Diurnal and Seasonal Patterns in Feeding Activity for the Western Drywood Termite, *Incisitermes minor*, for Naturally Infested Logs

by

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Abstract

Activity of colonies of the western drywood termite, *Incisitermes minor*, was measured by acoustic emission (AE) in five loquat (*Eriobotrya japonica*) logs. All logs came from the same tree and were similar in length and age. The AE activity was monitored for one year under ambient conditions in a small wooden structure maintained at the University of California Richmond Field Station. All AE, temperature, and humidity data were automatically collected and entered into a database for analyses. Termites in all five logs displayed a similar diurnal cycle of activity, peaking in the late afternoon. AE activity was greater during the warmer summer months compared to the cooler winter months. Daily and seasonal fluctuations in temperature were significantly associated with activity, whereas humidity did not appear to affect activity. Possible mechanisms that drive the circadian rhythm and the possible implications for inspections and post-treatment analysis will be discussed.

Key Words – feeding periodicity, seasonality, drywood termites, Kalotermitidae, Isoptera.

Introduction

Seasonal activity patterns of drywood termites are very important for their detection and treatment. A common seasonally activity for drywood termites is swarming. In California, drywood termites annually swarm during the day starting in summer and continuing into fall (Ebeling 1978). Feeding and foraging is another drywood termite activity; however, little is known when it occurs. The cryptic and hidden behavior of drywood termites deep inside wood hinders studies that explore their normal feeding and foraging behavior. Using AE technology to record *Incisitermes minor* (Hagen) feeding, Lemaster et al. (1997) found no periodicity in feeding in a 24-hour day. However, the investigation only ran for 1 week. Researchers at Kyoto University also used AE to monitor *I. minor* feeding when affected by different laboratory temperatures and relative humidity (%); however, they did not report diurnal or seasonal AE cyclical activity (Indrayani et al. 2006). Another investigation using AE monitoring of local chemical treatments from field studies in southern California, found *I. minor* infestations in untreated locations of structures declined in activity during winter months (V. Lewis, unpublished data). Since this study involved only four post-treatment inspection dates, it is impossible to make definitive statements on seasonal foraging of drywood termites.

Little research has been conducted on the movement patterns of drywood termites. Currently, only the speed of locomotion of *I. minor* (1.4 cm/s) in response to temperature and light is known (Cabrera and Rust 1996, 2000). Although, drywood termite (*I. fruticavus*) movement was inferred from studies that measured daily changes in temperature inside galleries for the Jojoba shrub, *Simmondsia chinensis* (Link) (Rust et al. 1979), the seasonality of movement for drywood termite species within structures for California remains poorly understood. The purpose for our study was to explore for diurnal or seasonal patterns of drywood termites feeding and vibrational activity from naturally infested logs. The applications of this research include improved inspections by knowing the best times of the day and year when drywood termites are most active, future natural history investigations, and pre-treatment and post-treatment evaluations of remedial treatments.

Materials and methods

Preparation and selection of naturally infested logs. Seven logs from a large Loquat (*Eriobotrya japonica* (Thunb.) Lindl.) tree was collected from a private residence in southern California (Granada Hills, CA.) The logs were similar in maximum diameter, length, and age. To verify candidate logs were active with drywood termites, using the methods from Lewis and Haverty 1996, three 1-min recordings from their centers along the top long side were taken using a hand-held device (Tracker, Dunegan Engineering, Midland, TX). All logs having at least 300 counts per minute were chosen to be included in the study. Five were logs used to record AE activity and two logs containing termites were chosen as controls (containing no termites) to measure background AE activity from the surroundings. For the control logs, they were put into an oven (Isotemp model 655F, Fisher Scientific, Pittsburgh, PA) at 105 ^{o}C for three days to kill any termites within the logs. All seven logs had a subsurface sensor installed into their long center by drilling a 2.4 mm diameter hole and inserting the sensor probe 1.2 cm deep into wood. All log and sensor assignments were chosen randomly. The 3-m long cable from the last of the seven sensors was connected into a port in the back of an AE smart device (Dunegan 2005) and dedicated computer (Dell Corporation, Austin, TX) that stored all data. Seven, 3-minute recordings were recorded randomly among the seven sensors for each 60 minute period during the study. In addition, temperature and humidity data (Omega Engineering, Stamford, CT) was recorded for each 3-minute recording and also stored and saved to an electronic spread sheet (Excel Corporation, Lubbock, TX). A backup battery power supply (Back-ups, APC Corporate, W. Kingston, RI) was also installed in the event of unexpected power outages. The entire AE gathering and stored system was run twenty-fours a day for almost one year (June 2008 to May 2009). All logs, AE and temperature equipment were stored in a small wooden building at the University of California Richmond Field Station, Richmond, CA. The building had five windows for natural light. There was no air conditioning, heaters, or insulation in the building.

Statistical analysis. The averages for AE activity, temperature, and relative humidity were plotted for each sensor per hour per day for active and inactive logs. Statistical comparisons for significant differences in AE activity among hour of day, month of year, and treatment (active and inactive logs) were made using ANOVA (SAS 1994).

Results

Diurnal patterns in AE activity. Within a 24-hour day, AE activity (both event and ring down count had similar results but only ring down counts are presented in this paper to save space) among the logs displayed a non-linear pattern of activity (Fig. 1). The pattern of AE activity data was sinusoidal in shape and statistically significant for all sensors. AE activity was lowest during the morning, increased in the afternoon, and peaked in late afternoon (6 pm), then declined until mid-morning. For log (#1), a second peak of AE activity (events and ring down counts) was recorded late into the evening at midnight and was also statistically significant. From the AE activity sensor results (y-axis), the infestations could be categorized into three groups; sensor 3 represented the smallest, sensors 1, 4, and 5 were roughly three times the size of sensor 3, and senor 2 was the largest, almost seven times the size of sensor 3. Temperature was correlated with the rise and fall in AE activity; warmer temperatures were associated with increasing activity (Fig. 1). However, relative humidity was not statistically correlated with AE activity.

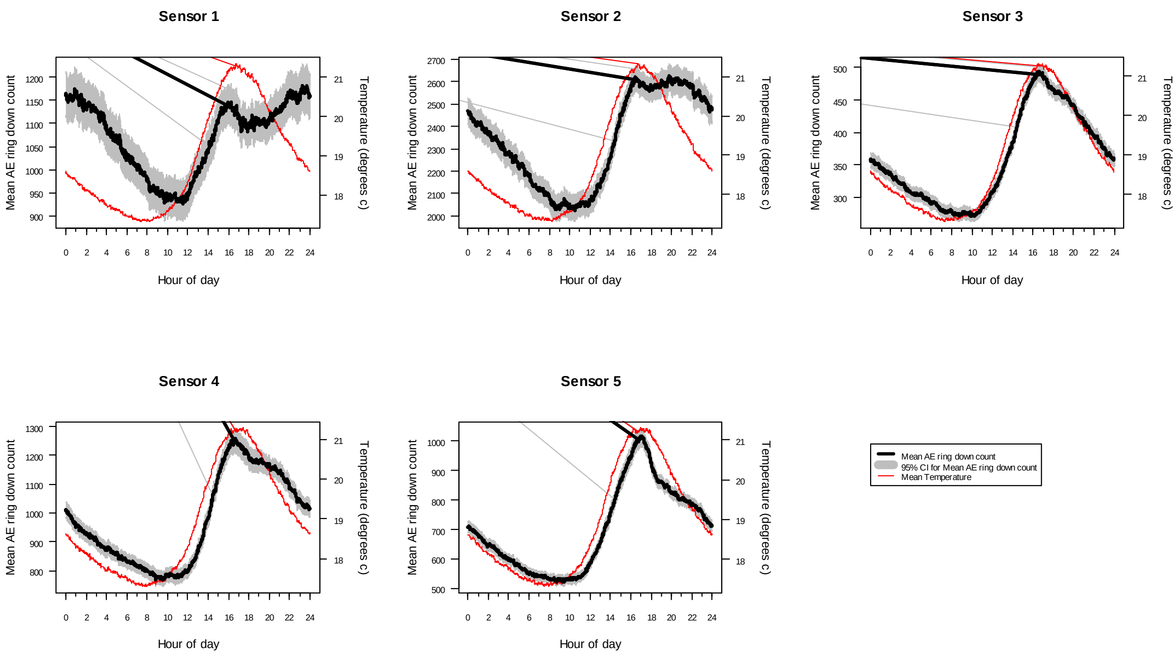

Figure 1. The mean hourly AE ring down count for each sensor (1-5) that occurred during the twenty-hour diurnal cycle. The heavy dark line is the mean AE ring down count. The red line is the temperature trace during the same 24 hour diurnal cycle measured in Celsius (^{o}C). The average AE ring down count for the untreated logs (sensors 6 and 7) were statistically flat and near zero and are not shown in the figure. AE data for all logs was collected from June 2008 to May 2009.

Seasonal patterns in AE activity. Seasonally, AE ring down counts displayed a non-linear pattern of increasing and decreasing values associated with temperature (Fig. 2). The relationship between seasonal AE activity and month during the year was statistically significant. AE activity was highest during the warmer spring and summer months compared to winter. However, an increase in daytime temperature or a sudden heat wave, even in January and February 2009, resulted in an increased burst of AE activity (Fig.1). Seasonally, there was a statistically significant association between temperature and AE activity. Humidity did not have a statistically significant impact on AE activity during the 11-month study.

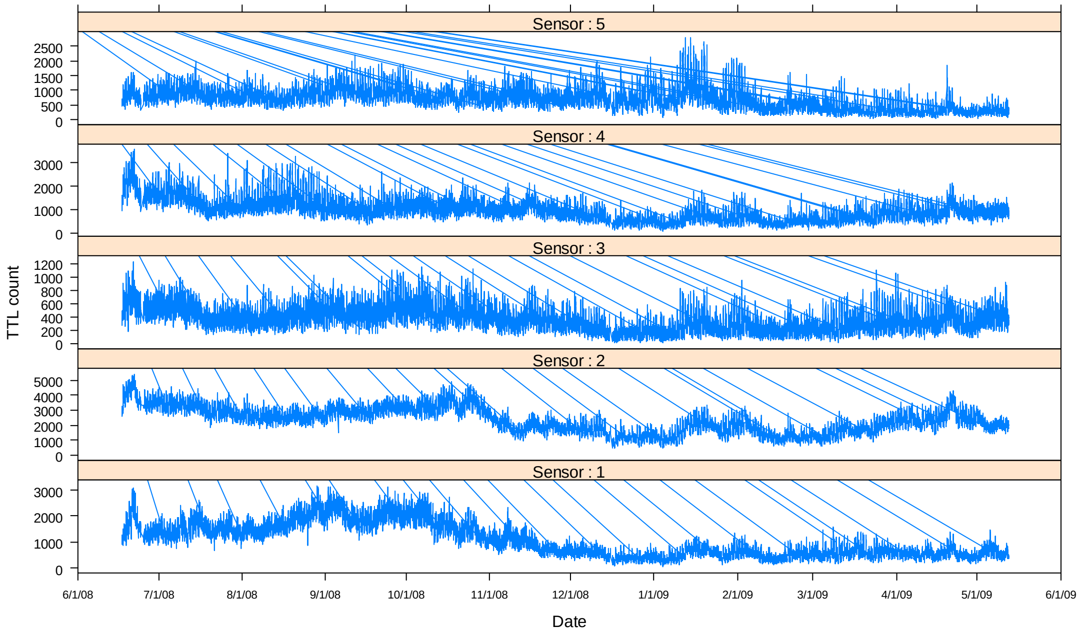

Figure 2. The seasonal mean hourly AE ring down count for each sensor (1-5) that occurred during the 11-months from June 2008 to May 2009. The heavy dark line is the mean AE ring down count. The average AE ring down counts for the untreated logs (sensors 6 and 7) were statistically flat and near zero and are not shown in the figure.

Discussion

There are few papers that present diurnal or seasonal AE activity data for *I. minor*. Using 100 workers contained in an artificially infested wooden block held at constant temperature and humidity, Lemaster et al. 1997 reported AE events results from a single sensor during seven days of testing for *I. minor*. There was no statistical significant cycling or periodicity in AE activity found. The plot of AE activity appeared flat and hovered from 100 to 200 events per hour.

There is considerable variance in the size and number of drywood termites dissected and reported from naturally infested logs and structural wood and ranges from 7 to 2,943 (Harvey 1934, Scheffrahn et al. 1993, Lewis and Haverty 1996, Lewis and Power 2004, Lewis et al. 2005). Obviously, larger colonies and infestation produce greater AE activity. And also clearly evident is that when drywood termites are allowed to search and forage for wood naturally under ambient conditions, their activity follows a cyclic pattern common to many terrestrial animals.

A second AE activity study was conducted by Indrayani et al. 2006. For this laboratory study *I. minor* workers were also used (10) in small wooden blocks to test the affects of varying temperature and humidity. The tests were of short duration, 12 hr. This study reported that the optimum temperature for peak AE activity was 30^{o} C. Reviewing the temperature and data from our study, AE activity increased with temperature, even during warm days during seasonally cold months (November 2008 to February 2009; Fig. 1).

Knowledge on optimal times for drywood termite foraging could be important to termite inspections. Two species, *Incisitermes minor* (Hagen) and *Cryptotermes brevis* (Walker), are responsible for a majority of the damage caused by drywood termites in the United States (Light 1934, Su and Scheffrahn, 1990, Grace, 2009). The economic cost of control and repair of damage is second only to that of subterranean termites (Su and Scheffrahn, 1990). Traditional inspections are visual and based on visual searches for damaged wood or pellets. The data from this study suggests searches for pellets could be enhance by heating the wood to at least 25^{o} C prior to inspection to simulate foraging and feeding, even in winter. Understanding the underlying mechanism that controls the cyclic pattern, called Zeitgeber (Schotland and Sehgal 2001), will require additional study that include the exclusion of natural light, running additional tests for naturally infested logs at constant temperature and humidity, and modifying the AE system collection hardware and software to sort out locomotion from feeding AE activity.

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