INTEGRATED PEST MANAGEMENT IN UNIVERSITY OF FLORIDA STRUCTURES AND LANDSCAPES

By

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To my family and friends

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TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

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Integrated Pest Management (IPM) incorporates a variety of methods to control pests ranging from human behavioral changes to the use of biological controls and least-toxic pesticides. IPM's ultimate goal is to reduce pest and pesticide risks to human and environmental health. Research was conducted in collaboration with the Department of Housing and Residence Education (DHRE) to assess and advance the campus IPM program and describe the biology of the invasive ant pest, *Brachymyrmex patagonicus* Mayr. The IPM program opted for cultural and physical control methods over use of chemical treatments based on a formal decision-making process and set of urban IPM actions. Cultural controls are actions influenced by the behavior of the residents while the physical controls are materials and devices installed or used by the pest control and maintenance personnel.

Pesticide and pest complaint data collected from 220 campus apartments in Maguire Village between 2003 and 2008. There was a decrease in the mean monthly amount of pesticide active ingredients used per year from a peak of 41.08g to 1.96g, and high-risk pesticides were replaced with low-risk pesticides. There was no change in the number of pest complaints. Apartments were less pest-conducive after the advancement of IPM due to education of the residents and frequent sanitation inspections by the DHRE staff. These results demonstrate that

using a comprehensive IPM program can minimize pesticide use in university housing with no increase in pest complaints.

The landscape at Maguire Village had eight ant species, but only *B. patagonicus* was abundant. *Dorymyrmex bureni* (Trager) was the second most abundant and six others were observed: *Solenopsis invicta* Burenm, *Pseudomyrmex gracilis* (Fabricius), *Crematogaster ashmeadi* (Emery), *Pheidole megacephala* (Fabricius), *B. obscurior* Forel, and a second *Dorymyrmex* species. *Brachymyrmex patagonicus* was found nesting in trees, the soil, and wall voids. It fed on sweet substances found on mealybugs, aphids, and in plant sap. There was a 12-month cycle of complaints about *B. patagonicus* with the majority of complaints during the summer months. The relative abundance of *B. patagonicus* probably resulted from environmental disruptions due to past pest management and maintenance activities at Maguire Village.

CHAPTER 1
LITERATURE REVIEW OF THE HISTORY AND DEVELOPMENT OF URBAN INTEGRATED PEST MANAGEMENT (IPM), URBAN IPM, AND THE IPM PROCESS

History and Development of Urban IPM

Integrated Pest Management (IPM) is a phrase coined only 50 years ago, yet it is a centuries old agricultural practice (Stern et al. 1959, Jacobsen 1997, Kogan 1998). There are over 60 definitions of IPM, but IPM is generally defined as "…a decision based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests in an ecologically and economically sound manner" (Kogan 1998, Prokopy 2003). IPM is an efficient and sustainable pest management practice that focuses on long-term prevention with the least amount of human and environmental health impacts by manipulating the entire ecosystem (Benbrook and Groth 1997, Lewis et al. 1997). IPM has received praise as being the only rational pest management option (Wearing 1988, Kogan 1998).

Prior to IPM's formal introduction in the mid 20th century and the increased availability of synthetically produced pesticides, agricultural producers relied more on non-chemical controls; many required knowledge of the pest's biology in order to develop management tactics (Gaines 1957, Kogan 1998). These practices included but were not limited to: planting crops in seasons when the pests were not abundant; hand picking or using mechanical devices to kill the pests; removing infected plants from the fields; and tilling crop residue during off-season field maintenance (Gaines 1957). In addition, available chemicals such as sulfur, arsenic, wood ash, and plant extracts were used on the crops to deter pests, many of which are still used in underdeveloped countries (Gaines 1957, Banjo et al. 2003).

In the 1940s, many people in agriculture abandoned the cultural and physical pest management practices and replaced them with quicker-acting pesticides, such as dichloro-diphenyl-trichloroethane (DDT), organophosphates, and others as they became available. This change also shifted research focus from insect biology and ecology to chemical development (Brattsten et al. 1986, Kogan 1998). Soon thereafter, problems arose from the indiscriminate use of pesticides (Ehler 2006).

Researchers began to notice a resurgence of pest insects after chemical treatments. This was most likely caused by an unforeseen reduction of natural enemies and competitive species (Ripper 1956). Both predators and competitors helped keep the pest populations balanced. Insects also began to develop resistance to the pesticides (Stern et al. 1959, Jacobsen 1997). In one case, the amount of organophosphate needed to control an aphid increased four-fold within seven years after the chemical became commercially available in the 1950s (Stern and Reynolds 1958). Human and environmental health concerns were also voiced during those times.

The book *Silent Spring* shed light on the environmental impacts of pesticides, particularly the effects of DDT on bird communities (Carson 1962). DDT exposure reduces the thickness of eggshells causing egg breakage and fewer progeny (Lincer 1975). DDT and other organochlorines have also been shown to cause cancer in animals, and health care professionals now suggest these chemicals increase the risk of breast cancer in humans (Hunter and Kelsey 1993, Wolff et al. 1993).

Combinations of the above factors led to the development of "integrated control" out of California, which later expanded into the IPM concept (Stern et al. 1959, Kogan 1998, Ehler 2006). Stern et al. (1959) developed the prelude to modern IPM, suggesting that pest control should be an integration of both biological and chemical controls. Biological control was seen as a long-term solution because natural enemies are sustained in the environment while many chemicals degrade quickly after application (Stern et al. 1959). On the other hand, chemicals were to be used when a pest population grew beyond the control of natural enemies or when crop damage would have an economic impact on the grower. This led to the concept of economic injury level and economic threshold.

Economic injury levels and economic thresholds were defined in order to determine the necessity of action against pests. Economic injury level is the minimum pest population density that inflicts economic damage, and economic threshold is a pest density at which action is taken to prevent the pest population from reaching the economic injury level (Stern et al. 1959). The economic threshold is therefore set below the economic injury level. By following this strategy, growers will not apply pesticides on a crop until necessary, thus saving money.

Throughout the 1960s, American environmental awareness grew stronger and during this time, the National Environmental Policy Act (NEPA) (NEPA 1969) was signed into law. NEPA aimed to prevent environmental damage by understanding ecological systems. This act also established the Council on Environmental Quality. Additionally, Richard Nixon's administration presented the Reorganization Plan No. 3 of 1970 (Nixon 1970). This plan formed the Environmental Protection Agency (EPA), a governmental agency responsible for improving the quality of the air, land, and water by reducing levels of pollution. Five years later, the United States Department of Agriculture (USDA) Cooperative Extension Service, established in 1914 by the Smith-Lever Act, provided funding for IPM in all states (Jacobson 1997). The current national IPM program, spawned from the USDA Cooperative Extension Service, has since expanded into a network that includes all 50 states and six commonwealths (Leppla et al. 2009). These initiatives have furthered the development of IPM in agricultural as well as urban settings.

Modern IPM was formalized in the 1970s, as the ideas of various groups were pooled and non-insect pests were included in management programs (Kogan 1998, Ehler 2006). In 1971, Senate Bill 1794 resulted in the funding and development of an IPM pilot program. This program is commonly referred to as the Huffaker Project (Jacobsen 1997, Kogan 1998). The Huffaker project, which lasted from 1972 to 1978, was one of the first IPM projects in which entomologists, nematologists, plant pathologists, and weed scientists collaborated, truly forming an integrated strategy for pest management (Jacobsen 1997, Kogan 1998). Upon critical review of this project, the investigators were able to describe not only the successes, but also the shortcomings and necessary changes for a successful agricultural IPM program (Huffaker 1980, Kogan 1998). From this project bloomed the IPM of today, which includes but is not limited to the management of insects, plants, diseases, and wildlife that are viewed by humans as pests for economic, medical, or aesthetical reasons.

The success of the Huffaker Project paved the way for a second multidisciplinary study conducted between 1979 and 1984. This project, the Adkisson Project, resulted in increased adoption of IPM tactics in the production of four crops—alfalfa, apple, cotton, and soybean—solidifying the case for IPM (Kogan 1998).

At the end of the 1970s, Jimmy Carter (1979) directed federal agencies to implement IPM wherever it was practical and adequate resources were available. He additionally formed an IPM Coordinating Committee to oversee its implementation, consequently leading to the formal adoption of IPM on the properties of federal agencies in urban settings.

The concepts of agricultural IPM also made their way to urban properties as horticulturalists adapted the economic injury level developed by Stern et al. (1959) to suit their needs. Ornamental plants and turfgrasses in established urban environments are not grown as commodities, so horticulturalists determined that aesthetic values, in addition to economic values, determine the action levels (Olkowski 1974, Zungoli and Robinson 1984). Thus, aesthetic injury level allowed IPM programs to translate from crops to urban environments (Hellman et al. 1982).

The structural pest management industry began to adopt IPM in the 1980s by applying the concepts of IPM to control indoor pests (Kramer 2004). These early structural IPM programs incorporated the sociological and psychological aspects of residents to determine the aesthetic injury levels (Zungoli and Robinson 1984). Pilot IPM programs were developed for German cockroaches during this time, which focused on determining site-specific aesthetic injury levels based on resident perceptions and the needs of building managers (Zungoli and Robinson 1984). In addition to the established injury levels, education became an important concept in a successful IPM program (Robinson and Zungoli 1985). The goal of education is to change an individual's or a group of individuals' behavior to prevent an infestation from occurring, as opposed to waiting for an infestation to occur and eliminating it *ex post facto*. Behavior is changed through education geared toward altering one's lifestyle so people create a less favorable pest habitat. Behavioral changes include better sanitation and maintenance and a higher tolerance of non-risk pests (Robinson and Zungoli 1985).

A pioneering structural IPM program, sponsored by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), was developed in the 1980s for library and archival facilities (Parker 1988). There was concern for both the documents housed in the facilities and the health of the people who worked in or visited the facilities. The program encompassed five key actions: 1. Inspect the facilities for pests; 2. Identify the pests, their location, and the extent of the damage; 3. Devise an IPM program for prevention and control of the pests; 4. Supervise the program; and 5. Monitor the program and make any necessary changes (Parker 1988). These key actions are the backbone for modern structural IPM programs and have been adopted by other urban institutions and property managers.

In 1994, the EPA introduced the Pesticide Environmental Stewardship Program, a voluntary program whose members advocate reducing pesticide use in both agricultural and non-agricultural settings in order to safeguard both environmental and human health (EPA 2004). Two years later, the Food Quality Protection Act (1996) was passed requiring stronger pesticide regulation, re-registration, and the promotion of IPM by federal agencies. This act was passed in response to concerns that children were being exposed to pesticides through their diets (Eskenazi et al. 1999). The stronger pesticide regulations forced the advancement of IPM programs for structures throughout the 1990s and 2000s. The primary targets of IPM during this time were federal structures, multi-unit, low income residential housing, and public schools (Greene and Breisch 2002, Brenner et al. 2003, Lame 2005).

In the 1990s, a survey found that pesticides were used to treat 90% of New York schools, but faculty, students, and parents were never notified of such actions, which raised health concerns within the community (Volberg et al. 1993). It was suggested that legislation should be proposed that would require schools to have mandatory IPM programs. As a part of these programs, schools would be required to post notifications of pesticide use (Volberg et al. 1993, Gibb and Whitford 1998). National legislation for school IPM has not been passed by congress, e.g. the School Environment Protection Act of 1999 sponsored by Sen. Robert Torricelli never made it past committee hearings, but 33 states as of 2002 have their own laws regarding pesticide use around schools (Gibb and Whitford 1998, Fournier et al. 2003, Green and Gouge 2008). There is an initiative lead by the IPM Institute of North America to implement IPM in all American schools by 2015 (Green and Gouge 2008). Only 10 states currently have legislation requiring IPM on public property (Feldman and Hepting 2007). The states with IPM legislation include Arizona, California, Connecticut, Maine, Michigan, Minnesota, New Jersey, Ohio, Oregon, and Washington. Though there is no national legislation, the federal government has made IPM more accessible for schools.

The EPA (1993) developed an IPM template providing administrators a foundation with which to set up and sustain a school IPM program. The publication provided a systematic process that included policy development, delegation of pest management roles, and IPM strategies. Later that decade, the EPA produced a comprehensive “how-to” manual for schools that detailed pest specific control strategies (Daar et al.1997).

In addition to the EPA’s efforts to establish IPM in schools, other school IPM models were developed to further meet the needs and desires of schools’ community of students, staff, and parents (Carter 2003, Lame 2005, Gouge et al. 2006, Webster and Rajotte 2006). The basis behind these school IPM philosophies is to increase communications and partnerships between the schools, the public, and, if applicable, the pest control operators (Lame 2005, Webster and Rajotte 2006).

Though IPM has only been conceptualized for approximately 50 years, it has advanced considerably to what it is today. IPM, a process of using multiple tactics to control pests in an ecologically sound manner, is a pest control philosophy initially developed to control crop pests by understanding the pest’s biology (Lewis et al. 1997). IPM has developed and now works well for urban properties, including lawns, gardens, and structures (Prokopy 2003). IPM programs have become economically and environmentally sustainable, and as effective as conventional pest management programs with the benefit of a low pesticide risk (Brenner et al. 2003, Williams et al. 2005).

Urban IPM

As the world's population increases so does urbanization. Urbanization results in close associations with pests that thrive in urban environments (Schal and Hamilton 1990). Common urban pests include insects and rodents that flourish in structures that have excessive moisture, accessible food sources, and cracks, crevices, or clutter that provide harborages (Brenner et al. 2003).

A goal of urban IPM is to use alternatives to high-risk pesticides and may consist of mechanical controls, biological controls, and least-toxic pesticides such as botanicals, growth hormones, and other low-risk chemicals to manage infestations. As pests develop resistance to pesticides, exclusive control with chemicals becomes less feasible. It was shown in the 1950s that cockroaches, for example, developed resistance to chlorinated hydrocarbons, organophosphates and carbamates (Cornwell 1976). Resistance is a growing concern as human and animal pathogens vectors, and known pest allergens become increasingly hard to control using plant derived and synthetically produced chemicals (Koehler and Patterson 1986, Valles 2004). Cockroaches not only display resistance to traditional pesticide formulations but also have an aversion to bait-formulated pesticides (Wang et al. 2004). They have not shown resistance to growth regulators, boric acid, or diatomaceous earth (Schal and Hamilton 1990, Baldwin 2005). Pesticide resistance often results in the use of more pesticide and broader spectrum, higher risk formulations that increases the risks associated with these chemicals (Schal and Hamilton 1990, Hemingway and Ranson 2000).

Studies show that pesticides are linked to health issues, and one indoor pollution study conducted in New York City found that all of the pregnant women tested had detectable airborne exposures to at least three insecticides (Riley 2000, Whyatt et al. 2002, Alarcon et al. 2005).

People spend a considerable amount of time indoors, as much as 87%, and much of this time is spent either active or sleeping in their homes (Jenkins et al. 1992). Because airborne pesticide concentrations are generally much higher inside than outside there is an increased risk of exposure to people during the time they spend indoors (Whitmore et al. 1993).

Children are at risk, more so than adults, due to their behaviors, rate of physical development, and body size (NRC 1993, USGAO 1999). Between 2000 and 2005, over 52,000 American children between the ages of six and 19 were reported to have been exposed to pesticides (Litovitz et al. 2001, 2002, Watson et al. 2003, 2004, 2005, Lai et al. 2006, 2005). Children are not only exposed to pesticides used at home, but also to those used in schools. Children who spend a significant amount of time in the classroom areas are of the most concern regarding risk. Pests pose the risk of allergens, stings, bites, and the potential spread of pathogens, so schools are expected to provide a pest free environment (Goddard 1999, Williams et al. 2005, Peters et al. 2007). Due to this expectation, schools have a tendency to resort to pesticide usage for a quick knockdown of pests and calendar treatments to prevent infestations. Scherer (2001) determined that areas in schools with the highest levels of child activity had the highest number of pest treatments due to the number of pest complaints. A study conducted in 1999 documented that in a span of three years there were well over 2,000 reported complaints of pesticide exposures in American schools (USGAO 1999). When tested, some schools and healthcare facilities had detectable amounts of chlorpyrifos, pyrethroids, acephate, and propetamphos on non-target surfaces (Fischer et al. 1999, Williams et al. 2005). Making buildings less desirable for pests decreases the need for pesticides and can reduce exposure risks.

Exposure to pest related allergens is another significant concern for public health, especially those associated with cockroaches. Cockroach allergen exposure and sensitivity can be more prevalent than those to pets and dust mites in human dwellings (Peters et al. 2007). People can develop allergies through the presence of insect feces and exoskeletons, which can persist for a long time after the insect dies. Killing insects with pesticides leaves behind the exoskeletons throughout the dwelling, so reducing the initial population of insects through an IPM program will decrease the allergen exposures (Eggleston 2005, Peters et al. 2007).

Insects are also mechanical vectors of many pathogens. Cockroaches often enter houses through sewer pipes where they are able to pick up a large number of the bacteria and viruses that they are known to carry and potentially spread throughout a house (Schal and Hamilton 1990, Brenner 1995). Studies have shown *Escherichia coli* can survive in cockroach feces for over a week, and viable *Salmonella enterica* can be recovered from cockroaches a week after exposure (Branscome 2004, Zurek and Schal 2004). *Salmonella* has also been recovered from cockroaches up to two months after inoculation (Olson and Rueger 1950). Once human food is inoculated, *Salmonella* can survive up to four years (Olson and Rueger 1950, Rueger and Olson 1969). It is possible for cockroaches to contaminate food and food preparations surfaces with these microorganisms.

Cockroaches are not the only insects that can spread pathogens. Houseflies are attracted to feces and decomposing matter where they can become contaminated with various pathogens. Houseflies are closely associated with humans, so it is common for houseflies to land on food and utensils. It is possible for flies to transfer the pathogens acquired from microbe-infested materials (Levine and Levine 1991).

Aside from minimizing health concerns, IPM also provides an opportunity to save money. Although there may be an initial increase in cost to implement IPM, once it is established the costs will decrease (Brenner et al. 2003, Miller and Meek 2004). The initial costs are mostly associated with labor but savings eventually result from fewer pest control callbacks and material requirements (Williams et al. 2005).

Health concerns and economic factors are the driving forces for urban IPM and, in order to have a well-run and efficient IPM program, a written policy is needed that includes an action plan, IPM-based treatment practices, and a list of acceptable materials (Feldman and Lewis 1995, Owens and Feldman 1998). IPM programs may not be pursued or can fail if the practices are not effective or if the people involved are not committed (Ramirez and Mumford 1995).

The Urban IPM Process

Urban IPM programs use the most economical combination of cultural, physical, and least hazardous chemical controls to manage pest infestations and minimize damage (Brenner et al. 2003). Education is also necessary for the prevention of infestations and informed selection of species-specific pest management options (Schal and Hamilton 1990, Greene and Breisch 2002, Brenner et al. 2003). Based on an assessment of the problem, the treatment options range from "no action taken" to the use of an effective, least-toxic pesticide. Non-chemical methods that include tolerance, sanitation, and exclusion are preferred, and least-toxic pesticides are used when non-chemical treatments are ineffective. Least-toxic pesticides are defined as those labeled "CAUTION" or those exempt from EPA registration (Anonymous 2007). Exceptions are made when pest related medical risks are high and current IPM options have previously been deemed ineffective (Anonymous 2007). Pesticide treatments are conducted during appropriate times to maximize the efficacy of the products and minimize the potential for human exposure. All pesticides are handled according to state and federal laws.

Species-specific plans to prevent and expeditiously manage pest problems need to be developed. These plans should accomplish the following objectives to maintain a safe and healthy environment (Daar et al. 1997, Pim and Campbell 1998, Altman 2007, Anonymous 2007):

- Protect residents by suppressing pests that threaten public health and safety.
- Minimize exposure of residents to pesticides by responsibly applying least-toxic pesticides only when needed.
- Prevent or reduce any pest damage to properties through accurate pest identification and actions based on knowledge of the pest's biology.
- Reduce environmental pollution through the careful selection and proper placement of pesticides.
- Reduce the costs of pest management.
- Prevent the transfer of pests between facilities and residences through education and pest suppression.
- Enhance the quality of life for the people who work or reside in the structures by maintaining a safe and sustainable environment.

IPM Technicians need to be identified and responsible for overseeing implementation, evaluation, and improvement of the IPM program. The IPM technician's responsibilities include (Daar et al. 1997, Pim and Campbell 1998, Altman 2007, Anonymous 2007):

- Maintaining records of all pest complaints and sightings by residents and staff.
- Maintaining detailed, up-to-date records of all pest control actions including pesticide use.
- Maintaining a current and readily accessible set of all material safety data sheets for all pesticides used or stored in-house.
- Approving the need for treatments and, when necessary, pesticide applications.
- If applicable, communicating with other departments when maintenance or sanitation issues need to be addressed to aid with IPM.
- Posting signs and notifying the appropriate people when applying a pesticide.
- Evaluating the effectiveness of the IPM program and making any necessary changes.
- Maintaining pesticide applicator licenses.

- Maintaining a library of up-to-date pest control and IPM literature.
- Maintaining a network of pest control professionals for consultation.
- Maintaining and pursuing opportunities for continuing education.

Pest control employees have many critical responsibilities, so they need to be trained in the practices and principles of IPM, continually educated as IPM advancements are made, and licensed as commercial pesticide applicators by the state in which application takes place (Anonymous 2007). Applicators must follow state and federal regulations and pesticide label instructions. Pest control technicians must comply with the IPM policy. People working in the buildings will be educated about potential pest problems and IPM methods used to achieve the pest management objectives. They are required to keep current and available records on pest complaints, sightings, and treatments to verify the need for treatments and track the effectiveness of the IPM program (Daar et al. 1997, Pim and Campbell 1998, Anonymous 2007). A detailed pesticide use database that includes active ingredient and quantity used should be maintained. Written notification for any use of high-risk pesticides shall be posted in appropriate locations prior to application and remain posted after treatments based on local laws (Daar et al. 1997). Pesticide purchases will be limited to the approximate amount needed during the year. Pesticides will be labeled appropriately, including the date when received. All pesticides will be stored appropriately at a secure site not accessible to unauthorized personnel or locked in the technician's vehicle according to federal and state law. Only the amount of pesticide needed immediately for a treatment will be prepared, and it will be stored in an appropriate container and labeled. All expired pesticides and those not re-registered by EPA review will be disposed of in accordance with label directions or state and federal regulations.

The IPM decision-making process (Figure 1-1) begins with either a pest complaint or a pest sighting during routine service. The pest control technician confirms the presence of a pest, and makes an assessment. The assessment includes: 1. Identifying the pest 2. Locating the infestation 3. Identifying the possible causes of the infestation, and 4. Determining whether or not the pest population is above the action level. If the population is above the action level, the pest control technician will determine the appropriate species-specific IPM options for managing the pest. Once the action has been taken, the pest control technician will return to the site later to evaluate the effectiveness of the option. If the problem has not been solved, the situation will be reassessed, and additional IPM options will be used. If the infestation has been managed, the pest control technician will continue to monitor the site during routine service.

Monitoring is a major component of an IPM program. It is essential for detecting and locating the source of an infestation (Wang and Bennett 2006). Monitoring is also helpful for determining the success of the treatment options (Rust 1994). Monitors, which are various kinds of traps, are placed throughout structures during the initial inspection. The monitors are then checked for insects during routine service. Monitor placement is important to get an accurate assessment of the pest problem (Wang and Bennett 2006). Monitors should be placed in locations where insects are commonly observed or near potential insect harborages. The monitors should be placed where they are not disturbed or affected by factors that may hinder their performance, including under sinks, behind the stove or refrigerator, in cabinets, and in closets (Hollingsworth et al. 2002).

If a pest is detected during an inspection, the proper IPM option should be taken. The options include cultural controls, physical controls, and chemical controls.

Cultural controls

In the context of urban IPM, cultural controls are defined as factors influenced by people’s behaviors (Kramer 2004). Pest control technicians can alter people’s behaviors through education. They can educate clients by providing written documents, e.g. brochures, newsletters, and guidelines, or by oral communications on pest control policies and procedures. People management is a factor in IPM programs, and that includes educating people about sanitation and pest tolerance (Rust 1994, Baldwin 2005). Cockroach infestations are correlated with sanitation, so people should be made aware that maintaining a clean environment with little clutter will deter pests (Schal 1988, Schal and Hamilton 1990). Education regarding less-harmful species may help clients develop a tolerance of those insects, while education may also help people develop an intolerance of more-harmful species.

Clients should be educated about the potential risks of over-the-counter pesticides and encouraged to minimize their exposure through reduced pesticide use. Low risk pest treatments, which can be utilized by the residents, should be encouraged by the technicians. These treatments include physical methods such as using flyswatters, vacuuming insects, and spraying insect pests with soapy water. Clients are urged to collect specimens so the pest control technician can identify the pest and take the appropriate action.

Physical controls

Physical controls are tangible materials and devices used to control pests. They involve routine maintenance, exclusion, and use of mechanical devices such as traps and flyswatters (Hollingsworth et al. 2002). Maintenance personnel are essential partners in an IPM program (Hollingsworth et al. 2002). Whenever a pest control technician or resident discovers a maintenance problem, e.g. leaking pipes, cracks in walls, etc., the building manager should be notified so the problem can be addressed. Structural maintenance is also important to keep pests from entering the buildings (Schal and Hamilton 1990, Hollingsworth et al. 2002). Windows and doors should seal tightly and any holes or cracks should be fixed immediately. Sealing around pipes and electrical conduits can prevent the spread of infestations (Schal and Hamilton 1990). It is helpful if pest control technicians keep a caulk gun with them so they can fill any cracks or crevices during routine inspections.

Chemical controls

Judicious use of least-toxic pesticides is warranted when the above treatments are deemed ineffective. The residents are encouraged to use EPA exempt formulations as a substitute for over-the-counter pesticides. One substitute for over-the-counter pesticides is a mixture of dishwashing liquid and water, which kills cockroaches on contact (Baldwin and Koehler 2007).

In campus residential settings, only trained pest control technicians will apply any EPA registered pesticides. Baits, dusts, and crack and crevice aerosols are the preferred formulations and are placed in locations that minimize the risk of human exposure (Hollingsworth et al. 2002).

Purpose of the project

This study developed and implemented a formal IPM pilot program in graduate student and family housing at the University of Florida. It also identified the primary pest, an ant, and described its ecology. Prior to this study, the few IPM studies conducted in public housing were focused on low income units primarily in inner-city neighborhoods (Campbell et al. 1999, Brenner et al. 2003, Williams et al. 2006). There are no known publications examining the effectiveness of an IPM program in university graduate student and family housing, even though it is a sensitive environment that houses students and often their children. The residents are not expected to perform their own pest control, so the responsibility and liability falls on the university. Because of this, it is in the best interest of the university to implement IPM, a pest management policy that reduces the risks associated with pests and pesticides. The results of this research will be used to support the initiation of a campus-wide, formal IPM program.

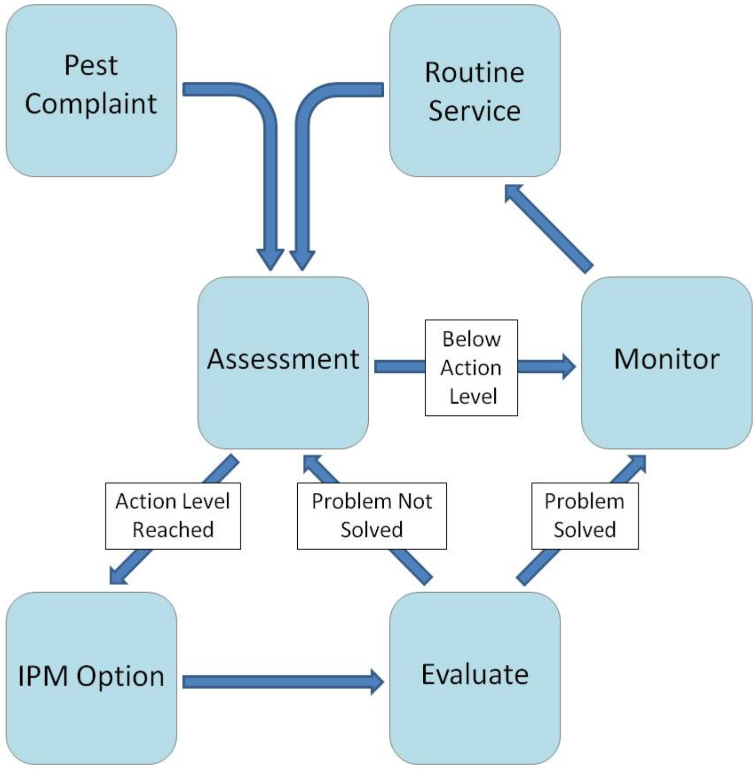


Figure 1-1. The integrated pest management decision-making process.

CHAPTER 2
INTEGRATED PEST MANAGEMENT IN UNIVERSITY OF FLORIDA STRUCTURES AND LANDSCAPES

Introduction

Insect and rodent pests are major problems in urban settings, especially in multifamily complexes that have sanitation and maintenance deficiencies (Brenner et al. 2003). Pests sometimes are aesthetic nuisances, but more importantly, many may pose health concerns. Cockroaches, for example, mechanically vector pathogens and produce allergens (Brenner 1995, Rosenstreich et al. 1997, Peters et al. 2007). In one study, 85.3% of low-income homes had detectable levels of cockroach allergens and 36.8% of the children in them reacted to cockroach allergens when tested (Rosenstreich et al. 1997). Rosenstreich et al. (1997) determined the morbidity due to asthma in that sample of children was associated with cockroach allergies and exposure to high levels of cockroach allergens in the home. There is high allergen exposure when cockroach populations are large. German cockroach populations, for example, can number in the ten thousands per apartment in low-income housing even with routine organophosphate applications (Koehler et al. 1987). To maintain an environment with a reduced pest risk it is essential to manage the insect populations, but there are also risks associated with many pesticides used for insect control (Eskenazi et al. 1999).

Pesticide exposures can have both acute and chronic effects on residents. Acute poisonings can occur when doses of pesticides enter the body through inhalation, ingestion, or absorption through the skin and immediately affect the nervous system (Ecobichon 1994, Anwar 1997). On the other hand, many pesticides are carcinogenic in animal bioassays and chronic pesticide exposure is correlated with cancer and other debilitating illnesses (Zahm and Ward 1998). Studies have shown high lung cancer rates in licensed pesticide applicators, and there is a link between pesticide exposure and leukemia, brain cancer, and lymphoma in children (Blair et al. 1983, MacMahon et al. 1988, Zahm and Ward 1998). Pesticides not only have been linked to cancer, but also have neurologic, reproductive, and genotoxic effects (Sanborn et al. 2007, Eskenazi et al. 1999). Utilizing an advanced integrated pest management (IPM) program in urban housing will reduce the risks associated with pests and pesticides by maintaining the pests at very low levels with low risk approaches.

IPM is a continuum ranging from minimal IPM practices, to an advanced IPM program that focuses on prevention and low risk approaches (Jacobsen 1997). In agricultural settings, advanced IPM is a bio-intensive program utilizing biological controls (Jacobson 1997). Although in some urban settings biological control may be feasible, in many it is not (Schal and Hamilton 1990). Where biological controls cannot be used, advanced IPM constitutes a program that focuses on pest prevention through other means, such as cultural and physical controls. Education is the key component for advanced IPM, so all personnel should be IPM trained, follow a written policy, and judiciously use low risk pesticides when needed (Robinson and Zungoli 1985, Brenner et al. 2003, Lame 2005). Not only should the pest control technicians be educated, but the residents should have a basic understanding of IPM.

Advancing IPM

The University of Florida Department of Housing and Residence Education's (DHRE) pest control technicians who service Maguire Village, Gainesville, Fl. used basic components of IPM prior to the introduction of the advanced IPM pilot program. These practices included routine apartment inspections, sanitation, and the use of least toxic pesticides and baits. To differentiate past DHRE's pest control strategies from advanced IPM, we define advanced IPM as a program having:

- A written IPM policy statement

- Identified IPM specialist
- Defined pest prevention practices
- Pest monitoring, identification and record keeping
- Written pest complaint, control and record keeping protocols
- Rapid response and decision-making process for pest control actions
- Use of non-chemical pest control strategies prior to the responsible use of least-toxic pesticides
- An IPM program evaluation component
- Education for residents regarding pests and pest control
- An IPM plan of action

IPM pilot program development

The DHRE's advanced IPM program was initiated in January 2008 at Maguire Village. The advanced IPM program consisted of following the above definition and managing pest infestations according to the "IPM Treatment Option Manual for University Housing" (Juneau et al. 2009). An IPM policy was drafted that describes the roles of the various university housing services concerned with pest control, the order in which IPM actions are taken, and other aspects of an IPM program. According to the advanced IPM policy, pest control technicians use chemical treatment options after non-chemical options are deemed ineffective. An IPM action plan flow chart (Figure 1-1) specific for university housing was developed to aid in the IPM decision-making process.

Prophylactic chemical treatments were stopped in January 2008, and all existing bait stations were removed from the apartments between 11 March 2008 and 11 April 2008. In place of the bait stations, six monitors were placed in the kitchens and bathrooms of the apartments (Figure 2-1). One monitor was placed under the bathroom sink, one under the refrigerator, one in each of the cabinets next to the stove, and two under the kitchen sink. These locations were chosen because the kitchens and bathrooms had the highest incidence of infestations and were locations of the previous prophylactic bait station placement. The pest control technicians placed additional monitors in other locations when necessary.

IPM Florida is a cooperative extension, and educational outreach to clientele is an important part of the program. Because of this, IPM educational brochures were produced for residents to educate the residents about IPM and provide information about what they can do to help prevent pests in their homes (appendix A-E). In October 2008, these documents were e-mailed to the residents, linked in the online newsletter "The Villager," placed in the commons area, and both PDF and HTML files were made available on the IPM Florida website (http://ipm.ifas.ufl.edu). The pest control technician provided an orientation regarding IPM to new residents throughout the year. During routine services or when assessing pest complaints the pest control technician also educated the residents about IPM.

Household cleaners, including dish soap, have been shown to kill insects on contact (Baldwin 2005, Baldwin and Koehler 2007). Spray bottles (Figure 2-2) were provided to the residents of each apartment at Maguire Village between 22-25 July 2008. The one-liter spray bottles provided residents an alternative to over-the-counter pesticides, such as "bug bombs" and insecticide aerosol sprays. The bottles' label (Figure 2-3) included directions to mix a 6% dish soap and water solution to "clean up insects" and an instruction brochure was handed out with the bottles (appendix F).

This study was undertaken to justify the implementation of IPM in residential settings, including university housing. These results will encourage UF and universities elsewhere to utilize IPM as the primary pest control method. This research is a pioneering study in the area of IPM, as no known research has been published quantifying IPM practices in university housing.

The goal of this study was to advance and assess the IPM program in graduate and family housing at the University of Florida. It is hypothesized that a successful advancement of the IPM program will result in a reduction of the pesticides needed to control pest infestations with no increase in the number of pest complaints.

Materials and Methods

Study location

Maguire Village, a United States Department of Housing and Urban Development apartment complex located on the University of Florida's main campus in Gainesville, Florida, USA (29^{o}38'27"N, 82^{o}22'14"), was chosen in collaboration with DHRE to serve as the IPM pilot program. Maguire Village houses single graduate students and both undergraduate and graduate families, most of whom are international students. The complex consists of 28 residential buildings and one additional building with a commons area, office, and laundry room. Twenty-seven of the residential buildings contain eight apartments and one has four apartments. In all, Maguire Village has 220 apartments. Half of the apartments are one-bedroom, and the other half are two-bedroom (Figure 2-4). The complex covers an area of approximately 5 hectares (Figure 2-5).

Pesticide use

Pest control technicians at the University of Florida have been keeping detailed records on pesticide use since 2003. The records contain the type and amount of pesticides, dates they were used, and apartments in which the pesticides were applied. Monthly pesticide data, from 1

January 2003 to 31 December 2008, for each apartment in Maguire Village (n=220) were extracted from the database.

The total mass of each pesticide's active ingredient was calculated for solid, gel, liquid, and aerosol formulations. Pest control technicians entered the solid and gel products into the database as mass, and liquid and aerosol products as volume. From this data and the information on the EPA label and material safety data sheets (MSDS), the mass of each active ingredient was calculated. Active ingredient was calculated for solid and gel formulations by multiplying the mass of the product used by the percentage of active ingredient listed on the product label. Liquid and aerosol active ingredient mass was determined by first calculating the product's density by multiplying its specific gravity to 1g/ml, the density of water. The specific gravity of each product is documented on the MSDS. The product's density was then multiplied by the total volume of the product used, resulting in the total mass of product used. That mass was then multiplied by the percent of active ingredient in the product, listed on the label, to determine the mass of active ingredient used (Table 2-1).

1. $Density_{product} = Specific\ Gravity_{product}\ x\ Density_{water}$
2. $Mass_{product} = Volume_{product}\ x\ Density_{product}$
3. $Mass_{active\ ingredient} = Mass_{product}\ x\ \%\ active\ ingredient\ in\ product$

The pesticides were grouped according to class (Table 2-2) (Kegley et al. 2008). Any pesticide rarely used or those that did not belong to a major class were grouped in the "other" category.

The mass of active ingredients in each pesticide class was totaled for each month. The data from January 2003 to December 2007 represent IPM prior to this study, while the data from

January to December 2008 represent the advancement of the IPM program. These data were summarized using JMP 7.0 (SAS institute 2007) and trends over time were visually determined.

Pest complaints

The pest control technicians documented pest complaints made by the residents. Pest complaint data, from 1 January 2003 to 31 December 2008, for each apartment in Maguire Village (n=220) were extracted from the database and grouped by pest. Any rare pest complaints or pests that did not fit in the major groups were pooled into the “other” category. The “other” pests include spiders, mites, booklice, bed bugs, mice, mosquitoes, wasps, and those reported as unknown.

The data were totaled for each pest group by month. The data from January 2003 to December 2007 represent IPM prior to this study, while the data from January to December 2008 represent the advancement of the IPM program. The number of complaints were plotted over time to visually describe any changes in complaints and a time series analysis was preformed for all complaints to determine cyclic activity. All analyses were performed using JMP 7.0 (SAS institute 2007).

The monthly average temperatures between January 2003 to December 2008 were extracted from historical weather data collected from a weather station located at the Gainesville Regional Airport, Gainesville, Florida (29°41’24.20”N, 82°16’18.40”W). This data was plotted with the complaints to visually determine correlations.

Apartment inspections

The apartments at Maguire Village were inspected for pest-conducive cultural and maintenance infractions prior to and after advancement of the IPM program. The form used for inspections contained two parts with a total of 34 potential infractions. One part assessed cultural infractions (23 possible), including sanitation issues, improper food storage, etc. The second part assessed physical infractions (11 possible) focusing on maintenance issues such as improperly sealing doors and windows, holes leading to wall voids, etc.

IPM inspections were conducted before and after implementation of the more advanced IPM program. An initial survey was conducted between 11 March 2008 and 11April 2008 after the bait stations were removed from the apartments. This was followed by another inspection between 5 and 26 January 2009. An infraction was indicated by a “1” and no infraction by a “0”. Infractions were pest conducive conditions found in or around the apartments (Tables 2-3 and 2-4). The total number of cultural infractions was tallied for each apartment (n=155) and analyzed with a paired t-test using JMP 7.0 (SAS institute 2007). Vacant apartments and those with new residents during the second inspection were not included in the analysis. The number of maintenance infractions was analyzed using the same methods as above. During the inspections, the presence of over-the-counter pesticides was documented, and during the follow-up inspection, IPM soap and water spray bottles were noted.

Results and Discussion

Pesticide use

The average amount of pesticides used per month increased from 18.22 g in 2003 to 41.08 g in 2005 then decreased to 1.96 g in 2008 (Figure 2-6). The primary pesticide classes used at Maguire Village have been amidinohydrazones, borates, desiccants, organophosphates, pyrazoles, and pyrethroids. The “other,” synergist, and insect growth regulator groups were used infrequently and did not contribute appreciably to the overall mass of insecticides. The use of amidinohydrazones, borates, desiccants, organophosphates, and pyrazoles decreased over time. Pyrethroids continue to be the predominant pesticide used at Maguire Village since their formulations are user friendly, repellant, labeled for many insects, and often have immediate results. Though the mass of pyrethroids remained relatively unchanged for individual treatments, they were used less frequently (Figure 2-7).

During 2003 the pest control technicians primarily used bait formulated amidinohydrazones and borates to treat cockroaches and ants, respectively. In 2004, they increased their use of pyrethroids to treat ants and cockroaches, then increased the use of the much heavier, albeit less toxic, borate products leading to the large amount of pesticides used per month in 2005. Desiccants replaced much of the borates in 2006. Also around this time, the formulation of cockroach baits changed from hydramethylnon to fipronil, a pyrazole. The amount of fipronil per product (0.05%) is less than hydramethylnon (2%). This decreases the active ingredient necessary to treat a pest. Organophosphate usage stopped in mid-2005. This was attributed to both the loss of product EPA registration and voluntary removal of organophosphates as a pest control option. There was a decrease in the amount of pesticides used after the summer of 2006. During this time the pest control technicians became more aware of IPM and began to take more strategic approaches to pest control, therefore requiring less pesticide needed per treatment.

Prior to 2008, the pest control technicians used prophylactic pesticides in university housing. Whether there were pests present or not, the technicians would place borates and desiccants in wall voids and under cabinets. They also placed cockroach baits throughout the kitchen. In the spring of 2008, prophylactic pesticide treatments were stopped, and all baits were removed from the apartments. The switch from calendar pesticide applications to a strategy where pests are treated only after they are discovered accounts for the low mass and sporadic use of pesticides in 2008, as they were only used when pest presence was confirmed.

After the advancement of IPM in the spring of 2008, pesticides were used more judiciously. In May 2008, the pest control technicians used an aerosol pyrethroid to control mosquitoes resting during the day in a stairwell. There was a bed bug infestation in June that was treated with desiccant and pyrethroid products. In conjunction with the pesticides, a heat treatment was performed on the sensitive items, such as bedding, the mattress and box spring, furniture, and clothing. The pesticides were only placed into wall voids, behind baseboards, and in crack and crevices. Finally, in September, October, and November of 2008, the pest control technicians treated fire ants with a hydramethylnon product after a complaint was made. All these insects were health concerns, so immediate action was taken to remedy the situation after an initial assessment. In 2008, there were also many *Brachymyrmex* spp. complaints, and they were treated with boric acid baited with honey. Though pesticides were used for each complaint, low risk products were chosen and were placed in locations where exposure risks were minimal.

It is difficult to use the total pesticide masses as an indicator of pesticide risk, because there does not appear to be a correlation between compound mass and LD_{50}—some heavy pesticides have a high LD_{50}, and some light pesticides have a low LD_{50} and vice versa. It can be assumed, however, that the reduction in each primary group of pesticides leads to a reduction in their risks. The masses of amidiohydrazone, borates, desiccants, and organophosphates were reduced; therefore, their risks were reduced. Although, pyrethroids were used in relatively large quantities, their risks have been reduced because they were used less frequently.

The pest control technicians were able to reduce the risks associated with pesticides by using least-toxic alternatives and reducing the frequency and amount of product used to treat infestations. The pest control technicians did not rely on single compounds to treat infestations, but rotated the products, therefore reducing the probability that the pests will develop pesticide resistance or aversion.

Pest complaints

The complaints remained relatively similar pre- and post-advancement of the IPM program with the exception of May 2008 (Figure 2-8). There was a large number of ant complaints that month. There was a 12-month cycle in complaints with the majority of the complaints occurring during the summer months while the winter months had fewer .

The summer months in Florida are warm (Figure 2-8), so there is increased insect activity, especially for the ants that may be invading the residences from outdoors (see chapter 3). Many residents kept windows and doors open during the warm months providing access for pests to enter the apartments. The colder winter months reduce the activity of pests and windows and doors are closed to prevent heat loss, therefore reducing access to the apartments.

The pests that caused the majority of complaints per month were ants (4.03 ± 0.53), primarily *Brachymyrmex* spp. Most of the complaints occurred during the summer months. Cockroaches (1.38 ± 0.16) were the second major pest and there was no seasonal pattern to the complaints. Complaints for stored product pests (0.21 ± 0.05), termites (0.31 ± 0.09), and others (1.0 ± 0.13) were intermittent throughout the time between January 2003 and December 2008 (Figure 2-9).

The ant complaints appeared unchanged after the advancement of the IPM program, although there were 29 ant complaints in May 2008. This unusually high number of complaints was most likely due to construction occurring at Maguire Village. High-speed internet cables were buried around each of the buildings and a lot of soil was disturbed during the process. This could have forced the ants indoors. Ants were treated almost exclusively with a borate and honey formulation. Other than this spike in complaints, there was no visible increase in ant complaints after the advancement of IPM. There was also a 12-month seasonal cycle in ant complaints described in detail in chapter 3.

Cockroach complaints remained steady with no major increases per month after the advancement of IPM and no cyclic activity. The two cockroach species at Maguire Village were the German cockroach, *Blattella germanica* L., and American cockroach, *Periplaneta americana* L. Their exact proportions cannot be determined because they were often listed in the database as "cockroach." Cockroach infestations are often tied to sanitation issues, so it is possible that the presence of food, water, and harborage are the factors driving the infestations in Maguire Village (Schal 1988). Increased sanitation may further reduce the numbers of cockroach infestations in Maguire Village. There is no cyclic activity because German and American cockroaches are domestic and peridomestic respectively, so the outdoor weather would have little if any influence on these insects that reside indoors with stable conditions (Hagenbuch et al. 1988, Atkinson et al. 1990).

The remainder of the pests, stored product pests, termites, and others, had infrequent complaints during the six years. There were a total of 15 stored product pest complaints over that time period. The food in which these pests were found was simply discarded. There were 22 termite complaints, nine of which were subterranean termites and 13 were drywood termites. The subterranean termites where treated with bait stations with either a borate or fipronil product trench and rod fipronil applications. The drywood termites were treated with imidacloprid. "Others" were pests occasionally reported, and they were treated on a case by case basis.

Apartment inspections

Inspections of Maguire Village apartments were conducted before and approximately nine months after the advancement of the IPM program. The number of cultural infractions decreased significantly from 4.14 to 2.65 infractions per apartment while the maintenance issues remained unchanged (Table 2-5).

The 12 major cultural issues, those with more than 10% of apartments with infractions, during the first inspection were pest harborage in the landscapes, open screen doors, odor, presence of mold, uncovered garbage cans, opened food on counters, spilled food in the cabinets, unacceptable unwashed dishes or dirty sink, excessive clutter, food and dust under the refrigerators, improper food storage, and poor organization. Upon a second inspection, the major issues decreased to six that included open screen doors, odor, uncovered garbage cans, food stored open on the counter, food spilled in the cabinets, and improper food containments (Table 2-3).

After the advancement of IPM, all but three of the cultural infractions improved. The three included screen doors propped open, carpet in poor condition, and food containment. There was one more apartment with a propped screen door and five more apartments that did not store their food in air tight, pest proof containers. The single carpet issue remained unchanged.

Six infractions were improved upon (10 or more apartments improved) and they were outdoor pest harborage, odors in apartment, mold, uncovered garbage cans, food stored open on counter, and food spills in the kitchen. The greatest improvements included the mold, uncovered garbage cans and food stored open on the counters, each with over 30 apartments improving.

These major infractions discovered during the first inspections were the focus for improvement during advancement of the IPM program, and education was geared toward them through brochures and other modes of education. The DHRE also enacted routine apartment inspections to improve sanitation issues in the apartments. They have the authority to discipline any resident who does not comply with the DHRE sanitation guidelines, and in some cases have given resident a citation or pursued university disciplinary actions. There were no changes in the level of maintenance issues after the advancement of IPM (Table 2-5).

The inspections exposed any major maintenance deficiencies, and they should be the focus for improving the IPM program at Maguire Village. Though many apartments still had substandard sanitation, there was vast improvement after IPM was advanced, including the apartment sanitation inspections conducted by DHRE. Mold is a problem in Florida, and the residents have been made more aware that it is a health concern due to mold spores (Jacob et al. 2002). The frequent apartment inspections have also made the residents more conscious of their sanitation. Inspections combined with educational efforts can influence residents to practice IPM, which includes improved sanitation (Campbell 1999).

Improvements have been made with the residents, but none has been made with the maintenance issues. Better communication between the pest control technicians and a more receptive maintenance department may improve the situation, but lack of manpower, time, and cost of supplies may be the primary issue on which to focus. Because there were no changes in the number of apartments with infractions, it does not mean that the same apartments had the infractions. The apartments are in a constant state of repair and remodeling. As the IPM program advances, the pest control technician can make the maintenance department aware of ways they can help exclude pests from the apartments. This may require the maintenance personnel to carry a calking gun to repair cracks and holes, and they can quickly inspect the apartments and remedy other pest conducive maintenance issues while fulfilling work orders.

As part of the advancement of IPM, spray bottles in which to mix dish detergent and water as a pesticide alternative were passed out to all the Maguire Village residents. During the second inspection, 156 of the 220 apartments in Maguire Village had the spray bottles present. The residents were encouraged to take the spray bottles with them when they moved out of the apartments. There were 65 residents that moved out of Maguire Village, so it may be that many of these residents took or discarded the spray bottles. The number of over-the-counter pesticides decreased 8.77% from 57 (25.91%) to 52 (23.63%) apartments. The apartments with over-the-counter pesticides were still approximately one quarter. This was most likely because residents are reluctant to discard unused products once they have been purchased. By offering future residents the pesticide alternative, the number of over-the-counter pesticides is expected to decrease as the apartments turn over to new residents.

Though the advancement of IPM in Maguire Village is recent, there has been a reduction in the use of pesticides and improvement of cultural practices conducive to pest infestations. The number of complaints has remained relatively unchanged. This shows that improving resident education concerning cultural practices and limiting pesticides use, pest control technicians can reduce the risks associated with pesticides. This project has lead to an improvement of the communication and education between the pest control technicians and the residents, which are keys to a successful IPM program (Campbell et al. 1999, Brenner et al. 2003, Williams et al. 2006). It is not realistic to assume that all issues will be resolved in a single year, but as the IPM program further advances, the remainder of the maintenance and cultural issues can be improved upon, and if these are improved, the pest complaints should also decrease at Maguire Village. This study is a prime example of how an IPM program can be successful in a university setting.

Table 2-1. The liquid and aerosol products, active ingredients, and mass per volume of active ingredients used by University of Florida Department of Housing and Residence Education's pest control technicians between 2003 and 2008 at Maguire Village, University of Florida.

Product	Active ingredient	(g/ml)
Catalyst®	Propetamphos	0.079
PT Cy-Kick CS®	Cyfluthrin	0.047
Demand CS®	Lambda-cyfluthrin	0.101
Engage®	chlorpyrifos	0.004
Phantom®	chlorfenapyr	0.103
Precor®	methoprene	0.009
Precor 2000 Zoecon®	methoprene	0.0007
	permethrin	0.003
	Phenothrin	0.002
	PBO	0.011
	MGK-264	0.016
Premise Foam®	Imidacloprid	0.0005
PT 230 Tridie®	Pyrethrin	0.01
	PBO	0.083
	Silica gel	0.138
PT 280 Orthene®	Acephate	0.008
PT 3-6-10 Aero-Cide®	Pyrethrin	0.012
	PBO	0.024
	MGK-264	0.04
PT 565 Plus XLO®	Pyrethrin	0.005
Round-Up®	Glyphosate	0.569
Suspend SC®	Deltamethrin	0.005
Termidor SC®	Fipronil	0.017

Table 2-2. The pesticide class, active ingredient, and mode of action for each product used between 2003 and 2008 at Maguire Village, University of Florida.

Pesticide class	Active ingredient	Mode of action
Amidinohydrazone	Hydramethylnon	Electron transport inhibitor
Borate	Boric acid	Feeding disruption
	Disodium octaborate tetrahydrate	Feeding disruption
	Orthoboric acid	Feeding disruption
Desiccant	Diatomacious earth	Water balance disruption
	Silica gel	Water balance disruption
IGR	Methoprene	Juvenile hormone analog
Organophosphate	Acephate	Acetylcholine esterase inhibitor
	Chlorpyrifos	Acetylcholine esterase inhibitor
	Propetamphos	Acetylcholine esterase inhibitor
Other	Acetamiprid	Nicotinic acetylcholine receptor
	Albamectin	Chloride channel activator
	Eugenol	Octopamine receptor inhibitor
	Imidacloprid	Nicotinic acetylcholine receptor
	Indoxacarb	Sodium channel blocker
	Glyphosate*	5-enolpyruvylshikimate-3-phosphate synthase inhibitor
	Sulfuramid	Uncouples oxidative phosphorylation
Pyrazole	Chlorfenapyr	Uncouples oxidative phosphorylation
	Fipronil	GABA chloride channel blocker
Pyrethroid	Bifenthrin	Sodium channel modulator
	Cyfluthrin	Sodium channel modulator
	Deltamethrin	Sodium channel modulator
	D-trans allethrin	Sodium channel modulator
	Esfenvalerate	Sodium channel modulator
	Lambda-cyhalothrin	Sodium channel modulator
	Permethrin	Sodium channel modulator
	Phenothrin	Sodium channel modulator
	Pyrethrin	Sodium channel modulator
Synergist	N-octyl bicycloheptene dicarboximide (MGK-264)	Cytochrome P-450 mixed function oxidase inhibitor
	Piperonyl butoxide (PBO)	Cytochrome P-450 mixed function oxidase inhibitor

* herbicide

Table 2-3. Summary of the 23 possible cultural infractions evaluated at during apartment inspections before and after the advancement of integrated pest management (n=155).

	Before Count (%)	After Count (%)	Difference Before - After
1. Outdoor pest harborage	18 (11.61)	7 (4.52)	11
2. Screen door open	39 (25.16)	40 (25.81)	-1
3. Odor in apartment	36 (23.23)	26 (16.77)	10
4. Mold present	45 (29.03)	1 (0.65)	44
5. Carpet in poor condition	1 (0.65)	1 (0.65)	0
6. Garbage cans not covered	113 (72.9)	77 (49.68)	36
7. Garbage spilled around can	15 (9.68)	6 (3.87)	9
8. Food stored open on counter	75 (48.39)	44 (28.39)	31
9. Food stored in rooms not kitchen	15 (9.68)	12 (7.74)	3
10. Rotting food present	15 (9.68)	11 (7.10)	4
11. Kitchen sink dirty	16 (10.32)	9 (5.81)	7
12. Kitchen floor dirty	14 (9.03)	8 (5.16)	6
13. Kitchen counters dirty	14 (9.03)	12 (7.74)	2
14. Kitchen cabinets cluttered	13 (8.39)	4 (2.58)	9
15. Food spills in kitchen cabinets	44 (28.39)	23 (14.84)	21
16. Bathroom sink or tub dirty	9 (5.81)	2 (1.29)	7
17. Bathroom floor dirty	7 (4.52)	1 (0.65)	6
18. Carpet dirty	12 (7.74)	7 (4.52)	5
19. Clutter throughout apartment	16 (10.32)	15 (9.68)	1
20. Stove dirty	6 (3.87)	1 (0.65)	5
21. Under refrigerator dirty	23 (14.84)	14 (9.03)	9
22. Improper food containment	70 (45.16)	75 (48.39)	-5
23. Poor general organization	18 (11.61)	11 (7.10)	7

Table 2-4. Summary of the 11 possible maintenance infractions evaluated during apartment inspections before and after the advancement of integrated pest management (n=155).

	Before Count (%)	After Count (%)	Difference Before - After
1. Cracks or holes in wall	7 (4.52)	7 (4.52)	0
2. Window screens not secure	49 (31.61)	49 (31.61)	0
3. Windows do not seal	49 (31.61)	49 (31.61)	0
4. Inadequate door sweeps or seals	36 (23.23)	35 (22.58)	1
5. Improper gutter drainage	49 (31.61)	49 (31.61)	0
6. Walls with evidence of water leaks	7 (4.52)	7 (4.52)	0
7. Improper escutcheon plate installation	80 (51.61)	80 (51.61)	0
8. Condensation present on plumbing	1 (0.65)	1 (0.65)	0
9. Pipe leaks	4 (2.58)	4 (2.58)	0
10. Inadequate ventilation	63 (40.65)	63 (40.65)	0
11. Cracks or holes in ceiling	99 (63.87)	99 (63.87)	0

Table 2-5. The number of cultural and maintenance infractions before and after the advancement of integrated pest management.

	Before	After	DF	t value	P>|t|
Cultural	4.14 (±0.27)	2.65 (±0.22)	154	5.29	<0.0001*
Maintenance	2.85 (±0.14)	2.86 (±0.14)	154	1	0.3189

*means statistically different at P< 0.05 (paired t-test).

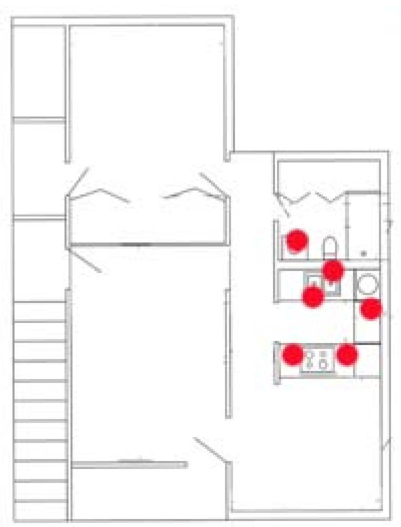


Figure 2-1. The location, red dots, of sticky-trap monitors in the kitchen and bathroom of a one bedroom apartment. The monitors were placed in the same locations in two bedroom apartments.

Figure 2-2. An IPM Cleaner Solution spray bottle for a soap and water alternative to over-the-counter pesticides.

Figure 2-3. The IPM Cleaner Solution label, which includes directions on how to mix a 6.5% solution of dish soap in water.

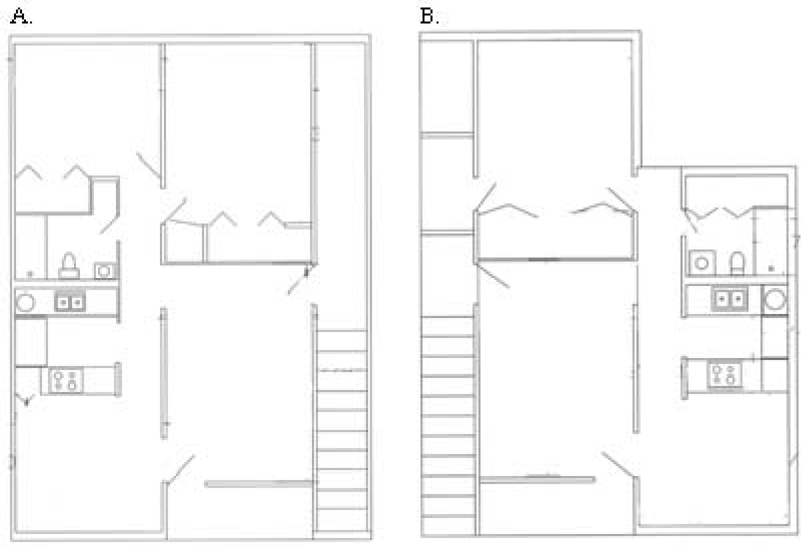


Figure 2-4. The floor plan of two bedroom (A) and one bedroom (B) apartments on the right side of the apartment buildings at Maguire Village. Apartments on the left side are mirror images of those shown above.

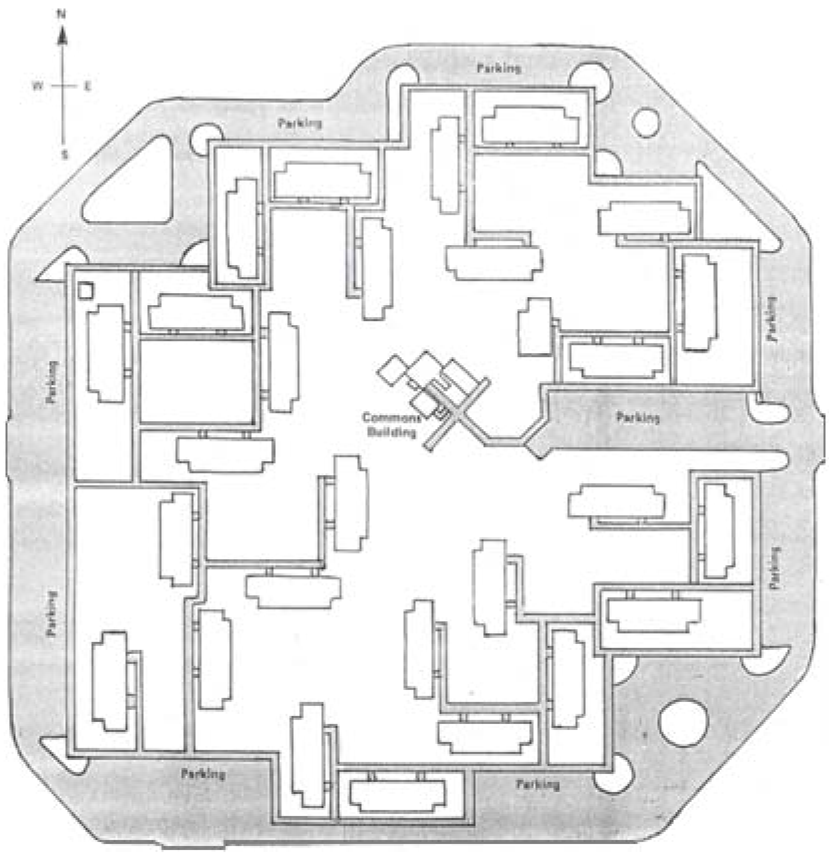


Figure 2-5. The layout of Maguire Village, University of Florida.

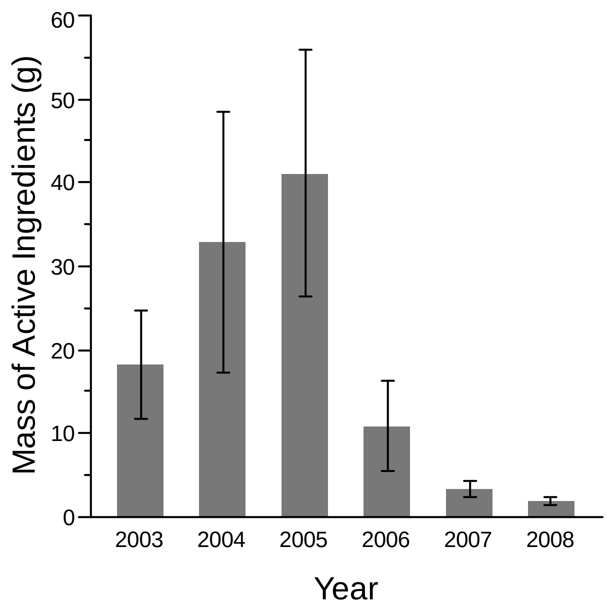


Figure 2-6. The amount of pesticides used each month at Maguire Village between 2003 and 2008. Error bars represent standard error of the mean.

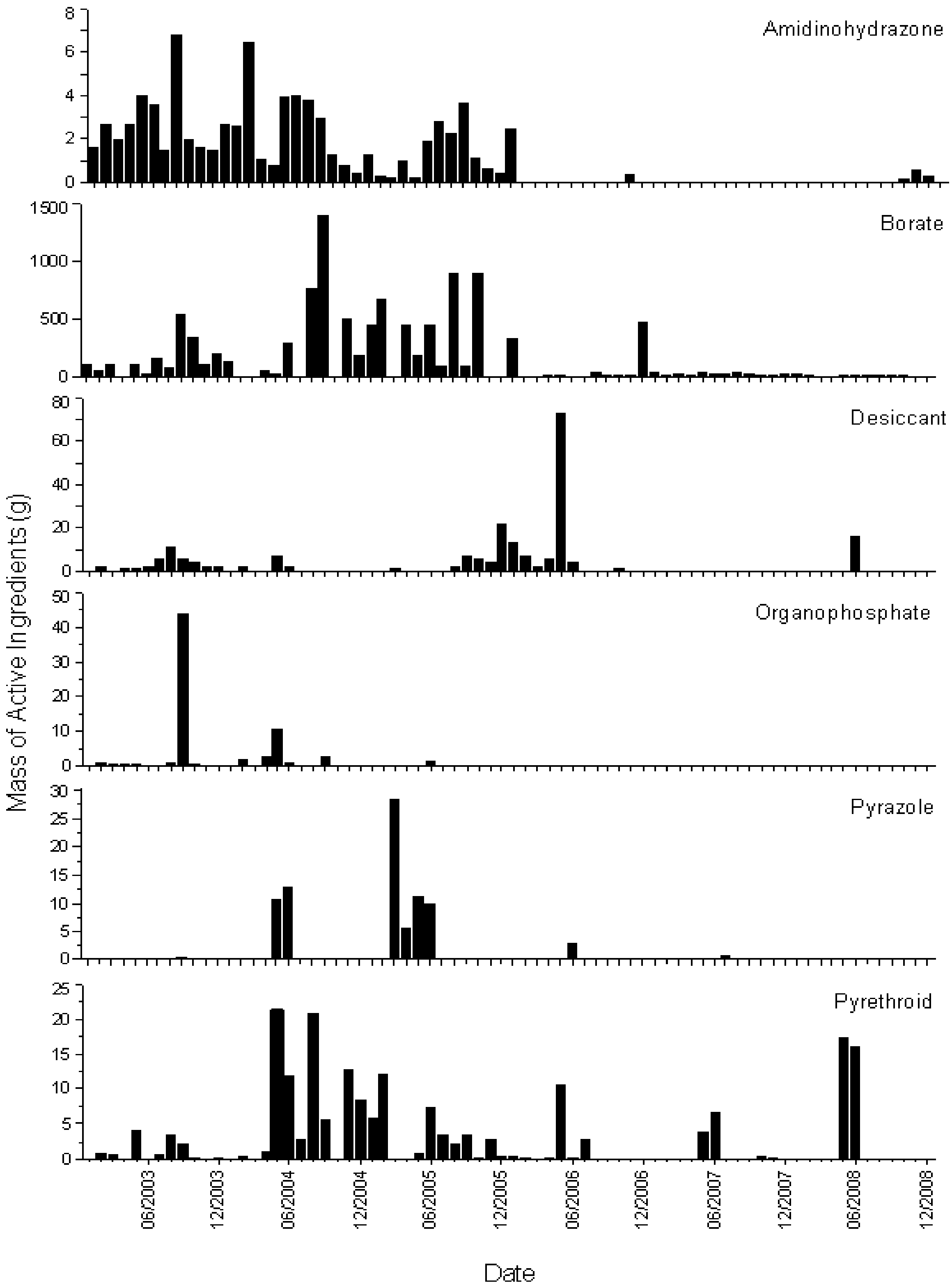


Figure 2-7. The amount of pesticide in indicated classes (Table 2-2) used per month in Maguire Village from January 2003 to December 2008.

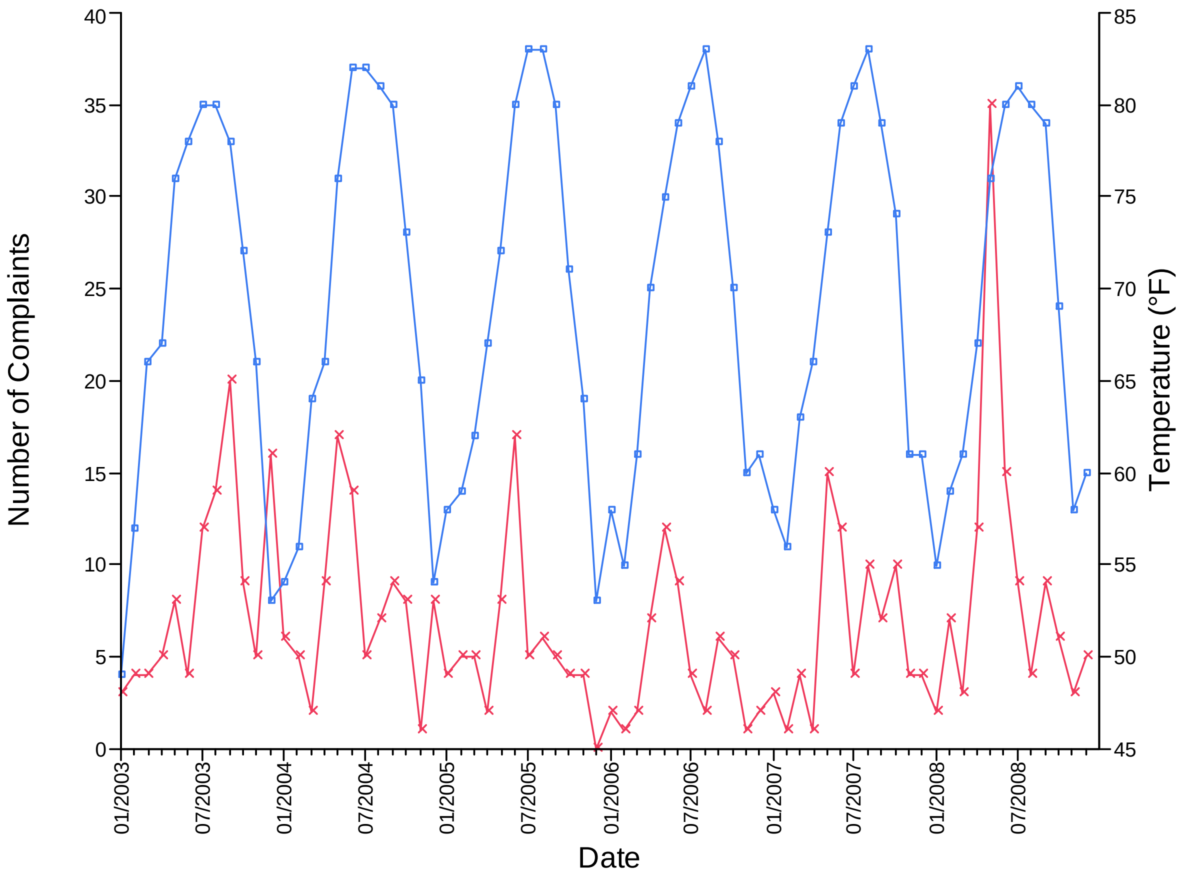


Figure 2-8. The total number of pest complaints at Maguire Village (red line) and average temperature in Gainesville, Fl (blue line) for each month from January 2003 to December 2008.

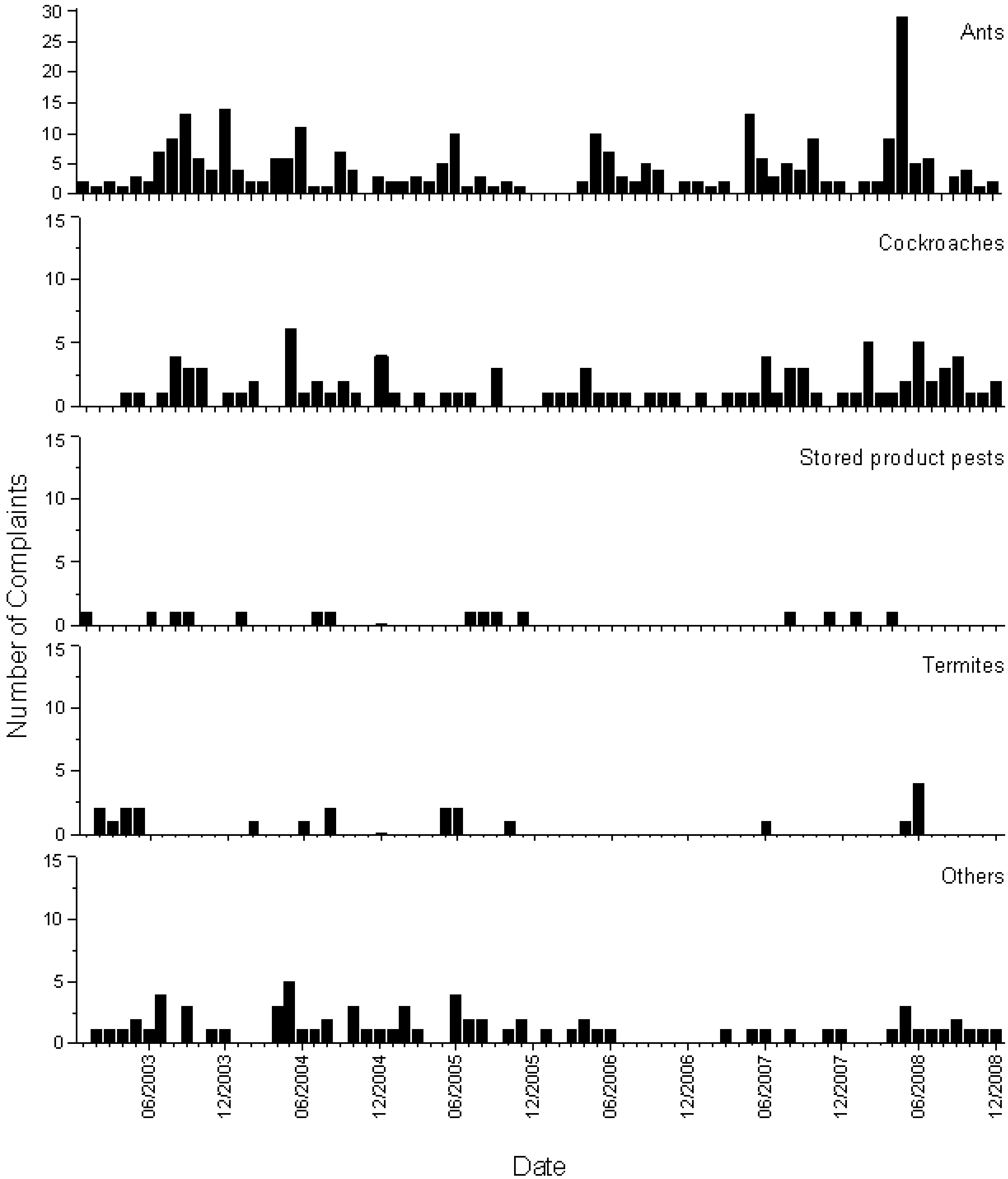


Figure 2-9. The total number of pest complaints per month for each of the pest groups at Maguire Village from January 2003 to December 2008.

CHAPTER 3
THE MAJOR ANT PEST IN UNIVERSITY OF FLOIRIDA GRADUATE STUDENT AND FAMILY HOUSING

Introduction

Ant pests have a significant economic impact in the United States; however, the actual impact for many species cannot be determined because the information on their biology is incomplete (Whitmore et al. 1992, Klotz et al. 1995). Ant research primarily focuses on agriculturally or medically important species—especially the red imported fire ant, *Solenopsis invicta* Buren, which in 2005 cost over $1 billion annually due to the agricultural damage it causes, e.g. crop loss and killed livestock, and the measures to control the ants (Klotz et al. 1995, Pimentel et al. 2005). The cost due to red imported fire ants may now be up to $5 billion annually (P. Koehler, personal communication). This focus on the agriculturally and medically important species leaves the cryptic nuisance ant species' not well understood, although their economic impact may be significant. A survey of Florida pest control technicians conducted in 1993 concluded that most ant complaints were made because customers saw their ant infestations as a nuisance, not because of medical worries (Klotz et al. 1995). By studying the biology of cryptic pest species, one can better understand the mechanisms of their success and use the knowledge to better develop control methods (Tsutsui and Suarez 2003).

One cryptic ant genus, *Brachymyrmex,* is becoming a major household pest in the southeastern United States (MacGown et al. 2007). Collectively called "rover ants," the ants in the genus *Brachymyrmex* are small (<2.5mm in length), subterranean, monomorphic insects that nest in soil, bark, or rotting wood, although some species in the genus are known to be arboreal (Dash 2004, Quirán et al. 2004, MacGown et al. 2007). Their 9-segmented antennae easily identify workers and queens of this genus (Quirán et al. 2004).

These ants are non-biting and non-stinging and are often associated with honeydew-secreting insects, such as mealybugs and leafhoppers (Stegmaier 1973, Moya-Raygoza 2005). *Brachymyrmex* also exploit plant sugar sources when honeydew-secreting insects are seasonally scarce (Moya-Raygoza and Larson 2001). One example is *Brachymyrmex obscurior* Forel, which tends honeydew-producing Hemiptera and feeds from the extra floral nectaries of Mexican acacia trees during the dry season (Moya-Raygoza 2005).

Although the taxonomy of the genus *Brachymyrmex* is in question, there are currently 38 described species in this genus worldwide with five found in Florida, three of which are not native (Table 3-1) (Bolton 1995, Deyrup 2003).

The type species of the genus, *Brachymyrmex patagonicus* Mayr, has been described as a nuisance pest that behaves as a typical invasive organism (MacGown et al. 2007). It occurs in disturbed urban settings with few trees such as parks, parking lots, and highway edges (Rossen 2004, MacGown et al. 2007). This species also inhabits the longleaf pine savannas in north-central Florida and possibly other natural areas (Trager and Fiske 2006). Like many invasive organisms, *B. patagonicus* is able to reestablish quickly after control is attempted (MacGown et al. 2007). Currently, *B. patagonicus* may be in the "explosive phase" of population growth (M. Deyrup, personal communication); a theoretical phase based on the behavioral trends and growth rates of newly established invasive species (Sakai et al. 2001).

Brachymyrmex patagonicus was first described in North America in 1976 and most likely came into the United States from Argentina through one of the northern Gulf of Mexico ports (Wheeler and Wheeler 1978, Quirán et al. 2004, MacGown et al. 2007). This species has spread from the area where it was first discovered in the United States and now occurs in Texas, Louisiana, Arkansas, Alabama, Mississippi, Georgia, and Florida (MacGown et al. 2007). It is widespread throughout Florida with the greatest abundance in the northern part of the state (Deyrup et al. 2000, Deyrup 2003).

Brachymyrmex patagonicus nests in myriad locations, which include loose bark on tree trunks, in both forest and prairie ground litter and soil, in landscaping mulch, in and under rotting wood, and at the base of plants on beaches (MacGown et al. 2007). Colonies of *B. patagonicus* contain hundreds of workers and are often found in close proximity to other colonies. These groups display tolerance of each other as they cross paths (MacGown et al. 2007). The reproductive alates swarm from the nests in the summer between June and August (Colby and Prowell 2006).

This species has become a major nuisance pest within the past 15 years. Prior to 1993, it was considered only an occasional pest, often encountered as alates floating in outdoor swimming pools but has since been found infesting kitchens, bathrooms, and other indoor locations (Klotz et al. 1995, MacGown et al. 2007). Colony numbers of *B. patagonicus* tend to increase after area wide chemical suppression of fire ants (Dash et al. 2005, MacGown et al. 2007).

Currently the major insect pest problem in housing at the University of Florida (UF) is an unidentified species of *Brachymyrmex*. This study seeks to 1) identify the *Brachymyrmex* spp. infesting UF campus apartments 2) describe the ant community dynamics on UF housing properties, 3) describe *Brachymyrmex patagonicus* nesting behavior, 4) identify *Brachymyrmex patagonicus* food sources, and 5) determine the seasonality of *Brachymyrmex* spp. complaints. Pest control technicians at UF will be able to control these ants better by understanding their biology.

Methods

Study location

All surveys occurred at Maguire Village, a United States Department of Housing and Urban Development apartment complex located on the University of Florida main campus in Gainesville, Florida, USA (29°38’27”N, 82°22’14”). The complex covers an area of approximately 5 hectares.

The grounds at Maguire Village consist primarily of “weedy” vegetation, e.g. grasses, and invasive weeds, such as Florida pusley, *Richardia scabra* L., white moneywort, *Alysicarpus vaginalis* (L.), and Mascarene Island leaf-flower, *Phyllanthus tenellus* Roxb. Because of both the high resident traffic on the grounds and climatic stresses on Florida vegetation, much of the landscape has completely exposed soil or scarce ground cover (Figure 3-1). Trees within the Maguire Village property include species from the southern yellow pine complex, *Pinus* spp.; oaks, *Quercus* spp.; the sycamore, *Platanus occidentalis* L.; and various shrub and tree ornamentals.

The soil types at Maguire Village are Arrendondo-Gainesville-Millhopper series consisting of hyperthermic grossarenic paleudults and hyperthermic coated typic quartizamments (Thomas et al. 1985), but builders may have imported soil and sand during the construction of the apartment buildings. The Arrendondo-Gainesville-Millhopper series includes well to moderately well drained soils that are rapidly to moderately permeable. All soils in the area were formed from marine sediments (NRCS 2004).

Identification of indoor ant pests

Ants found indoors by the pest control technicians at the UF were collected using an aspirator. The specimens were preserved in 70% ethanol at room temperature. Ants were viewed with a Leica S8AP0 stereomicroscope (Leica Microsystems, Heerbrugg, Switzerland) under 80x power. The ants were identified to genus using keys developed by Fisher and Cover (2007) and, if in the genus *Brachymyrmex,* to species using Dash (2004) and MacGown (2008).

Ant community structure

Ten pitfall traps were placed haphazardly (not statistically random) throughout Maguire Village grounds to sample the ant fauna on 19 July 2008. These traps were fabricated from 9-dram clear styrene specimen vials with the inside surface coated with fluoropolymer resin (PTFE-30) (Figure 3-2). The vials were 7 cm tall and had a 2.5 cm inside diameter. A 1 cm diameter hole was drilled into the plastic snap-top. The traps were baited with a cotton ball soaked in a 50% honey and deionized water solution immediately prior to placement. Honey was used because the primary ant pests at Maguire Village, *Brachymyrmex* spp., are known to be sweet-feeding ants, and UF pest control technicians use sweet baits when treating for ants (Moya-Raygoza 2005).

Five pitfall traps were buried in the soil, so the tops were even with the ground surface. Five were secured to tree trunks using preexisting vines on the trees (Figure 3-3). All traps were collected three days later on 21 July 2008 and the ants were identified as above. ANOVA was performed using JMP 7.0 (SAS institute 2007).

The pitfall trap data were pooled and used to make a preliminary description of the ant community structure. The description includes species richness and evenness using the Shannon-Wiener index formula (Equation 3-1). Evenness was calculated from the Shannon-Wiener index (Equation 3-2, Equation 3-4). Diversity was then calculated with the Simpson-Yule index (Equation 3-5, Equation 3-6).

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \qquad 3\text{-}1$$

$$H'_{max} = -\sum_{i=1}^{S} \frac{1}{S} \ln \frac{1}{S} \quad (3\text{-}2)$$

$$Evenness = \frac{H'}{H'_{max}} \quad (3\text{-}3)$$

$$\mathrm{D} = \sum_{k=0}^{S} (p_i)^2 \quad (3\text{-}4)$$

$$Diversity = 1 - D \quad (3\text{-}5)$$

Species richness is the number of different species caught. In the Shannon-Wiener equations, "S" is the species richness, p_i is the proportion of species "*i*" in the total sample, and H' is the Shannon-Wiener function. D is the Simpson-Yule index, which is the probability that when two individuals are selected from a population, the second individual is the same species as the first (Southwood and Henderson 2000). Excel® (Microsoft Office Enterprise, Redmond, Washington, USA, 2007) was used for all calculations.

***Brachymyrmex patagonicus* nesting behavior**

During the summer and fall of 2008, fifty index cards (7.5 cm x 12.5 cm) baited with honey were placed haphazardly (not statistically random) throughout Maguire Village. After approximately one hour the index cards were inspected for *B. patagonicus* (Figure 3-4). If ants were observed on a card, the trailing ants were followed back to their nest. Individual ants from each card were placed into a plastic bag, brought to the lab and identified as above. Additionally, the grounds were visually searched for *B. patagonicus* nests.

Every nest discovered in the ground was marked with a piece of vinyl flagging tape pierced by a 16d galvanized nail and placed 15 cm due north from the nest (Figure 3-5). Any nest discovered in a tree branch was marked by tying flagging tape around the branch 15 cm from the nest on the side of the branch closest to the trunk. Flagging tape and nails were placed immediately below suspected nests in building walls, and the entrance holes were marked using indelible ink with an arrow pointing to the hole.

The location of each nest was documented, and, when applicable, the nest's ground cover type (bare, sidewalk, leaf litter, or vegetation) was recorded and percent soil exposure was visually approximated within 1 m^2 around the nest. The distances to the nearest tree, building and ant nest were measured. The ant species of the nearest adjacent nest was also identified. Mound dimensions (height, diameter, and entrance hole diameter) were measured. After measurements were taken, at least one ant from the nest was collected for identification.

Brachymyrmex patagonicus food sources

During the summer and fall of 2008, *B. patagonicus* ants were observed foraging at Maguire Village. Ant trails were followed to suspected food sources on the ground or in tree branches within reach, approximately 2 m from the ground. Any tended honeydew-producing insects and their host plants were collected and submitted to the UF Insect Identification Laboratory in the Entomology and Nematology Department and the Florida Department of Agriculture and Consumer Services, Division of Plant Industry for identification. The plants with *B. patagonicus* feeding on sap were collected and sent to the Florida Department of Agriculture and Consumer Services for identification.

Brachymyrmex seasonality

The UF Department of Housing and Residence Education (DHRE) pest control technicians documented each *Brachymyrmex* spp. complaints and encounter from 2005 to 2008 that required a treatment. These data were used to determine the seasonality of *Brachymyrmex* spp. infestations across the entire UF campus. Cyclic activity was determined using time series analysis in JMP 7.0 (SAS institute 2007).

Results and Discussion

Identification of indoor ant pests

All ants collected in Maguire Village apartments between January and April 2008 were identified as *B. patagonicus*, an adventive species from South America (MacGown et al. 2007, Wheeler and Wheeler 1978). Additional samples of these ants were sent to and verified by Ernesto Rodriguez at Northern Arizona University using molecular techniques. This species was collected inside the apartments most often in kitchens. To locate the source of these ants, their trails were followed. The ants were observed entering the living spaces through cracks in the drywall and from the air handling ducts. Walls were not opened during this study to follow the trails further, but maintenance staff reported large colonies of what were suspected to be *B. patagonicus* in bathroom and kitchen walls that were opened or demolished during apartment remodeling. These observations were similar to previous reports of these ants nesting in wall voids (MacGown et al. 2007). Because of the small size of this species, it is impossible to seal every potential crack through which these ants can enter a building; however, their trails can be followed, and the entrances can be baited with a crack and crevice pesticide bait before they are repaired. Preventing access to living spaces may be as simple as sealing cracks with caulking, repairing any openings, or replacing weather stripping on doors and windows. Although MacGown et al. (2007) suggest these ants travel long distances from outdoor nests to forage in living spaces, storing food in airtight containers and cleaning spills may help prevent these ants from establishing colonies in wall voids closer to available food sources. Repairing any source of moisture in wall voids, e.g. condensation and leaking plumbing, will eliminate water for these ants.

Ant community structure

One of the pitfall traps placed into a tree was dislodged, therefore, is not included in the results. More ants were caught in the pitfall traps placed into the ground (P=0.018) than those placed in the trees (Table 3-2). The species of *Brachymyrmex* in the pitfall traps was identified as *B. patagonicus* (Figure 3-6) and 200 individuals were caught. *Dorymyrmex bureni* (Trager) was the second most abundant species with 10 caught, and one *Solenopsis invicta* Buren was caught. Though not caught in the traps, *Pseudomyrmex gracilis* (Fabricius), *Crematogaster ashmeadi* (Emery), *Pheidole megacephala* (Fabricius), *B. obscurior* Forel, and a second *Dorymyrmex* sp. were observed at Maguire Village.

The ants observed at Maguire Village appeared to be strong trailers, especially *B. patagonicus.* When they fed in trees they deviated little from their paths, even when a new food source was introduced centimeters from a trail. This behavior is important because it suggests that when trailing to a preexisting food source these ants may not be attracted to or discover pesticide baits, especially poorly placed baits. When placing an ant bait for *B. patagonicus* one needs to place it directly in the path of the trail so the ants will immediately discover and ideally feed on the bait. The foraging behavior and movement on the ground appeared more erratic, with few established trails observed. This would explain the large number of *B. patagonicus* caught in the traps placed in the ground where trails were not established. Although, once a food source was discovered on the ground, e.g. the baited index cards, the ants quickly formed a trail.

There were eight species of ants observed at Maguire Village, although only three were caught in the pitfall traps. Between these species there was low evenness (0.22) meaning that one species, *B. patagonicus*, was the dominant species, with more individuals in the community than the others. These ants are the pests most often treated for by pest control technicians (see chapter

2). The thriving population of these ants outdoors provides an ideal source of individuals to invade and infest the residencies at Maguire Village. The actual sources of indoor ant infestations were not located during this study, but it is possible that many infestations originated from outdoor colonies.

Alachua Co, Florida has a reported ant richness of 110 species though only eight species were observed during this study (Johnson 1986). There was also low diversity (0.11), which means that the probability of randomly selecting two individuals of the same species is high because the community is dominated by *B. patagonicus*. This may be due to fire ant management. The pest control technicians treated the grounds surrounding each building routinely for fire ants with a broadcast hydramethylnon and methoprene bait. This pesticide could have adverse effects on non-target species, reducing the richness of ants in the areas treated. Though not tested, *B. patagonicus* are a small, sweet-feeding ant, so it is possible they did not feed on the fire ant baits, which are coarse, pesticide infused corn grits with a lipid attractant. The baits kill the fire ants and many non-target species, opening niches and reducing competition for *B. patagonicus.* In Louisiana, these ants have increased in pest status where fire ants have been suppressed, so it is reasonable to believe that *B. patagonicus* were establishing populations where fire ants are managed (Rosson 2004). A fire ant management strategy targeting individual mounds would have fewer non-target effects, potentially allowing other ant species to establish populations and compete with *B. patagonicus* while continuing to keep the fire ant population low.

The pitfall trap sampling method used for this study may have resulted in inaccurately low diversity and richness indices. This study had a limited number of samples on which to base any inferences. Only ten traps were used during one sampling period, so more samples in a variety of seasons would provide results that are more accurate. As mentioned above, only a honey and water bait mixture was used because the majority of the pest ants at Maguire Village are sweet feeding, and the DHRE pest control technicians used a honey baited pesticide formulation when treating for any indoor ant infestation. By using a variety of baits, including lipids and proteins, a larger number of ant species could be caught. Though beyond the scope of this project, improved sampling would have more accurately describe the community dynamics of ants at Maguire Village.

***Brachymyrmex patagonicus* nesting behavior**

Twenty *B. patagonicus* nests were located at Maguire Village and all but three nests were located within 10 m of buildings. Fourteen nests were found in the ground, four were located in brick walls in cracks and behind loose mortar, and two were arboreal. One arboreal nest was discovered under the bark where a plum tree, *Prunus* sp., branch was lacerated. The other arboreal nest was located behind the loose bark of a slash pine, *Pinus elliottii.* The subterranean nests were primarily located in areas with little or no living ground cover (Table 3-3) but with some leaf litter. At Maguire Village, the nests were positioned closer to buildings than trees (P=0.037). All but three of the nests were located within two meters of another ant nest, mostly *B. patagonicus*, although five were in close proximity to *D. bureni.* The inconspicuous nests were between 2 and 3 cm in diameter and less than 1 cm in height (Figure 3-5).

Brachymyrmex patagonicus at Maguire Village is a generalist nester. The small ant nests were located most often in disturbed areas with a high percentage of soil exposure and close to apartment buildings. This coincides with reports that these ants take advantage of many nesting locations in disturbed urban areas (Rossen 2004, MacGown et al. 2007). Many of the *B. patagonicus* nests were clustered, especially in sites with the most soil exposure. Maintaining a healthy, undisturbed lawn may inhibit the colonization of these ants by reducing potential nesting locations.

Brachymyrmex patagonicus are tolerant of nearby colonies of the same species (MacGown et al. 2007). Members of clustered nests at Maguire Village showed a high level of tolerance when they crossed paths or explored the area around different nests. Although tolerant within nest clusters, when workers of two *B. patagonicus* colonies collected from opposite corners of Maguire Village were placed into a single shoebox sized container, they fought and few living ants remained a day later. This may suggest that clustered colonies are closely related. Molecular techniques could be used to determine the relationship between the nests in a given area.

***Brachymyrmex patagonicus* food sources**

Brachymyrmex patagonicus were observed tending aphids and mealybugs at Maguire Village. One each of the aphid and mealybug samples collected could not be identified because the insects died and deteriorated prior to processing. These insects could not be found again on the original host plant. One tended aphid was identified as *Microparsus olivei* (Smith and Tuatay), which was feeding on white moneywort. A second tended aphid present on a plum tree was not identified. The ants tended both subterranean and foliar mealybugs. The subterranean mealybug was identified as the solanum mealybug, *Phenacoccus solani* Farris, which was feeding on Mascarene Island leaf-flower. The tended foliar mealybug located on a plum tree was not identified. The ants were observed trailing from ground nests to the canopy of trees, including pines, oaks, and many ornamentals. It is possible that these ants were foraging on honeydew producing insects in the tree canopies. *Brachymyrmex patagonicus* also fed on the sap of Florida pusley. The sap formed pools in the calyxes of the senescing flowers. Because *B.*

patagonicus ants were observed tending honeydew producing hemipterans living both above and below ground and on plant sap, it can be concluded that they are generalist sweet-feeding ants. Any pesticide used to control these ants should be baited with a sweet substance. These ants may also be controlled by controlling the insects on which they feed. Aphid and mealybug resistant plants should be used in the landscape, and groundskeepers should maintain a healthy lawn free of flowering weeds on which these ants are known to feed.

***Brachymyrmex* seasonality**

There is a 12-month cycle of *Brachymyrmex* spp. complaints at Maguire Village. They were observed most often during the summer months and least often during the winter months (Figure 3-7). The number increased sharply in April and peaked in May. From the May peak, the population decreased steadily until February.

Spring and summer were the seasons when these ants were observed swarming, so during these times, the colonies were reproducing and the population was increasing (Klotz et al. 1995, Colby and Prowell 2006). A larger population would increase the number of individuals foraging on the grounds. These ants are known to forage long distances, so more indoor encounters are expected when populations are large. It was unclear in the database if these complaints are due to worker ants or alates, but it is possible that many of the complaints were due to alates flying into the apartments. Statewide, the alates of these ants are known nuisance pests (Klotz et al. 1995).

In Florida, the summer months are warmer than the winter months. Ant foraging activity is correlated with temperature, so the activity of *B. patagonicus* can vary depending on the season and temperatures (Porter and Tschinkel 1987). The warmer season would increase metabolic activity thus increasing foraging activity. On the other hand, the winters are cooler and lower metabolic requirements would decrease their foraging activity. There is also a larger population of honeydew producing insects, including aphids, during the summer months that would provide an ample food to support large ant populations (Dixon 1977).

Brachymyrmex spp. complaints were used to indicate the ant's seasonality. Though not a complete or direct measurement of *Brachymyrmex* spp. occurrence at Maguire Village, complaints show trends important for pest control. The incidence of *Brachymyrmex* spp. infestation was low during the fall and winter, so little control was needed at that time. The pest control technicians should increase their awareness of these ants beginning in March, prior to the sharp increase in ant encounters. This would enable the pest control technicians to manage the infestations before they become overwhelming.

It is important to identify the infesting ants as workers or alates when the apartments are assessed. Workers forage from an established colony while alates do not. Foraging worker ants bring food back to the colony and provide it to the brood, queen, and other workers by tropholaxis (Hölldobler and Wilson 1990). A slow acting pesticide bait would be preferred in this case because the worker would bring it back and spread it throughout the colony. Unless directly applied to the nest, non-bait pesticide treatments would be ineffective for *Brachymyrmex* spp. because the insects can forage long distances and would die before reaching the nest (MacGown et al. 2007).

Unless individuals are observed swarming out of wall voids, alates found in apartments do not indicate that an established colony is present. Pesticides should not be used to treat for alates, rather physical and mechanical controls are preferred. Fixing any accesses to the apartment or keeping doors and windows closed will prevent alates from entering. Restricting access to the apartment is the only effective alate control (MacGown et al. 2007). Any alates that enter an apartment can be vacuumed or sprayed with soap and water.

This study only scratches the surface of the biology of *B. patagonicus* but provides the foundation for further research. Overall, these ants appear to be behaving in a fashion expected of invasive species with little intraspecific aggression, forming simple nests in highly disturbed habitats, and feeding from a variety of sources (Holway et al. 2002, Tsutsui and Suarez 2003). Control of these ants while they are in the "explosive phase" of population growth will prove to be difficult, but as their biology becomes better understood more efficient control methods can be developed.

Table 3-1. List of known *Brachymyrmex* spp. in Florida and their unofficial common names (Deyrup et al. 2000, Deyrup 2003, MacGown et al. 2007).

Scientific Name	Common Name
Brachymyrmex brevicornis Emery[1]	Short-Feelered Rover Ant
Brachymyrmex patagonicus Mayr[1,2]	Little Mouse Rover Ant or Dark Rover ant
Brachymyrmex minutus Forel[1]	Tropical Yellow Rover Ant
Brachymyrmex depilis Emery	n/a
Brachymyrmex obscurior Forel	n/a

[1]The adventive species.
[2] This species was previously reported as *Brachymyrmex musculus* Forel.

Table 3-2. The richness and diversity of ant species captured in pitfall traps at Maguire Village.

	Ground & Tree	Ground	Tree	*Brachymyrmex patagonicus*	*Dorymyrmex bureni*
Total caught	211	196	15	200	10
Mean caught	23.44±8.2	39.2±10.02	3.75±1.03	22.11±15.44	2 ±1.26
Richness[1]	3	3	2		
Diversity[2]	0.11	0.11	0.12		
Evenness[3]	0.22	0.221	0.35		

[1] The number of species.
[2] The probability that a second individual selected from a community is the same species as the first, subtracted from one.
[3] The equality of populations in a community.

Table 3-3. Characteristics of *Brachymyrmex patagonicus* nests at Maguire Village (n=20).

% soil exposure	86.36±5.64
Distance to nearest tree (m)	4.54±0.64
Distance to nearest building (m)	2.66±0.56
Distance to nearest ant nest (m)	0.64±0.13
Mound diameter (cm)	2.40±0.66
Entrance diameter (cm)	0.49±0.16
Mound height (cm)	0.72±0.36

Figure 3-1. The layout of Maguire Village at the University of Florida main campus. Note the brown areas in the landscape where ground cover is scarce (Google Earth 2007).

Figure 3-2. A baited pitfall trap with captured ants. The inside surface is coated with a non-stick surface, so the ants are unable to escape.

Figure 3-3. A baited trap secured to a tree using a *Parthenocissus quinquefolia* vine.

Figure 3-4. A honey-baited index card (7.5 cm x 12.5 cm) with *B. patagonicus* (black ants) and two *Dorymyrmex bureni* (brown ants in the honey) foraging.

Figure 3-5. *Brachymyrmex patagonicus* ant mound (indicated by red arrow) and the location of vinyl flagging tape placed 15cm due north of the mound.

Figure 3-6. *Brachymyrmex patagonicus* collected from Maguire Village. Note the nine-segmented antennae and large eyes, diagnostic of this species (photo L. Buss, University of Florida).

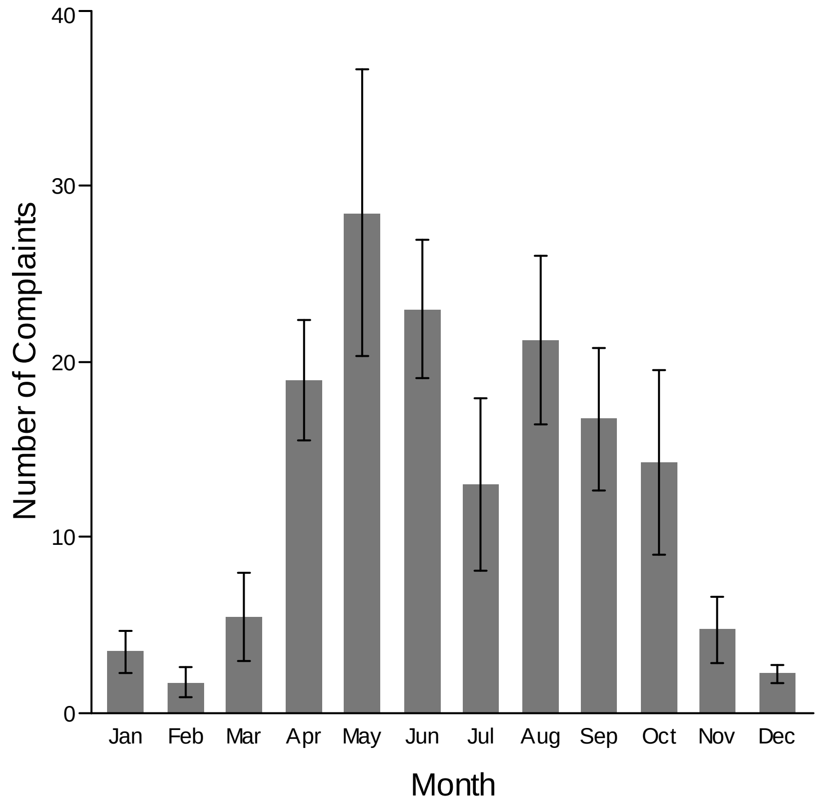
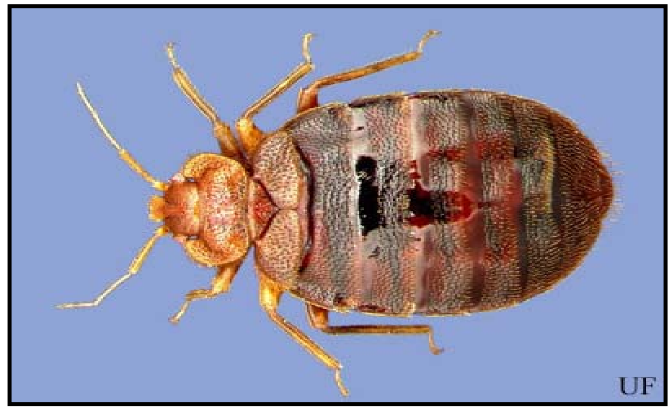


Figure 3-7. The monthly distributions of *Brachymyrmex* spp. complaints at the University of Florida based on documented pest complaints averaged during each month for 4 years. Error bars represent standard error of the mean.

APPENDIX A

BED BUG PREVENTION AT THE UNIVERSITY OF FLORIDA

During the past few years, bed bug infestations have increased at an alarming rate in motels, hotels, and homes in the U.S. and around the world. There also have been bed bug infestations in UF residence facilities. This information is provided to help you keep bed bugs out of your home.



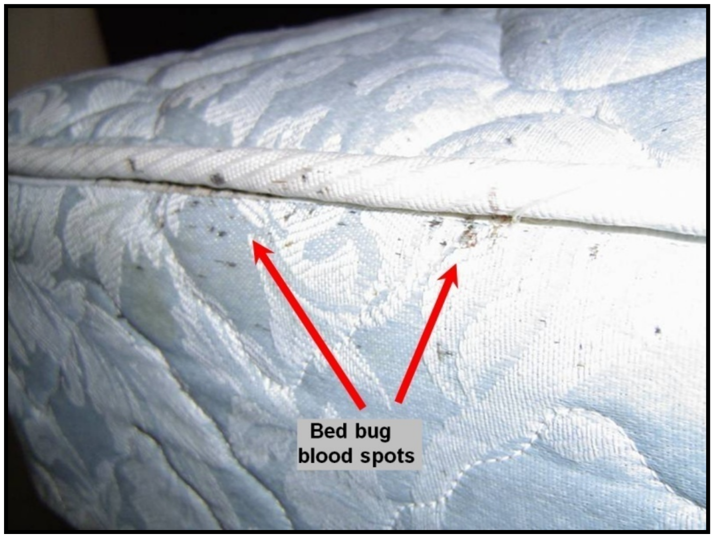
Adult bed bugs are oval, flat, and about 3/16 inch (4-5 mm) long. They are insects with piercing-sucking mouthparts, so they bite and suck blood like a mosquito. These insects hide during the day in bedding, mattresses, behind baseboards, and other furnishings. Bed bugs most often feed on people at night while the victims are asleep in their beds. Bed bugs normally bite the upper body where skin is exposed. Bed bugs do not transmit disease, but their bites leave small white to red welts that itch intensely. If you find you have bed bugs in your apartment, you will not eliminate the problem without UF's professional help. The UF Department of Housing and Residence Education provides free pest control.

Used furniture: Bed bugs are often spread through used furniture. It is best to buy new furniture, but if you acquire used furniture, such as a bed or couch, carefully inspect it before bringing it into the apartment. Check the seams and stitching for bed bugs or blood spots (see next page). **If you find bed bugs on furniture, do not purchase it!** If you discover bed bugs after you bring the furniture home, immediately contact the UF Housing and Residence Education pest control professionals by filling out a work order or through the Housing Automated Work-request Kiosk (H.A.W.K): www.housing.ufl.edu.

Hotels and motels: The cleanliness of a motel or hotel is not always a true indication of whether there might be a bed bug problem. A guest who stayed in the room before you may have left some of these pests. Bed bugs are spread in luggage and clothing from a motel or hotel to other locations, such as your home in the UF residence facilities.

To avoid bringing bed bugs back with you from travel:

- Never place your luggage on or next to the beds.
- Before you settle into the hotel room inspect the bed and furniture. Check behind the headboard. This is the best place to look for bed bugs because it is where they are not disturbed, yet still close to their food source.
- Take the sheet, pull it back, and look at the folds and seams of the mattress. Check the mattress for blood spots about the size of a pencil point.
- When packing to leave, check your clothing and luggage for signs of the small insects. Check seams and folds carefully.
- If you are bitten while staying in a motel or hotel room, look very carefully around the mattress and bed to try to determine if bed bugs or another biting insect, such as a mosquito, caused it. If you discover bed bugs, report the situation immediately to motel/hotel staff.
- You can kill bed bugs with heat in excess of 113°F (45°C). If you discover bed bugs in your clothing or linen, wash the items in hot water and dry them in a clothes dryer.



If you take care to inspect the areas where you stay and check your luggage before coming home to the residence facility, you will significantly reduce the chances of a bed bug infestation.

If you discover bed bugs in your apartment, immediately contact the UF Housing and Residence Education pest control professionals by filling out a work order or sending a H.A.W.K. request. www.housing.ufl.edu.

UF Housing & Residence Education UNIVERSITY of FLORIDA

IPM Integrated Pest Management Florida

APPENDIX B
EXTENDED VACATION CHECKLIST

If you are leaving your apartment for a vacation longer than two weeks or are spending a semester off campus please use this checklist to help the Department of Housing and Residence Education prevent pest infestations in your apartment.

___**Notify the Department of Housing and Residence Education's pest control with the dates that you will be away from your apartment.** waynew@housing.ufl.edu. While you are away, the pest control technician will occasionally check your apartment and remedy any potential pest problems.

___**Discard all perishable food from the cupboards, counters, and refrigerator.** Pests can eat open food in your apartment, while food left in the fridge will rot. Discard food into the outdoor garbage receptacles rather then pour it down the drain or garbage disposal. Examples of perishable food include open snacks such as cookies or potato chips, any fruit or vegetables, leftovers, and milk.

___**Empty the trash.** Trash provides food and harborage for pests. After you empty the trash, rinse the trash container with soapy water.

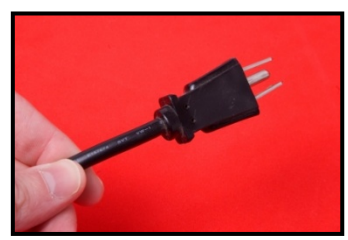
___**Close and lock all windows.** Locking your windows assures they are closed and sealed. No pests can enter your apartment through locked windows.

___**Clean all dishes.** Do not leave dirty dishes in the apartment when you leave. Dirty dishes provide food and water for pests.

___**Close drain plugs in the kitchen sink, bathroom sink, and tub.** This helps prevent drain traps from drying out and pests from coming into the apartment from the sewers.

___**Place packaging tape over the overflow holes in the bathroom sink and tub.** This also prevents the traps from drying out and pests from coming into the apartment from the sewers.

___**Place plastic wrap over the toilet if you will be away for the semester.** The water in the toilet evaporates if the toilet is not used for a long period of time. This allows pests to enter your apartment. Plastic wrap helps prevent evaporation of the water and keeps pests from entering your apartment.



___**Unplug all non-essential electronics, such as the television, computers, and radios.** This not only saves electricity, it reduces the number of warm hiding places for pests that may enter your apartment while you are away. If you turn off the power to the entire apartment, make sure the refrigerator and freezer are empty because any food left in them will rot. Also, leave the refrigerator and freezer open slightly to prevent mold growth.

We hope you enjoy your time away from campus.

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UNIVERSITY of FLORIDA

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APPENDIX C
CAMPUS GARDENING TIPS FOR UNIVERSITY OF FLORIDA STUDENTS

Gardens come in various types, including both those planted in the ground or in pots and planters. Many people on campus grow plants as a hobby or for food. By following some helpful tips you, can reduce the number of pests that eat your plants or invade your apartment. Also, by planting certain flowers and herbs you can attract butterflies and birds while attracting beneficial insects, such as ladybugs and lacewings that eat pests.

- **Plant native flowers and shrubs:** Native plants tend to be more resistant to pests and diseases, and are more tolerant of our hot, humid climate. Therefore, native plants are easier to maintain! Visit the Florida Yards and Neighborhood's website for more information on native plants: http://floridayards.org.

- **Attract beneficial insects to your garden:** Beneficial insects, such as ladybugs, lacewings, damsel bugs, and predatory wasps, eat pest insects that attack your garden. You can plant various flowers and herbs to attract beneficial insects. Learn more about beneficial insects by visiting IPM Florida's home gardening website: http://ipm.ifas.ufl.edu/community/home_gardening.

Plants that attract beneficial insects:

- Yarrow	**- Dill**
- Sunflowers	**- Parsley**
- Fennel	**- Coriander**
- Daisies	**- Thyme**
- Rosemary	**- Mint**

- **Attract butterflies to your garden:** You can attract many kinds of butterflies by planting flowers and herbs on which they feed or reproduce. Butterflies can add to the beauty of your flower garden.

Flowers for a butterfly garden:

- Milkweed	**- Daisies**
- Asters	**- Impatiens**
- Sunflowers	**- Butterfly Weed**
- Yarrow	**- Lilies**
- Butterfly Bush	**- Irises**
- Purple Passionflower	**- Pentas**

- **Attract birds to your garden:** Plant vines with flowers that produce a lot of nectar attractive to hummingbirds. You can also plant shrubs and vines that produce berries as food for Florida songbirds.

You should not use insecticides or herbicides in your campus garden especially if you are growing vegetables to eat or have children that play in the garden. These chemicals, when not used properly, can be dangerous and have both human and environmental health risks. If you notice weeds or pests in your garden, you can take care of the problem by following these tips:

- **Pick weeds by hand:** You can probably pull all the weeds out of your garden in a short amount of time.

- **Use soap and water to kill pest insects:** You can kill the insects that are damaging your flowers or vegetables by mixing a small amount of dishwashing liquid with water and spraying it on the insects. Be careful not to use too much soap because a large amount can burn the plant. We recommend using ½ teaspoon of dishwashing liquid per cup of water on plants, a 1% solution.

- **A small number of pests will not do much damage:** If you notice only a few pests in your garden there is no need to worry. You can simply ignore them or you can pick them off your plants by hand.

- **Keep your garden maintained:** If you let your garden get out of control and cluttered, pests will have plenty of hiding places and can find ways into your apartment. Pruning shrubs away from the building and keeping the garden clutter free will reduce the number of pests.

- **Do not use wood:** Wood used on the ground for planters, dividers, or other ornamental purposes can become infested with termites. Termites can easily move from the wood in a garden to the wood in an apartment. By removing wood in the gardens, you eliminate a food source for termites. Use plastic or terra cotta pots and build any raised gardens with stone, concrete blocks, or bricks.

UF Housing & Residence Education UNIVERSITY of FLORIDA

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APPENDIX D

SOME HELPFUL TIPS TO KEEP PESTS OUT OF YOUR APARTMENT

You can reduce the number of pests in your apartment by following these simple tips:

- **Store your food in airtight glass, metal, or plastic containers:** You can re-use empty food jars for storage. You can also keep food in zip-up plastic storage bags. Remove items from paper or cardboard boxes (sugar and pasta) and place the food into containers. Insects cannot get into sealed food. Make sure any screw-top containers have a rubber seal in the lid. Small ants can crawl into containers that do not have the rubber seal, such as peanut butter. Place these containers into zip-up plastic bags and stored in the cabinet. You can store dried goods, like beans and flour, in the freezer.

- **Place your fruit into the refrigerator or eat it immediately:** Fruit flies, ants, and roaches can feed on fruit and vegetables left out on the counter, but they cannot get to it in the refrigerator.

- **Clean up all spills:** It is essential that you clean any food and beverage spilled in the apartment immediately. Spills provide pests with the food and water on which they need to live.

- **Wipe out cabinets:** Cabinets are often overlooked during routine cleaning. Spices, rice, sugar, or pasta spilled in cabinets can provide food for hiding pests.

- **Clean counters, stove, and floor regularly:** Keeping your kitchen clean prevents grease and food from building up. Pests eat this build up if it is not removed. Keeping your floor swept and mopped removes any spilled food, beverage, and hair that pests like to eat.

- **Clean dishes in a timely manner:** Clean your dishes often. If you do leave dishes in the sink, rinse them. Pests will eat any food left on your dishes. Also, do not let water pool in dishes. This serves as a water source for pests and promotes mold and bacterial growth.

- **Wipe up any water and check for water leaks:** Wipe up any water splashed around the sinks after you clean dishes or brush your teeth. Also, look for water leaks under the sinks and behind the toilet or bathtub. Immediately notify maintenance if you have any water leaks or dripping faucets.

- **Take out the trash:** Do not let food rot in the trash. Rotting food not only stinks, but also it is food for pests. Rinse out your trash can often. Clean spills around the floor and the walls near your trashcans.
- **Vacuum:** Vacuuming both your floor and furniture will remove spilled food and any pests that you may not see. Vacuuming also gets rid of dust and allergens present in your apartment.

- **Pick up any clutter:** Clutter provides harborage for pests and makes it harder to control them. Excessive clutter is a fire hazard, will not be tolerated, and may result in referral through the student judicial process.

- **Run your air conditioner:** This will reduce humidity and temperature making your apartment less attractive to insects. If you choose not to run your air conditioner, open windows so your apartment can air out.

- **Check your door sweep and door seal:** If you can see light coming in from under doors, the seal needs to be fixed. The same goes for windows and screens. Any openings will allow pests to enter the apartment. Contact maintenance and they will fix the problem for free.

- **Do not store items in cardboard boxes:** Remove cardboard boxes once they are unpacked because they are both harborage and a food source for pests. We recommend that you store your possessions in plastic tubs, which can be purchased inexpensively at any store with a home care section.

- **Do not line stoves or the areas above the stove with aluminum foil:** Grease can get underneath the foil or buildup in the folds. It also provides a place for insects to hide. Metal drip pans for stove burners are available at the housing office.

Remember: Maintenance is available to fix any issues with the apartment for free. They will fix leaking faucets and plumbing, seal cracks and crevices, fix the door sweeps and window seals, and repair most other problems.

Report any insect or maintenance problems to the Department of Housing and Residence Education by sending an electronic H.A.W.K. request online at www.housing.ufl.edu or fill out a work order and drop it off at the office.

Violations of the Department of Housing and Residence Life Community Standards may result in referral through the student judicial process. Visit http://www.housing.ufl.edu for up-to-date Community Standards.

UF Housing & Residence Education UNIVERSITY of FLORIDA

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APPENDIX E
IDENTIFICATION OF COMMON INSECT PESTS IN UF HOUSING

Identification of common insect pests

in UF housing

UF Housing & Residence Education
UNIVERSITY of FLORIDA

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Ants: Ants are social insects that have many workers and one to a few queens in their colonies. In your apartment, you will most often encounter the wingless workers trailing to a food source. These pests range in length from 1-6 mm.

Do not use your own pesticides on ants. This can cause a colony to divide into many colonies, making the problem worse. Ants require professional attention, so call the Department of Housing and Residence Education for free pest control.

Bed bugs: Bed bugs are becoming a large problem in hotels and on campuses across America. These insects feed on people while they sleep. These bugs are wingless, flat, and oval-shaped. They are brownish-red in color and 4-5 mm long.

If these insects are not eradicated immediately when discovered they can become a huge problem and spread to other apartments. If you see bed bugs in your apartment immediately contact the Department of Housing and Residence Education for free pest control. It takes a professional to get rid of bed bugs.

Bees and wasps: These are beneficial insects in the wild because they prey on pest insects and pollinate plants. They are flying insects 12-35 mm long often with yellow and black markings. Bees appear fuzzy while wasps are not.

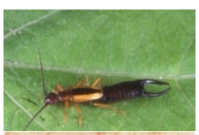
These insects can sting and many people have bee and wasp allergies, but they can simply be avoided unless they are building a nest close to human activity. If you notice nests above your doorway, on playground equipment, or any other place where the wasps and bees can interfere with human activity, call the Department of Housing and Residence Education for free pest control. If a bee or wasp enters your apartment you can kill it with a fly swatter and remove it with a vacuum cleaner or paper towel.

Cockroaches: Cockroaches are oval-shaped insects with long antennae. They come out at night and often are seen in the kitchen or bathroom. These insects have wings, but cannot fly well. The American and German cockroaches are the most common cockroach pests on campus.

American cockroaches: The large reddish-brown adults are up to 4 cm long. Each has a light colored ring on its body behind its head. These pests can come into your apartment through openings to the outdoors and also from the sewers.

German cockroaches: This pest is lighter in color and smaller than the American cockroach, about 1.5 cm long as an adult. It has two black stripes on its body behind its head. These pests are unknowingly brought into an apartment by either residents or guests and can spread from one apartment to another.

Cockroaches can be sprayed with soap and water and wiped up. If you see cockroaches in your apartment, call the Department of Housing and Residence Education for free pest control.



Earwigs: These brown insects are between 5-16 mm in length and have "pinchers" at the end of their abdomens. Earwigs are most often found outside in mulch, but can occasionally invade your apartment.
If you see earwigs in your apartment, you can spray them with soap and water and wipe them up.

Flies: As adults, these pests have two wings and are able to fly. Immature flies are called maggots and need rotting organic matter to live. The most common indoor fly pests include house flies and fruit flies.

House flies: Adults are grey with black stripes. They are up to 7 mm long. Their larvae (maggots) are white and 3-5 mm long.

Fruit flies: These insects are very small, yellowish-brown flies with red eyes. They are less than 4 mm long. These flies are most often seen on and around fruit, dirty dishes, and garbage cans.

Large numbers of house flies and fruit flies often are seen in apartments with rotting food on the counters, on dirty dishes, or in the garbage. Cleaning spilled food or beverages, taking out the trash regularly, cleaning the dishes, and storing all fruit in the refrigerator will help prevent fly infestations. Flies can be sprayed with soap and water and wiped up. Fly swatters also work well to kill house flies.

Silverfish: Silverfish are grey, carrot-shaped insects. They are 12-19 mm in length and have long antennae and three long bristle-like tails.
They can be found throughout an apartment but prefer areas with high moisture. They feed on fabric and paper.

The easiest way to eliminate silverfish is to reduce moisture in your apartment and remove any food source. Do not let water pool on the bathroom floors, clean up water behind sinks, and run the air conditioner to reduce the humidity. Store paper and any fabric in airtight plastic containers. When you see silverfish, they can be wiped up after being sprayed with soap and water.

Stored product pests: There are many different types of stored product pests. The most common on campus include moths and weevils. These pests are brought home from the grocery stores in contaminated food, often in dried beans and corn, grains, or rice. One species of weevil, the sweet potato weevil, infests sweet potatoes.

Moths: Moth caterpillars range in length from the 7 mm grain moth up to the larger 12 mm Indianmeal moth. These cream-colored caterpillars can be mistaken for maggots. Maggots will not be found in dry foods. The caterpillars become yellowish-brown flying adults, which are 2.5 cm in length.

Weevils: Stored product weevils are small beetles with long snouts. These insects are smaller than the moths, being 2-4 mm in length. They are brown or black in color. This insect drills holes in beans and corn to insert its eggs.

Check any beans, grains, and rice for insects at the store before you purchase them. Infested sweet potatoes will have many holes in it. Do not purchase food if you notice any insects in the packages or on produce.

Remember, report any insect problems to the Department of Housing and Residence Education by sending an online H.A.W.K. request at www.housing.ufl.edu or fill out a work order and drop it off at the office.

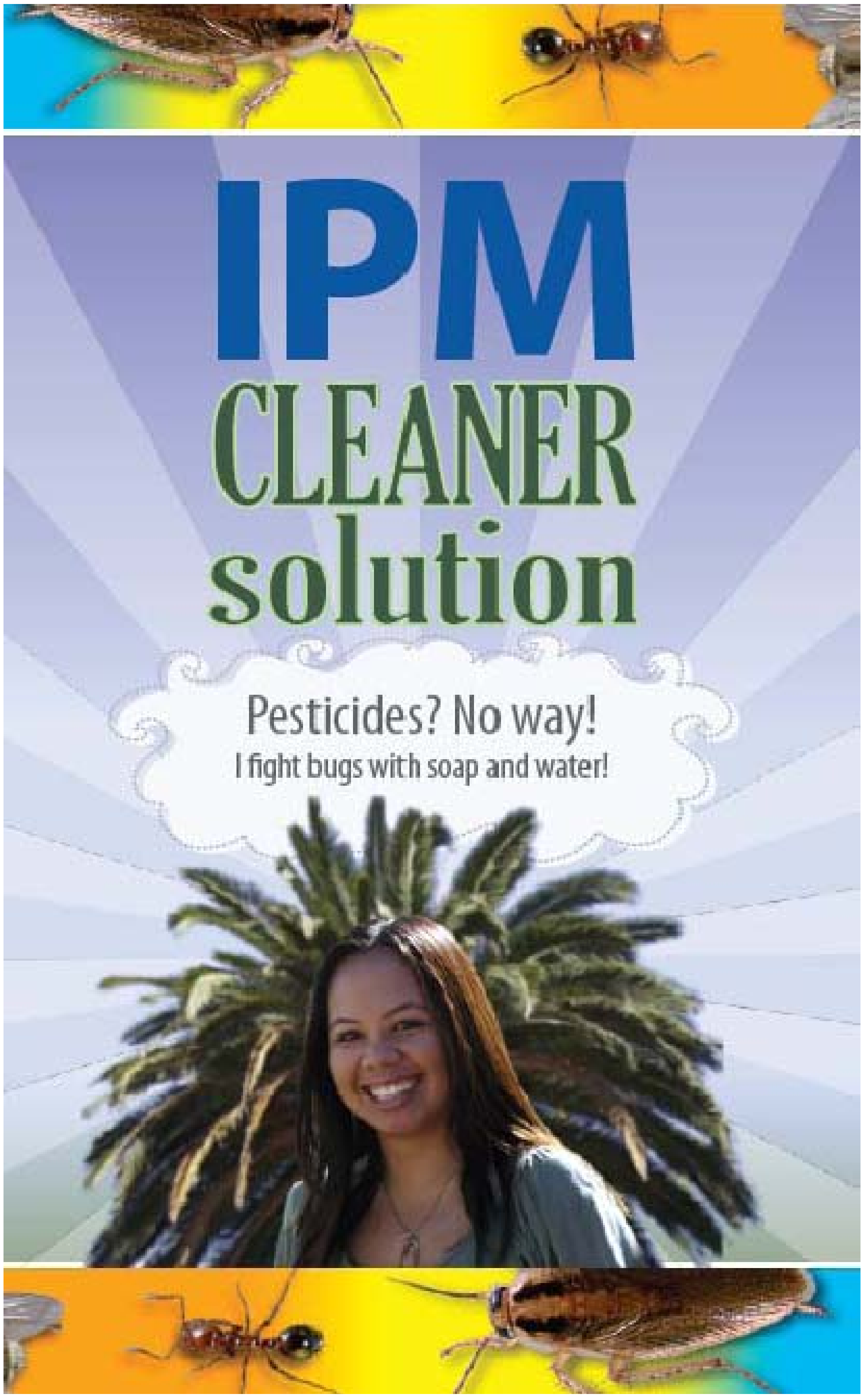
<u>Insect collection</u>

Collecting the pest insects in your apartment will allow the pest control technician to identify them and properly decide how to treat the problem.

You can help by following these tips:

- **Kill the insect with soap and water.** Do not squash any insect to be identified.
- **Place the insect into a storage container.** Plastic food containers or plastic zip-up bags work well. You can use a tissue, or tweezers to pick up the insect if you do not want to touch it.
- **Write the location where you found the insect on a piece of paper and place it into the container.** For example write “found on the kitchen counter.”
- **Store the container with the insect in the freezer.** This will preserve the insect so the pest control technician can make an accurate identification.
- **Fill out a work order or H.A.W.K. request for free pest control.**
- **Give the collected insect to the pest control technician.**

APPENDIX F
IPM CLEANER SOLUTION INSTRUCTIONS



IPM Cleaner Solution

- It is the goal of the Department of Housing and Residence Education to reduce both pest numbers and the amount of pesticides used to make the campus a healthier place to live.
- Housing has taken many steps to reduce the amount of pesticide on campus, so we ask that residents also contribute to our goal.
- Residents can help by reducing the use of store bought pesticides, such as ant and cockroach sprays or bug bombs.
- Instead of using store bought pesticides, reduce the risks of pests and pesticides by using IPM Cleaner Solution!

Directions:

1. Remove the lid of the provided "IPM Cleaner Solution" spray bottle.
2. Pour in liquid dish detergent to the 2 oz. line at bottom of bottle.
3. Add water to the 30 oz. line at top of bottle.
4. Replace lid and shake gently.
5. Clean up insects.

Sprayed surfaces may be slippery when wet.
Never use "IPM Cleaner Solution" to clean up wasp, yellow jacket, or bee nests.

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BIOGRAPHICAL SKETCH

Kevyn J. Juneau was born in Plattsburgh, New York to Kevin Juneau and Janice Crawford. Kevyn grew up in a town in northeastern New York nestled between the Adirondack Mountains and Lake Champlain where he also earned his Bachelor of Science in biological sciences with minors in English and psychology under the advisement of Drs. C. Leon Harris and Nancy Elwess. Before attending graduate school at the University of Florida (UF), Kevyn worked as a lab technician for Wyeth Research. At UF, Kevyn worked with Integrated Pest Management Florida as a graduate research assistant under the supervision of Dr. Norman Leppla. After graduating from UF with his Master of Science in entomology and nematology, Kevyn plans to pursue a Ph.D. in forest science at Michigan Tech. Kevyn is a self-proclaimed outdoorsman whose hobbies include birding, hiking, and cycling.