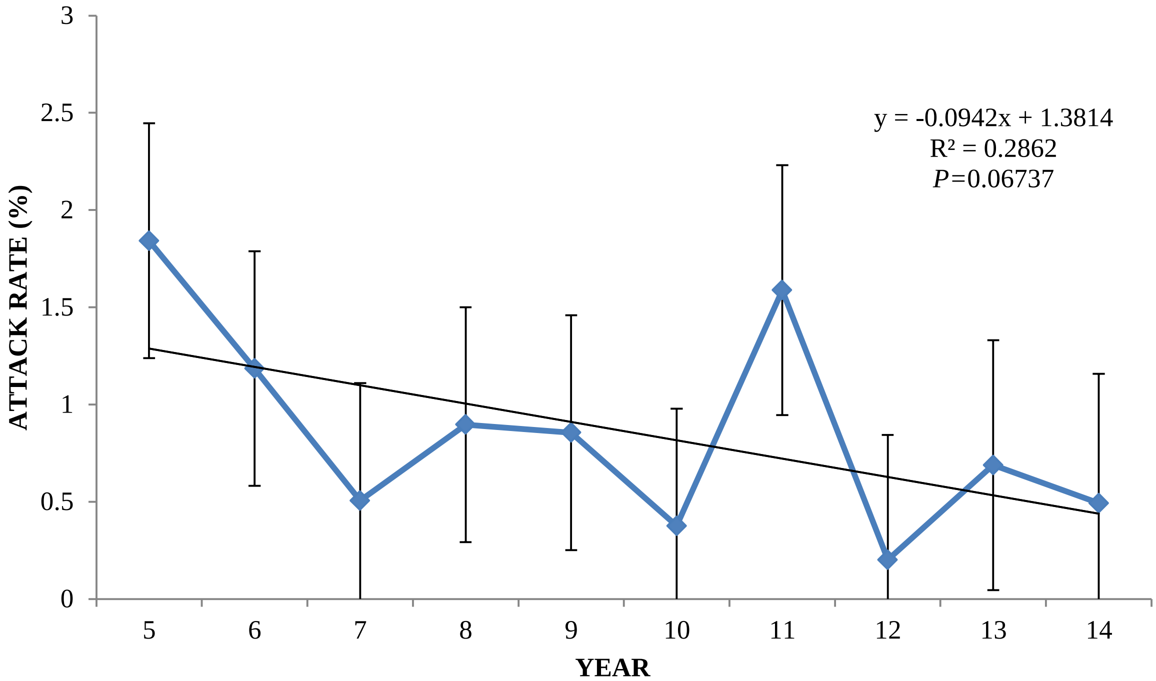

Figure 6. Changes in Attack Rate (±SEM) of Termites in Years 5–14 in Operation Full Stop. Y1–Y4 data N/A.

Table 6. Attack Rate and Number of Hits, Stations, and Inspections in Operation Full Stop Years 5–14 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
5	128	267	2018	39
6	204	267	3204	22
7	200	267	3140	10
8	145	267	2280	16
9	204	267	3204	21
10	187	258	3052	8
11	180	254	3048	15
12	180	254	3048	9
13	180	254	3048	11
14	142	238	2467	4

Note. Y1–Y4 N/A.

2.3.7 Percentage of baits attacked in years 6–14

There was no significant difference in Attack Rates in years 6–14 (*F*=0.54; DF=8; *P*=0.8209) (Figure 7). The decreasing trend of Attack Rate observed from Year 6–14 had a slope

of (Y=-0.1229x+1.33) (Figure 7). Number of hits increased until Year 10; Year 10–14 hits decreased (Table 7). Number of stations inspected decreased slightly in Year 12–14 (Table 7).

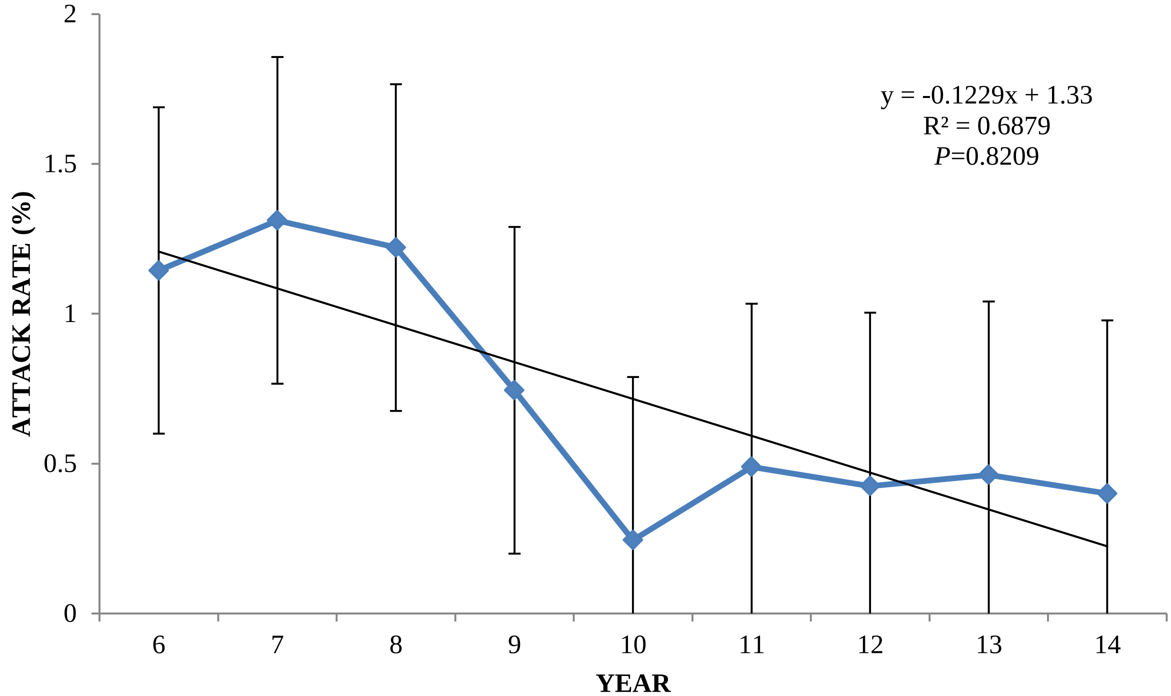

Figure 7. Changes in Attack Rate (±SEM) of Termites in Years 6–14 in Operation Full Stop. Y1–Y5 data N/A.

Table 7. Attack Rate and Number of Hits, Stations, and Inspections in Years 6–14 in Operation Full Stop

Year	Inspections	Stations in ground	Stations inspected	Hits
6	44	132	686	4
7	108	132	1584	24
8	72	132	1056	24
9	108	132	1584	21
10	108	132	1584	13
11	106	132	1556	5
12	96	118	1416	7
13	96	118	1416	7
14	96	118	1416	8

Note. Y1–Y5 N/A.

2.3.8 Percentage of baits attacked by month

There was a significant difference in Attack Rate between summer months and winter months; From May through September the Attack Rate was significantly higher than December through February (*F*=11; DF=9.98; P<.0001) (Figure 8). Most hits recorded occurred in May, June and July (Table 8). Number of hits trended upward January through July peaking in June and trended downward August through December (Table 8).

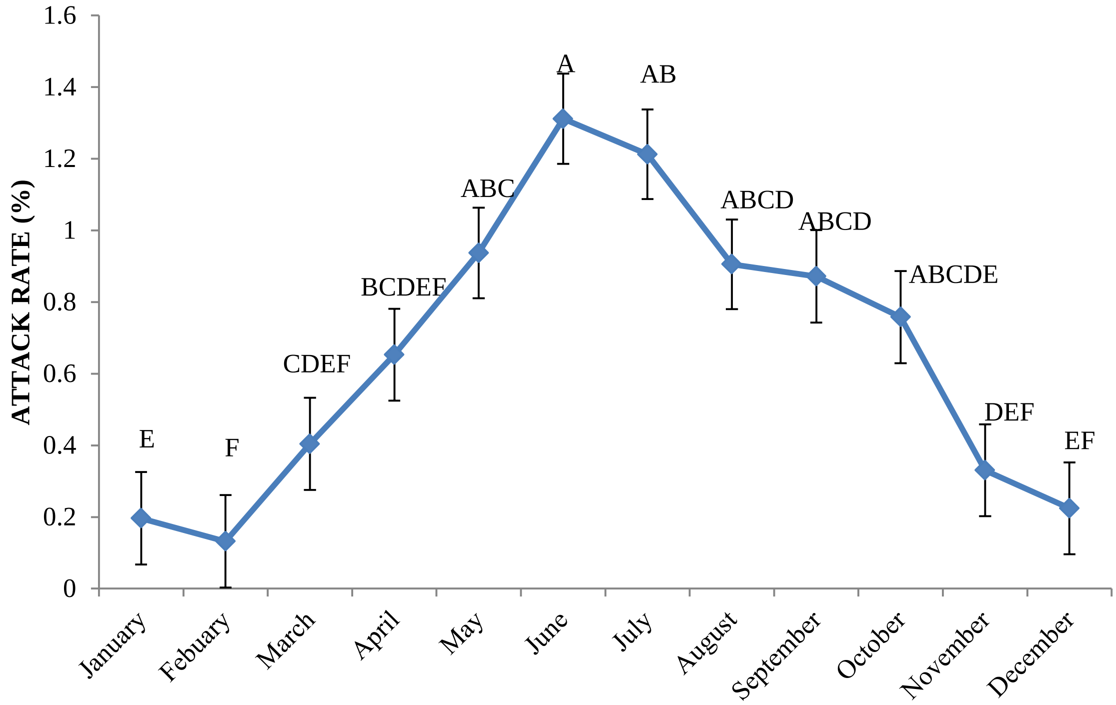

Figure 8. Changes in Attack Rate (±SEM) of Termites per Month in Operation Full Stop (1998–2011).

2.3.9 One-time repeated activity

There was a significant difference in a station getting hit 1-time more after it had been hit initially (Figure 9, Table 9). Number of stations hit once after the initial hit were significantly higher than the number stations not hit again after initial hit.

Table 8. Attack Rate and Hits per Month in Operation Full Stop (1998–2011)

Month	Hits
January	19
February	15
March	42
April	75
May	127
June	153
July	144
August	123
September	94
October	93
November	44
December	27

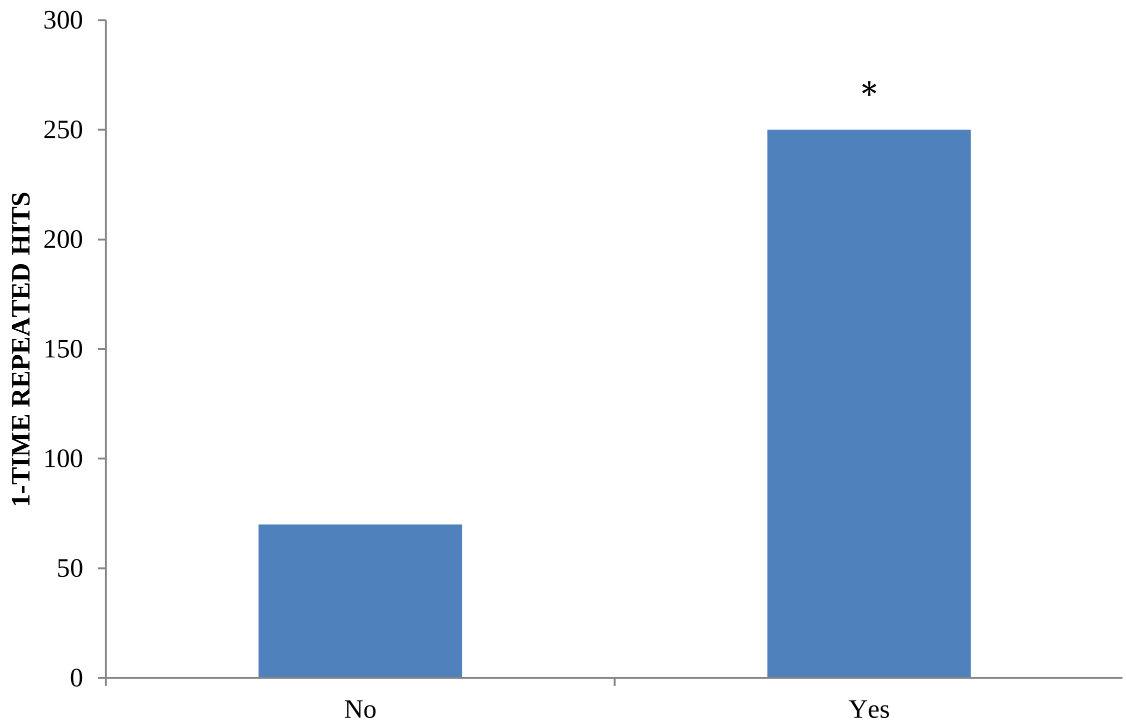

Figure 9. Number of Stations of Same Station Getting Hit 1 Time More After the Initial Hit. Asterisk indicates a significant difference.

Table 9. 1-Time Repeated Activity Hits

	Hits
Total number of hits	956
Hit once after initial hit	250
Not hit again after initial hit	70

2.3.10 Two-time repeated activity

There was a significant difference in a station not getting hit 2-times or more after the original hit (Figure 10, Table 10). Number of stations hit two or more times after the initial hit was significantly lower than stations not hit two or more times after the initial hit.

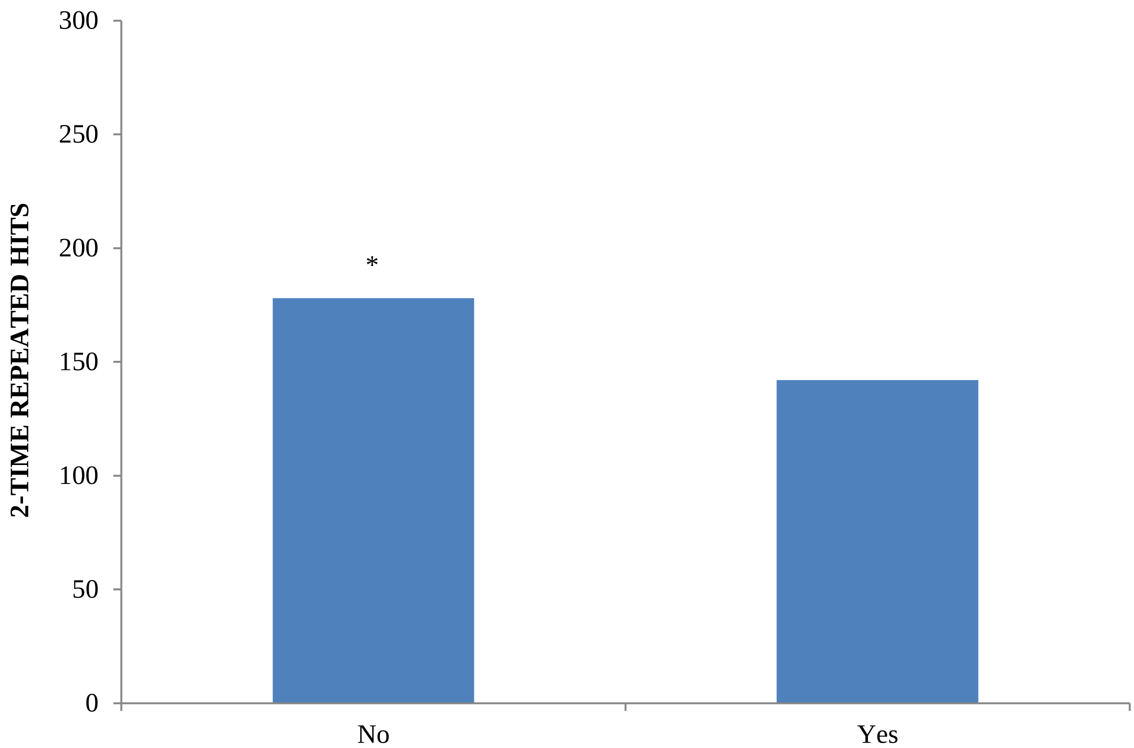

Figure 10. Number of Stations Getting Hit 2 or More Times after the Initial Hit.

Table 10. 2-Time Repeated Activity Hits

	Hits
Total number of hits	956
Hit twice after initial hit	178
Not hit twice after initial hit	142

2.3.11 Percentage of baits attacked: slab versus pier

There was no significant difference in Attack Rate between pier houses and slab houses (*T*=0.11; DF=98; *P*=0.9159) (Figure 11). The Attack Rate of pier structures was slightly higher than the Attack Rate of slab structures (Table 11). The number of slab houses was 3x higher than the number of pier houses (Table 11).

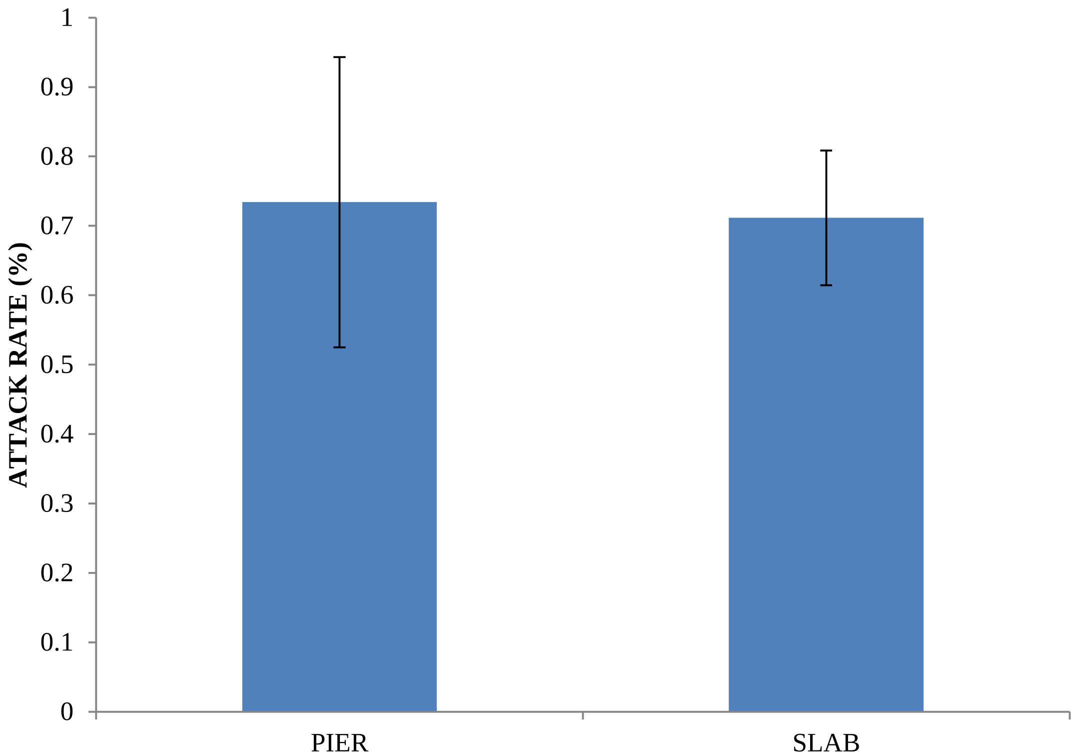

Figure 11. Change in Attack Rate (± SEM) of Termite in Pier versus Slab Structures.

Table 11. Slab and Pier Data during Operation Full Stop

Construction type	Accounts	Inspections	Stations in ground	Stations inspected	Hits
Slab	78	8331	12914	141764	776
Pier	22	1818	2519	23183	180

2.3.12 Percentage of bait attacked: known versus preventative

There was no significant difference in Attack Rate between ‘known treatments’ and ‘preventative treatments’ (*T*=0.64; DF=68; *P*=0.5227) (Figure 12). The Attack Rate of ‘known

treatments' was greater than the Attack Rate of 'preventative treatments' (Figure 12). The number of 'preventative treatments' was greater than the number of known treatments (Table 12).

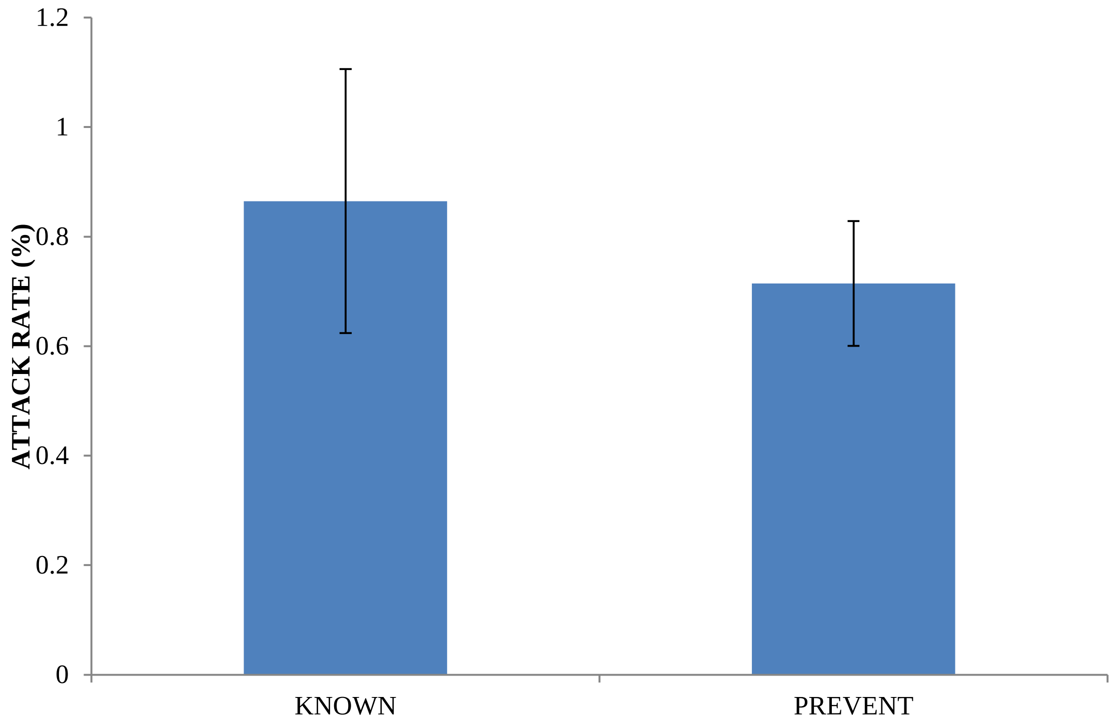

Figure 12. Change in Attack Rate (±SEM) of Termites on Known Treatments versus Preventative Treatments.

Table 12. Known and Preventative Treatment Data during Operation Full Stop

Type of treatment	Accounts	Stations in ground	Number of inspections	Stations inspected	Hits
Slab	24	3855	2826	71294	286
Pier	46	6588	4143	42821	433

2.3.13 Percentage of bait attacked: chemically treated over or under five years

There was no significant difference in Attack Rate between structures that were chemically treated within or over five years at the time of baiting installation (T=-0.78; DF=56; P=0.4386) (Figure 13). The Attack Rate of structures chemically treated less than five years at the time of baiting installation was not significant. Attack Rate of structures chemically treated

less than five years was greater than the Attack Rate of structures chemically treated within five years (Table 13). The number ‘Over’ treatments was greater than the number of ‘Under’ treatments (Table 13).

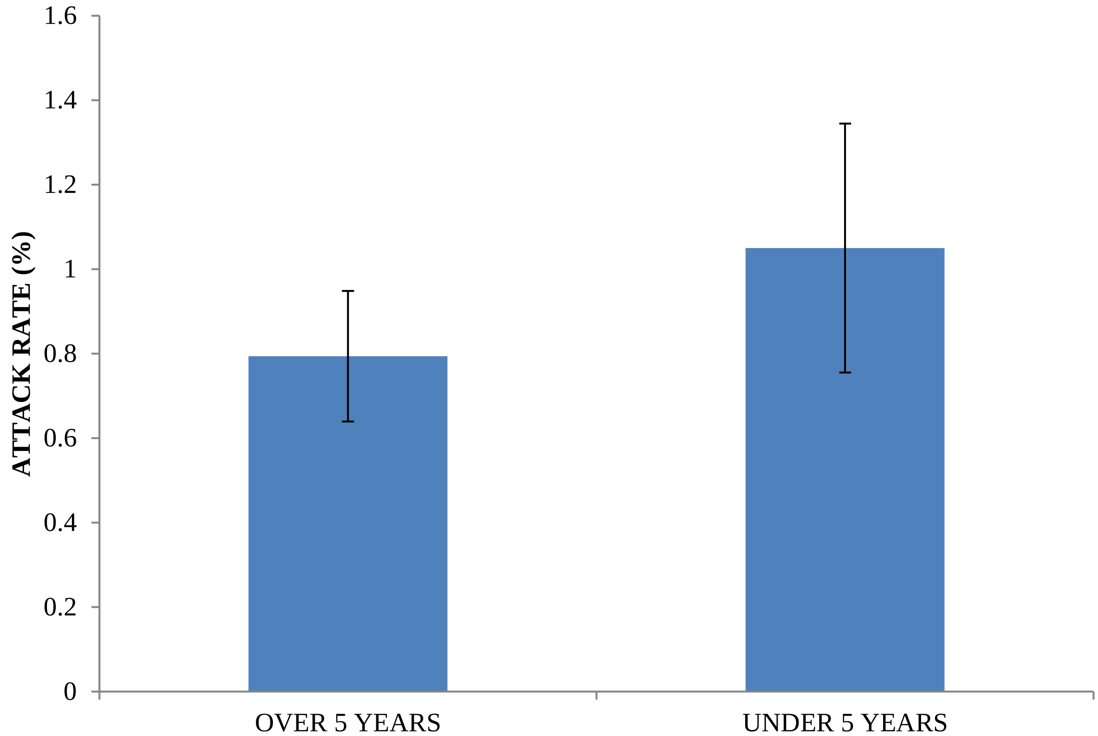

Figure 13. Changes in Attack Rate (±SEM) of Termites on Structures that Were Chemically Treated within 5 Years or over 5 Years.

Table 13. Over and Under 5 Years since a Chemical Treatment Data during Operation Full Stop

Over or under 5 years	Accounts	Number of inspections	Stations in ground	Stations inspected	Hits
Over	45	3918	5641	60809	348
Under	13	1420	1819	19585	201

2.3.14 Percentage of bait attacked by linear footage of a structure

There was no significant difference in Attack Rates based on linear footage of a structure (F=2.28; DF=3; P=0.0844) (Figure 14). The decreasing trend Attack Rate based on linear footage (Y=-0.0403x+0.82) (Figure 14). The Attack Rate was the greatest in structures between

300 and 399 linear feet and lowest in structures 400+ linear feet (Table 14). The highest number of accounts was structures between 200 and 299 linear feet, whereas the lowest number of accounts was structures 400+ linear feet (Table 14).

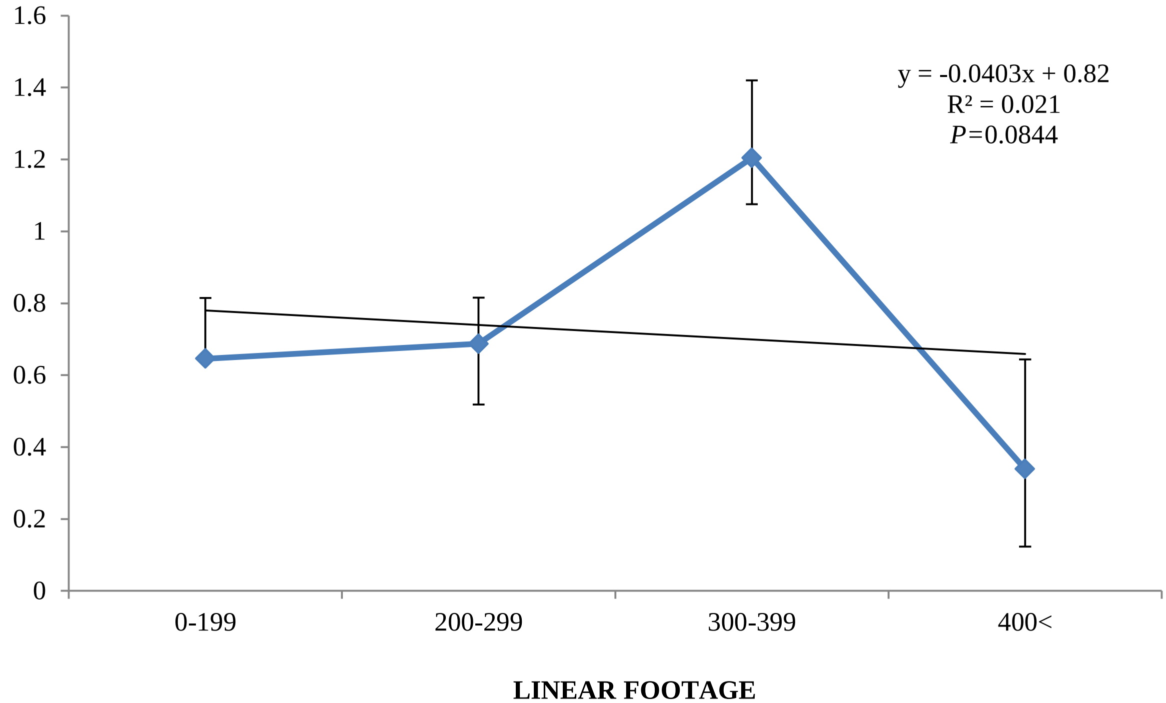

Figure 14. Changes in Attack Rate (±SEM) of Termites on Structures that Were Chemically Treated within 5 Years or over 5 Years.

Table 14. Linear Footage Data during Operation Full Stop

Linear feet	Accounts	Inspections	Stations in ground	Inspections	Hits
0–199	26	2814	3337	36593	256
200–299	45	1697	5557	60130	313
300–399	16	4223	2489	27252	269
400<	8	761	3580	40004	118

2.3.15 Percentage of bait attacked: with above ground bait versus without above ground bait

There was no significant difference in Attack Rate between structures the possessed an above ground bait station and structures which did not possess an above ground bait station (*T*=-1.26; DF=98; P=0.2114) (Figure 15). The Attack Rate was greater in structures without an above

ground bait station than structures with an above ground station (Table 15). The number of accounts without above ground bait was greater than those without above ground bait (Table 15)

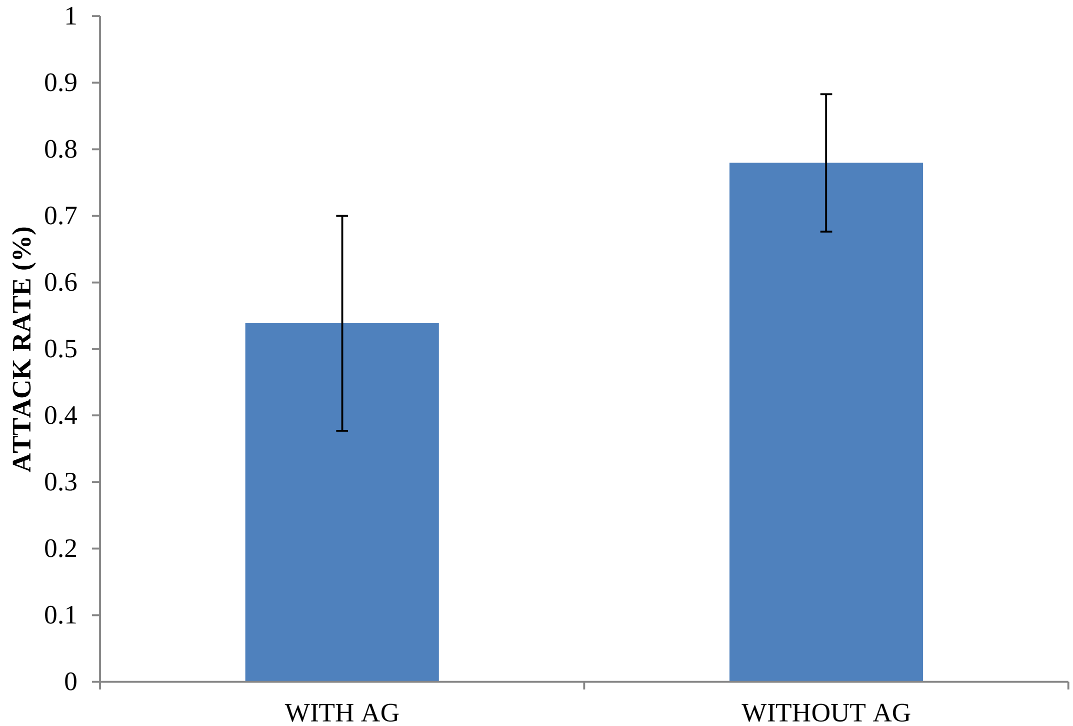

Figure 15. Changes in Attack Rate (±SEM) of Termites in Structures that Possessed an Above Ground Station versus Structures that Did Not Ever Possess an Above Ground Station in Operation Full Stop.

Table 15. With or without Above Ground Bait Data during Operation Full Stop

With or without AG	Accounts	Inspections	Stations in ground	Stations inspected	Hits
With	29	3295	5290	57942	249
Without	71	6808	10223	78073	707

Note. AG = Above ground bait.

2.3.16 Percentage of bait attacked by number of stations

There was no significant difference in Attack Rate based on the number of stations around a structure (*F*=1.01; DF=3; *P*=0.3927) (Figure 16). There was a decreasing trend in Attack Rate by number of stations (Y=-0.1926x+0.9765) (Figure 16). Attack Rate was the

highest in structures with 1–15 stations and the lowest with 31–45 stations (Table 16). The number of accounts decreased from structures with 1–15 stations to 45+ stations (Table 16).

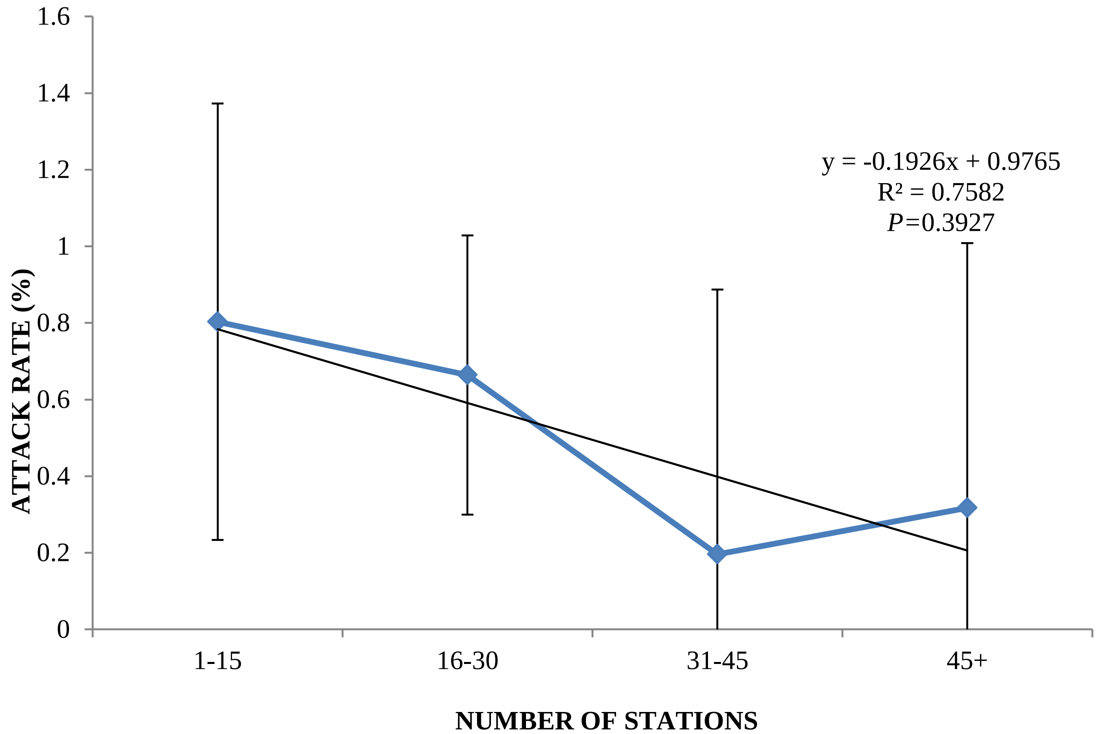

Figure 16. Changes in Attack Rate (±SEM) of Termites by Number of Stations in Operation Full Stop.

Table 16. Number of Stations Data during Operation Full Stop

Number of stations	Accounts	Inspections	Stations in ground	Stations inspected	Hits
1–15	57	5653	5715	60567	449
16–30	35	2644	4659	50659	223
31–45	5	587	1853	20942	46
45+	3	344	2012	22357	80

2.3.17 Termites present or absent in stations

There was a significant difference in number of accounts that had termites in stations than accounts that did not have termites in stations (DF=1; $P<.0001$) (Figure 17). The number of accounts with termites present was greater than number accounts with termites absent (Table 17).

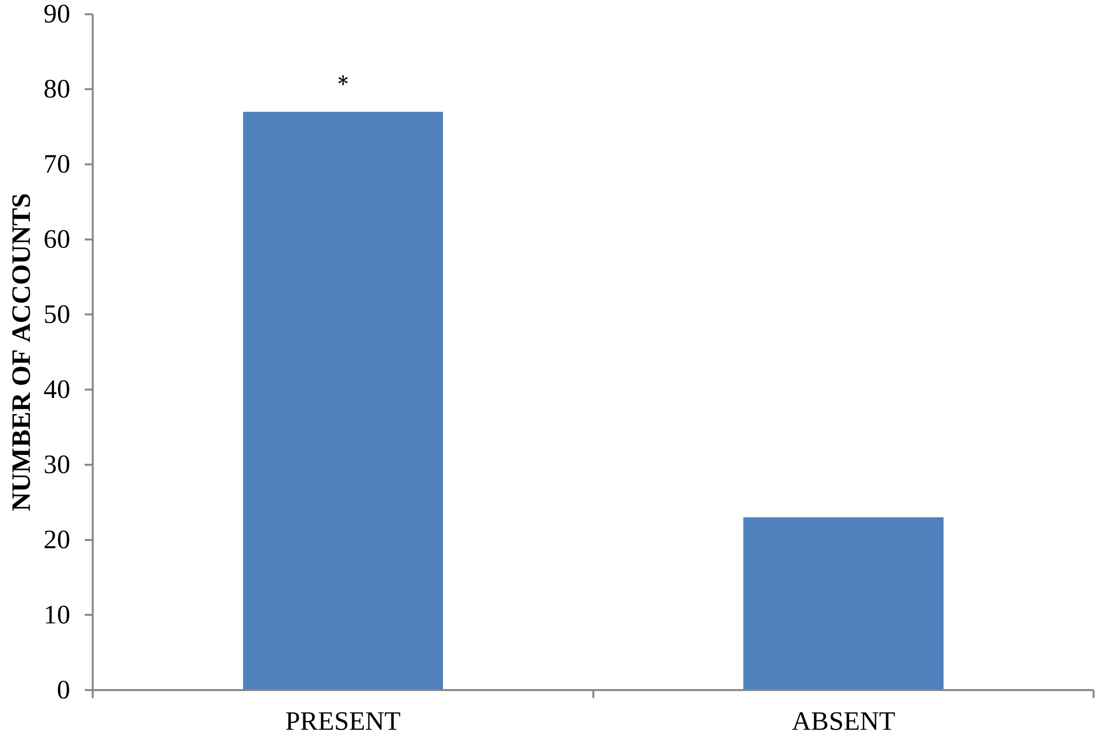

Figure 17. Change in Number of Accounts (±SEM) of Termites Present or Absent in Stations in Operation Full Stop.

Table 17. Termites Present or Absent Data during Operation Full Stop

Termites present or absent	Accounts	Inspections	Stations in ground	Stations inspected	Hits
Present	78	8747	13858	149735	956
Absent	22	1909	2634	28342	0

2.4 Discussion

Terminix was involved from the start in Operation Full Stop and wrote more contracts with French Quarter residents for termite treatments than any other single company. As a result, when it was clear that no final analysis of the millions of dollars spent on testing new colony reduction products in a USDA funded area-wide treatment program was not going to occur, Terminix decided to allow access of their 13 years of data whereby over 1,000,000 bait station

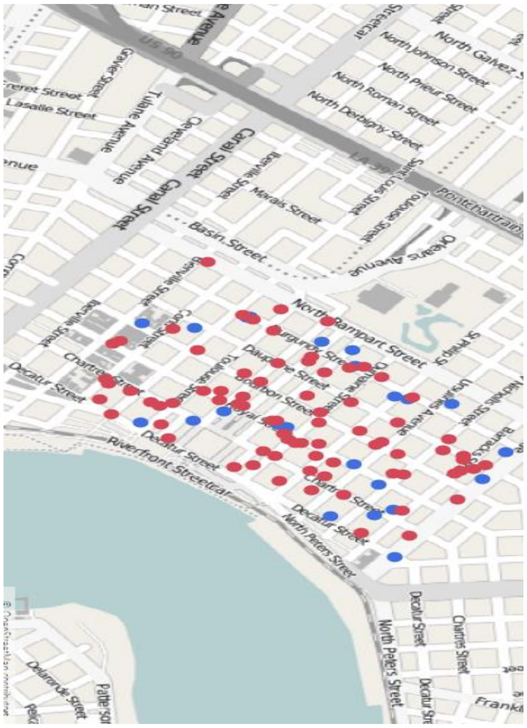

Figure 18. Sampled Terminix Accounts in Operation Full Stop (1998–2011). Red = termites present; Blue = termites absent.

checks for termite attack were analyzed. This represents the longest-longitudinal evaluation on termite baits in the field on record. In almost all measures preformed in this analysis it was clear that a decreasing trend in termite attacks on baits occurred in this historical evaluation of termite control. Most notable in this research was the significant decrease in termite attacks as measured using an Attack Rate in the French Quarter overall. This suggests a corresponding decrease in termite populations and signifies an important success to the original goal of the program, to reduce termite pressure in the Quarter. Attack Rate decreased significantly from 1998 to 2011. This suggests that baiting in the French Quarter decreased termite activity in Terminix accounts. Attack Rate was the greatest in 1999 and the lowest in 2011. In a report produced by the USDA in 2000 and 2001 50% fewer alates were trapped in the same traps compared to 1998 and 2000 (Spillman 2002). The LSU AgCenter reported a similar decrease in the average number of alates caught per trap from 1998 to 2003 and a decrease of 85% from 2002 to 2010, in all likelihood a

result of the treatment effort in the French Quarter (Henderson and Ring 2010). Guillot et al. (2010) reported a decrease in the percentage of active in ground stations from 2003 to 2007 with an increase of percentage in 2008 and 2009. These results are consistent with our results where a decrease in Attack Rate was found from 2003 to 2007 with an increase in Attack Rate in 2008. Furthermore, the LSU AgCenter reported a decrease in alate populations in the French Quarter and increase outside the French Quarter from 1997 to 2003 (LSU AgCenter). The similarity in trends could suggest that Formosan subterranean termites are behaving similar in the New Orleans French Quarter. This could indicate that Formosan subterranean termites are behaving as a ‘supercolony’ in the French Quarter as Henderson suggested in 1998 (Schleifstein and Mcquaid 1998). Thus, that instead of fighting and competing for resources they may be combing efforts and acting cooperatively (Schleifstein and Mcquaid 1998). Increases and decreases in termite activity in ground stations almost may be related to Formosan subterranean termite search activity (Hedlund and Henderson 1998). Hedlund and Henderson (1998) showed that as food size and consumption increased exploratory tunnel decreased. This result suggests that a large food supply could affect bait efficacy (Hedlund and Henderson (1998). Moreover, Guillot et al. (2010) suggested that termite infested trees could have been contributing to termite density because they were not originally treated in the pest control contract. Nonetheless, decreased termite activity in stations could be a result of toxicant; however, it also could be a result of already established colonies consuming suitable food sources in the French Quarter.

A study at the University of Florida showed that baits reduce damage potential (Su et al. 1991). Trapping termites in an urban environment has proved to be successful where 10,000 termites may occupy a single trap (Su and Scheffrahn 1988). The results of this report suggested that Operation Full Stop could be successful if implemented correctly with the proper type of

baiting insecticide. This success was demonstrated using the Sentricon® system, the same product used by Terminix, when entire colonies of several million termites were eliminated (Su 1994).

The trend of Attack Rate was shown to decrease in baits attack by calendar year. This result suggests that termite baiting over a period of time decreases termite activity. A study utilizing ground stations and above ground stations on subterranean termites using hexaflumuron showed that subterranean termite colonies were eliminated in 3 to 11 months on Liberty Island (Su et al. 1988). A study conducted in New Orleans during Operation Full Stop demonstrated colony elimination of Formosan subterranean termites within 3 months using hexaflumuron in Louis Armstrong Park (Messenger et al. 2005). Their work suggests the possibility that reinvasion of stations in our study was due to new colonies after elimination of the previous vacated space. A study conducted in the Cabildo in the New Orleans French Quarter demonstrated elimination of the Formosan subterranean termite infestations using hexaflumuron in ground stations and above ground baits (Su et al. 2000). The infestations in Cabildo were eliminated in 3 to 9 months with no visible dispersal of within two years of the treatment (Su et. al 2000). Messenger et al. (2005) also claimed that new colonies Formosan subterranean termites will occupy space and Sentricon® stations previously occupied by the eliminated colony Huesseneder et al. (2007) found that extended families and simple families of Formosan subterranean termites moved into ground stations in New Orleans on the River Front Railroad that were previously occupied by eliminated termites using hexaflumuron. Fifteen colonies were treated in ground stations and within a year were not found again; eighteen new colonies were later found after the treatment in ground stations (Husseneder et al. 2007). This prior research shows the effectiveness of the Sentricon® system in eliminating termites which suggest that our

results demonstrated the baiting system decreased termite activity over time in Terminix accounts. Nevertheless, prior research shows that once a colony is eliminated from feeding in ground stations that new colonies will invade the vacated space Husseneder et al. (2007), Messenger et al. (2005). The constant number of hits in the findings of this research over an approximate 13-year period shows evidence of the heavy Formosan subterranean termite population in New Orleans. This population has been described as possibly the heaviest in the world (Lax and Osbrink 2003). However, the two stated goals of Operation Full Stop were to reduce termite pressure and increase awareness of Formosan subterranean termites in the French Quarter (Morgan et al. 2005). Therefore, increased awareness as stated in Morgan et al. (2005) of Formosan subterranean could have resulted in property owners and managers to report and/or treat termites on their property. Furthermore, treatments nearby or within Operation Full Stop by other pest control companies whether it be baiting stations or non-repellent liquids, could have resulted in decreased termite activity in Terminix' s ground stations. Nonetheless, the decreasing trend of termite activity suggests that baits were effective in decreasing termite activity over time; however, there is no scientific evidence stating that colonies were completely eliminated in this study

Seasonal weather patterns such as air and soil temperature can influence subterranean termite feeding (Evans and Gleeson 2001). Summer month Attack Rates were significantly higher than winter months (Evans and Gleeson 2001). Similar findings were reported in foraging populations in New Orleans where numbers of termite castes were significantly affected by month (Cornelius et al. 2015). Attack Rate and number of hits were the highest in Operation Full Stop in the summer months peaking in June. This result remains consistent with a PCOs bulletin stating that subterranean termites become more active in summer months because they are

searching for food sources (Moore 2004). This increased activity is a result of termites becoming more active when the soil is moist with moderate air temperature (Moore 2004). This is also consistent with Cornelius et al. (2015) findings that feeding in monitoring stations was correlated with the temperature. A study conducted by LSU stated that there was a significant difference in tunneling or excavations dependent on temperature for Formosan subterranean termites (Guatam and Henderson 2012). Nevertheless, seasonal changes, which significantly affected Attack Rate in our results, are similar to Gautam and Henderson (2012) which found that increased temperature significantly effects wood consumption and termite survival. Gautam and Henderson (2012) results are consistent with seasonal changes also recorded in Delaplane et al. (1991) in Lake Charles, LA where workers feeding rate was the highest in cypress trees during the summer months. A study in New Orleans showed untreated bait consumption the highest in summer months and lowest in winter months (Henderson and Forschler 1996). These results are consistent that seasonal variation plays a role in termite's activity. The results indicate that a bait system will be more effective in summer months than winter months.

Termites have shown a strong commitment to discovered viable food sources and the foraging behavior is influenced by pre-existing tunnels and conditions such as food size and wood species (Henderson and Fei 2002). Over the course of implementing data for this thesis it was noticed that station numbers repeated themselves when calculating Attack Rate and hits. The number of one-time or repeated hits was significant. This supports the idea that the foraging behavior of Formosan subterranean termites is dependent on preexisting conditions such as tunnels, type of wood, size of wood, and colony size. Thus, it has been demonstrated in Messenger et al. (2002) and Husseneder et al. (2007) that different Formosan subterranean termites occupy the vacated or eliminated space of previous colonies. This could suggest that

these new colonies for termites are using the preexisting conditions of their counterpart to reduce energy costs. However, Messenger et al. (2005) states that selected colonies took three months to be eliminated. Therefore, our results show termite activity in stations for after the initial hit. Stations hit two or more times after the initial hit could indicate feeding on the station for a prolonged period, three or more months, or a new colony discovering the ground station as described in Messenger et al. (2002) and Husseneder et al. (2007). Thus, the results indicate that once a station is hit once it likely to get again. Stations hit twice are not likely to get hit again which could indicate a decline in termite activity.

Formosan subterranean termites are capable of finding small cracks in cements (Su and Sheffrahn 2013). Formosan subterranean termites will attack non-cellulose materials e.g. brick, mortar, and concrete in an effort to find food and moisture (Su and Scheffrahn 2013). Therefore, Formosan subterranean termites are capable of finding small cracks in slabs or piers. Our results in slab versus pier showed no difference in Attack Rate. Most Pier houses in the French Quarter are brick which could limit the route of entry and availability of non-cellulose objects as described in Su and Scheffrahn (2013). Formosan subterranean termites will make foraging routes out of small cracks in concrete (Su and Scheffrahn 2013). Therefore, brick piers or slabs were treated with a repellent insecticide before Operation Full Stop could have caused termites to forage elsewhere for food and moisture. Nonetheless, there is little difference between the Attack Rates suggesting that bait is effective on both types of structures.

The most effective way to protect a structure from termites is prevention and inspection (Meiracker et al. 2000). Preventative treatments had a higher number of accounts than preventative treatments which most likely resulted in a greater number of hits, stations inspected, and number of inspections. Known Attack Rate could be higher because termites were already

present at the time of installation. Above ground stations were likely placed on all ‘Known’ accounts at the time of installation and still resulted in a higher Attack Rate in ground stations than ‘Preventative’ treatments. Attack Rate for “known” could be higher because of pre-existing conditions in or around the structure (Henderson and Fei 2002).

Treatments before the implementation of Operation Full Stop were conventional liquid soil treatments (Henderson, Personal Communication 2015). Liquid repellent termiticides deter termites from a structure or prevent entry by lethal contact (Su and Scheffrahn 2013) but do not generally reduce the population overall. Attack Rate was greater in structures which houses had been treated chemically in less than five years. This suggests a difference in the efficiency and efficacy of conventional chemical treatments performed in less than 5 years of the baiting treatment. This could indicate that recent chemical treatments were not as effective as prior chemical treatments since the removal of the highly effective organochlorines in 1988 (Lax and Osbrink 2003). Non-repellents were not on the open market before Operation Full Stop and were being introduced and tested in Operation Full Stop in 1998 (Appendix A and Henderson personal communication, 2015). Pyrethroids used in conventional termite control were repellent termiticides. Repellent termiticides deter the termites away from the treated surface (Su and Scheffrahn 1990). Subterranean termites have the ability to forage through small-untreated places which is why liquid termite treatments can fail (Potter 2004). However, subterranean termites have the ability to bypass baiting stations as well. So both conventional liquid treatment and baiting can have a disadvantage. However, repellent liquid termite treatments in the French Quarter were costly and sometimes inefficient. Termite pathways such as common walls, floor covering, and other obstructions make a applying a proper liquid treatment difficult (Potter 2004). Our Results suggest that houses treated over five years before the ban of organochlorines

are less likely to encounter termite activity in stations because of the chemical present. While structures treated within five years of treatment are more likely to encounter termite activity in stations indicate an inefficient barrier.

Attack Rate was the highest in 300–399 linear feet structure. This category had the most number of inspections likely due to the structures length in the program. Number of hits was the greatest in 200–299. This result demonstrates that that termite activity is likely higher in structures with greater linear footage. Attack Rate was the greatest between 1–15 stations .This category had the most hits, stations inspected, and number of inspections. However, Potter (2004) suggests that the more ground baits installed the better chance of the stations encountering colonies of termites.

Formosan subterranean termites construct aerial nests within the structures they infest (Gold et al. 2005). An aerial nest within a structure and subterranean nest nearby can increase the chance of damage in the structure (Gold et al. 2005). Above ground baiting effects can be more rapid because bait is placed directly or on the pathway of the termites which reduces the waiting time (Potter 2004). Our results indicate that structures without an AG had a higher Attack Rate because the structure never had above ground stations placed on live termites. On the other hand, structures with an AG could have a lower Attack Rate because the above ground station eliminated that termite colony. A prior study involving above ground stations showed that stations with hexaflumuron placed on active aerial infestations of Formosan subterranean termites eliminated four out five Formosan subterranean colonies (Su et al. 1997). The remaining ground colony from the study decreased foragers significantly. Consequently, this trial did not achieve elimination which shows that baiting techniques can result in control rather than elimination. Nonetheless, colony control is crucial in dealing with the Formosan subterranean

termite colony sizes with estimates up to 70 million termites (Mcquaid 1998). Furthermore, a study conducted by the University of Hawaii showed that Formosan subterranean termites infestations were eliminated in approximately seventy two days in rooms of a USDA facility where above ground stations were installed (Yates and Grace 2000). Monitoring stations installed at this site in the study showed above ground monitoring stations remained active with dyed termites suggesting that multiple subterranean colonies were infesting the building. Exterior in ground monitoring stations were active but possessed no dyed termites from monitoring above ground stations (Yates and Grace 2000). When hexaflumuron was added to the exterior in ground monitoring stations termites in the in ground monitoring stations and remaining monitoring above ground stations were eliminated (Yates and Grace 2000). This could demonstrate multiple colonies within a building and around a building.

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CHAPTER 3. SUMMARY AND CONCLUSION

On April 15, 2011 Congress ended federal funding for Operation Full Stop when earmarks used to fund the program were taken away which were used to fund the program (Morgan and Ring 2011). Sandy Miller of the USDA of Agricultural Research Services (ARS) stated that the program was a victim of the federal government's decision to end of 'earmarks' introduced by congress to fund pet projects for their constituencies and the required cutbacks to major USDA research projects due to the ailing economy (Schleifstein 2013). At the end of Operation Full Stop, French Quarter property owners and PCOs were notified that the program had ended and that any further contracts with PCOs would be at the property owner's expense (Morgan and Ring 2011, Schleifstein 2013). In the letter of notification, the LSU AgCenter advised property owners that are crucial to maintain their contracts with their PCOs because new Formosan subterranean termites will travel into vacated spaces former colonies once inhabited (Schleifstein 2013). Terminix sent out a letter advising their customers that any customer renewal after April 15 will be receiving a bill to continue termite control (Schleifstein 2011). Terminix kept the majority of their Operation Full Stop accounts after the program ended (Schleifstein 2013). In 2015, Terminix holds 284 of their once 404 Operation Full Stop baiting accounts, a 70% retention rate roughly 4 ½ years after the programs conclusion (Pest Control Systems, Jackson, Mississippi). A normal baiting retention rate would be around 97% (Martin, personal communication 2015). In 2012 there was an attempt to restore funding to Operation Full Stop in the fiscal budget, but the attempt failed (Shleifstein 2013).

Terminix's current recommended treatment method in the French Quarter is implementing the Sentricon Colony Elimination System®. Today, the majority of Terminix accounts in the French Quarter are bait. Future of termite treatments in the French Quarter will involve better detection methods for termites inside buildings. After full stop Terminix had many

isolated colonies above ground that were not going to baits in the ground (Schleifstein 2013). During Operation Full Stop researchers were conducting inspection of buildings testing different types of instruments, including ones they detect heat content (Schleifstein 2013). Detection instruments, similar to devices tested during Operation Full Stop, will be vital in French Quarter termite treatments in the future. Terminix hopes for new and improved technology in baiting (Martin, personal communication 2015). Martin states that 'the company is winning the individual battles against Formosan subterranean termites in individual buildings; however, nature is winning the war'

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APPENDIX. LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER MEMO

LSU AgCenter Research & Extension

(16) LSU Ag Center Muller

September 20, 2007

Dear Pest Management Professional,

This letter is directed to pest management professionals (PMPs) with contracts on properties in the second expansion (third phase) (see Attachment 1, MAP) of the Formosan Subterranean Termite Program in the Vieux Carre and to PMPs who plan to participate in the program. The fourth expansion, (Phase V) will be bordered by the following streets: Bienville, Dauphine, Rampart, and St. Phillip (please refer to map). Funding for the program is contingent on appropriations from the United States Congress.

The program emphasizes suppression of Formosan subterranean termite densities through a community-based, wide-area integrated pest management approach. It is important that all structures throughout the entire target area be treated. All available technologies approved by the Louisiana Structural Pest Control Commission and the Louisiana Department of Agriculture and Forestry (LDAF) for controlling Formosan subterranean termites are allowed in this target area including baits, soil treatment, spot treatments borates, and fumigants, but only specific technologies will be paid for by the program. Elimination of conditions conducive to termites, including the removal of wood-to-soil contact and correction of moisture problems is critical, but the cost of eliminating these conditions is the property owner's responsibility.

Baits and the non-repellent insecticides are the only treatments currently available that are specifically for reducing Formosan subterranean termite numbers. All baits and non-repellent insecticides approved by the Louisiana Structural Pest Control Commission will be included in the program. When new baits or non-repellent insecticides are approved by the Louisiana Structural Pest Control Commission, they will be eligible for use in the program after approval by the LSU AgCenter.

The program will pay for treatment with an approved bait or a non-repellent insecticide on properties within the target area as follows: (l) properties that have not been treated and are not under a termite contract, (2) properties that have been treated but not with an approved bait or a non-repellent insecticide and, (3) renewals of existing contracts using the approved technology. Properties treated on or after September 20, 2007 are eligible for consideration. Properties treated prior to September 20, 2007 are eligible for consideration as renewals. A decision on payment for treatment with products other than approved bait or a non-repellent insecticide will be made on a case-by-case basis and preference will be given to treatments that are part of an integrated pest management program. Properties treated with soil treatments other than a non-repellent insecticide that are infested or become infested with Formosan subterranean termites must be treated with approved bait or a non-repellent insecticide shortly after the infestation is discovered.

The program will not pay for: (l) treatments other than those specified above, (2) the use of more than one bait treatment or non-repellent insecticide on the same property, (3) the treatment of properties outside the target area, (4) prorating existing contracts, (5) fumigation costs, (6) treatments that do not comply with the Louisiana Structural Pest control law and the rules and regulations of the Louisiana Pest Control Commission, (7) treatments applied by persons who are not licensed as structural pest control operators by the Louisiana Department of Agriculture and Forestry, (8) applications of termiticides that are not labeled by the EPA and registered by the Louisiana Pest Control Commission (9) applications that are not in accordance with label directions,(10) treatments that are not in

REQUIREMENTS FOR PMPs

1. Be licensed as a structural pest control operator by the Louisiana Department of Agriculture and Forestry (LDAF). – LES.un
2. Be a certified applicator as required by the LDAF.
3. Comply with the Louisiana Structural Pest Control law and the rules and regulations of the Louisiana Structural Pest Control Commission.
4. Apply only termiticides approved by the EPA, LDAF, and the Louisiana Structural Pest Control Commission using approaches agreed to by the LSU AgCenter and ARS. Make all applications in accordance with label requirements.
5. **Place bait stations at a spacing NOT to exceed TEN feet unless permission is requested from (provide an explanation of the need) and granted by the LSU AgCenter. Place a station within THREE feet of each property line.**
6. Provide a diagram of the property on graph paper showing the position of baits(with station numbers), liquid treatments and trees. Include linear footage of all structures. **Indicate which stations will be placed in concrete and which will be placed in soil.** Indicate the number of feet represented between two lines on the graph paper.
7. **Place bait stations near trees (3 stations), woody plants (shrubs, vines, woody ornamentals, other host plants), and planters found on the land of properties treated with bait at no cost to the program.**
8. Cooperate with representatives of the LTC in the selection of test sites.
9. Provide copies of their contracts with the property owners, including the terms of renewal to the LSUAC. Contracts must have been approved by the Louisiana Structural Pest Control Commission.
10. Agree that should an active infestation (meaning the presence of live termites) of subterranean termites occur in any portion of the building(s) covered by the contract, the company will treat such infested portions within thirty (30) days of discovery of such infestation at no additional charge to the program, except as otherwise noted within the contract. This applies to existing as well as new contracts. Active infestations must be reported to the LSUAC shortly after it occurs.
11. Submit to LSUAC evidence that the property owners have agreed to allow the LSUAC, LTC, LTC representatives, and PMPs access to the properties and to pay that portion of the contract exceeding what will be paid by the LSUAC. The evidence will consist of a form signed by the property owners, attached to the contracts for treatment, agreeing to the terms for participation in the management program.
12. Provide the LSUAC the names and the frequency of application of the termiticides used on properties under contract within the test area.
13. Treat the properties in accordance with the contracts.
14. Allow LSUAC and LTC or their representatives to accompany PMP employees during application of termiticides, inspections, and to collect data for assessment of treatment results.
15. Notify LSUAC personnel before all treatments and annual inspection.
16. Notify LSUAC personnel after completion of treatment. Notiification shall consist of treatment records as required by LDAF.
17. **Monitor bait stations and report these data to the LSU Agricultural Center on a monthly basis even if termites are not present. Annually, inspect properties treated with liquid termiticides and report these data to the LSU Agricultural Center even if such properties are baited.**
18. Indicate dates of renewal period on all renewal invoices.
19. Recognize that payment for treatment and renewals is not expected to exceed five years and is dependent on continued funding from the U. S. Congress.

PROCEDURES AND REQUIREMENTS FOR PEST MANAGEMENT PROFESSIONALS INITIATING OR RENEWING CONTRACTS IN THE FRENCH QUARTER PROGRAM

Send the following information to: Gia Parkes, SRRC, 1100 Robert E. Lee Blvd., New Orleans, LA 70124. (504-286-4268)

1. A copy of a signed, **APPROVED CONTRACT** between the PMP and the property owner(s) (NOT renter) including all costs for treatment and renewal. An annual inspection report for all renewals.
2. A detailed **DIAGRAM** or diagrams of the property showing the location of proposed treatments. Include the proposed location of stations. See # 12 below.
3. A copy of the attached **AUTHORIZATION FORM** signed and dated by property owners and the PMP.
4. Completed copy of the attached **GENERAL INFORMATION FORM** for each property.
5. A survey when requested.

All forms, surveys, and contracts with signatures of the PMP and property owner(s) must be received and approved by The LSU Agricultural Center before treatment is begun.

After the above items have been submitted, PMPs will:

1. Receive written notification from the LSU AgCenter that the proposed treatments will be paid for. A purchase order will be issued for the properties chosen. **If the property is a new treatment, an inspection by a representative of the LSU AgCenter must be organized prior to written permission being issued**. Please contact Chris Dunaway (504) 286-4539 to organize this inspection.
2. Treat properties according to the requirements for property owners and pest management professionals.
3. Inform Gia Parkes at (504) 286-4268 between 8:00 a.m. and 4:30 p.m. Monday - Friday after treatments have been made. Provide an invoice.
4. Assist in inspecting treatments if asked. Provide a numbered diagram showing bait stations.
5. Provide monthly bait and annual inspection reports to the LSU AgCenter from treated properties including in- and above-ground stations.
6. Notify LSU AgCenter personnel before all treatments and annual inspections and of infestations of Formosan or other subterranean termites in structures within the target area.

Payment for initial treatments will be made to the PMP after treatments have passed inspection and a numbered diagram (# 13) and invoice are received. Payment for renewals will be made after monthly bait and annual inspection reports and an invoice is received.

VITA

Edward Joseph Martin IV, a native of New Orleans, Louisiana, received his bachelor's degree in Business Administration from the University of Mississippi in 2011. Thereafter, he worked at Terminix Service Co. Inc. in Metairie, Louisiana. As his interest in Entomology grew, he made the decision to enter graduate school in the Department of Entomology at Louisiana State University in Spring 2014. He is a candidate for his master's degree in August 2016 and plans to continue his work as an entomologist at Terminix Service Co. Inc. upon graduation.