Dynamics of Arbovirus Transmission

St. Louis Encephalitis and West Nile viruses in South Florida

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What are dynamics?

- Changes in time and space
- May be monitored or modeled at different scales
  - Single season
  - Between years
- Scale used depends on questions asked
Arboviruses in Florida

- St. Louis encephalitis virus
  - South Florida – vector *Culex nigripalpus*
  - Bird-mosquito cycle
  - Human infection incidental

- West Nile virus
  - Vectors varied, *Culex* species dominant
  - Bird-mosquito cycle
  - Human & domestic animal infection incidental
Arbovirus Transmission cycle

Models of transmission dynamics
Model development: questions

SLEV in Florida

1. Can variation and seasonality in mosquito vectors explain variability in SLEV transmission dynamics? No!

2. How does seasonality in bird populations interact with mosquito populations to affect transmission?
Assumptions are a key part of a model

Keep the model simple
  - still addressing the question

Need to include
  - Seasonal dynamics in mosquitoes and birds
  - Temperature effects

One species of mosquito
  - populations described based on field data
  - Variation in seasonal patterns

One host species with two age classes
  - Seasonal reproduction
Incorporating variability

- Sources of variability
  - Biological: spatial, temporal, species
  - Gaps in knowledge
- Sensitivity analysis
  - Explore the parameter space
  - Assess consequences of variability
- Analysis
  - Outcome: is there an epidemic in birds?
  - Statistical analysis: the contribution of each parameter to the outcome of the simulation
Model output
Likelihood of epidemics

Logistic Model $R^2 = 0.34$

Mosquito population
Mosquito mortality (baseline)

Time of peak bird recruitment
Time of summer peak in mosquitoes
Multiple vector species

- How do multiple vector species affect transmission dynamics?
  - Tradeoffs in population abundance, vector competence, seasonality
  - Less competent vector allowing transmission during “off” season

- Work in progress!
Species A
Species B

Population

Out of phase

Species equal

Partial phase

One Species better

Vectorial Capacity

Hot-cool season

Time (days)
Acknowledgements

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  - Jonathan Day
  - Roxanne Connelly
  - Walter Tabachnick

- **Technical staff**
  - Leah Peak, Carol Thomas, Sara Lynn, Jonathan Fung
## Size of epidemic in birds and mosquitoes

<table>
<thead>
<tr>
<th>Juveniles</th>
<th>Adults</th>
<th>Mosquitoes</th>
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<tbody>
<tr>
<td>Juvenile recovery rate</td>
<td>Adult recovery rate</td>
<td>Mosquito population size</td>
</tr>
<tr>
<td>Transmission from adults to vectors</td>
<td>Days between blood meals</td>
<td>Spread of summer peak</td>
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<tr>
<td>Baseline mosquito population</td>
<td>Transmission from juveniles to vectors</td>
<td>Adult recovery rate</td>
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<tr>
<td>Spread of summer peak</td>
<td>Juvenile recovery rate</td>
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<td>Stepwise model</td>
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<tr>
<td>$R^2 = 0.92$</td>
<td>0.63</td>
<td>0.42</td>
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Why use models?

- Allow integration of many aspects of a system
- Facilitates exploration of alternate hypotheses
- Consider variability and uncertainty
- Exploration of consequences of policies or activities
- Establish research or policy priorities
- Prediction of future activity or outbreaks
Model structure

- as simple as possible
- including critical features necessary to ask the questions
- Need to include
  - Seasonality in mosquitoes
  - Seasonality in birds
  - Other seasonal aspects: temperature effects
- Simplifications
  - Detailed population dynamics
Assumptions & Structure

- Basic structure as before
- Add second vector
  - Still descriptive, not mechanistic
  - Simplify seasonal patterns
- Include variability - differences between vector species
  - Seasonal patterns
  - Other aspects of vector competence
Planned simulations & analysis

- Selected pairs of species
  - Examine for enhancement of transmission with multiple vectors
  - Preliminary study to consider parameter ranges
- Larger sensitivity analysis
  - Increased variation in population & competence parameters
  - Statistical analysis for relationship between parameters and outcome