

Modeling Zoonoses to Identify Potential Vulnerabilities and Data Gaps: Rift Valley Fever in the United States

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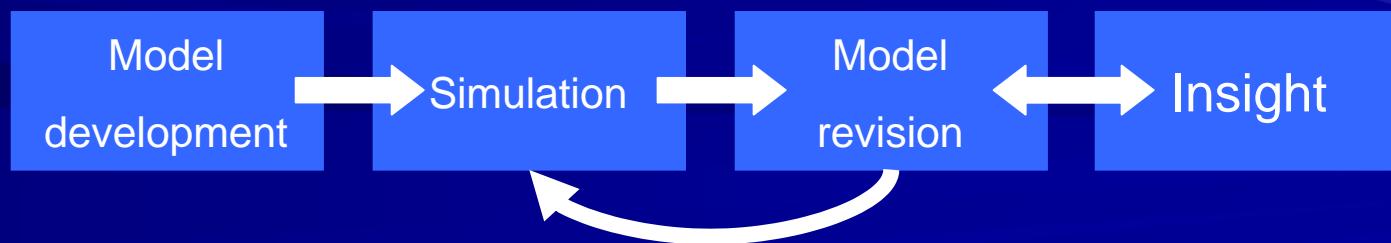


Outline

- Modeling versus simulation
- Rift Valley fever model
- Results and implications
- Next steps & conclusions

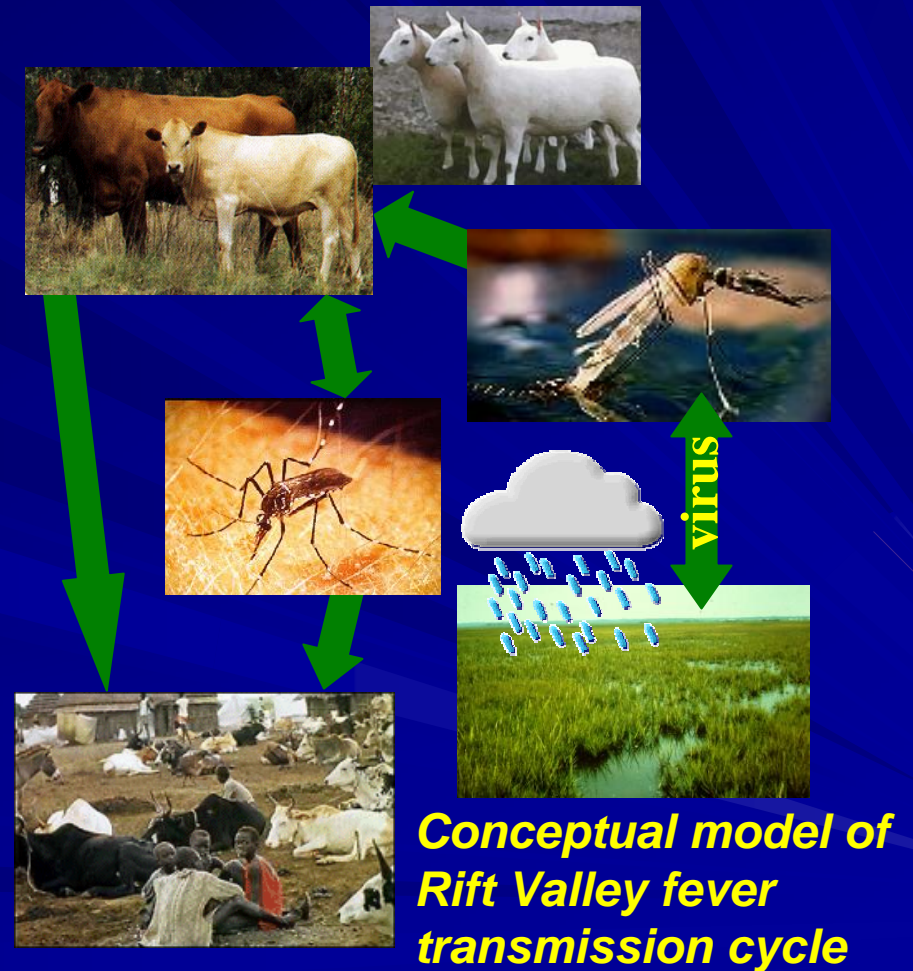
Models & Simulation

- A “model” is a simplified representation of a system, intended to promote understanding of the actual system
 - Underlying drivers of system dynamics
 - Causal factors and pathways
- “Simulations” are the computational results of a detailed model, meant to enable the user to anticipate system behavior under a given set of circumstances
 - Often predictive instead of diagnostic in nature
- Modeling and simulation can be used in conjunction to develop a level of understanding of the interaction of system parts versus entire system
 - Often used when actual experiments are not possible



Rift Valley Fever

- A viral disease of sub-Saharan Africa recognized in 1931
- Transmission tied to environment
 - Rains/water, availability of hosts, competent vectors & their breeding habitats
- Animal impact
 - Abortion in cattle, sheep
 - Mortality in newborns
 - Mortality in pregnant ewes
 - Morbidity in adult animals
- Typically flu-like in humans

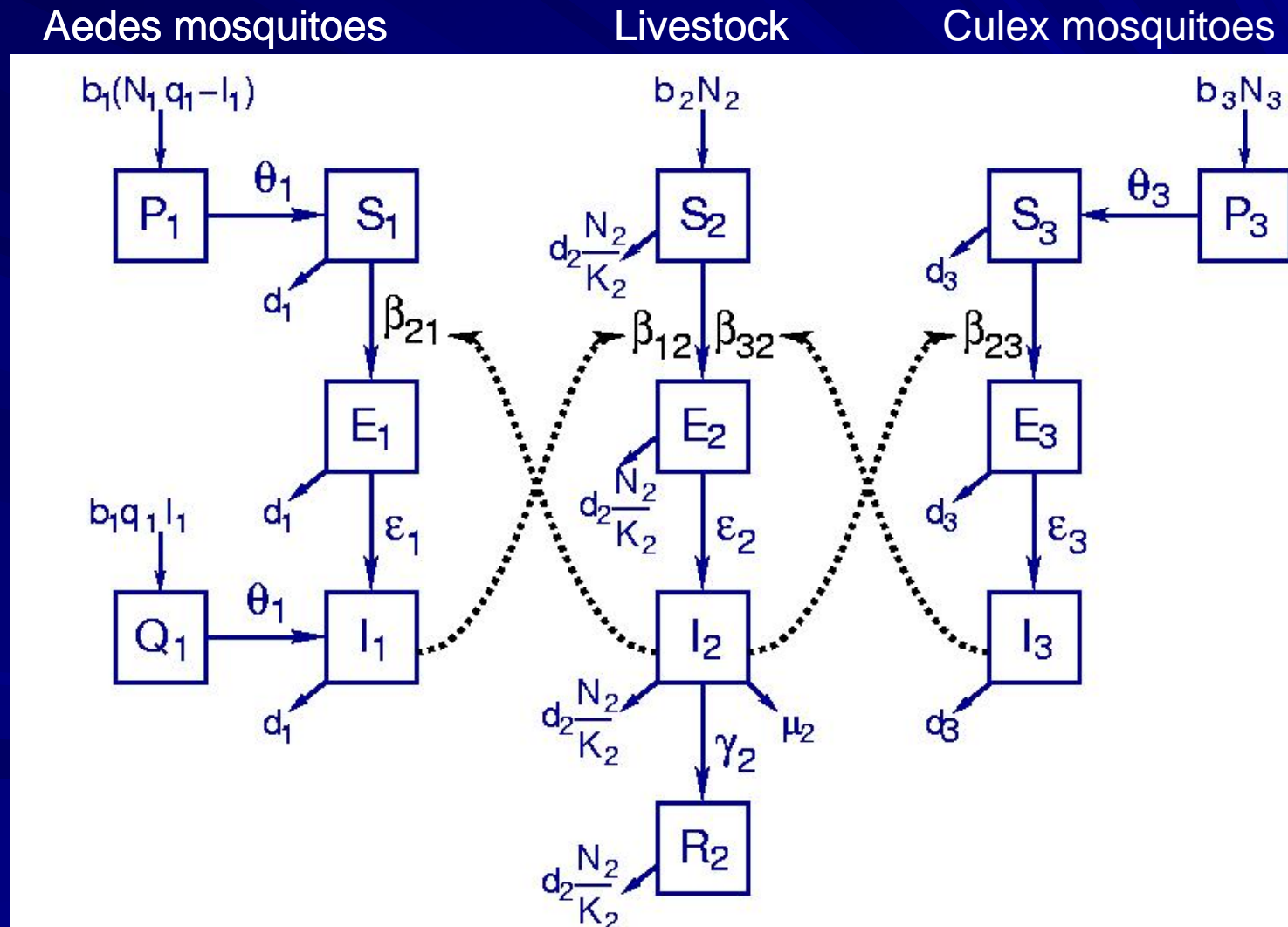


RVF Can Move

- Confined to sub-Saharan and southern Africa throughout 1900s
- Exception: massive Egyptian outbreak 1977-78
 - 20K-200K human cases in 3 months
 - Devastating impact on livestock production: cattle, sheep, buffaloes
- Jumped from Africa to Arabian Peninsula 2000
- Possibility of translocation to the US (like WNV in 1999)



RVF Model



Model Formulation

- Each box in the conceptual model is represented by a differential equation
 - 13 equations must be solved for single locale model
 - Other mathematical techniques are possible
- Resulting model is deterministic
 - Correct on average
 - Neglects stochastic effects potentially important at onset of an outbreak
- Runs on desktop PC
 - Written in C++, portable to other software and languages such as R, MATLAB, FORTRAN
- Analysis combination of numerical simulation and mathematical theory

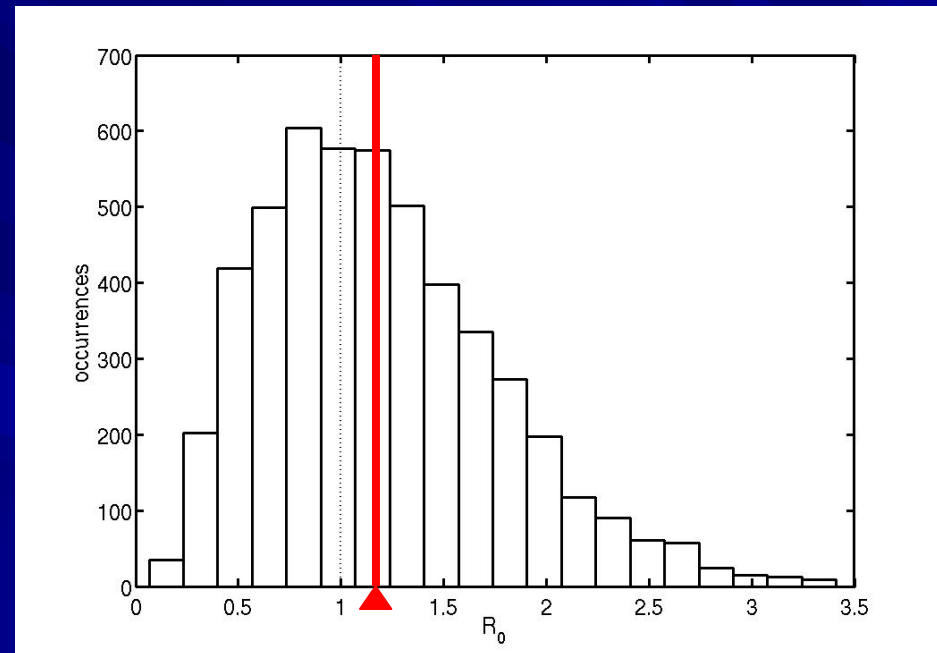
Basic Reproduction Ratio, R_0

- Threshold parameter derived from models
 - Estimates number of secondary cases in a susceptible population given introduction of a single infectious individual
 - Robust with respect to species of introduction
- When $R_0 < 1$ the pathogen will eventually die out, even without control and intervention measures
- When $R_0 > 1$ pathogen can become endemic in the absence of control measures

<i>Disease</i>	R_0
Smallpox	3-6
Measles	5-18
Cholera	4-12
SARS	1-8
RVF	???

R_0 Sensitivity Analysis

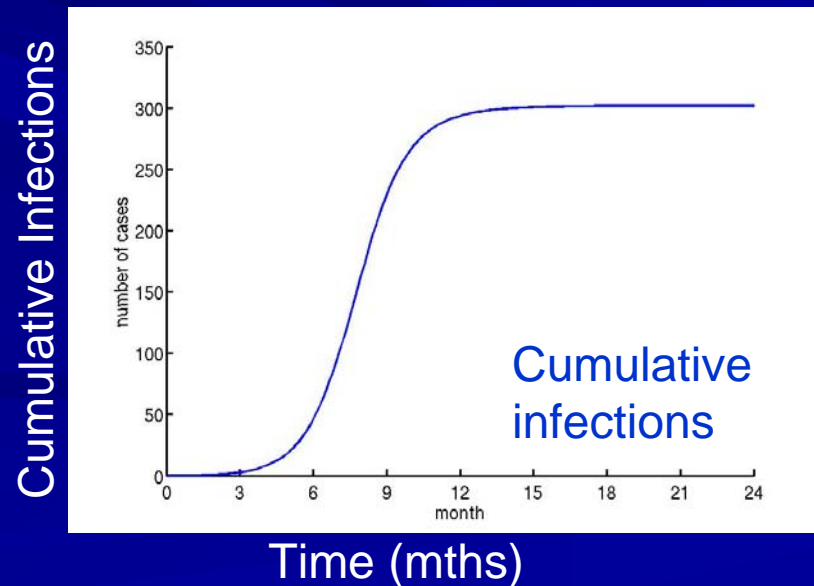
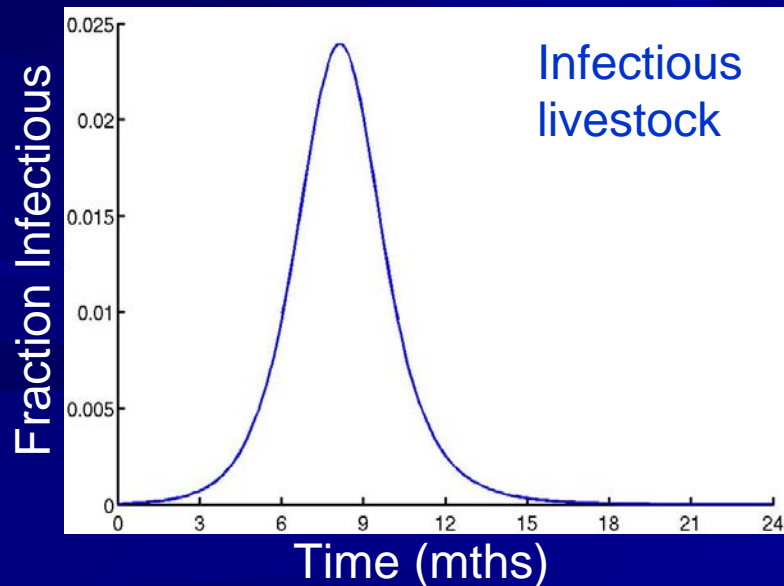
- R_0 estimated by picking component parameters from distributions or ranges
 - Contact rates, periods of infectiousness, lifetimes, incubation periods, others
 - Latin hypercube sampling scheme used to ensure efficient sampling
- Point estimate and range:
 - Mean ~ 1.2
 - Median ~ 1.1
 - Range $\sim (0.07, 3.4)$



➔ R_0 estimated to be greater than 1 ←

Typical Output

- Scenario: single locale with 10,000 Culex eggs, 9,999 uninfected & 1 infected Aedes eggs, 1,000 susceptible livestock
- Infection curve suggests that an epidemic would peak in ~6 months following an introduction, with ~2-3% of livestock being infected



Gaps

- Overall paucity of data
- Few field observations and data on transmission rates
 - E.g., what is the lifespan of the vector in the wild?
- Transovarial transmission rates unknown

Next Steps

- Link RVF model to livestock model underway at FAZD Center
- Incorporate meteorology and climate effects
 - Influences mosquito response and behavior, including incubation periods, biting rates, population size
- Incorporate vaccination and vector control into model
- Generalize existing RVF model into a spatial framework

Conclusions

- Models provide a method for exploring the dynamics of complex systems
- Models do not have to incorporate great detail to provide useful results
 - Degree of detail needed depends upon the questions being asked
- Models can identify important quantities to measure for decisionmaking
- Even with a paucity of data, models can be made and meaningful inferences can be drawn