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Thermal Pest Eradication in Structures

By William Quarles

Photo courtesy of Dr. Walter Ebeling

This is the prototype heater used by Forbes and Ebeling in their first structural experiments. The small structure was tarped, and hot air was blown underneath through the plastic heating duct. Convective heating from the hot air raised wood temperatures to 120°F (48.8°C).

Heat as a commercial structural pest control method was developed by Dr. Walter Ebeling and Dr. Charles Forbes, who reported on their work in a number of IPM Practitioner *articles in the 1980s and 1990s. They joined forces with Dr. Michael R. Linford and David Hedman who then commercialized the process and added significant patents. Their joint venture was called TPE Associates. Structural heat treatment is now called ThermaPure® or ThermaPureHeat® and is still going strong, with a larger number of providers and an expanded pest range. For customers seeking alternatives to pesticides for termites, bed bugs, mold and other problems, heat can be an effective solution.*

For at least a century, entomologists have used extreme temperatures to kill insects. Early field trials of heat disinfestation were conducted in the early 1900s in flour mills. Stored product beetles and moths were killed at temperatures of 120°F (49°C). Heat was considered less dangerous than fumigation and caused less disruption of ongoing operations. The heat process was called "superheating" (Ebeling 1997; Dean 1911; Pepper and Strand 1935), and in one instance in 1922, steam heat at 135°F (57.2°C) for 24 hours was used to kill termites infesting a hospital (O'Kane and Osgood 1922).

Heat has now been used to treat for museum pests, cockroaches, termites, woodboring beetles, carpenter ants, fleas, bed bugs, mold, pathogens, "sick" buildings containing volatile organic compounds (VOC), and even rats. The technique is a licensed technology called ThermaPure® or ThermaPureHeat® (see Resources). Either whole structures or parts of structures can be treated (Hedman 2006; Forbes and Ebeling 1987; Ebeling et al. 1989; Ebeling 1994abc; Ebeling 1997; Rust and Reierson 1998; Zeichner et al. 1998).

Use of heat can result in the application of less pesticide. By weight, chemical fumigants represent about half of the total amount of pesticide applied in structural pest control in California, and very roughly about 40 lbs (18.2kg) of fumigant are used for each fumigation (Quarles 2002; Quarles 2001). Substitution of heat treatments or other alternate methods could lead to a reduction in fumigant use. Though heat is not normally used for cockroach control, when it was used as part of a cockroach cleanup by the U.S. Army, the treatment led to "an 83% reduction in sprays, a 62% reduction in dust applications, a 21% reduction in bait applications, and a 67% reduction in labor hours" (Zeichner et al. 1998).

The original method of superheating is still being used in flour mills. Portable or permanent

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Update

heaters fueled by steam, gas, or oil, are used, and fans circulate the hot air. Chemical pesticides are not required, workers are better protected, and there are no regulatory or commercial barriers to its use (Heaps 1988; Heaps 1996). Heat can be used to disinfest both buildings and grain. Grain is blown into a column of hot air and reaches disinfestation temperatures of 138 to 149°F (59 to 65°C) (Dermott and Evans 1978; Mason and Strait 1998).

There are some problems in disinfesting large buildings. "Factors that can seriously reduce effectiveness of heat treatments in large structures...include large temperature gradients that develop from strong convection currents, inadequate air circulation, pockets of static air inside machinery, equipment, double walls, and the prevalence of unsealed openings in floors, walls, and roofs" (Rust and Reierson 1998). These problems have been addressed by improvements in technology and good site preparation (see below).

Thermal Limits

Since insects, unlike mammals, have no way to metabolically regulate their temperatures, they are vulnerable to extremes. Each species has an optimal temperature, and a temperature above or below which they cannot survive. For instance, larvae of the rat flea, *Xenopsylla cheopis*, will die after one hour at 103°F (39.4°C), but the body louse, *Pediculus humanus*, is more resistant, requiring 116°F

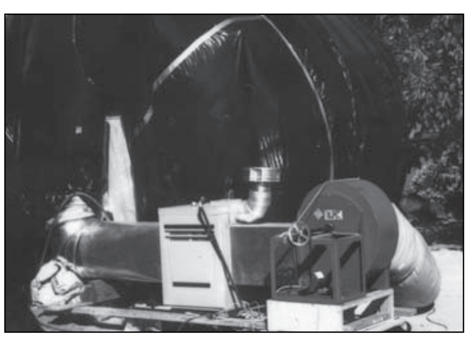


Photo courtesy of Dr. Walter Ebeling

This photo shows the equipment in operation. In the early experiments, the hot air was recycled through the heater.

(46.6°C) for one hour (Mellanby 1932; Ebeling 1994a). At 130°F (54.4°C), heat will kill male German cockroaches, *Blattella germanica*, in 7 min, a nymph of the western drywood termite, *Incisitermes minor*, in 6 min; an adult flour beetle, *Tribolium confusum*, in 4 min; and an adult Argentine ant, *Lithepithema humile*, in 1 minute (Forbes and Ebeling 1987).

Though effects of heat are a function of both temperature and time, even brief exposures to high temperatures can be lethal. High temperatures can cause separation of DNA strands, conformational changes in proteins, enzyme inactivation, cellular disruption, desiccation and other effects. If thermal changes are slow, insects may adapt through heat shock proteins and other mechanisms. If the thermal changes are rapid, insects are not able to adapt, and quickly die (Denlinger and Yocum 1998).

For many museum pests, the lethal temperature is 37-64°C (99-147°F), depending on length of exposure. Shorter times are needed at higher temperatures. At the upper temperature limits, great increases in the speed of mortality can come from small increases in temperature (Rust and Reierson 1998). For instance, Forbes and Ebeling (1987) found "surprisingly little tolerance of four species of insects, including drywood termite pseudergates, to temperatures above the normal range in nature." The greatest gain in insecticidal efficacy came from the increase from 115 to 120°F (46.1 to 48.9°C), "particularly for adults of the flour beetle, *Tribolium confusum*, and [western] drywood termite pseudergates. For these insects, there was an approximately eight-fold decrease in the period required for 100% mortality as the temperature increased from 115 to 120°F (46.1 to 48.9°C)." These laboratory experiments led Forbes and Ebeling (1987) to establish 120°F (48.9°C) for 30 minutes as the minimum thermal standard for drywood termite mortality. Commercial heat operators currently use exposures of 130°F (54.4°C) for one hour as a practical standard. Termite intestinal microbes that are responsible for digesting cellulose die at lower temperatures. So even if a termite should initially survive a heat treatment, it would probably die of starvation (Mannesman 1969;1970; ThermaPure 2006).

Thermal Parameters

Using a heating cabinet operated at 160°F (71.1°C) in the laboratory, Ebeling (1994a) studied the effects of heat on wooden structural materials. He found that the time needed to raise temperatures from room temperature to lethal temperatures increased with the density of the wood. Hardwoods such as oak took longer times than Douglas fir or redwood. Denser wood also took longer times to cool. The physical size of the wood members are also a factor, large beams take longer to heat and cool than small ones. As a result of laboratory work, Ebeling concluded that heat treatment of a wooden structure could be done within a reasonable time.

Forbes and Ebeling (1987) then built a small wooden structure to test efficacy of heat treatment under simulated field conditions. They used this structure to calculate the size of the heaters and blowers that would be needed for typical homes. The basic technology of hot air heating was developed using this mockup.

Initial Field Trials

Success with preliminary work led to full-scale field trials. According to Ebeling (1997), "my co-researcher Charles Forbes and I bought a two-bedroom stucco house with a concrete slab foundation in Buena Park, California in April, 1988. We used this house to study whole-structure heat treatment under field conditions. In addition, many "isolation treatments," where heat is confined to the infested section of the structure, were successfully completed in Orange and Los Angeles Counties. We were greatly aided by a fumigator, David Lawson, in the logistics and labor of

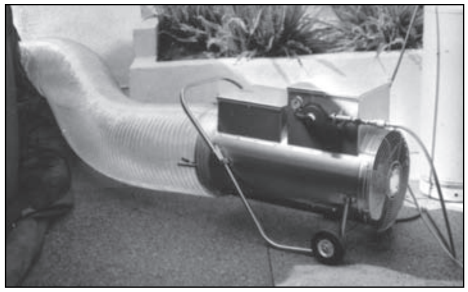


Photo courtesy of Dr. Walter Ebeling

Early commercial treatments used these mobile 400,000 BTU propane-powered heaters. Hot air is blown by the electric fan through the Mylar® heating duct.

field tests. Most of the buildings which we disinfested with heat were those in which chemical fumigation had failed.

"Forbes and I also treated houses and other structures in Arizona, Texas and Florida. At Buffalo National River in Arkansas, in cooperation with the National Park Service, we treated three "historic buildings" infested with powderpost beetles. At this site, we collected wood scraps infested with powderpost beetles (Lyctidae) from the crawl space under one of the buildings. We took the infested wood back to our laboratory at UCLA, where we found the same conditions that killed termites, core temperatures of 120°F (48.9°C) for 30 minutes, likewise stopped all larval activity of powderpost beetles. Thus, we found that powder continued to drop from untreated controls and ceased where heat had been applied" (Ebeling et al. 1989; Ebeling 1997).

Original Heat Treatment Process

The original Thermal Pest Eradication process is detailed in (Forbes 1989; Ebeling 1994b; Forbes and Ebeling 1987; Ebeling 1997). Heat is generated by propane-fueled heaters located outside an infested building. A propane heater (400,000 BTU) draws in air and blows it past a ring of flame at the other end, which heats it, producing what is called the "processed air." The heaters are equipped with wheels and handles to facilitate movement and placement. When the proper number of heaters are used and all are in the proper position for maximum effect, they are suitable for practically any type of heat job.

Flexible, collapsible, Mylar® ducts conduct the hot, processed air into the building and under thermal barriers (tarps) suspended from the eaves. Tarps are required because heat must penetrate the outer wall from both sides. Field experience has shown that the roof need not always be covered. It may have composition shingles or roofing paper, as under tile, which would not allow hot air to escape. Wood shingles allow for passage of air, but not so rapidly as to prevent adequate heating of infested wood members in the attic.

There must be a powerful heat-resistant fan in every room to rapidly mix process and ambient air and prevent stratification of hot air. The fan is used to blow hot air down against the floor, the air moves across the floor in all directions, then up the walls and across the ceilings.

Heat Bubbles

In 1990, Linford patented polyethylene tubes that could be inflated to cover cement floors or fill air space to reduce treatment times in non-infested portions of structures (Chaudoin and Linford 1991). The polyethylene "bubbles" were rapidly inflated in a room with the blower from a heater before the burner was activated. According to Ebeling (1997), "the inflated bubble can take up most of the space in a room, leaving little air space to heat, thereby decreasing treatment time by as much as 70%. Another benefit from the bubble is that it covers most of the floor area. Especially in the case of concrete floors, as in a garage or basement, the inflated bubble can eliminate the adverse influence of a substantial heat sink." Heat bubbles are not widely used in current applications, but are part of the developmental history of structural heat.

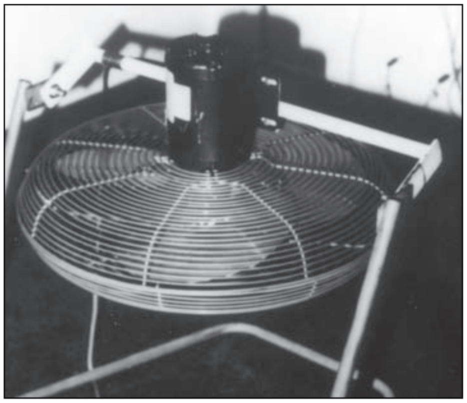


Photo courtesy of Dr. Walter Ebeling

Heat resistant fans like this one are used to insure even heating from top to bottom.

Isolation Treatment

Heat has the important advantage over fumigation in that either the whole building or part of it can be treated. In the case of fumigation, the entire building is always treated. Most often, part of a building is heated in an "isolation" or local treatment. Isolation treatment can only be used when inspection shows a limited number of drywood termite or other woodboring insect colonies whose location is known. Isolation or local treatments depend on reliable inspections. A number of novel technologies, including termite sniffing dogs, acoustic, microwave, and thermal detectors are available to help with inspection (Ebeling 1997; Quarles 2004).

Isolation treatment is of particular interest to occupants of condos and other multiple-family dwellings. Occupants of fumigated dwellings have to find some other place to live, and wait until the fumigant concentration drops to below 5 ppm (in the case of Vikane) to allow safe reentry. Fumigation with Vikane is a 3-day process, and methyl bromide takes even longer. Even then, some fumigant remains in wall voids mattresses, cushions, and other items and is slowly released over a period of weeks (Quarles 2001).

New Technology

The heat technology for insects orginally developed by Forbes and Ebeling and commercialized by Linford and Hedman involved propane heaters that used blowers to direct hot air into structures. Heating was monitored with thermocouples placed into large beams and other areas that are more difficult to heat. The temperatures inside the largest beams were used to decide when the heat had "cooked" all the termites in the structure.

Heat treatment for insects is licensed by TPE Associates, which is owned and operated by Hedman and Linford. A new company called E-Therm licenses and trains companies in the use of ThermaPureHeat for microbial and chemical remediation (see below). This new company is owned by David Hedman, who was issued a patent for treating microbials and chemicals with heat. Hedman is "deeply passionate about IPM" and views heat as a "cornerstone technology for IPM." He also sees ThermaPure as a tool to reduce the use of biocides and other chemicals in environmental remediation (Hedman 1999; 2002; 2006).

The patent base for ThermaPure and ThermaPureHeat has been expanded to include 13 patents or patents pending, 27 Trademarks, and volumes of copyrighted and trade secret materials. Research and development by Hedman and Linford has resulted in major changes in the area of heat generation. Now, heat is produced at a central source such as a trailer. Water is heated to a high temperature, then pumped through insulated hoses to heat exchangers located near or inside a structure. This technology makes it possible to produce air temperatures of 150°F (65.6°C) without exposing structures to flames or heater exhausts. Heat can be transmitted through fairly long distances through the hoses, and the easy deployment of hot water hoses makes treatments of high rises and large industrial plants possible.

Photo courtesy of Dr. Walter Ebeling

Shown here is an isolation treatment. The area underneath the tarp is being treated with heat.

Another big change is the incorporation of computer technology. The heat distribution is monitored by infrared cameras and digital thermal probes connected to a laptop computer. Cold spots can be quickly identified by thermal imaging, while digital probes monitor temperatures inside wood. Feedback controls allow fans to change the heat distribution to insure that cold spots are treated. The computer monitoring also produces a paper trail of the heat process that allows clients to be presented with a written report (Hedman 2006).

Heat as a Synergist

Heat can be used as a stand-alone treatment or can be employed to effectively enhance other insecticides. For instance, a 2-hour exposure to 110°F (43.3°C) will not kill the confused flour beetle, *Tribolium confusum*. Boric acid by itself is also ineffective. However, if beetles are confined to a thin film of boric acid and heated in this manner, they will all die (Ebeling 1990).

In January of 1990, Columbia Pest Control, a company operated by Mike Linford, treated a 90,000 ft3, free standing restaurant in Irvine, CA. The treatment process began at midnight and continued until about 5 AM. Voids of the structure had been previously dusted with boric acid. Since wall void temperatures only reached 115°F (46.1°C), the crew believed that the treatment had not obtained lethal temperatures long enough to kill all the roaches (Quarles 1995; Linford 2006).

A week later a health inspector called. She had planned to shut down the restaurant as a health hazard, instead her monitoring traps showed no roaches after two days, and only one roach in 20 monitoring traps two weeks later. Linford later concluded that nonlethal heat had synergized with the slow-acting boric acid, and the combination had eradicated the roaches. Linford applied for and received a patent on heat synergism in September of 1990 (Linford 2006; Chaudoin and Linford 1990).

Heat and Silica

Heating and desiccation with amorphous silica also show synergistic insecticidal effects (Ebeling 1971; 1994c; 1997). According to Ebeling (1997), "the cuticle of the American cockroach, *Periplaneta americana,* [is] highly susceptible to thermal breakdown, beginning to disintegrate somewhere between 35 and 40°C (95-104°F) and continuing to progressively break down with increasing temperature and duration of exposure. This breakdown leads to a lethal rate of water loss, a process that is accelerated by contact of the cuticle with dust desiccants" (Machin and Lampert 1987; 1989).

Synergism of this sort is used during heat disinfestation of stored product facilities. Heat is combined with the amorphous silica, diatomaceous earth (DE). Insects that are hard to kill with either heat or DE are killed by a combination of the two (Dowdy and Fields 2002; Fields and White 2002; Quarles and Winn 2006).

Heat and Humidity

Insects exposed for short times to heat and humid air die faster than they do exposed to heat and dry air, possibly because the humid air slows evaporative cooling. For longer exposures, dry air and heat leads to quicker mortality, probably because of added desiccation effects (Forbes and Ebeling 1987; Rust and Reierson 1998).

Pest control operators (PCOs) in humid areas sometimes worry about the effect of humidity on efficacy of heat treatment against drywood termites. Scheffrahn et al. (1997) found that the amount of water vapor in the air had no effect on heat tolerance of the powderpost termite, *Cryptotermes brevis*, within exposure times of 25, 35, and 45 minutes at 45°C (113°F). They also noted that gradual acclimation of *C. brevis* pseudergates at 35°C (95°F) over a period of ten days had no significant effect on their tolerance to heat. The Florida entomologists found the eastern drywood termite, *Incisitermes snyderi* to be more resistant to heat mortality than *C. brevis* (Scheffran et al. 1997).

Photo courtesy of ThermaPure

New heating technology uses hot water to transfer heat to heat exchangers, producing hot air for thermal eradication.

Heat Tolerance and Avoidance

Sometimes during a hot summer, the wood in some parts of an attic can reach the lethal temperature for termites. How can a drywood colony survive under these natural conditions? They may be able to walk away from slow heat increases. Cabrera and Rust (2000) conducted heat experiments with the western drywood termite, *Incisitermes minor*, in the laboratory. They found that these termites will move away from a hot area at 1.41 cm/sec (0.5 in/sec) until the temperature drops below 40°C (104°F). Termites preferred temperatures about 29-32°C (84.2-89.6°F), but could establish galleries at about 42-44°C (107.6-111.2°F). Though they might move away from natural hot spots in an attic, a heat treatment occurs too quickly for termites to move, and there is no cool area to move to.

Drywood termites are generally more heat resistant than subterranean species (Woodrow and Grace 1998ab). Among subterraneans, the Formosan subterranean termite, *Coptotermes formosanus*, can tolerate higher temperatures than the eastern subterranean termite, *Reticulitermes flavipes* (Sponsler and Appel 1991; Hu and Appel 2004). Though heat is not used to treat termite colonies in the ground, occasionally *C. formosanus* will establish an aboveground colony within a structure. To make sure that all species of termites that are structural pests are killed, commercial heat operators heat all wood to 130°F (54.4°C) for one hour (ThermaPure 2006).

Dr. Ken Grace of the University of Hawaii conducted field studies with Linford in 1994 to determine the efficacy of treating detached aerial Formosan colonies. Grace found that ThermaPureHeat was efficacious in this type of application (Linford 2006; Woodrow and Grace 1997).

Efficacy for Termites

An important standard of efficacy in structural pest control is the callback. If there are problems with the treatment, the operator is called back to mitigate it. For structural fumigation for termites, callback rates have been estimated at 5-15% (Ebeling 1997). According to heat treatment operators surveyed by the author, heat is this good or better (Quarles 1998). Pest control operators that do heat treatments are usually happy with the flexibility that heat provides and the low frequency of callbacks (Quarles 1994ab; Quarles and Bucks 1995).

Lewis and Haverty (1996) compared heat with structural fumigation and other alternate termite treatments such as electrogun and microwaves in a small (400 ft2; 37.2 m2) structure built for this purpose. Boards infested with nymphs of the western drywood termite were placed in the attic, drywalls and subarea of the test building (Lewis 2003). Boards artificially infested were used in Trial 1, and naturally infested boards were used in Trial 2. In both heat tests, the structure was heated until monitoring thermacouples embedded in the wood showed 120°F (48.9°C) for 30 minutes. Commercial heat treatment operators now use 130°F (54.4°C) for an hour as the treatment protocol. **Table 1** shows the results of the tests.

As can be seen from the Table, none of the techniques were 100% effective in all tests. Liquid N_2 caused 100% mortality in both Trials when relatively large amounts were used. Standard fumigation with Vikane killed all the termites in Trial 1, but not Trial 2. Heat led to 100% termite mortality in Trial 2, but was somewhat less effective in Trial 1.

Why was heat less effective in Trial 1? Since heat rises, it is more difficult to kill termite colonies that are in subareas or near heat sinks such as concrete foundations. According to Ebeling (1997), "In heat Trial 1, the heat treatment operator made no provision for circulation of the heated air to the subarea of the structure. Adequate circulation of hot air is required for efficient transfer of heat from air to solid surfaces. As a result, a few termites survived in the subarea. In the second treatment (Trial 2), a fan that fit into the subarea's access hole was provided. All termites in the subarea as well as in the attic and drywall were killed."

Heat and Bed Bugs

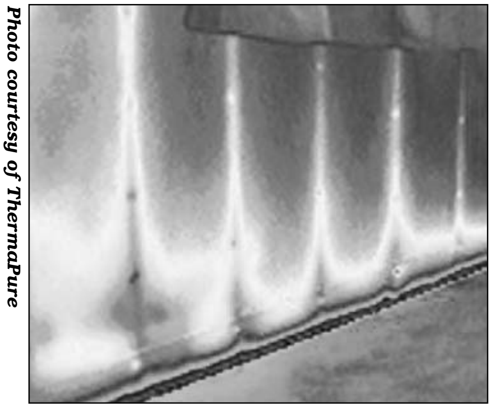
The pest control industry was founded on treatments for bed bugs and rats. These pests can be so difficult to eliminate that professional help is often needed. Bed bugs have shown a resurgence in the last few years, especially in commercial lodgings. According to Linford and Currie (2006), "Special difficulties that hotels, motels, and multiple units face with respect to bed bugs are significant. If a client is exposed to pesticidal residue and gets sick, the person may sue. If the inhabitant is bitten several times, the result may be the same..."

Even when standard pesticide sprays and dusts are used, bed bugs may not be eliminated. Bed bugs hide in books, clothes, cracks, crevices and other areas. Heat can reach lethal levels inside mattresses, pillows, wall voids, books and all contents within a given habitation. According to Linford and Currie (2006), "Because bed bugs typically migrate upward, rooms on several floors can be treated simultaneously within 4 to 8 hours depending on the number of heaters and the size of the treatment. What that means is that rooms can be rented out by 6 PM if treatment commences in the morning hours. The loss of revenue is minimized, or eliminated altogether..."

Bed Bug Protocol

To be successful for bed bugs, heat should be used as part of an IPM protocol. The presence of bedbugs are first confirmed by inspection. Then a treatment plan is prepared. The client is given instructions to prepare for heat treatment by removing clutter, washing clothing and bedding, and caulking cracks and crevices. Heat probes are inserted into the most difficult places to heat, and into known attractive harborages. Heat treatment is concluded after probes show temperatures of 140°F (60°C) for two hours (Linford 2006).

Photo courtesy of ThermaPure



Infrared cameras are used to find hot and cold spots. The hot studs in the wall can be detected by the camera. Fans can direct heat toward cool spots.

Even Rats

Though heat technology was developed for elimination of termites and woodboring beetles from structures, the heat process can also kill other insects inside a structure and has been used to treat bed bugs, fleas, and other insects.

Heat technology can even be used for rodent control. Rat nests can be identified with thermal imaging, and heat can be used in conjunction with exclusion. The rats have to leave during heating. And the hot air which blows out of the structure allows identification of rat holes and entry points. These can then be sealed (Hedman 2006).

Table 1. Mean Percent Mortalities from Six Different Termite Treatments (adapted from Lewis and Haverty 1996)

Treatment	*Mean Percent Mortality Trial 1 (artificial infestation)	**Mean Percent Mortality Trial 2 (natural infestation)	***Mean Percent Mortality Controls
Liquid Nitrogen (381.8 kg/m3)	100	100	18.4
Liquid Nitrogen (122.7 kg/m3)	98.2	99.8	18.4
Vikane®	100	99.9	22.0
MeBr/CO2	100	99.8	32.8
Electrogun	98.5	95.1	8.3
Heat	97.5	100	33.5
Microwave	92	98.7	23.3

*Mean % mortality measured at 4 weeks posttreatment, artificial infestation
**Mean % mortality measured at 4 weeks posttreatment, natural infestation
***Mean % mortality measured at 4 weeks, untreated artificial infestations

Update

Mold and Microbials

The major extension of the technology has been for heat remediation of microbials. Many microbials can be killed by heating to pasteurization temperatures of 150-160°F (65.5-71.1°C) for at least 30 minutes. Some viruses, such as hantavirus, are inactivated at these temperatures. According to Hedman, at least 50 structures in U.S. parks have been treated to inactivate hantavirus. The odors and particulates associated with rodent urine are also removed by the hot air and filters (Hedman 2006).

Incorporation of air filters during the heating process has allowed ThermaPure to do a better job and to extend the pest range. Heat desiccates dust inside a structure, and the blowers agitate air currents so that dust becomes airborne. Filters then remove dust mite allergens, microbials and other components of house dust. According to Hedman (2006), this means that mold fungi and other airborne particulates that are "deleterious to respiratory health" are removed from the air.

When heat is used in mold remediation, standard mold remediation techniques are used first. So damaged materials are removed in a containment area. The heat treatment is used to further purify the air and the structure by thermally inactivating remaining mold, and removing microbials and allergens from the air by filtration (ThermaPure 2006).

Thermal Cure of "Sick Buildings"

Many volatile organic compounds (VOCs), such as carpet adhesives, paints, and formaldehyde from particle board, are built into a building at the time of construction or in remodeling. Others are maintenance products such as cleansers, polishes, disinfectants, deodorizers, and pesticides. Pesticides and VOCs found inside cause an estimated 3,000 cases of cancer each year (Wright et al. 1991; Jantunen et al. 1997; Ott and Roberts 1998).

Photo courtesy of ThermaPure

The gridlike object in the foreground is a portable air filter. The heated air is filtered to remove dust and microbials.

Air sampling has found more than 300 different VOCs in structures, causing symptoms ranging from unpleasant odors to headaches, nausea, eye, nose and throat irritation, and coughs. Other symptoms are central nervous system depression, vertigo, fatigue, irritablity, memory loss, and decreased reaction time. In various mixtures and concentrations, and perhaps combined with microbials, VOCs can cause the "sick building syndrome" (Jantunen et al. 1997).

Air in many buildings is more contaminated than outside air. According to a World Health Organization estimate, nearly 30% of the buildings in the United States have indoor-air-quality problems. The recirculation of indoor air, contaminants and all, resulted in a rise in employee complaints about headaches, watery eyes, and fatigue (Jantunen et al. 1997; Ott and Roberts 1998).

Heat can be used for thermal removal of VOCs. According to Ebeling (1997), the house that he and Forbes bought for heat experiments "had, at the time of purchase, a strong odor of paint, cigarette smoke, and other odors of unknown origin. All odors were completely eliminated by our first heat treatment, using temperatures up to 150°F (65.5°C)....Rapid circulation of a high volume of hot air, along with continued egress of contaminated air, appears to be an efficient and highly effective way of ridding a building of contamination by unhealthful VOCs, including pesticides." VOCs have also been removed by a slow bakeout at 90°F (32.2°C) over the period of several days (Girman 1989).

Safety

For chemically sensitive individuals, heat or some other alternate method may be the only technique possible. Heat treatment means freedom from toxic technology. Thousands of heat treatments have been performed on structures in California and elsewhere since 1987. Generally, any damage has been minor. Care must be taken to remove heat sensitive items from a treatment area, or protect them with a thermal blanket. Special care must be given to vinyl windows. Over the course of more than 100,000 ThermaPureHeat treatments, there has been only one fire associated with a treatment. This may have started as a brush fire (Hedman 2006). Even with this blemish, heat has a better record than structural fumigations, where explosions have occurred when natural gas has built up underneath the fumigation tent (Smith 2003), and where deaths have been recorded when the security of the fumigation tent is breached, or when occupants enter too soon (Derrick et al. 1990; Pest Control 1987).

Acknowledgement

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Resources

To find a licensed ThermaPure company, or to obtain a license, check the website at www.thermapure.com. Or contact ThermaPure, 180 Canada Larga Rd., Ventura, CA 93001; 888/heat-mold; Fax 805/649-1314.

Update

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Book Reviews

Complete Guide to Pest Control—With and Without Chemicals, 4th ed. George W. Ware. 2005. Meister Pro Information Sources. www.meister-pro.com. Paperback. 433 pp.

Any book that goes through several editions has to be doing something right. This book has a lot of good information, especially about the basics of pesticides. This includes chemical classes of active ingredients, kinds of chemical formulations, pesticide laws, hazards of pesticides, how to read pesticide labels, and how to handle and store pesticides.

There are many other good things about this book. For instance, the author points out early on that there are choices in pest control, and that biological, cultural, physical, and approaches other than chemical pesticides exist. Another good thing about the book are the capsule summaries of pest biology. Knowledge of a pest's weakness is the key to pest management within an IPM context. Another strong point is the pest-by-pest organization and the capsule summaries of non-chemical controls. In the Appendices there are pesticide lists with acute toxicity tables, brandnames, and general use patterns can be a helpful starting point for evaluation of a particular material.

Since this book was first written in 1980, great changes have taken place in public awareness and in methods of pest control. One big change is the exponential increase in organic agriculture. Another is passage of the Food Quality Protection Act, which mandates that pesticide risks from all sources of exposure have to be evaluated, including residues both from food and from structural pest control. Another big change has been development of biorational pesticides such as insect growth regulators, spinosad, neem and bait formulations that are recognized as reduced risk. These more targeted materials have less of an impact on biological controls and allow a more seamless integration of chemical methods into an overall pest management plan.

The author alludes to all these changes, but the chemical controls he recommends for many of the pest problems he describes are still "hard" pesticides from the 1980s such as carbaryl, malathion, ethion, disulfoton, dicofol, and propoxur.

This general bias toward "hard" pesticides can be detected in several places. For instance, in reference to the persistent chlorinated hydrocarbons chlordane and dieldrin, "it would be elementary to say that these insecticides are the most effective, long-lasting, economical and safest termite control agents known." If they have such strengths, Ware should also explain why they were banned.

Or, "one of the old standbys is diazinon, which appeared first in 1952. With the exception of DDT, more diazinon has been used in and around homes than any other insecticide. It is no longer registered for use." Again, he should explain the problems with diazinon that led to its demise.

Finally, Ware makes too much of the word "safe." There are several instances where he declares that pesticides are safe. FIFRA and other pesticide laws do not allow a pesticide to be marketed as safe. All pesticides have risks, and they are only registered if benefits exceed risk. They are not inherently "safe." For instance, he says that pyrethroids are "quite safe to use around pets and humans..." Actually, cats are extremely sensitive to the toxic effects of pyrethroids.

Overall, the intent of the author has been met. That is to "present how-to-do-it information for the layperson in a simple, understandable way, that provides an appreciation for the very important chemical and non-chemical tools and a knowledge of the biology and ecology of the pests they are intended to control..." *—Bill Quarles*

West Coast Gardening: Natural Insect, Weed and Disease Control. Linda A. Gilkeson, Ph.D. 2006. Trafford Publishing, Suite 6E, 2333 Government St., Victoria, BC V8T 4P4, Canada; 250/383-6864; www.trafford.com. Paperback. 152 pp.

Linda Gilkeson is a Ph.D. entomologist who specializes in pest management and organic gardening. Though this book was written for West Coast gardeners, many of the pests are common throughout North America, and exclusion, prevention, trapping, and least-toxic chemical controls can be used anywhere.

Linda emphasizes prevention, since "preventative methods are safe, usually cheap and do a good job of avoiding damaging infestations." This approach includes resistant plants, floating row covers, mulch, proper care, and putting the "right plant in the right place." Prevention is so effective that Linda says, "although I list least-toxic pesticides as controls in this book, in 20 years of gardening on the West Coast, I have had to resort to such products only a handful of times." The short list of least-toxic products includes *Bacillus thuringiensis* (BT), oils, insecticidal soap, diatomaceous earth, pyrethrins, acetic acid, corn gluten meal, sulfur, lime sulfur, and ferric phosphate. Also mentioned are garlic, hot pepper, and herbs.

The book is broadly organized into general pest management principles, and problems with insects, diseases and disorders, and weeds. Information is arranged pest-by-pest and includes a description of the pest, life cycle, damage, prevention, and control. Insect pests are arranged according to chewers, sap suckers, and root feeders.

There is a good section containing capsule summaries of damage along with diagnosis. There are over 130 photos and illustrations that make it easy to identify insect pests, beneficial insects and plant diseases. I especially like the ruler that is included with each photo that allows an estimate of actual size. Quite often, concepts of size are omitted from gardening books, or dimensions are given without a visual cue.

We are given lists, photos, and

descriptions of beneficial insects. "There are literally thousands of species of predatory and parasitic insects native to the coast," and Linda tells us how to attract and encourage them. To attract them, make sure there is a source of drinking water and insectary plants such as kale, parsley, dill, cilantro, sweet alyssum, calendula, candytuft, thyme, lovage, yarrow, daisies and goldenrod.

Methods of diagnosis, descriptions, photos, and methods of prevention and control are given for the most common garden diseases. For instance, to prevent damping off, plant fresh seed in well-drained soil; do not overwater; ensure good ventilation; incorporate compost, or use teas of horsetail or compost.

As a bonus, there is a section on maintaining healthy lawns without using herbicides. Emphasis is on prevention, cultural methods, and hand weeding. A good tip is to use boiling water to control weeds growing through cracks in hard surfaces such as driveways or patios.

For organic gardener's and others looking for effective solutions to pest problems without turning to harsh chemicals, this book is highly recommended.—*Bill Quarles*

Wildlife Pest Control around Gardens and Homes, 2nd ed. Terrell P. Salmon, Desley A. Whisson and Rex E. Marsh. 2006. Pub. No. 21385, University of California, Agriculture and Natural Resources, Oakland, CA, 510/642-2431; http://anrcatalog.ucdavis.edu. Paperback. 122 pp.

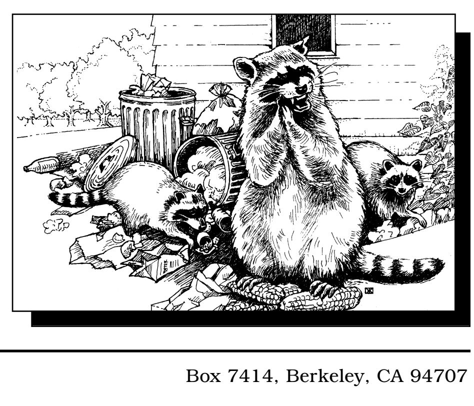
Many of us in urban areas with modest backyards have learned to live with and enjoy creatures such as squirrels, birds, raccoons and deer. The Humane Society and the National Wildlife Federation encourage this approach. Sometimes, however, numbers can increase to the point that our visitors can become pests. If our dwellings are reasonably sound, and pests are excluded, much of the friction occurs in garden situations. They want to eat it, and maybe we do not want to share.

This book by wildlife experts at the University of California, Davis is in its second edition. One of the reasons this book has been successful is the use of IPM methods. According to the authors, "IPM is an ecological approach..and usually involves the use of two or more management methods...encompassing exclusion, sanitation, modification of habitats, trapping, chemical repellents, frightening devices, and the selective use of appropriate toxic pesticides..."

The authors give good descriptions of how to use netting to prevent damage from birds, squirrels and other wildlife pests. Inverted strawberry baskets can protect young seedlings, shiny reflective tape stretched over garden rows is repellent. And what better use of old CDs than to stretch them on a string over garden plants to frighten birds?

Control of wildlife has some legal aspects to it that the authors help clarify. For instance, the use of steel jawed leghold traps is not permitted in California. Only European starlings, house sparrows and pigeons may be controlled without a permit in California, however, other species can be frightened away or excluded from the house or garden. Most repellents are not registered for food crops.

Though rat baits may be sometimes necessary, the authors recommendation of poison baits for gophers in a home and garden situation seems unnecessary. Exclusion and trapping methods are effective controls. Poisons that kill mammals are inherently dangerous, and secondary poisonings are also well documented. If used at all, they certainly should be used with great care.—*Bill Quarles*



ESA 2005 Annual Meeting Highlights– Part 3

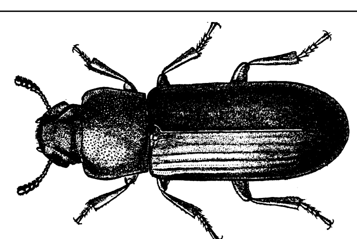
By Joel Grossman

This is Part 3 of Conference Highlights from the hurricane-delayed annual meeting of the Entomological Society of America (ESA), Dec. 15-18, 2005, in Fort Lauderdale, Florida. ESA's next annual meeting is December 10-14, 2006, in Indianapolis, Indiana. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org).

Improved Trécé Dome Trap

According to Michael Mullen (Trécé, Inc, Adair, OK 74330; mikemullen@bulloch.net), "the Storgard® Dome trap system has become the most effective monitoring system for stored-product beetles including the red flour beetle, *Tribolium castaneum*, and the confused flour beetle, *T. confusum*." The system uses a combination of an aggregation pheromone, a kairomone, and unique trap design. The pitfall trap and dome cover make it escape proof and dust resistant. However, manufacture of the trap requires that the ramp leading to the pitfall be hand sanded to precision tolerances.

Trécé has improved the trap with a precision molded surface, an improved locking mechanism and lure holder, and a synergized kairomone. *Tribolium* sp. are not good climbers and a surface that will allow them to grip and climb was essential. Mullen tested several molded surfaces and found one that was both easy for the insects to climb, and easy to produce in a mold. "When compared to the hand-sanded trap, the new molded surface of the trap increased capture of red flour beetles by 17%."



Confused flour beetle, *Tribolium confusum*

The new molded traps can be easily stacked, and the lure holder can hold up to three lures. "The function of an effective kairomone in this system is that it is attractive to the target pest, maintains its effectiveness as a killing agent and is stable over time," said Mullen. Adding a synergist to the kairomone produced a new blend "27% more effective for attracting *Tribolium* sp. than the original kairomone alone." The improved blend lasted several months and "significantly improved the effectiveness of the Dome system for monitoring *Tribolium* sp." However, the kairomone blend did not improve capture of saw-toothed grain beetles, *Oryzaephilus surinamensis*.

Short-Range Pheromone MicroDots

"The use of pheromone-baited traps is the best way to monitor for insect infestations," said Donna Lingren (Trécé Inc, 3177 Manchester Ct, Palo Alto, CA; donnalingren@earthlink.net). "The sex pheromone ZETA [(Z,E)-9,12- tetradecadien-1-ol acetate] is one of the most powerful pheromones for stored-product moths. Most traps baited with the pheromone are adequate to detect the presence of the Indianmeal moth, *Plodia interpunctella*, and other pyralid moths. The difficulty in locating infestations is exacerbated by the power of the pheromone." The pheromone is so good at attracting moths from long distances that it is hard to pinpoint the source of infestations.

"Pinpointing infestations can reduce the need for generalized control treatments and will result in lower treatment costs," said Lingren. Several methods are available to pinpoint local infestations. Traps can be concentrated in the area of the suspected infestation or statistical methods such as spatial mapping can be used. But these methods require "intensive labor" and "an extended trapping period." A shorter monitoring period necessitates a pheromone trapping system where moths are attracted from shorter distances.

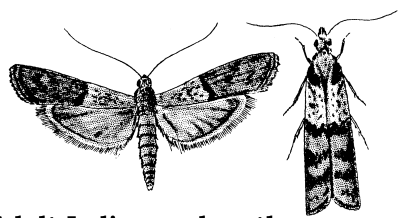
"Using a standard lure, males were found to land in the vicinity of the trapping surface and to walk towards the lure, a process that took about 8 seconds from landing to capture," said Lingren. "A lure loaded with a reduced amount of pheromone would decrease the amount of time from landing to capture and permit a mini-trap to be used. Several load rates were tested until one was found that reduced the time from landing to capture to approximately 2.5 seconds."

MicroDot® lures with reduced pheromone loads attracted fewer moths (1/4 as many as standard lures) over shorter distances (3-4 m; 10-13 ft), allowing infestation sources to be pinpointed and eliminated more quickly. In IPM programs, mini-traps with MicroDot® lures allow swift precision targeting of pest control efforts after standard lures indicate infestations.

Female Lures

"IPM has taken on greater prominence as the need for pesticide-free organic foods increases and also as insects develop resistance to conventional fumigants and insecticides," said Charles Konemann (Oklahoma State Univ, 127 Noble Res Center, Stillwater, OK 74078; koneman@okstate.edu). "The major drawback to using pheromone-based methods such as

Conference Notes



Adult Indianmeal moth, *Plodia interpunctella*

mass trapping and mating disruption is that they target only males. Untrapped males or males unaffected by mating disruption can mate multiple times, thus maintaining a substantial moth population."

One female Indianmeal moth can lay 300 eggs in a lifetime, so traps with female attractants are a good IPM tool. At a close range, various foods and oils stimulate moth egglaying and could potentially lure and trap females.

"We now have an attractive extract that is a mixture of naturally occurring food volatiles...," said Konemann. A patent application has been filed and the product is called Moth Suppression® (Insects Limited Inc). In laboratory studies and field trials in a pet food warehouse, traps baited with Moth Suppression successfully captured female moths despite competing odor sources.

Looper Pheromone

"The periodicity of pheromone release (calling) and male responsiveness adds another potential dimension to reproductive isolation among species," said Kenneth Haynes (Univ of Kentucky, Lexington, KY 40506; khaynes@uky.edu). In some cases, species with similar, or even identical, pheromone blends may be reproductively isolated from other species by distinctive daily calling periods for females and temporally coordinated responses by males.

Haynes used "parent-offspring analysis" to investigate "heritable variation in the calling behavior" of cabbage looper, *Trichoplusia ni*. "The resemblance of mothers and their daughters in temporal aspects of their calling behaviors indicates that these characters would evolve under selection," said Haynes, who used infrared still photography to study each cabbage looper moth for 120 hours. According to Haynes, "The periodicity of calling behavior may adapt to extrinsic factors such as environmental temperature, the character of predators, or other species that share the communication channel."

Parasitoid Pheromones

Nancy Epsky (USDA-ARS-SHRS, 13601 Old Cutler Rd, Miami, FL; nepsky@saa.ars.usda.gov) talked about pheromone attractants for parasitoids. Sex pheromones alone or in combination with host fruit volatiles may provide an effective trapping system for the braconid parasitoid *Diachasmimorpha longicaudata*, which is mass produced for Caribbean fruit fly, *Anastrepha suspensa*. Male *D. longicaudata* produce a long range chemical attractant for females. Females may also produce small amounts of a short range pheromone. This pattern of males producing larger quantities of pheromones for long-range attraction of females and females producing smaller quantities of pheromones for short-range attraction of males may be common among parasitic wasps.

The male pheromone has two components that are being identified for formulation into commercial pheromone lures. Pheromone monitoring traps for parasitic wasps should aid biological control by providing a reliable method to monitor parasitoid populations. Geometry, trap color, and host volatiles can increase the attraction. According to Epsky, "Messing and Yang (1992) reported that capture of females was highest on yellow or green unbaited sticky spheres traps, and that the addition of fruit fly host volatiles increased capture of *D. longicaudata*."

In the field, *D. longicaudata* males aggregate in leks and "perform bouts of wing fanning both when alone or in the presence of other conspecifics," said Epsky. Wing fanning produces acoustic signals. Males approaching other males or females produce an "approach song," and a "pre-copulatory song" is produced during mating. When the recorded songs are broadcast, females become active and males become quiescent.

"Sounds directed towards females were found to have shorter buzzes and longer intervals between bouts than those directed towards other males, thus indicating a sexual function," said Epsky. Wing fanning could also be used to disperse pheromones from the male or to increase air flow over the male, improving orientation toward female odors.

Saltcedar Beetle Pheromones

"Saltcedar, *Tamarix* sp., was originally imported from Eurasia as an ornamental and for erosion control on streambanks and river channels," said Allard A. Cossé (USDA/ARS/NCAUR, 1815 N. University Street, Peoria, IL 61604; cosseaa@ncaur.usda.gov). These fast growing shrubs or small trees can become weeds causing economic and ecological damage. A saltcedar biological control agent, the leaf beetle *Diorhabda elongata*, was released in the U.S and is established in Lovelock, Nevada, and north of the 38th parallel.

To monitor *D. elongata* and study its biology and dispersal, "a male-produced aggregation pheromone was demonstrated, identified and synthesized," said Cossé. "Two pheromone components (2E,4Z-heptadienal and 2E,4Z-heptadien-1-ol) and several six-carbon general green leaf volatiles are highly attractive to the beetles in the field."

Early in the season, traps baited with either pheromone or leaf volatile lures captured equal numbers of male and female beetles. A combination of pheromone and leaf volatiles was synergistic. Field experiments with lures will evaluate release rates and ratios of leaf volatiles to pheromone blend components.

Pheromones for Loosestrife Biocontrol

"Purple loosestrife, *Lythrum salicaria*, is an invasive weed that has had a serious impact on North

American wetlands," said Robert Bartelt (USDA/ARS/NCAUR, 1815 N. University Street, Peoria, IL 61604; bartelrj@ncaur.usda.gov). As biocontrol agents, the leaf-eating beetles *Galerucella calmariensis* and *G. pusilla* "have been very effective in some, but not all, instances." Identifying the long-range beetle pheromones would be useful for monitoring and increasing the effectiveness of biocontrol releases.

Volatiles from feeding male and female beetles were vacuum collected for gas chromatography analysis. "*G. calmariensis* and *G. pusilla* males produce the same compound" as a pheromone, said Bartelt. A synthetic version of the pheromone attracted males and females of both beetle species. This raises the very important question of how these species stay separate in nature and also raises the practical question of how the shared pheromone may affect biocontrol efforts.

Purple loosestrife, *Lythrum salicaria*

Cactoblastis Pheromones

The South American cactus moth, *Cactoblastis cactorum*, is used worldwide as a biological weed control for prickly pear, *Opuntia* spp. Accidentally introduced into Florida in 1989, *C. cactorum* is rapidly spreading across the Atlantic and Gulf Coasts. *C. cactorum* is a potential threat to the U.S. southwest and Mexico, where native *Opuntia* cactus are important to desert ecosystem stability and biodiversity, as well as to economically important vegetable, fruit and forage industries.

Pheromones, cultural control (sanitation) and sterile male insect releases (SIT) are combined in an IPM approach designed to protect native *Opuntia* species by stopping *C. cactorum* before it reaches the southwestern U.S. and Mexico. The *C. cactorum* sex pheromone is useful for monitoring *C. cactorum* movement into new areas and evaluating sterile male insect releases.

One way of obtaining *C. cactorum* pheromone is cutting open female moth abdominal glands, said Robert Heath (USDA, 13601 Old Cutler Rd, Miami, FL, 33158; rheath@saa.ars.usda.gov). However, pheromone chemicals obtained in this way do not reflect actual release ratios, or the true pheromone components released in the wild. Natural pheromone blends are obtained by collecting volatile chemicals from calling female moths. Adding a live virgin female moth to gland extracts boosts male landing rates to 90%.

A little piece of *Opuntia* cactus in a modified film cannister with a live virgin female *C. cactorum* moth can serve as a pheromone trap lure. White Pherocon 1-C traps work well; wing traps are better than delta and bucket traps. The female moth's mate calling success can be measured in terms of variables such as the number of males attracted, duration of calling, how long it takes for males to arrive, and mating success.

However, caged virgin female moths in field traps are not the preferred IPM monitoring option. To detect low *C. cactorum* population levels over wider areas, "a complete pheromone system" with conventional lures is being sought. Conventional pheromone lures will allow trapping to extend beyond the leading edge of the *C. cactorum* infestation. Pheromone lures will enable monitoring of uninfested states from Alabama to California and into Mexico, where the threat to native *Opuntia* is high.

Insect Benefits Worth $60 Billion

"Beneficial insects are under an ever-increasing threat from a combination of forces, including habitat destruction, invasion of foreign species, and overuse of toxic chemicals," said John Losey (Cornell Univ, 2119 Comstock Hall, Ithaca, NY 14853; jel27@cornell.edu). Most insects that provide essential services are not, at least at the present time, rare or endangered. "The optimal strategies for conserving these still-common but declining beneficial insects are almost certainly very different from those that are most effective at conserving rare and endangered insects."

Insect economic benefits range from $50 billion for recreation to $3 billion for crop pollination, $380 million for dung burial and $4.5 billion for biological control. Natural control of native pests is valued at $21 billion, but only a third of that figure is attributed to insects. Part of the recreational value of insects is as a food source for fish, game, and birds. The value for recreational fishermen is $28 billion, and bird watchers get $20 billion in insect benefits. "It is imperative that some federal and local funding and effort be directed toward the study of these vital services," said Losey.

Insect Attitudes

Insect mythology can give important insights into a culture. The Navajo culture is one of the few that views flies (Diptera) as positive, said Carol Anelli (Washington State Univ, P.O. Box 646382, Pullman, WA 99164; sheppc@mail.wsu.edu). Among Navajos, Big Fly is a positive insect that mediates between humans and deities, riding along the shoulder of youth and providing helpful answers. Dragonflies (Odonata) symbolize pure water.

According to Navajo creation legends, humans began as insect people. The dragonfly and red and black ants and beetles were among the 12 types of insects; the cicada gave entry to the Fifth World, where humans are today. Butterflies (Lepidoptera) are found on prehistoric Navajo and Hopi pottery. The Hopi consider butterfly flight incomprehensible magic, and have the myth and ritual of the butterfly clan, butterfly kachinas and the butterfly dance.

Flies (Diptera) have mostly negative roles in world cultures, possibly because carrion-feeding maggots are associated with death and evil spirits, said Ron Cherry (Univ of Florida, 3200 E. Palm Beach Rd, Belle Glade FL. 33420), co-author of the book *Insect Mythology*. Also, biting flies and mosquitoes can seem like punishment. About 9% of fly myths and 37% of butterfly myths concern metamorphosis. In contrast to the negativity associated with flies, butterflies are mostly associated with the beauty of nature, the soul, freedom, femininity, foolishness, creation and creativity. Though in Serbia and Westphalia, butterflies are associated with witches. In his book Cherry explores whether our attitudes towards various insects are the result of inherent archetypes in the human mind or the evolution of parallel myths in different cultures.

Earwig Traps

"The European earwig, *Forficula auricularia*, plays a significant role in many orchard systems in the Pacific Northwest, both as pest and beneficial insect, depending on crop," said Jesse Benbow (Oregon State Univ, 569 Hanley Road, Medford, OR; jesse.benbow@oregonstate.edu). Beating tray sampling is commonly used to monitor arboreal insect populations, but the nocturnal nature of earwigs makes this method inadequate for monitoring effects of pesticides or cultural practices on earwig populations.

"Earwigs are nocturnal foragers that typically seek a small, secure crevice in which to hide during the day," said Benbow. "We determined that the small shelters created by a rolled tube of corrugated material would provide an attractive space for earwigs seeking shelter during daylight hours." Corrugated cardboard tube traps 10 cm (4 in) wide and 4 cm (1.6 in) in diameter attached to the trunks or major scaffold limbs of organic pear trees trapped more earwigs than similarly shaped plastic traps. The traps also caught larvae and pupae of the codling moth, *Cydia pomonella*, spiders and other insects.

Rolled, corrugated cardboard tubes can be used as inexpensive, yet efficient trapping device to monitor earwig populations in the field. The traps are simple to construct and easy to place and retrieve. Shorter length traps caught fewer earwigs total, but more earwigs per unit area than longer traps. Traps 25 cm (10 in) long monitored earwigs all season long in orchards treated selectively for codling moth.

Fly Light Traps

Matthew Aubuchon (Univ of Florida, Bldg 970, Natural Area Dr, Gainesville, FL 32611; aubuchon@ufl.edu) talked about light traps. He believes that light trap experiments should compensate for the high background illumination found in urban areas. This background can range from 27 to 91 lumens of light per m2 (10.8 ft2). House flies, *Musca domestica*, are sensitive to ultraviolet (UV) light and the 480-510 nanometer (nm) blue-green light of cool white fluorescent and other bulbs commonly used in buildings. The background light from these bulbs in buildings reduces blacklight trap catches of house flies, compared to a dark background.

When competing UV and 480-510 nm light bulb sources are eliminated in stores, restaurants and elsewhere, house fly catches in UV light traps are higher. UV bulbs are better than other daylight bulbs for catching house flies in urban areas, though competing light sources still reduce trap catches.

Aubuchon tested house flies with four qualitatively different fluorescent light sources and four different intensity levels and measured responses to UV light traps. All treatments were compared to dark controls with no competing light sources. As the intensity of competing light sources increased, the catch efficacy of insect light traps decreased. Even with a dark background, it required four hours to catch 92% of the flies. Thus, light traps alone without other IPM techniques do not provide complete 100% fly control.

Horn Fly Traps

Kelly Loftin and Bobby Hall (Univ of Arkansas Extension, 2301 S. University Ave, Little Rock, AR 72204; kloftin@uaex.edu) have been working on an alternative control method for horn fly, *Haematobia irritans*. "The project used a mechanical horn fly trap initially designed by USDA entomologist Willis Bruce in the 1930s" (Hall and Doisy, 1989). The trap was placed so that cattle must pass through it in order to gain access to water. Horn flies brushed off an animal's back with canvas strips are captured in trapping elements located on the sides of the trap. (see *IPMP* 19(9):1-4)

Once the cattle are acclimated to the trap, minimal attention is needed and insecticide use is minimized. "The *method* resulted in a 57% horn fly population reduction in comparison to the untreated control," said Loftin and Hall. Average horn flies per animal never exceeded 100, which was well below the economic injury level of 200.

Trapping is particularly useful when combined with other IPM techniques to control insecticide resistant horn flies (Steelman et al., 2003). "The estimated cost per animal for trap use was calculated at $1.30 based on a 20 year lifespan, $500 for initial construction materials and $300 in repairs over the 20 year period," said Loftin and Hall. "For comparison, the cost associated with using a back rubber and insecticide impregnated ear tag was about $0.41 and $1.85 per head, respectively."

Fly-Fighting Fungi

"Use of *Beauveria bassiana* (strain GHA) and *Metarhizium anisopliae* (strain ESCI) in dust bags or back rubbers for treatment of horn flies on cattle in the field needs to be evaluated," said Kimberly Lohmeyer (USDA-ARS, 2700 Fredericksburg Rd, Kerrville, TX 78028; Kim.Lohmeyer@ars.usda.gov). When 0.5 g (0.02 oz) of conidia or blastospores of *B. bassiana, Paecilomyces fumosoroseus* (strain ARSEF 3581) or *M. anisopliae* dusted on faux cattle fur were tested against adult horn flies for 2 hours inside clear plastic tubes covered with aluminum, *B. bassiana* "caused the highest mortality and had the shortest LT50 in adult horn flies when compared to the untreated control." *M. anisopliae* also caused significantly more mortality than the untreated control.

At 4 days post exposure, flies treated with *B. bassiana* had an average of 98.4% mortality compared to 43.5% from treatment with *M. anisopliae* and 13.0% from treatment with *P. fumosoroseus*. At 7 days post exposure, flies treated with *B. bassiana* had an average of 100.0% mortality compared to 73.0% from treatment with *M. anisopliae* and 33.3% from treatment with *P. fumosoroseus*. The LT50 was 2.70 days for *B. bassiana*, 4.98 days for *M. anisopliae*, 7.97 days for *P. fumosoroseus* and 9.42 days for the control.

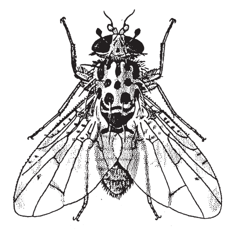
Essential Oil Lures

"Early in the last century, citronella oil was discovered by accident to be attractive to male *Bactrocera* fruit flies in India," said David Robacker (USDA ARS, 2413 E. Highway 83, Weslaco, TX 78596; drobacker@weslaco.ars.usda.gov). "This oil was attractive because it contained a small amount of methyl eugenol, which to this day is the most powerful attractant for males of any species of fruit fly."

Most essential oils decreased the attractiveness of AFF lures for Mexican fruit flies, *Anastrepha ludens*. But grapefruit, rose, and lemongrass oil enhanced the attractiveness of AFF lures by 20-30% to both males and females. The work will now begin to identify the attractive principals in grapefruit, rose and lemongrass oils that enhance the attractiveness of the AFF lure.

Neem Safety for Medfly IPM

"Azadirachtin is probably the most well known bioactive secondary metabolite produced by the neem tree, *Azadirachta indica*," said Massimo Cristofaro (ENEA, Rome, Italy; massimo.cristofaro@casaccia.enea.it). This compound shows high toxicity for phytophagous insects, acting as a feeding deterrent and sterilant, interfering with insect growth regulation, neurosecretory gland activity, and chitin synthesis.



Medfly, *Ceratitis capitata*

Cristofaro investigated the effect of neem on *Psyttalia concolor*, a braconid wasp released for biological control of medfly, *Ceratitis capitata*; olive fruit fly, *Bactrocera oleae*; and other fruit fly pests in Hawaii, Central America and the Mediterranean Basin.

"Although neem-based products are widely used in least-toxic, sustainable integrated pest control practices, the effects of azadirachtin on beneficial insects, such as parasitoids and predators, are still unclear, and subject of controversial opinions in the scientific community," said Cristofaro. "This work showed that azadirachtin treatment of the host affects only partially the parasitoid, allowing it to complete its life cycle...the field applications of azadirachtin-based pest control strategies appear to be safe for beneficial insects." (see *IPMP* 27(5/6):1-14)

Grubs in Oklahoma

According to Joseph Doskocil (Oklahoma State Univ, Stillwater, OK 74078; ctjaked@yahoo.com), "There are more than 150 known species of white grubs, *Phyllophaga* spp. in North America; however, only 25 species are known to feed on turfgrasses." In many regions of the U.S., the species of *Phyllophaga* that are important to the turf industry have not been identified, despite the fact that they are important turf pests. May and June beetle grubs feeding on grass roots limit turf development and quality, resulting in "damaged turf that lifts easily like carpet."

"Species that are economically important pests of turfgrasses in Oklahoma are not documented," said Doskocil, in part because *Phyllophaga* adult and larvae are difficult and time-consuming to identify. Doskocil collected 2,700 adult *Phyllophaga* from seven golf courses using a 1.2 m (4 ft) high blacklight trap. Of the 12 *Phyllophaga* species captured, the most common *were P. crassissima, P. glabricula, P. crinita, P. praetermissa*, and *P. congrua*. Flight times and adult emergence varied for the different *Phyllophaga* species during the April to July survey period.

Giant Salvinia Biocontrol

"Giant salvinia, *Salvinia molesta*, is a free-floating aquatic fern that is one of the world's most serious tropical and subtropical aquatic weeds," said Leeda Wood (USDA-APHIS-PPQ, 22675 N. Moorefield Rd. #S-6414, Edinburg, TX 78541; leeda.a.wood@aphis.usda.gov). Originating in southeastern Brazil, it was first found outside of cultivation in 1995 in South Carolina and was quickly eradicated. In 1989 it was detected in Texas and has since been recorded in numerous drainages in 13 states, including Hawaii and Puerto Rico.

Giant salvinia reproduces vegetatively and aggressively colonizes slow-moving and quiet open waters. Its potential U.S. distribution is expected to be similar to that of another aquatic weed, water hyacinth... Biological control of giant salvinia using the salvinia weevil, *Cyrtobagous salviniae*, has been a successful strategy in at least 12 countries throughout the world. In all cases, the giant salvinia populations were rapidly controlled and reduced to less than 1% of their original infestations without non-target impacts.

According to Daniel Flores (USDA-APHIS-PPQ, 22675 N. Moorefield Rd. #S-6414, Edinburg, TX 78541; daniel.flores@usda.gov), salvinia weevils are reared in greenhouses and outdoor field cages for release in Louisiana and Texas. A total of 651,136 larvae, pupae and adult forms of the weevil were released in late 2001 at five sites in East Texas. The weevil became quickly established and "populations of the federal noxious weed were reduced to less than 10% of the original infestation at all of the release sites" and dissolved oxygen significantly increased in pond waters.

Calendar

July 18-21, 2006. Tree Seed Symposium. Fredericton, New Brunswick, Canada. Contact: www.tss2006.org

July 26-27, 2006. 5th Annual California Biocontrol Conference. Mission Inn, Riverside, CA. Contact: Lynn LeBeck, Academic Coordinator, Center for Biological Control, UC Berkeley, Berkeley, CA 94720; 559/360-7111; Fax 559/646-6593; www.cnr.berkeley, edu/biocon/

July 29-August 2, 2006. Annual Meeting American Phytopathological Society. Quebec City, QC, Canada. Contact: APS, 3340 Pilot Knob Road, St. Paul, MN 55121; Fax 612/454-0766; www.apsnet.org

July 29-August 3, 2006. Annual Meeting Canadian Phytopathological Society. Quebec City, Canada. Contact: R. Belanger, FSAA Phytologie Dept., Pav Comtois, Univ. Laval, Quebec, QC, GlK 7P4; richard.belarner@plg.ulaval.ca

August 10-13, 2006. 27th Annual Conference, American Community Gardening Association. Los Angeles, CA. Contact: Betsey Johnson, ACGA, c/o Franklin Park Conservatory, 1777 East Broad St., Columbus, OH 43203, betsyjohnson@communitygarden.org

August 15-17, 2006. National SARE Conference, North Central Region. Contact: www.sare.org/ncrsare/2006

August 21-23, 2006. Introduction to Soil Foodweb with Elaine Ingham. Sustainable Studies Inst., Corvallis, OR. Contact: Joe Whaley, 541-752-5066; www.sustainablestudies.org

August 24, 2006. Compost Seminar with Elaine Ingham. Sustainable Studies Inst., Corvallis, OR. Contact: Joe Whaley, 541-752-5066; www.sustainablestudies.org

August 25, 2006. Compost Tea Seminar with Elaine Ingham. Sustainable Studies Inst., Corvallis, OR. Contact: Joe Whaley, 541-752-5066; www.sustainablestudies.org

August 26, 2006. Microscope Class with Elaine Ingham. Sustainable Studies Inst., Corvallis, OR. Contact: Joe Whaley, 541-752-5066; www.sustainablestudies.org

September 10-15, 2006. 7th Intl. Symp. Fruit Flies. Salvador, Bahia, Brazil. Contact: www.fruitfly.com.br

September 22-24, 2006. Renewable Energy Roundup. Fredericksburg, TX. Contact:Renewable Energy Roundup, PO Box 9507, Austin, TX 78766; www.the roundup.org

September 23, 2006. Annual Meeting American Horticultural Society. Alexandria, VA. Contact: AHS, 800/777-7931; www.ahs.org

September 24-28, 2006. 15th Australasian Weeds Conference. Managing Weeds in a Changing Climate. Adelaide, SA, Australia. Contact: events@plevin.com.au; www.plevin.com.au/15awc2006/

September 29-30. Annual Meeting, Hawaii Pest Control Association, Honolulu, HI. Call 808/533-6404.

October 7-11, 2006. Annual Conference Community Food Security. Vancouver, BC, Canada. Contact: www.foodsecurity.org

October 20-22, 2006. 17th Annual Conference Bioneers. Marin Center, San Rafael, CA. Contact: www.bioneers.org

November 10-12, 2006. The Future of Farming. Washington Tilth, Vancouver, WA. Contact: Tilth Producers, PO Box 85056, Seattle, WA 98145; 206/442-7620.

November 26-29, 2006. Northeastern Mosquito Control Association. Saratoga Springs, NY Contact: www.nmca.org

December 10-14, 2006. Annual Meeting Entomological Society of America. Indianapolis, IN. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; Fax 301/731-4538; www.entsoc.org

Conference Notes

Synergistic Waterhyacinth Biocontrol

"Waterhyacinth, *Eichhornia crassipes*, is an important invasive floating aquatic weed in the southern U.S.," said Patrick Moran (USDA-ARS, 2413 E Hwy 83, Weslaco, TX 78596; pmoran@weslaco.ars.usda.gov). In the 1970s two congeneric curculionid weevils, *Neochetina bruchi* and *N. eichhorniae*, were released, and these weevils have reduced waterhyacinth populations. However, millions of dollars are still spent annually for mechanical and chemical control of waterhyacinth in the U.S.

Inoculating waterhyacinth weevils with the plant pathogenic fungi, *Cercospora piaropi* and *Acremonium zonatum*, "prior to augmentative releases could lead to additive or synergistic biological control" of floating waterhyacinth, said Moran. The concept of vectoring, or carrying of plant pathogen inoculum by leaf-feeding beetles is well-established in crops but has not been widely applied to biological control of weeds.

Weevils remained capable of infecting 80-90% of the weeds with plant pathogens for two weeks after exposure to fungal suspensions. Releasing weevils inoculated with plant pathogens caused as much waterhyacinth damage as "simultaneous infestation with non-inoculated weevils and foliar application of the fungus" as a bioherbicide.

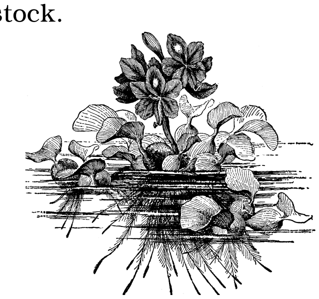
"Additional work is needed to maximize the potential for waterhyacinth weevil vectoring to improve biological control," said Moran. The seasonal timing of weevil release may be important. Plants may be most vulnerable when their growth or size is lowest, such as during cooler periods in areas where weevils are active year-round, or early in spring in areas where dormancy occurs. Formulation technology could improve the utility of plant pathogenic fungi as vectored biocontrol agents by improving the adherence, survival and dispersal of fungal inoculum.

Poison Hemlock Biocontrol

"Poison hemlock, *Conium maculatum*, a Eurasian weed naturalized in North America, contains high concentrations of piperidine alkaloids" and in the U.S. "was largely free from herbivory until approximately 30 years ago," said Eva Castells (University of Illinois at Urbana-Champaign, 320MH 505 S Goodwin Ave, Urbana, IL 61801; castells@life.uiuc.edu). Poison hemlock's tendency to invade fields of alfalfa and other forage crops has led to livestock death through contamination of green-chopped hay. Rank odor and profuse growth also make poison hemlock an eradication target.

Biological control is limited by the fact that very few insects feed on poison hemlock. An aphid, *Hyadaphis foeniculi*, accidentally introduced from Europe is among the few abundant insects attacking poison hemlock in California. A European leaf-rolling caterpillar, *Agonopterix alstroemeriana*, sometimes causes complete defoliation of poison hemlock in the Pacific Northwest. *A. alstroemeriana* "has demonstrated potential for systematic use as a biocontrol agent," said Johnson, and in the western U.S. "has quickly become established naturally in infested locations and has established itself when it has been intentionally released."

In experiments, the caterpillar laid more eggs and caused more damage to poison hemlock plants possessing lower levels of defensive monoterpene and alkaloid compounds. Thus, prolonged reassociation of the caterpillar and weed may exert selective pressure for poison hemlock plants containing higher levels of the coniine and piperidine alkaloids noxious to humans and livestock.



Waterhyacinth,
Eichhornia crassipes