Spatial Disparities in Dengue Risk along the US-Mexico Border

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Mosquito-borne Disease Ecology

- **West Nile Virus**
  - **Main Cycle**
  - **Accidental**

- **Dengue Virus**
  - **Main Cycle**
  - **Symptoms:** muscle and bone ache, fever, and hemorrhagic manifestations in rare cases
  - **Endogenous transmission in Florida + Texas**
  - **4 serotypes of virus**

- **Mosquito Life Cycle**
  - **egg**
  - **larva**
  - **pupa**
  - **adult**

- **Annually ~96 million cases of disease worldwide**
Environment - Vector - Virus Connections

Diagram showing the relationships between various factors and processes:
- Environment:
  - Temperature
  - Immature Habitat
  - Precipitation
- Vector:
  - Development
  - Survival
  - Reproduction
- Pathogen:
  - Development
  - Transmission

Legend:
- Blue: Positive Relationship
- Red: Negative Relationship
- Green: Positive or Negative Relationships
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)
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

- Dengue Cases per 100,000
  - Epidemics asynchronous
  - Very Similar

- Precipitation
  - Variable
  - Very Similar

- Max Temp
- Min Temp
• 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
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
Dengue Transmission in Nogales

- 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)
Hermosillo/Nogales Comparison: Mosquitoes

- 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
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?