NC STATE UNIVERSITY

Public health

IPM

Baits

Conclusions

Cockroach Related Biocontainments and Health-Related Impacts

1. **Cockroaches & <u>Public Health</u>**
2. **Integrated Pest Management**
   - Why does IPM often fail?
   - How do we make it work?
3. **<u>Baits</u>**: highly effective!
   - Challenges with baits

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North Carolina State University

National Institute of Environmental Health Sciences

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Public Health: Cockroaches

What are 2 major reasons why cockroaches are important in PUBLIC HEALTH?

1. Pathogen, disease & antibiotic resistance transmission
2. Allergens & respiratory disease

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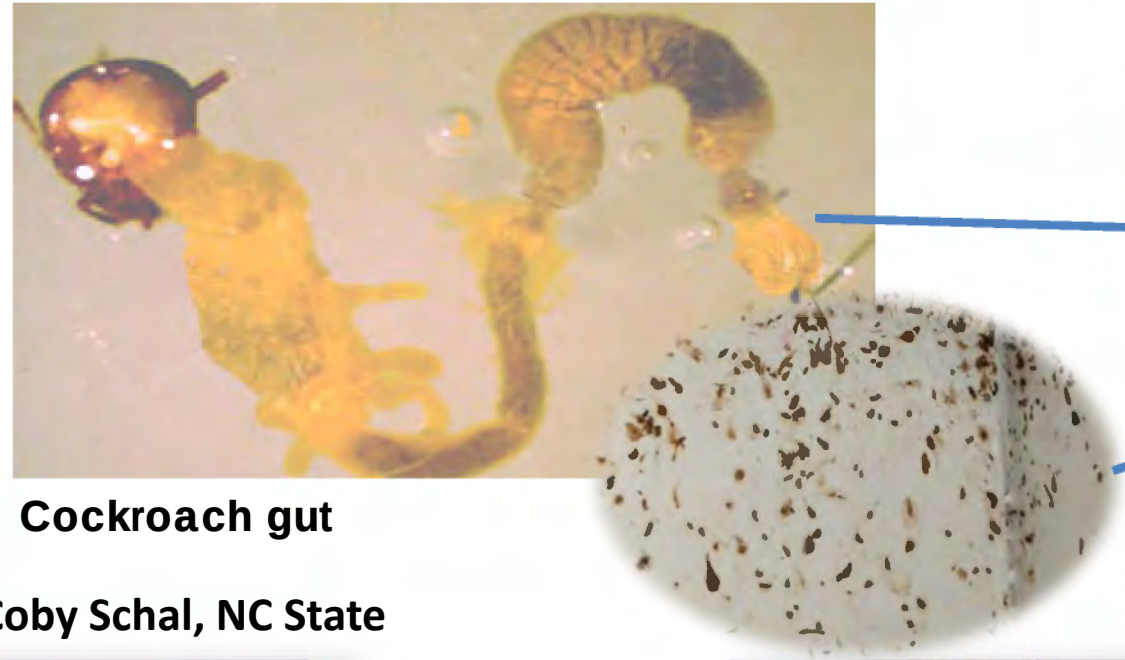
Public Health 1. Pathogen transmission

Microbiome/Microbiota:
microbial community (bacteria, fungi, viruses) at a specific site (e.g., gut)



Cockroach gut

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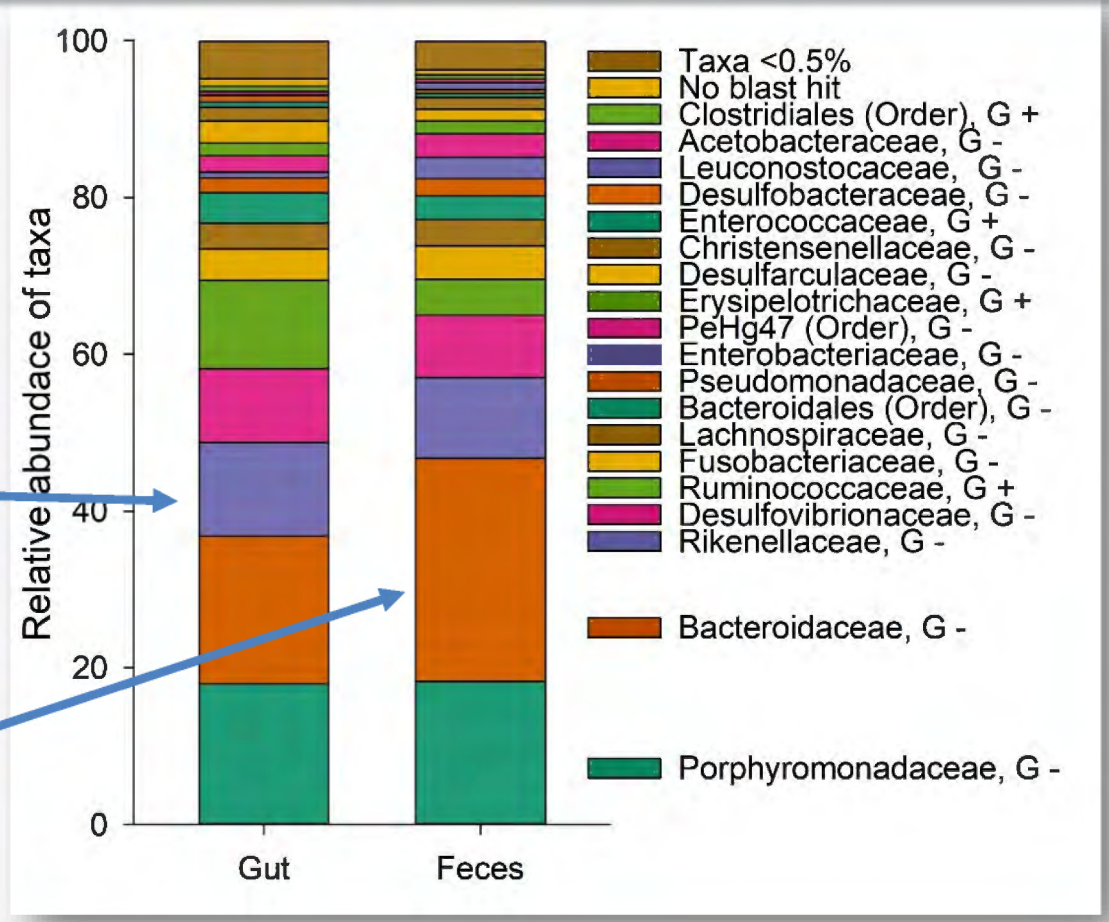

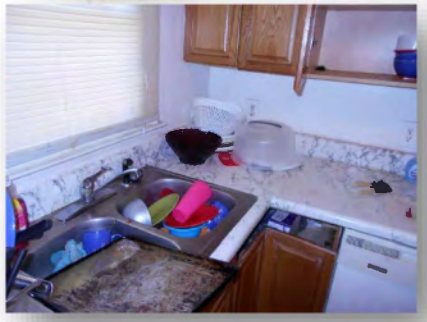

Same bacteria in **gut** and **feces**

Cockroach **gut** can vector **pathogens** from **toilet** to **kitchen**

Public Health 1. Pathogen transmission

Bacterial pathogens **isolated** from cockroaches:

- **bubonic plague** (*Pasteurella pestis*)
- **dysentery** (*Shigella alkalescens*)
- diarrhea (*Shigella paradysenteriae*)
- urinary tract infection (*Pseudomonas aeruginosa*)
- abscesses (*Staphylococcus aureus*)
- **food poisonings** (*Clostridium perfringens, Escherichia coli, Streptococcus faecalis, P. vulgaris*)
- **gastroenteritis** (*Salmonella schottmuelleri, S. bredeney, S. oranienburg*)
- typhoid fever (*Salmonella typhosa*)
- leprosy (*Mycobacterium leprae*)
- nocardiosis (*Actinomyces* spp.).
- **cholera, pneumonia, diphtheria** (*Corynebacterium diphtheriae*)
- anthrax (*Bacillus anthracis*)
- black leg (*Glostridium chauvoei*)
- tetanus (*Glostridium tetani*)
- **tuberculosis** (*Mycobacterium* spp.)

But…

poor documentation of pathogen & disease transmission by cockroaches

2011

CHAPTER 2
COCKROACHES

2021

CHAPTER 2
Public health and veterinary importance

Many fungi:
Alternaria sp.
Aspergillus spp.
Candida spp.
Penicillium spp.

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Public Health 1. Antibiotic Resistant Bacteria

- 8 million pigs in NC (10M people)
- > $6 billion annually
- **Antibiotics fed to promote pig growth**

sped up 1.5X

Ahmad et al. BMC Microbiology 2011, 11:23
http://www.biomedcentral.com/1471-2180/11/23

BMC Microbiology

RESEARCH ARTICLE Open Access

Insects in confined swine operations carry a large antibiotic resistant and potentially virulent enterococcal community

Aqeel Ahmad[1,4], Anuradha Ghosh[2], Coby Schal[3], Ludek Zurek[1,2*]

Rick Santangelo

- Many **antibiotic resistant bacteria** in the cockroach **gut**
- Antibiotic resistance profiles are **identical** in bacteria from **pig feces** and **cockroach feces** (few antibiotic resistant bacteria in cockroaches from homes in Raleigh, NC)
- **Cockroaches as potential vectors of pathogenic & antibiotic resistant bacteria!**

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Public Health 2. Allergens & Asthma

Asthma: An old… but surging pulmonary disease

- Long-term lung disease that inflames and narrows the airways
- Induced by exposure to an allergen

Cockroaches → **Allergens** → **Allergies & Asthma** ← Medical interventions

- 24.6 M Americans have **asthma**
  - **> 7 million children**
- $82 billion annual costs
- 1.75 M emergency room visits

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Public Health 2. Allergens & Asthma

Cockroach Infestation

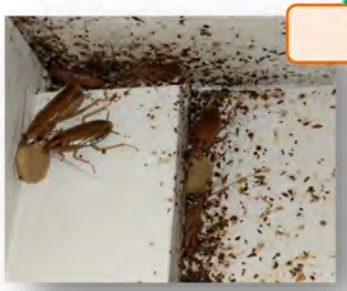
Allergens

Socio-economics

Allergies & Asthma

Medical interventions

Genetics



Environmental interventions

Pest Control is Central to Environmental Interventions

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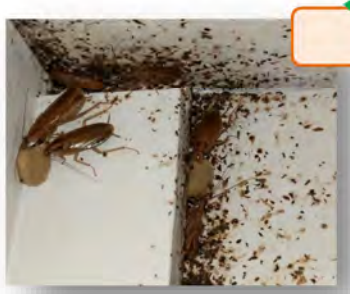
Public Health 2. Allergens & Asthma



Cockroach Infestation

Environmental microbes

organics

Allergens

Bacteria, fungi and others

Endotoxins Glucans

Live microbes

Secondary metabolites

Environmental interventions

Pest Control is Central to Environmental Interventions

Socio-economics

Allergies & Asthma

Medical interventions

Genetics

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Public health

IPM

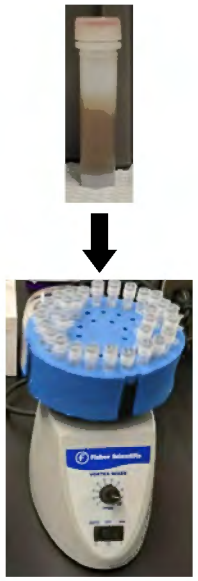
Baits

Conclusions

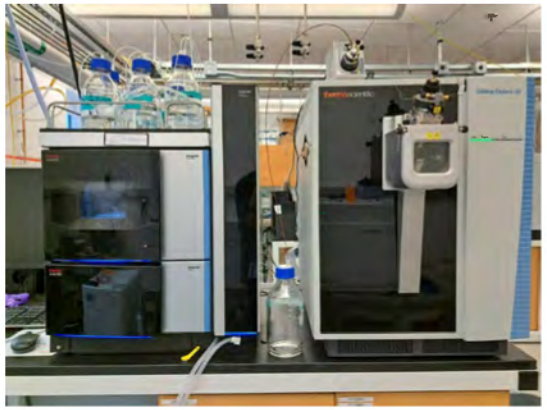
Association of Emerging Biocontaminants with Cockroaches

Objective: Understand the association of cockroach infestations and emerging indoor metabolites

Sample Collection

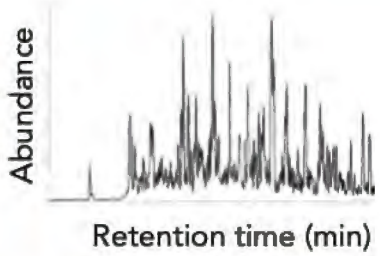


Sample Extraction



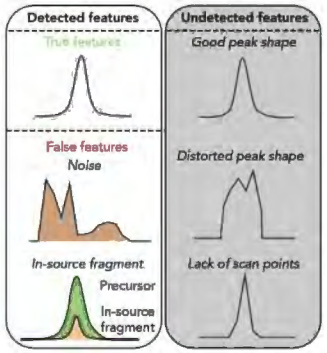
LC-MS Analysis

Raw data



Data processing

Metabolomics: CHHE-METRIC



Final data

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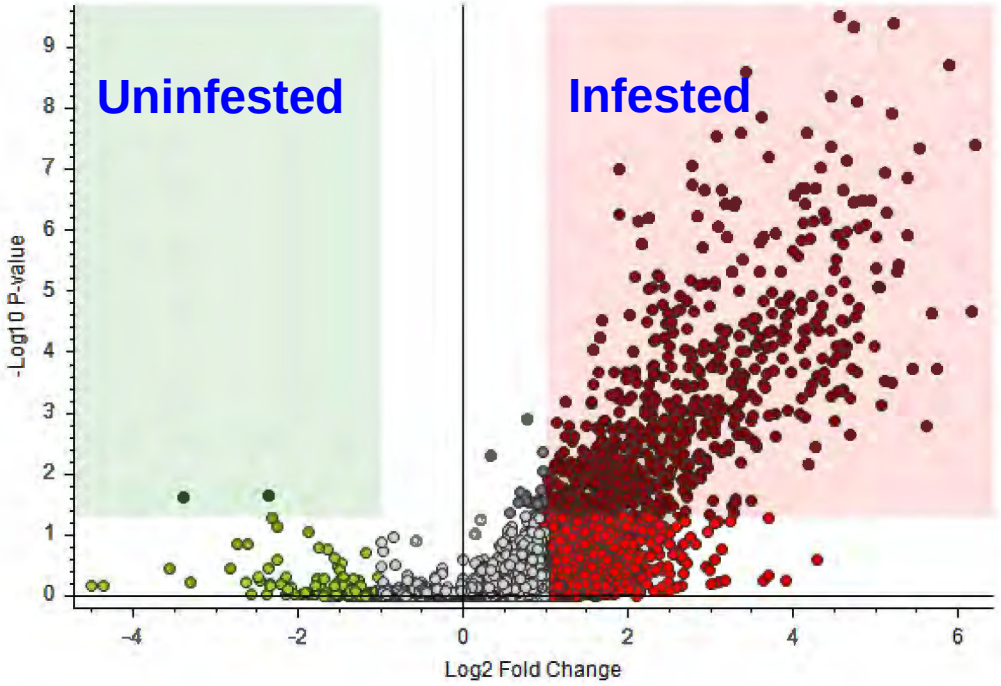
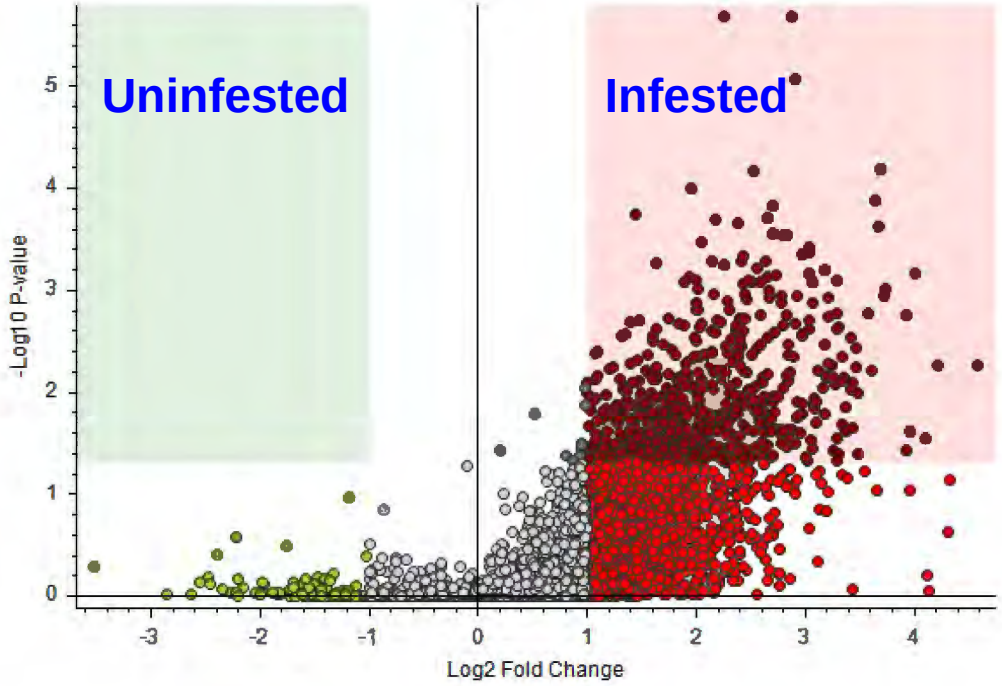
Association of Emerging Biocontaminants with Cockroaches

Kitchen



Bedroom



- Settled floor dust of cockroach-**infested homes** contains hundreds of significantly elevated chemicals compared to **uninfested homes**
- Compounds of concern for human health:
  - Pesticides, **mycotoxins**

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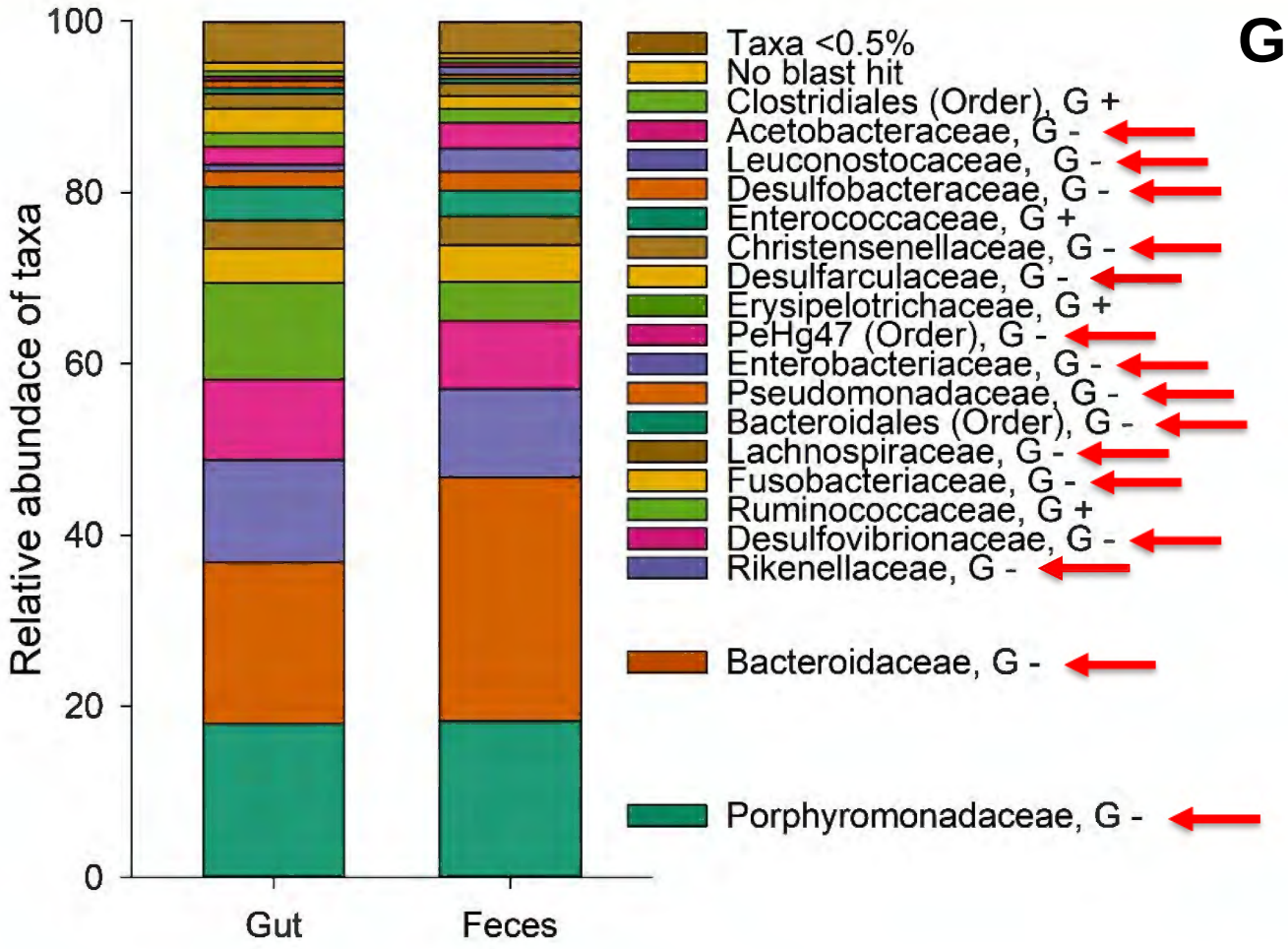
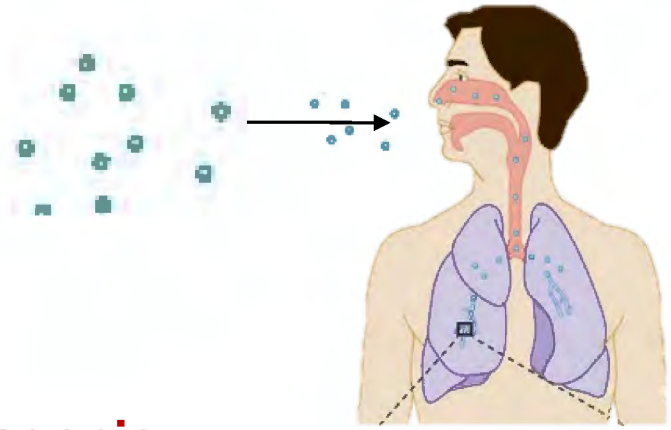
Danger of Cockroach Feces: Microbial contaminants



Gram-negative Bacteria Produce

Endotoxins



- Pyrogenic
- Respiratory track inflammation

Cockroach gut has a large community of Gram-negative bacteria

Do cockroaches defecate endotoxins into homes?

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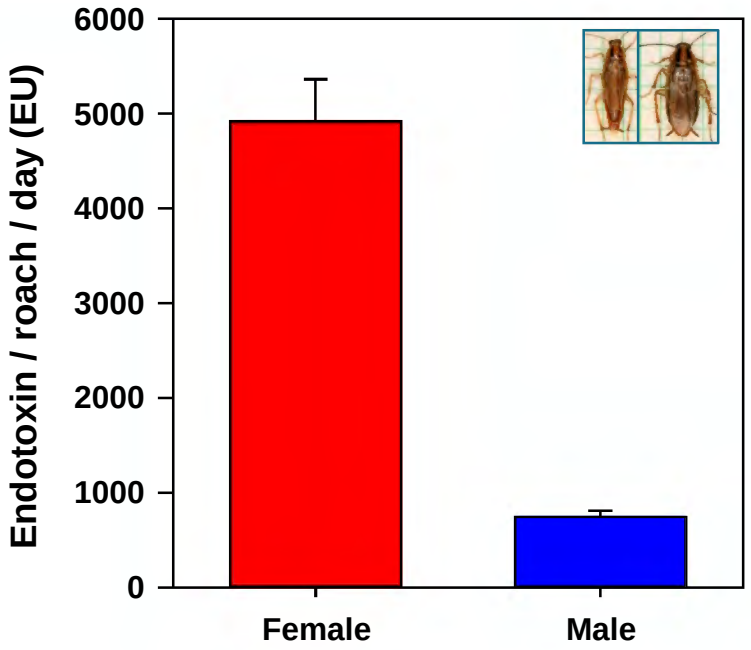
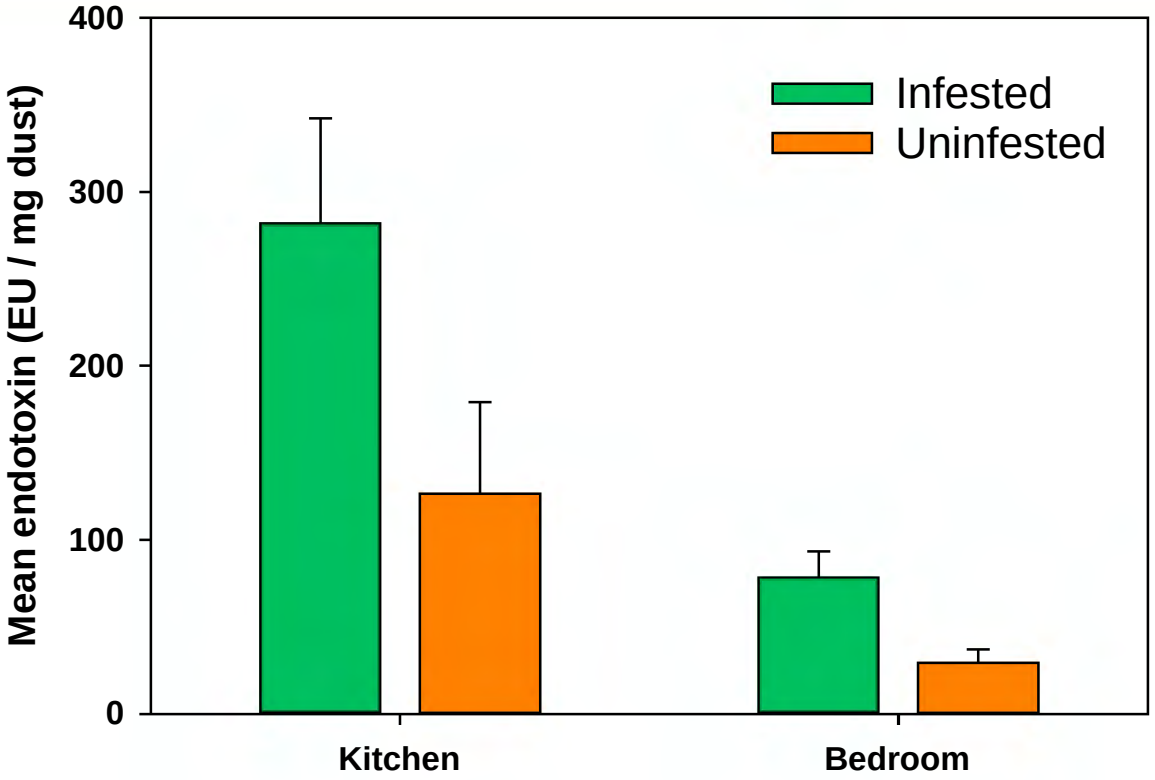
Association of Endotoxins with Cockroaches





- Cockroaches defecate large amounts of endotoxins
- Females eat more and defecate more endotoxins than males
- More **endotoxins** in **Infested** than **Uninfested** homes
- More **endotoxins** in **Kitchens**, where there are more cockroaches

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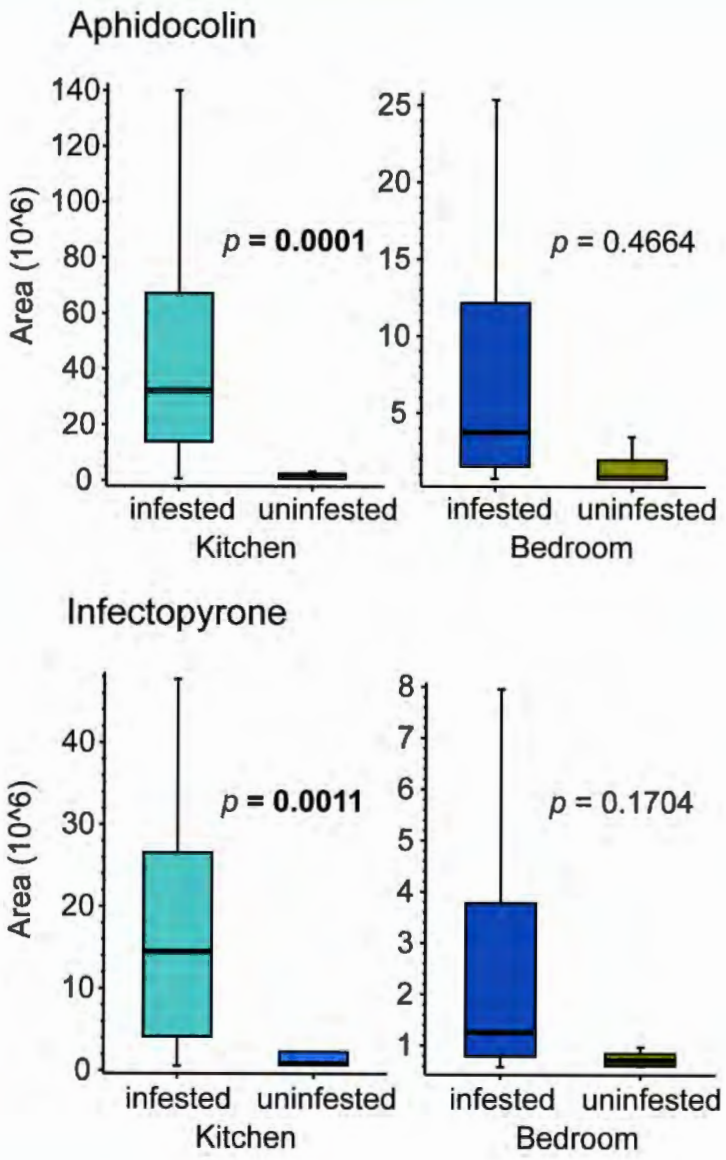
Association of Emerging Biocontaminants with Cockroaches



- Mycotoxins (fungal toxins) in household dust
- Significantly elevated levels in **infested homes**
- **Ongoing:**
  - Do cockroaches have any role in the accumulation of these mycotoxins?
  - Do these metabolites interact with allergens to affect asthma?

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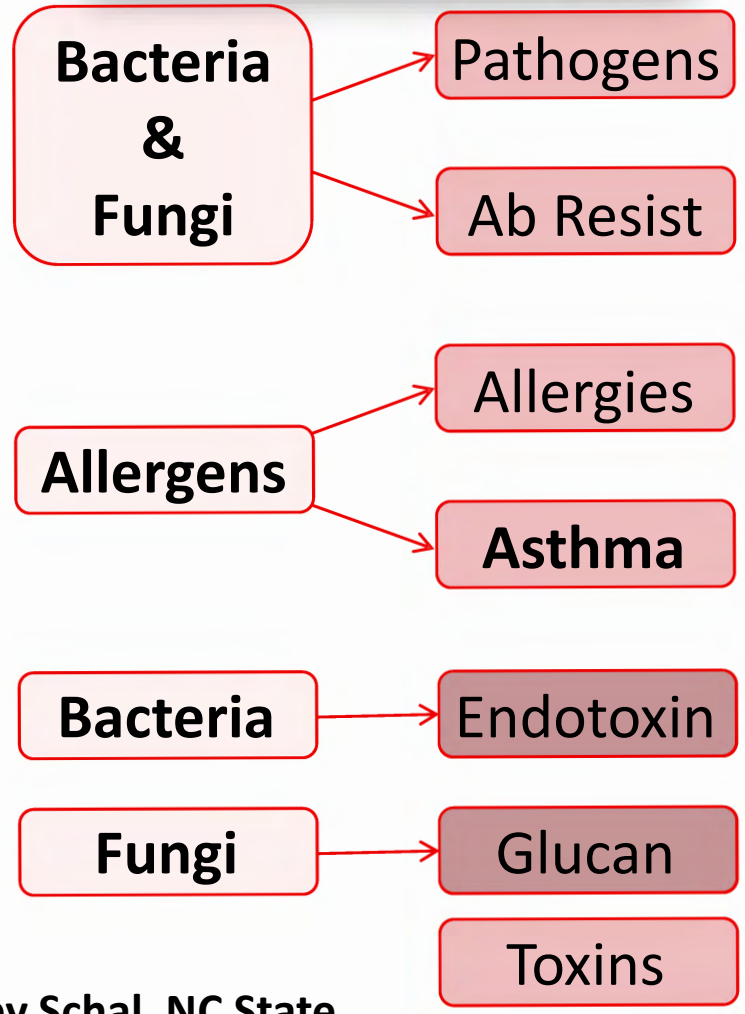
Public Health: Recap

Cockroaches

- Carry and disseminate **pathogenic microbes**, including **antibiotic resistant bacteria**;
- Produce potent **allergens** that trigger asthma, especially in sensitized children;
- Produce potent **endotoxins** and other **microbial toxins** that increase the allergic and asthmatic responses.



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Residents with Cockroaches: What to Do?

- **Hire a professional**
  - Only if they can afford it…
- **Live with the problem**
  - Bad idea, major health consequences
- **Use over-the-counter products**
  - Cheap and affordable, but **what to use?**

+ amazon

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Public health

IPM

Baits

Conclusions

Bug Bombs

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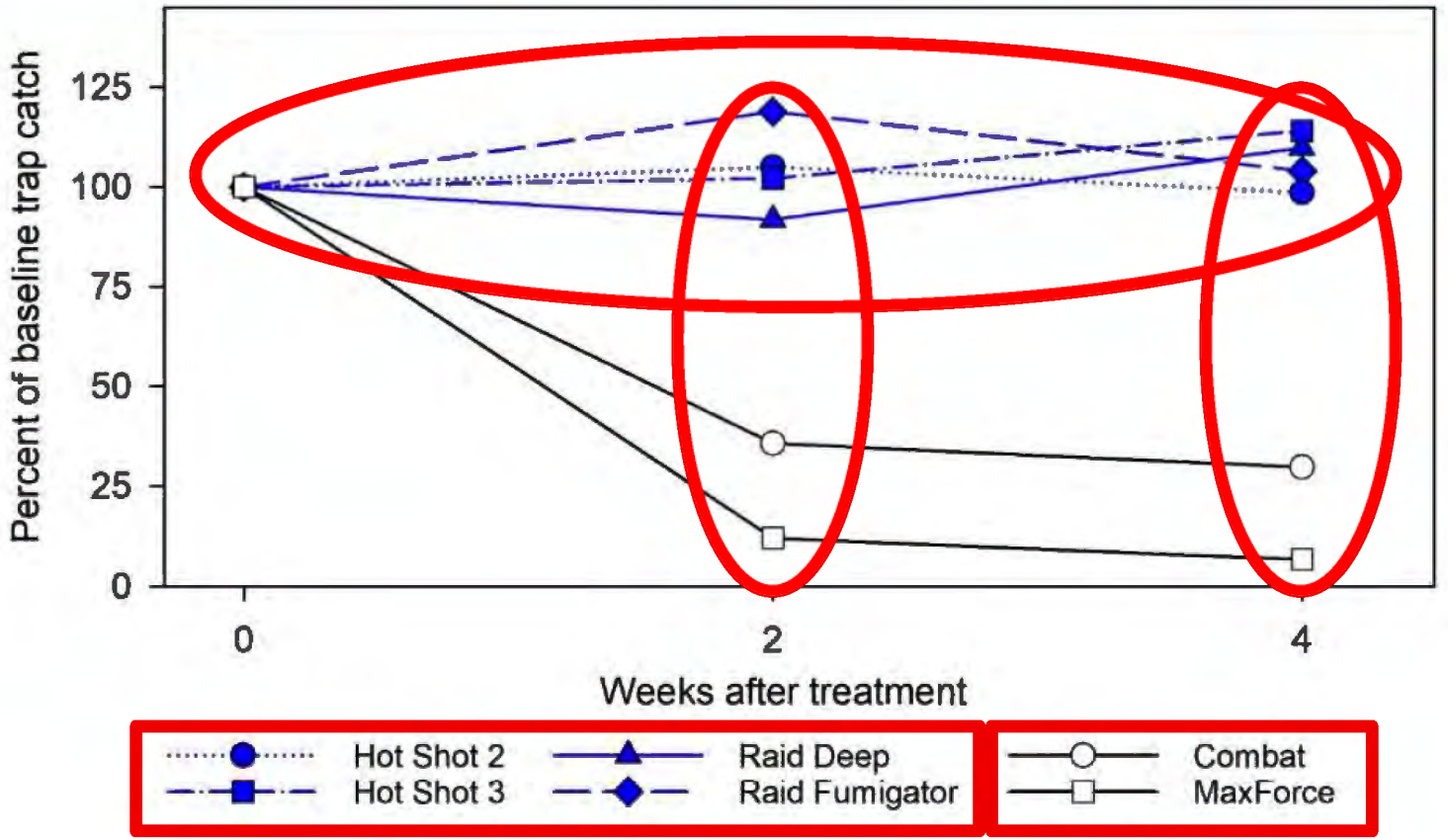
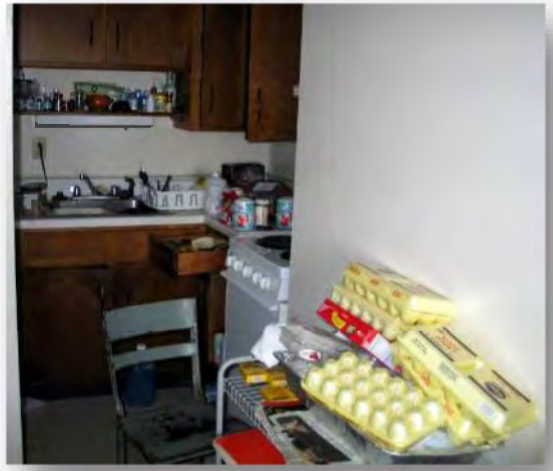
Baits

DIY Total Release Foggers (TRFs)





DeVries et al. BMC Public Health (2019) 19:96
https://doi.org/10.1186/s12889-018-6371-z

BMC Public Health

RESEARCH ARTICLE Open Access

Exposure risks and ineffectiveness of total release foggers (TRFs) used for cockroach control in residential settings

Zachary C. DeVries[1,2,3*], Richard G. Santangelo[1], Jonathan Crissman[1,4], Russell Mick[1] and Coby Schal[1,2,3]

- TRFs did not reduce roach populations
- Gel baits did

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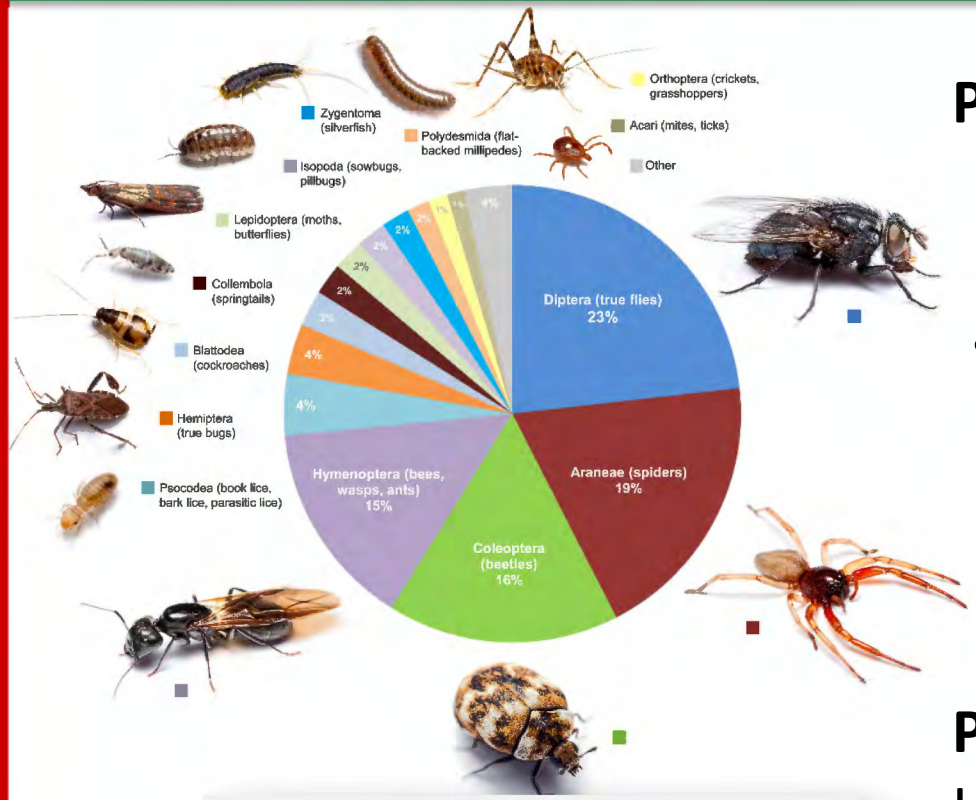
Pest management strategies: IPM



Pest management

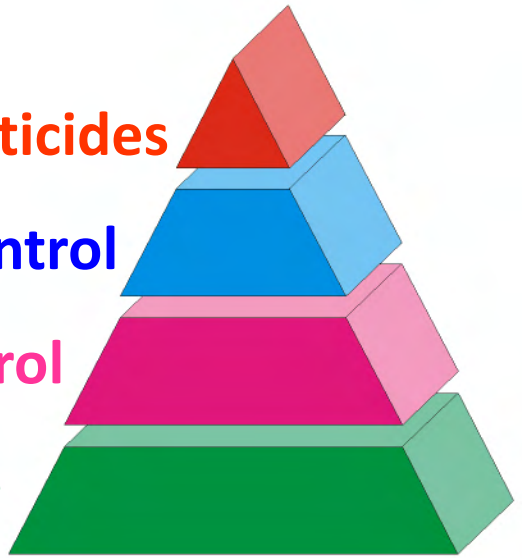
Interventions

Pesticides

Biological, genetic control

Physical/mechanical control

Cultural/sanitation practices



Pest Prevention

Limiting resources

Single-family home

- **Preventative**
- **Mainly outdoors**
- **Expensive**
- **Time-consuming**
- **Usually effective**

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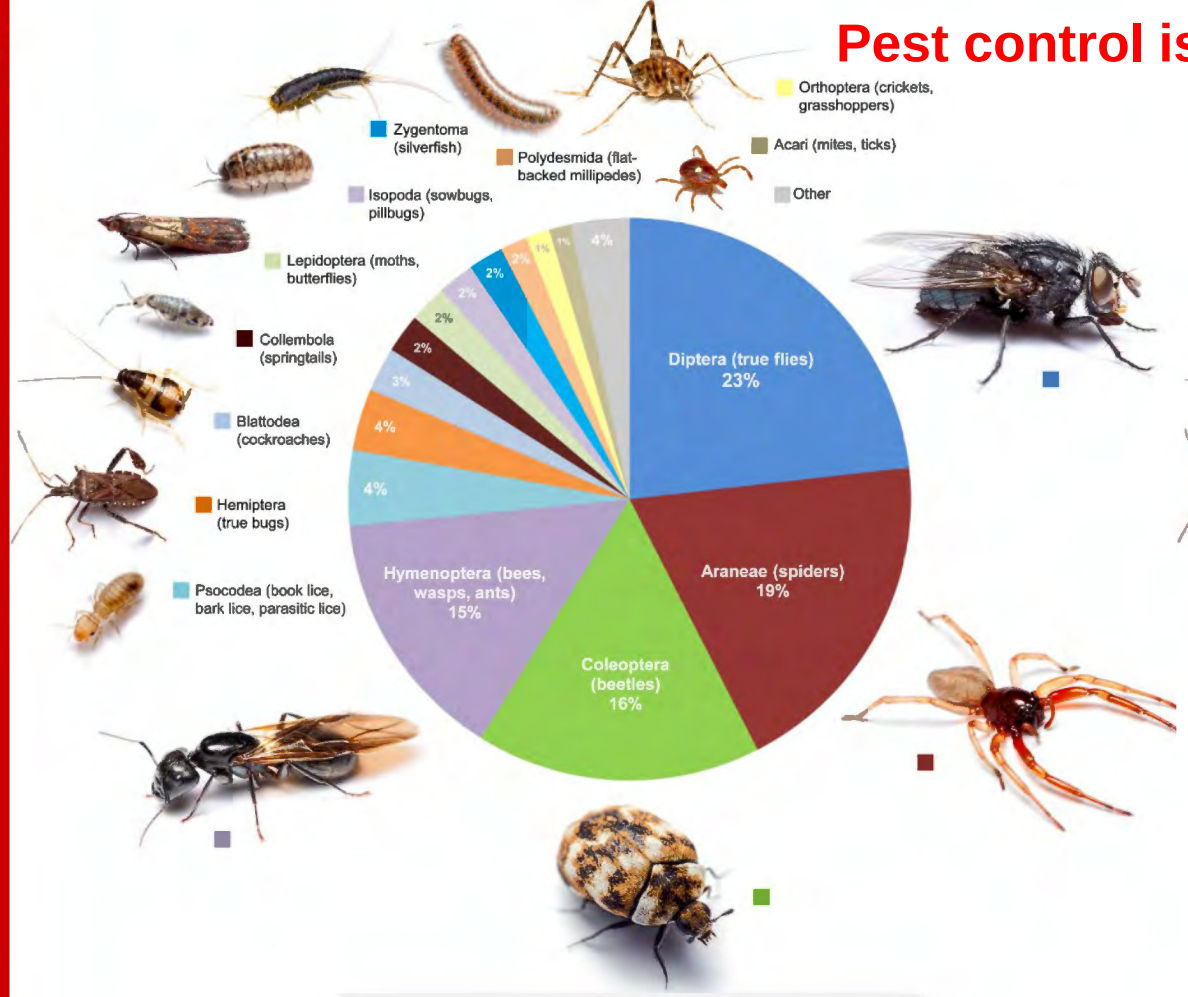
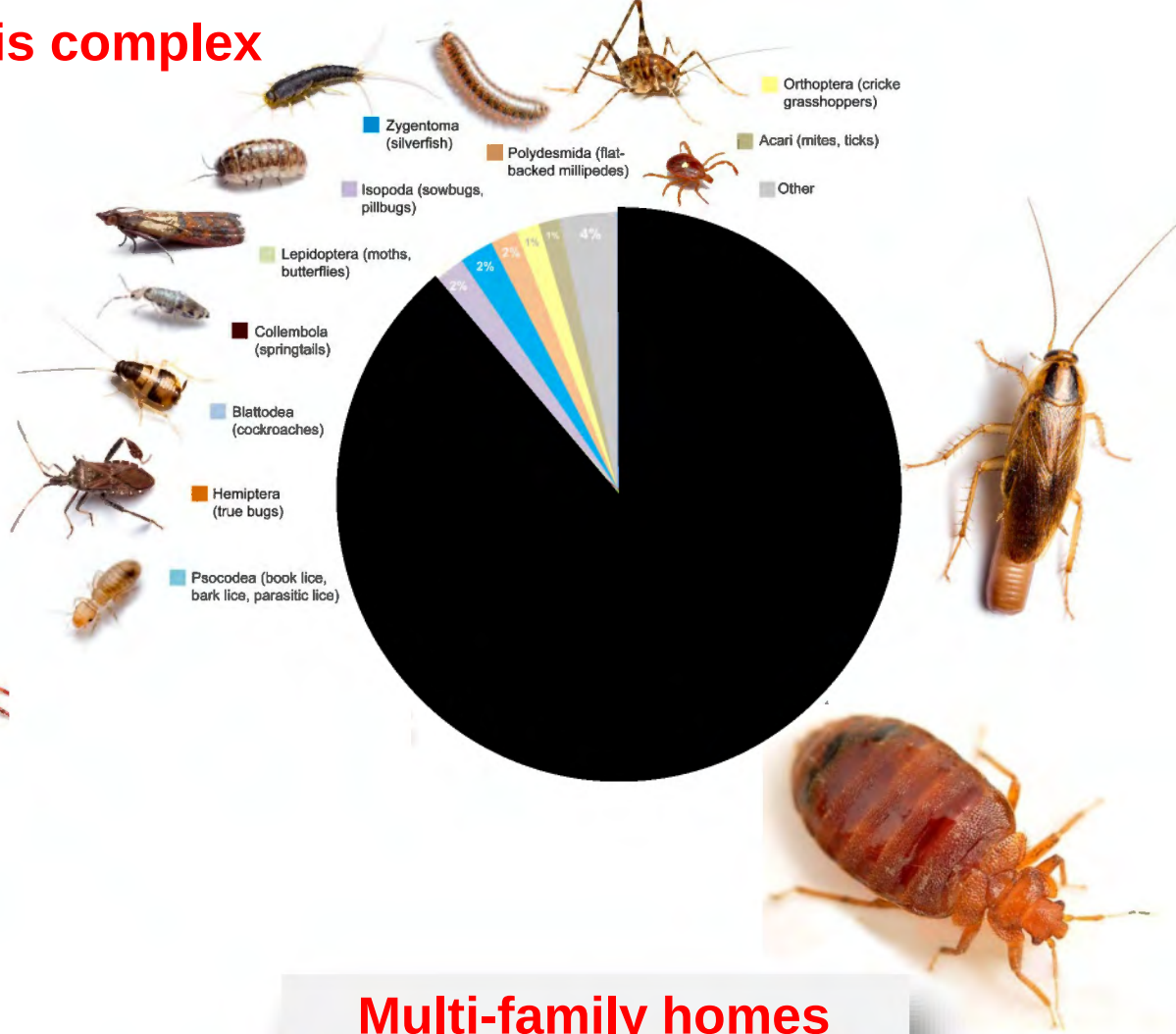
Pest control is complex





Single-family home

Multi-family homes

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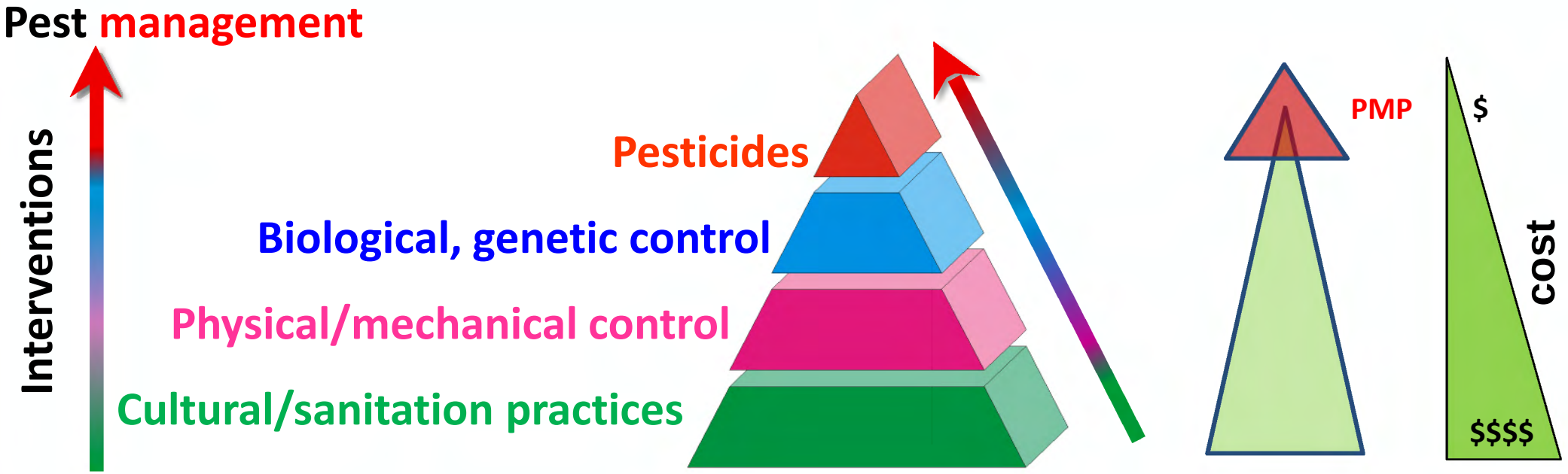
Pest management strategies: IPM



Limiting resources

- Expensive
- Time-consuming
- Invasive, Indoors
- Requires resident participation
- … Often ineffective

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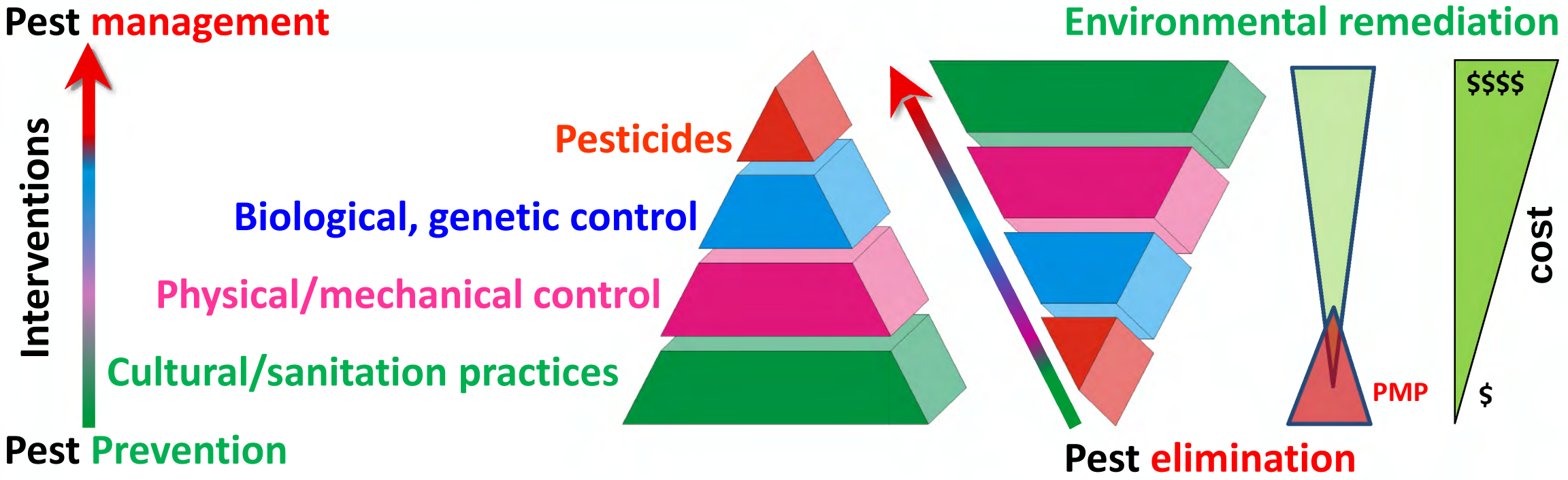
The solution: "upside-down practical IPM" – elimination, then remediation: Bait first!



Inexpensive
Less time consuming
Does not require resident participation

Is it as effective as expensive IPM?

Proof-of Concept: Baits

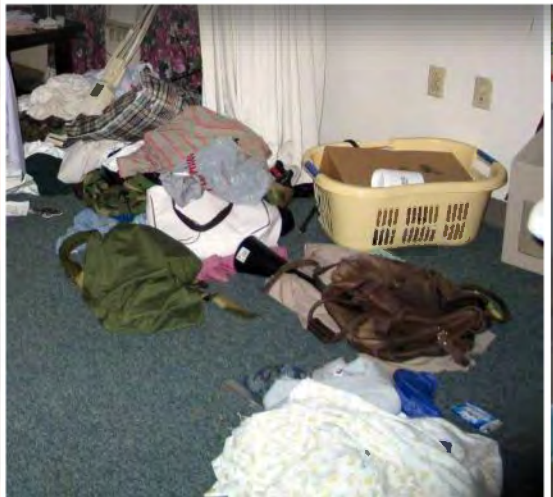
- Can **baits** effectively compete with household foods?
- Can **baits alone** eliminate cockroaches
- Can **baits alone** improve health outcomes?

Environmental and occupational disorders

Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: Month 12 continuation results

J ALLERGY CLIN IMMUNOL

Samuel J. Arbes, Jr, DDS, MPH, PhD,[a] Michelle Sever, BS,[a] Jigna Mehta, BA,[a] J. Chad Gore, MS,[b] Coby Schal, PhD,[b] Ben Vaughn, MS,[c] Herman Mitchell, PhD,[c] and Darryl C. Zeldin, MD[a] *Research Triangle Park, Raleigh, and Chapel Hill, NC*

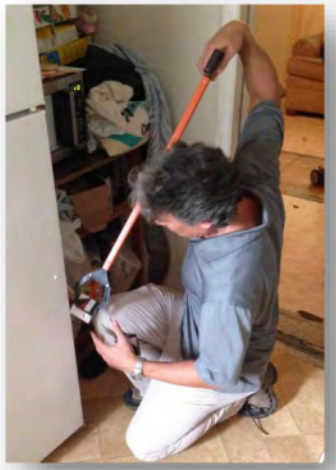


"Practical IPM": Intervention design

Recruitment:
NCSU IRB (Institutional Review Board approval) – Human subjects research

Intervention:
- **Baits only**

Collect dust (allergens)



Monitoring-based

Trap:
Estimate infestation size

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- Organic compounds (metabolites)
- Pesticides, bacterial toxins, mycotoxins

- Allergens are released into the environment through feces, molts and body fluids
- Degrade and become part of inhalable dust

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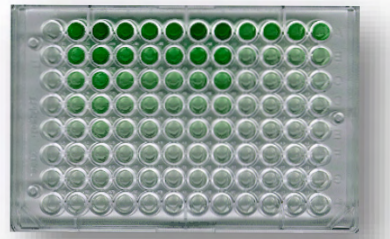
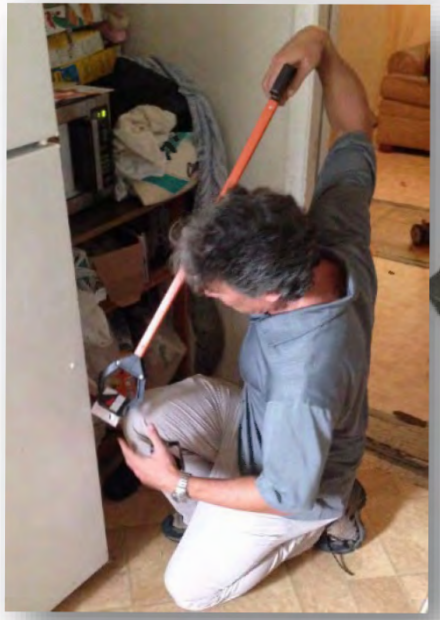
“Practical IPM”: Intervention design

Quantify allergens



Bla g ELISA

Quantify cockroaches



kitchen
living room
bedroom

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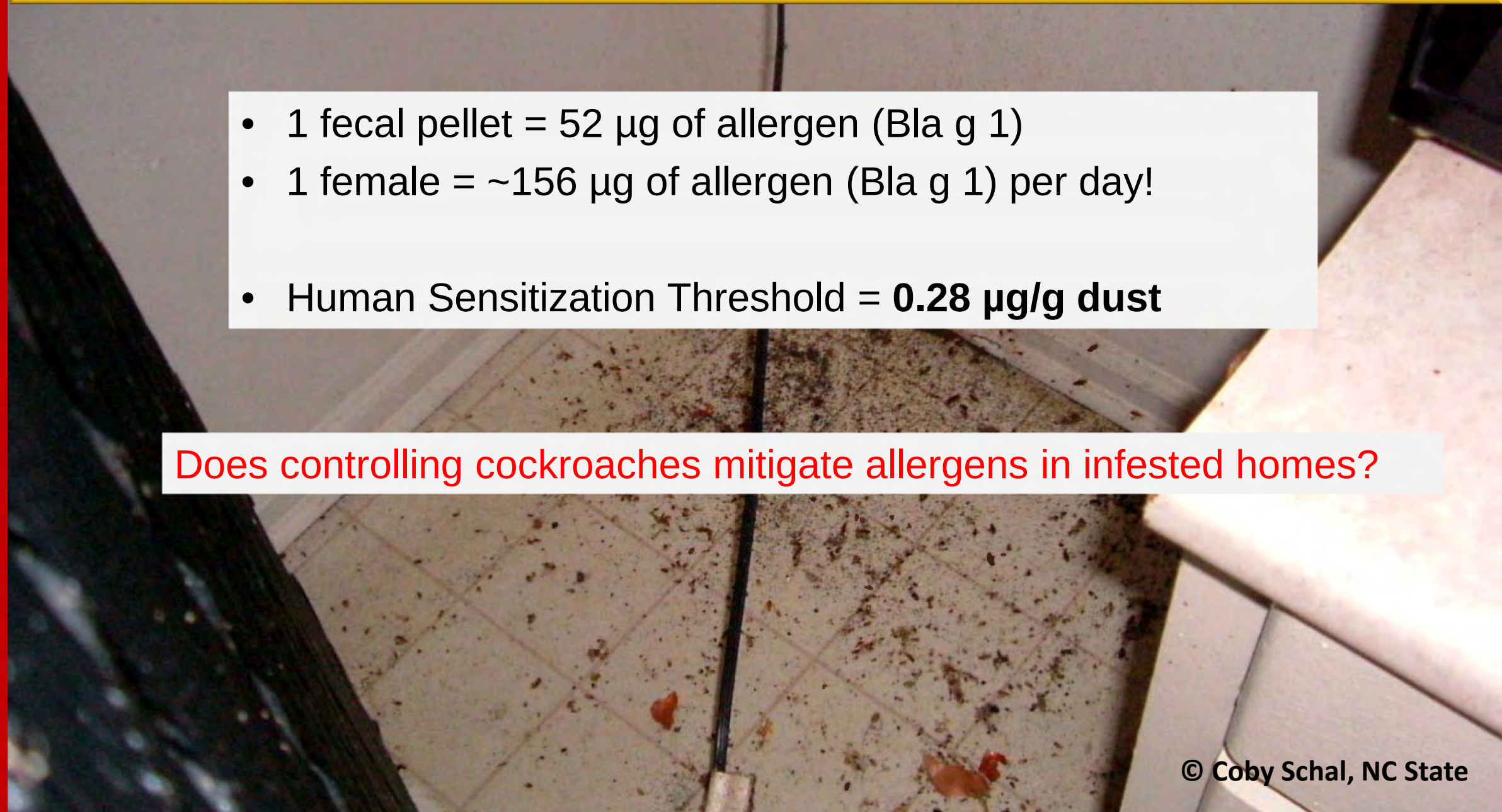
Danger of Cockroach Allergens



- 1 fecal pellet = 52 µg of allergen (Bla g 1)
- 1 female = ~156 µg of allergen (Bla g 1) per day!

- Human Sensitization Threshold = **0.28 µg/g dust**

Does controlling cockroaches mitigate allergens in infested homes?

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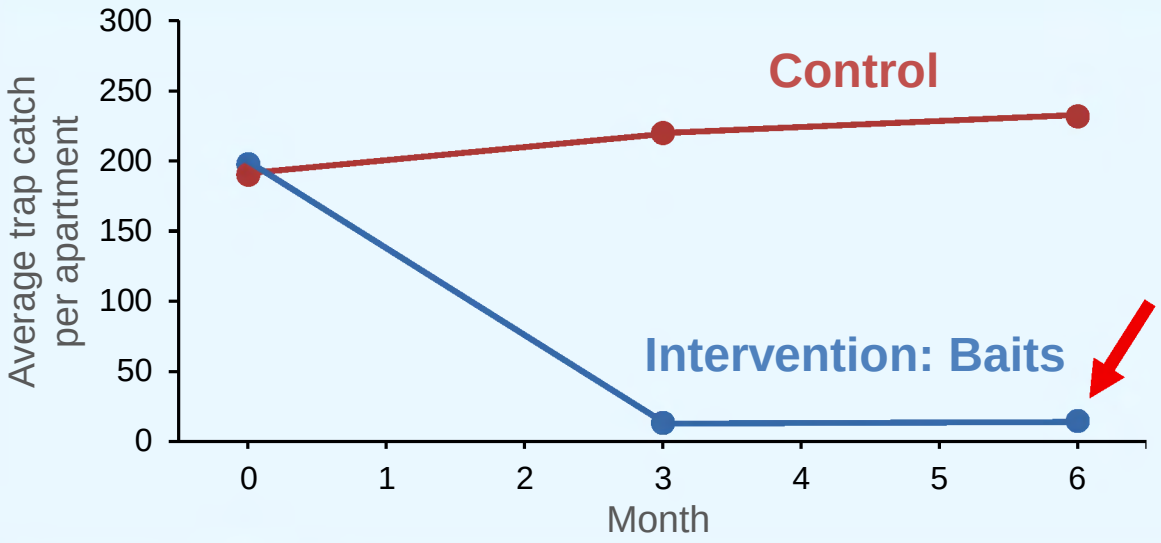
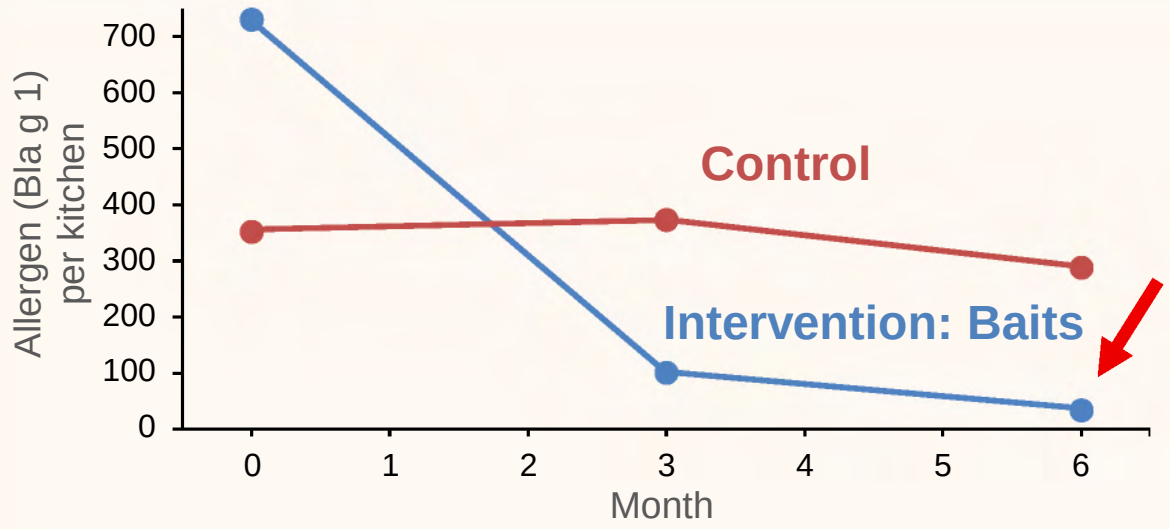
Public health IPM Baits Conclusions

"Upside-Down" IPM: Baits ONLY





Environmental and occupational disorders

Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: Month 12 continuation results

J ALLERGY CLIN IMMUNOL

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Cockroach control: Baits only

- no change in untreated control homes
- >97% reduction in treated homes
- elimination in 9 of 16 homes

Allergen reduction: Baits only

- no change in untreated control homes
- >97% allergen reduction in treated homes
- several homes below clinical thresholds

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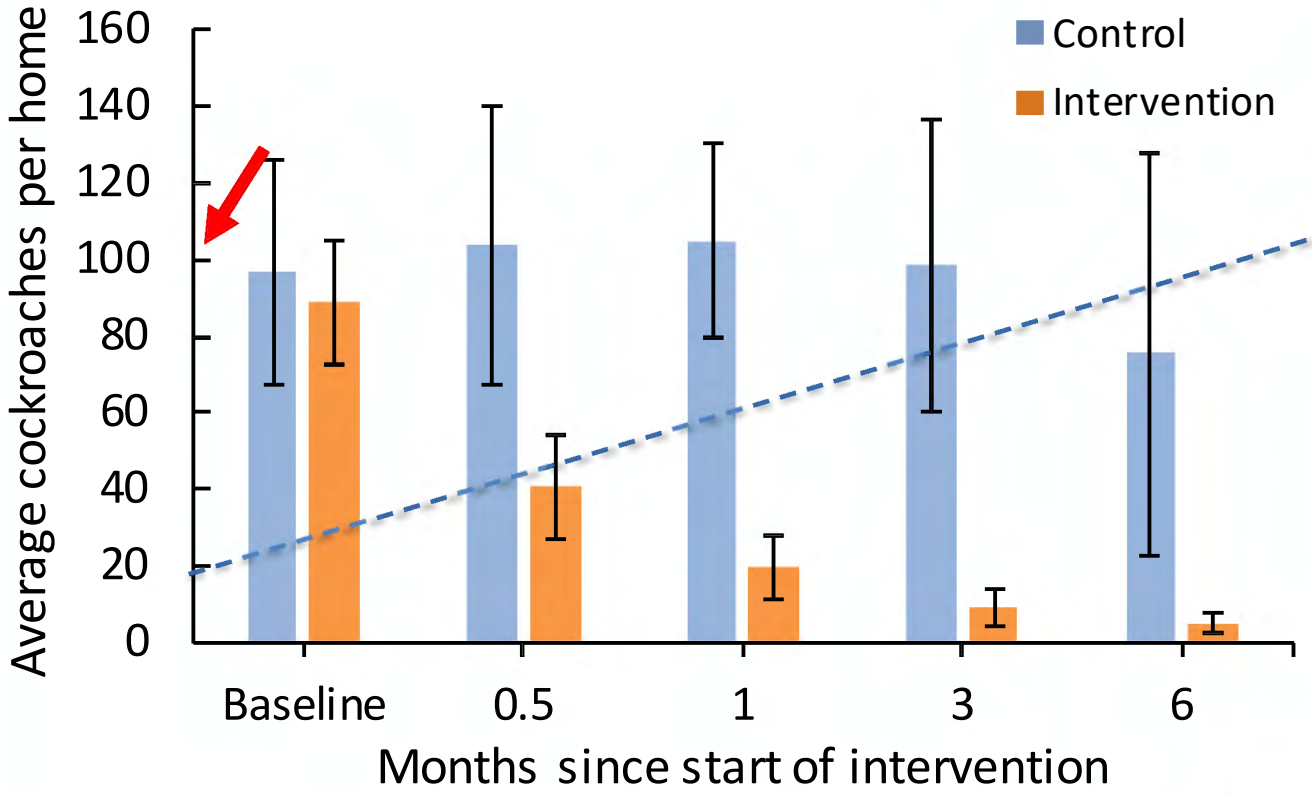
"Upside-Down Practical" IPM: Baits ONLY

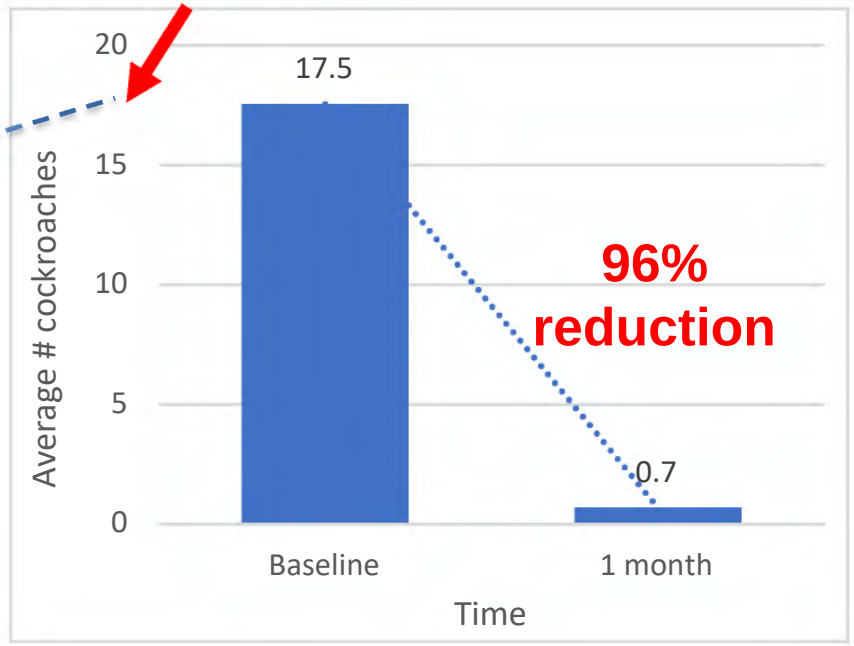
Another example: Moderate infestations

Intervention = Baits alone



'Light' infestations

57 apartments



Bait deployment (when, where) should be
monitoring-based
Monitoring = traps, visual

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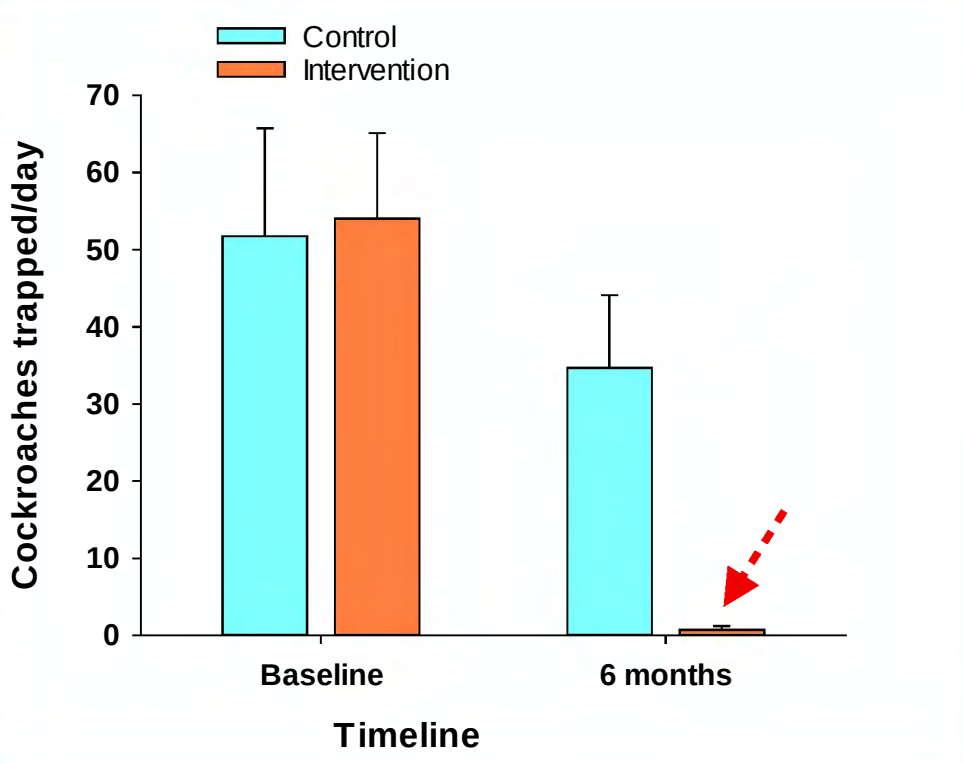
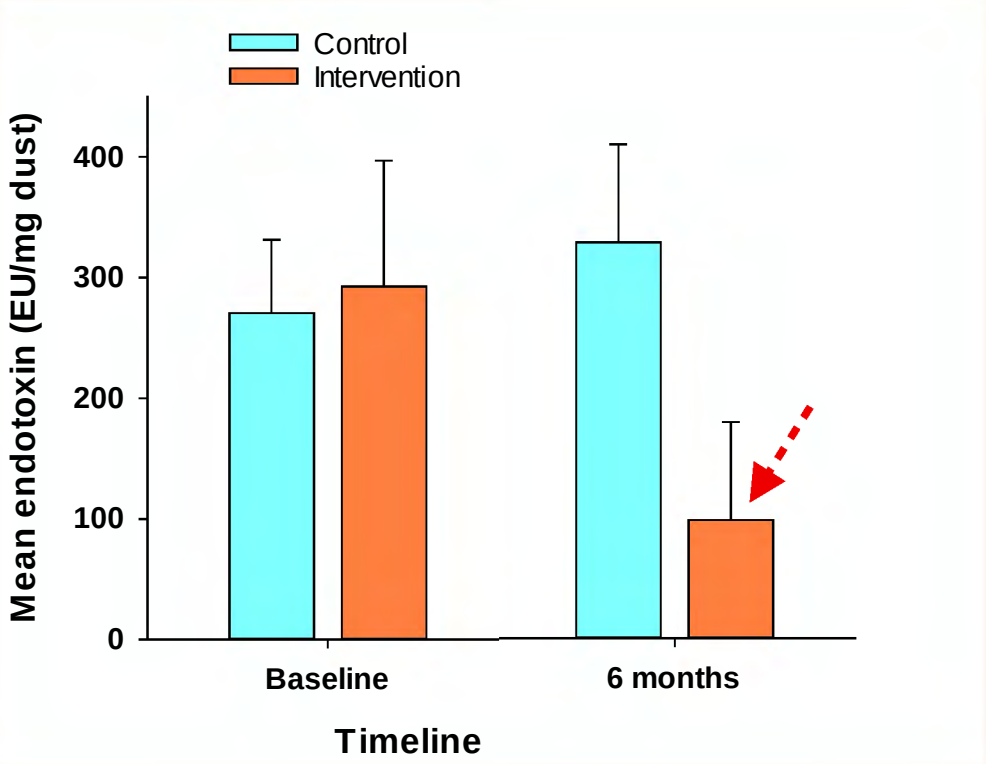
Interventions with Baits also Reduce Endotoxins





Cockroach control: Baits

- no change in untreated control homes
- Large cockroach reductions with baits

Cockroach control: Endotoxins

- no change in untreated control homes
- Large endotoxin reductions with baits

© Coby Schal, NC State

"Upside-Down Practical" IPM: Baits ONLY – Health outcomes

- Intervention homes had significantly **fewer** cockroaches than control homes
- Children in intervention homes had **fewer** asthma symptoms and **fewer** unscheduled health care utilizations in the previous 2 weeks
- Children in intervention homes had **better** pulmonary function than children living in control homes.

J ALLERGY CLIN IMMUNOL
AUGUST 2017

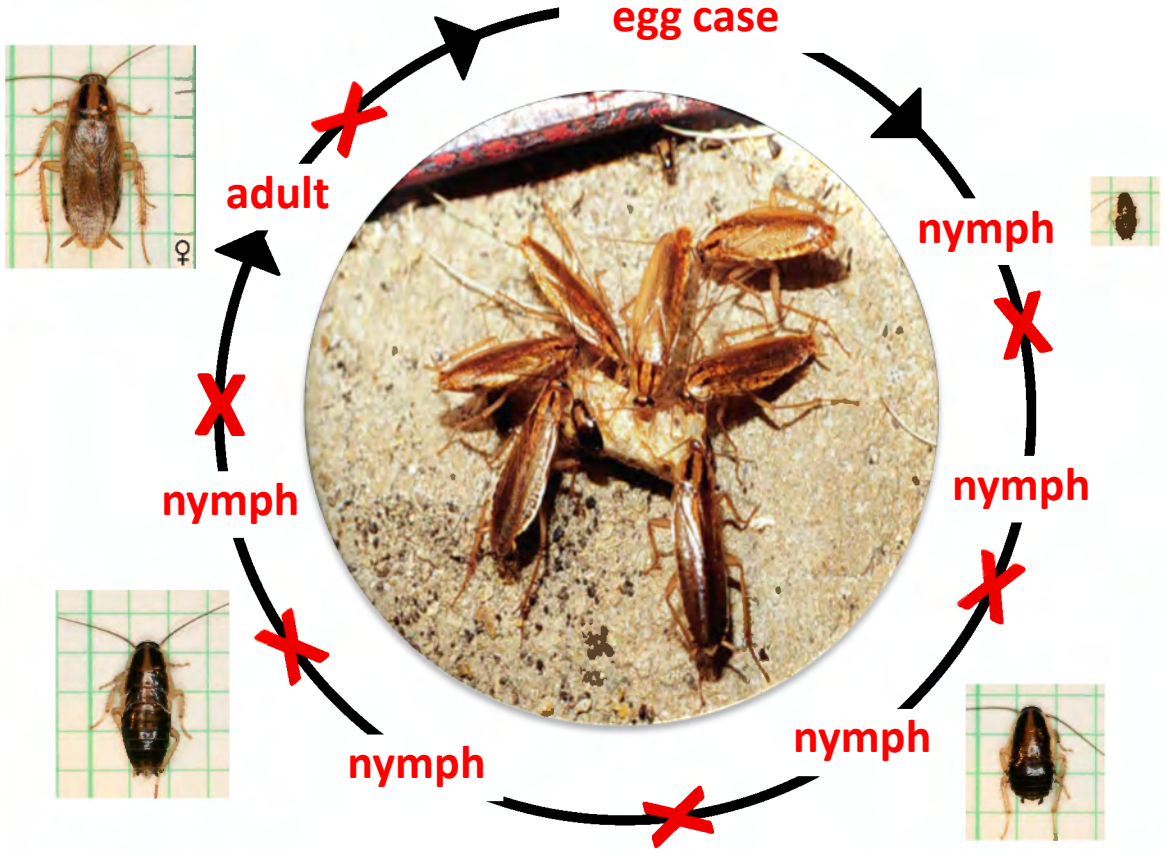
Environmental and occupational disease

A single intervention for cockroach control reduces cockroach exposure and asthma morbidity in children

Felicia A. Rabito, PhD, MPH,[a] John C. Carlson, MD, PhD,[b] Hua He, PhD,[a] Derek Werthmann, MPH,[a] and Coby Schal, PhD[c] *New Orleans, La, and Raleigh, NC*

Why do baits work so well?

1. Target all life stages (cf. mosquito)



2. Bioavailable

Baits >>> Residual

Active ingredient	Bait	Fold AI needed to kil
Fipronil	Maxforce FC	550X
Indoxacarb	Advion	267X

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Baits are highly efficacious – not rocket science!

- No fancy equipment needed
- Bait close to aggregations
- Near travel routes: structural edges, table legs, and electrical conduits
- Small dabs, <u>not</u> streaks, <u>not</u> caulking

Baits alone can **ELIMINATE** cockroach infestations and allergens

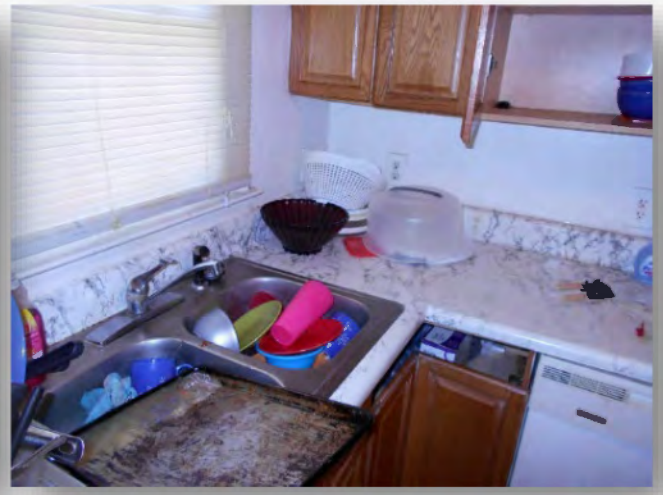
Baits effectively compete with household foods; but use more bait

Baits are more cost-effective than other strategies

Baits should always be the 1st step in residential interventions

Challenges with implementing bait interventions

- Perceived to be more expensive? Not necessarily!
- Thought to be more labor intensive? Yes, but only early in the intervention!
- Sanitation to eliminate food sources? Yes, but usually over-stated
- **Misapplication & misuse of bait**
- **Resistance**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Resistance: German cockroach

1. **Physiological** – to the insecticide
   - Metabolic breakdown, excretion, sequestration
   - Target site insensitivity
   - Reduced penetration

2. **Behavioral** – to the insecticide or inert ingredients
   - Movement away from treated surface
   - No consumption of insecticide or inert ingredients

Resistance is pervasive!

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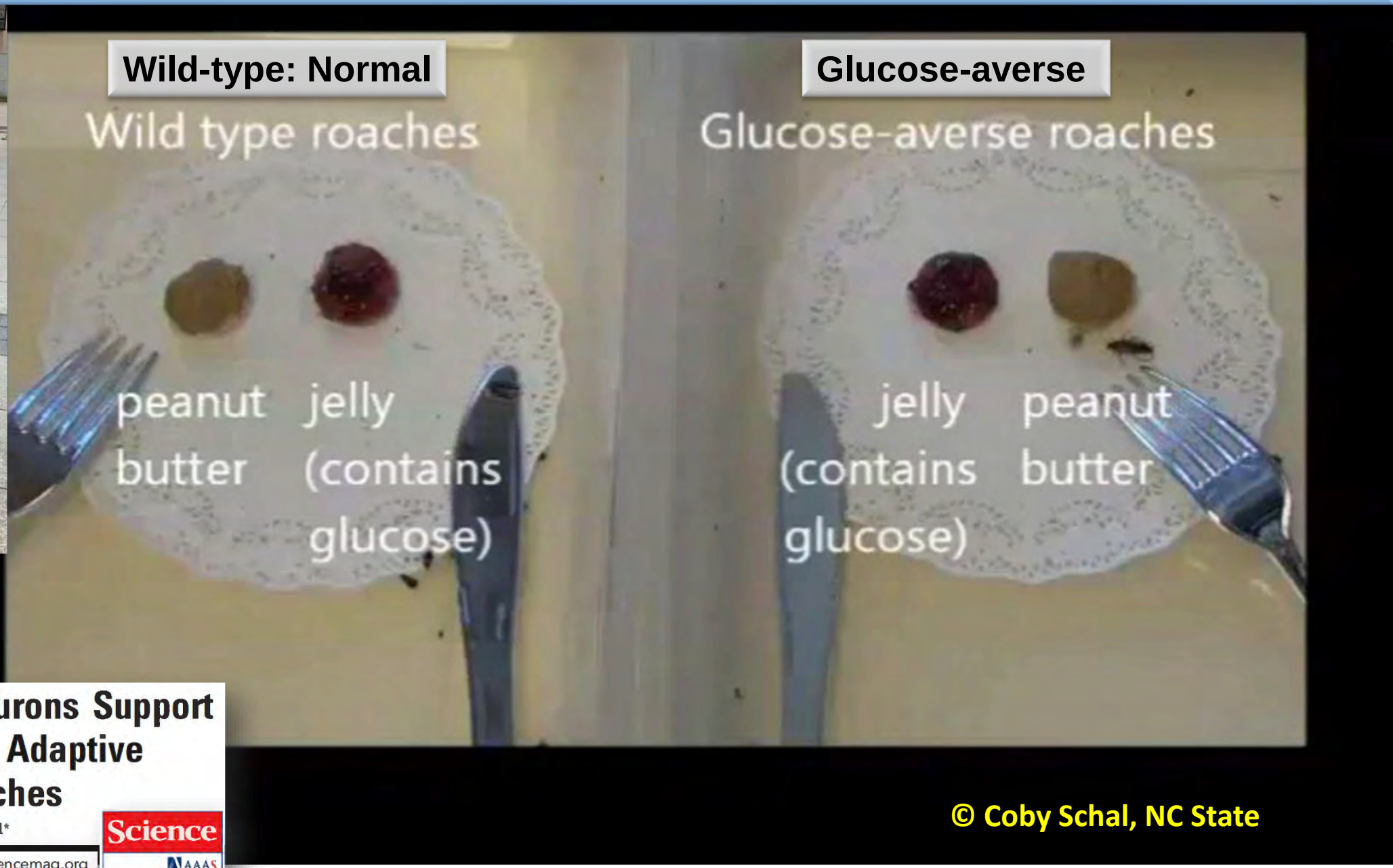
Behavioral **Resistance** to baits: Glucose aversion



Changes in Taste Neurons Support the Emergence of an Adaptive Behavior in Cockroaches

Ayako Wada-Katsumata, Jules Silverman, Coby Schal*

Science AAAS

24 MAY 2013 VOL 340 SCIENCE www.sciencemag.org

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Behavioral resistance to baits: **Beyond** Glucose aversion

We used to think…

Sugar	Wild-type	Glucose-averse
Glucose	accept	reject
Fructose	accept	Accept
Sucrose (Glucose + Fructose)	accept	Accept?
Trehalose (2X Glucose)	accept	Accept?
Maltose (2X Glucose)	accept	Accept?
Maltotriose (3X Glucose)	accept	Accept?

Wild-type

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Behavioral resistance to baits: **Beyond** Glucose aversion

But roaches proved us wrong…

Sugar	Wild-type	Glucose-averse
Glucose	accept	reject
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insects

Insects **2021**, *12*, 263.

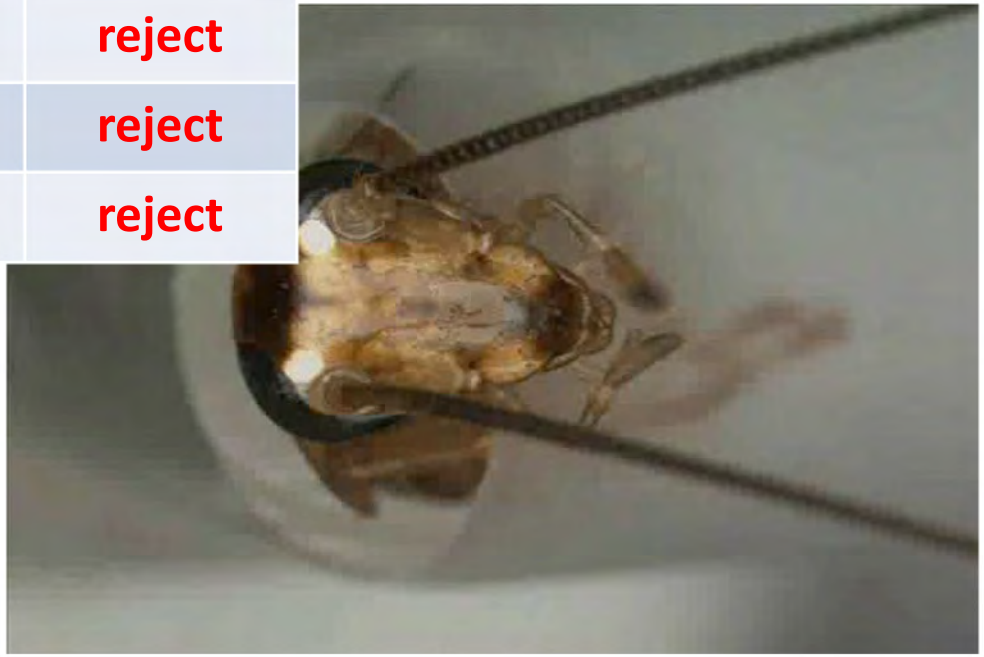
MDPI

Article

Salivary Digestion Extends the Range of Sugar-Aversions in the German Cockroach

Ayako Wada-Katsumata * and Coby Schal *

Glucose-averse



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Public health

IPM

Baits

Conclusions

Know your modes of action

Indoxacarb –
oxadiazine

Emamectin benzoate –
avermectin

Fipronil –
phenylpyrazole

Clothianidin –
neonicotinoid

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neonicotinoid

Pyriproxifen –
IGR

Abamectin –
avermectin

Dinotefuran –
neonicotinoid

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Boric acid –
inorganic

Also: Hydramethlnon (Maxforce, Combat), Imidacloprid (neonic; InVict), Boric acid (many)

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- **Rotations of Active Ingredients:**

Either within manufacturers or across manufacturers

Also: Hydramethlnon (Maxforce, Combat), Imidacloprid (neonic; InVict), Boric acid (many)

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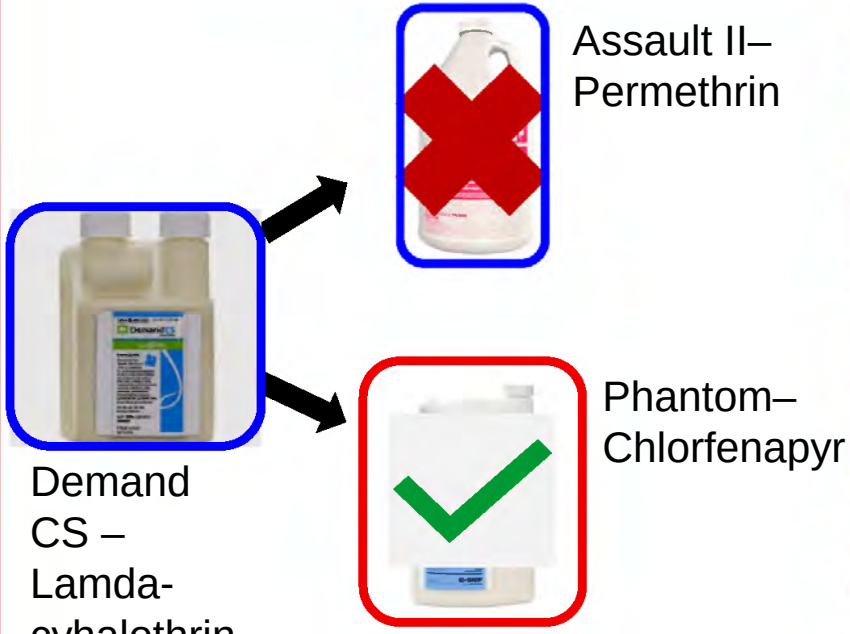
Rotations – How do you know MOA? There's an app for that!

IRAC Insecticide Resistance Action Committee

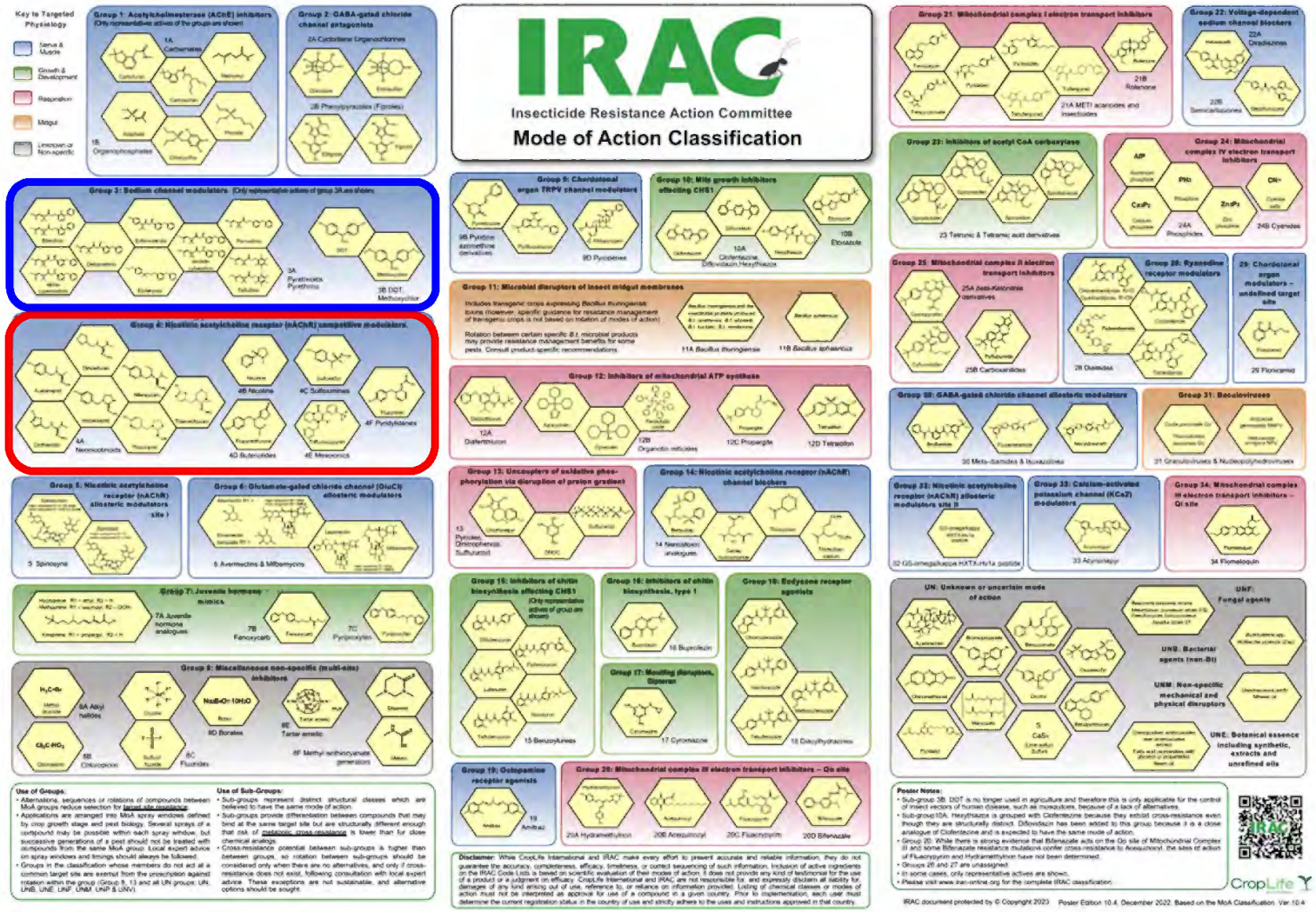
App: http://www.irac-online.org/



Assault II– Permethrin

Demand CS – Lamda-cyhalothrin

Phantom– Chlorfenapyr



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Rotations – How do you know MOA?

PCT

SPONSORED CONTENT

Mixing it Up! A Technician's Guide to Cockroach Baits

IPM

BY ZACHARY DEVRIES | MARCH 2023

Baits

Bait	Active Ingredient	Manufacturer	Formulation	MOA[1]
Maxforce® FC	Fipronil (0.01%)	Envu	Gel	2
Maxforce® FC Select	Fipronil (0.01%)	Envu	Gel	2
Maxforce® FC Magnum	Fipronil (0.05%)	Envu	Gel	2
Maxforce® FC Roach Killer Bait Stations	Fipronil (0.05%)	Envu	Bait Station	2
Alpine® Rotation 1	Dinotefuran (0.5%)	BASF	Gel	4
Alpine® Rotation 2	Dinotefuran (0.5%)	BASF	Gel	4
InVict™ Gold	Imidacloprid (2.15%)	Rockwell Labs	Gel	4
Apex Cockroach Bait	Imidacloprid (2.15%)	Solutions Pest & Lawn	Gel	4
Maxforce® Impact	Clothianidin (1%)	Envu	Gel	4
Vendetta®	Clothianidin (0.50%) and	MGK	Gel	4
Nitro[2]	Pyriproxyfen (0.50%)			7
Avert® Dry Flowable	Abamectin (0.05%)	BASF	DF[3]	6
InVict™ AB	Abamectin (0.05%)	Rockwell Labs	Gel	6
Abathor Gel Bait	Abamectin (0.05%)	Ensystex	Gel	6
Optigard®	Emamectin Benzoate (0.1%)	Syngenta	Gel	6
Vendetta®	Abamectin (0.05%)	MGK	Gel	6
Vendetta®	Abamectin (0.05%) and	MGK	Gel	6
Plus[2]	Pyriproxyfen (0.50%)			7
Magnetic	Boric Acid (33.3%)	Nisus	Gel	8
Advion®	Indoxacarb (0.6%)	Syngenta	Gel	22
Advion® Cockroach Bait Arena	Indoxacarb (0.6%)	Syngenta	Bait Station	22
Advion® Evolution	Indoxacarb (0.6%)	Syngenta	Gel	22
Advion® MicroFlow	Indoxacarb (0.22%)	Syngenta	DF[3]	22
Doxem® Precise	Indoxacarb (0.6%)	CSI	DF[3]	22

[1] Different numbers indicated active ingredients with different modes of action (MOAs) based on the IRAC classification scheme:
2: GABA-Gated Chloride Channel Blockers
4: Nicotine Acetylcholine Receptor Competitive Modulators
8: Miscellaneous Non-Specific Inhibitors
22: Voltage-Dependent Sodium Channel Blockers

[2] This product contains two active ingredients with different

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Summary – Take-home points

- Beyond nuisance and aesthetics – cockroaches are significant public health pests (allergens, pathogens, contamination, insecticide residues)
- Most DIY approaches don't work!
- IPM has been broadly adopted by the clinical (asthma mitigation) community, but complex IPM is too expensive, unsustainable, inefficacious(?)
- Baits work extremely well, they are safe, placement is easy, they don't contaminate, highly bioavailable
- Baits eliminate (not just reduce) infestations!
- Baits also face challenges: Aversion, resistance, misapplication, too little applied
- **Solution: Pay attention! Rotate bait products! Monitor!**

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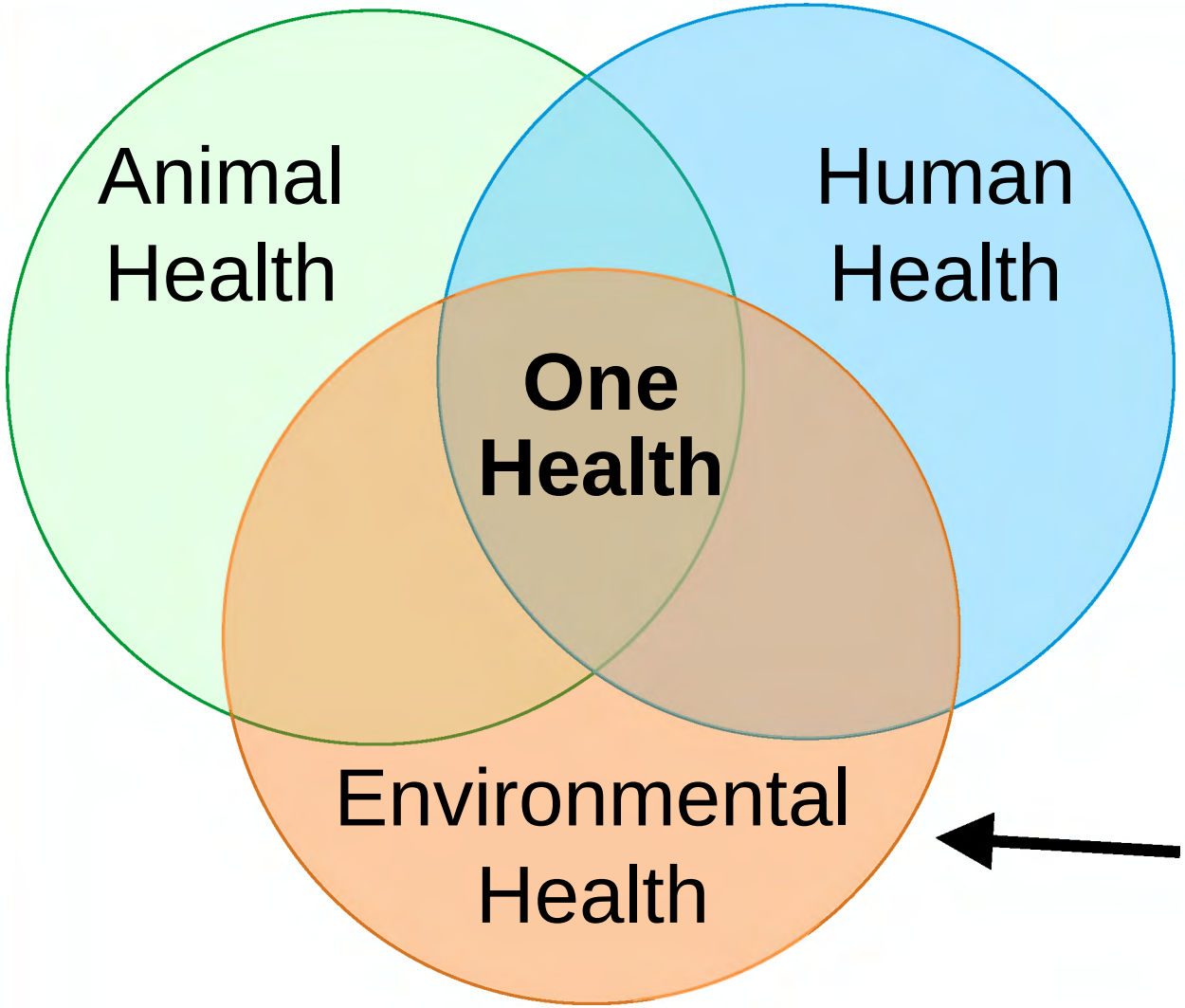
Integrate Public Health into Indoor Pest Control (esp. in multi-unit buildings)



integrated, unifying approach to balance and optimize the health of people, animals and the environment.

The past….

Focus on pests

- Exterminators
- Pest Control Operators
- Pest Management Professionals

The future…

Focus on public health & the environment

- Public Health Professionals
- Environmental Specialists
- Environmental Remediators

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ASPCRO Goal

…to protect the health and welfare of the citizens of each state through the fair and effective regulation of the pest control industry which is vital in the control of pests of public health and economic significance…

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Questions?

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