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The Distribution and Movement of American Cockroaches in Urban Niches of New Orleans

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Abstract

American cockroaches are an important source of household allergens in tropical and semitropical climates. To determine which outdoor niches produce American cockroaches, traps were placed at 40 homes in New Orleans to collect nymphs. Nymphs were collected from the sewers, yards, and within the homes themselves. To compare sewers and yards as sources of cockroaches entering homes, adult cockroaches were collected, marked, and released into yards and sewers. No sewer-released cockroaches were collected in homes. Cockroaches released into yards were collected in the homes, suggesting that yards, rather than sewers, are a more important source niche. A field trial applying boric acid granules to the yard was performed in an effort to reduce entry of cockroaches. There was a significant reduction in the cockroach antigen collected in intervention homes compared with controls.

Keywords

Periplaneta americana, cockroach, asthma, niche, mark-release-recapture, urban pest management

Introduction

The vast majority of cockroach species do not interact with humans, although a few have become pest species around the world. These include *Blattella germanica* (German cockroach), which are ubiquitous globally, and *Periplaneta americana* (American cockroach), endemic to tropical and subtropical climates and found elsewhere in sewers and other subterranean locations. The proximity of these species to human populations creates a public health problem because they are potential mechanical vectors of human diseases.[1,2] Cockroach exposure has also been linked to cockroach allergy, sensitization, asthma incidence, and severe asthma exacerbations in adults and children.[3-6] In warm, humid regions, American cockroaches are the predominant species found indoors.[7]

Effective control of German cockroach by indoor treatment leads to cockroach control and lower rates of sensitization and asthma morbidity in US cities.[3,8] However, indoor treatment is presumed to be ineffective against cockroaches that reproduce in large numbers outside the home, such as the American cockroach. Both American and German cockroaches are implicated in asthma development and exacerbation and share significant homology in major allergens,[9,10] but their ecology varies significantly. The differences in ecology have important implications for designing effective cockroach mitigation programs. Although German cockroaches do not generally reproduce outside human structures, American cockroaches are capable of maintaining large populations in outdoor niches. Preliminary observations within New Orleans, supported by reports in the literature, suggest that American cockroaches reproduce within detritus, vegetation, and debris in yards; storm drains; sewers; and within homes, often at very high densities, particularly in locations where water accumulates. Of these, several studies have implicated sewer systems as the major source of urban American cockroaches.[11-14] Migration from sewers into houses can occur via aboveground and belowground routes and has been experimentally linked to fluctuations in niche population pressure.[12] Increasing population pressure drives outward migration, whereas areas with low populations attract migrating roaches. Population movements into houses may also be motivated by escape from cold or inclement weather.[11]

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Currently, integrated pest management (IPM) for cockroaches is the recommended strategy for controlling cockroaches that reproduce indoors.[8,15,16] IPM strategies for reducing pests include source reduction, in which habitat that generates abundant pests is physically manipulated to prevent reproduction (eg, eliminate standing water to reduce mosquito populations), combined with other noninsecticide approaches to reducing pests. IPM also incorporates targeted application of insecticides with low potential for toxicity to humans and domestic pets when source reduction is impractical.

To reduce exposure to cockroaches in the southern United States and tropical areas, sustainable cockroach control techniques are needed that factor in the movement of American cockroaches from source niches. If the most important niches can be clearly identified, an approach may be designed that reduces populations of American cockroaches where they reproduce, before they enter the home. Identifying and treating outdoor sources will also result in reduced use of pesticides in the home, a growing public health concern, particularly for residents of urban centers.[17,18]

The overall goals of this project were to identify the niches that serve as population sources for American cockroaches found within homes using niche-specific locations of nymphs (phase 1), to describe the relative contribution of American cockroaches to the indoor environment from various population sources using mark-release-recapture experiments (phase 2), and to reduce movement of cockroaches from outdoor source niches using boric acid granules (a low-toxicity insecticide effective against cockroaches) in order to reduce cockroach exposure indoors (phase 3).

Methods

A convenience sample of 40 homes in New Orleans, Louisiana, was recruited into the study in spring 2013. Homes were eligible for inclusion if they were raised above the ground (at least 1 foot) and owner occupied, and the home's resident reported a minimum of 1 non-German cockroach observed in the home per month for the past 6 months. To identify the most important source niches for American cockroaches, sticky traps (Victor M331 traps, Woodstream, Lititz, PA) were placed at each home in locations where cockroaches are typically found (5-10 inside the home and 6-12 outside). Banana peel and bread soaked in beer were used to attract cockroaches into the traps.[2,19] The volatile compounds from these foods are especially attractive to American cockroaches. Inside trap locations included near the kitchen sink, refrigerator, stove, food storage, bathroom sink, and bedroom or in other locations where the homeowner had seen cockroaches. Outdoor traps were placed in the following locations: the 2 nearest storm drains, near the bathroom and kitchen sewer lines, under the house (bathroom, kitchen, bedroom, and/or living room), and at 2 sites of yard debris near the house and 2 sites of yard debris away from the house. Five days after placement, traps were collected and transported to labs at Tulane School of Public Health and Tropical Medicine. Cockroaches in the sticky traps were counted, identified to species by the study entomologist, and classified as adult (with wings) or nymphs (without wings).

Niche-specific demographics were used to identify the most important outdoor sources. Niches with the highest prevalence of nymphs trapped were designated as the most important source niches from which cockroaches found indoors might be originating. To determine which of these possible niches were actual sources of roach migration and, therefore, candidates for cockroach control, a mark-release-recapture study was conducted.

Cockroach releases were performed on a rolling basis over fall 2014 and spring/summer 2015. Adult American cockroaches were collected by hand from storm drains and sidewalks around New Orleans and kept outdoors overnight in buckets. Within 24 hours, the cockroaches were marked with color-coded fluorescent powder (Bioquip Products, Rancho Dominguez, CA) and released into the 2 most important outdoor source niches (identified as described above): yards and lateral sewage lines connecting homes with municipal sewers. Cockroaches released into the lateral lines connecting homes with the sewer lines under the streets were marked with pink powder, and those released into yards were marked with blue powder. Immediately following the release, baited sticky traps were placed in the locations listed in Table 1 and monitored by study staff every other day for the 14 days following the release. The number of mark-release events per day was dependent on the number of cockroaches collected the previous evening. When cockroaches were trapped, they were examined for fluorescent powder, and a fresh trap was placed to avoid contamination. Recapture rates were calculated for each trapping location.

In spring/summer 2016, in an effort to demonstrate whether cockroach control in the implicated niche has an impact on the number of American cockroaches entering homes, study homes were randomly assigned to either a treatment group (insecticidal baiting in the identified niche) or a control group. Block randomization was used to control for seasonality. A total of 19 homes were randomized into the control group, and 21 were randomized into the intervention group. Niban granular bait (5% boric acid; Nisus Corporation, Rockford, TN),

Table 1. Location of Traps for Indoor and Outdoor Niches.

Indoor Niche Trap Sites		Outdoor Niche Trap Sites	
Kitchen sink	Storm drain	Nearest inlet	Second nearest inlet
Refrigerator	Sewer lines	Bathroom line	Kitchen line
Stove	Under house	Under bathroom	Under kitchen
Food storage	Under house	Under bedroom	Under living room
Bathroom sink	Yard debris	Near house side 1	Near house side 2
Bedroom	Yard debris	Away house side 1	Away house side 2

Table 2. Collection of Cockroaches in and Near Homes.

	Rate of Cockroach Trapping by Species and Developmental Stage					
	American		German		Smokey Brown	
	Adults Per 100 Traps	Nymphs Per 100 Traps	Adults Per 100 Traps	Nymphs Per 100 Traps	Adults Per 100 Traps	Nymphs Per 100 Traps
Indoors	5.53	35.32	6.38	35.32	2.13	2.13
Storm drain	21.74	4.35	0.00	0.00	33.33	1.45
Sewer line	0.00	16.67	0.00	0.00	0.00	8.33
Under house	4.29	15.00	1.42	4.29	5.00	17.86
Yard	15.71	27.14	1.88	6.43	16.25	5.63

a widely used product for outdoor cockroach control,[20,21] was placed around the perimeter of intervention homes according to manufacturer's directions, at a rate of 6 ounces per 100 square feet in a band 2 feet wide. In control homes, no insecticide was applied. American cockroach antigen (Bla g 1) dust levels were assessed in all homes. At the baseline visit of phase 3, dust samples were collected from the kitchen floor. Dust sample collection was repeated 12 days later, at the end of the follow-up period. Dust samples were collected in accordance with the Vacuum Dust Sample Collection Protocol for Allergens developed by the Department of Housing and Urban Development's Office of Healthy Homes and Lead Hazard Control (http://www.hud.gov/offices/lead/hhi/hhts.cfm). Dust samples were processed using standardized ELISA analysis (Indoor Biotechnologies, Inc Charlottesville, VA.) The proportion of homes with detectable levels of Bla g 1 allergen (≥0.08 μg/g) was assessed in both groups. Fisher's exact test was used to detect differences between the treatment groups.

Results

Table 2 includes trapping results for German, American, and Smoky Brown cockroaches (*P fuliginosa*, which is physically and ecologically similar to *P americana*). Phase 1 trapping resulted in the identification of 3 niche types with the highest prevalence of American cockroach nymphs. These were the sewer line (16.67 per 100 traps), the yard (27.14 per 100 traps), and the interior of the home (35.32 per 100 traps). The highest trapping rates for German cockroaches were found indoors for both adults and nymphs (6.38 and 35.32 per 100 traps, respectively). The highest rate of smoky brown cockroaches trapped was in the storm drain for adults (33.33 per 100 traps) and under the house for nymphs (17.86 per 100 traps).

Based on these results, the 2 most important outdoor niches were identified: the yard and the sewer lines. In phase 2, mark-release-recapture studies were conducted at each home in these niches. Of cockroaches recaptured indoors, 100% originated from the yard release. None of the cockroaches released into sewers were recaptured indoors. Additionally, of cockroaches recaptured under the home, a majority (62.50%) originated from the yard. Of cockroaches released in the sewer, the majority were recaptured in the sewer (90%), and 10% were recaptured in either the yard or under the home. The overall recapture rate was 1.82%; 1.13% released in the yard were recaptured, and 5.73% released in the sewer were recaptured (Table 3).

During phase 3, Bla g 1 levels inside the home were assessed preintervention and postintervention to determine if there was a difference between intervention and control homes (Table 4). Dust samples were analyzed for

Table 3. Recapture Counts of Marked Cockroaches.

	Recaptured Marked Cockroaches by Location		
Location	Yard Releases Recaptured[a]	Sewer Releases Recaptured[b]	Total Marked Recaptured
Indoors	4 (100.00%)	0 (0.00%)	4
Under home	5 (62.50%)	3 (37.50%)	8
Yard	9 (81.81%)	2 (18.19%)	11
Sewer	0 (0.00%)	45 (100.00%)	45
Total	18	50	68

[a]38 Homes, 1585 roaches.
[b]23 Homes, 872 roaches.

Table 4. Proportion of Homes With Detectable Levels of Bla g 1.

Preintervention[a]				Postintervention[b]			
Group	Bla g 1 Detected (≥0.08 µg/g)	Bla g 1 Undetected	Total	Group	Bla g 1 Detected (≥0.08 µg/g)	Bla g 1 Undetected	Total
Control	7 (43.75%)	9 (56.25%)	16	Control	9 (56.25%)	7 (43.75)	16
Intervention	14 (77.78%)	4 (22.22%)	18	Intervention	16 (88.89%)	2 (11.11%)	18

[a]$P = .08$.
[b]$P = .05$.

16 control and 18 intervention homes. At baseline, there were no significant differences between the proportion of homes with detectable levels of Bla g 1 in intervention and control homes ($P = .08$). Dust levels were resampled 12 days later. At follow-up, the proportion of homes with detectable levels of Bla g 1 was lower in homes receiving the insecticidal baiting intervention versus control homes (43.7% vs 11.11%; $P = .05$).

Discussion

American cockroaches are a public health concern. They are implicated in the transmission of pathogens and are an important source of allergen exposure in homes in tropical regions worldwide.[1,7,13,22] They are associated with asthma development and severe asthma morbidity. Large populations of American cockroaches are typically found in sewers, and sewers have been a presumed source of cockroaches entering homes.[11,12,14] Our study identified large populations of cockroaches in the sewers of New Orleans, but this did not appear to be a source of cockroaches entering homes and, therefore, may not be the most effective target for pest control in tropical and semitropical locations. Instead, we identified yard niches as an important source of cockroaches entering homes.

In this study, we also collected significant numbers of smoky brown cockroaches in and around homes. The medical significance of this species has not been extensively studied, but based on the close phylogenetic relationship between these species, it is possible that allergic sensitization to American cockroaches may cause reactions to antigens from smoky brown cockroaches. Although data were not presented here, we also collected smaller numbers of Surinam cockroaches in homes, with most specimens collected outdoors. German cockroaches were frequently collected indoors as well, and field cockroaches were collected outdoors at a small number of homes.

The reduction in the proportion of homes with detectable levels of Bla g 1 in those homes receiving an application of boric acid granules in the yard was higher compared with untreated homes. We observed a 50% decrease in detectable levels in intervention homes versus a 12.5% reduction in control homes. Boric acid is considered a low-toxicity insecticide, and we used this approach in hopes that a least-toxic approach would be sufficient to control American cockroach migration into homes.

An unexpected finding was the observation of large numbers of American nymphs indoors, indicating that the homes themselves were a source of American cockroaches. This finding suggests that treatment of outdoor niches may not be effective in all homes with American cockroach infestation. Application of insecticidal baits indoors (as performed for control of German cockroaches) may be a more effective strategy to control American cockroaches in homes that have reproducing populations indoors. Additional research on American cockroaches reproducing inside homes is warranted.

Conclusion

This study highlights the importance of traditional ecological approaches to understanding human disease risk. Identifying source niches by differentiating between different life history stages was necessary to distinguish probable migratory sources from niches that serve only as harborage. Treatment of the relevant source niches may reduce exposure to allergens associated with asthma.

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Author Contributions

JC and MF contributed to study design, data collection, interpretation of results, and writing the manuscript. FR and DW participated in data collection, analysis and writing the manuscript.

Declaration of Conflicting Interests

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References

1. Brenner RJ, Koehler PG, Patterson RS. Health implications of cockroach infestations. *Infect Med*. 1987;(5):349-359.
2. Lee C-Y, Lee L-C. Influence of sanitary conditions on the field performance of chlorpyrifos-based baits against American cockroaches, *Periplaneta americana* (L.) (Dictyoptera: *Blattidae*). *J Vector Ecol*. 2000;(25):218-221.
3. Morgan WJ, Crain EF, Gruchalla RS, et al. Results of a home-based environmental intervention among urban children with asthma. *N Engl J Med*. 2004;351:1068-1080.
4. Rabito FA, Carlson J, Holt EW, Iqbal S, James MA. Cockroach exposure independent of sensitization status and association with hospitalizations for asthma in inner-city children. *Ann Allergy Asthma Immunol*. 2011;106:103-109.
5. Rosenstreich DL, Eggleston P, Kattan M, et al. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. *N Engl J Med*. 1997;336:1356-1363.
6. Kanchongkittiphon W, Mendell MJ, Gaffin JM, Wang G, Phipatanakul W. Indoor environmental exposures and exacerbation of asthma: an update to the 2000 review by the Institute of Medicine. *Environ Health Perspect*. 2014/10/10 2014.
7. Tungtrongchitr A, Sookrung N, Munkong N, et al. The levels of cockroach allergen in relation to cockroach species and allergic diseases in Thai patients. *Asia Pac J Allergy Immunol*. 2004;22:115-121.
8. Arbes SJ, Sever M, Mehta J, et al. Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: month 12 continuation results. *J Allergy Clin Immunol*. 2004;113:109-114.
9. Pomes A, Melen E, Vailes LD, Retief JD, Arruda LK, Chapman MD. Novel allergen structures with tandem amino acid repeats derived from German and American cockroach. *J Biol Chem*. 1998;273:30801-30807.
10. Schou C, Lind P, Fernandez-Caldas E, Lockey RF, Løwenstein H. Identification and purification of an important cross-reactive allergen from American (*Periplaneta americana*) and German (*Blattella germanica*) cockroach. *J Allergy Clin Immunol*. 1990;86:935-946.
11. Eads RB, VonZuben F, Bennett SE, Walker OL. Studies on cockroaches in a municipal sewerage system. *Am J Trop Med Hyg*. 1954;3:1092-1098.
12. Jackson WB, Maier P. Dispersion of marked American cockroaches from sewer manholes in Phoenix Arizona. *Am J Trop Med Hyg*. 1955;4:141-146.
13. Rust MK, Reierson DA, Hansgen KH. Control of American cockroaches (Dictyoptera: *Blattidae*) in sewers. *J Med Entomol*. 1991;28:210-213.
14. Schoof HF, Siverly RE. The occurrence and movement of *Periplaneta americana* (L.) within an urban sewerage system. *Am J Trop Med Hyg*. 1954;3:367-371.
15. Arbes SJ, Sever M, Archer J, et al. Abatement of cockroach allergen (bla g 1) in low-income, urban housing: a randomized controlled trial. *J Allergy Clin Immunol*. 2003;112:339-345.
16. Sever ML, Arbes SJ, Gore JC, et al. Cockroach allergen reduction by cockroach control alone in low-income urban homes: a randomized control trial. *J Allergy Clin Immunol*. 2007;120:849-855.
17. Chen M, Chang CH, Tao L, Lu C. Residential exposure to pesticide during childhood and childhood cancers: a meta-analysis. *Pediatrics*. 2015;136:719-729.
18. Hernández AF, Parrón T, Alarcón R. Pesticides and asthma. *Curr Opin Allergy Clin Immunol*. 2011;11:90-96.
19. Waldow U. CNS units in cockroach (*Periplaneta americana*): specificity of response to pheromones and other odor stimuli. *J Comp Physiol A*. 1977;116:1-17.
20. Ebeling W, Reierson DA, Pence RJ, Viray MS. Silica aerogel and boric acid against cockroaches: external and internal action. *Pest Biochem Physiol*. 1975;5:81-89.
21. Kaakeh W, Reid BL, Bennett GW. Toxicity of fipronil to German and American cockroaches. *Entomol Exp Appl*. 1997;84:229-237.
22. Kassiri H, Kazemi S. Cockroaches [*Periplaneta americana* (L.), Dictyoptera; *Blattidae*] as carriers of bacterial pathogens, Khorramshahr County, Iran. *Jundishapur J Microbiol*. 2012;5:320-322.