Spatial Disparities in Dengue Risk along the US-Mexico Border

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Mosquito-borne Disease Ecology

- Annually ~96 million cases of disease worldwide
- Endogenous transmission in Florida + Texas
- Symptoms: muscle and bone ache, fever, and hemorrhagic manifestations in rare cases
- 4 serotypes of virus

Mosquito Life Cycle

West Nile Virus

Dengue Virus

Main Cycle

Accidental

Gina Mikol, www.scientificillustrator.com
Modeling Dengue Fever in Sonora, Mexico

- Dengue ecology
  - Mosquito population dynamics
  - Virus transmission dynamics

- *Aedes aegypti* mosquitoes
  - Urban, container breeding
  - Live in tropical habitats
  - Anthropophilic

- Sonora Mexico
  - Arid climate
  - Monsoon precipitation
  - Seasonal cycles of dengue transmission
  - Large annual variations in epidemics

Source: Centers for Disease Control and Prevention (CDC)

www.sigfridoaguilar.org
Data and Methods

• Study area
  • 4 sites in Sonora, Mexico

• Meteorological/Dengue case data
  • Daily maximum and minimum temperatures (NLDAS)
  • Daily precipitation (TRMM, NLDAS)
  • Weekly suspected dengue cases by city 2006-2011

• Model
  • Parameterized for *Aedes aegypti* mosquitoes, daily time step
  • Run from 2005-2011 under varying parameters (500)
  • Best 3% of runs chosen by comparison with suspected case data (R^2)
Model Parameter Estimation

• Containers
  • Based on household surveys (Hermosillo)
  • Human managed and open containers
  • Used mean values and +/- 25% and 50%

• Minimum infectious rate
  • Minimum amount of infectious humans
  • Maintains virus within the population
  • Based on case data and previous study in San Juan, PR

• Maximum larval density
  • Used to calculate density-dependent mortality
  • Based on observations, literature, and previous study in San Juan, PR
Modeling *Aedes aegypti* and Dengue Virus Ecology
Dengue and Climate Comparisons

Epidemics asynchronous

Very Similar

Variable

Very Similar
2008 and 2010 are largest dengue years

Epidemics follow monsoon rains

Precipitation magnitude not correlated with dengue case incidence
  - Introduction rate is likely important
Climate, Dengue, Simulations: Guaymas

- Dengue is highest in 2010 despite dry conditions
  - Similar to Hermosillo
- Driest city examined
  - Importance of human managed water sources
- Model has difficulty simulating seasons with no peak
  - 2008 + 2011
• Lowest annual variability in dengue cases
• Model has difficulty simulating seasons with no peak
  • 2011
Climate, Dengue, Simulations: Navojoa

- 2008 is highest dengue year
- Dengue transmission is low in 2010
  - Unlike Hermosillo and Guaymas
- Model has difficulty simulating seasons with no peak
  - 2006, 2007, and 2010
Why is there little/no dengue transmission in nearby Nogales?

Hypothesis: Climate conditions are cooler

- Suppression of mosquito population
- Extension of extrinsic incubation period (EIP)

Experiments:

1. Rerun Hermosillo simulations with Nogales meteorological data
2. Perform experiment 1 with 1°C warming

Performed during large epidemic years (2008 and 2010)
• Little/no dengue is simulated under Nogales meteorological conditions

• With warming, the mosquito population is higher under Nogales conditions in 2010
  • No dengue

• With warming, there is a modest mosquito population increase in 2008
  • Results in increased virus transmission
Hermosillo/Nogales Comparison: EIP

- EIP is considerably longer under Nogales conditions
- Under Nogales conditions, the EIP is longer during the transmission season in 2008
  - Prevents completion of EIP during mosquito lifetime
- EIP shortened under 1°C warming conditions
  - Especially during transmission season
Challenges in Climate and Health Research

- **Reporting problems**
  - Misdiagnosis
  - Subclinical cases
  - Reporting errors/bias
  - Availability of data

- **Knowledge gaps**
  - Incubation periods
  - Transmission probabilities
  - Evolution and adaption of virus and human immunity

- **Human vs. climate influences**
  - Socioeconomic status
  - Microclimatic influences
  - Human adaptions to climate

regblog.org

CDC.gov
Conclusions

• Nearby locations can exhibit very different patterns of dengue transmission
  • Differences in virus introduction
  • Small climatic differences can make large differences

• Dengue epidemics follows monsoon rains
  • Timing is consistent, however, the magnitude is not well correlated

• Climate is an important regulator of dengue transmission in Nogales
  • Affects mosquito population dynamics and the virus incubation period
  • Year to year variability is important

• Dengue transmission dynamics in northern Mexico may affect dengue risk in the United States
  • Travel, climate change
  • Recent dengue epidemic in Nogales
Next Steps

• Run model for additional locations along US/Mexico border
  • Does transmission vary?
  • Why?
• Perform fine scaled model runs
  • How does risk vary within a city?
• Consider socioeconomic conditions in model
Thank You for Your Attention!

Questions?