Mosquito Management Programs and West Nile Virus in Michigan 2002

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Michigan State University

National West Nile Virus Conference

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- Michigan West Nile virus working group

Purpose of the Presentation

- Resume the 2002-2003 outbreaks of WNV in Michigan
- Present epizootic and epidemic spatial and temporal profiles in relation to West Nile virus infection rates in field populations of mosquitoes
- Present a posthoc risk, modeling and statistical analysis:
  - Quantifying spatial and temporal lags that describe an underlying biological process:
    - Dead crow reporting data suggest localized extinction of crows, or exhaustion of the susceptible crow subpopulation, within an epizootic region
  - Suggesting vector control was effective in reducing risk
    - Mediated through a reduction in virus infection rate in the *Culex* vector populations
    - Reflected in a quantifiable risk reduction analysis in the human population

Michigan Department of Community Health Announces Probable Human Cases of West Nile Virus

August 16, 2002

Michigan Department of Community Health Chief Medical Executive, David R. Johnson M.D., today announced two probable human cases of West Nile virus. Laboratory samples have been sent to the Centers for Disease Control and Prevention for confirmatory testing.

The first case involves an 82 year-old male from Southeast Michigan who was hospitalized and has been released in good condition. The second involves a 63 year-old male from Southeast Michigan who is currently hospitalized and appears to be improving.

"We are encouraged that both of these gentlemen appear to be recovering and we will continue to work with health care providers throughout Michigan to quickly identify any other potential human cases," said Dr. Johnson. "The most important thing a person can do to protect themselves from West Nile virus is to follow the common-sense precautions to minimize exposure to mosquitoes."

Department of Community Health

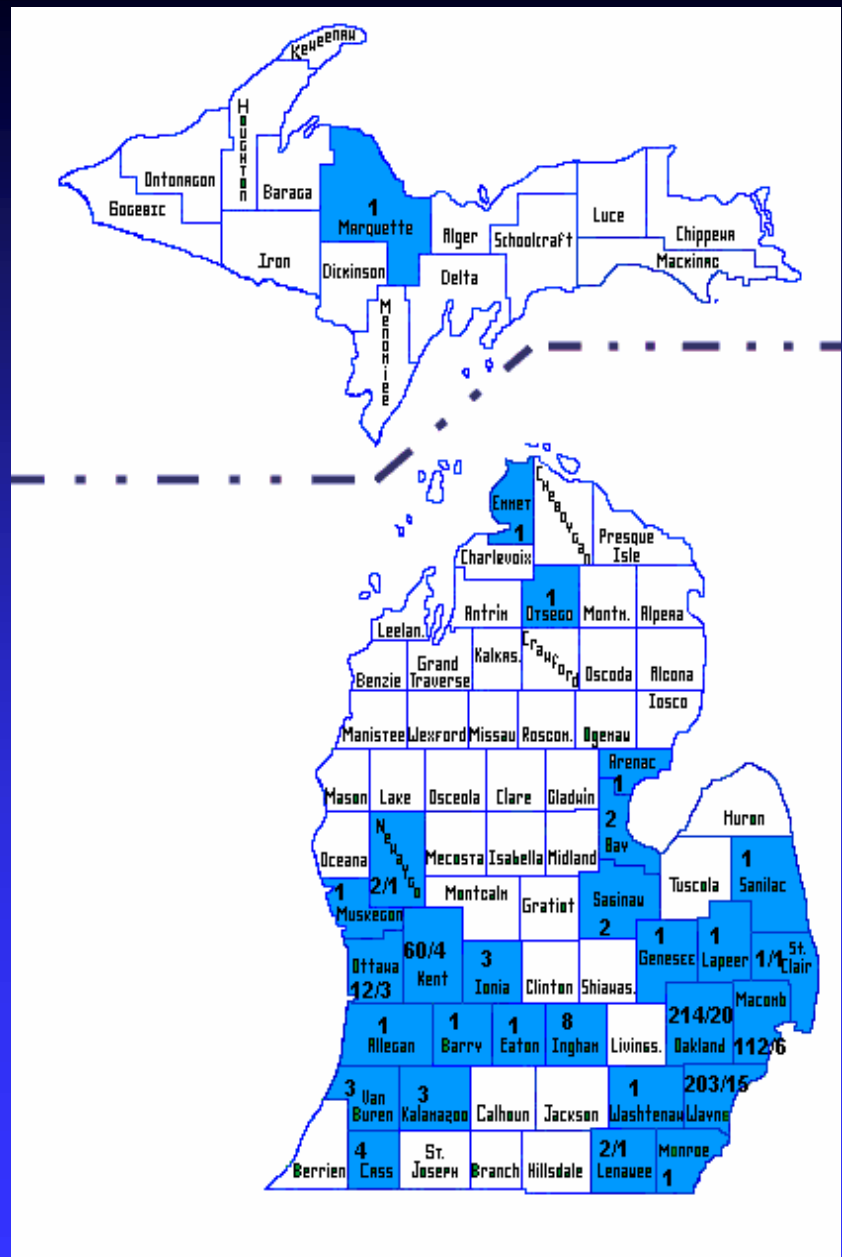
WNV Human cases Michigan 2002*

(Includes probable and confirmed cases, all clinical syndromes)

644 cases

51 deaths

***(Total Cases/Deaths)**



Department of Community Health

West Nile Virus Case Summary

Total Laboratory Positive Cases: 644

West Nile Meningo-encephalitis cases: 559 (87%)
- **Age range: .75-95 yrs**
- **Average age: 57.8 yrs**

West Nile Fever cases: 57 (9%)
- **Age range: 3-80 yrs**
- **Average Age: 47.7 yrs**

Unknown cases: 28 (4%)

Deaths: 51 (9%)
- **Age range: 24-95 yrs**
- **Average age: 74.5 yrs**

MDCH Department of Community Health

Additional Arboviruses in 2002

- St. Louis Encephalitis: 3 cases
- Eastern Equine Encephalitis: 6 cases
- LaCrosse Encephalitis: 11 cases
- Powassan virus: 1 case (Emmet Co.)

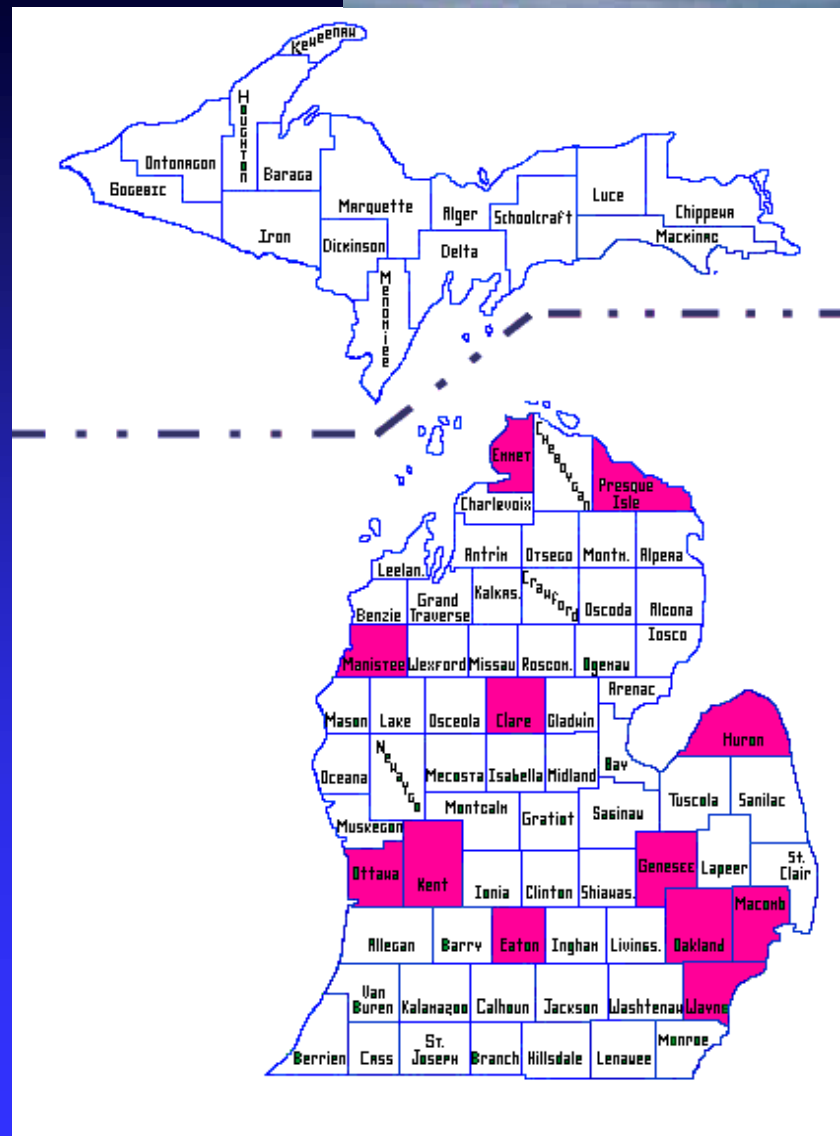
  (tick borne encephalitis)

  First case in the state

MDCH Department of Community Health

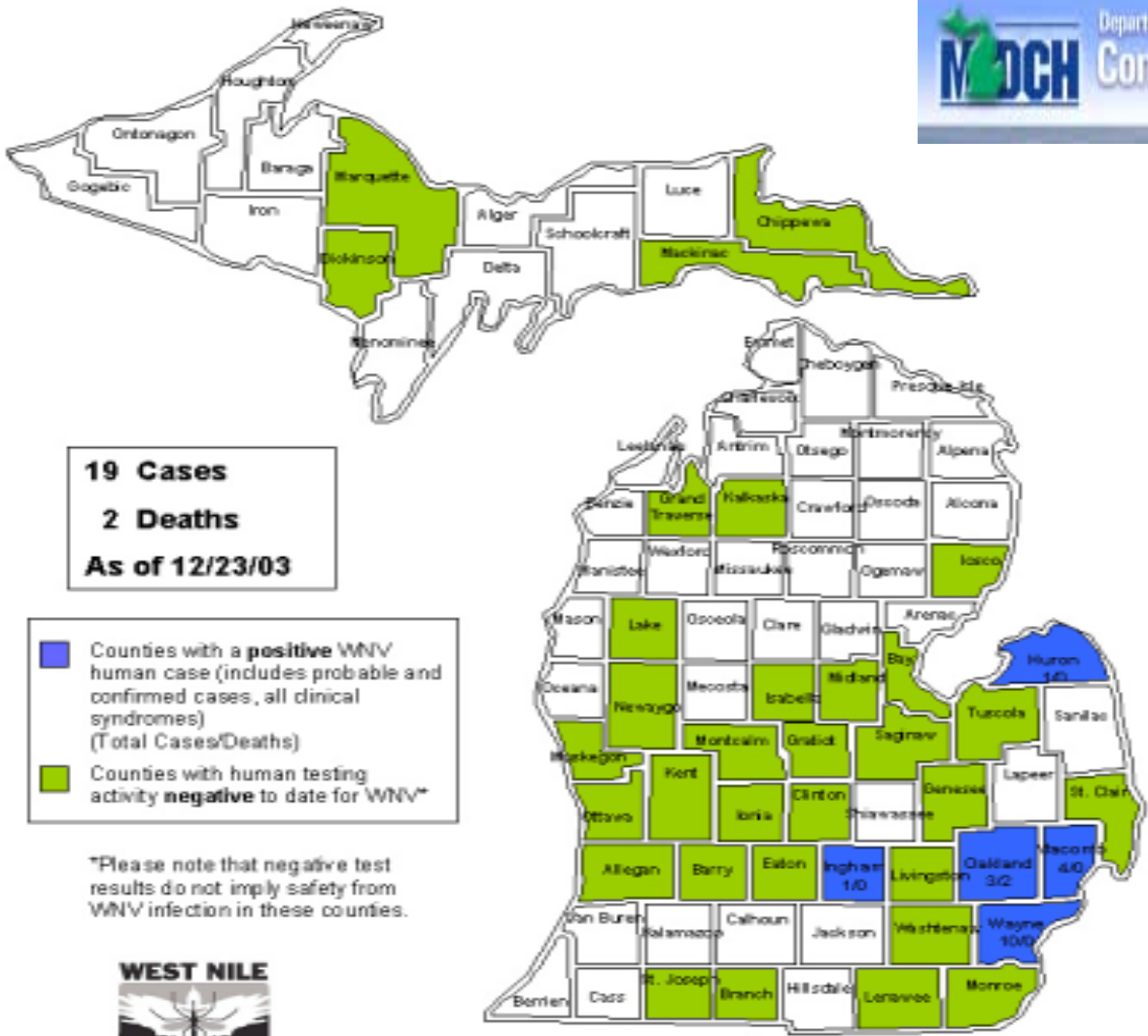
Additional Arbovirus Cases Michigan, 2002

County	SLE	EEE	LAC	POW
Clare			1	
Eaton			1	
Emmet				1
Genesee			3	
Huron	1			
Kent			1	
Macomb		2	1	
Manistee			1	
Oakland		1	2	
Ottawa		1		
Presque Isle			1	
Wayne	2	2		



2003 Michigan West Nile Virus Human Testing & Cases
As of December 23, 2003

Department of Community Health



19 Cases
2 Deaths
As of 12/23/03

- Counties with a **positive** WNV human case (includes probable and confirmed cases, all clinical syndromes) (Total Cases/Deaths)
- Counties with human testing activity **negative** to date for WNV*

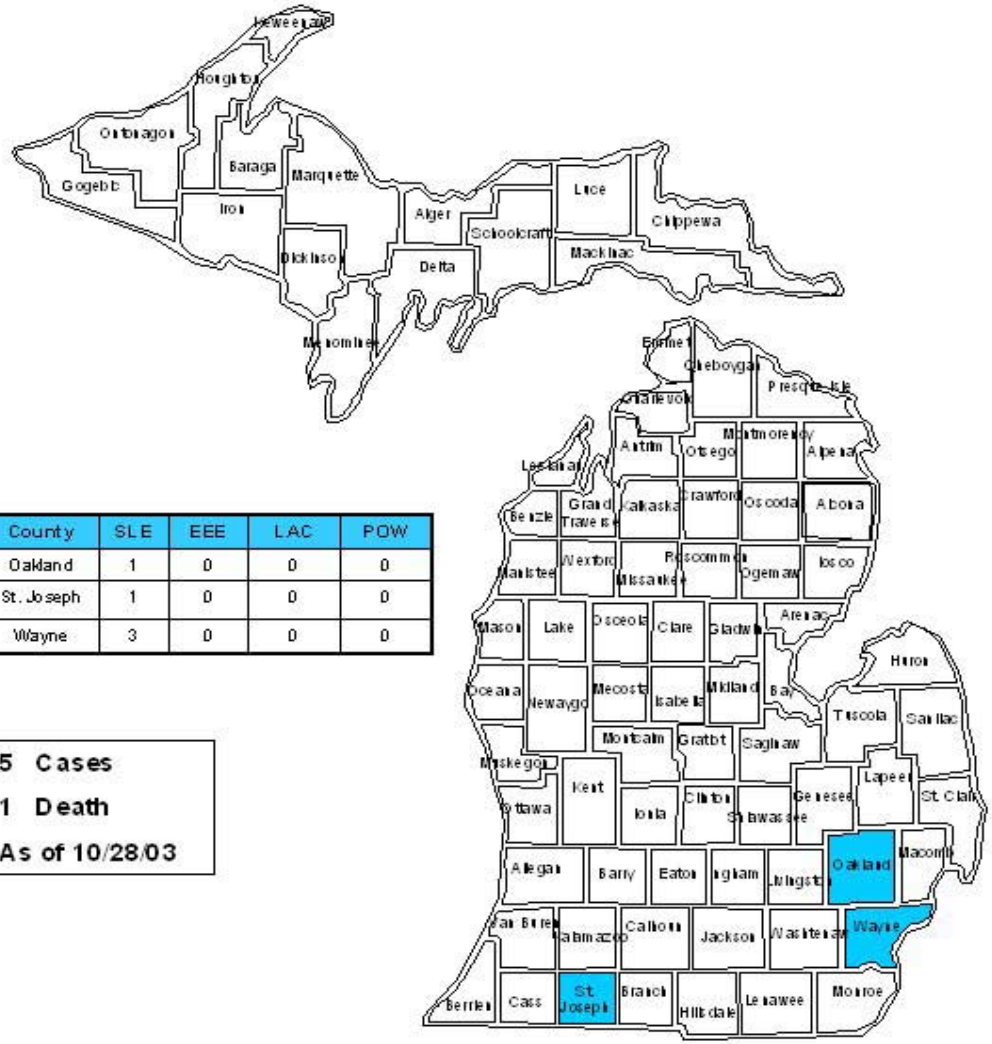
*Please note that negative test results do not imply safety from WNV infection in these counties.

WEST NILE VIRUS Working Group

Michigan Department of Agriculture
Michigan Department of Community Health
United States Department of Agriculture
Michigan Department of Natural Resources
Michigan Department of Environmental Quality
Michigan State University

Note: In 2002, there were 644 human cases in 28 counties with 51 deaths in 8 counties.

Other Arboviruses in Michigan, 2003



County	SLE	EEE	LAC	POW
Oakland	1	0	0	0
St. Joseph	1	0	0	0
Wayne	3	0	0	0

5 Cases

1 Death

As of 10/28/03

Michigan Department Of Community Health

MDCH

Note: In 2002, there were three cases of SLE, six cases of EEE, eleven cases of LAC, and one case of POW in Michigan.

2002 vs 2003: Michigan WNV In Humans

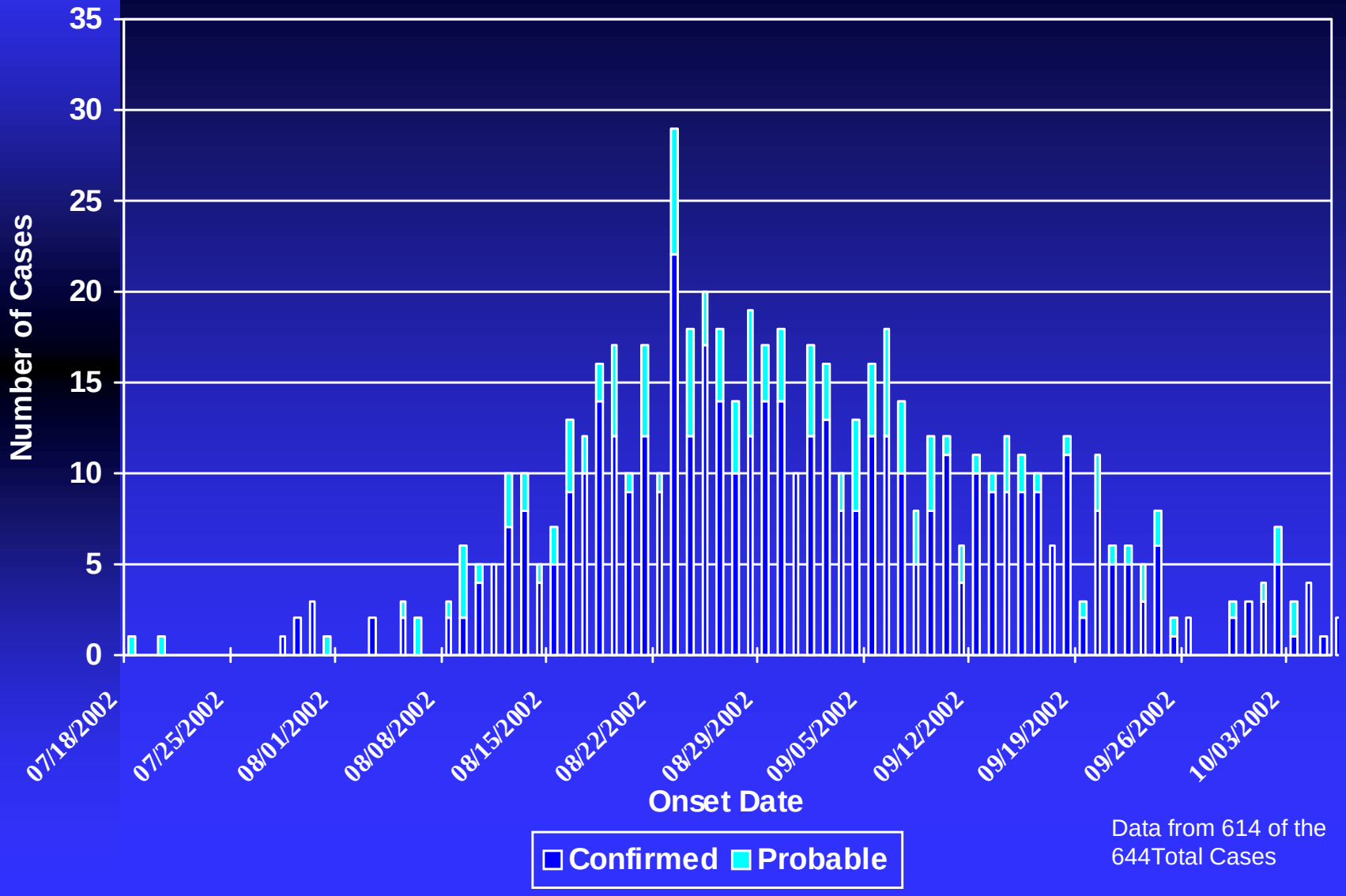
2002:

- 644 cases
- 51 deaths
- 559 cases of serious neurological illness (87%)
- 3 SLE cases (no deaths)

2003:

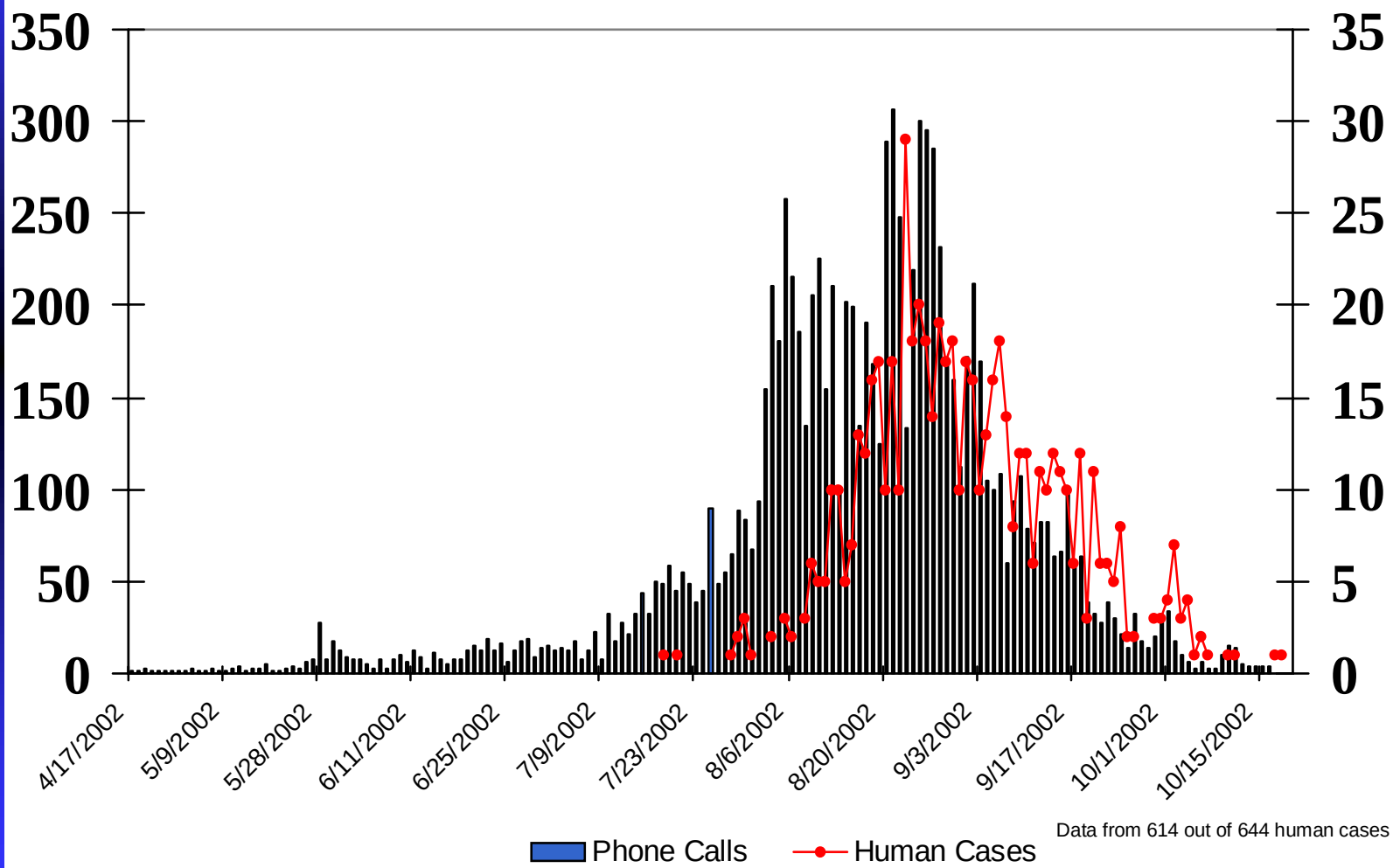
- 19 cases
- 2 deaths
- 15 cases of serious neurological illness (79%)
- 5 SLE cases (one death)

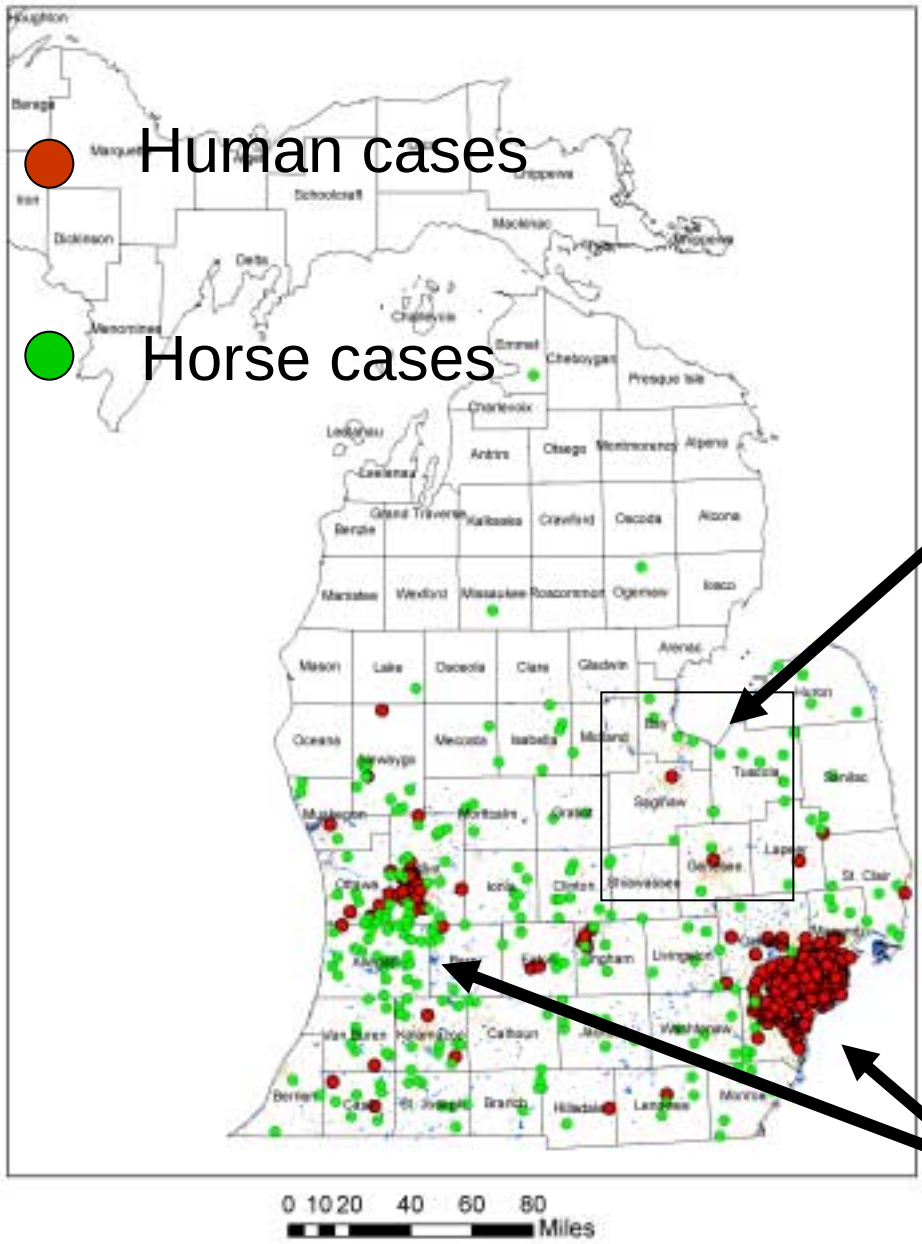
Onset Date of Symptoms Among Human West Nile Virus Cases in Michigan for 2002



Data from 614 of the 644Total Cases

Phone Reports of Dead Birds versus Human Cases in Michigan for 2002





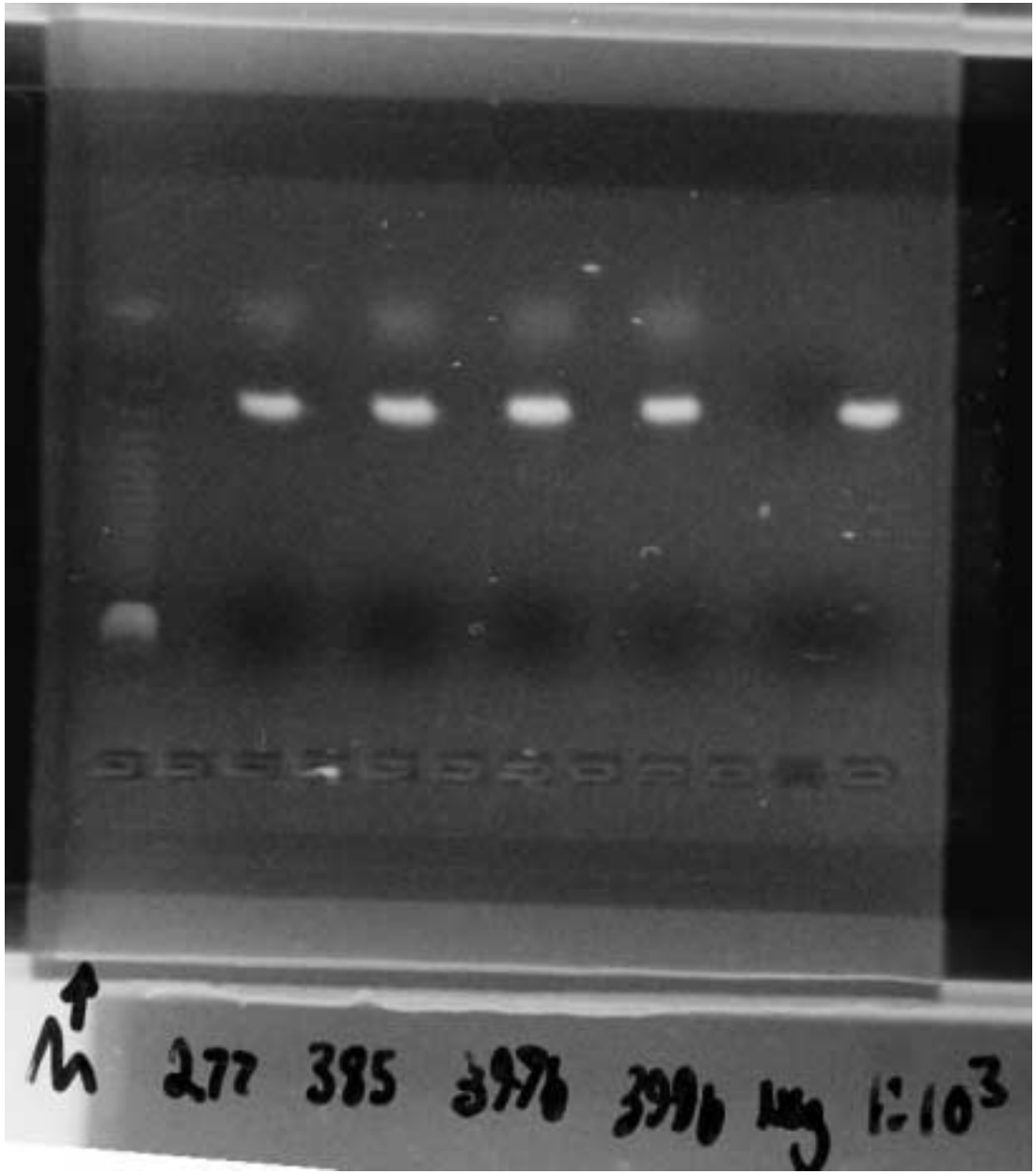
GIS database for human, horse, and bird cases established for 2002 data

Vector control: 4 county level programs, one partial county program, and several township and town programs

No vector control, and Little emergency control Response in 2002

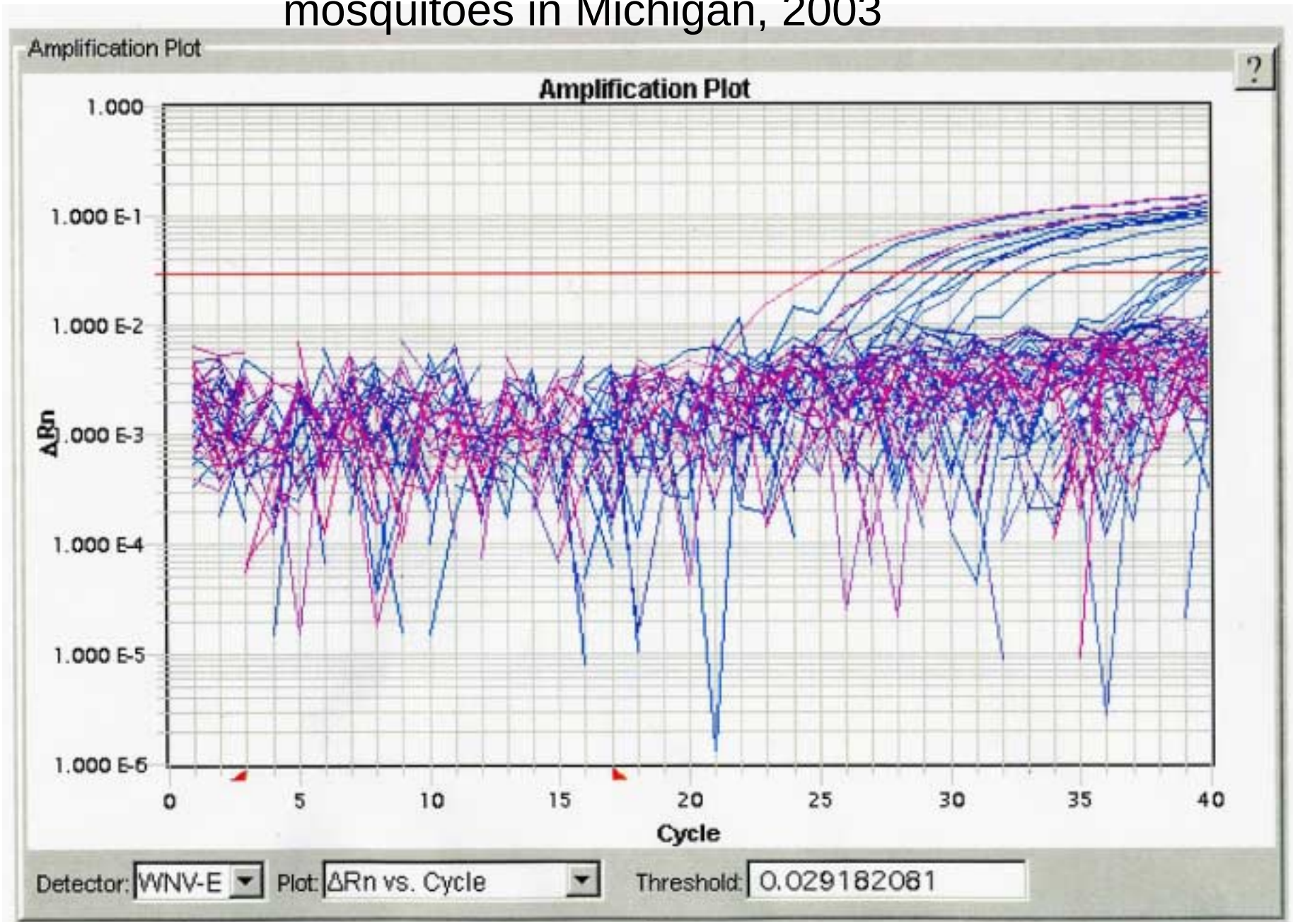
Analysis of Mosquito Infection Rates, 2002, Michigan

- Mosquitoes sampled by light trap and gravid trap networks
  - Mosquito control programs
  - Michigan State University research network
  - County health department networks
- Sorted to species, pooled, tested by standard RT-PCR and quantitative RT-PCR
- Data expressed as Minimum Infection Rates

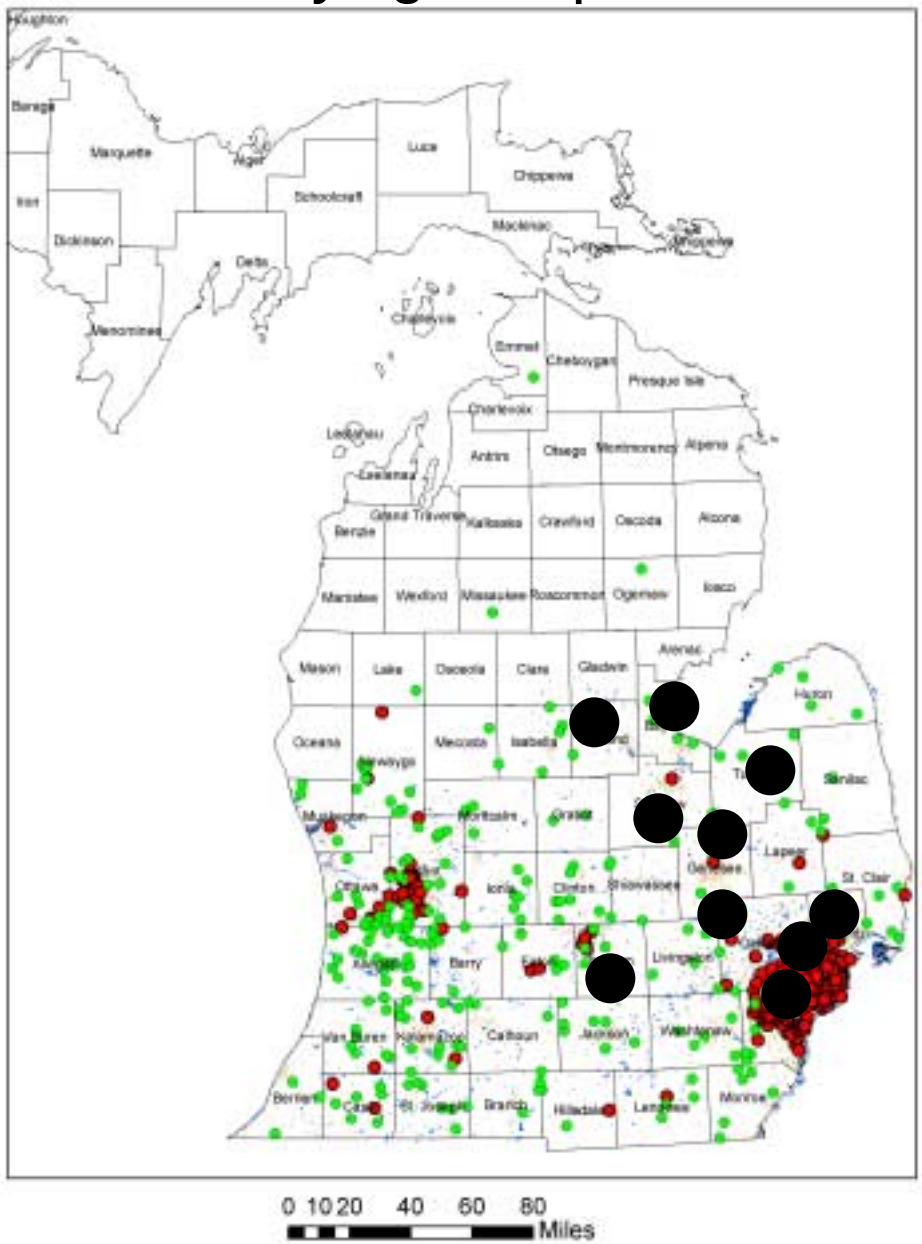


Reverse transcription PCR detection of WNV in field caught mosquitoes from Michigan, 2002

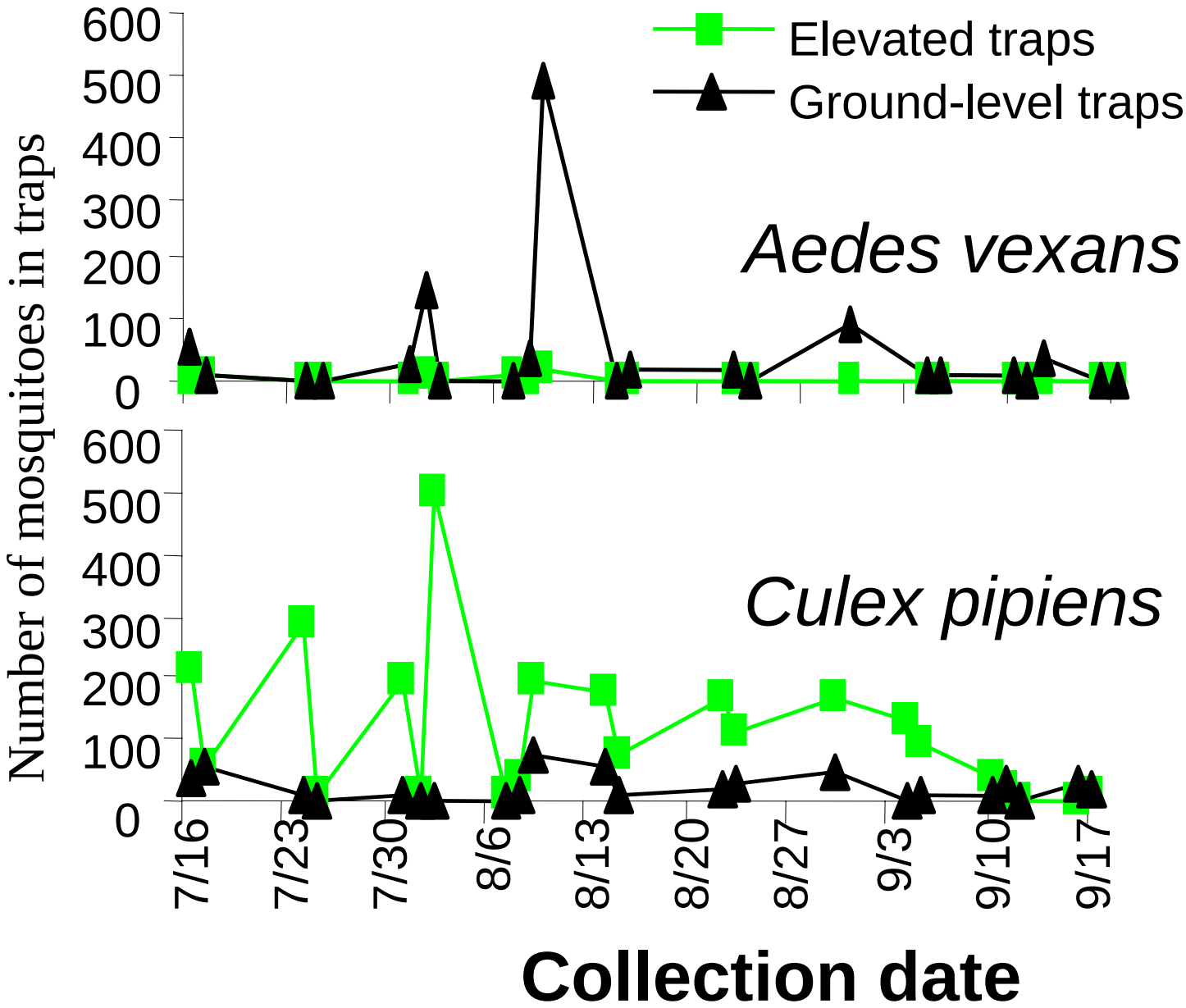
Quantitative PCR amplification of WNV naturally infected mosquitoes in Michigan, 2003



Sources of mosquito collections for testing, from light traps, gravid traps, and New Jersey light traps, 2002



Culex pipiens females were more abundant in CDC traps
In the tree canopy than at ground level, 2002

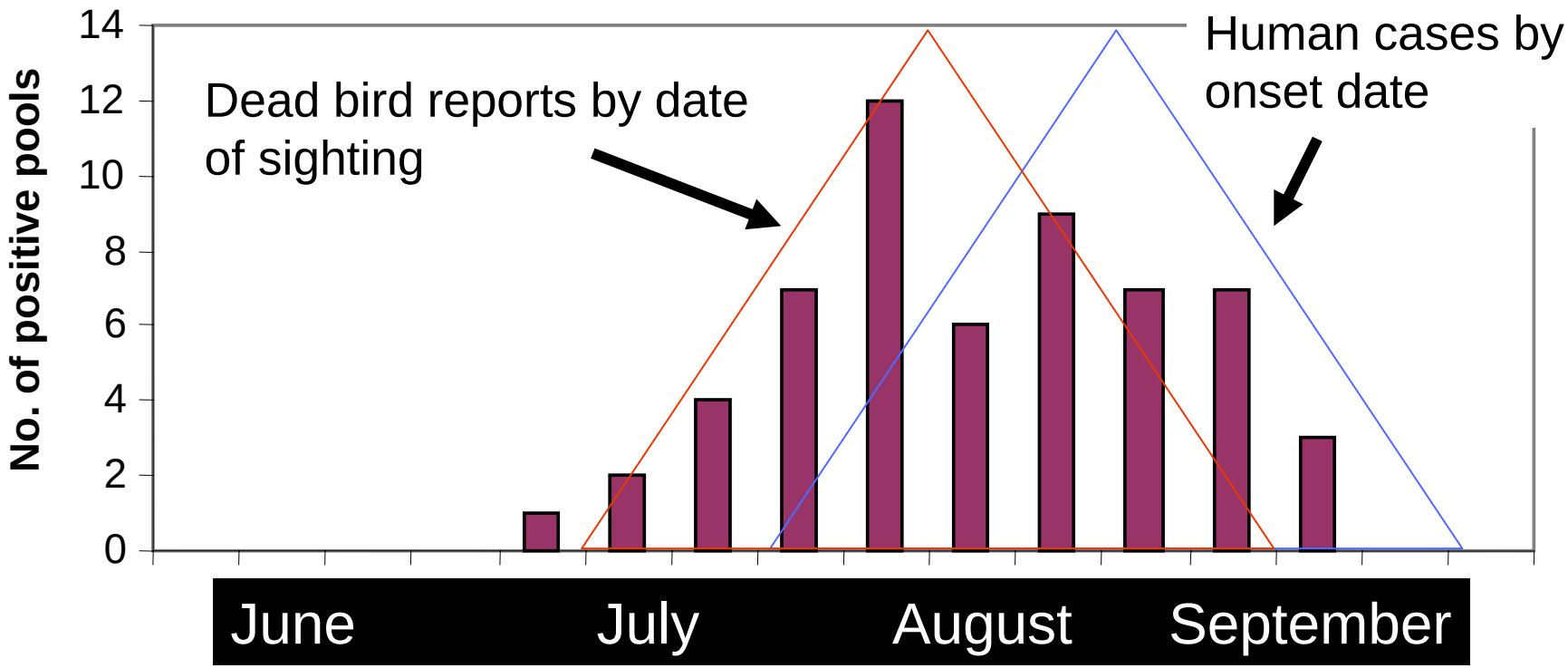


Minimum infection rates in Michigan mosquito populations, West Nile virus epidemic, 2002

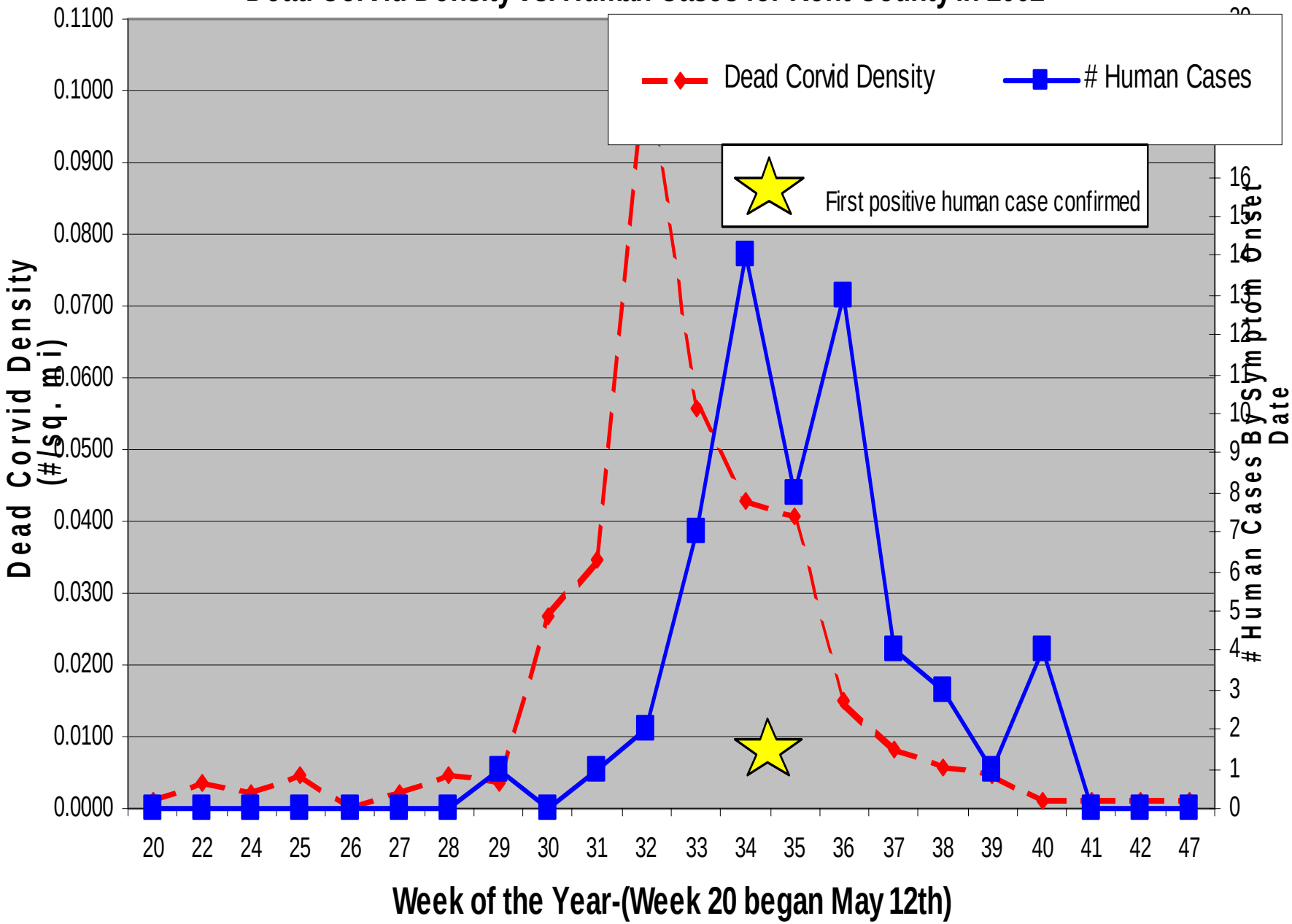
Species	No. tested	No. pools	No. positives	estim. MIR*
Culex spp	5768	431	27	4.7
Cx. pipiens	1182	121	23	19.5
Cx. restuans	58	25	3	51.7
Cx. salinarius	318	30	2	6.3
Cx. territans	2	2	0	0.0
Cq. perturbans	2000	201	1	0.5
Culiseta spp.	188	28	0	0.0
Ochl. triseriatus	76	30	0	0.0
Ochl. trivittatus	569	31	1	1.8
Or.signifera	7	6	0	0.0
Ochl. canadensis	32	7	0	0.0
Ae. vexans	2003	188	1	0.5
An. punctipennis	270	83	0	0.0
An. quadrimaculatus	337	74	0	0.0
Ur. sapphirina	14	8	0	0.0
TOTAL	12824	1265	58	4.3

*Maximum likelihood method, number pf positive pools/1,000 mosquitoes tested

Positive Mosquito Pools by Week of Year, Michigan, 2002
Diagrammatic representation of events



Observation: West Nile virus co-amplified in mosquito and corvid populations in Michigan, 2002; and this process preceded the onset of human cases



Observation: note acceleration of reports of dead corvids at week 29, which preceded human epidemic curve staring in week 31. Grand Rapids metropolitan area, 2002.

IEAST: Integrated Environment for Analysis of STARMA Models

- STARMA: Space-Time Autoregressive Moving Average
- Based on Space Time Partial Autocorrelation Functions
  - Drop off in partial autocorrelation, vs. decay, indicates a significant temporal or spatial lag correlation
- Collaborators: Dr. Bryan Epperson, graduate student Cheng Yu Lee
- http://fried.for.msu.edu/~ieast/
- The following information does not constitute citable publication of these preliminary findings

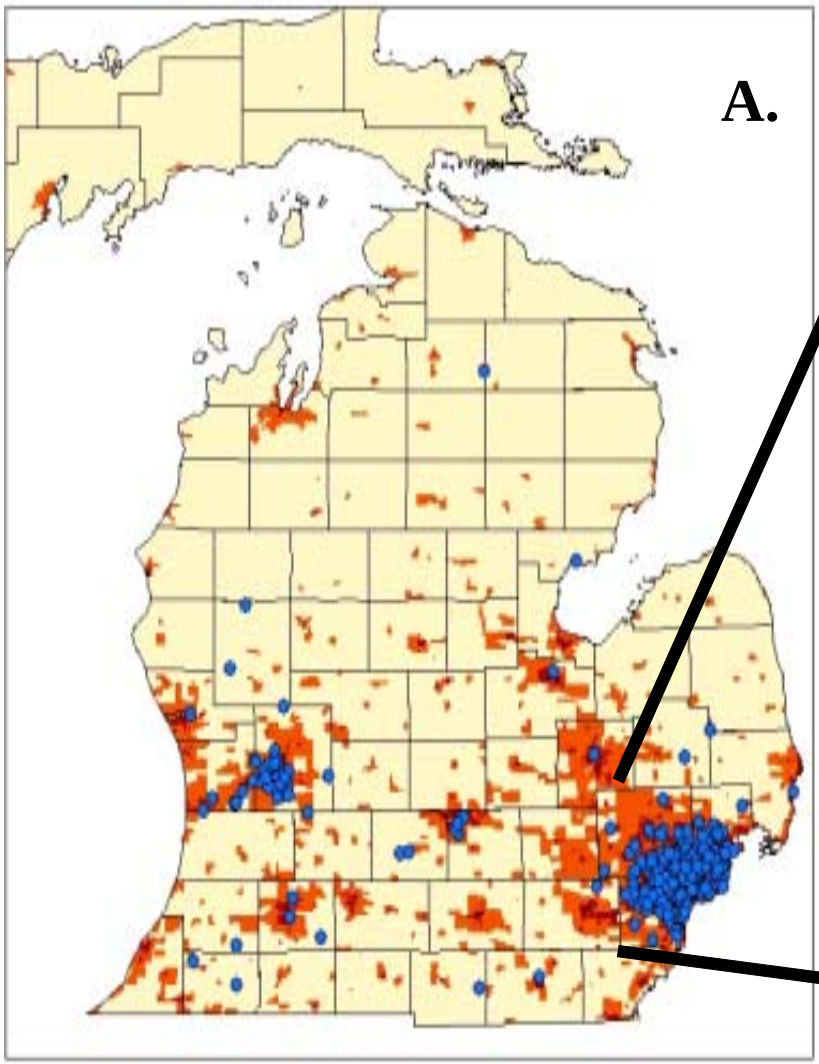
Conceptual spatial lag process for dead corvids during an epizootic of WNV: Modeling Space Time Autoregression Moving Average approach:

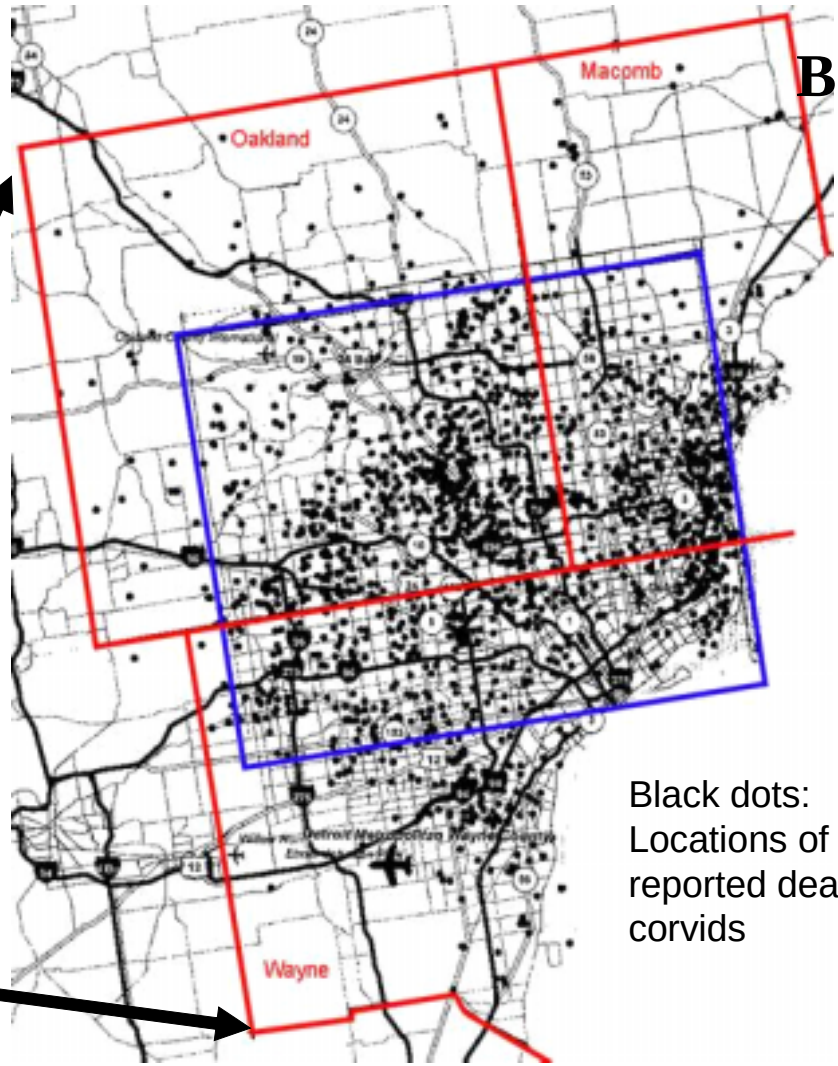
	4	3	4	
4	2	1	2	4
3	1	0	1	3
4	2	1	2	4
	4	3	4	

Landscape is divided into cells of equal size.

Modeling considers lags in space (from centroid cell 0 to surrounding cells) simultaneously with lags in time (here, weekly lags were used)

A. Home address georeferenced human cases (blue dots)
B. Georeferenced dead crow sightings in SE Michigan (ca. 1,557 corvid sightings where precise locations were determined)





Results of IEAST (STARMA) Modeling

Spatial Lag Analysis

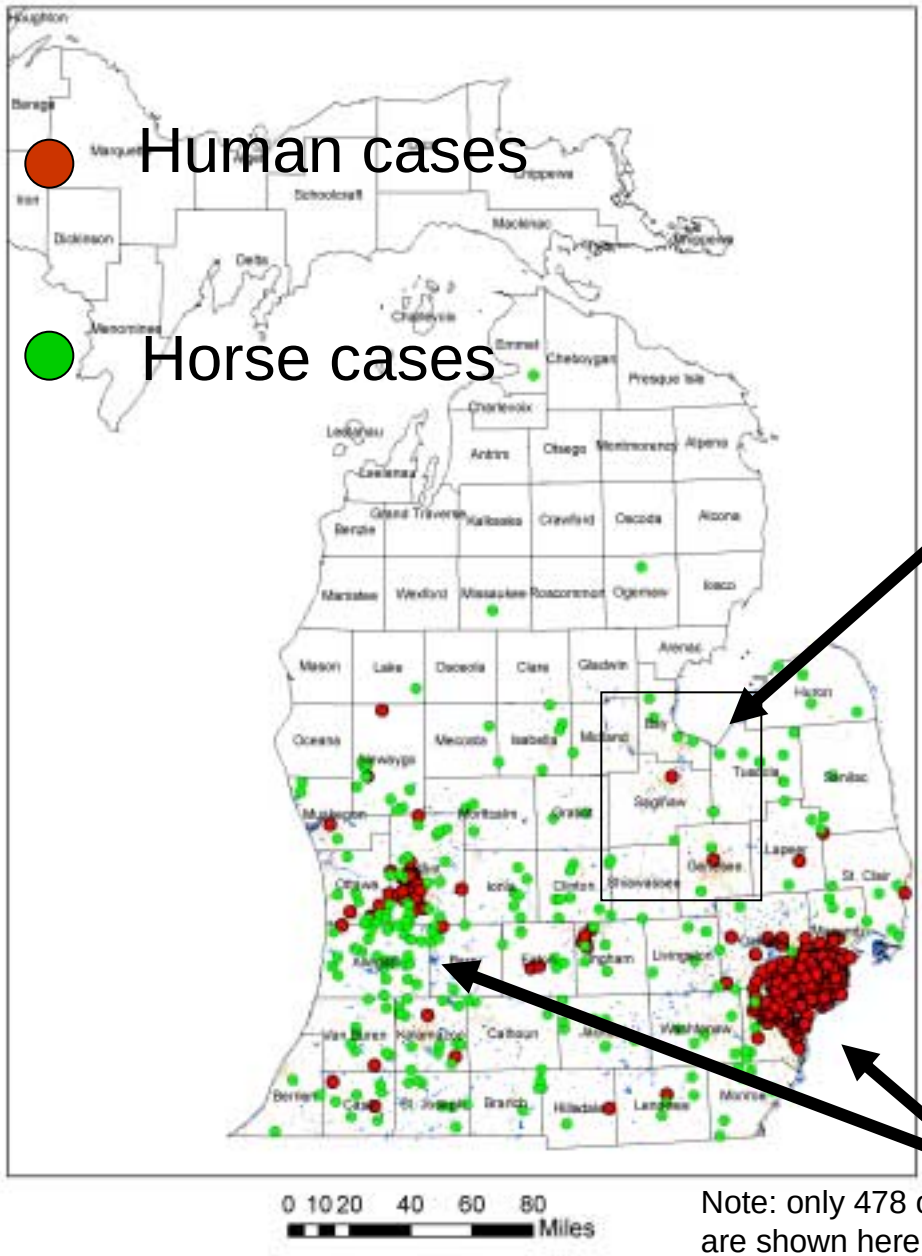
Week Lag 0 Lag 1 Lag 2 Lag 3

1. $Z_t = (0.29)Z_{t-1} + (0.43)W_1Z_{t-1}+(0.05)W_2Z_{t-1}+(-0.06)W_3Z_{t-1}$
2. $+(0.04)Z_{t-2}+(-0.16)W_1Z_{t-2}+(-0.12)W_2Z_{t-2}+(-0.05)W_3Z_{t-2}$
3. $+(-0.01)Z_{t-3}+(-0.07)\ W_1Z_{t-3}+(-0.12)W_2Z_{t-3}+(-0.05)W_3Z_{t-3}$

- There was no correlation after temporal lag 3 (i.e., three weeks)
- The parameters beyond spatial lag 3 were statistically insignificant
- Spatial lags 0 and 1 at week 1 were positive, but at week 2 and 3 tended to be zero or negative; suggesting that crow populations were “exhausted” locally in small clusters of epizootic activity
- Red coefficients are statistically significantly different from zero

Observation: in week one, the spatial lags are positive and very local. By week two, these spatial lags become negative. The analysis suggests that there was a localized extinction of corvids (mostly American crows) by week 2 and 3 of the epizootic, and that transmission is locally intense; i.e., there were hot spots of epizootic activity within the urban landscape in metropolitan Detroit, 2002.

Did Mosquito Control Make A Difference In Michigan in 2002?



Mosquito control

Visit www.mimosq.org
For further information
On Michigan mosquito control programs and the state mosquito control association

No mosquito control

Note: only 478 of the 644 human case locations are shown here. Horse case data provided by Mich Dept of Agriculture, Animal Industry Division

Relative Risk of WNV in Michigan Citizens

- Analyst: Dr. Paul Bartlett, former EIS officer and MSU faculty member in veterinary epidemiology
- Data: Number of human cases of confirmed WNV infection classified by residence within the jurisdiction of an established mosquito control program or not
- Analysis adjusted for human population density (ca. 10% of state's population lives within mosquito control district jurisdictions)
- Epi Info incidence tabulation and relative risk analysis analysis was invoked to estimate relative risk

Relative Risk of WNV in Michigan Citizens, 2002, continued

- 5 county area with mosquito control: 6 human cases, population = 900,480
- Remainder of state: 638 human cases, population = 9,090,337
- Epi Info analysis of relative risk by incidence tabulation: Relative risk = 0.09, 95% CI = 0.04 to 0.21
- Preventive fraction = 90.51%, 95% CI = 78.8 – 95.8%
- Evidentiary conclusion: people living inside a mosquito control jurisidiction in Michigan had a ca. 0.09 relative risk of WNV infection compared to people living outside of the vector control jurisdictions
- Conversely, there was a ca. 10.53 elevated risk of WNV infection in people in Michigan living outside of the mosquito control jurisdictions, with 95% CI = 4.7 to 23.5.

West Nile Virus Infection Rates and Mosquito Control, Michigan, 2002

- Mosquito control jurisdictions
- 6,844 *Culex* in 579 pools tested
- 25 pools positive
- Minimum field infection rate = 3.65/1,000
- Maximum likelihood method

- Outside of mosquito control jurisdictions
- 1,052 *Culex* in 106 pools
- 30 pools positive
- Minimum field infection rate = 28.5/1,000
- Maximum likelihood method

2 x 2 contingency table analysis of number of positive *Culex* pools tested in a region of Michigan with mosquito control programs compared to areas without mosquito control, 2002 WNV epidemic

	No. Pos. Pools	Total Pools
Mosquito Control	25	579
No Mosquito Control	30	106

Mosquito control MIR: 3.65
No mosquito control MIR: 28.5

Chi-square with Yates correction for continuity:
49.24, 1 degree of freedom
A two-tailed test $P < 0.0001$

Observation: WNV infection rates in *Culex* populations were ca. 7.8 times lower in areas with mosquito control programs in Michigan, 2002

2 x 2 contingency table analysis of number of positive *Culex* pools tested in a region of Michigan with mosquito control programs compared to areas without mosquito Control, 2003 WNV season

	No. Pos. Pools	Total Pools
Mosquito Control	37	2247
No Mosquito Control	22	966

Mosquito control MIR: 37 pools/20,007 mosquitoes tested =1.85

No mosquito control MIR: 22 pools/8,578 tested = 2.56

Chi-square with Yates correction for continuity:

1.11, 1 degree of freedom

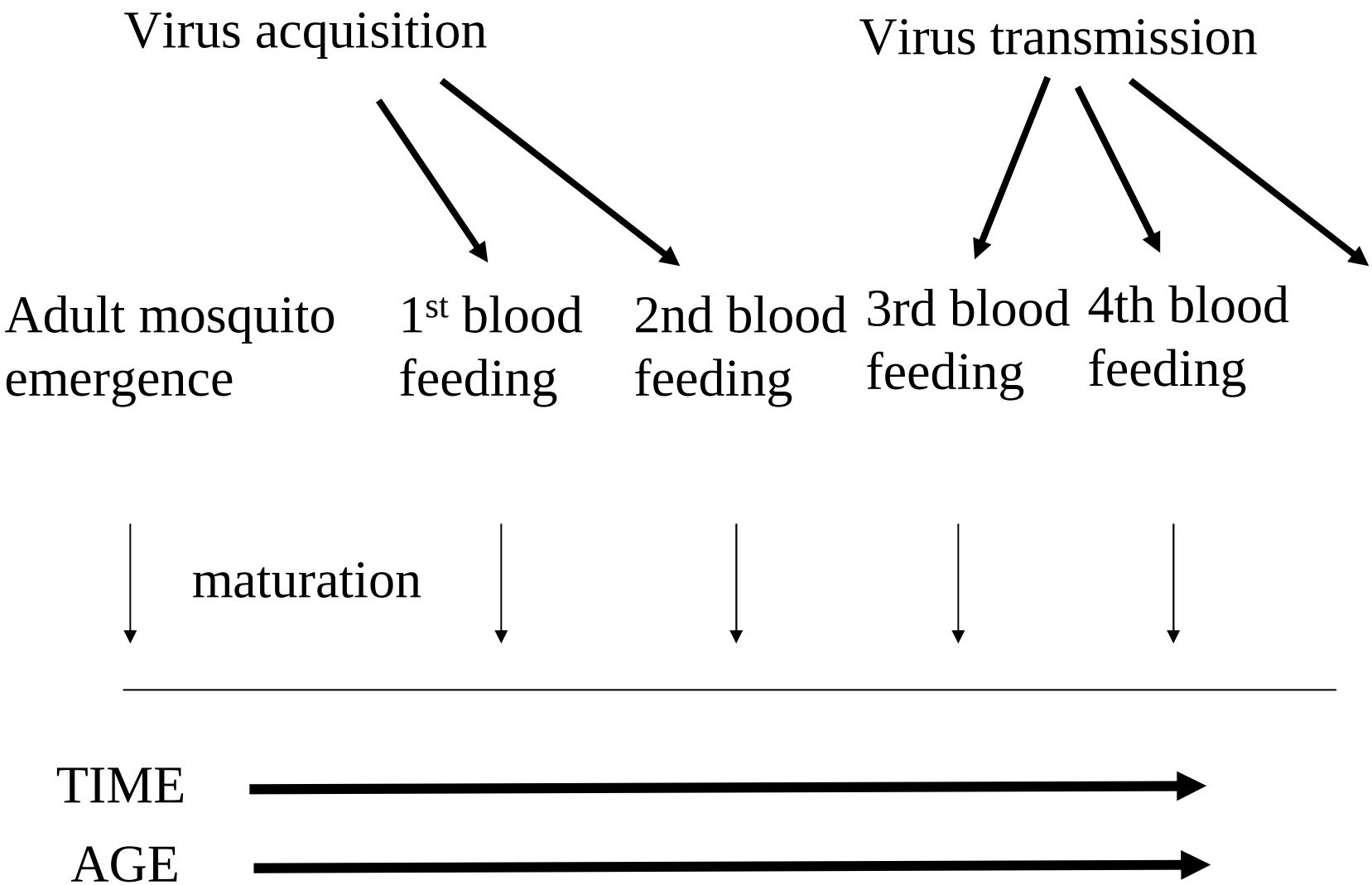
A two-tailed test P = 0.29

Observation: in a year with low epizootic activity, there was no significant difference in MIR in *Culex* in Michigan, between areas with or without mosquito control programs, compared to a year with high epizootic activity (see previously slide)

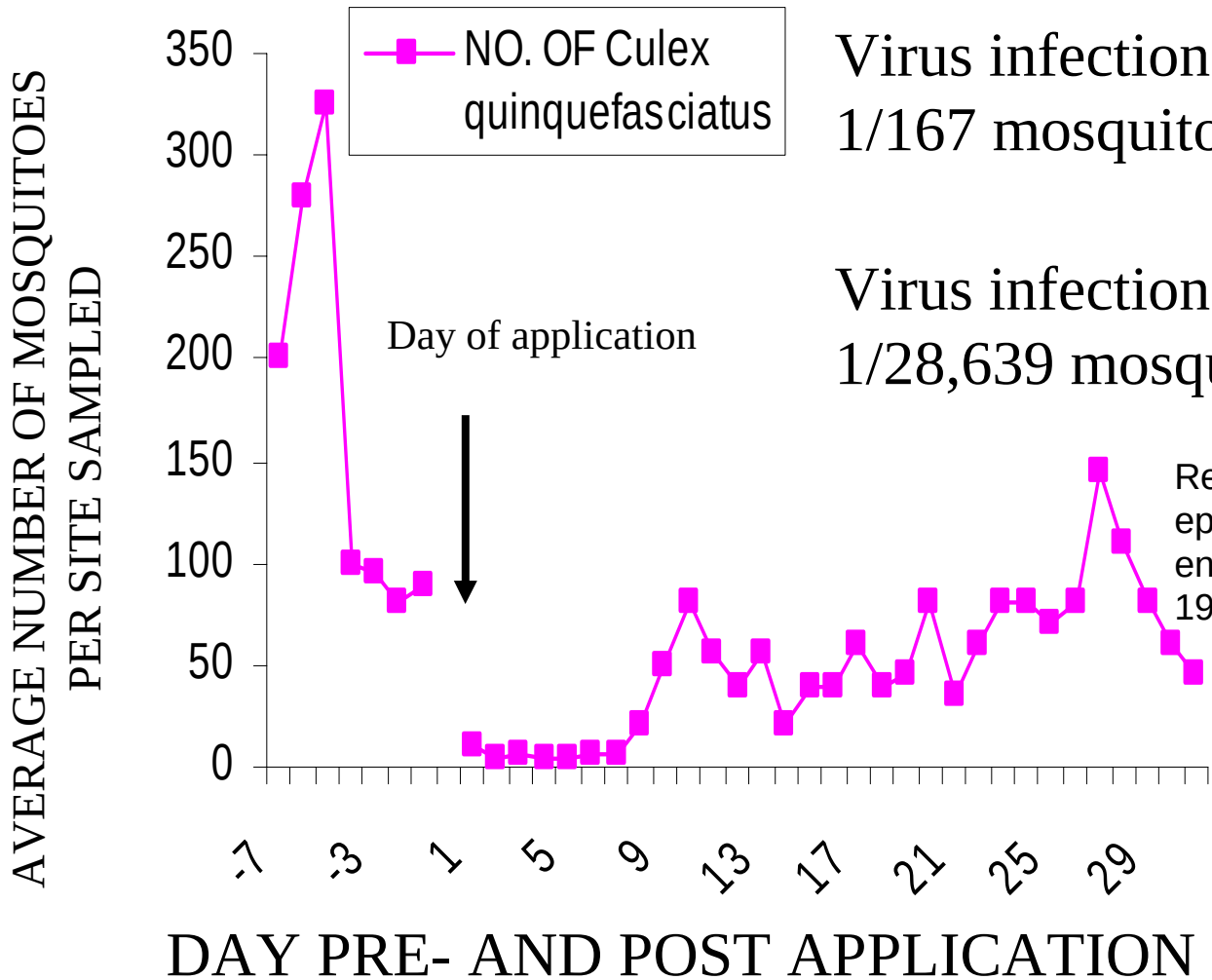
Prevention of Mosquito Borne Disease

- Prevent mosquito bites
  - Personal protection
  - Physical barriers
  - Personal behavior
- Reduce mosquito population density
  - Suppress larval production
  - Reduce adult mosquito population density
- Reduce virus infection rates in mosquito populations
  - Reduce adult mosquito population density (effect kills older mosquitoes by chance, reducing mean population age, probability of daily survival, and probability of infection)

Principles of virus transmission and mosquito aging



Efficacy of aerial ultralow volume application of insecticides to control transmission of SLE virus during an epidemic in Dallas, Texas 1966: evidence that infection rate is reduced as a consequence of an antimosquito measure directed against adult Culex



Virus infection rate before spray: 1/167 mosquitoes

Virus infection rate after spray: 1/28,639 mosquitoes

Ref: Hopkins, CC et al. 1975. The epidemiology of St. Louis encephalitis in Dallas, Texas in 1966. Amer J Epidemiol 102: 1-15.

Summary

- **An epidemic of WNV meningo-encephalitis occurred in Michigan in 2002, with a smaller outbreak in 2003**
- **The human epidemic in 2002 was preceded by an epizootic in corvids, characterized by intense, localized population processes in urban areas as indicated by a space-time modeling analysis**
- **Empirical observations and retrospective risk analysis suggest that citizens living outside of mosquito control jurisdictions had a ca. 10.5 times increased risk of WNV infection compared to people living inside of these jurisdictions**
- **Empirical observations suggest that the WNV infection rate in 2002 was ca. 7.8 x's lower in *Culex* populations within mosquito control jurisdictions compared to *Culex* populations outside of these jurisdictions**
- **The retrospective analyses here suggest that organized mosquito control programs offered protection to the citizens of Michigan from exposure to WNV-infected mosquitoes, perhaps by lowering virus infection rate in the *Culex* mosquito populations**
- **Further research involving more carefully constructed prospective studies is needed but opportunities to do it depend upon serendipity more than prior experimental design**
- **A meta-analysis would be helpful to examine these relationships further, but it should be controlled for intensity of the epidemic**

Acknowledgements, Revisited

- Dr. Paul Bartlett, Population Medicine Center, Michigan State University College of Veterinary Medicine: Risk Analysis
- Dr. Bryan Epperson and Cheng Yu Lee, Department of Forestry, Michigan State University: STARMA IEAST modeling
- Michigan Department of Community Health: data sharing on human cases and corvid death data
- Michigan West Nile virus working group: multiagency advisory group to citizens and sate and local government
- Michigan mosquito control community: sampling efforts in 2002-2003
- Walker Laboratory: mosquito testing for WNV infection and mosquito field sampling, 2002-2003
- Erik Foster, Amy Williams, Dr. Kim Signs: data cleaning and GIS database preparation