Bed Bug Management in Multifamily Housing:

Reasons for failure, keys to success

Part One

Richard Cooper, PhD
R Cooper Consulting, LLC
Rutgers Univ. Urban Entomology Lab

R COOPER CONSULTING

SKA BRA
SKADEDYRBEDRIFTENES
BRANSJEORGANISASJON

Presentation Overview:

Part One

1. **Resurgence of bed bugs in the United States**
2. **Behavioral ecology (bed bug movement)**
3. **Detection of bed bugs**

Part Two

1. Bed bug management methods (US perspective)
2. Applying what we have learned (community-wide bed bug management)

Bed bugs were virtually eradicated from the U.S. in the post WWII era

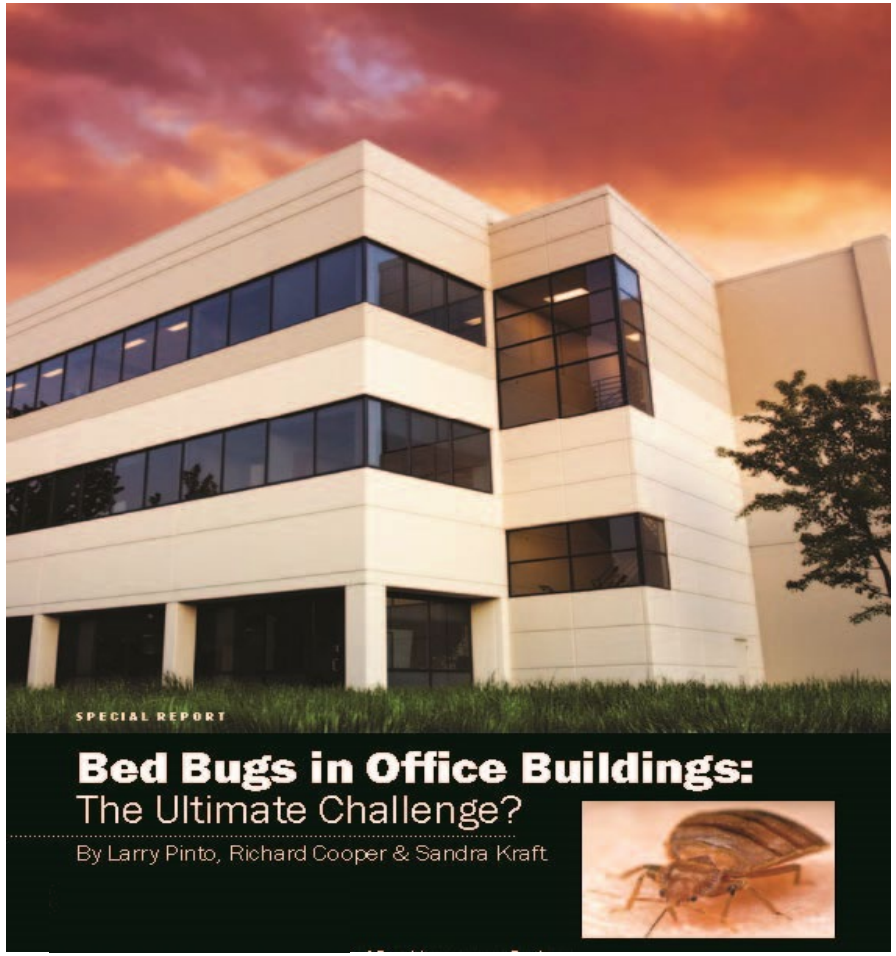
1999 limited mostly to hotels

Quickly spread to residential sector

© Richard Cooper


© Richard Cooper

Bed bugs in schools and the workplace



Within less than 10 years bed bugs were being found everywhere

- Hotels & motels
- Apartments
- Private homes
- College dorm rooms
- Schools and day care
- Youth hostels
- Used furniture outlets
- Furniture rental stores
- Moving/delivery vans
- Health care facilities
- Fire stations
- EMT vehicles
- Airplanes & cruise ships
- Public transportation
- Laundries & dry cleaners
- Libraries
- Office buildings
- Retail stores
- Movie theaters

2010’
The year bed bugs took over NYC!

“1 of 15 New Yorkers dealing with bed bugs” - NYC Dept. of Health

Hollister

NYC 311 Call Center

Google’s Offices

Mid Manhattan Library

King’s Co. Hospital

Bloomingdales

DA’s Office

Macy’s Herald Sq.

Abercrombie & Fitch

Time Warner Center

AMC Movie Theaters

Empire State Building

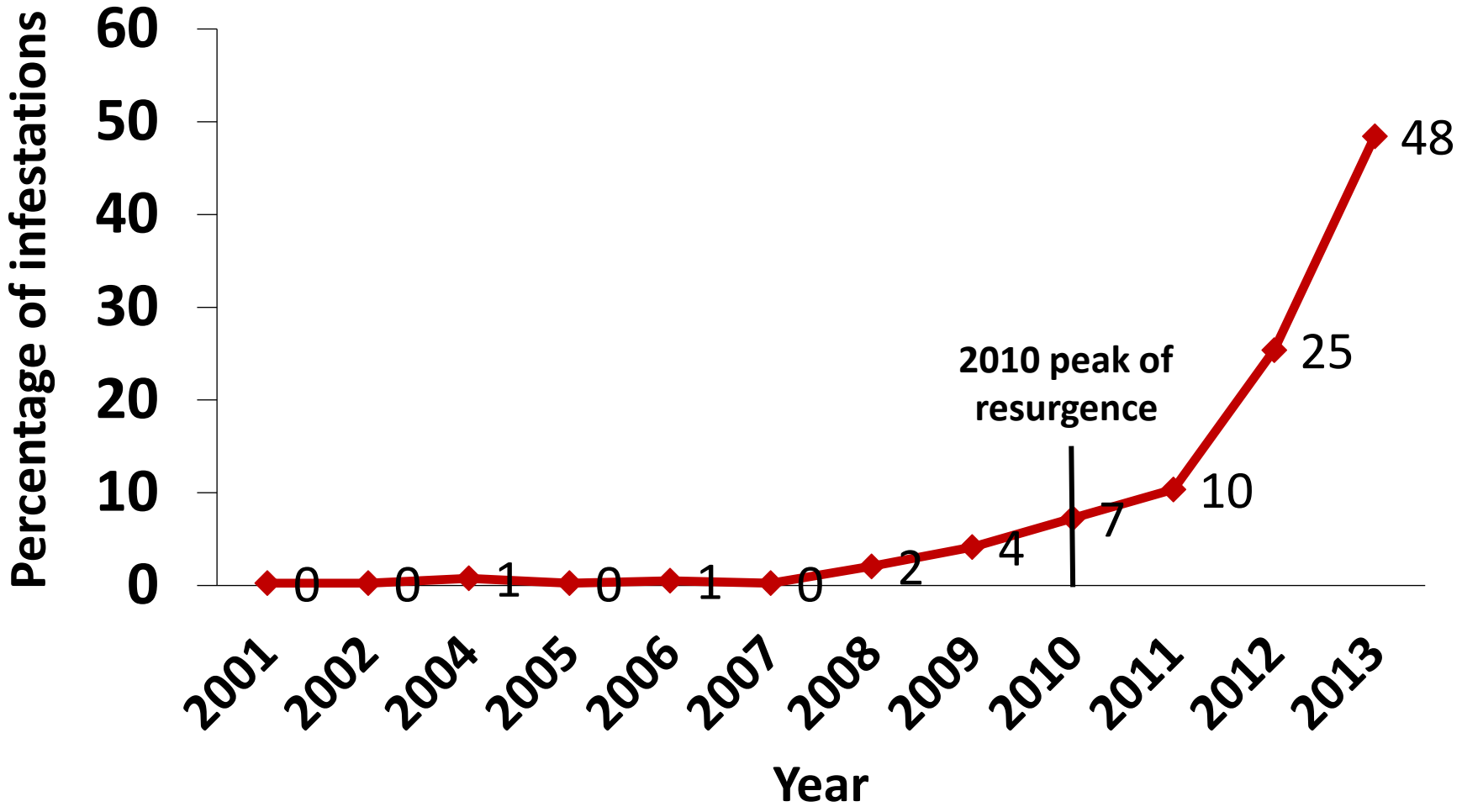
Victoria’s Secret

Goldman Sachs

Contrary to popular belief, bed bugs were not a lower socio-economic problem

Shelters, low income housing and congested urban areas

Lag in resurgence in affordable housing communities



Affordable housing communities are now serving as a bed bug reservoir!

Disproportionately high pest infestation rates

- Low bid pest control & poorly written contracts
- Poor quality pest management

The costs of suboptimal bed bug management are profound!

Residents

- Decreased quality of life, social injustices
- Economic hardship
- Risks associated with self-treatment

Property management

- Escalating infestation rates
- Increased pest management costs
- Damage to reputation and property value
- Increased liability

External community

- Spread of bed bugs from living community to external community

Costs for suboptimal bed bug management can be high

- **$800,000** (MFH) 2013’
- **$2,450,000** class action (MFH) 2016’
- **$3,500,000** class action (MFH) 2017’
- **$1,700,000** class action (MFH) 2022’
- **$2,400,000** class action (MFH) 2023’
- **$4,100,000** class action (MFH) 2024’

Several ongoing class action cases with expected awards in $millions

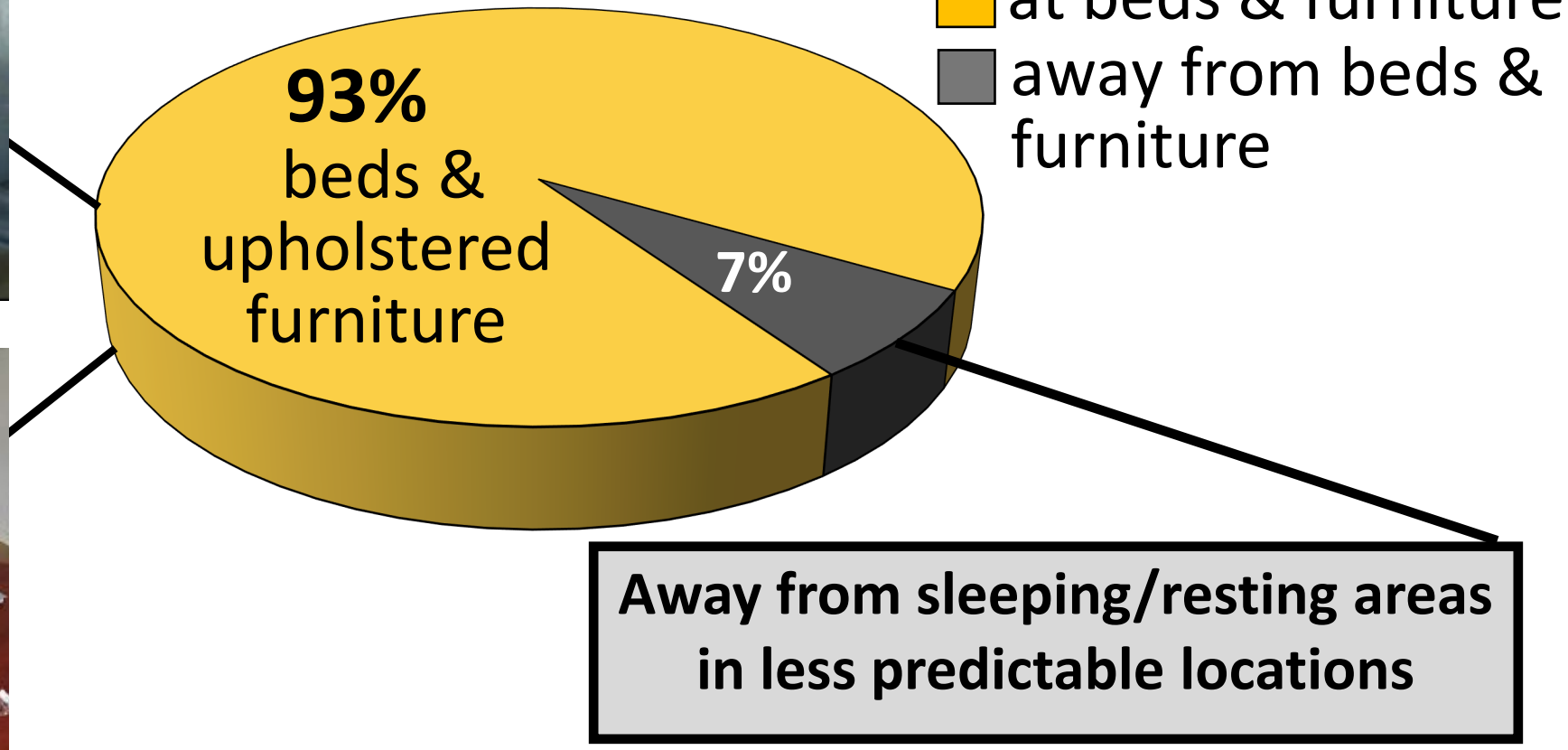
Understanding the challenges?

Extensive field research in multifamily housing

- Behavioral ecology (bed bug movement)
- Importance of detecting low level populations
- Effective bed bug control methods (what works)
- Pro-active versus reactive approach to control

Understanding bed bug movement

Classic bed bug distribution model



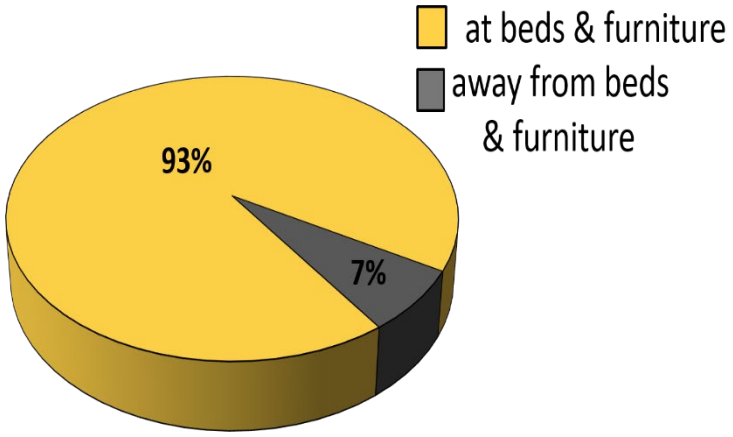
Away from sleeping/resting areas in less predictable locations

Modified from Potter et al. 2006

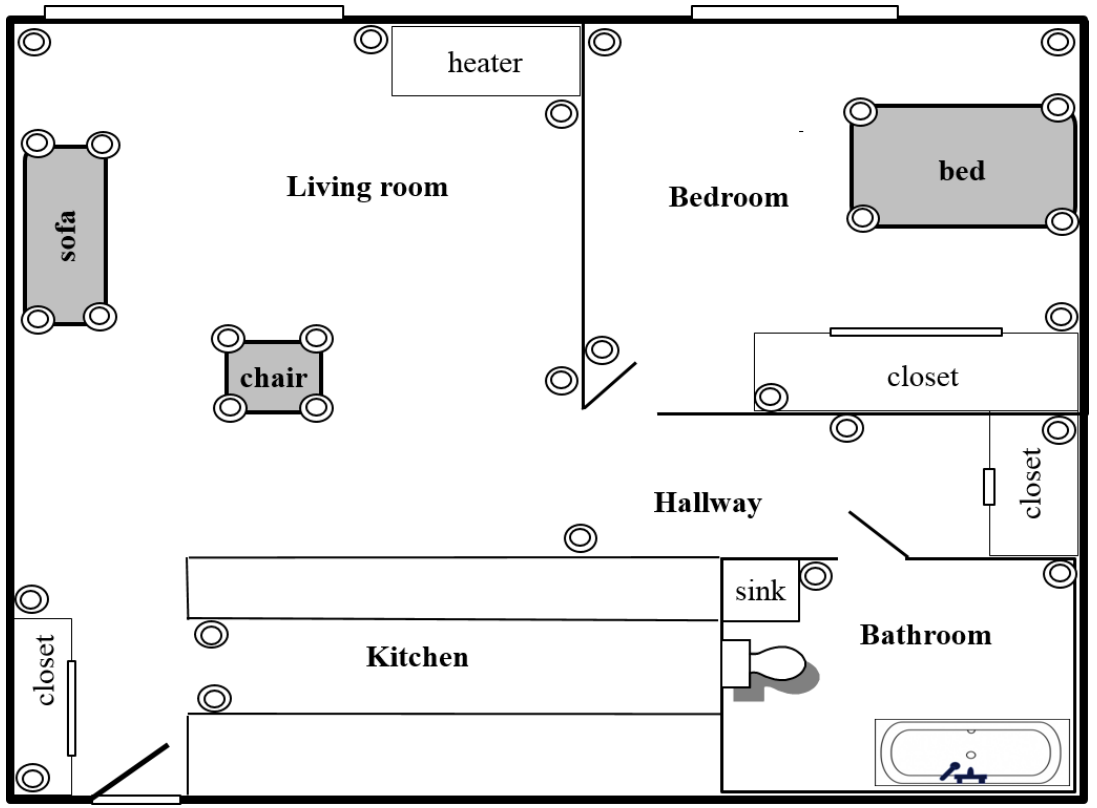
Using interceptor traps to study bed bug movement within apartments

Very effective at detecting bed bug activity when placed at and away from sleeping and resting areas

Revisiting the classic distribution model



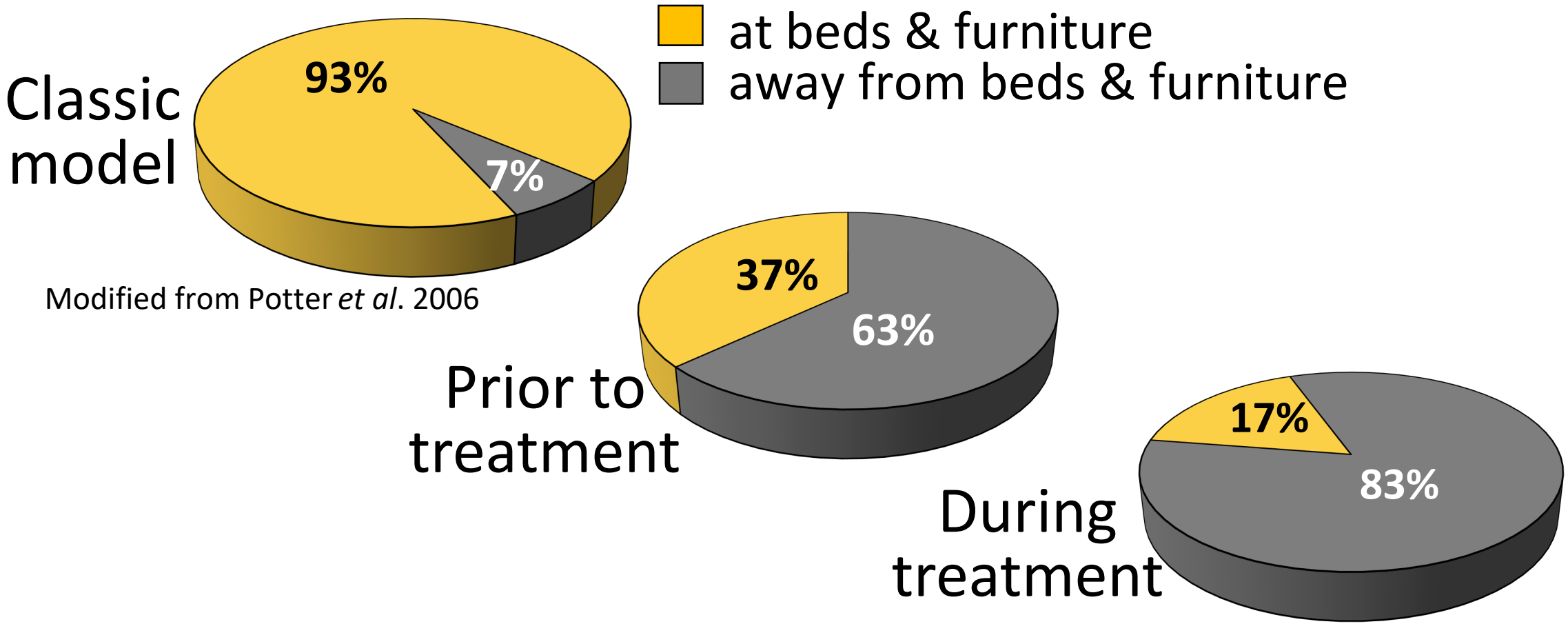
Modified from Potter et al. 2006



Average of 28 interceptors in each apartment

- 10 under legs of furniture
- 18 throughout apartment away from furniture

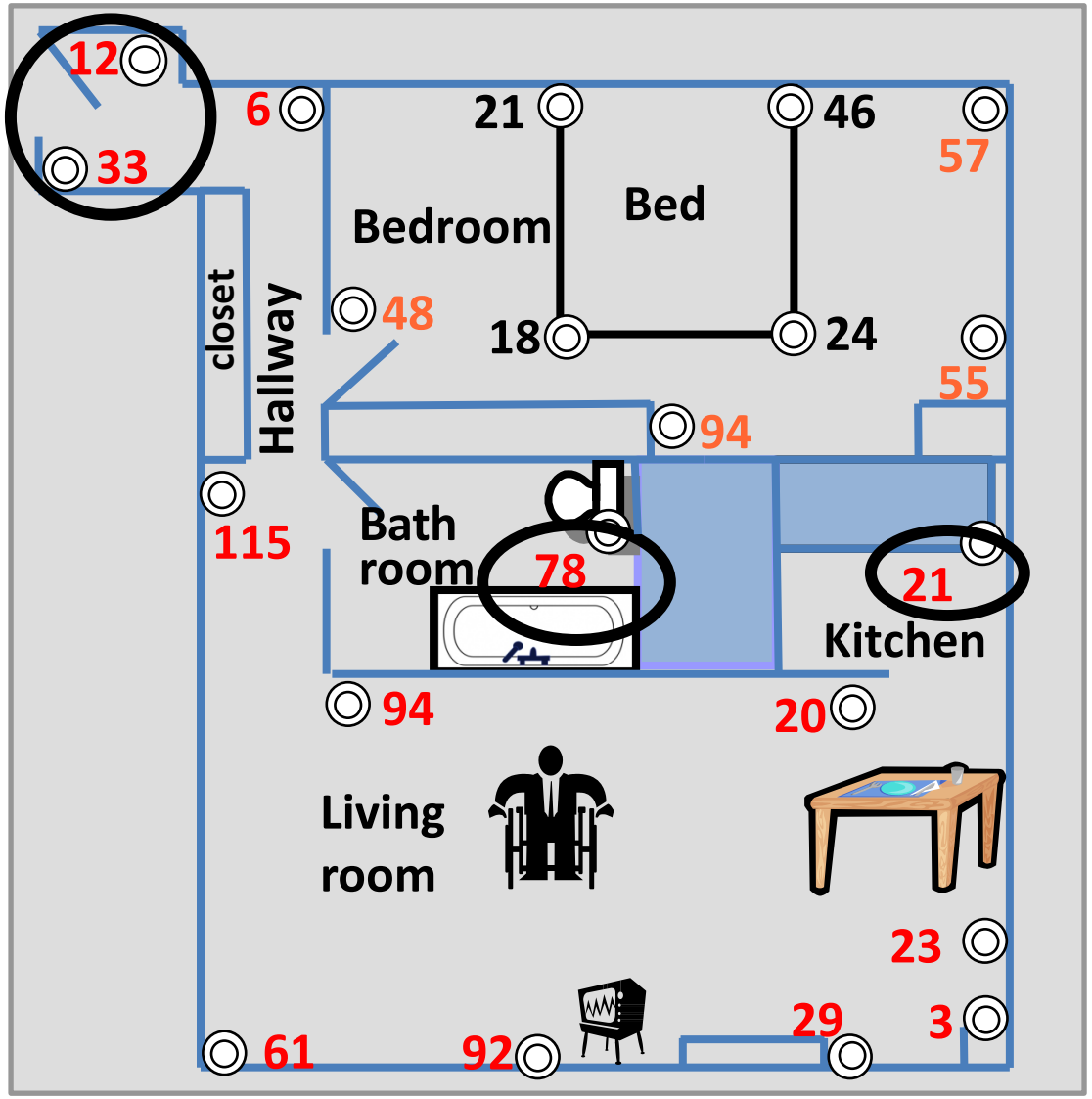
Detection of bed bugs by area



Modified from Potter *et al*. 2006

Cooper and Wang unpublished results

Distribution of bed bugs based upon apartment-wide monitoring (14 days)



Bed = 109 bugs

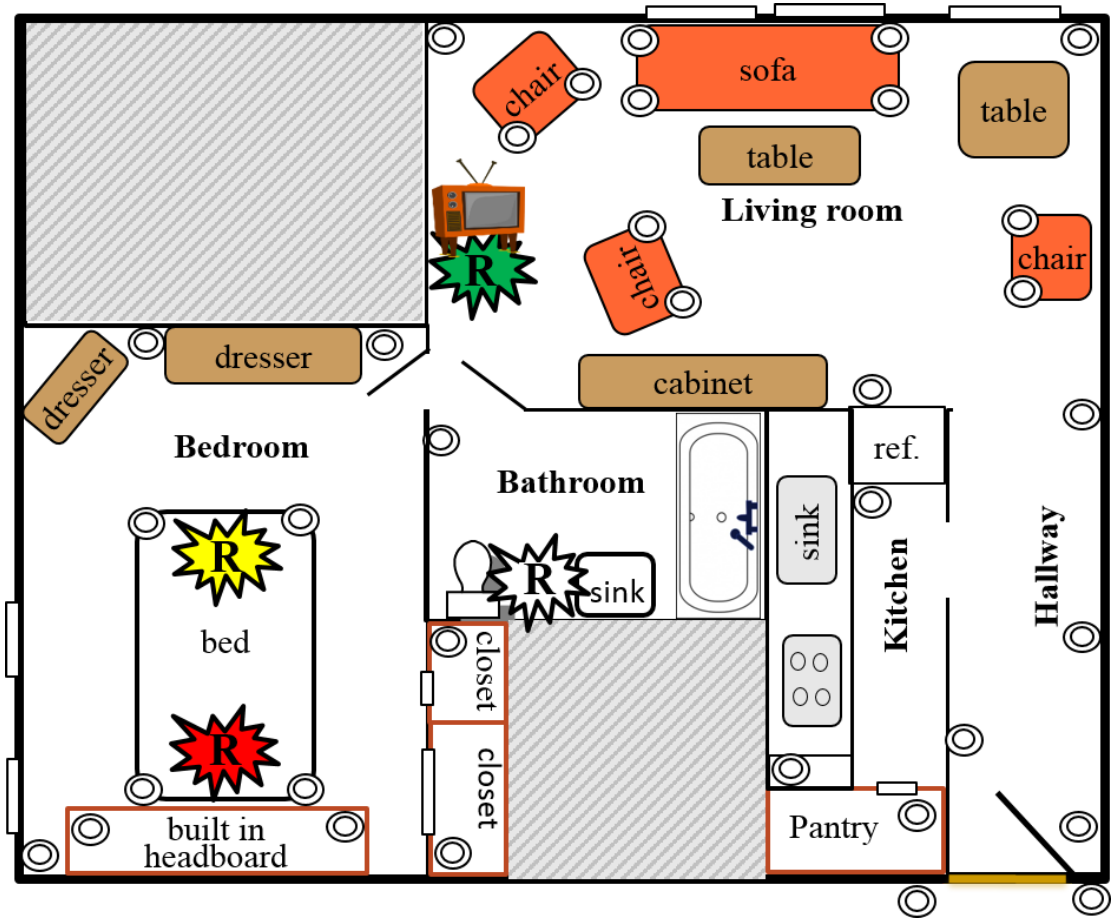
Bedroom = 254 bugs

Rest of apt. = 587 bugs

88% captured away from bed

Wang and Cooper PestWorld 2012

Mark, Release, Recapture study

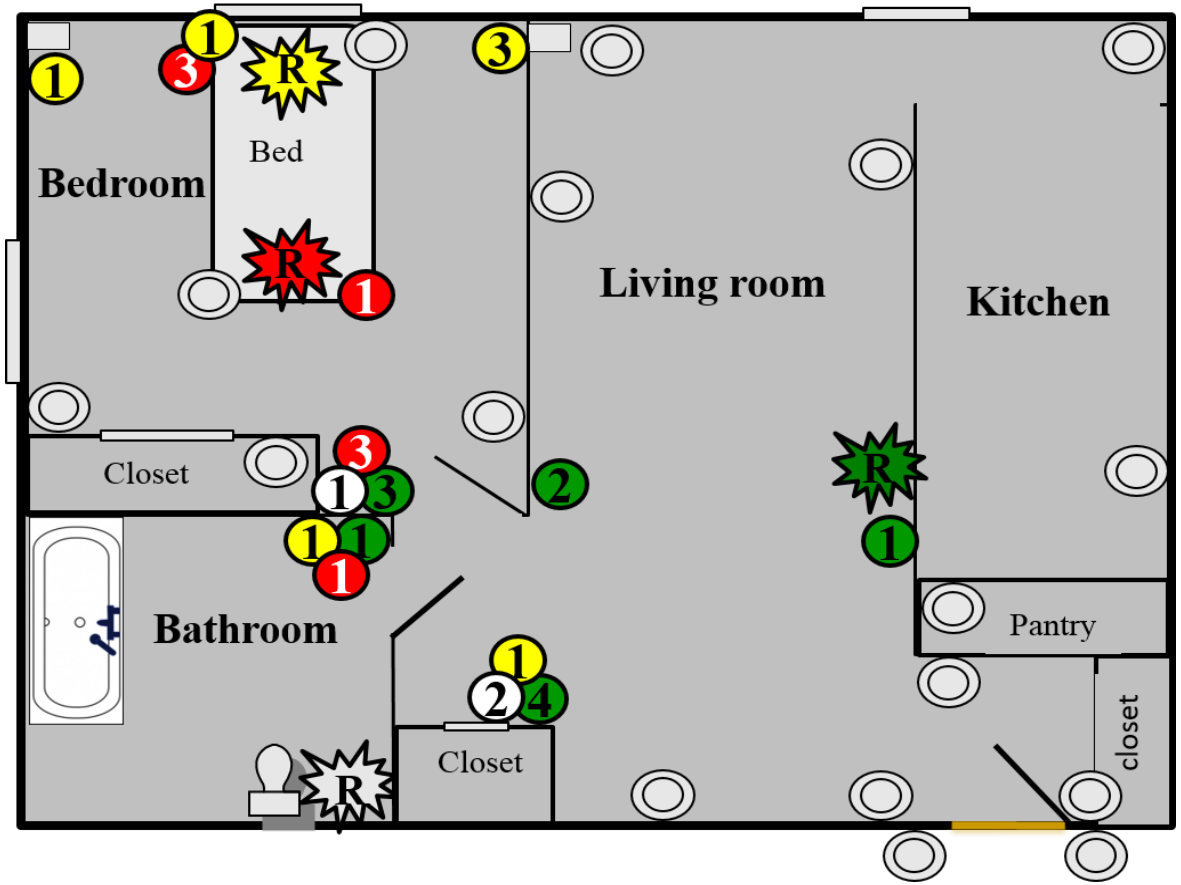


6 apts. in study (4 occupied and 2 vacant)

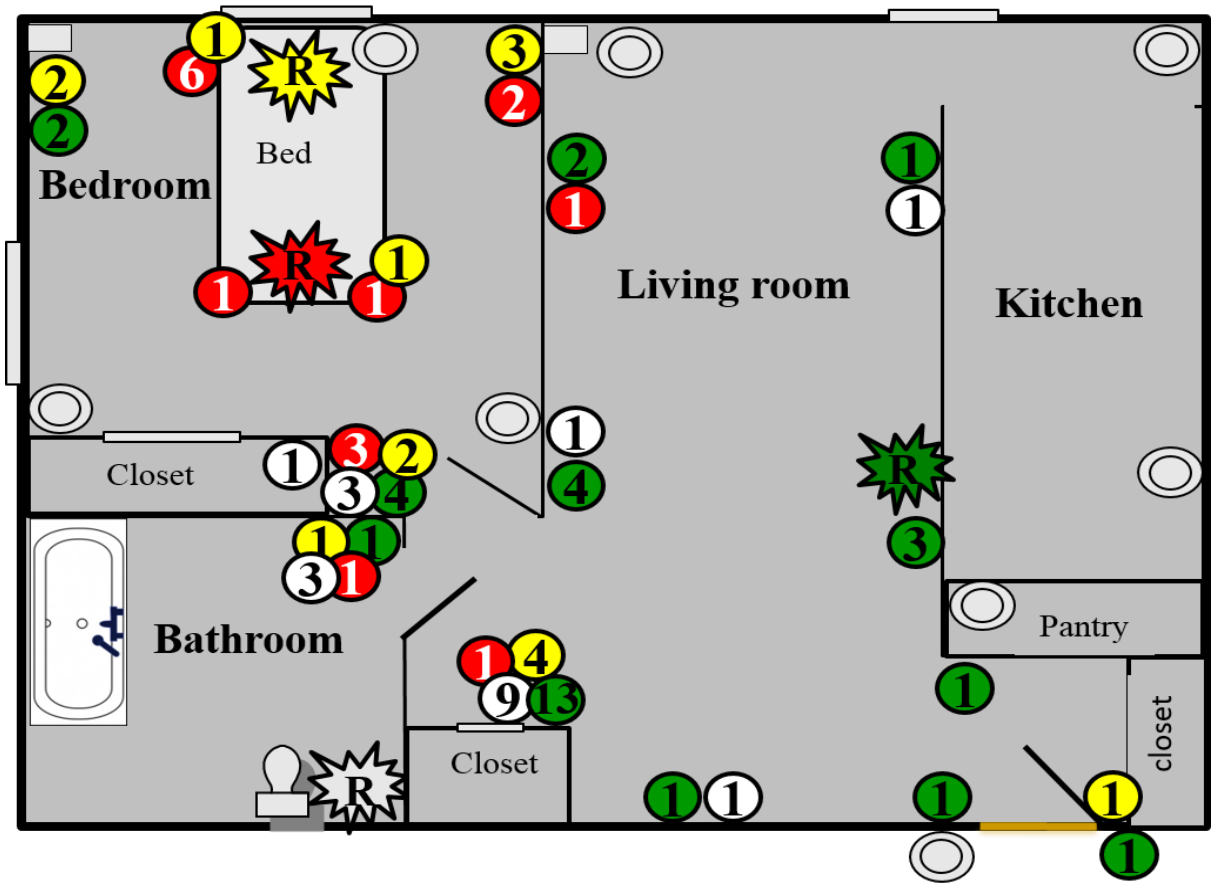
Cooper et al. Plos One 2015

Movement of marked bed bugs

24 hours



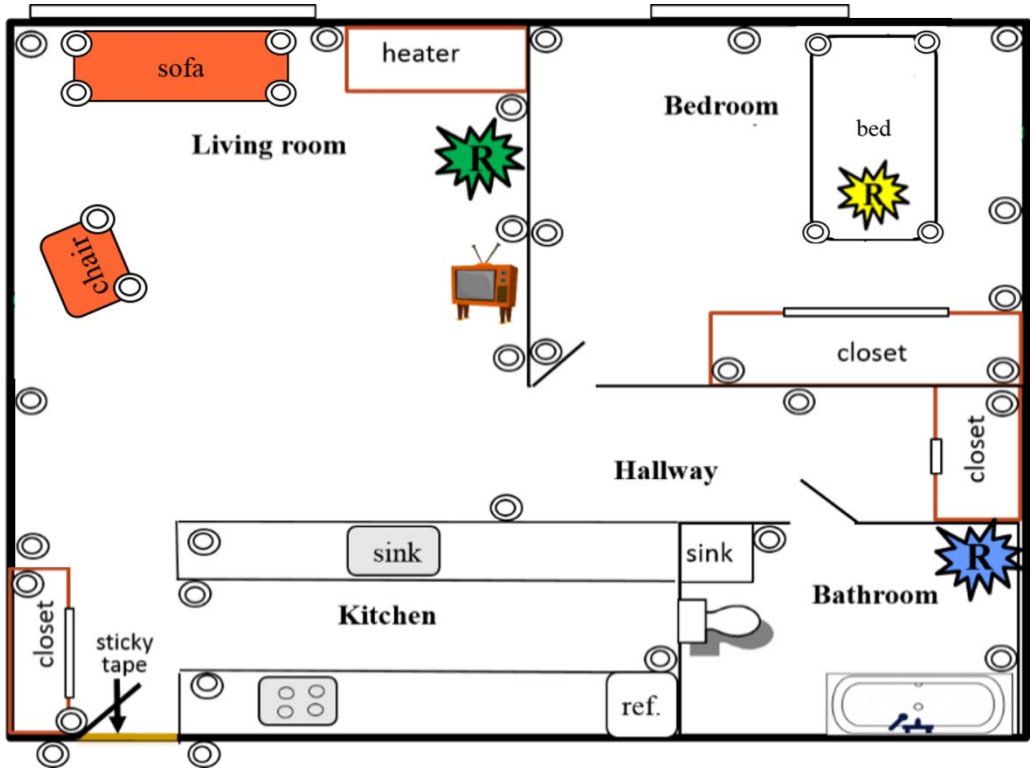
14 days

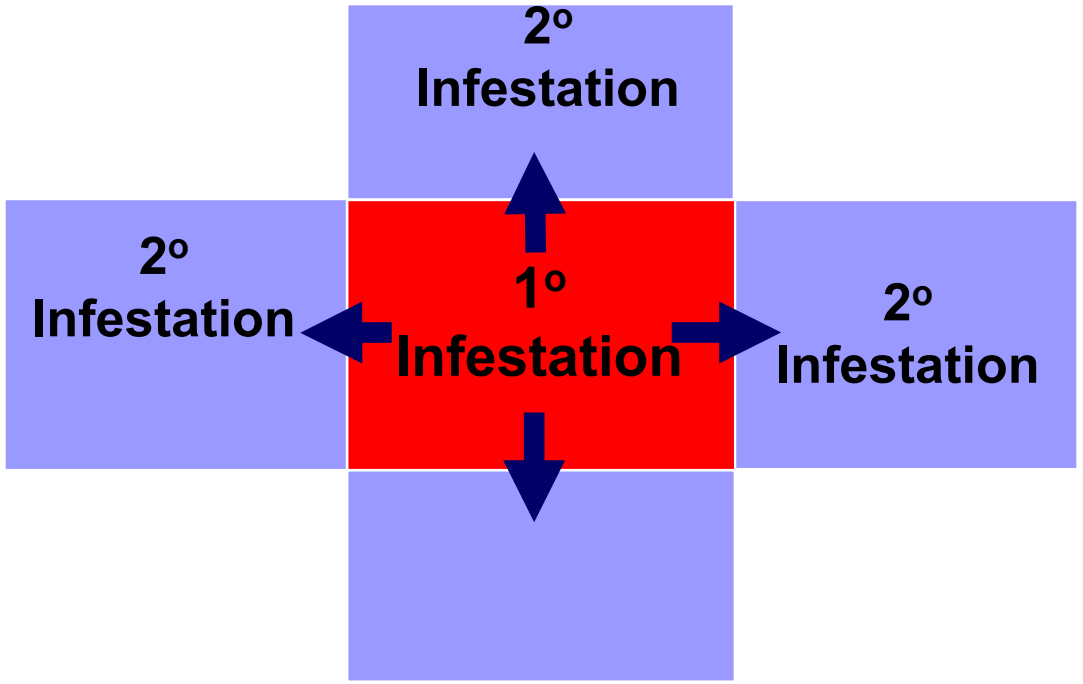


Occupied unit

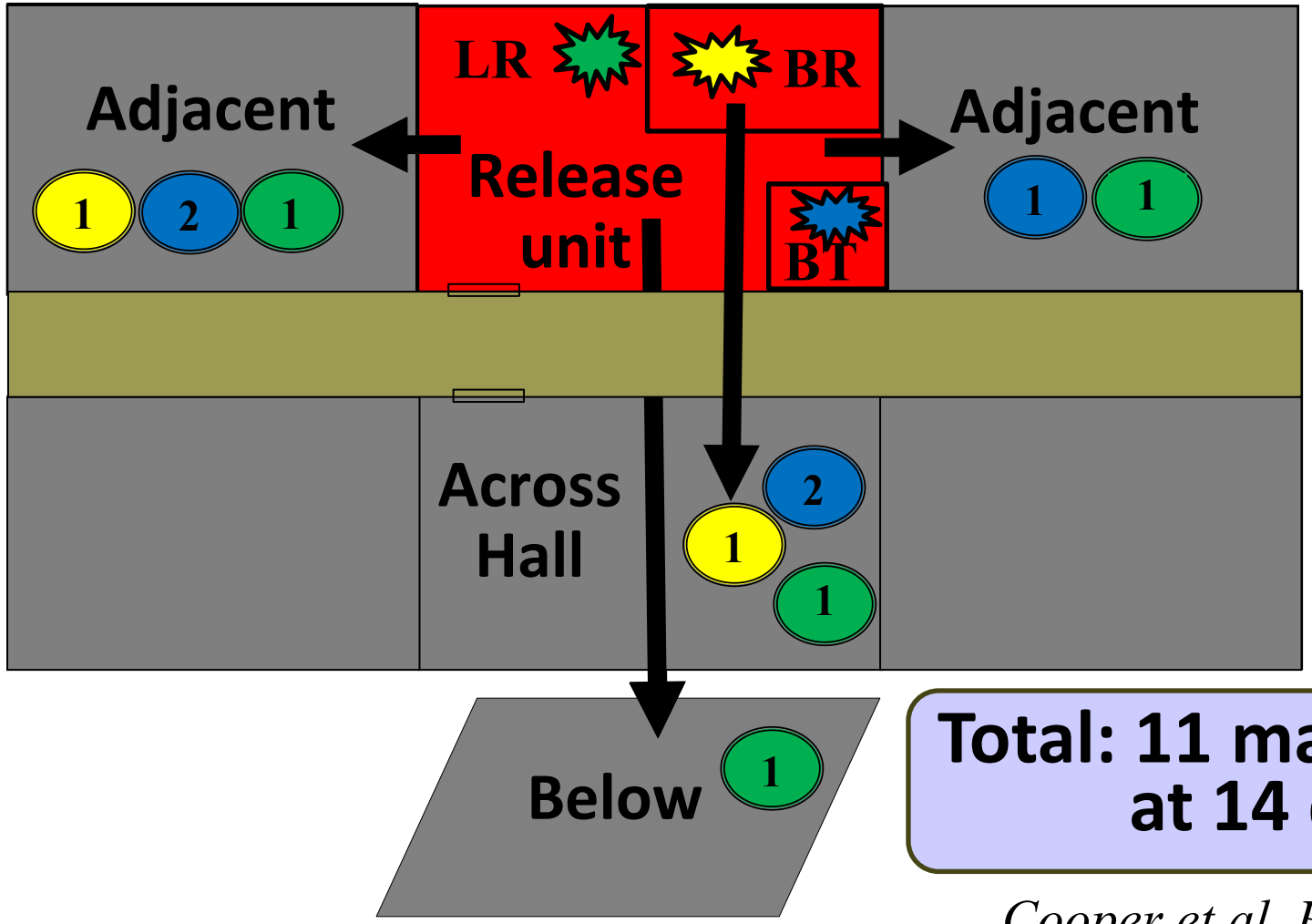
Cooper et al. Plos One 2015

M-R-R used to study movement between units





Active dispersal of marked bed bugs between apartments

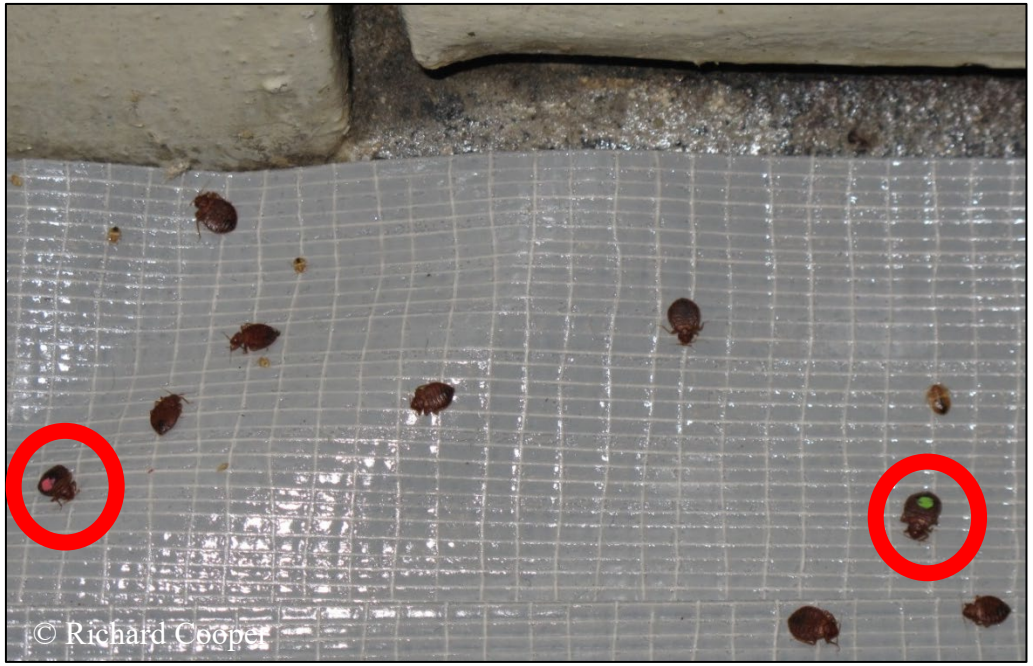


at 3d

Total: 11 marked bugs at 14 days

Cooper et al. Plos One 2015

Bed bugs captured on sticky tape barriers



Marked and unmarked bed bugs trapped on sticky tape barrier (3:1 adult female to male ratio)

Cooper et al. Plos One 2015

Active dispersal of marked bugs to neighboring apartments (30 days)

Apt.	Status	Dispersal to neighboring apt.	Sex	
			♀	♂
1	Vacant	Yes	5	
2	Vacant	Yes	2	
3	Occupied	Yes	1	
4	Occupied	Yes	1	
5	Occupied	Yes	2	1
6	Occupied	no	-	-
Dispersal		**5 of 6 apts.**	**12**	**1**

Cooper et al. Plos One 2015

Most infestations in multifamily housing communities are found in clusters

# bldgs.	# of apts.	# Infest. apts.	Neighboring apts. infested	Adj.	Above or below	Across hall
6	**1078**	**312**	**97%**	**42%**	**33%**	**25%**

Including neighboring apartments in your scope of service is critical!

Take home messages: bed bug movement

1. Bed bugs are much more mobile than previously believed
2. The majority of bed bugs are found away from sleeping and resting areas, especially following treatment
3. Treatments should not be limited only to rooms where bed bug activity has been seen
4. Active dispersal of bed bugs between apartments occurs frequently and independently of host availability
5. The apartment entry serves as a major route of active dispersal between apartments (across hall ~ 25% of time)
6. Surround unit inspections should be expanded to units across the hall

What have we learned about bed bug detection?

What we know comes from studies done in multi-family housing

Effective detection of bed bugs is essential

1. Detect the introduction of bed bugs
2. Evaluation of treatment efforts
3. Confirming elimination

Must be able to detect bed bugs in very small numbers

1. **At onset**
2. **Prior to elimination**

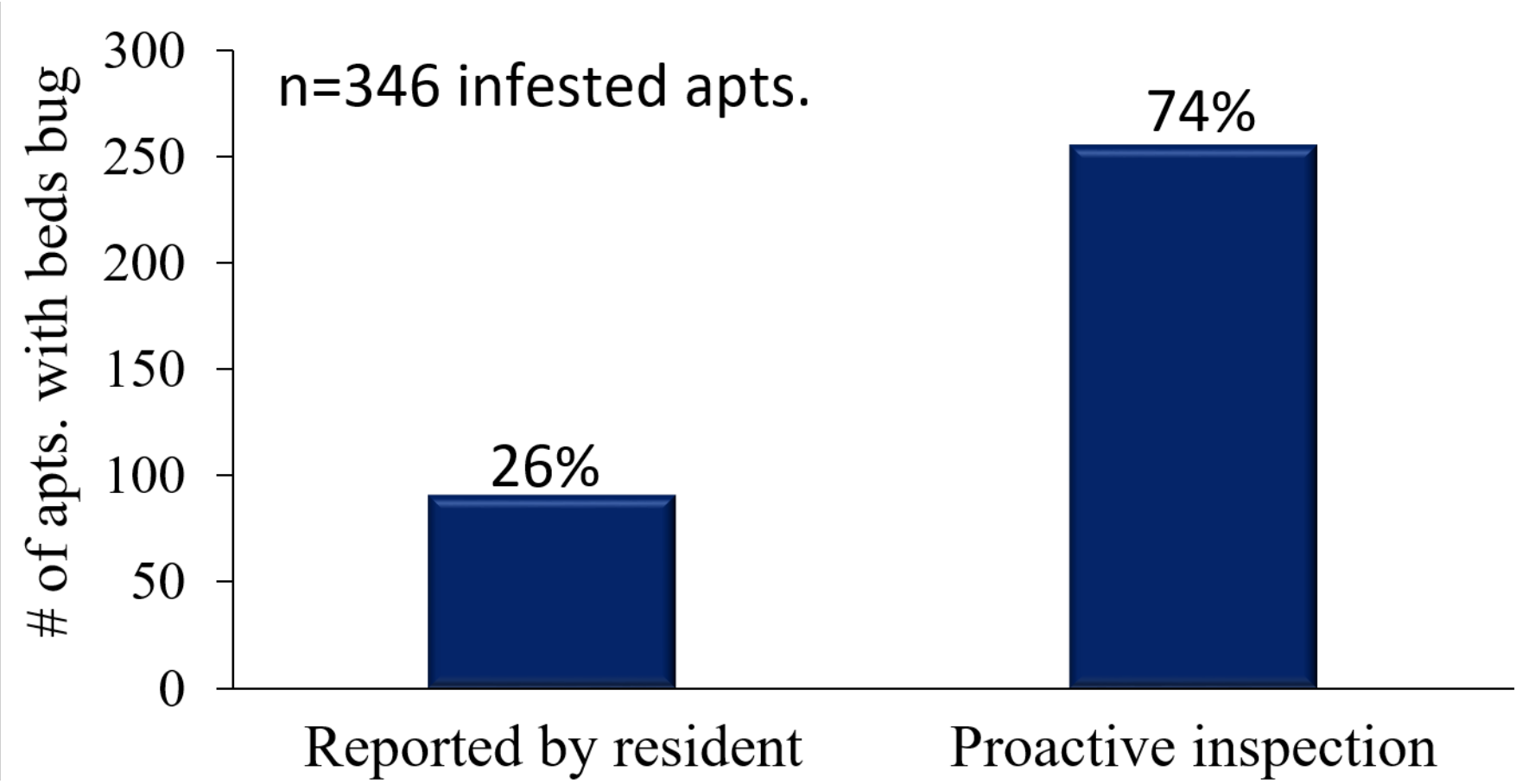
Early detection is the key to preventing the spread of bed bugs within housing communities

Because the longer an infestation goes undetected…

- The more complex the problem becomes
- The more difficult and costly it is to eliminate
- The more likely it is to spread

It’s the infestations you are not aware of that promote failure of community-wide control efforts and the escalation of costs

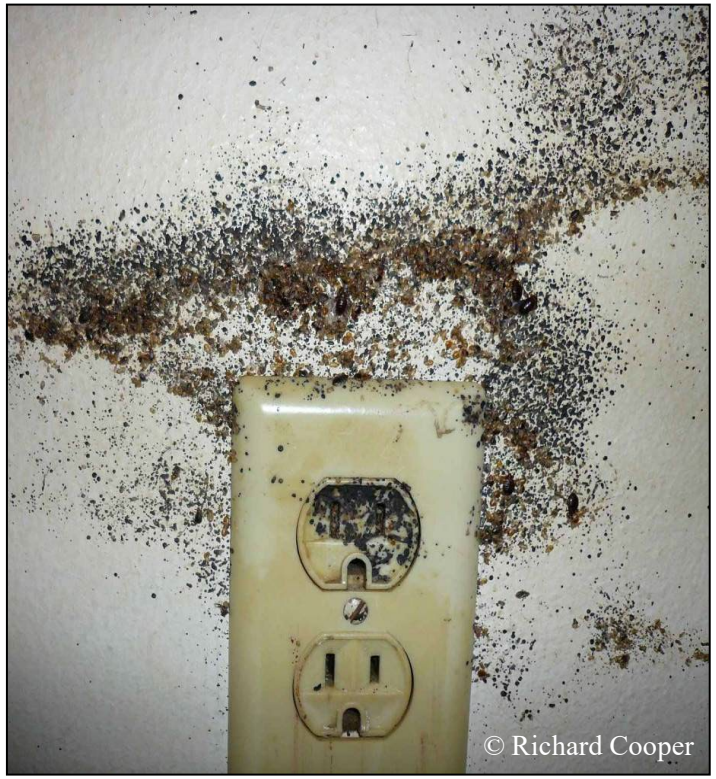
Most communities rely upon residents to report activity



Cooper et al. 2015. Pest Mgmt. Sci
Wang et al. 2016. J. Med. Entomol.


© Richard Cooper


© Richard Cooper


© Richard Cooper


© Richard Cooper

How does this happen?

1. **Unwilling to report the problem**
   - Apathy (nothing ever changes)
   - Fear negative repercussions
   - Trying to avoid attention from management
     - unauthorized occupants, illegal activities
   - Ashamed or embarrassed

2. **Unaware of bed bugs**
   - Don’t see bugs
   - Not reacting to bites (especially the elderly)
   - Mental disability

Other methods to confirm bed bug activity

Other methods:

- Verbal interview
- Visual inspection
- Scent dogs
- Monitors/traps

Verbal interview

Advantages

- No specialized equipment needed
- Quick and inexpensive
- Can get insight about the bed bug activity
- Provides an opportunity for education

Disadvantages

- Only as reliable as the information provided by the person being interviewed

Visual inspection

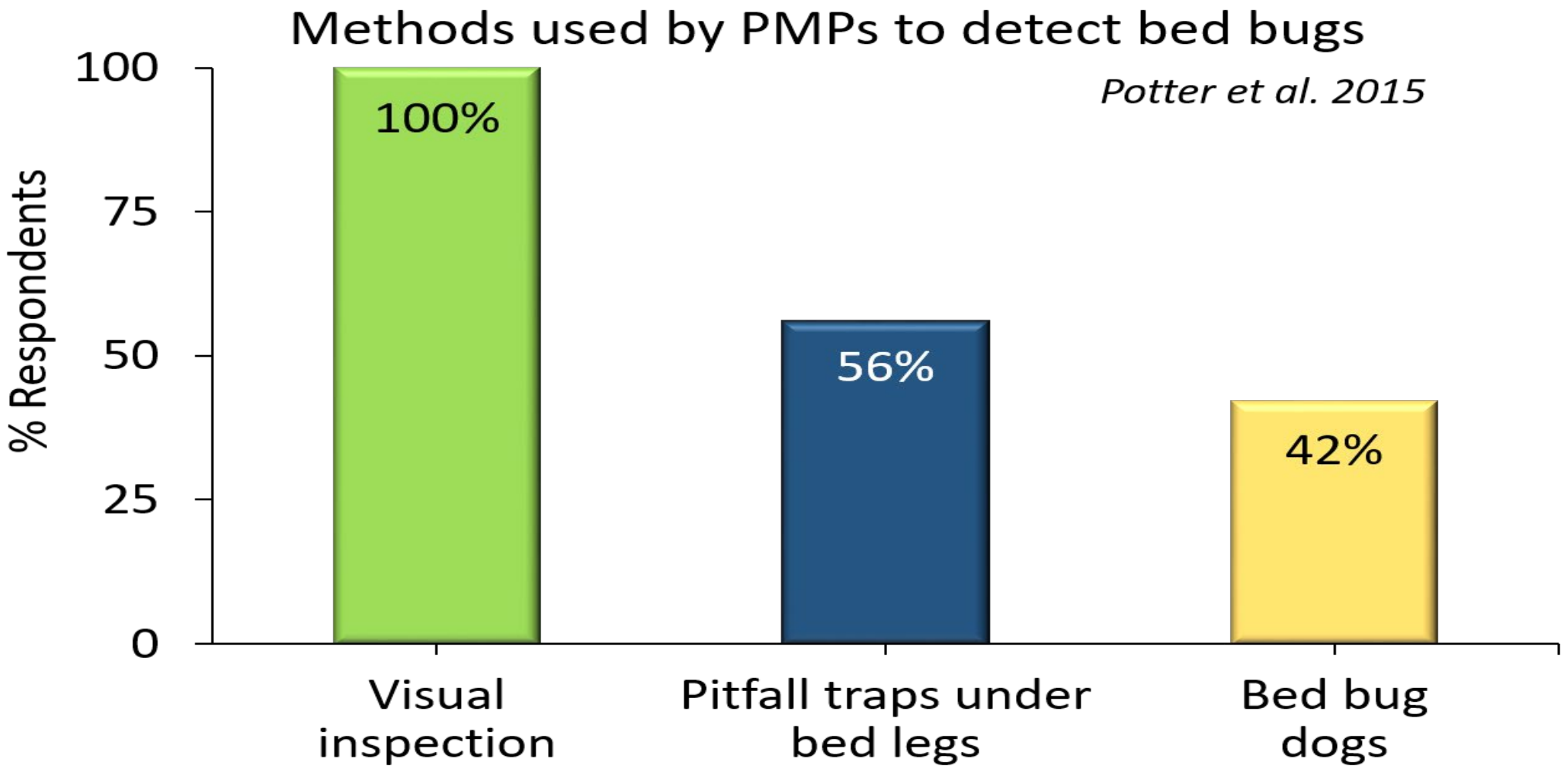
Advantages

- No specialized equipment
- Provides immediate results

Disadvantages

- Labor intensive and physically demanding
- Results dependent upon extent of inspection and skill of inspector

Most pest management professionals rely upon visual inspection



Visual inspections are fine for heavy bed bug infestations

Most infestations are not severe

Infestation rates (n=291)

~ 10% severe infestations

~ 25% moderate infestations

~ 65% low-level infestations

Many low-level and some moderate level infestations will be missed during a visual inspection

Canine Scent Detection

Advantages

- Can detect bed bugs in areas not visually accessible
- Well suited for large scale inspections & non-traditional environments (schools, offices, retail, theaters, etc.)
- Can provide immediate results in a single visit

Disadvantages

- Expensive to get into the business
  - Requires large capital investment ($80,000 – $100,000)
- Significant ongoing expenses
  - Constant training with dog/handler team
  - Maintenance of dog (veterinary, kenneling, etc.)
- Accuracy is highly variable (risk of false positive results)

Monitors/traps

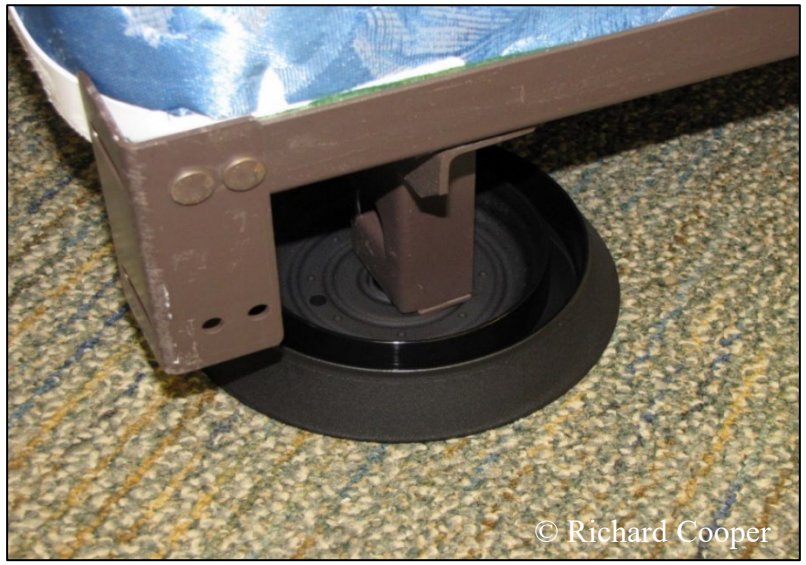
Advantages

- Continuous collection of data (24/7)
- Increased ability to detect low-level bed bug activity

Disadvantages

- Requires at least two visits (results not instantaneous)
- Not economically practical for large scale inspections
- Great variability among monitors in regard to effectiveness, ease of use, and cost

Pitfall-style interceptor traps have proven to be the most effective & reliable monitor



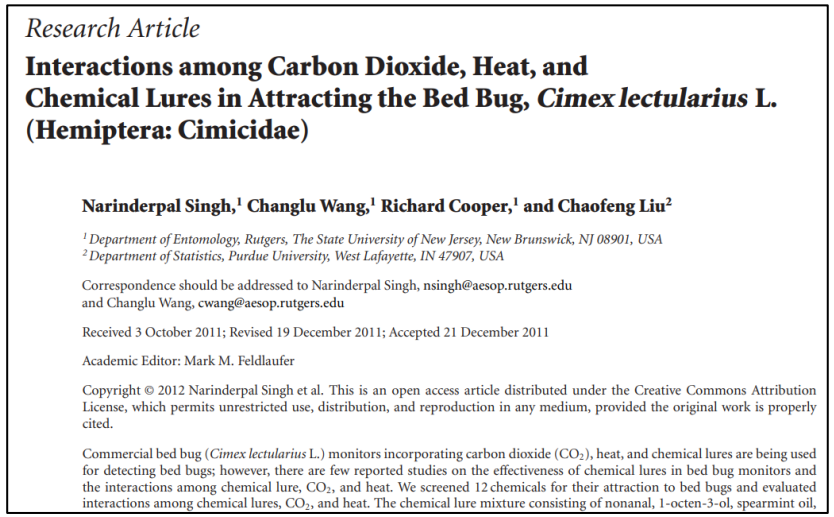
- Intercept bugs as they travel to and from sleeping and resting areas (beds and upholstered furniture)
- Considered passive, but uses most effective lure when used beneath legs of beds (natural host is serving as the attractant)
- Effective both at and away from sleeping and resting areas

Chemical lures can be used to turn a passive into an active trap

Lure developed by Rutgers University

- Increases trap catch by >2x

Singh et al. 2012 Psyche



Research Article

Interactions among Carbon Dioxide, Heat, and Chemical Lures in Attracting the Bed Bug, *Cimex lectularius* L. (Hemiptera: Cimicidae)

Narinderpal Singh,[1] Changlu Wang,[1] Richard Cooper,[1] and Chaofeng Liu[2]

[1] *Department of Entomology, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901, USA*
[2] *Department of Statistics, Purdue University, West Lafayette, IN 47907, USA*

Correspondence should be addressed to Narinderpal Singh, nsingh@aesop.rutgers.edu and Changlu Wang, cwang@aesop.rutgers.edu

Received 3 October 2011; Revised 19 December 2011; Accepted 21 December 2011

Academic Editor: Mark M. Feldlaufer

Copyright © 2012 Narinderpal Singh et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Commercial bed bug (*Cimex lectularius* L.) monitors incorporating carbon dioxide (CO_2), heat, and chemical lures are being used for detecting bed bugs; however, there are few reported studies on the effectiveness of chemical lures in bed bug monitors and the interactions among chemical lure, CO_2, and heat. We screened 12 chemicals for their attraction to bed bugs and evaluated interactions among chemical lures, CO_2, and heat. The chemical lure mixture consisting of nonanal, 1-octen-3-ol, spearmint oil,

Addition of lure to Intercepetors

- 30% higher detection rate

Sked et al. 2019 J. Econ. Entomol.

Comparative field studies in MFH communities

Comparison of methods for building-wide assessment of bed bug activity

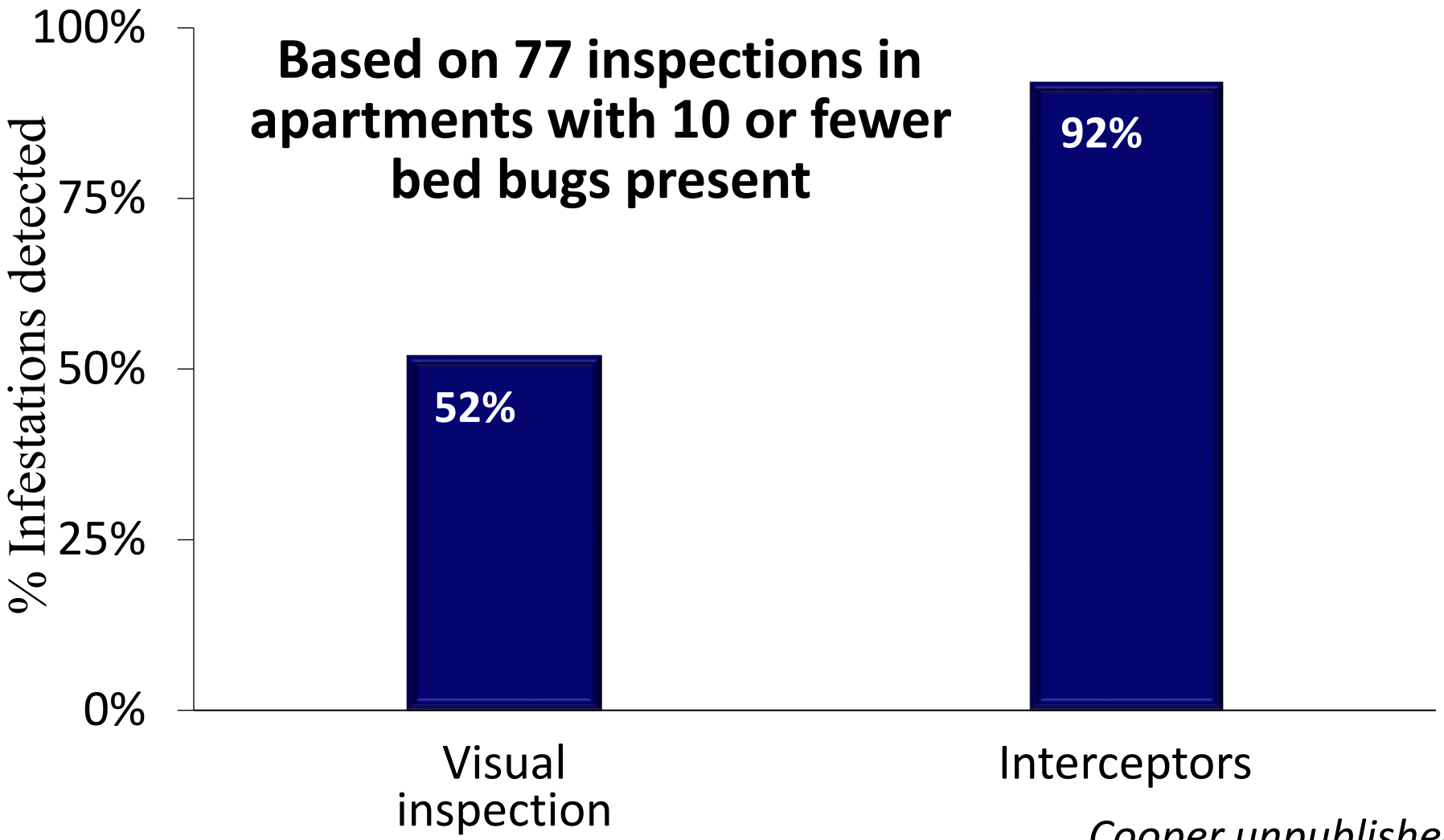
358-unit apartment building (elderly residents)

71 infested apartments identified
Mixed infestations (low-level to severe)

- 23% (16) reported to management by residents
- 30% (21) identified through resident interview
- 69% (49) identified through visual inspection
- 96% (68) identified with pitfall traps under legs of beds and upholstered furniture (14 d)

Cooper et al. 2015 Pest Mgmt. Sci.

Detection of low-level populations



Cooper unpublished results

How effective are bed bug dogs?

Under controlled conditions

- 95-98% detection rate
- 3% false alert rates

Pfiester et. al. 2008 J. Econ. Entomol.

Under natural field conditions

- Detection rates lower than in training exercises
- Results highly variable from one team to the next and one inspection to the next

Cooper et al. 2014 J. Econ. Entomol.

Comparison of scent dogs vs. interceptors

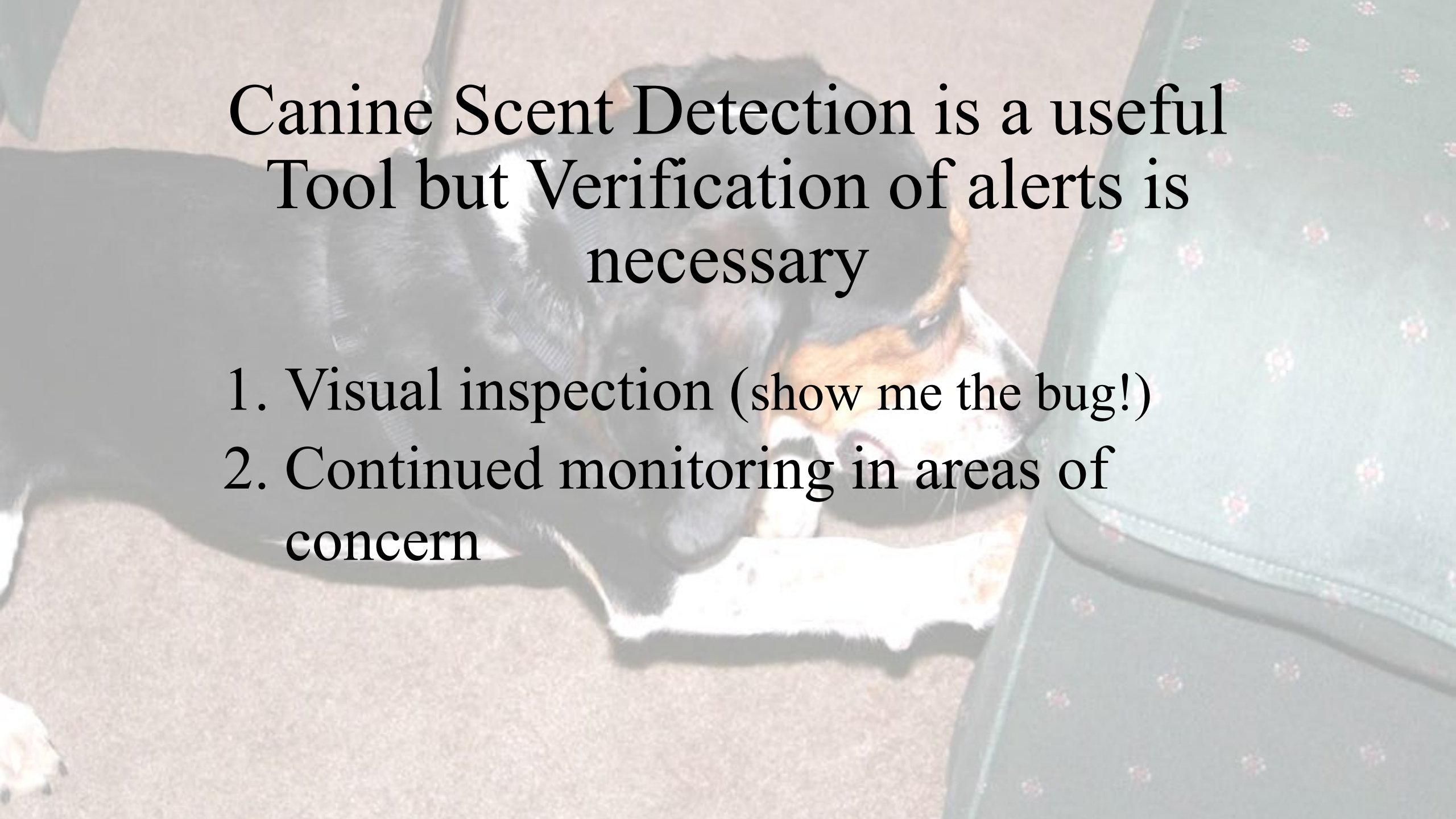
vs.

276 apartments inspected (67 w/ bed bug activity)

Dog teams were inconsistent (11 teams tested)
- mean detection rate 44% (range: 10-80%)
- mean false positive rate 14% (range: 0-57%)

Interceptors (7-14 d)
- 90% detection rate

Cooper et al. 2014 J. Econ. Entomol.



Canine Scent Detection is a useful Tool but Verification of alerts is necessary

1. Visual inspection (show me the bug!)
2. Continued monitoring in areas of concern

Most effective detection method

Combination of:

1. Visual inspection

and

2. Pitfall-style interceptors

Cooper et al. 2014. J. Economic Entomology, Cooper et al. 2015. Pest Management Science, Wang et al. 2016. J. Medical Entomology

Take home messages: bed bug detection

1. Most communities rely on residents to report activity
2. Less than 1/3 of infestations are reported by residents
3. The majority of the pest industry relies upon visual inspection to detect bed bug activity
4. Visual inspections are unreliable for low-level infestations
5. Pitfall-style interceptors (ClimbUp and BlackOut) have been demonstrated to be the most effective and reliable method for detection of low-level bed bug activity.
6. It's best to use a combination of detection methods (i.e. visual inspection plus interceptors)

Monitor from *Silverfish*

Developed for Silverfish - food-based lure

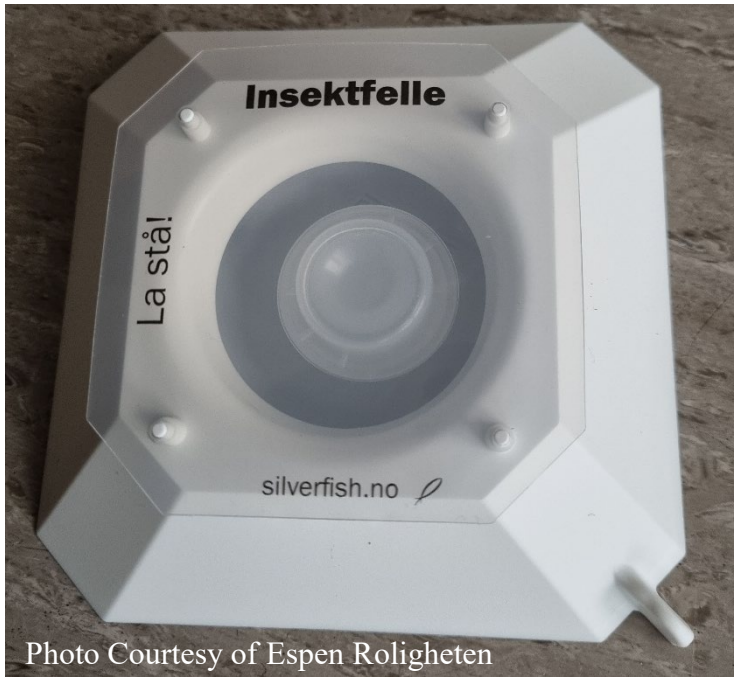


Photo Courtesy of Espen Roligheten

Photo Courtesy of Espen Roligheten

Bed bugs - without lure

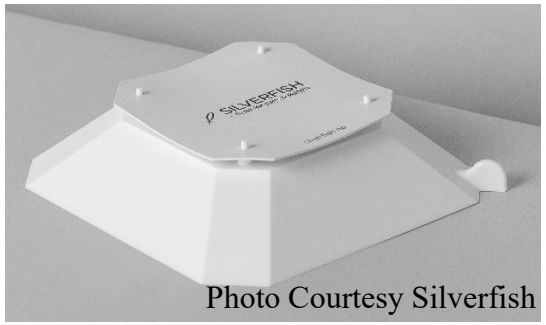

Photo Courtesy of Espen Roligheten

Has also been working well with bed bugs in the field (personal communication with Espen Roligheten)

Active Monitor (CO2 + Chemical Lure) - *Skatek*

Used in combination with bed bug monitors

+



- Well suited for detection of low-level bed bug activity
- Well suited for activating bed bugs in the absence of a host

Thank You

Richard Cooper
R Cooper Consulting
rick@rcooperconsulting.net

Bed Bug Management in Multifamily Housing:

Reasons for failure, keys to success

Part Two

Richard Cooper, PhD
R Cooper Consulting, LLC
Rutgers Univ. Urban Entomology Lab

R COOPER CONSULTING

SKA BRA
SKADEDYRBEDRIFTENES
BRANSJEORGANISASJON

Presentation Overview:

Part One

1. Resurgence of bed bugs in the United States
2. Behavioral ecology (bed bug movement)
3. Detection of bed bugs

Part Two

1. **Bed bug management methods (US perspective)**
2. **Applying what we have learned (community-wide bed bug management)**

What have we learned about bed bug management?

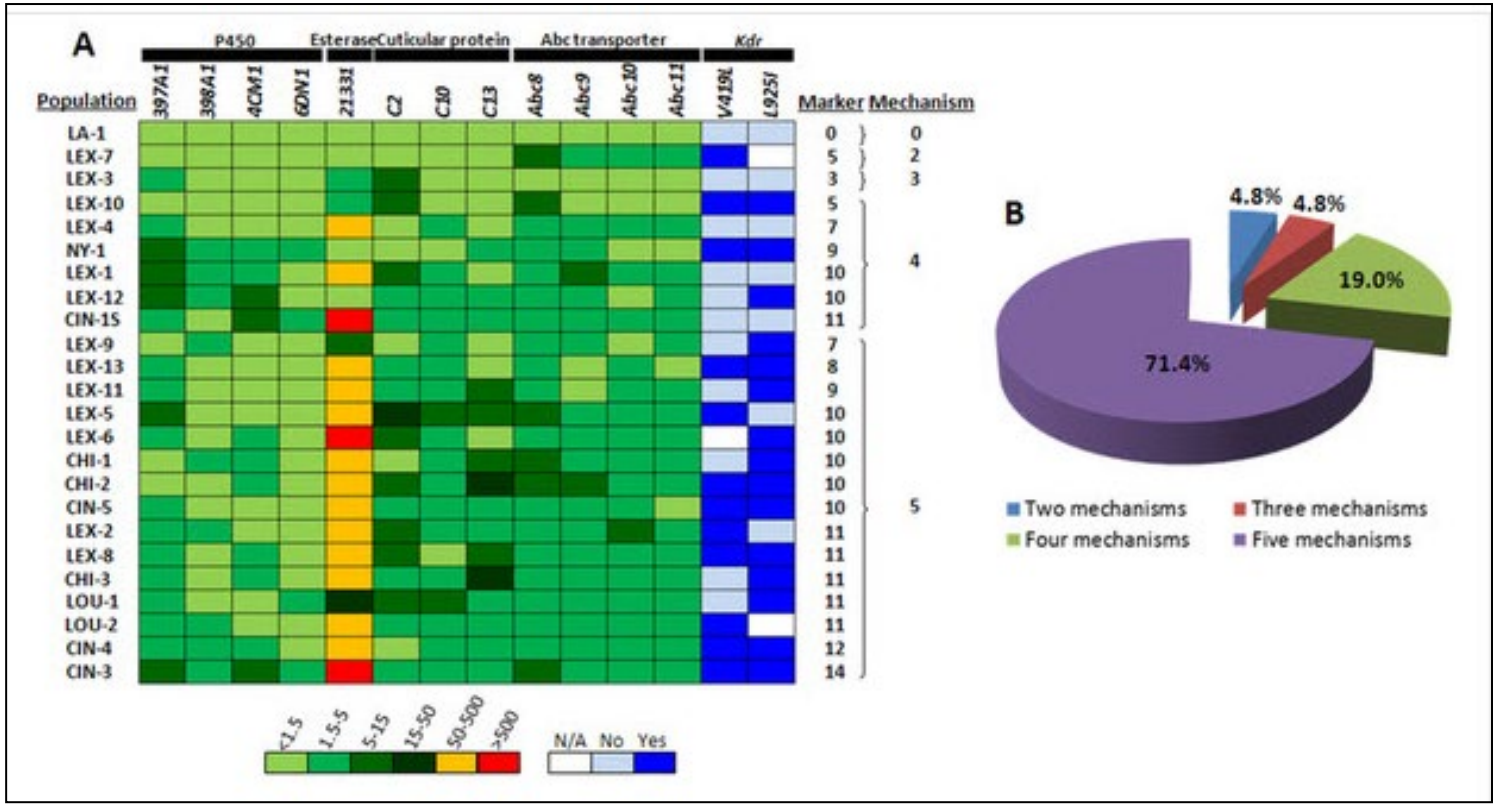
Relying solely on pesticides for control is a big mistake!


Photo: Stephen Doggett

88% of field tested bed bugs are highly resistant to commonly used pesticides

Zhu et al. 2013. Scientific Reports

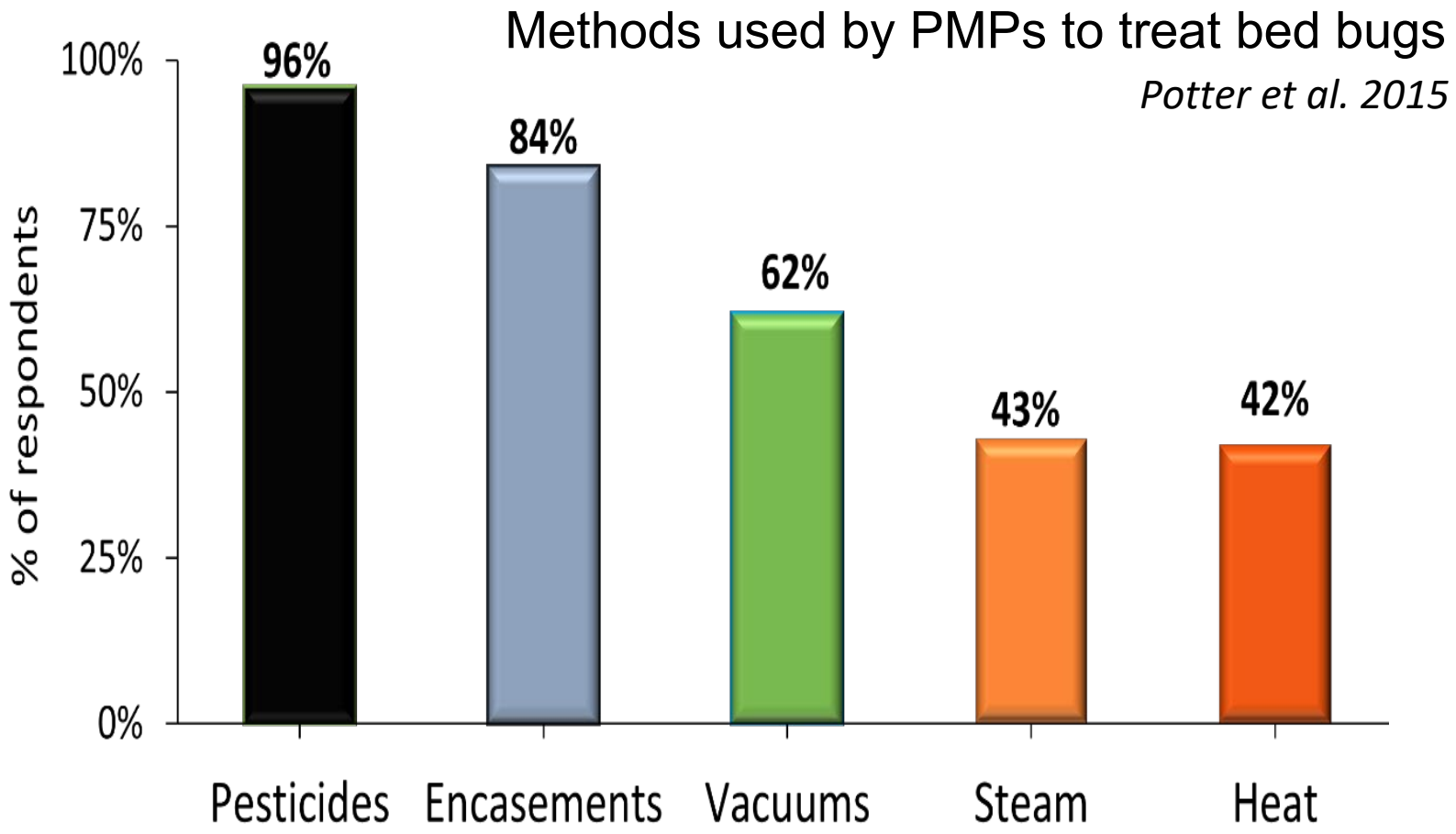
Multiple mechanisms of resistance is common



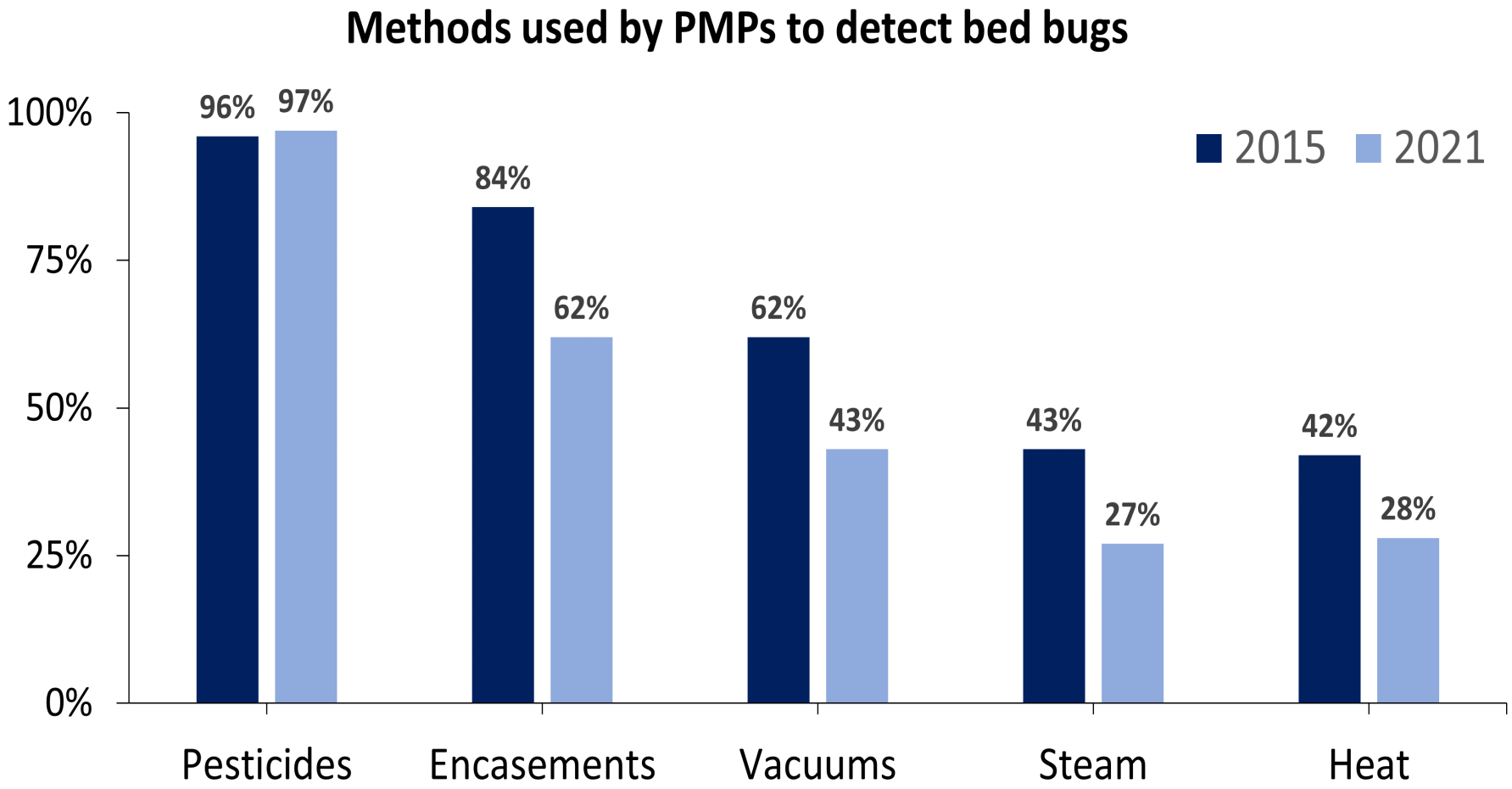
Among 24 populations 90% have 4-5 different mechanisms of resistance!

Fang et al. Nature, Scientific Reports 2013

Most pest management professionals rely upon pesticides for control



Disturbing trend: Greater reliance on pesticides



2011 PCT Bugs without Borders Survey
2022 PCT Bed Bug State of the Industry Survey

Non-chemical methods are among the most effective methods

- Encasements
- Vacuums
- Exposure to heat
  - Laundering
  - Steam
  - Portable heat chambers
  - Structural heat
- Exposure to freezing temps (freezers)
- Interceptors (not just for early detection)

Encasement of mattresses & box springs

Encasements crash populations quickly and easily

Decreased labor and more effective follow up visits

Vacuums efficient elimination of bed bugs on surfaces

Other benefits of a vacuum

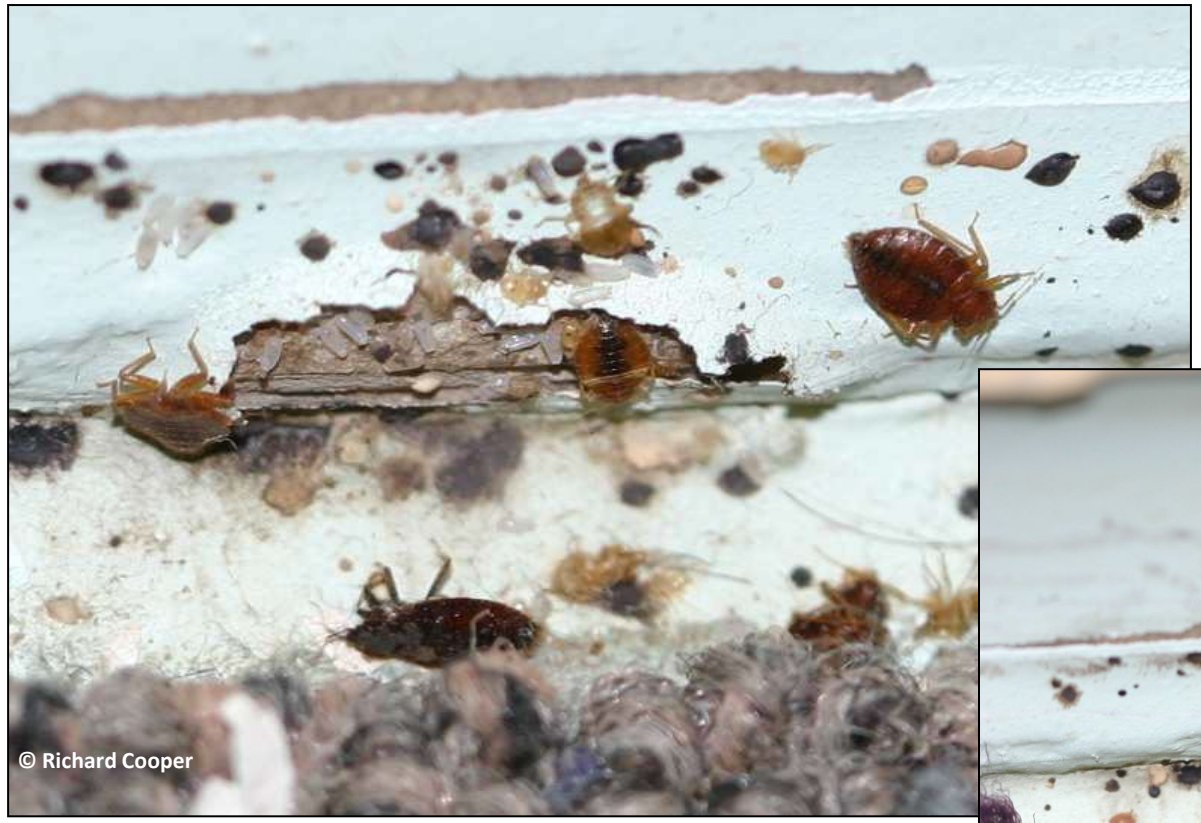
- Removal of dust and debris from areas to be treated
- Removal of dead bugs and shed skins
  - ✓ Eliminates old evidence
  - ✓ Eliminates harborages for young instars

Wang et al. 2009. J Med Entomol.
Cooper et al. 2015. J. Econ. Entomol.

Vacuuming has its limitations

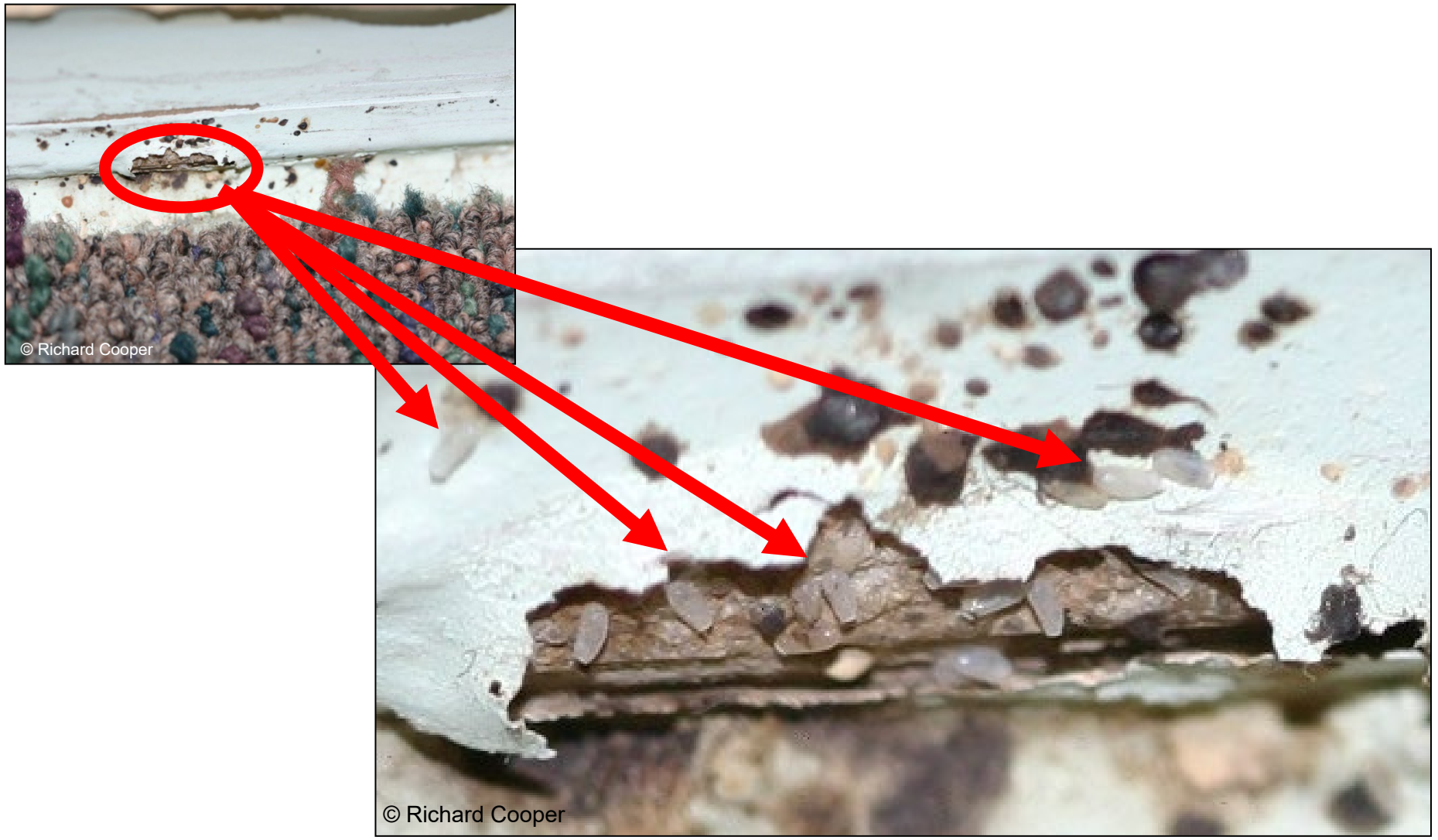
Vacuums won't effectively remove bugs from crevices

Eggs are not easily dislodged



Pre-Vacuuming

Post-Vacuuming


© Richard Cooper
© Richard Cooper

Steam overcomes limitations of vacuums

- **Penetrates cracks to depth of 6 cm**
- **Penetrates fabric to depth of 2 cm**

Stephen Kells 2007

Destroys all stages including eggs

Penetration of fabric & cracks

Inside Box Spring

198.5°F (92.5°C)

Window Frame ¼” Wood Panel

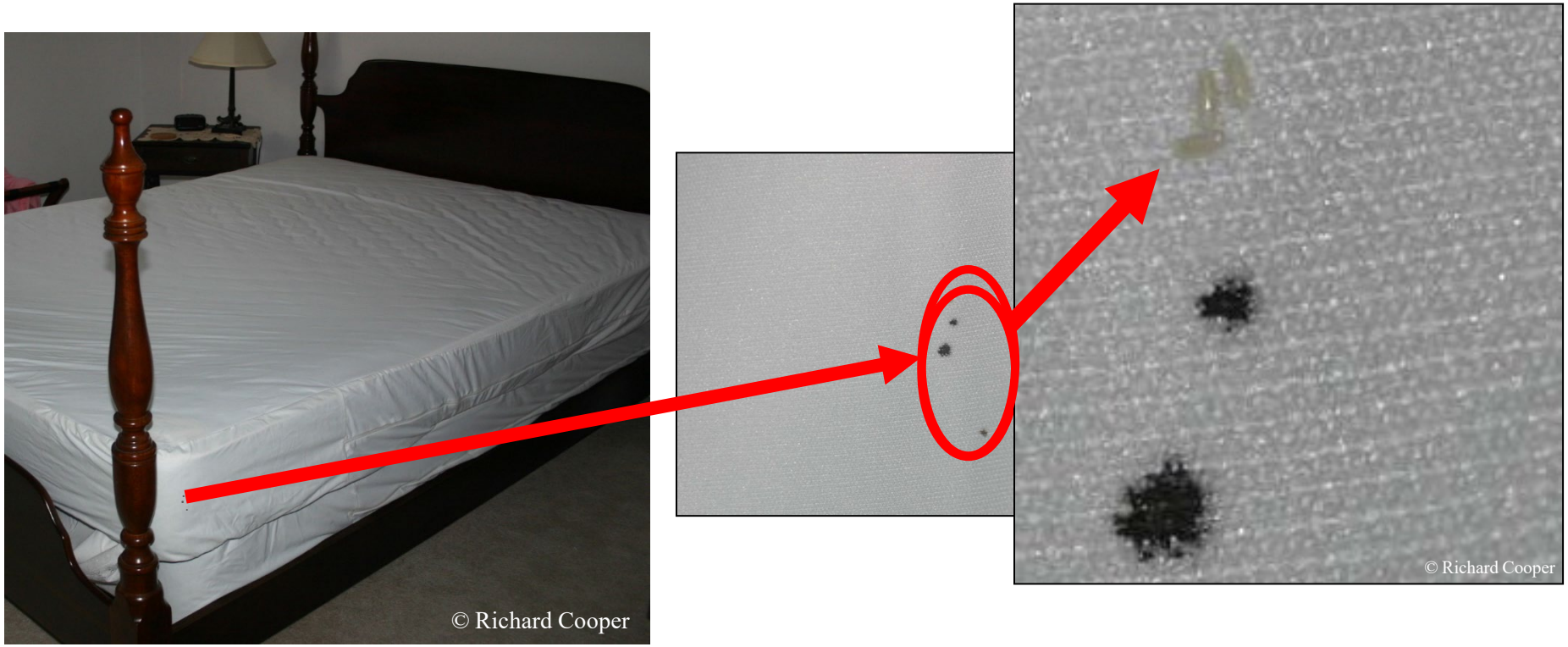
211.1°F (99.5°C)

Using steam doesn't have to be labor intensive

Not necessary to steam the entire sofa

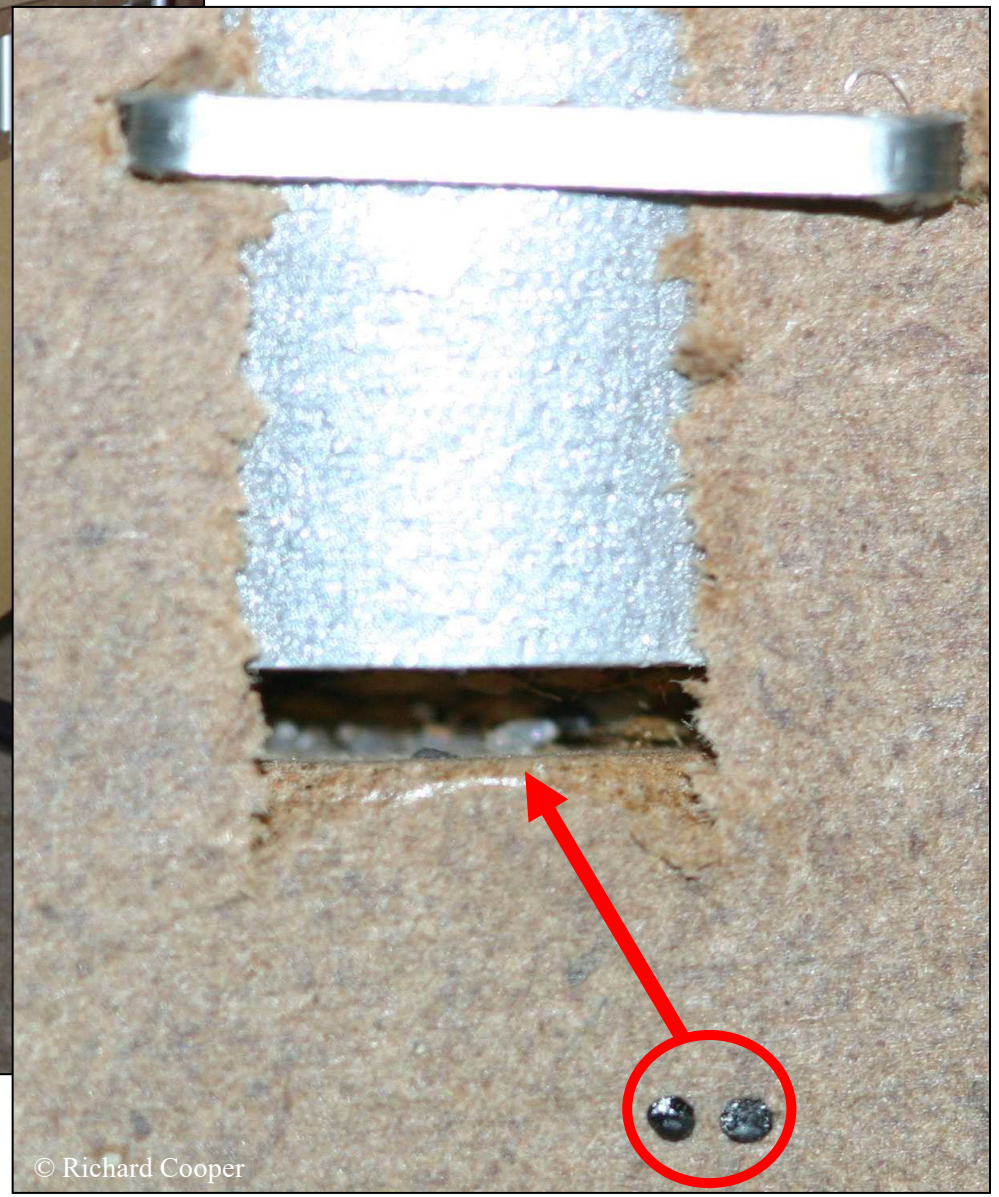
Limit steam to areas where evidence of bed bugs exists

Steaming areas where evidence exists can make the difference between success and failure



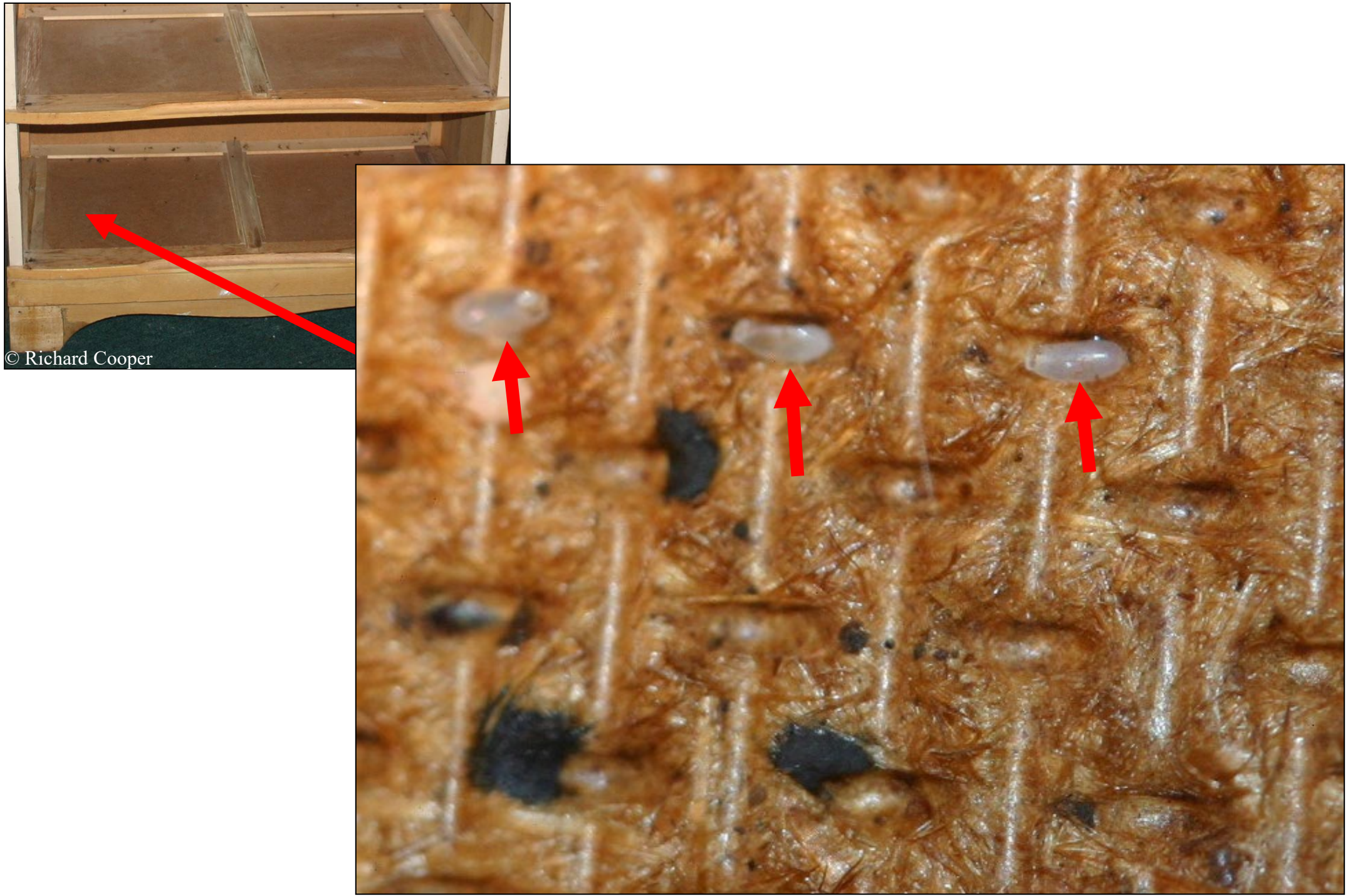
Eggs are often deposited close to fecal spots


© Richard Cooper

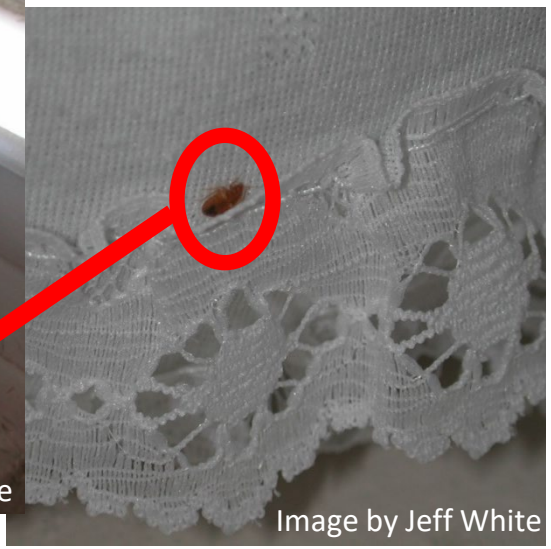

© Richard Cooper


© Richard Cooper


© Richard Cooper


© Richard Cooper

Hot laundering an effective method for destroying bed bugs and their eggs!



Portable heat chambers

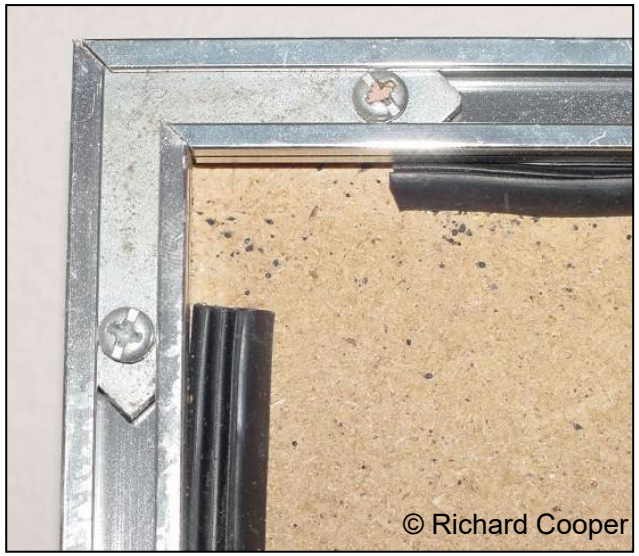


Photo courtesy of ZappBug

Personal items that can’t be hot laundered

Whole Structure Heat Treatment

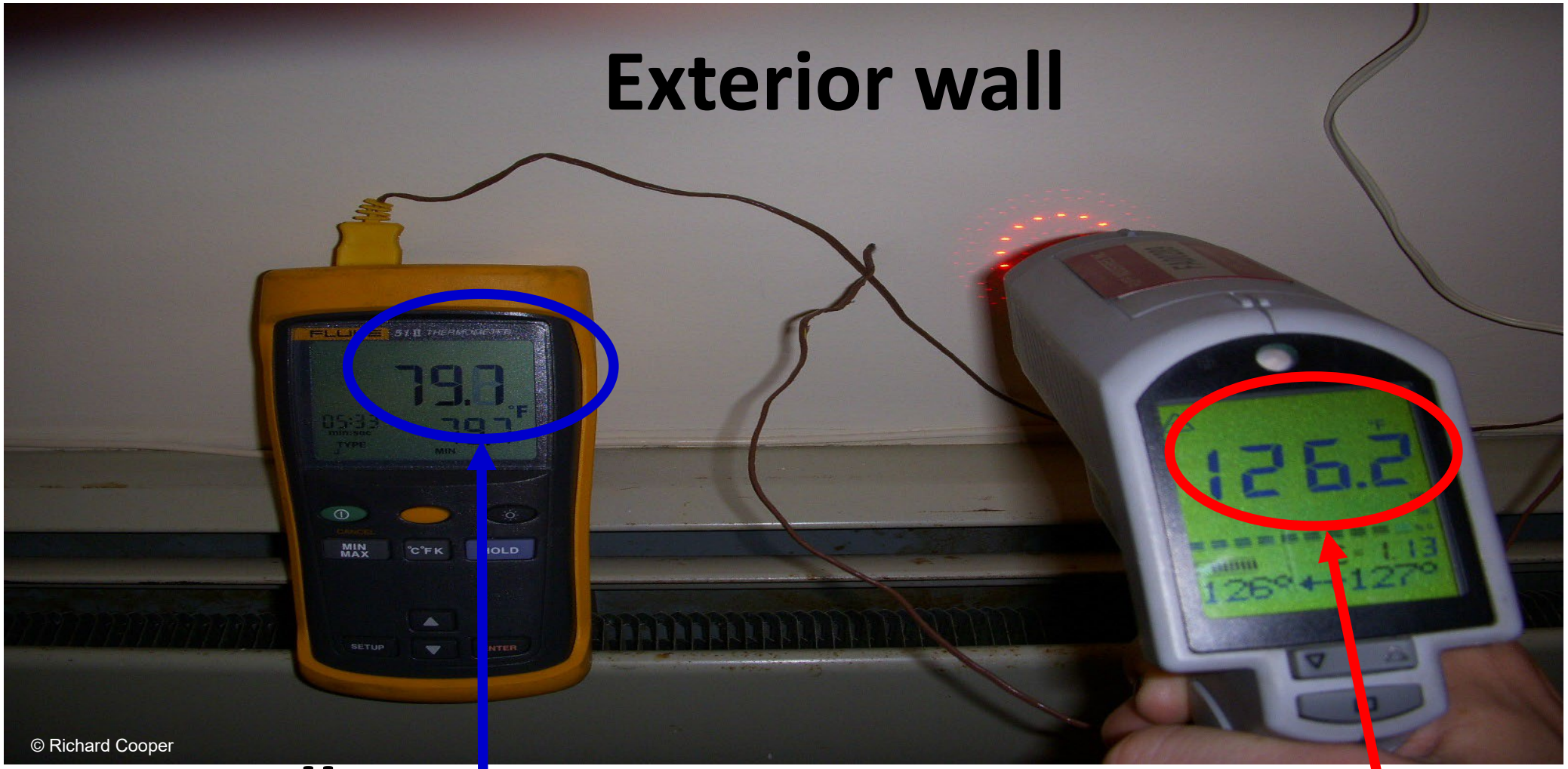
Need at least 122°F (50°C) in all locations

Some areas are difficult if not impossible to bring up to temperature

- **Heat sinks**
  - slabs, block walls, room contents
- **Cool spots**
  - base of wall, ext. insulated walls
- **Areas of Heat Loss**
  - crawl spaces, attics, poorly sealed structures

A heat treatment is typically a 4-6 hour job (or longer)

Ambient air temp @ 135°F (57.2°C)



Wall Void 79.7°F (26.5°C)

Surface of Wall 126.2°F (52.3°C)

Heat will not overcome excessive clutter like this!

What do we know about heat treatments?

- Requires a large capital investment to get proper equipment
- Expensive to protect fire suppression systems
- Requires skill, technique & field experience to reach lethal temperatures throughout structure
- Does not address clutter on its own, constant manipulation of environment is necessary
- Very effective at getting bugs out of all types of furniture (mattresses, box springs, sofas etc)
- Elimination is often possible in single visit but not always
- Best not to view as a stand-alone treatment

Freezing Temperatures (kills all stages including eggs)

Freezer

-18°C 4 days; below -20°C 48 hrs.

HOUSEHOLD AND STRUCTURAL INSECTS

Cold Tolerance of Bed Bugs and Practical Recommendations for Control

JOELLE F. OLSON,[1,2] MARC EATON,[1] STEPHEN A. KELLS,[1] VICTOR MORIN,[3] AND CHANGLU WANG[4]

J. Econ. Entomol. 106(6): 2433–2441 (2013); DOI: http://dx.doi.org/10.1603/EC13032

ABSTRACT Bed bugs were exposed to freezing temperatures for various exposure times to determine cold tolerance and mortality estimates for multiple life stages. The mean supercooling point for all bed bug life stages ranged from −21.3°C to −30.3°C, with the egg stage reporting the lowest value. A probit analysis provided a lower lethal temperature (LLT_{99}) of −31.2°C when estimates from all life stages were combined, demonstrating that all stages of bed bugs are not capable of surviving temperatures below body freezing and are therefore freeze intolerant. At conditions above the LLT_{99}, bed bug mortality depended on temperature and exposure time at temperatures above LLT_{99}. Based on our model estimates, survival was estimated for temperatures above −12°C even after 1 wk of continuous exposure. However, exposure to temperatures below −13°C will result in 100% mortality in d to ensure mortality of all life stages. Unfortunately, sublethal exposure to lower temperatures did not prevent subsequent feeding behavior in surviving stages. Practical recommendations for management of potentially infested items are discussed.

KEY WORDS freezing, bed bug, supercooling point, cold tolerance, nonchemical control

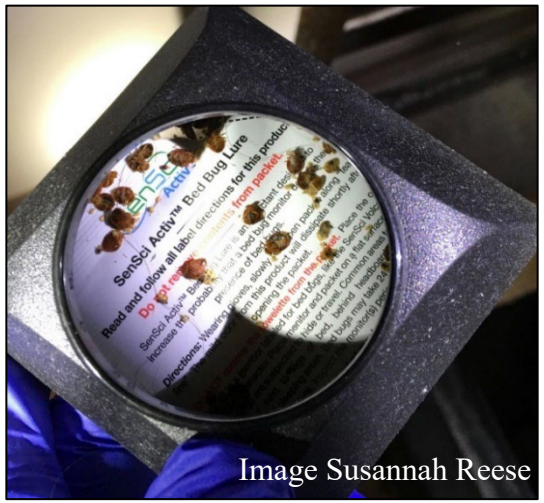
Bed bugs (*Cimex lectularius* L.) are a significant pest of humans and domestic animals. Changes in traditional pest management practices, insecticide resistance, increased international travel, and lack of public awareness may have attributed to the recent global resurgence of bed bugs (Pinto et al. 2007, Potter et al. 2010). Although bed bugs are not recognized as a disease vector, continuous human exposure may result in depression, anxiety, lack of sleep, and increased sensitivity to their bites (Goddard and deShazo 2009, in areas where bed bugs harbor (Potter et al. 2011). Recent reports demonstrating resistance to pyrethroid insecticides (Moore and Miller 2006, Romero et al. 2007, Steelman et al. 2008) and restrictions on indoor insecticide applications highlight the importance of an effective integrated pest management (IPM) program. An IPM program for bed bugs should include both chemical and nonchemical means for control.

Extreme temperatures have been used to control

Olsen et al. 2013. J. Econ. Entomol.

Interceptors are more than just a detection tool

Under legs in sleeping & resting areas



Away from sleeping areas

Other benefits include:

- Provide relief to clients (fewer bugs are able to get a blood meal)
- Mass trapping can lead to elimination of low-level infestations
- Can help pinpoint problems in difficult to solve infestations

Wang et al. 2009. J Med Entomol.
Cooper et al. 2015. J. Econ. Entomol.

Pesticides should be only be used for bed bug activity that occurs between service visits

1. **Never treat a bug that you see** (physically remove or destroy it)
2. **Use desiccant dust (i.e. CimeXa) to address movement of bed bugs between services** (treat areas that bed bugs are likely to encounter)

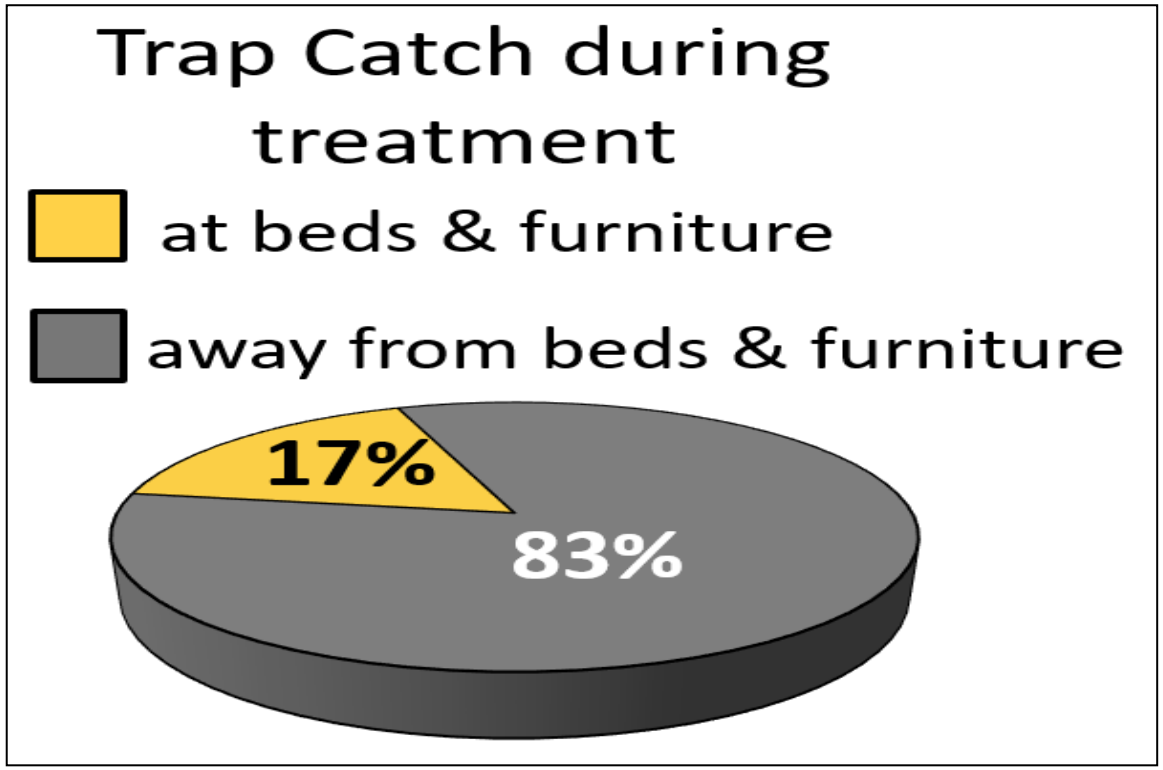
Infestations are rarely eliminated in a single visit

Multiple visits are often needed to eliminate infestations particularly when they are well-established

Cooper et al. 2015 Pest Management Science

Follow-up visits should be conducted at two week intervals and continue to until the infestation is eliminated

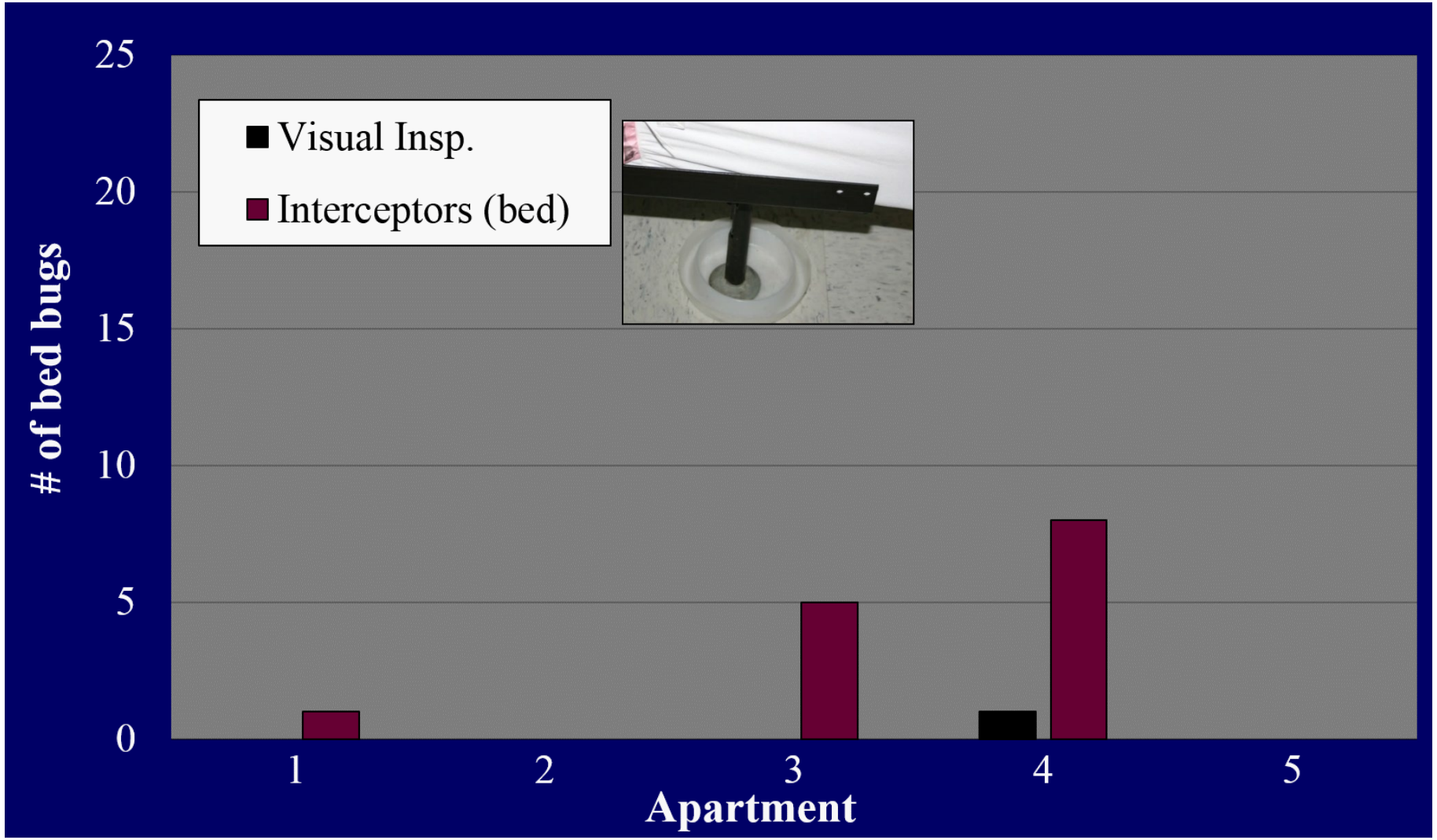
Confirming elimination is more difficult than detecting an infestation in the first place!



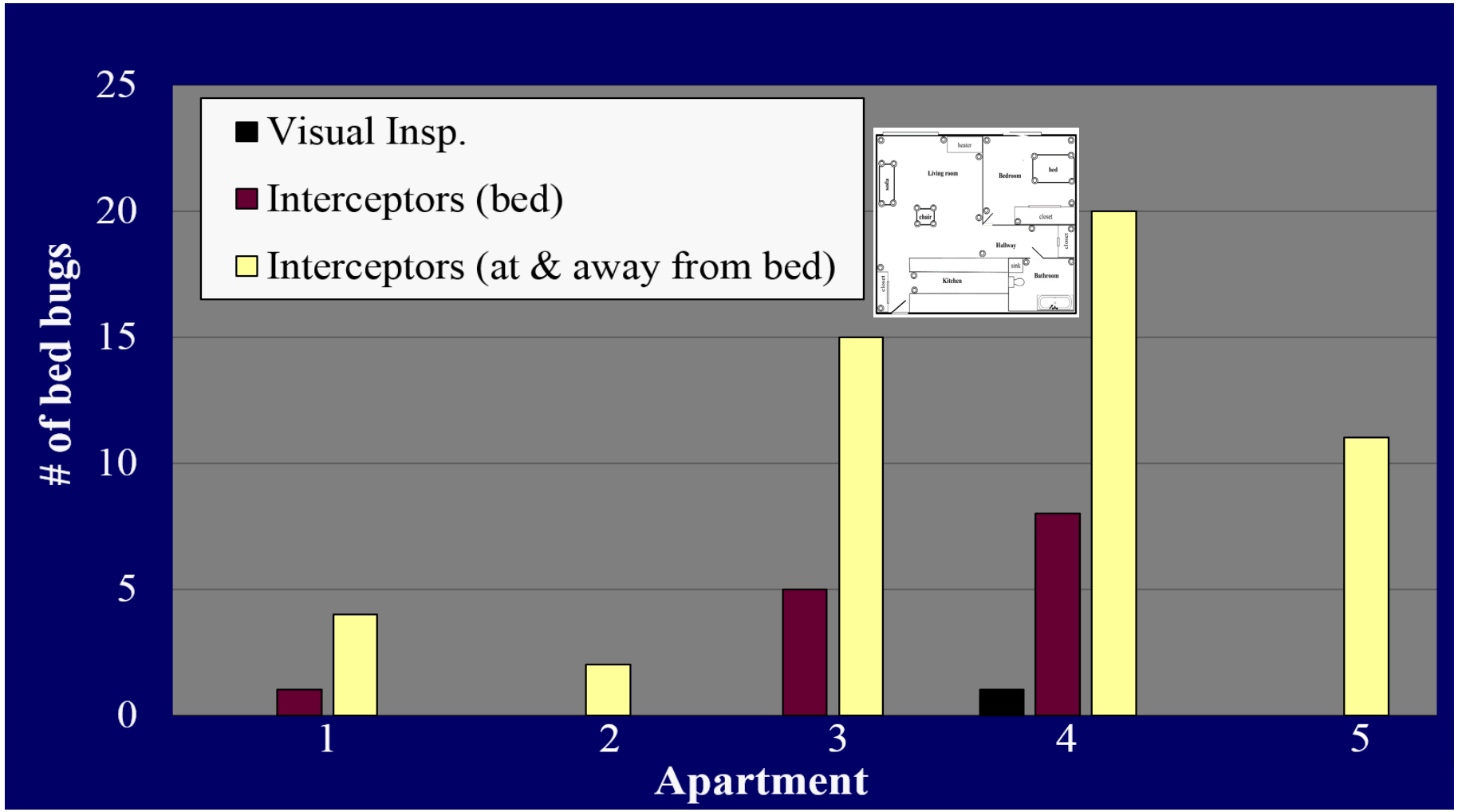
Just because you don't find them doesn't mean they aren't there!

Visual inspection (~ 20 min)

Addition of interceptors at beds (7d)



Addition of interceptors away from sleeping areas (7d)



Bed bug activity following termination of treatment efforts

Pitfall-style interceptors were placed at and away from beds and upholstered furniture for two weeks immediately after apartments were declared bed bug free (based upon visual inspection)

- 64% (41 of 64) of apartments had activity after bugs were believed to be gone
- 54% (22 of 41) of the time bugs only detected away from sleeping areas

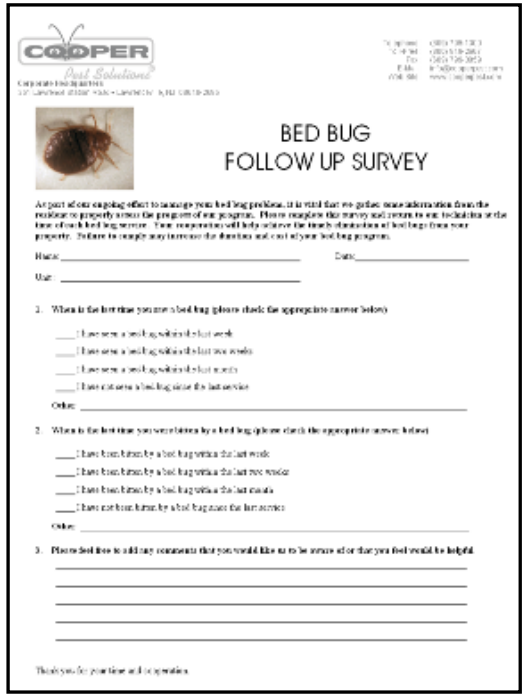
Cooper et al. J. Econ. Entomol. 2015

End result:

Infestations are often reduced
to low-levels rather than eliminated

Promotes the potential rebound of
populations and continued
spread of infestations

Multiple criteria used to determine when follow-up visits can be terminated



“Bug Free” & “Bite Free” for two weeks

Take home messages: treatment methods

1. Resistance to pesticide is widespread and bed bugs are well adapted to develop resistance to new chemistries
2. The majority of the industry relies upon pesticides that may or may not work
3. Fewer and fewer companies are using highly effective non-chemical measures (i.e. encasements, vacuums, and steam)
4. Reliance on pesticides will only continue to place greater selection pressure for resistance
5. It is important to have a robust procedure in place to determine when infestations have been eliminated in order to prevent premature termination of follow-up visits.

Applying what we have learned

Commercial implementation of an "assessment-based" program

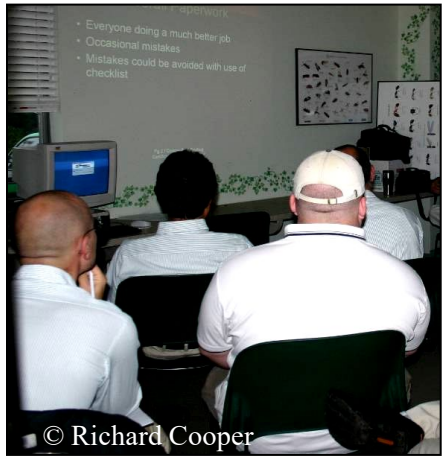
Affordable housing community in Newark, NJ

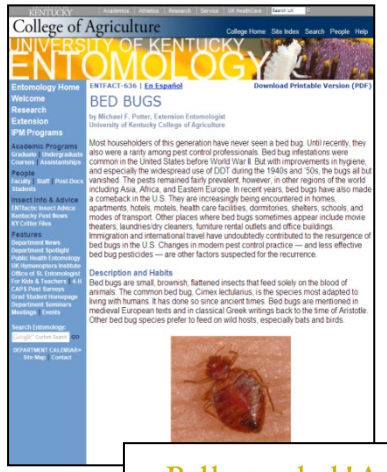
- Two 5-story bldgs. (360 apts.) with a chronic and severe bed bug problem
- Spending ~ $150,000 per year to treat bed bugs

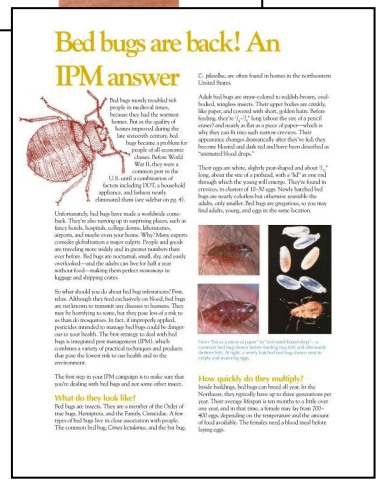
Educated apartment community (residents & staff)

Everyone needs to know:

1. **That bed bugs exist**
2. **How to avoid them**
3. **How to recognize the signs & symptoms of an infestation**
4. **What do if an infestation is suspected**







Annual community-wide inspection program

1. Visual inspection

2. Interceptors under beds & furniture 14 d

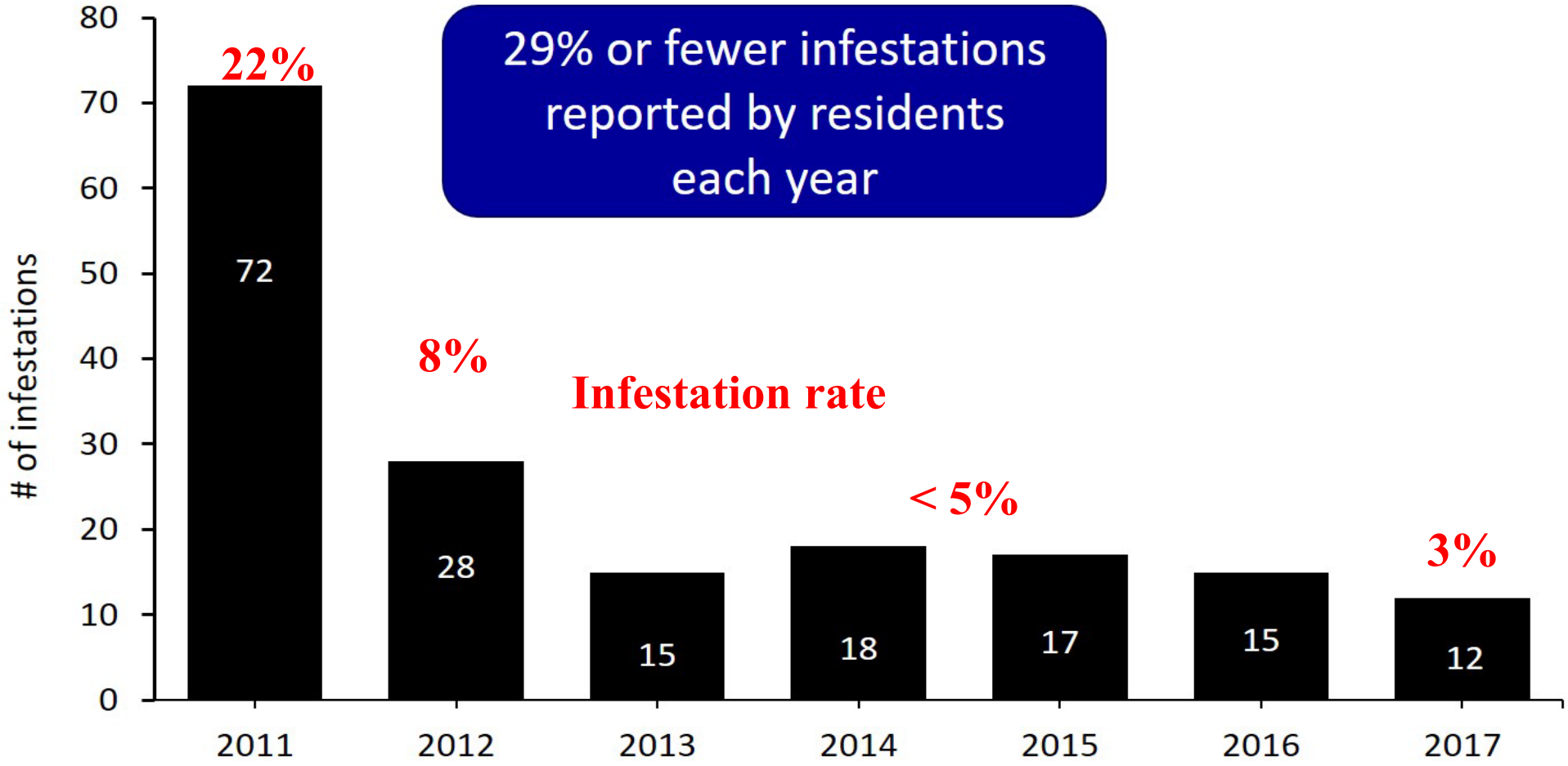
Treatment protocol

- Vacuum live bed bugs, shed skins, carcasses
- Steam upholstered furniture
- Encase mattresses and box springs
- Interceptors at beds & upholstered furniture
- Targeted pesticide applications
- Follow-up visits every 2 weeks until problem resolved
  - No bugs, bites or new evidence for 2 weeks

Additional proactive measures

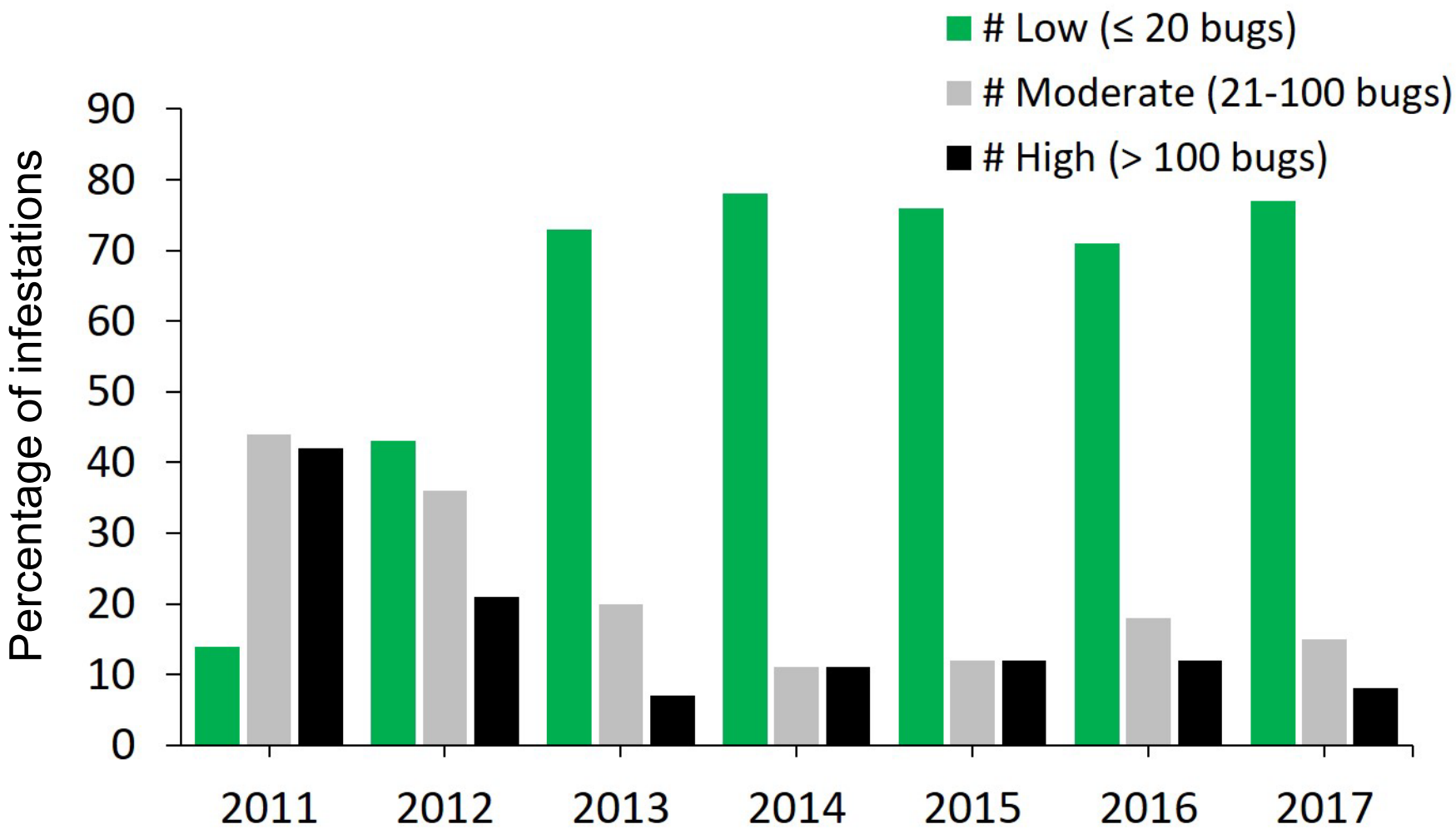
1. **New resident move-in program**
   Identify infestations at the gate
   - Inspect high risk items coming off moving truck
   - Address as best as you can, schedule treatment
2. **Resident move-out program**
   Prevent infested vacant units
   - Inspect & monitor when notified lease is not being renewed
   - Opportunity to treat problem prior to vacancy

Results over 7 years



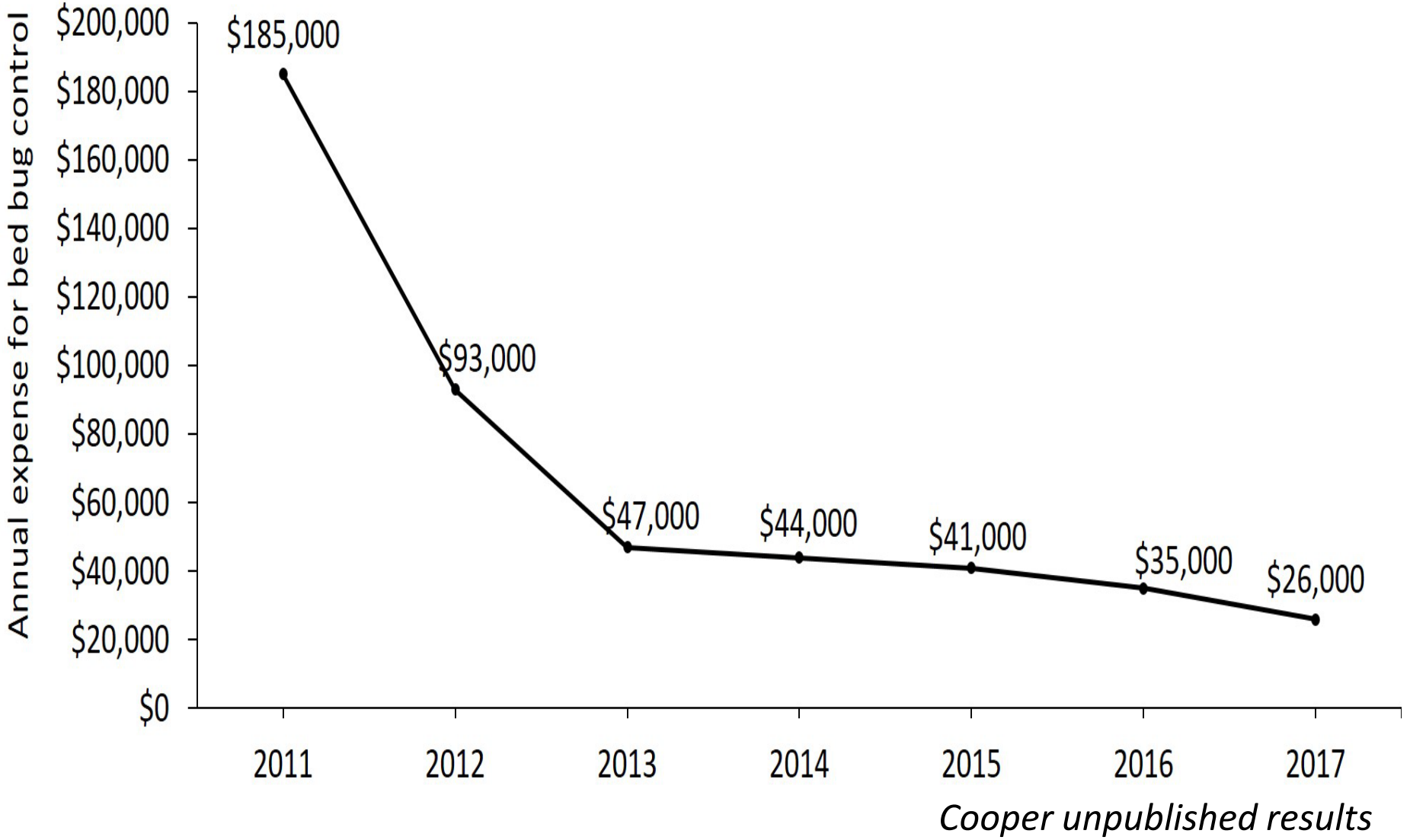
Cooper unpublished results

Severity of infestations over time



Cooper unpublished results

Annual cost savings over time



Cooper unpublished results

Keys to an effective bed bug management program

1. Use interceptors for early detection as well as to evaluate effectiveness of control effort, and to determine when an infestation has been eliminated
2. Avoid extensive one-size fits all client preparation
3. Don’t limit treatments only to rooms where bugs are seen
4. Utilize the most effective tools (integrate non-chemical methods into your program)
5. Include neighboring units in the scope of service (including across the hall)
6. Recommend building wide inspections for communities with known infestation rates of ≥5% or with chronic bed bug infestations

Thank You

Richard Cooper, PHD
R Cooper Consulting, LLC
Rutgers Univ. Urban Entomology Lab
rick@rcooperconsulting.net

R COOPER CONSULTING

SKA BRA
SKADEDYRBEDRIFTENES BRANSJEORGANISASJON