

DISPERSAL FLIGHT, POST FLIGHT BEHAVIOR AND EARLY COLONY
DEVELOPMENT OF THE WEST INDIAN DRYWOOD TERMITE *Cryptotermes brevis*
(WALKER) (ISOPTERA: KALOTERMITIDAE)

By

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To my Dad, who was the first to support my love for entomology.

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Abstract of Thesis Presented to the Graduate School
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DISPERSAL FLIGHT, POST FLIGHT BEHAVIOR AND EARLY COLONY
DEVELOPMENT OF THE WEST INDIAN DRYWOOD TERMITE *Cryptotermes brevis*
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The termite species *Cryptotermes brevis* is a serious structural pest. It is a drywood species spending most of its life inside wood and is only found outside of it when the dispersal flights occur. This important life stage is covered in this study.

The major weather cues that trigger the dispersal flights were covered in this study. These appear to be rainfall, humidity, and air pressure. The time of the flights occurred mainly between 1:00 and 2:00 am.

In this study, the attraction of alates to light was analyzed. Alates colonized more in areas with higher light intensity than in darker areas. Also, it was shown that the dealates display negative phototaxis, preferring to colonize holes in darker areas, after being first attracted to light.

The post flight behavior of the alate including wing release was analyzed. These behaviors were timed, counted for occurrence, and described. The preference for a diameter of colonization site was evaluated, showing that there was a preference for small diameters between 2.3 and 3.3 mm.

Early colony development was observed. The time to oviposition was measured, as well as the number of days until each egg hatched. The maximum number of eggs laid per colonizing pair was counted.

Observations from this study suggested a method for colonization prevention based on post flight behavior, which was tested. The results were unfavorable and putative reasons for the lack of success are discussed.

CHAPTER 1 INTRODUCTION

The West Indian termite *Cryptotermes brevis* (Walker) is a drywood termite belonging to the family Kalotermitidae. It was first described in Jamaica and is a structural pest found globally (except for Asia), infesting buildings and furniture, being mainly reported in the tropical and subtropical areas with some isolated occurrences in warmer temperate regions (Light 1934c; Edwards and Mill 1986). It is endemic to Chile and Peru where it occurs in nature, away from structural wood (Scheffrahn et al. 2008).

As like other drywood termites, *C. brevis* is a cryptic species which nests in its food source, wood, spending most of its life cycle inside it. *C. brevis* is a social insect and its colonies comprise three main castes: the reproductives (king, queen, and unmated winged forms called alates); the soldiers; and the immature reproductives, soldiers, and false workers or pseudergates (Snyder 1926). Both the male and female reproductives remain in the colony as king and queen and may be replaced by secondary reproductives when one or both die allowing the colony to continue. A colony of drywood termites can vary in size from hundreds to a few thousand termites (Nutting 1970) and several colonies can be found inside a single piece of wood.

This species has a life cycle which involves a dispersal flight where the alates leave their previous colony in order to form new colonies. The dispersal flights are the only occasion when this species is found outside wood (Kofoid 1934). Otherwise, it never leaves the nest to exploit new food sources (Korb and Katrantzis 2004). After flying, the alates shed their wings and associate as pairs of female and male dealates. These pairs will crawl around in the substrata in tandem, with the male following the female, searching for a suitable place to start a new colony (Snyder 1926, Wilkinson 1962, Minnick 1973). The new colony does not produce alates for about 5 years, at which point the colony is considered mature.

The drywood termites are a serious pest accounting for about 20% of the budget spent on termite control in the United States (Su & Scheffrahn 1990). One of the main methods used for controlling this pest has been the use of fumigants to eliminate existing colonies. This method however does not prevent new infestations from occurring. Understanding the dispersal flights of *C. brevis* is important to develop innovative ways of preventing the formation of new colonies.

The dispersal flights of termites occur at different times of the year depending on the species. For *C. brevis* the flight season in South Florida occurs between April and July, with a secondary smaller flight season in November. Some studies have been done on the weather cues that may be involved in the dispersal flights of several termite species, including cues such as air pressure, temperature, relative humidity, rainfall, and wind speed with the occurrence of flights (Minnick 1973, Akhtar and Shahid 1990, Rebello and Martius 1994, Medeiros et al. 1999). Not much work has been done on light attraction for alates of termites although it is commonly accepted that alates are attracted to light when flying (positive phototaxis) and after landing they seek refuge in dark areas (negative phototaxis) (Minnick 1973). Also after landing, termite alates of some drywood species engage in several behaviors including tandem running/crawling, calling and dealation (Nutting 1969). The choice of a colonizing site by some species of drywood termites that cannot bore into wood involves choosing a crack or hole of a limited size with enough space to allow turning but small enough to be economically sealed (Nutting 1969). The early colony development is slow for the Kalotermitidae family and numbers are small in the first year for species like *C. brevis* (Nutting 1969).

The main objectives for this study were to extend the knowledge of the dispersal flight of *C. brevis*, observe and quantify post flight behavior and the early colony development and use this knowledge to improve pest control techniques for this species. With these objectives in

mind, this study analyzed: i) what time of the year these dispersal flights occur, what possible weather cues may be involved in their occurrence, and the time of day they occur; ii) when flying, is there a positive phototaxis and does this depend on light intensity, and is this positive phototaxis followed by a period of negative phototaxis after landing?; iii) once an alate lands, what behavior does it exhibit, how long does it crawl in search for a colonizing site, and is there a preferred size for that site?; iv) after a pair is formed and a colonization site is chosen, how long does it take for the first eggs to be laid and for the first larvae to appear?; v) and finally, with the knowledge of post flight behavior, can a lesser area be treated with non-repellent insecticides with the same efficiency as the whole surface treatment?

CHAPTER 2 DISPERSAL FLIGHTS' TIME OF OCCURRENCE AND RELATION WITH WEATHER CONDITIONS

Introduction

Cryptotermes brevis has dispersal flights at different times of the year depending on the location in the world where their infestations occur. These different times of flight occurrences seem to indicate that weather conditions may have a role in cueing the species in to what is the most favorable time to have dispersal flights.

The dispersal flight season of *C. brevis* in South Florida occurs between the months of April and July, with a second smaller season in November. The occurrence of dispersal flights of some termites have been correlated with some weather conditions. On a monthly basis the dispersal flights can occur either before or at the end of the rainy season (Rebello and Martius 1994), and they can occur at an optimum temperature (Akhtar and Shahid 1990). On a daily basis the occurrence of flights appears to be correlated with the air pressure, temperature, and humidity (Minnick 1973). The influence of wind speed on the dispersal flights of termites depends on the species with some showing a strong correlation between low wind speeds and the occurrence of flights (Akhtar and Shahid 1990), while others have no apparent correlation.

Observations have been made on the time of day of dispersal flights for *C. brevis*, these being described as crepuscular events (Minnick 1973). Other *Cryptotermes* species also appear to be crepuscular or nocturnal in their dispersal flights (Wilkinson 1962).

The objectives of this study were to analyze the relationship between five atmospheric variables (temperature, rainfall, relative humidity, wind speed, and air pressure) and the occurrence of dispersal flights of *C. brevis*, and analyze the time of occurrence of the dispersal flights during a 24-hour period.

Materials and Methods

All experiments were conducted at the Fort Lauderdale Research and Education Center (FLREC), Davie, Florida, in UF building 5031. The experiments were conducted in a room of the building partially filled with *C. brevis* infested wood originated from several infestation sites and kept at ambient temperature and relative humidity, without air conditioning.

Data Collection

All data were collected between April 2006 and June 2008. The 2006 data was collected by Boudanath Maharajh under the same conditions as all subsequent data.

A water trap was set up consisting of a basin of 30x19x5 cm filled up to three quarters full with water. A fluorescent light was placed about 20 cm above the basin with an intensity of 1400 lux. The light was left on continuously throughout all the collecting time. All alates found in the basin were counted daily and placed in separate alcohol vials.

The data for weather conditions were provided by the Florida Automated Weather Network and by the National Climatic Data Center (NCDC). The weather variables used were temperature (°C), wind speed (kmph), rainfall (mm), relative humidity (%), and pressure (mmHg) daily averages.

In order to determine the time of day the alates performed their dispersal flight, a Nikon Coolpix S50 point and shoot camera was used. The camera was set up facing the water trap and programmed for time-lapse movie mode by taking a picture every 30 minutes. The time-lapse videos were analyzed frame by frame using the Picture Project software (version 1.6.2 Nikon), and alates in the water trap were counted for every frame.

Data Analysis

The correlation between the daily flights and the weather conditions were analyzed with a Principal Components Analysis and a General Linear Model, proc GLM (SAS Institute 2003).

The influence of the weather on the occurrence of flight was analyzed with a non-parametric Kruskal-Wallis test for all the variables. For this analysis, any data below 1% of the total of alates for that year were considered as a no flight so that outlier flights would not influence the results.

The “time of day the species flies” data were analyzed with a proc ANOVA to test if there were intervals of time when the “number of alates flying” variance was significantly different and the differences were analyzed by a Tukey grouping test (SAS institute 2003).

Results

A total of 5,684 alates were collected from the water trap between April 2006 and June 2008. There were two peak flights per flight season per year. In 2006 the peak flights occurred on April 20th and May 2nd, in 2007 the peak flights took place on May 18th and June 14th, and in 2008 the peak flights occurred on May 6th and June 4th(Figure 2-1). The second flight season was not considered because there were only data for 2007.

The Principal Components Analysis (PCA) revealed no correlation between any of the variables and the occurrence of flights. However, when analyzed with a simple GLM, relative humidity showed a significant effect on flight occurrence ($p=0.002$). The model created by GLM showed a negative effect of relative humidity although the r-squared value was not high enough to consider the model generated to be the best fitted model ($r\text{-squared}=0.04$). Using the non-parametric tests however, two patterns emerged showing that there was a significant difference between the occurrence of flights and the occurrence of no flights that was dependent upon relative humidity and air pressure values. Flights occur significantly more when air pressure and relative humidity were on average 761.2 mmHg and 70.23% respectively (Table 2-1).

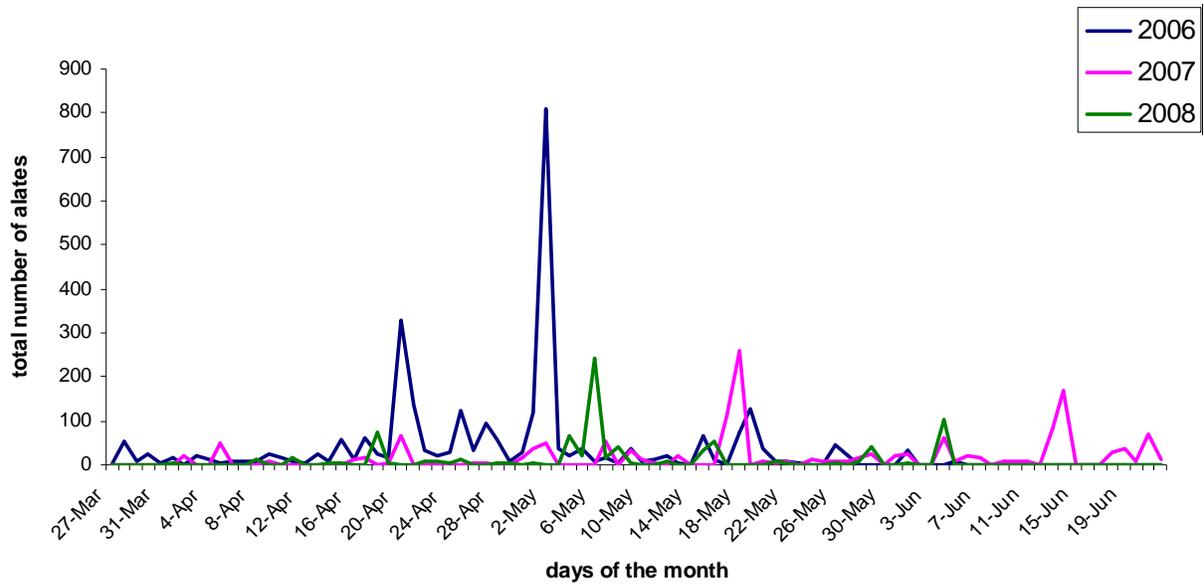


Figure 2-1. Total number of alates in the water trap per day for each year of study between March 27th and June 22nd.

Table 2-1. Average value for occurrence or no occurrence of flight for each variable. For each column variables with the same letter had no significant differences for $\alpha < 0.05$.

	temperature (°C)	pressure (mmHg)	wind speed (kmph)	rainfall (mm)	relative humidity (%)
Flight	24.62a	761.2a	14.42a	4.57a	70.23a
No flight	23.79a	762.5b	15.45a	3.81a	73.21b

Visually it is possible to see a threshold of air pressure (763.5 mmHg) above which fewer flights occur (Figure 2-2) and the same is visible for the relative humidity data (83%) (Figure 2-3).

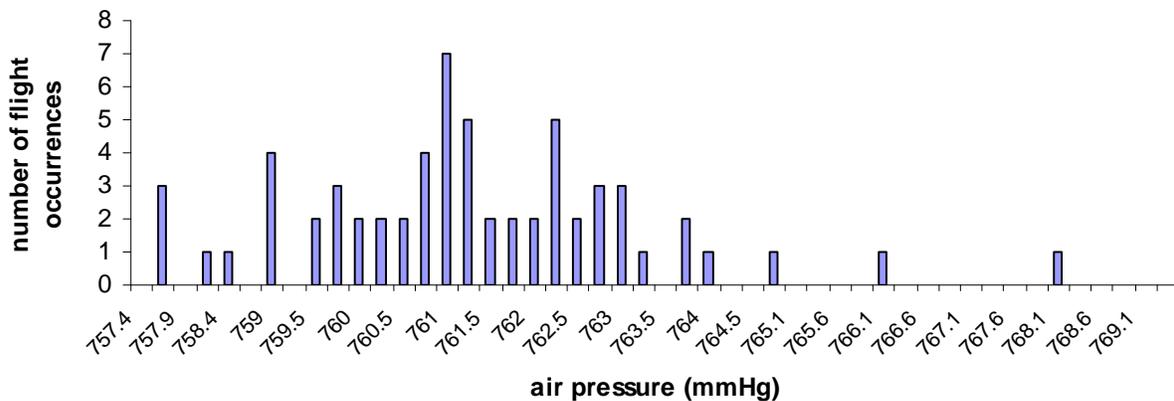


Figure 2-2. Total number of times that flights occurred for each value of air pressure for the three years of study.

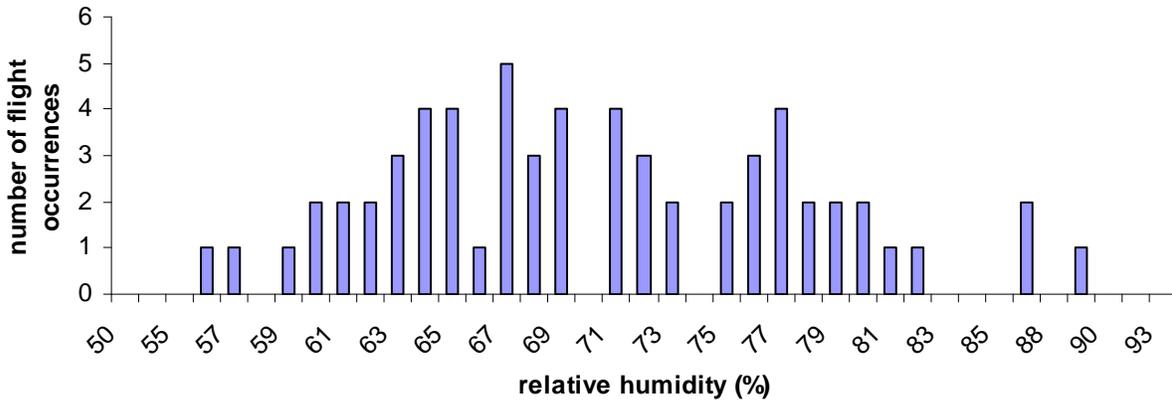


Figure 2-3. Total number of flight occurrences for each value of relative humidity for the three years of the study.

Observations during 2007 suggest that the flights are dependent on rainfall with higher activity in the months where rainfall is low and lower activity in the months when rainfall is higher with the exception of June (Figure 2-4). However, no correlation between rainfall and occurrence of flights was found ($p=0.47$).

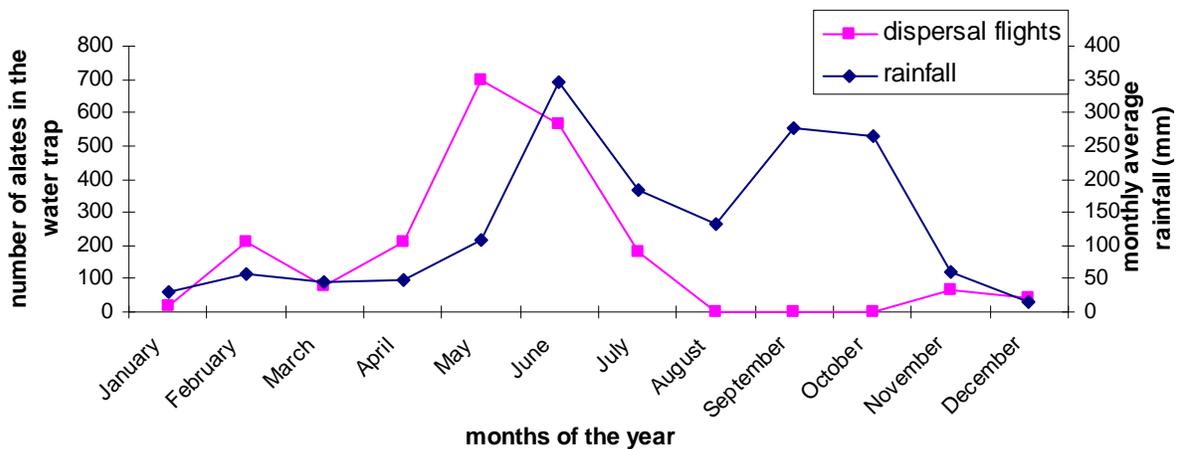


Figure 2-4. Total number of alates in the water trap in 2007 per month and rainfall values in inches for the same period.

There were significantly more flights between the hours of 21:00 and 8:00 than during other times of the day, with a significantly high peak between 1:00 and 2:00 am. The lowest occurrence of flights was between 16:00 and 17:00 which was significantly lower than the other

times of the day. Significant differences were also observed for flights occurring between 13:00 and 19:00 hours and the other times of day. (Figure 2-5).

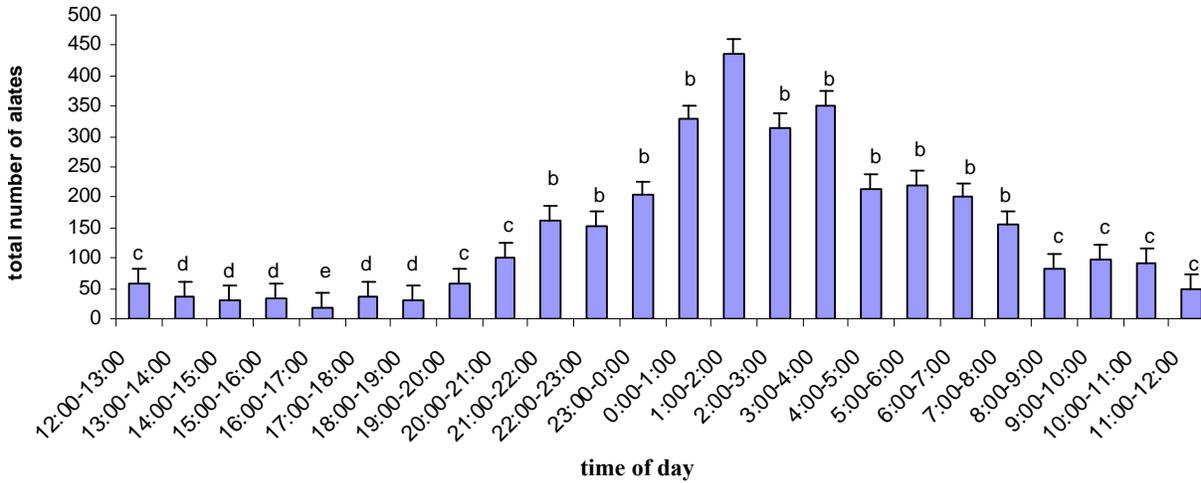


Figure 2-5. Total number of alates found in the water trap for each hour of the day for the 3 years of the study. Bars with same letter were not significantly different for $\alpha < 0.05$.

Discussion

The water trap data provided proportional information on the relative number of alates flying the room, even though there was lag between the actual emergence of the alates from their galleries and the time they land in the water trap, this lag is short with alates not flying more than half an hour.

The peak dispersal flights of *C. brevis* occurred between late April and early June in this study. However for each year the flight season shifts a little, with the first peak flight occurring about a month before the second peak. These shifts of the dispersal flight season seem to indicate that there may be weather related cues that trigger the beginning of the flight season.

The results of this study showed that relative humidity and air pressure influenced the occurrence of flights. Both the GLM and the non-parametric tests showed that relative humidity had a negative effect on the occurrence of flights. Williams (1976) argued that *C. brevis* could thrive in drier conditions in Africa than other species of the same genus, which may indicate the

effect that lower relative humidity has for this species. Minnick (1973) also observed that, on an hourly basis, the dispersal flights would occur in relation to the fluctuations of relative humidity and air pressure, the flights occurring following the lowest air pressure of the day. As for relative humidity the dispersal flights occurred on the low and high peak of relative humidity for that day (Minnick 1973). However, the results of this study indicate that on a daily basis the flights occurred significantly more when the mean relative humidity was 70 % with a threshold of 83% above which fewer flights occurred. Very few flights occurred above the air pressure threshold of ≈ 763.5 mmHg. This could be a good indicator as to when dispersal flights may occur as long as the relative humidity is not too high. In the future, studies pertaining to accuracy of dispersal flight predictions based on air pressure may bring more information about the cues causing the alates of this species to fly.

When looking at a whole year, the relationship between the occurrence of dispersal flights and rainfall was conspicuous although not statistically valid. The flights increased at the beginning of the rainy season and at the end with very few flights occurring during most of the season. This is in accordance with other termites belonging to the Kalotermitidae where this phenomenon has been observed (Rebello and Martius 1994). Although the number of termites flying at the end of the rainy season is not large, it is interesting to see that flights occur when the rainfall drops to values close to 50.8 mm per month. Rainfall seems to be an important cue for the beginning of the flight season, with the peak month being the first month with rainfall above 101.6 mm per month, even though on a daily basis the rainfall did not show any influence upon the dispersal flights. However, termites were inside wood inside a building so rainfall itself did not influence the dispersal flight season and maybe the changes in the atmospheric conditions due to rainfall acted as cues.

Contrary to what Minnick (1973) observed, the time of occurrence of the dispersal flights happened mainly during the night and was not a crepuscular event. The water trap captures were most common between 1:00 and 2:00 am. During the months of dispersal flights, the sunrise and sunset times varied between 5:29 and 6:12 and 18:38 and 19:17 respectively. Thus dispersal flights occurred more at about 2 hours after sunset through about 2 hours after sunrise. This is contrary to what Minnick (1973) reported with flights occurring 80 min after sunset and 30 min after sunrise. It is also interesting to note that alates fly throughout the day, but were significantly less common in the middle of the afternoon (between 16:00 and 17:00). It would be interesting to investigate other populations to see if time of dispersal flights concurs with our observations or if population variability could account for the differences observed between this study and Minnick's work in Key West, Florida.

CHAPTER 3
ALATES POSITIVE PHOTOTAXIS AND DEALATES NEGATIVE PHOTOTAXIS

Introduction

Many arthropods will move toward (positive phototaxis) or away (negative phototaxis) from light. The most common example of nocturnal flying insects that are attracted to lights involves moths (Frank 1988). Many nocturnal flying insects are attracted or confused by lights and this characteristic is often used for catching insects with light traps (Nabli et al. 1999).

While most of the castes of termites are negatively phototactic, the alates are attracted to lights and seek to emerge into openings and flying into light (Light 1934a). Termites with crepuscular and nocturnal flights are known to be attracted to lights (Minnick 1973, Sakanoshita and Ōga 1971, Wilkinson 1962) and light traps are a common tool for capturing alates. Termites flying towards light does not ensure that colonization will be higher in lit areas, and no studies we are aware of confirm this.

Another aspect of the dispersal of *C. brevis* is that after positive phototaxis of alates occurs, the dealates exhibit negative phototaxis as observed for this and other species of the genus (Minnick 1973, Wilkinson 1962), although no data have been produced to confirm this observation.

The objectives of this study were to analyze if *C. brevis* alates were attracted to light and colonized more in lit areas than in dark areas, if light intensity had an effect on the number of colonizations, and if there was negative phototaxis in colonization for dealates. The hypothesis tested was that wood with dark areas will be colonized depending upon light intensity as opposed to a control where colonization will occur randomly.

Materials and Methods

All experiments were conducted at the Fort Lauderdale Research and Education Center in UF building 5031 in the room described in Chapter 2.

Light versus Dark Experiment

Experimental process

Data for this experiment were collected between April and July of 2007. To analyze the difference between colonization in lit and dark areas, 24 transparent plastic boxes (36x23x28 cm) were wrapped in aluminum foil to isolate the light in one box from an adjacent box. The boxes were placed with the cut lid facing the infested wood and a hole was cut on the side (now top) of the box in order to fit the light bulbs (Figure 3-1). The lights were LED Christmas lights (WF model No TS-70) strung in a series of 5 single light bulbs attached with tape and hung through the hole. Black tape was used to position the light bulbs in place as well as prevent light from dispersing through the cut hole, so the only light source were in the lit boxes. The lights were randomly distributed with 12 lit boxes and 12 dark boxes (replicates). The dark boxes had no light bulbs in them. The lit boxes had a light intensity of approximately 40 lux as measured by a light meter (Extech Instruments model No 403125) and the dark boxes had approximately 0.11 lux (due to contaminating light of nearby experiments). A cube of wood (5 cm³) with 6 drilled holes was placed in the center of the box. Each hole was 1.5 cm deep and 2.3 mm diameter and there was a single hole per face of the block. Four thumb push pins were placed on the underside to allow for enough space for the termite to access the hole on the underside.

After the dispersal flight season was over, the blocks of wood were collected and the number of colonized holes was counted per block. A hole was considered to be colonized when a complete fecal seal was present.

Data analysis

The data were analyzed using a non-parametric Wilcoxon Matched Pairs test (SAS Institute 2003) to test if the number of colonizations in the dark areas and lit areas were different.

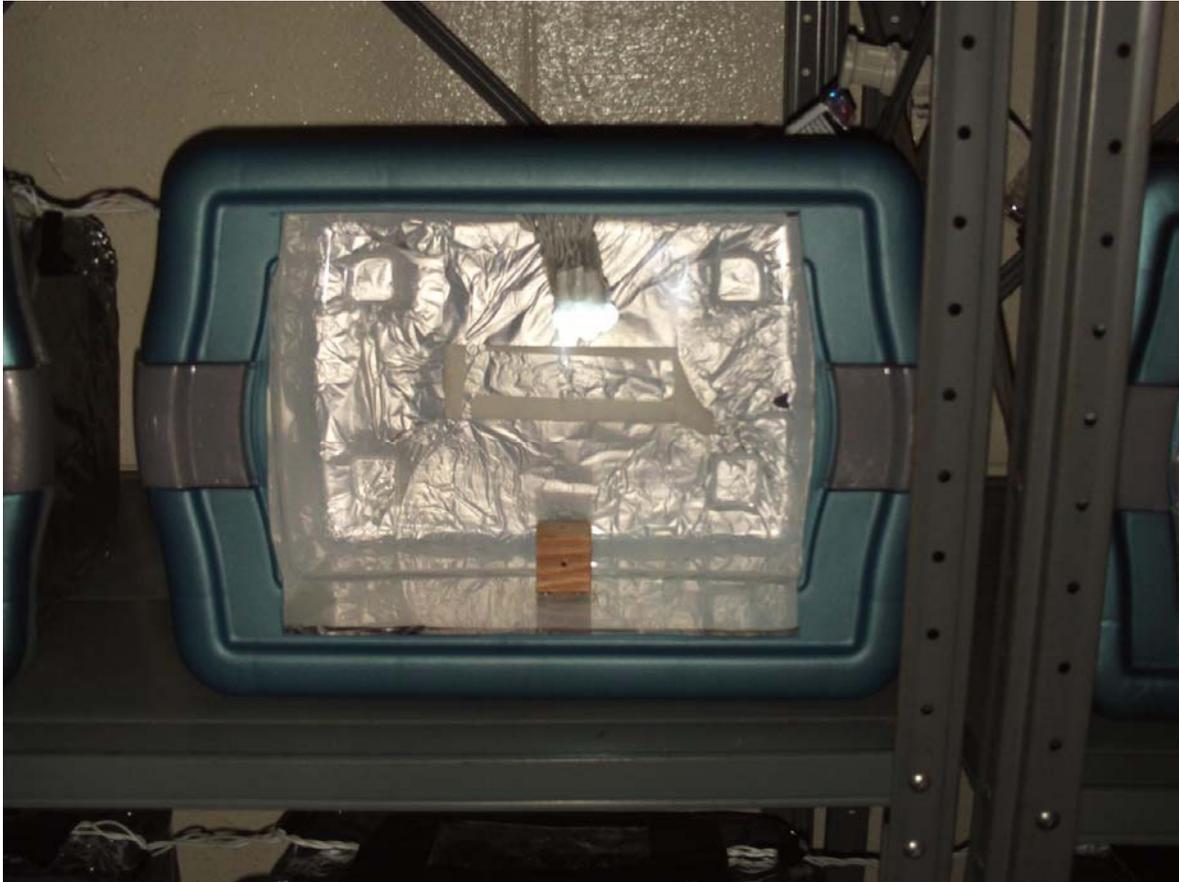


Figure 3-1. Experimental set-up for light versus dark experiment. One can see the cut lid of the box, the aluminum foil isolating the box and the LED Christmas lights above the block of wood.

Different Light Intensities Experiment

Experimental process

These experiments were performed between April and June of 2008. For the different light intensities experiment, the same 24 boxes used for the previous experiment were used. The LED Christmas lights were also used but this time there were four different set ups for the different light intensities with 6 replicates per light intensity (measured by the light meter): 6 of the boxes

had no light bulbs (≈ 0.11 lux); 6 boxes had only one LED light bulb with an intensity of approximately 11 lux; 6 boxes had 5 LED's together (≈ 40 lux); and 6 boxes had 10 LED's attached with an intensity of approximately 480 lux. The boxes were randomly distributed. A block of wood (15x2x9 cm) with 24 holes 1.5 cm deep and 2.3 mm diameter was placed in each box center. After three months, the blocks were collected and the number of colonized holes was counted per block. Colonization was quantified as described above.

Data analysis

To test if differences between the light intensities were significant, a t-test was used (SAS Institute 2003).

Negative Phototaxis Experiment

Experimental process

In order to analyze the negative phototaxis of the dealates a white PVC pipe, 51 cm long by 7 cm inside diam. was wrapped with black tape and closed off on one of the sides. A 102x2x5 cm board was placed inside with 2.3 mm diam. holes drilled 2.5 cm apart on a grid with a total of 40 holes. The outermost holes were 1cm from the edge of the board. Of these 40 holes, 20 were always exposed to light and 20 were exposed to decreasing levels of light towards the closed side of the PVC pipe. The board was visually divided into 10 cm blocks excluding 1 cm at each end of the board which included 4 holes each and measurements of the light intensity were made outside and inside the PVC pipe (Table 3-1). A board with the same dimensions and number of holes was used as control which was completely exposed to light. This was replicated 4 times. The 10 cm blocks were lettered as follows: A) the first 10 cm from the closed end of the PVC pipe, B) the following 10 cm, and so on, with blocks A, B, C, D, E inside the PVC pipe and blocks F, G, H, I, and J outside, with block J being the farthest away from the PVC pipe. For the controls, the blocks were lettered the same way as above even though they were all exposed to

light. The number of colonized holes was counted for each 10 cm block using the previously described colonization criteria.

Table 3-1. Measurements of light intensity (lux) outside and inside the PVC pipe per 10 cm block

	outside	E	D	C	B	A
Light intensity (lux)	600	0.70	0.20	0.08	0.04	0.01

Data analysis

A Chi-squared test for independence (SAS Institute 2003) was used to test if the distribution of colonizations was dependent on the light intensity. To analyze if the differences between the number of colonizations in each 10 cm block were significant, a t-test for dependent variables was used (SAS Institute 2003).

Results

Light versus Dark Experiment

In the light versus dark experiment a total of 43 holes were colonized. There were significantly more holes colonized in the lit areas than in the dark areas with a p-value <0.0001 (Figure 3-2).

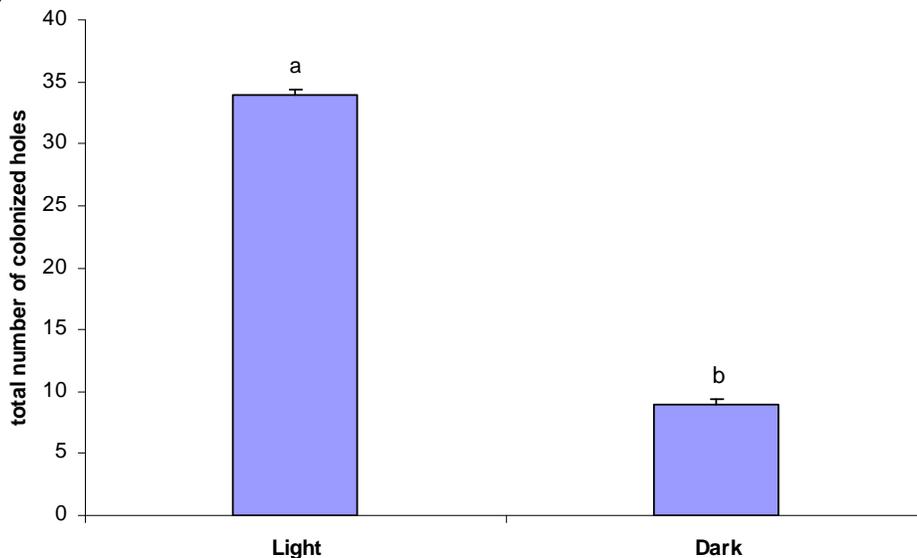


Figure 3-2. Total number of holes colonized in lit and dark areas. Different letters represent significant differences for $\alpha < 0.05$.

Different Light Intensities Experiment

For the different light intensities, a total of 76 holes were colonized. An increasing number of colonizations were observed with increasing light intensity. There were significant differences between the dark areas and all other light intensities. For the highest light intensity (480 lux) this was not significantly different from 40 lux but was significantly different from 11 lux intensity. The number of colonizations for 11 lux light intensity was also not significantly different from that of 40 lux intensity (Figure 3-3).

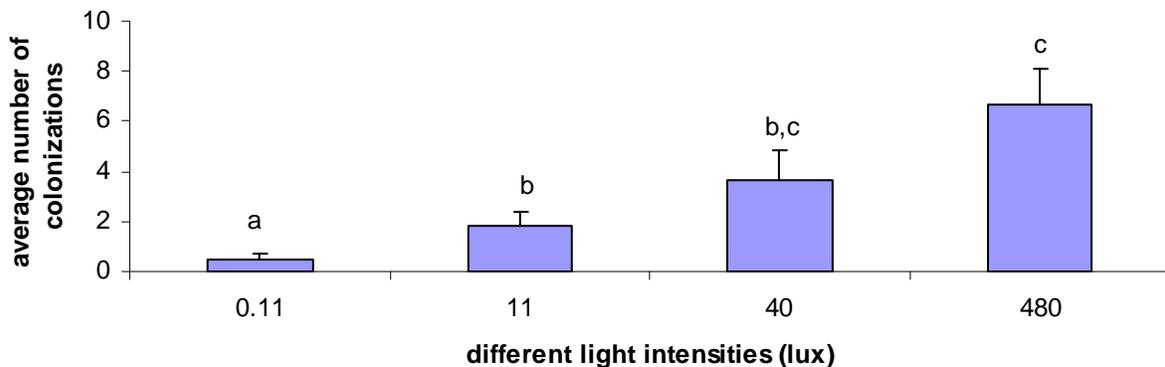


Figure 3-3. Average number of holes colonized per light intensity. Different letters represent significant differences for $\alpha < 0.05$.

Negative Phototaxis Experiment

In this experiment a total of 175 holes were colonized. The controls had no significant differences between the 10 cm blocks (Figure 3-4) and showed that the distribution of colonization was independent of the block (Chi-squared p value: 0.75). The boards placed in the PVC pipes (Figure 3-5) showed that colonization distribution was not independent of the 10 cm block where it occurred (Chi-squared p value: 0.001). There were decreasing averages of colonizations from the darkest area of the PVC pipe to the lightest area. There were no significant differences between the first blocks A, B, C, and D in the dark area. Block E was significantly different from the first four, and not from blocks G, H, I, and J. Block F, the closest

to the PVC pipe, was not significantly different from blocks A, B, C, and D and was significantly different from the remainder of blocks (Figure 3-6).

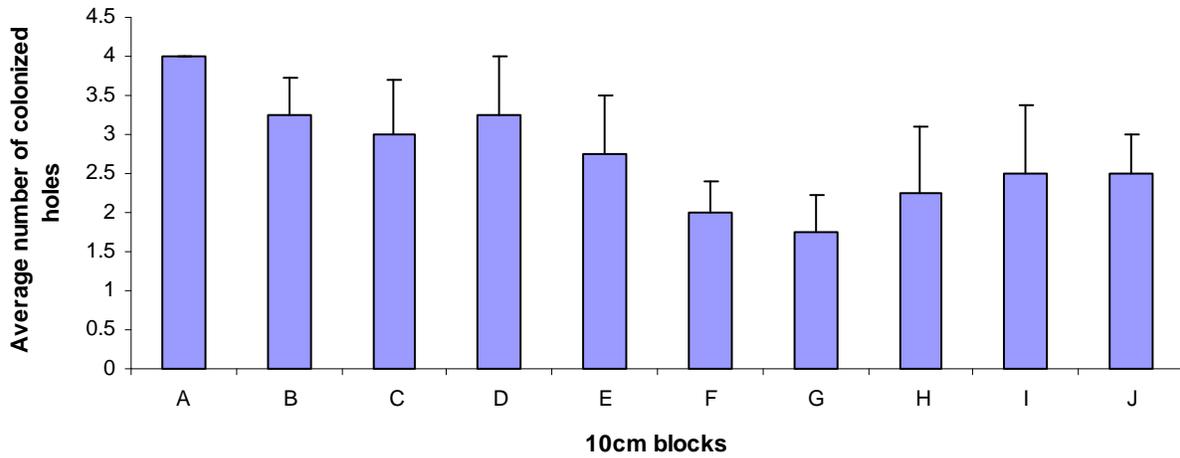


Figure 3-4. Average number of colonized holes per 10 cm block. No significant differences were observed for $\alpha < 0.05$



Figure 3-5. Negative phototaxis bioassay. Board inside PVC pipe (top) and control (bottom).

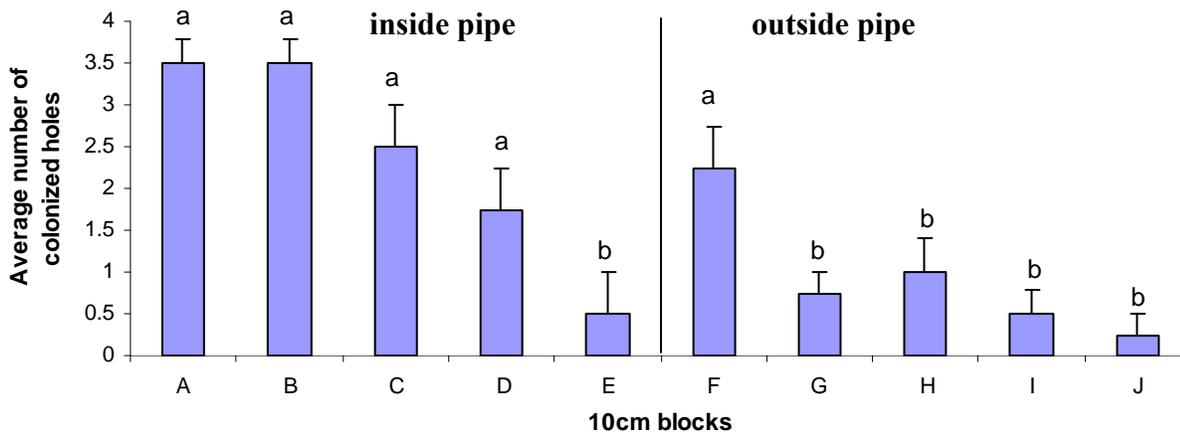


Figure 3-6. Average number of colonized holes per 10 cm blocks with dark and light. Blocks A, B, C, D, and E are inside the PVC pipe and blocks F, G, H, I, and J are outside the PVC pipe. Bars with the same letter were not significantly different for $\alpha < 0.05$.

Discussion

Light versus Dark Experiment

The results for the light versus dark experiment confirm the hypothesis that colonization occurs significantly more in lit areas than in dark areas. This shows that wood located in areas that are lit during the night may be more susceptible to infestation by *C. brevis*. In a world where artificial lights are becoming more and more common these may cause a change of behavior for some species of animals (Longcore and Rich 2004), but the role of artificial lights is beneficial to structure infesting termites like *C. brevis*. In a practical view this attraction to artificial lights puts structures that have wood and that have a continuous light on during the dispersal flight season more at risk to being infested than structures that are not lit. On the other hand, this attraction to light can also be used (and has been used) to create traps inside structures that are already infested, in order to minimize the spread of the infestation.

Different Light Intensities Experiment

The different light intensities experiment has also shown that there are significantly more colonizations in lit areas than in dark areas as seen before, but it also showed that increasing light intensity does increase the number of colonizations occurring in that area. Minnick (1973) reported differences in the wavelength of light preferred by *C. brevis* but did not produce any light intensity results as far as light attraction goes. The fact that the middle intensity was not significantly different from the other two shows that the increase in light intensity causes a gradual increase in colonization by the termites. Again when looked upon from a practical point of view, if an area is lit during the night the more intense the light the more susceptible to infestation it will be. On the other hand, if a light trap is to be used to capture *C. brevis* the more intense the light then the more it will attract.

Negative Phototaxis Experiment

Previous experiments with *Cryptotermes havilandi* (Sjostedt) (Wilkinson 1962) and *C. brevis* (Minnick 1973) showed negative phototaxis behavior for these species in dealates. After landing, the dealates search and colonize darker areas. Due to the nature of wood structures, it could be argued that this is not really negative phototaxis but that cracks and holes that provide a good colonizing focus are usually hidden and in dark areas. However, the present study has proven that negative phototaxis did occur. That the controls had an independent distribution of colonizations and the semi-shaded blocks did not have an independent colonization confirmed the negative phototaxis hypothesis. The lighter block inside the PVC pipe, block E, had significantly less colonizations than the darker blocks A, B, C and D which indicated that more colonizations occurred in darker areas than in lighter areas inside the PVC pipe.

However, block F which was 10 cm closer to the PVC pipe showed no significant differences in number of colonizations to the darker areas inside the PVC pipe. This might have occurred because the termites colonizing that area had searched for colonizing sites in the dark area all the way and the “best” sites were already taken by previous colonizers inside the PVC pipe. Also they may have landed near the PVC pipe cueing in on the darker area nearby and colonizing the sites near that dark area. However, further studies on this are needed to understand why the 10 cm closer to the PVC pipe on the light side were significantly more colonized than the 10 cm inside the dark PVC pipe where it would be expected considering the negative phototaxis behavior. A hypothesis as to why this happens is that the “best” holes are already taken. One way to approach this might be using a higher density of colonizing holes, so that the number of holes is not a limiting factor.

CHAPTER 4 POST FLIGHT BEHAVIOR AND PREFERENCE OF COLONIZATION SITE DIAMETER

Introduction

The post flight behavior of termites varies according with the species in question. For higher family termites the sequence of behavioral acts are strictly followed while in lower families this sequence is more flexible (Nutting 1969). However some behaviors such as search for a colonizing site, tandem behavior, calling, and dealation are common, although in some species like *C. havilandi* no tandem behavior has been observed (Wilkinson 1962).

The pairs of reproductives form after they have landed. After the pair forms, tandem behavior of female leading the male is often observed (Minnick 1973). Although some observations of the post flight behavior of this species have been done, little is known about this behavior, its duration, and frequency of occurrence.

Termites often choose a suitable site to start a new colony. Wilkinson determined that for *C. havilandi* the preferred nuptial site chosen by termites was a hole in wood that varied between 2 and 3mm, the size was big enough to allow for the termites to turn inside the future copulatorium but small enough that the amount of energy spent sealing it would not be too high (Wilkinson 1962).

The objectives of this study were to describe all the behaviors that could be observed that occur after the dispersal flight, time the behaviors and record the frequency that they occur, and determine if there is a preferred hole diameter for colony initiation.

Material and Methods

All experiments were conducted at the Fort Lauderdale Research and Education Center, in UF building number 5031 in the room described in Chapter 2.

Post Flight Behavior

This experiment was run between April and May of 2008. Arenas were set up in order to analyze the post flight behavior of the *C. brevis*. These consisted of white pine boards (18.4x18.4x2 cm) placed on an aluminum tray. The edges of the board were sealed into the aluminum tray with silicone (Master Flow, water based air duct sealant) applied with a caulking gun in order to prevent the termites from crawling underneath the board and out of sight. Sixteen 2.3 mm diam. holes 1.5 cm deep were drilled to provide colonizing sites. The trays were placed under a light to attract the alates. An Apitek A-HD 720p video camera was placed above the arena. Videos were taken between 8:30 pm and 8:30 am and later analyzed using Quiktime software. Three replicates were done. All observed behaviors were described and timed.

Colony Site Diameter Preference

Experimental process

These experiments took place during May of 2007 and May of 2008. To determine if there was a preferred diameter of colonization site, 25 blocks of white pine (10x5x5 cm) were placed under a light for alate attraction. On the surface of these blocks a total of 10 holes were drilled per block. These holes consisted of two holes of equal diameter per five different diameters. The diameters used were: 1.6 mm; 2.3 mm; 3.3 mm; 4 mm; and 4.4 mm and the holes were randomly distributed on the surface of the block. A hole was considered colonized following the criteria used in Chapter 3.

Data analysis

The number of colonized holes per diameter size was counted and a t-test for independent variables (SAS Institute 2003) was used to test if the number of colonizations were significantly different between the five diameter choices.

Results

Post Flight Behavior

The behavior of a cohort of 30 termites was observed and 10 different behaviors were described as follows:

- **Landing:** when termite lands on the substrate following its dispersal flight.
- **Take off:** when termite flies away from the substrate not returning to it.
- **Wing release behavior:** Termite twists around for a few seconds sometimes turning on its back and shaking until one to all of the wings are released. Some termites release their wings inside a hole leaving them inside the hole not allowing for the observation of wing release behavior.
- **Hole antennation:** termite approaches a hole and uses antennae to palpate the hole, circles around it and eventually leaves.
- **Crawling:** when the termite crawls around the substrata.
- **Entering hole:** when the whole body of the termite is inside the hole.
- **Inside hole:** termite enters a hole and remains inside for a certain amount of time
- **Exiting hole:** when the whole body of termite is outside the hole, following being inside the hole.
- **Flickering:** succession of quick take off and landings on the substrate, ending on landing on the substrate.
- **Tandem crawling:** when two primary reproductives crawl one in front of the other.

The average time spent by a termite on each behavior varied between 9 seconds to 436 seconds (Table 4-1). The occurrence of some of the behaviors did not vary much, with each behavior occurring on average between 1 to 3 times per termite (Table 4-2). Of the 30 termites observed, tandem crawl occurred only once and only 6 pairs were formed inside the holes. All the termites would eventually enter a hole and not exit it again forming a pair with a previously occupying termite or remaining in the hole by themselves.

Table 4-1 – Mean time in seconds spent on each behavior per termite.

behaviors	crawling	tandem crawl	inside hole	flickering	wing release behavior	hole antennation
average time (s)	436	368	328	9	15	10
N	30	1	18	6	20	21

Table 4-2. Mean number of times behavior occurred per termite.

behaviors	holes checked	holes entered and exited	take off	flickering	wing release behavior
number of occurrences	3	2	1	1	1.4

A typically observed post flight behavior from a termite can be described as follows. A termite lands on the substrate and flicker for a few seconds (sometimes it will take off). After that, it crawls for a few minutes stopping to antennate up to three holes. It then engages in wing release behavior for a few seconds, enters a hole, remains there for some minutes, comes out, and does the same in another hole. If a second termite lands they may engage in tandem crawling for a few minutes and antennate some holes and enter others until they choose a final hole for colonization.

Colony Site Diameter Preference

The diameters of 2.3 mm and 3.3 mm had significantly higher occurrence of colonizations than the remainder diameters (Figure 4-1).

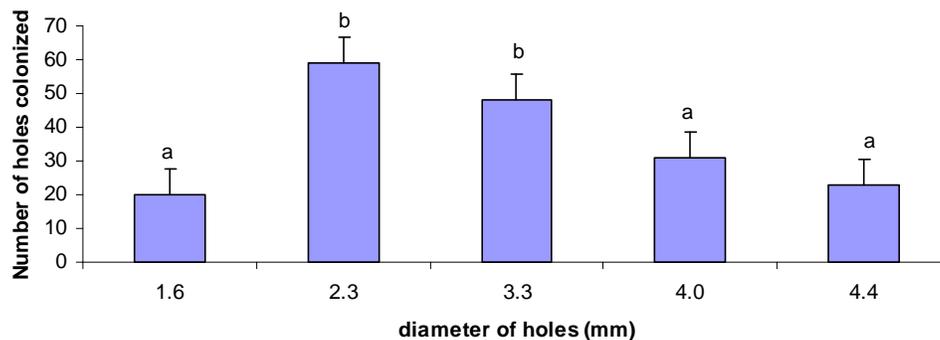


Figure 4-1. Total number of colonized holes for each diameter. Bars with same letter are not significantly different for $\alpha < 0.05$.

Discussion

Post Flight Behavior

The results obtained in this study for the post flight behavior are congruent with previous observations with the crawling behavior, tandem behavior and dealation occurring. No calling behavior as described by Minnick (1973) was observed. The crawling behavior in search of an opening lasted on average a little over 7 minutes (436 seconds). During this time the termite (or termites if in tandem) antennates some holes or actually enters and exits the hole, remaining an average of about 5 and a half minutes inside (328 seconds). This entering and exiting of the hole has often been observed although no reports had been made on how much time was spent on this behavior. The arena design did not, however, allow for an observation of what happened inside the hole while a termite remained in there. Because only about half of the termites observed actually formed colonizing pairs, it is important to try and understand what happens when a termite enters a colonizing hole. Most of the pairs were formed by a termite entering an already occupied hole. This behavior is not often observed and begs interesting questions. For instance, does the termite inside the hole leave any chemical cue to signal other termites that the hole is occupied? And if so, is it a repellent cue to individuals of the same sex? More research on this matter is needed.

The wing release behavior has been observed for *C. brevis*, although Minnick (1973) did not give a detailed description. The turning of the termite on its back as it shakes helps the final release of the wings. Dealation took on average 15 seconds which is more time than reported for *C. brevis* (Minnick 1973) or *C. havilandi* (Wilkinson 1962) where both reports stated that the behavior is too quick to observe, and lasted less than one second. The behavior however was reported to occur mostly out of sight due to negative phototaxis so it is possible that the conditions of the arena allowed for this behavior to be fully observed during this study.

The fact that tandem behavior was observed only once is somewhat surprising because this termite species is known to display this type of behavior (Minnick 1973). However, it is possible that the number of colonizing sites available may have helped in decreasing the occurrence of this behavior. With many holes available, perhaps termites tend to spend less time in searching behavior, finding a hole rather quickly and maybe decreasing the probability of encountering another termite on the substrate and initiating the tandem behavior. Further experiments with fewer colonizing sites available may help in understanding the low occurrence of tandem behavior. It may also show if the number of available colonization sites influence the amount of time spent crawling in search of a hole.

A question that remains unanswered however is how far a termite will crawl in search of a colonizing site. Due to some software problems the images obtained from this experiment were not usable for analyzing the distances covered by the termites. However the technology is now available and further research should be done on this subject.

Colony Site Diameter Preference

As for the experiments of colony site diameter preference, the results obtained were congruent with previous results obtained for this species although no statistical analysis had been performed before (Guerreiro et al. 2007). These results were also congruent with those found for *C. havilandi* (Wilkinson 1962). It has been shown for both species that there is a preferred diameter for colonization that is located between 2 to 3 mm. This was confirmed with the present study, with the preferred diameters being 2.3 and 3.3 mm which is why for other experiments in the present study 2.3 mm diam. was used. This continues to support the hypothesis that colonizing pairs prefer a size of hole that allows for enough space to turn around but small enough to be economically sealed (Wilkinson 1962). Another reason for avoidance of bigger diameter holes is that the time spent in sealing these may take too long leaving the termites

vulnerable to predation. Also, smaller voids may be easier for maintenance of ideal conditions to start a colony, with the volume of the cavity having an effect on conditions like relative humidity.

This information may be important in that the diameter preferred is rather small and any small crack or hole in a piece of wood is susceptible to colonization and the sealing of these may be necessary in order to decrease the probability of having a colony founded, especially in areas with high nocturnal flight intensity.

CHAPTER 5 EARLY COLONY DEVELOPMENT

Introduction

Drywood termite colonies are usually small with only hundreds to a few thousands individuals per colony (Nutting 1970). This is in contrast with higher termites which can have millions of individuals in their colonies. The development of a drywood colony is slow and a colony may not be mature for at least 5 years, when all the castes are present including the reproductive alates (Nutting 1969).

Observations have been made on the early development of *C. brevis*'s colonies showing that the development of this species is slow with few eggs being laid and with a pause between the laying of a batch of eggs as long as 5 months. Also, after the first year a colony may have as few as 3 to 4 individuals (Nutting 1969). Aside from these observations very little has been done relative to understanding the early development of a colony of *C. brevis*.

The objectives of this study were to increase the knowledge of early colony development for *C. brevis*, analyzing the number of eggs laid, the time it takes for oviposition, how long is the incubation period, and how many larvae can a batch of eggs produce.

Materials and Methods

All experiments were conducted at the Fort Lauderdale Research and Education Center in UF building 5031 in the room described in Chapter 2. The early development of the colony was observed for a minimum of 30 days and a maximum of 100 days, between March and June 2008.

To study the early colony development nuptial chambers were constructed. These consisted of a block of white pine 8x4x2 cm with a 2.3 mm diam. hole drilled on the upper side through to a 2 cm diam., with the larger area 1.5 cm deep and the smaller area 0.5 cm deep. The wider hole was made using a wood drill. These blocks were placed on a 9 cm diam. Petri dish

with the larger diameter facing down. The blocks were kept in place by applying silicone (Master Flow, water based air duct sealant) to the edges of the wood board with a caulking gun. Fifteen blocks were left to be colonized with the smaller diameter facing up, and placed under a light. After two termites occupied the chamber, the blocks were removed from the light source and placed with the Petri dish side up and covered with a black plastic bag. The chambers were then checked daily for eggs and larvae (Figure 5-1) with the help of a hand-held magnifying glass (10x). The blocks were kept in the afore mentioned room without controlled temperature or humidity in order to simulate the beginning of a colony in an attic (where many infestations occur) without air conditioning.

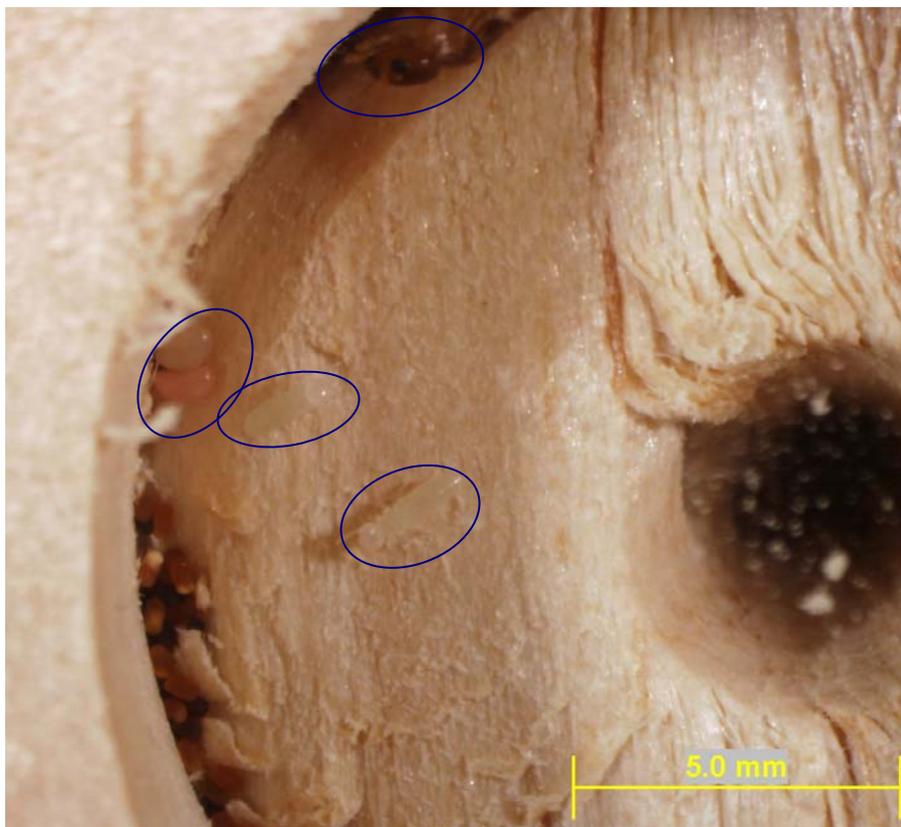


Figure 5-1. Colonizing chamber showing two larvae, two eggs and a primary reproductive of *C. brevis*.

Results

Of the 15 blocks placed under the light, only 12 were colonized, each was occupied by 2 or 3 dealates and of these 12 only 9 produced active egg laying pairs. A maximum of 5 eggs and a maximum of 4 larvae were observed per colonizing pair (Figure 5-2).



Figure 5-2. Image of 3 of the 4 larvae in the chamber and a primary reproductive of *C. brevis*.

The average time (days) for each egg to be laid and each larva to eclose are depicted in Table 5-1. The average incubation time of an egg was 54.5 days. The eggs went through a change in color as development proceeded starting out pink and getting increasingly white towards the time of eclosion (Figure 5-3). No cannibalism of the eggs was observed.

Table 5-1. Average time (days) until eggs were laid and larval eclosion. Numbers with * indicates single observations.

	1st egg	2nd egg	3rd egg	4th egg	5th egg	1st larva	2nd larva	3rd larva	4th larva	Incubation
Average number of days	13.4	17.7	24.8	34	63*	68.5	71.5	86*	99*	54.5

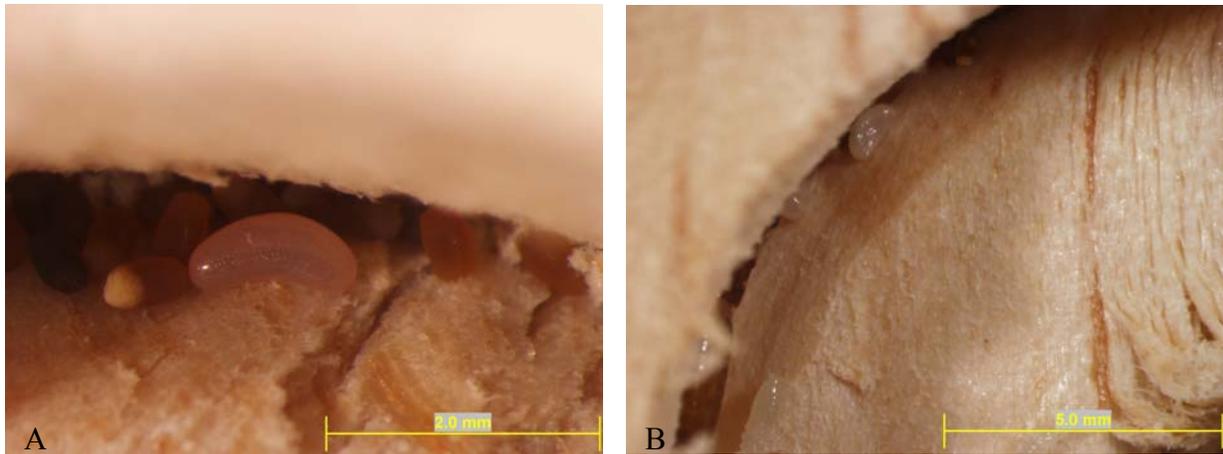


Figure 5-3. Coloration of the eggs throughout development. A) pink young egg, B) white egg near eclosion.

Discussion

The results obtained in this study are consistent with the previous finding that drywood colonies are slow developing in early stages (Nutting 1969). Of all the initial colonies observed only one pair produced a 5th egg with all other pairs producing a maximum of 4 eggs. Also in the 100 days of observations only one pair produced 4 larvae from the eggs and no further egg lay was observed. This pause between oviposition has been previously observed for this species (Nutting 1969) and is also observed for other termite species (*Coptotermes formosanus* (Shiraki)) where cycles of oviposition have been observed (Raina et al. 2003). The fact that only a maximum of 4 eggs was laid is in agreement with observations of only 3 to 4 individuals within the first year of colony development for *C. brevis* (Nutting 1969). The queens of *C. brevis* are not physogastric and as such will not lay as many eggs as larger queens in higher termites (Snyder 1926). This may account for the small number of eggs laid per batch and the slow development observed for drywood termites (Nutting 1969). Also maybe adults can only supply food for 4 larvae at a time until the larvae reach the pseudergate stages.

Egg incubation times are slightly faster than previously observed, with the termites in the present study taking an average of 54.5 days of incubation while previously the incubation took

between 75 to 81 days (Nutting 1969). Possible explanations for these discrepancies include: first the type of wood used may differ and this may have an influence on the amount of protein that is provided by the mother to the egg and eventually the slower or faster development of the egg. Also conditions of temperature and humidity have an effect. Observations were conducted under “laboratory temperatures” (Nutting 1969) while the colonies in the present study were maintained at room temperature (average 25 °C) which was not controlled and varied with the normal weather variations, as well as the relative humidity. This may also have had an impact on the period of incubation. Lastly, the different results may simply be due to the use of different populations and there may be some variations in the incubation periods between populations. For *C. havilandi*, for example, the population studied by Wilkinson (1962) had an incubation period much more similar to the one found here with a mean of 53 days even though it is a different species.

No cannibalism of eggs was observed for these colonies, although it is often reported that the primary reproductives will often consume their own eggs even with adequate nutrition (Nutting 1969). The coloration of the eggs for *C. havilandi* started out semi-transparent and became white later. For *C. brevis*, the initial color was pink, but just as for *C. havilandi*, the eggs became an opaque white, which is also the color of the newly hatched larvae. Further studies may be necessary to determine what components are present in the egg at the different stages and what causes the color change. Also a more prolonged study of the colony development is needed in order to better understand the population dynamics of a *C. brevis* colony.

CHAPTER 6
EFFICACY OF TWO CHEMICALS IN PARTIALLY TREATED WOOD TO PREVENT
COLONY FOUNDATION

Introduction

It has been observed that alates are attracted to light and after they land near the substrate they engage in tandem behavior where the female leads the male in search of a colonizing spot (Snyder 1926, Wilkinson 1962, Minnick 1973). This search for a colonizing spot can last for some time and the alates can cover a large surface area (personal obs.). Because the dispersal flight season is the only time drywood termites are naturally outside the wood, this is a suitable time for termiticide exposure, especially in preventing new colony establishment.

The chemicals that were tested in this study were of two different classes. The first was chlorfenapyr which is an aryl-substituted cyanopyrrole. This chemical was first synthesized in 1988 (Treacy et al. 1994) and it has been used for agricultural pest control purposes. It has been registered for house-hold pests since 2001, but little work has been done in termites (Rust and Saran 2006). The second chemical was fipronil, which is an N-phenylpyrazole. This chemical was first marketed in the USA in 1996 (Cox 2005). It is an insecticide used for a variety of insects, from cockroaches (Zhao et al. 2003), fire ants, to crop pests such as coleopteran larvae, lepidopterans, and orthopterans (Hainzl and Casida 1996). It is also widely used for the control of subterranean termites and its efficacy against these has been well demonstrated (Hu 2005, Saran and Rust 2007).

Considering the behavior of the dealates in this study the hypothesis underlying this section of the study was that the dealates searching behavior would increase the likelihood of contact for dealates with a non-repellent insecticide that is applied on the wood surface. Also, the mortality would be the same whether the entire surface was treated or when only portions of the

surface were treated. Chlorfenapyr was hypothesized to be as efficient as previously well-tested products containing fipronil.

With this in mind, the objectives for this study were to determine if treating only a part of the surface area with chlorfenapyr would be enough to prevent colonization by *C. brevis* using bioassays which represent infested areas that include inaccessible portions, evaluate the efficacy of chlorfenapyr as a colonization preventative, and compare the efficacy of chlorfenapyr and fipronil (an industry standard).

Materials and Methods

All experiments were conducted at the Fort Lauderdale Research and Education Center in UF building 5031 in the room described in Chapter 2. The bioassays were assembled between May and June of 2007.

A total of 35 white pine wood boards were used in this experiment. The surface area of each board was 134 cm² (18.4 x 18.4 cm) and 2 cm thick. On the surface of these boards sixteen 2.3 mm diam. holes were drilled equally distanced from each other to a depth of 1.5 cm. The control boards had no treatment at all and consisted of 5 replicates. As for the treatments, two surface treatments were used with three treatments. A chlorfenapyr surface treatment was applied to the whole surface of the board, 50% of the surface and 12.5% of the surface. Each of these treatments had 5 replicates. The same process was used for fipronil, where for 5 replicates each with 100%, 50%, and 12.5% of the surface treated. Both the chlorfenapyr (Phantom, BASF) and fipronil (Termidor, BASF) were used at label rate of 0.125% (A. I. 0.0021g/cm²) and 0.06% (0.0017g/ cm²) respectively. To simulate the worst case scenario for a homeowner, the holes on the boards with whole surface treatment were drilled after the treatments were applied. This was intended to simulate a person that applies the treatment and then drills new holes which can be new entry points for alates. The boards were then placed in aluminum trays so that they could be

isolated from each other and placed under a light in for alate attraction. When the holes in the boards were colonized, the trays were removed from light and disassembled one week later. All the live and dead termites were recorded and a t-test for independent variables (SAS Institute 2003) was used to assess the differences between the percentage mortality in the different treatments.

Results

A total of 1,356 dealates were documented both in the chambers created for them and on the surface of the boards. All the controls had a significantly lower percentage of mortality than both the chlorfenapyr and fipronil treatments with less than 10% of mortality (Figure 6-1). None of the treated boards showed 100% mortality. The differences between the treatments of chlorfenapyr and fipronil when the boards were treated for 12.5 or 50% of the surface were not significantly different from each other. On the other hand, in the whole (100%) surface treatment, there were differences between chlorfenapyr and fipronil. Fipronil had significantly more mortality for the whole surface treatment while chlorfenapyr was not significantly different for the whole surface treatment compared to the other treatments.

Discussion

Prevention of colony foundation for *C. brevis* has been studied before with many different chemicals tested (Scheffrahn et al. 1998, 2001). *C. brevis* has been found to have as much as 2 founded colonies with brood in a total of 22 nuptial chambers (Scheffrahn et al. 2001). This shows that investment in colony prevention is important because if 9% of nuptial chambers produce brood and possibly develop into colonies, it is a high enough number to consider prevention. The hypothesis underlying this study is the possible use of less insecticide obtaining the same results as with a larger amount which can be more user-friendly.

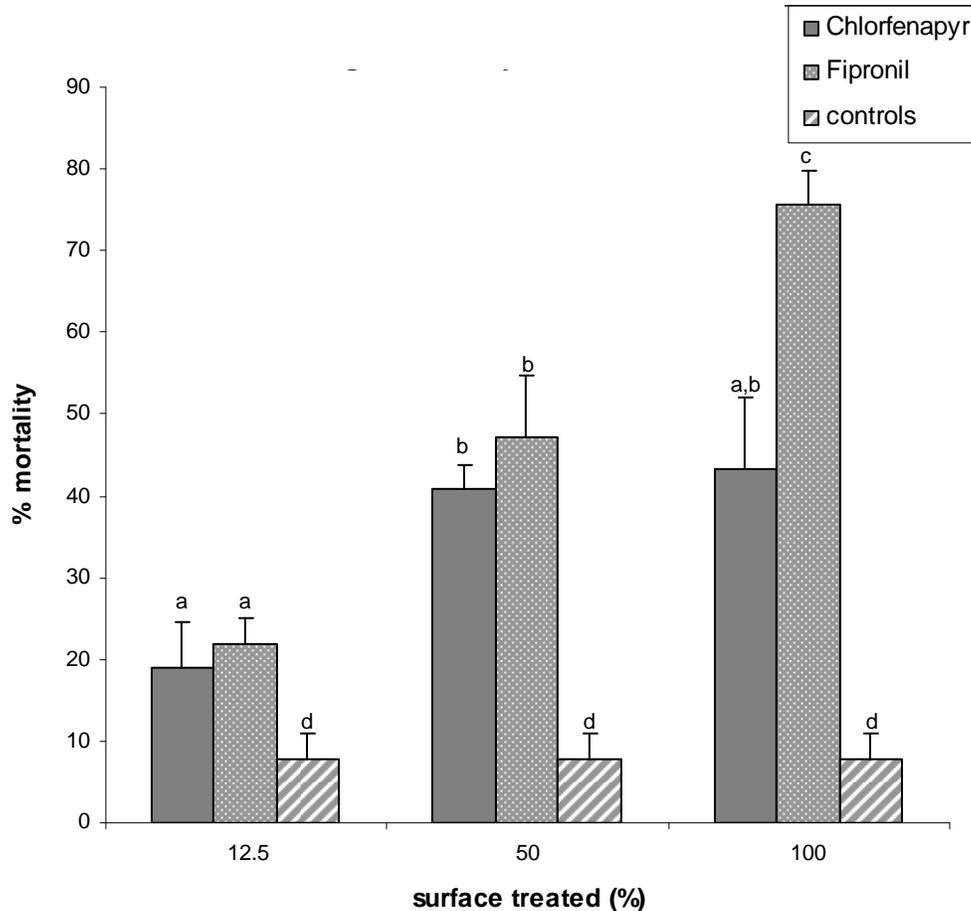


Figure 6-1. Mean percentage of mortality for treatments with chlorfenapyr, fipronil, and controls for 12.5, 50, and 100% of the surface treated. Bars with the same letter are not significantly different for $\alpha < 0.05$.

From the results obtained in the present study, it was seen that chlorfenapyr mortality was below 50%, never achieving a high level of efficacy. Several explanations can be considered for these results. First, it is possible that chlorfenapyr is not effective against termites. However, its efficacy has been demonstrated against subterranean termites where mortality for 500 ppm chlorfenapyr showed 100% mortality after 5 days of exposure (Shelton et al. 2006). Concentrations as low as 10 ppm (Rust and Saran 2006) resulted in >70% mortality for subterranean termites. These studies were performed with workers of subterranean termites and the effect of chlorfenapyr on primary reproductives is unknown. The dealates have a well-developed pigmented chitinous exoskeleton while workers and nymphs have a thinner

unpigmented exoskeleton (Light 1934b). The thicker exoskeleton may provide some protection from absorbance of chlorfenapyr. Other arthropods have been shown to be less susceptible to this particular chemical (Herron and Rophail 2003) although for unknown reasons. Also the dealates may not transfer the toxicant from an exposed nestmate to an unexposed nestmate as it has been seen for *Incisitermes snyderi* (Ferster et al. 2001).

Another consideration is that chlorfenapyr is considered a slow acting insecticide (Moore and Miller 2006) being an inhibitor of oxidative phosphorylation, preventing the formation of the crucial energy molecule, adenosine triphosphate (ATP). The effects of this may take longer to act and high mortality may not have been observed because enough time had not elapsed between the contact with the chemical and eventual death. Some mortality was always observed and it was significantly different from the controls, thus showing that chlorfenapyr has some effect.

Fipronil on the other hand, caused high mortality when the whole surface was treated. This indicates that the efficacy of fipronil is higher than chlorfenapyr. Fipronil has acute toxicity after only 24 h for termite workers (Ibrahim et al. 2003) and this may be why it shows better results for the whole surface treatment than chlorfenapyr. Although this mortality was only slightly above 70%, it does not support the hypothesis that the crawling behavior would be enough for the termites to come in contact with the non-repellent chemical. The fact that mortality was significantly higher for the whole surface treatment suggests that when there are areas of the surface left untreated, the proportion of surviving termites, increases significantly leading to more colonizations than with whole surface treatments. Perhaps the crawling behavior is too fast and the contact with the chemical is too short to provide enough contact for the chemical to cause 100% mortality. Also some termites may not crawl as much as others or may not even come into contact with the chemical at all, when only part of the surface is treated. New studies

with higher concentrations or different formulations that are more easily dislodged, like microcapsulation, may help resolve this question, because it may allow for greater mortality even if the contact is very brief. This may shed some light on whether the low mortality for partially treated wood is due to the limited contact during the crawling behavior in itself or the inefficiency of the chemical.

CHAPTER 7 CONCLUSIONS

From the work done in these studies several conclusions can be drawn about the dispersal flights of the species *Cryptotermes brevis*. The dispersal flights of this species occur in South Florida between April and June, with most of the alates flying during the night hours with a peak between 1 and 2 am. Several weather cues seem to be involved in triggering these flights, with rainfall being an apparent cue to the start of the flight season on a monthly basis. On a daily basis, lower relative humidity and lower air pressure seem to be the cues to trigger dispersal flights.

When flying, the alates are attracted to lights and will colonize more in lit areas than in dark areas with increasing colonization occurring with increasing light intensity. After the alates land they demonstrate a negative phototactic behavior, colonizing in darker areas as opposed to lighter areas.

The alates of *C. brevis* showed a variety of post flight behaviors which include crawling in search of colonizing sites, a wing release behavior upon which they release their wings becoming dealates. Also they will antennate several colonizing sites, and enter the site. When a second termite is present they engage in tandem crawling. When searching for a colonizing site they showed a preference for small diameter openings between 2.3 and 3.3 mm.

After choosing the final colonizing focus the pairs started a new colony with few (4 to 5) eggs during the initial stage. These eggs will incubate for about 54 days after which the larvae hatched with a maximum of 4 larvae observed per pair within the first 4 months of colony development.

Finally, even though the termites engaged in crawling behavior when landing on a substrate, this was not enough for a termite to have adequate contact with a non-repellent

insecticide long enough to cause high mortality. This makes surface treatments that do not reach the entire surface less effective in the prevention of colonization by this species. There is still much work that can be done on the colonization phase that can suggest new methods of control for this damaging pest.

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BIOGRAPHICAL SKETCH

Maria Teresa Monteiro da Rocha Bravo Ferreira was born in 1982, in Lisbon, Portugal. Born and raised in a big city, her love for insects did not arise until later in life.

Between the years of 1994 and 2000, she attended Liceu Camões, a very respected and traditional high school in Lisbon. There she developed her love for science by taking several different laboratory courses in chemistry and biology. In 2000, she graduated from High School and went on to be a freshman in college pursuing a biology major. At the Animal Biology Department at the Faculdade de Ciências da Universidade de Lisboa (Science College of the University of Lisbon) she joined the small entomology group in 2003 doing volunteer work in insect capturing and sorting. She did a year study in the Azorean Isle of São Miguel working with Diptera diversity in her final year in college. She graduated from college in July 2005, but continued her volunteer work with the entomology group until early 2006.

In 2006, she moved to the Azorean Isle of Terceira where she began work as a technician on a project to determine management tools for the *Cryptotermes brevis* infestation in the Azores. She worked in this project until the end of that year.

In 2007, she entered the graduate program at the University of Florida in the Department of Entomology and Nematology. She is continuing her studies and research at the Fort Lauderdale Research and Education Center.