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USING MONITORS TO DETECT AND ASSIST IN TREATMENT OF THE COMMON BED BUG (HEMIPTERA: CIMICIDAE)

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Abstract *Cimex lectularius,* continues to spread across the world, and developing effective and efficient control and monitoring techniques is the focus of researchers and pest control professionals. In the research presented here, interception devices were implemented as part of a bed bug treatment protocol and the impact the devices had on the bed bug population were evaluated. Results show that interception devices can impact bed bug control by capturing bed bugs between services, many of which were hiding in difficult-to-treat environments and traveling towards the host for food. Interception devices were also evaluated as a tool to assist in the detection of bed bug infestations by installing the monitors in all apartments within a building. Installing devices combined with visual inspections was effective in detecting infestations. Stand-alone interception devices detected low-level bed bug infestations: 68% within 4 weeks of installation compared to 57% by visual inspection, and they were 20-64% more efficient to use in whole-building monitoring programs. Results of these studies provide insight on how to control bed bugs more efficiently and effectively.

Key words Inspection, trap, BlackOut®, ActivVolcano™, Climbup®, detection

INTRODUCTION

Bed bugs, *Cimex lectularis* L., were a common pest in the United States prior to World War II. Due to the introduction of DDT and other residual pesticides to the commercial marketplace, bed bugs were pushed to the brink of elimination in many developed countries. In the past 20-30 years many of the residual pesticides that pushed bed bugs towards elimination have been banned for use inside homes thus opening the door for the resurgence of this insidious pest. Bed bug infestations are now on the rise in all 50 states within the U.S. as well as increasing in many countries across the world (Usinger, 1966; Potter, 2006; Potter, 2011; Potter et al., 2015).

Due the widespread resistance to synthetic pyrethroids being reported within bed bug infestations, many pest management professionals and researchers are searching for alternatives to assist in detecting and controlling bed bugs (Davies et al., 2012; Dang et al., 2013). Interception devices, which can be used both to detect infestations and assist in treatment, are one tool that has drawn the attention of both researchers and PMP's. These devices are pitfall traps that can be placed either under the legs of furniture or as stand-alone devices that can trap bed bugs as they move around an infested home (Potter et al., 2013; Cooper et al., 2015c). Several studies have also demonstrated the positive impact the installation of interception devices across entire communities can have on the management of community-wide bed bug infestations. Installing these devices in every apartment overcomes the complication of residents not reporting infestations and assists in reducing the number of bed bug infested units to an acceptable level (Cooper et al., 2015a; Wang et al., 2016). To date though, data has been needed to further evaluate the time required to install interception devices in all apartments across a community so that protocols can

be streamlined and allow these programs to be more affordable to implement. In addition to be used to detect infestations, interception devices can also be used as part of a bed bug treatment protocol to assist in reducing the number of bed bugs present in an infested home (Koganemaru and Miller, 2013; Cooper et al., 2015b). That being said, although the positive effects these devices have on bed bugs have been demonstrated through several studies, nearly half of pest control companies surveyed as part of a study published in 2015 incorporate these devices into their detection and management protocols (Potter et al., 2015).

In one study interception devices were installed under the legs of bed and couches after treatment was rendered to further evaluate the number of bed bugs that could be captured by these devices between services to demonstrate how many bed bugs were not addressed by an initial bed bug treatment. Also, a high-rise building in Canton, OH that was struggling to address community-wide bed bug infestations had monitors installed under the beds in all apartments. In addition, visual inspections were conducted in all units to compare the detection rate of monitors and visual inspections in low-level bed bug infestations. Lastly, operational efficiencies were compared when using under-the-leg interception devices versus free-standing devices to provide data to suggest the feasibility of building-wide installation of these devices for community-wide bed bug management.

MATERIALS AND METHODS

Interception Devices as Part of a Treatment Protocol. Bed bug services rendered by Cooper Pest Solutions (Lawrenceville, NJ) were used to complete this study. On the initial service, all bed bugs within the infested home were counted prior to service. Service would then be rendered according to Cooper Pest Solutions bed bug protocol which included the use of pesticides, bed encasements, steam and vacuums. No preparation of the apartment by the tenants was completed prior to service. After the initial service was rendered, Climbup Insect Interceptors® were installed under the legs of the beds and couches. Approximately 10 days after treatment the bugs collected by the interception devices were counted. Bed bugs collected in the inner well versus the outer well of the devices was noted.

Stand-alone Interception Devices for Proactive Detection. The study was conducted in a 199-apartment complex located in Canton, Ohio. The apartment complex had a history of sporadic bed bug issues and management had been unable to reduce the incidences of bed bugs to an acceptable level. At the start of the study 7 bed bug infested units were known to exist by property management and installation of the monitors was conducted by Gold Seal Pest Control (Indianapolis, IN) which was assisted by the management team of the apartment complex. The apartments were divided into three groups and three treatments were installed into the apartments: 1) 2 ActivVolcano's™ under each bed placed on the floor near the head legs of the bed; 2) 4 ActivVolcano's™ installed next to each bed leg (or the corner four bed legs); 3) 4 Volcano's® installed next to each bed leg (or the corner four bed legs).

Devices were then left for 2 weeks and inspected for the presence of bed bugs. If no bed bugs were detected the devices were left in place for an additional two weeks and inspected again. If bed bugs were found in the devices after two weeks, the apartment would be scheduled for treatment. At the 4-week conclusion of the study the monitors were inspected and a 5-10 minute visual inspection was conducted in each unit (visual inspection would involve turning the bed and couch over and inspecting all hiding places within those pieces of furniture). If bed bugs were collected by the monitors or noted during visual inspection, all bed bugs were counted to determine the extent of the infestation.

Comparison of Operational Time of Two Interception Devices. A low-income, governmentally subsidized apartment complex was selected from North Bergen, NJ. The apartments selected for the study consisted of 103 high-rise apartments contained within 3 buildings and 52 garden-style apartments. Approximately half of the apartments in the study would receive 2 SenSci ActivVolcano's™ under every

bed and couch. One device was installed on each side of the head of the bed (two devices total) and one device to each side of the back of the couch (2 devices total). The other half of the apartments would receive a BlackOut Bed Bug Detector® under each leg of the bed and couch.

On the first day of the study each apartment was visually inspected for 1-2 minutes. Any easily visible area of the mattress and box spring was briefly inspected as well as the ceiling-corners and walls. If bed bugs were noted on the visual inspection the apartment would still receive monitors to determine if the monitors would detect the infestation until the apartment could be treated by pest management professionals. After inspection each apartment received the aforementioned devices. The time to install the devices by floor in the high-rise buildings or by building within garden-style apartments was recorded. The total time for each floor or building was divided by the number of apartments to acquire an average time per apartment.

Two weeks after installation, all monitors were inspected. The time to inspect the devices by floor in the high-rise buildings or by building within garden-style apartments was recorded. The total time for each floor or building was divided by the number of apartments to acquire an average time per apartment. Monitors were then placed back under the beds. If bed bugs were detected by the monitors, the apartment was visually inspected and the bed bugs observed were counted to determine the extent of the infestation. The apartment was then scheduled for treatment. If monitors were missing upon inspection the missing monitors were recorded and replaced.

Four weeks after monitor installation, all monitors were inspected. All BlackOut® monitors were cleaned using a microfiber cloth and placed back under the legs of the bed or couch. ActivVolcano™ monitors do not require cleaning due to their design and after inspection were placed back under the bed or couch. The time to inspect the devices by floor in the high-rise buildings or by building within garden-style apartments was recorded. The total time for each floor or building was divided by the number of apartments to acquire an average time per apartment. If bed bugs were detected by the monitors, the apartment would be visually inspected and the bed bugs observed were counted to determine the extent of the infestation. The apartment was then scheduled for treatm1ent. If monitors were missing upon inspection the missing monitors were recorded and replaced. Week 4 concluded the study.

RESULTS

Interception Devices as Part of a Treatment Protocol. At the start of the study there were 746 bed bugs of all developmental stages noted in 116 apartments (an average of 6.43 bed bugs per apartment). Two weeks after installation the interception devices collect 1619 bed bugs of all developmental stages (an average of 13.96 bed bugs per apartment). Within the interception devices, 1328 bed bugs were collected in the outer trap well and 291 bed bugs were collected in the inner trap well (Table 1).

Table 1. Number of bed bugs observed prior to treatment and collected by Climbup® Insect Interceptors two weeks after treatment.

Prior to Treatment	
Number of apartments	116
Total number of bed bugs Observed	746
Average number of bed bugs observed	6.43
Two Weeks After Monitors Installed	
Total number of bed bugs captured	1619
Average number of bed bugs captured	13.96
Bed bugs in outer wall	1328
Beg bugs in inner wall	291

Stand-alone Interception Devices for Proactive Detection. While property management knew of 7 infestations at the start of the study, 29 apartments were confirmed to have active bed bug infestations through the use of monitors and visual inspection (Figure 1). In 8 of the 29 apartments the infestations were found by visual inspection in the couch where monitors were not placed (monitors were only placed under the bed). In addition, the monitors were tampered with in 2 infestations. The 8 infestations found in the couch and 2 infestations where the monitors were tampered with were taken out of the sample size and further analysis was conducted on the 19 infestations where bed bugs were confirmed in the beds. Due to a small sample size of only 19 infestations detected within bedrooms, all treatment groups were combined and the data was analyzed as infestations detected by monitors under bed versus "infestations detected by visual inspection".

Of the 19 infestations found associated with the beds, all but 2 were found to be low level infestations (less than 20 bed bugs found upon inspection). Within 2 weeks of installation 6 of 19 infestations were detected by the monitors under the bed. Four weeks after installation the detection count increased to 13 of 19 infestations being detected by the monitors (68.4% detection rate of primarily low level infestations). At the conclusion of the 4 week monitor evaluation, visual inspection detected 11 of 19 infestations (57.9% detection rate of primarily low level infestations). In 8 of the 13 infestations where monitors detected infestations, the visual inspection was unable to detect bed bugs. In 6 of the 11 infestations where visual inspection detected bed bugs, the monitors did not collect bed bugs (Figure 2).

Comparison of Operational Time of Two Interception Devices. Installation of SenSci ActivVolcano™ in 51 high-rise apartments required 3.24 minutes per apartment on Day 1, while follow-up inspections in 53 apartments of ActivVolcano™ on Day 14 and 28 required 2.62 min/apt and 2.63 minutes per

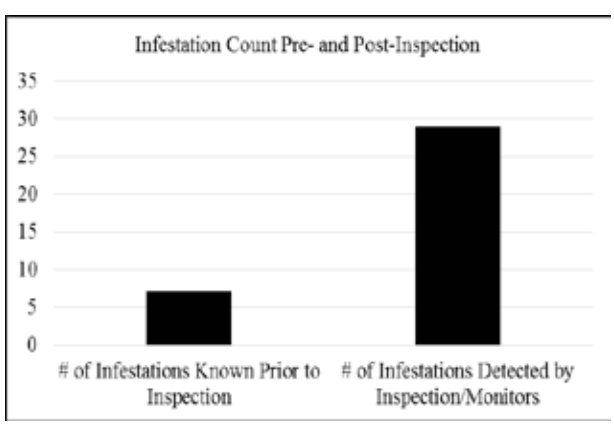

Figure 1. Number of infestations known by management prior to whole-building inspection and number of infestations found by both monitors and visual inspections.

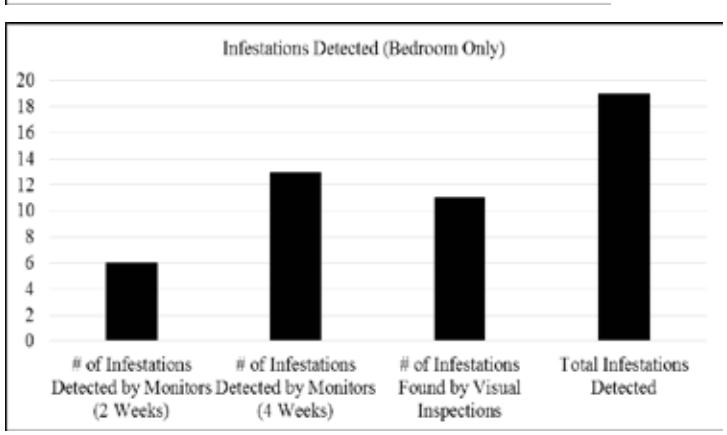

Figure 2. Number of infestations detected by monitors 2 and 4 weeks after installation compared to the number of infestations detected by visual inspection and total number of infestations detected.

apartment, respectively. Installation of BlackOut Bed Bug Detector® in 48 high-rise apartments required 4.53 minutex per apartment on Day 1, while follow-up inspections of 48 apartments with BlackOut® on Day 14 and 28 required 3.76 minute per apartment and 4.07 minutes per apartment, respectively (Table 2). Installation of SenSci ActivVolcano™ in 34 garden-style apartments required 4.18 minutes per apartment on Day 1, while follow-up inspections in 32 apartments of ActivVolcano™ on Day 14 and 28 required 3.51 minutes per apartment and 4.14 minutes per apartment, respectively. Installation of BlackOut Bed Bug Detector® in 25 garden-style apartments required 6.84 minutes per apartment on Day 1, while follow-up inspections of 26 apartments with BlackOut® on Day 14 and 28 required 4.29 minutes per apartment and 5.65 minutes per apartment, respectively (Table 2).

Table 2. Overview of the average time to install and inspect SenSci ActivVolcano™ bed bug monitors and BlackOut Bed Bug Detectors® per apartment and the increase in time to install and inspect BlackOut® during the study.

High-Rise Apartments			
Activity / Day	**SenSci ActivVolcano™**	**BlackOut Bed Bug Detector®**	**Operational Time Increase (BlackOut®)**
Average time to install - Day 0	3.24 min/apt	4.53 min/apt	39.8%
Average time to inspect - Day 14	2.62 min/apt	3.76 min/apt	43.5%
Average time to inspect - Day 28	2.63 min/apt	4.07 min/apt	58.6%
Garden-Style Apartments			
Activity / Day	**SenSci ActivVolcano™**	**BlackOut Bed Bug Detector®**	**Operational Time Increase (BlackOut®)**
Average time to install - Day 0	4.18 min/apt	6.84 min/apt	63.6%
Average time to inspect - Day 14	3.51 min/apt	4.29 min/apt	22.2%
Average time To inspect - Day 28	4.14 min/apt	5.65 min/apt	36.5%

Table 3. Percentage of missing monitors on day 14 and day 28 inspections.

High-Rise Apartments		
	SenSci ActivVolcano™	**BlackOut Bed Bug Detector®**
Day 14	4.3%	3.3%
Day 28	4.9%	2.8%
Garden-Style Apartments		
	SenSci ActivVolcano™	BlackOut Bed Bug Detector®
Day 14	5.3%	3.9%
Day 28	4.1%	4.6%

In the high-rise apartments a total of 4.3% and 4.9% of ActivVolcano's™ were missing from apartments during the day 14 inspection and day 28 inspections and BlackOut® were missing from 3.3% and 2.8%, respectively. In the garden-style apartments a total of 5.3% and 4.1% of ActivVolcano's™ were missing from apartments during the day 14 inspection and day 28 inspections and BlackOut® were missing from 3.9% and 4.6%, respectively (Table 3).

No infestations were detected across the entire community by the 1-2 minute visual inspection conducted in every unit at the start of the study as well as the 14 day inspection of the monitors. Two bed bug infestations were detected in the high-rise portion of the property on the day 28 inspection in apartments that received BlackOut Bed Bug Detectors®. Both units were treated shortly after they were detected. The two infestations detected on day 28 were the only two infestations found on the property during the study.

DISCUSSION

The most important topic being researched today may be evaluating methods to address pesticide resistance through integrated pest management approaches to bed bug control. Interception devices are proving to be a great option for pest management professionals to consider which can provide value as both a treatment and detection tool. When evaluating Climbup Insect Interceptors® as part of a treatment program, over 1600 bed bugs were collected after the first treatment was rendered which demonstrates how many bed bugs are often missed during a first service. Over 80% of the bed bugs collected were trapped in the outer well of the interception device which suggests those bed bugs were hiding in areas away from the beds and couches and traveling to the bed to feed on the human sleeping within it. This study illustrates the value interception devices can provide in a bed bug treatment protocol by capturing host seeking bed bugs as they travel throughout an infested home thus reducing the stress and bites received by the resident. In addition, interception devices can reduce the time required by PMP's treating the home by not having to search through personal belongings and areas away from the bed in search of every last bed bug.

In addition to assisting in the treatment of bed bug infestations, previous research has indicated that under-the-leg interception devices can provide assistance in proactively detecting infestations. These community-wide monitoring programs thus lead to the proactive treatment of unknown infestations that were not being reported by the tenant and reducing community-wide infestations. The study conducted in Canton, OH, illustrated that stand-alone interception devices provide similar value as part of a proactive monitoring program in a high-rise apartment community. Past research conducted at Rutgers University

has demonstrated that under-the-leg interception devices (such as Climbup® or BlackOut®) can detect 90% of low-level infestations with two weeks of installation (Cooper et al., 2015a). This study in Canton, OH is the first study to evaluate stand-alone interception devices as part of a building-wide monitoring program. Although the study did demonstrate that stand-alone devices may only detect approximately 70% of low-level infestations within 4 weeks of installation, the design of the device does not require lifting the bed or couch to place the devices under the legs and does not need to be cleaned periodically. In addition, the devices detected approximately 70% of low-level bed bug infestations compared to a 57% detection rate by visual inspections. The study demonstrated that combining the use of stand-alone devices with a visual inspection is an effective approach to proactively inspection and treat building-wide bed bug infestations.

While research has indicated that community-wide monitoring programs can dramatically reduce bed bug infestations across entire communities, the feasibility of implementing and cost-effectiveness of these programs has been questioned. The cost of the interception devices and time required to install, inspect and treat any infestations found is often high and many communities that need these programs struggle to find available time and funds to implement these programs. While under-the-leg interception devices may be the most effective monitor to detect bed bug infestations, the time required to install the devices under furniture legs and clean them monthlymay make implementing the programs difficult for management companies to afford. Stand-alone interception devices provide an alternative to under-the-leg devices. Although the detection rate was slightly lower than under-the-leg interception devices, when combined with a 5-10 minute visual inspection all infestations were detected by stand-alone devices and the time and money saved by using these devices may provide another option for management companies to consider. Not having to install stand-alone devices under the legs nor clean them on future follow-ups reduces the amount of time required to use the devices by 20-64% depending upon the type of apartment being inspected. In addition, although the rate of missing devices was slightly higher for the SenSci ActivVolcano™ (average of 4.7% for ActivVolcano™ and 3.7% for BlackOut®), neither missing device rate was considered significant by the management company that implemented the programs.

These studies demonstrate that interception devices can provide value both as part of a treatment protocol and to proactively detect bed bugs. Under-the-leg interceptors (BlackOut®) increase the chance that you detect an infestation if one is present but the devices must be installed under the legs to optimize the detection rate and should be cleaned once-per-month to prevent bugs from escaping. Stand-alone interception devices (ActivVolcano™) may detect a few less infestations compared to under-the-leg interceptors but still detect a high-rate of infestations and reduce the time investment required to use the device by not requiring to move the bed to install or clean them periodically. Both devices should be seen as effective methods to detect bed bug infestations and offer management companies multiple options to detect infestations proactively.

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