Urban Ecology of WNV in Atlanta Georgia, 2008-2013

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GMCA Meeting, Oct 2013
Urban Ecology of West Nile virus in Atlanta, GA

Collaborators
Gonzalo Vazquez-Prokopec, Luis Chaves, Rebecca Levine, Donal Bisanzio, Uriel Kitron - Emory
Danny Mead – UGA
Rosmarie Kelly – GA-DPH
Thomas Burkot – CDC/JCU
Neuro-invasive WNV cases significantly lower in GA and most SE States

Why WNV spill-over in Georgia (and the SE) is that low?

Source: CDC ArboNet. 2009-2012
Why is WNV spill-over that low?

Low mosquito abundance?
Absence of transmission hot-spots?
Low enzootic transmission?
Absence of competent reservoir hosts?
Complex bird community “dilutes” transmission?
Different viruses?
Low human exposure?

Mosquitoes

• *Culex quinquefasciatus* the most important Vector. Found in >84% of WNV+ tested pools.

Common urban habitats for *Cx quinquefasciatus*:
- unmanaged residential pools and containers
- catch basins
- Wastewater treatment facilities

Source: R. Kelly
The Risk of West Nile Virus Infection Is Associated with Combined Sewer Overflow Streams in Urban Atlanta, Georgia, USA

Gonzalo M. Vazquez-Prokopec, Jodi L. Vanden Eng, Rosmarie Kelly, Daniel G. Mead, Priti Kolhe, James Howgate, Uriel Kitron, and Thomas R. Burkot

1Emory University, Atlanta, Georgia, USA; 2Centers for Disease Control and Prevention, Atlanta, Georgia, USA; 3Georgia Division of Public Health, Atlanta, Georgia, USA; 4University of Georgia, Athens, Georgia, USA; 5Fulton County Department of Health and Wellness, Atlanta, Georgia, USA; 6Fogarty International Center, National Institutes of Health, Bethesda, Maryland, USA

Hot-spots of transmission

**Cx. quinquefasciatus** abundance

**WNV infection in Cx. quinquefasciatus**

**WNV infection in dead corvids**

**WNV infection in humans**

WNV infection in mosquitoes, birds and humans clustered in close proximity to CSO streams.
Role of CSOs in mosquito ecology and population dynamics.

Observational, laboratory, and semi-natural experiments

Oviposition preference
Fitness and behavior
Density dependence

Peavine creek
Non-CSO

CDC insectary

Tanyard creek
CSO
Monitoring CSO (T) and non-CSO (P) streams

Lund et al. submitted Year 2008
Water quality and vector productivity

![Graph showing water quality parameters](graph.png)

- **Dissolved oxygen (mg/L)**
- **Ammonia (mg/L)**
- **Phosphate (mg/L)**

**Legend:**
- **DSO**
- **T**
- **P**

**Dates:**
- 7/1
- 7/15
- 7/29
- 8/12
- 8/26
- 9/9
- 9/23
- 10/7
- 10/21

**Notes:**
- *Cx quinquefasciatus*
- *Ammonia and Phosphate*
- *Lund et al. submitted*
CSOs and mosquito oviposition

- Experimental work in semi-natural conditions

Combined Sewage Overflow Enhances Oviposition of *Culex quinquefasciatus* (Diptera: Culicidae) in Urban Areas

LUI S FERNANDO CHAVES, CAROLYN L. KEOGH, GONZALO M. VAZQUEZ-PROKOPEC, AND URIEL D. KITRON

Combined sewage overflow accelerates immature development and increases body size in the urban mosquito *Culex quinquefasciatus*

L. F. Chaves\(^1\), C. L. Keogh\(^2\), A. M. Nguyen\(^3\), G. M. Decker\(^1\), G. M. Vazquez-Prokopec\(^1\) & U. D. Kitron\(^1,4\)

Weather variability impacts on oviposition dynamics of the southern house mosquito at intermediate time scales

L.F. Chaves\(^*\) and U.D. Kitron
Why is WNV spill-over that low?

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Infection in birds

- 2001-2007 dead bird surveillance: 1,884 (+) / 7,396 tested (25%). Most (89%) infected dead birds were crows and blue Jays.

- Northern cardinals, rock pigeons and ground doves seem to play a significant role in virus amplification.
Enzootic Transmission

Monitoring residential and recreational areas in Atlanta, GA (work led by Rebecca Levine)

Performing comprehensive avian sampling, serology and virus isolation (at UGA)

Mist-netting

Blood sampling
Limited Spillover to Humans from West Nile Virus Viremic Birds in Atlanta, Georgia

Rebecca S. Levine, Daniel G. Mead, and Uriel D. Kitron

Table 1. Avian Species and the Number of Unique Individuals Sampled in Urban Atlanta, GA, 2010–2012

<table>
<thead>
<tr>
<th>Species common name</th>
<th>Species name</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Cardinal</td>
<td><em>Cardinalis cardinalis</em></td>
<td>156</td>
</tr>
<tr>
<td>American Robin</td>
<td><em>Turdus migratorius</em></td>
<td>131</td>
</tr>
<tr>
<td>Carolina Wren</td>
<td><em>Thryothorus ludovicianus</em></td>
<td>47</td>
</tr>
<tr>
<td>Northern Mockingbird</td>
<td><em>Mimus polyglottos</em></td>
<td>44</td>
</tr>
<tr>
<td>Brown Thrasher</td>
<td><em>Tachybaptus rufus</em></td>
<td>41</td>
</tr>
<tr>
<td>Gray Catbird</td>
<td><em>Dumetella carolinensis</em></td>
<td>37</td>
</tr>
<tr>
<td>European Starling</td>
<td><em>Sturnus vulgaris</em></td>
<td>26</td>
</tr>
<tr>
<td>Swainson's Thrush</td>
<td><em>Catharus ustulatus</em></td>
<td>17</td>
</tr>
<tr>
<td>Common Grackle</td>
<td><em>Quiscalus quinquaedula</em></td>
<td>16</td>
</tr>
<tr>
<td>Blue Jay</td>
<td><em>Cyanocitta cristata</em></td>
<td>14</td>
</tr>
<tr>
<td>Eastern Towhee</td>
<td><em>Pipilo erythrophthalmus</em></td>
<td>14</td>
</tr>
<tr>
<td>Tufted Titmouse</td>
<td><em>Baeolophus bicolor</em></td>
<td>11</td>
</tr>
<tr>
<td>Wood Thrush</td>
<td><em>Hylocichla mustelina</em></td>
<td>11</td>
</tr>
<tr>
<td>Song Sparrow</td>
<td><em>Melospiza melodia</em></td>
<td>9</td>
</tr>
<tr>
<td>Eastern Bluebird</td>
<td><em>Sialia sialis</em></td>
<td>6</td>
</tr>
<tr>
<td>Gray-Cheeked Thrush</td>
<td><em>Catharus minimus</em></td>
<td>5</td>
</tr>
<tr>
<td>Hooded Warbler</td>
<td><em>Setophaga citrina</em></td>
<td>5</td>
</tr>
<tr>
<td>White-Breasted Nuthatch</td>
<td><em>Sitta carolinensis</em></td>
<td>5</td>
</tr>
<tr>
<td>Brown-Headed Cowbird</td>
<td><em>Molothrus ater</em></td>
<td>3</td>
</tr>
<tr>
<td>Eastern Phoebe</td>
<td><em>Sanyris phoebe</em></td>
<td>3</td>
</tr>
<tr>
<td>Great-Crested Flycatcher</td>
<td><em>Migriolus crissalis</em></td>
<td>3</td>
</tr>
<tr>
<td>House Finch</td>
<td><em>Haemorrhous mexicanus</em></td>
<td>3</td>
</tr>
<tr>
<td>Ovenbird</td>
<td><em>Setus auripennis</em></td>
<td>2</td>
</tr>
<tr>
<td>Red-Bellied Woodpecker</td>
<td><em>Melanerpes carolinus</em></td>
<td>2</td>
</tr>
<tr>
<td>White-Throated Sparrow</td>
<td><em>Zonotrichia albicollis</em></td>
<td>2</td>
</tr>
<tr>
<td>Yellow-Shafted Flicker</td>
<td><em>Colaptes auratus</em></td>
<td>2</td>
</tr>
<tr>
<td>Black-and-White Warbler</td>
<td><em>Mniotilus varia</em></td>
<td>1</td>
</tr>
<tr>
<td>Chestnut-Sided Warbler</td>
<td><em>Setophaga pensylvanica</em></td>
<td>1</td>
</tr>
<tr>
<td>Downy Woodpecker</td>
<td><em>Picoides pubescens</em></td>
<td>1</td>
</tr>
<tr>
<td>House Sparrow</td>
<td><em>Passer domesticus</em></td>
<td>1</td>
</tr>
<tr>
<td>House Wren</td>
<td><em>Troglodytes aedon</em></td>
<td>1</td>
</tr>
<tr>
<td>Indigo Bunting</td>
<td><em>Passerina cyanea</em></td>
<td>1</td>
</tr>
<tr>
<td>Kentucky Warbler</td>
<td><em>Geothlypis formosa</em></td>
<td>1</td>
</tr>
<tr>
<td>Magnolia Warbler</td>
<td><em>Setophaga magnolia</em></td>
<td>1</td>
</tr>
<tr>
<td>Mourning Dove</td>
<td><em>Zenaida macroura</em></td>
<td>1</td>
</tr>
<tr>
<td>Northern Waterthrush</td>
<td><em>Parksia verebroaurea</em></td>
<td>1</td>
</tr>
<tr>
<td>Rose-Breasted Grosbeak</td>
<td><em>Phenicicus ludovicianus</em></td>
<td>1</td>
</tr>
<tr>
<td>Red-Eyed Vireo</td>
<td><em>Vireo olivaceus</em></td>
<td>1</td>
</tr>
<tr>
<td>Red-Winged Blackbird</td>
<td><em>Agelaius phoenicus</em></td>
<td>1</td>
</tr>
<tr>
<td>Veery</td>
<td><em>Catharus fuscens</em></td>
<td>1</td>
</tr>
<tr>
<td>Yellow-Bellied Sapsucker</td>
<td><em>Spizella pusilla</em></td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>630</td>
</tr>
</tbody>
</table>

Table 2. West Nile Virus Viremia Titters in Wild Passerines Sampled in Atlanta, GA, 2010–2012

<table>
<thead>
<tr>
<th>Species common name</th>
<th>Species name</th>
<th>Age</th>
<th>Location captured</th>
<th>Sample year</th>
<th>Sample month and day</th>
<th>Virus titer (log_{10} PFU/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Cardinal</td>
<td><em>Cardinalis cardinalis</em></td>
<td>Hatch-year</td>
<td>Park-Woods</td>
<td>2010</td>
<td>August 13</td>
<td>3.74</td>
</tr>
<tr>
<td>American Robin</td>
<td><em>Turdus migratorius</em></td>
<td>Hatch-year</td>
<td>Park-Woods</td>
<td>2010</td>
<td>September 1</td>
<td>Below detectable levels</td>
</tr>
<tr>
<td>Northern Cardinal</td>
<td><em>Cardinalis cardinalis</em></td>
<td>Hatch-year</td>
<td>Residential</td>
<td>2011</td>
<td>July 28</td>
<td>3.47</td>
</tr>
<tr>
<td>Northern Cardinal</td>
<td><em>Cardinalis cardinalis</em></td>
<td>Hatch-year</td>
<td>Zoo Atlanta</td>
<td>2011</td>
<td>August 3</td>
<td>1.69</td>
</tr>
<tr>
<td>Carolina Wren</td>
<td><em>Thryothorus ludovicianus</em></td>
<td>After Hatch-Year</td>
<td>Zoo Atlanta</td>
<td>2011</td>
<td>August 3</td>
<td>4.69</td>
</tr>
<tr>
<td>Northern Cardinal</td>
<td><em>Cardinalis cardinalis</em></td>
<td>Hatch-year</td>
<td>Park-Water</td>
<td>2011</td>
<td>August 9</td>
<td>3.87</td>
</tr>
</tbody>
</table>

pfu, plaque-forming units.
• 48 out of 141 samples WNV seropositive (34%)

2011 followed a similar trend

Northern Cardinal: a competent reservoir host in the SE

Levine et al. VBZD 2013
Other contributors to virus amplification

- Work led by Donal Bisanzio (DVM, PhD).
- Work done in Grant Park. Bi-weekly squirrel sampling

<table>
<thead>
<tr>
<th>Site</th>
<th>Tested pool of Culex genus N pools (N mosquitoes)</th>
<th>Mir (N positive pools) (95% CI)</th>
<th>Captured Squirrel (Density/ha)</th>
<th>Seroprevalence % (N positive) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site A</td>
<td>17 (102)</td>
<td>9.8 (1) [0.2; 53.4]</td>
<td>11 (22.0)</td>
<td>45.5% (5) [16.8-76.6%]</td>
</tr>
<tr>
<td>Site B</td>
<td>40 (558)</td>
<td>7.1 (4) [1.9; 18.2]</td>
<td>10 (16.5)</td>
<td>30.0% (3) [6.7-65.2%]</td>
</tr>
<tr>
<td>Site C</td>
<td>26 (243)</td>
<td>4.1 (1) [0.1; 22.7]</td>
<td>9 (20.6)</td>
<td>33.3% (3) [7.4-70.1%]</td>
</tr>
<tr>
<td>Site D</td>
<td>44 (561)</td>
<td>8.9 (5) [2.9; 20.6]</td>
<td>3 (14.8)</td>
<td>100% (3) [29.2-100%]</td>
</tr>
<tr>
<td>Site E</td>
<td>31 (323)</td>
<td>6.1 (2) [0.7; 22.2]</td>
<td>3 (21.2)</td>
<td>33.3% (1) [0.8-90.5%]</td>
</tr>
<tr>
<td>Site F</td>
<td>30 (351)</td>
<td>2.8 (1) [0.1; 15.7]</td>
<td>18 (20)</td>
<td>38.9% (7) [17.3-64.3%]</td>
</tr>
<tr>
<td>Site G</td>
<td>120 (1850)</td>
<td>2.7 (5) [0.8; 6.2]</td>
<td>15 (19.5)</td>
<td>13.3% (2) [1.6-40.4%]</td>
</tr>
<tr>
<td>All sites</td>
<td>308 (3988)</td>
<td>4.7 (19) [2.8; 7.4]</td>
<td>69 (18.9)</td>
<td>34.7% (24) [23.7-47.2%]</td>
</tr>
</tbody>
</table>

![Number of squirrel distribution by month and Culex genus MIR](image)
Why is WNV spill-over that low?

Low mosquito abundance?

Absence of transmission hot-spots?

Low enzootic transmission?

Absence of competent reservoir hosts?

Complex bird community “dilutes” transmission?

Different viruses?

Low human exposure?
Simulation models to assess interaction between bird and mosquito communities.

- **Pref-H**: highly preferred host
- **Semi-H**: moderately preferred host
- **Poor-H**: low preference host
- **Mosquito**

*Bisanzio et al. in prep.*
Increasing the proportion of Pref-H reduces the number of birds infected in the other two groups.

Bird population composition has more impact on WNV prevalence within bird groups than in the overall population.
Bloodmeal ID from field-caught mosquitoes

Cardinals represent 24% of all bird sources and humans 37% of total samples.

Evidence of human-bird mixed feeds!

Karen Wu et al. Unpublished
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Some thoughts

Low spill-over in GA not associated with low virus amplification or availability of competent hosts.

All data indicates more virus spill-over into humans should be occurring.

Is the low human infection rate confounded by low reporting (in all SE states?). How do we explain low neuro-invasive WNV?

We need to learn more about contact rates between humans-mosquitoes and birds-mosquitoes.

“Let me tell you the secret that has led me to my goal. My strength lies solely in my tenacity.” (Louis Pasteur)
Understanding linkages between vectors, hosts and built environment

“Much remains to be discovered about the complex biological and ecological relationships that exist among pathogens, vectors, hosts, and their environments.”

“Such knowledge is essential to the development of novel and more effective interventions”

Acknowledgements

Emory students who participate in all field and lab activities.

Danny Mead for helping with sample processing at UGA.

Rosemarie for her constant support.

Emory University for continued support to undergraduate and graduate students involved in the lab.

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Questions?