

Bed Bug Movement in Residential Environments & What to Do



Cuyahoga County Bed Bug Task Force, Nov. 1, 2019, 11 am – 12 pm

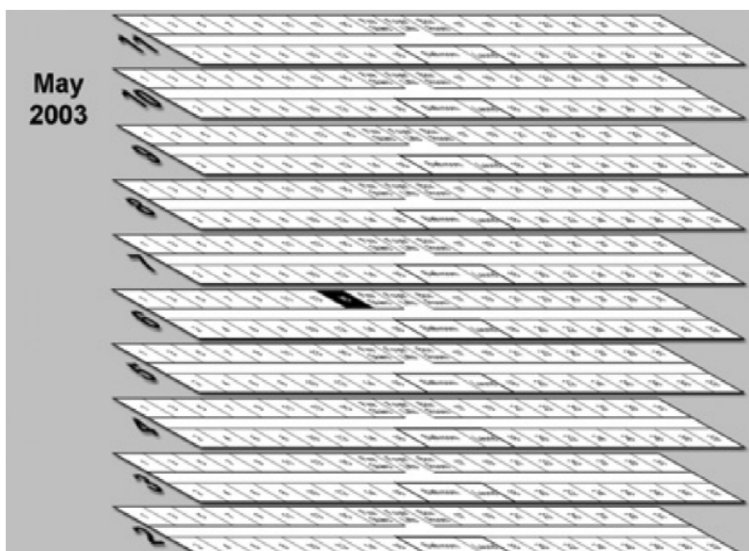
Karen Vail, kvail@utk.edu
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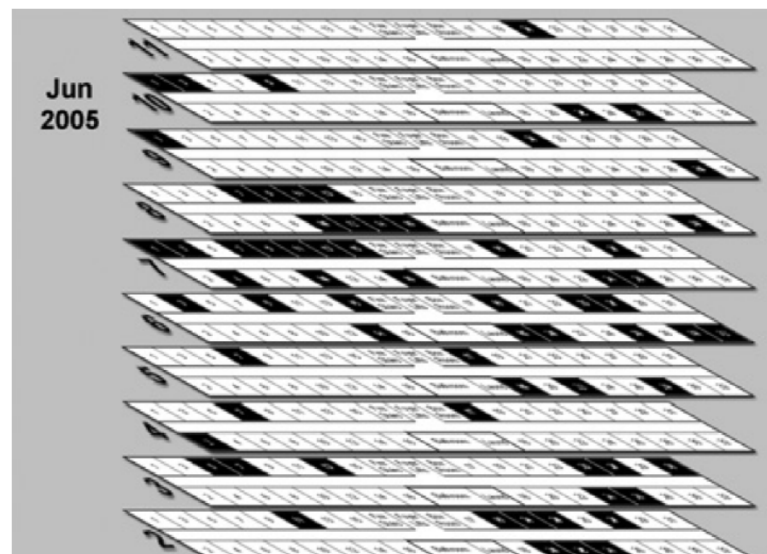
THE RESURGENCE OF BED BUGS, *CIMEX* SPP. (HEMIPTERA: CIMICIDAE) IN AUSTRALIA

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Characteristics of *Cimex lectularius* (Hemiptera: Cimicidae), Infestation and Dispersal in a High-Rise Apartment Building

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J. Econ. Entomol. 103(1): 172–177 (2010); DOI: 10.1603/EC09230

- 45% of 223-unit apartment building infested in 41 months
- Average 6 bed bugs dispersing through apartment entry doors
- Adults 9 times more likely to disperse than nymphs
- 53% of adjacent apartments also infested



CASE #1

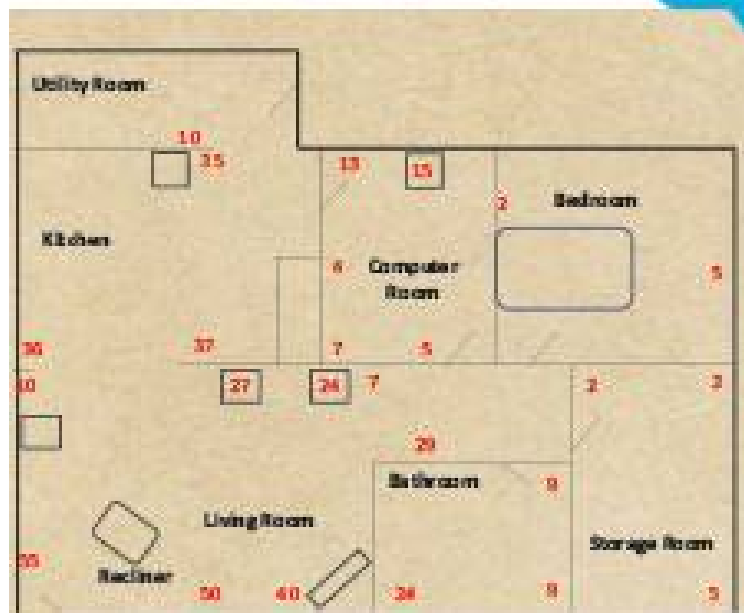


Fig. 1. Numbers of bed bugs captured in pitfall monitor locations one week after installation (Case Study #1).

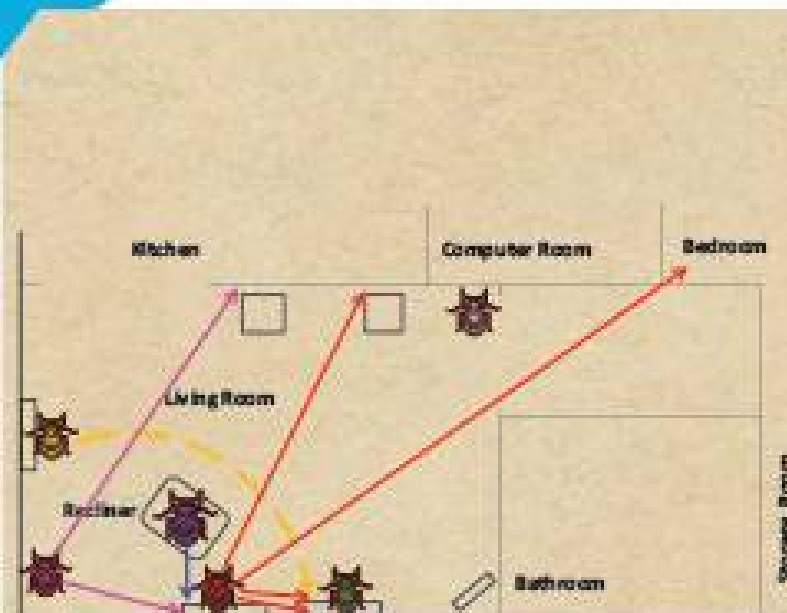
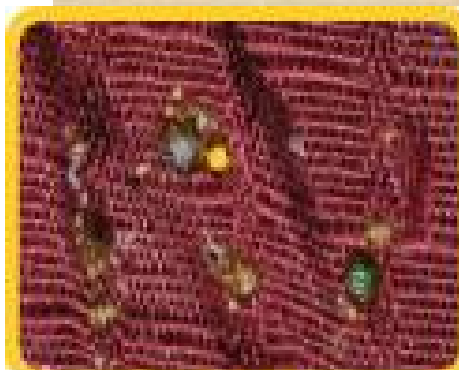


Fig. 2. Movement of marked bed bugs in case study #1. Colored arrows indicate where bugs were initially marked and found one week later.



a



b

Image 2a: Bed bugs initially residing on this window curtain were denoted with green paint. The yellow one traveled from another set of curtains about 15 feet away. Image 2b: The green and red bugs in this Blackout station originated from different sets of curtains in the living room.

<https://www.pctonline.com/article/pct0613-bed-bug-night-mobility/>

CASE #2



Fig. 3. Numbers of bed bugs captured in pitfall monitor locations one week after installation (case study #2).

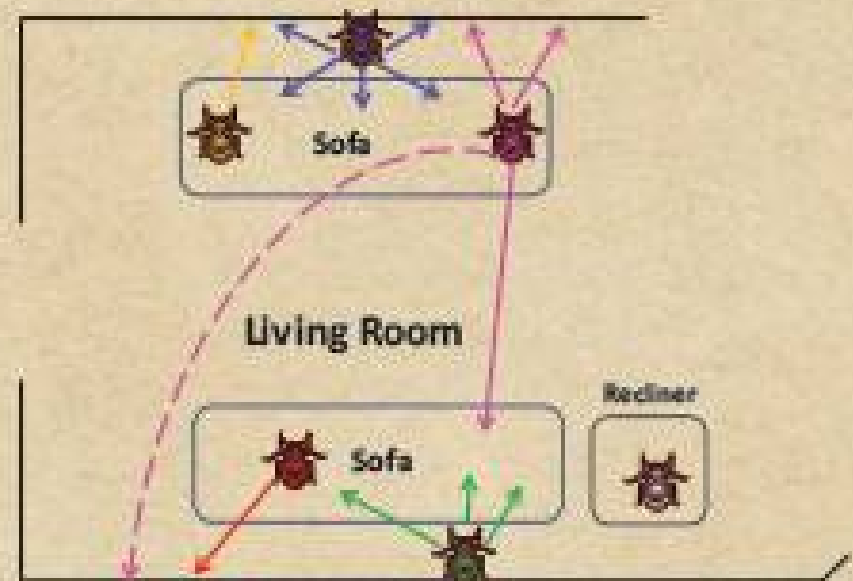


Fig. 4. Movement of marked bed bugs in case study #2. Colored arrows indicate where bugs were initially marked and found one week later.

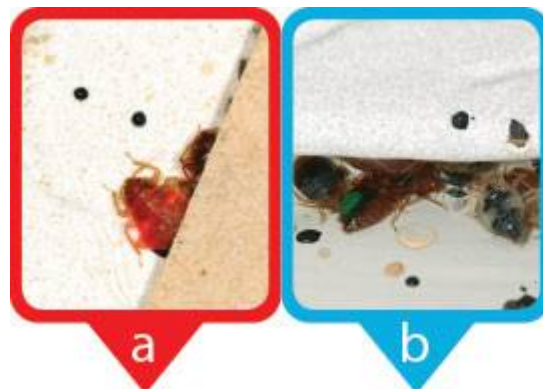


Image 3a: This bed bug moved from the floor to the back of a picture frame. Image 3b: The green-marked bug was spotted near the ceiling (the translucent-looking one had recently molted).

RESEARCH ARTICLE

Mark-Release-Recapture Reveals Extensive Movement of Bed Bugs (*Cimex lectularius* L.) within and between Apartments

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(2015) PLoS ONE doi:10.1371/journal.pone.0136462

Table 2. Trap and escape of bed bugs from interceptors.

Rep.	Number of bed bugs trapped in interceptors in 4 days					Number of bed bugs escaped from interceptors within 10 days				
	Adult males	Adult females	1 st instar nymphs	3 rd -5 th instar nymphs	Total	Adult males	Adult females	1 st instar nymphs	3 rd -5 th instar nymphs	Total
1	14	22	15	13	64	0	0	1	0	1
2	22	22	18	14	76	0	0	3	0	3
3	17	20	9	16	62	0	0	3	0	3
4	19	20	10	20	69	0	0	4	0	4
5	18	20	20	16	74	0	0	4	0	4
6	23	26	26	20	95	0	0	1	0	1
Sum	113	130	98	99	440	0	0	16	0	16
Mean	19	22	16	17	73	0	0	2.7	0	2.7

doi:10.1371/journal.pone.0136462.t002



Fig 2. Apartment diagrams and interceptor locations. Letters a to f refer to apartments #1 to 6, respectively. Circles indicate interceptor. Colored symbols with an “R” inside, indicate where marked bed bugs of a particular color were released.

Table 3. Cumulative recapture rate of marked and released bed bugs after 14 days.

Apt.#	Total recapture rate	Recapture rate by stage and adult sex			Recapture rate by release site ^a		
		Large nymphs	Male	Female	Bedroom	Living room	Bathroom
1	40%	^b	31%	54%	37% ^c		52%
2	31%		25%	38%	18%	76%	37%
3	28%		25%	30%	5.0%	60%	40%
4 ^d	6%		6%	7%	7%	5%	
5	72%		64%	79%	72%		
6	44%	50%	31%	38%	48%	45%	39%

^a This rate is the number of bed bugs released in a given room that were recaptured throughout the apartment divided by the number released in that room.

^b No marked bed bugs were released or the resident discarded harborages with marked bed bugs on the day of release (apt. #4).

^c Studio units (#1 and 5) had no distinction between the bedroom and living room.

^d Resident interfered with study by moving and emptying interceptor traps.

Table 4. Movement of marked bed bugs within apartments based on 14 day cumulative trap catch.

Apt.#	Total number of recaptured marked bed bugs	Percentage of marked bed bugs recaptured by location based upon point of release											
		Released in bedroom				Released in living room				Released in bathroom			
		Bed-room	Living room	Bath-room	Other ^a	Bed-room	Living room	Bath-room	Other	Bed-room	Living room	Bath-room	Other
2	85	73	18	6	3	23	71	3	3	24	64	6	6
3	22	50	0	0	50	0	75	0	25	38	25	12	25
6	208	51	21	12	16	24	51	11	14	27	33	22	18
Mean	105	58.0	13.0	6.0	23	15.7	65.7	4.7	14.0	29.7	40.7	13.3	16.3

^a Other areas include the apartment entry door, kitchen, hallway, and closets.

Table 5. Active dispersal of bed bugs revealed from m-r-r technique over 14–15 days.

Apt. #	# of unmarked/ marked bed bugs trapped in mark- release apt.	Number of unmarked/marked bed bugs captured in apts. surrounding the m-r-r apts.					% dispersal rate ^a	Areas where marked bed bugs dispersed from	Areas where marked bed bugs were recaptured in neighboring apts.
		Adjacent to the right	Adjacent to the left	Across hall	Above	Below			
1	3,090/280	8/1	3/0	6/0	120/0	37/0	0.4	Bed	Bedroom
2	220/85	3162/1	na	Na	1/0	1/0	1.2	Bed	Kitchen
3	288/22	0/0	0/0	Na	0/0	7/0	0	None	None
4	1,020/30	575/1	87/0	na.	1/0	0/0	3.2	Bed	Kitchen
5	11,315/258	2/0	na	2/0	5/0	1/0	0	None	None
6	1,924/208	26/2	27/4	7/4	na	3/1	5.0	Bedroom, living room, bathroom	Kitchen, hall, living room

^a Dispersal rate is calculated as the total number of marked bed bugs recaptured in neighboring apartments divided by the total number of marked bed bugs recaptured.

doi:10.1371/journal.pone.0136462.t005

3 apts – 1 bed bug moved to another apartment

1 apt – 11 bed bugs dispersed to 4 apartments (right, left, across, below, no apt above)

Table 6. Bed bug population estimation based on m-r-r technique.

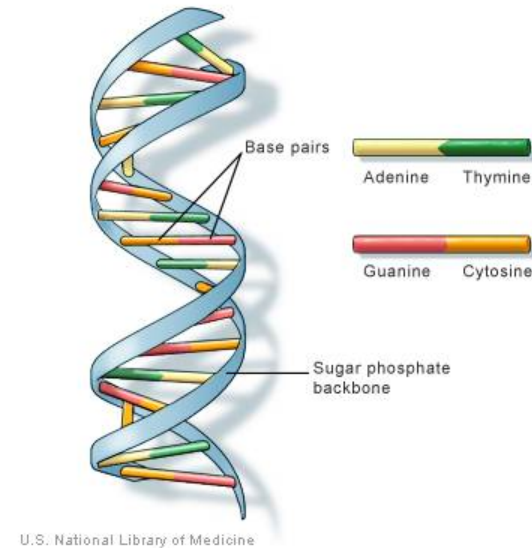
Apt. #	Trapping period	Total # of marked adult bed bugs existed at 4 d ¹	Proportion of marked adult bed bugs ²	Estimated total adults	Proportion of adults in unmarked bed bugs	Estimated total population	Standard deviation
1	4 to 7 d	505	0.3778	1,337	0.09354	14,291	1,578
2	4 to 6 d	226	0.7059	320	0.13158	2,433	381
5	4 to 7 d	177	0.1396	1,268	0.10304	12,305	1,630
6	4 to 7 d	173	0.5476	316	0.02794	11,306	1,586

¹ This is the number of bed bugs initially released minus the recaptured marked bed bugs during the first three days.

² This is the $(R+1)/(C+1)$ used in the formula for population estimation.

What is DNA?

- Hereditary material passed from parent to offspring
- Made up of 4 bases: A, T, C, G
- A always pairs with T,
- C always pairs with G



What are microsatellites?

- Microsatellites are small tandem repeats in DNA sequences



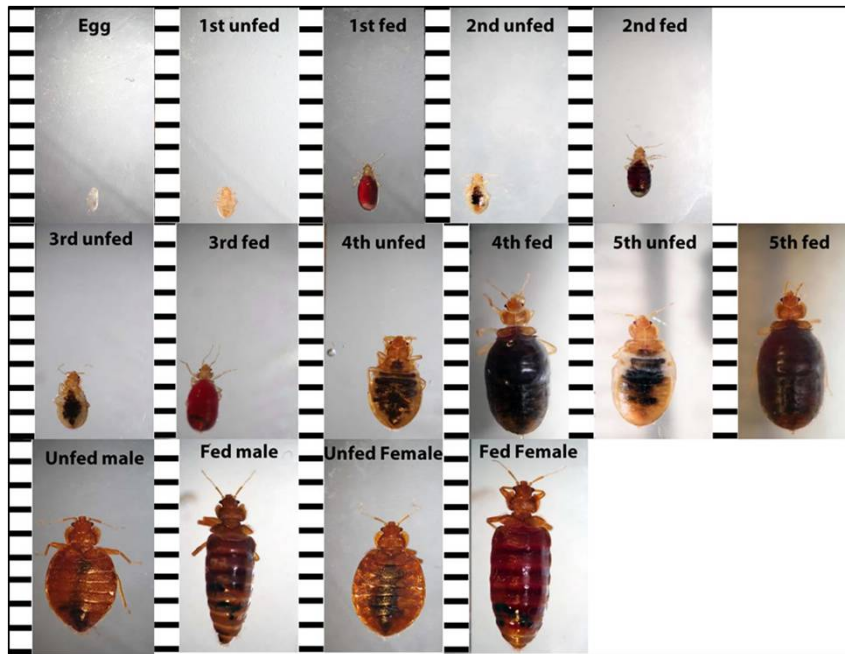
- Microsatellites can be used to determine relatedness of individuals

Molecular Markers Reveal Infestation Dynamics of the Bed Bug (Hemiptera: Cimicidae) Within Apartment Buildings

WARREN BOOTH,^{1,2} VIRNA L. SAENZ,¹ RICHARD G. SANTANGELO,¹ CHANGLU WANG,³
COBY SCHAL,¹ AND EDWARD L. VARGO¹

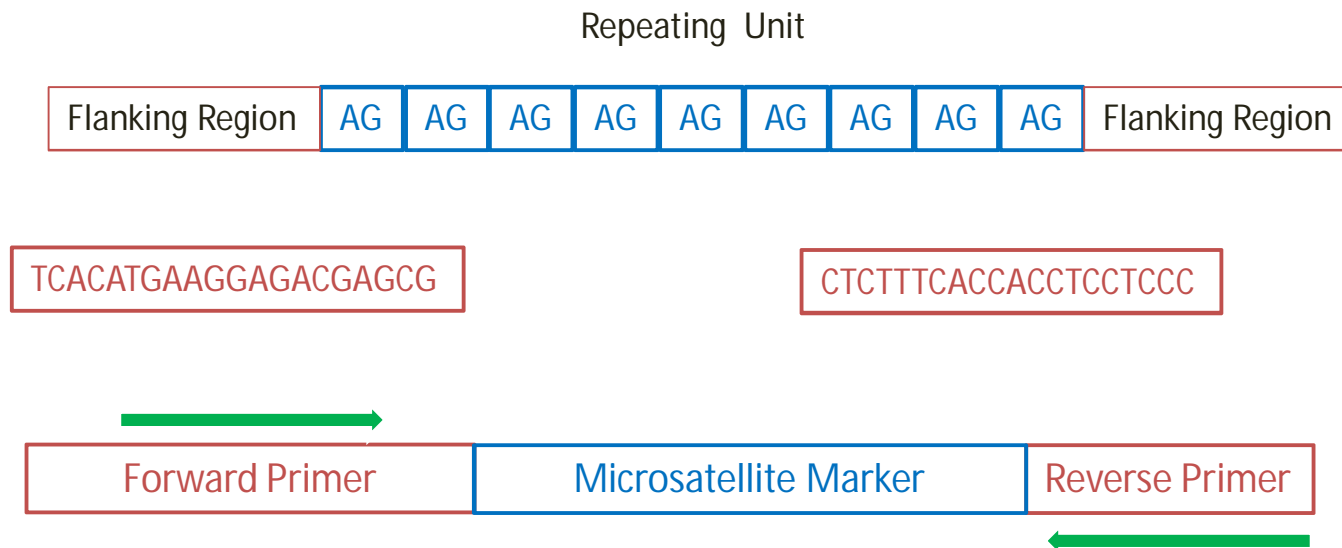
- In Raleigh, NC: a single introduction followed by extensive spread.
- In Jersey City, NJ: two or more introductions followed by spread are evident in two buildings.
- Spread within buildings is extensive, supporting both active and human-mediated dispersal.
- **What's happening in low-income multifamily housing in eastern TN??**

Bed bug biology refresher



- Females can store sperm & produce fertile eggs for ~60 days. In a lab setting, females laid ~3.5 eggs/day for ~70 days. (Matos et al 2017)
- Nymphs must feed to molt to the next life stage

Microsatellite markers & primer development

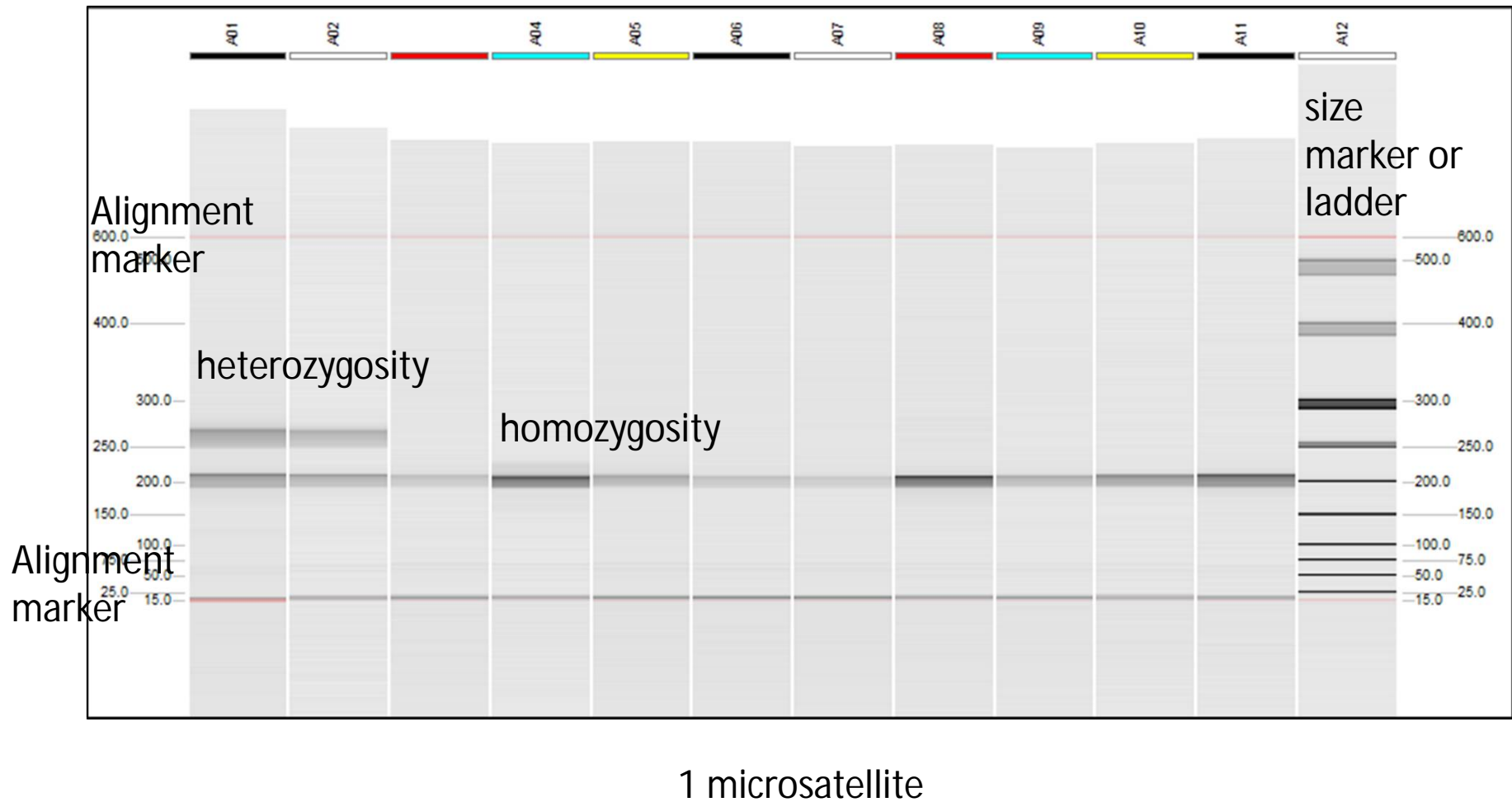


Amplification of 17 microsatellites for genotyping

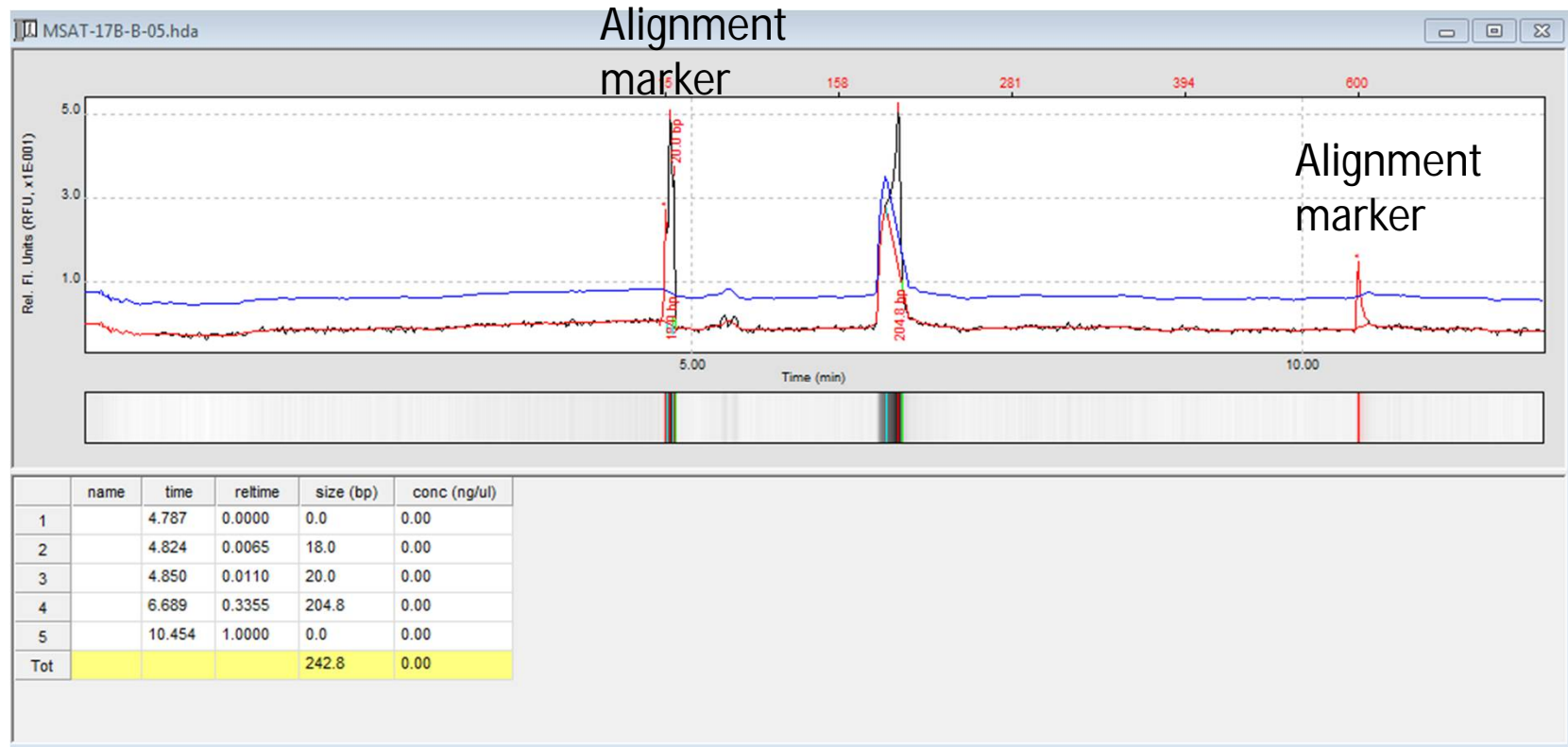


PCR to make lots of DNA

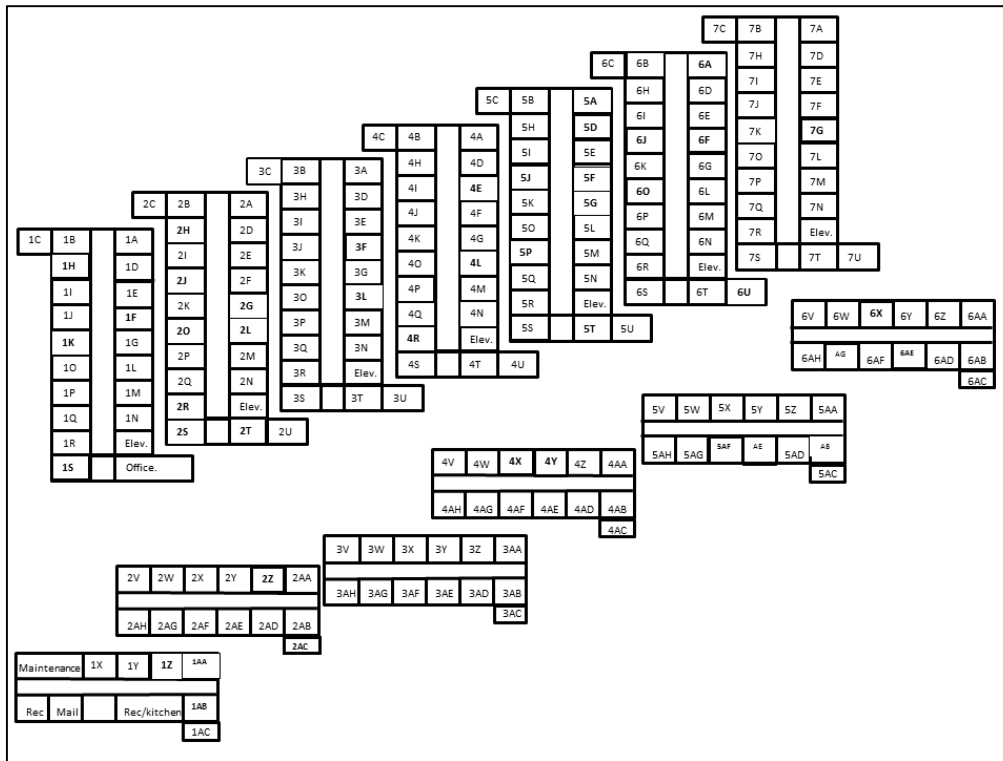
QIAxcel capillary electrophoresis



Raw allele lengths compared to determine differences



Buildings sampled



Buildings sampled

7A	7B	7D	7F	7H		7L	7N	7P	7R	7S
	7C	7E	7G	7I	7J	7K	7M	7O	7Q	
6A	6B	6D	6F	6H		6L	6N	6P	6R	6S
	6C	6E	6G	6I	6J	6K	6M	6O	6Q	
5A	5B	5D	5F	5H		5L	5N	5P	5R	5S
	5C	5E	5G	5I	5J	5K	5M	5O	5Q	
4A	4B	4D	4F	4H		4L	4N	4P	4R	4S
	4C	4E	4G	4I	4J	4K	4M	4O	4Q	
3A	3B	3D	3F	3H		3L	3N	3P	3R	3S
	3C	3E	3G	3I	3J	3K	3M	3O	3Q	
2A	2B	2D	2F	2H		2L	2N	2P	2R	2S
	2C	2E	2G	2I	2J	2K	2M	2O	2Q	
1A	1B	1D	1F	1H		1L	1N	1P	1R	1S
	1C	1E	1G	1I		1K	1M	1O	1Q	

- Building B:
 - 132 studio & 1 BR with 2BR on ends of hallways
 - Senior, disabled & near-elderly

Buildings sampled

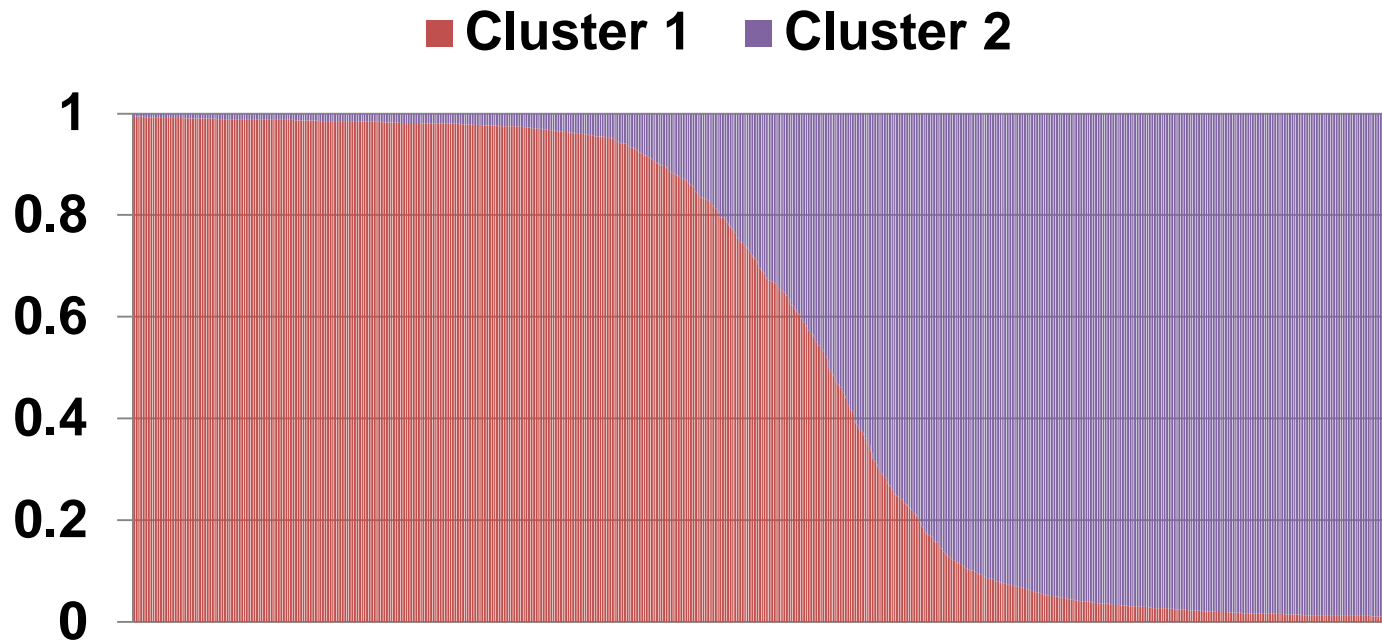
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	13S	13R	13P	13N	13L		14J	14H	14F	14D	14B	14A
12V	12U	12S	12Q	12O	12M		13K	13I	13G	13E	13C	
	12S	12R	12P	12N	12L		13J	13H	13F	13D	13B	13A
11V	11U	11S	11Q	11O	11M		12K	12I	12G	12E	12C	
	11S	11R	11P	11N	11L		12J	12H	12F	12D	12B	12A
10V	10U	10S	10Q	10O	10M		11K	11I	11G	11E	11C	
	10S	10R	10P	10N	10L		11J	11H	11F	11D	11B	11A
9V	9U	9S	9Q	9O	9M		10K	10I	10G	10E	10C	
	9T	9R	9P	9N	9L		10J	10H	10F	10D	10B	10A
8V	8U	8S	8Q	8O	8M		9K	9I	9G	9E	9C	
	8T	8R	8P	8N	8L		9J	9H	9F	9D	9B	9A
7V	7U	7S	7Q	7O	7M		8K	8I	8G	8E	8C	
	7T	7R	7P	7N	7L		8J	8H	8F	8D	8B	8A
6V	6U	6S	6Q	6O	6M		7K	7I	7G	7E	7C	
	6T	6R	6P	6N	6L		7J	7H	7F	7D	7B	7A
5V	5U	5S	5Q	5O	5M		6K	6I	6G	6E	6C	
	5T	5R	5P	5N	5L		6J	6H	6F	6D	6B	6A
4V	4U	4S	4Q	4O	4M		5K	5I	5G	5E	5C	
	4T	4R	4P	4N	4L		5J	5H	5F	5D	5B	5A
3V	3U	3S	3Q	3O	3M		4K	4I	4G	4E	4C	
	3T	3R	3P	3N	3L		4J	4H	4F	4D	4B	4A
2V	2U	2S	2Q	2O	2M		3K	3I	3G	3E	3C	
	2T	2R	2P	2N	2L		3J	3H	3F	3D	3B	3A
							2K	2I	2G	2E	2C	
							2J	2H	2F	2D	2B	2A

- Building C:
 - 276 studio & 1BR apts
 - Seniors
 - 2nd & 3rd floors offer supportive services
 - 14 stories. Only collected samples from 2nd-4th & half of 5th floors

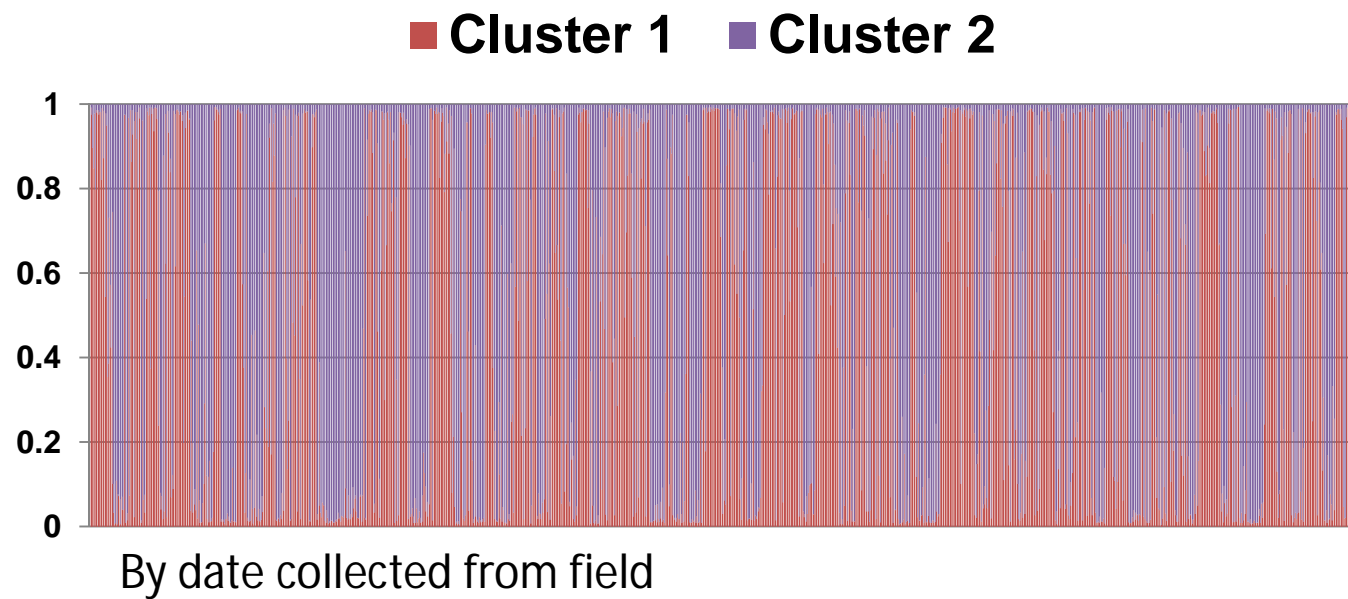
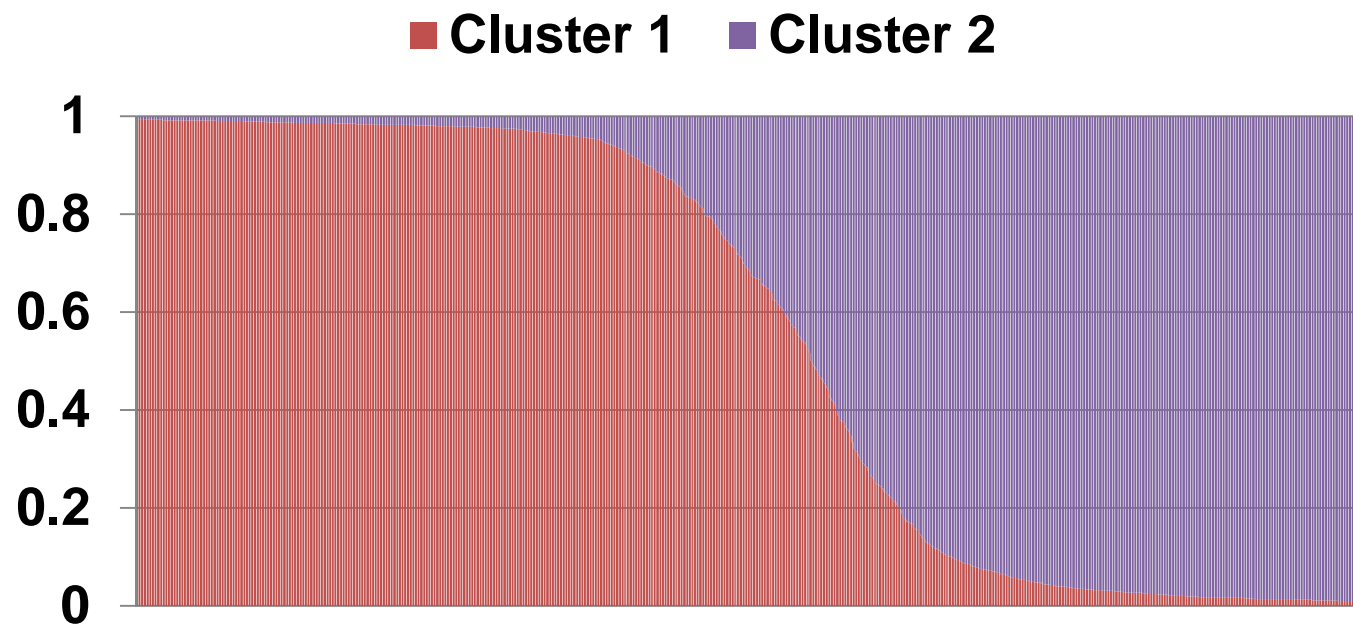
Bed bug collection

Site	No. of apartments	No. of bed bugs	Adults	Nymphs
Building A	64 + 10 opportunistic	1093 Range 1-126	430	663
Building B	23	294 Range 1-77	121	173
Building C	14 + office	142 Range 1-29	62	80
Total	101	1529	613	916

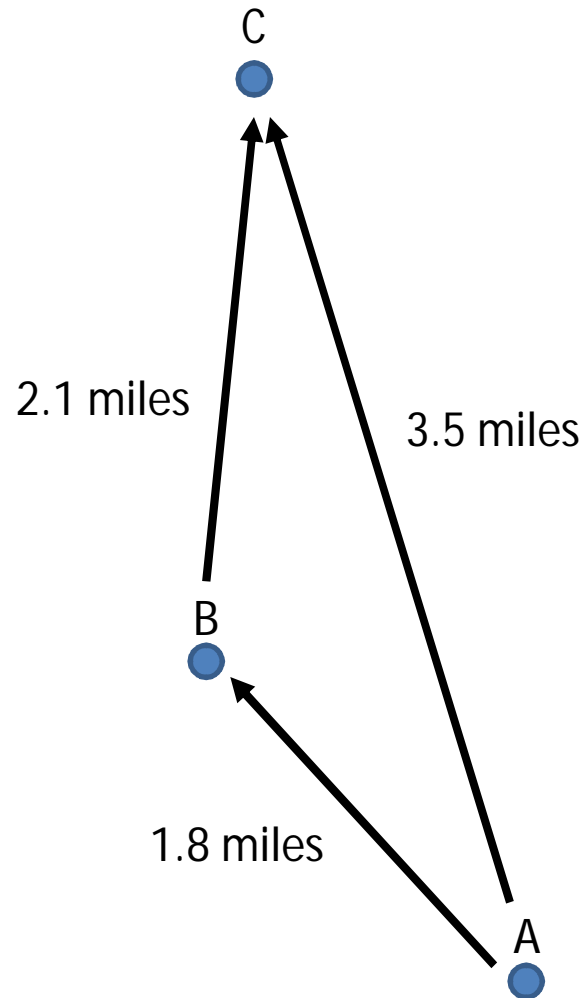
Collection dates 12-2013 through 3-2014



Site	Cluster 1 # bugs (# apts)	Cluster 2 # bugs (# apts)	Unassigned # bugs (# apts)
Building A	440 (43)	503 (59)	150 (39)
Building B	157 (19)	81 (14)	56 (15)
Building C	79 (13)	38 (8)	25 (11)
Total	676 (75)	622 (81)	231 (65)



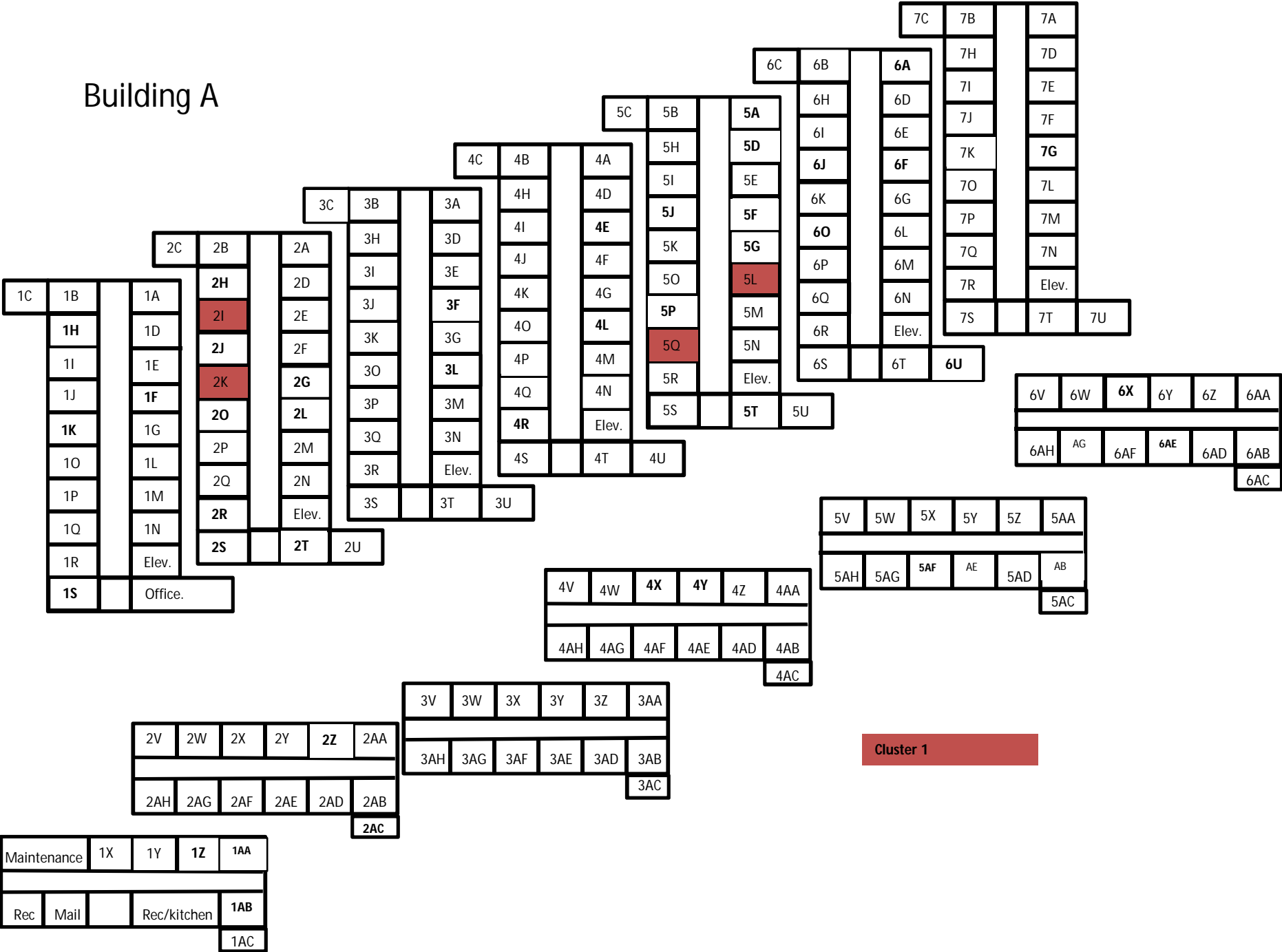
Distance between buildings



Things we don't know

- Which cluster/population was introduced first
- How long ago the bed bugs were introduced
- Which apartment(s) the bed bugs were first introduced
- Where the bed bugs were introduced from

Building A



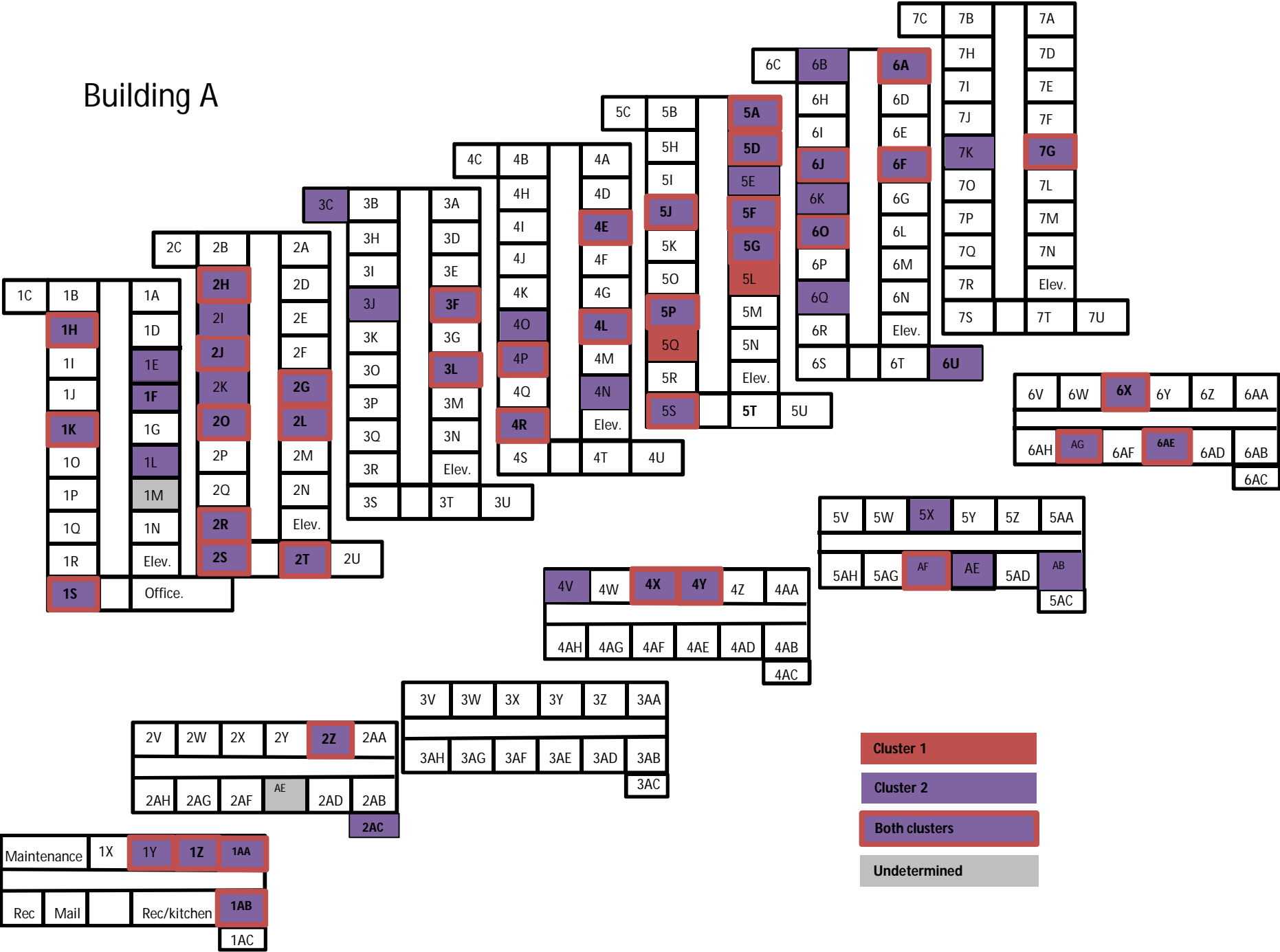
Building A

The floor plan shows a complex arrangement of rooms across multiple levels. Rooms are color-coded into two clusters:

- Cluster 1 (Red):** Includes rooms 2I, 2K, 5L, 5Q, 5R, 5U, 6A, 6F, 6G, 6H, 6I, 6J, 6K, 6O, 6P, 6Q, 6R, 6S, 6T, 6U, 6V, 6W, 6X, 6Y, 6Z, 6AA, 6AH, 6AG, 6AF, 6AE, 6AD, 6AB, 6AC.
- Cluster 2 (Purple):** Includes rooms 1E, 1F, 1L, 1N, 1S, 2A, 2B, 2C, 2D, 2E, 2F, 2G, 2H, 2J, 2L, 2M, 2N, 2O, 2P, 2Q, 2R, 2S, 2T, 2U, 2V, 2W, 2X, 2Y, 2Z, 2AA, 2AB, 2AC, 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3I, 3J, 3K, 3L, 3M, 3N, 3O, 3P, 3Q, 3R, 3S, 3T, 3U, 3V, 3W, 3X, 3Y, 3Z, 3AA, 3AB, 3AC, 4A, 4B, 4C, 4D, 4E, 4F, 4G, 4H, 4I, 4J, 4K, 4L, 4M, 4N, 4O, 4P, 4Q, 4R, 4S, 4T, 4U, 4V, 4W, 4X, 4Y, 4Z, 4AA, 4AB, 4AC, 4AH, 4AG, 4AF, 4AE, 4AD, 4AB, 4AC, 5A, 5B, 5C, 5D, 5E, 5F, 5G, 5H, 5I, 5J, 5K, 5L, 5M, 5N, 5O, 5P, 5Q, 5R, 5S, 5T, 5U, 5V, 5W, 5X, 5Y, 5Z, 5AA, 5AB, 5AC, 5AH, 5AG, 5AF, 5AE, 5AD, 5AB, 5AC, 6A, 6B, 6C, 6D, 6E, 6F, 6G, 6H, 6I, 6J, 6K, 6L, 6M, 6N, 6O, 6P, 6Q, 6R, 6S, 6T, 6U, 6V, 6W, 6X, 6Y, 6Z, 6AA, 6AB, 6AC, 6AH, 6AG, 6AF, 6AE, 6AD, 6AB, 6AC.

Other rooms include: 1C, 1B, 1A, 1D, 1H, 1I, 1J, 1K, 1O, 1P, 1Q, 1R, 1S, 1X, 1Y, 1Z, 1AA, 1AB, 1AC, 2A, 2B, 2C, 2D, 2E, 2F, 2G, 2H, 2J, 2L, 2M, 2N, 2O, 2P, 2Q, 2R, 2S, 2T, 2U, 2V, 2W, 2X, 2Y, 2Z, 2AA, 2AB, 2AC, 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3I, 3J, 3K, 3L, 3M, 3N, 3O, 3P, 3Q, 3R, 3S, 3T, 3U, 3V, 3W, 3X, 3Y, 3Z, 3AA, 3AB, 3AC, 4A, 4B, 4C, 4D, 4E, 4F, 4G, 4H, 4I, 4J, 4K, 4L, 4M, 4N, 4O, 4P, 4Q, 4R, 4S, 4T, 4U, 4V, 4W, 4X, 4Y, 4Z, 4AA, 4AB, 4AC, 4AH, 4AG, 4AF, 4AE, 4AD, 4AB, 4AC, 5A, 5B, 5C, 5D, 5E, 5F, 5G, 5H, 5I, 5J, 5K, 5L, 5M, 5N, 5O, 5P, 5Q, 5R, 5S, 5T, 5U, 5V, 5W, 5X, 5Y, 5Z, 5AA, 5AB, 5AC, 5AH, 5AG, 5AF, 5AE, 5AD, 5AB, 5AC, 6A, 6B, 6C, 6D, 6E, 6F, 6G, 6H, 6I, 6J, 6K, 6L, 6M, 6N, 6O, 6P, 6Q, 6R, 6S, 6T, 6U, 6V, 6W, 6X, 6Y, 6Z, 6AA, 6AB, 6AC, 6AH, 6AG, 6AF, 6AE, 6AD, 6AB, 6AC.

Building A



Building A Vertical Dispersal?

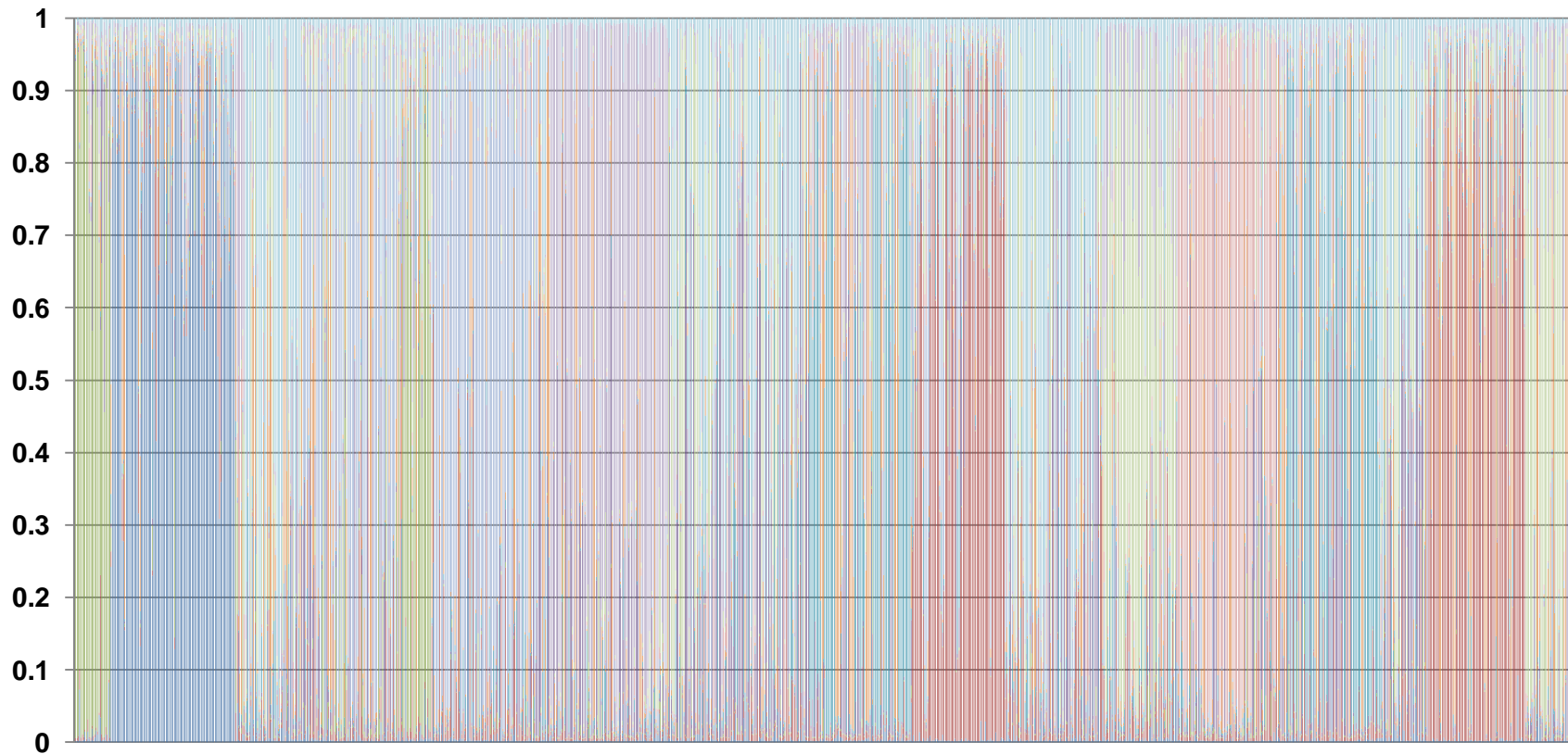


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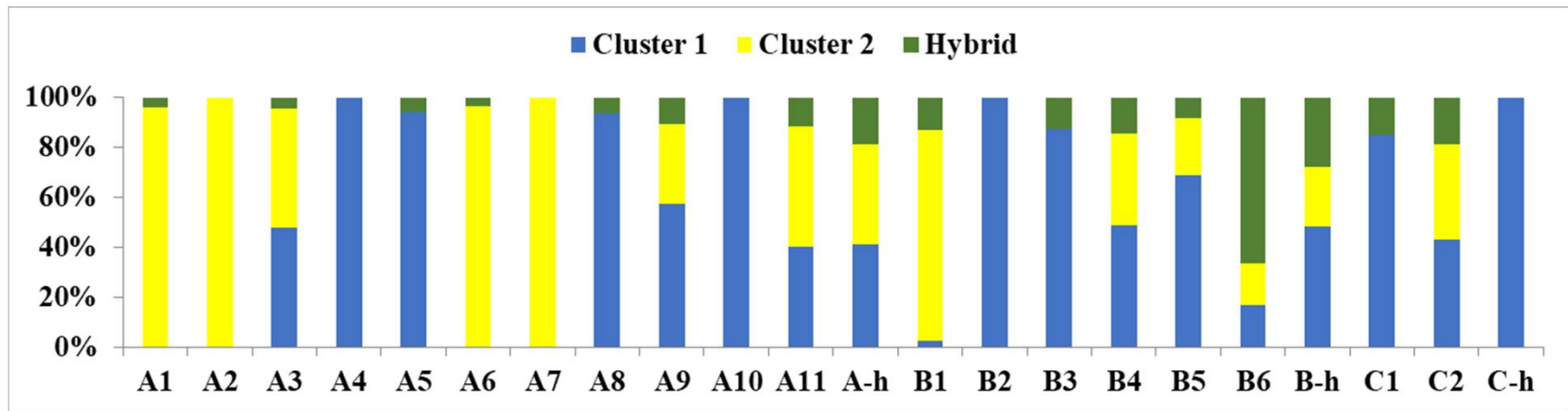
Both clusters

Building A 1039x17: Structure graphs by date collected from building

■ Sub11:1 ■ Sub11:2 ■ Sub11:3 ■ Sub11:4 ■ Sub11:5 ■ Sub11:6 ■ Sub11:7 ■ Sub11:8 ■ Sub11:9 ■ Sub11:10 ■ Sub11:11



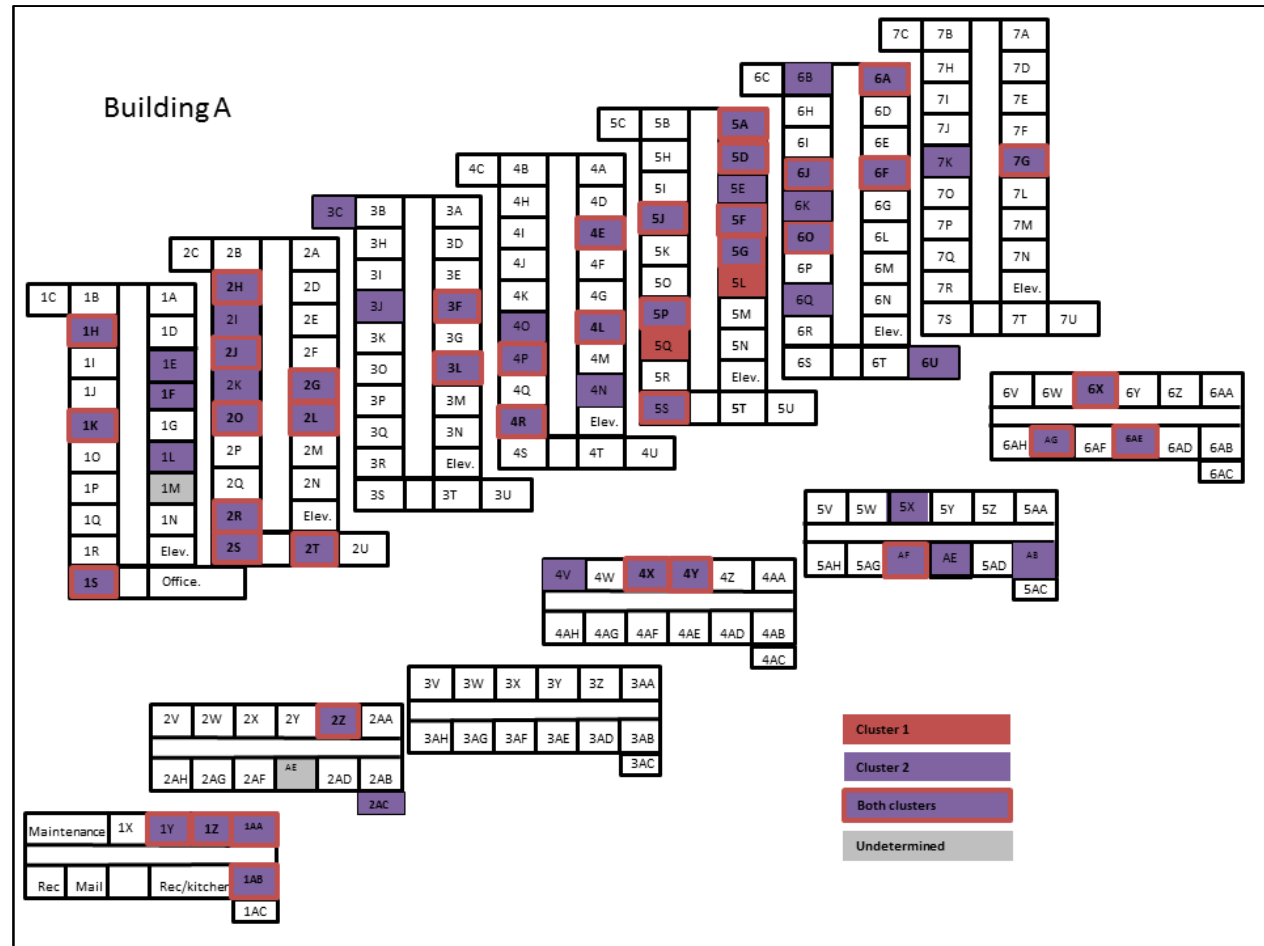
Subpopulations



Building A

11 subpopulations

# subpop	# apts
11	1
10	0
9	1
8	5
7	4
6	6
5	5
4	2
3	7
2	4
1	14



Building B

	7B	7D	7F	7H		7L	7N	7P	7R	7S
	7C	7E	7G	7I	7J	7K	7M	7O	7Q	
6A	6B	6D	6F	6H		6L	6N	6P	6R	6S
	6C	6E	6G	6I	6J	6K	6M	6O	6Q	
5A	5B	5D	5F	5H		5L	5N	5P	5R	5S
	5C	5E	5G	5I	5J	5K	5M	5O	5Q	
4A	4B	4D	4F	4H		4L	4N	4P	4R	4S
	4C	4E	4G	4I	4J	4K	4M	4O	4Q	
3A	3B	3D	3F	3H		3L	3N	3P	3R	3S
	3C	3E	3G	3I	3J	3K	3M	3O	3Q	
2A	2B	2D	2F	2H		2L	2N	2P	2R	2S
	2C	2E	2G	2I	2J	2K	2M	2O	2Q	
1A	1B	1D	1F	1H		1L	1N	1P	1R	1S
	1C	1E	1G	1I		1K	1M	1O	1Q	

Cluster 1

Building B

	7B	7D	7F	7H		7L	7N	7P	7R	7S
	7C	7E	7G	7I	7J	7K	7M	7O	7Q	
6A	6B	6D	6F	6H		6L	6N	6P	6R	6S
	6C	6E	6G	6I	6J	6K	6M	6O	6Q	
5A	5B	5D	5F	5H		5L	5N	5P	5R	5S
	5C	5E	5G	5I	5J	5K	5M	5O	5Q	
4A	4B	4D	4F	4H		4L	4N	4P	4R	4S
	4C	4E	4G	4I	4J	4K	4M	4O	4Q	
3A	3B	3D	3F	3H		3L	3N	3P	3R	3S
	3C	3E	3G	3I	3J	3K	3M	3O	3Q	
2A	2B	2D	2F	2H		2L	2N	2P	2R	2S
	2C	2E	2G	2I	2J	2K	2M	2O	2Q	
1A	1B	1D	1F	1H		1L	1N	1P	1R	1S
	1C	1E	1G	1I		1K	1M	1O	1Q	

Cluster 1

Cluster 2

Building B

7A	7B	7D	7F	7H		7L	7N	7P	7R	7S
	7C	7E	7G	7I	7J	7K	7M	7O	7Q	
6A	6B	6D	6F	6H		6L	6N	6P	6R	6S
	6C	6E	6G	6I	6J	6K	6M	6O	6Q	
5A	5B	5D	5F	5H		5L	5N	5P	5R	5S
	5C	5E	5G	5I	5J	5K	5M	5O	5Q	
4A	4B	4D	4F	4H		4L	4N	4P	4R	4S
	4C	4E	4G	4I	4J	4K	4M	4O	4Q	
3A	3B	3D	3F	3H		3L	3N	3P	3R	3S
	3C	3E	3G	3I	3J	3K	3M	3O	3Q	
2A	2B	2D	2F	2H		2L	2N	2P	2R	2S
	2C	2E	2G	2I	2J	2K	2M	2O	2Q	
1A	1B	1D	1F	1H		1L	1N	1P	1R	1S
	1C	1E	1G	1I		1K	1M	1O	1Q	

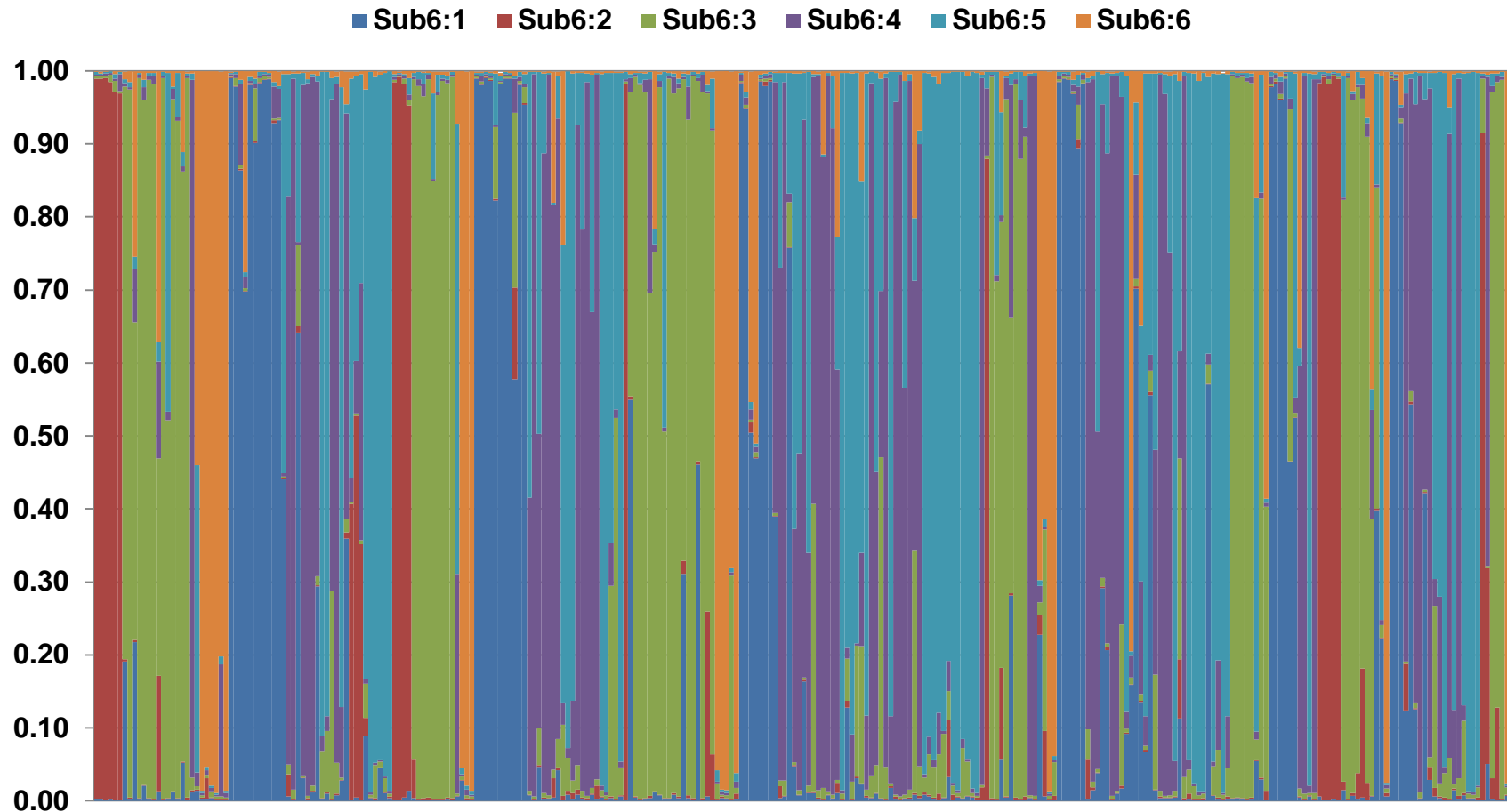
Cluster 1

Cluster 2

Both clusters

Undetermined

Building B 249x17: Structure graphs by date collected from building



Building B

6 subpopulations

# sub pop	# apts
6	3
5	3
4	3
3	1
2	1
1	11

7A	7B	7D	7F	7H		7L	7N	7P	7R	7S
	7C	7E	7G	7I	7J	7K	7M	7O	7Q	
6A	6B	6D	6F	6H		6L	6N	6P	6R	6S
	6C	6E	6G	6I	6J	6K	6M	6O	6Q	
5A	5B	5D	5F	5H		5L	5N	5P	5R	5S
	5C	5E	5G	5I	5J	5K	5M	5O	5Q	
4A	4B	4D	4F	4H		4L	4N	4P	4R	4S
	4C	4E	4G	4I	4J	4K	4M	4O	4Q	
3A	3B	3D	3F	3H		3L	3N	3P	3R	3S
	3C	3E	3G	3I	3J	3K	3M	3O	3Q	
2A	2B	2D	2F	2H		2L	2N	2P	2R	2S
	2C	2E	2G	2I	2J	2K	2M	2O	2Q	
1A	1B	1D	1F	1H		1L	1N	1P	1R	1S
	1C	1E	1G	1I		1K	1M	1O	1Q	

Cluster 1
Cluster 2
Both clusters
Undetermined

Building C

13V	13U	13S	13Q	13O	13M		14K	14I	14G	14E	14C	
	13S	13R	13P	13N	13L		14J	14H	14F	14D	14B	14A
12V	12U	12S	12Q	12O	12M		13K	13I	13G	13E	13C	
	12S	12R	12P	12N	12L		13J	13H	13F	13D	13B	13A
11V	11U	11S	11Q	11O	11M		12K	12I	12G	12E	12C	
	11S	11R	11P	11N	11L		12J	12H	12F	12D	12B	12A
10V	10U	10S	10Q	10O	10M		11K	11I	11G	11E	11C	
	10S	10R	10P	10N	10L		11J	11H	11F	11D	11B	11A
9V	9U	9S	9Q	9O	9M		10K	10I	10G	10E	10C	
	9T	9R	9P	9N	9L		10J	10H	10F	10D	10B	10A
8V	8U	8S	8Q	8O	8M		9K	9I	9G	9E	9C	
	8T	8R	8P	8N	8L		9J	9H	9F	9D	9B	9A
7V	7U	7S	7Q	7O	7M		8K	8I	8G	8E	8C	
	7T	7R	7P	7N	7L		8J	8H	8F	8D	8B	8A
6V	6U	6S	6Q	6O	6M		7K	7I	7G	7E	7C	
	6T	6R	6P	6N	6L		7J	7H	7F	7D	7B	7A
5V	5U	5S	5Q	5O	5M		6K	6I	6G	6E	6C	
	5T	5R	5P	5N	5L		6J	6H	6F	6D	6B	6A
4V	4U	4S	4Q	4O	4M		5K	5I	5G	5E	5C	
	4T	4R	4P	4N	4L		5J	5H	5F	5D	5B	5A
3V	3U	3S	3Q	3O	3M		4K	4I	4G	4E	4C	
	3T	3R	3P	3N	3L		4J	4H	4F	4D	4B	4A
2V	2U	2S	2Q	2O	2M		3K	3I	3G	3E	3C	
	2T	2R	2P	2N	2L		3J	3H	3F	3D	3B	3A
							2K	2I	2G	2E	2C	
							2J	2H	2F	2D	2B	2A

Cluster 1

Building C

13V	13U	13S	13Q	13O	13M		14K	14I	14G	14E	14C	
	13S	13R	13P	13N	13L		14J	14H	14F	14D	14B	14A
12V	12U	12S	12Q	12O	12M		13K	13I	13G	13E	13C	
	12S	12R	12P	12N	12L		13J	13H	13F	13D	13B	13A
11V	11U	11S	11Q	11O	11M		12K	12I	12G	12E	12C	
	11S	11R	11P	11N	11L		12J	12H	12F	12D	12B	12A
10V	10U	10S	10Q	10O	10M		11K	11I	11G	11E	11C	
	10S	10R	10P	10N	10L		11J	11H	11F	11D	11B	11A
9V	9U	9S	9Q	9O	9M		10K	10I	10G	10E	10C	
	9T	9R	9P	9N	9L		10J	10H	10F	10D	10B	10A
8V	8U	8S	8Q	8O	8M		9K	9I	9G	9E	9C	
	8T	8R	8P	8N	8L		9J	9H	9F	9D	9B	9A
7V	7U	7S	7Q	7O	7M		8K	8I	8G	8E	8C	
	7T	7R	7P	7N	7L		8J	8H	8F	8D	8B	8A
6V	6U	6S	6Q	6O	6M		7K	7I	7G	7E	7C	
	6T	6R	6P	6N	6L		7J	7H	7F	7D	7B	7A
5V	5U	5S	5Q	5O	5M		6K	6I	6G	6E	6C	
	5T	5R	5P	5N	5L		6J	6H	6F	6D	6B	6A
4V	4U	4S	4Q	4O	4M		5K	5I	5G	5E	5C	
	4T	4R	4P	4N	4L		5J	5H	5F	5D	5B	5A
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2V	2U	2S	2Q	2O	2M		3K	3I	3G	3E	3C	
	2T	2R	2P	2N	2L		3J	3H	3F	3D	3B	3A
							2K	2I	2G	2E	2C	
							2J	2H	2F	2D	2B	2A

Cluster 1

Cluster 2

Building C

13V	13U	13S	13Q	13O	13M		14K	14I	14G	14E	14C	
	13S	13R	13P	13N	13L		14J	14H	14F	14D	14B	14A
							13K	13I	13G	13E	13C	
12V	12U	12S	12Q	12O	12M		13J	13H	13F	13D	13B	13A
	12S	12R	12P	12N	12L							
							12K	12I	12G	12E	12C	
11V	11U	11S	11Q	11O	11M		12J	12H	12F	12D	12B	12A
	11S	11R	11P	11N	11L							
							11K	11I	11G	11E	11C	
10V	10U	10S	10Q	10O	10M		11J	11H	11F	11D	11B	11A
	10S	10R	10P	10N	10L							
							10K	10I	10G	10E	10C	
9V	9U	9S	9Q	9O	9M		10J	10H	10F	10D	10B	10A
	9T	9R	9P	9N	9L							
							9K	9I	9G	9E	9C	
8V	8U	8S	8Q	8O	8M		9J	9H	9F	9D	9B	9A
	8T	8R	8P	8N	8L							
							8K	8I	8G	8E	8C	
7V	7U	7S	7Q	7O	7M		8J	8H	8F	8D	8B	8A
	7T	7R	7P	7N	7L							
							7K	7I	7G	7E	7C	
6V	6U	6S	6Q	6O	6M		7J	7H	7F	7D	7B	7A
	6T	6R	6P	6N	6L							
							6K	6I	6G	6E	6C	
5V	5U	5S	5Q	5O	5M		6J	6H	6F	6D	6B	6A
	5T	5R	5P	5N	5L							
							5K	5I	5G	5E	5C	
4V	4U	4S	4Q	4O	4M		5J	5H	5F	5D	5B	5A
	4T	4R	4P	4N	4L							
							4K	4I	4G	4E	4C	
3V	3U	3S	3Q	3O	3M		4J	4H	4F	4D	4B	4A
	3T	3R	3P	3N	3L							
							3K	3I	3G	3E	3C	
2V	2U	2S	2Q	2O	2M		3J	3H	3F	3D	3B	3A
	2T	2R	2P	2N	2L							
							2K	2I	2G	2E	2C	
							2J	2H	2F	2D	2B	2A

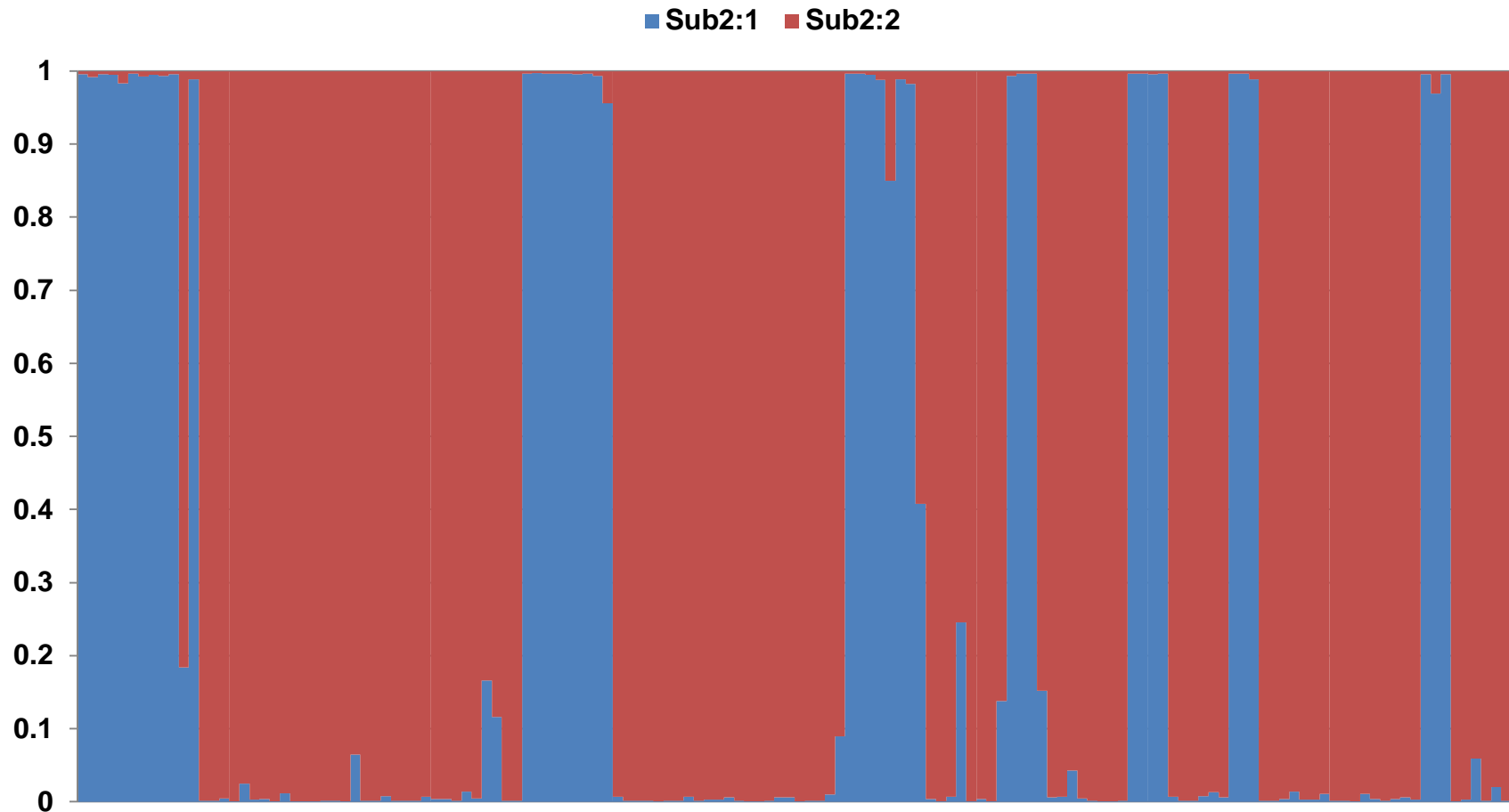
Cluster 1

Cluster 2

Both clusters

Undetermined

Building C 142x17: Structure graphs by date collected from building



Building C
2 subpopulations
Both present in
all apts except
4Q & 4 P

13V	13U	13S	13Q	13O	13M		14K	14I	14G	14E	14C	
	13S	13R	13P	13N	13L		14J	14H	14F	14D	14B	14A
12V	12U	12S	12Q	12O	12M		13K	13I	13G	13E	13C	
	12S	12R	12P	12N	12L		13J	13H	13F	13D	13B	13A
11V	11U	11S	11Q	11O	11M		12K	12I	12G	12E	12C	
	11S	11R	11P	11N	11L		12J	12H	12F	12D	12B	12A
10V	10U	10S	10Q	10O	10M		11K	11I	11G	11E	11C	
	10S	10R	10P	10N	10L		11J	11H	11F	11D	11B	11A
9V	9U	9S	9Q	9O	9M		10K	10I	10G	10E	10C	
	9T	9R	9P	9N	9L		10J	10H	10F	10D	10B	10A
8V	8U	8S	8Q	8O	8M		9K	9I	9G	9E	9C	
	8T	8R	8P	8N	8L		9J	9H	9F	9D	9B	9A
7V	7U	7S	7Q	7O	7M		8K	8I	8G	8E	8C	
	7T	7R	7P	7N	7L		8J	8H	8F	8D	8B	8A
6V	6U	6S	6Q	6O	6M		7K	7I	7G	7E	7C	
	6T	6R	6P	6N	6L		7J	7H	7F	7D	7B	7A
5V	5U	5S	5Q	5O	5M		6K	6I	6G	6E	6C	
	5T	5R	5P	5N	5L		6J	6H	6F	6D	6B	6A
4V	4U	4S	4Q	4O	4M		5K	5I	5G	5E	5C	
	4T	4R	4P	4N	4L		5J	5H	5F	5D	5B	5A
3V	3U	3S	3Q	3O	3M		4K	4I	4G	4E	4C	
	3T	3R	3P	3N	3L		4J	4H	4F	4D	4B	4A
2V	2U	2S	2Q	2O	2M		3K	3I	3G	3E	3C	
	2T	2R	2P	2N	2L		3J	3H	3F	3D	3B	3A
							2K	2I	2G	2E	2C	
							2J	2H	2F	2D	2B	2A

Cluster 1

Cluster 2

Both clusters

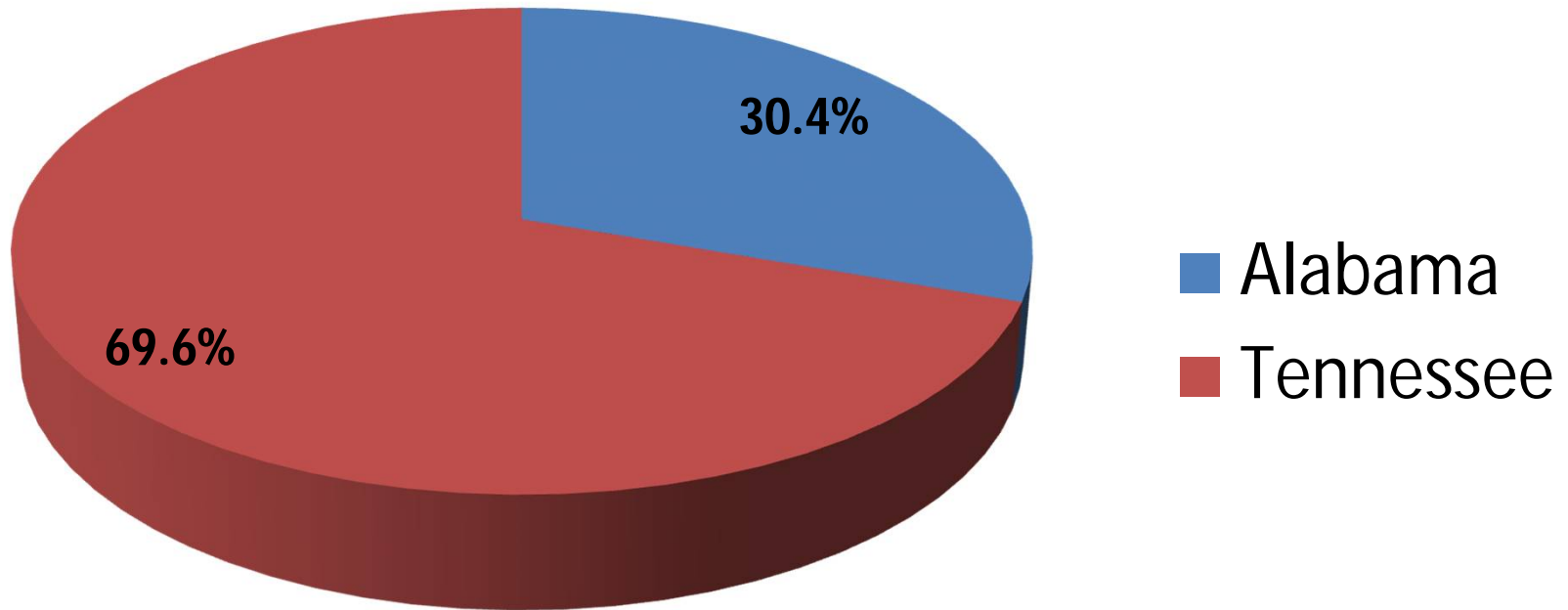
Undetermined

Summary

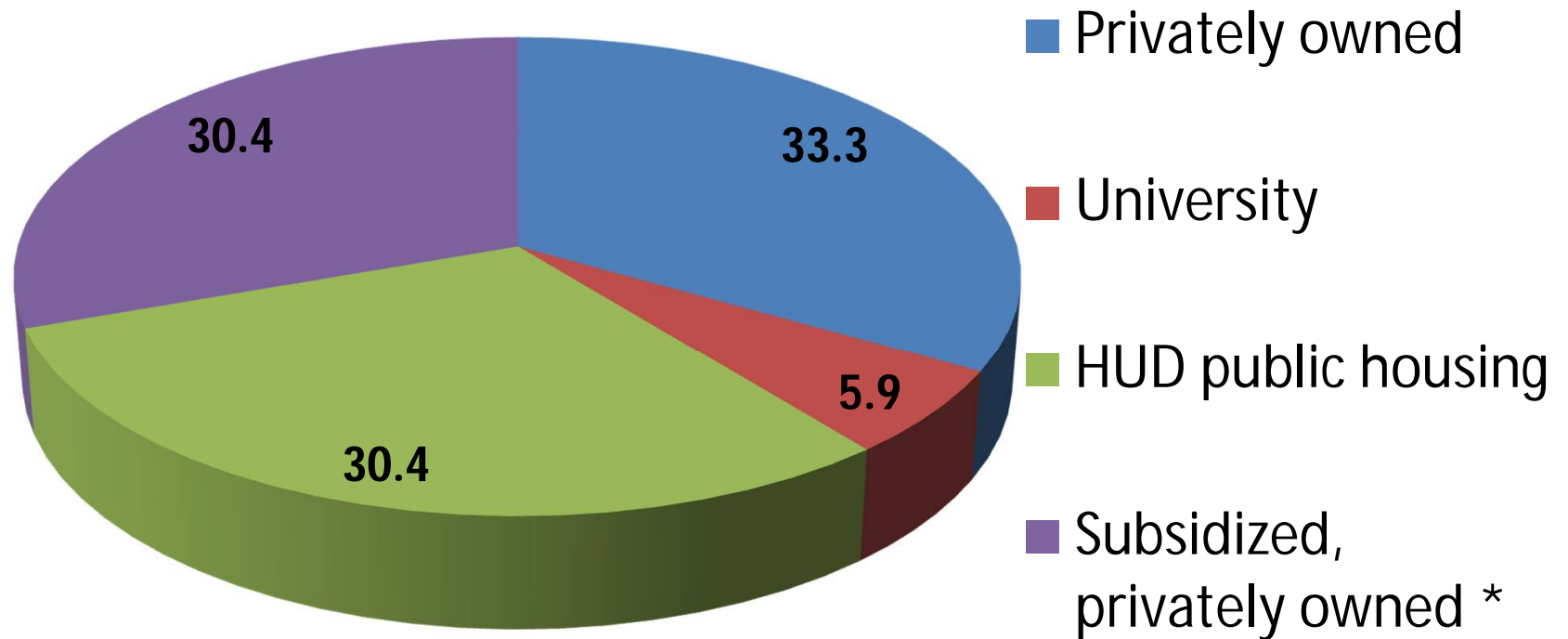
- Unique introductions into buildings appear to be rare
- Once infestations are established in an apt there is the potential for extensive spread throughout a building
- Early detection is key

2014 Apartment Managers' Survey

Respondents by State (n=156)

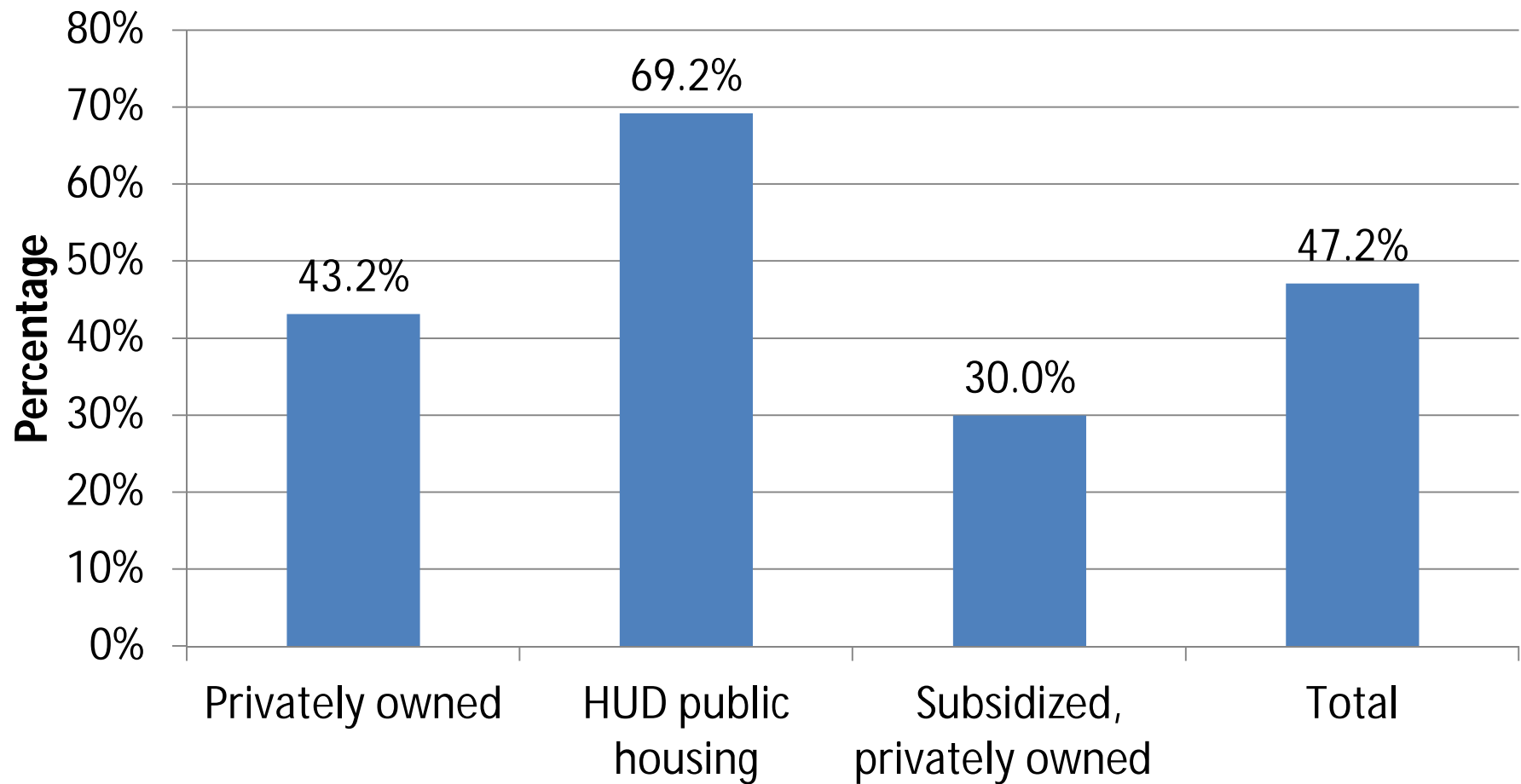


Respondents by Property Ownership (%)

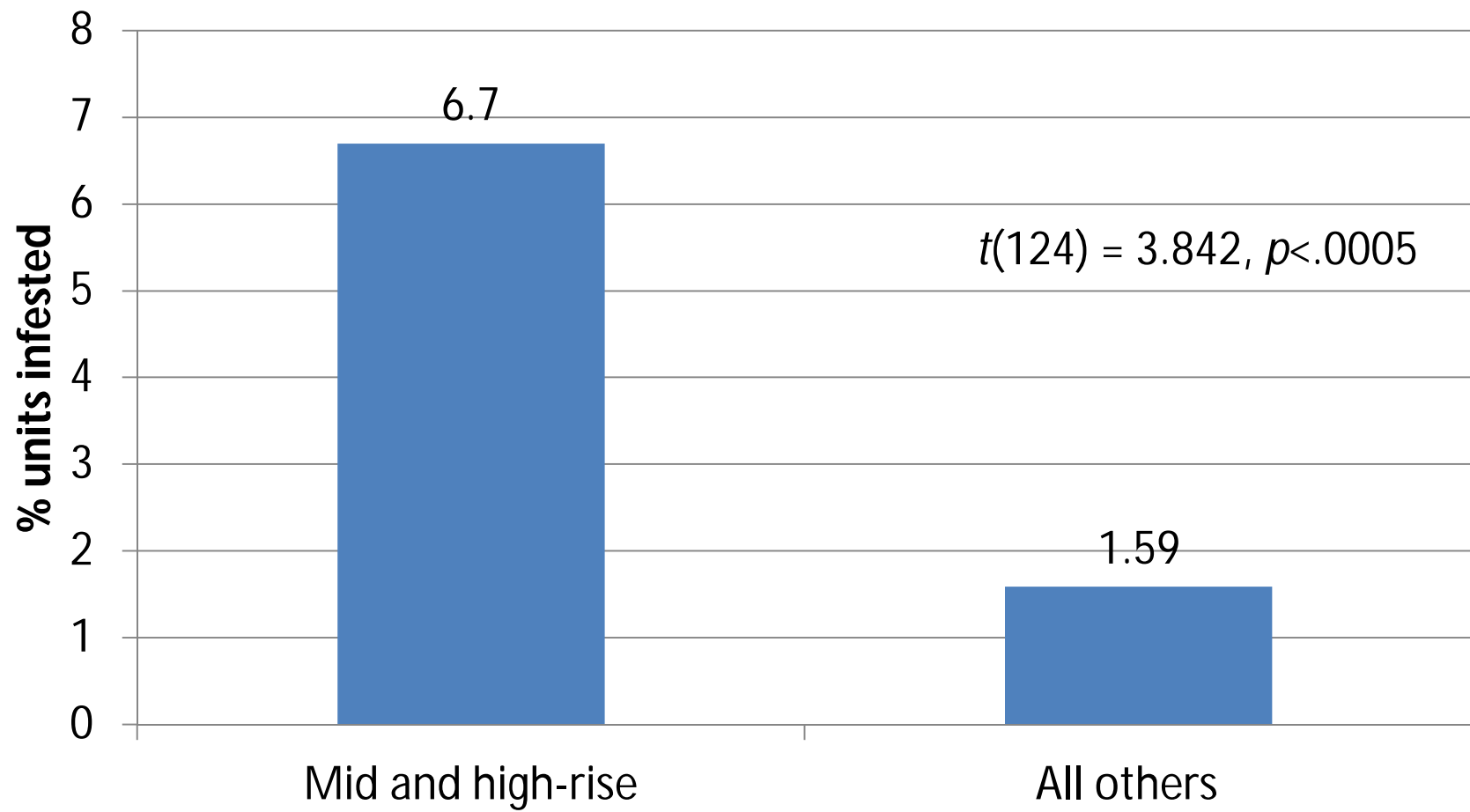


* Includes HUD Section 8, Low-income housing tax credit program, HUD and USDA subsidized disabled/elderly & other respondent-identified privately

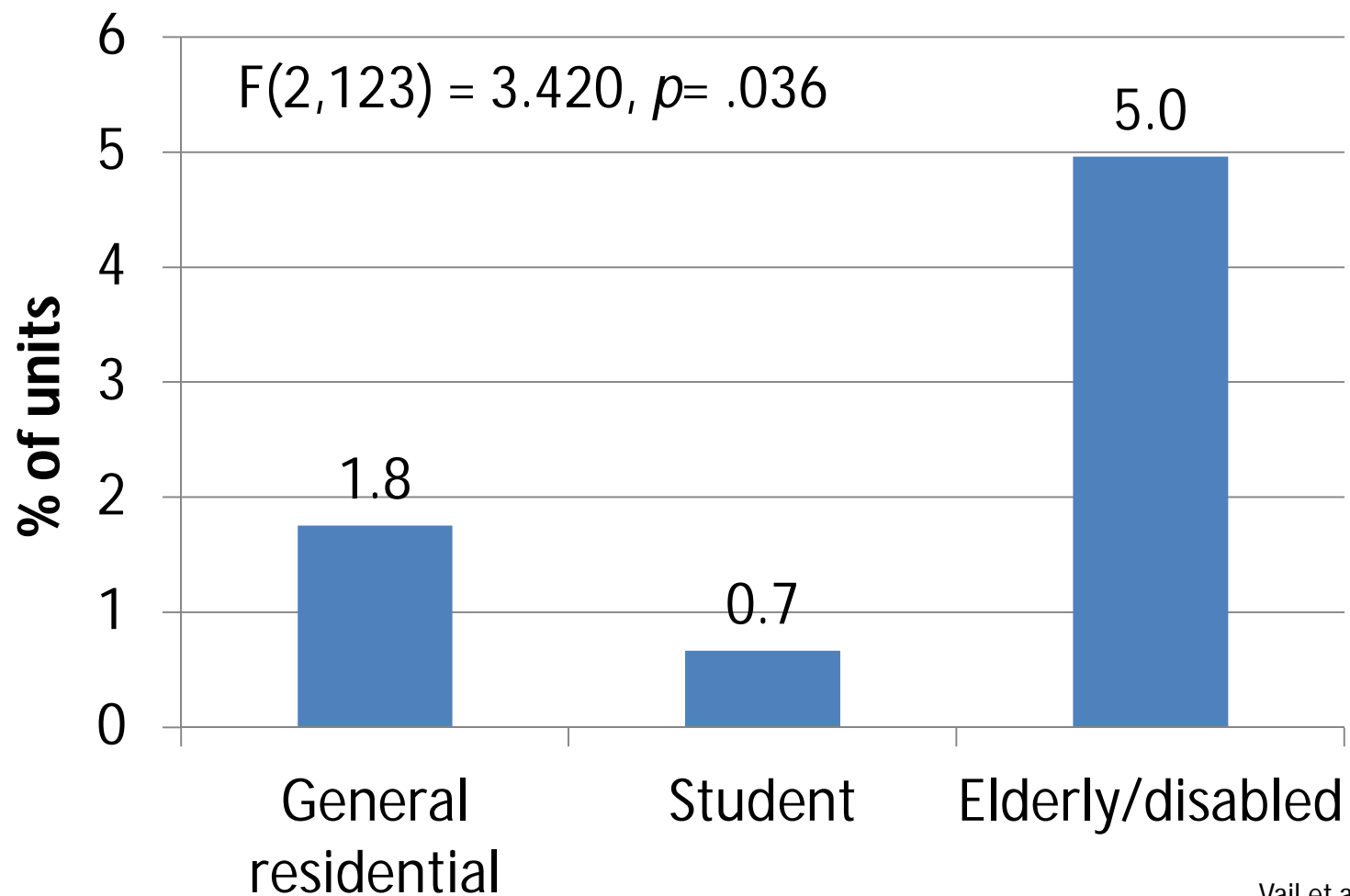
% of Properties with Bed Bugs in 2013, by Property-ownership Type



Mid- and High-rise Construction Types had Higher Shares of Units Infested Than Other Construction Types in 2013



% of Units Infested in 2013, by Predominant Residential Type



Why Does Multi-unit
Housing for Elderly &
Disabled
Favor Bed Bug
Infestations?

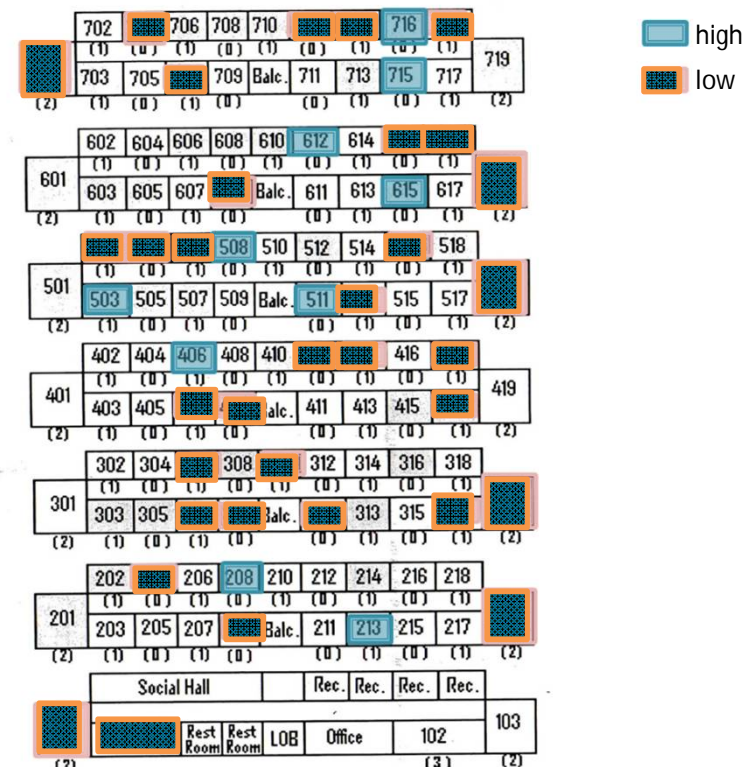
Multi-unit Housing for Elderly & Disabled Favor Bed Bug Infestations

Resident Issues

- Socializing
 - Ind. rooms or
 - Large communal areas
- Sharing belongings
- Clutter (lifetime's accum. of goods)
- Used furniture
- Vision and bite rxn reduced in elderly
- In-home services
- Movement aids (wheel chairs, walkers)
- Transportation (vans)

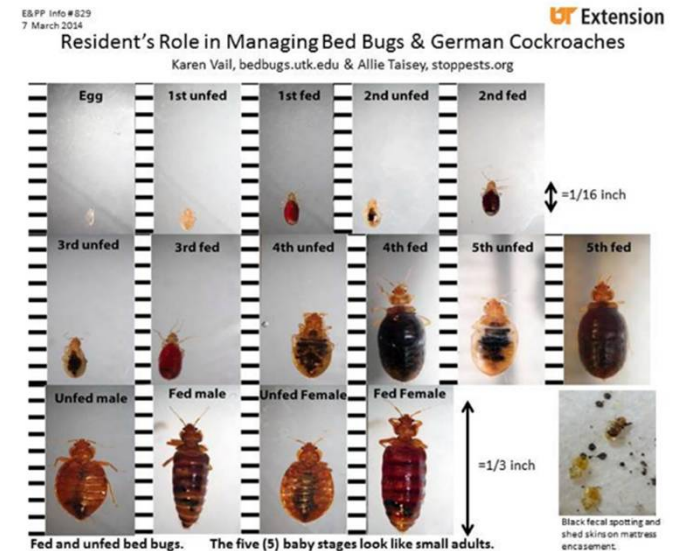
Building Issues

- BB travel pipes, wires, ducts
- Elevators



Management

1. Identification
2. Education & Cooperation
3. Inspection/Detection
4. Nonchemical and Chemical Control
5. Follow-up Eval & Add. Measures



2013 – 2014

TN HUD Housing Inspections

Buildings	# rooms inspected	# rooms with bed bugs	% rooms with bed bugs
A	110	33	30
B	77	18	23
C	164	73	45
D	62	19	31
		AVERAGE	32

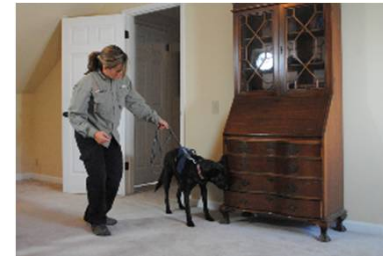
- Indicated by canine scent detection team or visual inspection and confirmed through specimen collection.
- Problem could be worse because of rooms skipped due to potential unsafe environment for canines.

Early Detection Important

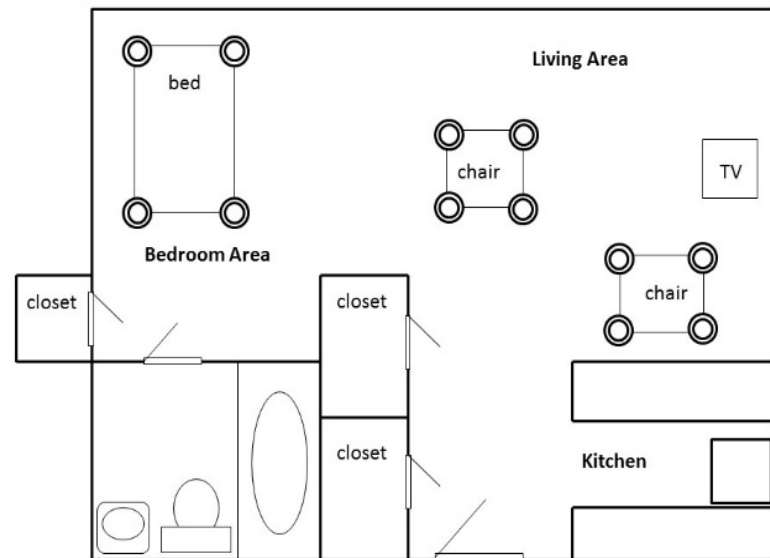
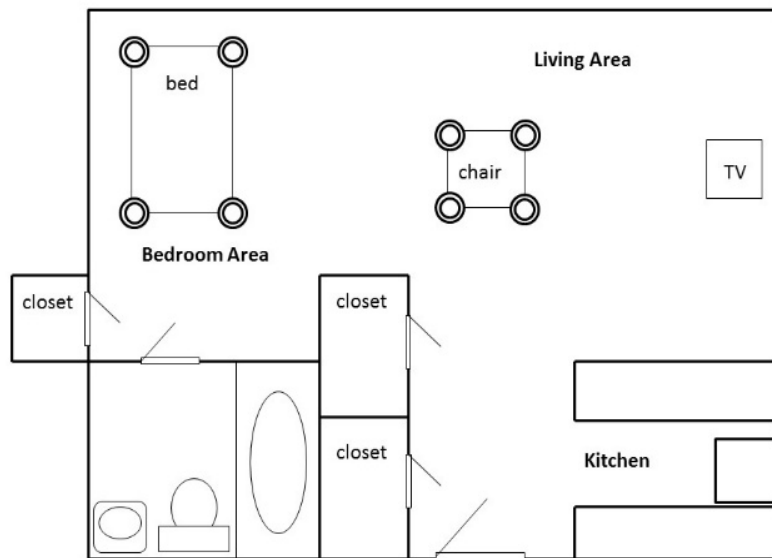
- Caught early, less likely to spread to neighboring units
- If less than 10 bed bugs found per apartment, nonchemical control sufficient
- Furniture can be treated rather than thrown away
- Residents more likely to report an infestation if not lose their furniture or need extensive preparation

Bed Bug Detection Tools

- Complete Visual Inspection
- Canine Scent Detection Teams
- Monitors
 - Active Monitors
 - Passive, Pitfall Monitors
- Combinations
 - Quick Visual Inspection with Monitors
 - Canine with visual/monitors



Passive, Pitfall Monitor Traditional Placements

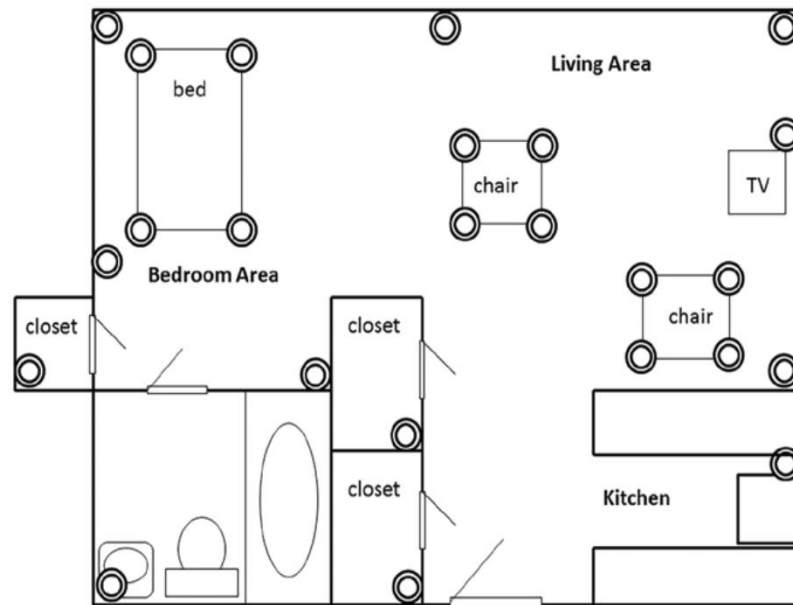


Inspection interval: 2 weeks, 89 to 94% detection rate

Cooper, R. A., Wang C., and Singh N. 2015b. Evaluation of a model community-wide bed bug management program in affordable housing. *Pest Manag. Sci.* 72: 45–56

Wang, C., Singh, N., Zha, C., and Cooper, R. 2016. Bed bugs: prevalence in low-income communities, resident's reactions, and implementation of a low-cost inspection protocol. *J. Med. Entomol.* Doi: 10.1093/jme/tjw018.

Passive, Pitfall Monitor Placements After Treatment to Determine Areas of Continued Activity and Bed Bug Elimination



Objective 2

- Determine the minimum number and location of bed bug monitoring devices needed to detect bed bugs at low infestation levels in multifamily housing.



United States
Department of
Agriculture

National Institute
of Food and
Agriculture

SRIPM Grants Program

9 Treatments

3 Monitors



ClimbUp Insect
Interceptor BG
(black grip)

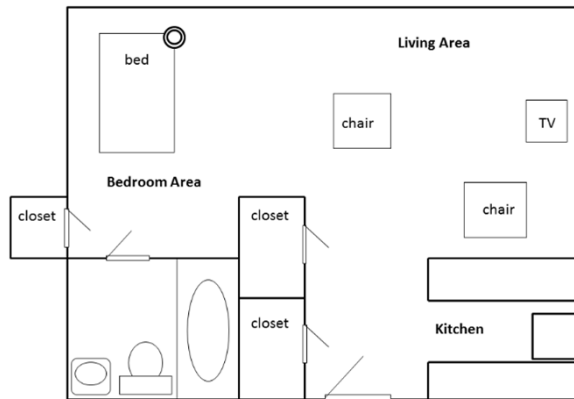


BlackOut BedBug
Detector

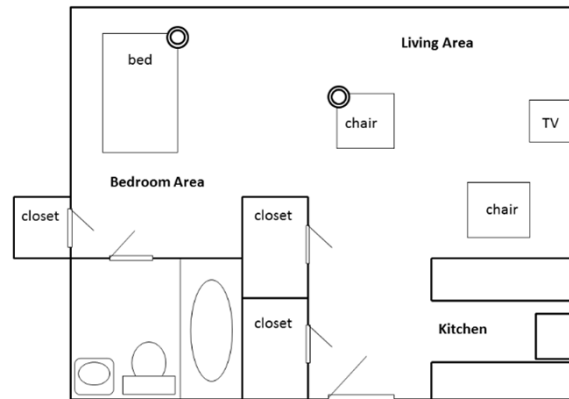


Catchmaster BDS
(Bedbug detection
system)

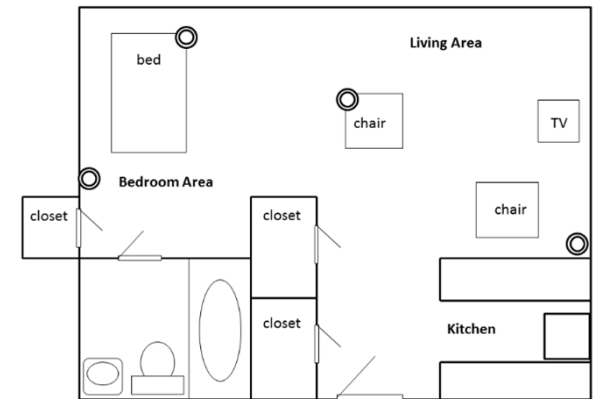
Passive, Pitfall Monitor Placements – Reduced



One



Two



Four

Dog Inspectors

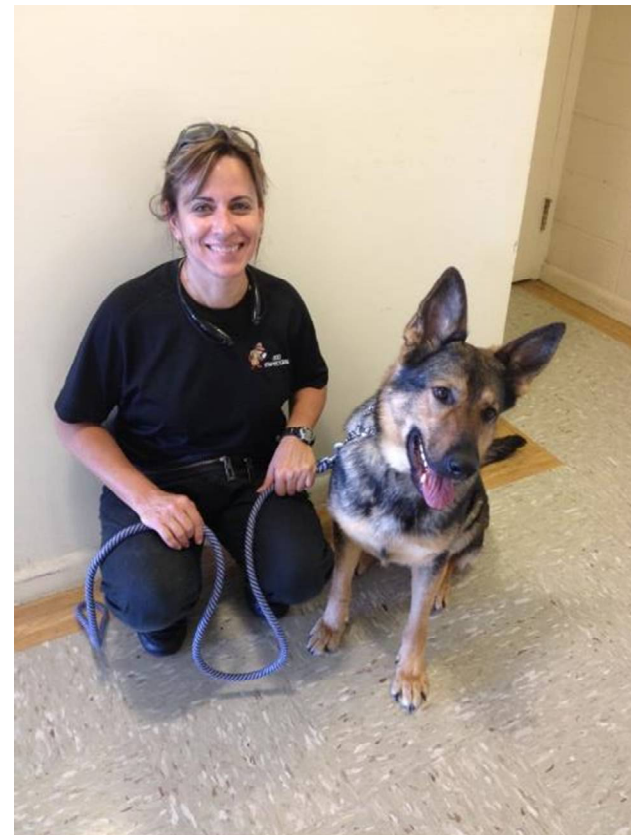
December 2013

Inspections:

Building B: 9th, 10th

Building C: 12th, 13th

Building D: 16th

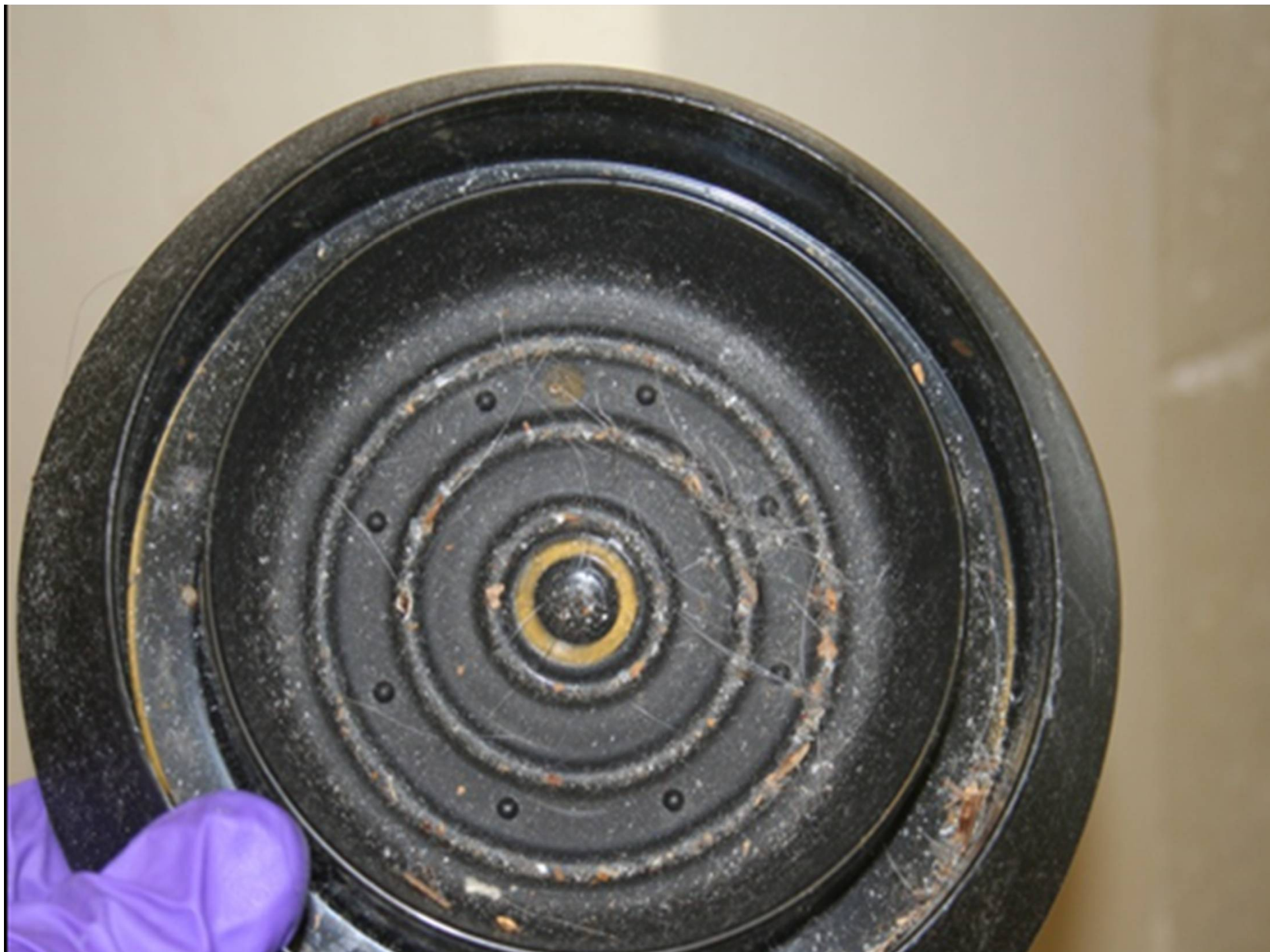


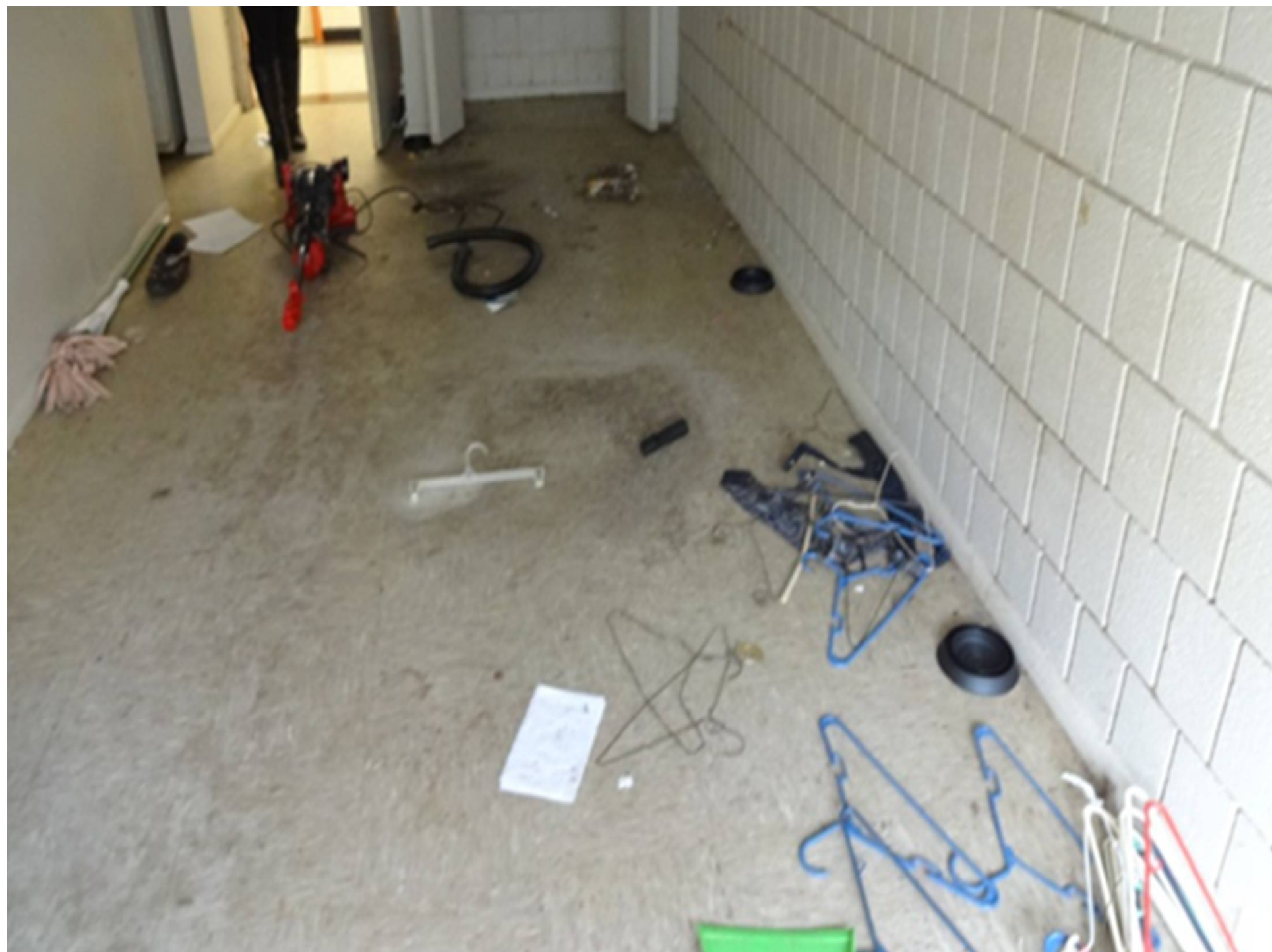
Results



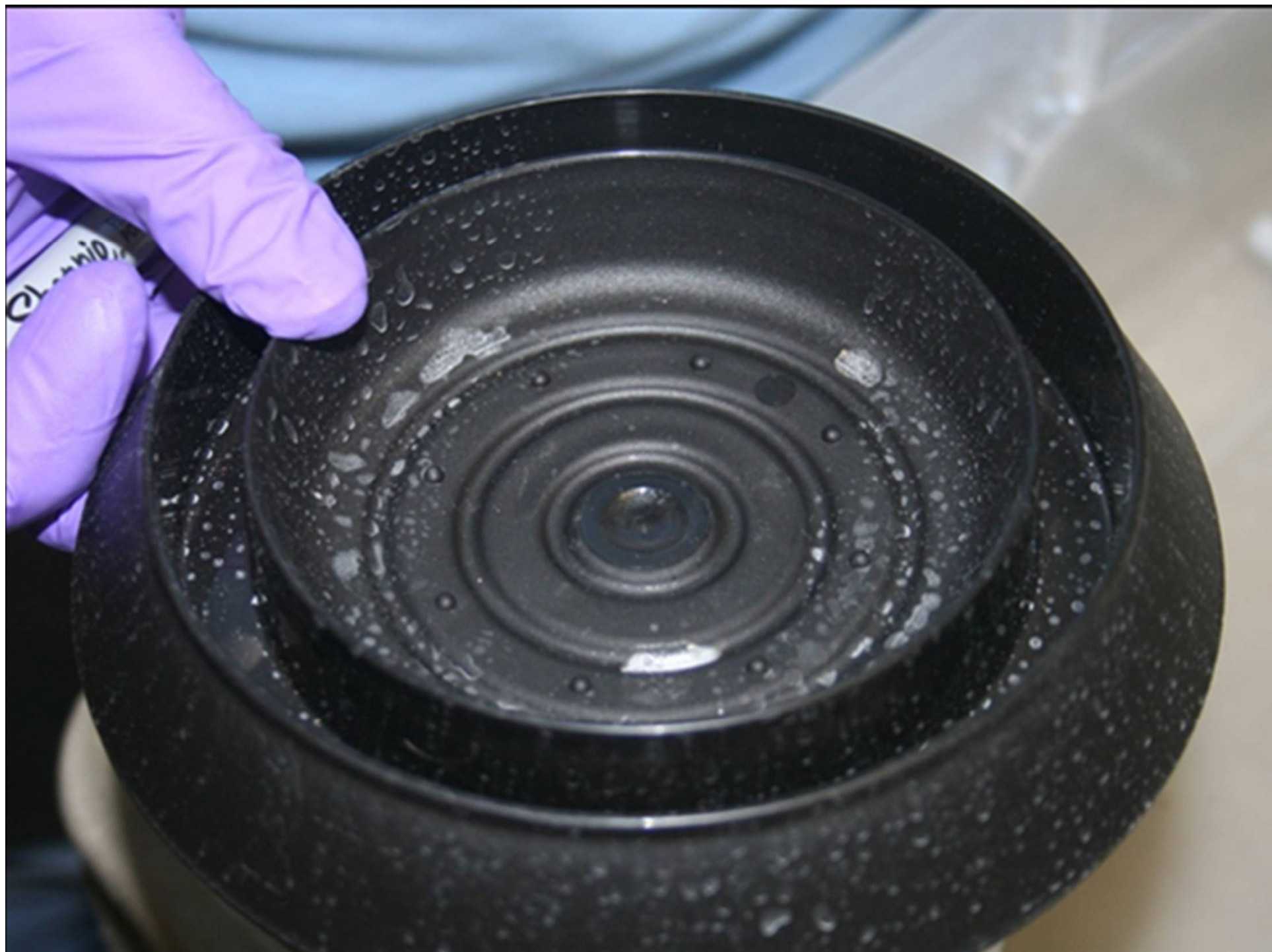














Results

- BDS less effective (time to first catch [7.4 wk], 39% positive rooms)
- 79% detection w/BlackOuts and 88% w/Black ClimbUps
- Excluding the BDS,
 - 1,2 or 4 monitors equally effective in detecting bed bug (80 – 90% at 8 wks)
 - 3- 4 wks to first find w/1,2, or 4 monitors.
- Bed bugs more commonly found on bed/sleeping furniture

Extension Objective 2

Use the awareness created and knowledge gained about bed bug detection to increase IPM adoption in multifamily housing.



United States
Department of
Agriculture

National Institute
of Food and
Agriculture



Training Day – StopPests.org

**Allie Taisey, Cornell U, Northeast IPM Center
(now with NPMA)**

Agenda

*Times may be adjusted to accommodate trainees' needs.
The training takes 7 hours.*

- 8:15 Overview and Introductions
- 8:45 Cockroaches
- 9:45 *Break*
- 10:00 IPM and Pesticide Use
- 11:00 Indoor Demonstrations
- 11:45 *Working Lunch: discuss potential implementation projects*
- 12:43 Video: "The Tenants' Role in IPM"
- 1:00 Engaging Residents in IPM
- 1:15 Address any pest questions that are not covered in the course materials.
- 1:30 Rodents
- 2:15 Outdoor Demonstrations
- 2:45 *Break*
- 3:00 Bed Bugs
- 4:00 IPM Exam and Course Evaluation

Adjourn



36 Floor Meetings in All 3 Facilities for 733 residents (March – August 2014)

- Show EACH resident a display box of all bed bug stages and fecal spotting
- Discuss two handouts on bed bugs and cockroaches
- Demonstrate 1 gal wet/vac with stocking insert to remove bed bugs
- Distribute
 - 2 BlackOuts (1 bed, 1 chair) and
 - 3 cockroach sticky traps (1 under sink, under refrig. and in bathroom) per apartment



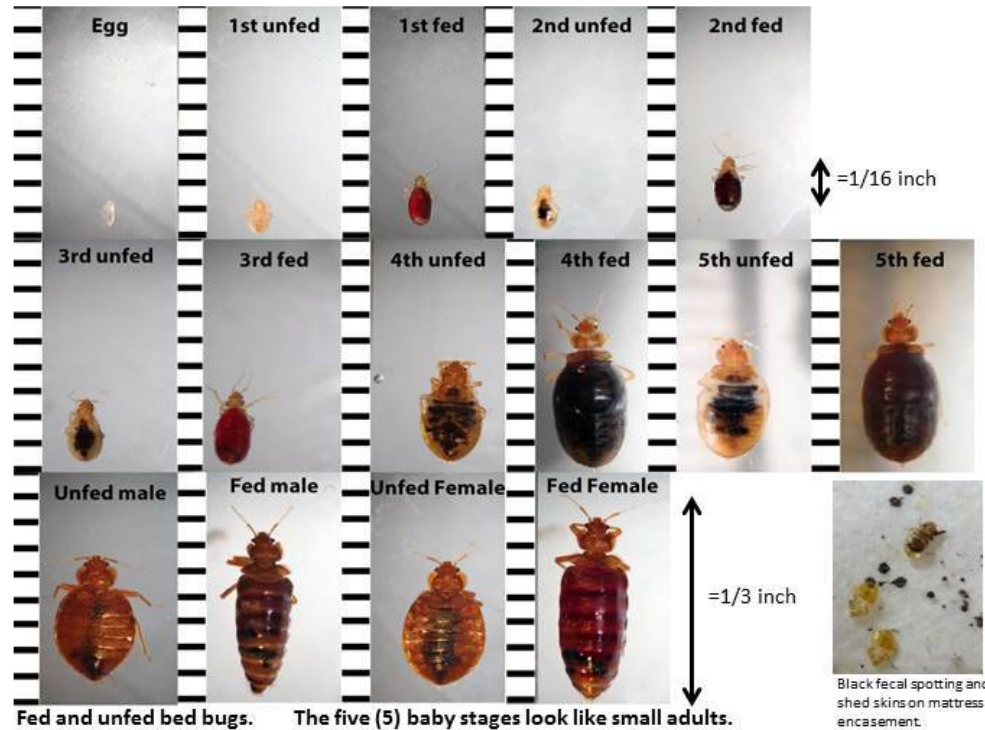
36 Floor Meetings in All 3 Facilities for 733 residents (March – August 2014)

- UT placed traps if residents unable to or requested it
- Attempted to place 1 or 2 wks before scheduled pest control services
- Traps to be inspected by
 - PMP (quarterly service),
 - facility personnel (housekeeping inspection, maintenance request) or
 - resident



Resident's Role in Managing Bed Bugs & German Cockroaches

Karen Vail, bedbugs.utk.edu & Allie Taisey, stoppests.org



1. Place one (1) BlackOut bed bug monitor against one of the legs at the head of your bed. Ideally, between the leg and the wall.
2. Place one (1) BlackOut under the chair/sofa you use most. Place the BlackOut against the chair leg nearest the wall.
3. Check monitors weekly.
4. If you find a bed bug, call the housing office desk [redacted] Management will confirm it's a bed bug and work with you and a pest professional to get rid of them.



If pests are found early, then control will be faster and there will be less work for you to do!

What you can do to help manage bed bugs:

- **Straighten up your home and vacuum.** Being neat does not decrease your chances of getting bed bugs, but it makes them easier to find and will make the control efforts work better.
- **Wash your sheets weekly and other bedding at least once a month.** Dryer heat kills bed bugs.
- Do NOT use bug bombs or over-the-counter sprays. Foggers can be unsafe and won't get rid of the bugs.

When you pay rent, you pay for pest management! You will not be blamed, charged, or evicted due to a pest infestation. Housing wants you to call [redacted] to report pests (including bed bugs)!

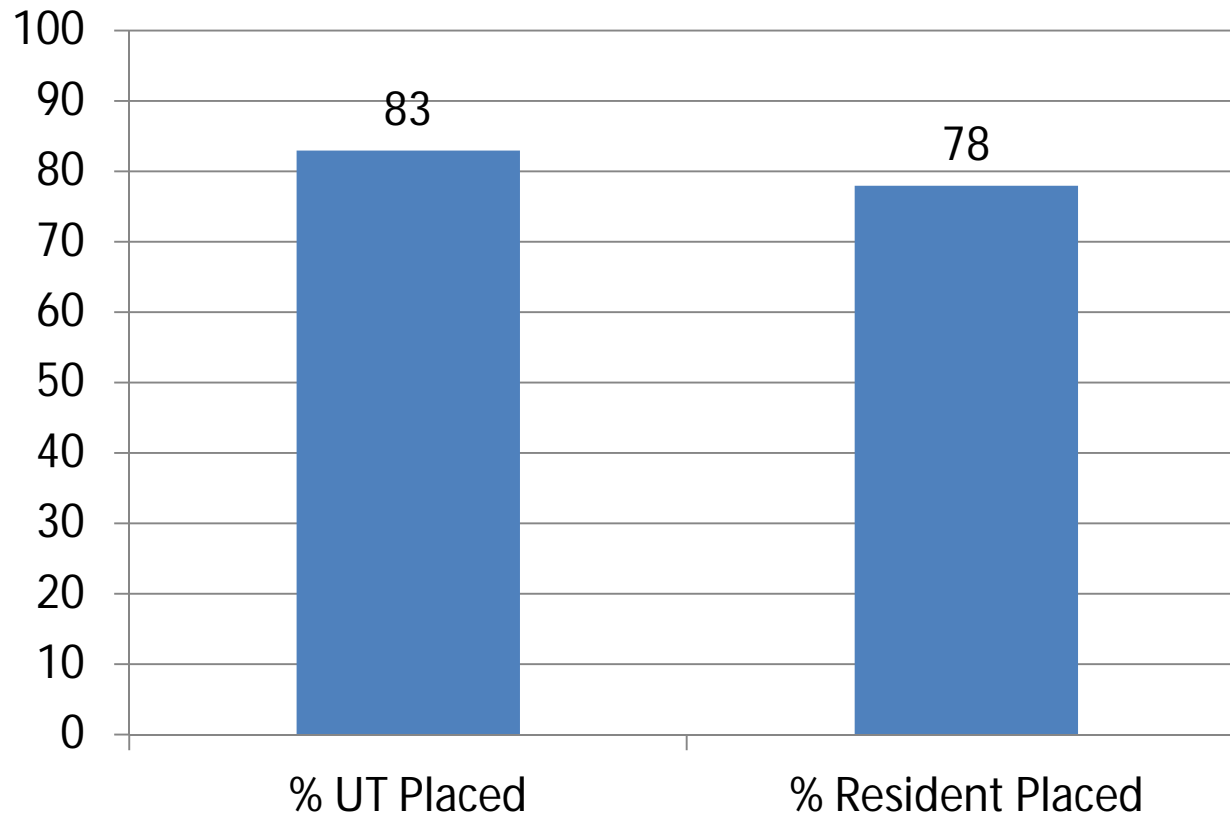
Case Study: Two Monitors Per Apartment



Monitor Inspection – Building D

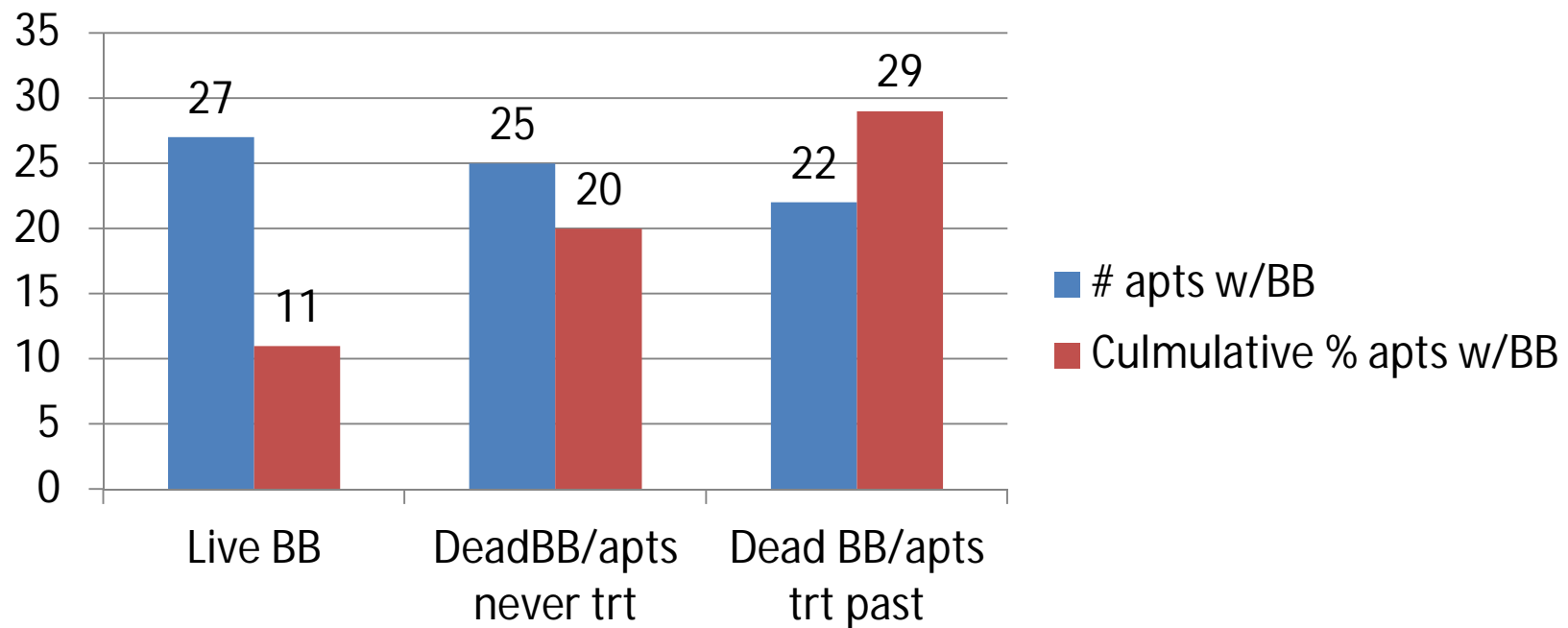
Placed: April – June 2014

Inspected: January 6 – 9 2015 (**7-9 mo**)



January 6 – 9 2015 (Bldg D)

Results of monitor check
7 – 9 months after placement
Checked Monitors 256/277



31% infestation rate in 2013

Complete Visual Inspection



Quick Inspection



Quick Inspection



Add Monitors After Quick Inspection if Live Bed Bugs Suspected but Not Found

- Evidence of bed bugs (fecal spotting, shed skins, etc.)
- Evidence resident treating for bed bugs
- Residence reports seeing bed bugs or bites
- Apartment was treated in the recent past



Case Study 2:

Combination Quick Inspection with Two Monitors Already in Place—
Buildings A & B

Placed: March 2014

Inspected: Quick Visual & Monitor check

January 25-28, 2016 (**1 yr 10 mo.**)

Inspected 245/249

Quick inspection:

- Check the Blackouts
- Pull back fitted sheets to examine mattress seams
- Inspect upper surfaces and crevices of upholstered furniture (chair, love seats, sofas).
- Did NOT turn over furniture



Case Study 2:

Combination Quick Inspection with Two Monitors Already in Place–
Buildings A & B

Monitors placed: March 2014

Inspected: Quick Visual & Monitor check

January 25-28, 2016 (1 yr 10 mo.)

Inspected 245/249

- Could manager and assistant do this themselves?
- Still may have missed apartments that were infested



Case Study 2:

Combination Quick Inspection with Two Monitors
Already in Place - Buildings A & B,
January 25-28, 2016, 1 Yr 10 Months Later

Bed bug monitors placed March 2014 (1.75 yrs ago) by	% apts w/at least 1 monitor still in place Jan 2016
Residents or UT	83

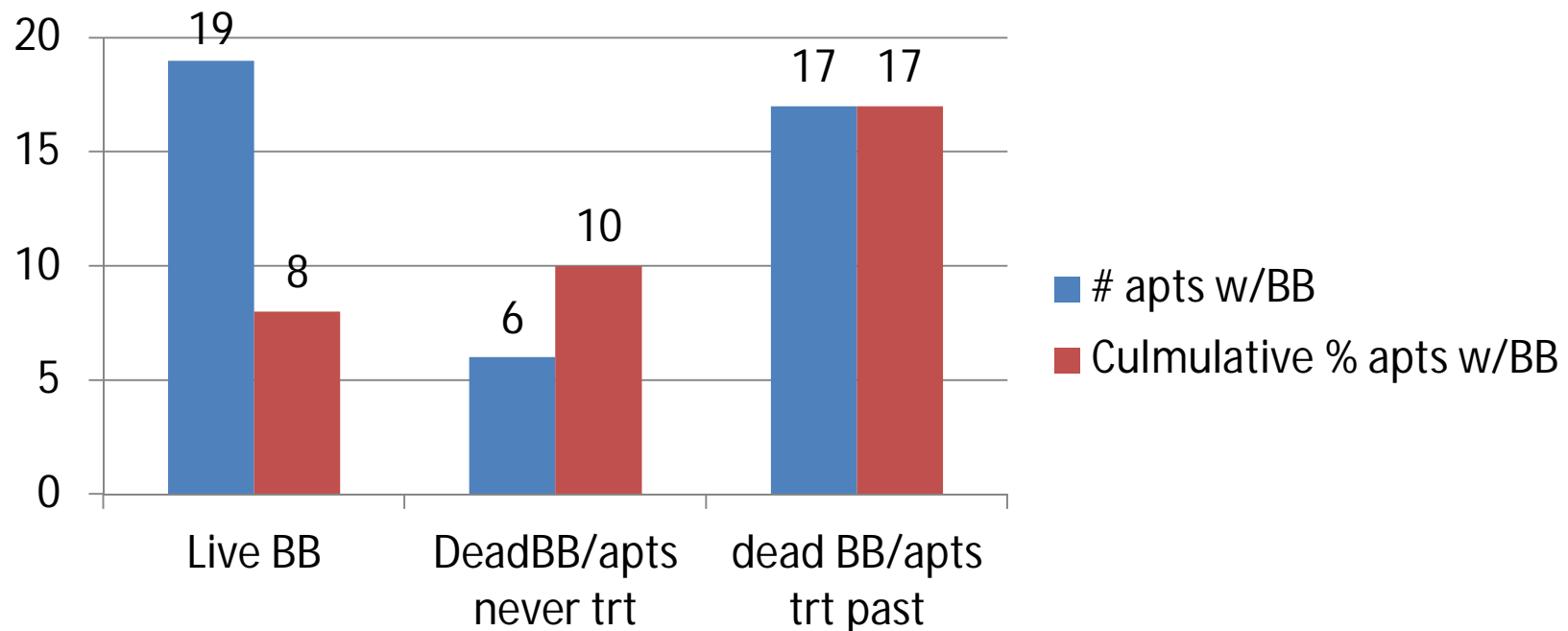
Only 10% of apartments had clean monitors

Case Study 2– Buildings A & B

Placed: March 2014

Inspected: Quick Visual & Monitor check
January 25-28, 2016 (1 yr 10 mo.)

Inspected 245/249



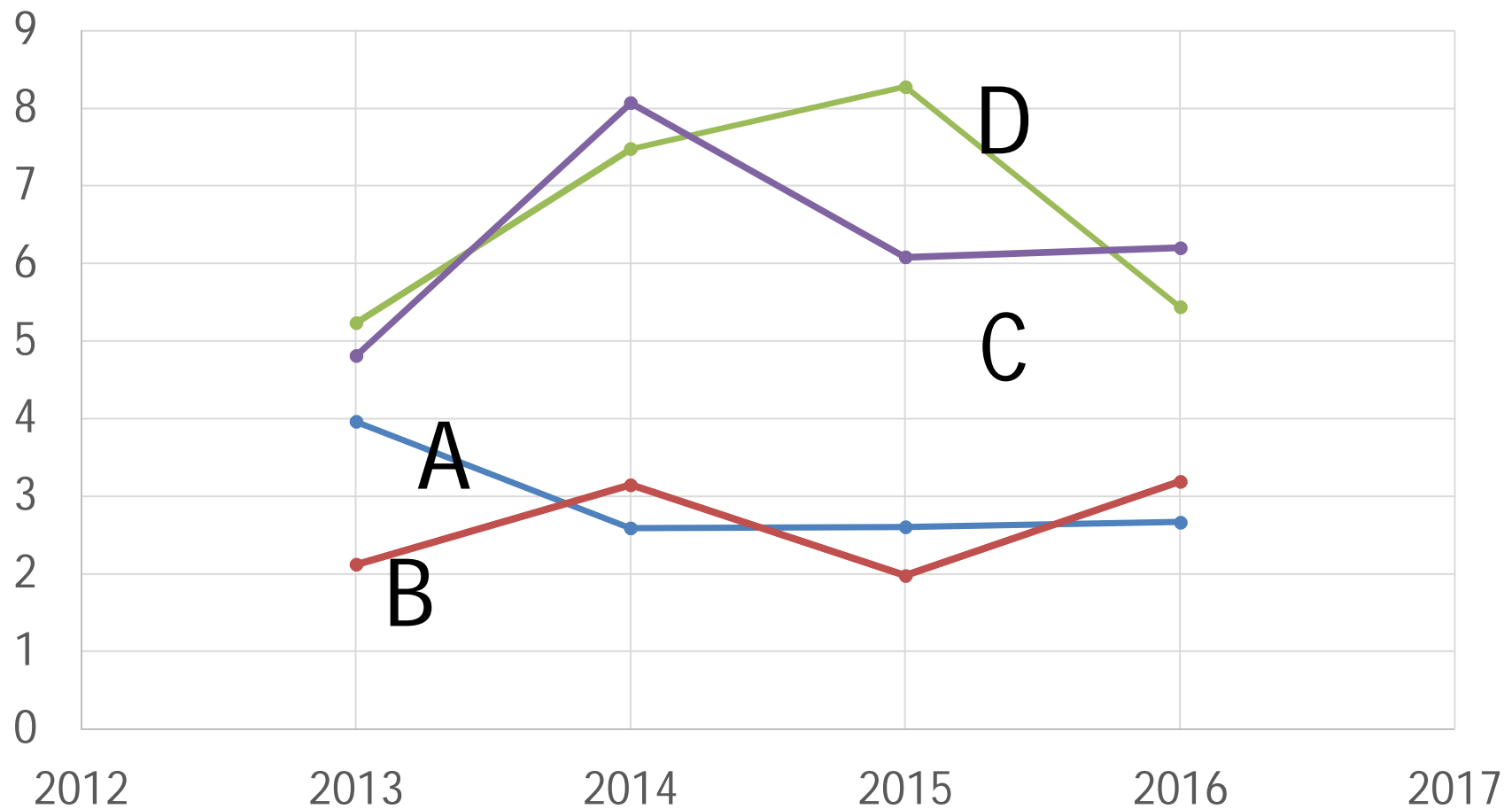
10 of the 19 apts with live BB treated in 2015, 1 in 2014, 2 in 2013, 6 never treated

27% infestation rate in 2013

Buildings A & B

- What percentage of infested apartments was management aware of?
 - Manager aware of 4 of the 19 apartments infested = 21%
 - **Missed 79% of infested apartments**
- Take number of apartments self-reported and multiply by 4.75 to get closer estimate to the number of apartments infested?

Mean # of bed bug trt/service day



UT 2017 SRIPMC Enhancement Prog. Capstone Grant

Compare 8 building-wide inspections

We propose to determine the inspection type (two or four monitors alone or a quick visual inspection with two, four or eight monitors where bed bugs suspected), and the inspection interval needed (2 week or 3 month) to **give the highest building-wide bed bug detection rates in low-income, high-rise apartments requiring the least amount of time and funds.**

UT 2017 SRIPMC Enhancement Prog. Capstone Grant

Compare 8 building-wide inspections

- 6 buildings with quick inspection (QI) & monitors placed where BB suspected. Monitors checked at different intervals
 - QI with 2 monitors BB suspected, check monitors at 2 wk
 - QI with 4 monitors BB suspected, check monitors at 2 wk
 - QI with 8 monitors BB suspected, check monitors at 2 wk
 - QI with 2 monitors BB suspected, check monitors at 3 mo
 - QI with 4 monitors BB suspected, check monitors at 3 mo
 - QI with 8 monitors BB suspected, check monitors at 3 mo

UT 2017 SRIPMC Enhancement Prog. Capstone Grant

Compare 8 building-wide inspections

- 2 buildings with 2 or 4 monitors in all apts and QI where no BB found
 - 2 monitors per apt in all apts, QI where BB not found in monitor, check monitors and inspect at 3 mo
 - 4 monitors per apt in all apts, QI where BB not found in monitor, check monitors and inspect at 3 mo

2017 Building-wide Inspections

- Quick inspections
- 2 monitors where bed bugs suspected
- monitors checked at 2wk or 3 mo



Bld g	Type	Date	Monitor inspection	# Apts insp.	# Apts Live BB QI	# Apts Live BB mon	% infestation rate	% mgr not aware
A	Pub/sr-d	4/11-12	2wk	130	33		25.4%	
		4/26				2	26.9%	91.4%
						2	28.5%	91.9%
D	Pub/sr-d	6/6-7 8/29	3mo	143	32	2	22.4% 23.8%	Missing records

2017 Building-wide Inspections

- Quick inspections
- 2 monitors where bed bugs suspected
- Monitors checked at 2wk

Results:

- 133 apts, BB in 33QI, 4M
- 29% infestation rate, mgr unaware 92%

- Quick inspections
- Quick inspections
- 2 monitors where bed bugs suspected
- Monitors checked at 3 mo

Results:

- 143 apts, BB in 32QI, 2M
- 24% infestation rate, mgr unaware ?%

- Quick inspections
- Quick inspections
- 4 monitors where bed bugs suspected,
- Monitors checked at 3 mo

Results:

- 153 apts, BB in 11QI, 1M
- 8% infestation, mgr unaware 18%

- Quick inspections
- 8 monitors where bed bugs suspected
- monitors checked at 2wk

Results:

- 118 apts, BB in 2QI, 0M
- 1.7% infestation rate, mgr unaware 50%

- Quick inspections
- 8 monitors where bed bugs suspected
- Monitors checked at 3mo

Results:

- 150 apartments, BB in 6QI, 1M
- 4.7% infestation rate, mgr unaware of 100%

2017 Building-wide Inspections

- Quick inspections
- 2 monitors where bed bugs suspected
- Monitors checked at 3 mo

Results:

- 143 apts, BB in 32QI, 2M
- 24% infestation rate, mgr unaware ?%

2017 Building-wide Inspections

- Quick inspections
- 4 monitors where bed bugs suspected,
- monitors checked at 2wk or 3 mo



Bldg	Type	Date	Monitor Inspection	# Apts insp.	# Apts Live BB QI	# Apts Live BB mon	% infestation rate	% mgr not aware
B	Pvt/proj-b sec8 /LITC	4/18-19 5/2	2wk	146	18	1	12.3% 13.0%	89.5%
E	Pvt/proj-b sec8 /LITC	6/27-28 9/19	3mo	153	11	1	7.2% 7.8%	18.2%

2017 Building-wide Inspections

- Quick inspections
- 4 monitors where bed bugs suspected,
- Monitors checked at 2wk

Results:

- 146 apts, BB in 18QI, 1M
- 13% infestation rate, mgr unaware 90%

2017 Building-wide Inspections

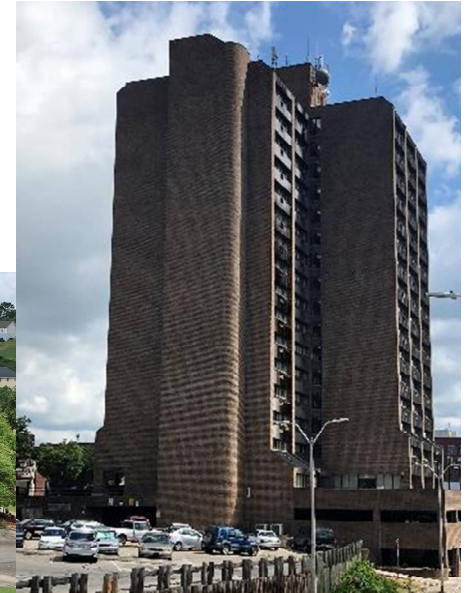
- Quick inspections
- 4 monitors where bed bugs suspected,
- Monitors checked at 3 mo

Results:

- 153 apts, BB in 11QI, 1M
- 8% infestation, mgr unaware 18%

2017 Building-wide Inspections

- Quick inspections
- 8 monitors where bed bugs suspected
- Monitors checked at 2wk or 3 mo



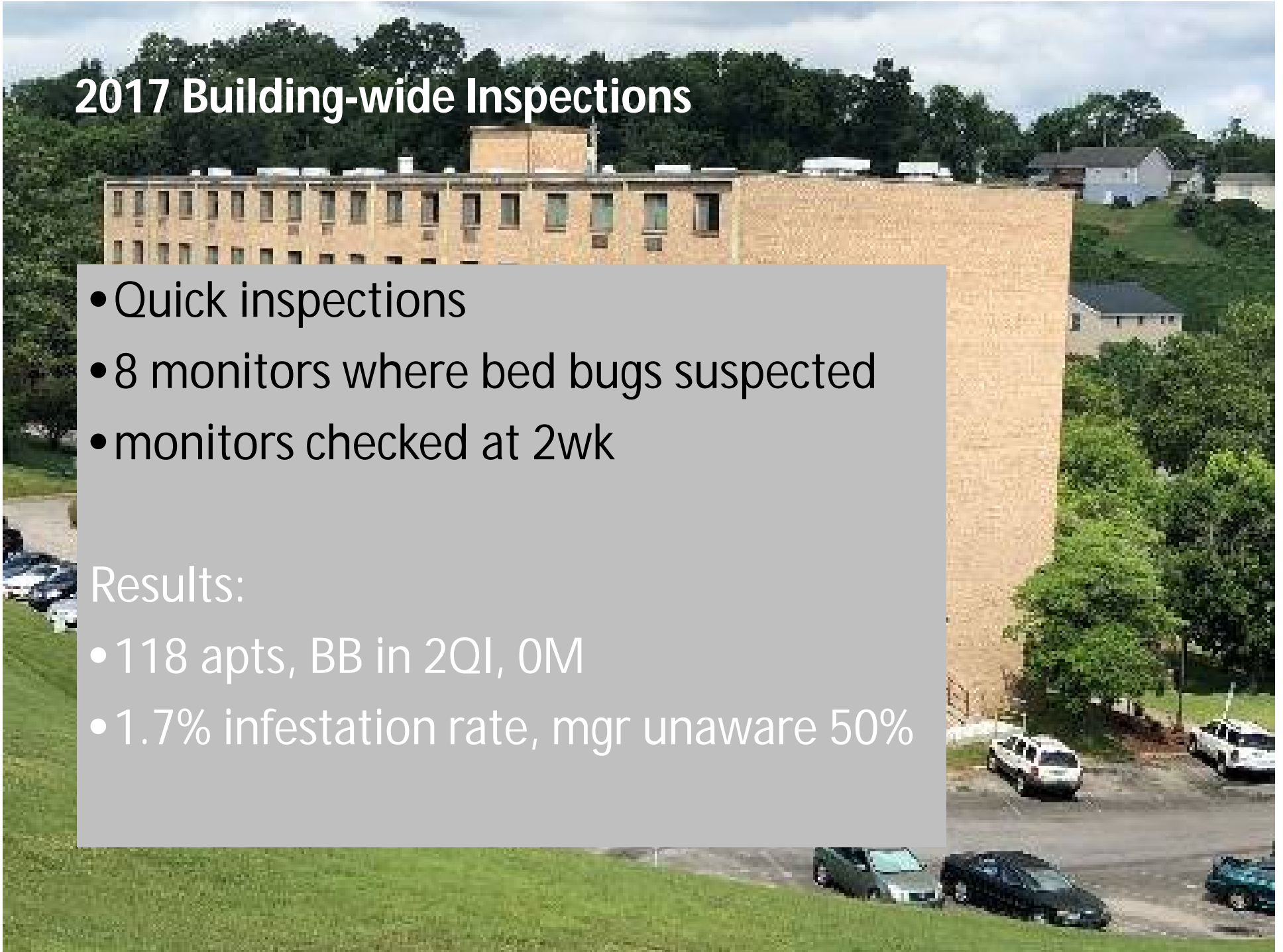
Bld g	Type	Date	Monitor Inspection	# Apts insp.	# Apts Live BB QI	# Apts Live BB mon	% infestation rate	% mgr not aware
C	Pub/sr-d	5/9-10 5/23	2wk	118	2	0	1.7%	50%
F	Pub/sr-d	8/1-2 10/24	3mo	150	6	1	4.0% 4.7%	100%

2017 Building-wide Inspections

- Quick inspections
- 8 monitors where bed bugs suspected
- monitors checked at 2wk

Results:

- 118 apts, BB in 2QI, 0M
- 1.7% infestation rate, mgr unaware 50%



2017 Building-wide Inspections

- Quick inspections
- 8 monitors where bed bugs suspected
- Monitors checked at 3mo

Results:

- 150 apartments, BB in 6QI, 1M
- 4.7% infestation rate, mgr unaware of 100%

2017 Building-wide Inspections

- 2 or 4 monitors in all apts,
- monitors checked at 3 months,
- quick inspection when no bed bugs in monitors



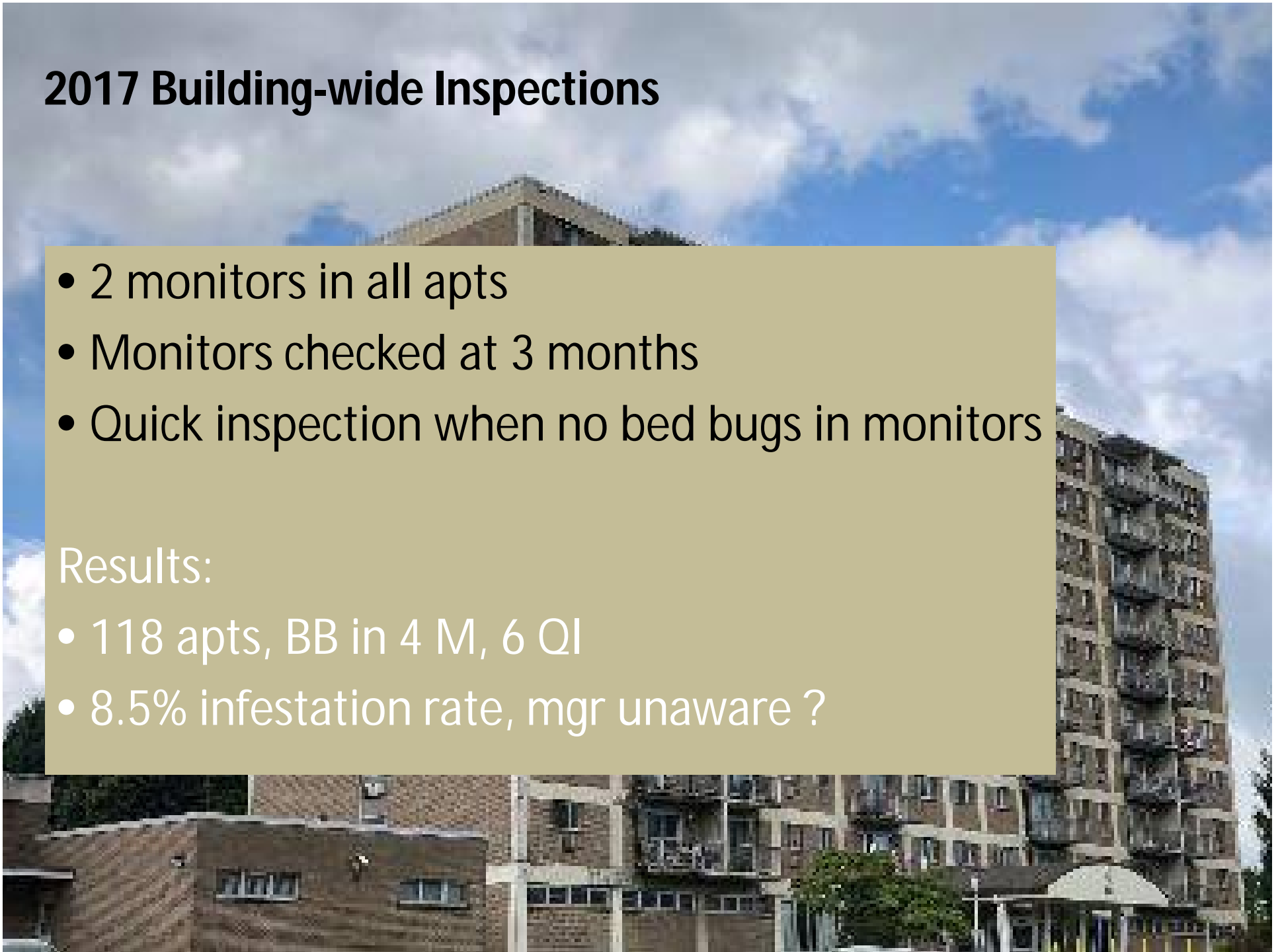
Bld g	Type	Date	# Monitors per Apt	# Apts insp.	# Apts Live BB QI	# Apts Live BB mon	% infestation rate	% mgr not aware
G	Pub/sr-d	8/22 11/14	2	118	4	6	8.5	?
H	Pub/sr-d	9/5 11/28	4	92	1	9	10.9	?

2017 Building-wide Inspections

- 2 monitors in all apts
- Monitors checked at 3 months
- Quick inspection when no bed bugs in monitors

Results:

- 118 apts, BB in 4 M, 6 QI
- 8.5% infestation rate, mgr unaware ?



2017 Building-wide Inspections

- 4 monitors in all apts
- Monitors checked at 3 months
- Quick inspection when no bed bugs in monitors

Results:

- 92 apts, BB in 9M, 1QI
- 11% infestation rate, mgr unaware ?

Bldg	High-Rise Type	2017 Date	Technique	# Apts insp.	% infestation rate	% mgr not aware
A	Pub/sr-d	11-Apr 26-Apr	QI, 2 mon	120	25.4% 26.0%	91.4% 99%
						ing rds
						5%
						2%
						%
						0%
G	Pub/sr-d	14-Nov	QI nd 3mo	118	8.5%	?
H	Pub/sr-d	5-Sep 28-Nov	4 mon all, QI nd 3mo	92	10.9%	?

**Apartment managers
unaware of an average
of 73% of the bed bug
infestations.**

Bldg	# Apts insp.	Time to enter (sec) per apt	Time (min) inside, apts, NO monitors placed Mean ± SD	Cost per apt only QI (\$50/hr = \$0.83/min, * 2 people)	Time (min) inside, apts monitors placed Mean ± SD	Number(%) apts monitors placed	Cost per QI & mon apt Time* (\$1.67/min), monitor (\$2.50/mon)	Total cost (\$) per building
A	130	28.4	2.51	\$4.98	4.82	17(13.1%)	\$14.30, \$5.00 = \$19.30	562.74 + 328.1 = \$890.84
D	143	26.5	2.58	\$5.05	5.00	14(9.8%)	\$14.50, \$5.00 = \$19.50	651.45 + 273 = \$924.45
B	146	45.9	2.05	\$4.70	4.75	10(6.8%)	\$16.51, \$10.00 = \$26.51	639.2 + 265.1 = \$904.3
E	153	46.5	2.36	\$5.23	6.34	13(8.5%)	\$19.19, \$10.00 = \$29.19	732.2 + 379.47 = \$1111.67
C	118	23.0	1.84	\$3.71	4.03	7(5.9%)	\$16.05, \$20.00 = \$36.05	411.81 + 252.35 = \$664.16
F	150	28.0	3.04	\$5.85	7.80	5(3.3%)	\$23.26, \$20.00 = \$43.26	848.25 + 216.3 = \$1064.55
Avg	140	33.1	2.40	\$4.92	5.46	11(7.9%)	\$28.97	\$926.67

* = estimated time to pick up 2 monitors from bldg. G (2.8 min) and 4 monitors from bldg H (3.6 min) data. Using $y = 0.4X + 2$ estimate of time to pick up 8 monitors as 5.2 min

Time & Cost of QI followed by monitors where BB suspected

Bldg	# Apts insp.	Time to enter (sec) per apt	Time (min) inside, apts, NO monitors placed Mean \pm SD	Cost per apt only QI (\$50/hr = \$0.83/min, * 2 people)	Time (min) inside, apts monitors placed Mean \pm SD	Number(%) apts monitors placed	Cost per QI & mon apt Time* (\$1.67/min), monitor (\$2.50/mon)	Total cost (\$) per building
Avg	140	33.1	2.40	\$4.92	5.46	11(7.9%)	\$28.97	\$926.67

Average=\$6.62/apt

*= estimated time to pick up 2 monitors from bldg. G (2.8 min) and 4 monitors from bldg H (3.6 min) data. Using $y=0.4X + 2$ estimate of time to pick up 8 monitors as 5.2 min

Time & Cost of Monitors in All Apts and followed by QI

Bldg	# Apts insp.	# mons per apt	Time (sec) to enter to place monitors Mean \pm SD	Time (min) inside to place monitors Mean \pm SD	Time (sec) to enter apt to inspect monitors (and quick inspection, if needed) Mean \pm SD	Time (min) inside apt to inspect monitors (and quick inspection, if needed) Mean \pm SD	Total time (min) per apartment to enter twice, place and inspect monitors and conduct quick inspection, if necessary Mean \pm SD	Cost per apt Time (\$1.67/min, Monitors (\$2.50)	Total cost per building
Average			34.8	0.95	51.3	3.2	5.6	\$16.85	\$1721.54

Average=\$16.40 per apt

Bldg	# Apts insp.	# mons per apt	Time (sec) to enter to place monitors Mean \pm SD	Time (min) inside to place monitors Mean \pm SD	Time (sec) to enter apt to inspect monitors (and quick inspection, if needed) Mean \pm SD	Time (min) inside apt to inspect monitors (and quick inspection, if needed) Mean \pm SD	Total time (min) per apartment to enter twice, place and inspect monitors and conduct quick inspection, if necessary Mean \pm SD	Cost per apt Time (\$1.67/min , Monitors (\$2.50)	Total cost per building
G	118	2	32.1	0.7	50.5	2.8	4.9	\$8.18 + \$5 = \$13.18	\$1555.24
H	92	4	37.5	1.2	52.1	3.6	6.3	\$10.52 + \$10 = \$20.52	\$1887.84
Average			34.8	0.95	51.3	3.2	5.6	\$16.85	\$1721.54

2018 Building-wide Inspections



Bldg	High-Rise Type	Date	Technique	# Apts insp.	% infestation rate	# apts w/low, medium, heavy infestation	% mgr not aware
2018A	Pub/sr-d	Feb. 6-9, 2018 Feb. 20	QI and BO under/against legs of bed and upholstered chairs, check 2wk	267 apts in 14 stories	18.7% 22.1%	25 low 17 medium 17 heavy	84% 86.4%

Wait for residents to report bed bugs. Monitors in some apts placed by UT at various times, not checked by anyone. Trt protocols same as Bldgs A&D 2017.

low infestation = 1-10 bb, med infestation 11-50 bb, heavy infestation >50 bed bugs seen



Fifth floor: Placed April 16, 2014 and found during QI under bed against wall with 1 living adult on February 8, 2018 (3 yrs and 10 mo later). Only sign of bed bugs in room. Did the monitor prevent bed bugs from establishing?

2018 Building-wide Inspections



Bldg	High-Rise Type	Date	Technique	# Apts insp.	% infestation rate	# apts w/low, medium, heavy infestation	% mgr not aware
2018B	Pvt/Sec 8	Mar 5 -7, 2018 Mar. 21	QI and BO under/against legs of bed and upholstered chairs, check 2 wk	215 apts in 11 stories	0.9% 1.39%	2 low, 1 medium	33, 67 or 100%

- Smoke free building for several years.
- Quarterly canine scent detection team inspections.
- If bed bugs found, heat treatments. Dust with DE.
- One bed bug educational meeting per year delivered by PMP.
- Residents move belongings into building 9-4 M-F.
- Furniture must be inspected by management/maintenance at move-in and any time new furniture brought by resident or business (such as rental center).
- Residents clean up dead bed bugs after treatment.
- Most apts had low clutter levels.

2018 Building-wide Inspections



Bldg	High-Rise Type	Date	Technique	# Apts insp.	% infestation rate	# apts w/low, medium, heavy infestation	% mgr not aware
2018C	Public/elderly & disabled	April 11, 2018 May 9	QI and BO under/against legs of bed and upholstered chairs, check 4 wk	36 apts in 4 stories	8.3% 8.3%	3 low	100%

- Not smoke free except in hallways.
- In-house pest control. Heat treatments, electric & propane.
- Building-wide inspection every 3-4 months, at a minimum of every 6 months. Sometimes insecticidal dust.
- Maintenance wraps and removes bed bug infested furniture if removal necessary.
- If management/maintenance find discarded furniture at the dumpster, they find out who took it out so they can check their apt for bed bugs.

Bldg	Average time (min) inside, apts, NO monitors placed	Average cost to quick inspect, NO monitors placed	Average time (min) inside, apts monitors placed	% Apts in which monitors placed	Average time (min) in apt to inspect monitors	Average # monitors placed per apt	Average cost for apts with monitors (\$2.50/month)	Range cost (\$) per building
2018 ABC	2.84 min	\$4.74	6.41 min	8.7%	4.45 min	8.0	\$18.13 + \$20=\$38.13	\$288 - \$2107

Average= \$7.90/apartment

Cost Calculator?

Cost Predictor for Building-wide Inspection?

Constant = 2.84 min QI; 10.9 min QI, place monitors and check;
91.3% apts QI; 8.7% apts monitors;

Input variables= # apts, hourly wage for 2 technicians, # monitors per apartment, Cost per monitor

275 apts, \$50/hr, 8 mon/apt, \$2.5/month

[illegible]

cost estimator.xlsx - Excel

Vail, Karen M

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW ACROBAT

Clipboard: Cut, Copy, Paste, Format Painter

Font: Calibri, 11, Bold, Italic, Underline, Text Color, Background Color

Alignment: Wrap Text, Merge & Center

Number: General, Currency, Percentage, Decimals, Fractions

Conditional Formatting: Normal, Bad, Good, Neutral, Calculation, Check Cell

Cells: Insert, Delete, Format

Editing: AutoSum, Fill, Clear, Sort & Filter, Find & Select

Q11

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
2	Assume																				
3	2.84 minutes for quick inspection only																				
4	10.86 minutes to quick inspect, place monitors, and check monitors																				
5	91.3% of apartments only require quick inspection																				
6	8.7% of apartment require monitors																				
7	\$2.50 per monitor																				
8	8 monitors per apartment																				
9	Cost for two technicians \$1.67/min																				
10																					
11	Costs to quick inspect, 91.3% apts																				
12	# apts X 0.913 2.84 min/X \$/min rate for 2 technician equals																				
13	275																				
14																					
15	Cost for quick inspection, monitor placement and monitor inspection, 8.7% apts																				
16	# apts X 0.087 10.86 min X \$/min rate for 2 technician X \$/monitor X # monitors																				
17	275																				
18																					

Sheet1

READY

Type here to search

1:37 PM 11/2/2013

Bldg	High-Rise Type	2017 Date	Technique	# Apts insp.	Non chem. control	Building-wide inspections ?	% infest. rate	% mgr not aware
A	Pub/sr-d	11-Apr 26-Apr 11-May	QI, 2 mon 2wk	130	No	No	25.4% 26.9% 28.5%	91.4% 91.9%
D	Pub/sr-d	6-Jun 29-Aug	QI, 2 mon 3mo	143	No	No	22.4% 23.8%	Missing Records
B	Pvt/proj-b sec8 /LITC	18-Apr 2-May	QI, 4 mon 2wk	146	No	3 fl/wk	12.3% 13.0%	89.5%
E	Pvt/proj-b sec8 /LITC	27-Jun 19-Sep	QI, 4 mon 3mo	153	No	3 fl/wk	7.2% 7.8%	18.2%
C	Pub/sr-d	9-May 23-May	QI, 8 mon 2wk	118	Yes, situational	At least 2x/yr	1.7%	50%
F	Pub/sr-d	1-Aug 24-Oct	QI, 8 mon 3mo	150	Yes, situational	At least 2x/yr	4% 4.7%	100%
G	Pub/sr-d	22-Aug 14-Nov	2 mon all, QI nd 3mo	118	Yes, in- house steam & zph, PMP as backup	Inspection take place, but interval and floor # unknown	8.5%	?
H	Pub/sr-d	5-Sep 28-Nov	4 mon all, QI nd 3mo	92	"	"	10.9%	?

Bldg	High-Rise Type	2018 Date	Technique	# Apts insp.	% infestation rate	Non-chemical control	Conducting building-wide inspections	# apts w/low, medium, heavy infestation	% mgr not aware
2018A	Pub/sr-d	Feb. 6-9 Feb. 20	QI and BO under/against legs of bed and upholstered chairs, check 2wk	267 apts in 14 stories	18.73% 22.09%	No	No	25 low 17 medium 17 heavy	84% 86.4%
2018B	Pvt/Sec 8 /sr-d	Mar 5 -7 Mar. 21	QI and BO under/against legs of bed and upholstered chairs, check 2 wk	215 apts in 11 stories	0.9% 1.39%	Yes, heat, contracted	Yes, 4x/yr	2 low, 1 medium	3,67 or 100%
2018C	Pub/sr-disabled	April 11 May 9	QI and BO under/against legs of bed and upholstered chairs, check 4 wk	36 apts in 4 stories	8.3% 8.3%	Yes, heat, in-house	Yes, 2-4x/yr	3 low	100%

low infestation = 1-10 bb, med infestation = 11-50 bb, heavy infestation >50 bed bugs seen.
Monitors placed in an average of 8.7% of apts/bldg.

Conclusions

- Building-wide inspections are needed
- A variety of these techniques were effective
- Little difference in the time to conduct each when quick inspection performed first (~\$7-8/apt)
- Placing 2 or 4 monitors in every room did increase the time and cost (~\$16-17/apt)
- No building-wide inspections and only chemical control led to higher infestation rates and higher levels of infestations

Statistical analyses have not been conducted yet

Credits

- "This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award numbers 2013-34103-21213 and 2013-41530-21214, a 2017-18 Southern IPM Center Enhancement Program Capstone Grant and a USDA, NIFA, CPPM, EIP grant."
- "Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture."



United States
Department of
Agriculture

National Institute
of Food and
Agriculture



Bed Bug Movement in Residential Environments & What to Do



Cuyahoga County Bed Bug Task Force, Nov. 1, 2019, 11 am – 12 pm, panel 3:15 – 4 pm

Karen Vail, kvail@utk.edu
University of Tennessee

