

Social and ecological dimensions of urban mosquitoes in Baltimore, Maryland

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Collaborators & Funders



Shannon LaDeau (Cary Institute)

- USDA-NIFA and the Northeastern Integrated Pest Management Center (MD-2011-00540)
- NSF-Couple Natural Human Systems Program (DEB-1211797)
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Citizen Science:
Rebecca Jordan (Rutgers)



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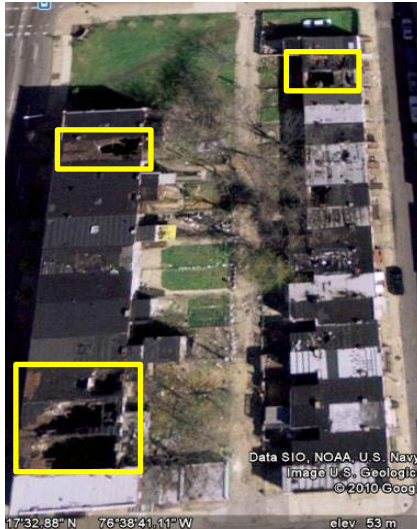


Community connections:
Guy Hager (Parks and People Foundation)

...numerous graduate and undergraduate students

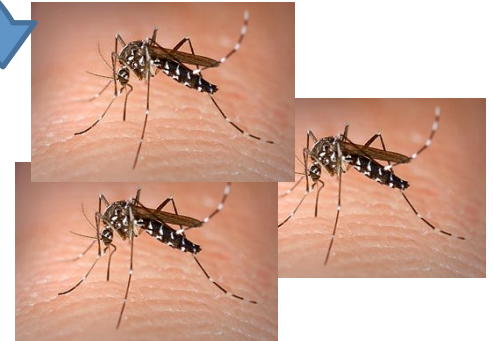


Urban disamenities and pests in Baltimore, MD



Urban decay leads to more mosquito habitat & adult exposure

Mosquito pestilence leads to reduced use, valuation, and care of outdoor environment

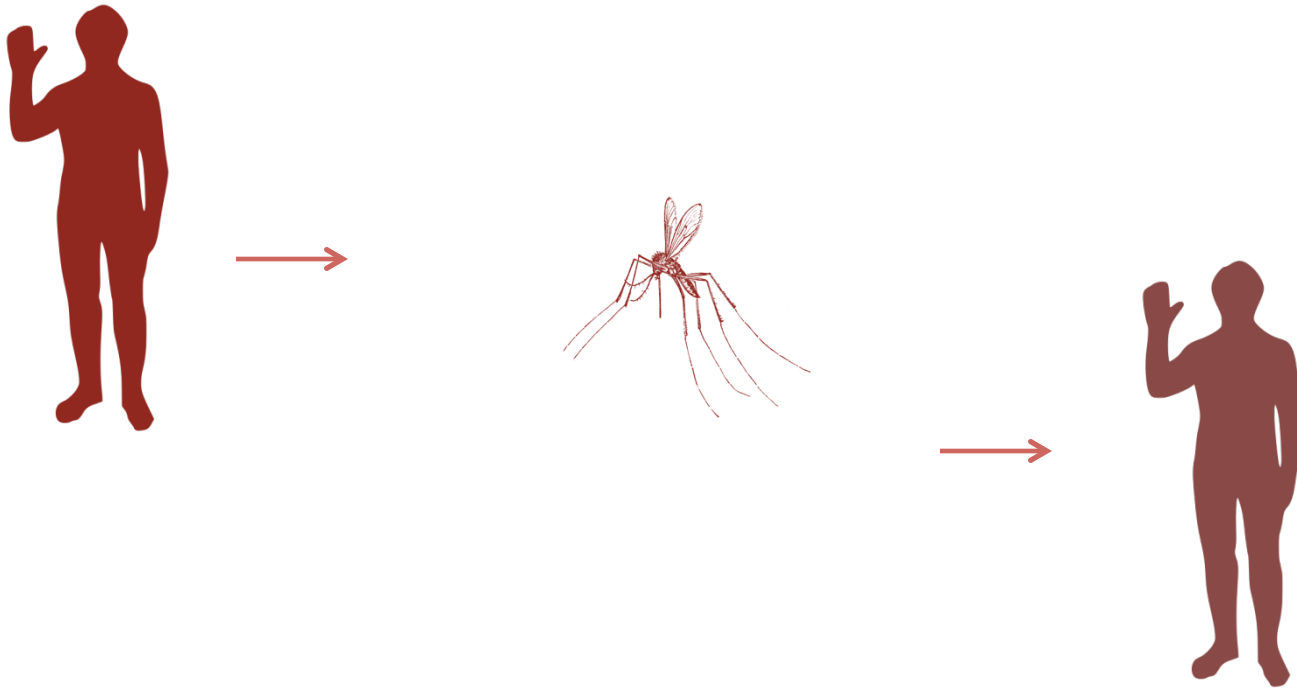


Talk Outline

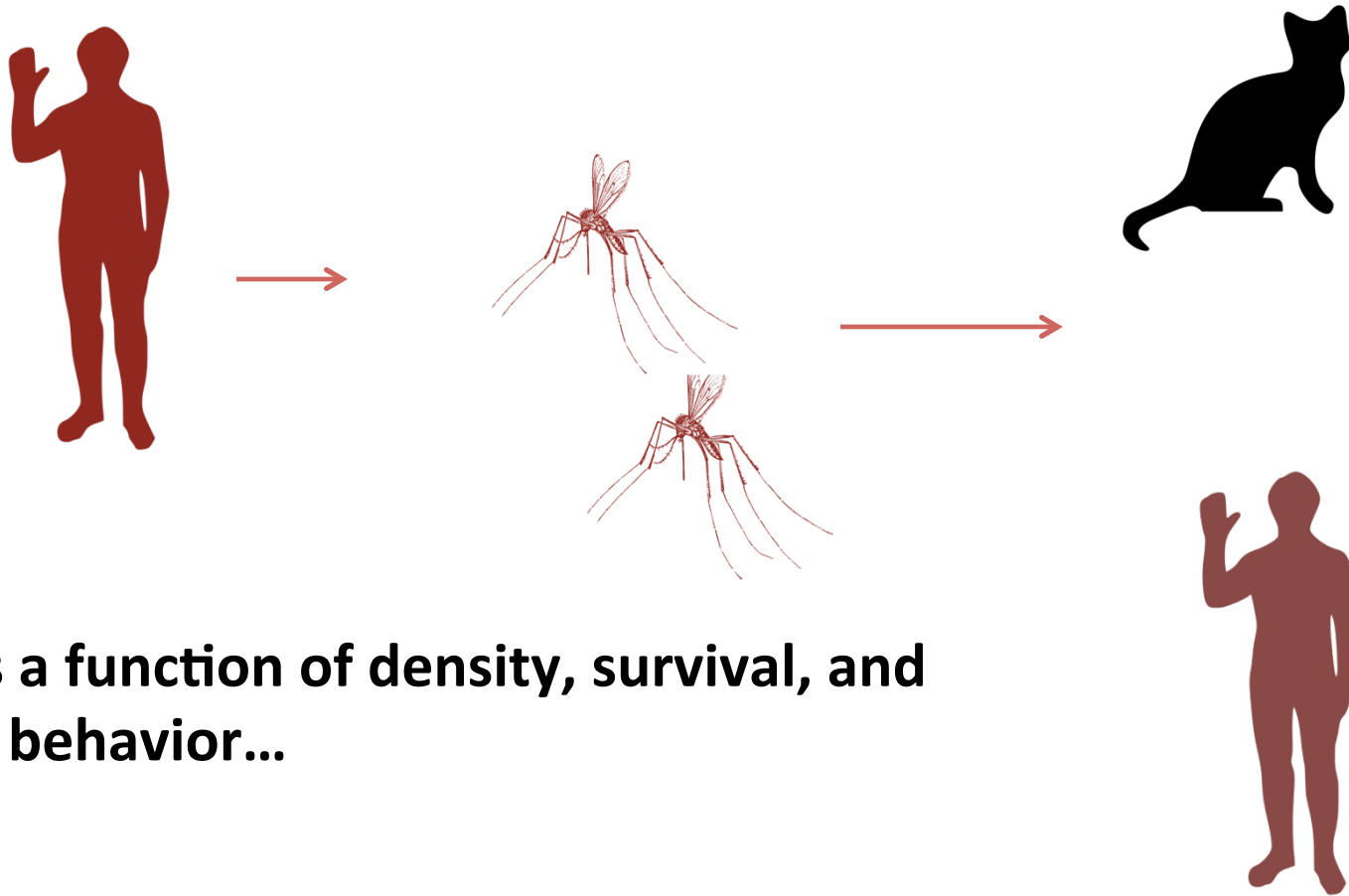
- Background on urban mosquitoes and disease risk
- Synthesis of mosquito abundance data from Baltimore, Maryland
- Effects of container condition on competition of *Ae. albopictus* on *Cx. pipiens*



For mosquito-borne disease, **risk** is related to how likely a mosquito is to pick up a new infection and pass it on:



In mosquito-borne disease, **risk** is related to how likely a mosquito is to pick up a new infection and pass it on:



This is a function of density, survival, and biting behavior...



Vectorial Capacity (infective bites/person/day)

$$V = \frac{m a^2 p^n b}{-\ln(p)}$$

m = biting ♀♀/person (density)

a = proportion ♀♀ biting/cycle (biting rate)

p = daily ♀ survival

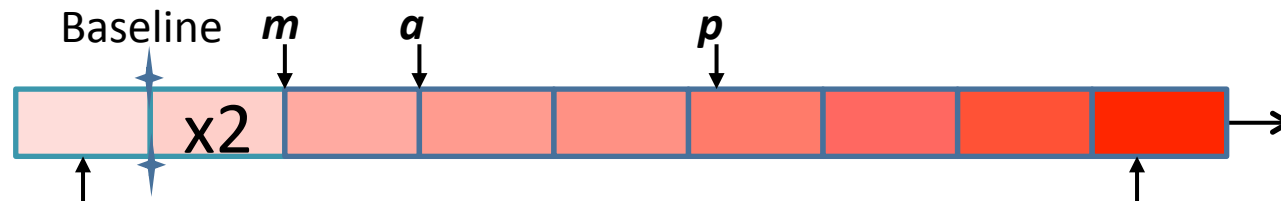
b = vector competence (probability infection given an infectious meal)

n = extrinsic incubation period (days bet. infection & transmission capability)



Changes in mosquito density (m), biting rate (a) and survival (p) influence RISK in predictable ways:

Vectorial capacity, V



Low vector survival
(when m & a doubled, but p halved)

Doubled rates
(when m , a , & p doubled at same time)

Functional Ecology



Functional Ecology 2015

doi: 10.1111/1365-2435.12487

ECOLOGY OF ORGANISMS IN URBAN ENVIRONMENTS

**The ecological foundations of transmission potential
and vector-borne disease in urban landscapes**

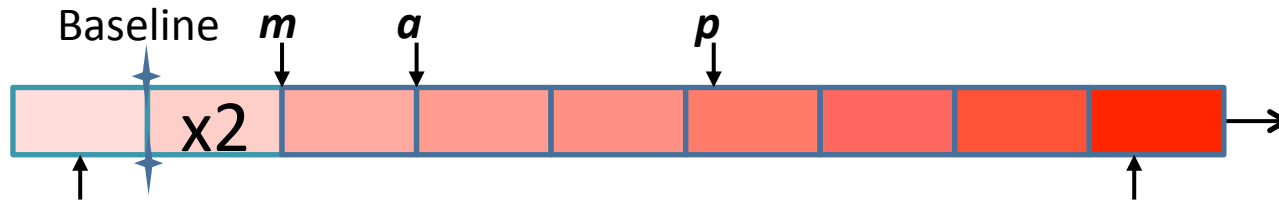
Shannon L. LaDeau^{*1}, Brian F. Allan², Paul T. Leisnham³ and Michael Z. Levy⁴



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Vectorial capacity, V



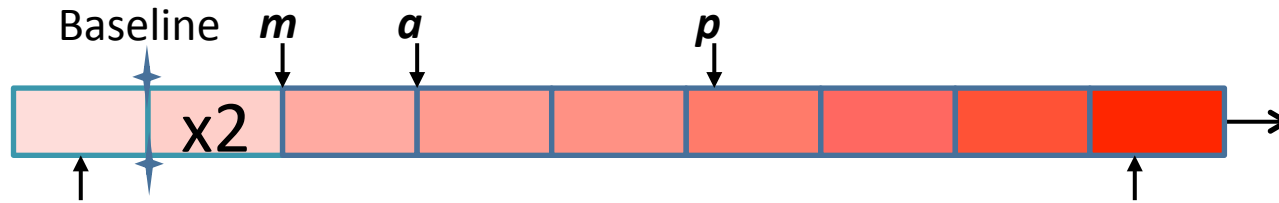
Low vector survival
(when m & a doubled, but p halved)

Doubled rates
(when m , a , & p doubled at same time)

Control and management historically focused **on reducing individual mosquito survival (adulticide).**



Vectorial capacity, V



Low vector survival
(when m & a doubled, but p halved)

Doubled rates
(when m , a , & p doubled at same time)



Control and management post DDT is often **focused on limiting densities** (larval control).

Biorational larvicides
Source reduction
Biological control



Mosquitoes in urban landscapes



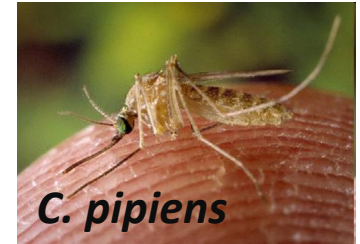
- Container habitats difficult to access and manage
 - Numerous, cryptic, private land
- Larviciding impractical

Resident-based container management is important



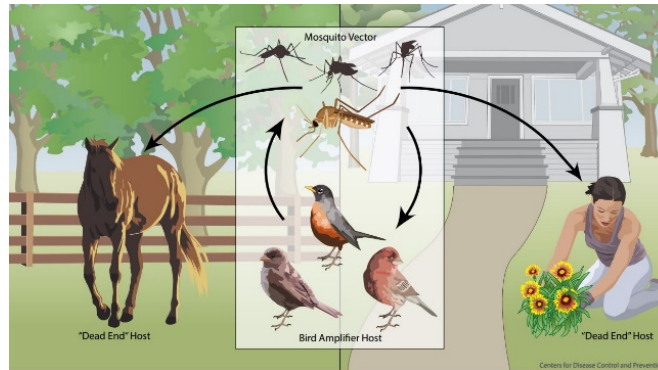
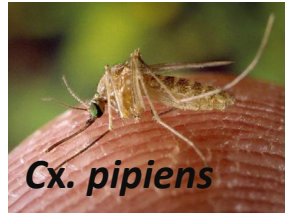
Mosquito Invasions in Eastern North America

- Prominent diasporas since 15th C.
 - *Culex pipiens* complex (400 years ago)
 - *Aedes aegypti* (200 years ago)
 - *Aedes albopictus* (mid-1980s)
 - *Aedes japonicus* (late-1990s)

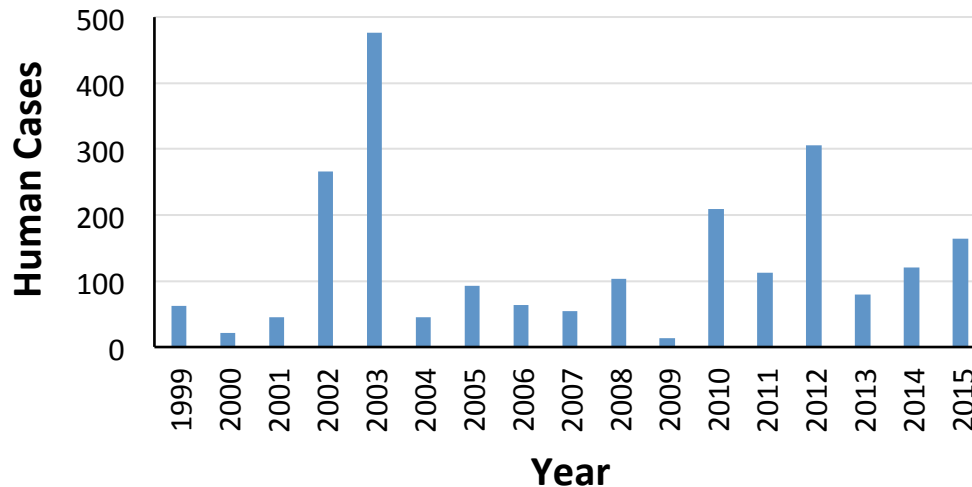


Medical Importance

West Nile virus



Reported West Nile cases in the northeast region



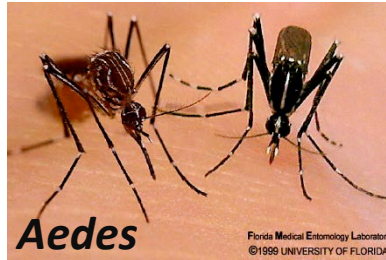
2235 total human cases in the northeastern regions

ArboNET, Arboviral Diseases Branch, CDC



Medical Importance

Zika virus



- 1533 total travel associated cases; 0 locally-acquired cases (CDC)

New Results

Defining the risk of Zika and chikungunya virus transmission in human population centers of the eastern United States

Carrie Manore, Richard Ostfeld, Folashade Agosto, Holly Gaff, Shannon LaDeau

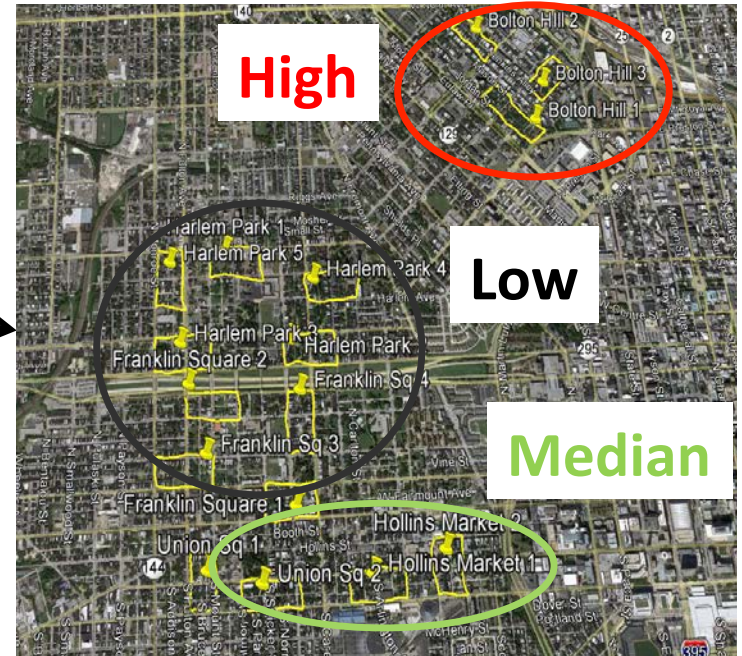
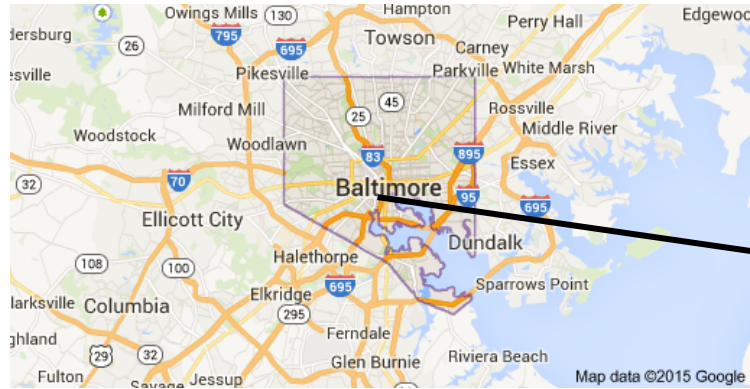
doi: <http://dx.doi.org/10.1101/061382>

This article is a preprint and has not been peer-reviewed [what does this mean?].

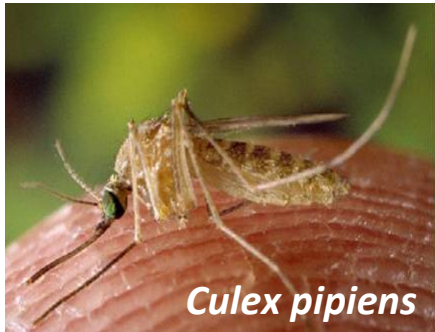
- “...**one of every two infectious** travelers arriving at peak mosquito season **could initiate local transmission** and **> 10% of the introductions** could **generate a disease outbreak of at least 100 people.**”
- “Despite *Ae. albopictus* propensity for biting non-human vertebrates, we also demonstrate that local virus transmission **and human outbreaks may** occur when vectors feed from humans **even just 40% of the time.**”



Baltimore, Maryland

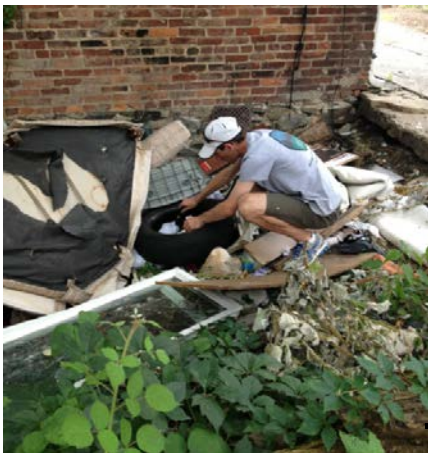
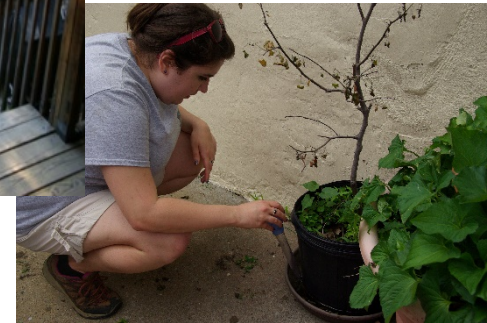
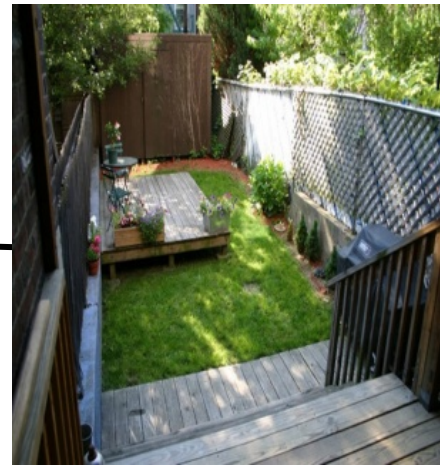


Dominant species



median household income
City: \$41,385







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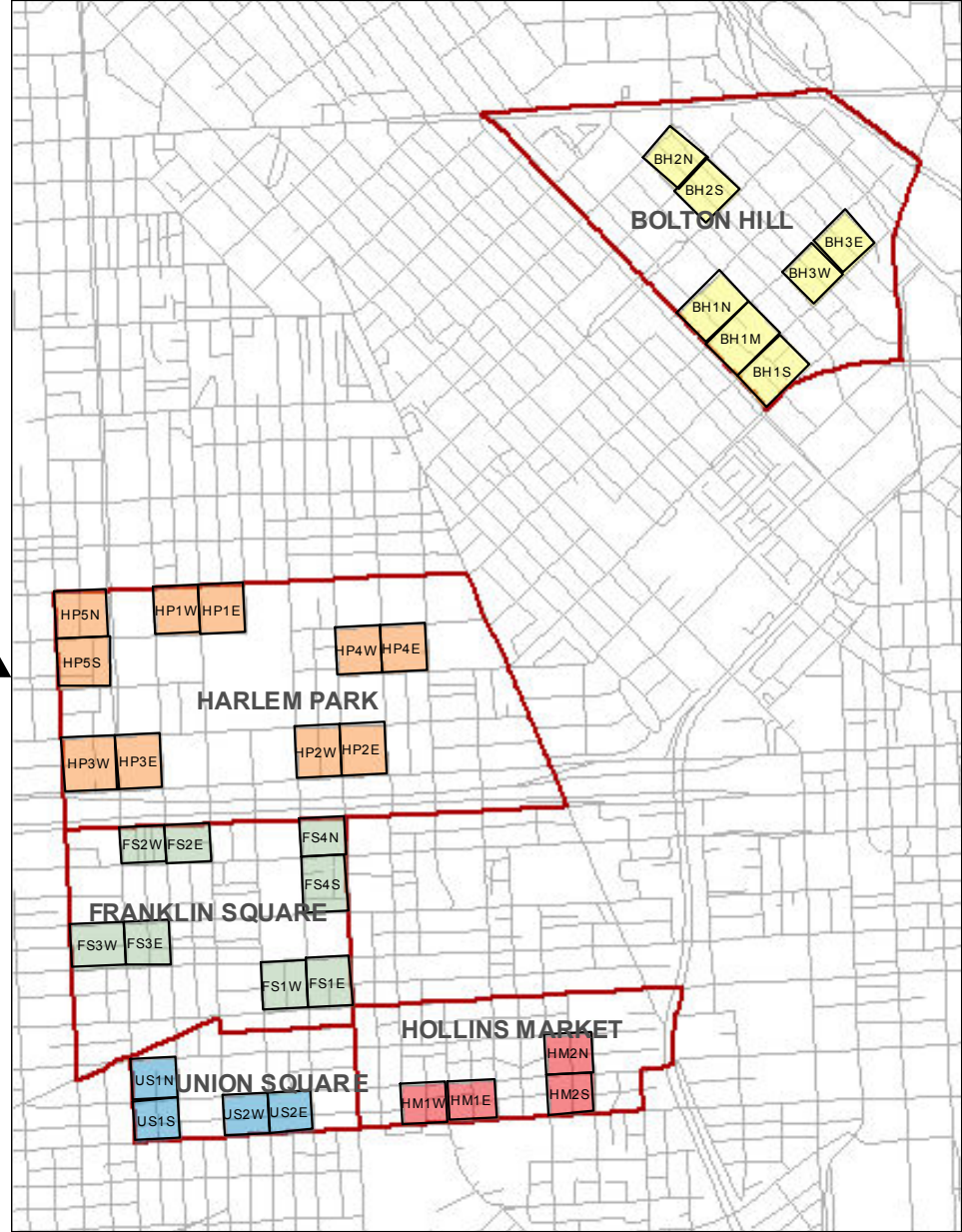
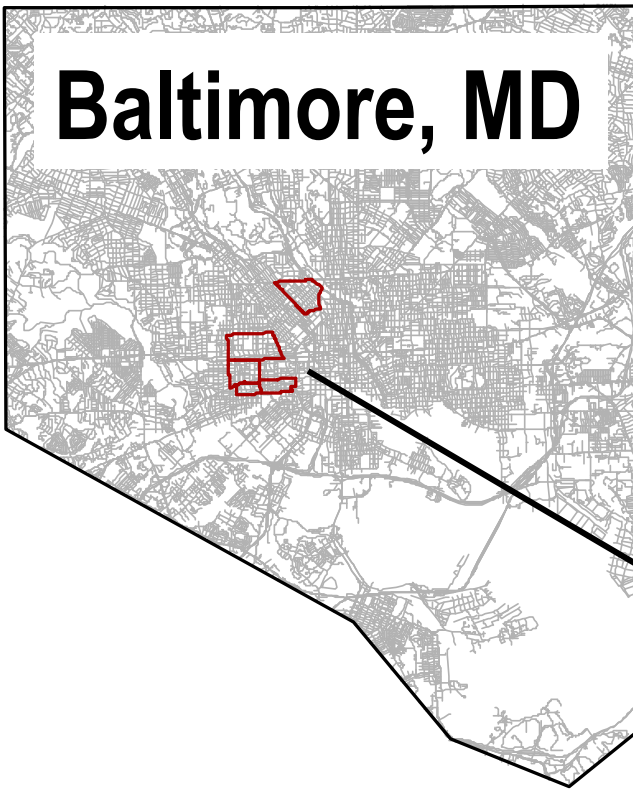
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Do trash containers in low SES neighborhoods support greater *Ae. albopictus* production

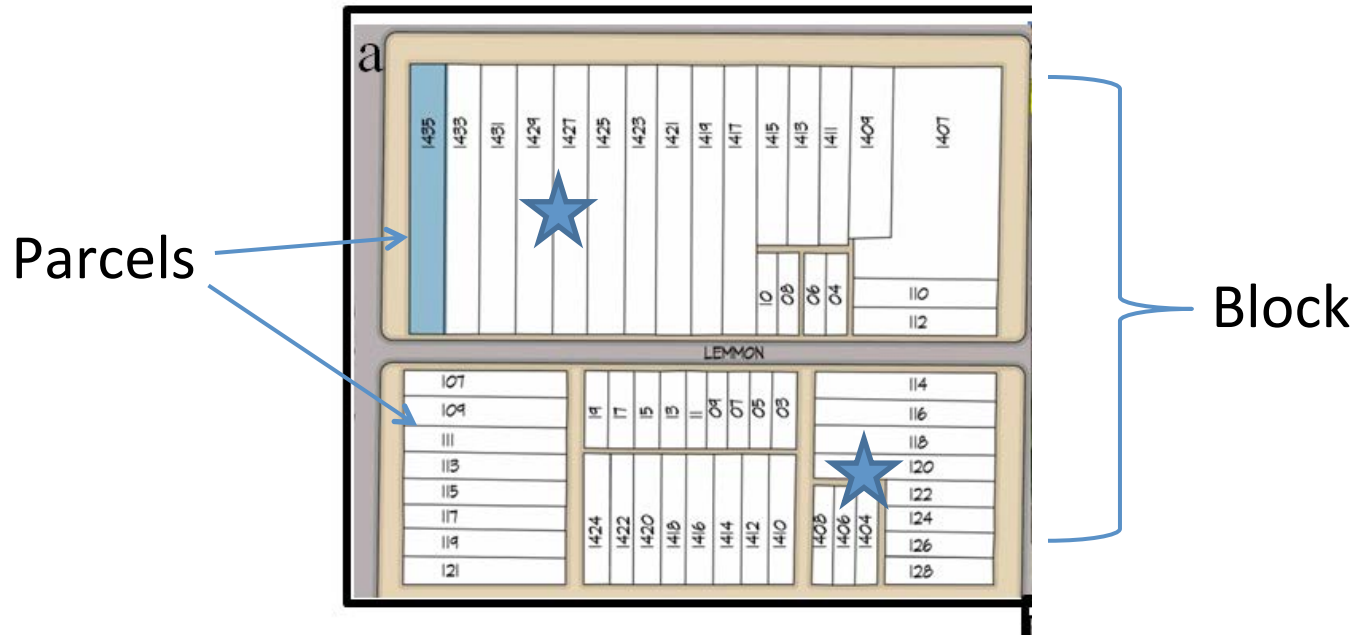


Baltimore, MD



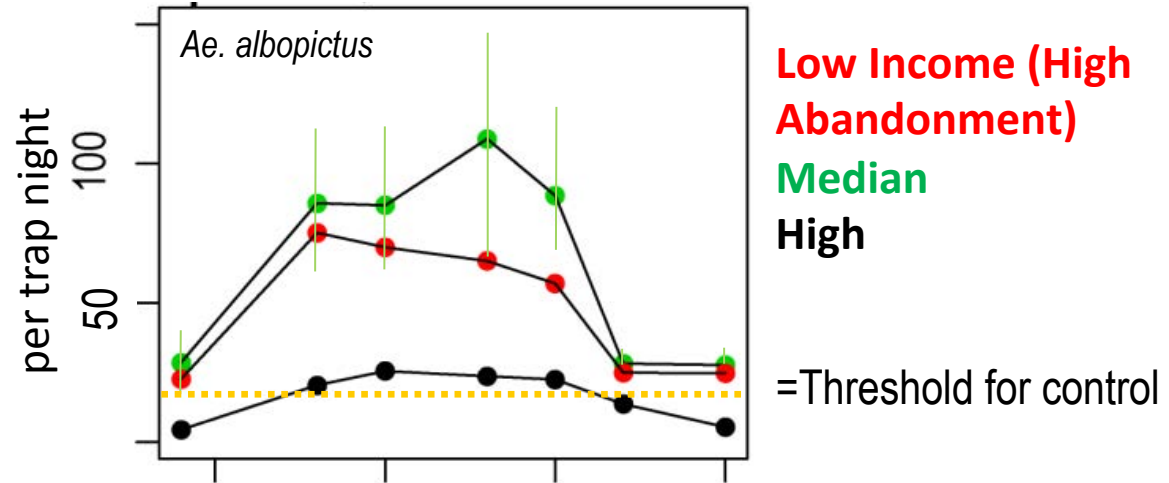
Field Sampling (2013-2015)

- Adults at 24 sites on 12 blocks (BGS traps)
- Eggs at 24 sites on 12 blocks (ovitrap)
- Larvae on ~1400 parcels (33 blocks)
- KAP surveys of ~700 households (33 blocks)
- 3 sampling periods per year

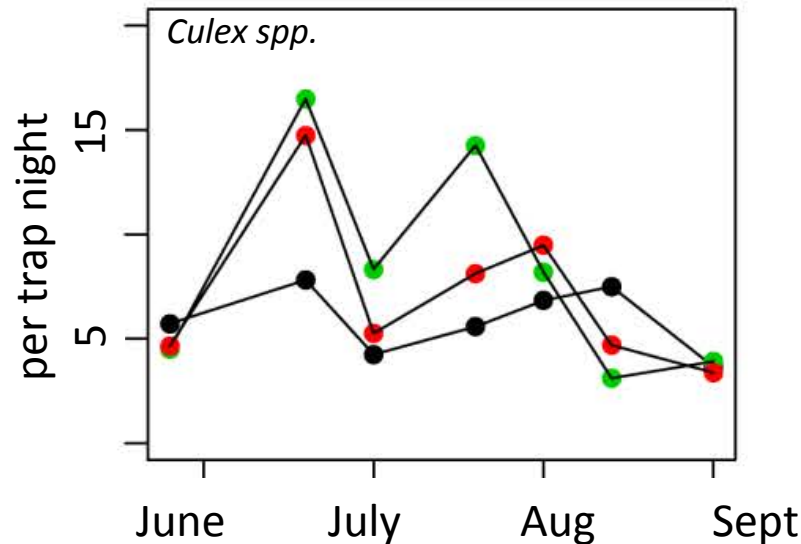


Adult female abundances (2013)

3X fewer in Low Income



Similar across
all SES levels



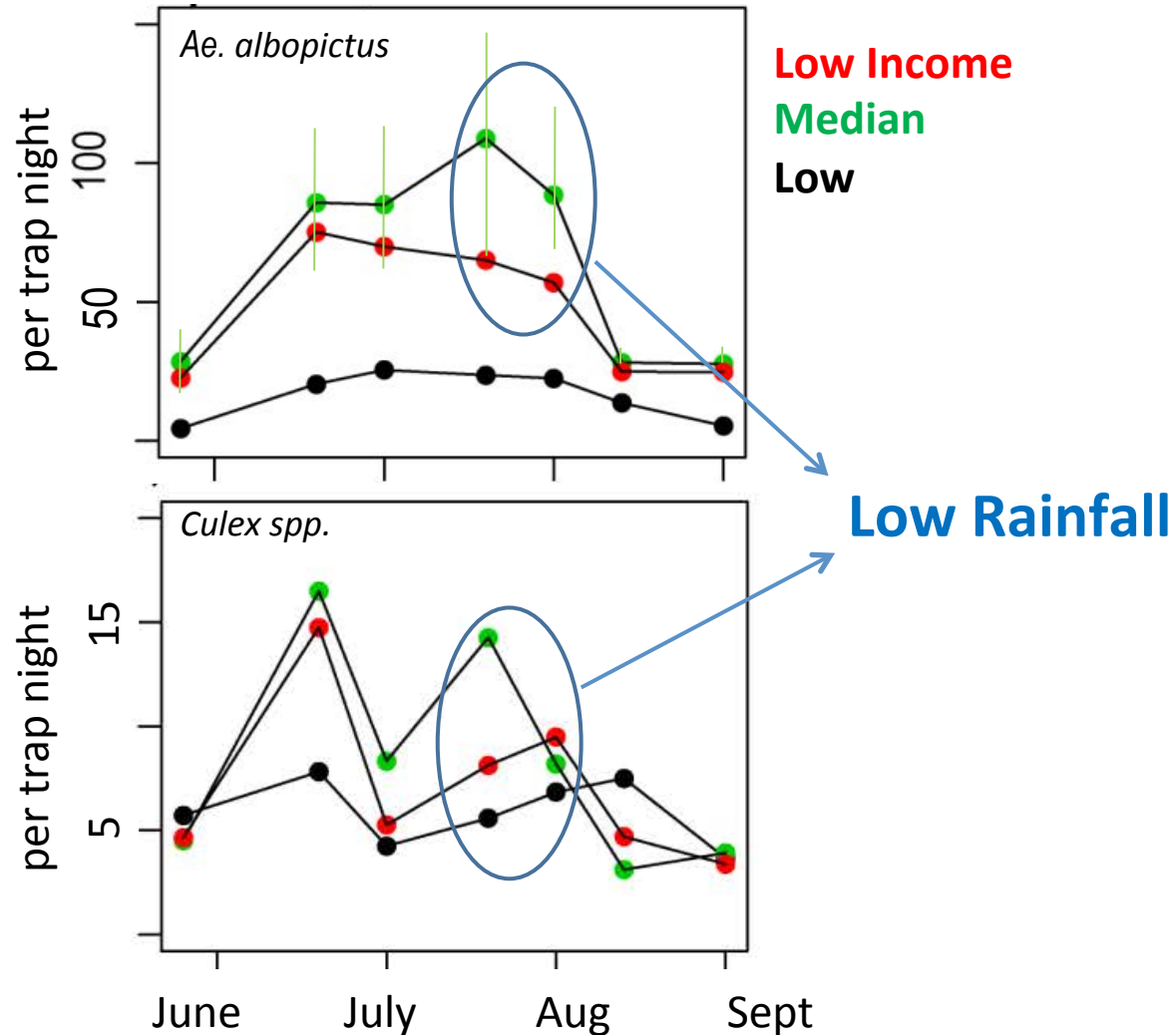
Error bars demonstrate block-to-block variability



Adult female abundances (2013)

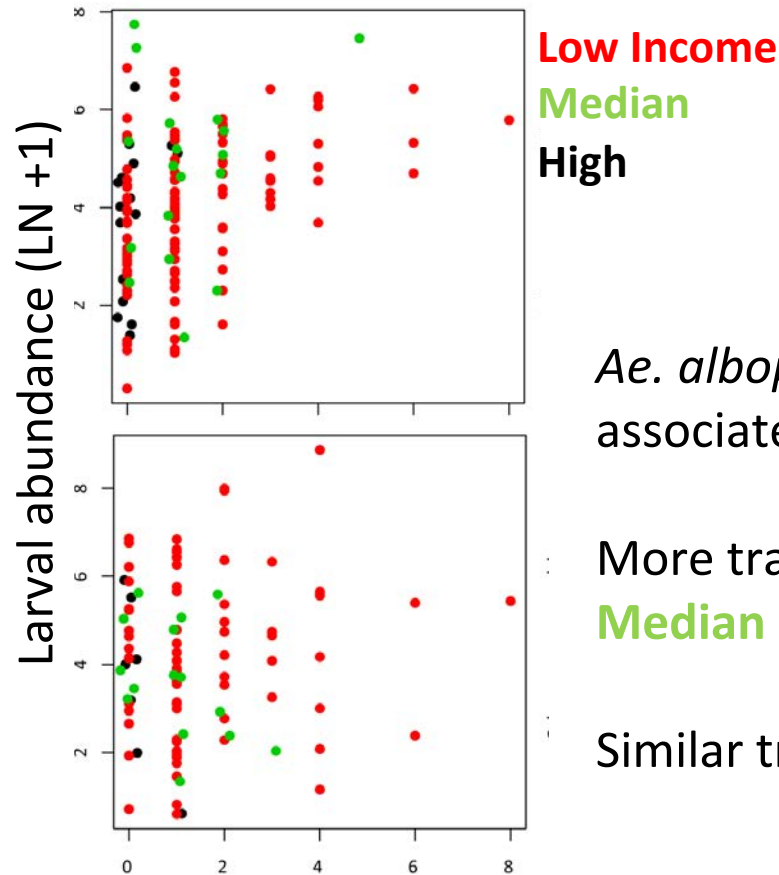
3X fewer in
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Similar across
all SES levels



Larvae (2013): Yard-scale

Ae. albopictus



Cx. pipens

Trash containers per yard

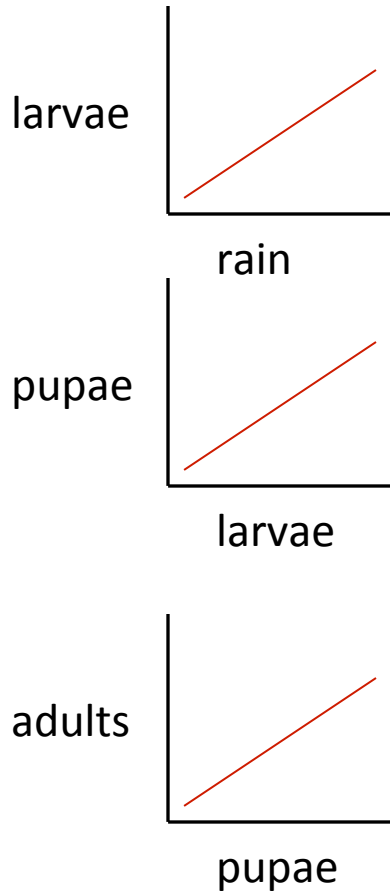
Ae. albopictus abundances associated with trash containers

More trash containers in **Low** & **Median** income

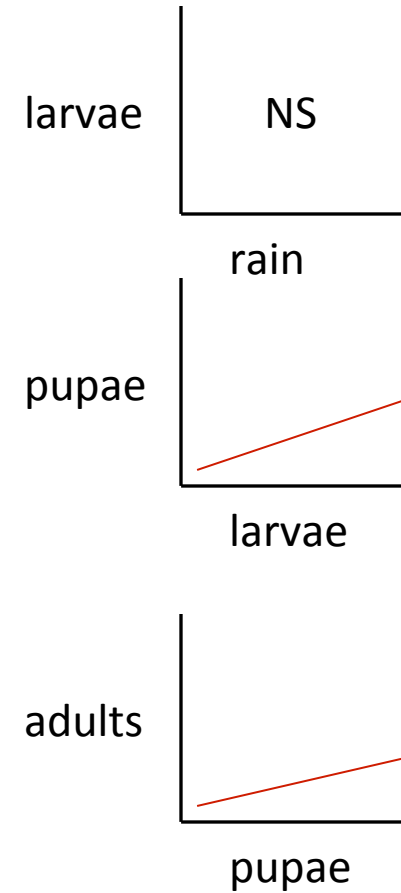
Similar trends for pupae



Low Income



High Income



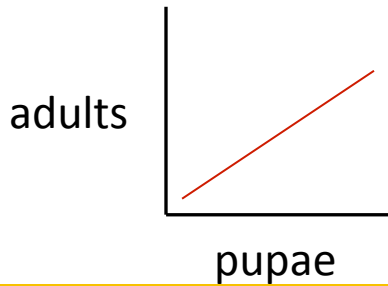
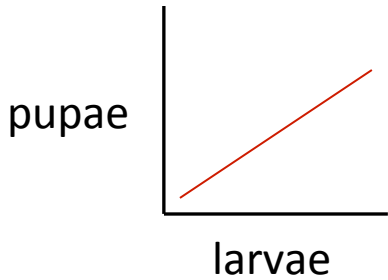
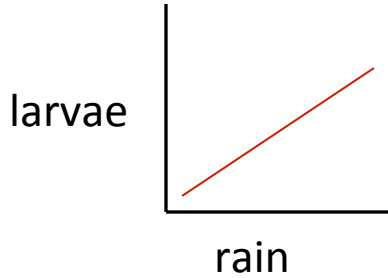
Environmental vs Human Regulation of habitat

Trends similar for both species but stronger for *Ae. albopictus*

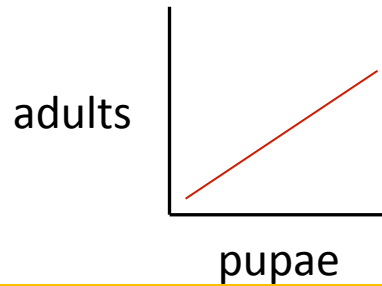
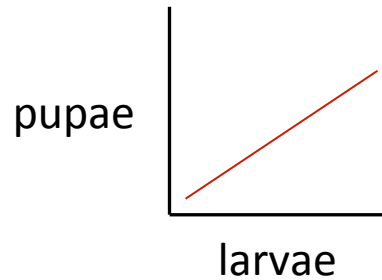
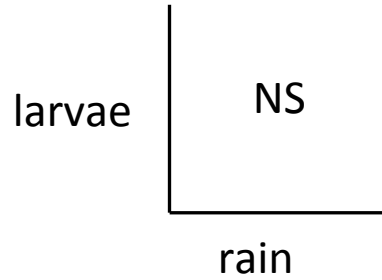
Trends at block scale



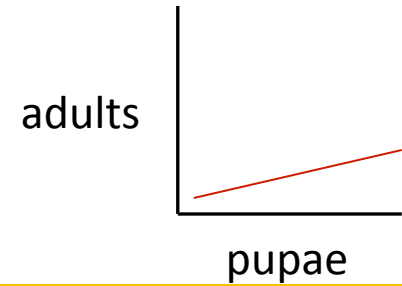
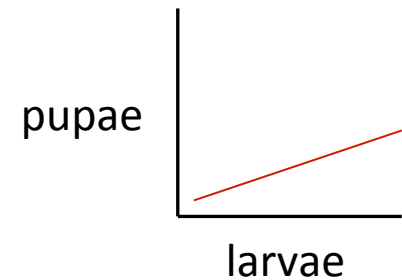
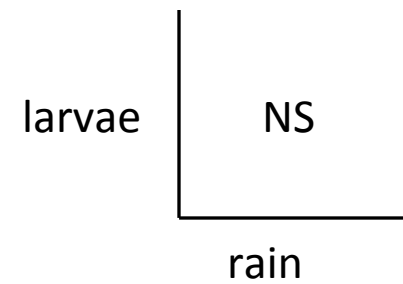
Low Income



MEDIAN



Low Income



Conclusions

Human behavior plays an important role in defining spatial heterogeneity in *Ae. albopictus* production

Weather conditions interact with human behavior in different ways across SES boundaries

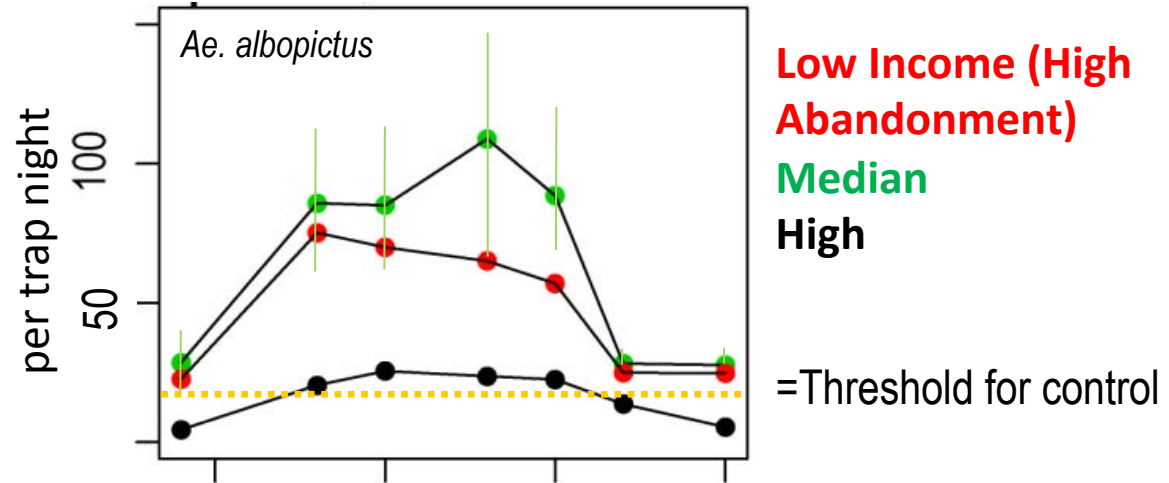
Ae. albopictus disproportionately utilizes trash habitats which are regulated by rainfall

Median income blocks may support high *Ae. albopictus* under wet and dry rainfall conditions

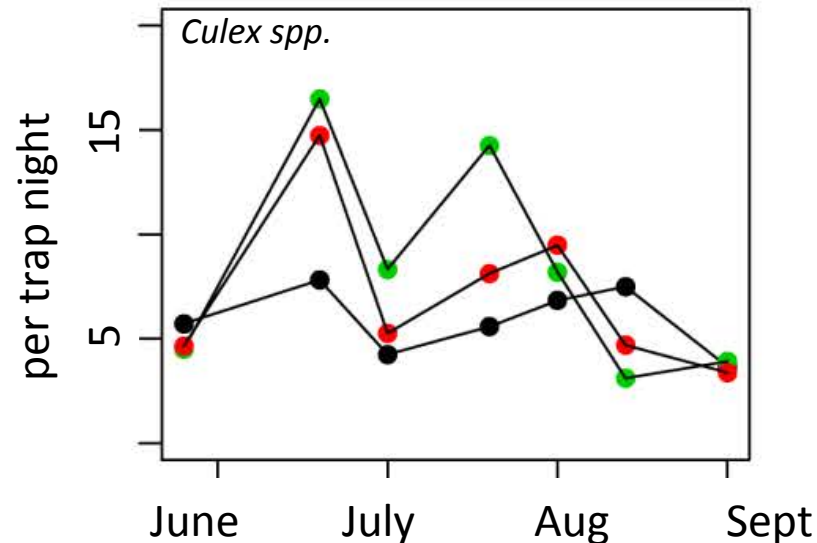


Adult female abundances (2013)

3X fewer in Low Income

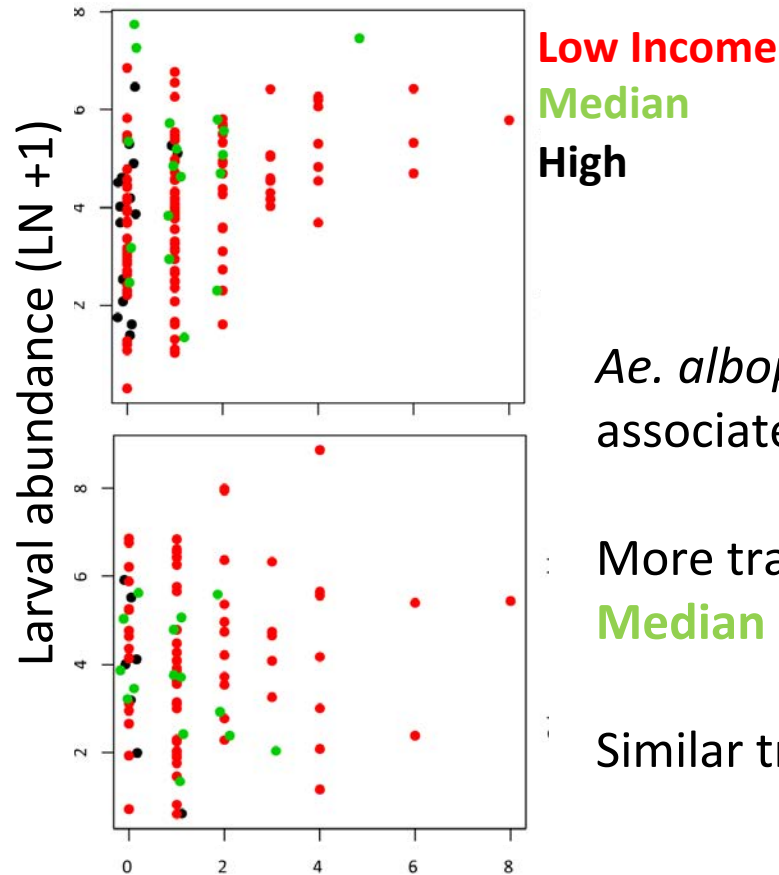


Similar across
all SES levels

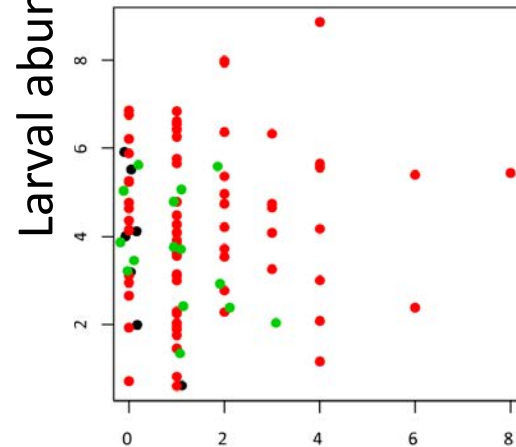


Larvae (2013): Yard-scale

Ae. albopictus



Cx. pipens



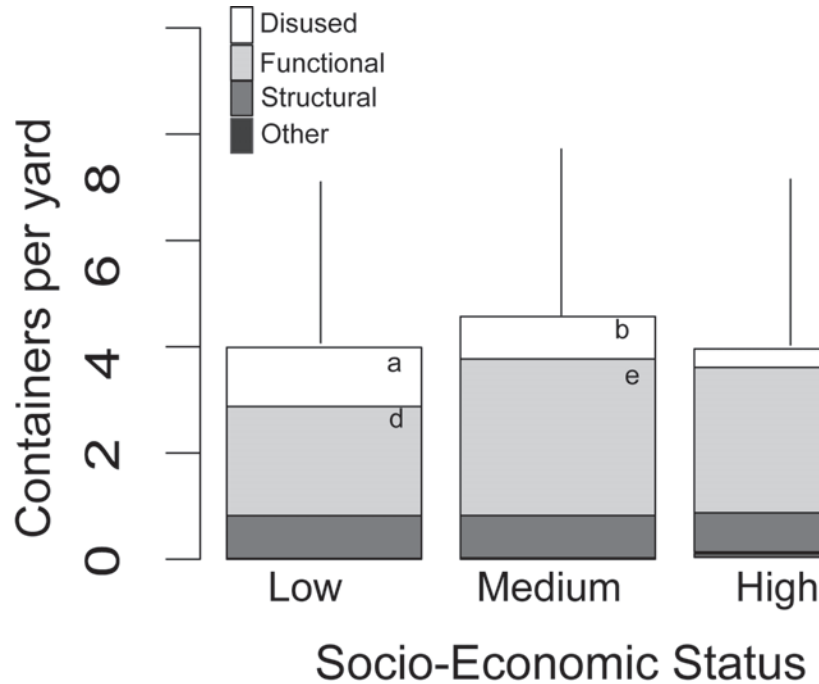
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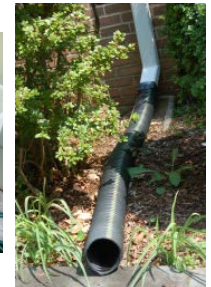
Containers and mosquito species vary by SES status



Ae. albopictus



Cx. pipiens



POPULATION AND COMMUNITY ECOLOGY

Socioeconomic Status Affects Mosquito (Diptera: Culicidae) Larval Habitat Type Availability and Infestation Level

ZARA DOWLING,¹ SHANNON L. LADEAU,² PETER ARMBRUSTER,³ DAWN BIEHLER,⁴ AND PAUL T. LEISHAM^{1,5}

J. Med. Entomol. 50(4): 764-772 (2013); DOI: <http://dx.doi.org/10.1603/ME12250>



Competition among container mosquito

- Resources limited (detritus, FPOM & microbes)
- Ephemeral & lack vertebrate predators

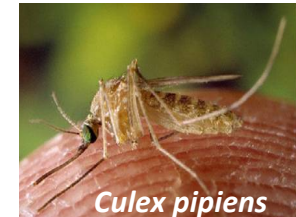


- Well documented effects of competition in structuring communities (reviewed by Juliano 2009)



Ae. albopictus vs. *Cx. pipiens*

- Competitively superior to *Cx. pipiens*
 - Costanzo et al., 2011; Costanzo et al. 2005; Carrieri et al. 2003
- Little research testing competition using resource conditions and densities typical of different types of urban containers



Do functional/structural containers relax competitive impacts of *Ae. albopictus* on *Cx. pipiens* and promote *Cx. pipiens* persistence?



Research Hypotheses



- Interspecific competition is important in conditions typical to what *Ae. albopictus* and *Cx. pipiens* interact in urban containers
- Persistence of *Cx. pipiens* in some container types occurs because contents alter the outcome of competition



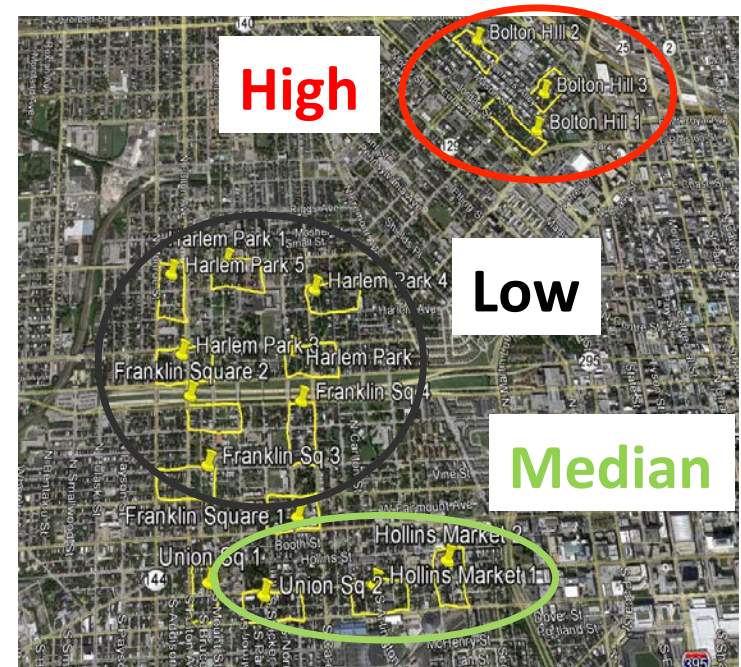
Testable Predictions

- *Cx. pipiens* and *Ae. albopictus* co-occur in field habitats & proportion larvae that are *Cx. pipiens* vary among container types
- Competition among larvae detectable at densities observed in the field
- Competition varies among aquatic conditions found in different container types



Methods: Field Data

- Sampled containers in three periods in 2015:
 - May, July-Aug., Sept.
- 608 containers
- Mean density: 0.33 larva per mL
 - Baseline field density



Methods: Field Survey

- 3 most common trash & functional/structural container types

Trash



Plastic trash



Dumped tire

Styrofoam trash

Functional/Structural



Bucket



Trash can



Fence pole

- Calculate proportion containers with mixed species & proportion total larvae that are *Cx. pipiens*

Methods: Competition Trial



Late May 2016: ~300 mL homogenized sample from four randomly selected containers from each container type (24 total containers)

Applied one of three density treatments to each microcosm from each container



Divided sample into three 90 mL microcosms



REDUCED: 15 *Cx. pipiens*



CONTROL: 15 *Cx. pipiens* + 15 *Ae. albopictus*
Baseline field density



INCREASED: 15 *Cx. pipiens* + 30 *Ae. albopictus*

106- μ m sieved to remove larvae and large detritus



Methods: Competition Trial

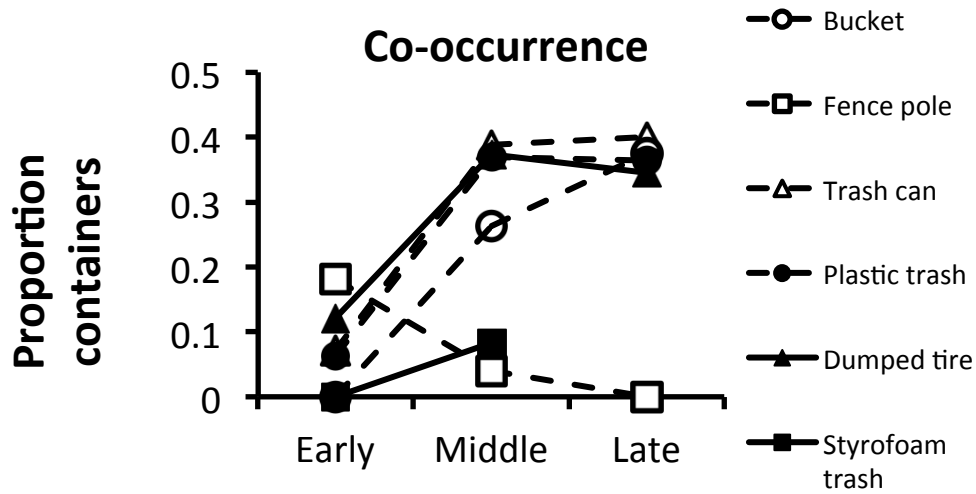


- 72 total microcosms (6 types x 3 density treatments X 4 reps)
- Incubator set at 24°C @ 18:10 L:D
 - Isolate effects from container contents
- Proportion survival and development time of *Cx. pipiens* after 6 days
- Data analyzed with linear mixed models

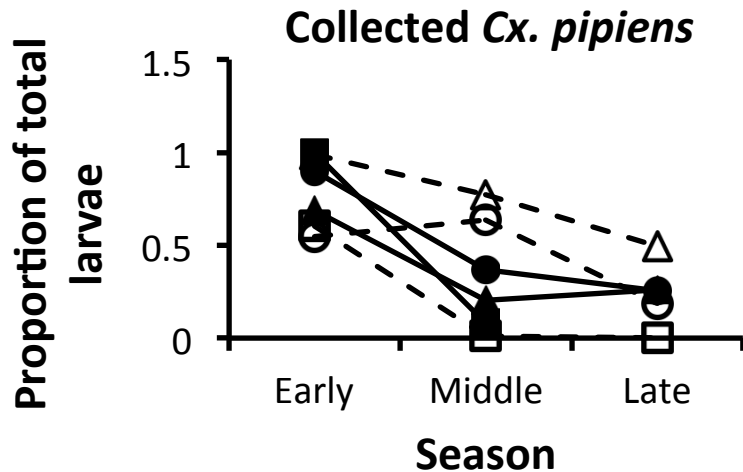
Pilot trial conducted in 2015. Results not shown for brevity



Results: Field Survey



Co-occurrence was common within 2/3 trash and 2/3 functional container types



Milder decreases of *Cx. pipiens* from early to late season in 2/3 functional container types



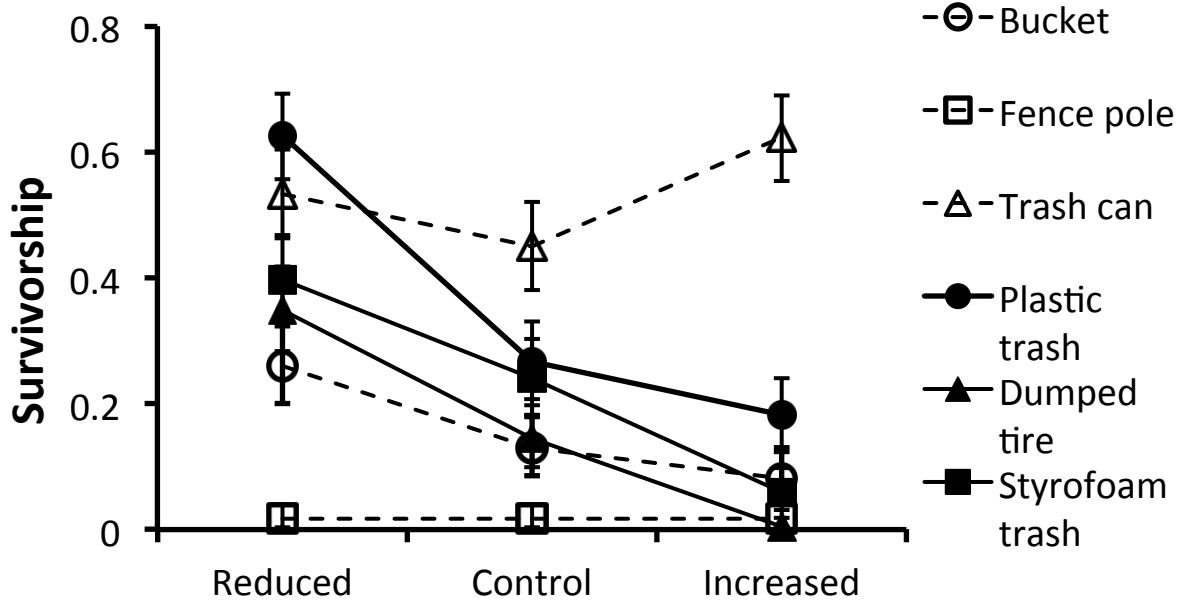
Results: Competition Trial

Source	<i>Survival</i>			<i>Development Time</i>		
	dfs	<i>F</i>	<i>P</i>	dfs	<i>F</i>	<i>P</i>
Container Type	5,18	27.54	<0.0001	5,17.9	124.29	<0.0001
Treatment	2,36	25.60	<0.0001	2,33.7	15.49	<0.0001
Container Type x Treatment	10,36	4.57	0.0003	10,31.5	2.80	0.0134

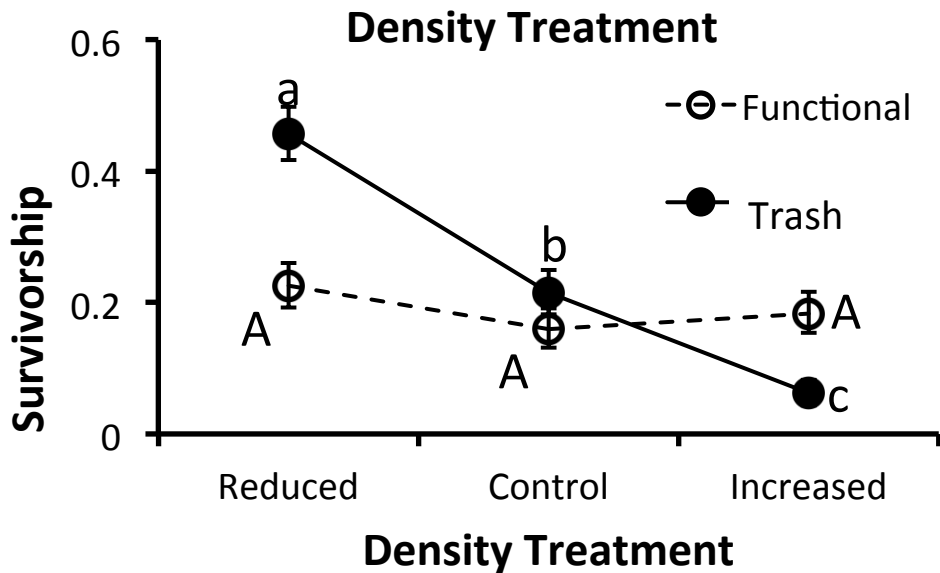
Container (Container Type) included as a random variable

Development Time could not be calculated in 11 microcosms that had no survivorship

Results: Survival

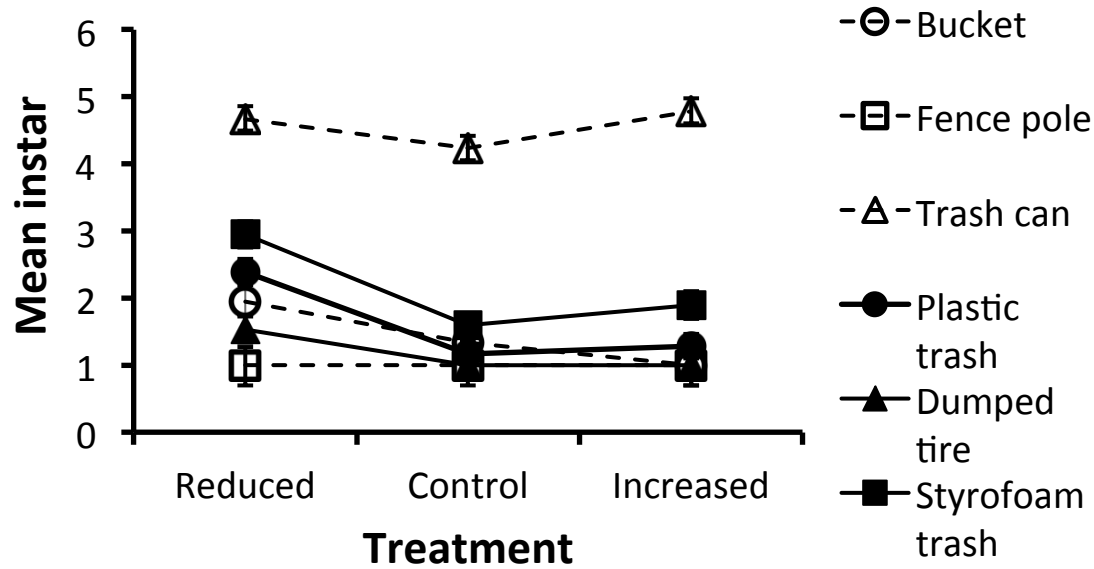


Lower survival in **Increased** vs. **Decreased** treatments for **Trash** container types

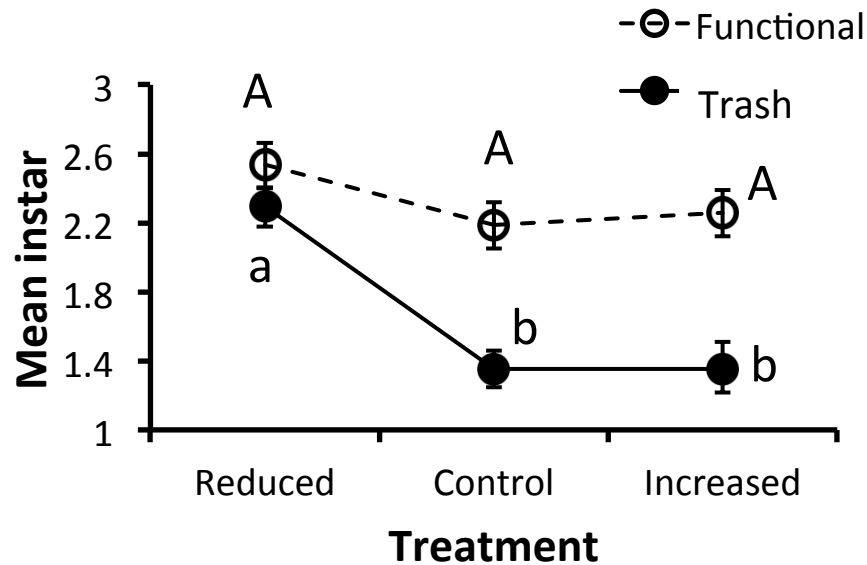


Strong effects of *Ae. albopictus* competition in **Trash** containers

Results: Development Time



Slower development in **Increased** vs. **Decreased** treatments for **Plastic** and **Styrofoam** trash & functional **Buckets**



Strong effects of *Ae. albopictus* competition in **Trash** containers

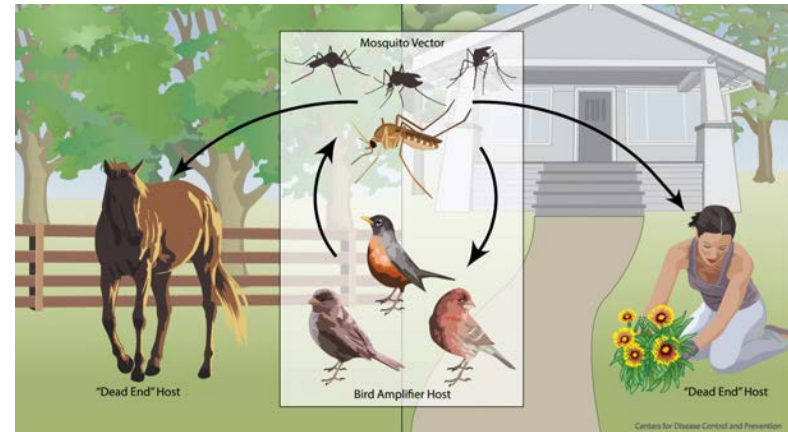
Results Summary

- Overall negative competitive effects of *Ae. albopictus* on *Cx. pipiens* at densities relevant to urban container conditions
- But little evidence of competitive impacts in Functional containers
 - Likely due to greater FPOM, nutrient & microbial resources
- First robust study to show persistence of *Cx. pipiens* after *Ae. albopictus* invasion in urban container conditions
- Interspecific competition likely important in structuring *Ae. albopictus-Cx. pipiens* communities
 - In addition to other ecological processes



Implications

- Persistence *Cx. pipiens* with *Ae. albopictus* may increase transmission risk
 - Simultaneous zoonotic and bridge transmission of WNV
- Functional Trash Cans good habitat for *Cx. pipiens*
 - Control requires resident-based behavior change

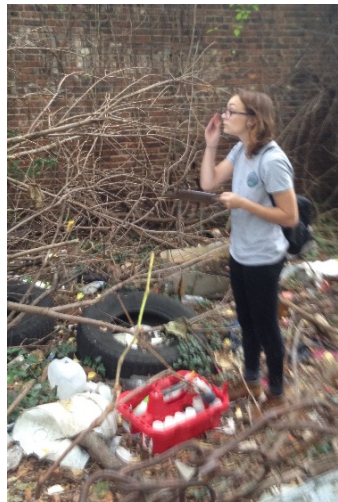


Conclusions

- Cities are heterogeneous socio-ecological systems
- Social factors can affect vector ecology across SES boundaries in subtle ways at different scales
- Capacity to detect and control disease impaired by a lack of data on vector biology at *within-city* spatial scales



Thank you



Zara Dowling
Ivana Terry
Rachel Pozzatti
Diane Peng
Nicole Kirchoff
Sophie Jin
Oswaldo Villena
Brian Becker
Heather Goodman
Guy Hagar
Samantha Keane



Extra slides



KAP surveys reveal relationship between knowledge, attitudes, practices

EcoHealth
DOI: 10.1007/s10393-013-0818-6

ECOHEALTH

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Original Contribution

Linking Mosquito Infestation to Resident Socioeconomic Status, Knowledge, and Source Reduction Practices in Suburban Washington, DC

Zara Dowling,¹ Peter Armbruster,² Shannon L. LaDeau,³ Mark DeCotiis,² Jihana Mottley,² and Paul T. Leisnham¹

¹Department of Environmental Science and Technology, University of Maryland, 1443 Animal Sciences Bldg (#142), Environmental Science and Technology, College Park, MD 20742
²Department of Biology, Georgetown University, Washington, DC 20057
³Cary Institute for Ecosystem Studies, Millbrook, NY 12545

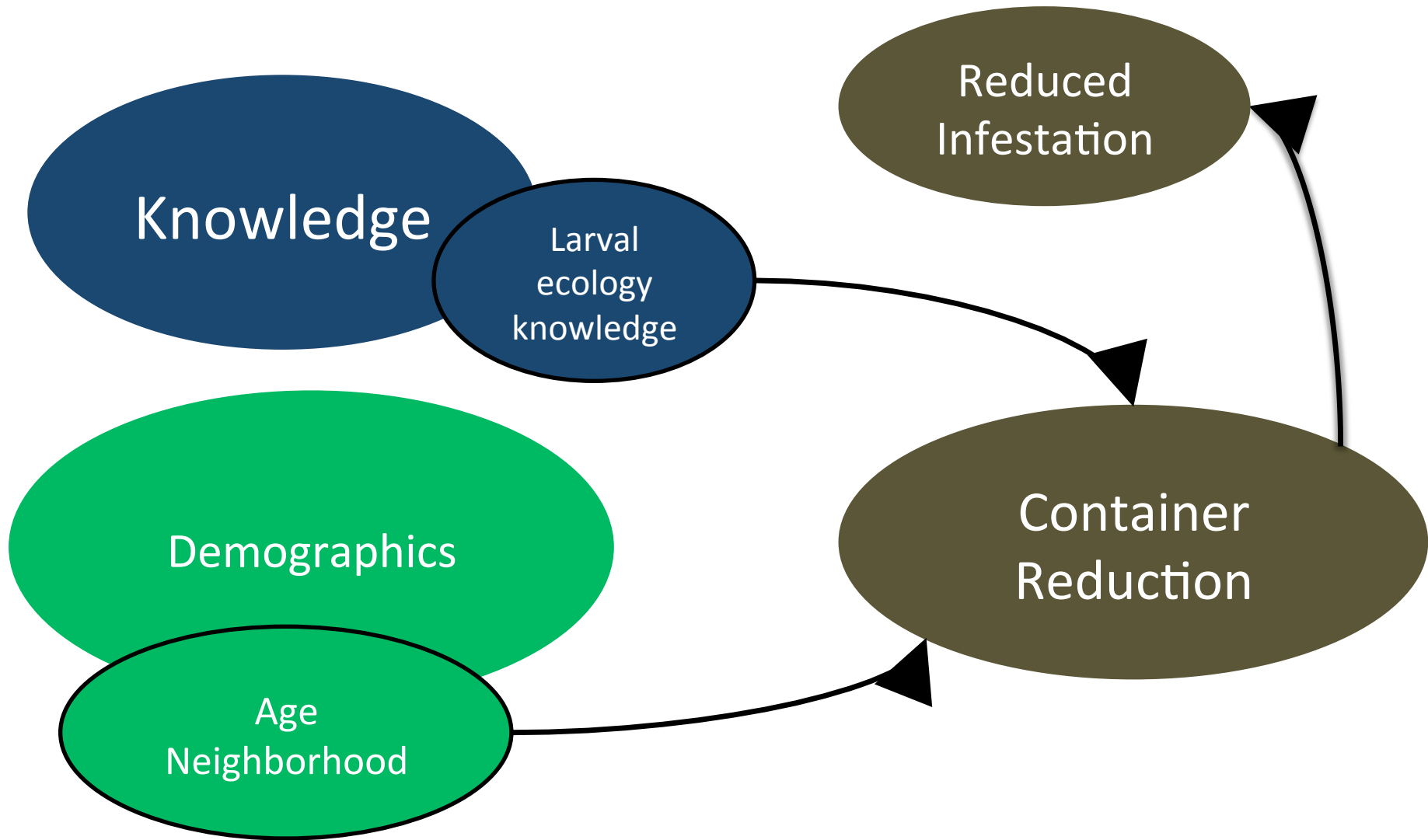


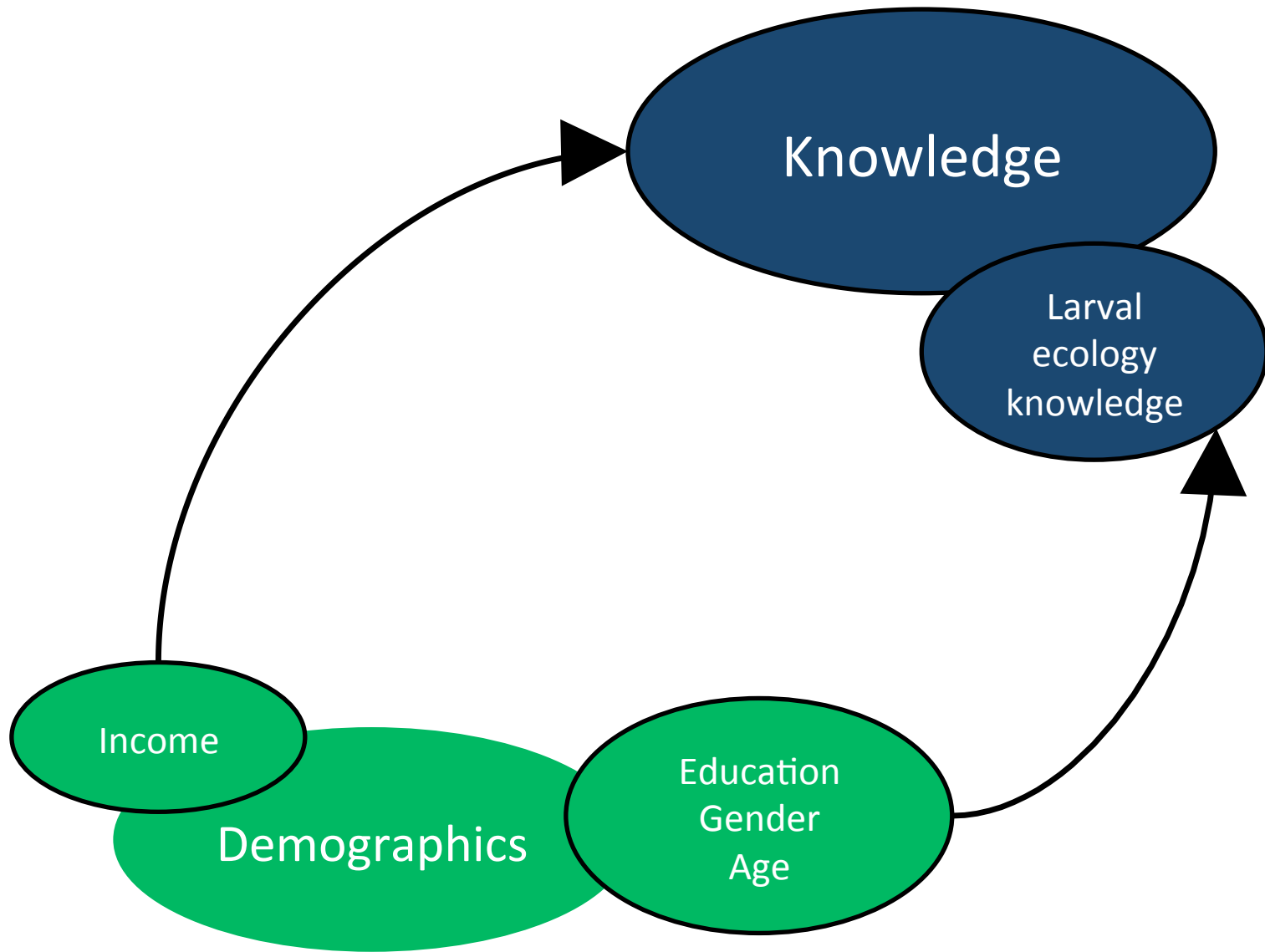
NSF Urban Long-Term Research Area Exploratory Grant Proposal # 0948947



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Is education outreach effective at improving resident-based mosquito management?





RESEARCH ARTICLE

Effectiveness of Print Education at Reducing Urban Mosquito Infestation through Improved Resident-Based Management

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Is education outreach effective at improving resident-based mosquito management?

Flyer



tip&trash
Mosquitoes breed in standing water—let's empty it!

Mosquitoes can develop from egg to biting adult in less than two weeks! Most mosquitoes in your neighborhood are breeding in peoples' yards, not in marshes or puddles.

Mosquito Life Cycle Info

Don't forget to check **Under the Porch**, **Behind Your Shed**, or **In the Bushes** for hidden containers. Even upside-down containers can accumulate water and mosquitoes in the rim.


And Remember...Empty Everything Once A Week!

Check out the back of this flyer for Top Mosquito Larvae Hotspots.
www.enst.umd.edu/tipntrash

UNIVERSITY OF MARYLAND | IPM Centers | USDA | NIFA | Cary Institute of Ecosystem Studies | UMBC

Source: University of Maryland, Department of Environmental Science & Technology, Regional IPM Centers, and USDA, National Institute of Food and Agriculture.

Notepad



tip&trash

Check your yard for standing water **ONCE A WEEK!**

TIP containers that may hold water!
Throw away TRASH!

Use **MOSQUITO DUNKS** in water you can't empty!

Use this notepad to add additional tips and share it with your neighbors and friends—Let's get everyone **tipping and trashing** their standing water!

www.enst.umd.edu/tipntrash

Magnet



tip&trash
The mosquito said...

This yard must be "Eden".
It's got trash cans, plant pots, tires and drains to "breed'n".
I'll lay eggs when it rains, and in a week all my kids will be "feed'n".

www.enst.umd.edu/tipntrash

Calendar



tip&trash
Mosquitoes breed in standing water—let's empty it!

May 2011-December 2011

Help Maryland and Washington DC cut down on the mosquito population by following these **tip and trash** recommendations for the rest of the calendar year!

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LINKING EDUCATION INTERVENTION WITH CHANGES IN KAP

Individual-level changes

EDUCATION INTERVENTION (VS. CONTROL)

DEMOGRAPHICS

Income

Age

Baseline knowledge

KNOWLEDGE IMPROVEMENT

ATTITUDE CHANGE

Concern

Responsibility

PRACTICE CHANGE

Source reduction adoption (self-reported)

EDUCATION INTERVENTION (VS. CONTROL)

Week

Baseline knowledge

PRACTICE CHANGE

Container numbers

MOSQUITO EXPOSURE

Change in abundances



Key Summary

1. Container reductions were associated with reductions in *A. albopictus*, but not *C. pipiens*
2. Respondents in households that received education had greater odds of reporting source reduction, independent of any improvements of knowledge or attitude
3. Respondents in households that received education had greater odds of decreased concern, and their yards had lower odds of fewer containers



Conclusions

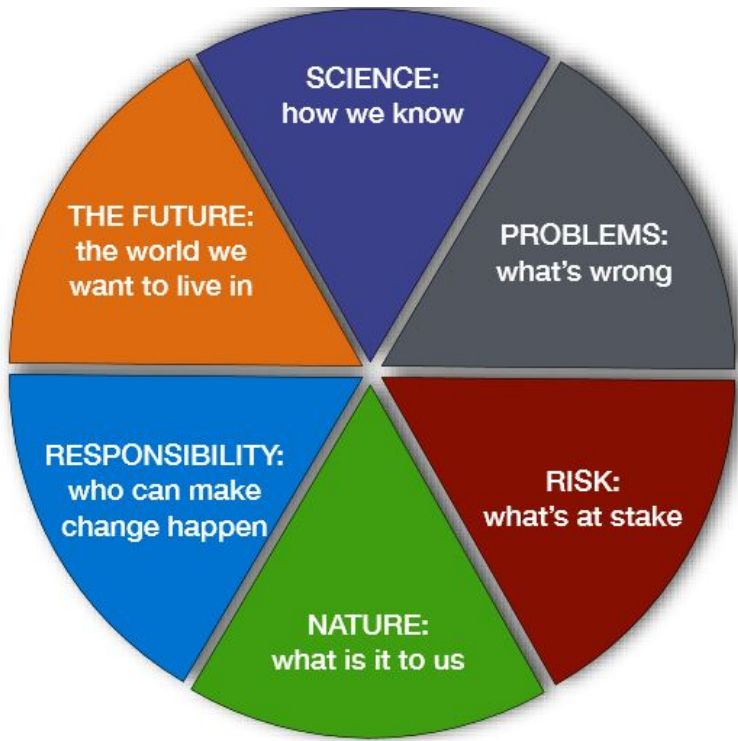
1. Container reduction is important for reducing mosquitoes
 2. Education materials may be effective at increasing source reduction of individuals, but unclear how
 3. Effectiveness of education materials absent at household scale
 - Source reduction \neq container reduction
 - Reduced concern after education
 - Other household behaviors offset source reduction?
 - Education materials failed to resonate with important values?
 - Self-reporting bias?
- Little evidence for education effectiveness



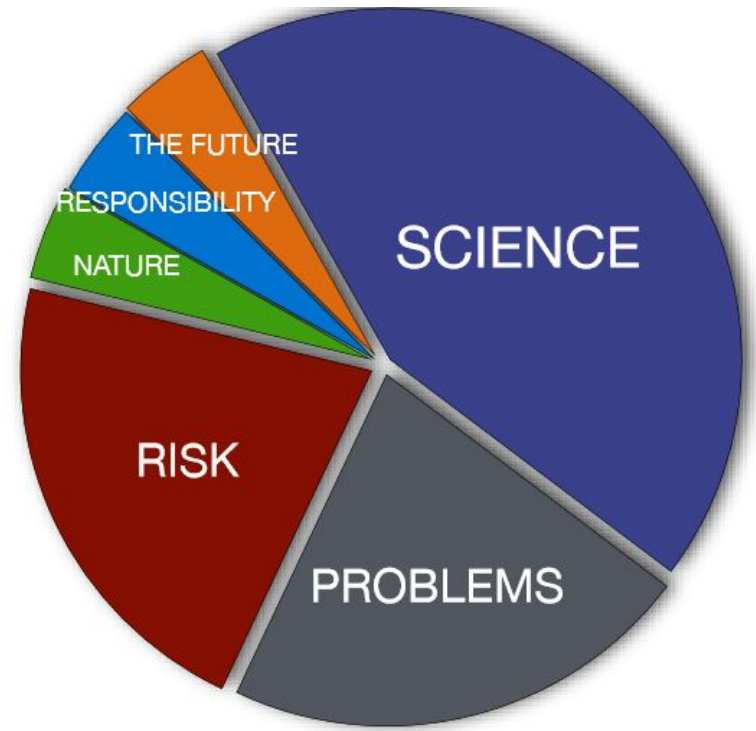
Summary of Social Science Interviews

- Residents across income groups already connect mosquitoes with social and environmental changes in their neighborhoods
- Education that stresses only individualized response could provoke cognitive dissonance
- Education and activities can build on existing “lay ecologies”





Key ingredients of environmental communication



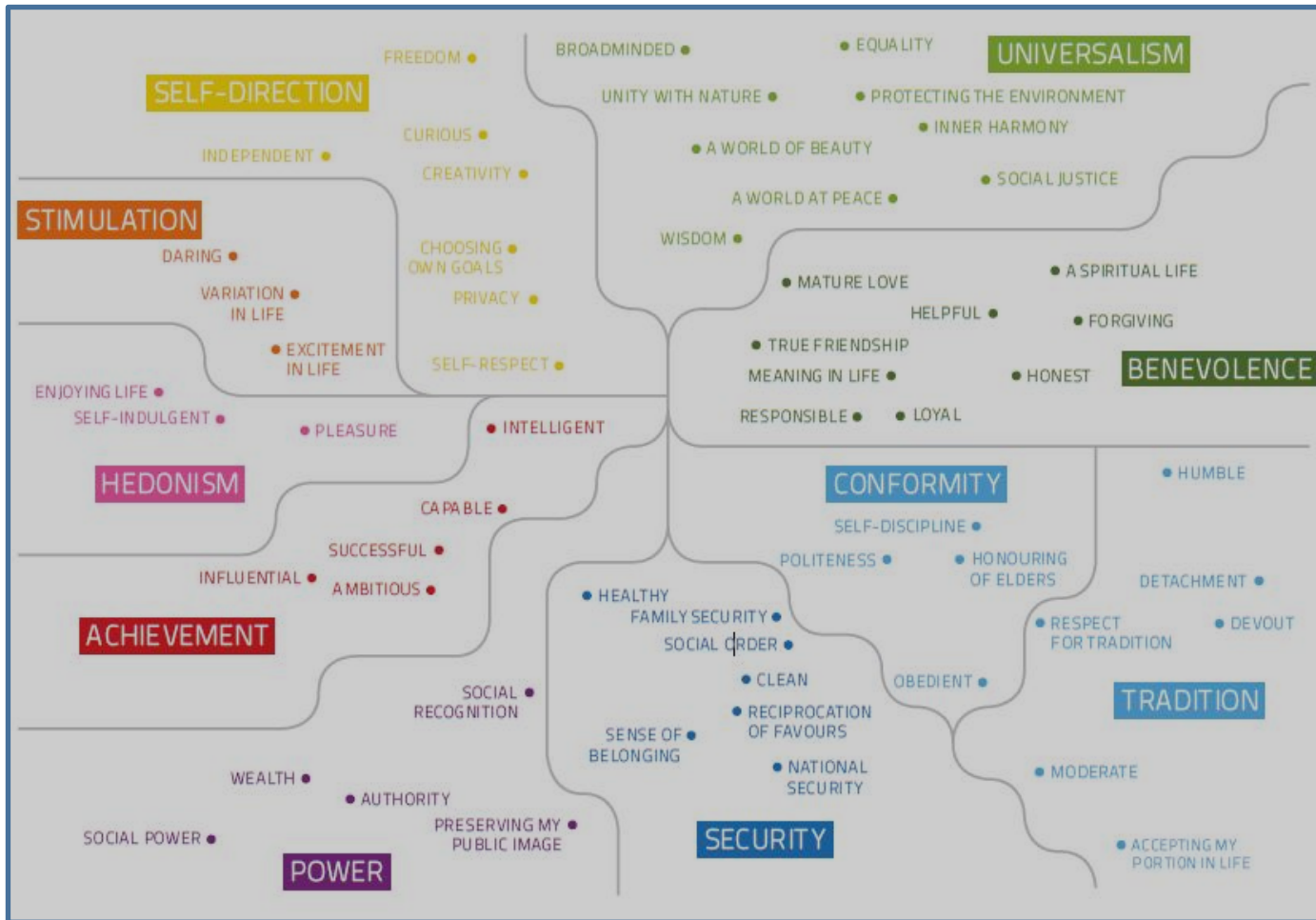
Typical techno-science message

Assumes knowledge deficit is the main problem

Mark Meisner *Founded and Directed the Environmental Communication Network, until it was merged into the International Environmental Communication Association (IECA - theieca.org).*



Values driving motivation and action are related



Values are prioritized over others and vary by individuals

Closer values are more likely to be of similar importance to the same person

Common Cause Foundation, <http://valuesandframes.org/handbook/>



Mosquito (Zika) control

- Source reduction
- Spraying of Naled & Malathion organophosphate insecticides
- Use of GMO mosquitoes

