Urbanization and West Nile virus transmission in the South-eastern US

Krisztian Magori
Center for Forest Sustainability
School of Forestry and Wildlife Sciences
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Water is important – for mosquitoes, too!

• Among the animals, mosquitoes are responsible for the most number of human death!

• Mosquito larvae develop in water!
Dengue – the most important mosquito-borne viral disease globally

- 50-100 M cases annually
- 500,000 DHF cases
- 22,000 deaths
- 4 related viruses in Flaviviridae
- Transmitted by Aedes aegypti
- Anthropophilic, breeds in artificial containers
- Water resource problem
- Southern Florida and southern Texas
Symptoms of WNV infection

• Asymptomatic
• WNV fever: flu-like illness (1 in 5)
• WN Neuroinvasive Disease (1 in 140)
  – Meningitis
  – Encephalitis
  – Polyomyelitis
  10% of patients with WNND die
• No specific treatment
• No vaccine (only equine)

Kramer, Styer, Ebel Annu. Rev. Entomol. 2008
Mostashari et al., Lancet 2001
Ecology of WNV

• Enzootic cycle (passerine birds and *Culex sp.* mosquitoes)

• Humans dead-end hosts

*Kramer, Styer, Ebel Annu. Rev. Entomol. 2008*
WNV arrives in the US

- Discovered in Uganda, 1940s
- Birds dying – NYC, summer of 1999
- 59 cases of encephalitis and meningitis in NYC, 7 died
- Epidemiological investigation
- Source unknown

Brownstein et al. Vector-borne and Zoonotic Diseases, 2002
Lanciotti et al., Science 1999
Mostashari et al., Lancet 2001
Westward spread of WNV

- Overwinter
- Estimated speed of 1000 km/yr
- Accelerating spread
- Long-distance dispersal through birds

Pybus et al., PNAS 2012
Mundt et al., Am. Nat 2009
WNV in 2012

- As of October 23
- 4,725 total cases
- 2,413 WNND cases
- 2,312 WNF cases
- 219 deaths
- 70% of cases in TX, LA, CA, MS, SD, MI, OK, IL
- >1/3 of all cases in TX
Effect of developed land-cover on WNV incidence

Culex quinquefasciatus

- Most important vector of WNV in the Southeast
- Feeds from dusk to dawn
- Feeds on both birds and mammals
- Breeds in tires, containers, bird baths, but also storm-water catch basins, septic tanks, detention and retention ponds
- Females prefer to put their eggs in nutrient-rich water
- Only adult females bite!
- Larvae feed on bacteria and algae
- According to the literature, it requires high nutrient content in breeding sites
CSO facilities

- Combined Sewage Overflow
- Combined Sewer System = stormwater + wastewater
- Too much stormwater → Overflow!
- 850 billion gallon/year
- Old system
- EPA CSO Control Policy 1994
- City of Atlanta paid $2.5M penalty
- Reconstruction at a cost of $809M

Tibbets, Env. Health Persp., 2005
WNV in Atlanta, GA

(A)

WNV human incidence (per 100,000)

Spatial clustering

Positive

Negative

CSO facilities

CSO streams

Streams

(B)

ML WNV infection intensity
(No. infected per 1,000)

< 1.0

1.0 - 3.0

3.1 - 6.0

6.1 - 12.0

12.1 - 25.0

Local clustering (G1(d)) of infection intensity

G1(d) > 3.7; P < 0.05

Local clustering (Bernoulli test)
of WNV infection presence

Log-likelihood ratio > 5.4; P < 0.1

Vazquez-Prokopec et al., Env. Health Persp. 2010
Urban streams (in general) can be dirty!

Urban streams in general could contribute to *Culex quinquefasciatus* reproduction and WNV transmission!

BUT are urban streams dirty enough?
Mesocosm experiment
How is urbanization linked to WNV transmission?

More infectious bites

WNV Transmission
How is urbanization linked to WNV transmission?

1. More infected mosquitoes
2. More infectious bites
3. Higher exposure
4. WNV Transmission
How is urbanization linked to WNV transmission?

More mosquitoes $\rightarrow$ More infected mosquitoes $\rightarrow$ More competent birds

More infectious bites $\rightarrow$ Higher exposure

WNV Transmission
How is urbanization linked to WNV transmission?

- More containers -> More high quality breeding sites
- More high quality breeding sites -> More mosquitoes
- Reduced water quality -> More infected mosquitoes
- More mosquitoes -> More infected mosquitoes
- Less forest structure -> More competent birds
- More competent birds -> More infected mosquitoes
- Higher exposure -> More infectious bites
- More infectious bites -> WNV Transmission
How is urbanization linked to WNV transmission?

Urbanization

- Less forest structure
- Reduced water quality

- More high quality breeding sites
- More containers

- More mosquitoes
- More infected mosquitoes

- More infected bites
- Higher exposure

WNV Transmission
Final message

- Water management is critical to control mosquitoes and their associated diseases
- Discard unused containers, tires, clean gutters, and other rubble!
- Drain unused swimming pools!
- Use larvicide (Bti) or put fish in standing water!
- Don’t help the mossies!

Thank you!