Modeling the Potential Range of the Zika Virus Vector Aedes aegypti

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ISIB 2016
University of Iowa
July 21, 2016

Outline

The Zika Virus

Arbovirus

ARthropod-BOrne Virus

History

http://www.who.int/emergencies/zika-virus/zika-historical-distribution.pdf?ua=1

The Zika Virus (continued)

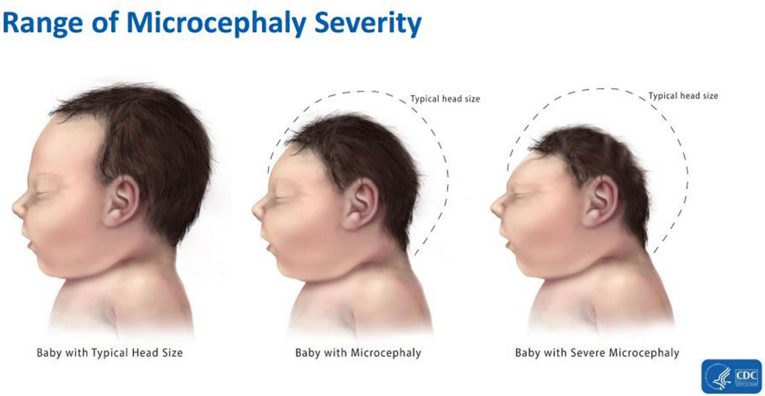
Symptoms

- Fever and/or Headache
- Rash
- Joint and/or Muscle Pain
- Conjunctivitis
- Neurological Birth Defects

Microcephaly

- Microcephaly is a generally uncommon birth defect in which a baby's head and brain are smaller than expected.
- Microcephaly often leads to other issues including seizures, developmental delays, and intellectual disabilities.
- There are still many unknowns surrounding the relationship between pregnancy, microcephaly, and Zika.

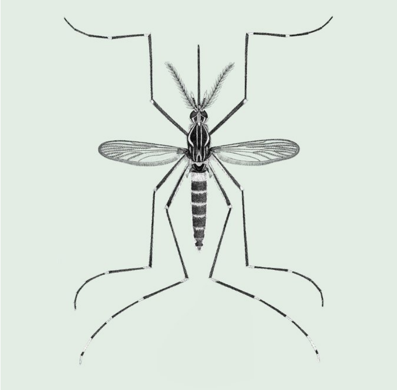
Microcephaly (continued)



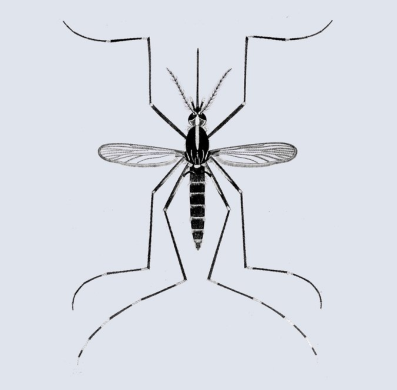
[1]

[1] http://www.nbcnews.com/storyline/zika-virus-outbreak/it-s-official-zika-virus-causes-birth-defects-n555571

Mosquito Vectors



Aedes aegypti



Aedes albopictus

Vichai Malikul/Dept of Entomology/Smithsonian Institution [2]

[2] http://www.nytimes.com/2016/06/29/nyregion/mosquitoes-diseases-zika-virus.html?$_r = 0$

Mosquito Vectors (continued)

Aedes aegypti

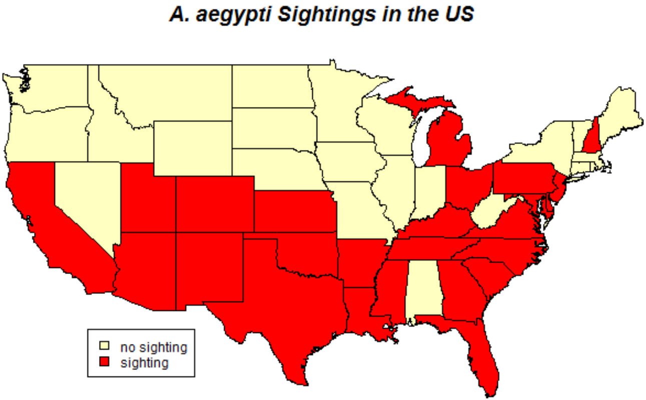
- Prefers warmer conditions
- Sip-feeds
- Smaller range
- Lays eggs in water
- Spreads Dengue and Chikungunya
- Feeds on humans

Aedes albopictus

- Feeds on lower extremities
- Will feed on animals
- Farther range
- Lays eggs in water
- Spreads Dengue and Chikungunya
- Feeds on humans

State-by-State Data Used

- Response Variable
  - Mosquito sighting (yes/no) [3]



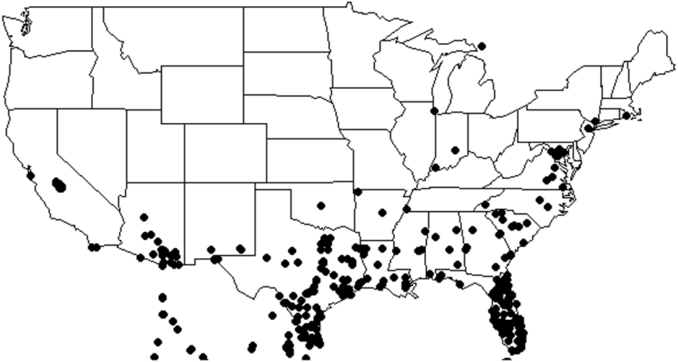
[3] http://www.nature.com/articles/sdata201535

State-by-State Data Used(continued)

- Predictor Variables
  - **Jun** average temperature in June
  - **Dec** average temperature in December
  - **Average1** annual average temperature
  - **precip** average annual precipitation
  - **Afternoon** average humidity in the afternoon
  - **Morning** average humidity in the morning
  - **co2ave** CO_2 average emission
  - **grassland** grassland cover
  - **ene.use** energy consumption per capita
  - **pop.sqmi** population by square mile
  - **urban** urbanization

Point-by-Point Data Used

- Response Variable[4]
  - Mosquito sighting (yes/no)
  - Given by latitude and longitude
  - 20,000 worldwide, 650 in N.A., 444 in USA
- A. aegypti sightings



[4]http://www.nature.com/articles/sdata201535

Point-by-Point Data Used (continued)

- Predictor Variables
  - **tmin7** average July minimum temperature
  - **tmax1** average January maximum temperature
  - **prec7** average July precipitation
  - **anthro** anthropogenic biomes - factor variable
    - recoded "wild forests" to "remote forests"
    - recoded "barren" to "remote rangeland"

Logistic Regression

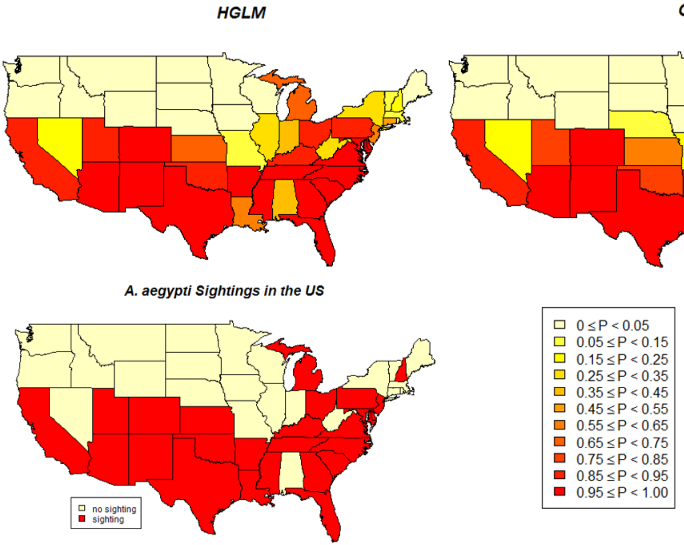
- Binomial or dichotomous response variable
  - Either a mosquito was not sighted (0) or a mosquito was sighted (1)
- Interested in p, the probability of sighting a mosquito given the characteristics of a location
- $\ln \frac{p}{1-p} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$
- In R, the functions glm and hglm perform this regression analysis
- hglm takes into account spatial correlation

HGLM and GLM Tables of Coefficients and P-Values: First Model

HGLM	Estimate	Std. Error	t-value	Pr(>|t|)	
Jun	2.1975316	1.1240455	1.955	0.0580	.
Average1	-4.0827940	2.0781034	-1.965	0.0568	.
Afternoon	-0.2968083	0.1306983	-2.271	0.0289	*
Dec	2.4152475	1.1380448	2.122	0.0404	*
ene.use	-0.0106655	0.0052916	-2.016	0.0510	.
pop.sqmi	-0.0042416	0.0025911	-1.637	0.1099	
urban	0.0009315	0.0007048	1.322	0.1942	

GLM	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	-4.9330692	10.3266367	-0.478	0.6329	
Jun	2.0705656	0.9757733	2.122	0.0338	*
Average1	-3.6871047	1.7711481	-2.082	0.0374	*
Afternoon	-0.2714887	0.1105421	-2.456	0.0141	*
Dec	2.1532477	0.9754965	2.207	0.0273	*
ene.use	-0.0098849	0.0045083	-2.193	0.0283	*
pop.sqmi	-0.0035785	0.0022398	-1.598	0.1101	
urban	0.0008812	0.0005726	1.539	0.1239	

Probability of Sighting A.aegypti Due to Environmental Factors

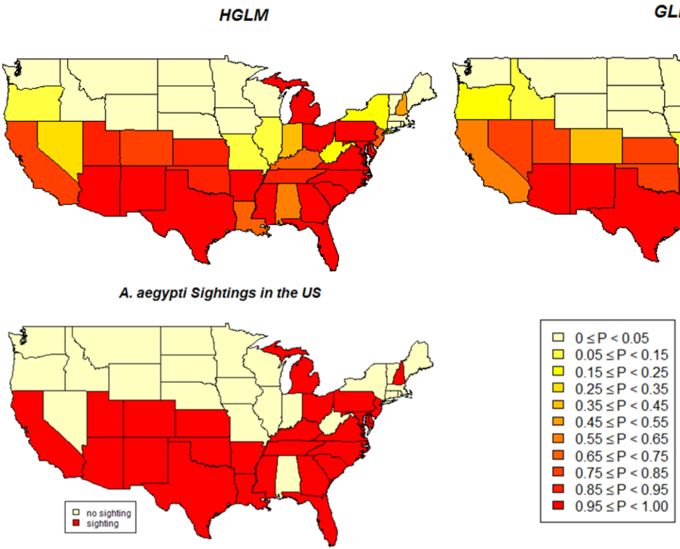


HGLM and GLM Tables of Coefficients and P-Values: Second Model

HGLM	Estimate	Std. Error	t-value	Pr(>|t|)	
Jun	3.1665093	1.5236635	2.078	0.0447	*
Average1	-7.1559163	3.3739711	-2.121	0.0407	*
Afternoon	-0.9952385	0.4639207	-2.145	0.0386	*
Dec	4.7814874	2.1573120	2.216	0.0329	*
co2ave	0.0259530	0.0145098	1.789	0.0819	.
precip	-0.6180143	0.3043027	-2.031	0.0495	*
grassland	-0.0003297	0.0001813	-1.818	0.0771	.
Morning	0.8193666	0.4112484	1.992	0.0537	.

GLM	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	-6.6316666	10.1708462	-0.652	0.5144	
Jun	1.9576004	0.8232388	2.378	0.0174	*
Average1	-4.0223452	1.7131545	-2.348	0.0189	*
Afternoon	-0.6793151	0.2853446	-2.381	0.0173	*
Dec	2.7147974	1.1074659	2.451	0.0142	*
co2ave	0.0180823	0.0098537	1.835	0.0665	.
precip	-0.3902584	0.1739865	-2.243	0.0249	*
grassland	-0.0002269	0.0001193	-1.903	0.0571	.
Morning	0.4908419	0.2325590	2.111	0.0348	*

Probability of Sighting A.aegypti Due to Environmental Factors

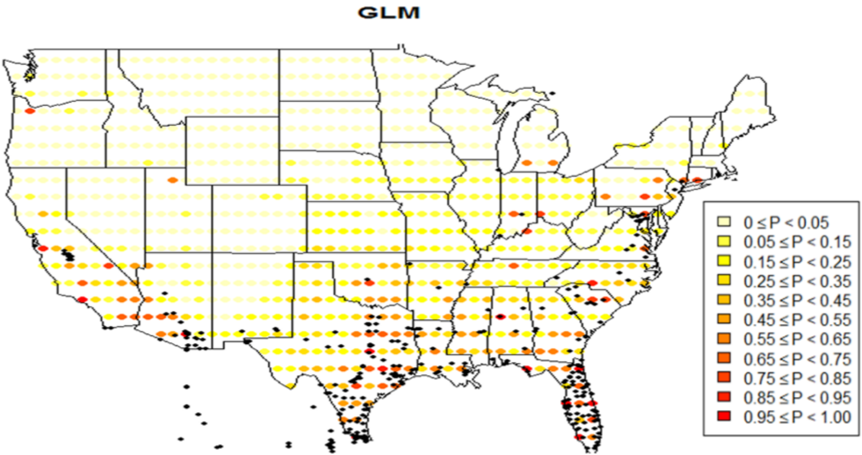


GLM and HGLM Summary Tables

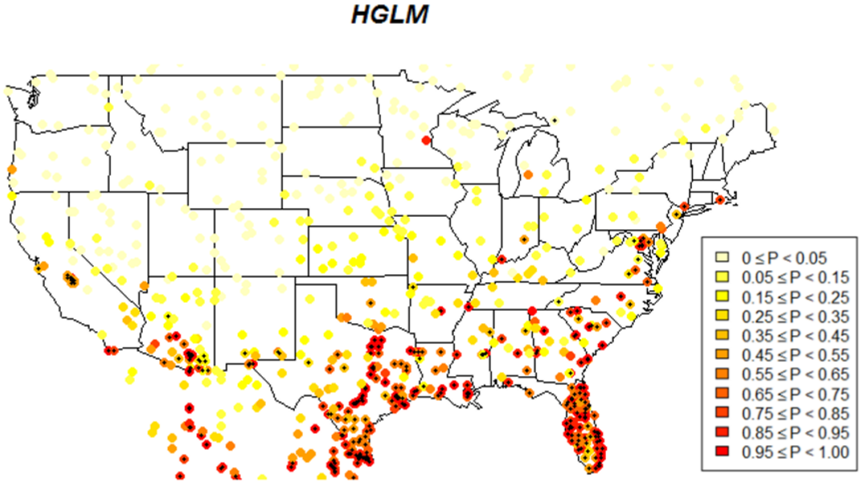
GLM	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	-1.818393	0.758286	-2.398	0.01648 *
tmin7all	0.021095	0.003384	6.234	4.55e-10 ***
tmax1all	0.011507	0.001566	7.348	2.02e-13 ***
anthallnumfact2	-1.478668	0.598932	-2.469	0.01356 *
anthallnumfact3	-3.632262	0.506576	-7.170	7.49e-13 ***
anthallnumfact4	-4.630921	0.532974	-8.689	< 2e-16 ***
anthallnumfact5	-5.632761	0.565565	-9.960	< 2e-16 ***
prec7all	-0.003780	0.001239	-3.050	0.00229 **

HGLM	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	-0.983376	0.763879	-1.287	0.198258
tmax1all	0.013464	0.001597	8.431	< 2e-16 ***
tmin7all	0.015601	0.003241	4.813	1.70e-06 ***
prec7all	-0.005015	0.001443	-3.476	0.000529 ***
anthallnumfact2	-1.907404	0.575521	-3.314	0.000950 ***
anthallnumfact3	-3.518135	0.502755	-6.998	4.63e-12 ***
anthallnumfact4	-4.894315	0.536166	-9.128	< 2e-16 ***
anthallnumfact5	-5.150937	0.574133	-8.972	< 2e-16 ***

Predicted Probability of Sighting A. aegypti



Predicted Probability of Sighting A. aegypti



Conclusions

- We found locations with higher summer and winter temperatures to have a higher probability of mosquito sighting.
- We found locations with more precipitation had a lower probability of mosquito sighting.
- Overall, both the state-by-state and point-by-point analyses produced the same, or similar, statistically significant predictor variables.
- To our knowledge this is the first analysis concerning Aedes aegypti range that utilizes spatial modeling techniques, as well as CO_2 emissions and energy emissions as predictor variables.

Study Limitations

- Not all mosquito sightings are reported, therefore the data tends to be small
- Mistaken identity of mosquitoes
- There can be A. aegypti in certain states but maybe they are not reported
- Choosing background/absence points

Future Research

- Use predicted future values of climatic variables to model the potential spread of Aedes aegypti
- Incorporate information on the Zika virus such as prevalence and odds ratios
- Map data of microcephaly occurrence against our model
- Expand our models from the United States to worldwide, specifically South America
- Follow the spread of Zika from Brazil post-Olympics

Acknowledgments

We would like to offer our thanks to the following:

- Dr. Kate Cowles
- Dr. Gideon Zamba
- Lauren Sager and Javier Flores
- Terry Kirk and Miles Dietz
- The entire Biostatistics Department
- The University of Iowa
- ISIB Program sponsored by the National Heart Lung and Blood Institute Grant: HL131467

R Citations

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R Citations (continued)

- Original S code by Richard A. Becker, Allan R. Wilks. R version by Ray Brownrigg. Enhancements by Thomas P Minka and Alex Deckmyn. (2016). maps: Draw Geographical Maps. R package version 3.1.0. `https://CRAN.R-project.org/package=maps`
- Douglas Nychka, Reinhard Furrer, John Paige and Stephan Sain (2015). fields: Tools for spatial data. doi: 10.5065/D6W957CT (URL: http://doi.org/10.5065/D6W957CT), R package version 8.4-1, `www.image.ucar.edu/fields`.

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