Assessment of Bed Bug (*Cimex lectularius* L.) Prevalence, Control Strategies, and Challenges Facing Urban Pest Management Professionals in South Carolina[1]

Margie P. Lehnert,[2,4] Eric P. Benson,[2] Patricia A. Zungoli,[2] and Patrick D. Gerard[3]

J. Agric. Urban Entomol. 28: 16–24 (2012)

ABSTRACT Bed bug infestations have been recorded in all 50 states of the United States and they were listed as the number one urban pest problem in 2010 by urban pest management professionals. The objective of this research was to survey urban pest management professionals of South Carolina about the importance and prevalence of bed bugs, types of infested dwellings, most common treatment strategies, and most common problems encountered when treating for bed bugs. Survey forms were distributed at the South Carolina Pest Control Association's annual meeting in 2011. Data were separated according to regions of South Carolina (upstate, midlands, and low country) for analysis. Ants and cockroaches ranked as the two most important pests in all regions, while bed bugs consistently ranked fifth in importance. Houses and apartments were reported to have the most infestations, and insecticides and mechanical removal were the most common treatment strategies. This information is beneficial to state agencies, pest control companies, and extension specialists in South Carolina who are repeatedly called for advice about bed bugs and their infestations.

KEY WORDS Survey, control difficulties, urban pest management professionals

The bed bug, *Cimex lectularius* L., has been associated with humans for the past 3500 years (Panagiotakopulu & Buckland 1999). The mid-1940s ushered in a reprieve from bed bugs in developed nations (Pinto et al. 2007) that lasted until the late 1990s (Boase 2001). Today, bed bugs are well established across the world (Potter et al. 2010). In the United States, bed bug infestations have been documented in all 50 states, with most reports coming from cities with high populations and turnover/traffic of people (Gilbert 2010). South Carolina, however, has never been individually assessed for bed bugs.

Bed bugs were reported as the number one pest problem in the United States, by urban pest management professionals surveyed in 2010; 99% encountered a bed bug infestation in 2010. They have found this pest in typical locations such as houses and hotels, as well as atypical locations such as daycare centers, movie

[1]Accepted for publication 23 April 2012.
[2]Department of Entomology, Soils, and Plant Sciences, 114 Long Hall, Clemson University, P.O. Box 340315, Clemson, SC 29634-0315 USA.
[3]Department of Mathematical Science, Martin O-114, Clemson University, Clemson, SC 29634-0975 USA.
[4]Corresponding author (melehne@clemson.edu).

theaters, and on public transportation (Potter et al. 2010). The variety of dwellings in which bed bugs can occur, their cryptic nature (Usinger 1966), and resistance to pesticides (Romero et al. 2007) have made control of this pest difficult. Fumigation and temperatures greater than 45°C effectively eliminate infestations (Pereira et al. 2009, Pinto et al. 2007), but may not be economically suitable for all infestations, depending on the type of infested dwelling. Temperatures of −80°C have been shown to kill bed bugs as well (Drain 2010), but no scientific study has been performed to assess the efficacy of this treatment method. Because an integrated approach to battling bed bug infestations is usually necessary (Pinto et al. 2007, Potter 2010), the varying severity of infestations can lead to many problems for urban pest management professionals.

The objective of this research was to survey South Carolina urban pest management professionals about: 1) the importance of bed bugs as a pest, 2) the prevalence of bed bug infestations, 3) the most commonly infested dwellings, 4) the most common treatment strategies, and 5) the most common obstacles when dealing with bed bug treatments. We hypothesized that bed bugs are widely distributed in South Carolina, but their perceived importance is limited to urban areas.

Materials and Methods

Survey preparation, distribution, and content. A survey form was prepared to assess bed bug importance and prevalence, control strategies, and challenges facing urban pest management professionals in South Carolina. These forms were distributed at the South Carolina Pest Control Association (SCPCA) annual meeting in January 2011. Forms were specifically targeted toward attendees registered as managers of their pest control companies. This was done to prevent duplication of submissions from the same company within a region thus creating a better survey of the state as a whole. Therefore, a company with multiple branches in a region may have completed multiple surveys, one per branch manager. In total, five questions were asked of each participant (Figure 1). The companies that opted not to treat bed bug infestations, or have not yet had to treat a bed bug infestation, still ranked pests according to importance. Therefore the sample size for question one is larger than for the other questions.

Statistical analysis. Surveys (n) were separated according to region (upstate, midlands, or low country) (Figure 1) for comparative statistical analysis. Survey questions were analyzed separately. A nonparametric Kruskal Wallis test (Conover 1999) with a one-way classification was used to compare rankings between regions for each pest group, dwelling, or treatment strategy. Within a region, data were analyzed by analysis of variance of ranks after they were ordered, with the ordered ranks computed within a rater, to allow for comparing rankings for responses across raters. Means were separated according to *t*-tests with LSD (Conover 1999). All tests were performed using SAS software version 9.2 (SAS Institute, Cary, NC).

Results

Of the 100 surveys that were distributed to registered managers at the 2011 SCPCA annual meeting, 40 were returned. In the upstate (n = 7), ants were

1. Please rank the following pests in order of importance, based on the number of treatments performed in 2010 by your company, for each pest (1 having the most treatments, 7 having the least treatments):

_____ Ants
_____ Bed bugs
_____ Cockroaches
_____ Termites
_____ Stored Product Pests
_____ Spiders
_____ Other (please specify)
_____

2. Please list all South Carolina cities and counties in which you have performed bed bug treatments

3.Please rank the following dwellings in order of number of bed bug infestation occurrences (1 is most number of infestations, 5 is least number of infestations) :

_____ Hotel
_____ Apartment
_____ Single family home
_____ Multi family home
_____ Other (please specify) _____

4. Please rank the following treatment strategies in order of relevance to your bed bug treatment protocol (1 is most relevant, 6 is least relevant):

_____ Heat
_____ Cold/Freezing
_____ Chemical sprays
_____ Mechanical removal (vacuuming, etc,)
_____ Fumigation
_____ Other (please specify) _____

5. What are your greatest obstacles/problems concerning bed bug treatments ?

Fig. 1. Survey questions concerning bed bugs that were presented to pest control professionals in South Carolina.

significantly ranked as the most important pest ($F = 10.45$, df =12, 48, $P < 0.0001$, Table 1), with bed bugs and stored product pests considered the least important. Ants were significantly ranked most important in the midlands (n = 17), closely followed by cockroaches and termites ($F = 9.77$, df = 21, 118, $P < 0.0001$). In the low country (n = 14), ants, cockroaches, and termites statistically shared the rank as most important pest ($F = 8.71$, df = 19, 97, $P < 0.0001$). Across each region, there were no significant differences among pest group rank, except for ants ($F = 5.08$, df = 2, 35, $P = 0.0116$). Pest write-ins in the 'other' category included rodents, mice, moles, fleas, dust mites, earwigs, pillbugs, mosquitoes, centipedes, and bees.

Only one respondent ranked bed bugs as the primary pest problem; this company performs bed bug treatments in the midland counties of Richland, Lexington, and Kershaw, which includes the Columbia metropolitan area. One respondent ranked bed bugs as the second most important pest problem; this company performs bed bug treatments in Horry and Georgetown counties, which are along the northern coast of South Carolina and contain the tourist city Myrtle Beach. One respondent ranked bed bugs as the third most important pest problem; this company performs bed bug treatments in Charleston County, another coastal county in which tourism is important. Bed bugs had a ranking of fourth through seventh on all other surveys.

South Carolina counties (Figure 1) and cities (Table 2) in which bed bug treatments were performed included 27 of the state's 46 counties and almost all

Table 1. Rankings (mean ± standard deviation) of pest groups based on the overall number of treatments performed in three regions of South Carolina in 2010, with lower numbers meaning higher importance.

Pest	Upstate	Midlands	Low country
Ants*	1.00 ± 0.00a	1.76 ± 0.83a	2.36 ± 1.22a
Termites	2.57 ± 0.79b	3.06 ± 1.39bc	2.29 ± 0.91a
Cockroaches	2.86 ± 0.69b	2.24 ± 1.15ab	2.00 ± 1.11a
Spiders	4.29 ± 1.25c	3.88 ± 1.11c	4.21 ± 1.25b
Bed bugs	5.71 ± 1.11d	4.88 ± 1.36d	5.14 ± 1.46bc
Other	5.71 ± 1.70d	6.59 ± 0.71e	6.14 ± 1.35d
Stored product pests	5.86 ± 0.69d	5.59 ± 1.42d	5.86 ± 0.77cd

Means within a column followed by different letters are significantly different ($P < 0.05$).
*Signifies significant differences across regions.

major cities. There were no significant differences (Table 3) among infestation location occurrences in the upstate (n = 7, $F = 0.94$, df = 9, 27, $P = 0.5146$), midlands (n = 15, $F = 0.51$, df = 17, 59, $P = 0.9311$), or the low country (n = 12, $F = 0.16$, df = 14, 47, $P = 0.9997$). There also were no significant differences for each infestation location occurrence across regions. Write-ins included reference to trailers, schools, hospitals, college dorms, and beachfront rental properties.

The most relevant bed bug treatment strategies for companies in the upstate (n = 7) were insecticides (chemicals) and mechanical removal of bed bugs ($F = 5.00$, df = 10, 34, $P = 0.0006$) (Table 4). This was also true for the low country (n = 12, $F = 6.11$, df = 15, 59, $P < 0.0001$), but insecticides were the sole most significant treatment strategy in the midlands (n = 15, $F = 2.11$, df = 18, 74, $P = 0.0172$). Cold, heat, and fumigation were never ranked within the top two treatment strategies. Write-ins included inspection, de-clutter, and removal/discarding of furniture from dwellings.

Participants listed many different obstacles impacting bed bug treatments. Customer cooperation with pest management pre-treatment needs (cleaning, decluttering, etc.) was the most common issue companies identified, followed by customer resistance to price and the labor-intensive nature of bed bug treatments. Other problems included media influence, liability, failed insecticide treatments, and costly treatment alternatives (such as heat/cold/fumigation).

Discussion

According to participating pest control companies in South Carolina, bed bugs were not ranked as a top pest problem. This is surprising, as 20% of surveyed urban pest management professionals in a nationwide survey reported to have performed more than 100 bed bug jobs in 2009, with 7% having performed more than 500 (Potter et al. 2010). South Carolina only holds about 1.5% of the nation's population (United States Census Bureau 2010). However, the three company managers that listed bed bugs as one of their top three pest problems performed treatments in Richland, Lexington, Kershaw, Horry, Georgetown, and Charles-

Table 2. South Carolina counties and cities in which bed bug treatments were performed in 2010.

County	Cities
Aiken	Aiken, North Augusta
Anderson	Anderson, Pendleton
Beaufort	Bluffton, Hilton Head Island
Berkeley	Goose Creek
Charleston	Charleston, Isle of Palms
Chesterfield	Cheraw
Colleton	—
Darlington	Society Hill
Dillon	—
Dorchester	Summerville
Florence	Florence, Scranton
Georgetown	—
Greenville	Greenville, Greer, Mauldin, Simpsonville
Greenwood	—
Hampton	—
Horry	Conway, Myrtle Beach, North Myrtle Beach, Surfside Beach
Jasper	Ridgeland
Kershaw	Camden
Lexington	Chapin, Gaston, Irmo
Marion	—
Marlboro	Bennettsville, Blenheim, Clio, McColl, Wallace
Newberry	Whitmire
Oconee	Seneca
Orangeburg	—
Pickens	Clemson
Richland	Blythewood, Columbia
Saluda	—
Spartanburg	Spartanburg
York	—

Table 3. Rankings (mean ± standard deviation) of dwelling types based on occurrences of bed bug infestations in three regions of South Carolina in 2010, with lower numbers meaning higher importance.

Dwelling type	Upstate	Midlands	Low country
Single-family housing	1.57 ± 1.13	2.53 ± 1.34	2.96 ± 1.48
Apartment	3.00 ± 1.12	2.13 ± 1.17	2.33 ± 1.07
Hotel	3.14 ± 1.18	2.77 ± 1.16	2.67 ± 1.37
Multi-family housing	3.14 ± 0.85	3.27 ± 0.80	2.46 ± 0.99

There were no significant differences within or across regions ($P > 0.05$; t-test LSD; SAS Institute).

Table 4. Rankings (mean ± standard deviation) of treatment strategies based on relevance to bed bug treatment protocols in three regions of South Carolina in 2010, with lower numbers meaning higher importance.

Treatment strategy	Upstate	Midlands	Low country
Chemical	1.43 ± 0.79a	1.87 ± 1.41a	1.79 ± 1.08a
Mechanical	2.29 ± 1.25a	2.87 ± 1.25b	2.17 ± 0.94a
Heat	3.43 ± 0.98b	3.50 ± 1.43b	4.13 ± 1.00b
Fumigation	4.29 ± 0.76b	3.83 ± 1.10bc	4.17 ± 1.17b
Cold	4.43 ± 0.53b	4.53 ± 0.93c	4.50 ± 0.48b

Means within a column followed by different letters are significantly different ($P < 0.05$).

ton counties. These counties, containing about 30% of South Carolina's population (United States Census Bureau 2010), hold the capitol city Columbia, which has a high turnover/traffic of business-related people, and Myrtle Beach and Charleston, which are tourist destinations and thus also have a high turnover of people. While bed bugs are not seen as a major pest problem overall in South Carolina, 27 out of 46 counties (Figure 2) have reported bed bug infestations, suggesting that bed bugs are widespread in the state. The 19 counties that did not report bed bugs contain about 19% of the state's population (United States Census Bureau 2010). It is possible that bed bugs may not become a serious problem in these counties, of which a majority are rural and those living there may not partake in much travel. However, there is little data on the effect of bed bugs in rural areas, as the media and academic studies tend to focus on the highly-affected urban areas.

Most infestations were reported to occur in apartments and single-family houses in all regions, although there is no statistical significance to this claim. This follows along with the national survey, in which 89% of participants found bed bugs in apartments, and 88% found them in single family homes (Potter et al. 2010). As the majority of counties where bed bug infestations have been reported are areas where there is a constant influx and outflow of people, it is surprising that bed bug infestations were not more widely-reported in hotels. It might be that hotels are not aware of bed bug infestations, they are not approaching pest control companies to eliminate bed bug problems, or that they are not facing a bed bug issue. The last possibility seems the most unlikely due to the dispersal habits of female bed bugs (Pfiester et al. 2009), and there are multiple South Carolina hotels listed on the bed bug registry (Ceglowski 2011). However, it must be noted that anyone can report bed bugs to this website. It is most likely that hotels have secrecy contracts with pest management businesses, as having bed bugs can carry with it a negative stigma (Usinger 1966) and cause companies to lose business.

Chemical sprays (insecticides) were consistently ranked as the top treatment strategy across South Carolina. Although bed bug resistance to insecticides exists (Romero et al. 2007), many companies use chemical sprays as a main treatment strategy. Mechanical removal can be a useful supplement to chemicals and aid in

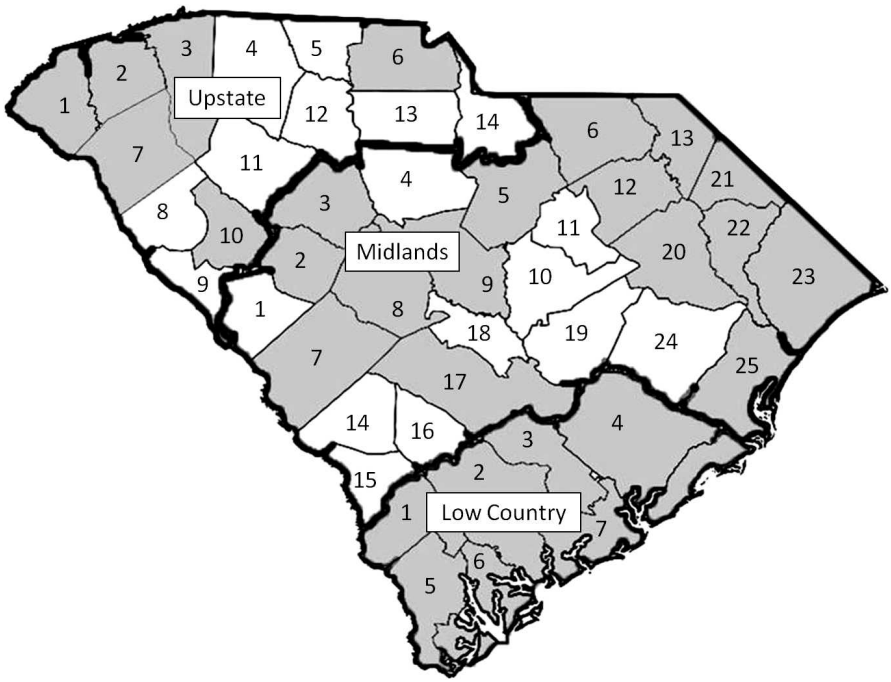

Fig. 2. Grouping of South Carolina counties into three regions (upstate, midlands, and low country) that were used for comparative statistical analysis. Counties in gray had urban pest management professionals that reported treatment of bed bug infestations, while counties in white did not. Numbers refer to counties in each region. Upstate counties are (1) Oconee, (2) Pickens, (3) Greenville, (4) Spartanburg, (5) Cherokee, (6) York, (7) Anderson, (8) Abbeville, (9) McCormick, (10) Greenwood, (11) Laurens, (12) Union, (13) Chester, and (14) Lancaster. Counties in the midlands are (1) Edgefield, (2) Saluda, (3) Newberry, (4) Fairfield, (5) Kershaw, (6) Chesterfield, (7) Aiken, (8) Lexington, (9) Richland, (10) Sumter, (11) Lee, (12) Darlington, (13) Marlboro, (14) Barnwell, (15) Allendale, (16) Bamberg, (17) Orangeburg, (18) Calhoun, (19) Clarendon, (20) Florence, (21) Dillon, (22) Marion, (23) Horry, (24) Williamsburg, and (25) Georgetown. Counties in the low country are: (1) Hampton, (2) Colleton, (3) Dorchester, (4) Berkeley, (5) Jasper, (6) Beaufort, and (7) Charleston.

reducing populations, but will not eliminate a population on its own. Eggs are attached to surfaces with a sticky adhesive that acts as cement when it dries (Usinger 1966). This adhesive can prevent vacuum cleaners from removing all eggs. Also, the variety of locations that bed bugs and their eggs can exist within an infestation would make it difficult to mechanically all of them (Usinger 1966, Pinto et al. 2007).

Heat, steam, or a combination of the two can be effective tools if used properly (Pereira et al. 2009), but these techniques were not ranked as top control strategies in any region. Many participants wrote that they are unable to

purchase the necessary equipment to use heat treatments because they do not perform enough bed bug treatments to recover their investment. It seems that heat may not be a popular treatment strategy in South Carolina until bed bugs become a pest of higher significance and more common.

As identified by this survey, the main problem pest control companies have while dealing with bed bug treatments is educating the customer to comply with company requirements. The National Pest Management Association recently released a guide to 'Best management practices for bed bugs' (NPMA 2011). This publication states that "a pest management firm should clearly delineate the preparations that the customer must make and the preparations that the pest management firm will perform" (NPMA 2011). For example, some college housing departments have manuals for treatment of bed bug infestations. Included is a detailed checklist of what is expected of the affected party and that failure to comply with the checklist will result in a delay of bed bug treatments (Pereira et al. 2008). Once again, the variety of harborages in which bed bugs can live is a crucial point that must be relayed to customers, which is why it is essential that customers clean and de-clutter dwellings before treatments can be performed. Also, because of the integrated nature of bed bug treatments, the protocol that return visits are necessary, and the high cost of alternative treatment equipment, bed bug treatments may be economically high in cost, which can lead to resistance from the customer. Three points that might influence a customer's perspective are understanding the difficulty of treating this insect, understanding that many chemicals do not kill the egg stage so repeat visits are necessary, and realization that the amount of labor invested in a thorough bed bug treatment is high (Walker et al. 2008). A list distinguishing when a procedure will be performed, why it is necessary, and the cost of that procedure could be helpful information for a customer and lessen their resistance to price. It is interesting to note that bed bug resistance was not listed as a main problem encountered by pest management professionals in South Carolina. This suggests that resistance issues may be overcome if customers comply with company policy during treatment of bed bug infestations.

While this survey was intended to gather information about the nature of bed bugs in South Carolina, it is important to note that only 40 pest control managers participated. The anonymity of the survey prevents us from indicating how many different companies participated; it is therefore possible that the information is weighted towards larger companies with many managers/branches, especially since this survey was distributed at a conference in which there was a registration fee. Smaller companies may not have been able to send as many managers as larger companies. However, the information presented is beneficial to South Carolina agencies, pest control companies, and extension specialists, who are repeatedly called for advice about bed bug issues. These data provide a baseline of bed bug information for South Carolina, and provides information that can be used to educate and bring awareness to South Carolina residents and urban pest management professionals.

Acknowledgments

The authors thank Jackie Ellis and Tammy Morton for help in printing and distributing the survey. We also thank the South Carolina Pest Control Association for allowing survey

distribution at their annual meeting. Technical Contribution No. 6021 of the Clemson University Experiment Station.

References Cited

Boase, C. 2001. Bedbugs-back from the brink. Pestic. Outlook 12: 159–162.

Ceglowski, M. 2011. The Bedbug Registry. <http://bedbugregistry.com/>, accessed 1 August 2011.

Conover, W. J. 1999. Practical nonparametric statistics, 3rd ed. John Wiley & Sons, Inc., New York.

Drain, J. 2010. Terminix International is putting the "freeze" on bed bugs via its RapidFreeze program. Pest Control Technol., August 2010 issue, <http://www.pctonline.com/>, accessed 15 April 2012.

Gilbert, C. 2010. New report ranks top U.S. cities for bedbug infestations. <http://www.terminix.com/Media/PressReleases.aspx>, accessed 1 August 2011.

NPMA (National Pest Management Association). 2011. Best management practices for bed bugs. <http://bedbugbmps.org/>, accessed 1 August 2011.

Panagiotakopulu, E. & P. C. Buckland. 1999. *Cimex lectularius* L., the common bed bug from Pharaonic Egypt. Antiquity 73: 908–911.

Pereira, R. M., P. G. Koehler & E. Thoms. 2008. Bed bugs: Containerized fumigation and heat treatment. <http://ipm.ifas.ufl.edu/resources/grants_showcase/people_and_communities/bed_bugs_manual.pdf>, accessed 1 August 2011.

Pereira, R. M., P. G. Koehler, M. Pfiester & W. Walker. 2009. Lethal effects of heat and use of localized heat treatment for control of bed bug infestations. J. Econ. Entomol. 102: 1182–1188.

Pfiester, M., P. G. Koehler & R. M. Pereira. 2009. Effect of population structure and size on aggregation behavior of *Cimex lectularius* (Hemiptera: Cimicidae). J. Med. Entomol. 46: 1015–1020.

Pinto, L. J., R. Cooper & S. K. Kraft. 2007. Bed bug handbook: The complete guide to bed bugs and their control. Pinto & Associates, Mechanicsville, Maryland.

Potter, M. F. 2010. Bed bugs. Entfact-636, Univ. Kentucky, <http://www.ca.uky.edu/entomology/entfacts/ef636.asp>, accessed 14 April 2011.

Potter, M. F., B. Rosenberg & M. Henriksen. 2010. Bugs without borders-executive summary; defining the global bed bug resurgence. Nat. Pest Manage. Assoc., <http://www.npmapestworld.org/documents/bbsurveyexecsummaryjuly26.pdf>, accessed 14 April 2011.

Romero, A., M. F. Potter, D. A. Potter & K. F. Haynes. 2007. Insecticide resistance in the bed bug: A factor in the pest's sudden resurgence? J. Med. Entomol. 44: 175–178.

United States Census Bureau. 2010. State and County QuickFacts. U.S. Dept. Commerce, Washington, D. C., <http://quickfacts.census.gov/qfd/states/45000.html>, accessed 1 August 2011.

Usinger, R. L. 1966. Monograph of Cimicidae: (Hemiptera-Heteroptera). Entomol. Soc. Am., College Park, Maryland.

Walker, W., K. Glover, P. G. Koehler, E. Thoms & E. Hobelman. 2008. Bed bug control: Fumigation, steam, dusting, and labor. Pest Control Technol., January 2008 issue, <http://www.pctonline.com/>, accessed 15 April 2012.