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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National Institute of Environmental Health Sciences

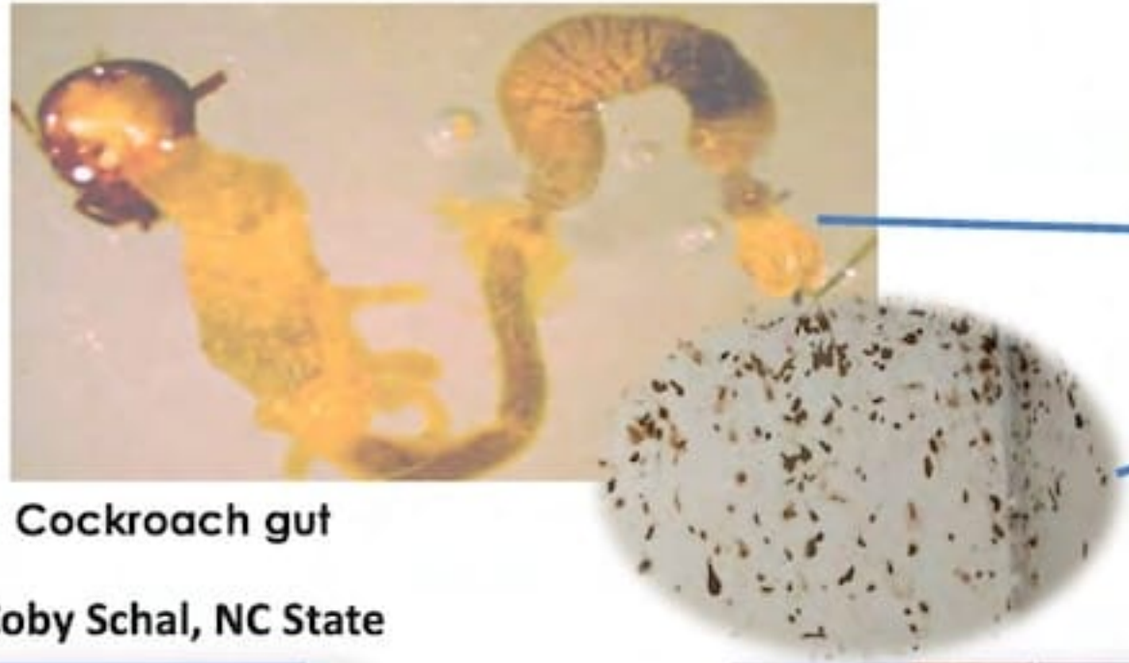
Public Health: Cockroaches

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

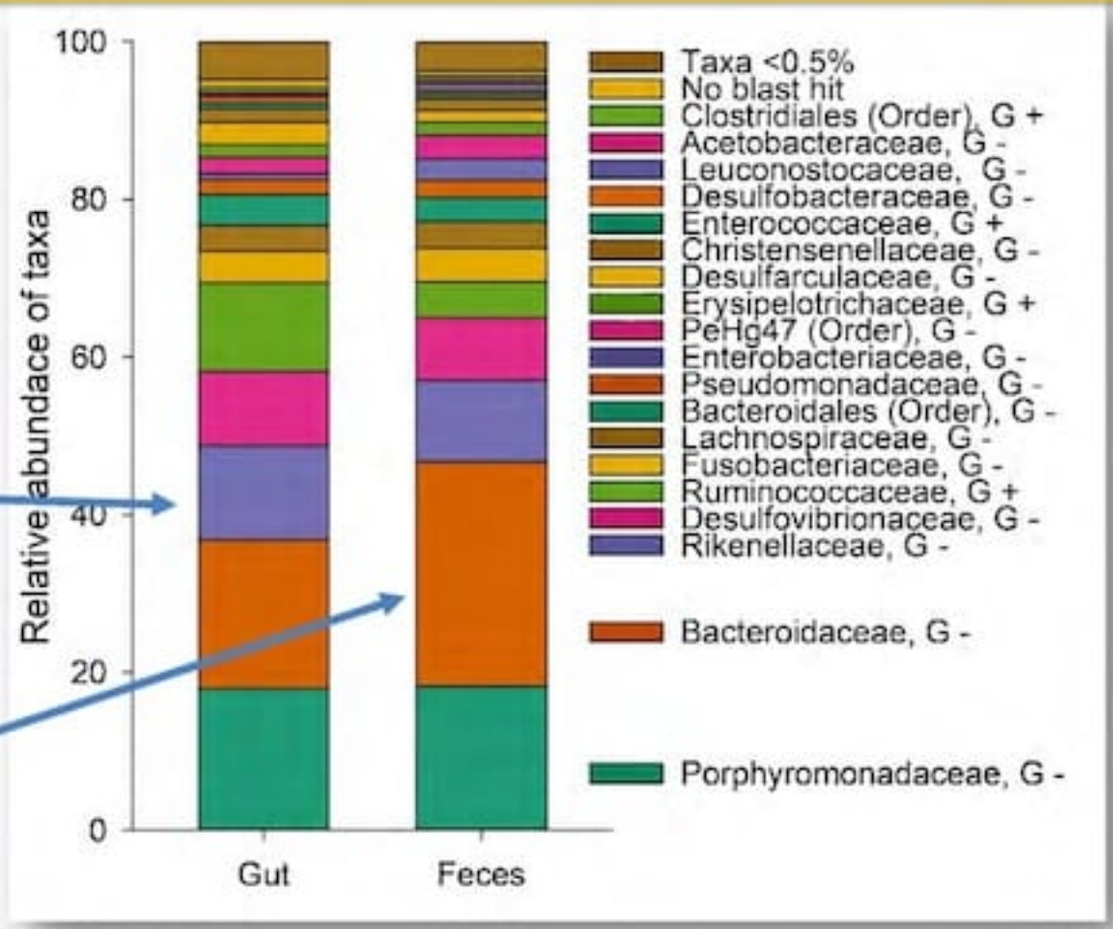
1. Pathogen, disease & antibiotic resistance transmission
2. Allergens & respiratory disease

Public Health 1. Pathogen transmission

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



Cockroach gut



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: 2011 2021

- **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. hemolyticus*)
- **gastroenteritis** (*Salmonella schottmuelleri, S. bredeney, S. cholerae-suis*)
- 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

CHAPTER 2
Public health and veterinary importance

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

Public Health 1. Antibiotic Resistant Bacteria

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

Rick Santangelo

sped up 1.5X

- 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!**

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

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

Public Health 2. Allergens & Asthma

Cockroach Infestation

Allergens

Socio-economics

Allergies & Asthma

Medical interventions

Genetics

Environmental interventions

Pest Control is Central to Environmental Interventions

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

Association of Emerging Biocontaminants with Cockroaches

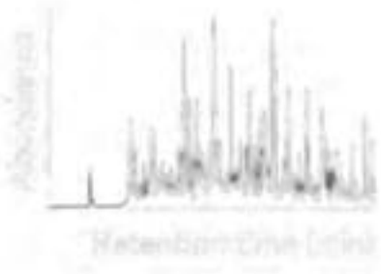
Objective: Understand the association of cockroach infestations and emerging indoor metabolites

Sample Collection

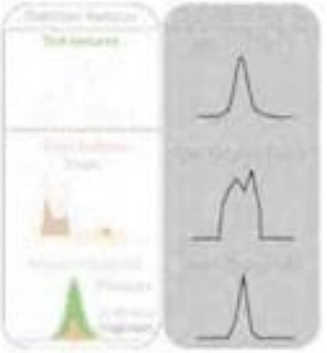
Sample Extraction

LC-MS Analysis

Raw data



Data processing



Final data

Metabolomics: CHHE-METRIC

Association of Emerging Biocontaminants with Cockroaches

Kitchen

Uninfested Infested

Bedroom

Uninfested Infested

- 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**

Danger of Cockroach Feces: Microbial contaminants

Gram-negative Bacteria Produce

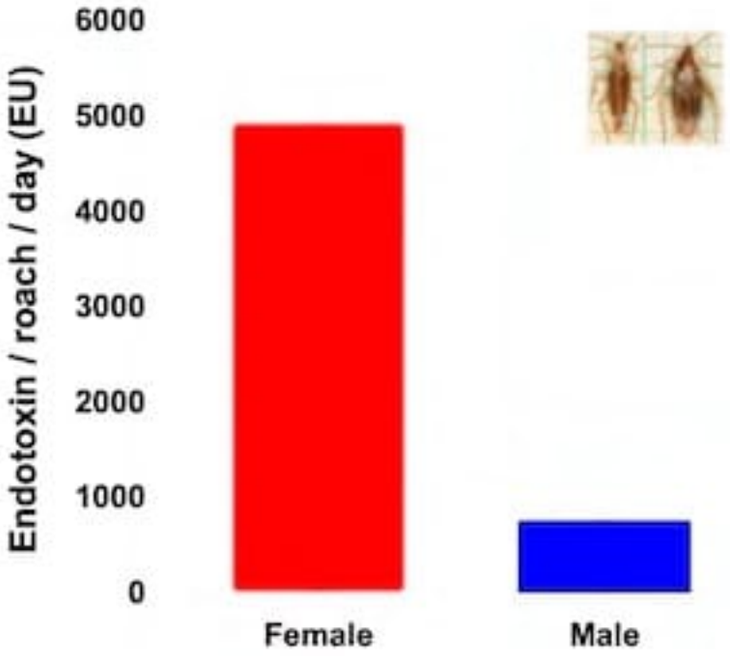
Endotoxins

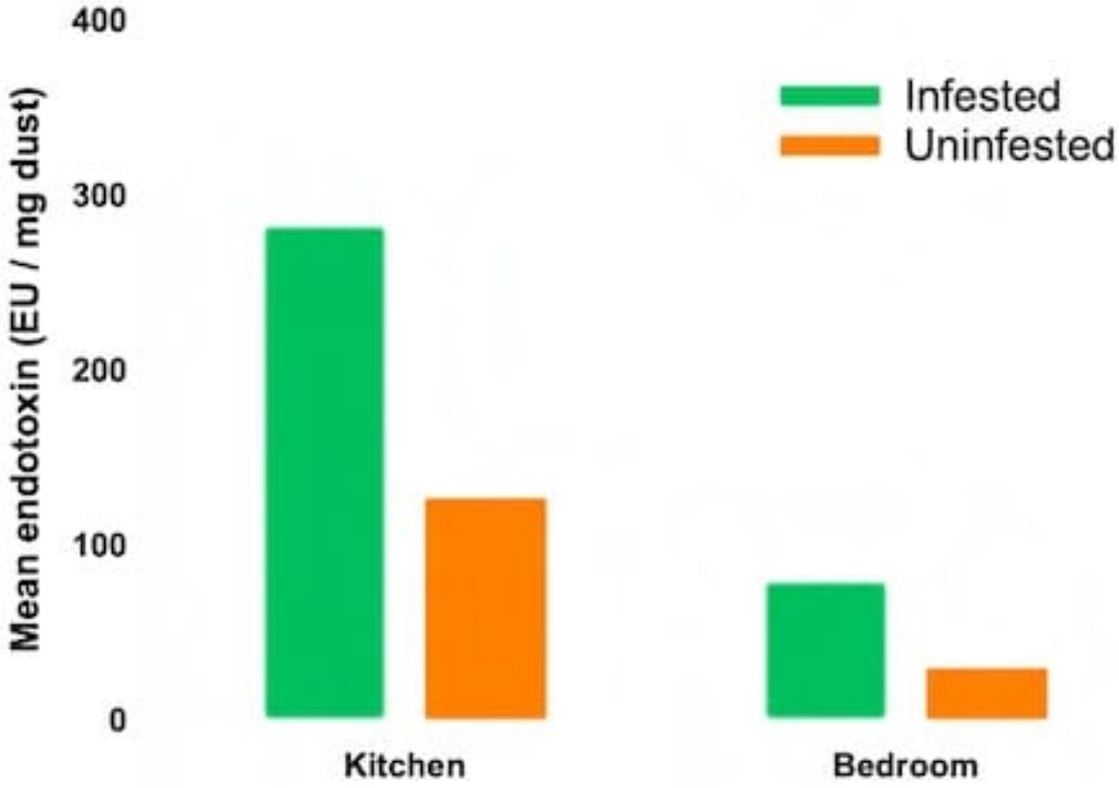
- Pyrogenic
- Respiratory track inflammation

Cockroach gut has a large community of Gram-negative bacteria

Do cockroaches defecate endotoxins into homes?

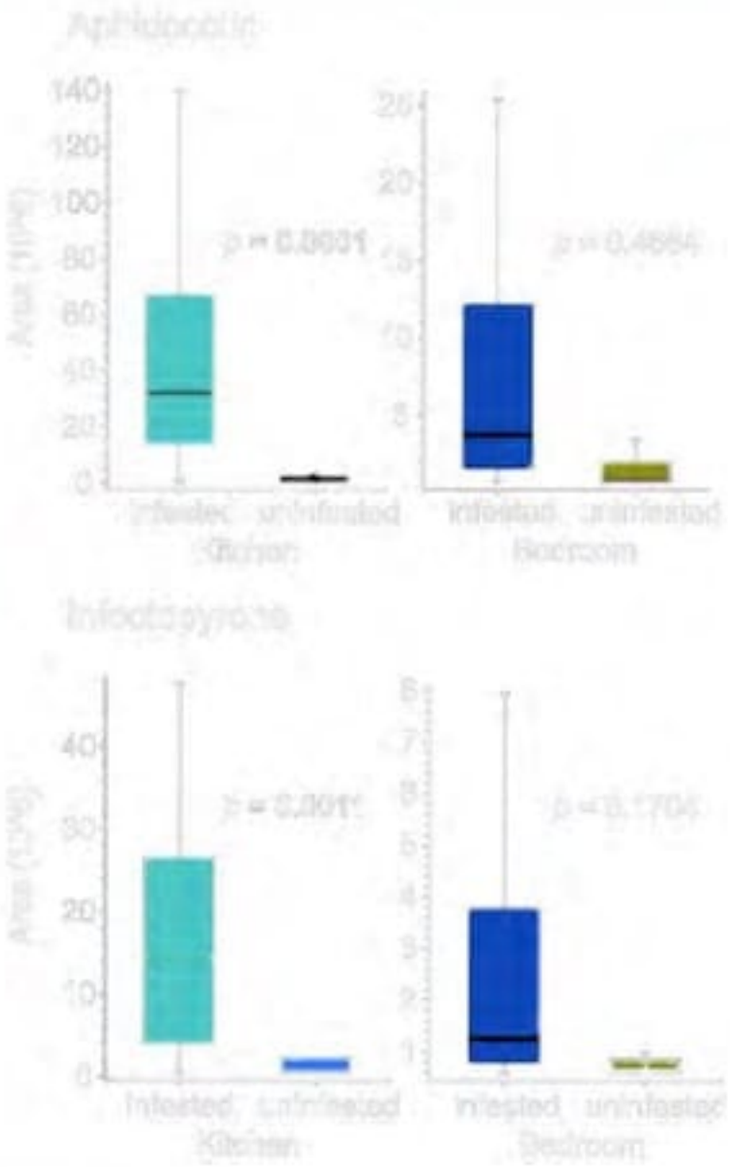
Association of Endotoxins with Cockroaches





- 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

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?

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.

Bacteria & Fungi	Pathogens
	Ab Resist
Allergens	Allergies
	Asthma
Bacteria	Endotoxin
Fungi	Glucan
	Toxins

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

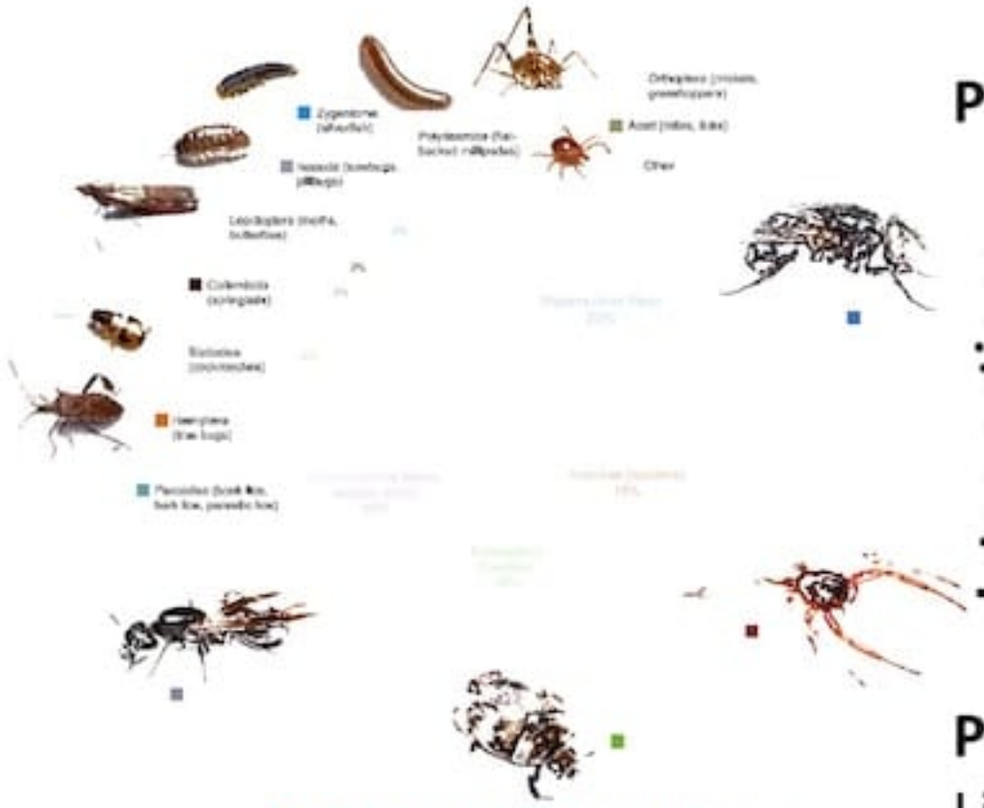
DIY Total Release Foggers (TRFs)

Public health

IPM

Baits

- TRFs did not reduce roach populations
- Gel baits did



Single-family home

Pest management

Interventions

Pesticides

Biological, genetic control

Physical/mechanical control

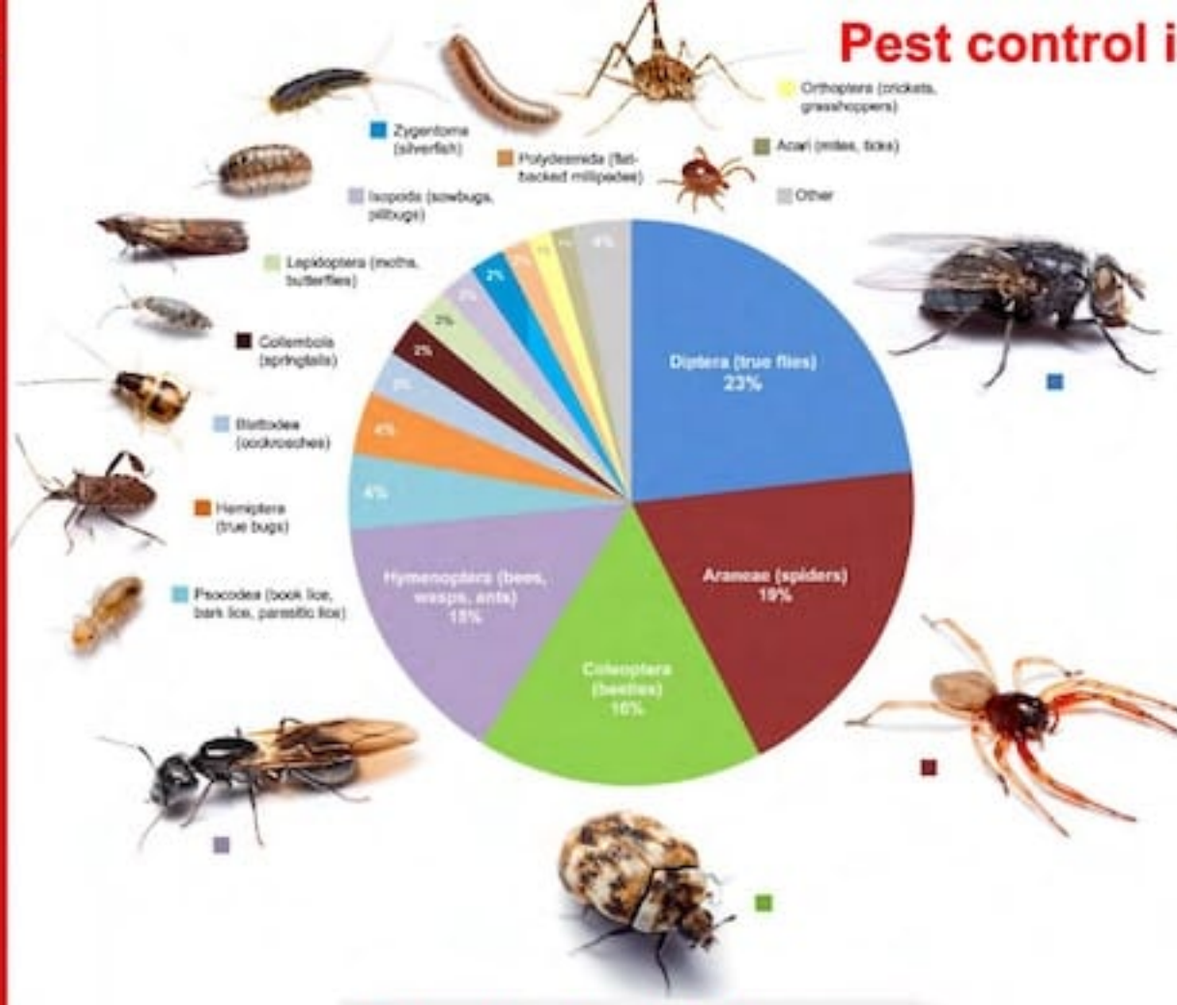
Cultural/sanitation practices

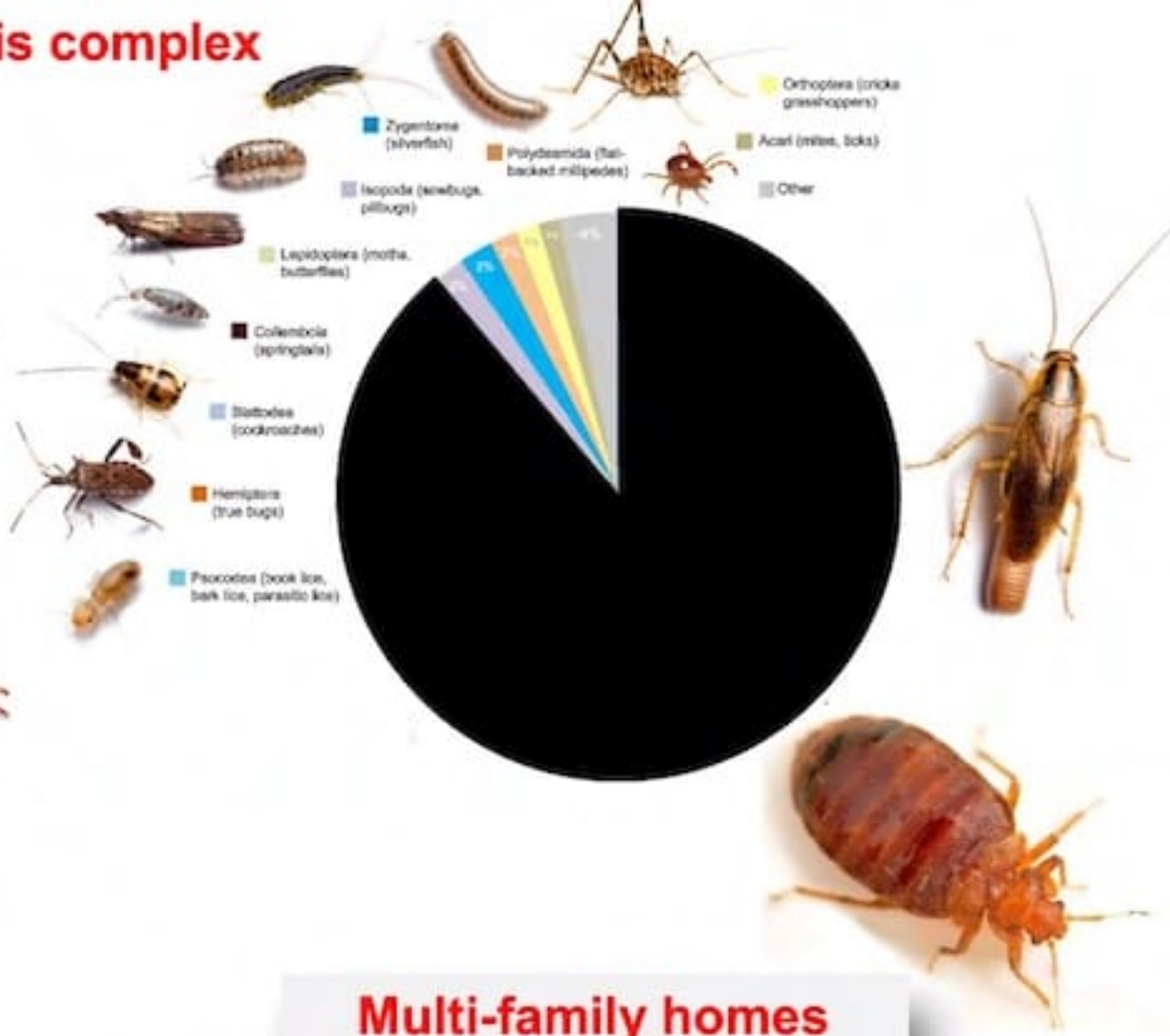
Pest Prevention

Limiting resources

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

Pest control is complex

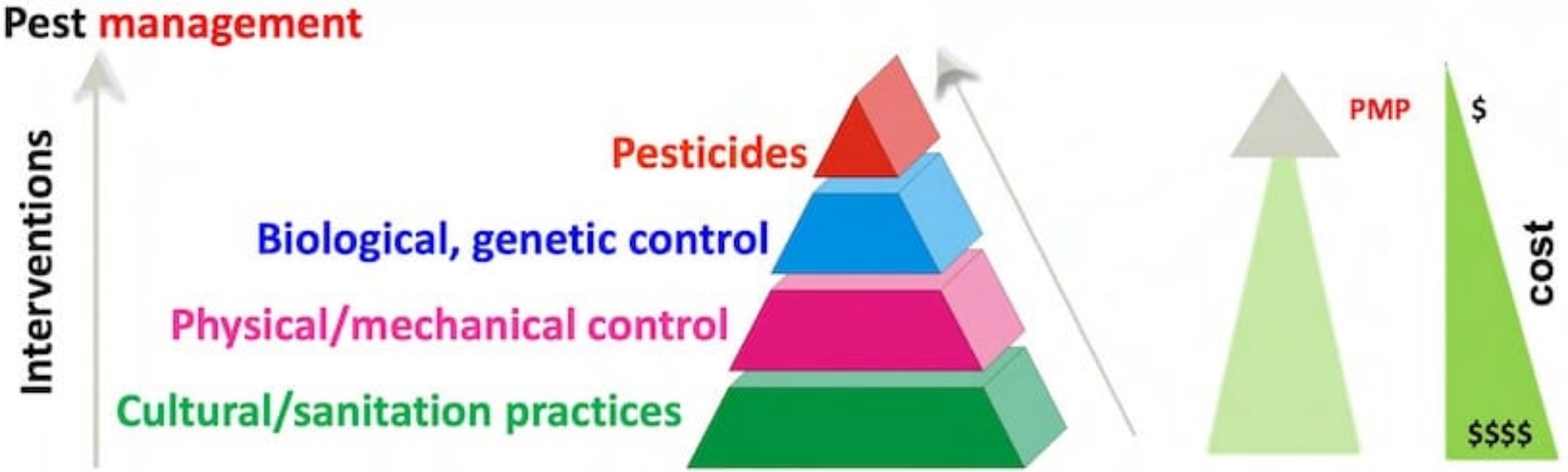




Single-family home

Multi-family homes

Pest management strategies: IPM



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

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

Pest management

Environmental remediation

$$$$

Interventions

Pesticides

Biological, genetic control

Physical/mechanical control

Cultural/sanitation practices

cost

PMP $

Pest Prevention

Limiting resources

Pest elimination

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?

"Practical IPM": Intervention design

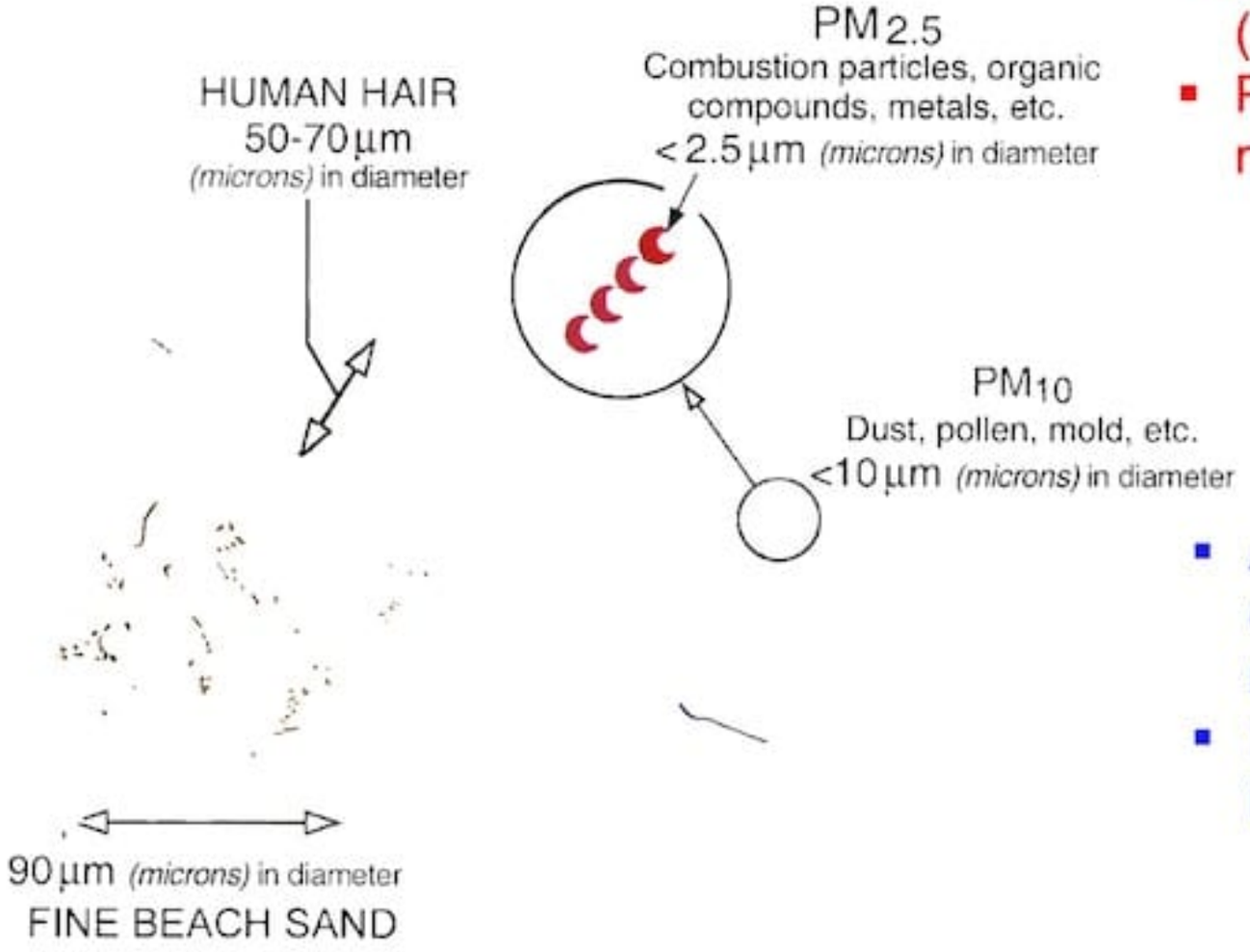
Recruitment:
NCSU IRB (Institutional Review Board approval) – Human subjects research

Intervention:
- Baits only

Collect dust (allergens)

Monitoring-based

Trap:
Estimate infestation size



- 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

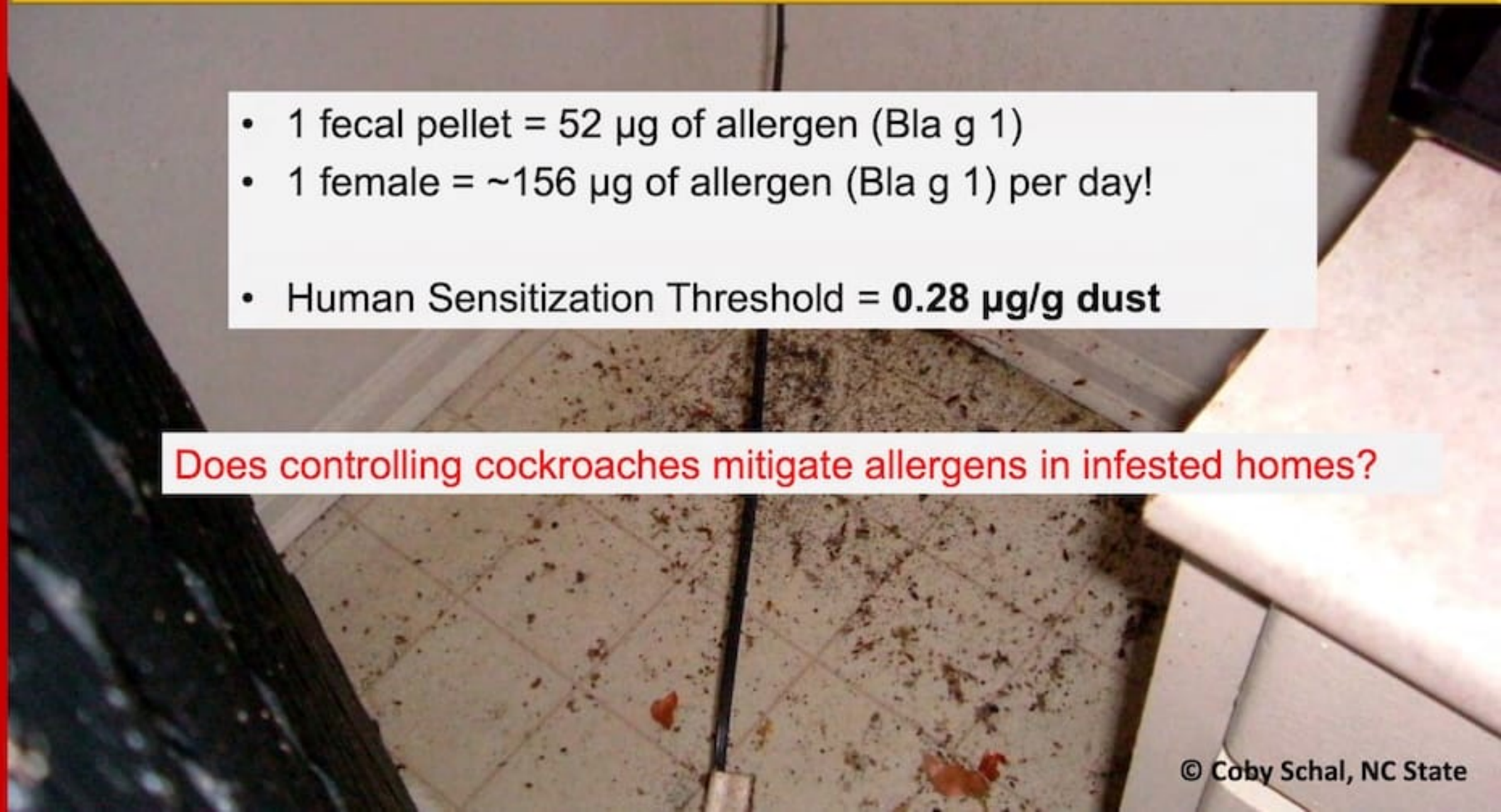
Quantify allergens

Bla g ELISA

Quantify cockroaches

kitchen
living room
bedroom

Danger of Cockroach Allergens

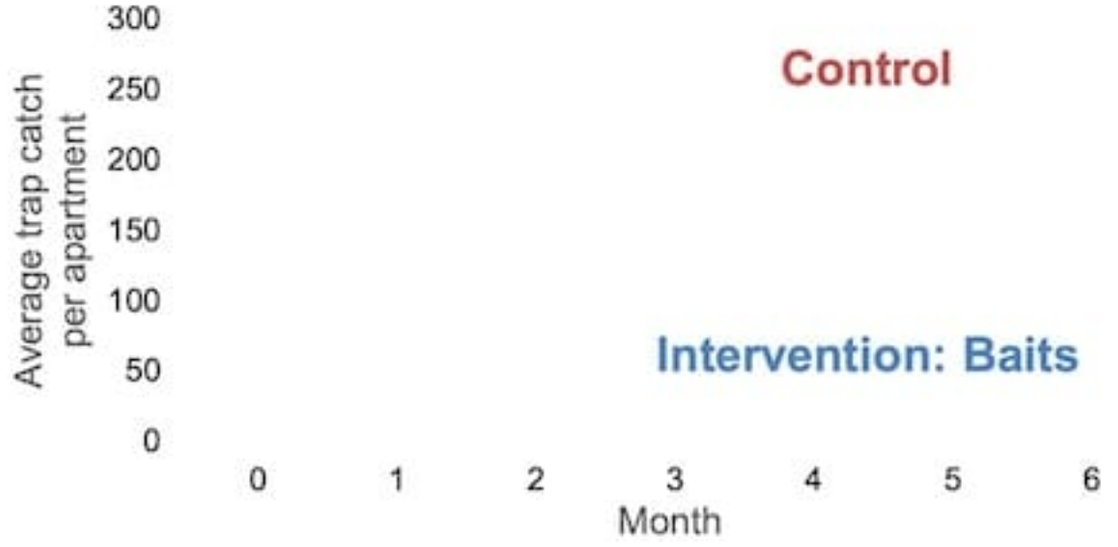


- 1 fecal pellet = 52 µg of allergen (Bla g 1)
- 1 female = ~156 µg of allergen (Bla g 1) per day!

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

Does controlling cockroaches mitigate allergens in infested homes?

"Upside-Down" IPM: Baits ONLY



Cockroach control: Baits only

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

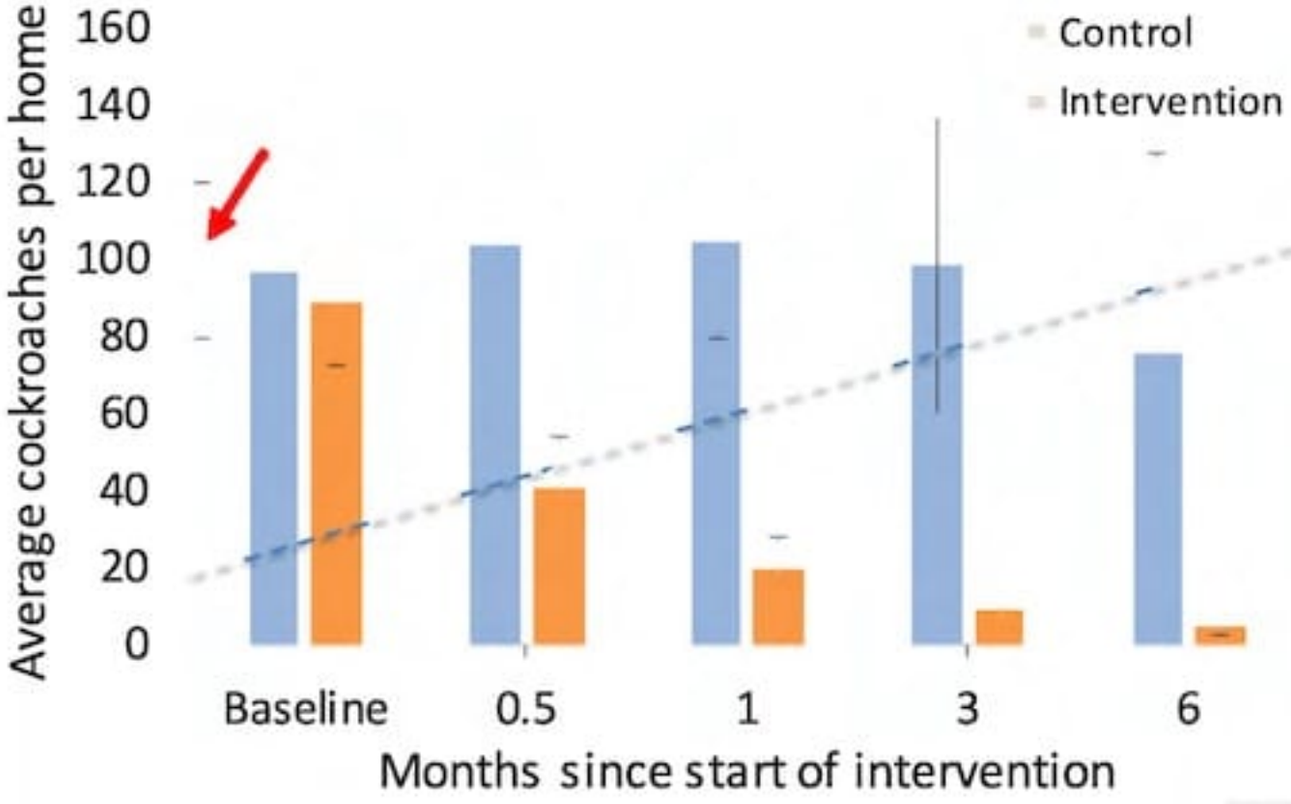
Allergen reduction: Baits only

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

"Upside-Down Practical" IPM: Baits ONLY

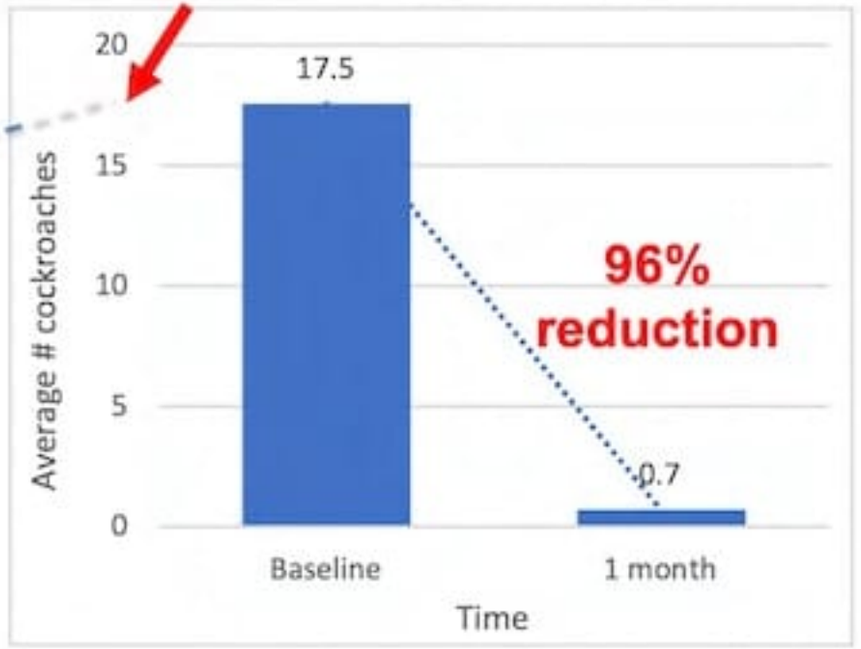
Another example: Moderate infestations

Intervention = Baits alone



'Light' infestations

57 apartments



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

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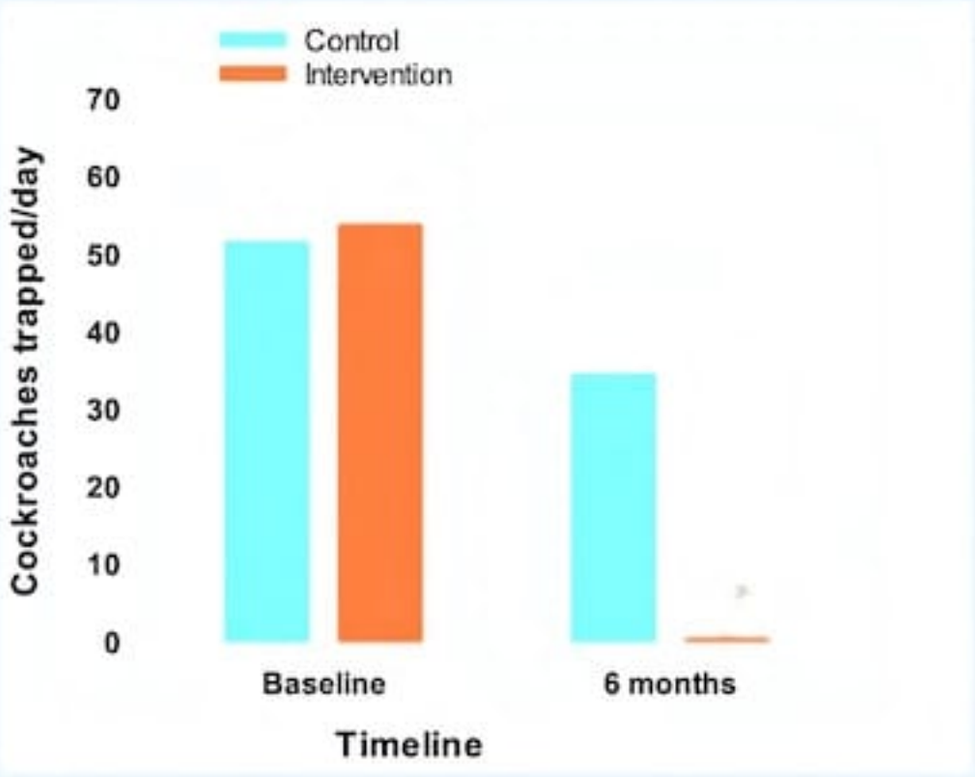
Public health

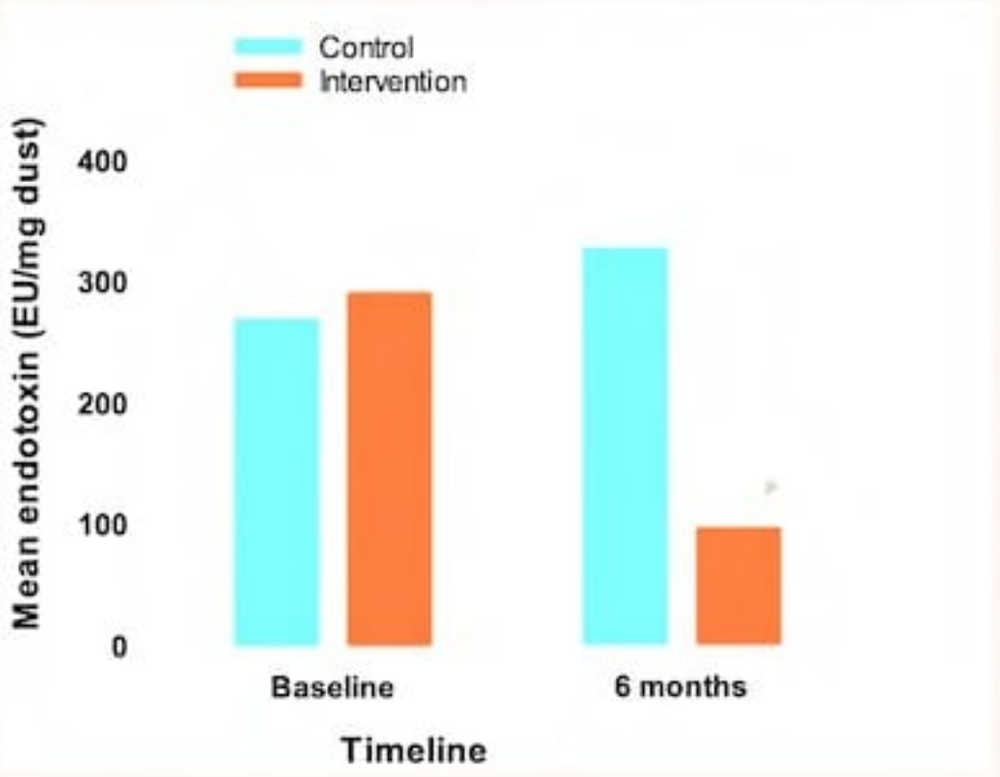
IPM

Baits

Conclusions

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

"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

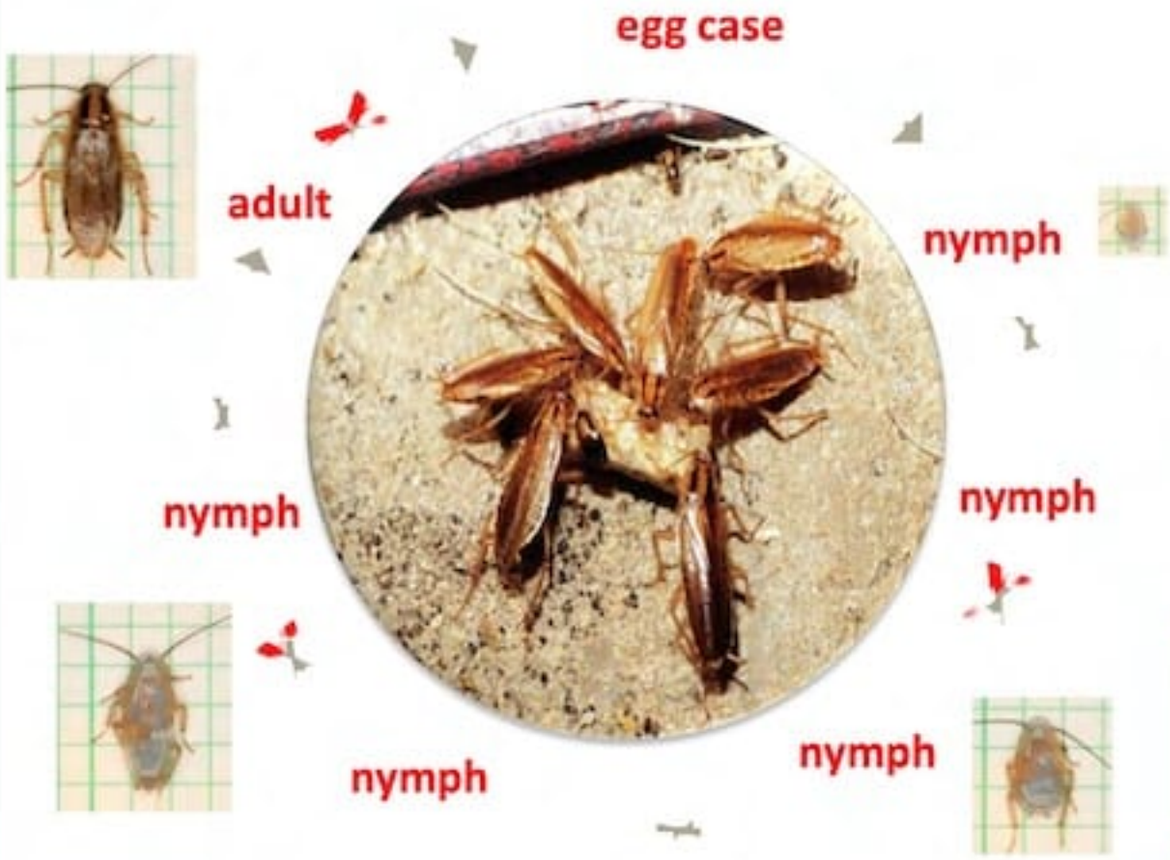
Environmental and occupational disease

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

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, not streaks, not 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**



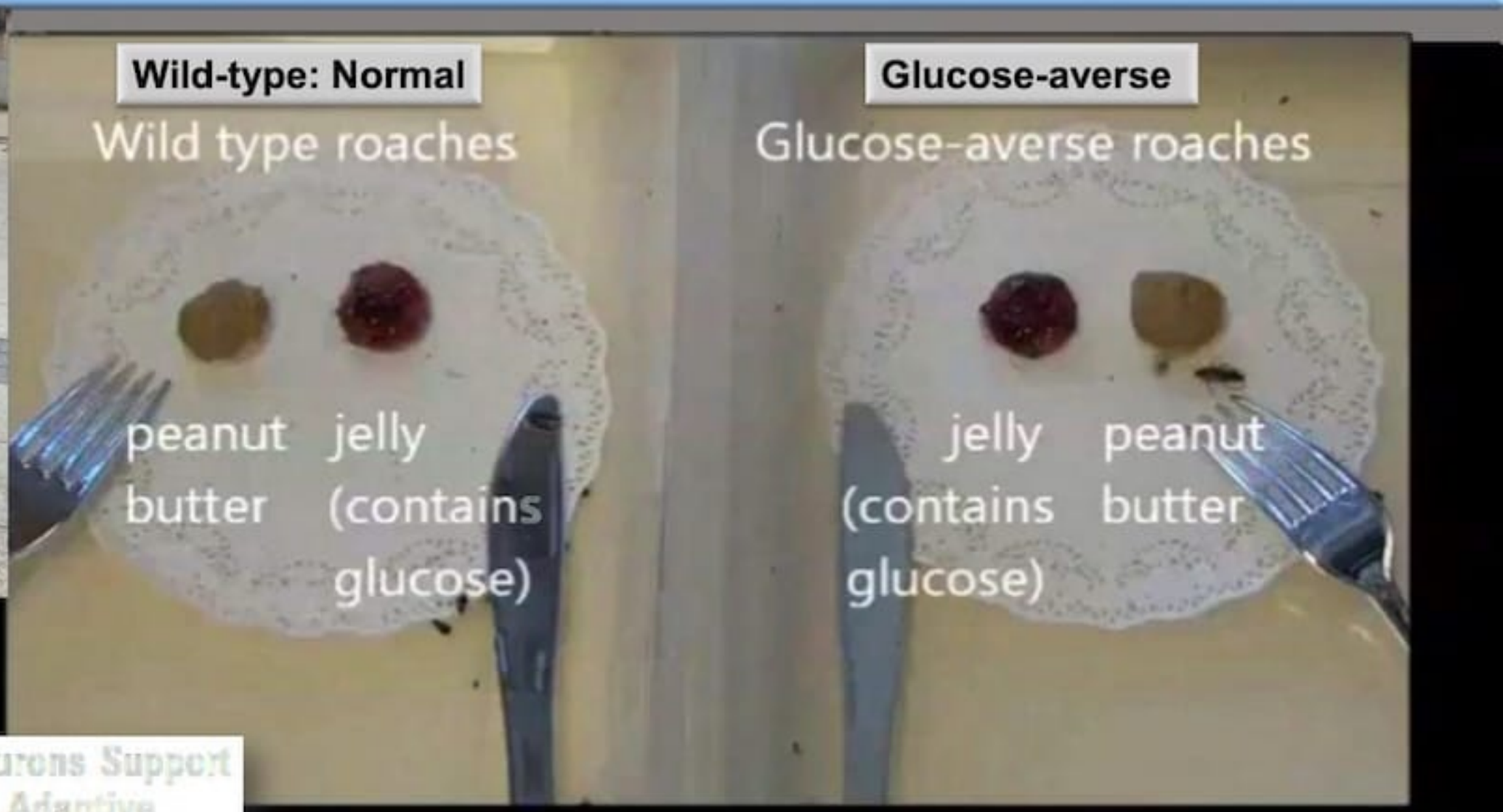
Resistance: German cockroach

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!

Behavioral **Resistance** to baits: Glucose aversion




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

Science

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

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

But roaches proved us wrong…

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

Glucose-averse

Know your modes of action

Public health

IPM

Baits

Conclusions

Indoxacarb – oxadiazine

Emamectin benzoate – avermectin

Fipronil – phenylpyrazole

Clothianidin – neonicotinoid

Clothianidin – neonicotinoid

Pyriproxifen – IGR

Abamectin – avermectin

Dinotefuran – neonicotinoid

Dinotefuran – neonicotinoid

Boric acid – inorganic

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

Know your modes of action

Indoxacarb – oxadiazine

Clothianidin – neonicotinoid

Pyriproxifen – IGR

Emamectin benzoate – avermectin

Abamectin – avermectin

- **Rotations of Active Ingredients:**

Either within manufacturers or across manufacturers

Fipronil – phenylpyrazole

Dinotefuran – neonicotinoid

Boric acid – inorganic

Clothianidin – neonicotinoid

Dinotefuran – neonicotinoid

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!

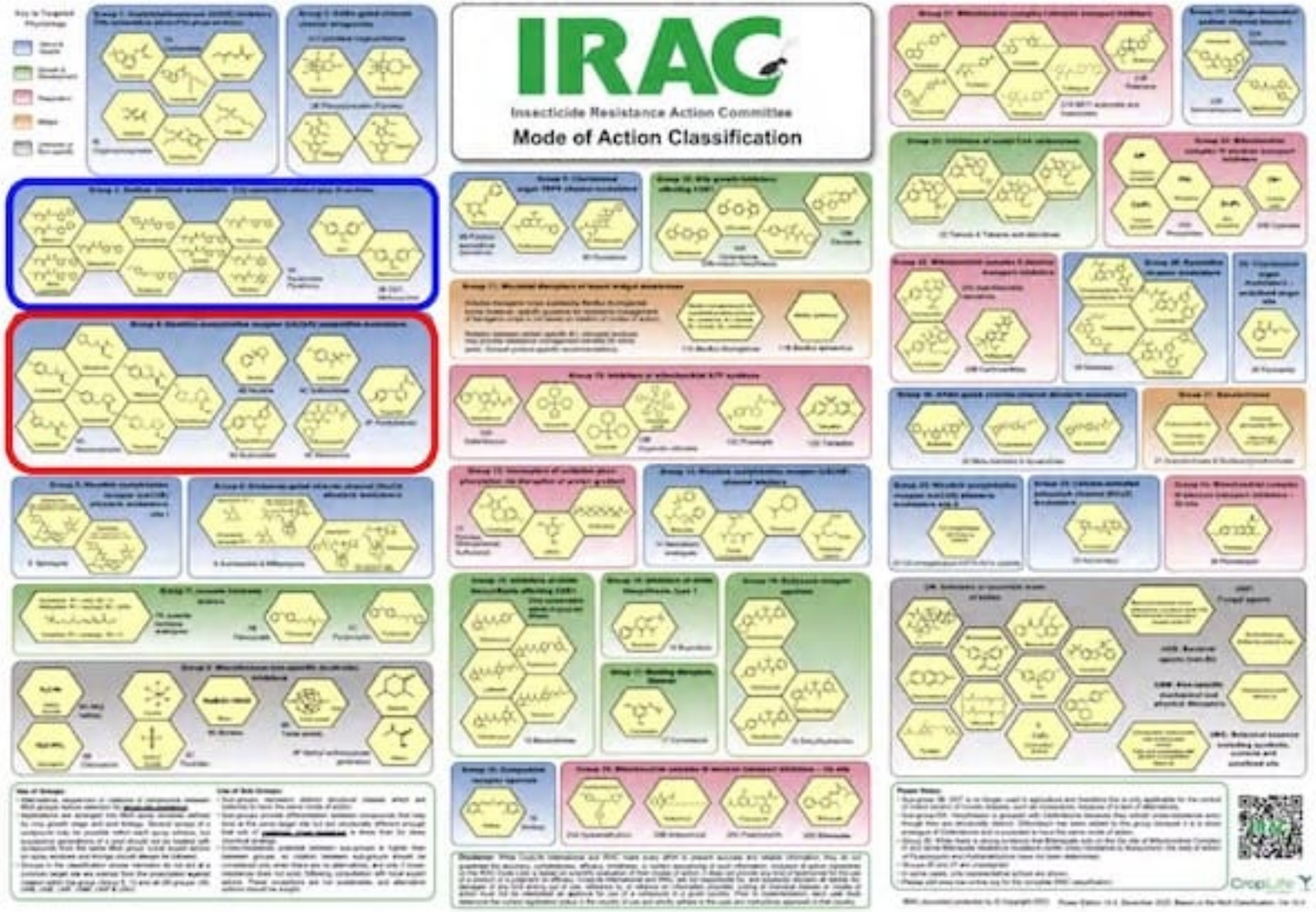
IRAC
Insecticide Resistance Action Committee

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

Demand CS – Lamda-cyhalothrin

Assault II– Permethrin

Phantom– Chlorfenapyr



Rotations – How do you know MOA?

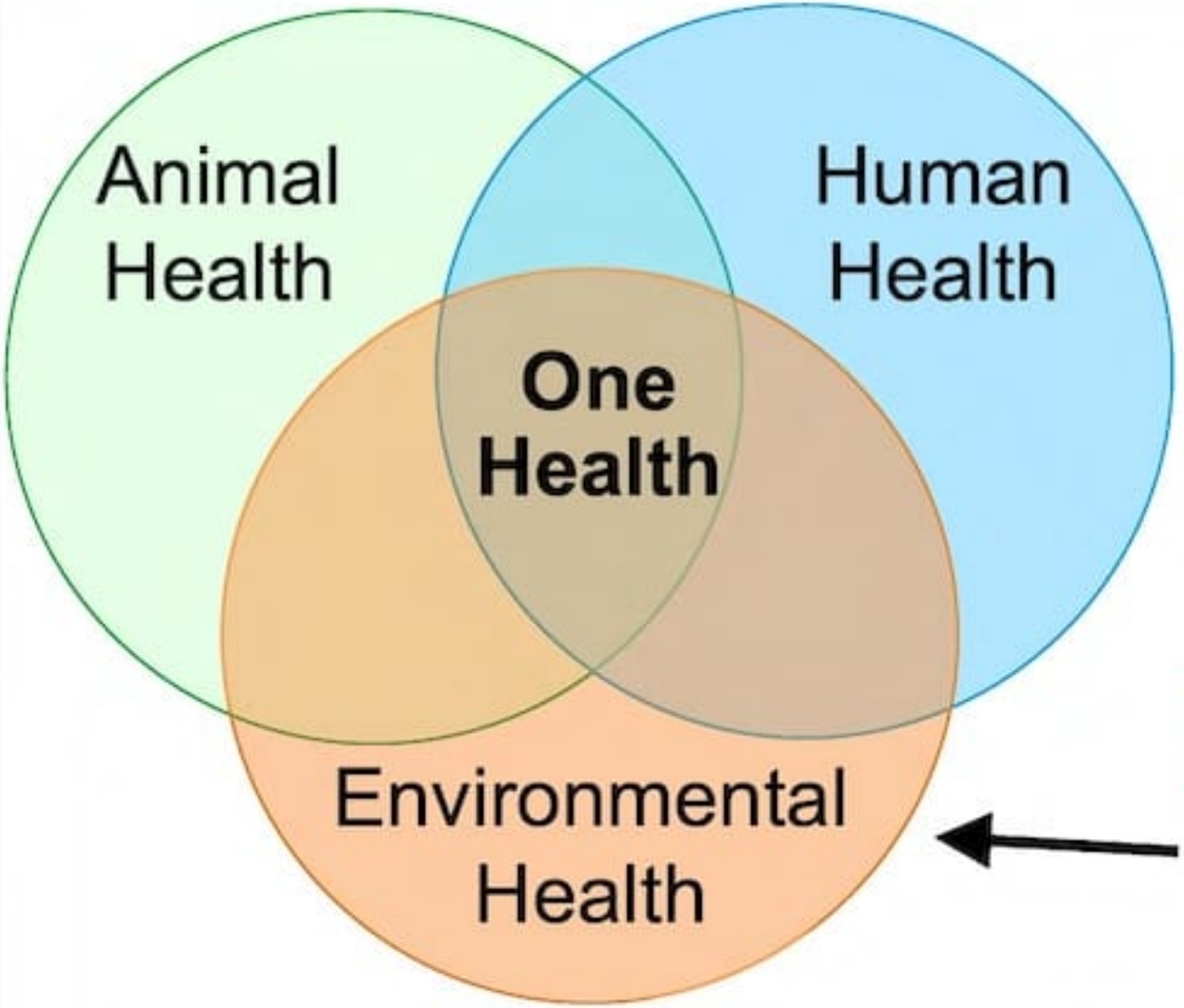
IPM

Baits

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!**

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

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…

NC STATE UNIVERSITY

Blanton J. Whitmire Endowment

Questions?

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http://schal-lab.cals.ncsu.edu/

Center for Human Health and the Environment