



Advancement of Integrated Pest Management in University Housing

Kevyn J. Juneau,¹ Norman C. Leppla,² and A. Wayne Walker³

¹School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931.

²Corresponding author, Entomology and Nematology, Department, University of Florida, P.O. Box 110620, Gainesville, FL 32611-0620 (e-mail: ncleppla@ufl.edu).

³Department of Housing and Residence Education, University of Florida, P.O. Box 112100, Gainesville, FL 32611-2100.

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ABSTRACT. Research was conducted in collaboration with the University of Florida (UF), Department of Housing and Residence Education (DOHRE) to assess and advance the campus integrated pest management (IPM) program they initiated in 2003. Beginning in 2008, the UF, DOHRE advanced IPM program was based on resident education, periodic inspection, and a systematic decision-making process whereby apartments were monitored, pests identified, action thresholds determined, and safe and effective pest management options used. The continuously improved process began with pest management methods based on resident behavior, such as sanitation and pest exclusion accomplished by the residents, accompanied by physical controls, including barriers installed by maintenance personnel and pest control devices maintained by DOHRE IPM technicians. If pest problems persisted, low risk materials were used, for example, dishwashing detergent solutions, boric acid, diatomaceous earth, bait stations, and botanical or microbial insecticides. There was a significant improvement in pest prevention behavior of the residents after the 2008 DOHRE IPM education and inspection campaign; however, there was no change in the already low annual number of pest complaints. From 2003 through 2008, ants were the most common pest reported, followed in order by cockroaches, stored product pests, and termites. The amount of insecticide active ingredient used per year decreased by $\approx 92\%$, virtually eliminating the use of hydramethylnon, borate, desiccants, organophosphates, fipronil, and pyrethroids. Further advancements can be made in campus IPM by increasing resident education and DOHRE IPM technician training, and the level of pest preventative inspection and maintenance.

Key Words: urban IPM; insecticides; pest insects

As in agriculture, urban IPM is a systematic approach to managing pests based on long-term prevention or suppression by a variety of methods that are cost effective and minimize risks to human health and the environment (Lewis et al. 1997, USDA 2004). Urban pests can just be a nuisance or cause significant health problems, damage to buildings, and additional economic losses because of food contamination, diminished esthetics, and pest management costs. The use of insecticides to manage urban pests also can have negative consequences, such as environmental pollution and adverse health effects for humans and animals (Buckley 2000, Alarcon et al. 2005). By systematically practicing sustainable urban IPM, risks associated with pests and pesticides can be minimized (IPM Institute 2011).

Urban IPM, developed by incorporating many of the established concepts of agricultural IPM (Stern et al. 1959), integrated biotic and abiotic factors, including the appropriate use of pesticides. Concepts, such as scouting, accurate pest identification, action thresholds, and conservation of natural controls were adapted for use in structural and landscape pest management (Flint et al. 1991). As urban IPM advanced, education became a key factor in preventing pest infestations, improving sanitation, and increasing tolerance of nonrisk pests (Byrne et al. 1984, Robinson and Zungoli 1985, Greene and Breisch 2002). Today, the goal of urban IPM is to manage pests primarily by prevention and elimination of their access to food, water and harborages, along with changing human behavior. Low-risk insecticides are used only when necessary and rarely those with the signal words “warning” or “danger” indicated on their U.S. Environmental Protection Agency (EPA) labels. Insecticide use in urban housing and associated health risks (Buckley 2000, Alarcon et al. 2005) can be minimized by instituting IPM based on low-risk practices that maintain pests at very low levels (Williams et al. 2006).

Universities often have campus IPM programs at some stage of development but rarely obtain, analyze and publish data on their methods, materials, experiences, and successes. IPM studies have been conducted in public housing (Greene and Breisch 2002) but most were restricted to low income units primarily in inner-city neighbor-

hoods (Rosenstreich et al. 1997, Campbell et al. 1999, Brenner et al. 2003, Williams et al. 2006, Peters et al. 2007). We are not aware of a published study on the effectiveness of an IPM program in university graduate student and family housing, even though ≈ 2.4 million students live in college and university housing nationwide (U.S. Census Bureau 2009). The purpose of this research was to document, assess and advance the University of Florida (UF) Department of Housing and Residence Education (DOHRE) IPM program after its first 5 years, 2003–2008. Specific objectives in maintaining UF, DOHRE properties with minimal exposure of residents to pests and pesticides were to (1) educate residents about pests and pest prevention, (2) assess pest problems systematically to determine the best IPM options, (3) base IPM actions on accurate identification of pests, knowledge of their biology, and reasonable thresholds, and (4) increase the effectiveness of the IPM program.

Materials and Methods

The DOHRE began using basic IPM practices for UF housing and residence halls in 2003, including routine apartment inspections, sanitation requirements, requests for maintenance to UF Facilities Management, and use of low-risk insecticides and baits. Low-risk products had the signal word “caution” on their EPA labels. To advance the initial UF, DOHRE IPM program, all bait stations for ants and cockroaches were removed from the apartments and prophylactic insecticide treatments were discontinued. In 2008, we instituted the following: a written IPM policy, a dedicated IPM specialist trained at UF, prescribed pest prevention practices, education of residents about insects, a pest monitoring system, accurate pest identification, an electronic pest complaint procedure, a rapid response and collaborative decision-making process, preferential use of nonchemical pest management methods, application of low-risk insecticides if necessary, continuous IPM program evaluation, and comprehensive record keeping. The advanced DOHRE IPM program has been documented in a training manual that describes how to institutionalize IPM, pre-

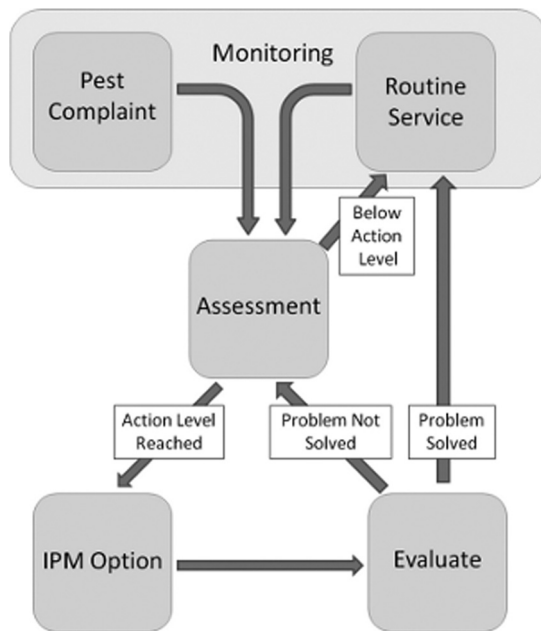


Fig. 1. The IPM decision-making process developed between initiation of the IPM program on 1 January 2003 and its advancement in 2008. The process begins with either a pest complaint by a resident or pest sighting during a routine service inspection. The potential infestation is assessed and appropriate action taken if a threshold is reached. The outcome is evaluated and additional action taken if warranted or monitoring is resumed.

vent pest problems, and select pest-specific IPM options (Juneau et al. 2009).

The systematic DOHRE IPM decision-making process is based on experience gained from 2003 to 2008 (Fig. 1). IPM actions begin with a pest complaint (pest management request) submitted by a resident or a pest sighting by a DOHRE IPM technician during routine service. In either case, the pest is identified and a thorough assessment made to determine if it has reached a level of abundance or caused damage that

triggers an IPM action. General action thresholds for the pests encountered in UF housing and residence halls were indicated in the IPM training manual (Juneau et al. 2009). Continued monitoring, perhaps with an increased frequency of inspection, is the only requirement if the action level has not been reached. Above the action threshold, IPM options are selected by the DOHRE senior IPM technician in consultation with the residents based on their effectiveness, safety, and cost. Examples of safe options are modifications to the physical environment, changes in resident behavior, animal traps with finger guards, and the judicious use of reduced risk insecticides (EPA 2011) to mitigate pest infestations. A subsequent evaluation is made to determine if the pest problem has been solved; if not, the IPM actions are reassessed. This decision-making process has two feedback loops to monitoring: (1) monitoring—assessment—below action level—continued monitoring and (2) monitoring—assessment—above action level—IPM options—evaluation—problem not solved—reassessment. Eventually, if the pest is no longer apparent or causing damage, continued monitoring is the only required IPM action.

Study Location. In collaboration with DOHRE, an ≈50-year-old U.S. Department of Housing and Urban Development (HUD) apartment complex located on the UF main campus in Gainesville, FL, was selected to serve as the study site. The complex consisted of 28 residential buildings encompassing 220 apartments and one additional support building containing a common area for residents, an office, and a laundry room. Twenty-seven of the residential buildings each had two 1-bedroom and two 2-bedroom apartments downstairs and upstairs. Another building had four 1-bedroom apartments. The complex housed single graduate students and both married undergraduate and graduate students and their families. Most of the residents were international students with a wide range of living habits and attitudes about pests and pest management.

Resident Education. The DOHRE senior IPM technician provided a 1-hour verbal orientation for new residents of the apartment complex at the beginning of the spring semester in January 2008. During an evening, the new residents gathered as a group in the common area to learn about pest prevention and associated apartment inspection criteria (Table 1). They were encouraged to contact DOHRE for pest management services, rather than attempt to control pests with over-

Table 1. Improvement in inspection criteria between the first (Mar. 11–April 11, 2008) and second (Jan. 5–26, 2009) inspection ($n = 155$ apartments)

Inspection criteria	Number of deficiencies		% Improvement
	First inspection	Second inspection	
1. Outdoor pest harborage	18	7	-11 (61.1%)
2. Screen door open	39	40	1 (-2.6%)
3. Odor in apartment	36	26	-10 (27.8%)
4. Mold present	45	1	-44 (97.8%)
5. Carpet in poor condition	1	1	0
6. Garbage cans not covered	113	77	-36 (31.9%)
7. Garbage spilled around can	15	6	-9 (60.0%)
8. Food stored open on counter	75	44	-31 (41.3%)
9. Food stored in rooms not kitchen	15	12	-3 (20.0%)
10. Rotting food present	15	11	-4 (26.7%)
11. Kitchen sink dirty	16	9	-7 (43.8%)
12. Kitchen floor dirty	14	8	-6 (42.9%)
13. Kitchen counters dirty	14	12	-2 (14.3%)
14. Kitchen cabinets cluttered	13	4	-9 (69.2%)
15. Food spills in kitchen cabinets	44	23	-21 (47.7%)
16. Bathroom sink or tub dirty	9	2	-7 (77.8%)
17. Bathroom floor dirty	7	1	-6 (85.7%)
18. Carpet dirty	12	7	-5 (41.7%)
19. Clutter throughout apartment	16	15	-1 (06.3%)
20. Stove dirty	6	1	-5 (83.3%)
21. Under refrigerator dirty	23	14	-9 (39.1%)
22. Improper food containment	70	75	5 (07.1%)
23. Poor general organization	18	11	-7 (38.9%)
Net improvement in IPM	634	407	-227 (35.8%)

the-counter pesticides. As an alternative to insecticides, a 1-liter spray bottle was provided to each household with instructions on how to mix a 6% solution of dishwashing detergent. Household cleaners, including detergents, have been shown to kill insects on contact (Baldwin and Koehler 2007) and can be used to remove insects, pheromone trails, frass, and associated debris. The residents received additional IPM information and instruction during routine inspections and in response to pest complaints. They also were given educational brochures produced for the DOHRE IPM program: Bed Bug Prevention, Tips to Keep Pests Out of an Apartment, Extended Vacation Checklist, Campus Gardening, and Identification of Common Insect Pests in UF Housing (Juneau 2009). These documents were e-mailed to the residents, linked to their on-line newsletter, The Villager, placed in the apartment complex common areas, and made available on the IPM Florida Web site (<http://ipm.ifas.ufl.edu>).

Apartment Inspections. An initial inspection of apartments was conducted between March 11 and April 11, 2008, followed by another during January 5–26, 2009. Vacant apartments and those with new residents during the second inspection were not included in the study. The final 155 apartments were inspected for pest-conducive physical defects and deficiencies in resident behavior based on 23 criteria (Table 1). There were 11 types of maintenance problems, including cracks or holes in walls, window screens not secured, windows not sealed, inadequate door sweeps or seals, improper gutter drainage, walls with evidence of water leaks, improper escutcheon plate installation, condensation on plumbing, pipe leaks, inadequate ventilation, and cracks or holes in the ceiling. The number and types of resident behavioral deficiencies and physical defects were recorded during the initial and subsequent inspection for each apartment. Changes in inspection criteria were analyzed with a paired *t*-test using JMP 7.0 (SAS Institute 2007).

Pest Complaints. Pest complaints had been recorded for each of the 220 apartments since January 1, 2003. These and subsequent complaints during this study were grouped by the most abundant pest types or listed as unknown, including spiders, mites, booklice, bed bugs, mice, mosquitoes, and wasps. The data were totaled for each pest type by month and a time series analysis was used to determine possible seasonal patterns. The numbers of pest complaints also were compared before and after resident IPM education and apartment inspections were intensified in January 2008. Pest complaints were used as a proxy because there were no historical records of the exact numbers of specific kinds of pests present in the apartments. Because many pests were not reported, complaints served as a conservative estimate of the actual pest exposure for the residents. The pest complaint data were analyzed as a time series using JMP 7.0 (SAS Institute 2007).

Insecticide Applications. DOHRE insecticide use records included the apartment numbers, product names and amounts, and application dates. Monthly data from January 1, 2003 to December 3, 2008 were analyzed by comparing the weight (mass) of active ingredients in insecticide products across widely varying formulations. Records for each apartment were kept on the total weight of active ingredients for solid and gel formulations but only on the volume applied for liquids and aerosols. Because these liquid products are almost all water, the mass of each was estimated by first multiplying its specific gravity (SG) derived from the Material Safety Data Sheet (MSDS) by the density of water (1 g/ml) to determine the density of the product. The density of a product was then multiplied by its volume to determine its mass. The percentage of active ingredient in each solid, gel, liquid, and aerosol product is listed on the EPA label, so the percentage times the mass of the product yielded an estimate of the mass of active ingredient:

$$\text{Density}_{\text{product}} = \text{Specific Gravity}_{\text{product}} \times \text{Density}_{\text{water}}$$

$$\text{Mass}_{\text{product}} = \text{Volume}_{\text{product}} \times \text{Density}_{\text{product}}$$

$$\text{Mass}_{\text{active ingredient}} = \text{Mass}_{\text{product}} \times \% \text{ Active Ingredient in the Product}$$

The insecticides were grouped according to class (Kegley et al. 2008) and the mass of active ingredients applied in each class was totaled monthly.

Results

Resident Education and Apartment Inspections. The UF, DOHRE IPM resident education and apartment inspection campaign improved pest prevention practices within the first year. Residents should have learned about proper food storage and sanitation from the orientation meeting and brochures provided in January 2008. However, the first inspections conducted in March through April 2008 revealed that they still had major shortcomings in their pest prevention behavior (Table 1). The apartment inspections reinforced the importance of sanitation and other pest prevention practices. During the second inspections in January 2009, the average number of deficiencies in inspection criteria per apartment decreased significantly from 4.14 ± 0.27 to 2.65 ± 0.22 (mean \pm SD; $n = 155$; paired *t*-test, $t = 5.29$; $P < 0.0001$). The maintenance defects remained unchanged from 2.85 ± 0.14 to 2.86 ± 0.14 . IPM cleaner solution spray bottles were present in all 155 apartments; however, the number of apartments with over-the-counter insecticides was reduced only from 57 to 52. DOHRE IPM technicians could conduct routine apartment inspections but did not have the authority to require residents to discard insecticides they had purchased.

The apartments were evaluated for all 23 inspection criteria during both the first and second inspection (Table 1). For the first inspection, 634 deficiencies were observed but the number declined to 407 for the second inspection, a 35.8% overall improvement. Decreases occurred in all but two of the inspection criteria, screen door open and improper food containment. There were 12 major deficiencies, those in $>15\%$ of the apartments, during the first inspection. These included outdoor pest harborage, screen door open, odor in apartment, mold present, garbage cans not covered, food stored open on counter, kitchen sink dirty, food spills in kitchen cabinets, clutter throughout apartment, under refrigerator dirty, improper food containment, and poor general organization. Of the entire set of 23 deficiencies, all except five were reduced by $>25\%$, including screen door open, food stored in rooms not kitchen, kitchen counters dirty, clutter throughout apartment, and improper food containment. Nevertheless, the percentage of apartments with screen door open, garbage cans not covered, food stored open on counter, and improper food containment remained unacceptable.

Pest Complaints. There was no overall pattern in the annual number of pest complaints preadvancement (2003–2007) and postadvancement (2008) of the IPM program (Fig. 2). However, complaints about ants and cockroaches appeared to increase after 2005, as did complaints for all pest types in 2008, except stored product pests. The mean \pm SD numbers of monthly pest complaints recorded for 72 months from 2003 to 2008 were ants (4.03 ± 0.53), cockroaches (1.38 ± 0.16), stored product pests (0.21 ± 0.05), termites (0.31 ± 0.09), and unknown (1.0 ± 0.13).

There were 290 complaints involving ants, the major pest being the dark rover ant, *Brachymyrmex patagonicus* Mayr (Hymenoptera: Formicidae), an adventive species from South America. Though not statistically significant ($P = 0.09$, autocorrelation = 0.314), ant complaints appeared to have a 12 month cycle with increases during the summer months and decreases during the winter (Juneau 2009). There was a peak in ant complaints during May 2008 probably resulting from ants being disrupted by the installation of high-speed Internet cables. Trenching around buildings redistributed the soil and created a barrier to foraging that forced ants indoors. In response to these complaints, the ants were treated almost exclusively with a borate and honey bait formulation. Inside apartments, the ants accumulated most often in kitchens. They were observed entering through air conditioning ducts and cracks in the drywall. Although we did not open walls to follow the trails, large colonies of *B. patagonicus* previously had

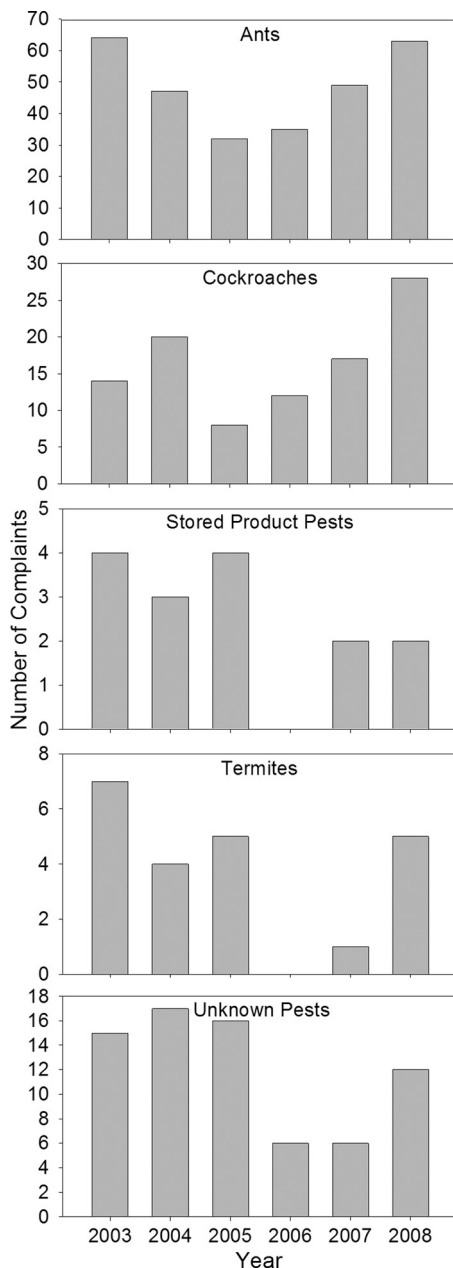


Fig. 2. The total number of pest complaints per year for each of the pest types from 220 apartments preadvancement (2003–2007) and postadvancement (2008) of the IPM program.

been discovered in bathroom and kitchen walls when apartments were renovated. These ants have been reported to nest inside walls (MacGown et al. 2007).

There were 99 complaints about cockroaches from January 2003 to December 2008 with no distinction between the two combined species, the German cockroach, *Blattella germanica* L., and American cockroach, *Periplaneta americana* L. (Blattodea: Blattellidae). The complaints were not cyclic because German and American cockroaches are domestic and peridomestic, respectively (Hagenbuch et al. 1988, Atkinson et al. 1990), and are only indirectly affected by outdoor weather. The relative abundance of the two cockroach species was not noted. Complaints about cockroach infestations increased in 2008 but remained infrequent regardless of deficiencies in apartment sanitation. The presence of food, water, and harborages supports cockroach infestations (Schal 1988), so increased sanitation possibly could reduce the number of complaints.

The remainder of the pest complaints involved stored product pests (15), subterranean termites (Isoptera: Rhinotermitidae) (9), drywood termites (Isoptera: Kalotermitidae) (13), and unknown (72). Complaints about stored product pests were intermittent and the unidentified insects were discarded with the contaminated food. Termite infestations were uncommon and various kinds of unknown pests were handled on a case by case basis.

Insecticide Applications. The classes of insecticides used at the apartment complex in 2003–2004 were primarily amidinohydrazone (hydramethylon), borate (boric acid), desiccants (silica gel and diatomaceous earth), and an organophosphate used to exterminate drywood termites (Fig. 3). Borate and desiccant insecticides were used to control ants, cockroaches, and other crawling insects. After 2004, EPA registrations were discontinued for most organophosphates. During 2004–2005, formulation of cockroach baits changed from hydramethylon to fipronil, a pyrazole. This decreased the weight of active ingredient necessary to treat for cockroaches in 2006 because the proportion of fipronil per product (0.05%) is less than hydramethylon (2%). Mosquitoes that rested in stairwells were treated with pyrethroids beginning in 2004 but only minor amounts of hydramethylon, silica gel and bifenthrin have been used at the apartment complex since 2006. Synergists and an insect growth regulator were used infrequently and therefore not included in the analysis. In 2007, trench and rod applications of an insecticide product containing fipronil were made around the apartment buildings to control subterranean termites. Pyrethroids continued to be the predominant insecticides applied because their formulations are effective, easy to use, repellent, and labeled for use on many insects.

The amount of insecticides used per year increased from 1952.45 g in 2003–4318.60 g in 2005, and then decreased to 155.61 g in 2008 as the advanced IPM program was implemented (Fig. 4). The switch from applying insecticides routinely to addressing only identified pest problems accounted for most of the subsequent low quantity and intermittent use of these chemicals. After spring 2008, borates and other desiccants were no longer routinely placed in wall voids, under cabinets, and throughout the kitchens, and all baits were removed from the apartments. There was a bed bug, *Cimex lectularius* L. (Hemiptera: Cimicidae), infestation in June 2008 that warranted the use of a desiccant and pyrethroid (Fig. 3). These insecticides were confined inside wall voids, behind baseboards, and in cracks and crevices. In conjunction with the insecticides, a heat treatment shown to kill bed bugs (Pereira et al. 2009), was used for sensitive items, such as a mattress and box springs, bedding, furniture, and clothing. From September to November 2008, a hydramethylon product was used to eliminate potentially harmful red imported fire ants, *Solenopsis invicta* Buren (Hymenoptera: Formicidae). Also in 2008, there were many complaints about ants, requiring applications of a boric acid and honey bait.

Discussion

This research documented and advanced the IPM policies and practices instituted by UF, DOHRE for the buildings and grounds they manage. As a result, DOHRE IPM technicians are trained to assess pest problems systematically, determine the best IPM options in consultation with the residents, and base their actions on accurate identification of pests, knowledge of pest biology, and reasonable thresholds (Juneau et al. 2009). Thresholds are reached before appropriate IPM options are selected, ranging from nonchemical methods and, if necessary, the use of effective, low risk insecticides. Nonchemical methods include exclusion, sanitation, trapping, or perhaps tolerating the pest. If insecticides become necessary, they are applied after the residents are notified and during appropriate times to maximize their effectiveness and protect human health and the environment. Low-risk products are selected and placed in locations where human exposure is minimal. All insecticides are handled according to state and federal laws and there are no routine, periodic applications.

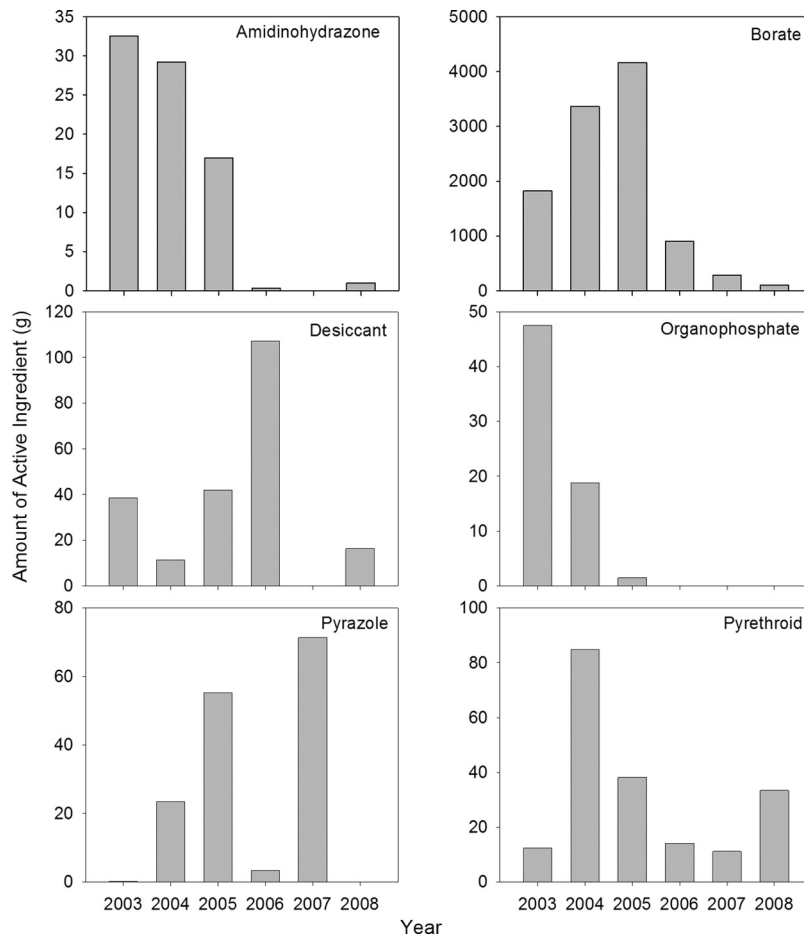


Fig. 3. The average amount (weight) of insecticide active ingredient in indicated classes used each year from 2003 to 2008.

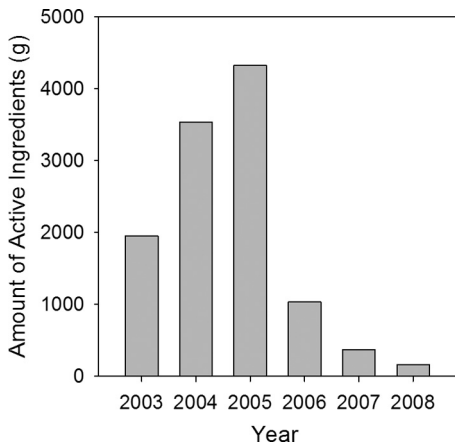


Fig. 4. The total amount (weight) of insecticide active ingredients used per year between 2003 and 2008.

The DOHRE IPM technicians and residents cooperate in determining that the IPM options they select are acceptable and effective in eliminating pest infestations.

The DOHRE IPM program for university housing achieved the goal of minimizing exposure of residents to pests and pesticides by altering the behavior of both residents and DOHRE IPM technicians. An IPM policy was instituted that emphasized education about pests and pest prevention. In a related pilot study, a brief educational session and booklet influenced residents to accept and comply with an IPM program (Campbell et al. 1999). In our study, residents improved their sanitation and food handling practices significantly after receiving

verbal guidance, associated written IPM educational materials, and thorough apartment inspections. However, after nearly a year of the advanced DOHRE IPM program, many of the residents still provided insects access through open screen doors, continued to have unacceptable odors and clutter throughout their apartments, and did not store food properly. Several years may be required to reduce the number and kinds of pests infesting the apartments, as in previous studies of public buildings (Greene and Breisch 2002). Further reductions are possible, however, because residents will receive IPM instruction repeatedly during their 3- to 6-year educational programs. It has been shown that continuing education is essential for changing attitudes about the presence of arthropods and implementing an urban pest management program (Byrne et al. 1984).

The public wants a pest-free environment but prefers pest management practices that minimize the use of pesticides (Potter and Bessin 1998). The UF, DOHRE IPM program is designed to achieve this goal. It effectively maintained minimal pest levels, indicated by a continuous low number of pest complaints, while decreasing the amount of insecticide applied by 92%. From 2005–2008, cockroach and ant complaints averaged less than two and five per month, respectively, for 220 apartments. The number of pest complaints fluctuated widely as the IPM program advanced and additional reductions may not be achievable. Pest complaints involve attitudes about pests and pesticides, as well as the level of pest exposure (Byrne et al. 1984, Potter and Bessin 1998). The use of amidinohydrazone, borate, and desiccant insecticides was minimized and organophosphate and pyrazole insecticides were eliminated. Conversely, pyrethroids were used in relatively large quantities, although less frequently. Active ingredients should be rotated to reduce the probability that the pests develop insecticide resistance or avoidance. The IPM program re-

cently achieved Green Shield certification (IPM Institute 2011) but can be improved further by increasing communication and cooperation between the residents, DOHRE IPM technicians, and Facilities Management.

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