WNV in Urban Areas – from Chicago to Atlanta

GMCA meeting,

Oct 15-17, 2008

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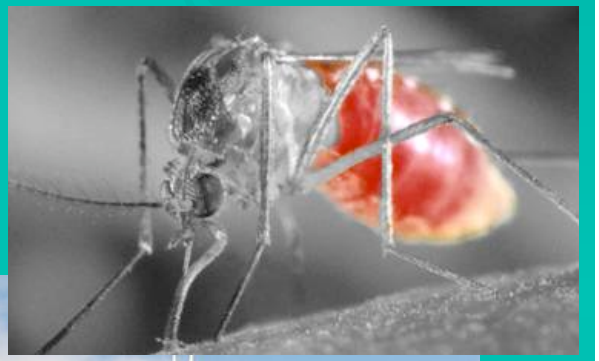
West Nile virus in Chicago

- Introduction
- Establishment
- Distribution in an urban area

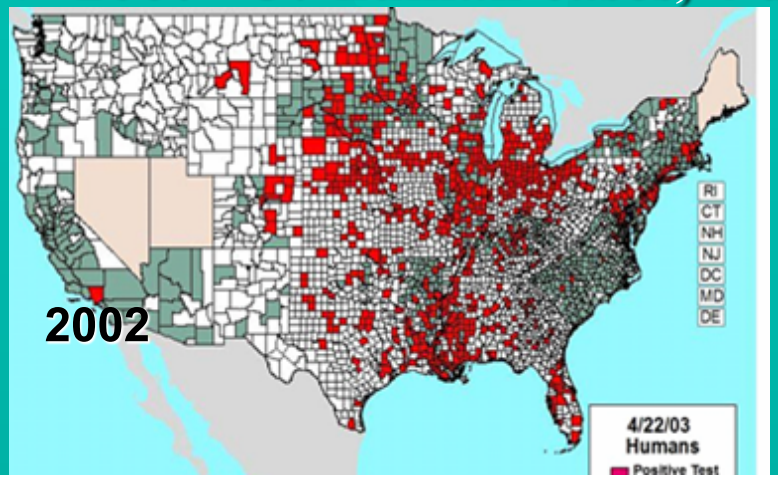


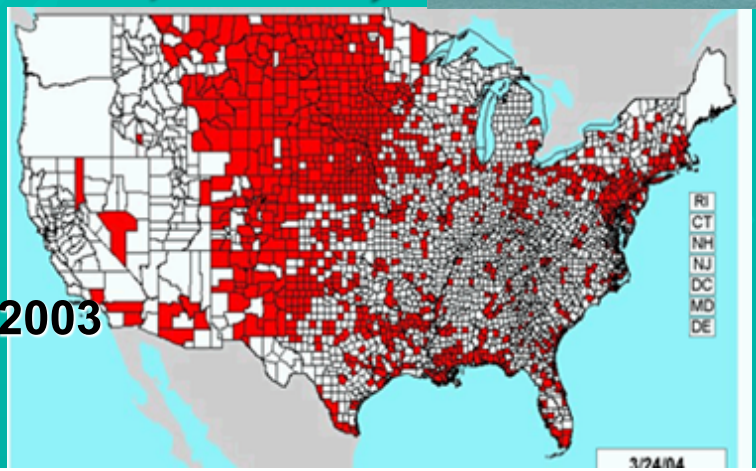
Collaborative study of: University of Illinois, Michigan State University, Illinois Department of Public Health, Audubon, Chicago Dept. of Public Health, South Cook Co. Mosquito Abatement District, local communities

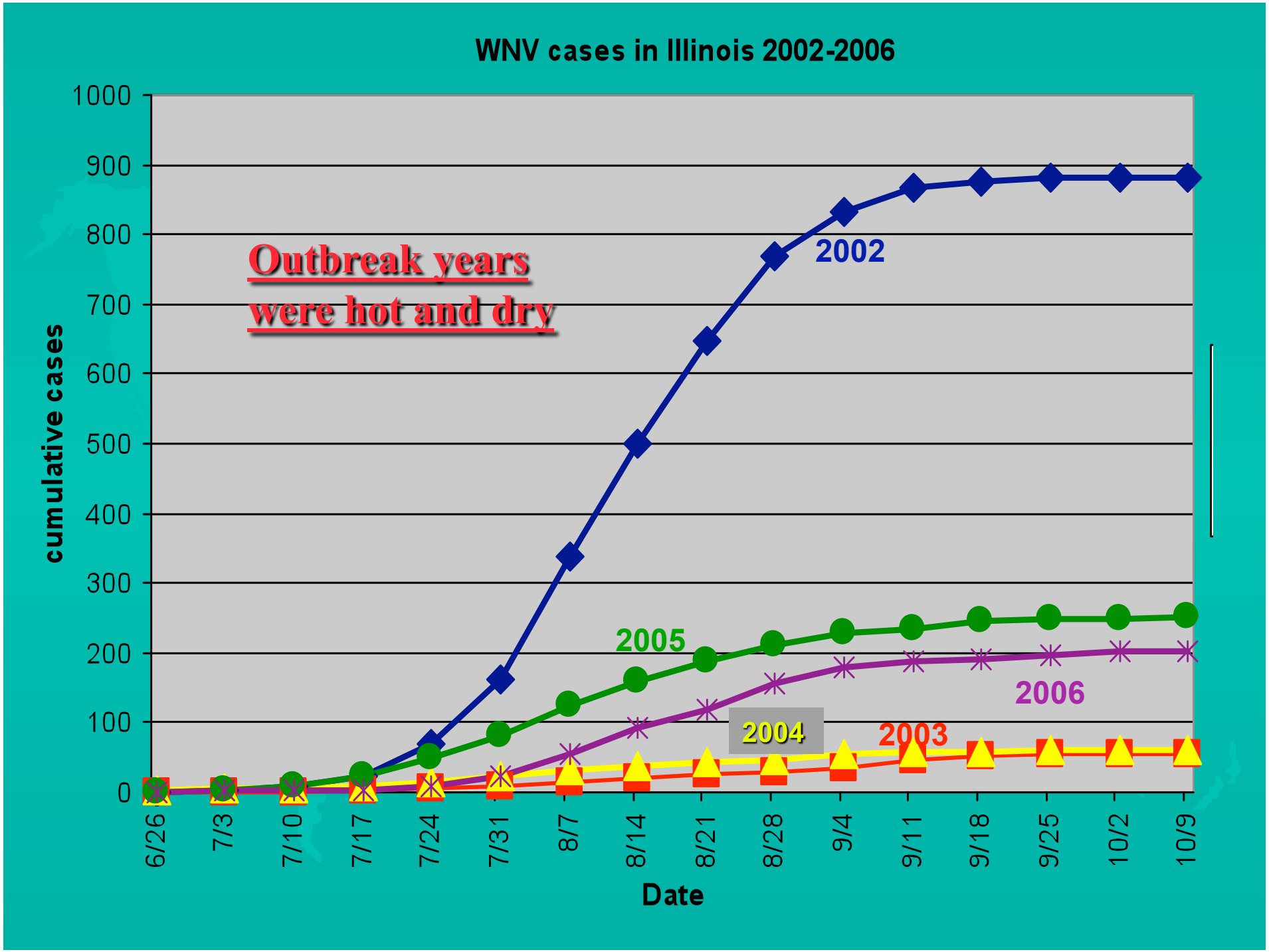
West Nile Virus in Illinois

- WNV appeared in NYC during 1999 (arrived from the old world)
- **2001 - 123 positive bird specimens, 0 human cases**
- **2002 - 884 human cases, 66 deaths, most in U.S. (4,156/284)**

  Over 680 cases occurred in Chicago area
- **2003 - 54 human cases, 1 death (U.S – 9,862/264)**
- **2004 - 60 human cases, 4 deaths (U.S. – 2,539/100)**
- **2005 - 252 human cases, 12 deaths (U.S. – 3000/119)**
- **2006 - 215 human cases, 10 deaths (U.S. – 4269/177)**
- **2007 - 57 human cases, 4 deaths (U.S. – 3,576/115)**

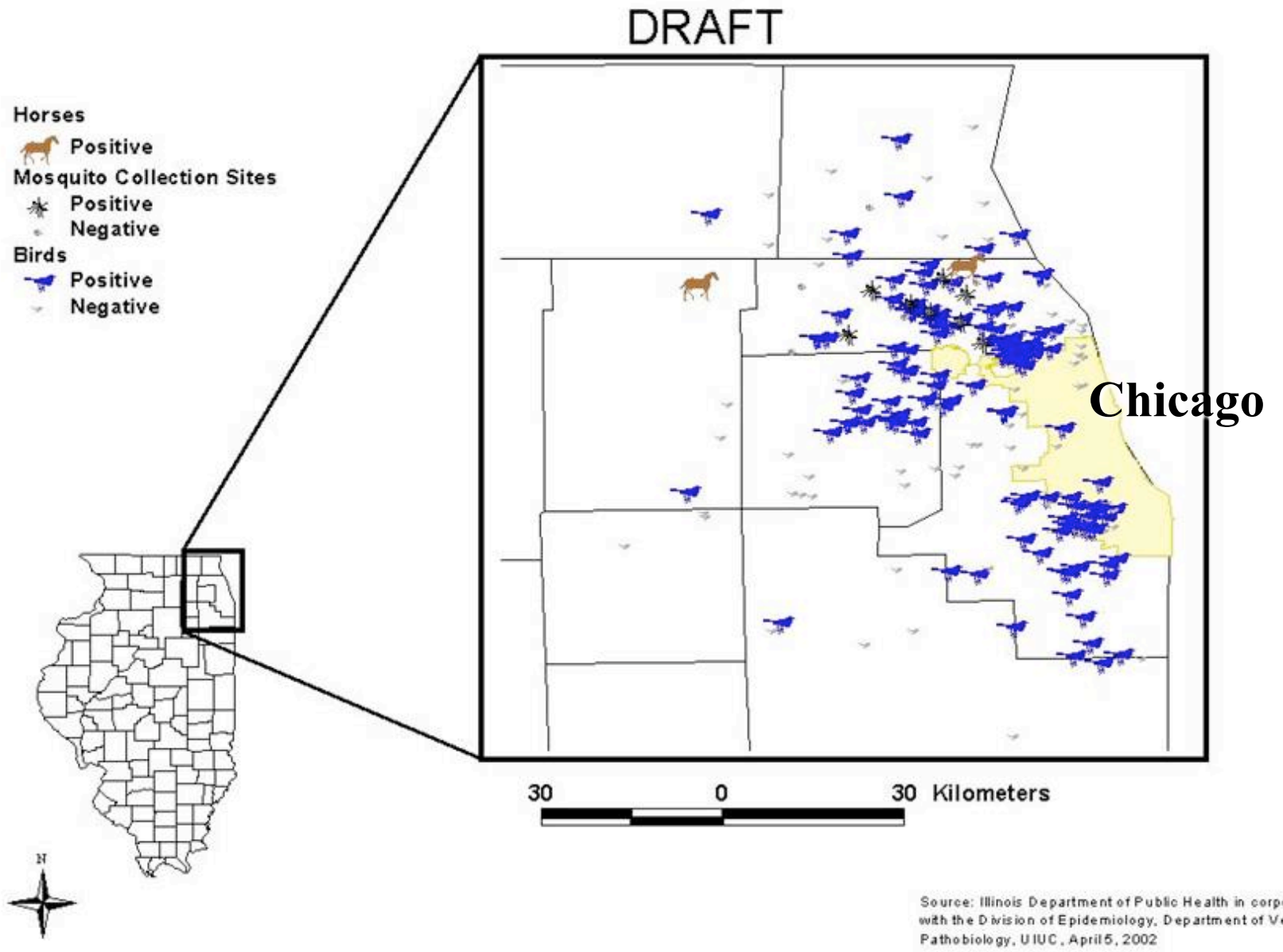





WNV cases in Illinois 2002-2006
cumulative cases
1000
900
800
700
600
500
400
300
200
100
0
Outbreak years
were hot and dry
2002
2005
2006
2004
2003
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
9/25
10/2
10/9
Date

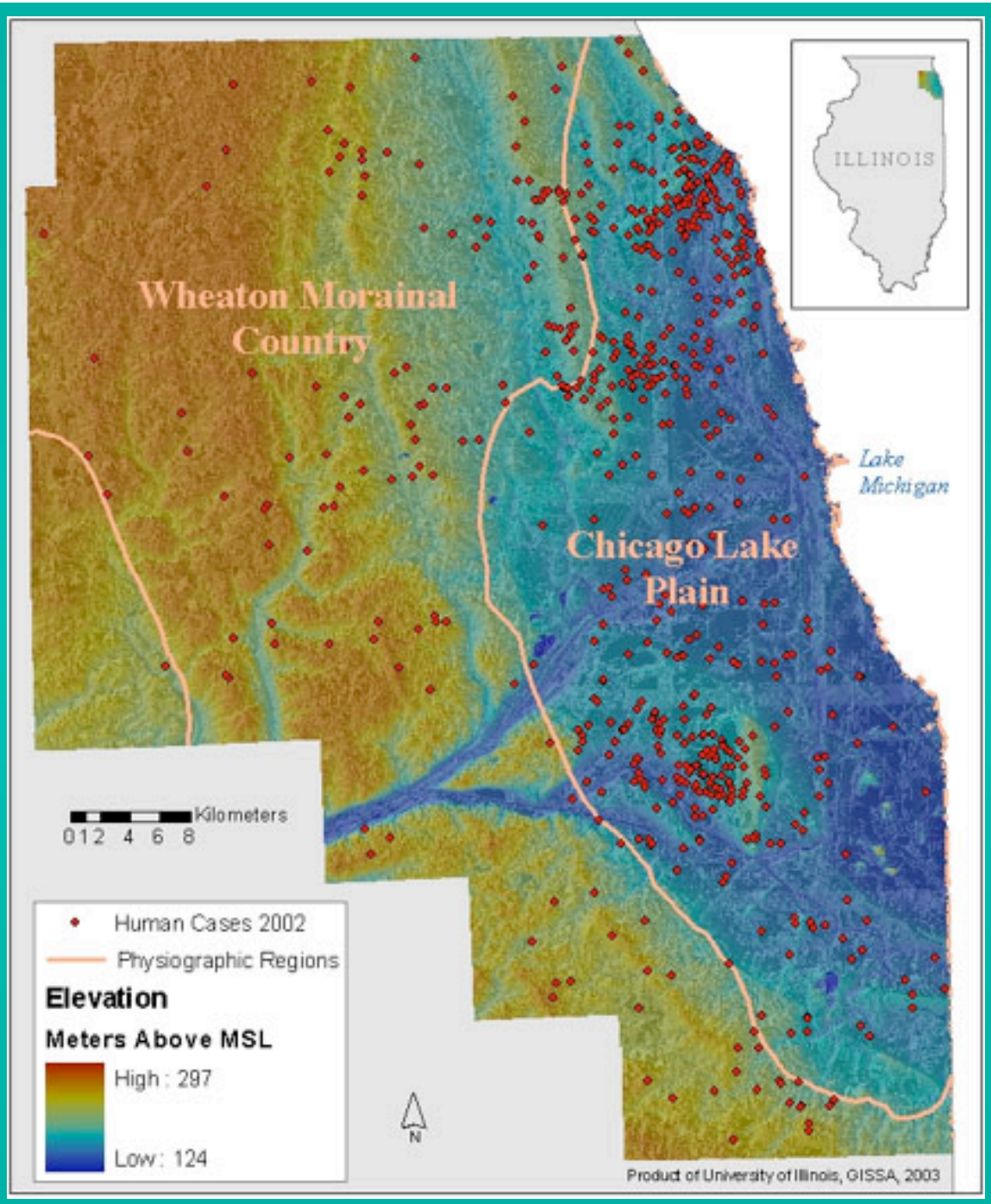
West Nile Virus (WNV) Tested Horses, Mosquitoes, & Birds:

August 19, 2001 - October 13, 2001



Source: Illinois Department of Public Health in corporation with the Division of Epidemiology, Department of Veterinary Pathobiology, UIUC, April 5, 2002

Distribution of human WNV cases in the greater Chicago area, 2002



A historical perspective…

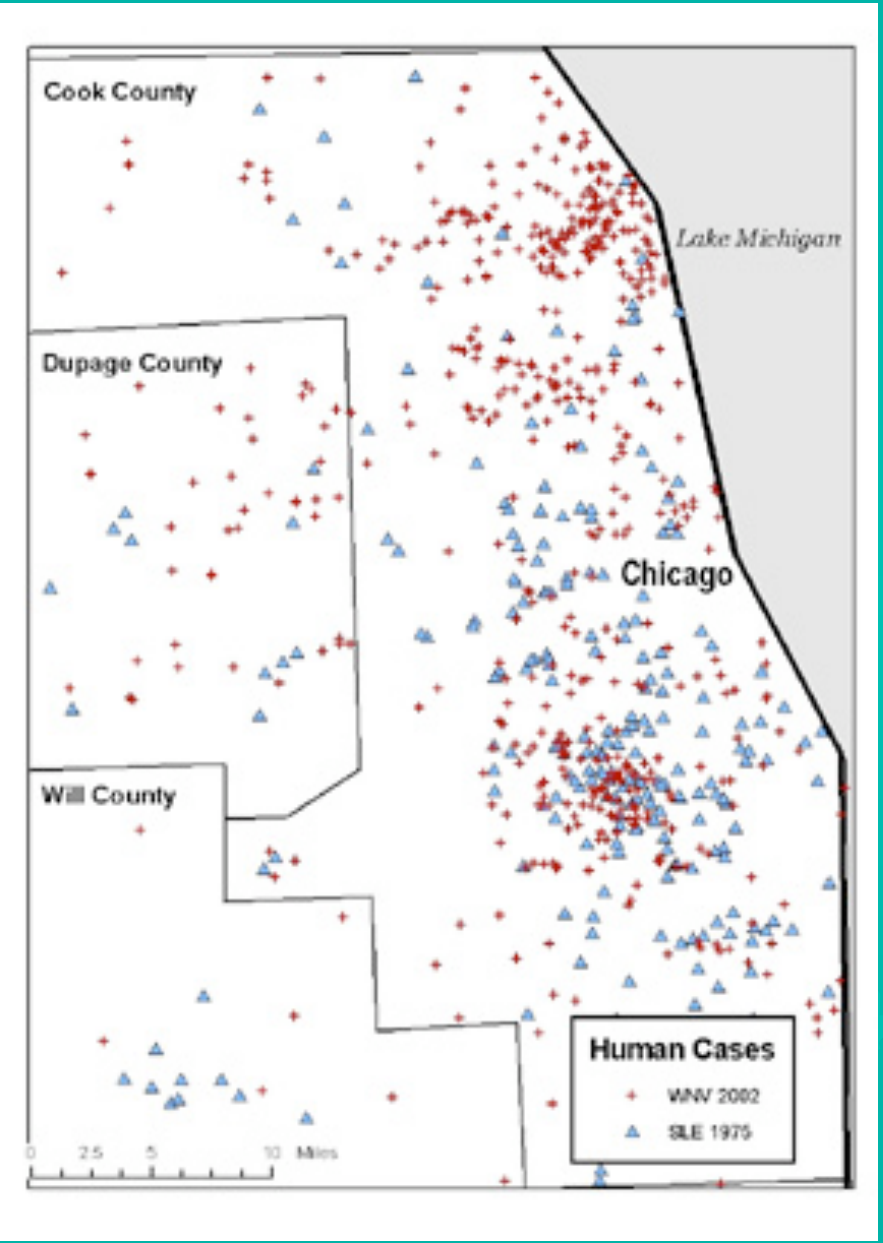
- **1901**: New York Times [referring to Chicago's 19th ward]: "dirty streets, filthy alleys, impure water cause[d an] epidemic of typhoid fever and malaria."
- **1975**: Outbreak of human St. Louis encephalitis, a virus related to WNV
- **2002**: Outbreak of WNV in humans


The New York Times.

ALLIED ARMIES LAND IN FRANCE IN THE HAVRE-CHERBOURG AREA; GREAT INVASION IS UNDER WAY

WNV and SLE

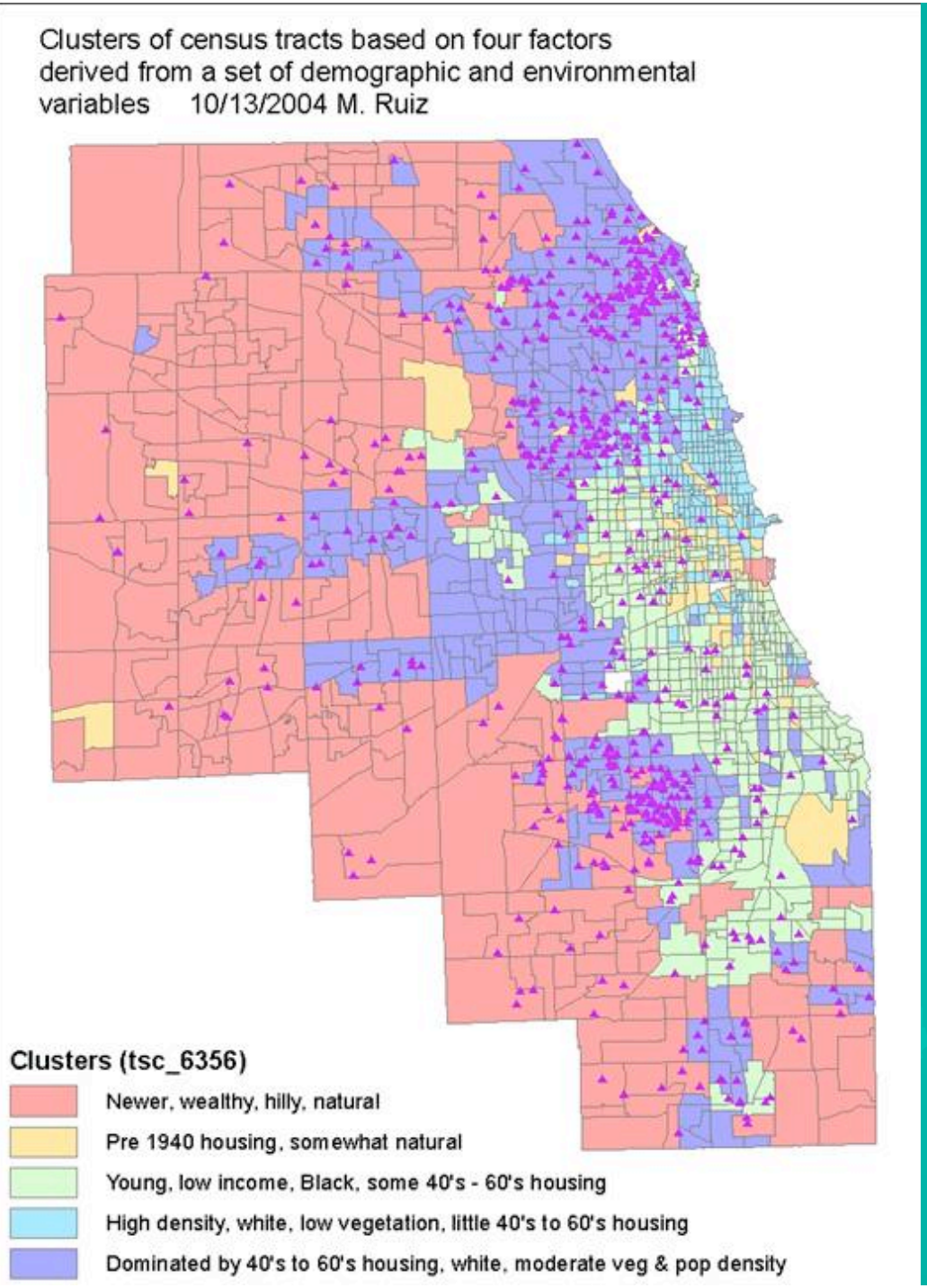
- Strong spatial pattern for both outbreaks
- Two statistically significant foci of viral activity:
  - North (Skokie/ Evanston)
  - South (Oak Lawn)



Dominant patterns in the Chicago urban landscape

- Each different colored area represents a place with a common set of factors related to housing, vegetation, socio-economics, and land use

Ruiz et al, Int'l J Health Geog 2004



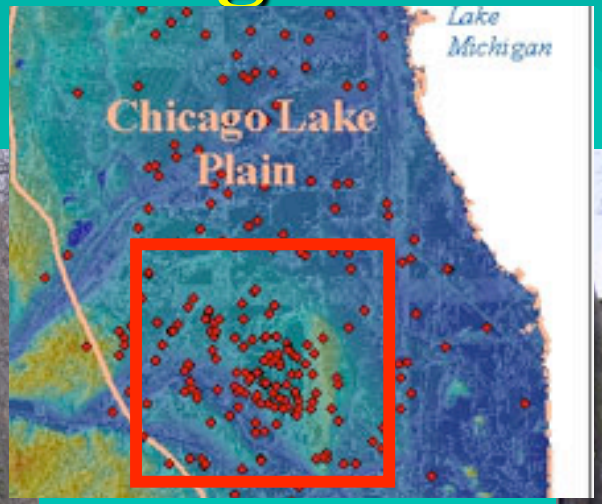
Urban Type 5, dominated by 40s and 50s housing. Mostly white, moderate vegetation and moderate population density.

435 cases (64%) were in this group, 2.27 cases per 10,000 people (RR>3.5). (All other types <0.65 cases per 10,000)

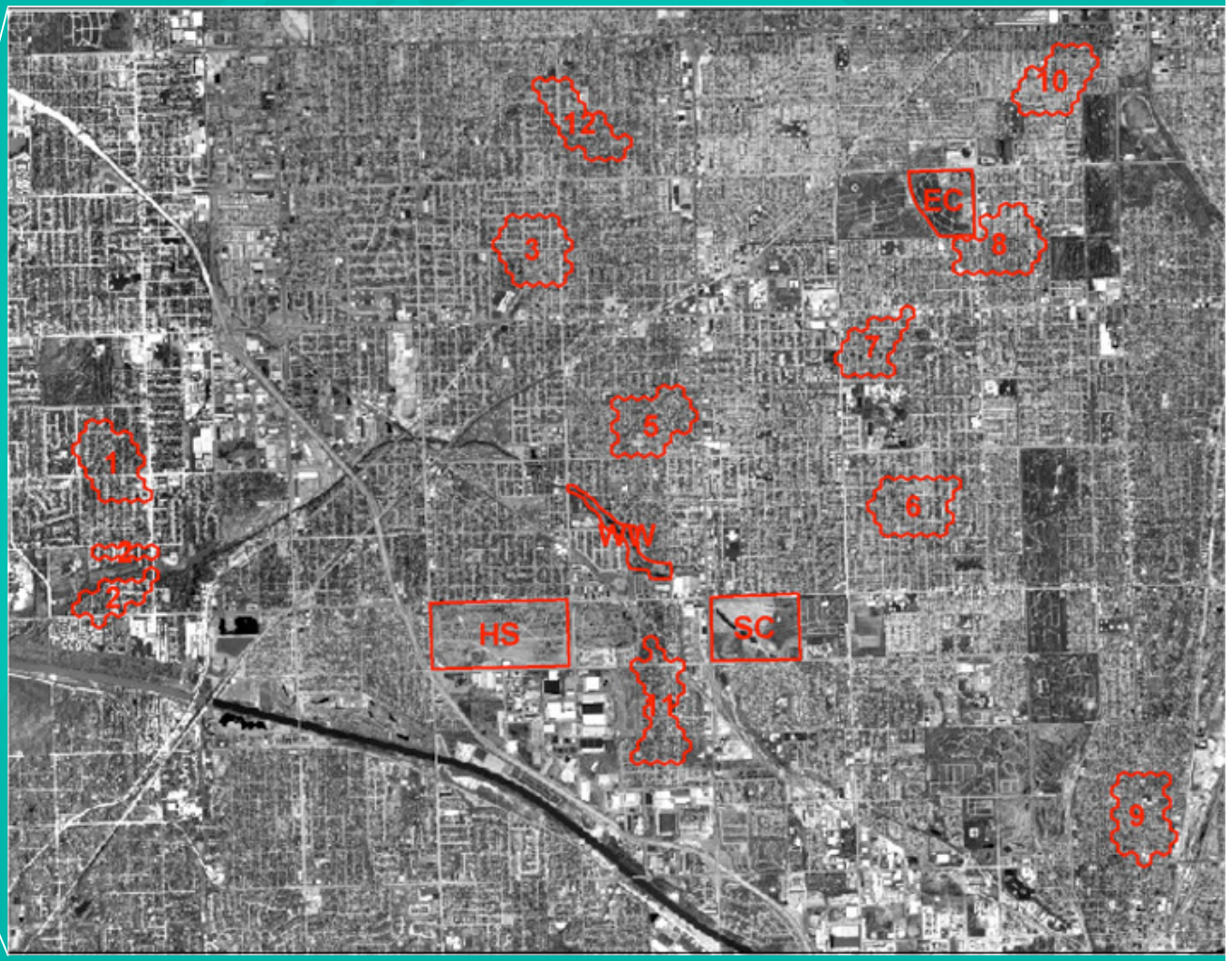
Area characterized by many undocumented storm drains

In hot dry years standing water with organic matter provide habitat for *Culex* mosquito larvae

What's happening within the hot spot?



12 Residential and 4 "Natural" Field



1 mile

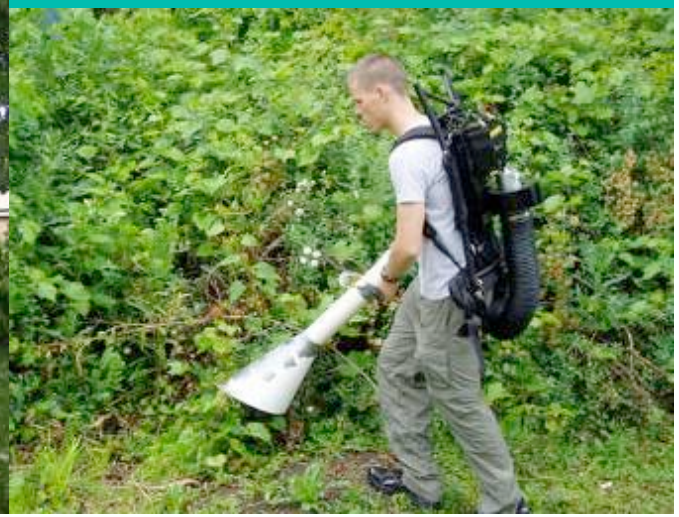
Methodological approach

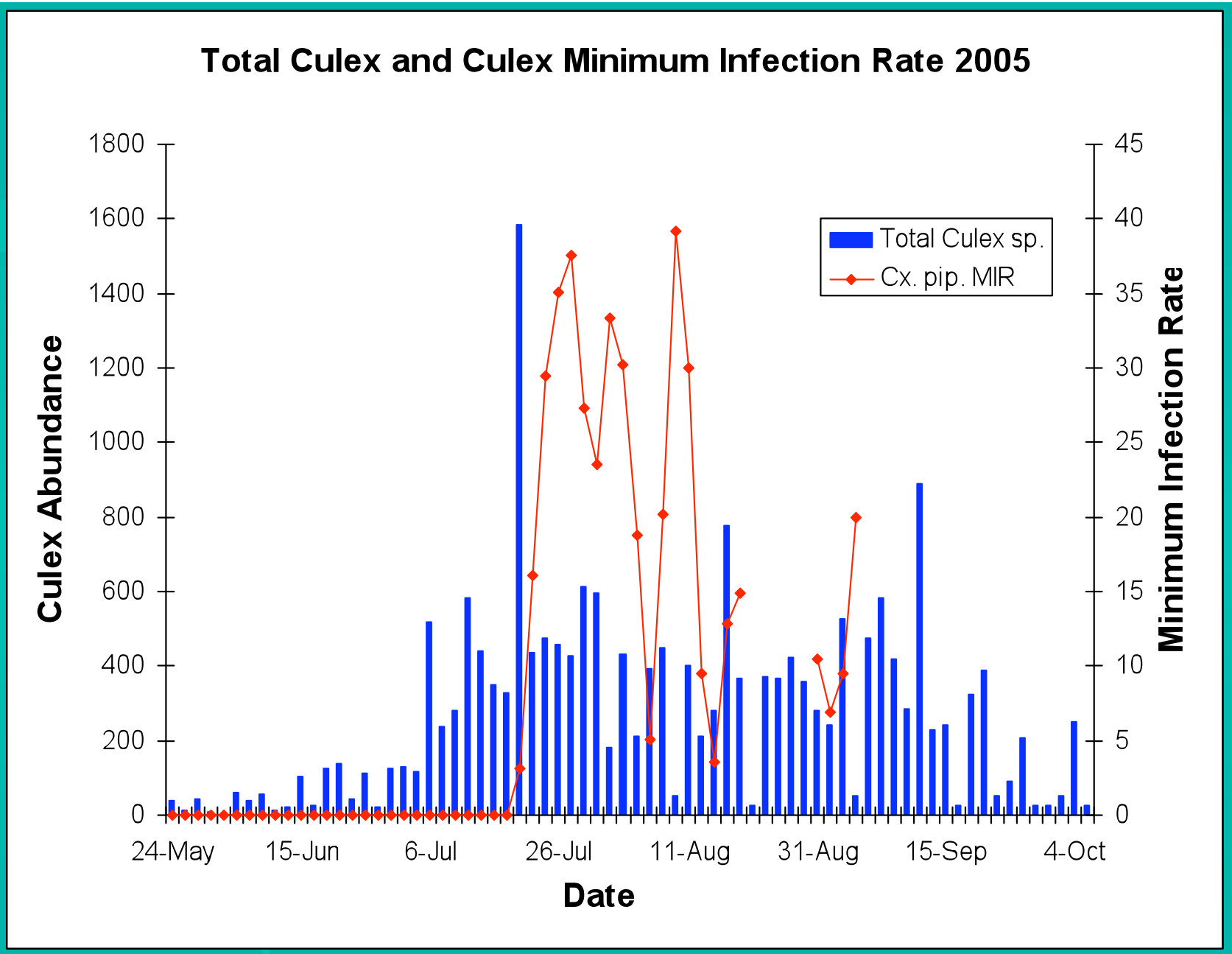
- **Mosquito vector** sampling to characterize patterns of viral amplification and host feeding preferences (blood meal analysis)
- **Avian host** sampling to characterize avian communities and infection rates
- **Molecular epidemiological** studies of WNV to infer patterns of transmission and evolution

Vector Community

1. Adult Mosquito Trapping - MIR
   - Light trap, gravid trap, aspirator
2. Quantification of Mosquito Productivity
   - Catch basins, containers
3. Index of Culex Density
   - Ovitraps
4. Mosquito Bloodmeal Analysis

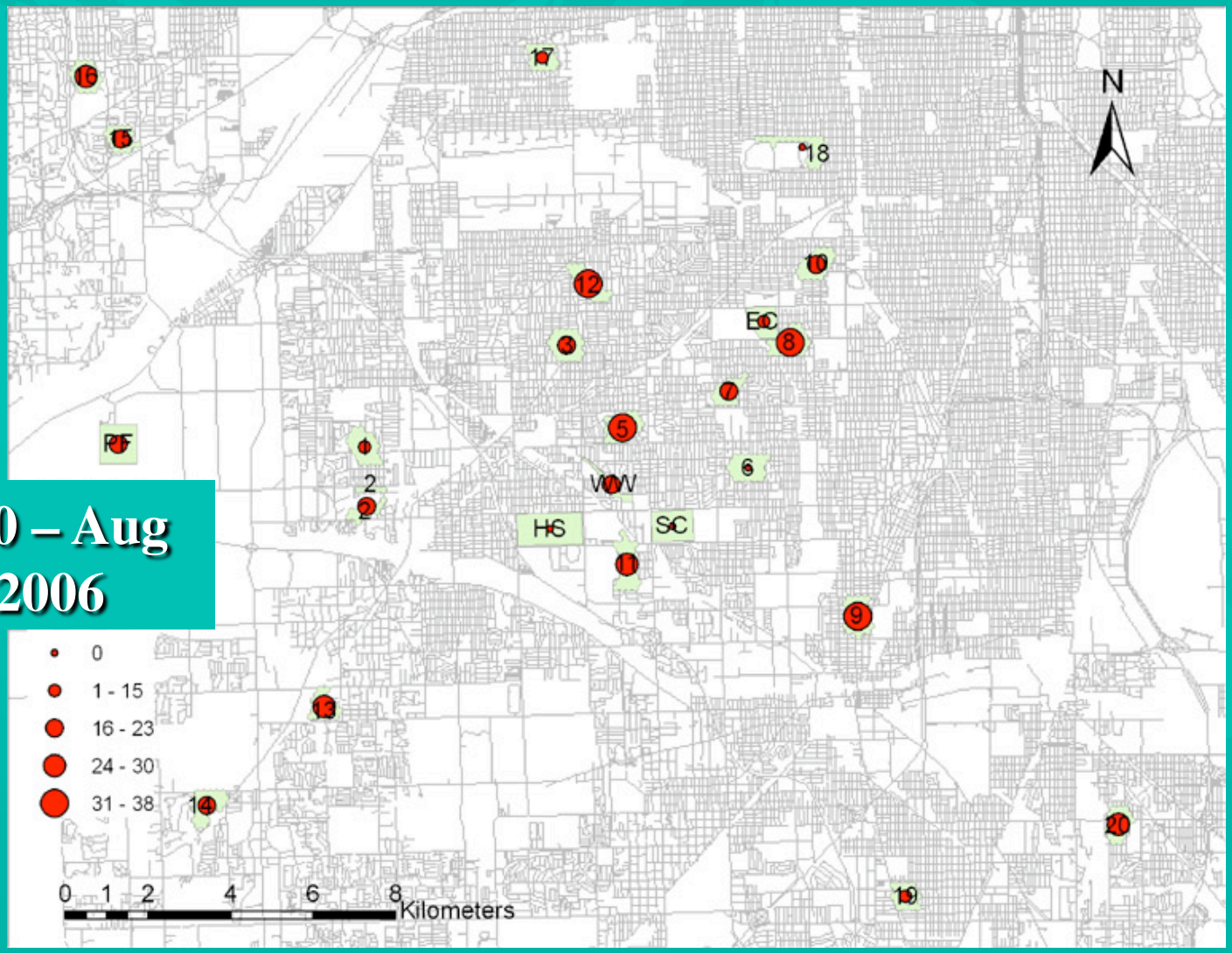






Sharp rise in MIR, coincides with appearance of fledging birds

Spatial heterogeneity in mosquito infection rates among sites within the "hot spot" area



July 30 – Aug 19, 2006

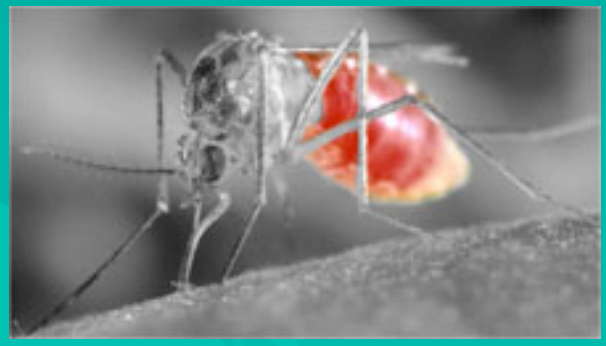
Avian Host Community

1. Bird Surveys
   - Line transect bird surveys during May and June
2. Bird Mist-netting
   - 6-8 nets/morning from sunrise to noon during May to October
3. Seropositivity of Captured Birds
   - ELISA
4. Virus Detection in Captured Birds (RT-PCR)

Density of competent avian hosts w within the study area

Species	Density/Acre
House Sparrow *(Passer domesticus)*	15.19
American Robin *(Turdus migratorius)*	8.62
Red-winged Blackbird *(Agelaius phoeneceus)*	2.49
Euro. Starling *(Sturnus vulgaris)*	2.08
Mourning Dove *(Zenaida macroura)*	1.88
American Goldfinch *(Carduelis tristis)*	1.75
Mallard *(Anas platyrhynchos)*	1.46
Common Grackle *(Quiscalus quiscula)*	0.83
Cedar Waxwing *(Bombycyllum cedrorum)*	0.29
American Crow *(Corvus brachyrhynchos)*	0.27

Blood meal analysis



- 1,112 bloodfed mosquitoes captured in 2005 and 2006
- 64% *Culex pipiens*, 17% *C. restuans*, 13% *Aedes vexans*
- Blood meal sources identified in 827 (74%) mosquitoes
  - Failure to ID blood meals reflected advanced stage of digestion
- For *C. pipiens*, 83% blood meals were avian, 17% mammalian.

Robins!

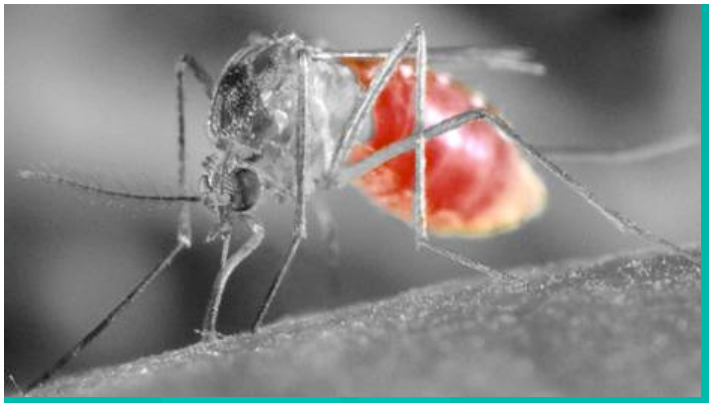
- Robins in suburban Chicago:
  - Abundant - 8.6 per acre (Second only to house sparrows)
  - Preferred by *Culex pipiens (feeding preference index >2) while* House sparrows are avoided (0.25)
  - Fledge and expand in population numbers at the same time that WNV IR increases in mosquitoes

"Smoking gun" mosquito

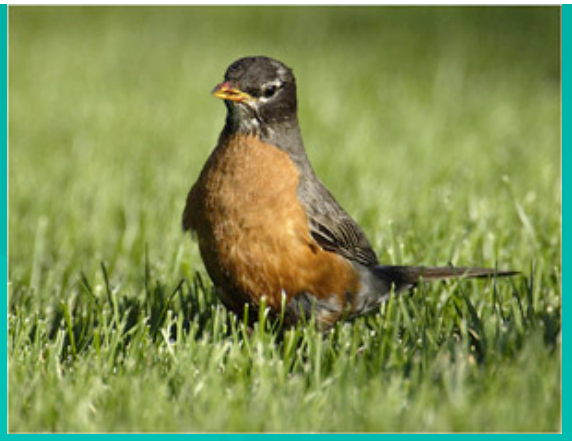
Blood meal analysis on individual *Culex pipiens* that were also positive for WNV by PCR

Date	Species	Bloodmeal ID
7/20/05	*Cx. pipiens*	House sparrow
8/19/05	*Cx. pipiens*	American Robin
8/20/05	*Cx. pipiens*	American Robin
9/7/05	*Cx. pipiens*	**Human**

Hamer et al., Journal of Medical Entomology, 2008.



Findings



- Sharp rise in MIR, coincides with appearance of fledging birds
- Robins are likely key reservoir hosts
- WNV detection from *Culex pipiens* containing American Robin and Human blood meals provides direct evidence of their role in transmission and as a bridge vector

Conclusions

Exceptional variation within hot spots

- Landscape ecology
- Vector ecology -
- Avian host ecology -
- Virus evolution

Fine-scale processes are the fundamental drivers of WNV transmission in urban settings and coalesce to create broader, regional patterns of amplification

Future directions

- Elucidate ***fundamental ecological process*** that drive fine-scale variation in WNV transmission within suburban Chicago hot
- Focus on spatial scales as fine as $10m^2$
  - Microgeographic studies of landscape ecology and climate
  - Measure dispersal patterns of mosquitoes from oviposition sites
  - Track daily (and nightly) aggregation patterns of robins
  - Map fine-scale WNV transmission using molecular methods
- WNV Research in Atlanta
  http://www.envs.emory.edu/news/WNV/index.htm

West Nile Virus in Atlanta, GA

Collaborators

Rosmarie Kelly - Georgia Department of Human Resources/Division of Public Health

Thomas Burkot - CDC

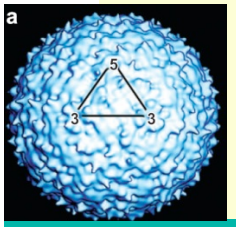
Jody Vanden Eng – CDC

Uriel Kitron – Emory University

Gonzalo Vazquez-Prokopec – Emory University

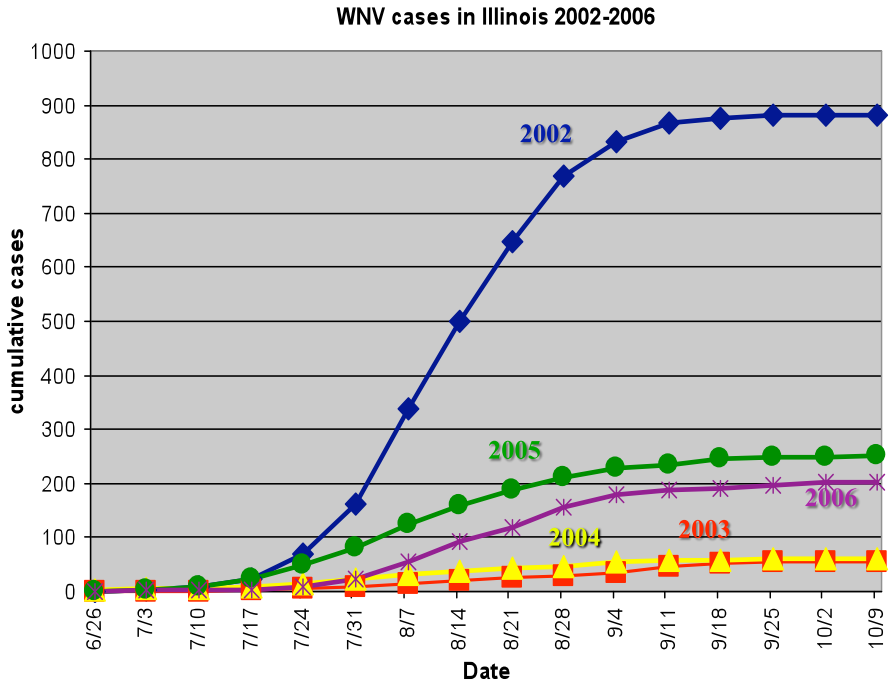
Luis Chaves – Emory University

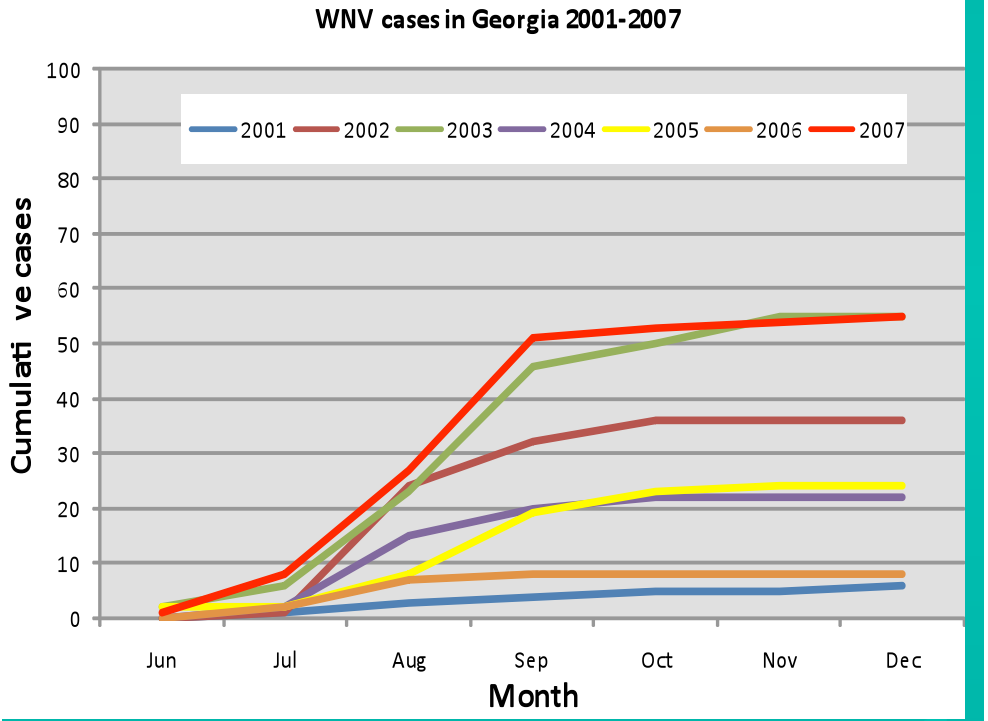
Danny Mead - UGA



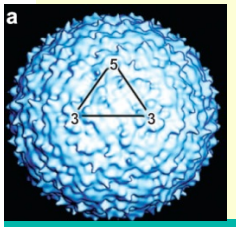
WNV in Georgia

Human cases in Georgia ~10 times lower than in Illinois





Why WNV transmission in Georgia is that low ?

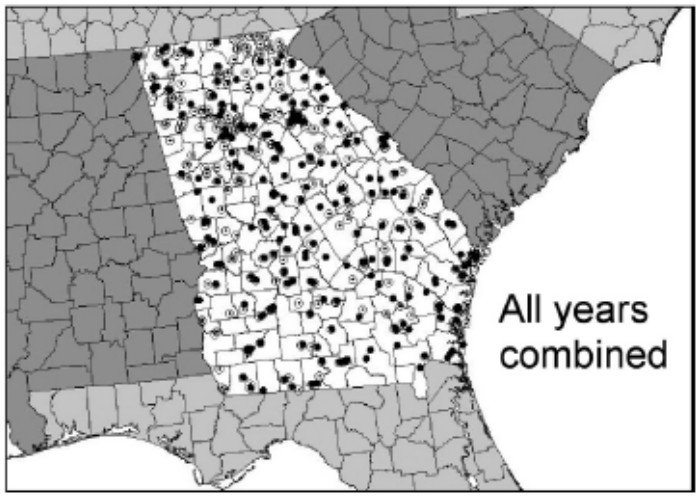


WNV in Georgia

Infection in birds

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

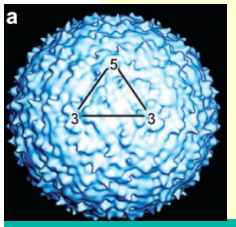
- Northern cardinals, rock pigeons and ground doves seem to play a significant role in virus amplification.



WNV pos WNV neg

Species	Total n	Total No. pos	Total % pos
Rock pigeon (*Columba livia*)	847	155	18.0
Northern Cardinal (*Cardinalis cardinalis*)	3000	443	14.8
Common ground dove (*Columbina passerina*)	61	15	24.6
Gray catbird (*Dumetella carolinensis*	264	25	9.5
Northern mockingbird (*Mimus polyglottos*)	329	32	9.7
Brown thrasher (*Toxostoma rufum*)	327	12	3.7
House finch (*Carpodacus mexicanus*	979	19	1.9
House sparrow (*Passer domesticus*)	1057	18	1.7
Tufted titmouse (*Baeolophus bicolor*)	489	3	0.6
Canada goose (*Branta Canadensis*)	2609	8	0.3
All species tested ($n = 83$)[a]	14077	868	6.2

Source: Gibbs et al. 2006



WNV in Georgia

Mosquitoes

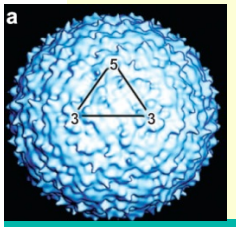
- *Culex quinquefasciatus* the most important Vector. Found in >84% of WNV+ tested pools.

Common urban habitats for *Cx quinquefasciatus*:

* unmanaged residential pools and containers
* catch basins
* **Combined Sewer Systems (CSS)**

Mosquito Surveillance (positive pools)		
14-Sep-07		
2007	EEE*	0
	Hart Park	0
	Flanders	93
	WNV*	64
5-Sep-06		
2006	EEE*	0
	Flanders	24
	WNV*	51
	Highlands J	0
6-Sep-05		
2005	EEE*	8
	Flanders	100
	WNV*	31
	Highlands J	6
8-Sep-04		
2004	EEE*	2
	Flanders	56
	WNV*	100
	Highlands J	0

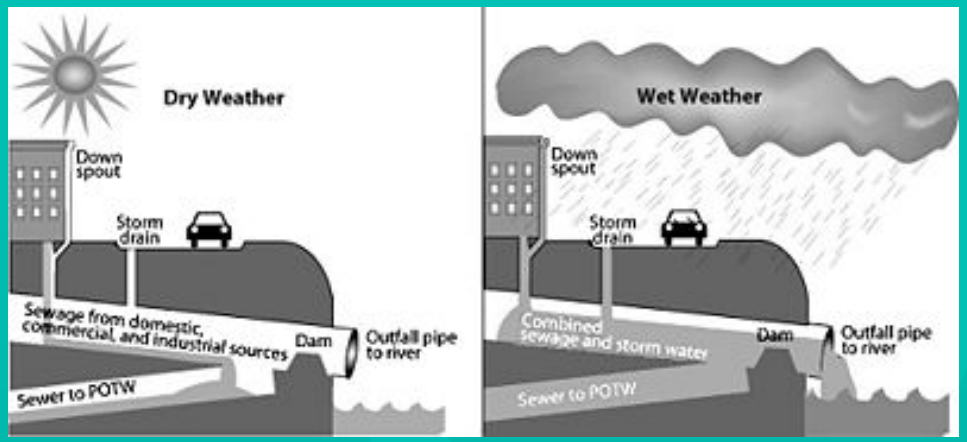
Source: R. Kelly



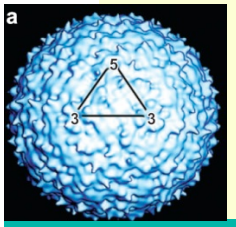
Combined Sewer Systems

Designed to carry both sewage and storm water.

After a heavy rain, water flow increases dramatically, and when it exceeds the maximum capacity of the sewer systems overflows directly into bodies of water with minor treatment.



Atlanta has 7 CSO facilities, many of them are located in close proximity to residential, commercial and recreational sites.



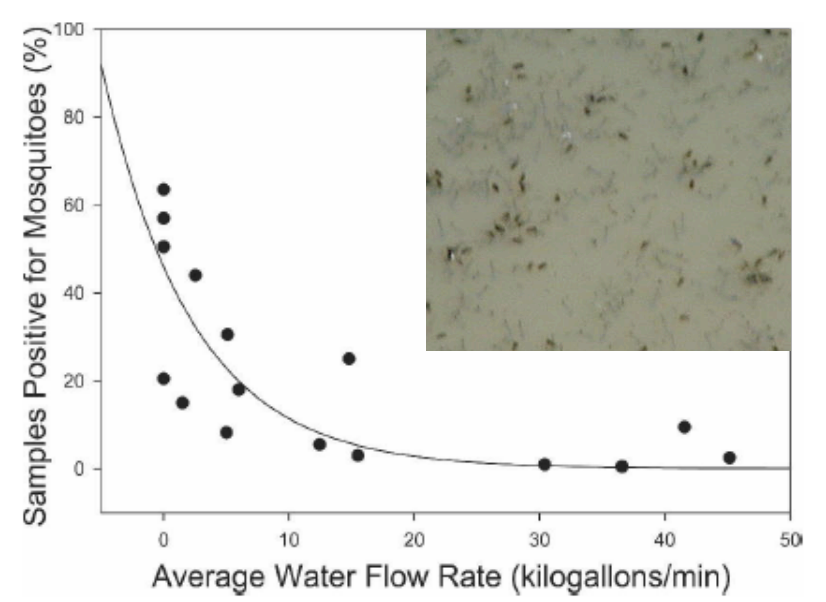
CSSs and WNV

Significant sources of *Cx. quinquefasciatus* larvae.

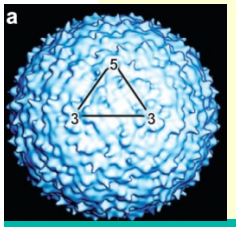
Am. J. Trop. Med. Hyg., 77(3), 2007, pp. 478–484

Combined Sewage Overflows (CSO) Are Major Urban Breeding Sites for *Culex quinquefasciatus* in Atlanta, Georgia

Lisa M. Calhoun, Melissa Avery, LeeAnn Jones, Karina Gunarto, Raymond King, Jacquelin Roberts, and Thomas R. Burkot*
Division of Parasitic Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia



Does the high mosquito productivity translates in a higher WNV transmission risk?



Geospatial Methods

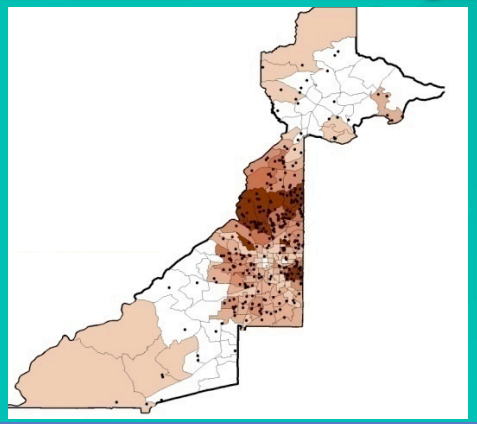
Spatial analysis of WNV infection in humans, birds and mosquitoes

2001-2007 geocoded records provided by Fulton County Department of Public Health

Integration of data into a GIS

Estimation of WNV incidence and infection prevalence at the census tract level.

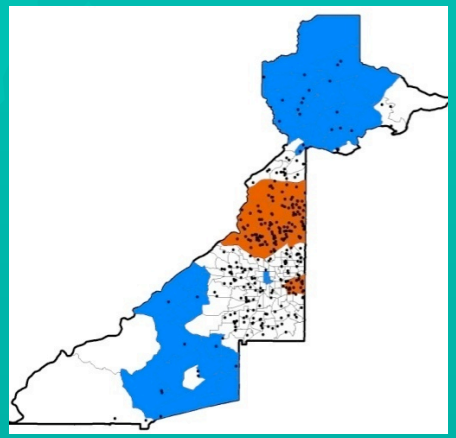
Application of explicit spatial statistical tests.



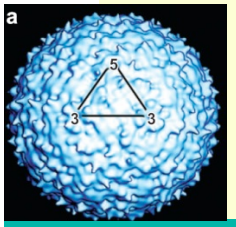
Smoothed rates

$$I = \frac{\frac{N}{S_0}\sum_i \sum_j W_{ij} Z_i Z_j}{\sum_i Z_i^2}$$

Local Moran's *I* test

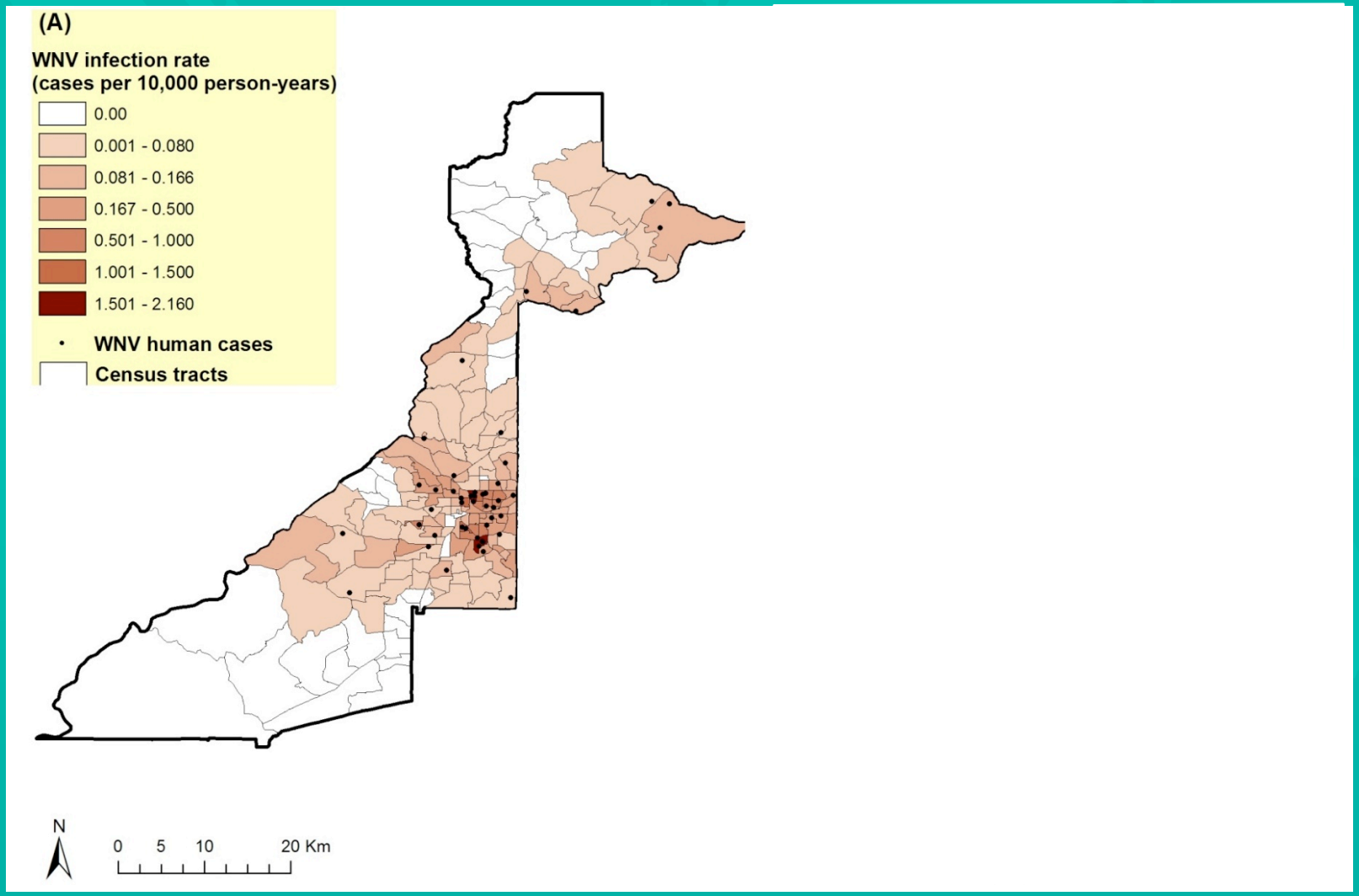


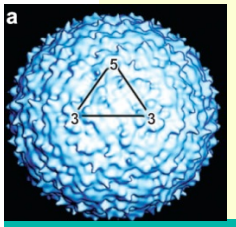
Significant clusters of high or low infection rates



Human infection

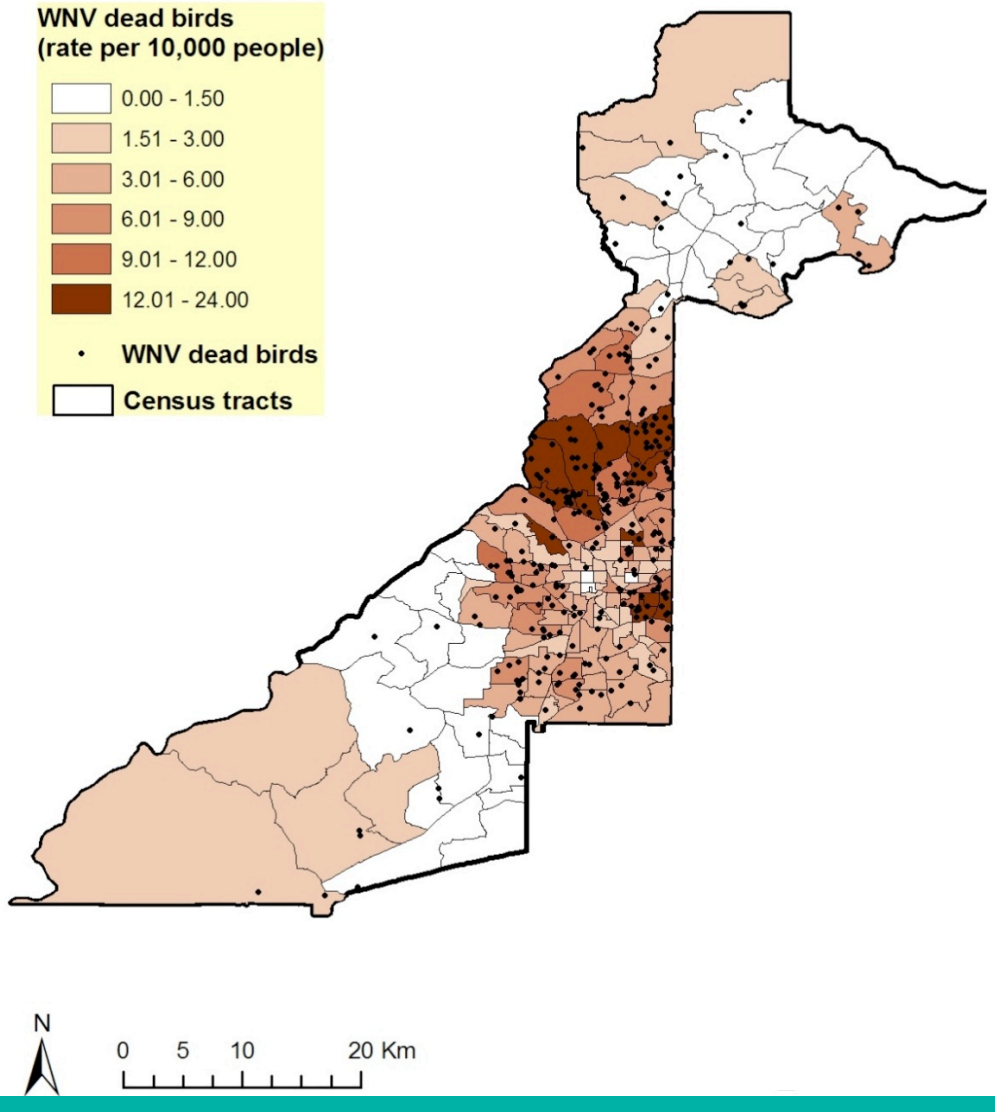
2001-2007 human cases per census tract.

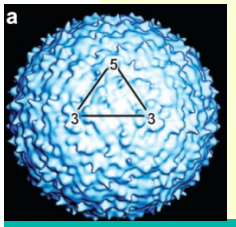




Dead bird surveillance

WNV dead birds per 10,000 people to correct for population distribution

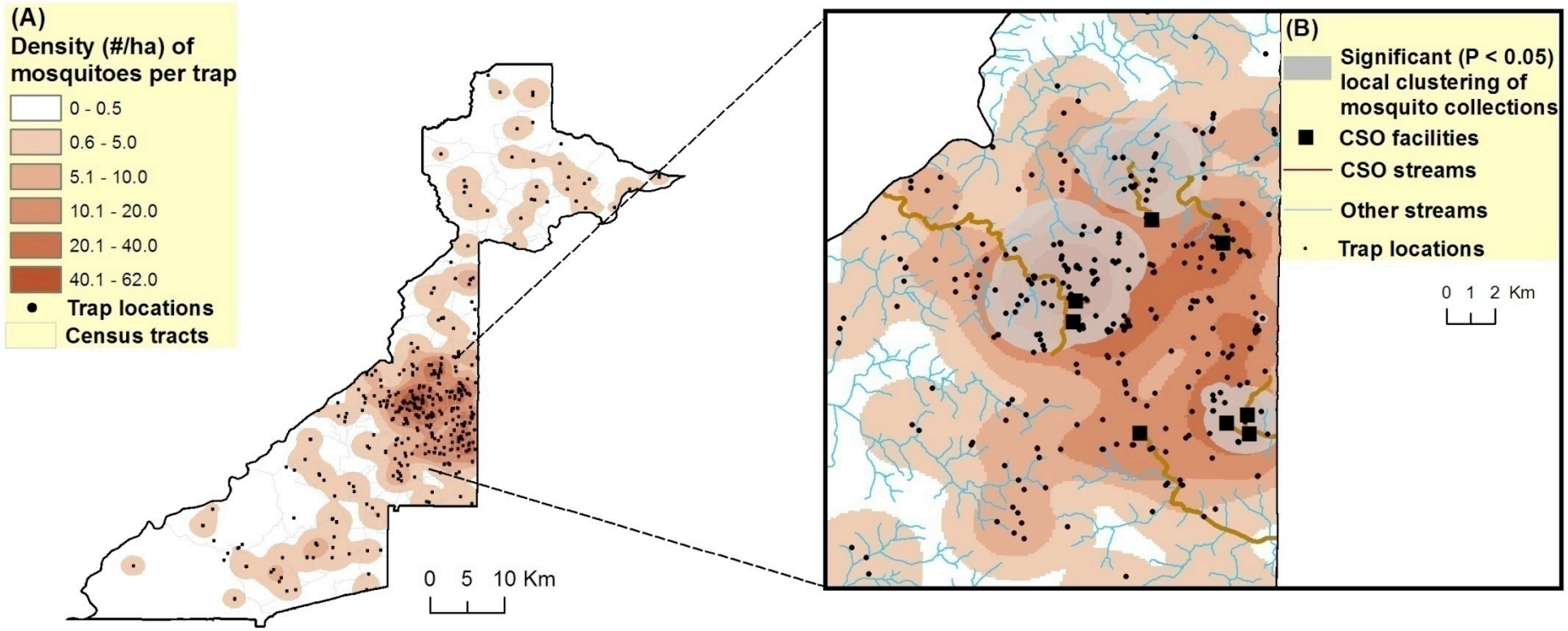


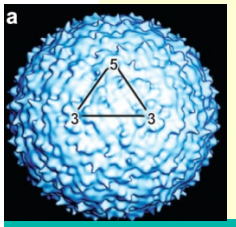


Mosquito surveillance

Number of *Cx. quinquefasciatus* per trap-night.

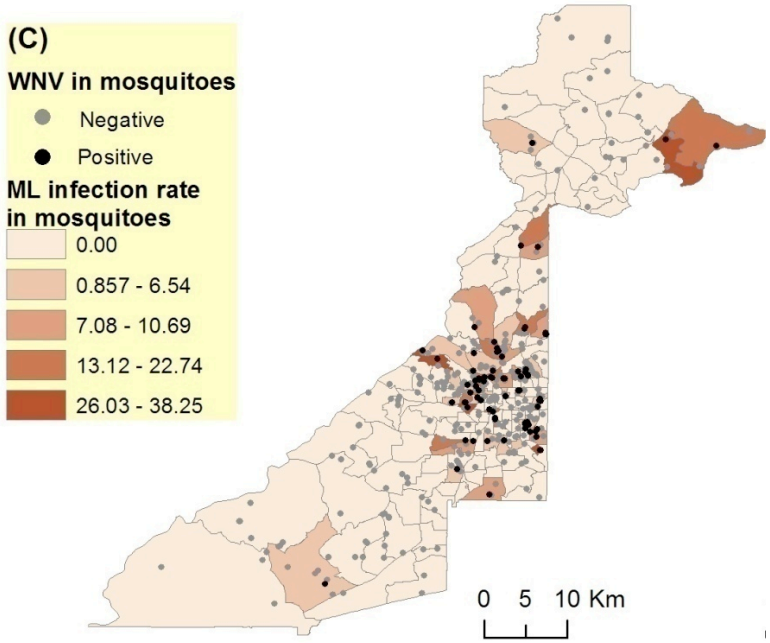
Significant local spatial clustering up to 1,900 m of a positive trap around 3 of the 4 CSO streams.



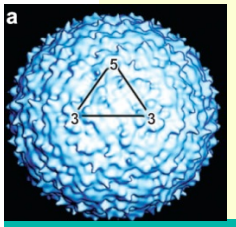


Mosquito surveillance

***Cx. Quinquefasciatus* ML Infection Rate (unequal pool size)**
Estimations at the census tract level to avoid bias.

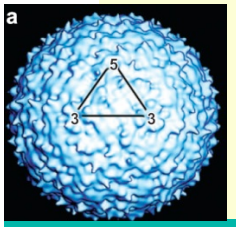


Although not statistically significant, southern transmission foci at the Grant Park – Zoo area.



Conclusions

- *Cx. quinquefasciatus* abundance and WNV infection in mosquitoes, birds and, humans were spatially clustered in close proximity to CSO streams.
- Southern (Confederate, Boulevard and Custer) CSO streams associated with human, bird and mosquito infections.
- Northern (North Ave. and Tanyard) CSO streams associated with bird and mosquito infections.
- Potential use for future monitoring of WNV in Atlanta

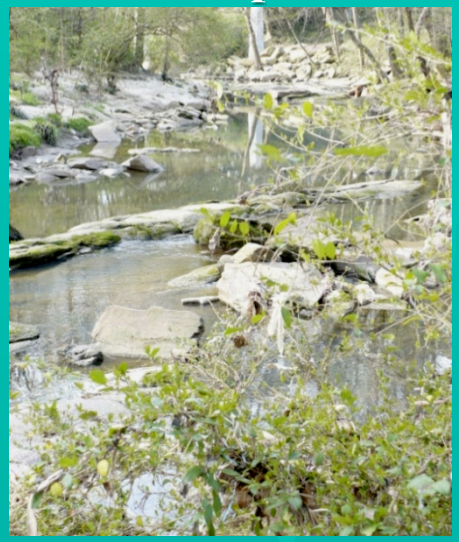


Ongoing research

1. Determinants of WNV spatial clustering.

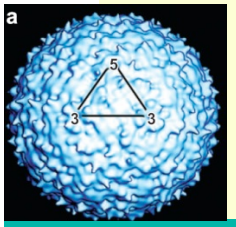
2. ENVS-Emory field and lab research to understand the effect of CSOs on *Cx. quinquefasciatus* population dynamics and WNV transmission.

http://www.envs.emory.edu/news/WNV/index.htm



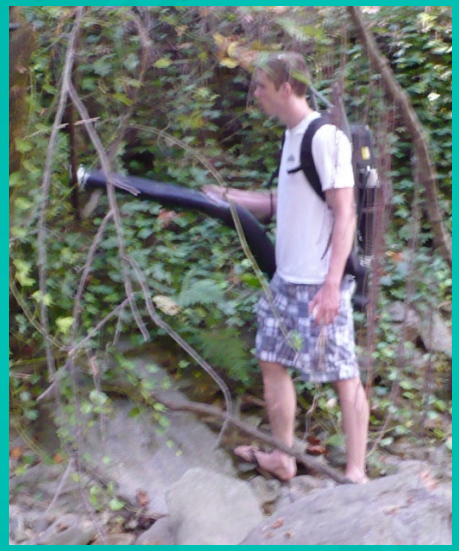
Tanyard creek
(CSO affected stream)

Peavine creek
(Non-CSO affected creek)



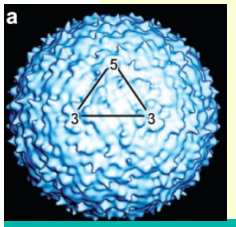
Field research

Weekly mosquito monitoring by dipping (immatures), light traps, gravid traps and back-pack aspirators (adults).



Weekly evaluation of water quality (Dissolved Oxygen, Ph, Temperature, Chlorine, Ammonia, Nitrates, Phosphates, Fecal coliforms and *E. coli*).

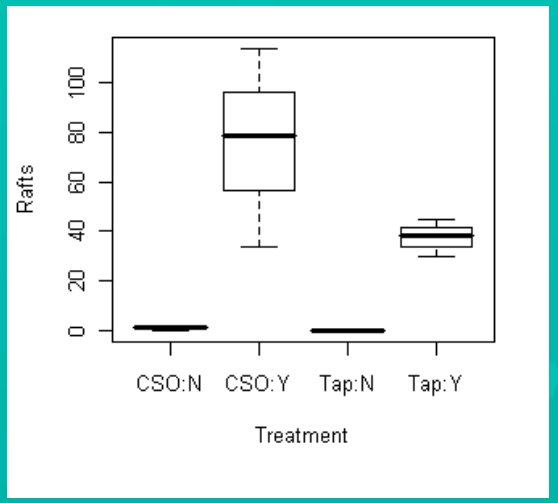
WNV and blood meal analysis of adult mosquitoes at UGA.

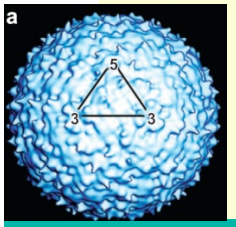


Experimental research

To perform laboratory and semi-natural experiments to understand the role of CSO on mosquito population dynamics.

* Oviposition preference
* Fitness and behavior
* Density dependence





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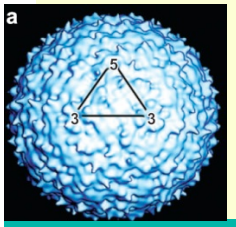

WNV in Georgia

Human cases

- Most of 2001-2007 GA human transmission occurred in metropolitan Atlanta, particularly in Fulton County (Atlanta), muscogee cty (Columbus) and Chatham Cty h).