Modeling the Introduction of Classical Swine Fever Virus into U.S. Domestic and Feral Swine Populations

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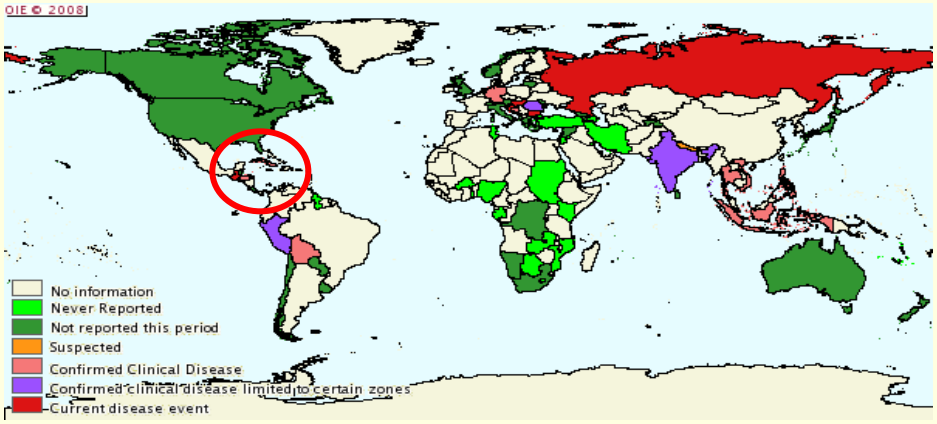
Objectives of Modeling

- Goal: quantitatively represent real world systems to understand complex biological processes and identify key features
- Identify and evaluate the effect of different control strategies, pre- and post-outbreak
  - E.g. Vaccination, pre-emptive slaughter, movement restrictions, surveillance zones
- A preparedness tool for informing decision-makers and policy, in addition to experimentation, epidemiologic data collection and analysis
- Models should be based on accurate data, verified, and used for the purposes they were developed

Classical Swine Fever (CSF) Virus

- Highly contagious, economically costly viral disease of swine
- Reportable to the World Organization for Animal Health (OIE)
- U.S. declared CSF free in 1978 after a 16 year eradication campaign, cost $140 million
- Transmission routes:
  - Direct contact between animals (esp. oronasal)
  - Indirect contact: infected meat, AI, contaminated clothes, equipment, transport trucks
  - Epidemiologic role of aerosol?
- Variable clinical signs, indistinguishable from other U.S. diseases
  - PRRS, erysipelas, *Salmonella*, *Pasteurella*, PMWS, enteric/resp. diseases unresponsive to antibiotics

CSF: Continual Risk of Introduction

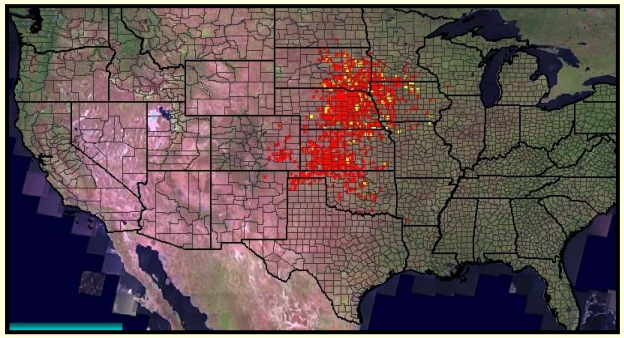


- Worldwide distribution
  - including Caribbean and parts of Mexico
- Ease of access to the virus
- Currently circulating viral strains are predominately low to mildly virulent, may delay detection

Source: World Animal Health Information Database (WAHID), OIE

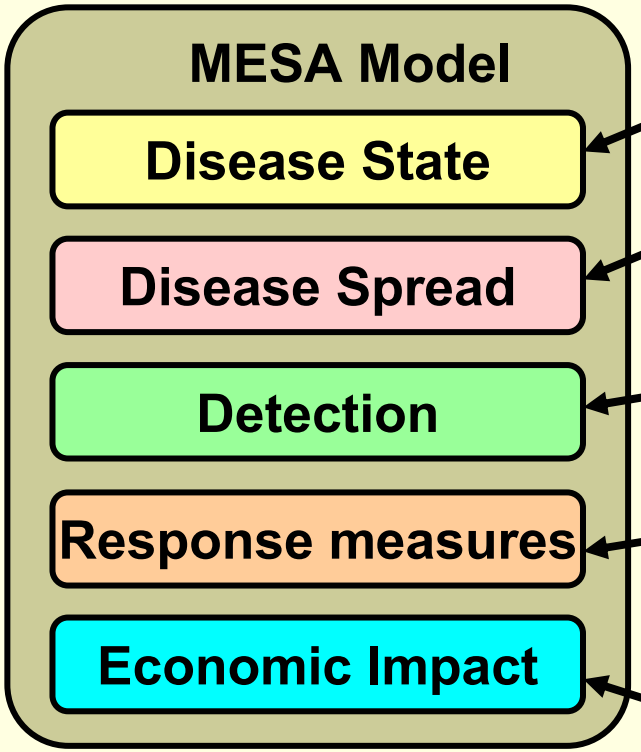
Multi-scale Epidemic/Economic Simulation and Analysis (MESA) Model

- A decision support tool developed at Lawrence Livermore National Laboratory (LLNL) that can analyze multiple and complex policy options simultaneously
- A spatial, stochastic, agent-based model with economic post-analysis
- Ability to simulate local, regional and national scale outbreaks
- Country can be divided into regions with region-specific attributes for contact rates and response measures



- 34 different facility types based on NASS data
  - Swine: farrow to finish, farrow to feeder, farrow to wean, nursery, finisher

MESA Model Overview



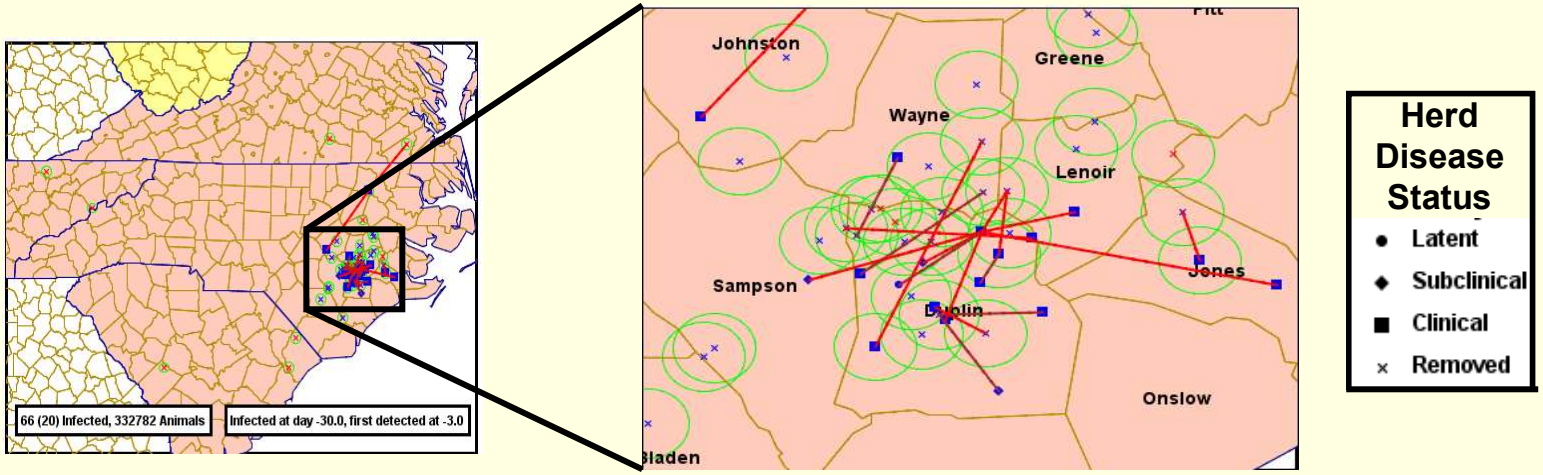
SEIR: susceptible, exposed/latent, infectious, recovered

- SEIR-based (intra-herd) disease model for each individual facility
- Disease spread between facilities by direct and indirect contacts using agent-based engine
- Detection of infected facilities leads to response measures
- Response measures include quarantine, movement controls, vaccination, depopulation, dependent on available resources
- Economic impact includes livestock industry losses and cost of control measures

Slide courtesy of Dr. Pam Hullinger, LLNL

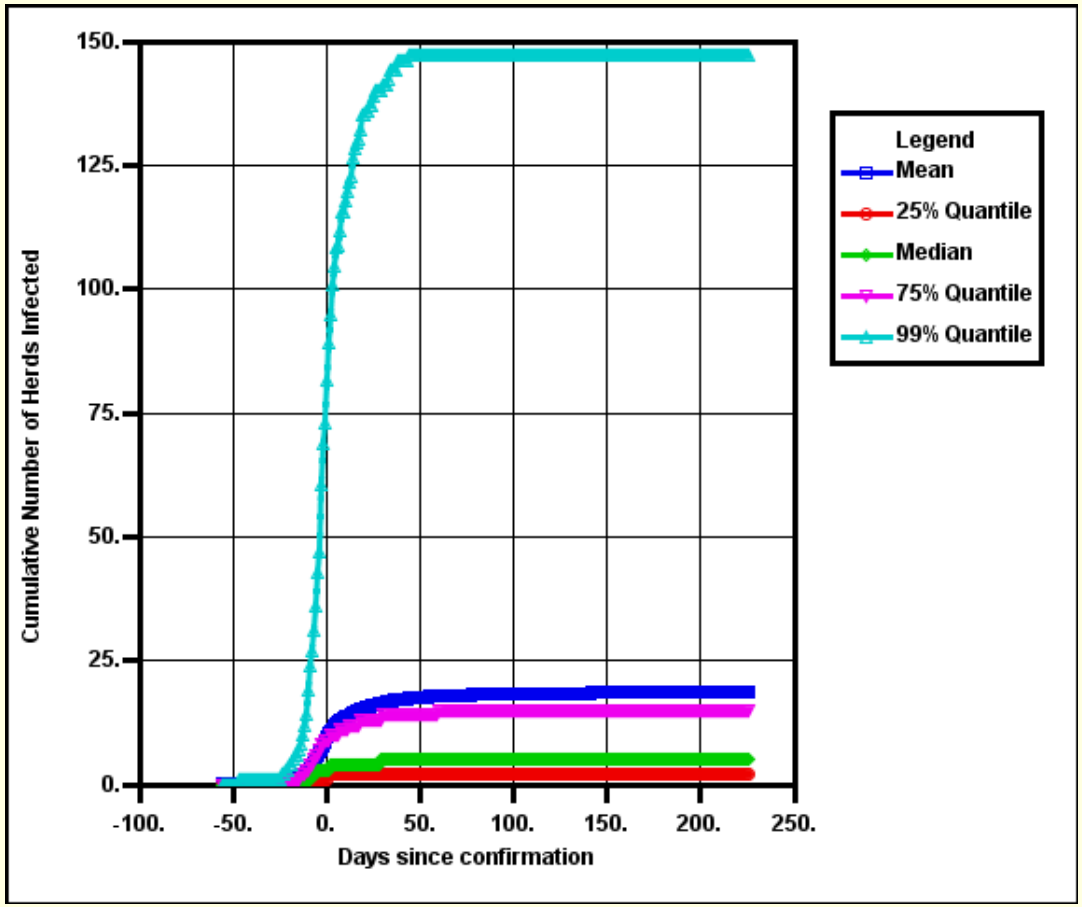
Evolution of Simulated Outbreak in North Carolina

- Outbreak initiated in Duplin County, North Carolina
- Highly Virulent CSF Strain
- Facility type to initiate outbreak chosen randomly for each simulation



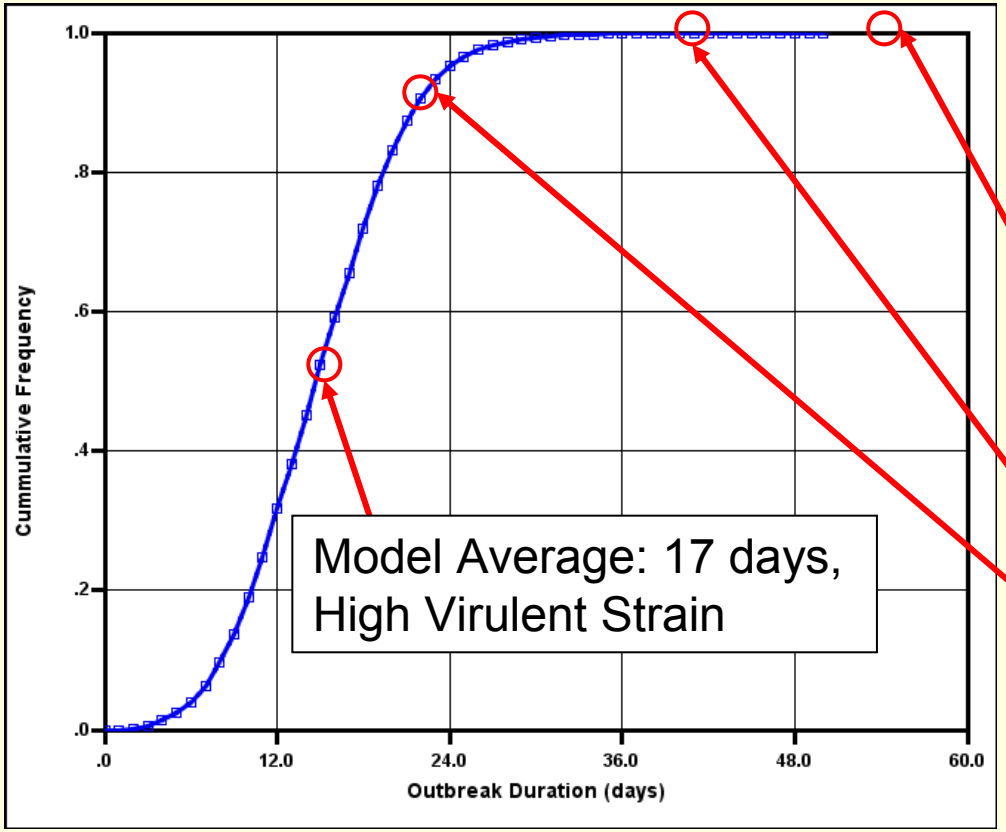
- Disease spread from one realization of the model scenario

Range of Possible Outbreak Outcomes



- Average Epidemic:
  - Infects 19 facilities
  - Infects 93,264 animals
  - Lasts 101 days
- Most of outbreaks were localized
- Large nurseries and large finishers were infected most often
- Larger outbreaks (50+ facilities infected) due to delay in detection, interstate spread before disease detected

Distribution of Time to Detect Outbreaks of High Virulent CSF Strain



- Actual time to detect past outbreaks of moderately virulent CSF strains:

Germany (1997): 8 weeks

Netherlands (1997-98): 6 weeks

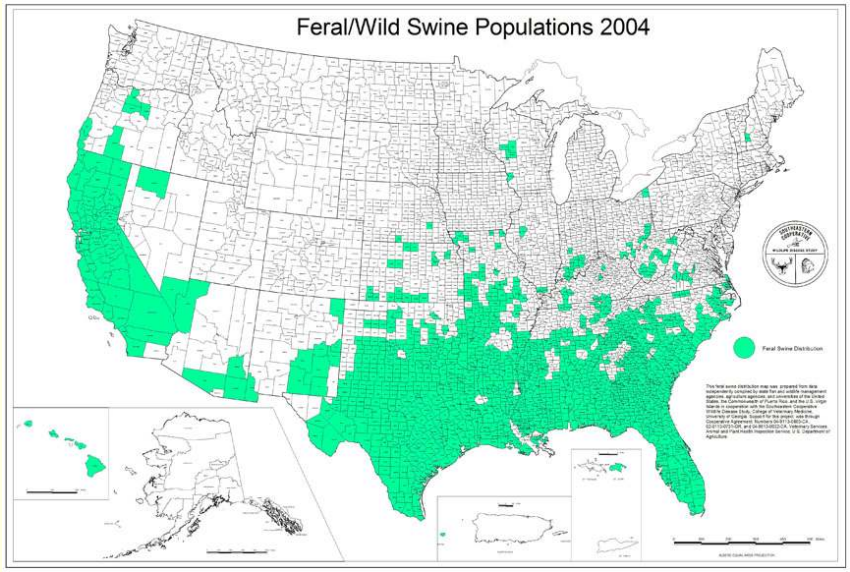
Belgium (1993): 3 weeks

Next steps

- Represent vertical integration of commercial swine industry
- Evaluate different response and control strategies; compartmentalization
- Evaluate outbreaks in different geographic regions, different facility types
- Model outbreaks of low to moderate CSF viral strains
- Develop a wildlife disease outbreak model to understand the epidemiologic and ecologic role of feral swine in outbreak scenarios

Wildlife Disease Modeling: Feral Swine

- Widespread distribution, populations continue to increase
  - Recent migrations/introductions in northern states
- Population estimates range from 4 to 5 million
  - Majority in California, Florida and Texas
- CSF in feral swine:
  - Disease fade-out or become endemic?
  - Time to detection?
  - Potential domestic/feral interaction?



Source: Southeast Cooperative Wildlife Disease Study
http://www.uga.edu/scwds/dist_maps/swine04.html

Wildlife Disease Modeling: Feral Swine

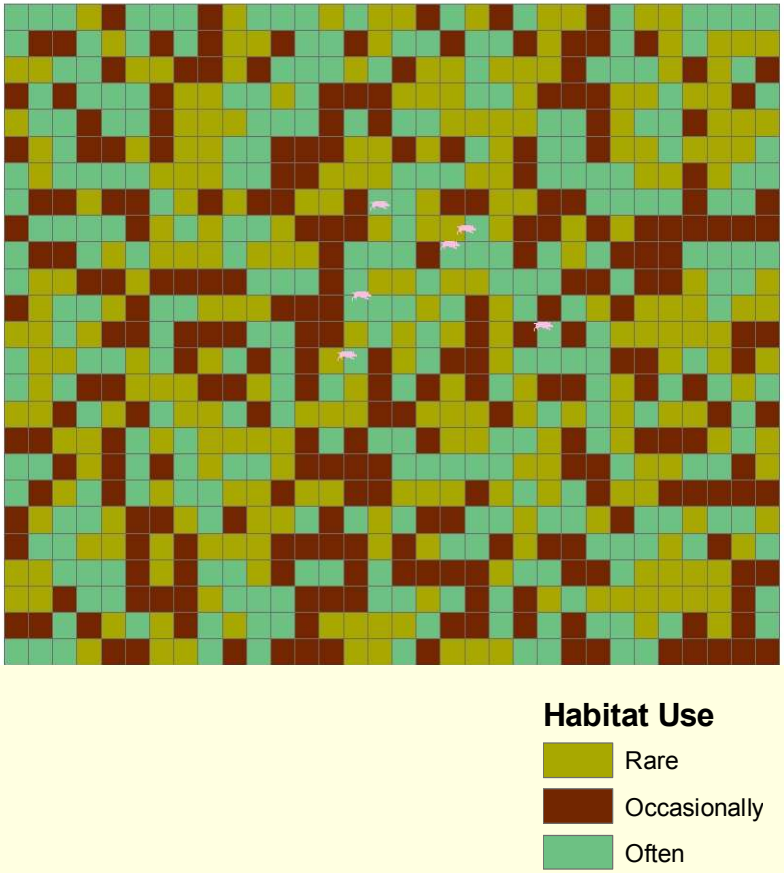
- Disease spread in feral swine populations: use of individual-based modeling (IBM)
- Ecological population dynamics foundation
  - Social structure, aging, natality/mortality, move freely, heterogeneous interaction across different landscapes, behavior change due to disease
- Ability to incorporate preferential habitat use and movement through different landscapes
- Evaluate how disease may spread through changing landscapes

Preferential Habitat Use and Function

- Host and environment interaction:
  - Habitat use
    - Where do they spend their time?
  - Habitat function
    - Where do they come into contact?
    - How do they move through different landscapes?

- **Disease spread in feral swine depends on population biology, connectivity and movement across different landscapes**

Hypothetical landscape mosaic



Conclusions

- CSF poses a significant economic threat to the U.S. swine industry for intentional or non-intentional introduction
- Although outbreaks of highly virulent strains characterized by high mortalities were common in the past, currently circulating strains are predominately of mild to low virulence; this may delay detection
- Lack of understanding of factors that influence local, regional and national spread of CSF in U.S. domestic/feral swine is a major limiting factor in foreign animal disease prevention and control
- Used appropriately, models can be a powerful tool for informing animal health policy