



Cockroaches, Allergens, Baits, Resistance (including sugar-aversions)



- Why cockroaches?
 - Pathogens
 - Allergens
- Pest control approaches
 - IPM
 - TRFs
 - Baits
 - Resistance
 - Glucose-aversion

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Why cockroaches? 1. Pathogens



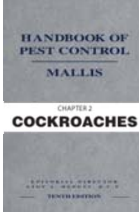
water: toilet, shower
 food: counter top, stove, fridge-stove, pantry
 shelter: fridge sink, cabinets, boxes, voids

Dozens of bacteria and fungi

Why cockroaches? 1. Pathogens

Pathogens isolated from cockroaches:

- bubonic plague (*Pasteurella pestis*)
- dysentery (*Shigella alkalescens*)
- diarrhea (*Shigella paradysenteriae*)
- urinary tract infection (*P. aeruginosa*)
- abscesses (*Staphylococcus aureus*)
- food poisonings (*Clostridium perfringens*, *Escherichia coli*, *Streptococcus faecalis*, *P. aeruginosa*)
- 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.)



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

Why cockroaches? 1. Pathogens


- 12 million swine (10 million people)
- > \$2.5 billion annually
- > 2,000 factory farms

sped up 1.5X



Why cockroaches? 1. Pathogens

- Antibiotic resistance patterns (responses to antibiotics) are **identical** in microbes from pig feces and cockroach feces
- Antibiotic resistance genes also **identical**
- No antibiotic resistant microbes or genes in cockroaches collected in Raleigh, NC
- **Cockroaches acquire, carry, and likely vector antibiotic resistant microbes**



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

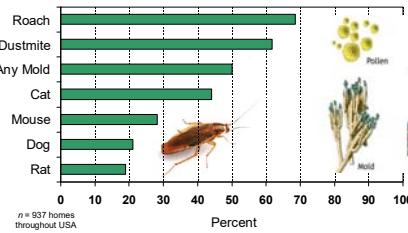
Asaad Ahmad¹, Anwarulhaq Shaikh¹, Coby Schal² and Ludvik Parvizi³
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² Department of Diagnostic Medicine and Pathobiology, Kansas State University, Manhattan, KS, USA
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JMC Microbiology 2013, 8:127 doi:10.1186/1475-2875-8-127

Why cockroaches? 2. Allergens

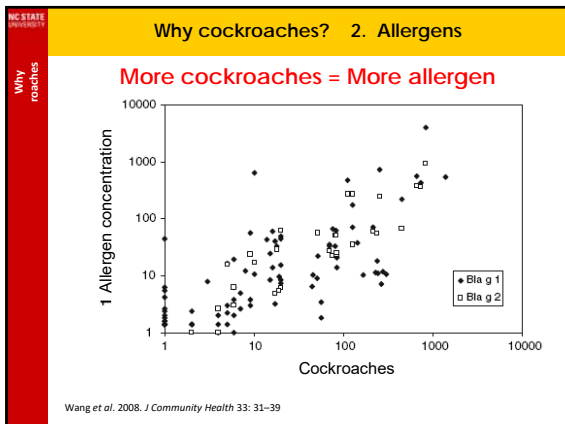
37% of Inner-City Children with Asthma are Sensitized to Cockroach Allergens!



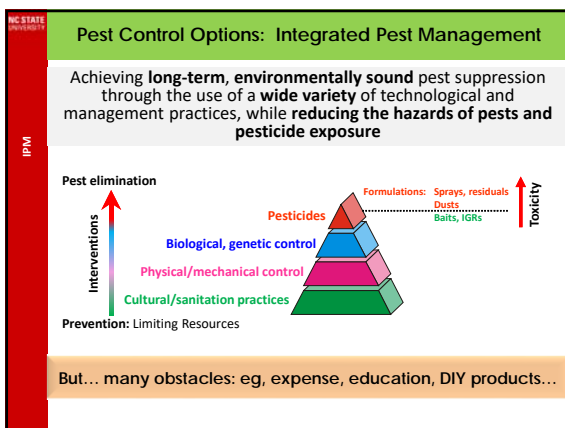
Allergen	Percent
Roach	~68%
Dustmite	~62%
Any Mold	~55%
Cat	~45%
Mouse	~35%
Dog	~25%
Rat	~20%

n = 537 homes throughout USA

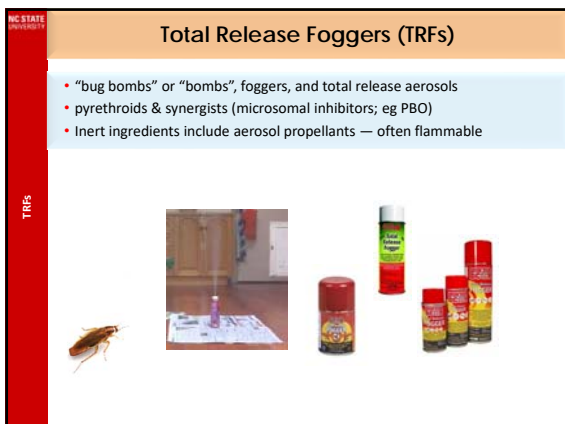
Rosenstreich et al. 1997 N Engl J Med; Morgan et al. 2004, N Engl J Med; Gore & Schal 2007, Annu Rev Entomol



- ### Why cockroaches? Recap
- Carry and vector **pathogenic microbes**, including antibiotic resistant microbes;
 - Produce potent **allergens** that trigger asthma, especially in sensitized inner-city children;
 - **Contaminate** foods, damage electrical circuits.
 - **Therefore, Need Pest Control Interventions;**
 - Large amounts of **insecticides** are used (and often mis-used) to control cockroaches.
 - **Solution: Integrated Pest Management – IPM**



- ### Challenges with implementing IPM
- Perceived as more expensive?
 - More labor intensive?
 - Requires better sanitation to eliminate food sources that compete with baits
 - Requires more training and education, cooperation
 - Insecticide Resistance to sprays and baits
 - **Contracts that call for monthly/quarterly sprays!**
 - **Competing DIY products? TRFs and sprays!**
-



Total Release Foggers


- 466 TRF-related ‘events’; NYC: 4 – 8 explosions/yr
- “TRFs pose a risk for acute, usually temporary health effects among users and bystanders.”
- “TRFs can reduce pest populations and often are used by consumers as a **low cost alternative to professional pest control services.**”

Efficacy?
TRFs vs. Baits

Why TRFs fail?
Insecticide resistance


HUD, EPA

Total Release Foggers: Study design



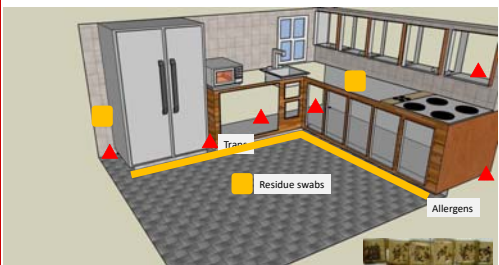
- 5 apartment complexes
- 6 apartments per complex
- 1 TRF-type per complex
- 1 bait treatment per complex (positive "gold standard" control)

Total Release Foggers: Study design



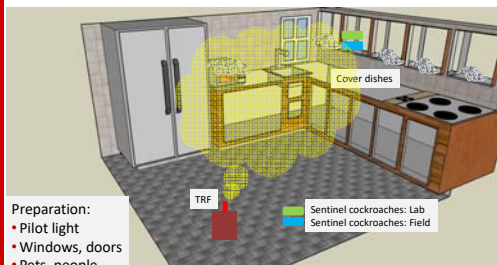
3-6 months before TRFs: Collected cockroaches → lab

Total Release Foggers: Study design



3-7 days before TRFs: allergens, traps (population size), pesticide residues

Total Release Foggers: Study design



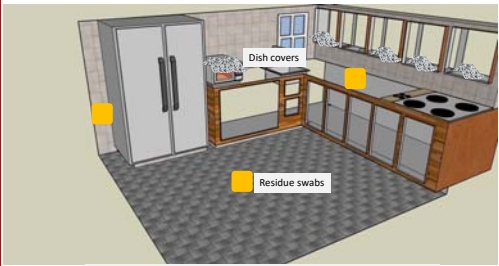
Preparation:

- Pilot light
- Windows, doors
- Pets, people
- Dishes, etc.

Intervention day

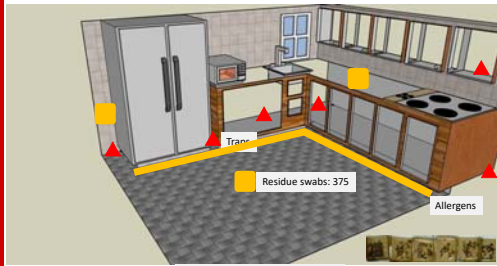
Sentinel cockroaches: Lab
Sentinel cockroaches: Field

Total Release Foggers: Study design

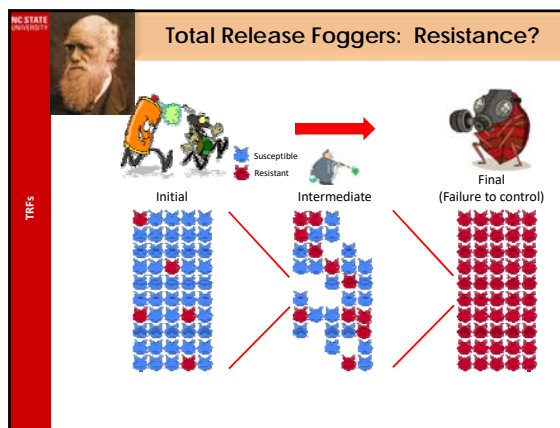
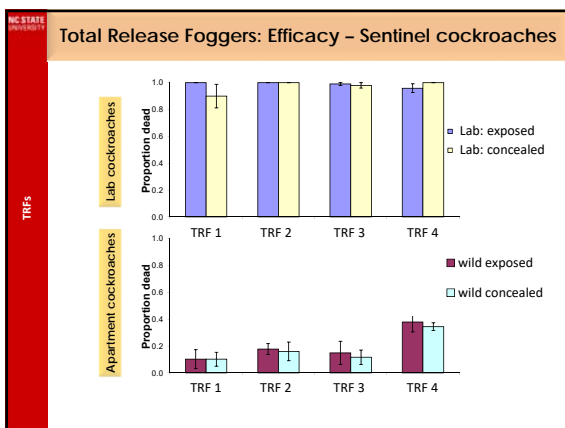
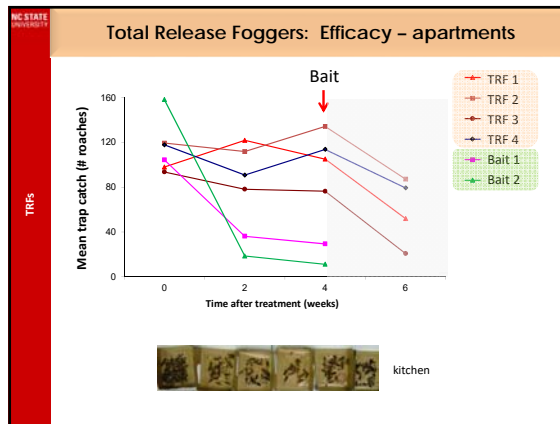
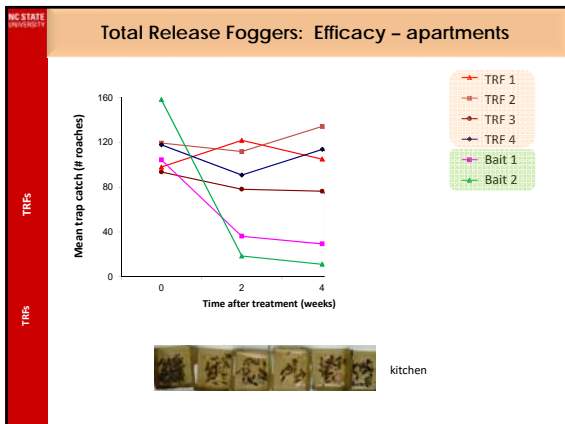


4-6 hrs later: ventilation, clean-up, pesticide residues

Total Release Foggers: Study design



Over time: 3 months



Total Release Foggers: Resistance

Apply a pyrethroid insecticide (cypermethrin) to lab (susceptible) roaches and to apartment-collected roaches

Lab strain LD₅₀ = 45 ng

- to kill 50% roaches = 45 ng

Apartment LD₅₀ = 10,000 ng

- 10,000 ng
- 10,000 ÷ 45 = > 200X
- High insecticide resistance
- Low efficacy of sentinels

TRF's

Comparative efficacy of total release foggers and baits in relation to insecticide resistance

	Total Release Foggers	Gel Baits
No efficacy:	<ul style="list-style-type: none"> On sentinels On apartment roaches 	<ul style="list-style-type: none"> Highly efficacious Population reduction Long-term efficacy
High resistance, few options	No change in allergens	Low resistance, many options
Cost: \$7 – 14 (but zero efficacy!)	Labor: Very high (preparation, pets, vacating the home for 4-6 hours, cleanup)	Allergen reduction
Pesticide residues: Extensive, long lasting		Low: 30 – 45 min
		Cost: \$7 – 14 (for 6 months to 1 year)
		Minimal, mainly due to translocation by roaches

TRF's

Pest Control Options

Formulation	Chemical				Physical
	Baits, Granular	Dusts	Residual sprays	TRF	Traps
Active ingredients	Fipronil Hydramethylnon Imidacloprid Indoxacarb Chlothianidin, etc.	Botic acid Diatomaceous earth Pyrethroids	Pyrethroids Chlorfenopyr IGRs	Pyrethroids	---
Attractants	Food odors	---	---	---	Food odors
Feeding stimulants	Glucose Fructose	---	---	---	---

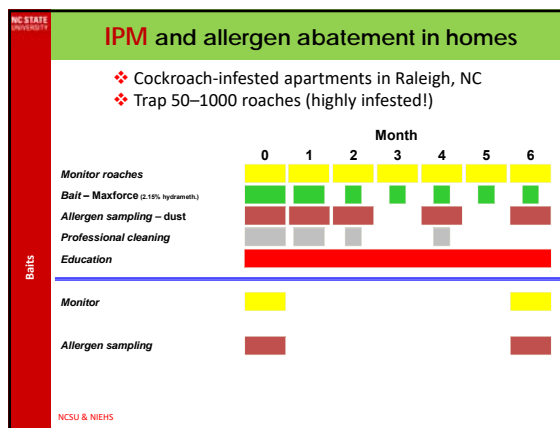
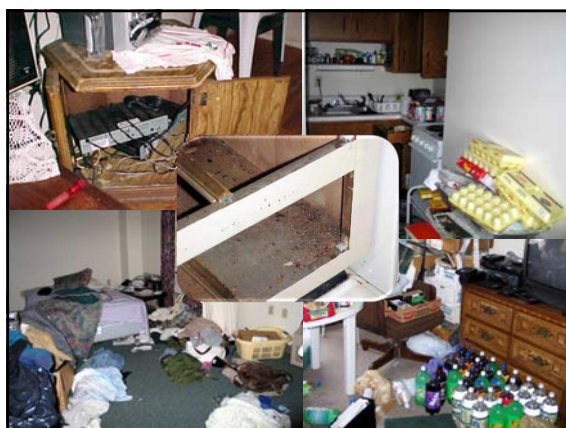
Why do baits work so well? Target all life stages

Sprays

- Difficult in clutter
- Long lasting residual
- Broad spectrum
- Extensive coverage: >AI
- Resistance!

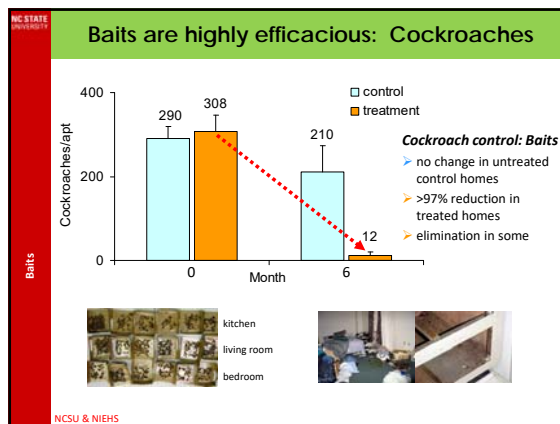
Baits >>> Residual >>>> TRFs

- Easy to use
- Long lasting residual
- Specific target sites
- Point sources: <AI
- More AIs; <Resistance
- Secondary kill
- Add-ons: attractants



IPM and allergen abatement in homes

- Thousands of cockroaches; Allergens that trigger asthma
- Food contamination; Large amounts of DIY insecticides



Baits are highly efficacious: Allergens

Bla g 1 ELISA

Month	Control	Treatment
0	351	633
6	287	24

Allergen reduction

- no change in untreated control homes
- >96% Bla g 1 reduction in treated homes
- several homes below clinical thresholds

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Allergens in cockroach feces

Bla g 1 = a potent aero-allergen
1 female = ~1500 Units Bla g 1/ day

Morbidity (illness) threshold
per grm dust = 8 Units

Gore & Schal. 2004. *J Medical Entomology*
Gore et al. 2005. *Med Vet Entomology*
Gore & Schal. 2007. *Annu Rev Entomol*

IPM in homes: Outcomes due to?

Outcomes due to...

1. Pest control (Baits)?
2. Professional cleaning?
3. Resident education?

- whole-home, follow-ups, traps
- new vacuum (with HEPA filter)

NCSU & NIEHS

Baits are highly efficacious – not rocket science!

- Baits can eliminate large infestations
- Reduce allergens that trigger asthma


Challenges with Baits & IPM Drivers

- More expensive? **No!**
- More labor? **No!** given the long-term activity
- Slow acting? **Actually, a good thing (secondary kill)**
- Alternative foods, sanitation? **Probably an issue**
- Competing products? **TRFs and sprays!**
- Misapplication, low application?
- **Resistance** emerging to insecticides in baits

Resistance

- **Physiological** – Insecticide
Selection for:
 - Metabolic breakdown, excretion, sequestration
 - Target site insensitivity
 - Reduced penetration
- **Behavioral** – Insecticide or inert ingredients
Selection for:
 - Movement away from treated surface
 - Non-consumption of insecticide or inert ingredients




Example of resistance to AI: PR712



San Juan, Puerto Rico

Commercial baits used for selections

- 0.05% Fipronil
- 2.15% Hydramethylnon
- 0.6% Indoxacarb

B. germanica not controlled by baits:

- Indoxacarb
- Fipronil
- Hydramethylnon

Resistance to commercial bait AI's

Strain	Insecticide	RR ₅₀	RR ₉₀
Orlando Normal	Fipronil	-	-
PR-712 unselected	Fipronil	5.6	9.8
PR-712 Fipronil selected	Fipronil	15.9	20.2

Topical application

Resistance to commercial bait AI's

Strain	Insecticide	RR ₅₀	RR ₉₀
Orlando Normal	Fipronil	-	-
PR-712 unselected	Fipronil	5.6	9.8
PR-712 Fipronil selected	Fipronil	15.9	20.2
Orlando Normal	Indoxacarb	-	-
PR-712 unselected	Indoxacarb	23.2	391
PR-712 Indoxacarb selected	Indoxacarb	~13,000	~54,000

Topical application


Resistance to commercial bait AI's

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Orlando Normal	Indoxacarb	-	-
PR-712 unselected	Indoxacarb	23.2	391
PR-712 Indoxacarb selected	Indoxacarb	~13,000	~54,000
Orlando Normal	Hydramethylnon	-	-
PR-712 unselected	Hydramethylnon	3.9	8.7
PR-712 Hydramethylnon selected	Hydramethylnon	19.3	351

Topical application

Summary - Insecticide resistance

- Poor performance of commercial baits in some field locations
- High levels of resistance found to indoxacarb, fipronil and recently even to hydramethylnon
- Resistance increases with selection pressure
- High mortality in primary-kill lab assays
- Baits are not "immune" to resistance!



Emergence of glucose-averse behavior



Extremely strong selection pressure for the evolution of insecticide resistance:

- Physiological: hundreds of insects
- Behavioral: rare, poorly understood



Emergence of glucose-averse behavior

J. Insect Physiol. 30, No. 11, pp. 923-933, 1993
 Printed in Great Britain. All rights reserved.
Glucose Aversion in the German Cockroach, *Blattella germanica*
 JULES SILVERMAN,* DONALD N. BIEMANZ
 Received 6 April 1993; revised 23 May 1993

Glucose
C(C1C(C(C(C(O1)O)O)O)O)O

COMBAT

DO NOT EAT

- Reject a bait ingredient – glucose
- No** resistance to the insecticide
- Genetically-based: maintained in the lab for >20 yrs
- Highly adaptive under toxic bait pressure
- Omnivore: Significant fitness costs when baits are not present

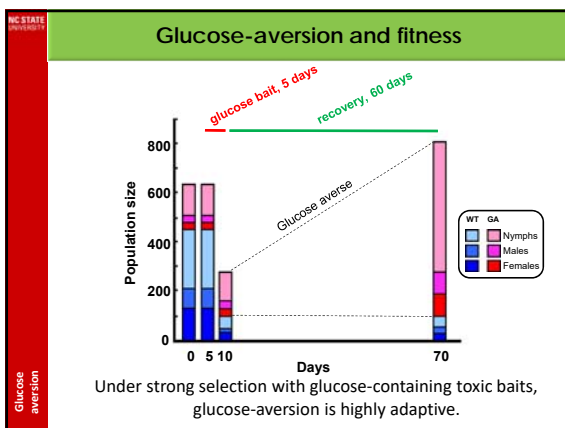
Emergence of glucose-averse behavior

Wild-type

Glucose-averse

Wild type roaches: peanut butter, jelly (contains glucose)

Glucose-averse roaches: jelly, peanut butter (contains glucose)



"Arms Race" between us and cockroaches

1950s	Spray pesticides	Insecticide resistance: DDT & OCs, OPs, carbamates, pyrethroids
1980s	Glucose baits	Glucose-aversion
2000s	Fructose baits	Fructose- and glucose-aversion
present	Other feeding stimulants? New insecticides?	New adaptive mutations!

The Evolution of Insecticide Resistance: Have the Insects Won?
 James Mallet

TECHNIQUES 1988 vol. 6, no. 11, November 1988

Insecticide resistance: DDT & OCs, OPs, carbamates, pyrethroids

Fructose- and glucose-aversion

New adaptive mutations!

What can we do?

- **Monitor** efficacy of various baits:
 - Rapid taste test! (Coke challenge)
- Use **multiple** bait formulations
- **Rotate** among bait products
- **Eradicate** infestations!

Tips for Successful Cockroach Control

- Take the time to understand the infestation!
- Use "**Fecal Focal Points**" as a road map for bait placements
- Increase the number of bait placements when sanitation is poor
- Be aware of bait depletion, replenish baits when dealing with large populations
- Don't place new baits in same locations as old baits
- Use Insect Growth Regulators to stimulate activity/feeding in pregnant females
- Use vacuums to remove large pockets of roaches before baiting

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Tips for Successful Cockroach Control

- Avoid resistance
 - Use a variety of baits (active ingredients, formulations)
 - Incorporate IGR's & boric acid products
 - Integrate new chemistries (chlorfenapyr, indoxacarb, acetamiprid)
 - Rotate through different baits every 3 – 4 months
- Good sanitation is critical
- Follow up with inspections & monitoring
- If the problem persists don't keep doing the same thing:
It Isn't Working!

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