Final Report[1]

Research Proposal to the California Structural Pest Control Board for Structural Pest Control Research Contract # 084-3635-6

Assessment of Devices and Techniques for Improving Inspection and

Evaluation of Treatments for Inaccessible Drywood Termite Infestations

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[1] The statements, figures, and tables contained in this report fulfill the reporting requirements of the contract and have not undergone peer review. Copies of all final peer-reviewed and accepted manuscripts from this report will be forwarded to the Structural Pest Control Board at a later date.

Executive Summary

Laboratory and field studies were conducted to evaluate and/or improve technology for the inspection and treatment of inaccessible drywood termite infestations. Our focus was to evaluate the usefulness of X-ray and temperature-enhanced infrared technologies in finding drywood termite infestations hidden behind wall coverings, such as drywall, stucco, and wood paneling, in both laboratory and field settings. These technologies exploit changes in wood density and temperature-response characteristics caused by the damaging effects of termites. Verification of active infestations of drywood termites included the use of commercially available microwave and acoustic emission (AE) devices. Field evaluations of these technologies were conducted in partnership with local pest control operators. Critical to these studies was documentation of (1) the constitution a drywood termite colony and (2) the frequency of feeding. Currently, the definition of a drywood termite colony is based on location; infested boards that are widely separated are assumed to contain different colonies. There are several biological definitions of what constitutes a drywood termite colony for conditions in California. The genetics of workers and chemical analyses of fecal pellets were used to separate colonies of drywood termites and to provide a measure of successful or failed treatments. Lastly, we found that drywood termites have uneven feeding patterns throughout a day and during the year. We used a computerized, multi-channel AE recording device to document variation in drywood termite feeding. The combination of these studies will allow for the better calibration of detection devices that exploit termite feeding and motion.

Background

Economic importance. Surveys of inspection reports reveal that drywood termites have a significant economic impact in California. One of the eight species of drywood termites found in California, *Incisitermes minor* (Hagen), has the greatest economic importance. Visual evidence of drywood termites contained in the wood-destroying pest inspection reports suggests drywood termite infestation rates can be as high as 46.8% of the structures inspected. Control of drywood termite infestations is predominantly by applying local treatments, not whole structure fumigations. Costs for control and repair of damage from drywood termites in California exceeds $300 million annually and are projected to increase. Not included in these costs are fears and perceived risks from treatments such as fumigation.

Visual inspections. A flashlight and metal probe are used to search for evidence of drywood termites: alate wings, fecal pellets, and damage to wood. The effectiveness of visual searches is unknown. Characteristic fecal pellets are considered diagnostic for drywood termites. The presence of fecal pellets has been used to demonstrate efficacy of chemical treatments, however there are no published reports on the chemical nature of pellets that relate to the active status of a drywood termite infestation.

Inaccessible infestations. The greatest challenge faced by PCOs during their inspections is to identify the existence and extent of inaccessible drywood termite infestations. For most filed reports, areas not inspected are noted as inaccessible to visual search. Without removing wall coverings, it is impossible to reliably delimit infestations

behind walls. From my personal experience in southern California inspecting apartments for dyrwood termite infestations, roughly one infested board was found for every 10 boards exposed after wall removal of covering. Because over 70% of treatments for drywood termites in California are localized, there is a critical need to be able to locate and circumscribe active, inaccessible infestations of drywood termites.

Alternatives to visual searches. There are at least seven devices and methods proposed as detection alternatives to visual searches. They include optical borescopes, dogs, electronic odor detectors, acoustic emission devices, microwaves, infrared, and X-ray. They all claim high levels of successful detection of termites; however, few have been scientifically tested.

Optical borescopes currently marketed use visual light passing through a hollow tube as a means to view evidence of drywood termites and damage within wall voids. A small hole must be drilled into walls to allow viewing. Fire blocking, insulation, and viewing through a fish-eye lens can impede the inspector's view.

Dogs have also been used to assist with drywood termite inspections, although scientific studies verifying the effectiveness are scarce. Dogs find termites by hearing or smell or both. In California, the effectiveness of beagles in finding subterranean termites infestations has been mixed. There have been no investigations in California to assess the ability of dogs to locate drywood termite infestations. Laboratory trials conducted in Florida found that dogs (beagle and German shepherd) correctly identified drywood termites in plastic containers 88.8% of the time. Currently, there are few commercial firms in the USA that train and provide dogs to assist with termite inspections.

Electronic odor detectors detect methane gas, commonly produced by termites. One device (Termitect II) was tested on subterranean termites and produce highly variable detection rates, 20 to 100%. There have been no reports on the use of electronic odor detectors successfully locating drywood termites, even though they produce methane.

Termites produce vibrations in wood; some can be heard by humans. Sounds made by drywood termites are produced during feeding and by vibratory movements of workers. The earliest commercial listening device for termites was the INSECTA-SCOPE. No data are available on its performance. Newer technology, that amplifies and records termite-feeding vibrations, is acoustic emission (AE). Surface and subsurface probes are available that successfully detect drywood termites in laboratory settings. Wall covering can impede sensor and AE performance. Detection is limited to ≈80 cm along the length of a board and < 8 cm across the grain. Excessive background noise can result in falsely identifying active drywood termite infestations. AE detection equipment is commercially available, although availability is very limited.

Microwaves comprise the frequency range 0.3 to 300Ghz and lie between radio and infrared region of the electromagnetic spectrum. Microwaves are commonplace in our daily lives and their commercial applications are many and varied. The use of microwaves as a commercial method for localized drywood termite control has been available in California for at least 15 years. Recently, portable microwave detection devices have been marketed in California. Success in detection of drywood termites using microwaves (TERM_A_TRAC™) was 86% in Australian laboratory studies. Detection distance was 35 mm along the long axis of test boards and 25 mm deep below the surface. However, water in wood, wall coverings, and excessive wind and motion can lead to false positives.

Infrared rays are part of the electromagnetic spectrum. Although invisible to the human eye, infrared energy has a penetrating heating effect. Most objects, living or not, give off infrared heat, whether internally generated or reflected. Initial uses of infrared were for military surveillance. Today, there are many nonmilitary uses and include measuring devices, binoculars, and night viewing for hunting. In structures, infrared devices have been used to find faulty electrical connections and heat and water leaks in walls and roofs; a more recent use includes termite detection. Commercial termite detection models are available, yet their effectiveness in finding termite infestations has not been scientifically tested. Infrared imaging has been used to detect internal voids intended to represent voids generated from biodeterioration. The results of these tests were promising, although detecting subsurface defects (voids) clearly represents a challenge.

Penetrating rays are part of the electromagnetic spectrum nearest ultraviolet rays. They are invisible, have smaller wavelength, and have a higher frequency (Hz) compared to the visible part of the spectrum. There are many commercial applications for X-rays. X-rays have the ability to penetrate nearly all materials. These penetrating rays have also been used to nondestructively view insects hidden in wood for at least seven decades. X-rays have been used to view structure-infesting beetle pests. Only recently has the potential use of X-ray in detecting drywood termite infestations been explored. Today's newer technology is lightweight and portable. Processing of images is accomplished with lasers that produce digital images that are enhanced by computer software. Newer sources of X-rays emitters and advances in safety monitoring equipment minimize radiation leakage and exposure.

Seasonal activity and pellets as indicators of failed treatments. 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 starting in summer continuing into fall. Little is known about when drywood termite feeding occurs. A commonly held belief is that drywood termites feed every hour of every day. The cryptic nature of drywood termites deep inside wood hinders studies that explore their normal feeding behavior. Early laboratory studies using AE technology to record drywood termite feeding found no periodicity in feeding in a 24-hour day. An unpublished field investigation in southern California, using AE monitoring of local chemical treatments, found drywood termite infestations in untreated locations of structures declined in activity during winter months. The movement of drywood termite may also be seasonally based, however the seasonality of movement for drywood termites within structures in California remains poorly understood. We need to determine whether drywood termite feeding and movement are seasonally based. These results will have a profound affect on inspections, and post-treatment evaluations for failures of localized treatments.

As drywood termite feed they void the undigested components as very dry fecal pellets. These pellets are hexagonal in cross section and are diagnostic for drywood termites. The number of pellets produced per termite is about one per day. We do not know whether changes in the chemical nature of pellets voided by drywood termites can indicate the active or in-active status of infestations.

Cuticular hydrocarbons are long-chain carbon molecules and are part of the waterproofing mixture of waxes on the outside surface of termites. These characteristic

mixtures can be used to identify termite species and have been reported for all castes of termites. However, the most conspicuous evidence of drywood termite infestations, voided fecal pellets and the chemicals they contain, has only recently been researched. Pellets of drywood termites contain the same mixture of hydrocarbons as the insects that produce them, in reasonably equivalent proportions. A need exists to explore chemicals contained in pellets that might indicate whether an infestation is active or inactive.

Molecular genetics. The use of genetic markers offers a powerful way to investigate colony social organization, and there has been a growing number of genetic studies of social organization in termites. Microsatellite genetic markers are especially useful markers for studies of colony and population genetic structure and for tracking the fate of individual colonies. There have been microsatellite markers developed for an increasing number of termite species, but until recently no microsatellites have been developed for any drywood termite species. Development of microsatellite markers for drywood termites will provide three new, practical techniques. First, a biological determination of what constitutes a colony of drywood termites will be established. Secondly, once the members of a colony have a genetic identity, failed treatments can now be determined if a new or different colony is found in the treated structure. Lastly, once it is firmly established what a drywood termite colony is, new least toxic treatment strategies, for example baits, can be developed and tested.

Research Objectives

The objectives of the research plan were ambitious with multiple components to identify and delimit inaccessible drywood termite infestations. Novel devices that included X-ray, infrared, AE, fiber optics (borescope), and microwaves were used to demonstrate that drywood termite infestations can be located nondestructively and accurately mapped out during the inspection process prior to treatment. The biological meaning of a drywood termite colony was investigated. Genetic and chemical techniques provide analytical baseline data that allow for the labeling of drywood termite colonies as being active, inactive, as well as treatment failures. The results of each research objective are summarized below.

1) Determine the effectiveness of the combination of X-ray, temperature enhanced infrared, AE, borescope, and microwaves in finding inaccessible drywood termite infestations in laboratory boards.

Laboratory and field investigations were conducted on termite detection technologies that included fiber optics (borescope), acoustic emissions (AE), infrared, and X-ray. For laboratory investigations, methods were developed for bench-top testing for the borescope. Additional methods were designed to calibrate X-ray and infrared camera for viewing artificially and naturally infested boards containing drywood termites. For the borescope, seven items were presented to seven laboratory participants in 5.5 cm clear plastic dishes. The design included the added features of being able to differentiate ants from termites, drywood termite fecal pellets from plant seeds, and pellets from debris. The ability to identify untreated checks (empty plastic zipper cases) was also included in the design. All participants had a high level of successfully identifying items presented them in plastic, sealed dishes, at least 90%. Similarly the success rate in correctly

identifying untreated checks among participants was also high, 100%. Laboratory investigations produced procedures and techniques to attempt field investigations involving infrared and X-ray that included exposure time and post-processing and enhancement of images obtained.

2) Determine the effectiveness of the combination of X-ray, temperature enhanced infrared, AE, fiber optics (borescope), and microwaves in finding inaccessible drywood termite infestations under field conditions.

For field investigations we used the Villa Termiti, a 400 ft^2 (37.2 m^2) wooden structure designed and constructed to compare termite detection and treatment technology. The testing protocol included the use of test boards that were active for drywood termites, inactive (damage only), as well as untreated checks (controls). In total, nine boards were searched with each microwave, AE, infrared, and X-ray equipment. The objective for these tests was to determine if any of these devices could singularly identify the presence of damage and active termites in test boards. An additional challenge or variable was to determine capability of these devices to make detection determinations through wall coverings that include wood paneling, dry wall, and stucco. At the end of field investigations, all test boards were cut into 10 cm sections and dissected for live and dead termites. Notes were also taken for the presence and location of gallery architecture. Under the field conditions of the Villa Termiti, only X-ray demonstrated the ability to accurately detect the presence of damage and termites, albeit these results were best for exposed boards. We were unable to determine whether boards were active with either termites or damage using infrared camera, even after heating the boards for 10 sec at 540^o C. AE and microwave produced reliable results (all test boards determined to be active with termites using both these techniques were verified active upon dissection), but were impeded when wall coverings were added, due to thickness or difficulty in drilling sensor-testing holes. Results using a borescope in blind tests presented to seven participants were mixed and highly variable depending on the number of pellets, presence of insulation, as well as the nimbleness and the ability among participants to bend down low to manipulate small drilled holes and tight wall void space. For infrared and X-ray, several hundred images of laboratory boards containing termites and actual real-world field conditions have been created and stored in a photo solon.

At this time we cannot recommend a single detection device that can reliably, with a high degree of certainty, demonstrate that termites are active in walls, especially for high locations (vaulted ceilings) and when wall coverings are in place. No, there is not a single “silver bullet.” The best option for drywood termite, or any other wood destroying insect, inspection is a trained operator with 20 years of field experience and permission to open walls for further inspection. The next best option would be after identifying a wall or better yet a single board, use an AE device with a subsurface sensor (small wood screw sensor) to determine the board is active for drywood termites. A second device, this time a portable microwave sensor, can be passed held against the board or even drywall (be careful not to hold the device, best to use a tripod to minimize false positives due to vibrations) to aid in identifying the exact locations of galleries. This detection

strategy works best for local treatment, where the exact knowledge of active boards and gallery architecture is critical to success.

3) Determine the nature and limits of drywood termite colonies in laboratory maintained boards and actual field infestations using molecular genetic markers.

Given the vast economic impact of western drywood termite, the understanding of population genetic structure and breeding systems is fundamental to the development of more effective management strategies. Modern molecular markers, such as microsatellites, are now commonly used to address critical biological questions. Microsatellite DNA consists of tandem repeats of between 1 and 6 base pairs, often in long arrays, and can comprise a large fraction of a termite's genome. Microsatellite markers offer the greatest potential for studies relating to breeding structure and colony identification, due in part to their co-dominant, Mendelian mode of inheritance, high mutation rate, high level of polymorphism, and ability to be amplified from small amounts of tissue. Microsatellites do not contribute to the genetic code for protein synthesis, thus there is no selection pressure, and the highly mutated sequences are inherited and passed on within a colony.

We developed an enriched library from which we isolated and characterized 15 polymorphic markers. The number of unique alleles per microsatellite locus ranged from three to fifteen. These markers yielded sufficient within and between colony/population polymorphism for the resolution of patterns of gene flow and colony breeding structure.

Termite colonies are considered to fall into three breeding categories. When reproduction involves only a single king and queen, the colony is referred to as a simple family. Following the death of one or both primary reproductives, the colony may undergo several rounds of inbreeding as a result of reproduction by secondary neotenics. This is referred to as an extended family. Finally, colonies have been shown to fuse: workers within a colony exhibit genetic ancestry to more than one colony. These are referred to as fused or mixed family colonies.

The objective of this study was to determine the levels of genetic diversity within geographically separate colonies of *I. minor* using a set of species specific microsatellite markers. Within two landscapes, urban and agricultural, we used these markers to examine the colony genetic structure, identity, and breeding structure. A total of 23 colonies were sampled from 11 distinct collection sites in California, 10 sites were classified as urban. Genomic DNA was extracted from 10 to 20 workers termites per site. These individuals were genotyped at five polymorphic microsatellite loci. Colonies were placed into one of three breeding structure groups: simple family, extended family, and mixed family colonies. Colony genetic structure was performed over all samples, among urban samples only, and among agricultural samples only.

Eleven of the 13 collections were considered unique colonies. Of the 13 urban samples, six colonies yielded genotypes consistent with those expected under a single pair of reproductives. No more than four genotypic classes were detected, all segregating with Mendelian ratios expected for a single pair of reproductives. Three colonies, while possessing no more than four alleles per locus, exhibited greater than four genotypic classes (i.e. too many homozygous genotype classes), or Mendelian segregation patterns inconsistent with a single pair of reproductives. These were therefore determined to be

extended families. The remaining four colonies exhibited greater than 4 alleles at one or more loci thus providing evidence for colony fusion or mixed colony structure.

All colonies sampled within the agricultural landscape were genetically distinct. Within the seven agricultural collections three colonies meet the criteria of being simple families. A further three exhibited an excess of genotypic classes while possessing no more than four alleles at each locus, and were therefore identified as extended families. The final colony exhibited greater than 4 alleles at more than one locus and was determined to be a mixed family.

Results presented here represent the first documentation of breeding structure, colony identification, and colony genetic structure to date for *I. minor* using highly polymorphic molecular markers. The high level of polymorphism (12 to 32 alleles per locus) exhibited at these five loci proved highly suitable for colony identification, and therefore may represent a powerful tool for future studies investigating colony survival and re-infestation events post insecticide treatment, informing the pest management professional of the efficiency of a given treatment.

Colonies composed of a single pair of reproductives and their worker/soldier progeny probably represent colonies that are up to or just over 5 years of age. These are colonies that have yet to produce neotenic reproductives or those that contain neotenics that have not yet produced progeny. Extended families composed of multiple reproductive neotenics represent colonies that are probably 10 years of age or older, and may be responsible for extensive structural damage to a building. Mixed family colonies, from colony fusion, may prove difficult to explain. Explanations as to how these mixed family colonies form have been broadly divided into two categories: those driven by worker foraging behaviors and those driven my alate reproductive strategies. Thus in this instance colonies may not actually represent a mixing of genetic lineages within a large colony, but rather an event were colony foraging areas overlap. An alternative explanation may be that samples collected that appear genetically as being fused/mixed may actually represent distinct colonies whose activity centers or nests were proximate within the sampled wood, but not actually fused. Thus, two distinct colonies may have been inadvertently collected and labeled as a single colony.

Given the significant economic impact of *I. minor* in the western U.S., the ability to accurately identify colonies, their breeding structure and genetic structure is of fundamental importance for the formulation of effective management strategies. We present the first results generated using highly informative microsatellite markers that will allow the following to be estimated with relative ease:

1) Colony size and age. Simple family structure may inform us that colonies are relatively small, detected in the early stages of infestation. Higher levels of inbreeding and the determination of colonies as being extended informs us that the colonies are likely to be extensive, containing numerous secondary reproductives each producing workers. Thus given the cryptic nature of this species we can now make an informed decision as to the likely extent of damage without extensive physical investigations of a structure.

2) Colony range. The treatment method employed may vary significantly depending on its range. Using these markers we can determine whether colonies are contained to small regions of a property, or if they extend throughout a building. Thus, in instances of a single colony ranging throughout a structure,

less environmentally intensive insecticide treatment (for example baits) may be developed to transmitted through the nest system from a single treatment point. 3) Treatment efficacy. When a structure is treated, resulting in apparent colony extinction, its efficacy can be determined through genetic testing. Sampling individuals prior to, and after, the treatment, assuming a structure becomes reinfested, will allow us to determine whether the original colony was successfully exterminated and therefore determine whether re-infestation occurred from an outside source, or if a fragment of the original colony survived to re-infest the structure.

4) Explore the existence of qualitative and quantitative differences in chemicals in fecal pellets, using cuticular hydrocarbon analyses, that lend themselves to determining the active or inactive status of drywood termite infestations.

Remedial control of drywood termites in the US relies primarily on (1) fumigation of the entire structure or (2) localized chemical or physical treatments designed to eradicate localized colonies. The presence of drywood termites is usually determined by the appearance of fecal pellets, which are ejected through a "kick hole" in the external surface of wood.

When fecal pellets appear after remedial treatment of a structure, it is difficult to determine whether the termites in the structure are alive or dead. Conveniently these fecal pellets contain the same mixture of hydrocarbons as the cuticle of the insects that produced them. The hydrocarbons in the fecal pellets can even be used to identify the termite species.

Rather than simply signaling the general presence of termites or providing a precise diagnosis of the species of termite inhabiting the wood, we wondered whether these pellets could be chemically characterized to determine the active or inactive status of a colony. We quantified the hydrocarbons in pellets of *I. minor* aged for up to one year after they were produced. We documented the changes in proportions of selected hydrocarbons as an indication of the age of the colony producing them.

Drywood termites were removed from a naturally infested board and placed on birch tongue depressors that were bundled together, placed in a plastic container, then lightly misted with water. Termites were held in a dark cabinet under ambient laboratory conditions prior to collection of fecal pellets. At the end of one week a 200 mg sample of fecal pellets was divided into three replicates each of four aging intervals: 1 week, 1 month, 3 months, and 1 year from the initial collection date. The hydrocarbons from fecal pellets were extracted, characterized, and quantified at the end of each time period.

The percentage of the total hydrocarbon for each hydrocarbon peak for each aging period was the response of interest. These percentages were regressed against the days of aging. Hydrocarbons with slopes statistically different from 0 were separated into two groups, those with a positive slope and those with a negative slope. For each aging period, an index of age (I_{age}) was created by subtracting the sum of the percentages of the hydrocarbons with a significant negative slope from the sum of the percentages of the hydrocarbons with a significant positive slope [$I_{age} = \sum (PEAK_{positive}) - \sum (PEAK_{negative})$]. The set of twelve I_{age} values (3 replications times 4 ages) was then regressed against age.

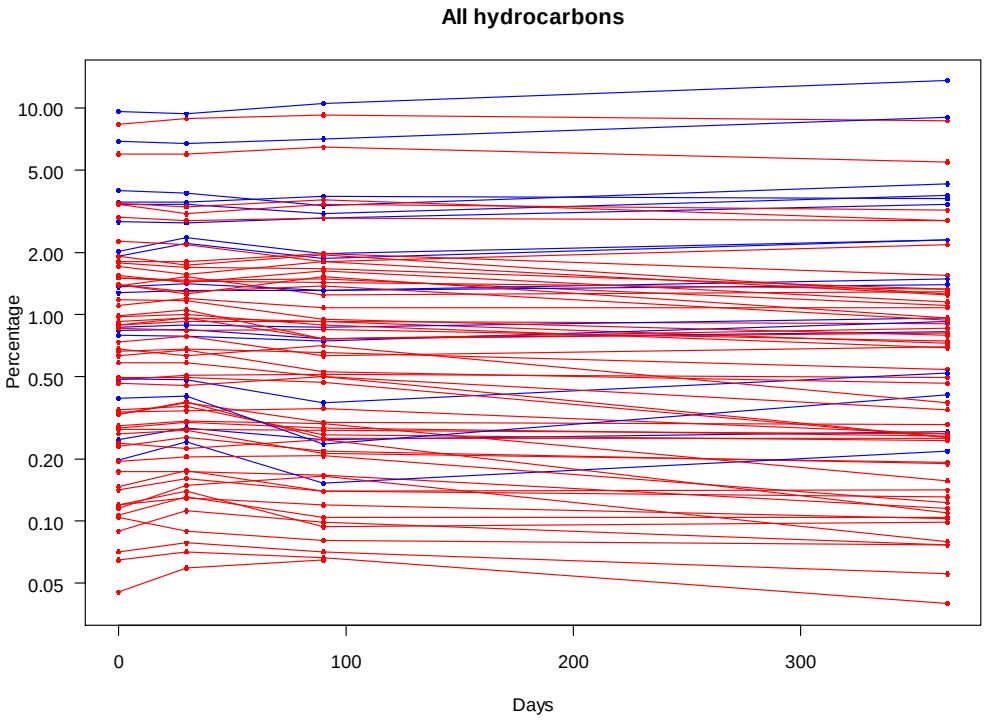
We identified 72 peaks containing 76 hydrocarbons. The change in relative

abundance for each hydrocarbon peak over the course of a year does not appear, at first glance, to be very dramatic. However, 19 of the 72 hydrocarbon peaks (26%) had a significant linear change over time; of those 5 had positive slopes and 14 had negative slopes.

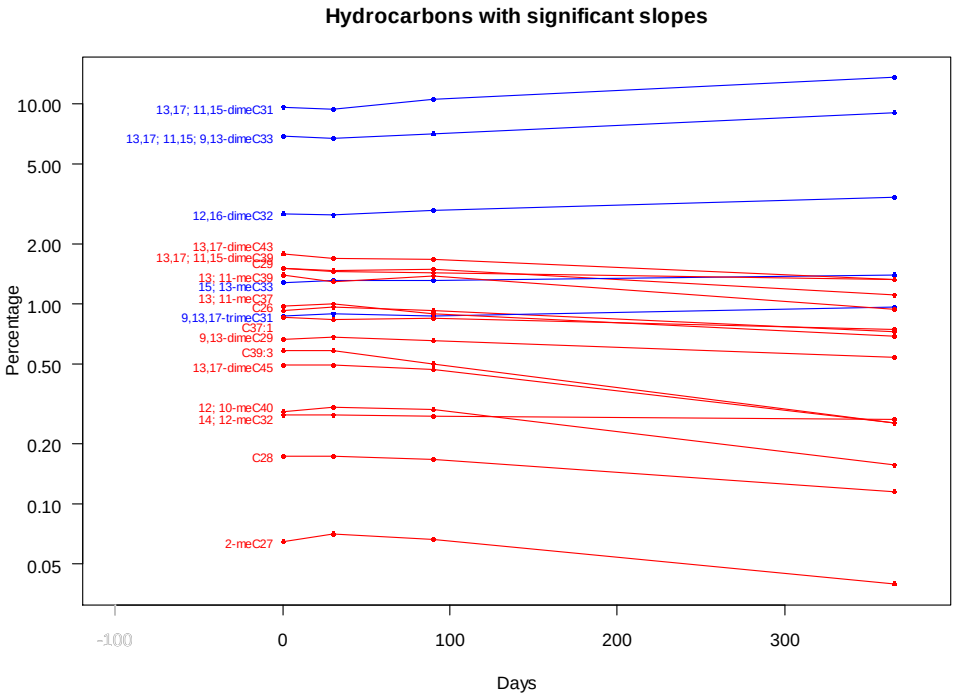
We took the 19 hydrocarbon peaks with significant regressions and created an index, I_{age}. A line was fit ($r^2 = 0.8879$) to show the variability of the replicates about the fitted line and the trend over time. This highly significant correlation strongly suggests that one might be able to predict the age of fecal pellets and thus the status of the colony that produced them.

At this point the chemical mechanism by which hydrocarbons increase or decrease in proportion over a one-year period is unknown. It is not clear to us that the hydrocarbons that increase in relative abundance are inherently more stable than those that decrease in relative abundance. Those that increased in relative abundance tended to have higher relative abundances to begin with.

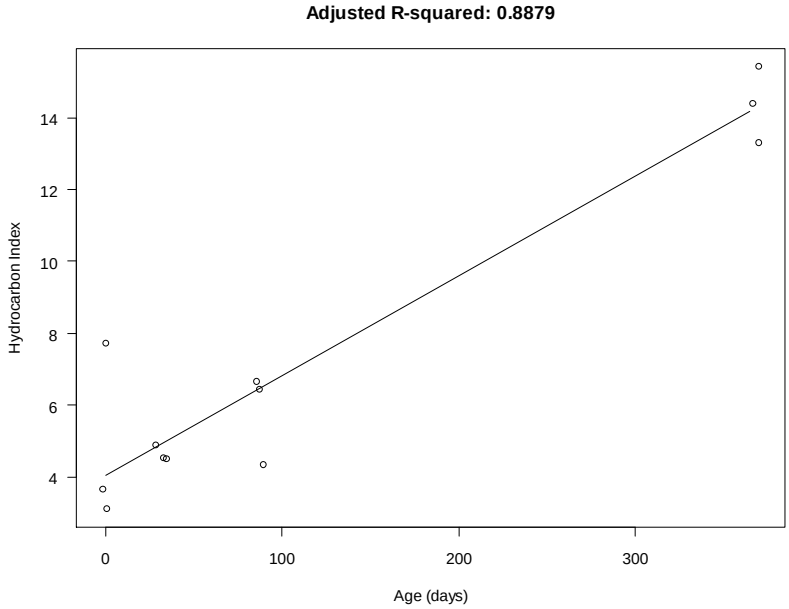
The motivation for this work was to aid in the post-treatment evaluation of success or failure for drywood termite treatments. We felt that there would be considerable interest by the industry, regulatory agencies, and consumers for a simple and accurate means to determine how long a "colony/infestation" has been in a structure.



Plots of the log of all hydrocarbon percentages of fecal pellets over time (averaged over the three replicates). A log scaling of the percentages is used to allow more visual separation of the individual hydrocarbon histories.



Histories of fecal pellet hydrocarbons with significant slopes over time.



Plot of index of age (I_{age}) against age.

5) Determine the seasonality in drywood termite foraging and feeding using AE remote sensing equipment.

Daily and seasonal activity patterns of drywood termites, such as feeding, are very important for the detection and treatment of drywood termite infestations. The cryptic behavior of drywood termites deep inside wood hinders studies to directly observe their behavior. The purpose of this objective was to explore diurnal and seasonal patterns of drywood termite feeding activity in naturally infested wood.

Logs from a large Loquat tree were collected from a private residence in southern California. The logs were similar in diameter, length, and age. To verify that candidate logs contained an active drywood termite population, we took three 1-minute AE recordings using a hand-held device. Seven logs producing at least 300 AE counts per minute were included in the study. Five of the seven logs were randomly chosen to record AE activity of drywood termites. Two of the seven logs were treated to kill all of the termites were used to measure background AE activity from the surroundings.

All seven logs had a subsurface sensor installed into their center, 1.2 cm deep into wood. A 3-meter-long cable from each of the seven sensors was connected into a port in the back of an AE smart device and a dedicated computer that stored all data. Twenty, 3-minute recordings were recorded randomly among the seven sensors for each 60-minute period during the study. In addition, temperature and humidity data were recorded for each 3-minute recording. The entire AE gathering and storage system was run 24 hours a day for 11 months (June 2008 to May 2009).

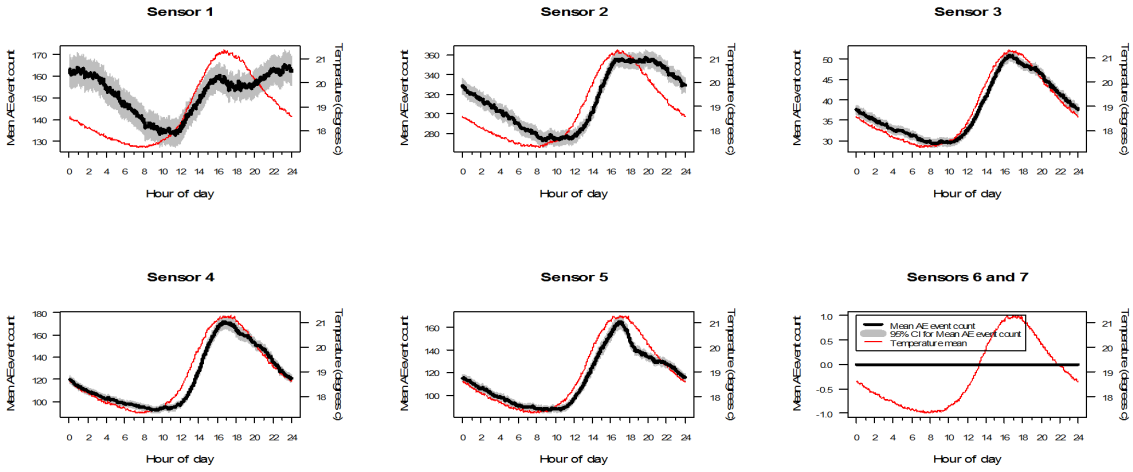
All logs, AE and temperature equipment were stored in a small wooden building at the University of California Richmond Field Station in Richmond, CA. The building had five windows for natural light. There was no air conditioning, heating, or insulation in the building. The averages for AE activity, temperature, and relative humidity were plotted for each sensor per hour per day for active and inactive logs. The linear association of AE activity and temperature per hour per day was also determined and plotted.

Within an average 24-hour day, AE activity was lowest during the morning, increased in the afternoon, peaked in late afternoon (6 pm), and then declined until mid-morning. For one of the logs (#1), a second peak of AE activity was recorded late into the evening at midnight. Temperature was significantly correlated with the rise and fall in AE activity; warmer temperatures were associated with increasing activity. Relative humidity was not statistically correlated with AE activity. Seasonally, AE activity (i.e. feeding activity) was highest during the warmer spring and summer months. 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.

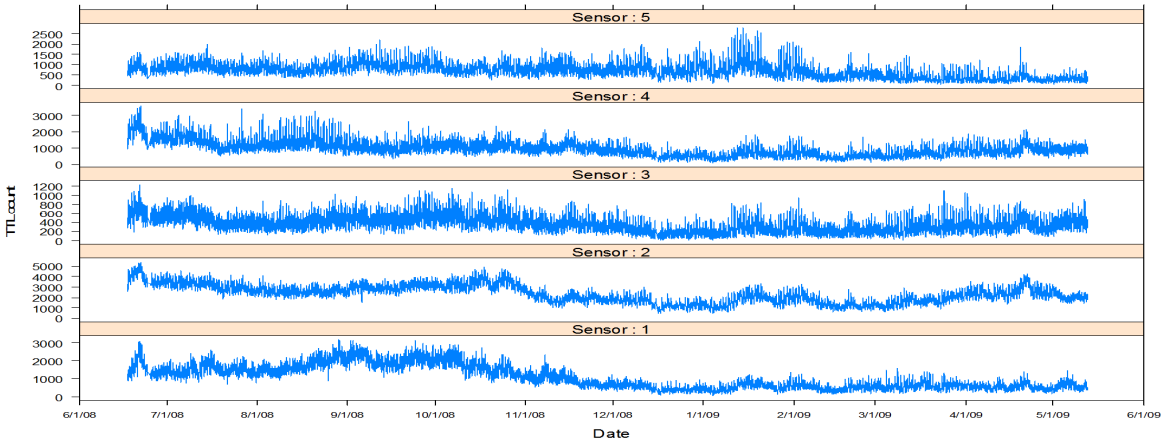
Knowledge of optimal times for drywood termite feeding will be important for evaluating termite inspections. Traditional inspections are based on visual searches for damaged wood or pellets. The data from this study suggest AE readings for active colonies could be enhance by heating the wood to at least 25^{o} C prior to inspection to stimulate feeding, even in winter. Understanding the underlying mechanism that controls the cyclic pattern will require additional studies that include the exclusion of natural light, running additional tests with naturally infested logs at constant temperature and humidity,

and the modification of the AE system collection hardware and software to separate locomotion and communication AE activity from feeding AE activity.

A practical application of this research should result in improved inspections by knowing the times of the day and year when drywood termites are most active for pre- and post-treatment evaluations of remedial treatments.



The mean hourly AE event count for each sensor (1-5) that occurred during the twenty-hour diurnal cycle. The heavy dark line is the mean AE event count. The red line is the temperature trace during the same 24 hour diurnal cycle measured in centigrade (ºC).



The seasonal mean hourly AE ring down count (TTL) for each sensor (1-5) that occurred from June 2008 to May 2009.

Conclusions

During the last three years, our laboratory has had access to, and used, some of the most sophisticated termite detection equipment and technology commercially available and beyond. We have produced results that have pushed the boundaries forward on our understanding of drywood termites, their biology, and ecology. Locating drywood termites and their treatment has always been challenging, and with the ushering in of the new decade, the industry has the additional challenges of continuing education on IPM and heightened awareness of water and air quality. How all these challenges are met by

the industry are complex. However, we are optimistic that all challenges will be met. We are prepared and willing to execute bold new investigations that, along with the industry, continue to insure that consumer protection is paramount.