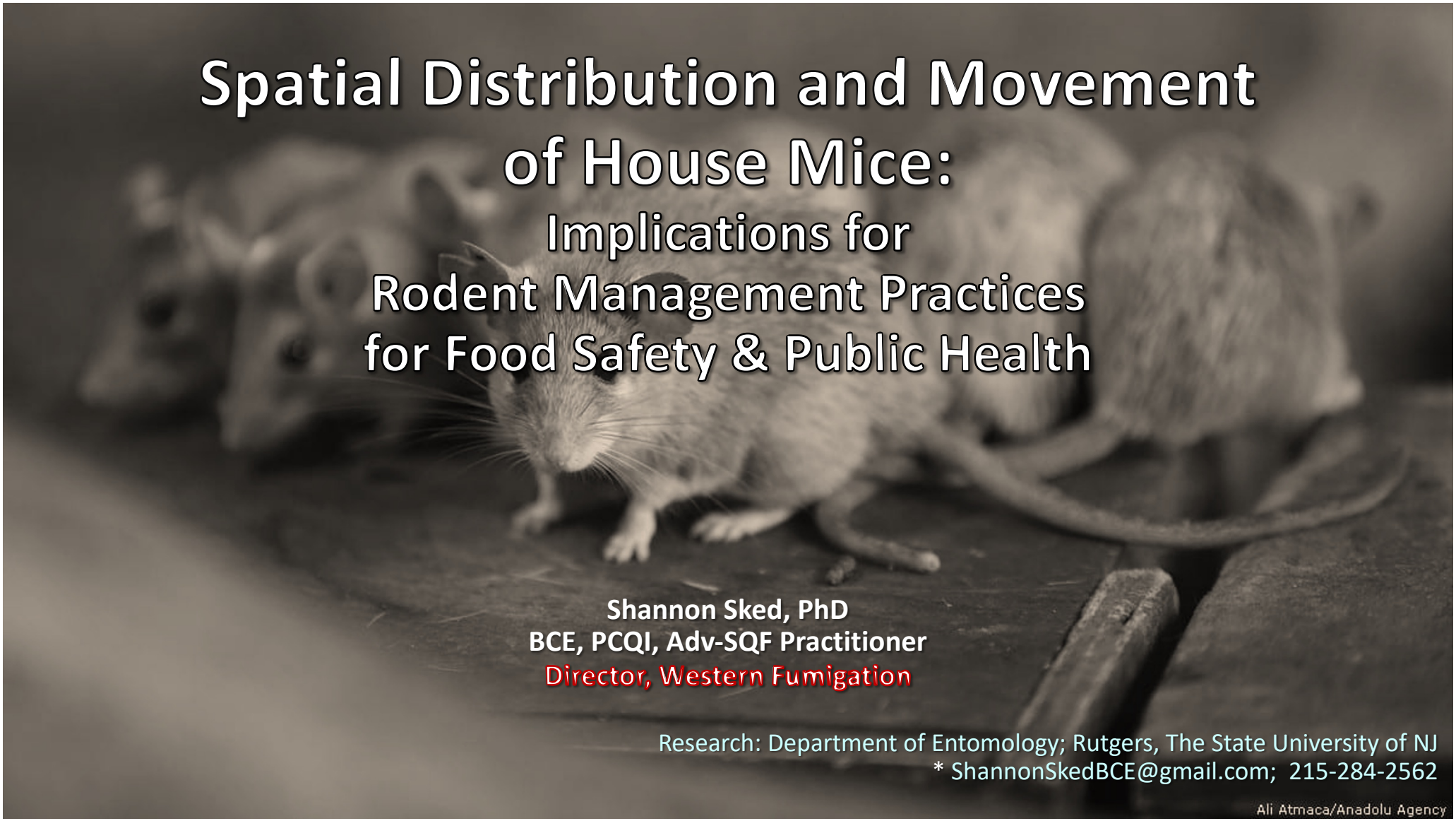

Spatial Distribution and Movement of House Mice:

Implications for Rodent Management Practices for Food Safety & Public Health

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Director, Western Fumigation

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Public Health Importance
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Public Health Importance

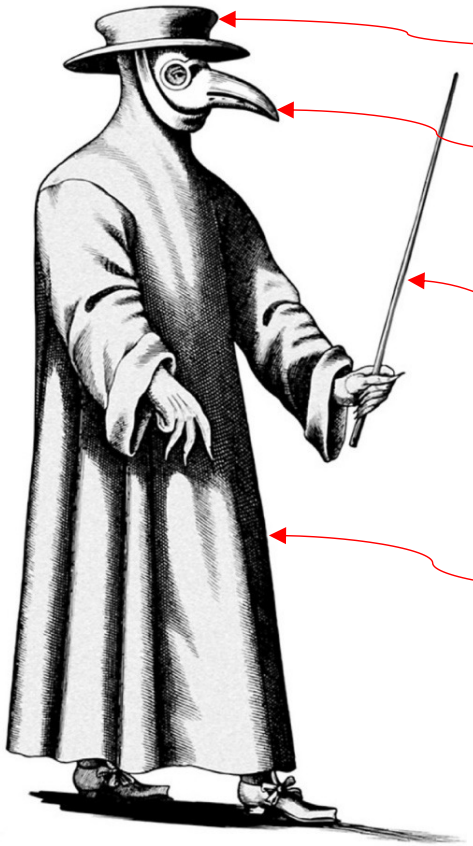
Commensal Rodents and the History of Disease

Yersinia pestis

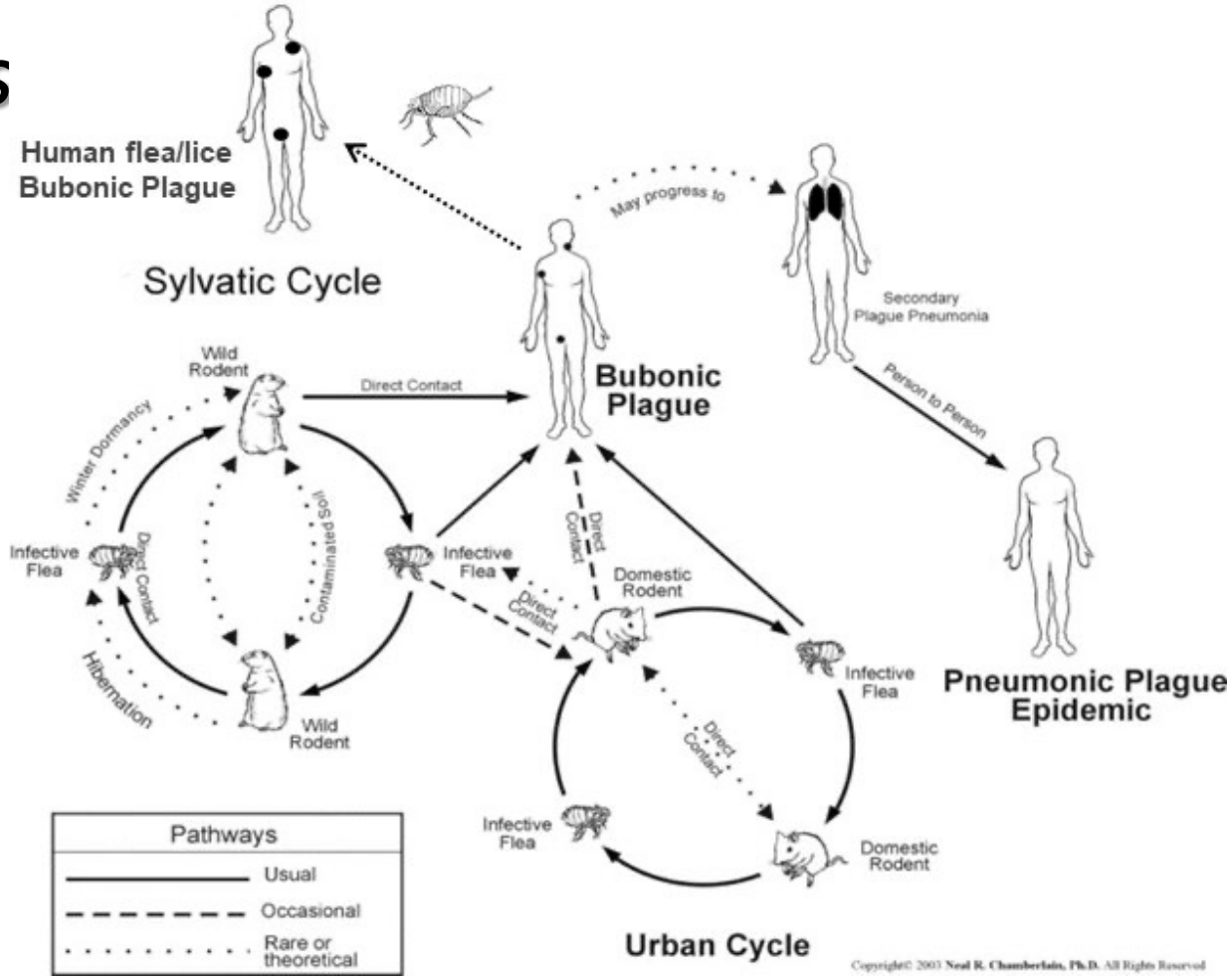
- ~1,800 BCE: Bronze age skeleton had DNA genomic material for plague
- ~1,000 BCE: Biblical (1 Samuel) discusses Philistines & “rodent tumors”
- 541 BCE: Justinian plague (India > Constantanople)
  - 15 subsequent waves through 750 CE (AD) from Persia to Ireland
- 1347 CE: Black Death-Messina, Sicily from Genoese ships from Asia
  - 1/3 (25 million) of European population succumbs
  - 1348 CE – France>Spain>Germany>Switzerland>Austria
  - 1349 CE – London
- 1665 CE: London lost 1/4th of its population

Yersinia pestis

- 1st HazMat Suit!



Yersinia pestis



Baril et al. 2019. Can we make human plague history? A call to action. *BMJ Global Health* 4(6):e001984

© 1750-1799 Metropolitan Museum of Art

H. Tiffin and Son Ltd.
1st PCO 1690, London
Bed bugs and Rats

Public Health Importance

Commensal Rodents and the History of Disease

Public Health Importance

Commensal Rodents and the History of Disease

Public Health Importance

Commensal Rodents and the History of Disease

Public Health Importance

Commensal Rodents and the History of Disease

Public Health Importance

Commensal Rodents and the History of Disease

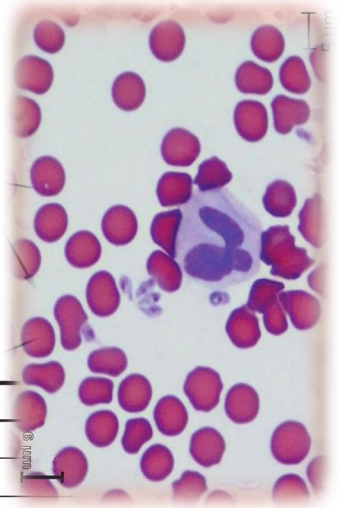
The House Mouse

Public Health Importance

Commensal Rodents and the History of Disease

The House Mouse

Public Health Importance



- Disease causing organisms carried:
  - 7 ectoparasites and 14 endoparasites (Battersby et al. 2008)

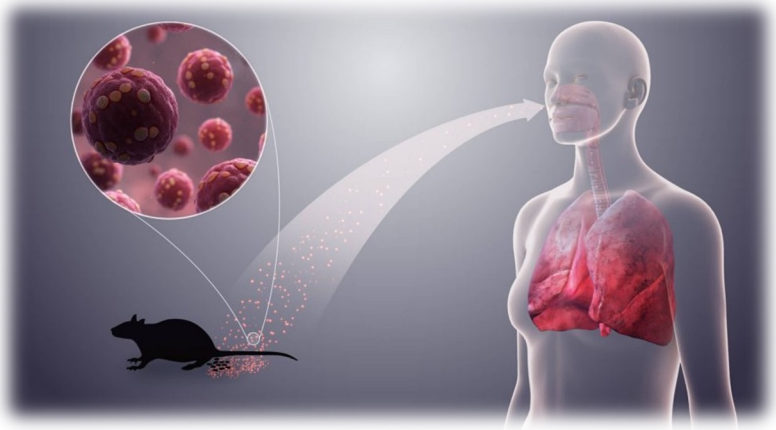
Table 12.1. Zoonoses associated with commensal rodents

Human disease	Ectoparasites
Bubonic plague	Asiatic rat flea – *Y. pestis*
LBRF	Body louse – *B. recurrentis*
Tick-borne relapsing fever	Ticks *(Ornithodoros hermsi)* – *Borrelia spp.*
Lyme disease	Ticks *(Ixodes spp.)* – *B. burgdorferi*
Rickettsial pox [a]	Rodent mite *(Liponyssoides sanguineus)* – *Rickettsia akari*
Murine typhus [a]	Asiatic rat flea – *R. typhi* Body louse – *R. typhi*

Human disease	Endoparasites
Capillariasis	*Capillaria* spp.
Toxocariasis	*Toxocara* spp.
Rat tapeworm infection	*Hymenolepis nana*
Diarrhoeal disease	*Trichuris* spp.
Diarrhoeal disease	*Hymenolepis* spp.
Diarrhoeal disease	*Taenia* spp.
Schistosomiasis ***	*Schistosoma* spp.
Trichinellosis*	*Trichinella* spp.
Cryptosporidiosis [a]	*C. parvum*
Toxoplasmosis [a]	*T. gondii*
Babesiosis	*Babesia* spp.
Sarcosporidiosis	*Sarcocystis* spp.
Coccidiosis	*Coccidia (Eimeria* spp.*)*
Amoebic dysentery	*Entamoeba* spp.

Public Health Importance

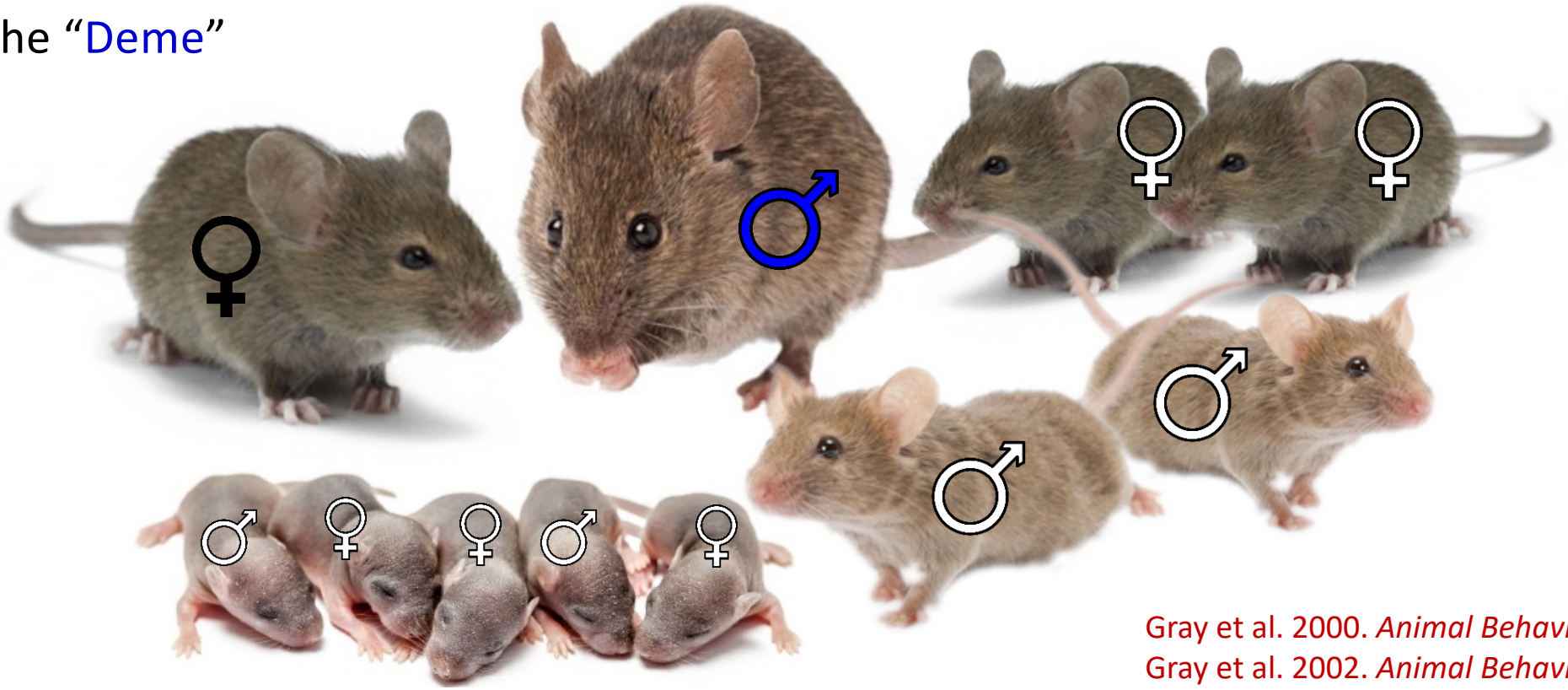
- Disease causing organisms carried:
  - 36 viruses (Williams et al. 2018b, Meerburg et al. 2009) with 6 of those being novel
    - Hantavirus (Mills and Childs 1998)
    - Tamiami (Calisher et al. 1970)
    - Whitewater Arroyo Virus (Fulhorst et al. 1996)




Social Structure of House Mice
WESTERN FUMIGATION
Ali Atmaca/Anadolu Agency

The Social Order of the House Mouse

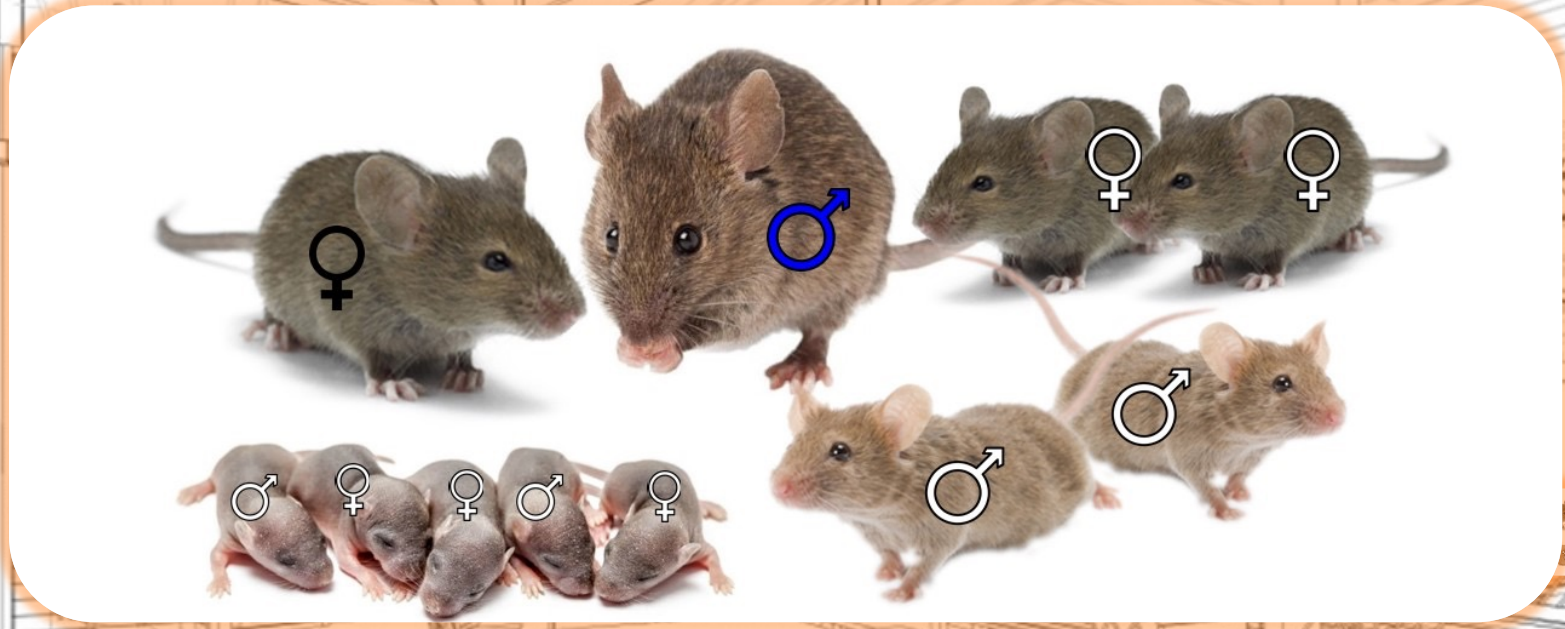
- The "Deme"



Gray et al. 2000. *Animal Behavior*
Gray et al. 2002. *Animal Behavior*

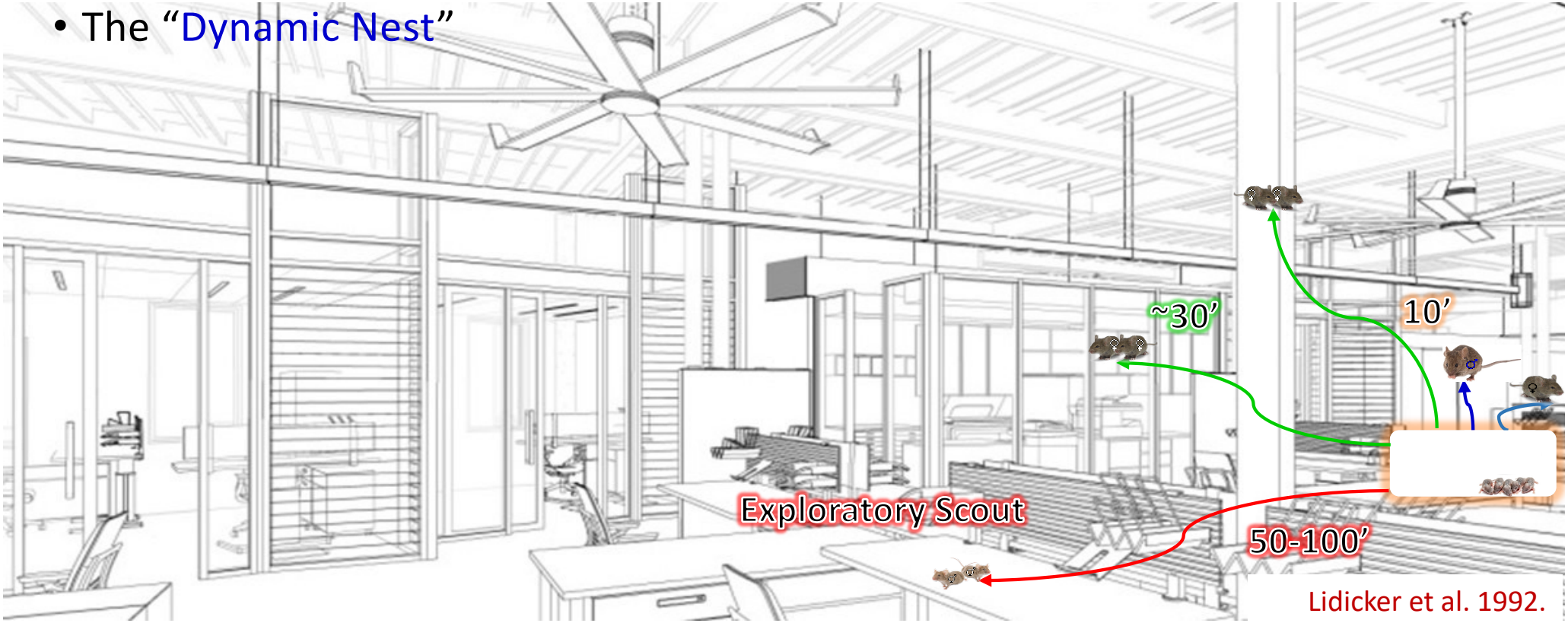
The Social Order of the House Mouse

- The "Nest"



The Social Order of the House Mouse

- The "Dynamic Nest"



Lidicker et al. 1992.

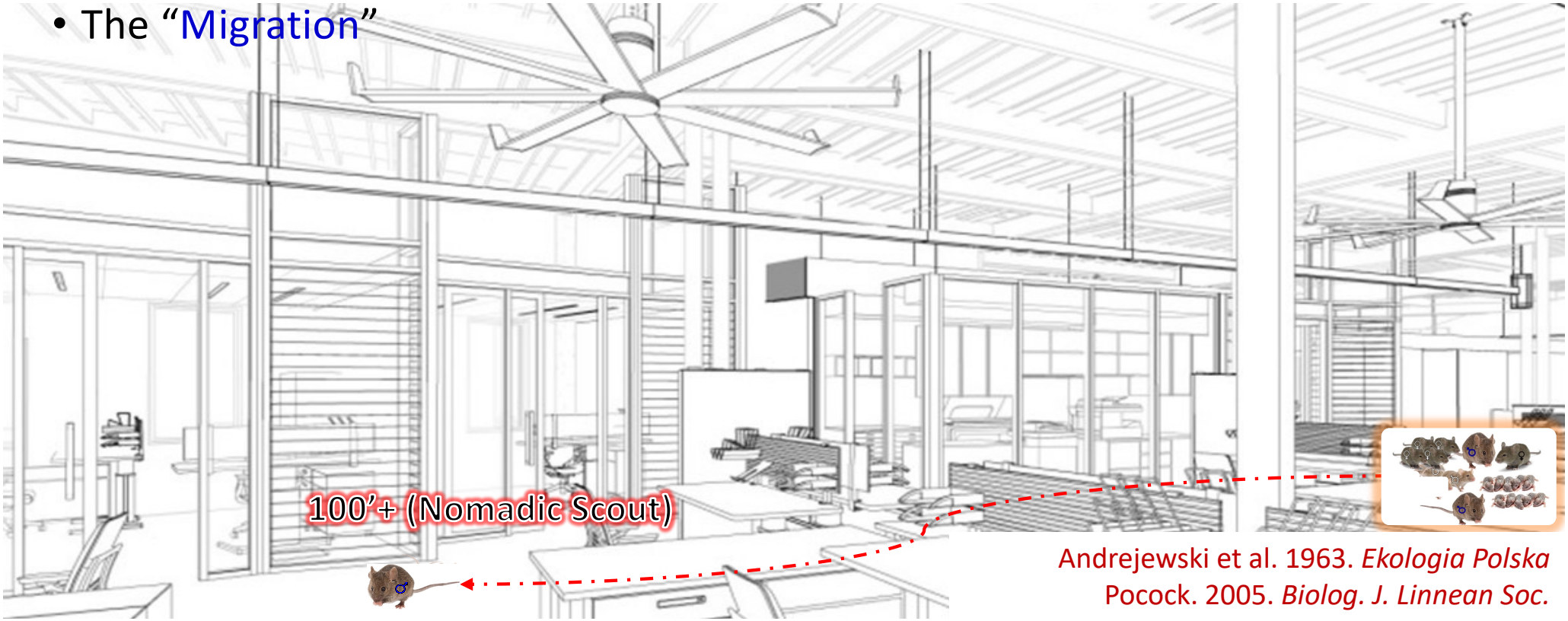
The Social Order of the House Mouse

- The "Growing Nest"

Battersby et al. 2008. Commensal Rodents

The Social Order of the House Mouse

- The "Migration"



Andrejewski et al. 1963. *Ekologia Polska*
Pocock. 2005. *Biolog. J. Linnean Soc.*

The Social Order of the House Mouse

- The "Budding Nests"

DeLong. 1967. *Ecol.*

Pocock et al. 2005. *Biolog. J. Linnean Soc*

The Social Order of the House Mouse

- The "Budding Nests"

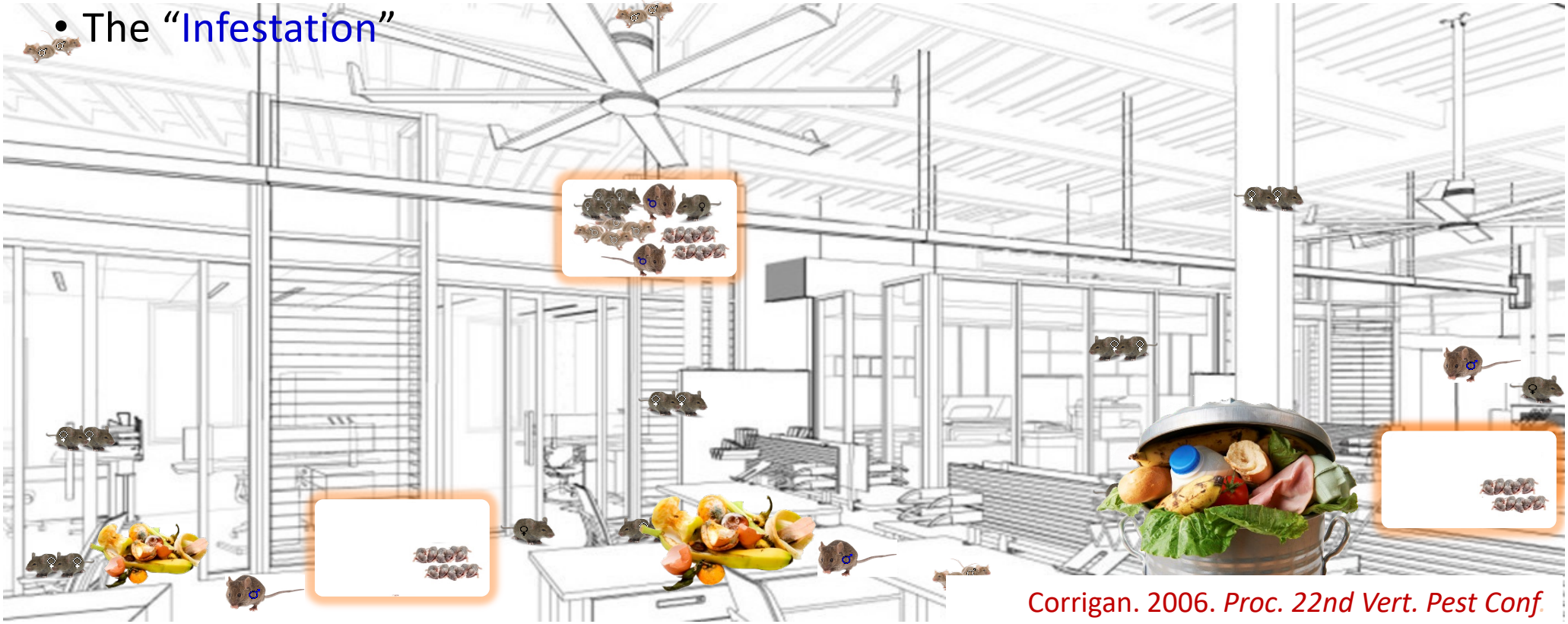
The Social Order of the House Mouse

- The "Deme Set"

The Social Order of the House Mouse

The Social Order of the House Mouse

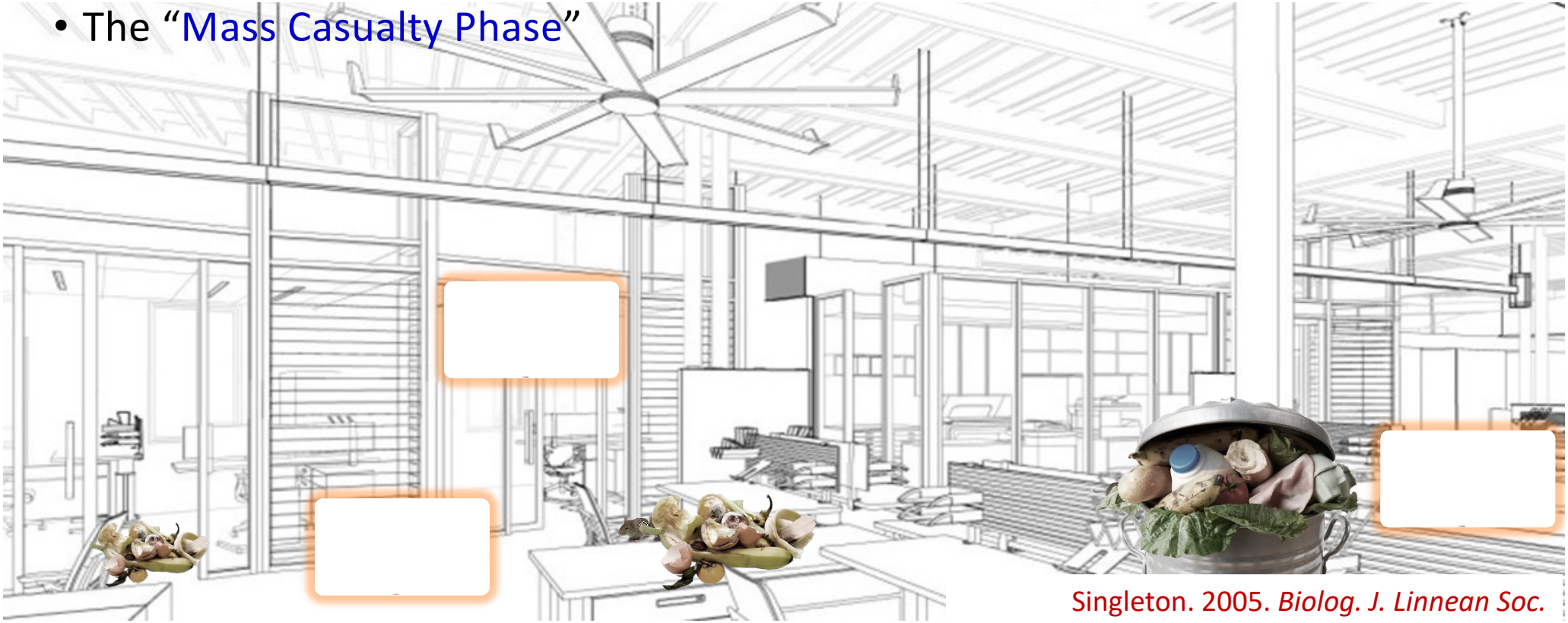
- The "Infestation"



Corrigan. 2006. *Proc. 22nd Vert. Pest Conf.*

The Social Order of the House Mouse

- The "Mass Casualty Phase"



Singleton. 2005. *Biolog. J. Linnean Soc.*

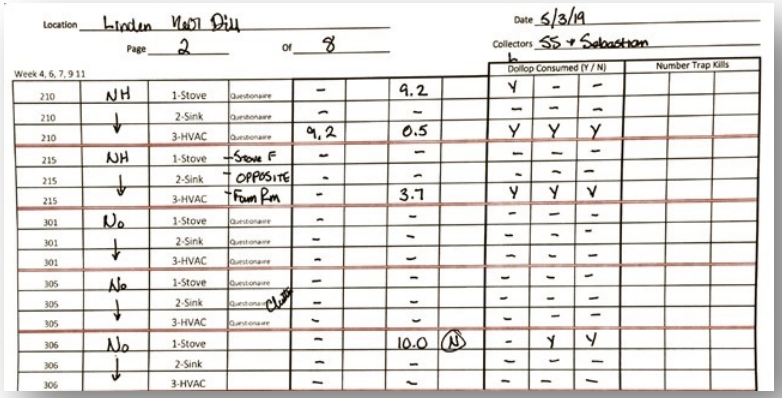

Research 1:
Monitoring & Treatment
WESTERN FUMIGATION
Ali Atmaca/Anadolu Agency

Part 1 Objectives: Monitoring and Treatment

- Are residents' complaints a reliable indicator of infestations?
- Compare effectiveness of non-toxic food baits for detection
- Do mice visit specific "in-apartment" bait placement locations more often?
- What aspects of IPM have long term effects

Part 1 Materials and Methods

1. Building-wide Evaluation & Interviews (Trenton=246 and Linden=200)
   a. Conduct resident questionnaire/interview
   b. Install 2 monitors with blank baits (10.5 g) & chocolate (~1g dabs)
   c. Return 1 week to determine presence / absence



Location Linden Mast Bill — Date 5/3/19
Page 2 Of 8 — Collectors SS + Sebastian
Week 4, 6, 7, 9 11

								Dollop Consumed (Y / N)			Number Trap Kills		
210	NH	1-Stove	Questionaire	–		9.2		Y	–	–			
210	↓	2-Sink	Questionaire	–		–		–	–	–			
210		3-HVAC	Questionaire	9.2		0.5		Y	Y	Y			
215	NH	1-Stove	–Stove F	–		–		–	–	–			
215	↓	2-Sink	OPPOSITE	–		–		–	–	–			
215		3-HVAC	Foam Rm	–		3.7		Y	Y	Y			
301	No	1-Stove	Questionaire	–		–		–	–	–			
301	↓	2-Sink	Questionaire	–		–		–	–	–			
301		3-HVAC	Questionaire	–		–		–	–	–			
305	No	1-Stove	Questionaire	–		–		–	–	–			
305	↓	2-Sink	Questionaire CLOSET	–		–		–	–	–			
305		3-HVAC	Questionaire	–		–		–	–	–			
306	No	1-Stove		–		10.0	(N)	–	Y	Y			
306	↓	2-Sink		–		–		–	–	–			
306		3-HVAC		–		–		–	–	–			

Part 1 Materials and Methods

2. Treatment: Start Week 4 (Trenton=19 and Linden=49 apartments)
   a. Install 3 bait stations with rodenticide in apartments with activity
   b. Return to service weeks 4 times (weeks 6, 7, 9, 11); weighed and replaced

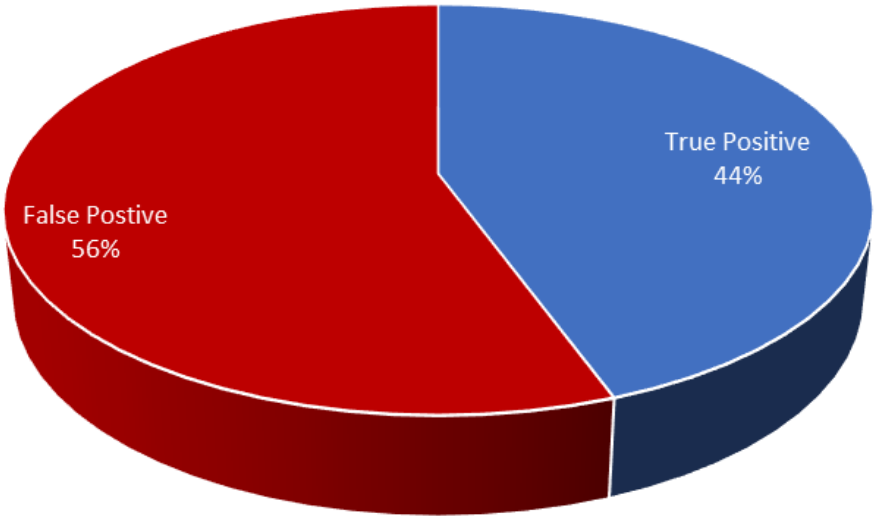
Part 1 Materials and Methods

3. Install 2 monitors with blank baits on week 11
   a. Return the following week to evaluate treatment effectiveness

4. Repeat building wide inspections on months 6 and 12
   a. Follow same process and protocols for initial inspection
   b. Determine if IPM treatments had a long term effect

Part 1 Results: Residents' Complaints

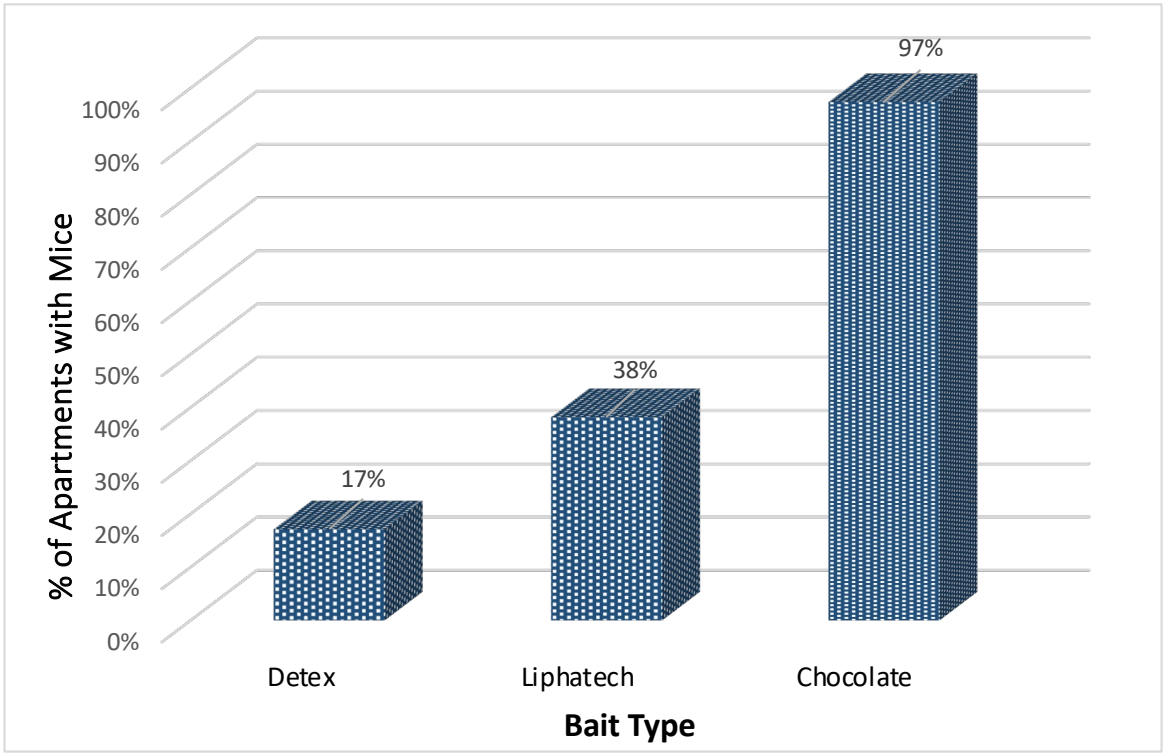
- Of 18 apartments with residents that thought they had mice,
  - 56% did not have mice
- Among 19 apartments with mice
  - Only 42% were aware of it



Proportion of observed activities confirmed or not by feeding activity

Part 1 Results: Effectiveness of Non-Toxic Baits

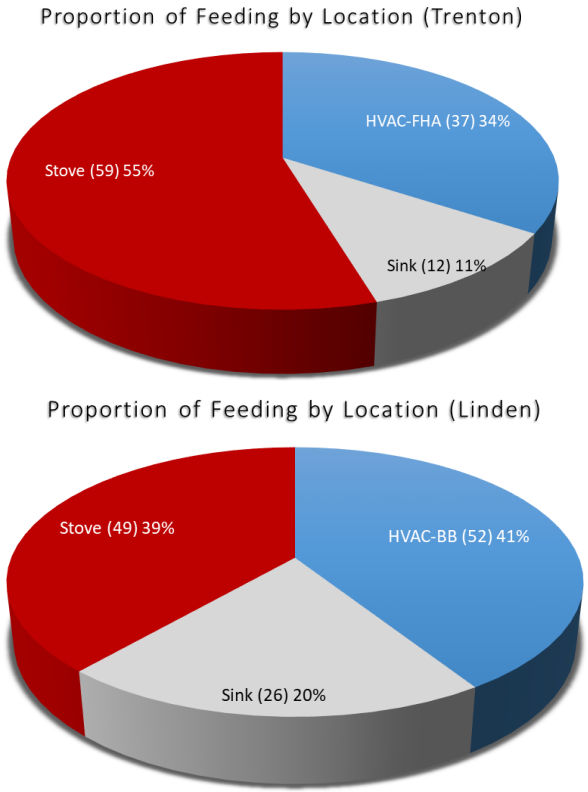
- Chocolate spread was fed upon more often than commercial baits
  - 69.5% of the feeding occurrences had only chocolate spread consumption
- Liphatech was consumed more than Detex soft bait



Part 1 Results: Location Effect

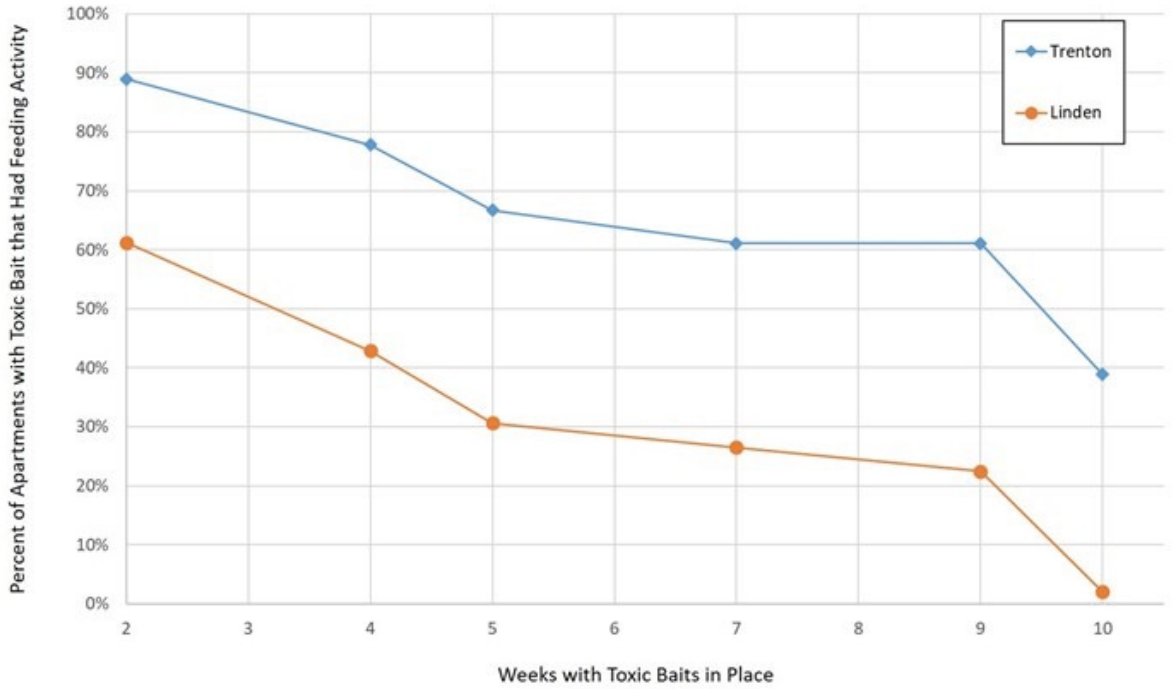
- Location preference was found among 3 locations

- However, this was different based on building construction
  - Trenton: Stove
  - Linden: HVAC & Stove



Part 1 Results: Impacts of IPM Treatments

- During the weeks the IPM was in place, there was a reduction in infestations



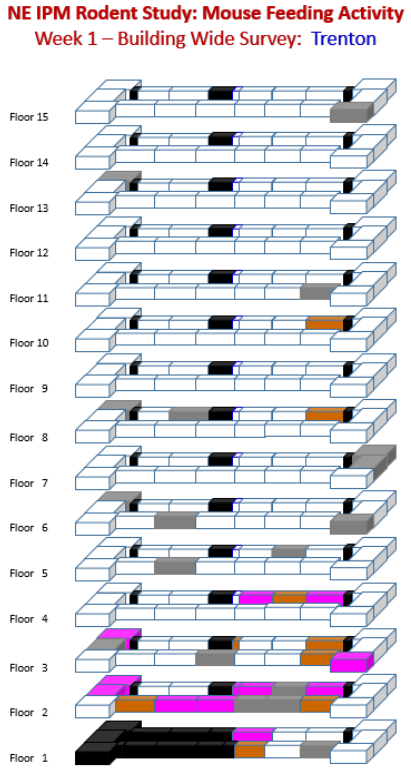
Part 1 Results: Effect of Sanitation/Clutter

- Individual apartment sanitation and clutter did not impact mouse activity during treatments
  - Separate or combined

Part 1 Results: Impacts of IPM Treatments

- Lower 3 floors were more likely to have feeding activity

- Exclusion has a significant impact
  - Building wide aspect



Part 1 Conclusions

1. Are residents' complaints a reliable indicator of infestations?
   - Resident complaints are not a reliable way to identify activity
   - Building wide monitoring should be implemented

2. Comparative effectiveness of non-toxic food baits for detection
   - Chocolate Spread > Liphatech > Detex (soft)
     - Bait preference is very complex, based on pheromones, behavior and genetics
     - Bait preference is also not stable; alternatives should be investigated

Part 1 Conclusions

3. Mice may occur more often in certain locations in an apartment
   - Understanding building construction for within-envelop navigation is important
   - Based on runway routes

4. Building wide exclusion is important for long term management
   - Building wide aspects are more important than individual resident conditions
   - Outer envelope exclusion is of primary importance


Research 2:
Spatial Movement
WESTERN FUMIGATION
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Part 2 Objectives: Spatial Movement

- Evaluate the risks associated with infested neighboring units between apartments within a building
  - Is there a correlation between neighboring units in their infestation status?

Part 2 Materials and Methods: Study Locations

- Utilize building-wide inspections of 4 buildings in 3 distinct cities in NJ
  - Inspections occurred at month 0 and 1 year later
  - Trenton (T_1), Linden (L_1), and 2 in Patterson (P_1 and P_2)

Part 2: Materials and Methods: Monitoring

- Installed mouse bait stations with 3 non-toxic baits in each apartment
  - Baits:
    - Detex® Soft Bait 9.5g
    - Liphatech® Rat and Mouse Attractant 10.4g
    - Hershey's Spreads Chocolate 3g in 3 separate dollops

- Returned 1 week after installation
  - Inspected & identified units with or without feeding

Part 2 Materials and Methods: Data Analysis

- Drawn out building layouts

- Organized data into matrix of pairs for each building
  - If 2 apartments are paired (shared wall, ceiling/floor) = 1
  - If 2 apartments do not share walls, ceiling/floors = 0

- Test independence of house mouse infestations and connected apartments
  - Conduct a permutation statistical test
    - Does having a “1” mean that it’s more likely that mouse activity will be present?
  - P-value<0.05 = correlation between neighboring units in their infestation status

Part 2 Materials and Methods: Study Locations

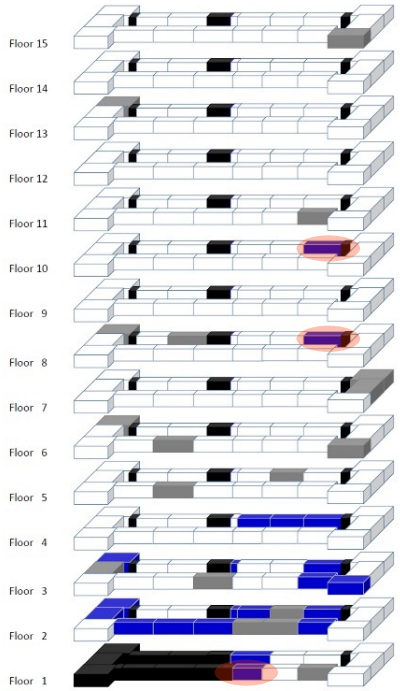
- Building attributes and pest management were similar
  - Exception: the proportion of apartments with shared walls
  - Will use the term "isolated" = no shared walls with apt on same floor

Building	% apartments with two shared walls	% apartments with one shared wall	% apartments with no shared walls
T_1	65%	35%	0%
L_1	60%	40%	0%
P_1	36%	43%	21%
P_2	33%	40%	27%

Part 2 Results: Observed Activity

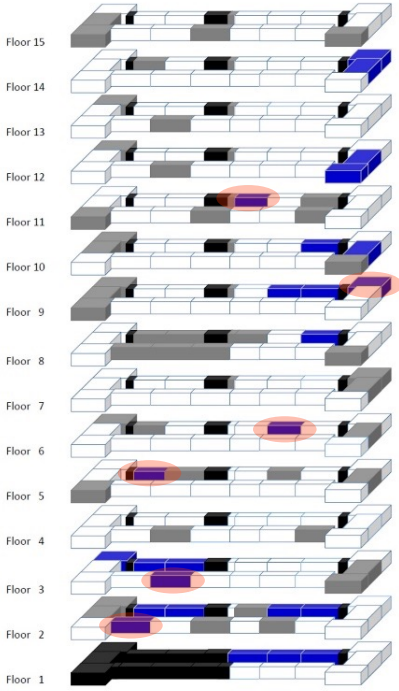
- T_1 Building

Initial Inspection

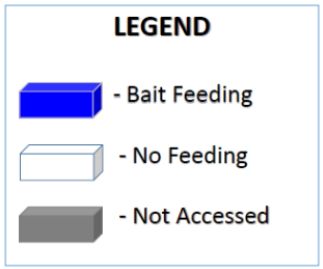


3 of 21 (14%) infestations were in apartments without infested neighbors

1-Year Inspection



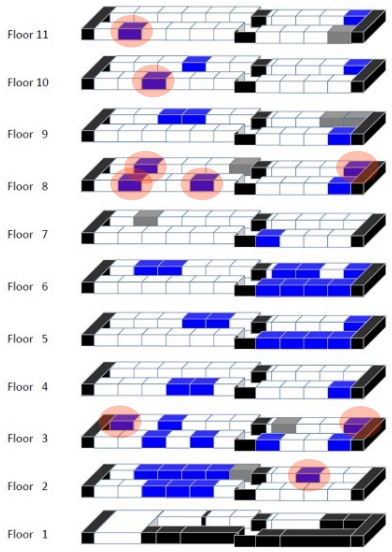
6 of 25 (24%) infestations were in apartments without infested neighbors



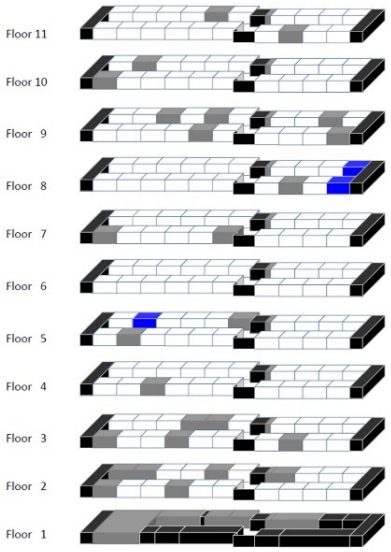
Part 2 Results: Observed Activity

- L_1 Building

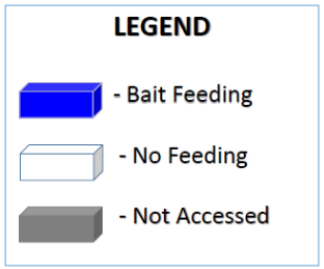
Initial Inspection



1-Year Inspection



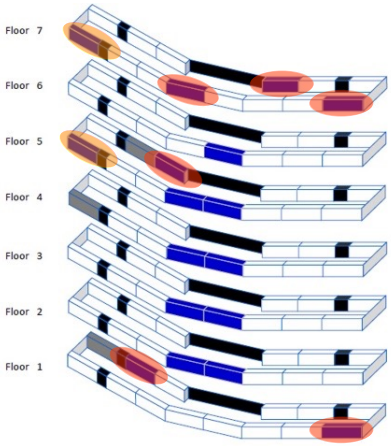
9 of 48 (19%) infestations were in apartments without infested neighbors



Part 2 Results: Observed Activity

- P_1 Building

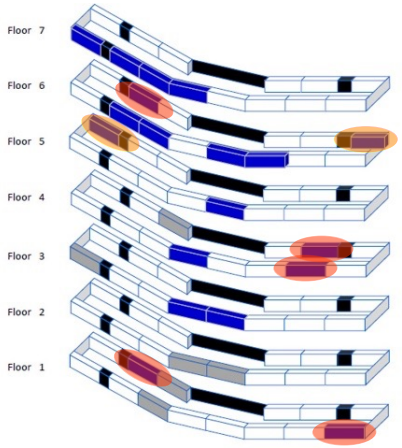
Initial Inspection



8 of 17 (47%) infestations were in apartments without infested neighbors

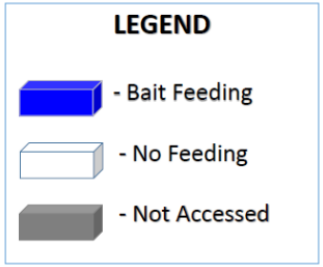
However, **2 of those 8** were isolated

1-Year Inspection



7 of 19 (37%) infestations were in apartments without infested neighbors

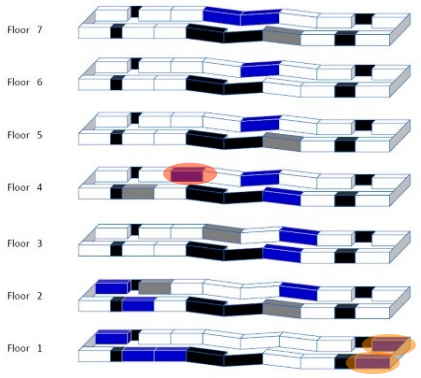
However, **2 of those 7** were isolated



Part 2 Results: Observed Activity

- P_2 Building

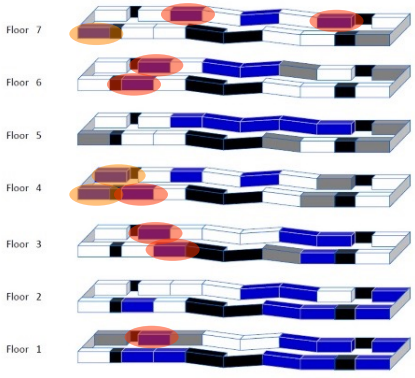
Initial Inspection



3 of 17 (18%) infestations were in apartments without infested neighbors

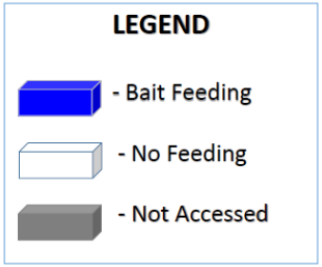
However, **2 of those 3** were isolated

1-Year Inspection



11 of 39 (28%) infestations were in apartments without infested neighbors

However, **3 of those 7** were isolated



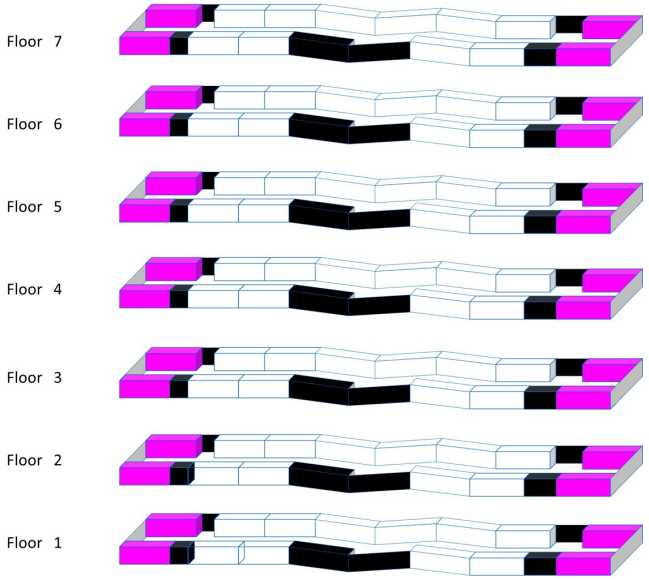
Part 2 Results: Data Analysis

- Significant correlation was found between neighboring units in their infestation status in 3 of the 4 buildings
  - * = L_1 could not be tested at the 1 year mark due to very few infestations
  - P_2 did not show significant correlation

Building	P-value	
	Initial visit	Second visit
T_1	0.00003	0.00003
L_1	0.00091	*
P_1	0.00053	0.03426
P_2	0.07014	0.09091

Part 2 Results: Data Analysis

- P_2 had the highest proportion of apartments that were isolated (27%)
  - Fewest opportunities for neighbors' infestation status to influence each other



Part 2 Conclusions

1. Apartments infestation status is correlated to neighboring units' status
   - This clustered distribution has implications for pest control operations

2. House mouse management should utilize this information during treatment
   - Building wide inspections can be used to identify infestations (Sked 2021)
   - During treatments, monitoring neighboring units can help to ensure elimination

3. Building construction and layout should considered for monitoring activities
   - Correlation is lessened in buildings with higher proportions of isolated apartments


Summary: Implications
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Summary

1. Building wide inspections by professionals are necessary to identify issues
   a) Reliance on patients, guests, residents alone may not prove reliable

2. Ongoing perimeter level facilities maintenance is key for prevention
   a) Involve engineering in root cause analysis – construction is important to consider

3. Once sources are identified, treat and monitor neighboring areas
   a) Use a variety of bait sources to identify what is preferred by resident population

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Thank you!

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Questions?