

PROCEEDINGS OF THE 2000 NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

MAY 14-16, 2000

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Close Encounters with Florida's Introduced Urban Pest Fauna

Moderator

**John L. Capinera, Department of Entomology and Nematology
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ALIEN INVADERS: IS IT REALLY A BIG DEAL?

John L. Capinera

**Professor and Chairman, Department of Entomology and Nematology,
University of Florida, Gainesville, FL**

The nation is increasingly sensitized to the threat posed by alien pest organisms that have established, or threaten to establish, damaging populations in the United States. Zebra mussel, Asian longhorn beetle, Africanized bee, and *Melaleuca* trees are just some of the high-profile pests that have been introduced accidentally and have caused concern. Florida, in particular, seems to have an alarmingly high rate of invasion and establishment. Is this just media hype or are we under attack? Are such introductions isolated incidents or are they symptomatic of an inherent problem in our regulatory environment? Are the threats and consequences substantial, or false perception? What does this mean to the urban pest management industry?

THE HISTORY AND STATUS OF NON-ENDEMIC TERMITES IN FLORIDA

Rudolf H. Scheffrahn

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Florida, because of its climate and geographic location, is inhabited by more exotic termite species than in any other state. Of the 19 termite species recorded from Florida, five were introduced by recent human activity. All five are pest species and include the drywood termites *Cryptotermes brevis* (Walker) and *Incisitermes minor* (Hagen), and the subterranean species *Coptotermes formosanus* Shiraki, *Co. havilandi* Holmgren, and *Heterotermes* sp. Of these five, *Cr. brevis* and *Co. formosanus* are the most widely distributed exotic termites in Florida and account for about 20 percent of the economic losses attributed to termites in the state. *Incisitermes minor* has been collected across much of Florida, but remains a rare pest. *Heterotermes* sp. was discovered in 1995 in a Miami neighborhood where it remains at present. *Coptotermes havilandi*, found in Miami in 1996, was discovered in Key West in 1999. These latter two species were probably introduced from the West Indies via shipboard infestations and

likely will not tolerate cooler climates. Their populations, however, are expected to flourish in tropical south Florida. In the coming years, exotic introductions into Florida are most likely to originate from the West Indies and other Neotropical localities and might include other species in the above-mentioned genera as well as in the genus *Nasutitermes*. Of the 14 endemic species in Florida, nine are shared with the Bahamas or Cuba, six are shared with other southeastern states, and one, *Amitermes floridensis* Scheffrahn, Su, and Mangold, is known only from Florida. *Reticulitermes flavipes* (Kollar) is the only Florida endemic that appears to have been introduced elsewhere--to Grand Bahama Island.

EXOTIC PEST ANTS IN FLORIDA

David F. Williams

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In the next 5 years, half of the world's 6 billion plus inhabitants will be living in cities and more than 80% of the population growth during this time will occur in urban areas. The world's population is quickly becoming urbanized and Florida is a good example of this. In 2000, Florida's population grew to 15 million and from 1997 to 1998 over 4,592 people per week were becoming new residents of the state with the large majority residing in urban areas. A 1992 study in the United States indicated that ants were the number one annoyance insect pests in households. This trend should continue into the future with an even greater impact of undesirable ants on the urban environment. Ants can cause numerous problems in Florida's urban environment. Their mere presence in people's homes causes annoyance and undue stress. They can introduce contamination and disease by spreading pathogens and some ant species such as fire ants inflict painful stings that can be life-threatening to hypersensitive individuals. Some ants cause damage to wooden structures, roofs, and electrical equipment. In addition, the detrimental impact of exotic ants on our native fauna and flora is increasing at an alarming rate which if continued, will bring some of these natives to an endangered level. The increase in problems can be related to the movement of pest ants around the world through international commerce, the use of new pest control practices for other urban pests, and a shift in dominant ant species due to urbanization. Future issues that we will certainly face will be to find answers to questions in basic research and behavior which will lead to new ideas for control. For example, we need to develop baits that work against multiple pest ant species, especially those that occur in dwellings, while at the same time develop species-specific ant baits for use against those widespread outdoor pest ants such as the imported fire ant. The development of biological control and other methods having less negative impact on the environment should be a priority. Finally, we still have many questions on foraging behavior, nutrition, pheromonal influences, genetics, mode of action of active ingredients, and several other areas that need answers. Exotic ants will continue to be introduced into Florida and some will become urban pests. There are more than 9,500 species of ants in the world and approximately 700 in the United States. Florida has about 200 ant species with approximately 20 species in the following genera: *Camponotus*, *Linepithema*, *Monomorium*, *Paratrechina*, *Pheidole*, *Solenopsis*, *Tapinoma*, *Wasmannia*, and *Technomyrmex* causing problems in the urban arena. Some of the exotic pest ant species in

Florida are imported fire ants, *Solenopsis invicta*, Argentine ants, *Linepithema humile*, bigheaded ants, *Pheidole megacephala*, Pharoah ants, *Monomorium pharaonis*, ghost ants, *Tapinoma melanocephalum*, crazy ants, *Paratrechina longicornis*, white-footed ants, *Technomyrmex albipes*, and little fire ants, *Wasmannia auropunctata*.

HUDDLED MASSES YEARNING TO BE FREE: THE COCKROACH IMMIGRANT EXPERIENCE

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Sixty-eight species of cockroaches are known from the continental United States, 41% (28 species) of which have been introduced since the European colonization. There are 44 species known from Florida, 48% of which are immigrants. These proportions are unusually high compared to most other insect groups. The large number of immigrant species is related to biological characteristics of cockroaches that make them amenable to transport, but also reflects the long, intimate, and involuntary associations between humans and cockroaches. Cockroaches are easily transported because of a strong harborage requirement, which may be some human artifact, their cryptic behavior, and a resistant egg stage (ootheca). Ironically, once introduced they are often slow to disperse.

It is convenient to recognize 3 categories of human-cockroach relationships. Domestic species such as the German cockroach, *Blattella germanica*, are able to reproduce and maintain populations entirely within human structures. Peridomestic species are those found in the near vicinity of structures and in highly altered urban environments. The third group consists of those that are found in relatively undisturbed natural communities. These categories are not mutually exclusive. None of the 40 native species in North America are domestic species. While all can be found in natural communities, several can become abundant in the peridomestic environment, such as the Florida woods roach, *Eurycotis floridana*. Of the 28 introduced species, 23% are truly domestic, while 51% appear to be restricted to disturbed peridomestic environments. 26% have successfully become naturalized in natural environments, as well as in peridomestic environments. No exotic species is known only from natural environments.

Most domestic species were introduced prior to 1900. Most of the peridomestic exotics have been introduced in this century at what appears to be an accelerating rate. This reflects speed of transportation and trade patterns. Up until the end of the 19th century, most successful cockroach immigrants were in fact domestic species, given that a prolonged sea voyage was a requirement. Most introductions were between ports. Many of these species are tropical species originating in Africa, the Middle East, and southeastern Asia which were already ship-borne inhabitants prior to their introduction in North America. As the speed of transport has increased, as well as commercial and military traffic from Latin America and the Far East, many species have been introduced from interior regions of their continent of origin. Most of these are peridomestic

species. Despite centuries of shipping originating in Europe bound for North American ports, the 3 European natives (peridomestic / natural habitats) were not detected in the U.S. until after the Second World War.

Termites
Commodore Ballroom

Co-moderators

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**AFLP DNA FINGERPRINT: A NOVEL PCR-BASED TECHNOLOGY FOR STUDYING
GENETIC RELATIONSHIPS IN SUBTERRANEAN TERMITES**

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It is imperative that we understand subterranean termite population genetic relationships because human impact on these termite societies will increase as urbanization, and the commercial traffic it promotes, continues to change land use patterns. Recently we published mitochondrial DNA (mtDNA) sequence data that questioned the monogyne colony structure, accepted morphometric species designations and suggested that termite populations move between stationary feeding sites with greater frequency than previously reported. But a mtDNA marker is limited by its maternal inheritance. A nuclear DNA (nuDNA) marker would therefore expand our testing base and experimental options. Sequencing a nuDNA gene would limit the data set to a single locus. The novel PCR-based AFLP fingerprint technology, however, is an automated, non-radioactive method, capable of generating 10-50 times more informative polymorphic loci per reaction than restriction fragment length polymorphism (RFLP), or simple sequence repeats (SSRs). AFLP fingerprints are more cost-effective than RFLPs, random amplified length polymorphisms (RAPD), or SSRs. Furthermore, no prior knowledge of the genome is necessary, as with SSRs, which eliminate upfront characterization cost. We therefore set up a study to determine the

discriminating power of AFLP fingerprints. Termites were collected from populations in different soil provinces. Restriction fragments of genomic DNA were generated for each collection with 6-base and 4-base endonucleases. Oligonucleotide adaptors of known sequence were ligated to each end of the fragments. A preselective amplification, which resulted in a 16-fold reduction of the complexity of the fragment mixture, was then performed. Selective amplification with fluorescent-dye-labeled primers followed. Labeled fragments were resolved by gel electrophoresis on the ABI 377 Automated DNA Sequencer. AFLP fingerprints were not only discriminating between species, populations and individuals, but they were reproducible between runs. These automated DNA fingerprints are therefore applicable to the study of subterranean termite colony structure, gene flow, species identification, and molecular evolution. Furthermore, a generally accessible database of AFLP characterized populations could form the foundation for building a true population management program for subterranean termites.

MARK RELEASE RECAPTURE FIELD DATA COMBINED WITH MITOCHONDRIAL
GENOTYPES INDICATE A DYNAMIC SOCIAL STRUCTURE FOR *RETICULITERMES*
SPP. (ISOPTERA: RHINOTERMITIDAE)

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Serious scientific scrutiny is beginning to be applied to the study of *Reticulitermes* social structure. Clement (1986. *Sociobiology* 11:311-23) examined the relationship(s) of termites collected from woody debris in specified areas using allozyme markers and behavioral bioassay. He concluded that certain European *Reticulitermes* live in "closed societies" where there is no sharing of resources and others lived in "open societies" that freely shared feeding sites on a seasonal basis. The majority of the work with *Reticulitermes* in the U.S. has relied on indirect measures of relatedness including mark release recapture (MRR) techniques. Recently, Haverty et al. (1999 *Ann. Entomol. Soc. Am.* 92: 269-77) used the combination of chemo-phenotypic profiles and agonism bioassay with termites collected from researcher-maintained termite inspection ports to determine relationships without MRR. Thorne et al. 1999 (*Ethology, Ecol. & Evol.* 11:149-169) examined published allozyme data from termites collected from woody debris to discuss concepts involving termite reproductive options centered around a monogyne colony structure.

We examined sequence data from a mitochondrial gene in a recent experiment designed to survey the maternal lineages (ML) of termites collected from a series of 6 separate inspection ports located along the wall of a single building. MRR was conducted in 1996 under a single-release protocol. Slightly over 2,000 Nile Blue-A marked *R. hageni* termites were released into one of the six inspection ports. Over the next 7 months, marked termites were collected from only three of the four inspection ports where *R. hageni* were collected in 1996-7. In 1998, one year after the MRR study, *R. hageni* termites were collected from two additional, nearby inspection ports that had been visited by *R. flavipes* since 1995. We assumed, based on previous MRR work and past experience, that all 6 inspection ports in 1998 represented a single *R. hageni*

colony. The ML data from those 6 inspection ports between 1997-1999 indicated that the termites visiting these locations represented four distinct MLs. All four MLs displayed site fidelity to a particular inspection port for the entire length of the study. The one exception involved a change of species - back to *R. flavipes*. Two of the inspection ports (where most of the marked termites were consistently collected in 1996-7) provided the same ML as did one of the two inspection ports that changed from *R. flavipes* to *R. hageni* in 1998. This justified inclusion of those ports in our 'colony' designation. However, all other inspection ports (including one where marked termites were recovered during the MRR study) had a different ML than the inspection port where the release was conducted. These data suggest that *Reticulitermes* display a social organization that is dynamic and opportunistic. We therefore conclude that studies of *Reticulitermes* colony associations must be multidisciplinary efforts that include a timeline of information on movement of termites between feeding sites and consider the possibility of a polydomous colony structure that is polygynous and formed by pleometrosis or fusion.

FRACTAL ANALYSIS OF SUBTERRANEAN TERMITE TUNNEL SYSTEMS

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Fractal analysis was used to describe the morphology of two subterranean termite tunnel systems, and to determine if termites' fractal dimension (D) is altered by the presence of wood. *Coptotermes formosanus* and *Reticulitermes flavipes* were introduced into the central chamber (35 cm away from four experimental chambers (EC)) of experimental arenas for about two weeks, and tunnel development was recorded daily on a transparent sheet of paper. The results indicated that these underground tunnels have a fractal structure (D: 1.225 - 1.297) within a scale range measuring (1.3-10.1 cm). Regardless of the presence of wood, D was highest before reaching any EC, indicating that more branching occurred at this time. After reaching an EC, *R. flavipes* built more tunnels than *C. formosanus*, regardless of the presence of wood. This type of analysis shows promise for use as a simple metric to evaluate changes on the tunnel development under different environmental conditions and to compare individual rates of resource utilization.

TUNNELING CONTRIBUTIONS AND INTERACTIONS OF DIFFERENT CASTES OF SUBTERRANEAN TERMITES (ISOPTERA: RHINOTERMITIDE: *RETICULITERMES*) IN LABORATORY BIOASSAYS

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The individual caste contribution of soldiers and brachypterous nymphs and the effect of different proportions of each caste on psuedergate tunneling in laboratory bioassays was evaluated. Brachypterous nymphs of *Reticulitermes virginicus* (Banks) demonstrated a small degree of tunneling. Brachypterous nymphs of *Reticulitermes flavipes* (Kollar) did not tunnel. The presence of brachypterous nymphs in both species decreased the tunneling performed by psuedergates in soil bioassays. Soldiers were not capable of tunneling. The presence of soldiers did not decrease the amount of tunneling by psuedergates in bioassays.

TRAIL-FOLLOWING IN TWO TERMITES SPECIES (TERMITIDAE: NASUTITERMITINAE): INTRASPECIFIC BEHAVIOR

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Nasutitermes corniger and *N. ephratae* are neotropical termite species that coexist in the same habitat. A circular shaped bioassay configuration was used to confirm the biological activity of the sternal gland extract of soldier and worker castes of both species. The activity generated by these artificial trails were significantly more active than that evoked by the thoracic extract for both castes of both species. An Y-shaped configuration was used to test orientation effects with soldier and worker castes of the same species. For *N. corniger*, soldier responses to their own sternal gland extract was significantly higher than the worker's extract. The worker's response was the same over the soldier's sternal gland extract. A GC comparison showed differences between both castes. The soldier of *N. ephratae* response to its own sternal gland extract was significantly lower than to the worker sternal gland extract. The worker of this species responded significantly higher to its own caste. A GC comparison showed differences between the compounds from sternal gland extract of both castes. In conclusion, we report here that caste differences exist in the trail following response of both species and these differences can be explained, partially, by differences in chemical composition of the trail-pheromone secretion between castes.

TERMITES AND PUBLIC ATTITUDES

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A telephone survey was conducted to probe people's attitudes and understanding about termites and their control. The survey was conducted 22 June through 16 July, 1999 in collaboration with the University of Kentucky Survey Research Center in Lexington. Households throughout

Kentucky were selected using computer-assisted random-digit dialing, and phone calls were made until 674 interviews were completed (53 percent female, 47 percent male; margin of error +/- 3.8 percent.) The findings indicate that consumers are very concerned about termites but know little about them. Most respondents believed that termites can cause serious structural damage to a house in a shorter period of time than they normally do. Consumer expectations run high for complete detection and eradication of the termite problem, and failure to do so will cause householders to hold the pest control operator responsible for retreatment and repair of damages, irrespective of when they occurred. The survey also showed that people are very concerned about the application of termite control chemicals inside their home, and that the majority prefer baits over liquid "barrier" treatments. Some opinions were influenced by the age, gender, education and income level of the respondent.

REGULATORY PERSPECTIVES AND CHALLENGES FOR TERMITE BAIT PRODUCT REGISTRATION

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Advances in termite control application methods, termiticide chemical discovery, and implementation of new technology will bring future regulatory challenges. This talk will describe how EPA will address these challenges. The discussion will focus on the new Pesticide Registration Notice and draft guideline for testing, labeling and registering termite bait products.

THE CONTROL OF SUBTERRANEAN TERMITES IN RESIDENTIAL STRUCTURES USING FIRSTLINE® TERMITE BAIT

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Twelve residential structures located in Florida were selected for the installation of monitors and/or FirstLine® Termite Baits. Although most of the structures had previously received one or more liquid termiticide treatments, the structures continued to have active termite infestations. Following the use of monitors and FirstLine baits, termite activity ceased both inside and in monitors outside the structures. FirstLine Termite Baits, used alone, provided protection against termite infestation to all of the structures. Monitors and baits must be inspected on a regular basis for the long term based upon the reality of future termite infestation.

RESPONSE OF *RETICULITERMES* SPP. (ISOPTERA: RHINOTERMITIDAE) COLONIES IN NORTHERN CALIFORNIA TO BAITING WITH HEXAFLUMURON USING THE SENTRICON™ TERMITE COLONY ELIMINATION SYSTEM

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Using a residential site in Novato, CA, a colony of *Reticulitermes* was baited using the Sentricon™ Termite Colony Elimination System. One colony occupying 7 monitoring stations, consisting of approximately 147,000 *Reticulitermes* foragers, was baited; 60 days later termites were absent from all monitoring stations which remained unoccupied for at least 18 months. Foraging *Reticulitermes* appeared in one of the 7 monitoring stations 18 months after baiting. Amongst these same 7 stations two more monitoring stations became occupied by termites, one 24 months after baiting and a third approximately 36 months after baiting. Utilizing cuticular hydrocarbon analyses and agonistic behavior studies, we determined that the termites occupying these monitoring stations were from 3 different colonies; none were members of the original colony eliminated by baiting.

EVALUATION OF COMMERCIAL BAITING SYSTEMS FOR PEST MANAGEMENT OF THE EASTERN SUBTERRANEAN TERMITE, *RETICULITERMES FLAVIPES* (KOLLAR) (ISOPTERA: RHINOTERMITIDAE)

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Commercially available subterranean termite baiting systems are currently being evaluated for efficacy in a termite management program. Termite baiting systems evaluated include Sentricon (Dow AgroSciences), FirstLine (FMC Corp.), and Terminate (United Industries Corp.). The study is being conducted in five urban areas in Texas (Austin, Beaumont, Corpus Christi, Houston, and San Antonio), utilizing five structures for each of the termite bait systems in each city, for a total of 75 structures. All structures qualified for the study with active infestations of subterranean termites, *Reticulitermes flavipes* (Kollar). Cooperating pest control operators (PCOs) authorized to use the termite bait systems installed and continue to monitor and report observations of termite activity. Data from the first twelve (12) or more months of the two-year project reveal mean numbers of days for first feeding on monitors, in monitored systems, or active ingredient bait tubes in non-monitored systems, with an extremely wide range. All three baiting systems have termite activity in at least one study site within twenty-five (25) days. All

three baiting systems also have study sites without any termite activity for an extended period of time; the Terminate system has one or more sites without any termite activity for over 300 days and the Sentricon system and the FirstLine system have one or more study sites that exhibit over 500 days without any termite activity. There is also a wide range in the number of alternating episodes of monitoring and feeding of the bait stations; some study sites have only the lengthy monitoring period episode, described above, while others exhibit nine (9) alternating episodes of monitoring and feeding. Observations of several of the study sites reveal constant feeding activity on active ingredient tubes for an extended period of time with no cessation, and hence, no claims of control. Five (5) study sites [Corpus Christi] utilizing the Terminate system exhibit this constant feeding activity for over 400 days, to date, with no cessation. Four study sites [Beaumont] utilizing the Sentricon system exhibit this constant feeding activity for periods of time ranging from 125 to 250 days. Any claims of termite control or management this first year for the study sites will be confirmed or refuted by the presence or absence of new shelter tubes and/or reproductives this swarming season.

SEASONAL FEEDING DEPTH OF THE EASTERN SUBTERRANEAN TERMITE,
RETICULITERMES FLAVIPES (KOLLAR) (ISOPTERA: RHINOTERMITIDAE)

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Subterranean termites are important structural pests that cause damage throughout North America. Among North American subterranean termites, members of the genus *Reticulitermes* are the most widespread. These termites construct diffuse gallery systems within the soil profile as they locate and feed on suitable food resources. These gallery systems can be quite extensive due to the three-dimensional nature of the subterranean habitat. This three-dimensional environment also allows for the possibility of vertical migration in response to seasonal changes in soil environmental factors. In this study, we examined the depth at which *Reticulitermes flavipes* (Kollar) colonies feed within the soil profile. Relationships between seasonal feeding depth, degree of feeding activity and soil environmental factors are explored. Eight field sites were selected based on similarity of habitat and evidence of recent subterranean termite activity. At each location, a single, active bucket-block trap was chosen to monitor seasonal feeding depth. Eight, 3/4 inch white pine dowels were driven into the soil profile around the bucket-block trap at each location. Each wooden dowel was marked with a line at the soil surface and a mark on the side of the dowel nearest the trap. At weekly intervals, all wooden dowels were carefully removed and examined for feeding marks. The depth and size of feeding marks were recorded and feeding marks were colored to distinguish previous feeding activity from new feeding activity during subsequent inspections. The dowels were then placed back into the soil. Weekly sampling covered one complete yearly cycle. Mean feeding depth varied seasonally between 6.3 and 30.9 cm. Analysis of variance revealed that feeding marks occurred at significantly greater depths during summer than during other seasons of the year. Regression analysis showed that feeding depth was positively correlated with soil temperature. This

suggests that subterranean termites migrate vertically within the soil profile and feed at depths where soil environmental conditions are most favorable. Mean feeding activity also varied seasonally and ranged between 1.0 and 3.1 cm. Feeding activity was highest during the summer and varied with mean soil temperature. Regression analysis revealed a strong positive correlation between feeding activity and mean soil temperature. Soil temperature appears to be an important variable influencing the feeding activity of *Reticulitermes flavipes*. Seasonal changes in the soil thermocline and the relationships between mean soil temperature, feeding depth, and feeding activity will be discussed.

EFFICACY OF RECRUIT® II TERMITE BAIT CONTAINING 0.5% HEXAFLUMURON AGAINST *COPTOTERMES CURVIGNATHUS* HOLMGREN AND *SCHEDORHINOTERMES JAVANICUS* KEMNER IN MALAYSIA AND INDONESIA

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The efficacy of Recruit® II bait containing 0.5% hexaflumuron (a component of the Sentricon® Termite Colony Elimination System, Dow AgroSciences LLC) against two colonies each of *Coptotermes curvignathus* Holmgren and *Schedorhinotermes javanicus* Kemner in Malaysia and Indonesia is described. Wooden survey stakes were installed around the perimeter of termite-infested structures and stakes that were subsequently attacked by termites were converted into monitoring stations (MS) consisting of plastic bucket traps containing wooden blocks. Prior to introduction of Recruit® II bait, estimations of colony foraging territory and population size were made using Triple-Mark Recapture methodology. In addition, wood consumption rates were determined. One colony of *C. curvignathus* (designated A), located at Universiti Sains Malaysia (USM) in northern Malaysia and a second *C. curvignathus* colony (designated B) located at a housing complex in Jakarta, Indonesia were characterized. Colony A had an estimated population size of 37,700 foraging workers and a foraging territory of 16.5 sq. meters. The mean wood consumption rate per MS ranged from 7.1-7.9 g wood consumed/station/day. Approximately 125 grams of Recruit® II bait was required for colony elimination, representing 0.63 mg active ingredient (ai) of hexaflumuron. The elapsed time from baiting to colony elimination was 68 days. The estimated population size of colony B in Jakarta was very large, and consisted of 1.7 million foraging workers with a foraging territory of 480 sq. meters. Prior to baiting, the average wood consumption rate ranged from 5.6-7.2 g wood/station/day. The colony was eliminated after 65 days of feeding on Recruit® II bait, with a total bait consumption of 184 grams (approximately 0.92 g ai of hexaflumuron). Two colonies of *S. javanicus* (C and D) located at Bogor, Indonesia (approximately 60 km from Jakarta) were characterized as described earlier. Estimated population size of Colony C was 613,588 workers with a foraging territory of 100 sq. meters. The wood consumption rate prior to baiting ranged from 0.95-2.53 g wood/station/day. The colony was eliminated after 110 days consumption and consumed approximately 132 grams of Recruit® II bait (0.66 g ai hexaflumuron). Colony D consisted of a foraging population of approximately 470,345 workers and a foraging territory of 224 sq. meters.

The wood consumption rate prior to baiting ranged from 1.23-2.24 g wood/station/day. The colony was eliminated after 160 days and consumed 639 grams of Recruit® II bait (3.2 g ai hexaflumuron). The research results described herein demonstrate the efficacy of Recruit® II termite bait to eliminate colonies of these two economically important subterranean termite species in southeast Asia.

POPULATION CONTROL OF SUBTERRANEAN TERMITE, *HETEROTERMES* SP., IN FORT CHRISTIANSVAERN, CHRISTIANSTED, ST. CROIX, US VIRGIN ISLANDS

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Fort Christiansvaern was built by the Danes in 1749 as an army garrison and police station. The structure was made of mostly brick and timber framing with masonry infill and plaster walls. Termite infestations (both drywood and subterranean species) have been recorded by the Park Service personnel since the 1980s, but these infestations probably originated much earlier. A termite survey conducted in 1995 - 1996 indicated multiple populations (colonies) of subterranean termite, *Heterotermes* sp., in wood posts or timber framing imbedded in masonry walls, and other wooden components of this historic fortress. Baits containing hexaflumuron were applied on active infestations of *Heterotermes* sp. as they were detected in 1996 - 1999. By the summer of 1999, all detectable populations found in the main building of the fortress were eliminated.

BAITING *HETEROTERMES AUREUS* (ISOPTERA: RHINOTERMITIDAE) IN TWO URBAN COMMUNITIES IN ARIZONA

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A study was initiated in 1999 to determine the effectiveness of termite baiting systems in controlling the desert subterranean termite *Heterotermes aureus* (Snyder) in Tucson and Phoenix, AZ. In this two year study, 15 curative and 15 preventative residential sites were established. Curative sites had termites within the structure, while preventative sites had evidence of termites within the area, but not within the structure. A total of 952 stations are being monitored monthly, 459 are at the preventative sites and 493 at the curative sites. Mean number of days to initial baiting for preventative sites was 109. Preventative sites in Phoenix required twice the number of days 180 to initial baiting compared to Tucson at 85 days. Mean initial baiting at the curative sites was 97 days, with Phoenix needing a few more days than Tucson, 102 vs. 94 respectively. Number of stations baited at the curative sites is over twice that of the preventative, 65 vs. 28 respectively. Percent auxiliary stations baited at the curative sites was nearly 4 times that of the preventative sites. Other data being collected includes % monitors consumed, % bait consumed, mold, termite number/species present and other invaders.

CONCENTRATION AS RELATED TO DEGRADATION RATE OF SELECTED SOIL TERMITICIDES AGAINST TWO SPECIES OF SUBTERRANEAN TERMITES

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The western subterranean termite, *Reticulitermes hesperus* Banks, and the desert subterranean termite, *Heterotermes aureus* (Snyder), are significant structural pests. They are geographically distinct, thought to be kept separate by environment. Differences in thermal tolerance, ability to regulate body water, and susceptibility to soil pathogens may be causative factors responsible for their distinct distribution. *R. hesperus* is the most economically important termite in California, while *H. aureus* is the most important in Arizona. A similar species, *R. tibialis* Banks, is reportedly sympatric with *R. hesperus*, but prefers more sunny, drier locations. Bait sometimes provides good control of subterranean termites but failures are common, presumably related to bait placement and to the search and feeding patterns of the termites. Preventive and remedial control of these termites often involves application of liquid termiticide, with varying degrees of success and longevity. This study incorporated tunneling and contact bioassays and chemical analyses to determine the minimum effective concentration (ppm) of bifenthrin (Talstar), deltamethrin (DeltaGard) and permethrin (Dragnet) in soil against *R. hesperus* and *H. aureus*. Knockdown 5d after 5-min contact correlated directly with inhibition of tunneling, similar ppm that provided 100% KD also providing complete inhibition of tunneling. Minimum effective rates with *R. hesperus* ranged from about 2 ppm for deltamethrin to >40 ppm for permethrin. Interestingly, higher ppm was needed for similar results with *H. aureus*, even though it has a smaller body size. Tests were not made with *R. tibialis* because sufficient numbers could not be collected for study. Because they are of similar size, it is presumed their response to insecticide would be intermediate between *R. hesperus* and *H. aureus*. Based on ppm, the effective longevity of termiticide is predicted from the profile of termiticide degradation shown by annual chemical analyses at 20 homes. Longevity of effectiveness is apparently predictable. Bioassays suggest that recommended label rates of application in California (often >325 ppm) are likely to prevent termite attack for approximately 6 years, by which time ppm diminishes to level at which it is no longer effective.

THE EFFECTS OF CHLORINE, FLUORINE AND PH ON THE DEGRADATION OF THE TERMITICIDES CHLORPYRIFOS AND PERMETHRIN

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Chlorpyrifos @ 1.0% and permethrin @ 0.5% were added to water containing either 1, 2 or 3 ppm chlorine or 0.3, 0.7 or 1.0 ppm fluorine. After 1, 4 and 24 hours samples of the emulsions were analyzed by gas chromatography and the remaining concentration of termiticide was

compared to the initial concentration. Neither chlorine nor fluorine at any concentration nor a combination of 3 ppm chlorine and 1 ppm fluorine had any effect on the degradation of chlorpyrifos or permethrin. Chlorpyrifos @ 1.0% and permethrin @ 0.5% were added to water of either pH 5, pH 6, pH 7, or pH 8. After 1, 4 and 24 hours samples of the emulsions were analyzed by gas chromatography and the remaining concentration of termiticide was compared to the initial concentration. The only increase in degradation occurred in the case of chlorpyrifos in water of pH 5.

TERMITICIDE LONGEVITY IN HAWAII

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Hawaii represents a rigorous environment for soil insecticides applied to control the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. Year-round warm temperatures, diverse soil types, and rainfall from 15 to over 200 inches per year are challenges faced by pest control operators in Hawaii when selecting and applying termiticides. Almost 20 years ago, six field sites for evaluation of termiticide longevity were established on the islands of Oahu, Kauai, Maui, and Hawaii. These sites offer a wide range of rainfall conditions, and termiticide treatments to screened sand and soil at each location, with each treatment covered by a 2.5 by 2.5-foot concrete slab, simulate soil pretreatment for termite control. Each year, soil cores are removed from beneath each treatment (concrete slab) at each location, and returned to our laboratory. We measure termite mortality during a 4-day laboratory bioassay with 150 *C. formosanus* (135 workers + 15 soldiers), and the distance tunneled by termites through a 4-cm core in the bioassay tube. In the case of the nonrepellent and relatively slower acting insecticides such as imidacloprid and fipronil, termites still alive at the end of the 4-day exposure period are retained for an additional 10 days to evaluate delayed mortality. In the current paper we report results from a 7-year evaluation of organophosphate and pyrethroid insecticides, and shorter term but multi-year evaluations of the newer nonrepellent termiticides.

FIPRONIL AS A SOIL APPLIED TERMITICIDE IN TEXAS

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In the Austin, Texas area, 13 structures with visible infestations of subterranean termites of the genus *Reticulitermes* were treated with 4 gallons of 0.06% fipronil per 10 linear feet around the foundation and every plumbing penetration through the slab was treated with the same rate of fipronil. No subterranean termite infestations were observed in the structures during inspections at 6, 12 and 18 months post-treatment. Soil treated with fipronil @0.06% was analyzed at 9 months post-treatment and found to contain sufficient fipronil to control subterranean termite

infestations. Bioassays conducted using several soils indicate that concentrations of ≥ 2 PPM caused 100% mortality in subterranean termites exposed to these soils for 5 days.

DYE RETENTION AND TOXICITY, FORAGING MOVEMENT, AND CASTE DISTRIBUTION OF THE DRYWOOD TERMITE, *INCISITERMES SNYDERI* (LIGHT)

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Twelve histological dyes were evaluated for retention time and toxicity in the drywood termite *Incisitermes snyderi* (Light). Several dyes showed prolonged retention time and low toxicity. Although Solvent Blue 35 had the greatest retention (97.4% at 2% conc.) and the lowest toxicity (5% at 2% conc.), it was readily lost by trophallaxis and excretion. After 28 days, Neutral Red showed a higher toxicity (21.25%) and lower retention (76.5%) at the 1% w/w on filter paper but was not transferred between colony members nor lost by excretion. Neutral Red at 1% was used to stain the termites extracted from six infested logs of Brazilian pepper, *Schinus terebinthifolius* Raddi. Log lengths ranged from 2.44-3.25 m. Stained termites were reintroduced into their respective logs to assimilate with nestmates. After 28 days, logs were cut into 10cm segments and these were dissected to remove all termites. Caste composition and dyed and undyed termites within the colony space were recorded in each segment. Foraging distances were measured from the segment of introduction of dyed termites to their points of recovery. Dyed termites were found up to 240cm away from their introduction point.

Examination of caste distribution showed that peak populations of colony members were found within 20cm of the soldiers and reproductives. Colony populations ranged from 169-2,178. Proportions of primary reproductives ranged from 0.06% - 0.30%, nymphs from 80% to 84.6%, larvae from 4.1% to 34.5%, and soldiers from 0.17% to 2.02%. No pseudergates, non-reproductive individuals that diverge from the imaginal line at a relatively late instar, were observed in these colonies. All immature workers had wing buds.

This study is the first to quantify foraging distance by individual drywood termites. These results suggest that slow-acting, transferable toxicants can be distributed colony-wide by foraging movements.

CYCLIC CO₂ RELEASE AND WATER LOSS BY *INCISITERMES MINOR* (HAGEN) AT VARIOUS TEMPERATURES

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Water loss and CO₂ release of *Incisitermes minor* (Hagen) pseudergates were recorded in real-time using flow-through respirometry. Traces were recorded over a temperature range of 20-40°C at 5°C intervals. Water loss tracked CO₂ release over time. Both cuticular and respiratory water loss rates were determined at all temperatures examined. Duration (min) and mass (mg) of respiratory and cuticular water loss events were recorded and used to calculate water efflux for *I. minor* pseudergates at each of the 5 experimental temperatures. Mean CO₂ release rates ($\mu\text{l hr}^{-1}$) were used to determine the effect of temperature and mass on *I. minor* pseudergate metabolic rate.

At 25°C, CO₂ cycling in *I. minor* pseudergates reduced water loss on a daily basis by 0.07 mg, a reduction of roughly 18% compared with estimated non-cyclic water loss rates. Under the dry, CO₂-free conditions of the respirometry chamber (at 100 ml min⁻¹ air flow; 25°C), *I. minor* pseudergates lose $\approx 23.5\%$ of their total body mass in 24 hr. Daily water efflux values at 25°C indicated that *I. minor* pseudergates lose only 4.7% of their daily water loss through respiration. Cuticular water loss accounted for 93.5% of *I. minor* pseudergates' daily water loss, and the remainder (1.8% at 25°C) is accounted for by fecal loss. Assuming an *I. minor* nest relative humidity of $\sim 25\%$, estimates of daily water influx at 25°C indicate that only 37.5% of the daily total water efflux is returned to *I. minor* pseudergates through the cuticle. These data could not be used to estimate daily respiratory influx, but the remaining 62.5% of daily water efflux unaccounted for by cuticular gain is unlikely to be due entirely to respiratory influx.

Daily water loss is affected by respiration pattern in *I. minor* pseudergates. Pseudergates exhibiting an acyclic respiration pattern (as CO₂ release) lost less water over 24 h at 30-40°C, than those exhibiting cyclic respiration patterns. These data do not support the hypothesis that cyclic respiration patterns are adaptive for reduction of respiratory water loss in *I. minor*.

EVALUATION OF *RETICULITERMES FLAVIPES* FEEDING RESPONSE TO THREE FUNGICIDES

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Feeding responses of *Reticulitermes flavipes* to three fungicides (chlorothalonil, methylparaben, and sorbic acid) were measured and recorded. Termites were allowed to feed for 144 hours on three treated and three untreated 15mm diameter cellulose based filter paper disks. The disks

were saturated separately with concentrations of 5.00, 0.50, and 0.05% of an aqueous suspension of chlorothalonil, and 0.001, 0.010, and 0.100 molar concentrations of methylparaben and sorbic acid in solution with acetone. Consumption of treated or untreated disks was measured using image analysis software. Significant feeding deterrence occurred for all three concentrations of chlorothalonil. No significant feeding deterrence occurred for methylparaben or sorbic acid at concentrations <0.1 molar.

POTENTIAL OF FUNGAL ATTRACTANTS/ARRESTANTS TO IMPROVE THE EFFICACY OF COMMERCIAL BAITS FOR CONTROL OF FORMOSAN AND EASTERN SUBTERRANEAN TERMITES

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Certain species of wood rot fungi, such as *Gloeophyllum trabeum*, elicit trail following behavior in the Formosan subterranean termite, *Coptotermes formosanus*, and in the eastern subterranean termite, *Reticulitermes flavipes*. Experiments were performed to test the responses of termites to *G. trabeum* and two other species of wood rot fungi, cultured on different substrates, to determine which species of fungi and which fungus-infested substrates elicited the greatest response from termites. For each experiment, termites were collected from two colonies of each termite species. Also, chemical analyses were performed to isolate and identify any compounds that affected termite behavior and to determine how differences in the substrate affected the production of compounds by the fungi. Experiments were also conducted to determine if compounds produced by the three species of fungi acted as attractants or arrestants. Based on these results, field experiments were conducted, using the most effective fungus-infested substrate, to determine if the presence of compounds produced by wood rot fungi increased the proportion of bait stations infested by termites.

A NUTRITIONALLY BASED BAIT MATRIX AS A TOOL TO CONTROL THE FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE)

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A novel bait matrix was developed based on the chemical composition of the wood species most preferred by the Formosan termite and the composition of its associated fungi. Laboratory studies show that *Coptotermes formosanus* significantly prefers the novel matrix over Southern yellow pine wood (*Pinus taeda*) and cardboard. Field studies showed that *C. formosanus* exploited the novel matrix 9 times more frequently than pine stakes. The use of chitin inhibitors with the novel matrix did not affect preference by the Formosan termite. Laboratory tests showed that 250 ppm of diflubenzuron, hexaflumuron, and EN001 incorporated in the matrix induced total mortality in colonies of 2,500 workers within 4 weeks in the presence of alternative food sources (pinewood

and cardboard). Field tests accomplished control in 2 households in the New Orleans area using 250 ppm of diflubenzuron in the novel matrix.

FOOD PREFERENCE AND NUTRITION OF THE FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE)

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The food preferences of *Coptotermes formosanus* were determined in two multiple-choice experiments. Twenty-four commercial wood species were tested in experiment 1. Experiment 2 consisted of 21 low preference wood choices. Consumption rates of birch wood (*Betula alleghaniensis*) were significantly higher than 23 other commercial wood species. Birch, Red gum (*Liquidambar styraciflua*), Parana pine (*Araucaria angustifolia*), sugar maple (*Acer saccharum*), pecan (*Carya illinoensis*), and red oak (*Quercus rubra*) were significantly more preferred than Southern yellow pine (*Pinus taeda*). Consumption rates of Bolivian rosewood (*Machaerium* sp.), Honduras rosewood (*Dalbergia stevensonii*), Indian rosewood (*D. latifolia*), Spanish cedar (*Cedrela odorata*), Mahogany (*Swietenia macrophylla*), Eastern red cedar (*Juniperus virginiana*), Alaskan yellow cedar (*Chamaecyparis nootkatensis*), Western red cedar sapwood (*Thuja plicata*), sinker cypress (*Taxodium distichum*), and sassafras (*Sassafras albidum*) were significantly lower than all other species tested. No consumption of Honduras rosewood was observed on 20 nests and 4 repetitions per nest.

The Future of Drywood Termite Management Commodore Ballroom

Organizer and Moderator
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CURRENT AND FUTURE PROSPECTS FOR DRYWOOD TERMITE (ISOPTERA: KALOTERMITIDAE) MANAGEMENT

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Drywood termites constitute a diverse and primitive family of about 500 wood-dwelling and one soil-inhabiting species (Krishna 1961). Less than one-tenth of these are either primary or occasional pests of sound, dry structural lumber and wooden furniture and occur in all tropical, subtropical, and some temperate regions. *Cryptotermes*, *Incisitermes*, and *Kaloterme*s contain the bulk of pest species worldwide (Harris 1971, Edwards and Mill 1986). Species requiring wood moisture greater than that provided by ambient relative humidity alone are referred to as dampwood termites (e.g. most *Neotermes* and *Gyptotermes* spp., many *Kaloterme*s spp., some *Incisitermes* and *Cryptotermes* spp. and all the Termopsidae). Dampwood species are often pests of structural lumber that is exposed to free water from rainfall or soil. The distinction between "drywoods" and "dampwoods" is often blurred by the abilities of some species to tolerate wide temporal deviations in wood moisture content.

Drywood termites account for a considerable portion of the over \$1 billion in damage and control costs attributed to termites in the U.S. (Su and Scheffrahn 1990) and worldwide losses are untold, but the bulk of damage likely exceeds that of the U.S. In 1987, the cost of fumigations for drywood termite control in southern Florida was conservatively estimated at \$30 million (Scheffrahn et al. 1988). In the city of Corpus Christi, Texas, drywood termites accounted for over \$2 million of the \$3.7 million in total termite losses during 1979 (Granovsky 1983). In 2000, Rust (unpublished observation) estimated the economic impact of drywood termites in California at \$250 million per annum. In line with Rust's assessment, I estimate that the current annual impact from drywood termites in the United States exceeds \$400 million and probably accounts for upwards of 20% of total termite losses nationally.

Cryptotermes brevis (Walker) is the most widely introduced and most important drywood termite pest worldwide (Gay 1967) however, its origin remains obscure (Scheffrahn et al. 2000). Other pestiferous *Cryptotermes* that have become established beyond their original range include the Indomalayan *C. cynocephalus* Light, *C. domesticus* (Haviland), and *C. dudleyi* Banks, and the African *C. havilandi* (Sjöstedt) (Gay 1967, Gay and Watson 1982). *Incisitermes minor* (Hagen), native to the southwestern United States, is now established in Florida (Scheffrahn et al. 1988), Louisiana (Messenger et al. 2000), Japan (Yamano 1998), and Hawaii (Scheffrahn et al. unpubl.) and has been collected in Texas (Howell et al. 1987), Georgia (Scheffrahn et al. 2001), and South Carolina (Hathorne et al. 2000). *Incisitermes snyderi* (Light) occurs in the southeastern U.S. while the more xeric-adapted *Marginitermes hubbardi* (Banks) is a structural pest in the southwestern U.S. deserts. *Kaloterme*s *flavicollis* F. is a pest of the Mediterranean region (Edwards and Mill 1986). Because infestations by kalotermitids are usually diagnosed on the basis of fecal pellets, damage, or wings, it is probable that many more species infest structures than are currently known. For example, *Tauritermes vitulus* Araujo and Fontes was described from collections in dry structural lumber in southern Brazil (Araujo and Fontes 1979). Distribution of the four major drywood termite pest species in the United States is given in Figure 1.

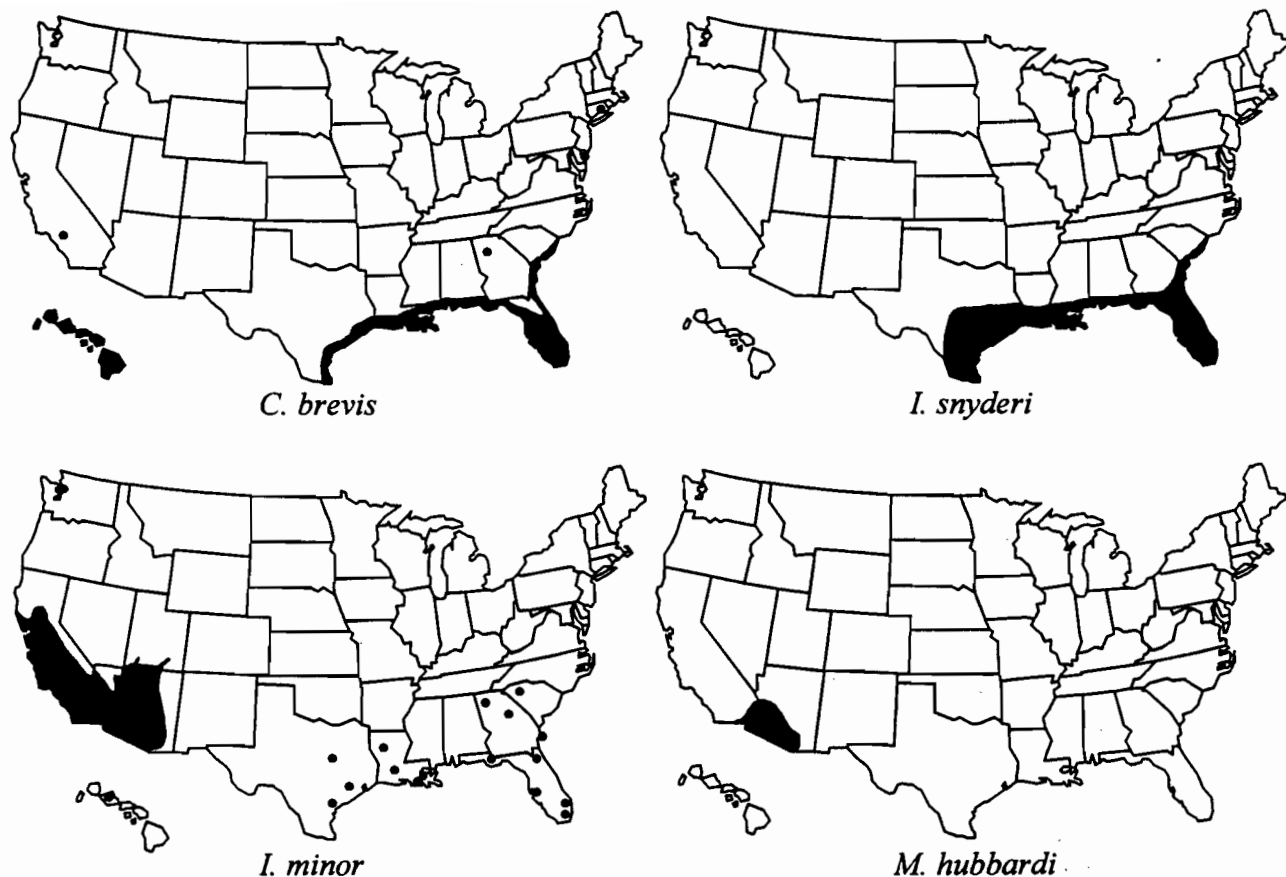


Fig. 1. Distribution of the four major drywood termite species in the United States. Maps based on collection data from cited literature and the author's records. Black dots represent recent collection localities for *C. brevis* and *I. minor*. *Cryptotermes brevis* is widespread in Puerto Rico and the U.S. Virgin Islands while the other three are absent from there.

Drywood termite colonies nest and forage solely in wood and give only subtle outward signs of their presence except during brief dispersal flights. Therefore, they are easily and unwittingly transported during the movement of infested goods, containers, or ships (Gay 1969, Myles 1995). Once introduced into suitable warmer climates, drywood species often thrive. New arrivals may even flourish in heated structures in cold temperate regions (Grace et al. 1991). Although not endemic to the West Indies, *C. brevis* has been introduced to every inhabited island in that region (Scheffrahn et al. 1994a).

Probably a greater variety of methods has been developed, marketed, and ultimately used to control drywood termites than any other structural or household pest (Table 1). There are several reasons for this plethora of treatments. One of the greatest determinants of treatment choice, and often one of the most uncertain and difficult to ascertain, is the location and extent of a drywood termite infestation. After many recolonization cycles, a structure may contain many infested wooden members, each infested by one or more colonies. Human access to some or all colonies may be limited. In such a case, fumigation and, possibly heat treatment may be the only viable means of eradication. Other considerations such as treatment cost, aversion to chemicals by the property owner, convenience, chance of success, and local availability of a given treatment all dictate what method will be employed.

TABLE 1. SUMMARY OF DRYWOOD TERMITE DETECTION, PREVENTION, AND CONTROL METHODS

DETECTION	CONTROL
Visual	WHOLE-STRUCTURE
Fecal pellets (Snyder 1950)	Chemical
Damage, probing (Snyder 1950)	Fumigation (Lewis & Haverty 1996, Scheffrahn et al. 1997a)
Dispersal flights: imagos, wings	Methyl bromide (Scheffrahn and Su 1992)
Non-visual	Sulfuryl fluoride (Osbrink et al. 1987)
Acoustic emissions (Scheffrahn et al. 1993)	CO ₂ synergism (Scheffrahn et al. 1994b)
Sound amplifier	Non-chemical
Metabolic gases, water	Heat (Haverty and Lewis 1996)
Canine olfaction (Lewis et al. 1997)	COMPARTMENTAL
Infra-red camera (Scheffrahn unpubl.)	Non-chemical
PREVENTION	Heat (Scheffrahn et al. 1997b, Woodrow and Grace 1998a,b)
Chemical Surface Applications	Cold, liquid N ₂ (Rust et al. 1997)
Wood Preservatives	LOCAL OR "SPOT"
Chromated copper arsenates (Scheffrahn et. al 1998)	Chemical
Coal Tar Creosote	Wood Surface
Pentachlorophenol paste	Pentachlorophenol paste
Disodium Octaborate Tetrahydrate (DOT) (Scheffrahn et al. 1998)	Lindane/oil
Insecticides	Aqueous DOT (Scheffrahn et al. 1997a, 1998)
Organophosphates	<i>d</i> -Limonene
Organochlorines	Wood Injection
Pyrethroids	Aerosol
Residual Alate Toxicants (Scheffrahn et al. 1998)	Chlorpyrifos (Scheffrahn et al. 1997a)
Silica gel or Drione	Dust
DOT	Arsenical (Scheffrahn et al. 1997a)
Non-Chemical	Silica gel
Alate exclusion	Chlordane
Traps: light, sticky	Carbamates
Caulking, paints, coatings	Liquids
Insect screening	Spinosad (Scheffrahn et al. 1997a, Scheffrahn and Thoms 1999)
Termite -resistant wood (Scheffrahn 1991)	DOT (Scheffrahn et al. 1997a)
Non-wood construction	DDT
	Gallery fumigant
	Ethylene dibromide
	Trichlorobenzene
	<i>d</i> -Limonene
	Non-Chemical
	Wood surface (Lewis & Haverty 1996)
	Electrocution (Ebeling 1983, Creffield et al. 1997)
	Microwave
	Wood injection
	Nematodes (Danthanarayana & Vitarana 1987)
	Fungi
	Wood removal
	Infested wood replacement

Detection

Before any treatment for drywood termites can be recommended, the viability and extent of the infestation must be determined. Better yet, pinpointing the exact location of termites within their gallery system will ensure more effective control if a local treatment is to be applied. The ability to detect termite activity also allows the pest control operator to monitor the success or failure of a given treatment.

Drywood termite detection relies mostly on wood probing and visual inspection. Canine olfaction and a variety of sound (electronic stethoscope) and metabolic gas/water vapor detection devices have been used to locate drywood termites, but each of these methods has its respective shortcoming: inherent difficulties in using dogs (Lewis et al. 1997), interfering audible background sounds, sporadic methane production (Wheeler et al. 1996), or insufficient moisture production by drywood termites.

Technological advances in filtration of background acoustics and amplification of termite-generated acoustic emissions, however, have tremendously improved the prospect of detecting drywood termites and other wood-feeding insects. Scheffrahn et al. (1993) demonstrated the performance and feasibility of using a hand-held, battery-powered acoustic emissions detector (AED) to locate and monitor termites in wood. It was concluded that this device offers a reliable method for localized, non-destructive detection of termites feeding on wood. An updated model, marketed in 1999 by Dow AgroSciences (Indianapolis, IN), can detect termite feeding from a sensor distance of up to 70 cm (Scheffrahn unpubl.). An inspector would simply affix a sensor on the surface of wood which is suspected to harbor drywood termites based upon Snyder's (1950) or Packard's (1951) list of existing visual evidence such as pellets, kick-out or emergence holes, or characteristic surface damage. The AED has been used to evaluate the efficacy of various treatments in the field (Scheffrahn et al. 1997a, Scheffrahn and Thoms 1999).

Recently, a hand-held, infrared-sensitive camera that records minute differences in IR wavelengths of objects (i.e., their thermal image) has shown some success in locating subterranean termites (Messenger, unpublished). Unfortunately, the device has not shown the same success with drywood termites because of the absence of IR-altering moisture fluxes. The application of hot air to the surface of infested wood, however, allows the user some visualization of large, subsurface galleries constructed by drywood termites (Scheffrahn, unpublished).

Prevention

Prevention of drywood termite colonization follows two approaches: making wood unpalatable to termites or preventing establishment of incipient colonies by intoxicating or excluding winged and dealated reproductives during their short dispersal forays and nuptial chamber constructions. Unpalatability includes using termite-resistant lumbers (Scheffrahn 1991) or susceptible lumber treated with wood preservatives (Hunt 1959, Randall and Doody 1934a, Scheffrahn et al. 1998). Because dispersing imagoes seek dark habitation after flight, attics, voids in walls and furniture, and crawl spaces are often foci for colony establishment. Silica aerogel dust was recommended as the choice desiccating toxicant for attic and wall void treatments to kill alates (Ebeling and Wagner 1959) and was shown to be toxic in the laboratory against *C. brevis* (Minnick et al.

1972). However, Scheffrahn et al. (1998) showed that colonies could establish on wooden blocks that were only partially dusted with silica gel/pyrethrum. Disodium octaborate tetrahydrate (DOT, TIM-BOR®) dust or aqueous solution, however, completely prevented small-block colonization. Bioassays with simulated attic modules, however, suggest that borates, silica gel/pyrethrum dust, and imidacloprid dust will greatly reduce or prevent colonization of partially-treated structural wood members (Scheffrahn, unpubl. obs.). No work has been done on the efficacy of alate exclusion methods such as screening and other exclusion devices for attics, foundations, and windows; or roofing material, caulking, or wood coatings. The efficacy of light or sticky traps is also unknown.

Whole-Structure Control

Structural fumigation with methyl bromide (BROM-O-GAS®) or sulfuryl fluoride (VIKANE®), administered per label directions, will completely eradicate drywood termites from a structure (Stewart 1957, Bess and Ota 1960, Osbrink et al. 1987, Scheffrahn and Su 1992, Lewis and Haverty 1996, Scheffrahn et al. 1997a). Therefore, fumigation has been the treatment of choice when drywood infestations are extensive or difficult to access or delineate. Early fumigants included most notably, hydrocyanic acid (Hunt 1949) and acrylonitrile. The inherent disadvantage of fumigation is the lack of residual protection. In California, where fumigation is often required prior to closing the escrow of infested structures, about 150,000 dwellings are fumigated annually. However, concerns about human exposure to fumigants has spawned new stringent laws governing structural fumigation practices in California (Anonymous 1992), and new restrictions will likely be adopted by other states. Methyl bromide has been recently implicated in atmospheric ozone depletion and is scheduled for phase-out by the year 2005 under USEPA guidelines (Anonymous 1999). The quantity of fumigant used to treat an average size home, approximately 5-10 kg, also puts structural fumigation at risk as this amount greatly exceeds the active ingredient requirements for most other pest control practices.

Carbon dioxide (CO₂) has long been known to enhance the toxicity of fumigants to control insects infesting raw food commodities (Cotton 1932); however its use was not developed for structural fumigation until recently. In 1993, California and Florida approved a structural fumigant label under the MAKR brand for the application of methyl bromide at 8 mg/l in admixture with CO₂ at 176 mg/l (10% v/v) for a 16-24 hour exposure (Anonymous 1993). Laboratory studies by Scheffrahn et al. (1994b) revealed that 5-10% CO₂ combined with methyl bromide or sulfuryl fluoride appreciably synergised the toxicities of both fumigants against *I. Snyderi* psuedergates by up to about 1.8-fold, equal to a reduction in required fumigant concentration of about 45%.

The outlawing of some localized chemicals (e.g., arsenic dusts, ethylene dibromide, pentachlorophenol, etc.) in most developed nations has intensified the reliance on structural fumigation for drywood termite control, especially in the United States where the cost is tolerated by necessity. Because fumigation is technically complicated and expensive, and regulatory concern about the practice is mounting (Calif. Struct. Pest Control Board, pers. comm., R. Sbragia 1992), there is a need to develop effective alternative treatments. In the United States, structural fumigation is the only method of pest control that occasionally results in accidental human mortality (e.g., Pazdera 1998, Robles 1999).

Compartmental Control

In recent years, heat treatment of structures has been promoted as a non-chemical means of drywood termite eradication (Forbes and Ebeling 1987). The thermal limit for *I. minor* was estimated at 49°C for 33 minutes (Forbes and Ebeling 1987) to 52°C (time not specified, Randall and Doody 1934a). Lewis and Haverty (1996) heated a 154 m³ building containing *I. minor*-infested boards until wood temperature of selected boards reached 50°C for ≥ 1 hour. Some termites survived only in a few infested boards adjacent to the concrete foundation (heat sink) where wood temperatures were not recorded. Scheffrahn et al. (1997b) obtained 100% mortality of *C. brevis* and *I. snyderi* pseudergates exposed to 48°C for 10 min and 50°C for 15 min, respectively. In additional tests with *C. brevis*, relative humidity and acclimation to warmth (35°C, 10 days) had no effect on heat tolerance. Woodrow and Grace (1998a) obtained 100% mortality of *I. immigrans* (Light) at 46°C exposures for 30 min while gradual heating from 28° at 0.7°C/min resulted in irreversible heat shock to *N. connexus*, *I. immigrans*, and *C. brevis* at 51°C. Ambient air and internal wood temperatures were monitored at 9 field sites in Hawaii during commercial heat treatments for *C. brevis* (Woodrow and Grace 1998b). Air temperatures ranged from 52-85°C (0.04-1.44°C/min) and wood temperatures from 39.2-72.3°C in treatments of building compartments and required 15-300 min to reach the wood target temperature of 49°C. Woodrow and Grace (1998b) did not evaluate termite mortality.

Low temperature spot treatments by introduction of liquid nitrogen (N₂) in the proximity of infested wood members are commercially available. Unlike heat treatments that can accommodate large volumes (≈500 m³), cooling with N₂ is suited only for small compartments (e.g. <1 m³) such as wall voids or similar sized areas where infestations can be enclosed by insulation blankets (Emshwiller 1989, Forbes and Ebeling 1986). Lewis and Haverty (1996) obtained 98% mortality of *I. minor* when N₂ was administered at 123 kg/m³. Rust et al. (1997) found that pseudergates of *I. minor* and *I. snyderi* succumbed to momentary exposures of -21°C and -17°C respectively when temperatures were lowered at 1°C/min. To achieve these temperatures within 10 min throughout wood framing in 2.4-m-high by 0.4-m-wide wall voids, N₂ was introduced at the top of the void at a minimum rate of 1.8 kg/min. Rust et al. (1997) also demonstrated that wall insulation hindered the cooling process. Because the N₂ can displace air, oxygen concentrations must be monitored for safety.

Local Control

Local or "spot" treatment for drywood termites is recommended when the extent of an infestation can be delineated and is accessible. Unlike whole-structure or compartmental treatments, these are applied directly to the infested wood members. The lower cost and greater convenience of some local treatments, like drill-and-treat applications, makes them attractive choices. Chemicals registered for spot application can be classified as to mode of application: wood surface or intragallery injection termed "drill and treat" by Packard (1951). DOT formulations are currently being used in aqueous or dust (TIM-BOR®), aqueous glycol (BORA-CARE®), or foam formulations as unpainted wood-surface treatments for both control and prevention of drywood termites. Until its outlaw, pentachlorophenol, applied in a petroleum-based paste (Woodtreat-TC), was the treatment of choice on bare infested wood surfaces (Ebeling 1978).

Although published data are lacking, the practice of injecting a mixture of ethylene dibromide (EDB) by itself or with a residual chemical such as chlordane, DDT, or other organochlorine, was widely used as a drill-and-treat formulation (Ebeling 1978). The EDB volatilized throughout the gallery system as a local fumigant. The organochlorine additive was intended to give long-term residual protection. Trichlorobenzene was suggested for use in the same manner as EDB (Snyder 1950). All these materials are no longer registered for use in the U.S. It has been shown that insects are susceptible to the gaseous phase of a number of non-halogenated volatile organic compounds based on natural products (Dettner et al. 1992) and at least one commercial product (Power Plant®) consists of *d*-limonene (Anonymous 1997). The toxicity of *d*-limonene to drywood termites, however, is expressed only by direct contact with the liquid (Scheffrahn, unpubl.).

Randall and Doody (1934b) showed that Paris green or copper aceto arsenite dust, when injected into galleries at 1-meter intervals, could successfully control extensive infestations of drywood termites in utility poles. Only 1 gram of arsenic dust was sufficient to treat a large infestation. The efficacy of Paris green was attributed to its slow activity and non-repellent quality against termite workers which, when contaminated, would actively spread the toxicant among uncontaminated nestmates. Any nestmates foraging in treated galleries would, likewise, be contaminated. Smith (1930) also noted the success of field tests with Paris green dust against *I. minor*. A formulation of 35% calcium arsenate (KALI-DUST) was a mainstay product in drill-and-treat applications for many years. Working with and injecting this dust was messy and exposed the pest control operator to the toxicant. Arsenic dusts, because of their acute mammalian toxicity and carcinogenicity, are no longer registered for pest control in the U.S.

Many chemicals such as cyfluthrin (Cy-Kick) or chlorpyrifos, most recently used in drill-and-treat applications in the U.S., rely on acute contact toxicity. Such insecticides may be repellent or deterrent to drywood termites (Scheffrahn et al. 1997). Drywood termites in untreated wood galleries might avoid foraging in treated portions of their gallery system and survivors might reinitiate colony development and redirect damage elsewhere in the wood members. Control success with these compounds is also related to treatment coverage which, in turn, depends on the accessibility of the infested wood. Therefore, control rendered by such drill-and-treat applications may be limited to small areas because only termites in chemically-treated galleries are certain to be contacted by the toxicant. Spinosad SC has emerged as a superior compound to pyrethroid, organophosphate, and borate treatments for drywood termite control. As a 0.5% aqueous solution, spinosad SC dries as a non-repellent, slow-acting residue that has the termiticidal characteristics of arsenic dust, but is an environmentally benign fermentation product (Anonymous 1995, Scheffrahn et al. 1997, 1998; Scheffrahn and Thoms 1999).

Microwave and electrocution treatments for local control of drywood termites have been commercialized in the U.S. Lewis and Haverty (1996) determined that inconsistent control of *I. minor* was achieved with microwave (high frequency electromagnetic energy) applications applied at 700W. In their study, infested wood members were treated for 8 minutes in 30-cm increments. The equipment provides no measurement of dose and is large, heavy, and poorly maneuverable, making treatment in some locations impossible.

A device called the "electrogun" produces a high-voltage, high frequency electric current to electrocute drywood termites in their galleries (Ebeling 1983). Lewis and Haverty (1996) reported 89-95% mortality to *I. minor* in boards that were fitted with metal pins and treated with the electrogun probe for between 1.5 min and 1.75 hr. Creffield et al. (1997) reported 100% mortality in a laboratory evaluation of the electrogun against the Australian species *C. primus* (Hill), however, bioassay blocks were small (15 x 10 x 4 cm) and treatment time lengthy (7-8 min). At this rate, it would take 15-17 hrs to treat a typical 2.1x 0.9 m door. As noted by Lewis and Haverty (1996), efficacy of this method is excessively technique driven. Although maneuverable, the electrogun provides no measurable dose parameter and is subjected to interference by metal and concrete.

At present, drywood termites have been elusive targets for biological control. A field trial with *Heterorhabditis* sp. nematodes on the Sri Lankan dampwood termite, *Glyptotermes dilatatus* (Bugnion and Popoff), suggests that control is possible by intragallery injection of nematodes in moist woody stems of infested tea plants (Danthanarayana and Vitarana 1987). However, the extremely dry conditions of typical structural infestations would present a much greater challenge to nematode survival and movement (R. Giblin-Davis, pers. comm.). The entomophagus fungus, *Metharhizium anisopliae* (Strain ESC 1) is registered for drywood termite control (Anonymous 1998), however, lack of moisture also inhibits its virulence (Scheffrahn unpubl. obs.).

Future Trends

The future portends that the remedial control of drywood termites will rely more on local treatments and less on whole structure methods (Table 1). This will be, in part, due to improvements in local treatment efficacy and because of increasing regulatory control of the fumigation industry from the standpoint of air quality and human hazard. Fumigations will also yield, in part, to the use of heat as techniques improve for the distribution of heat and the reduction of damage to household materials caused by heating.

The greatest area of development has, and will continue to be with intragallery treatments. Acoustic emissions detection will allow superior and non-invasive delineation of infestations to pinpoint treatment areas and to confirm the treatment efficacy. Compounds like spinosad and possibly some of the neonicotinoids will allow eradication of drywood termite colonies, even when galleries are only partially accessible (Scheffrahn et al. 1997a,b, 1998). Such treatments can be accomplished with minimal equipment, inconvenience, odor, and treatment time; and with no environmental hazard. Such treatments are well suited for untapped markets in developing countries.

As more is understood about the foraging behavior and dynamics of drywood termites, active ingredients and their formulations can be optimized for maximum exposure, transfer, and feeding. Development of preventative treatments (Scheffrahn et al. 1998) will offer protection from drywood termite infestation when installed in new as well as existing construction.

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LIFE HISTORY OF DRYWOOD TERMITES AND FUTURE PROSPECTS FOR THEIR MANAGEMENT

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Infestation of structures by drywood termites is common in parts of the southeastern and southwestern United States resulting in annual treatment costs of nearly \$400 million. Unlike subterranean termites, attack of buildings by drywood termites is always initiated by alates. Resultant incipient colonies grow slowly in the first few years, do little damage, and are difficult to detect. Studies on colony foundation and development with the West Indian powderpost drywood termite, *Cryptotermes brevis*, were initiated in 1997. Alates pair immediately after flight and, after tandem searching, select existing wood crevices, joints, or holes for nuptial chambers. Even in the absence of predation, <10% of dispersing alates are viable in chambers after 6 months. No alates have emerged from 3-year-old *C. brevis* colonies.

The traditional approach to drywood termite control in the United States has been either to apply treatments locally in areas of apparent infestation or to fumigate the entire structure. Fumigation remains an attractive treatment for drywood termites because it insures building-wide eradication. Fumigation, however, is technically demanding, inconvenient to building occupants, and its inherent danger has resulted in human fatalities. Heat treatment has gained in popularity in recent years as a safer and more convenient method of whole-structure eradication. The technical difficulties associated with manipulating heat dynamics in buildings and the potential for damage to heat-labile materials remain challenging issues to overcome although some progress has been made.

The greatest limitation for local drywood termite treatments remains the detection of and access to the infestations. Acoustic emission devices now allow for non-destructive verification and delineation of infestation, but only when wood surfaces are accessible. High-resolution infra-red video imaging may be one future method for locating termites in covered wood framing.

Wood injection treatments show the greatest promise for simple and fast local control. Formulation characteristics are essential for efficacy and commercial acceptance. Foremost are liquids that enhance gallery coverage and leave non-repellent and dislodgeable residues. These residues, in turn, allow for colony-wide dissemination of the toxicant via foraging through

contaminated galleries and social contact. The success of baits for drywood termite control will rely both on the discovery of feeding stimulants and the intensity of recruitment and trophallaxis by these insects.

THE DISTRIBUTION AND ABUNDANCE OF DRYWOOD TERMITES IN THE SOUTHWESTERN UNITED STATES

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Drywood termites belonging to the Family Kalotermitidae represent a major structural pest throughout much of the southwestern United States. The western drywood termite, *Incisitermes minor* (Hagen), is the most important economic pest species, but *I. fruticavus* Rust and *Marginitermes hubbardi* (Banks) have also been collected from structures. In a limited survey of termites of Arizona, alates of *M. hubbardi* and *I. minor* were both collected in about 13% of the homes inspected. In the Sonoran desert areas, the desert dampwood termite, *Paraneotermes simplicicornis* (Banks), is occasionally found attacking structures, especially in areas of excessive moisture. The exotic powderpost termite, *Cryptotermes brevis* (Walker), is reported on rare occasion and the infestations can be traced to commerce from tropics.

The distribution and abundance of *I. minor* are probably greatly influenced by the rapid urbanization of the arid southwest. In native settings, this species is often restricted to arroyos and canyons where sycamore, elderberry, willows and other large trees thrive. In urban areas in addition to structural lumber, *I. minor* infests walnut, ash, rosebushes, and other decorative shrubs and trees. In coastal cities of southern California such as Huntington Beach and Newport Beach, evidence of drywood termite infestations was found in 70 and 68% of the structures inspected. Inland cities such as Riverside and San Bernardino, drywood termites were reported in 51 and 65% of the structures inspected. As might be expected, newly developed areas of the inland have relatively low infestation rates of 13-25%. Surprisingly, a rapidly growing desert city such as Palm Springs had 19-22% incidence of drywood termites compared with an older city such as Barstow with only 2-16% infestation incidence.

Urbanization in the desert southwest has certainly increased the incidence of drywood termites. The importance of drywood termites as structural pests in California and Arizona will dramatically increase.

CASTE DIFFERENCES IN FEEDING AND TROPHALLAXIS IN THE WESTERN DRYWOOD TERMITE, *INCISITERMES MINOR* (HAGEN) (ISOPTERA, KALOTERMITIDAE)

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Differences in feeding and trophallaxis among castes of the western drywood termite, *Incisitermes minor* (Hagen), were determined using rubidium (Rb) as a tracer. Both 5th- and 6th-instar nymphs and 3rd- and 4th-instar larvae fed directly on Rb-treated paper and acted as both donors and recipients in trophallactic exchanges with other larvae and nymphs, and as donors for soldiers and alates. Soldiers and alates did not feed on Rb-treated paper suggesting that they do not feed directly on wood and are completely dependent on nymphs for their nutritional needs. Transfer efficiency, the percentage of the total Rb intake of donors that is passed to the recipients, ranged from 1.1% (nymphal donors to alate recipients) to 16.6% (larval donors to nymphal recipients).

EVALUATION OF A PROTO-TYPE ACOUSTICAL EMISSION DEVICE FOR DETECTING THE WESTERN DRYWOOD TERMITE (ISOPTERA: KALOTERMITIDAE) IN NATURALLY INFESTED BOARDS

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More than two hundred naturally infested boards were searched with a proto-type acoustical emission (AE) termite detection device. The device detects termites by measuring their feeding sounds. The objectives of the study were to determine the presence or absence of live termites in boards as well as the intensity of the infestation (i.e., number of live termites in the board). An additional objective was to determine if the AE device could be used to detect failed treatments. All infested boards were field collected and revealed visual signs of feeding damage and frass pellets by the western drywood termite, *Incisitermes minor* (Hagen). Board species included Douglas-fir, *Pseudotsuga menziesii* (Carr.); redwood, *Sequoia sempervirens* (D. Don); and ponderosa pine, *Pinus ponderosa* (Engelm). The most frequent board dimensional sizes tested were 1 by 8, 2 by 4, and 4 by 4. Board length varied, from 30 cm to 307 cm. One hundred two boards were also treated with one of six different drywood termite control methods: fumigation, excessive heat, liquid nitrogen, microwaves, and electrical shock. Ten boards were untreated and an additional ten boards did not contain any termites, dead or alive. Boards were searched with either a flat glue-mounted or screw-mounted sensor. Three 1-min AE recordings were taken at 91-cm increments in the center of boards along the long axis. All boards were later dissected and counts of live and dead termites conducted. Regression analyses revealed a statistically significant correlation with increasing AE counts and termite numbers. However, the regression was best for redwood boards searched with a screw-mounted sensor. There was considerable variance in termite number and caste proportions among treated and untreated boards. False positive rate for boards was low, <5% of boards searched and dissected.

GEOGRAPHICAL AND ECOLOGICAL PATTERNS OF TERMITE INCIDENCE IN SOUTHERN CALIFORNIA

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Southern California includes diverse natural habitats including deserts, scrub, chaparral, hardwood forests and coniferous forests. Elevations range from below sea level to over 14,000 feet. Superimposed on this natural mosaic are major human-dominated habitats and one of the largest urban concentrations in North America. Major objectives were to measure incidence of major economically important species of termites as reflected by the frequency with which they were found in structures based on PCO inspection reports and to relate these patterns to patterns of ecological communities, topography and climate, demographics and historical patterns of land use.

All inspection reports filed by PCOs in the state of California for Orange, Riverside, and San Bernardino counties for an 11-month period beginning in August 1992 and ending at the end of June 1993 were examined. Data were input into a computerized database including zip code, incidence and location of different wood-destroying pests. These data were combined with demographic and economic data from U.S. Census databases.

55% of properties professionally inspected in the study area showed evidence of infestation by drywood termites and 22% showed infestation by subterranean termites. Dampwood termite damage was observed but was insignificant. Within local zip code areas percentages of infested structures ranged from 0 - 90%. Two principal factors seem to account for these differences: eco-climatic zones and pattern of urbanization. For drywood termites the general trend of infestation rates (from highest to lowest) was coastal lowlands, inland valleys, high desert, low desert, and high elevations. Within a given region, however, the older urban centers showed significantly higher infestation rates than did areas of newer development. This strongly suggests that urban development actually increases the available habitat for drywood termites.

Infestation rates for subterranean termites were more complex. One of the areas with highest infestation rates was the low desert valleys where *Heterotermes aureus* is the dominant species. Infestations by *Reticulitermes* spp. were highest in foothill zones of the coast and inland valleys. This pattern was also affected by degree of urbanization and probably former land use.

FORTY YEARS OF PRODUCT STEWARDSHIP FOR STRUCTURAL FUMIGATION WITH VIKANETM GAS FUMIGANT: WHAT TO EXPECT FOR THE NEW MILLENNIUM

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Fumigation with VikaneTM gas fumigant (sulfuryl fluoride, Dow AgroSciences) is a highly efficacious remedial treatment for eradicating drywood termites throughout a structure. Vikane is also highly toxic to humans and other non-target animals and has no intrinsic warning properties: it is colorless, odorless, tasteless, and nonirritating at concentrations found in typical drywood termite fumigations. For these reasons, the label for Vikane requires the use of chloropicrin as a warning agent during fumigation of buildings, appropriate respiratory protection by fumigation personnel, and gas-specific detectors for confirming clearance of the fumigant after aeration.

Continuous improvements have been made in the safety-related equipment and procedures used with Vikane since market introduction. In 1961, acid gas canisters, which filtered the fumigant through a sorptive matrix, were used for respiratory protection. Canister respirators were replaced in 1984 by the positive pressure, Self-Contained Breathing Apparatus. From 1961 through 1986, the Davis detector and later the Vikane detector were the required clearance detectors. These detectors could only measure discrete air samples and required time to process them. Since 1986, the MiranTM specific vapor analyzer (Foxboro Co.) and in 1987, the InterscanTM gas analyzer (Interscan Corp), have been required clearance detectors for Vikane. Both instruments provide continuous readings. In 1993, extensive label changes, including revised aeration procedures, use of nylon polymer bags to protect foodstuffs, and occupant notification requirements, were instituted. Also in 1993, DowElanco mandated in its "CaretakersSM" product stewardship program that fumigators who use Vikane must attend annual training programs developed by DowElanco. The new Vikane gas fumigant Fumigation Program also includes voluntary Quality Assurance Reviews, conducted by Dow AgroSciences personnel, of fumigations using Vikane. Other recent stewardship initiatives include providing chloropicrin labeled by Dow AgroSciences to ensure availability, requiring the use of secondary locks, clarifying when state licensed applicators must directly supervise fumigations, and standardizing stewardship policies of Dow AgroSciences for probation or stop sale of Vikane to fumigators with safety-related label violations.

Product stewardship is the responsibility of all participants in the fumigation industry, including the fumigators, suppliers, and regulators. The Fumigation Committee in California and Fumigation Advisory Council in Florida provide guidance to applicators, manufacturers, and regulators on ways to improve fumigation safety. State regulatory agencies have taken steps to enhance enforcement of the structural fumigation industry. Beginning in 1994, fumigators in designated counties in CA pay \$5.00 per reported fumigation to subsidize fumigation inspections by state regulators. Dow AgroSciences remains committed to work with fumigators, suppliers,

and regulators to continue to improve equipment, procedures, and policies necessary for safe use of Vikane gas fumigant.

Making IPM in Schools Work

Ballroom North

Organizer and Moderator
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ADOPTION OF IPM BY SCHOOL ADMINISTRATORS

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Several states across the nation have responded to parental lobbying by enacting legislation which mandates various aspects of IPM in public school buildings. Each of these states has independently enacted laws and guidelines, all with the common goal of promoting responsible pest control and use of pesticides in public buildings. Where such laws have been mandated, school administrators and pest control professionals have often been left questioning how to actually implement IPM. Legislative mandates, without accompanying 'how to implement' guidelines, have caused frustration on the part of some schools attempting to comply with the rules. Other sincere efforts are thwarted because of a lack of long term support, technical resources and training opportunities. Adoption of an IPM program requires a concerted effort by experts in the field, working closely with school administrators, custodians, grounds keepers and pest control operators to initially implement the program and to demonstrate its value.

NATIONAL PERSPECTIVE ON IPM IN SCHOOLS

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The concept and practice of IPM in schools is gaining increasing attention and momentum since the first emergence of programs in 1990. Several collaborative IPM in Schools meetings of national significance have occurred during the last two years alone, involving interdisciplinary

efforts among Universities, pest management professionals, State Boards of Health, consultants, the Environmental Protection Agency, the U.S. Department of Agriculture, State pesticide regulatory agencies, school board corporations, the National Pest Control Association, and others. The overall goal of these meetings was to coordinate and study the IPM in schools issue from a national perspective, and to facilitate a common and national effort for implementing practical School IPM programs.

As of August 1999, approximately 50% of the states in the United States have some type of formal, structured Schools IPM program in place. The status of the remaining states varies from none, to programs “being considered”. (However, this does not necessarily mean that IPM programs are not being conducted in those states via progressive schools and pest management companies).

Of those states with formal programs, approximately seven states (Texas, W. Virginia, Michigan, Maryland, Illinois, Washington, and Louisiana) have state legislation mandating IPM in schools. Massachusetts has legislation pending. Eighteen states have “voluntary” IPM programs in place with varying degrees of formality and interdisciplinary involvement.

Several states have developed comprehensive IPM in Schools programs complete with associated booklets, manuals, videos, and public relation posters, (e.g., Texas, Maryland, North Carolina, Illinois, etc.). The University of Florida has developed a web site (The School IPM Website) which has emerged as probably the national representative web site on school IPM. Surely however, other states in the future will produce state-specific web sites, or likely be linked to the Florida site. For states and school corporations that have yet to address the IPM issue, the programs of the states above (or others) offer excellent templates from which to structure and streamline a new program.

Although the school IPM initiative is relatively recent, it is interesting to note that *urban IPM programs* have actually been in place and working in many different cities and sites since the late seventies. In fact, many of the current day school IPM models are based on previous IPM plans and strategies which were developed by the structural pest control industry for “sensitive accounts” such as zoological parks, health care facilities, food processing plants, pharmaceutical plants, and laboratory rearing facilities, just to name a few. Each of these sites, like schools, must focus on low-impact and minimal-use pesticidal programs. The specific sensitivity base may be different (e.g., children, vs. food, vs. exotic rare animals, etc.), but the general principles that necessitate an IPM program are nearly identical.

Thus, it is both ironic, and no doubt frustrating to structural pest management professionals, that some individuals new to the IPM (in schools) issue perceive the average “PCO”, as not progressive enough for a school IPM program. When in fact, in most states, the most knowledgeable person prepared to implement a cost-effective, quality school IPM program might be only as far away as the yellow pages.

It is also true, on the other hand, that there are still some pest control operators who either lack training and/or interest in IPM programs. Such companies continue to price, and “harvest” pests

from buildings via the spraying of baseboards in hallways, kitchens, and classrooms. But they are not alone in pursuing this ineffective and potentially hazardous method of combating pests. Indeed, many teachers and custodians throughout the United States still instruct their local PCO to "spray" their school each month, believing the myth that such applications "keep the bugs away".

Regardless of each state's current status in school IPM, the principles of effective pest management in "sensitive urban environments" remain as they were since the beginning. That is, pest management *begins* with the emphasis on non-chemical approaches: comprehensive pest proofing and sanitation programs for both interior and exterior areas, and all groups must be involved in the sanitation efforts. The use of mechanical methods for pest removal such as traps, and specialized pest-removing vacuum cleaners as well as the new technologies associated with pest proofing, and cleaning equipment are certainly benefiting the urban IPM cause.

Pesticides, when needed, also remain a vital component to the IPM program. But the selection of which pesticides, formulations, dosages applied, and application techniques are each issues that require the input of persons knowledgeable and experienced in pesticides, pesticide toxicology issues, and the application of pesticides in sensitive urban environments. Part of the impediment over the past several years with some school IPM programs, and no doubt with future programs, is lay persons attempting to label all pesticides used in any manner inside buildings as inherently dangerous. For example, some believe if the intended school pesticides are of a bait or a boric acid formulation, these are acceptable and "safe". Whereas, if a pesticide is applied as a spray or aerosol, it is dangerous and unacceptable application for school environments.

Nevertheless, relative to pesticide applications inside and around schools, the advent of the new highly effective, cockroach, termite, and ant (some) baits have greatly reduced the presence of pesticides inside schools from both spatial and toxicological aspects.

Structured, detailed monitoring programs hold great promise in formalizing and aiding in effective true integrated pest management programs. New monitoring tools, data collection, and technology serve to play a major role in future School IPM efforts.

Certainly not any less important in the entire school IPM process, is the need for constant communication and education among all involved parties including parents, students, teachers, administrators, food prep, janitorial, and maintenance staffs, and the local pest management professionals. *Structured* programs which facilitate good communication are critical to the success of IPM programs.

All of the above discussion is a moot point however, if a school corporation places a low priority on pest management relative to budgeting issues. Pest management is a critical issue relative to the health of the school and its occupants. Allocating the pest management service and program to the lowest bidder may be acceptable only if all the bids meet the criteria for performing quality IPM programs, backed up by verifiable results and good documentation.

Finally, school IPM programs must be cautious of over-reactions and over-engineering. Programs should be designed with sound science and experience as their foundations. All

involved parties must communicate and work together in promoting the same goal: how to spend the day at school learning without the threat of pests or unnecessary pesticide exposures. Various models are now in place to accomplish outstanding School IPM programs on a national level.

SUPPORTING RESOURCES FOR IPM IN SCHOOLS

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Pesticide use in sensitive environments such as schools has received increased attention and scrutiny in recent years. The dilemma facing school administrators and pest managers is how to achieve appropriate pest management while at the same time not creating additional risks regarding pesticide exposure to students, faculty, and staff.

In 1997 the School IPM World Wide Web Site was created through support from Region 4 of the US EPA. The site was initially planned as a regional resource but widespread acceptance and interest initiated its expansion into what is now known as the National School IPM World Wide Web Site (<http://www.ifas.ufl.edu/~schoolipm/>).

This one-stop clearing-house of information was designed to be useful to anyone working in the field of School IPM. The site is structured such that certain sections appeal to various viewers. There is introductory information about School IPM for parents, teachers, and school administrators. There is detailed technical information on how to control the major pests in school using IPM. There are downloadable PowerPoint presentations available for use as training tools. Regulatory officials and other leaders in the field will find the School IPM listserv useful for communicating with colleagues in other states. Also, policy makers will find the latest information available to assist in policy development regarding School IPM, as well as copies of present state manuals and training materials.

The National School IPM World Wide Web Site currently receives between 150 and 200 "hits" a week and seems to be a popular resource for those individuals around the country working to aid schools who want to transition from traditional "once-a-month spraying" of pesticides to Integrated Pest Management.

REGULATING IPM IN SCHOOLS

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State and federal lawmakers are passing legislation to implement integrated pest management (IPM) in schools in response to public concerns about pesticide risks. This abstract, primarily taken from two web sites that discuss both federal and state regulations, provides a synopsis of

federal legislation and examples of various regulatory activities related to IPM in schools.
www.epa.gov/reg5foia/pest/matilla/ipm_dir.html www.ncamp.org

The primary relevant federal legislation is the School Environment Protection Act (SEPA). Senators Toricelli (NJ) and Murray (WA) introduced the bill, S. 1716 (H.R. 3275) in October 1999. The Senate bill has been referred to the Agriculture, Nutrition, and Forestry Committee; the House Agriculture Committee is considering the House.

If passed, this federal law would require IPM in all schools. It would specifically prohibit the use of any pesticide found by EPA to cause cancer, mutations, birth defects, reproductive dysfunction, neurological and immune system effects, endocrine system disruption, and those pesticides rated as acutely or moderately toxic. This act would specifically allow the use of pesticides containing boric acid, silica gels, diatomaceous earth, and botanicals. These two rules illustrate the difficulty of writing effective IPM regulations because they do not consider the relationship between pesticide risk and pesticide exposure. Irresponsible application of less toxic pesticides may result in greater exposure and increase pesticide risk to children.

Other major components of SEPA include: 1) a 72-hour notification prior to pesticide application; 2) establishment of a 12-member Advisory Board representing parents, health care professionals, state IPM coordinators, independent IPM specialists, advocacy groups, school personnel, and pest control professionals; 3) an emergency pesticide use exemption when pest populations threaten human health; and 4) authorization of \$7 million per year through 2004 to implement IPM in schools.

The following bullets provide an overview of regulations pertaining to pesticide use around schools that have been enacted in approximately 30 states. Buffers from 300 feet to 2.5 miles restrict aerial applications of pesticides near schools. Indoor pesticide applications must be posted. The laws often pertain to all public buildings. Outdoor pesticide applications must be posted. The laws typically address all public areas. Pesticide notification regulations range from universal notification to notification by request. Some states establish time and/or distance restrictions to reduce potential pesticide exposure. Regulatory definitions of IPM from specific and inclusive to vague, meaningless statements. Only a few states (e.g., TX, LA) have laws that require schools to implement IPM. Texas requires a trained IPM coordinator; Louisiana requires an annual implementation strategy.

MARKETING IPM TO SCHOOLS

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For any concept to be adopted into a free market economy it must be marketable or it will be doomed to failure or relegated to a government bureaucracy. The growing attention to IPM has generated a great deal of attention but little practice. In 1992 Michigan mandated IPM in schools and a market was born. School administrators have historically asked for a pest management

program that minimizes costs, as neither pests nor pesticides had been significant concerns. The new law has presented challenges for school administrators, pest management professionals, and regulatory officials. This presentation focuses on some of the challenges that can be expected when IPM is required by law.

Ants
Ballroom West

Moderator
David H. Oi, USDA-ARS, CMAVE

ANTS: WHERE ARE WE NOW? WHERE ARE WE GOING?

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Urban pest ant control has become a high priority for the pest control industry. The National Pest Management Association (formerly the National Pest Control Assoc.) and trade journal articles have indicated that pest ants are a major concern for the pest control industry. Pest ant problems have significantly impacted pest control operators by causing numerous “callbacks”, or return visits to clients, thus impacting profits. This presentation will focus on ant control. To gauge where we are now and where we are going, it is useful to know where we have been. One of the most studied ants in the world is the imported fire ant. The efforts to control this ant have been well documented and provide a chronology of ant control practices that serve as a guide for ant control tactics being developed today and in the future.

Black imported fire ants, *Solenopsis richteri* Forel, and red imported fire ants, *S. invicta* Buren, were inadvertently introduced into the United States around 1918 and sometime between 1933-45, respectively, through the port of Mobile in Alabama. Government organized control programs began in 1937 with the application of calcium cyanide dust applied to individual nests on about 2,000 acres in Alabama. In 1948, Mississippi initiated a control program using chlordane dust applied to nests, and in 1957 Arkansas implemented an eradication program with the aerial application of granular heptachlor (@ 2 lbs per acre) to 12,000 acres. “Excellent results” were obtained with this latter method, and thus heptachlor applications were expanded to area-wide applications by ground and air in 1957. By 1958, there were environmental concerns over the use of heptachlor, hence, rates and application intervals were reduced in the spring of 1959-1960 (Lofgren 1986). The area-wide use of heptachlor for imported fire ant control was one of the programs criticized in Rachel Carson’s “Silent Spring”(1962). Meanwhile, in 1957, a

USDA Methods Development Laboratory was organized to improve fire ant control techniques. In 1960, Hays and Arant developed an ant bait consisting of kepone in peanut butter. In 1961, the USDA Methods Development Laboratory developed mirex ant bait, which consisted of mirex in a soybean oil attractant soaked onto a corncob grit carrier (Lofgren et al. 1963). This bait provided 98% control, which unlike kepone, caused no apparent harm to wildlife. Because of political pressure to eradicate imported fire ants, large-scale eradication trials (three sites of 255,892 to 2,130,993 acres!) were conducted to work out logistics and determine feasibility. By 1970 these trials were completed, resulting in 96% control using 3 applications of mirex bait at rates of 1.25 to 2.5 lbs per acre by aircraft. Because technical difficulties were thought to be surmountable, Banks et al. (1973) stated that "total elimination of imported fire ants from large isolated areas may be technically feasible". Prior to that, Lofgren and Weidhaas (1972) indicated that in theory it would be possible to eradicate imported fire ants with 3-9 applications of mirex if the level of control provided by each bait application ranged from 90 to 99.99%. Meanwhile from 1967 to 1975 mirex bait was applied to most infested states for a total of 111,845,009 treated acres (37,281,669 acres treated 3 times).

In 1977 the use of mirex was halted for several reasons including: persistence in the environment, accumulation in non-target organisms, toxicity to estuarine organisms, and carcinogenic potential. From the imported fire ant control effort using mirex, one could see that there was a pest ant crisis that led to political mandates of fire ant eradication. While eradication may have been possible, that goal was unobtainable given the restrictions on treatment applications and the biology of imported fire ants with its high reproductive rate, mobility, and diverse habitat range. With the cancellation of mirex, there was an intensive search to find a replacement. From 1976 to 1981, 3,052 chemicals were screened at the USDA-ARS laboratory in Gainesville, Florida against imported fire ants (Williams 1983). In 1980, Amdro fire ant bait, which contains the metabolic inhibitor hydramethylnon, received conditional registration. In the latter half of the 1980's, other fire ant baits containing fenoxycarb and abamectin were registered. These baits inhibited the production of new fire ants, and thus did not cause colony mortality as fast as mirex or hydramethylnon. In the late 1990's other insect growth regulating fire ant baits containing methoprene and pyriproxyfen were registered. The most recent fire ant bait registered this year contains spinosad, which affects the insect nervous system. Thus, despite the negative publicity surrounding mirex, there was still a mandate to find an alternative to it for fire ant control. In addition, the market potential of fire ant control products resulted in development of other imported fire ant baits and this development still continues. Methods and procedures used to develop the mirex bait continue to serve as a basis for the development of new fire ant and other ant baits.

So here we have a chronology of control tactics for imported fire ants that go from treating individual nests with a contact insecticide, to broadcast applications of a contact insecticide, to the broadcast application of an ant bait. Ant control in the pest control industry had a relatively similar pattern, where there was reliance on applying contact insecticides after the development of DDT and related insecticides, and followed by the development of ant baits. However, it is interesting to note that before DDT, ant baits containing sodium arsenite, tartar emetic, and thallium sulfate had been used for other pest ants, such as Argentine and Pharaoh ants, before mirex was developed (Flint and McCauley 1936, Smith 1936, Eckert and Mallis 1937). These

baits were formulated as liquids or semi-liquids and thus were confined to stations. Similarly, the methoprene bait developed by Edwards (1975) for Pharaoh ant control was formulated in a liver-powder/honey/sponge-cake carrier that required spot placements, unlike the mirex formulation and subsequent fire ant baits which could be broadcast.

So where are we now? Well, besides imported fire ants, we are now seeing a greater awareness of other pest ant species. This has led to the development of baits for other pest ants instead of just imported fire ants. Pest ant control has become a high priority due to several reasons. It is a public health concern, where mechanical disease transmission has been reported by Pharaoh ants (Beatson 1972) and deaths due to fire ant stings (deShazo et al. 1999). With regard to deaths attributed to fire ants, this represents a huge liability concern, and being able to identify ant species can be critical in alleviating fears and unnecessary treatments. Some pest ant species can be extremely invasive, where they may be a detriment to the biodiversity of habitats. Some examples of relatively recent introductions of invasive ants include red imported fire ants in California and the little fire ant, *Wasmannia auropunctata* (Roger), in Hawaii. Earlier invasions by the Argentine ant, *Linepithema humile* (Mayr), into the gulf coast states and California, and the white-footed ant, *Technomyrmex albipes* (Fr. Smith), in Florida and Hawaii have since increased in populations and are now serious problems.

With the need to control other ant species besides imported fire ants, several ant baits have been developed which target other pest ant species besides imported fire ants. Examples of such baits and their active ingredients are listed in Table 1. Note that many of the active ingredients were originally developed for imported fire ant baits.

Table 1. Examples¹ of commercially available baits for imported fire ants, for other ant species², and their active ingredients.

Fire Ant Bait	Active Ingredient	Ant Bait²	Active Ingredient
Amdro, Siege	hydramethylnon	MaxForce granules	hydramethylnon
Award, Logic	fenoxycarb	MaxForce FC	fipronil
Ascend, Clinch, Varsity	abamectin	Advance granular	abamectin
Extinguish	methoprene	Pharorid	methoprene
Distance	pyriproxyfen	Dual Choice, FluorGuard	sulfluramid
Bushwhacker	boric acid	Advance liquid	boric acid
Eliminator	spinosad	Dr. Moss's	boric acid
		Drax	boric acid
		Drax Liquidator	boric acid
		OutSmart	boric acid

¹Mention of trade names or proprietary products does not constitute an endorsement or recommendation for use by the U.S. Department of Agriculture.

²Imported fire ants may be included on label with other ant species.

Ant baits containing boric acid have been available for many years, but the percentage of active ingredient was usually around 5%. Research within the last decade has shown that liquid ant bait containing sucrose solution and a lower percentage of boric acid was effective against several

species of ants (Klotz and Moss 1996, Klotz et al. 1996). More recently, Klotz et al. (1998) have documented control of field populations of Argentine ants using a strategy of placing large volume bait stations on the exterior perimeters of buildings, and frequently replenishing these stations with a 0.5% boric acid in a 25% sucrose-water solution. Thus, we see a strategy of using a slow acting toxicant in a liquid attractant that is provided in high volume on the outside of structures. As a result, there has been an increase in commercially available liquid ant baits that contain 1% boric acid and also a variety of high volume bait stations that can dispense liquids. Studies have documented ant control with the exterior placement of numerous small bait stations (Forschler and Evans 1994, Oi et al. 1994, Blachly and Forschler 1996). However, high volume stations placed on the exterior of buildings at infrequent intervals may be more efficient to install and service, and may enhance the foraging efficiency of ants.

In addition to baiting, another approach to ant control is to reduce food sources utilized by ants. This strategy is being used against honeydew feeding ants such as Argentine or white-footed ants that have extraordinarily large outdoor populations. The strategy entails preventing ants access to aphids and other homopterans either by using insecticides as barriers to exclude ants from the homopterans or directly eliminating the honeydew producers. By removing a major food resource, it is thought that ant colonies will not develop huge, intolerable populations, and/or will move elsewhere. This approach can also be used to enhance feeding on baits. In essence, this tactic is a form of sanitation where favored food resources are made unavailable.

As mentioned previously, non-repellent contact insecticides with long residual activity was one of the early methods used against imported fire ants. Recently, broadcast applications of a granular formulation of fipronil have reportedly provided over one year of control of imported fire ants (Collins et al. 1999 unpublished interim report, Gulfport Plant Protection Sta. pp. 66-70). If this method of control is successful and widely used, there is a possibility that there will be a shift away from baiting as an ant control strategy, and a return to perimeter or even larger area treatments.

Finally, the use of self-sustaining biological control agents for ants are currently being evaluated for imported fire ant control. Phorid flies in the genus *Pseudacteon* have been released in several locations in the U.S. and to date have over-wintered in Florida at six of six release sites. Other locations in Louisiana, Alabama, and Mississippi have reported sightings of flies (S. D. Porter personal communication). The microsporidian (protozoan), *Thelohania solenopsae* has been recovered in 7 of 10 states where it has been introduced. Fluctuating reductions in fire ant populations have been documented in Florida over a 3-year period. This pathogen has been found naturally in several areas in Florida as well as in Mississippi, Texas, and Louisiana. If these biological control agents have a significant impact on imported fire ant populations, perhaps interest will be generated for future attempts to discover and release biological controls for other invasive pest ants.

As outlined above, ant control today has evolved, or more appropriately revolved, around some basic control tactics of contact insecticides, baits, and sanitation. Ant control research activity can provide an indication of the interest in ant control now and potential trends in the near future. "Formis99: Master Bibliography of Ant Literature" (currently being maintained by S. Porter & D.

Wojcik, USDA-ARS, Gainesville, FL) is an excellent database of ant literature that includes citations not available on most common literature databases. In the 1999 version there is a total of 28,871 citations. Using the search words "pest ant or control or management", 4,363 citations, or 15.4% of the citations, were listed. Figure 1 shows a general decline in the number of citations from the Formis99 database using the same search words for each year since 1990. However, there is an increasing trend in the number of ant presentations made in the Formal Urban Entomology Conference and in the Urban Entomology section at the annual meeting of Entomological Society of America since 1996 (Fig. 2) [Note that in 1998 ant and termite presentations were reduced probably because the ESA meeting coincided with the International Union for the Society of Social Insects meeting]. Similarly, there is an increasing trend in the number of submitted presentations on ants at the National Conference in Urban Entomology over the last five conferences (Fig. 3). In this year's meeting there were 7 submitted papers plus 2 invitational ant presentations. Thus, one can see an increase in research presentations on ants, and perhaps this will result in a reversal of the recent decline in pest ant control publications. A driving force for the increase in research activity/presentations on pest ants is increased funding. This is currently being illustrated in the imported fire ant research community, where universities in Arkansas, Texas, Alabama, Oklahoma, South Carolina, and Louisiana were appropriated extra funding by their state legislatures for imported fire ant research and extension. Correlated with these funding increases has been a rise in the number of presentations at the annual Imported Fire Ant Conference (Fig. 4). This rise can be directly attributed to research coming from the states with additional funding. With the 1998 discovery of imported fire ants in southern California, significant funding for fire ant control has been appropriated in this state resulting in increased research activity. Hopefully, the increase in fire ant research activity will expand to other pest ant species in the future.

With the increased interest in pest ants and their control, there is more potential for the development of new control strategies that account for the different biologies of individual pest ant species. Since most structure invading pest ants nest outdoors, ant control tactics will be directed toward the landscape. This approach will probably require more technical expertise and be more costly to implement. In contrast, the development of effective non-repellent, residual contact insecticides may result in ant control strategies reverting back to perimeter applications, requiring less expertise and implementation costs. A determining factor of which method will predominate, will be the duration of control. Ant control in landscapes may entail habitat modification, elimination of food sources, and baiting which presumably will result in long-term control. Profit from implementing and servicing such a program, as well as customer satisfaction, will determine if this type of control strategy is viable. If perimeter applications of residual insecticides provide control of similar duration as managing ants in landscapes and its use pattern is acceptable to the customer, then the simplicity of this method should make it the dominant ant control method. However, research on new active ingredients for either approach will most likely continue.

In conclusion, pest ant research seems to be gaining more interest as indicated by the increase in scientific presentations and the number of labs working on them. The renewed interest and funding for imported fire ant control may provide a base for the expansion of research to other

pest ants. With this expansion, it is important to remember the evolution of pest ant control to help guide future research.

Acknowledgments

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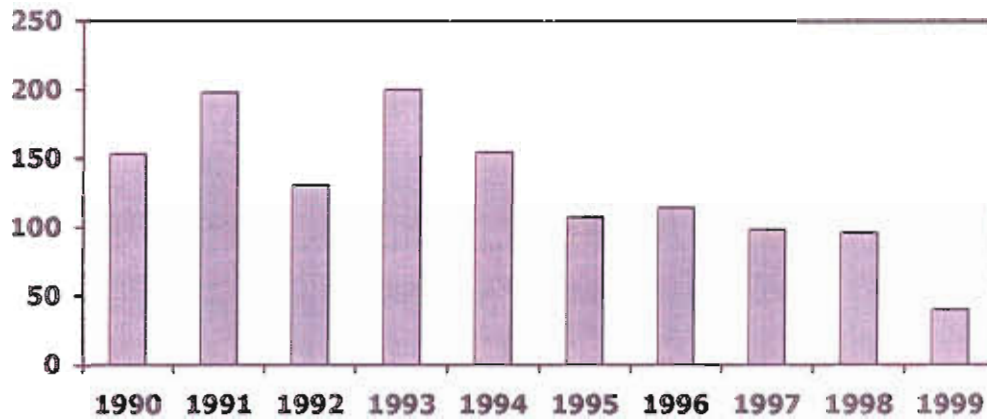


Fig. 1. Number of citations listed in “Formis99: Master Bibliography of Ant Literature” using the search words “pest ant or control or management” for the publication years 1990 to 1999.

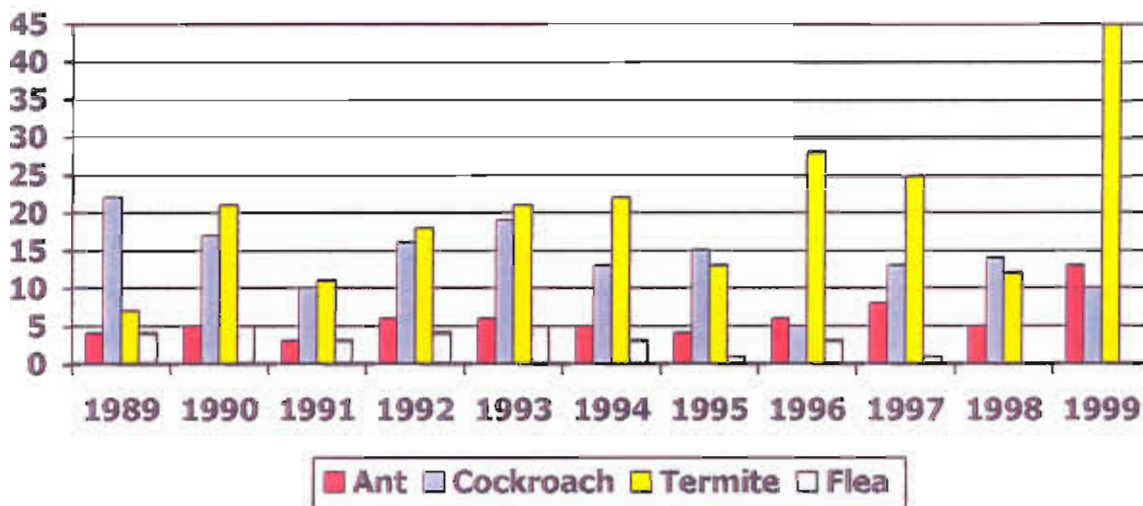


Fig. 2. The number of ant, cockroach, termite, and flea presentations made in the Formal Urban Entomology Conference and in the Urban Entomology section at the annual meeting of the Entomological Society of America (ESA) 1989 to 1999. Note that in 1998 ant and termite presentations were reduced probably because the ESA meeting coincided with the International Union for the Society of Social Insects meeting.

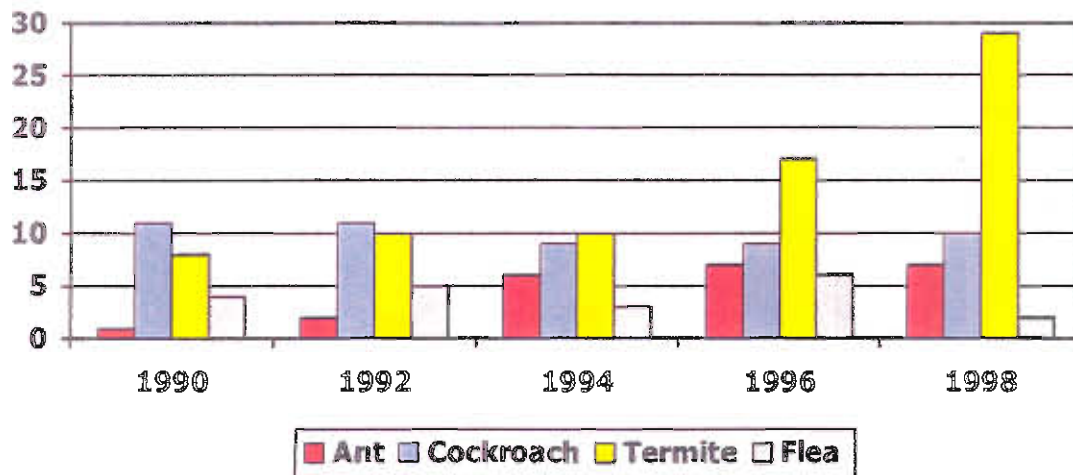


Fig. 3. Number of submitted presentations at the National Conference on Urban Entomology. In 1996 and 1998 ant presentations were allotted a separate section that was limited to a maximum of 8 presentations and were no longer grouped with fleas and other pests.

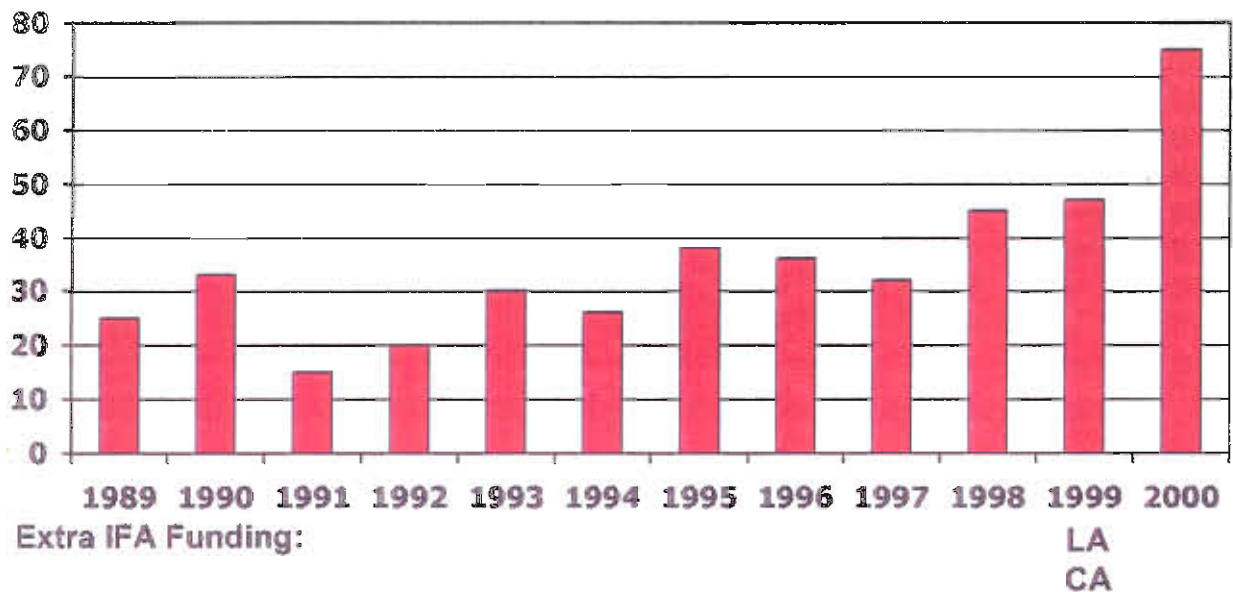


Fig. 4. Number of presentations at the Annual Imported Fire Ant Conference from 1989 to 2000. States with additional funding for imported fire ant control/education are listed under the year that funds initially became available.

REGIONAL PEST ANT SPECIES

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Ants have replaced cockroaches as the predominate pest of structures in most areas of the United States, particularly in residential environments. In the 2nd Edition of the *PCT Field Guide to the Management of Structure-Infesting Ants*, a total of 41 ant species are described as regular invaders of homes and businesses. Only a relative few of these could be considered serious structural pests. Which species are of most importance depends on the region of the country.

It is difficult to rate the top five ant species in the United States without dividing the country into regions. The regional lists included here were compiled by surveys of Terminix Technical Specialists around the country and other pest management professionals. Other published surveys were also consulted.

The United States was divided into the following regions:

New England—New York north to Maine

Atlantic Seaboard—From Virginia through Pennsylvania, north to New York

Southeast other than Florida—East Tennessee and Carolinas, east to Louisiana

Northern and Central Florida

South Florida

Midwest—Ohio north to Michigan and Minnesota, south to Tennessee, east to Oklahoma

Midsouth—West Tennessee, Northern Mississippi, and Arkansas

Texas

Southwest other than California—Arizona, New Mexico, and Nevada

Pacific Northwest—Idaho, Oregon, and Washington

Northern California

Southern California

Hawaii

New England

1. Black Carpenter Ant, *Camponotus pennsylvanicus*
2. Pavement Ant, *Tetramorium caespitum*
3. Larger Yellow (Citronella) Ant, *Acanthomyops interjectus*
4. Little Black Ant, *Monomorium minimum*

Alates of *Hypoponera punctatissima* have been reported several times in commercial buildings in Massachusetts and New York where they land on and sting persons in the building. These ants are transients carried north from Florida in the soil of potted tropical plants.

Atlantic Seaboard

1. Black Carpenter Ant, *Camponotus pennsylvanicus*
2. Pavement Ant, *Tetramorium caespitum*
3. Cornfield Ant, *Lasius alienus*
4. Odorous House Ant, *Tapinoma sessile*
5. Larger Yellow (Citronella) Ant, *Acanthomyops interjectus*

Richard Cooper of Cooper Pest Control notes that in New Jersey, *T. caespitum* and *L. alienus* are both significant pests of commercial structures. In residences, *L. alienus* is seldom seen, but *T. caespitum* is an important pest next to *C. pennsylvanicus*. *Camponotus nearticus* is also a carpenter ant commonly encountered. *T. sessile* is increasingly being seen in residences in New Jersey and is proving to be a difficult species to control. Sara Pettingill and Jerry Bukovsky of Terminix note the Pharaoh ant, *Monomorium pharaonis* is second in importance to *C. pennsylvanicus* in importance in Virginia. Sara also lists acrobat ants, *Crematogaster* spp., and *T. sessile* as top five pest species in Virginia. Chris Anfinson, also of Terminix, reports *M. pharaonis* and *T. sessile* as top five pests behind *C. pennsylvanicus* and *T. caespitum* in central Pennsylvania.

Southeast Other Than Florida

1. Argentine Ant, *Linepithema humile*
2. Red Imported Fire Ant, *Solenopsis invicta*
3. Black Carpenter Ant, *Camponotus pennsylvanicus*
4. Odorous House Ant, *Tapinoma sessile*
5. Crazy Ant, *Paratrechina longicornis*

In addition to *L. humile*, *C. pennsylvanicus*, and *T. sessile*, acrobat ants, *Crematogaster* spp., and the pavement ant, *Tetramorium caespitum*, are top five pests of structures in East Tennessee according to Jim Chase of Terminix.

Northern and Central Florida

1. Crazy Ant, *Paratrechina longicornis*
2. Ghost Ant, *Tapinoma melanocephalum*
3. Florida Carpenter Ant, *Camponotus floridanus*
4. Pharaoh Ant, *Monomorium pharaonis*
5. Red Imported Fire Ant, *Solenopsis invicta*

The above list was supplied by Dr. John Mangold and Chris Graham of Terminix. Ant diversity in Florida has been studied more widely in Florida than any other state (Klotz et al. 1995, Vail et al. 1994, Bieman and Wojcik 1990, Deyrup et al. 1988, Deyrup 1991) although many of these surveys pertain to all ants not just structure-infesting species. A survey by Klotz et al. (1995) analyzed samples provided by pest management professionals and found the same species as listed above as major pests. Their findings, however, showed *C. floridanus*, *P. longicornis*, and *S. invicta* to be the top three species. Dr. Mangold also reports the carpenter ant, *C. tortuganus* to also be of significance in many parts of Central Florida while he often sees the carpenter ant, *C. planatus* in the Bradenton and Sarasota area. Vail et al. (1994) list the black carpenter ant, *C.*

pennsylvanicus and the Argentine Ant, *Linepithema humile*, as major pests in northern Florida. This paper also notes that the big-headed ant, *Pheidole megacephala* can establish large extended colonies in some neighborhoods in central Florida. Acrobat ants, *Crematogaster* spp., and *Monomorium floricola* are also reported as infrequent but minor structural invaders. A survey by Bieman and Wojcik (1990) confirms these results.

South Florida

1. White-Footed Ant, *Technomyrmex albipes*
2. Ghost Ant, *Tapinoma melanocephalum*
3. Florida Carpenter Ant, *Camponotus floridanus*, *C. tortuganus*
4. Red Imported Fire Ant, *Solenopsis invicta*
5. Crazy Ant, *Paratrechina longicornis*

Klotz et al. (1995) and Bieman and Wojcik (1990) list the same ants as major pests but did not show *T. albipes* as a major pest. This species has become a serious pest since these surveys were completed. Vail et al. (1994) report the robust crazy ant, *Paratrechina bourbonica* is a major pest in South Florida. Ann Russell of Terminix confirms the observation of this paper that the big-headed ant, *Pheidole megacephala*, is a significant pest in many parts of this region. *Brachymyrmex* spp. alates become pests in South Florida by flying to swimming pools by the hundreds. The little fire ant, *Wasmannia auropunctata*, is widely spread in South Florida but is a minor pest being encountered most often outdoors on trees and shrubs.

Midwest

1. Black Carpenter Ant, *Camponotus pennsylvanicus*, *C. herculeanus*
2. Carpenter Ant, *Camponotus herculeanus*
3. Pavement Ant, *Tetramorium caespitum*
4. Odorous House Ant, *Tapinoma sessile*
5. Larger Yellow (Citronella) Ant, *Acanthomyops interjectus*

C. herculeanus is reportedly the second most common carpenter ant pest species in Minnesota (Hansen 1995). Dr. Mike Potter of the University of Kentucky reports *T. sessile* as an increasingly important and difficult to control species in Kentucky. He also notes infestations of Pharaoh ants, *Monomorium pharaonis*, are not uncommon in that state and reports several species of field ants of the genus *Formica* are common yard pests in Kentucky and are often misidentified as carpenter ants. Cameron Renn of Terminix lists *M. pharaonis* and acrobat ants, *Crematogaster* spp., among his top five in Ohio and Michigan. Jim Billings of Terminix lists the cornfield ant, *Lasius alienus*, and the little black ant, *Monomorium minimum*, as pest species in Illinois.

Midsouth

1. Odorous House Ant, *Tapinoma sessile*
2. Red Imported Fire Ant, *Solenopsis invicta*
3. Acrobat Ants, *Crematogaster* spp.
4. Little Black Ant, *Monomorium minimum*
5. Pharaoh Ant, *Monomorium pharaonis*

David Pence of Terminix lists the Argentine ant, *Linepithema humile*, as a top pest, but it is more evident further east in Tennessee and into Mississippi and Alabama. *T. sessile* is the predominant pest. The author has found a number of carpenter ant species, *Camponotus*, in this region, but they are infrequent invaders despite their common presence outdoors around homes. He has also found the small honey ant, *Prenolepis imparis* and big-headed ants, *Pheidole* spp., inside structures on a number of occasions. *S. invicta* is a recent newcomer to West Tennessee and central and northern Arkansas within the past decade and is increasingly becoming a serious pest of yards and homes.

Texas

1. Red Imported Fire Ant, *Solenopsis invicta*
2. Pharaoh Ant, *Monomorium pharaonis*
3. Crazy Ant, *Paratrechina longicornis*
4. Carpenter Ants, *Camponotus pennsylvanicus*, *C. ferrugineus*
5. Little Black Ant, *Monomorium minimum*

Like Florida, Texas has a wide diversity of ant species. The Argentine ant, *Linepithema humile*, may be encountered in parts of the state, particularly in and around Dallas-Fort Worth, according to Mike Kilpatrick of Terminix. From central to west Texas, harvester ants, *Pogonomyrmex* spp., may be found damaging lawns. Field ants of the genus *Formica* are also common in yards and landscaping where they may be confused with carpenter ants. In the Houston area, big-headed ants, *Pheidole* spp., are sometimes found inside structures. In central Texas from San Antonio north through Waco, the Texas leaf cutter ant, *Atta texana*, may be encountered as a serious threat to trees and shrubs in landscape beds.

Southwest Other Than California

1. Pavement Ant, *Tetramorium caespitum*
2. Harvester Ants, *Pogonomyrmex* spp.
3. Southern Fire Ant, *Solenopsis xyloni*
4. Crazy Ant, *Paratrechina longicornis*
5. Argentine Ant, *Linepithema humile*

Kyle Jaber of Terminix reports in New Mexico that carpenter ants, *Camponotus* spp., are a primary pest along with *T. caespitum* and *Pogonomyrmex* spp. He states odorous house ants, *Tapinoma sessile*, are a common pest and the Pharaoh ant, *Monomorium pharaonis*, are a minor pest. He has seen one confirmed case of *P. longicornis* in the Albuquerque area. In Arizona, Doug Seeman of University Pest Control in Tucson notes that big-headed ants, *Pheidole* spp., *T. sessile*, and the ghost ant, *Tapinoma melanocephalum*, have invaded homes in that city. He has participated in an eradication program for the red imported fire ant, *Solenopsis invicta*, in Yuma. He notes carpenter ants, *Camponotus* spp., are generally pests at higher elevations in Arizona. Steve Jenschke of Terminix also reports the little black ant, *Monomorium minimum*, to be a pest in Phoenix. In Las Vegas, *L. humile* is the predominate pest species and *T. caespitum* is the second most important according to Mary Lou Seely of Terminix.

Pacific Northwest

1. Carpenter Ant, *Camponotus modoc*
2. Carpenter Ant, *Camponotus vicinus*
3. Odorous House Ant, *Tapinoma sessile*
4. Pavement ant, *Tetramorium caespitum*
5. Field Ants, *Formica* spp.

Lonnie Anderson of Terminix and Dr. Laurel Hansen of Spokane Community Falls College both list "moisture" ants of the genera *Lasius* and *Acanthomyops* as common structural pests. Three to four species of *Lasius* are associated with nest-building in moist areas associated with leaks in homes. Lonnie Anderson also reports the Pharaoh ant, *Monomorium pharaonis*, and the ghost ant, *Tapinoma melanocephalum*, as pest species encountered in this region. Dr. Hansen also mentions the small carpenter ant species, *C. essigi*, as a commonly-encountered structural invader. The pine tree ant, *Liometopum luctuosum*, has been reported invading homes in Idaho.

Northern California

1. Argentine Ant, *Linepithema humile*
2. Velvety Tree Ant, *Liometopum occidentale*
3. California (Southern) Fire Ant, *Solenopsis xyloni*
4. Carpenter Ant, *Camponotus modoc*
5. Odorous House Ant, *Tapinoma sessile*

According to Lonnie Anderson of Terminix, the Pharaoh ant, *Monomorium pharaonis*, is encountered but is considered a minor pest. The Argentine ant is overwhelmingly the most pervasive pest of structures. *C. modoc* is common at higher elevations but not in the valleys. He also reports the ghost ant, *Tapinoma melanocephalum*, has been found in Redding and Eureka, California. A survey by Knight and Rust (1990) showed *Camponotus* spp, *L. humile*, and *T. sessile* to be the top three pest ants in Northern California.

Southern California

1. Argentine Ant, *Linepithema humile*
2. Harvester Ants, *Pogonomyrmex* spp.
3. California (Southern) Fire Ant, *Solenopsis xyloni*
4. Pharaoh Ant, *Monomorium pharaonis*
5. Red Imported Fire Ant, *Solenopsis invicta*

Dr. Hanif Gulmahamad of Terminix notes more than 90% of ant calls in Southern California are for Argentine ants. The other species are less common overall but may be significant pests in certain areas or neighborhoods. *S. invicta* has recently become established in the state and is expanding its range. He also notes the velvety tree ant, *Liometopum occidentale*, and the odorous house ant, *Tapinoma sessile*, are common house invaders in some areas. Knight and Rust (1990) found *L. humile* to be the predominate pest species seconded only by *S. xyloni*.

Hawaii

1. White-Footed Ant, *Technomyrmex albipes*
2. Carpenter Ant, *Camponotus variegatus*
3. Tropical Fire Ant, *Solenopsis geminata*
4. Ghost Ant, *Tapinoma melanocephalum*
5. Glaber Ant, *Ochetellus glaber*

This list was provided by Dr. Niel Reimer of the Hawaii Department of Agriculture. He notes that all these species are found throughout the islands except for *O. glaber* which is confined to Oahu. He notes the Argentine Ant, *Linepithema humile*, is found on Oahu at higher elevations and that the big-headed ant, *Pheidole megacephala*, is widespread outdoors but is an infrequent invader of buildings. Two species unique to Hawaii as pest ants are the long-legged ant, *Anoplolepis gracillipes*, and the “tiny yellow house ant,” *Plagiolepis alluaudi*.

As these lists demonstrate, the most important pest species may vary greatly from region to region, state to state, and even from different parts of the same city. Much of the information related here is anecdotal based on pest management professionals’ experience in working in these areas but this fact does not lessen the value of the information.

If one were to attempt to ascertain the top pest ants in the United States, it still would be important to regionalize the list. Across the northern U.S., the species of most importance would be two carpenter ant species, *Camponotus pennsylvanicus* and *C. modoc*, and the pavement ant, *Tetramorium caespitum*. In the southeast, the red imported fire ant, *Solenopsis invicta*, the crazy ant, *Paratrechina longicornis*, and the Argentine ant, *Linepithema humile*, are the predominate pests. In the southwest and west, the Argentine ant and the southern fire ant, *Solenopsis xyloni* are the most important. In 15 to 20 years, however, *S. invicta*, may be the species most talked about in the Southwest.

It would be prudent and interesting to organize and complete a national survey of structure-infesting ants. Such a survey should focus on those ants actually collected from inside buildings. The survey would be of most value if samples were collected each month by each participant over a period of several years. Identifying and cataloging the thousands of samples would be a daunting task. The hazards in such a survey is the necessary reliance on professionals who may prove negligent on keeping sound collection data given their busy, and often hectic, schedules. The author may undertake such an effort in the future and may call upon many of you reading this article for assistance.

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IDENTIFICATION GUIDE TO PEST ANTS OF PENINSULAR FLORIDA

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Pest control operators often have to make insect identifications in the field without the use of microscopic aids or dichotomous keys. However, researchers, once familiar with groups of insects, use a field characteristic gestalt not found in dichotomous keys or published species accounts to identify species by site as they fly, or forage, or feed in the field. We have developed a field guide to pest ants of Florida that uses such field characteristics, including behavior, movement, and color, instead of morphological characteristics that require microscopic inspection. With original photographs of ants and important field characteristics plus original illustrations and up-to-date distribution maps this guide uses unique methods to help PCOs identify ants while in the field. This method should prove to be simple and useable to both experienced and inexperienced people in the pest control industry.

BRACHYMYRMEX PATAGONICUS AND *B. DEPILIS*:
UNWELCOME HOUSEPESTS IN LOUISIANA

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In 1998 and 1999, pest control operators and county agents called about or sent vials of *Brachymyrmex* to LSU for identification and information. Because this occurred with increasing frequency and because our sampling indicated that these ants were present throughout Louisiana, we began to investigate the ants of this genus. The objectives of this study were to determine the seasonal occurrence of *Brachymyrmex* in an urban area of Baton Rouge and also to determine the food preferences of these species during the year. Once a month, we placed food traps in the front and back yards of 24 residences in greater Baton Rouge. Four different food items, Vienna sausage, peanut butter, honey, and ant diet (Hooper and Rust 1997), were placed in 20 ml scintillation vials. These food traps were opened and placed in yards for 2-4 h after which they were picked up and capped with the ants trapped inside. Sixteen species of ants were trapped in this year-long study. We collected data on the number of individuals at the traps, the seasonality of the appearance of each species, and the type of food the ants fed on during the study.

Brachymyrmex sp. c.f. *patagonicus* and *B. depilis* were two ants that we commonly found in the food traps. *Brachymyrmex patagonicus* and *B. depilis* are formicine ants that are characterized by small size and nine antennal segments without a club. Further investigation showed that both of these ants infest houses in the Baton Rouge area, with *B. patagonicus* being most common. Eight of ten homes in greater Baton Rouge being treated by a pest control operator for red imported fire ants also had heavy infestations of *Brachymyrmex* that led to customer complaints. These ants will forage into kitchens and bathrooms for water and will infest light sockets and electrical receptacles.

Brachymyrmex patagonicus was present in our food traps every month the study was conducted while *B. depilis* was present after the first two months for the remainder of the study. Both species rarely came to peanut butter. Only *B. patagonicus* was found in the ant diet trap and was most often found at the ant diet trap in August, September, and October. The presence of *B. patagonicus* at the ant diet may be seasonal but also could be due to the reduction of red imported fire ants in the area, since the area had been treated with broadcast granular baits. Both *Brachymyrmex* species were found foraging on Vienna sausage throughout the study with number of individuals being highest in August, September, and October. Honey was attractive to both species throughout the study and the greatest number of individuals of both species were found in the honey traps.

Pest control operators have expressed frustration in controlling *B. patagonicus* and *depilis*. Some contact insecticides are ineffective against *B. patagonicus* and *depilis*, while others can be effective if applied correctly. Since honey is preferred by *B. patagonicus* and *B. depilis* throughout the year, it may serve as a promising bait-base for the control of *Brachymyrmex* in Louisiana.

ARE SMALL ANTS BEST AT GETTING BIG FOOD? A TEST OF FORAGING THEORY USING ARGENTINE ANTS, *LINEPITHEMA HUMILE*

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Some foraging models predict that mass-recruiting ant species will more efficiently gather food from a few large resources than from many small, dispersed resources. In order to test this model, we allowed eight small laboratory colonies of the Argentine ant to forage in a 1.3 x 1.3 m arena containing either two adult male or 16 early instar German cockroaches that were randomly placed in the arena. We found that ant colonies sent similar numbers of workers into the foraging arena during the recruitment process, but returned a greater mass of food (86.1 mg vs. 40.4 mg) to the center of the arena from the small, dispersed resources than from the large resources. We attributed this difference to a difference in ant behavior at the different sized prey: individual ants tended to carry small prey back to the nest, but merely fed on large prey. Because individual ants readily carried much more weight in prey (4-9 mg) than they ingested (0.2 - 0.3 mg), they retrieved a greater mass in prey through carrying than through ingesting. Foraging models that predict food retrieval efficiency at different food densities may have to incorporate different retrieval behaviors for different food particle sizes.

COMPARATIVE ACCEPTANCE OF GEL AND LIQUID BAIT COMPOSITIONS BY ARGENTINE ANTS

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Liquid ant bait compositions are generally accepted by a broad spectrum of household ant species. Toxicant/sugar solutions are particularly amenable to being dispensed in this manner. However, liquid bait formulations suffer drawbacks, such as product loss and environmental hazards due to spillage. Suspension of the formulation within a gelatinous matrix should overcome the above drawbacks without substantially altering the palatability of the bait. To gain some understanding of how bait composition might affect retrieval and delivery of a toxicant to an ant colony, we compared the acceptance and consumption of 25% sucrose in gel and liquid matrices by the Argentine ant, *Linepithema humile*, in the laboratory.

One gel attracted 71% of the ants and this was used in all subsequent gel v liquid comparisons. Counts of workers feeding on the gel were significantly higher than those at the liquid. However, more than twice as much liquid sucrose was removed than gel through 5 days. Furthermore, *L. humile* workers resided at the gel bait 8 times longer than at the liquid, yet captured workers moving from the gel to the colony were 1/5 the weight of those returning from the liquid composition, indicating that sucrose removal from the gel required greater effort. Only when the gel was placed next to the colony and the liquid 8 meters away was there greater gel consumption. We have demonstrated that a gel matrix may not be a suitable alternative to a liquid form for toxicant delivery to Argentine ants, and perhaps other ant species. We also

suggest that counts of ants on and around a bait matrix may not provide an accurate assessment of bait acceptance.

A STUDY OF THE FOOD PREFERENCES AND FEEDING STRATEGIES OF *TETRAMORIUM BICARINATUM* NYLANDER (HYMENOPTERA: FORMICIDAE)

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This study was conducted to determine the food preferences and feeding strategies of *Tetramorium bicarinatum* Nylander. The objectives of this study were: to determine if *T. bicarinatum* could distinguish between a high (10%) and a low (1%) sucrose solution, to establish a preferred food particle size for *T. bicarinatum*, to discover a preferred food source among proteins, lipids, and carbohydrates, and to determine if *T. bicarinatum* would switch food sources when a more desirable food source is discovered after a least desired one. This species showed a distinct preference for the higher sucrose concentration. Foraging effectiveness is maximized when high-energy foods are preferentially collected. *Tetramorium bicarinatum* showed a preference for the largest particle size. Baits designed specifically for this species should include large particle sizes. Protein enriched bait was preferred. This type of food source is necessary for brood development. *Tetramorium bicarinatum* switched from the least preferred food source that was discovered first to the more preferred even when it was discovered later. This has far reaching implications for bait development. Baits prepared with preferred food sources will be fed upon regardless of the natural food sources available.

FIELD-PROVEN IPM PROGRAM EFFECTIVELY MANAGES THE WHITE-FOOTED ANT IN SOUTH FLORIDA

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The white-footed ant, *Technomyrmex albipes* (Fr. Smith), is a tramp-ant species that was recently introduced into Florida. A native of Asia, it was first identified by Mark Deyrup in 1990, but was actually collected earlier from a nursery in south Florida in 1986.

This species is considered a tramp ant because of the biological and reproductive habits it exhibits. It reproduces by swarming and/or budding, and a form called an "intercaste" which can consist of up to ca. 50% of the colony, is capable of laying viable eggs. Other individuals in the colony lay soft, jelly like eggs called trophic eggs which are fed to non-foraging workers and immatures in the colony. A search for an insecticidal compound capable of transovarial transmission is being conducted, but no compound has been shown to pass into these trophic eggs thus far. It can colonize just about any habitat, and is particularly attracted to habitats disturbed by human activity. It is an arboreal species primarily, but is commonly found nesting in aboveground areas in homes and businesses, and can be found many times in attics under

rolled insulation. It also nests in tree holes, under loose bark, in abandoned galls, palm tree crowns and many other areas in the landscape. This species does consume some dead insect protein, but exists primarily on honeydew and nectar found in the landscape around infested homes. They do not sting, but the sheer numbers often found in colonies (ca. 400,000-1,000,000 individuals) make it pestiferous. It is found mainly in south Florida, but is spreading northward.

Effective cultural controls exist and include trimming trees and shrubs away from structures, eliminating vegetation in a band around the structure and indoor and outdoor sanitation. These practices are often difficult to put into practice at many homes, however. Chemical control is often difficult because of the huge numbers of individuals in the colony, and their propensity to bud or split the colony if they encounter repellent pesticides such as pyrethroids. This species is very dependant upon honeydew as a food source, however, and when the honeydew producing insects such as aphids, mealybugs and scales are removed from the landscape plantings by way of a foliar treatment of imidacloprid (Merit 75WP at 1 teaspoon of formulation/10 gallons of water with an average volume of ca. 25 gallons finished solution per home) the white-footed ant population is drastically reduced to manageable levels. This compound applied foliarly is absorbed into the plant and exhibits translaminar movement in the leaf tissues. It is non-repellent to the ants, and will therefore not interfere with liquid ant baiting systems that are often used in managing this insect. Trails of ants may be treated sparingly with a contact insecticide, to provide some immediate relief to the homeowner, but care must be taken to avoid overuse of pyrethroids which can splinter the colony and make control more difficult.

This system was tested in South Florida and the treated homes averaged ca. 75% reduction in numbers of white-footed ants. Subsequently, an area wide program at 11 locations of Sears Termite and Pest Control Inc. in south Florida using this system showed that callbacks were reduced by ca. 27% over the previous year.

The white-footed ant is an exotic tramp ant species causing problems in south Florida, and is rapidly expanding into other areas of the state. Conventional control measures using contact pesticides have proven unsatisfactory due to the ants' ability to bud or split the colony when disturbed. An application to the landscape of imidacloprid, a non-repellent insecticide that controls honeydew producing insects, however, can reduce the population to a much more manageable level. Small plot research resulted in significant population reductions and an area wide program with a national pest control company showed that the program resulted in a ca. 27% reduction in callbacks.

EDUCATING THE PUBLIC ABOUT FIRE ANT CONTROL: A FIRE ANT CAMPAIGN IN DALLAS, TEXAS

M.E. Merchant, S.A. Russell and R. Porter
Texas Agricultural Extension Service / Texas A&M University System

Successful control of the red imported fire ant, *Solenopsis invicta*, has been technically feasible since the development of slow-acting fire ant baits in the early 1980s. In an earlier study, less than 20% of north Texas homeowners were satisfied or very satisfied with their ability to control

fire ants. The Texas Two-Step method for fire ant control was developed in 1992 to help consumers understand how to use fire ant insecticides most effectively. A public awareness campaign was begun in 1999 to increase awareness of the Texas Agricultural Extension Service as a source of technical assistance on how to control fire ants. Campaign components included billboard ads, banners on public buses, a telephone hotline, posters in shopping malls, theatre ads, and neighborhood demonstrations. In addition, a statewide telephone poll was conducted in the winter of 2000 to assess public awareness of the Two-Step Method. Poll results are reported and factors affecting the success of a large-scale public awareness campaign are discussed.

Cockroaches

Ballroom South

Moderator

**Deanna Branscome, Department of Entomology
University of Florida, Gainesville, FL**

INTEGRATED COCKROACH CONTROL IN ANIMAL PRODUCTION SYSTEMS

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Cockroaches have long been recognized as important pests in human-inhabited structures, and severe infestations have been associated with disease transmission and allergen dissemination. Although cockroaches also infest animal-inhabited structures, such as zoos, pet shops, and livestock production farms, such as swine production, little work has been reported on strategies to mitigate such infestations. Swine production is an important component of the agricultural economy of several states including North Carolina, and most swine are raised in confinement in structures. The favorable indoor habitat and an abundance of food and water can sustain large populations of pest cockroaches. However, management of cockroach populations is severely constrained by many factors including: cultural and production practices used at the facility, poor sanitation and building design, as well as frequent re-introduction of cockroaches by workers and suppliers. In addition, regulatory restrictions on the types and classes of pesticides that can be used in such facilities frequently result in overuse of a narrow spectrum of chemicals, increasing the potential for insecticide resistance in the cockroach population. The overall goal of this project was to document and demonstrate reduced-risk integrated pest management approaches in confined swine production systems. Central to the philosophy of integrated pest management (IPM) is the idea that treatment should be based on need. Yet, current cockroach suppression practices continue to rely heavily upon multiple scheduled applications of broad-

spectrum insecticides with little concern about pest population size. This is due primarily to lack of efficient detection and monitoring tools for cockroaches. Therefore, a major motivation of our research was to study the utility of visual inspections in the implementation of IPM principles in managing cockroaches. Specific objectives included identification of available pest management alternatives for broad-spectrum pesticides, developing and evaluating these alternative approaches for integrated pest management, demonstrating the efficacy of this program, and quantifying reduction in risks to animal and human health and the environment. The ultimate goal of this study will be to deliver an education program to production managers to allow them to implement an effective site-based pest management strategy.

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COCKROACH BAITS: DO WE HAVE THE MAGIC BULLET?

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Although insecticidal baits for cockroach control have been in use for many decades, it wasn't until the mid 1980's that the direction in German cockroach control shifted from residual liquid deposits towards baits. Although a fair amount is known about cockroach baits (reviewed in Reiersen 1995), we will briefly discuss some additional topics, which may shed further light on this increasingly popular control strategy.

Bait use and pest status – a link?

Is there a link between bait use and the presumed decline in the pest status of the German cockroach relative to other urban insects? Clearly, bait use has increased. In the past 10 years bait usage by PCO's went from 7% in 1989 to over 25% last year. During the early 1980's there was some skepticism about baits performing well alone. Consequently, they were used as an add-on to liquid residuals. With the published data on many of the commercially available baits being generally positive, the level of confidence is such that they are used in stand-alone applications.

From our experience, and from speaking with some other researchers that conduct efficacy trials, a successful bait treatment often results in a long interval before an apartment can be used again – sometimes a year or more. This is because cockroaches have either been wiped out, or their numbers have been reduced so drastically that a population rebound takes a very long time. A link between bait use and decline in German cockroach pest status is quite possible.

Why the shift towards baits?

What are some reasons for the shift towards baits? Probably first and foremost is that they work, due to the discovery of active ingredients with proven effectiveness, such as hydramethylnon, abamectin and fipronil.

Baits are also more acceptable from a regulatory standpoint because they limit toxicant exposure to non-target organisms compared with liquid insecticides. This is particularly true of containerized baits. In addition, no uniform coverage of surfaces by insecticide is required, therefore kitchen items do not need to be disturbed.

What makes a bait AI efficacious?

What is it that makes an insecticide perform well as a bait active? The actives that work well kill cockroaches within 1-3 days. Although the exact reasons are unknown, those AI's that kill quickly generally do not perform well in baits. Also, actives such as juvenoids, which take longer than several days to affect an individual, require an unusually long time to reduce the cockroach infestation.

A toxic dose should be acquired within a few visits, otherwise competitive food within the cockroach's environment could dilute the effect of the toxicant. An obvious critical factor is that the palatability of the bait base not be reduced by the active ingredient.

Although it is hard to pin down the contribution of horizontal transmission (secondary kill) to bait performance, the actives that are transmitted in this manner, especially hydramethylnon, perform well. Kopanic and Schal (1997) recently demonstrated, in a modified field experiment, that the impact of horizontal transmission on less mobile yet very abundant 1st instar nymphs was very great. They regard this form of insecticide translocation as a key factor in German cockroach population suppression.

What have we learned about bait application?

Conventional cockroach control by PCO's prior to the introduction of baits utilized monthly treatments. That was in part due to relatively short AI residual activity. An effectively formulated bait will suppress cockroach populations at least until all the bait is consumed, and in general a highly suppressed population could take a month or longer to rebound, even without any bait.

Since German cockroaches will generally not travel great distances from harborage to food, it is better to hedge ones bet by applying many smaller deposits than few large bait deposits. Appel and Benson (1995) determined that the same quantity of abamectin bait distributed in 50 deposits performed better than 12 deposits.

How precise should bait placement be? It is generally thought that placement within a corner or against an edge is better than away from an edge. But in reality how much food available to

cockroaches occurs in corners or edges? And which of the many edges and corners should be treated?

To test the hypothesis that precisely placed bait along presumed cockroach runways will get more visitation, and ostensibly greater consumption, we pre-weighed baits and placed them in many locations within several apartments, either within a corner or 25 cm from a corner. When bait consumption was determined after 1 and 5 days, we found that there was no difference in the amount of bait consumed (ANOVA $p > 0.05$) (Fig. 1). This may also translate to no difference in the level of control.

How can bait performance be compromised?

Clearly, in order for baits to continue to perform well, resistance issues will always have to be dealt with. There has been limited evidence of decline in bait performance due to physiological or biochemical resistance. Schal (1992) demonstrated in laboratory assays high levels of sulfluramid resistance in field populations. Presumably the removal of sulfluramid as a cockroach bait active ingredient indicated that field performance declined as well.

Hydramethylnon has been used as a bait active for many years, with no evidence of resistance development. Does it have to do with the site of action being within the electron transport chain – a site, which is highly, conserved evolutionarily thereby having little genetic heterogeneity? Sulfluramid also blocks electron transport and energy flow, yet resistance occurs. Therefore, this factor may not be responsible for hydramethylnon's continued success. High levels of abamectin resistance have been reported in houseflies and some other arthropods (Scott 1995), yet there's no published evidence that cockroach control has been compromised due to resistance. However, the appearance of resistance in other arthropods indicates that the potential exists for resistance development in *B. germanica*.

Likewise, fipronil is a relatively new bait active with no published evidence of bait failures due to resistance. Yet cross resistance to cyclodiene insecticides such as dieldrin have been reported, and this cyclodiene resistance persists despite cyclodiene use in this country ceasing many years ago (Bloomquist 1994).

Can changes in insect behavior be selected for by baits? Ross reported recently that the progeny of survivors fed a chlorpyrifos bait consumed little of this same bait or chlorpyrifos in a completely different matrix, compared with a wild-type strain. This response is indicative of behavioral resistance to the active ingredient. So, clearly, German cockroaches have the inherent ability to detect and avoid consuming an active ingredient.

Aversions to inert ingredients can also be selected for, as we have demonstrated earlier (Silverman and Bieman 1993). We found that two different corn syrups in a bait matrix did not change the performance of a hydramethylnon bait to a laboratory strain. However, a field strain survived bait treatment containing one of the corn syrups. The surviving strain (T-164) did not feed on one of the corn syrups (corn syrup 2) because it contained the monosaccharide glucose

(Fig. 2). Clearly the potential for genetically-based aversions to other inert ingredients exists if we find rejection of an important nutrient such as glucose.

The question - what happens if a bait gets sprayed by a residual liquid? - has been raised on several occasions. Robinson (1998) determined in a laboratory study that hydramethylnon gel bait was not compromised by direct applications of liquid and dust formulations. This may also be true under field conditions. However, we question the need to apply more than one type of insecticide in the first place. Why spray after baits have been placed? Except perhaps under extremely high population conditions, it should not be necessary to supplement baits with liquid or dust formulations.

Sanitation (competitive food) and bait performance

Can poor sanitation reduce the performance of baits? Possibly the greatest contributor to poor sanitation is the abundance of competitive food, which could reduce bait consumption. We conducted a study where dog chow was placed in numerous locations within apartments. One day later, fipronil bait stations were placed next to each of these dog chow pieces, then we determined whether this extra food reduced bait performance.

The addition of the dog chow did not reduce bait performance (ANOVA $P > 0.05$). The same reductions in population counts occurred at two days post-treat and 22 days post-treat whether dog chow was present or absent (Fig. 3). It is quite possible that the bait matrix was preferred to the dog chow. Food deposits that are more palatable than baits may be consumed at the expense of the bait.

Is bait efficacy sensitive to population levels?

We reviewed data from several hydramethylnon bait trials in apartments with a range of pre-treatment trap counts from 10 to ca. 9,000. With up to 24 bait trays per kitchen only slight mortality differences were observed at the 3 month post-treatment count (slope not different from 0). Even the highest population levels were reduced nearly 100%. Therefore, except under the most extreme circumstances, properly formulated baits should adequately reduce cockroach populations.

Can baits be substantially improved upon?

There are already commercial formulations available that are highly palatable to German cockroaches – and very efficacious. What else can be done?

It used to be thought that German cockroaches could not detect food odors over a distance greater than a couple of inches – yet traps with certain food materials trap more cockroaches than those without. It is generally recognized now that German cockroaches can orient to food odors over some distance.

Presumably, an effective attractant that did not deter feeding should improve the performance of a bait, and perhaps reduce the number of bait deposits needed for control. However, there is no field evidence for attractants that improve bait performance. Being fairly omnivorous, there are probably no single food-based odors that would attract a cockroach from a great distance. Consequently, it would be difficult for industry to commit a large effort to identify a unique attractant when R&D costs are unlikely to be offset by increased sales or product price.

Biological insecticides can improve the margin of safety in baits, however, results with currently available formulations of fungi and nematodes in bait-like dispensers have been disappointing, due in part to poor product stability.

Juvenoids and urate inhibitors are toxic to cockroaches, however, baits with these biologically-based actives need to be in place for weeks before cockroach reductions are evident.

Some chemistry unique to cockroaches may provide better paths to bait control success. For example materials derived from male tergal gland secretions may have promise as bait components. Females feed on the secretions before mating. The content of these secretions influences a female's decision to mate with a male. The "right formulation" might be a food that virgin females would seek out. There is no better stage to eliminate than virgin females; there is no population growth without them.

Why do we think the future is bright for baits in cockroach control?

Clearly the trend towards baits and away from residual liquids in cockroach control suggests that at least the near future looks promising for baits. We believe that this trend will continue because 1) we know the characteristics required for an efficacious active ingredient. Therefore, new chemistries that have these characteristics should be considered as bait AI's. 2) A broad range of inert mixtures should be effective against the relatively small complex of omnivorous pest cockroaches. 3) Researchers, manufacturers, and PCO's have developed a healthy respect for the German cockroach and understand that pest population changes due to resistance can render a once effective product ineffective. We currently have the tools to identify and respond to physiological and behavioral resistance issues. Finally, it is difficult to imagine the regulatory climate changing to one where more insecticide is better. Clearly, focused insecticide applications towards the target pest and away from non-target organisms are what we all should be working towards. The baiting strategy is an effective way to meet this objective.

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Fig. 1. Effect of bait location on consumption

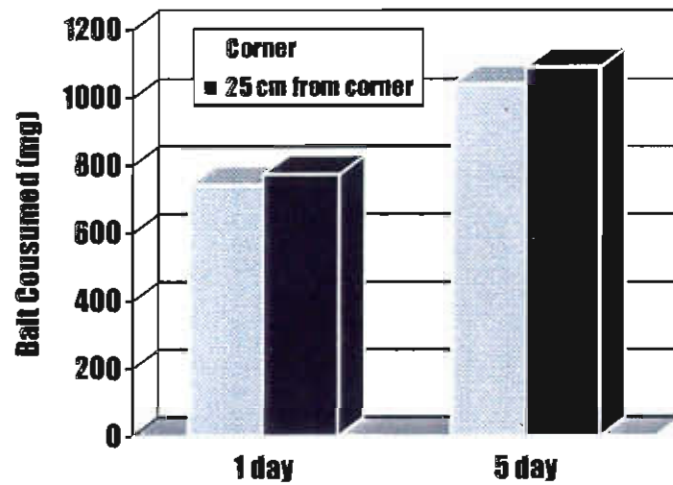


Fig. 2. Effect of corn syrup on bait performance against *B. germanica*

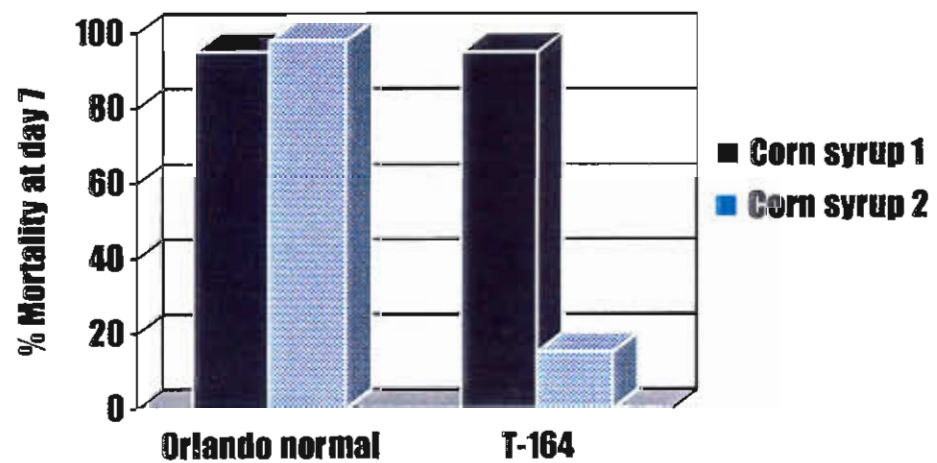


Fig. 3 Effect of added food on population reduction

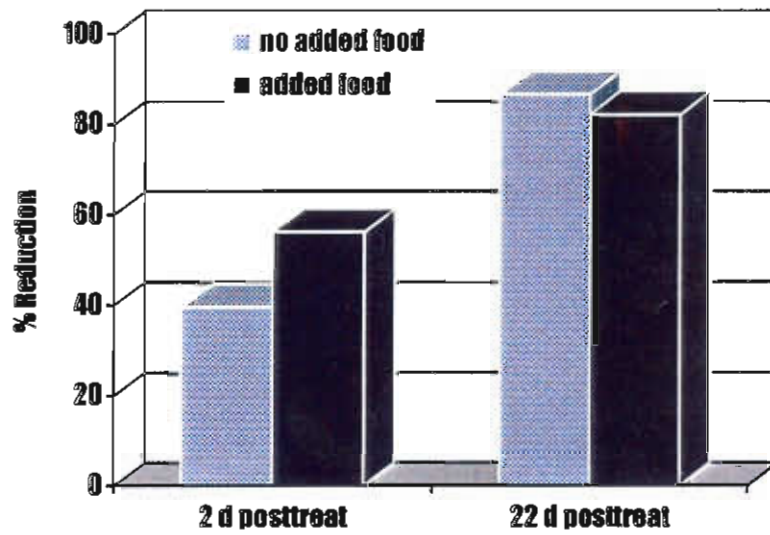
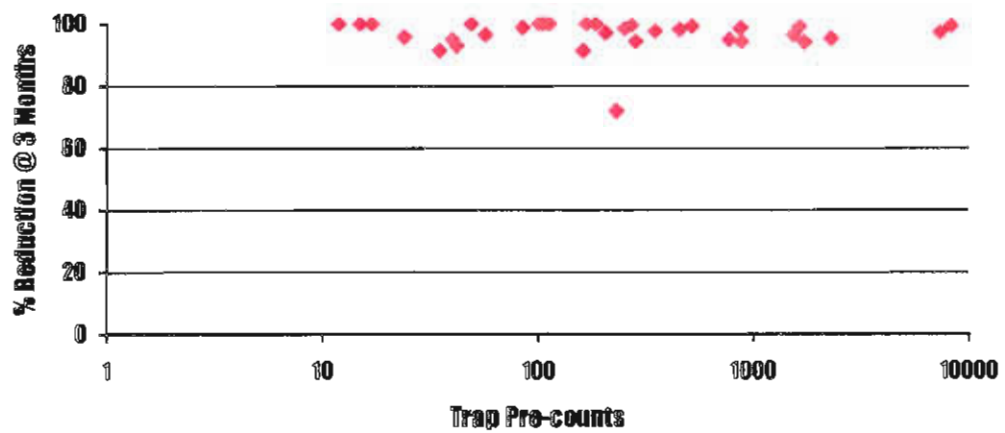


Fig. 4. Cockroach Populations in Apartments Treated with Hydramethynon Bait



COMPARISON OF THREE BAIT FORMULATIONS FOR TOXICITY AGAINST GERMAN COCKROACH NYMPHS AND SECONDARY KILL OF ADULT MALES

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Three toxic bait formulations were fed to 1st and 2nd instar German cockroach (*Blattella germanica* L.) nymphs to determine LT₅₀s. Nymphs killed by the toxic baits were then fed to adult male cockroaches to assess secondary kill. Nymphal LT₅₀s for Maxforce® (fipronil), Pre-Empt® (imidacloprid) and Siege® (hydramethylnon) were 8.4, 10.0, and 49.0 h, respectively. Killed nymphs were frozen for 1-3 days at which time they were fed to adult males. The mean 7 d consumption of nymphs was highest in the groups fed control (6.9) or hydramethylnon (4.4) killed nymphs, with the least consumption occurring in groups fed fipronil (2.2) or imidacloprid (2.8) killed nymphs. Conversely, mortality of adult males at 7 d was significantly higher for adults fed either the fipronil (99%) or imidacloprid (95%) killed nymphs compared to adults fed control (12%) or hydramethylnon (61%) killed nymphs.

A RADIOTRACER AND TIME-LAPSE VIDEO STUDY OF FIPRONIL-INDUCED SECONDARY KILL IN *BLATTELLA GERMANICA* (L.)

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Secondary mortality occurs when foragers ingest or contact a bait, return to the aggregation, and translocate the insecticide to the shelter and its vicinity. Relatively more sedentary stages of the population then contact the translocated insecticide and die. Fipronil was evaluated on a population of the German cockroach, *Blattella germanica*, for its potential to cause secondary mortality. Factors that affect the horizontal transfer of fipronil, a fast-acting insecticide, will be discussed in comparison to hydramethylnon, a delayed-action insecticide. One of the factors that affects secondary mortality is the quantity and type of residues exuded by intoxicated insects. We have used radiolabeled fipronil to assess the origin of these secretions, to quantify how much is produced and to determine the role and importance of these secretions in facilitating the transfer of this insecticide. The mechanisms by which fipronil residues are transferred from foragers to the non-foragers were also examined. Another factor that affects secondary mortality is the encounter rate between nymphs and translocated residues. We compared the amount of feces defecated and the distribution of dead males and their feces in fipronil- and hydramethylnon-fed cockroaches. The two baits resulted in dramatically different patterns. Contact insecticides can exert high, but transient secondary kill when nymphs encounter dying insects or the residues they excreted, whereas slow-acting insecticides result in greater accumulation of translocated residues and therefore greater long-term secondary kill.

ATTRACTIVENESS OF INSECTICIDE BAITS AND TRAP LURES TO THE GERMAN COCKROACH (DICTYOPTERA: BLATTELLIDAE)

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Several commercial insecticide bait formulations and trap lures that are commonly used for German cockroach, *Blattella germanica* (L.), control were examined for their attractiveness to cockroaches in olfactometer assays in laboratory and in trapping experiments in the field. The insecticide bait formulations in the assays were bait stations (Raid® Max, Maxforce® Station), gels (Siege®, Maxforce®, Avert®), pastes (It Works™, Magnetic Roach Food™), and a powder (Avert® PT®310). The following active ingredients were represented: abamectin, boric acid, chlorpyrifos and hydramethylnon. The trap lures included Trapper®, AgriSense GP-2®, Victor® food and Victor® Pheromone. Peanut butter and distiller's grain were also included in the trap lure study. There were significant differences among the baits and trap lures in their attractiveness to the German cockroach. Of the insecticide baits that were tested, Avert powder, Maxforce Roach Killer station and gel, and Siege gel were consistently attractive in both trapping experiments and in laboratory olfactometer assays with adult males. In olfactometer assays, AgriSense GP-2 was the most attractive trap lure, followed by peanut butter and distiller's grain. Trapper tablet, Victor pheromone, and Victor food lure elicited upwind orientation from < 50% of the test insects. In field trapping experiments, peanut butter and distiller's grain were equally attractive and they captured significantly more cockroaches than the GP-2 tablet or the Victor pheromone lure; the latter lures failed to attract significantly more cockroaches than the unbaited control traps. These results highlight the need for developing better attractants for cockroach detection, population monitoring and pest control.

IN VIVO STUDY ON COMBINED TOXICITY OF *METARHIZIUM ANISOPLIAE* (DEUTEROMYCOTINA: HYPHOMYCETES) STRAIN ESC-1 WITH SUB-LETHAL DOSES OF CHLORPYRIFOS, PROPETAMPHOS AND CYFLUTHRIN AGAINST GERMAN COCKROACH (DICTYOPTERA: BLATTELLIDAE)

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The effect of *Metarhizium anisopliae* (Metschnikoff) Sorokin ESC-1 alone and in combination with sub-lethal doses of commercial formulations of chlorpyrifos, propetamphos and cyfluthrin on mortality of CSMA strain of German cockroach, *Blattella germanica* (L.), was determined by conducting in vivo studies that included 3 bioassays. Spores of *M. anisopliae* cultured on SDAY media had germination of >90%. Based on bioassay 1, doses ranging from 50 to 300 ppm of chlorpyrifos and propetamphos, and 0.05 to 40 ppm of cyfluthrin were selected for bioassay 2 and 3. Cockroach mortality ranged from 5 to 20% for insecticides alone and 48 to 70% for insecticides + *M. anisopliae* in bioassay 2. In bioassay 3, mortality ranged from 15 to 60% for insecticides and 57.5 to 92.5% for insecticides + *M. anisopliae*. Percentage of cockroach

mortality resulting from insecticide + *M. anisopliae* combinations was significantly higher than insecticide alone. Mortality was also significantly higher in certain insecticide + *M. anisopliae* combinations than *M. anisopliae* alone. There was no significant interaction between *M. anisopliae* and insecticides with their concentrations in bioassay 2 indicating an additive effect. But in bioassay 3, a significant interaction was observed when *M. anisopliae* was combined with multiple insecticide concentrations. The interaction indicated an additive effect for chlorpyrifos and cyfluthrin, and a synergistic effect for propetamphos. There were significant differences in LT₅₀ among various treatment combinations. *M. anisopliae* alone or insecticide + *M. anisopliae* combinations did not affect body weight in treated German cockroaches.

Current Topics in Medical Entomology

Ballroom North

Organizer and Moderator

**Nancy C. Hinkle, Department of Entomology
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THE ROLE OF URBAN WILDLIFE AND THEIR ECTOPARASITES IN TRANSMISSION OF VARIOUS ZOO NOTIC DISEASES

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Growth and expansion of urban and suburban populations into previously rural or wild areas has inevitably promoted more interactions among humans and wildlife. Animals such as opossums, raccoons, skunks, and foxes readily adapt to life in an urban environment and consequently become regular residents in urban locations. Because most wild mammals carry a wide variety of ectoparasite species, humans and pets in close contact with urban wildlife are at risk for exposure to these ectoparasites and the diseases they may carry. A study was conducted in Manhattan, Kansas to determine the relative abundance and distribution of wild animals and their ectoparasites, and to identify the various species infesting the urban wildlife. During the summer trapping period (June 10 to August 4, 1999), 104 animals were trapped. Of the 55 opossums captured, 63.6 and 43.6 percent carried fleas and ticks, respectively. Of 47 raccoons, 39.1 and 95.7 percent were infested with fleas and ticks, respectively. Collected flea species included *Ctenocephalides felis* (Bouché), *Pulex simulans* Baker, *Orchopeas howardi howardi* (Baker), and *Ctenophthalmus Kolenati* sp., with *C. felis* as the dominant flea species found on these animals. The various tick species collected included *Dermacentor variabilis* (Say), *Amblyomma*

americanum (L.), and several different *Ixodes* Latreille spp. The dominant tick species was *D. variabilis*.

Throughout human history, arthropod-borne diseases have brought misery to people and damage to livestock and agriculture worldwide. Mosquitoes are responsible for transmitting malaria, yellow fever and various types of encephalitis to millions of people worldwide each year, while costing U.S. pet owners millions of dollars annually in heartworm control. Several species of fleas are implicated in the transmission of various diseases such as endemic typhus, dipylidiasis, and plague. In temperate zones, including the United States, the incidence of tick-borne disease in humans has increased dramatically with the discovery of newly emerging diseases such as human babesiosis, Lyme disease and ehrlichiosis. This presentation will be an overview of various zoonotic diseases (with emphasis on flea and tick vectors) maintained by urban wildlife and their ectoparasites, and the potential for such diseases to spread into human populations.

CONTROLLING MOSQUITOES AND THE PATHOGENS THEY TRANSMIT IN FLORIDA'S URBAN AREAS

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There are about 50 taxpayer-funded mosquito abatement districts in Florida that collectively spend approximately 80 million dollars annually on the control of pest and vector mosquitoes. Many of these districts were established more than 40 years ago primarily to combat annoyance caused by saltmarsh mosquitoes, such as *Aedes taeniorhynchus* and *Aedes sollicitans*, and by various species of freshwater mosquitoes. Without adequate control of these pest mosquitoes, two of the three main components of Florida's economy (tourism and real estate development) would be in serious trouble. Florida's major mosquito pests typically are produced in aquatic habitats on the periphery of urban/suburban areas. There are, however, several mosquito species that are city dwellers, often utilizing aquatic habitats provided by human activities. Included in this group are some important vector species. For example, the yellow fever mosquito, *Aedes aegypti*, and the Asian tiger mosquito, *Aedes albopictus*, are common urban mosquitoes in Florida, frequently occurring in discarded automobile tires, buckets, pails, and other types of artificial containers that collect rainfall. Both species are vectors of the viruses that cause dengue fever. The last dengue epidemic in Florida occurred more than 50 years ago. Yet, recent outbreaks of dengue in the Caribbean region and in Central and South America may enhance the chances of dengue becoming reestablished in Florida.

Twenty-seven Florida counties use sentinel chickens to monitor activity of the viruses that cause St. Louis Encephalitis (SLE) and Eastern Equine Encephalitis (EEE). SLE is the most important mosquito-transmitted disease in the United States. Major SLE epidemics occurred in Florida in 1959, 1961, 1962, 1977, and 1990. During 1999, 10 percent of the sentinel chickens (n = 1,765) produced SLE antibody. The rate was higher in south and central Florida than it was in northern

parts of the state. Still, only a few human cases of SLE were reported in Florida throughout 1999. The sentinel chicken program will probably be expanded in 2000 to include tests for West Nile virus.

In Florida the primary vector for SLE is *Culex nigripalpus*; whereas elsewhere in the southeastern United States the main SLE vector is *Culex quinquefasciatus*. The immature stages of both species thrive in nutrient-rich aquatic systems, particularly those provided by human activities. Generally, these *Culex* mosquitoes, which seldom cause major annoyance problems, are neglected by mosquito control operations until there is an SLE outbreak. A more effective approach for reducing the frequency and severity of SLE outbreaks would be to place greater emphasis on the elimination and reduction of aquatic habitats used by these mosquitoes.

Fleas and Others

Ballroom South

Moderator

**Marco E. Metzger, California Department of Health
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POTENTIAL OF TOPICAL PULICIDES FOR CONTROL OF PLAGUE VECTOR FLEAS

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Plague is a bacterial disease of rodents, and is readily transmitted to humans and a variety of other mammals by the bite of infected fleas. Plague in wild rodents is widely distributed in California, especially in and around the San Bernardino, San Gabriel, Sierra-Nevada, Tehachapi, and San Jacinto Mountains. The California ground squirrel, *Spermophilus beecheyi* (Richardson), is the primary rodent involved in plague epidemiology throughout most of this range. There are 3 species of fleas that occur on these animals during the year; *Oropsylla montana* (Baker), *Hoplopsyllus anomalous* (Baker), and the sticktight flea, *Echidnophaga gallinacea* (Westwood). It is believed that *O. montana* is responsible for most cases of plague to humans and domestic cats in California, whereas the role of the remaining two species in disease transmission is less clear. The continued urban expansion in California has put an increasing number of people in high-risk foothill areas where plague is endemic in rodent populations.

New host-targeted insecticides recently introduced for use on companion animals have revolutionized cat flea control. These compounds may also prove useful for controlling plague vector fleas on wild rodents and provide an alternative approach for vector control personnel to conventional organophosphate dust treatments. Colonies of California ground squirrel fleas were established on wild-caught *S. beecheyi* individually housed at the University of California, Riverside animal care facility. Commercially available topical formulations of fipronil and imidacloprid were evaluated for efficacy and longevity against the primary plague vector flea, *O. montana*. Laboratory squirrels were treated topically with fipronil (Frontline® Top Spot™) and imidacloprid (Advantage™ Flea Adulticide) at a dosage of 15 mg/kg and evaluated for residual activity every 2 weeks thereafter. Residual activity was determined by percent live *O. montana* adults recovered from treated and untreated squirrels after 48 hours. Imidacloprid failed to provide 100% kill of adult fleas after 2 weeks, with complete loss of efficacy by week 6. In contrast, fipronil provided 100% kill of adult fleas for at least 10 weeks, and up to 26 weeks on one animal. Based on these results, fipronil is a strong candidate for flea control on rodents and should be examined more closely to determine optimal doses as well as efficient and effective delivery systems.

CONTROL OF CHIGGERS WITH SUSPEND SC IN COPIAH COUNTY GAME MANAGEMENT AREA, MISSISSIPPI

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Chiggers are six-legged larval stage of mites in the family *Trombiculidae*. They are also sometimes called “harvest mites” or “red bugs”. Over 700 species of chigger mites occur in the world, but only about 20 species cause dermatitis or transmit diseases such as the agent of scrub typhus. Control of chiggers in parks, recreation areas or campgrounds has historically been considered somewhat impractical.

The objective of this study was to evaluate Suspend SC, a 4.75% suspension of deltamethrin, or DeltaGard®, as a residual treatment against chiggers in a game management area in Mississippi.

The first Suspend SC treatment trial was conducted in 1996 in Copiah County Game Management area in central Mississippi. Six 1/4 acre plots, three for treatments and three for controls, were chosen and flagged. Each plot was divided into 10 lanes approximately one meter wide. Sampling was done by using 12 x 12 inch white masonite panels placed in 3 randomly selected lanes for 2 minutes before counting chiggers crawling on panel. Four panels were used per lane for a total of 12 boards per 1/4 acre plot. Pre-counts were conducted several days before the treatment. Post-counts were conducted each week for total four weeks. Approximately 80% of plots were treated with 0.06% Suspend SC with a backpack sprayer at a flow rate of 0.33

gal/minute. Population reduction achieved 96% at 1 week and 90% at 2 weeks after the treatment. Three and four weeks after treatment, reduction remained at 63 to 65%.

A second Suspend SC trial was conducted in 1999, when Suspend SC was applied at 0.01% deltamethrin. Ten 1/8 acre plots were used. Each plot was divided into 12 lanes of equal length. Five plots were used as treatments and the other five were controls. Every effort was made to spray 100% of the ground surface in treatment plots, although in reality this is impossible in "natural" undisturbed habitats, for example in patches of impenetrable vegetation. A total of 91%, 90% and 78% control was achieved at 1, 2, and 3 weeks after the treatment.

The rise in chigger numbers 2 weeks after treatment could be a result of new chiggers hatching from eggs at or near the soil surface.

The study demonstrates that Suspend SC provides effective control of chiggers when applied in recreational areas as a residual treatment.

EFFICACY AND LONGEVITY OF CAPSTAR™ (NITENPYRAM) AGAINST ADULT CAT FLEAS

Marcella Waggoner, Michael K. Rust, Nancy C. Hinkle,
David Stansfield¹, and Sharron Barnett¹

Department of Entomology, University of California, Riverside, CA

¹Novartis Animal Health U.S., Greensboro, NC

House cats were infested with 30 pairs of adult male and female cat fleas, *Ctenocephalides felis* (Bouché), three days prior to oral treatment with Capstar™ (nitenpyram). The number of live and dead fleas on the cats and the number of live and dead fleas in trays under the cats were counted daily for 4 days after treatment. Each day the cats were combed to remove live fleas and a new cohort of 30 pairs of fleas was added. Flea egg production was recorded for the first four days. On day 4, the final aliquot of adult fleas was placed on each cat. These fleas remained on the cats and were undisturbed for the remainder of the test. From day 7 – 10, egg production was recorded and subsequent viability determined.

Capstar™ provided 100% kill of all the fleas on the host at the time of treatment. When fleas were placed on treated cats, 100% were killed for up to 48 hrs after treatment. When fleas were placed on cats between 48 and 72 hours after treatment, there was a 97.3% reduction in the number of fleas on the treated cats. Between 72 and 96 hours, there was a 61.3% reduction. Fleas placed on the cats at 96 hours appeared to be unaffected by the treatment. In the controls, grooming resulted in the removal of 0-20% of fleas in 24 hours. Egg production during the first four days after treatment was greatly reduced (less than 3%) compared to production in non-treated cats. Counts taken on day 7 indicate that egg production in the two groups was similar. The viability of eggs between the groups ranged from 60-70%.

Capstar™ was extremely effective at killing adult fleas on the cats and providing protection for up to 48 hours. The rapid adulticidal activity of Capstar™ makes it an attractive candidate for use with insect growth regulators that primarily affect the immature stages of cat fleas.

THE ROLE OF COCOON SILK IN CAT FLEA OVERWINTERING

Marco E. Metzger^{1,2} and Michael K. Rust¹

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Riverside, CA 92521-0314

²Vector-Borne Disease Section, California Department of Health Services
2151 Convention Center Way, Suite 218B, Ontario, CA 91764-5429

The cat flea, *Ctenocephalides felis* (Bouché), is a seasonal ectoparasite of domestic and feral mammals worldwide. Adult fleas are most abundant during the warm months of spring and summer and become scarce or absent during the cold winter months. The following spring, re-infestations of adult fleas presumably originate from an overwintering population, but the source of these fleas and their strategy for survival has remained a mystery. No life stage of *C. felis* is known to diapause and sub-freezing temperatures are lethal to both immatures and adults. The most likely source of overwintering fleas are probably protected microhabitats where adults remain quiescent inside cocoons for extended periods before emerging. Cool temperatures frequently increase the duration of adult quiescence, but other factors affecting this behavior are unknown. Flea cocoons vary in their structural rigidity. Stronger or thicker cocoons may provide a greater barrier to adult emergence and could play a significant role in maintaining adult quiescence within the cocoon.

C. felis were reared from egg to adult at three constant temperatures, 26.7, 21.1, and 15.5 °C, in 75% RH chambers to determine if larvae produce more cocoon silk in response to colder temperature. To quantify the amount of larval silk incorporated into individual cocoons and determine its effect on the quiescence of the pre-emerged adult, a water-soluble substrate was chosen as a pupation medium. Two substrates, silica sand (control) and granulated sugar, were sifted through a series of sieves to obtain equal size particles between 28-34 mesh. Mature third instars were removed from rearing media and placed in either pure sand or sugar for cocoon formation. After several days, cocoons were sifted from the substrates, placed individually in wells, and checked daily for adult emergence. Emerged adults were dried at 2% RH and weighed. Silk was isolated from cocoons spun in sugar by dissolving off the granules in distilled water. The resulting silk was dried and weighed to determine its total dry biomass. Data collected included the length of time prior to emergence, dry adult weight, adult sex, and silk weight for individual fleas. There were no significant differences in the pattern of adult emergence from cocoons spun in sugar or sand, but fleas emerging from cocoons spun in sugar were significantly smaller than those spun in sand at 26.7 °C. Mean silk weight did not differ significantly between sexes or among temperatures; however, a weak positive linear relationship existed between silk weight and the length of adult quiescence at 15.5 °C, for both males and females. Wild strains of fleas collected from different climatic regions might provide more definitive relationships between silk production and adult quiescence.

**PUBLIC HEALTH PESTICIDES, PROGRAMS, PESTS AND
THE FOOD QUALITY PROTECTION ACT (FQPA)**

Kevin Sweeney
Entomologist, U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue N.W.
Washington, D.C. 20460

The Food Quality Protection Act of 1996 addressed public health pests and pesticides and their consideration under FIFRA. This talk will highlight the issues concerning public health pesticides as discussed in the recently published draft PR Notice entitled "List of Pests of Significant Public Health Importance". Topics for public comment will also be mentioned.

Career Opportunities in Urban Pest Management
Ballroom West

Organizer and Moderator
Philip G. Koehler, Department of Entomology and Nematology,
University of Florida, Gainesville, FL

**EDUCATIONAL NEEDS OF THE PEST CONTROL INDUSTRY:
RESULTS OF A SURVEY**

Daniel R. Suiter¹ and Linda J. Mason²

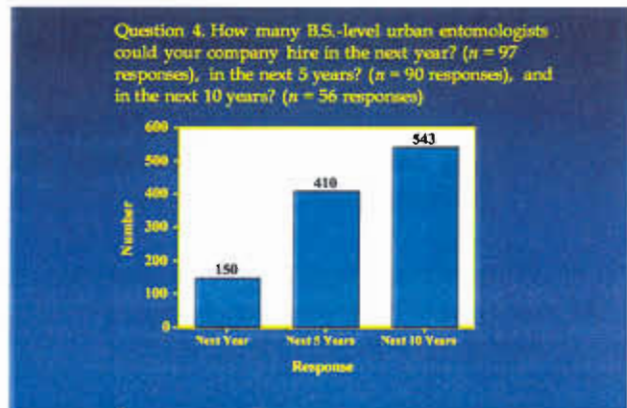
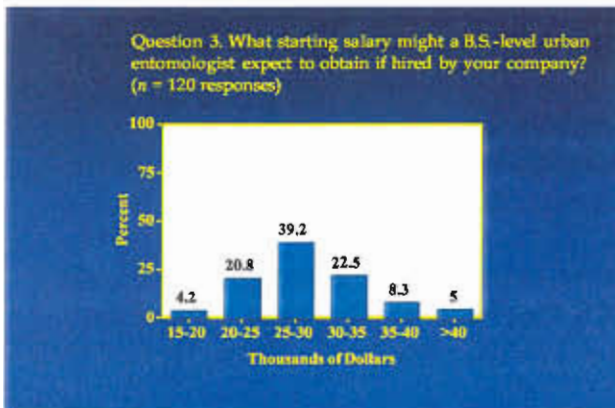
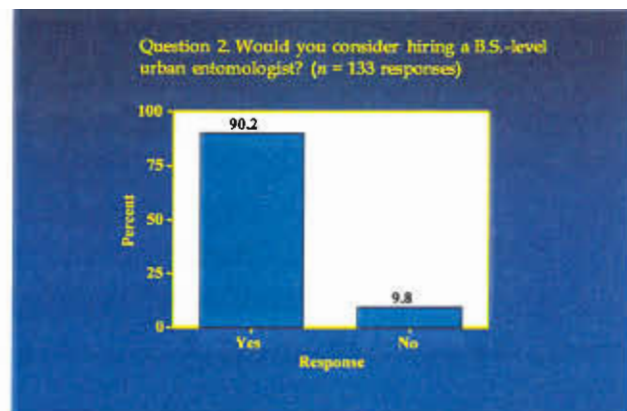
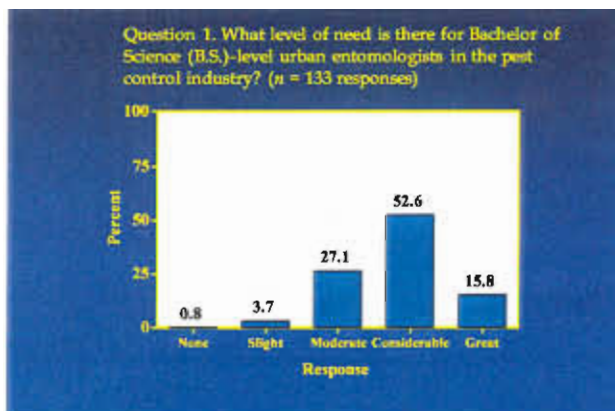
¹Department of Entomology, University of Georgia, Griffin, GA

²Department of Entomology, Purdue University, West Lafayette, IN

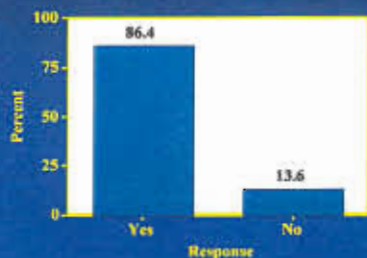
In May 1998 a survey regarding undergraduate education in Urban Pest Management was mailed to 498 pest control business owners throughout the U.S. One hundred thirty three surveys (i.e., 26.7%) were returned within three weeks.

As expected, the structural pest control industry is in need of educated people. Greater than two-thirds of survey respondents believe there is considerable to great need for Bachelor of Science (B.S.)-trained urban entomologists in the pest control industry (Question 1). Most companies indicated they would consider hiring B.S.-level urban entomologists (Question 2); most of the remaining 10% indicated they could not hire now, but that future job opportunities in their company were likely. The pest control industry will pay B.S.-level urban entomologists well. In our survey, 75% of projected starting salaries were $\geq \$25,000$ per year, and $\approx 13\% \geq \$35,000$ per year (Question 3). The potential job market for B.S.-level urban entomologists is excellent. For

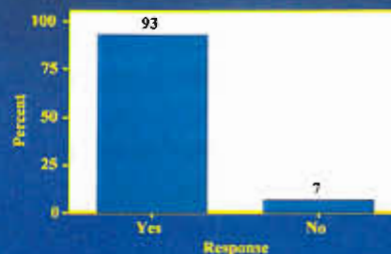
example, 97 responding companies told us they could hire a total of 150 B.S.-level urban entomologists (i.e., ≈ 1.5 per company) in the next year alone, and that this need will likely continue for at least the next decade (Question 4). The possibility of summer internships was also very exciting to survey recipients. About 86% of professionals surveyed said they would be interested in participating in a summer intern program (Question 5), and 93% said they would be willing to pay the intern a salary (Question 6). The potential for career growth for B.S.-level urban entomologists is considerable, but ultimately dependent upon the work ethic and professional commitment of the individual in question (Questions 7 and 8). Survey recipients told us that communication skills (e.g., oral and written) were the most important areas of education (Question 9). People (e.g., personnel management, human resources) and technical (e.g., pest biology and identification, IPM, pesticides) skills were next, and deemed equally important. Fourth was business skills (e.g., accounting, management, sales) and the least important area of education was in computer skills (e.g., the Internet, business software).



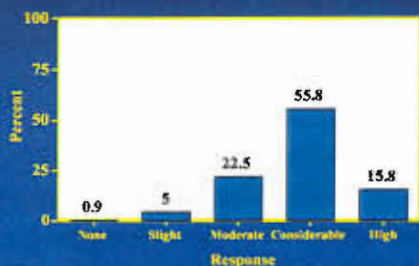
Question 5. Would your company be interested in participating in an intern program whereby prospective students might spend several months during the summer at your place of business? (n = 132 responses)



Question 6. Would you be willing to pay the student a salary for the summer internship? (n = 114 responses)



Question 7. If you were to hire a B.S.-level urban entomologist into your company, what might be the career growth potential for that individual in your company? (n = 120 responses)



Question 8. To what level might a B.S.-trained urban entomologist expect to settle in his/her career?

The response to this question was varied to the extent that a graphic depicting a trend could not be generated. Nearly all respondents, however, indicated that the potential for moving up in their company was directly dependent upon the professional commitment and work ethic of the individual in question.

Question 9. Please rank 1 to 5 (1 being the most important) the following five skill areas according to your sense of their importance toward training professionals for a career in the structural pest control industry (n = 106 responses)

Number of Votes for Skill Area					
Rank	Communication	Technical	People	Business	Computer
1	38	32	30	6	0
2	41	25	27	13	0
3	18	25	31	24	8
4	6	19	10	36	35
5	3	5	8	27	63

What They Said... The following are comments provided by survey participants on various aspects of preparation for a career in the pest control industry.

On the need for B.S.-level Urban Entomologists...

"We believe that there is a great need for trained urban entomologists in this industry. Many believe it now -- more will as time passes. This industry needs to reassess its values. We saw the need many years ago".

--James J. McDaniel

"The pest control industry is always looking for educated individuals at all levels. If we can better our industry by bringing in more entomologists, lets do it. I welcome the idea with open arms".

--Stuart Aust

On the importance of Internships...

"Would love to have an intern in my business for the summer - great idea".

--Mike McCauley

"We would be really interested in an intern program".

--Lonny L. Burton

"Some kind of co-op or internship should be required prior to graduation. Nothing beats practical experience".

--Anonymous

"As the pest control industry moves into the next century there will be more demand for qualified and trained individuals (e.g., B.S. in Urban Entomology). An ideal program with summer internships would be most beneficial for both the candidate and employer to evaluate each other".

--Anonymous

On the importance of Communication and People Skills...

"I see the pest control industry as a "people" business, not a "bug" business. I believe a successful pest control company must base its services on sound technology communicated to the technician level. However, technology alone does not guarantee success. We must implement our technology through people, both employees and customers. Therefore, if a person were to come to us with sound technical training supplemented with heavy doses of communication-, people-, and business- skills, he or she would have unlimited choices both inside and outside the industry".

--John W. O'Reilly

"There are probably about 100 species of urban pests that an entomologist should know. Couple that with people skills and the ability to write a report/proposal and you have a winner".

--Jay Nixon

"We have positions for 1 or 2 technical people with limited "people skills" but many more for people who possess the combination".

--Victor Hammel

"Above all, the ability to communicate well in this people oriented business is essential. Knowledge of pests, pest management techniques, safety, regulation and chemicals is useless without an accompanying ability to communicate - both verbally and written".

--Anonymous

On the importance of Business Education...

"In the past, graduate entomologists have been adequately schooled and trained in the technology of our business, but not in the process of managing a business. The competitive nature within today's pest control industry demands people that have an insight into the capitalist process, into solving personnel issues and the importance of marketing and how to grow a business, how to deliver a quality service, how to make a profit and do it all on a consistent basis".

--Harvey L. Massey

"Technical people are needed, but not many. Technical people who are business oriented have an outstanding opportunity with countless job opportunities".

--Anonymous

APPRENTICE AND MASTER TERMITE TECHNICIAN TRAINING PROGRAM

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In 1990 the South Carolina Master Termite Technician (MTT) School was established to provide advanced training for pest management professionals with experience in doing treatments for termites. In 1991 the South Carolina Apprentice Termite Technician (ATT) School was established to provide new or inexperienced professionals with basic instruction on proper treatments for termites. The overall goals of the programs are to enhance the knowledge and treatment skills of termite technicians, and to improve termite treatments for state residents. This is achieved through the increased compliance of pest control companies to state regulatory termite treatment standards. Both programs are offered twice a year. Each school is conducted for two days and involves classroom sessions and practical training at a custom-built foundation that incorporates a variety of building techniques common in South Carolina.

To provide quality, hands-on instruction, each MTT and ATT program is usually restricted to 25 students or less. Since their inception, the MTT and ATT programs have had 546 and 334 participants respectively. Approximately 78 % of the participants in the MTT programs have come from South Carolina. Over 87 % of the ATT participants have come from South Carolina. The remaining participants have represented 12 states and Saudi Arabia in the MTT program and seven states in the ATT program. Participants are most frequently pest management professionals, with 83 % of MTT and 87 % of ATT students in this category. Other MTT and ATT attendees have included Extension specialists, county agents, regulatory specialists, industry representatives and military personnel.

To pass the MTT or ATT programs, participants must score 70 % or higher on a written exam and a series of practical tests. The pass rate for MTT participants has been 76 % and 87 % for ATT participants. Many employers view the MTT and ATT schools as challenging. Passing the MTT or ATT courses often enhances the technician's career with elevated company status, expanded opportunities and increased salary benefits. The MTT and ATT schools also create revenue and career opportunities for a MTT and ATT schools/training coordinator, Clemson extension specialists and regulatory specialists (instructors) and other industry professionals. Thus, the MTT and ATT programs create more than training opportunities and compliance. They create career opportunities for pest management and allied professionals.

MASTER PEST CONTROL TECHNICIAN TRAINING PROGRAM

Patricia A. Zungoli and Eric P. Benson
Department of Entomology, Clemson University, Clemson, SC

Changes in the pest control industry over the past decade have increased the demand for programs to provide pest control professionals advanced information on identifying and solving urban pest problems with an emphasis on progressive approaches to control/management. Many options to provide educational opportunities for pest control professionals exist ranging from attending a single lecture to enrolling in a 4-yr degree program. One end of the spectrum is too brief to be of benefit beyond a single topic and the other is often more of a commitment than adult workers can make. With suggestions from surveyed members of the South Carolina Pest Control Association, the Master Pest Control Technician (MPCT) Course was developed.

The MPCT Course was a 10-week program designed to provide pest control professionals in South Carolina with a practical foundation for identifying, diagnosing and controlling pest problems in the urban environment. Pest management practices were emphasized, particularly understanding and modifying habitat to reduce pest populations. The core of the course was based on three, face-to-face labs and seven two-hour, satellite lectures. Each student was given an *NPCA Field Guide*, a resource notebook of additional information, and a hand lens. Labs were held at a location in the middle of the state and consisted of an all-day program to teach students insect identification and pest diagnosis. Students were taught to identify key characters using their 16X hand lens. Satellite lectures were delivered live from a studio at Clemson University to designated county Extension offices throughout the state. A 1-800 phone line was available to allow students to ask questions. Lecture topics included cockroaches, fleas, other ectoparasites, entomophobia and delusory parasitosis, stored product pests, termites and other wood destroying pests, stinging insects, spiders, flies, pest control regulations and legislation, providing service, and application equipment and inspection techniques. A web site was established for the course allowing students access to lecture outlines and course updates. Successful completion of the course was based on two examinations and two practical homework assignments requiring a 70% or higher to pass.

The first MPCT class had 21-students including pest control owners, managers and technicians, public housing staff and military personnel. On a 45-question evaluation, students gave the course high marks. On a five point scale, the course received a 4.85 for providing useful information and a 4.60 for recommending the course to another professional. Students liked the format of the video lectures (4.68), the opportunity to ask questions (3.95), and felt the labs were an important part of the course (4.85). Homework was regarded as a valuable component for learning (4.35), as was the web site (4.20). However, while students thought the web site should be retained as part of the course (4.50) and used the web site to access course notes (4.20), very few used it to communicate with instructors or other students (2.20).

Higher education needs for pest control professionals will increase in the future as issues such as cancellation and withdrawal of commonly used pesticides, decreased use of pesticides, and increased use of bait products remain important. Advanced educational opportunities will not

only increase professionalism among technicians, but may serve to increase retention rates by opening up more career opportunities for people who can design and implement integrated pest management programs.

TWO-YEAR TECHNICAL PROGRAM FOR PEST CONTROL PERSONNEL

Dini M. Miller

**Department of Entomology, Virginia Polytechnic Institute and State University
Blacksburg, VA**

The Urban Pest Management (UPM) emphasis is a part of the Agricultural business option in the Virginia Tech Agricultural Technology (AgTech) program. AgTech is a two-year, college-level program leading to an Associate of Agriculture degree. All students in the program receive training in communications, math and computer skills as well as business courses and urban pest management. The AgTech UPM course specializes in hands-on training for students preparing them for positions in the pest control industry. The 1999 UPM course included monitoring and baiting German cockroach infested apartments, crawling a termite infested home, and developing an IPM program for a sensitive environment.

UNDERGRADUATE AND GRADUATE EDUCATION IN URBAN PEST MANAGEMENT

Philip G. Koehler

**Department of Entomology & Nematology
University of Florida**

The undergraduate curriculum in urban pest management at the University of Florida is primarily oriented towards training entomologists to work with a pest control company, supplier, or manufacturer. The curriculum is a combination of science courses and business courses. Students typically take Chemistry, Biology, Physics, Computers, and Math as lower division undergraduates, as well as microeconomics, composition, technical writing, and oral communication. Upper division science courses include General Entomology, Biology & ID of Urban Pests, Principles of Urban Pest Management, Urban Pesticide Application, Medical & Veterinary Entomology, and related courses. Business and related courses include Advertising, Marketing, Business Law, Public Relations, Construction Materials, and Construction Techniques—Superstructures. Currently about 25 students are undergraduates majoring in Entomology and specializing in urban pest management.

The urban pest management graduate program for M.S. and Ph.D. students encompasses the traditional course work in Entomology and related science along with the normal research responsibilities. However, graduate students are required to participate in educational programs throughout the state for pest control operators, homeowners, and master gardeners. Extension calls and identification samples from the public are routinely handled by graduate assistants.

They also help prepare extension literature for fact sheets and web or computer based training programs.

The Urban Entomological Society is a club for students interested in urban pest management. Graduate and undergraduate students get together to form a support base for class work and social life. The club has a web site at "<http://www.ifas.ufl.edu/~urban/>." Club activities have been to exhibit research and extension materials at pest control meetings, sell reference insect collections to pest control companies, and sell themselves to potential employers.

And You Thought You Survived Y2K!

Ballroom West

Organizer and Moderator
Roger E. Gold, Department of Entomology
Texas A&M University, College Station, TX

THE FUTURE AIN'T WHAT IT USED TO BE

Steven A. Dansuer
Vice President of Orkin Pest Control
2170 Piedmont Rd. N.E., Atlanta, GA 30324

The speed of light and the speed of change in this new millennium are creating stress for Americans; their struggles to control this stress can and will affect the pest control industry.

Chaos is taking the fun out of life for Americans. They are working more and enjoying it less. They're losing sleep as they try to juggle dual household careers and raise their children. Americans are becoming cynics.

Some embrace all of this chaos, some run from it but most are just coping. Unfortunately, the growing solution is to drop things out of their life; it could be pest control service. "Getting control" is driving them to the Worldwide Web for research, "do-it-yourself" for short term closure and to Starbucks for a \$4.00 cup of relaxation.

There are five major trends in America that will affect our industry:

(1) Disney World Expectations - "Better, Faster and Cheaper" in electronics and high touch service experiences are turning delight into expectations for Americans.

(2) **Products or Services - Which is Which?** Product manufacturers are moving into service to compete with other products. It can, however, affect the pest control service industry.

(3) **Technology - The Driving Force.** Advances in technology are helping make service more personalized and life a little simpler. It also is a powerful business tool in the new millennium.

(4) **Choice is Power.** With so many choices in products and/or services the consumer is getting more “bargaining power”. However, managing all of the choices is challenging.

(5) **Power of Risk Management.** In a chaotic world Americans feel “at risk”; finding ways to reduce their risk could be an important millennium business tool.

Sticking to the basics and a willingness to “go with the flow” will determine if we survive this chaos.

PREPARING PEST MANAGEMENT PROFESSIONALS FOR THE FUTURE

Norman Goldenberg

Vice President & Director for Government Affairs, Terminix International,
860 Richlake Blvd., Memphis, TN 38120

Distinct challenges face today's pest management professionals in the urban arena. Certainly, the past twenty years has seen tremendous innovation in the technology, equipment, and products available in the industry. Regulatory activity is sure to continue a strong upward trend as will consumer concerns regarding pesticide use in the home and workplace.

The first “battleground” in this regard can be seen in the school pest control issue. Congress, members of the EPA, and a number of environmental groups have stepped up efforts to curb or eliminate pesticide usage in schools. The two arguments used to further this goal are the GAO report outlining the added risks of pesticide affects that might be posed on children due to their smaller size and the lack of real data regarding the types and amounts of pesticide actually applied within schools in the United States. Efforts are currently underway to pass legislation requiring notification of parents of any pesticide application in their children's school. Additionally, the EPA wants to quantify the nature of pesticide use in and around school properties.

In addition, the EPA has undertaken another initiative to require language on pesticide labels detailing re-entry times following application. Manufacturers will need to complete studies to determine a safe re-entry period, if any is needed (e.g., bait products), and include such statement on the label.

Such examples demonstrate the initiation of the pest control industry into the information age. Technology and computers are playing an increasing role in not only how a business is run, but also in how pest management services will actually be delivered. More and more information

needs to be captured, analyzed, and formalized into reports in order to improve service and to educate service professionals, customers, and regulators.

Factual data regarding pest control services and pesticide use will hopefully temper new pesticide regulations making them reasonable and economical to implement. The trend toward reduced pesticide use in structural environments shall continue. Preparing and equipping pest management service professionals in this new era of minimal pesticide applications will prove challenging. The most significant challenge will be the education of service professionals in the use and application of new technologies.

Only two decades ago, most of the treatments, for any pest other than termites, was accomplished using but a few products, Dursban and DDVP being two of the most widely used. Today, more than 20 ant bait products alone are available as well as at least six cockroach gel bait products.

Probably the most dramatic example of technology changing the industry has been the introduction of termite baits. Where previously hundreds of gallons of termiticide were required to treat a home, a mere few grams of active ingredient are used to achieve the same goal—a termite-free home. Information regarding a termite baiting service is captured using bar scanning technology, and the resulting computer-generated reports improve customer communication and analysis of the infestation.

The use of technology in this industry has only scratched the surface. Research completed by Dr. Richard Brenner of the USDA in Gainesville, Florida utilizes contour mapping of monitoring data to pinpoint key pest harborages in and around an infested building. His ultimate goal is the development of a handheld computer to accomplish this task but user-friendly for the average service professional.

Imagine arriving at a home and going to one corner of a building with a handheld computer and pushing a button to set an initial reference point. At each subsequent corner, the button is pushed again and the computer uses these settings to diagram the building. The user then sets a reference point for each site where a monitoring device is established and scans the bar code of that device. Other reference points can be set for pest-conducive conditions and pest activity. The software then generates a report printed in the service vehicle then discussed with the customer. On subsequent service visits, monitoring data entered is computed into a contour map that shows the service professional where he/she needs to direct his/her efforts. Any necessary treatments are thus pinpointed where they will accomplish the best results.

Another area where technology will be of great service is in communication. In the not too distant future, service vehicles will be equipped with computers that link to the office system, and customer files, scheduling changes, etc. will be instantly updated as the service professional inputs the information. Handheld computers are used by many companies to manage routes and print service tickets, thus saving considerable time and minimizing mistakes. Such technology also will enable managers to better analyze the services conducted by their work force, discovering inefficiencies then taking steps to improve service delivery. Customers also benefit from more additional concise, accurate information on service reports.

Technology, properly designed and implemented, results in improved productivity and efficiency and can lead to reduced use of pesticides while achieving results satisfactory to the customers of tomorrow. These goals are achievable only if employees can grasp and use the technology as intended. Thus, training must take an increased role in this industry's future. Employees at all levels will need to be comfortable with the use of computers and electronic equipment. Using computers for training will breed familiarity and should relieve anxieties with the use of the electronic tools utilized to manage routes, communicate with the office, and analyze pest infestations in order to target treatments.

The pest control industry is just beginning to explore the use of computers in training employees. Whitmire began this process a few years back by developing the WITTS™ Program. More a reference guide than a programmed teaching tool, WITTS™ provided professionals with at your fingertips information regarding the most common pests and their control using Whitmire's products. Dow AgroSciences has taken a step further in developing CD ROM training for the Sentricon™ Termite Baiting System. This program takes users through a process of programmed learning while teaching the use of the Sentricon™ system.

Both GIE Media (publishers of PCT Magazine) and Whitmire Micro-Gen are developing web-based training programs for the industry. Other industries are far ahead of ours in providing programs via the Internet. Smaller companies simply need Internet hookup to take advantage of such efforts. Many larger pest control companies have or are in the process of building intra-nets through which training, as well as day-to-day business operations, could be provided. Such companies can develop their own internal computer-based training designed specifically for their company.

Just because computers are used does not necessarily translate into well trained employees. The content may be sound but the presentation must be fun and repetitive in order to be successful with adult learners. For example, a company in Washington State takes photographs of rooms and buildings and then uses these to build virtual training situations that look exactly like the pictures. Using the mouse, a trainee can turn in any direction within the virtual room and also look up and down. The demo program shown at the 1999 NPMA Convention allowed the user to turn on the TV in the virtual room to see a video. As the user clicked on various objects or sites, the program might reveal a pest likely to be found in that spot. Such creative programming brings a measure of the real world to classroom training.

Computers also streamline the testing process. Effective computer-based training continually quizzes the trainee allowing him or her to see important facts repetitively. One place such computer-based testing will benefit the industry is for state licensing or registration exams. Results are known automatically, and can save days, even weeks, in a new professional completing work on his/her own. With such testing, exams could be offered every day at state regulatory offices or their designates by scheduling an appointment. No longer should one need to wait until the next available test date.

The greatest challenge facing the industry will be attracting employees with the skills to learn and utilize technology. Such employees may demand a higher wage and technology should improve productivity to the point where it is possible to provide considerably higher compensation. Many companies are accomplishing this goal now.

The future looks bright for the industry. The insects, spiders, scorpions, rodents, and birds are not going away. Pest management services will still require considerable amounts of “knee time” in search of pest activity. But as we become more efficient at gathering and analyzing information regarding infestations, using technology, much of such effort will be directed productively at the most likely harborage therefore maximizing time efficiency and minimizing pesticide treatments.

CONSUMER LAW AND RISK MANAGEMENT

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The pest control industry has sought to manage the risk of consumer-related liability by relying on contractual language limiting liability, by using EPA-approved language on product labels and in marketing materials, and by insisting on mandatory arbitration to resolve disputes. The assumption behind this strategy is that legal claims will be brought primarily by individual consumers relying on their rights under contract law, and by the state and federal agencies with direct responsibility for regulating the industry. But in the next decade, industry members are likely to face an increasing number of lawsuits based on state and federal consumer protection laws, more frequent involvement by state and federal consumer protection officials, and some well-financed legislative and court challenges to arbitration clauses. Ironically, the most effective industry response to these legal threats may be a less legalistic approach to risk management. Industry members may be able to minimize their own risk by minimizing the risk that their marketing practices will confuse or deceive consumers about what can reasonably be expected from pest control products and services.

2000 National Conference on Urban Entomology Planning Committee

Shripat T. Kamble (University of Nebraska), Conference Chair
Daniel R. Suiter (University of Georgia), Program Chair, Proceedings Editor
Roger E. Gold (Texas A&M University), Treasurer
Ellen M. Thoms (Dow AgroSciences), Local Arrangements Chair (with Rudi Scheffrahn and Nan-Yao Su [University of Florida])
Arthur G. Appel (Auburn University), Awards Chair (with Eric Benson [Clemson University] and Don Lesiewicz [Aventis Environmental Science])
Gary W. Bennett (Purdue University) and Bill D. McClellan (Zeneca Professional Products), Sponsorship

2000 National Conference on Urban Entomology Minutes of the Final Business Meeting

Date: Tuesday, May 16, 2000, 7:00 p.m.
Location: Radisson Bahia Mar Beach Resort, Fort Lauderdale, FL

- The NCUE will not formally reconvene until 2004.
- A NCUE Business Meeting will be held in 2002 at the 4th International Conference on Urban Pests, July 7-10 in Charleston, SC. At this business meeting, the following will be decided for the 2004 NCUE:
 1. Location
 2. Dates
 3. Local Arrangements Chair
- To maintain active not-for-profit status, the NCUE will award several scholarships for students to attend the 4th International Conference.
- In the future, the Awards Committee shall award, when appropriate and if qualified, scholarships to two Ph.D. and two Masters candidates. Furthermore, BS/Undergraduate level applications shall also be considered.
- In the future, students awarded a scholarship from the NCUE shall attend the conference for which they have been awarded the scholarship and will present either a poster or a paper.
- There were 268 attendees at the 2000 NCUE.
- Giving CEU credits for attending the NCUE and making it a standard practice was discussed. Currently, if someone wanted CEU credits for the NCUE, they would have to write a letter to Dr. Roger Gold and then he would handle it from that point.
- A decision needs to be made regarding scheduling the NCUE against the International Meeting, so that they do not conflict.

2004 National Conference on Urban Entomology^a Planning Committee

Daniel Suiter (University of Georgia), Conference Chair
Dini Miller (Virginia Tech), Program and Proceedings Co-chair
Bob Kopanic (S.C. Johnson Wax), Program and Proceedings Co-Chair
Roger Gold (Texas A&M University), Treasurer
Gary Bennett (Purdue University), Sponsorship Co-Chair
Bill McClellan (Syngenta), Sponsorship Co-Chair
Shripat Kamble (University of Nebraska), Awards Chair
Barbara Thorne (University of Maryland), Awards
Bob Davis (Aventis Environmental Science), Awards
Local Arrangements Chair (Two Positions To Be Decided in 2002 at the 4th ICUP, Charleston, SC)

^aThe National Conference on Urban Entomology will not reconvene again until 2004. The 2004 Planning Committee will meet at the 4th International Conference on Urban Pests, July 7-10, 2002 in Charleston, SC to determine: (a) the location of the 2004 NCUE and (b) a local arrangements chair.

Distinguished Achievement Award Recipients

- 1986 Dr. Walter Ebeling, University of California, Los Angeles
Dr. James Grayson, Virginia Polytechnic Institute and State University
- 1988 Dr. John V. Osmun, Purdue University
Dr. Eugene Wood, University of Maryland
- 1990 Dr. Francis W. Lechleitner, Colorado State University
- 1992 Dr. Charles G. Wright, North Carolina State University
- 1994 Dr. Roger D. Akre, Washington State University
Dr. Harry B. Moore, North Carolina State University
Dr. Mary H. Ross, Virginia Polytechnic Institute and State University
- 1996 Dr. Donald G. Cochran, Virginia Polytechnic Institute and State University
- 1998 Dr. Gary W. Bennett, Purdue University
- 2000 Dr. Michael K. Rust, University of California, Riverside

NCUE Conference Chairs

- 1986 William H. Robinson, Virginia Polytechnic Institute and State University
- 1988 Patricia A. Zungoli, Clemson University
- 1990 Michael K. Rust, University of California, Riverside
- 1992 Gary W. Bennett, Purdue University
- 1994 Judy K. Bertholf, DowElanco
Roger E. Gold, Texas A&M University
- 1996 Donald A. Reiersen, University of California, Riverside
- 1998 Brian T. Forschler, University of Georgia
Shripat T. Kamble, University of Nebraska
- 2000 Shripat T. Kamble, University of Nebraska

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BYLAWS

NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

ARTICLE I- NAME

The name of this organization is the National Conference on Urban Entomology.

ARTICLE II-BACKGROUND

In the spring of 1985, individuals representing urban entomology and the pest control industry came together to organize a national conference to be held biennial. The mission of these conferences was to open channels of communication and information between scientists in industry, academia, and government, and to foster interest and research in the general area of urban and structural entomology.

The primary scope of the National Conference is to emphasize innovations and research on household and structural insect pests. It is the intent; however, to provide flexibility to include peripheral topics that pertain to the general discipline of urban entomology. It is anticipated that the scope of the conference could change through time, but the emphasis would be to provide an opportunity for urban entomologist to meet on a regular basis. It is not anticipated that any specific memberships would be required or expected, but that the cost associated with the conference would be met through registration fees and contributions. In the event that funds become available through donations or from the sale of conference proceedings, that these resources will be spent to meet expenses, to pay the expenses for invited speakers, and to provide scholarships to qualified students working in urban entomology. It is the intent of this organization to be non-profit, with financial resources provided to the Conference to be used entirely in support of quality programming and the support of scholarship.

ARTICLE III-OBJECTIVES

The objectives of this organization are:

1. To promote the interest of urban and structural entomology.
2. To provide a forum for the presentation of research and extension programs related to urban and structural entomology.
3. To prepare a written proceedings of all invited and accepted papers given or prepared at the biennial meeting.
4. To promote scholarship and the exchange of ideas among urban entomologists.
5. As funds are available, scholarships will be awarded to students pursuing scholastic degrees in urban entomology. Two levels of scholarships will be offered: the first level is for Bachelors and Masters degree students; the second level is for Ph.D. candidates. These scholarships will be awarded based solely on the merits of the candidates, and the progress that they have made towards completion of their research and scholastic degrees.

ARTICLE IV-JURISDICTION

The jurisdiction of this conference is limited to events held within the United States of America; however, we will be supportive of international urban entomology conferences as they are organized and held.

ARTICLE V-MEMBERSHIP

There are no membership requirements associated with this organization except for the payment of registration fees which go to offset the cost of holding the conference, printing of proceedings and the offering of scholarships. All persons with an interest in urban entomology are invited as members to attend the conferences and associated events.

ARTICLE VI-OFFICERS

Leadership for the Conference will be provided by a Steering Committee composed primarily of representatives from academia, but may include pest control professionals from industry and government. There will be seven officers including: Chair of the Steering Committee, Chair of the Program Committee, Secretary/Treasurer, Chair of the Sponsorship Committee, Chair of the Awards Committee, Chair of the Local Arrangements Committee, and an Industry Representative. The Chair of the Steering Committee will preside at all Steering Committee Meetings and will be the Executive Officer for the organization and will preside at meetings. In the absence of the Chair of the Steering Committee, the Chair of the Program Committee may preside. The voting members for executive decisions of the conference will be by majority vote of a quorum which is here defined as at least five officers.

The duties of the officers is as follows:

Chair of the Conference Committee: To provide overall leadership for the Conference, to establish ad hoc committees as needed, and to solicit nominations for new officers as needed.

Chair of the Program Committee: To coordinate the conference in terms of arranging for invited speakers and scientific presentations as well as overseeing the printing of announcements, programs and proceedings.

Secretary/Treasurer: To provide minutes of meetings, documentation of expenditures and the collection and disbursement of funds.

Chair For Sponsorship: To contact contributors and potential contributors to seek donations and support for the conference and associated events.

Chair For Awards: To oversee and administer the Mallis Award, scholarships and other honors or awards as approved by the executive committee.

Chair For Local Arrangements: To act on behalf of the executive committee in making arrangements with hotels, convention centers and other facilities in which conferences are held. To arrange for audio/visual equipment and to oversee the general physical arrangements for the conference.

Industry Representative: To be the liaison between the commercial manufacturers and distributors of pest control products and the Conference Steering Committee. This position will also be involved in fund raising and in seeking sponsorship for various aspects of the conference.

ARTICLE VI-TERMS OF OFFICE

Officers may serve for a maximum of four conference terms (8 years); however, if no new nominations are received, the officers may continue until such time as replacements are identified and installed. The Conference Chair may serve for one conference after which time they will become the Chair of the Awards Committee. The Chair for Local Arrangements should change with each conference unless the meetings are held in the same location. The Chair of both the Sponsorship Committee and the Industry Representative will serve for two conferences. The Secretary/Treasurer will serve for two conference cycles, unless reappointed by the steering committee.

ARTICLE VII-COMMITTEES

The standing committees are as follows:

1. Conference Steering Committee-Composed of the seven officers as described above, and chaired by the Chair of the Conference.
2. Nomination Committee: Chaired by Chair of Conference Committee
3. Program Committee: Chaired by Chair of Program Committee
4. Sponsorship Committee: Chaired by Chair of Sponsorship Committee
5. Awards Committee: Chaired by Chair of Awards Committee
6. Local Arrangements Committee: Chaired by Chair for Local Arrangements
7. Industry Representative Committee: Chaired by Industry Representative
8. Other ad hoc committees may be formed as needed, but will not be maintained longer than one year.

ARTICLE VIII-NOMINATION OF OFFICERS

Nominations for any of the chair positions may come from any individual, committee, or subcommittee, but must be forwarded to the Chair of the Nominations Committee (Chair of the Conference) before the final business meeting of each conference. It is further anticipated that individuals may be asked to have their names put into nomination by the Chair of the Nomination Committee. In the event that there are no nominations, the existing Chair may remain in office with a majority vote of the Steering Committee for the conference. It is clearly the intent of these provisions that as many new people be included as officers of this organization as is possible, and no one shall be excluded from consideration.

ARTICLE IX-MEETINGS

Conferences of the National Conference on Urban Entomology will be held every two years. Meetings of the officers of this organization will meet at least annually either in direct meetings or by conference calls in order to plan the upcoming conference and to conduct the business of the organization.

ARTICLE X-FINANCIAL RESPONSIBILITIES

All financial resources of the Conference will be held in a bank under an account named, "National Urban Entomology Conference". Expenditures may be made in support of the conference, for scholarships and other reasonable costs; however, funds may not be used to pay officers of the organization for their time or ordinary expenses. In the event that this organization is disbanded, all remaining funds are to be donated to the Endowment Fund of the Entomological Society of America.

ARTICLE XI-FISCAL YEAR

The fiscal year will run from January 1 through December 31 of each year.

ARTICLE XII-AMENDMENTS

The bylaws for this organization may be amended by a two-thirds affirmative vote of the attendees at the business meeting, provided that the proposed amendments are available for review at least 48 hours in advance of the voting.

ARTICLE XIII-INDEMNIFICATION

The National Conference on Urban Entomology shall indemnify any person who is or was a party, or is or was threatened to be made a party to any threatened, pending or completed action, suit or proceeding, whether civil, criminal, administrative or investigative by reason of the fact that such person is or was an officer of the Committee, or a member of any subcommittee or task force, against expenses, judgments, awards, fines, penalties, and amount paid in settlement actually and reasonably incurred by such persons in connection with such action, suit or proceeding: (I) except with respect to matters as to which it is adjudged in any such suit, action or proceeding that such person is liable to the organization by reason of the fact that such person has been found guilty of the commission of a crime or of gross negligence in the performance of their duties, it being understood that termination of any action, suit or proceeding by judgment, order, settlement, conviction or upon a plea of nolo contendere or its equivalent (whether or not after trial) shall not, of itself, create a presumption or be deemed an adjudication that such person is liable to the organization by reason of the commission of a crime or gross negligence in the performance of their duties; and (II) provided that such person shall have given the organization prompt notice of the threatening or commencement (as appropriate) of any such action, suit or proceeding. Upon notice from any such indemnified person that there is threatened or has been commenced any such action, suit or proceeding, the organization: (a) shall defend such indemnified person through counsel selected by and paid for by the organization and reasonably acceptable to such indemnified person which counsel shall assume control of the defense; and (b) shall reimburse such indemnity in advance of the final disposition of any such action, suit or proceeding, provided that the indemnified person shall agree to repay the organization all amounts so reimbursed, if a court of competent jurisdiction finally determines that such indemnified persons liable to the organization by reason of the fact that such indemnified person has been found guilty of the commission of a crime or of gross negligence in the performance of their duties. The foregoing provision shall be in addition to any and all rights which the persons specified above may otherwise have at any time to indemnification from and/or reimbursement by the organization.

This letter has been included in the 2000 NCUE Proceedings at the request of the 2000 NCUE Treasurer.

Thompson, Derrig & Craig P.C.

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July 6, 2000

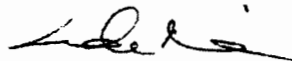
National Conference of Urban Entomology
Executive Committee Members
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We have completed the IRS Form 990-EZ for the years ended December 31, 1997, 1998 and 1999. This does not bring the organization completely in compliance for prior years. The IRS could request returns be prepared for the years prior to 1997, although it is unlikely. Reasons it is unlikely include the organization's classification as not for profit (which results in no tax due) and amounts involved are not significant.

For the 1997 through 1999 years, the information submitted to us included the check register and bank statements and enclosures for each year. Our procedures included checking the reconciled bank balance per the check register with the bank statements. We also looked at the reasonableness of the transactions in comparison with other years as well as anticipated activity based on the timing of the conferences. We found no transactions, which appeared unusual, based on the knowledge we have regarding the organization's activity. We did not perform an audit, nor did we perform procedures, which could detect fraud. However based on the services we performed, we found no transactions which we believe should be addressed in this letter.

We appreciate your business and will be happy to assist in anyway in the future.

Sincerely,



Andrea Derrig