Planning Informed by Epidemiological Simulation: The Geography of Avian Flu in Nigeria

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Geospatial Epidemiology Modeling of Zoonotic Diseases

- **Identify current and emerging zoonotic agents**
- **Identify wildlife reservoirs for human and agricultural animal infection**
- **Assess the importance of different modes of transmission**
  - Waterborne
  - Foodborne
- **Predict outbreaks**
- **Evaluate control strategies**
- **Effective biosurveillance planning**

Multiple Hosts Model

Combines the advantages of SEIR-like models:

- exponential epidemic rise, saturation, and fall in well-mixed compartments
- rapid to compute
- easy to match to empirical data

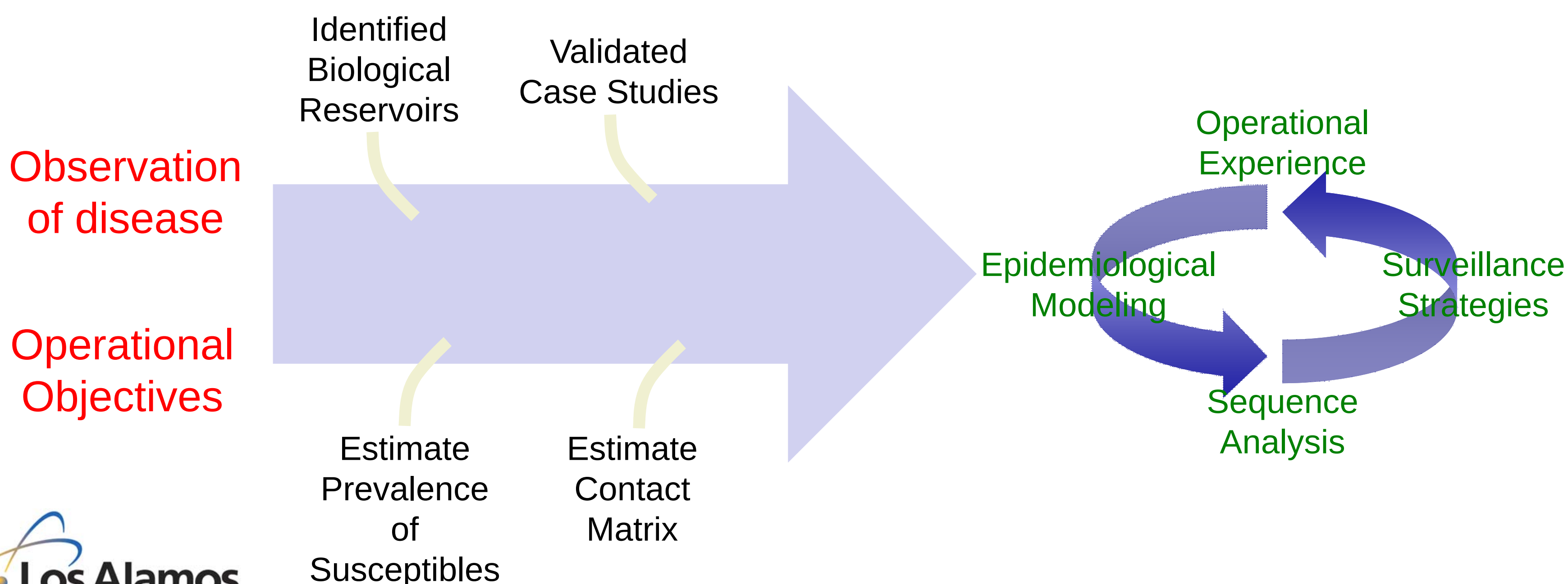
with the advantages of agent-based models at larger scales:

- flexible and explicit rule-based mitigations
- realism (transferability)
- multi-host, with arbitrary transmissibility and susceptibility matrices between hosts
- Geography for surveillance

Extending our multi-species epidemiological simulation tool

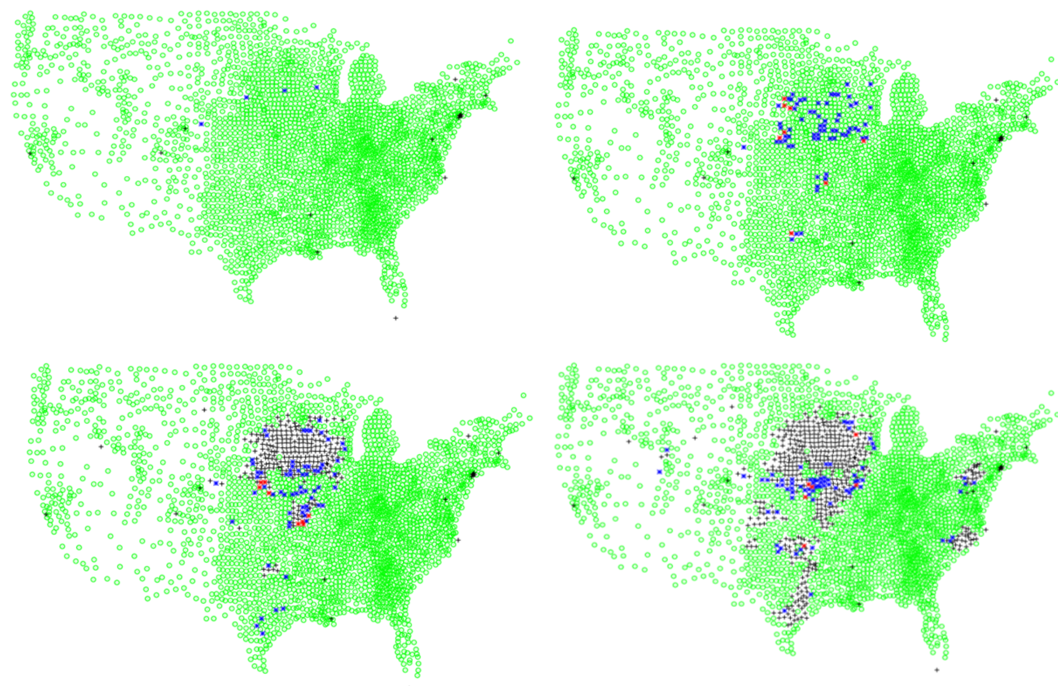
Case Study: Nigeria H5N1 avian influenza outbreak, 2006

- **Start with avian influenza model from U.S. studies**
- **Update with information from Nigeria**
- **Model viral spread and evaluate effect on operations**



Multi-Scale Simulation of Zoonotic Epidemics - MuSE

- **Severity of epidemic depends on reaching dense areas in the Midwest**
- **Control Methods**
  - **Faster response time in implementing movement restriction**
  - **Better surveillance in certain counties**
  - **Faster culling and quarantine response**
  - **Vaccination**



Time Series of Severe Rinderpest Epidemic In the U.S.

Manore C., B. H. McMahon, J.M. Fair*, J. M. Hyman, M. Brown, and M. LaBute. 2011. Disease Properties, Geography, and Mitigation Strategies in a Simulation Spread of Rinderpest Across the United States. *Veterinary Research.* 42:55-64

Input parameters

Model parameters for animal disease model.

- Transmission rate
- Infected animals that progress to symptoms
- Infected animals that die
- Infected animals that are culled
- Vaccination policy
- Culling rate
- Disease stage time
- Recovery time
- Inter-state movement control efficacy
- Quarantine policy
- Susceptibility

Similar to human disease model parameters

Validation and parameterization critical for both animal and human epidemiology model. Case studies are integral to both model development and validation.

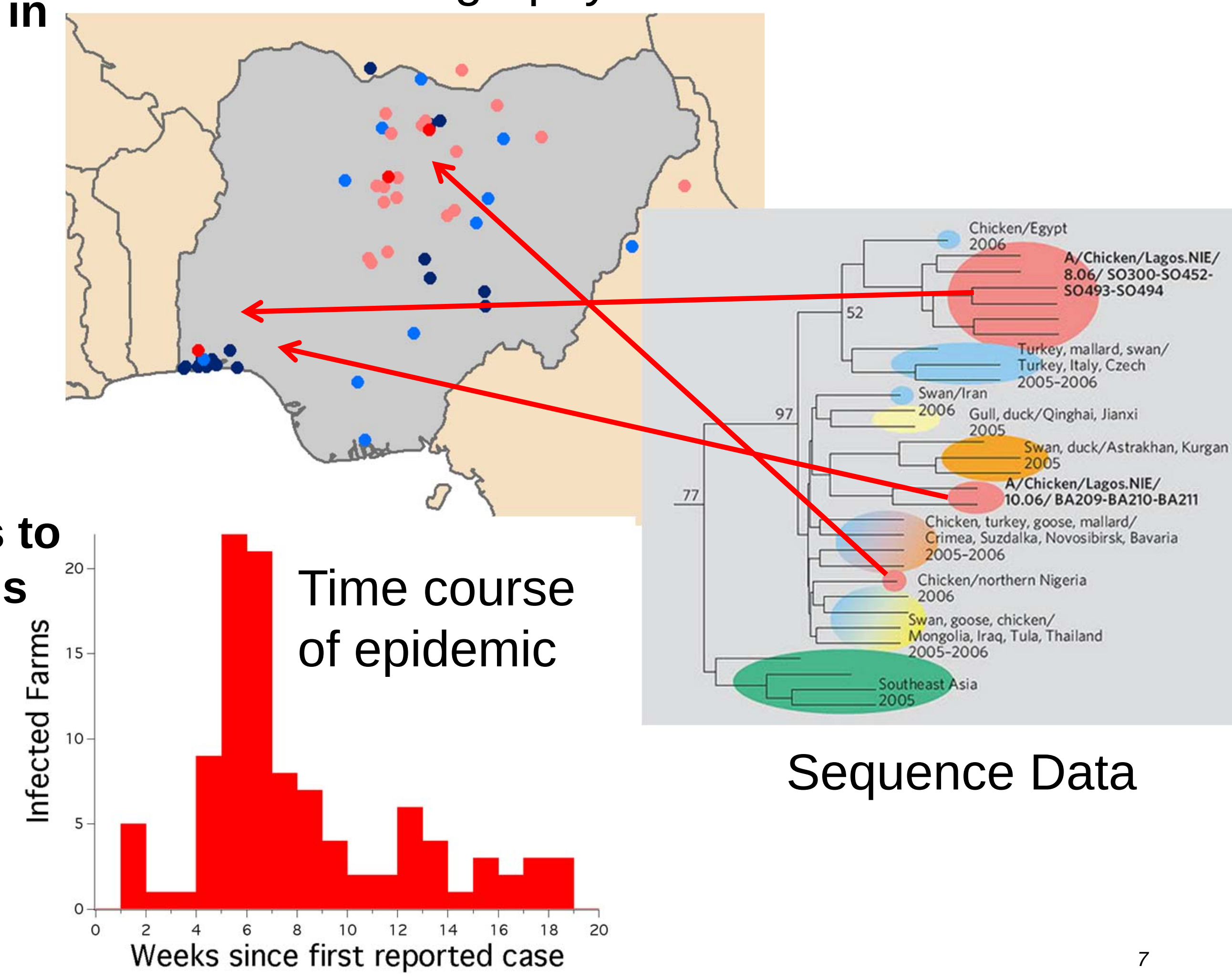
Completed Diseases

- Cattle and Sheep Diseases
- Foot-and-Mouth Disease
- Rinderpest
- Rift-Valley Fever
- Brucellosis
- Tularemia
- Nipah Virus
- Classical Swine Fever
- Poultry Diseases
- Highly Pathogenic Avian Influenza
- Newcastle Disease Virus

Nigeria – Biogeography of an outbreak

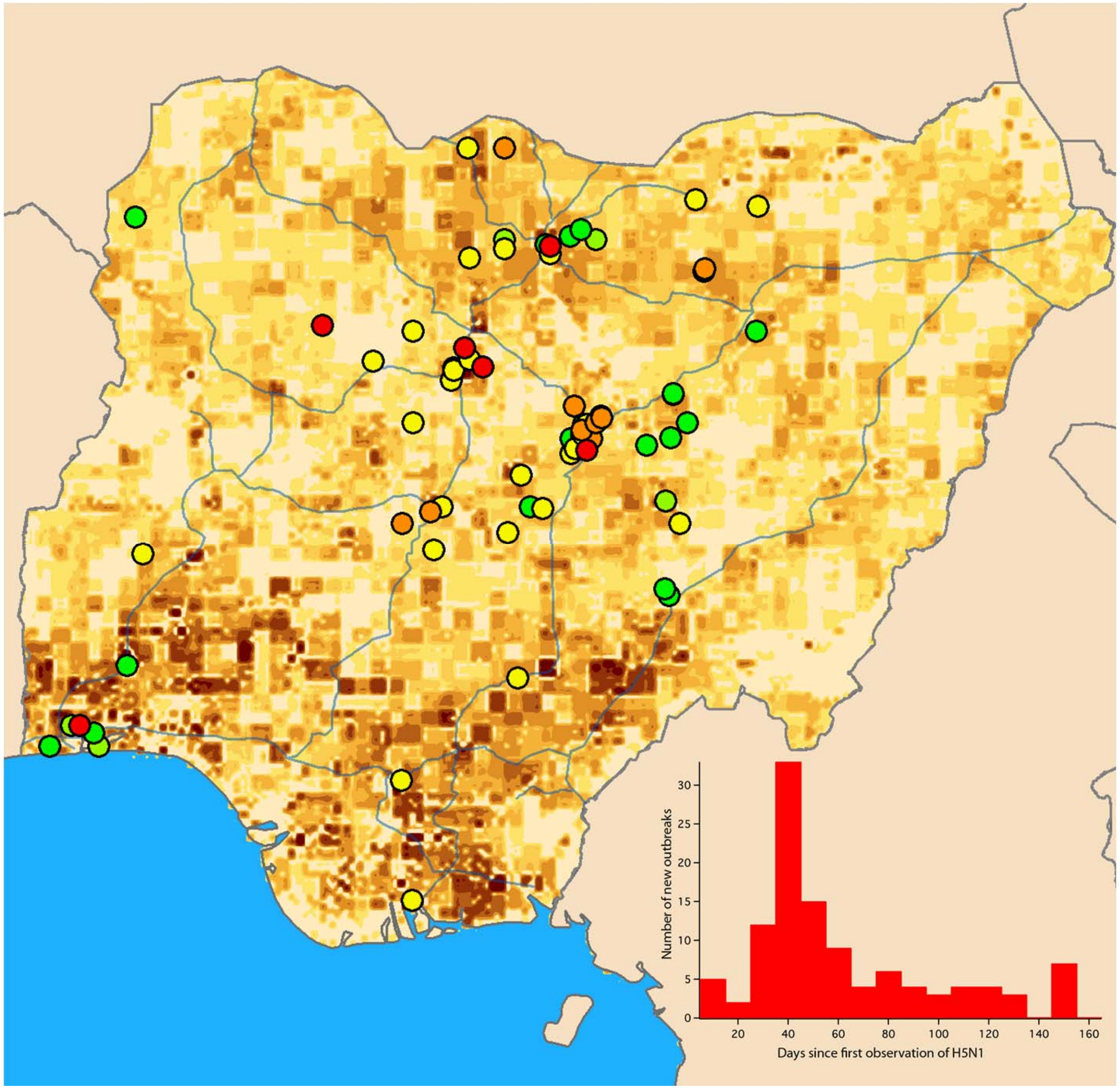
- **Nigerian AI outbreak in 2006 has been well – studied, allowing comparison with simulation output.**
- **Positive cases: 248**
- **Depopulated birds: 1,500,000**
- **Biogeography points to multiple introductions**

Geography



Time course of epidemic

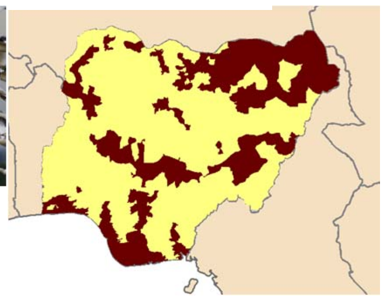
Sequence Data



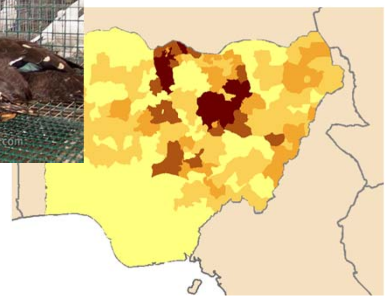
Number of new outbreaks
Days since first observation of H5N1
0
5
10
15
20
25
30
20
40
60
80
100
120
140
160

Needed Inputs for Multi-host Epidemiology Model

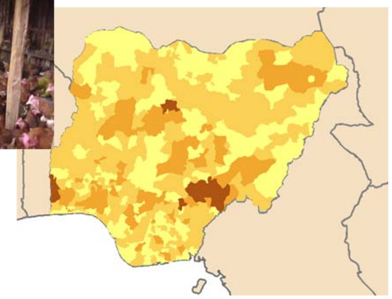
- Wild Birds (FAO)

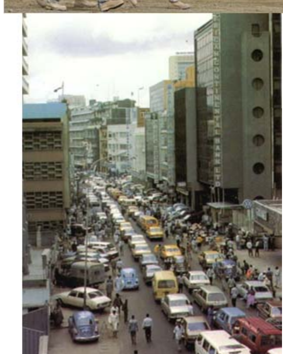
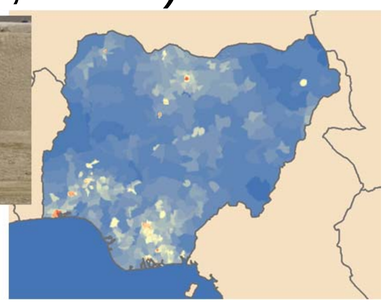
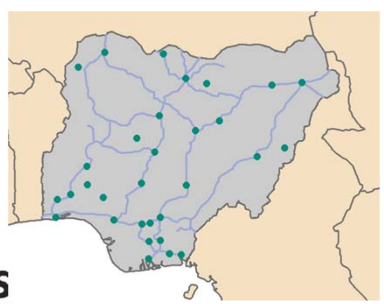
- Ducks (FAO)

- Chickens (FAO)

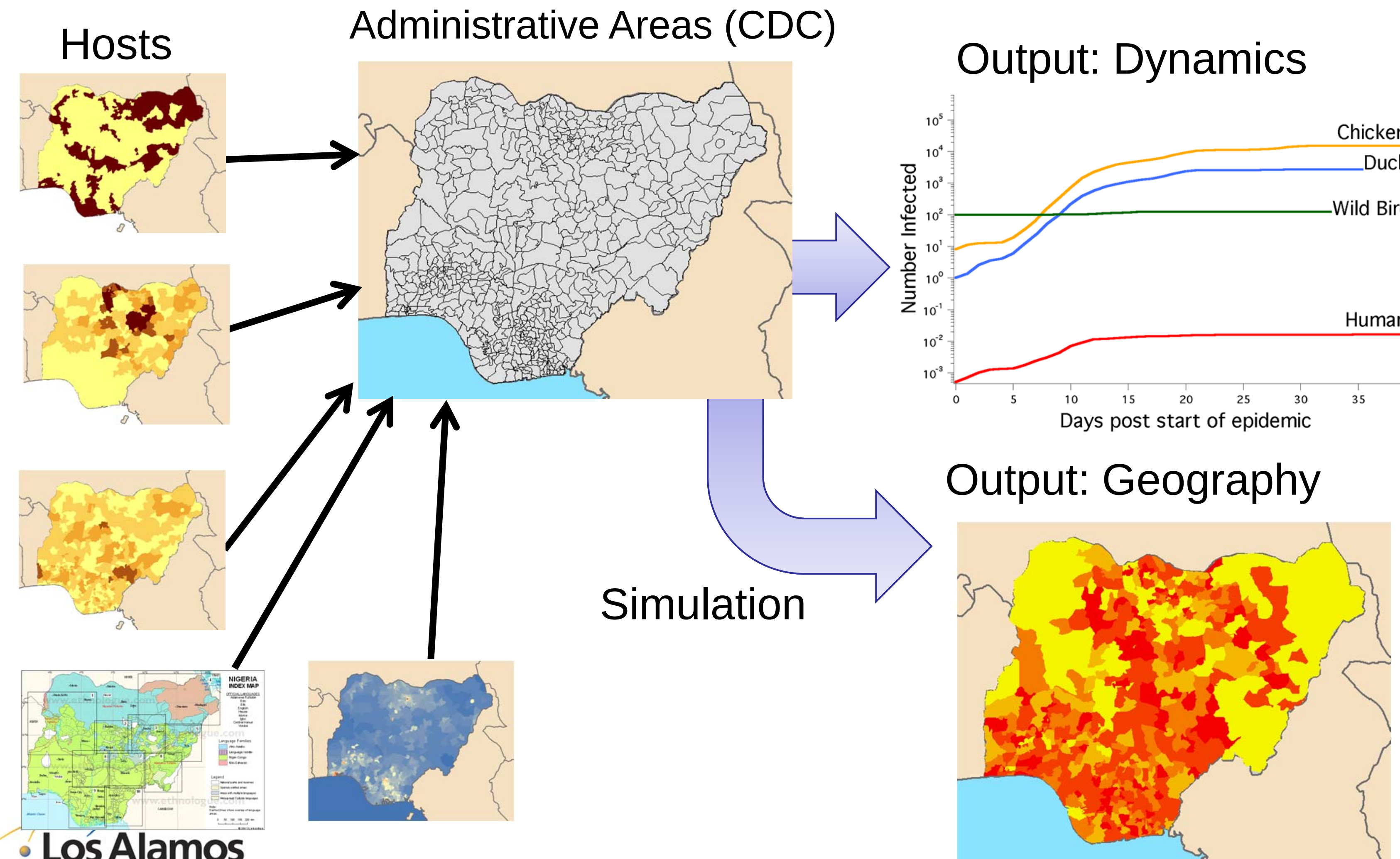
- People (UN, ESRI)

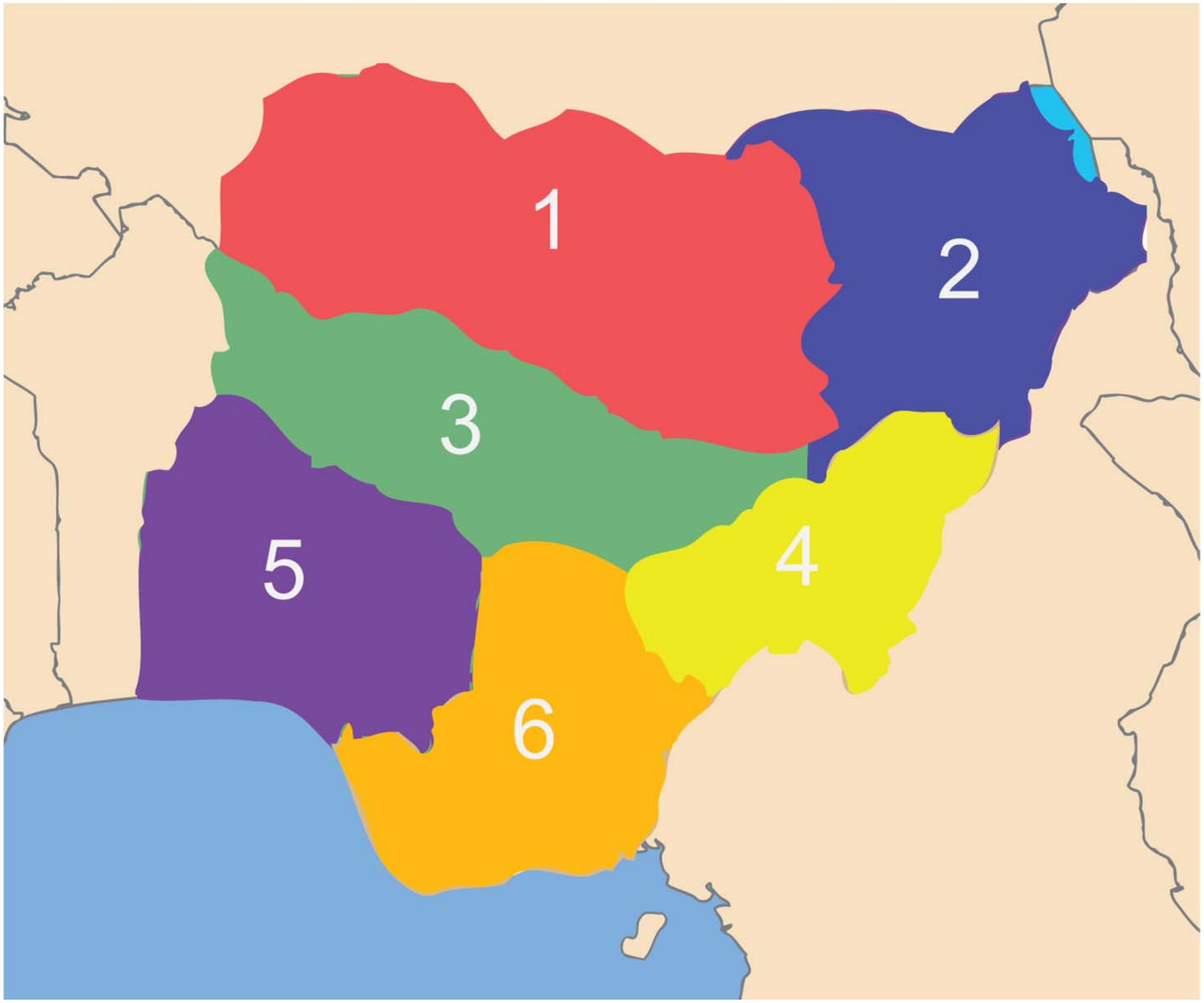
In addition to distribution of hosts, we need:

- Transmission vectors
- Susceptibility vectors
- Approximate long range transmission parameters
- Control measures and mitigative efficacies

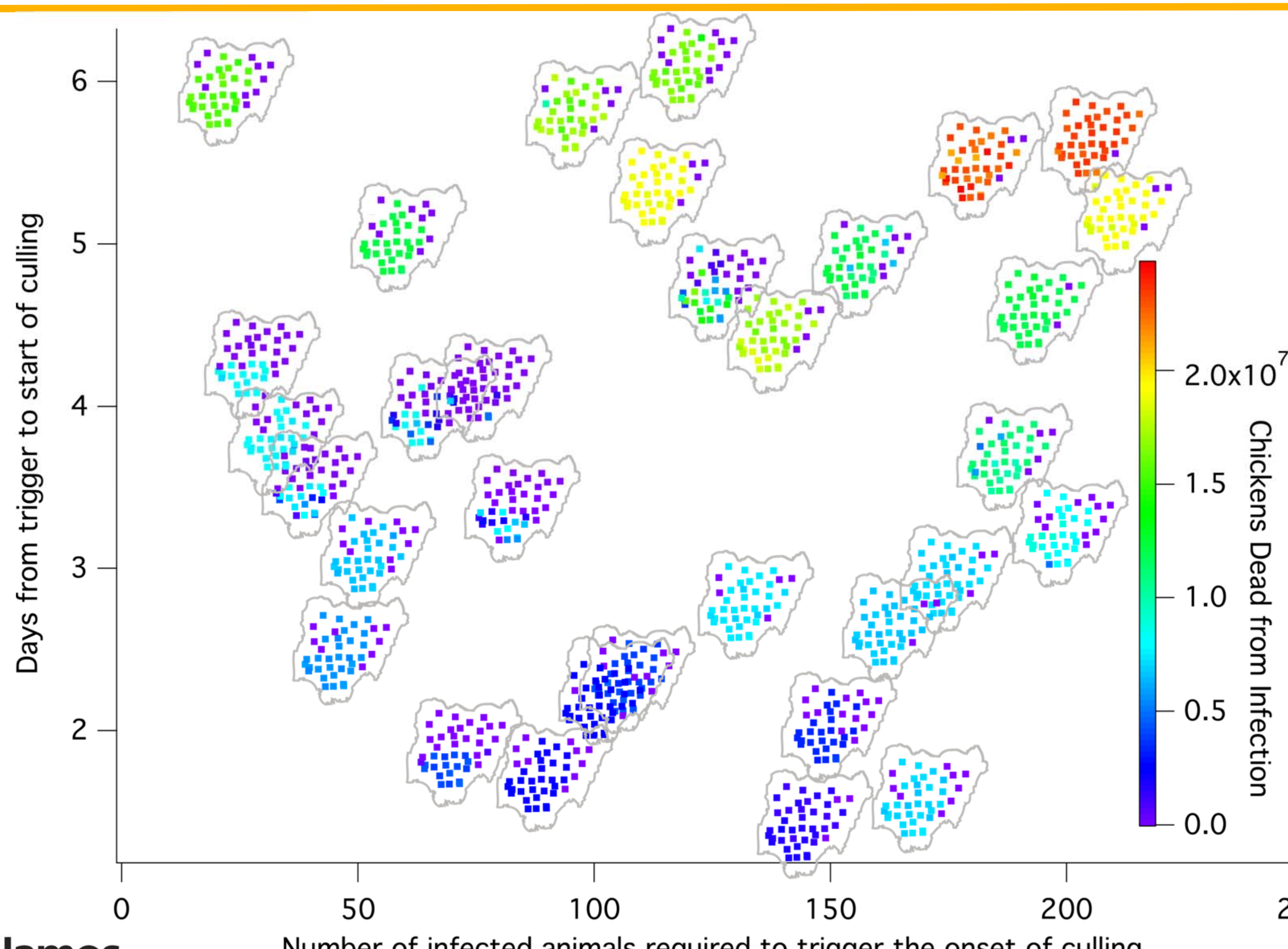
Multihost epidemiological model



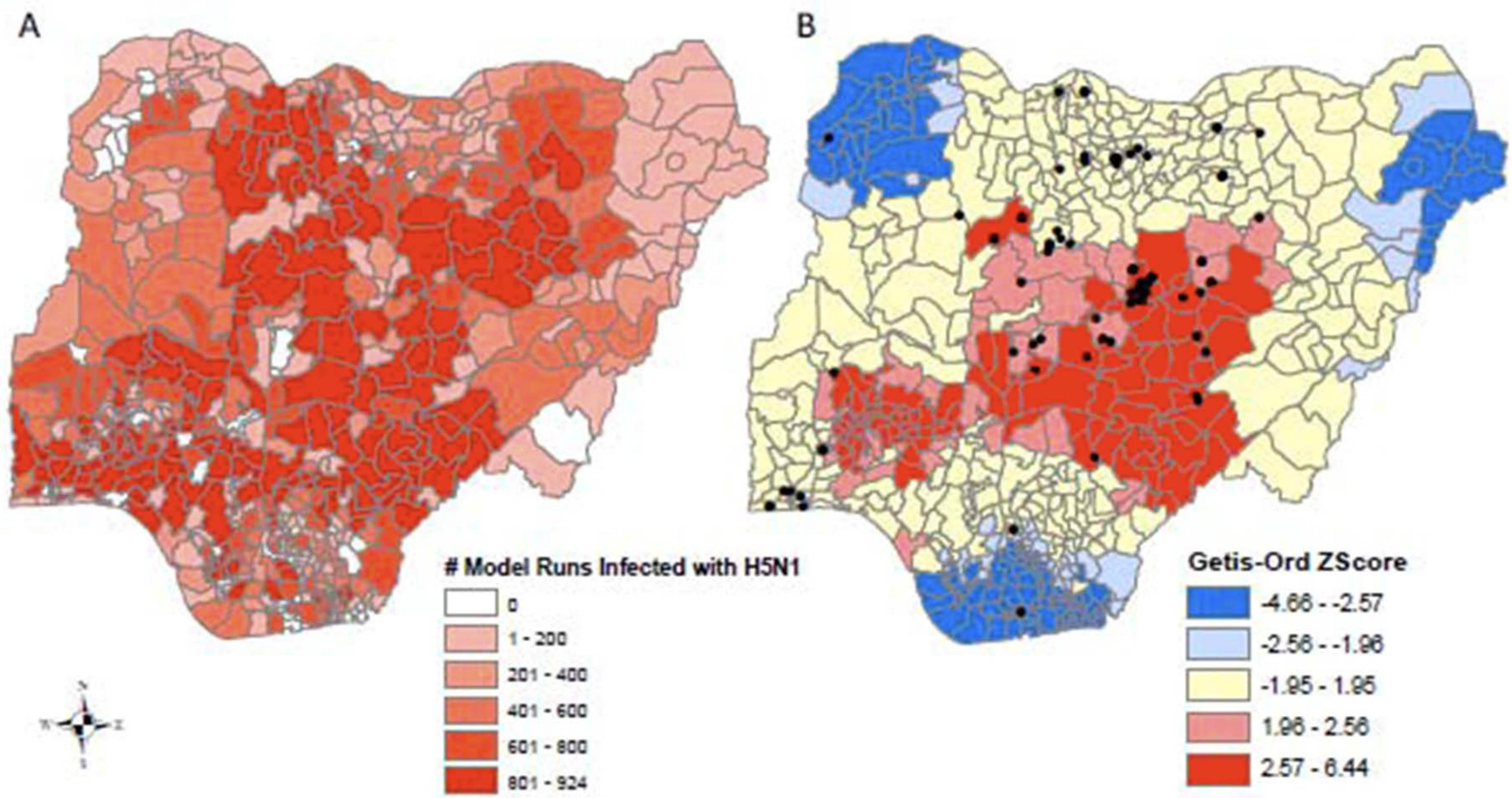
Regions of Nigeria



Experimental Design Results

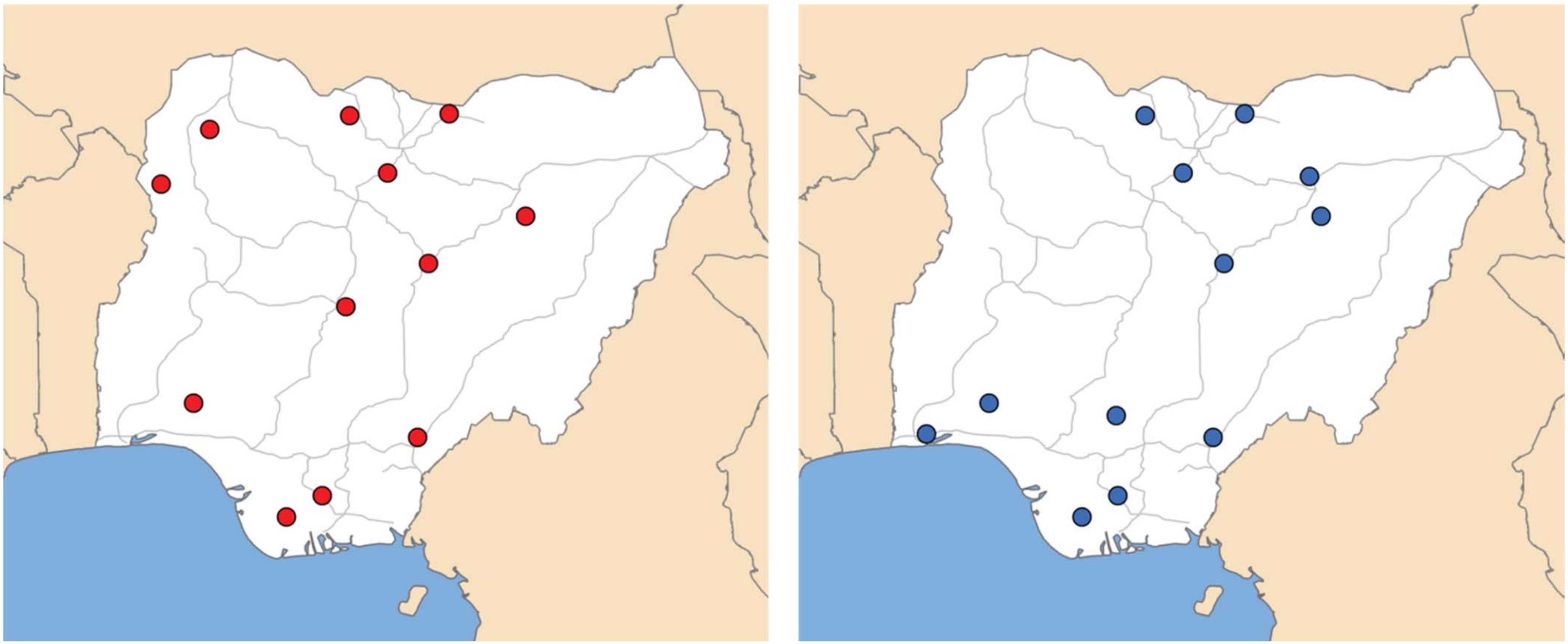


Simulation Results



Optimizing for Biosurveillance

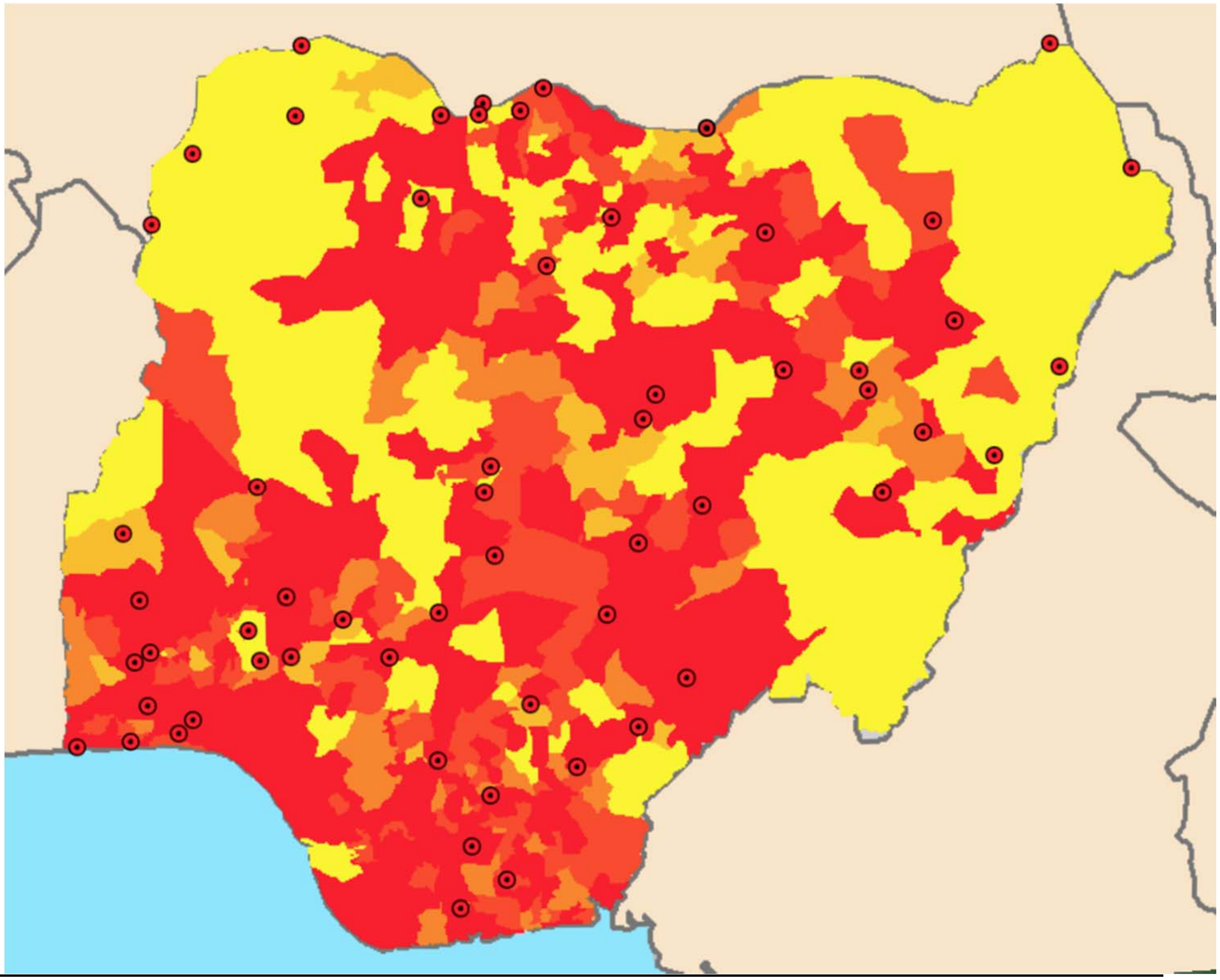
a. Optimized for probability of detection   b. Optimized for speed of detection



Building a Biosurveillance Architecture

- Overall epidemic consequence vs. location of start of epidemic (red indicates higher consequence).

- Markers indicate current surveillance points operated by the Nigerian government.



Gaps and Needs

- Incentives for reporting animal infections due to extensive and uncertain economic consequences
- Rapid, real-time genotyping
- High throughput laboratory capabilities
- Making the connection to the facts on the ground more literal and exact
- Spatial-temporal metadata = smart data
- Completion of spatial-temporal analysis

Acknowledgments

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