Stochastic, Spatially Explicit Models

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Model Categorizations

- Continuous vs. Discrete
- Compartmental (SI, SIS, SIR, SLICR…) vs. Individual Based (Microsimulation Model)
- Behavioral, Descriptive, and Normative
- Analytic vs. Numeric
- Deterministic vs. Stochastic
- Spatial vs. Non-spatial

Deterministic vs. Stochastic

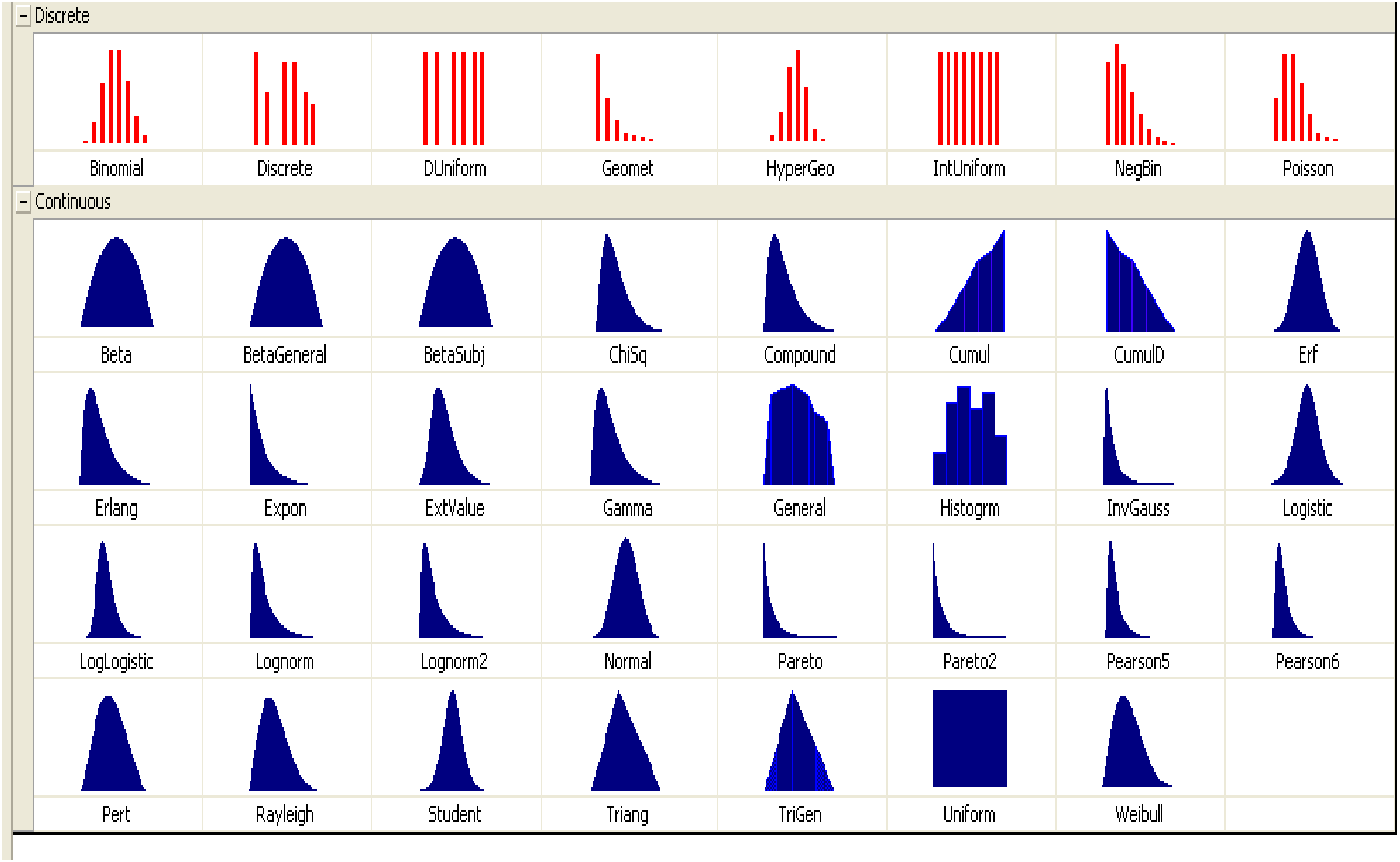
- Deterministic
  - Single input/output
  - No element of chance
  - Mean, median, mode, 95^{th} or 99^{th}%, extreme value(s)

- Stochastic (probabilistic or random)
  - Incorporates an element of chance
  - Reflects uncertainty and variability
  - Multiple input values and outputs
  - Statistical distribution based

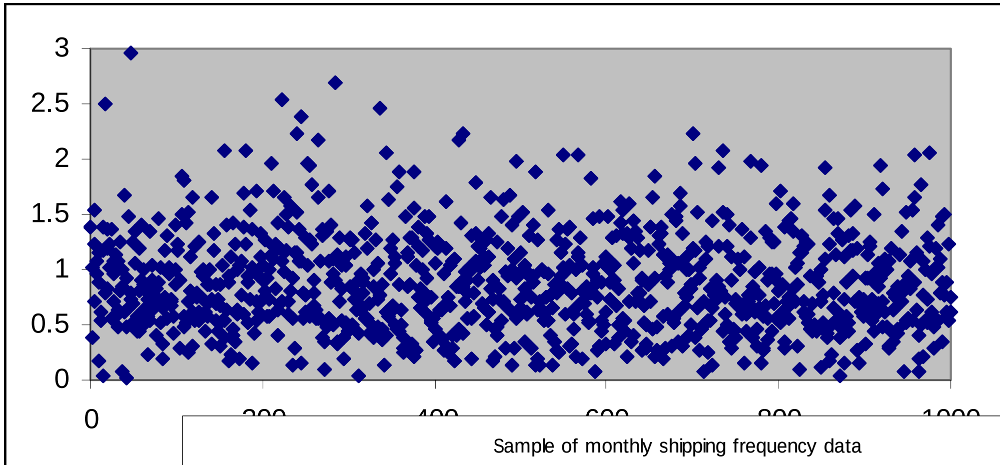
Defining Stochastic Inputs

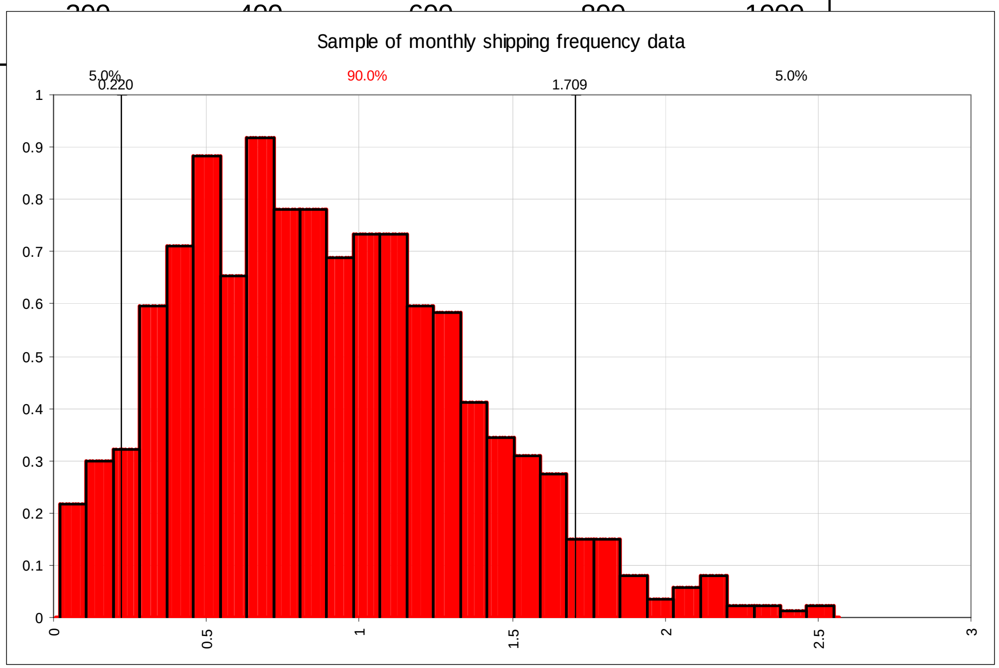
- Expert opinion
  - Survey
  - Individual interaction
- Data
  - Dataset
  - Survey
  - Literature

Potential Stochastic Inputs

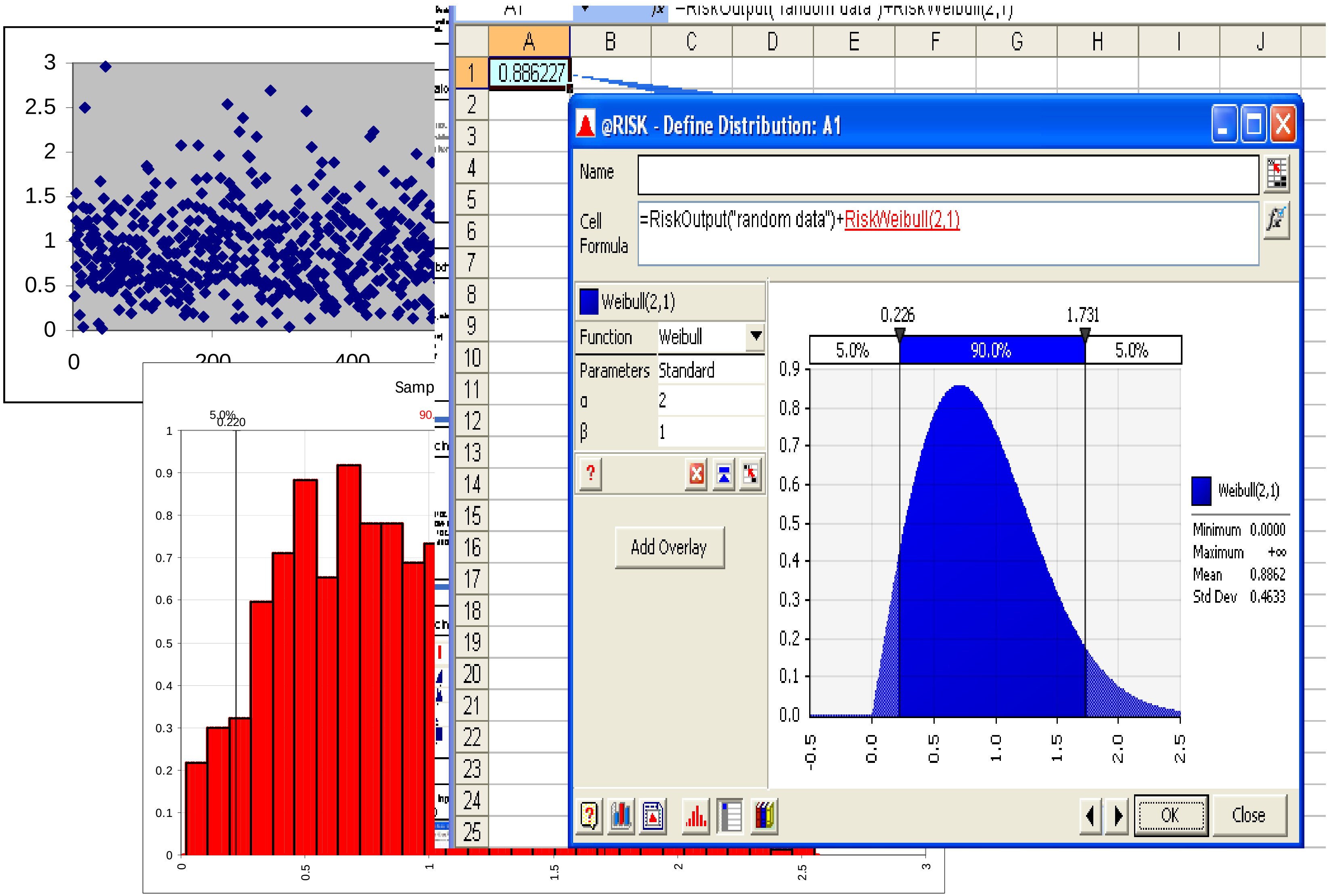


Defining Stochastic Inputs





Defining Stochastic Inputs

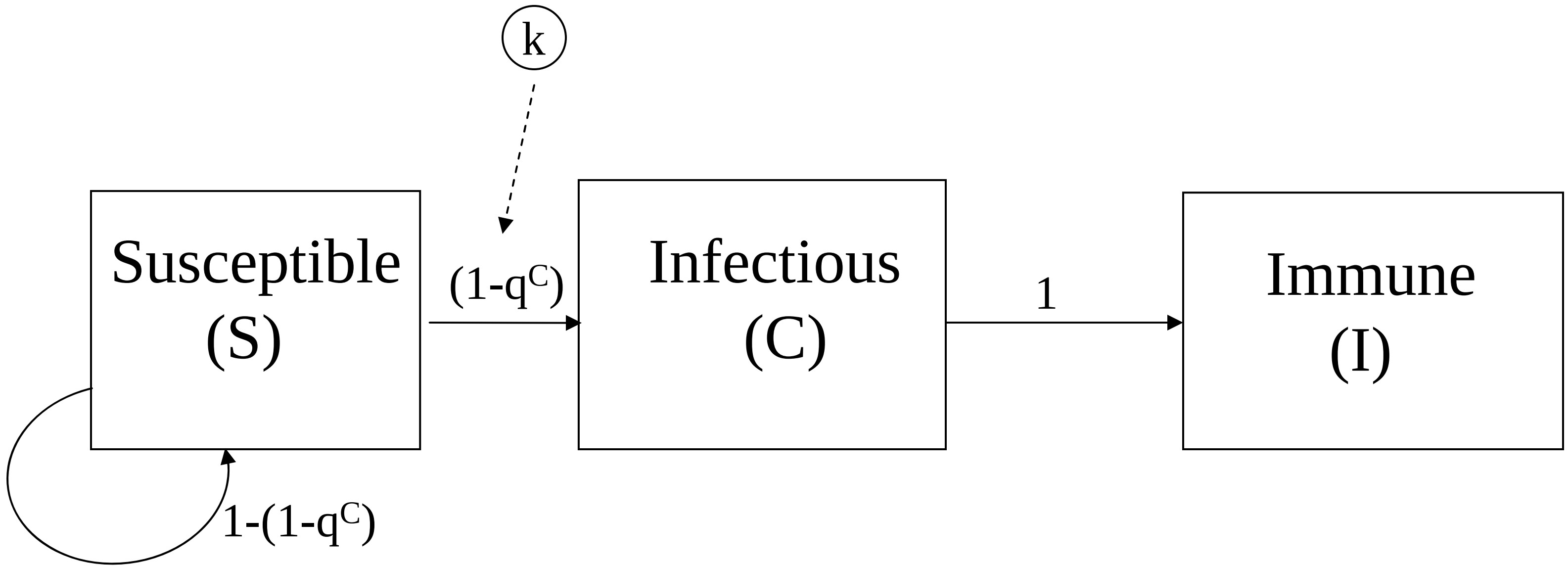


Stochastic modeling: Intraherd ex.

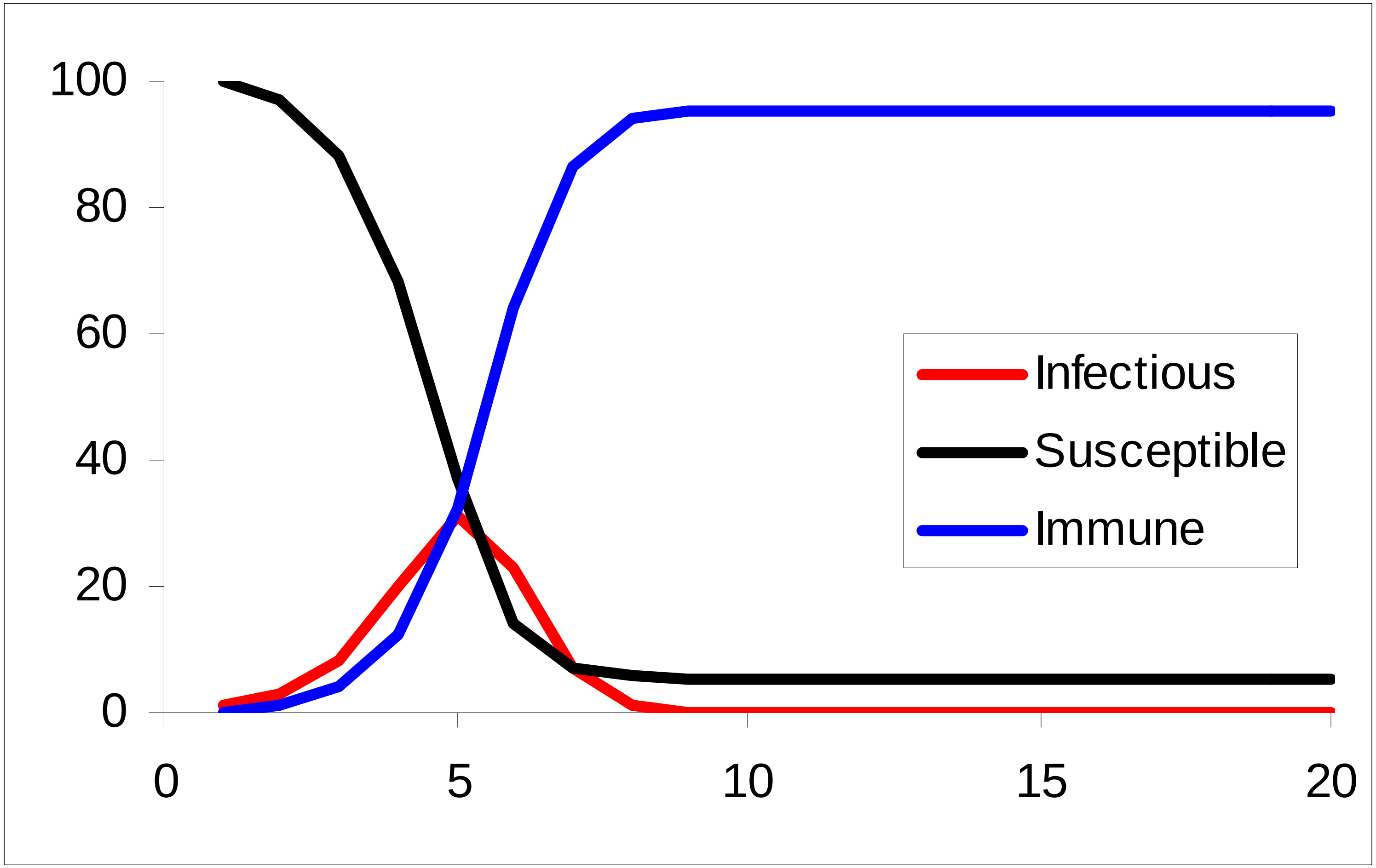
(number of adequate contacts (k); health state durations (D_i))

- Deterministic
- Stochastic
  - – Farm level
    - Dichotomous herd categorization
    - Homogeneous animal characteristics
  - – Truly individual animal

Flow diagram of Reed-Frost (SIR) model

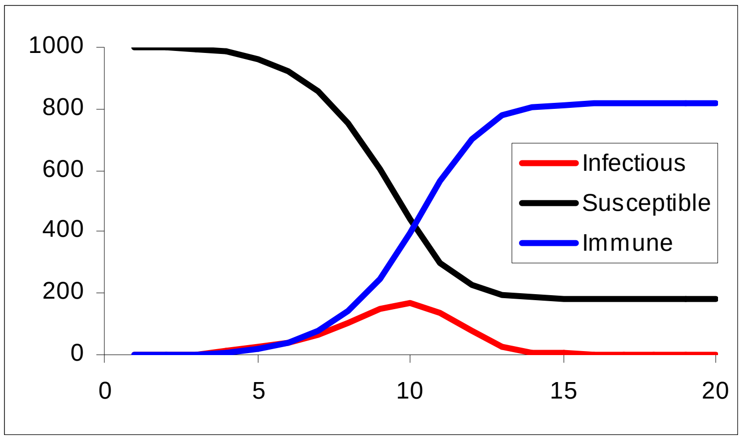


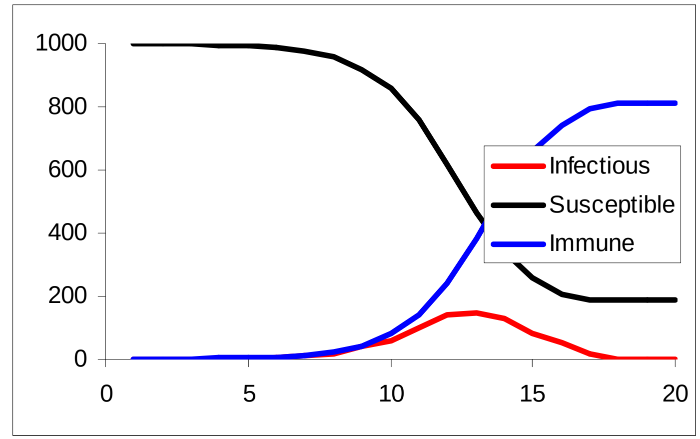
Deterministic SIR Model

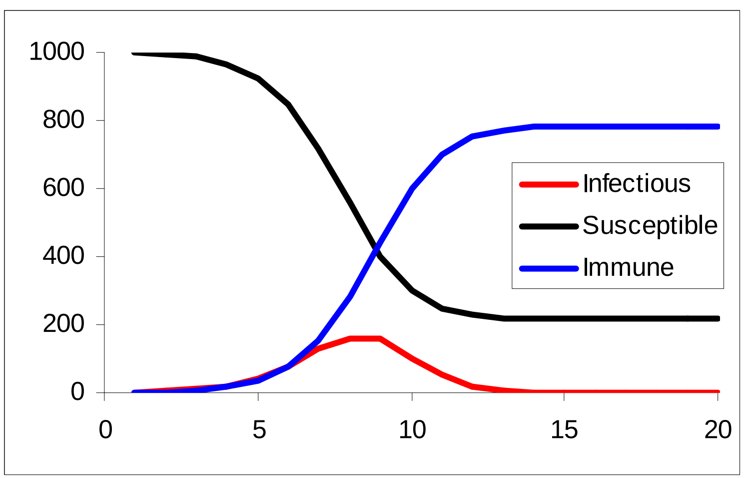


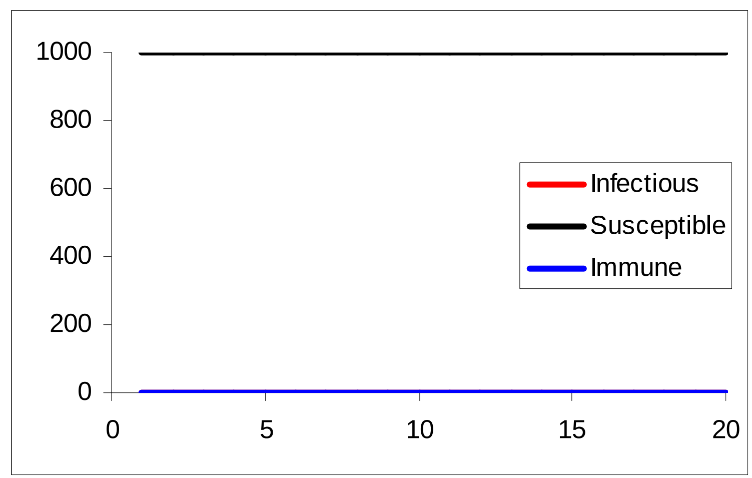
Stochastic SIR Model

(N = 1001, K = 2)

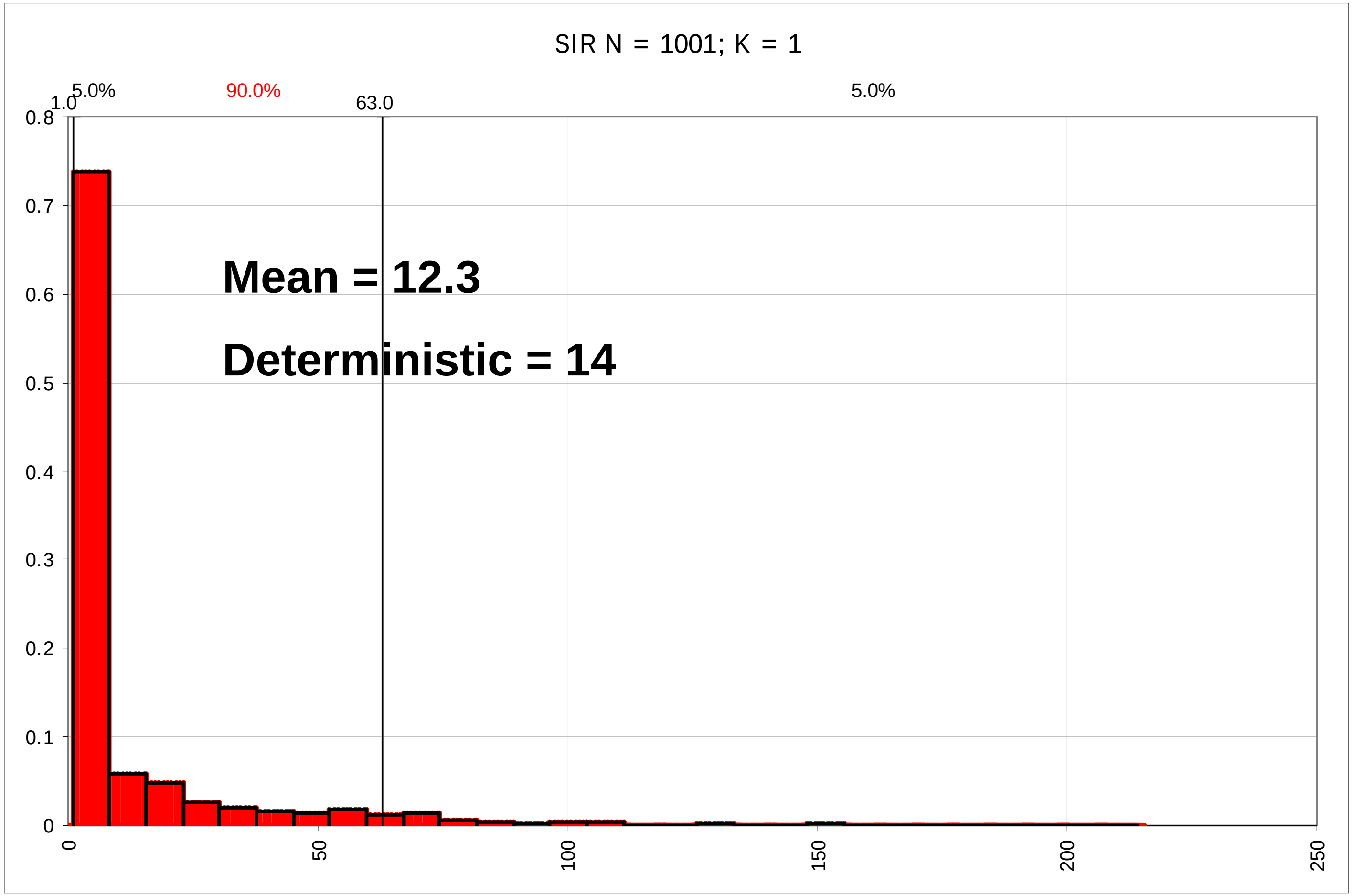




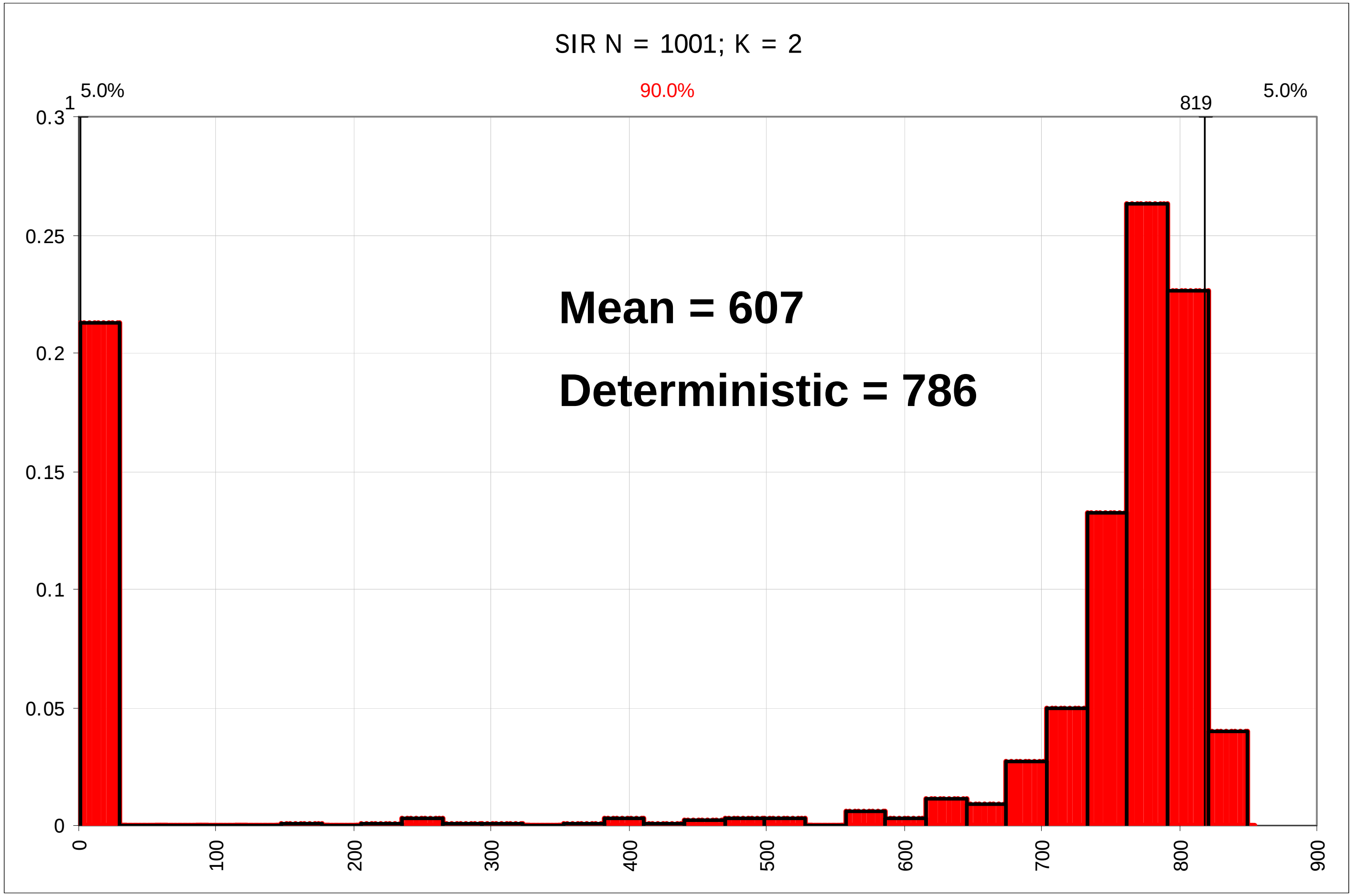




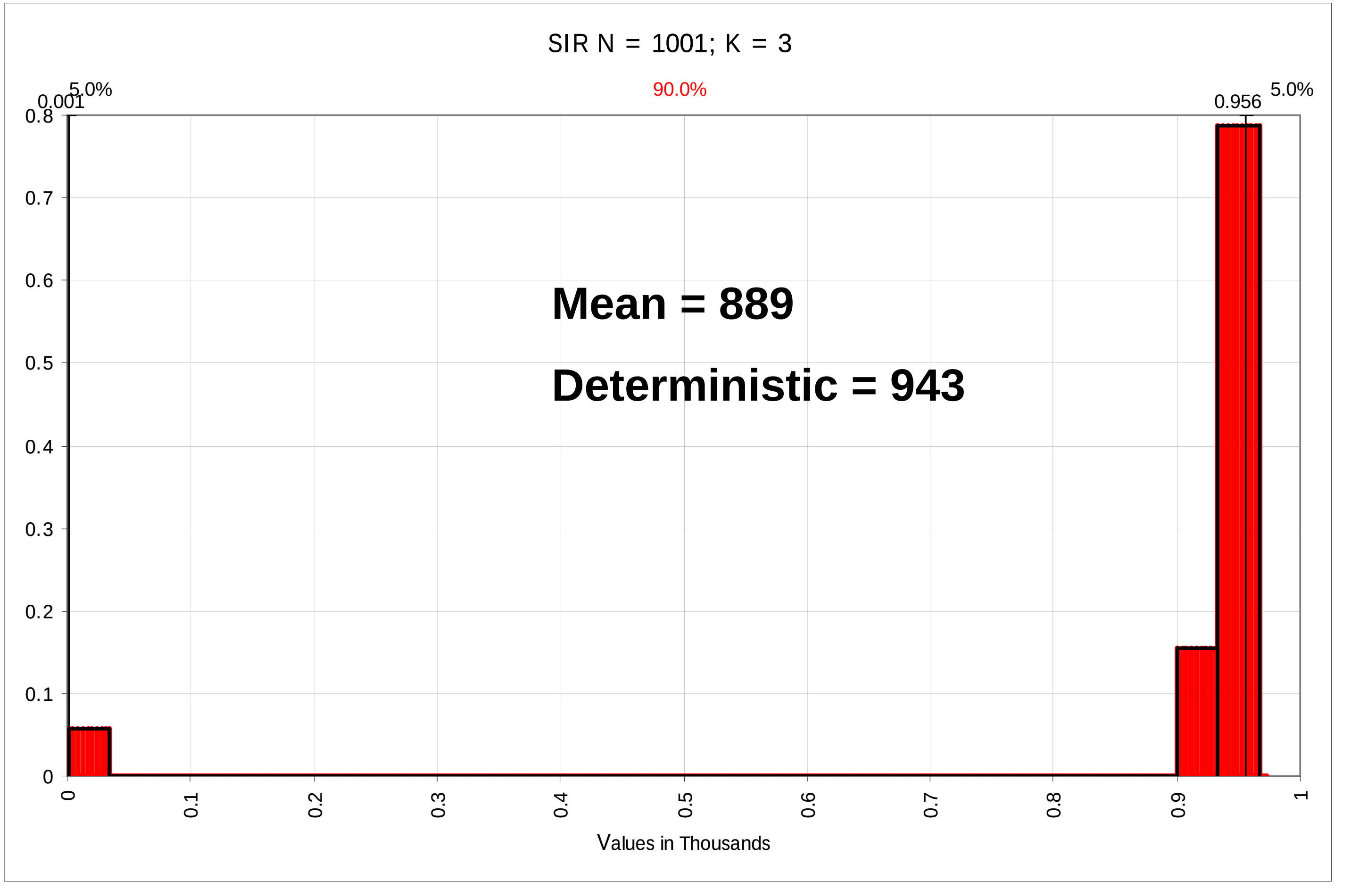
Stochastic SIR Model



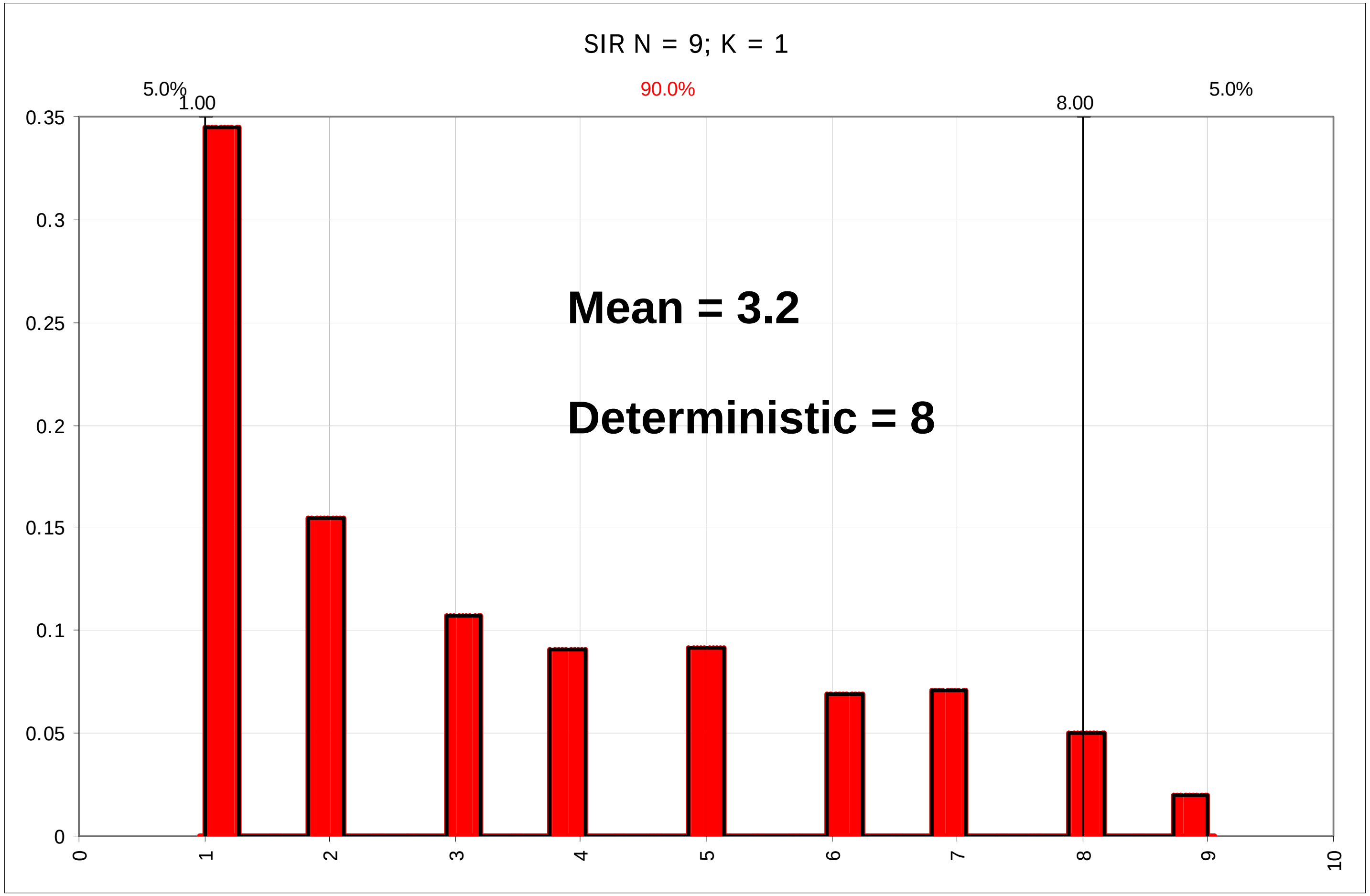
Stochastic SIR Model



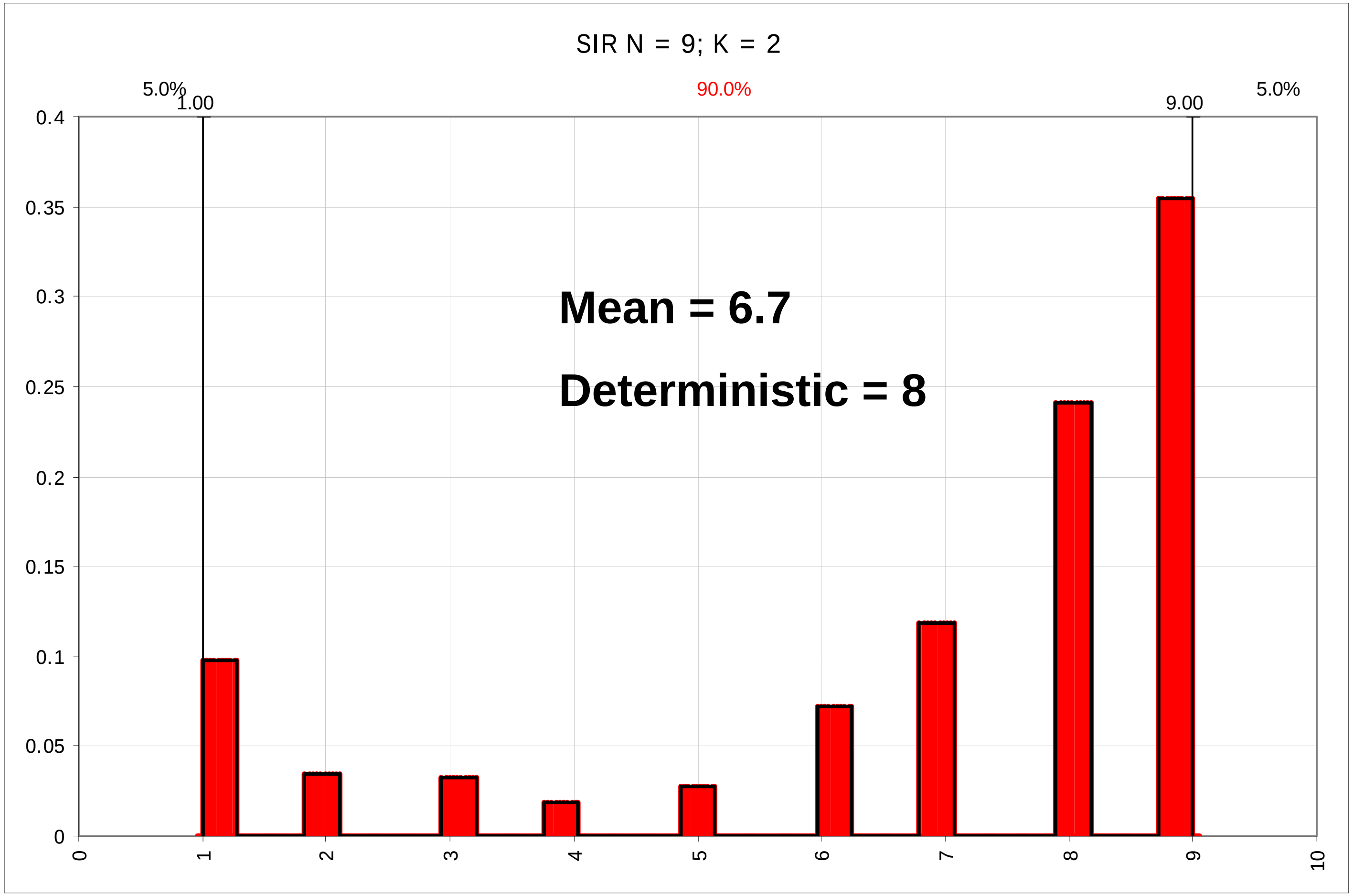
Stochastic SIR Model



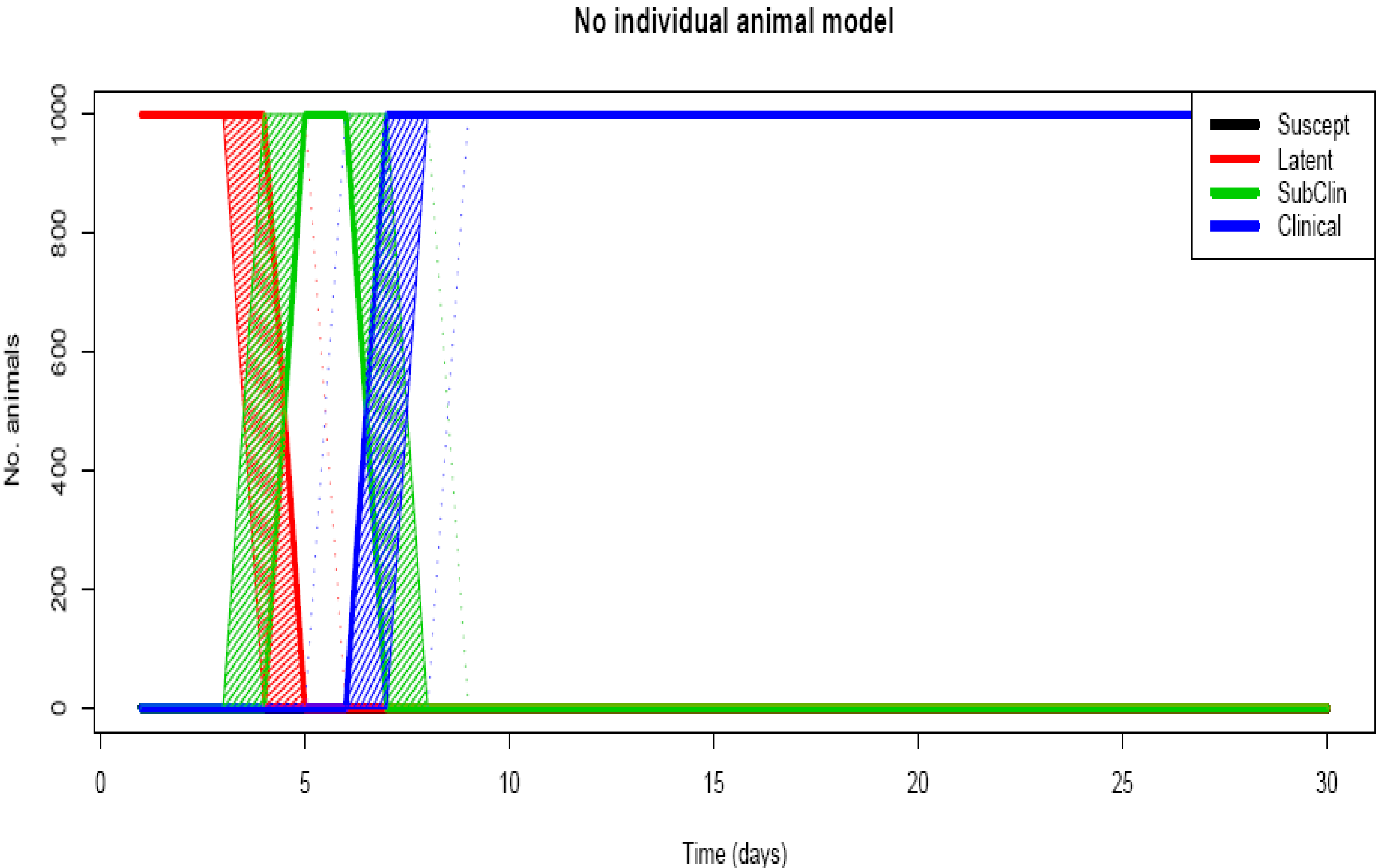
Stochastic SIR Model



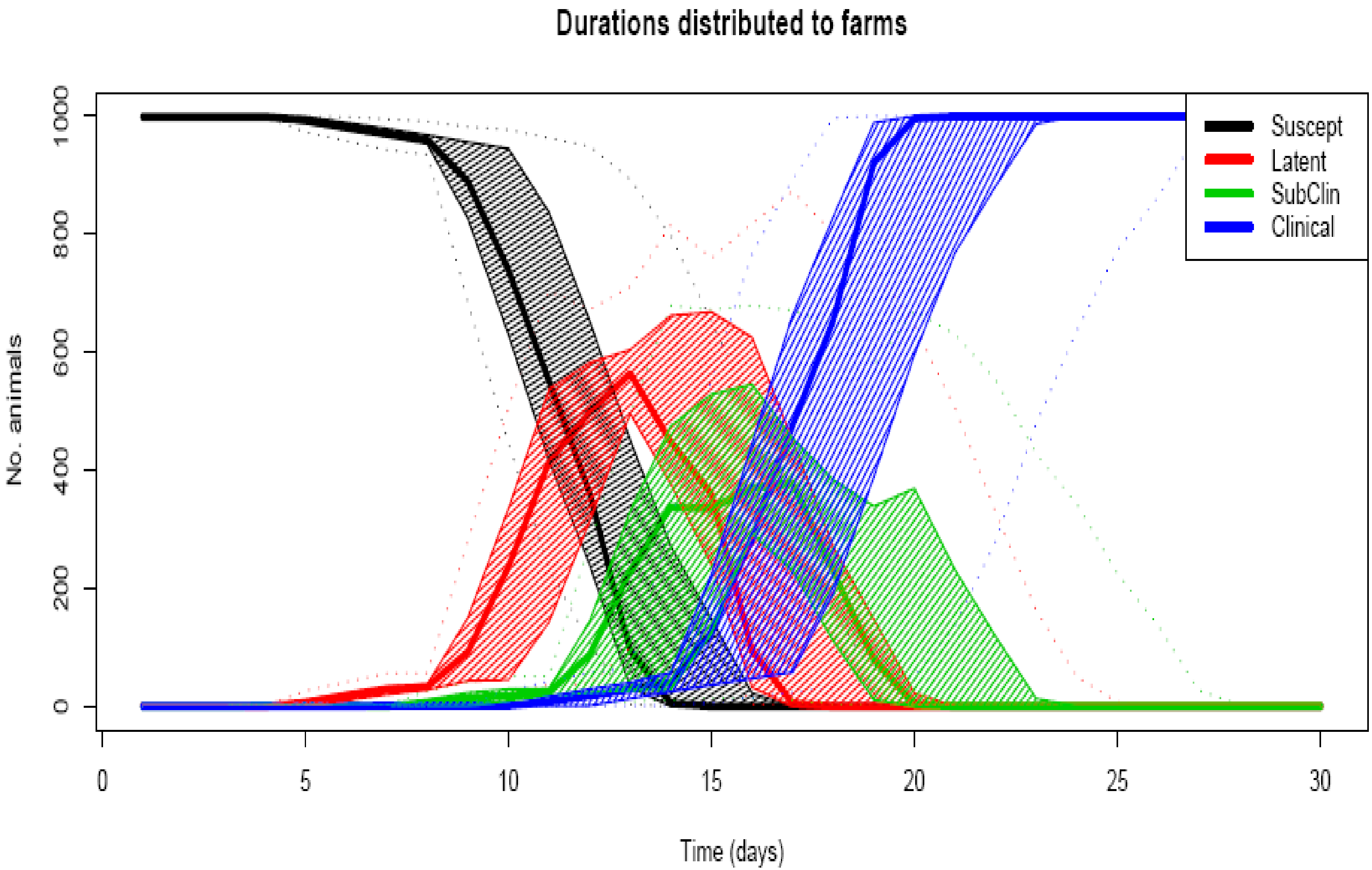
Stochastic SIR Model



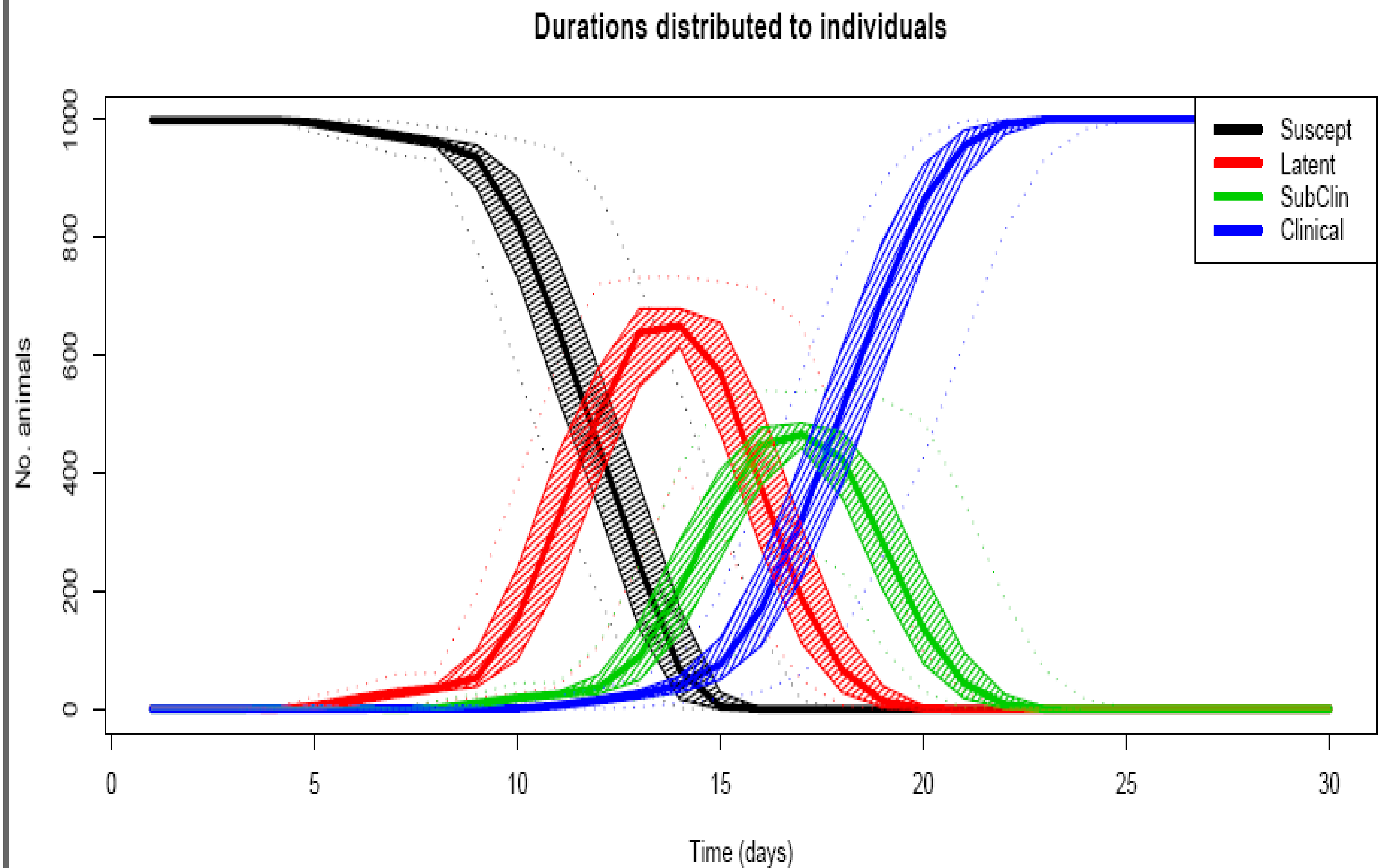
Stochastic SLIC
(no individual animal)



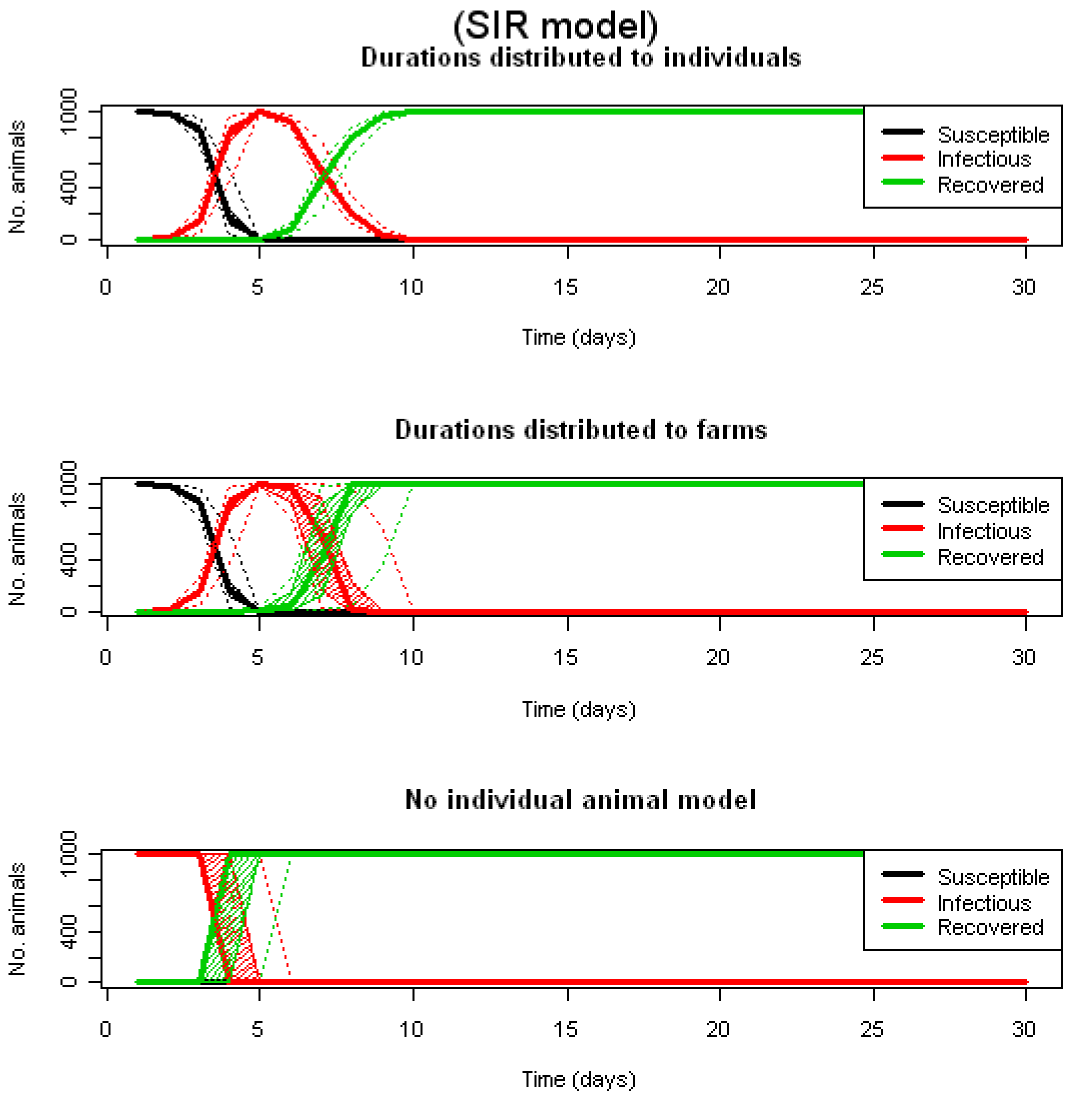
Stochastic SLIC
(farm level)



Stochastic SLIC
(true Individual Animal Based)

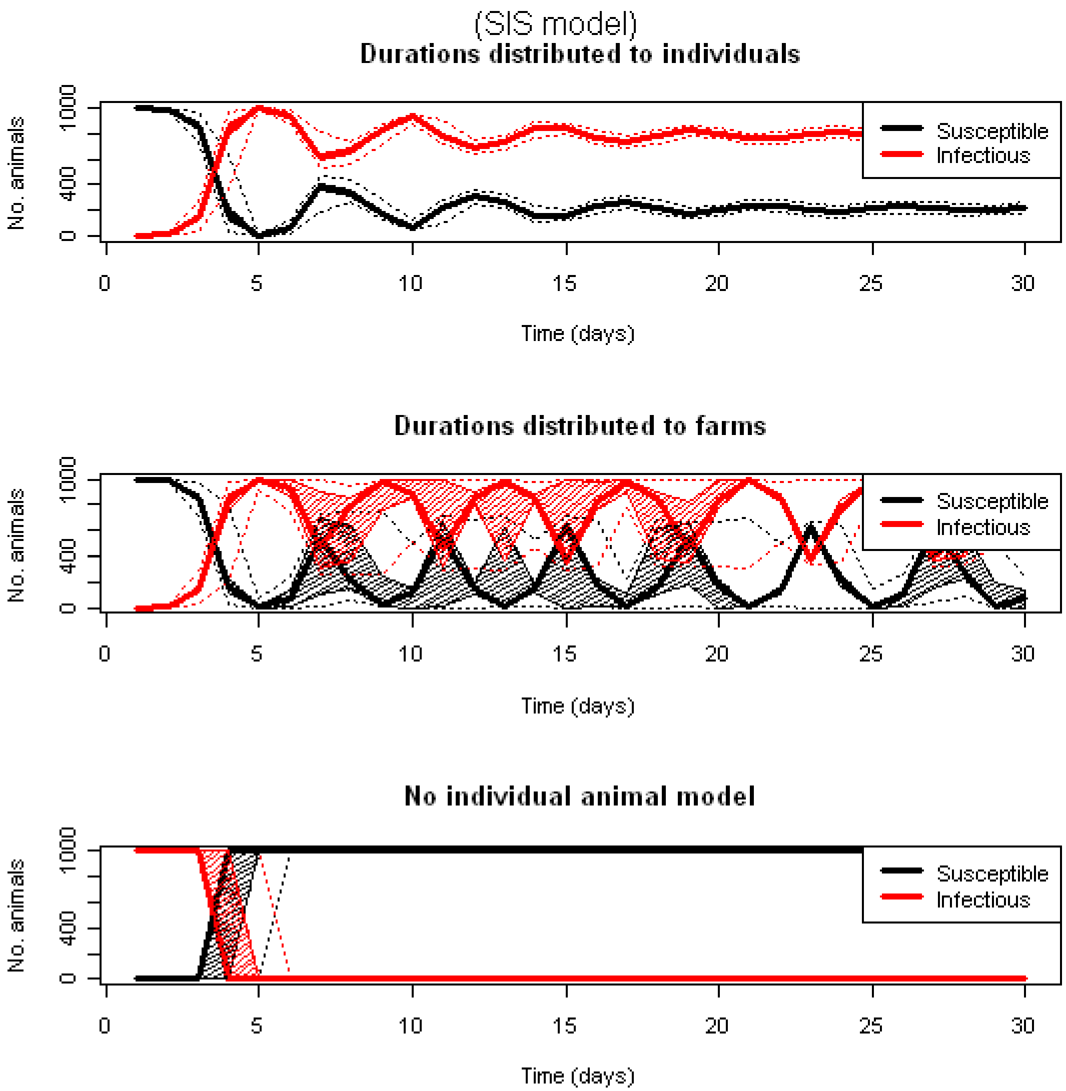


SIR Models



(SIR model)
Durations distributed to individuals
No. animals
0
400
1000
0
5
10
15
20
25
30
Time (days)
Susceptible
Infectious
Recovered
Durations distributed to farms
No. animals
0
400
1000
0
5
10
15
20
25
30
Time (days)
Susceptible
Infectious
Recovered
No individual animal model
No. animals
0
400
1000
0
5
10
15
20
25
30
Time (days)
Susceptible
Infectious
Recovered

SIS Models



(SIS model)
Durations distributed to individuals
No. animals
0
400
1000
Susceptible
Infectious
0
5
10
15
20
25
30
Time (days)
Durations distributed to farms
No. animals
0
400
1000
Susceptible
Infectious
0
5
10
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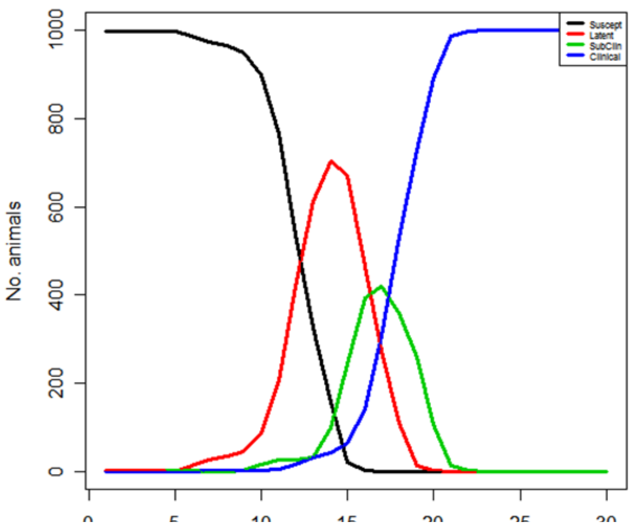
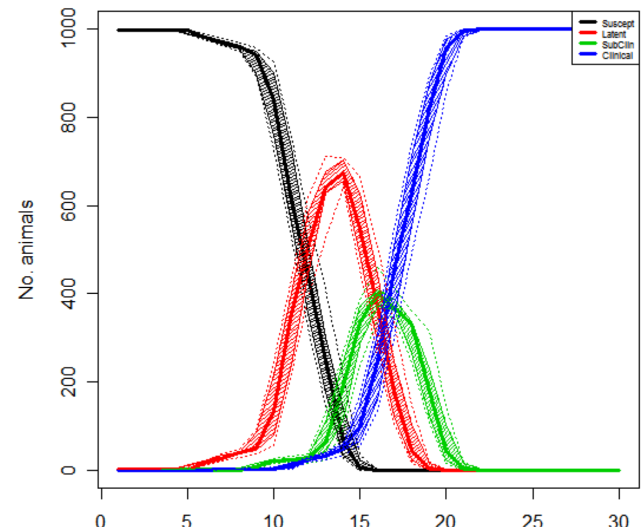
Time (days)
No individual animal model
No. animals
0
400
1000
Susceptible
Infectious
0
5
10
15
20
25
30
Time (days)

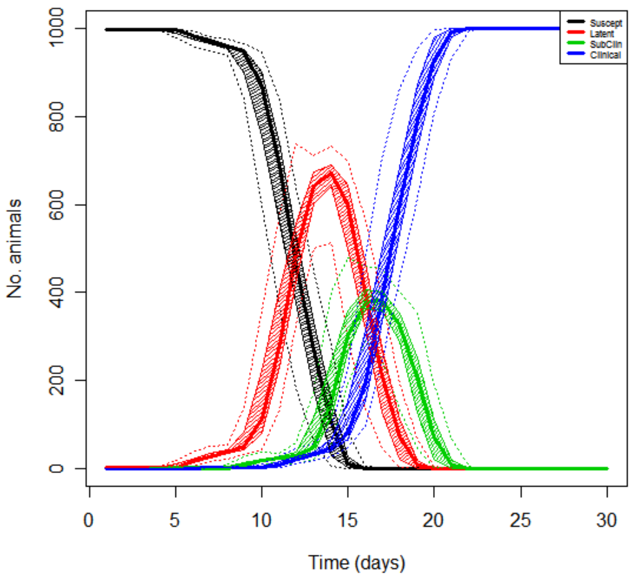
Deterministic vs. Stochastic IAB SLIC Model (N = 1001; Iterations =10, 100, 1000)



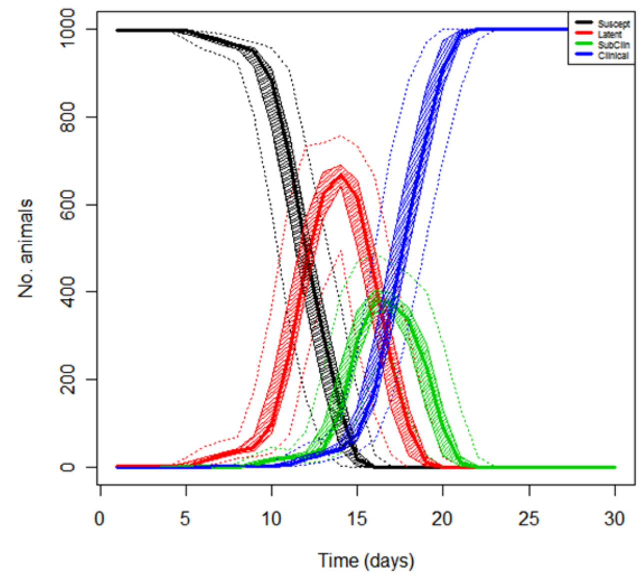
Iterations

1 10

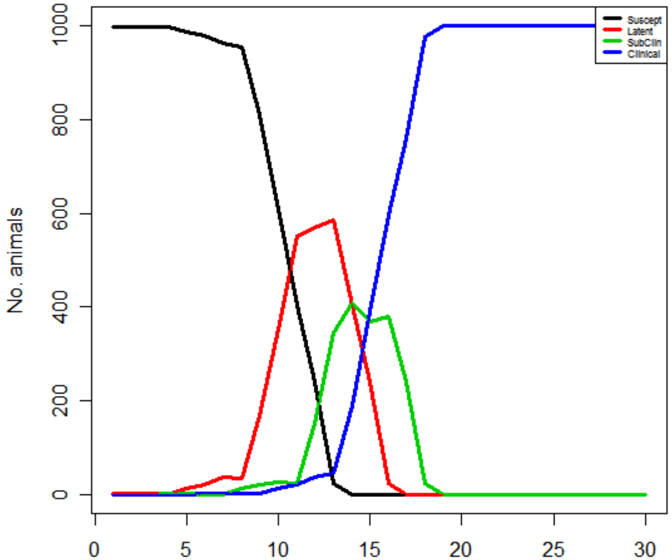




100 1000

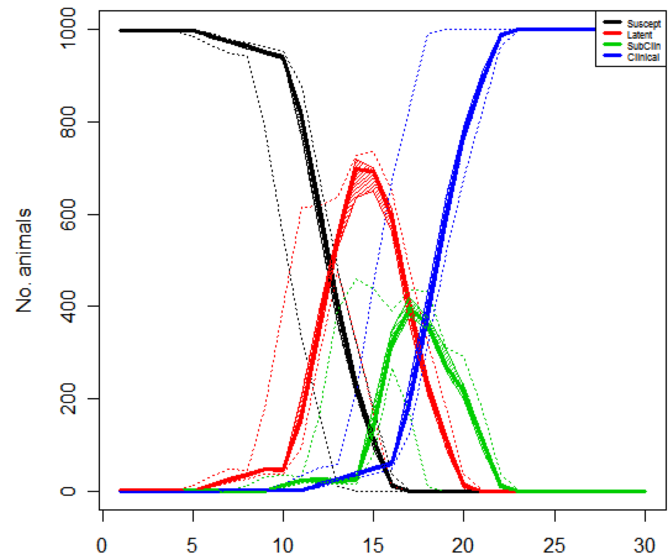


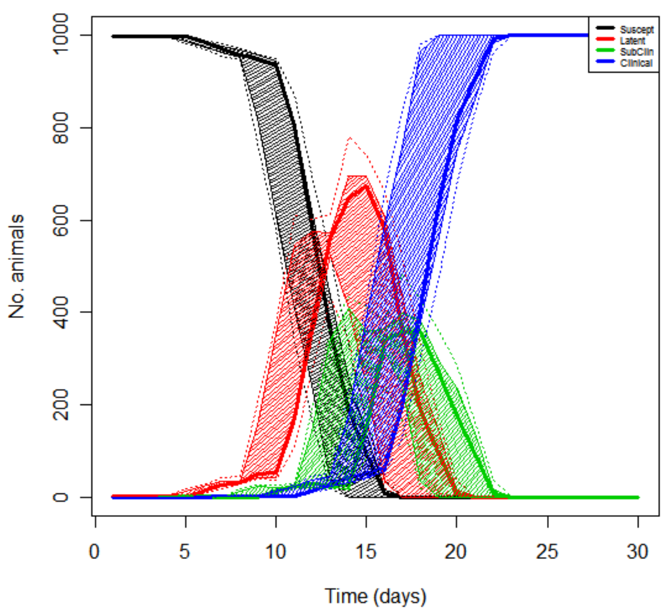
Deterministic vs. Stochastic Herd Level SLIC Model (N = 1001; Iterations =10, 100, 1000)



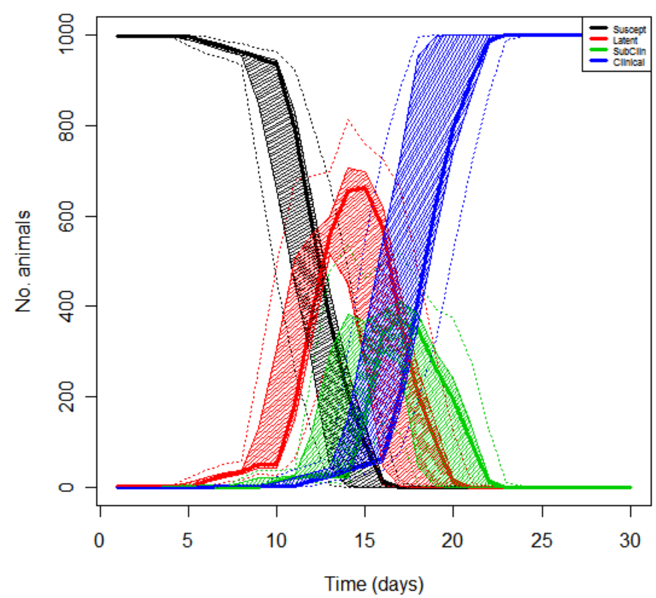
Iterations

1 10





100 1000

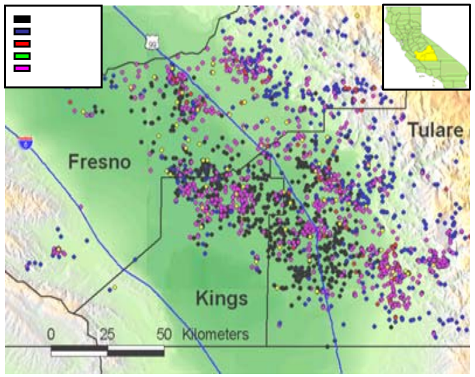


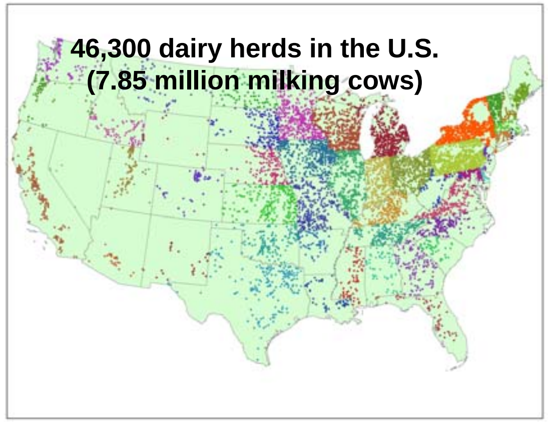
Stochastic Model Conclusions

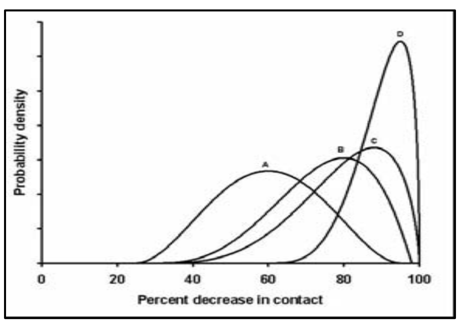
- Produce ranges of outcomes, which may provide more information than “average” results from deterministic models
- May avoid unreliable predictions resulting from epidemic “burn out”
- Caution should be used when using increased iterations (CIs vs. PIs)
- More (iterations) is better but “costs” more
- Require additional data/information

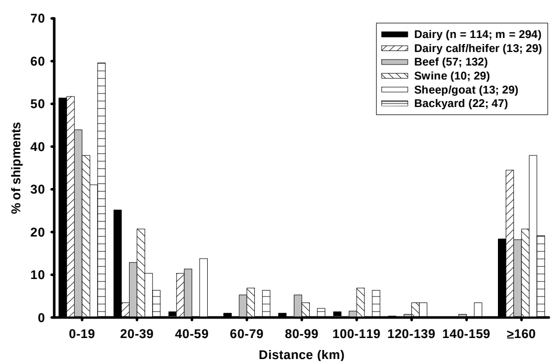
Spatial Models

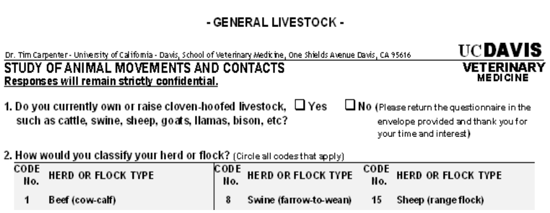
Davis Animal Disease Simulation (DADS) Model











- **Spatial**
- **Stochastic**
- **Data driven**
- **Resource constrainable**
- **Highly individual animal based**
- **National level spread & control**

Populating Spatial Models

- Surveys
- Federal level data (USDA National Agriculture Statistics Service (NASS))
- Industry collaborators
- State collaborators
- Merged databases

Use of heterogeneous operation-specific contact parameters changes predictions for foot-and-mouth disease outbreaks in complex simulation models

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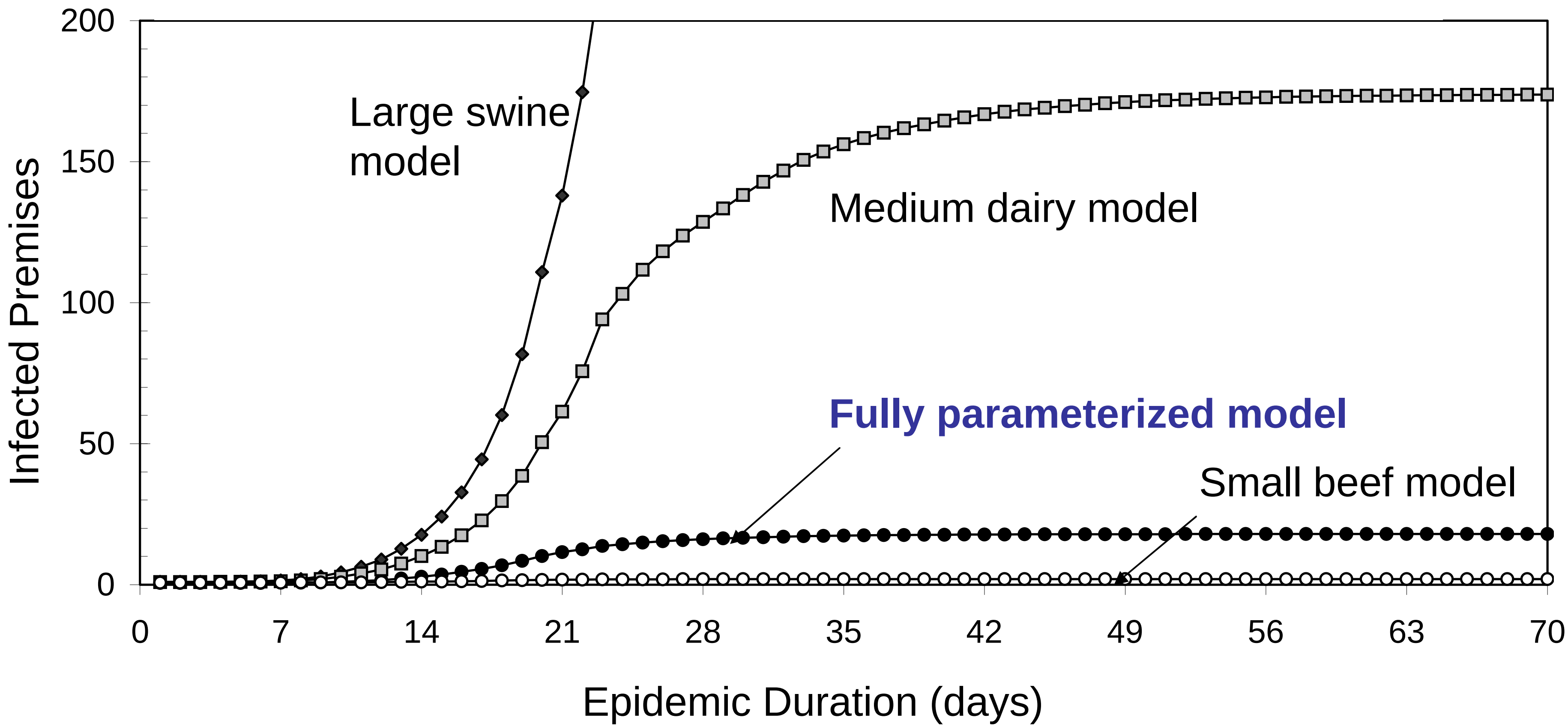
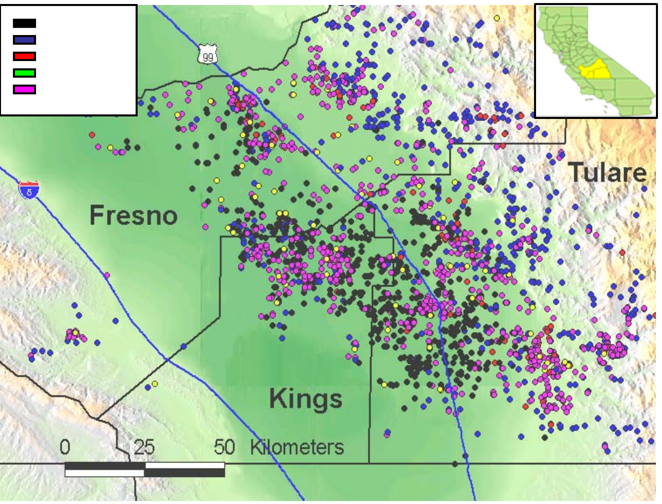
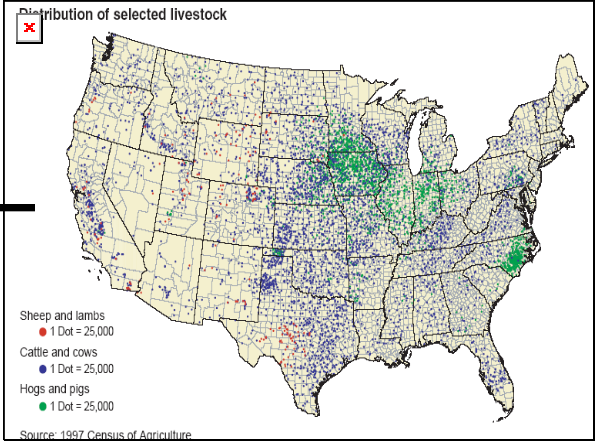
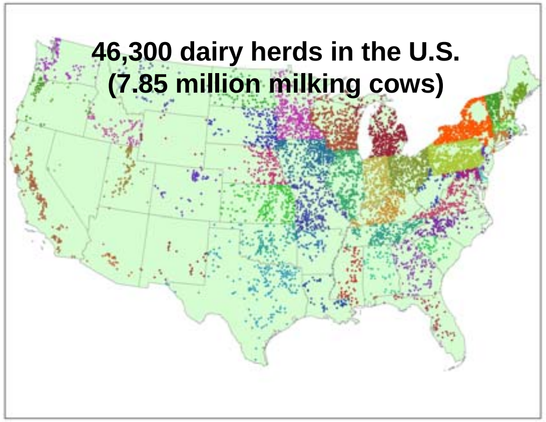
Received 21 November 2005; received in revised form 15 March 2008; accepted 24 April 2008

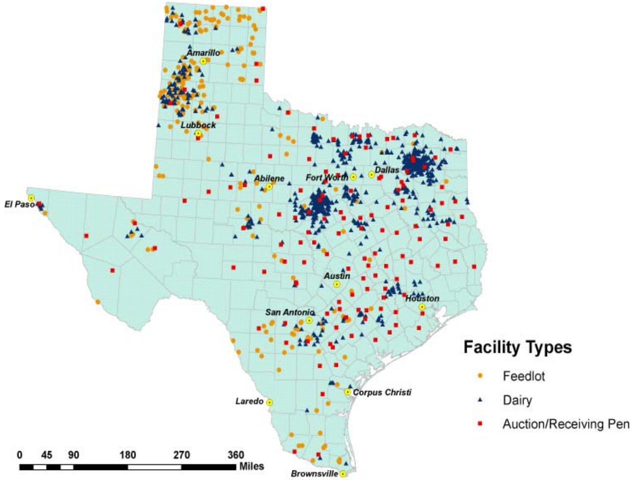


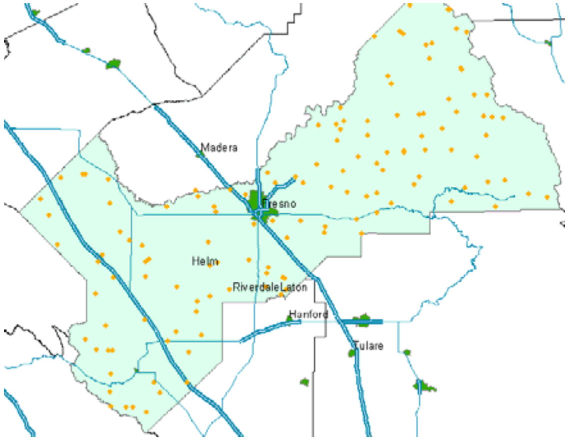
Geographic Data

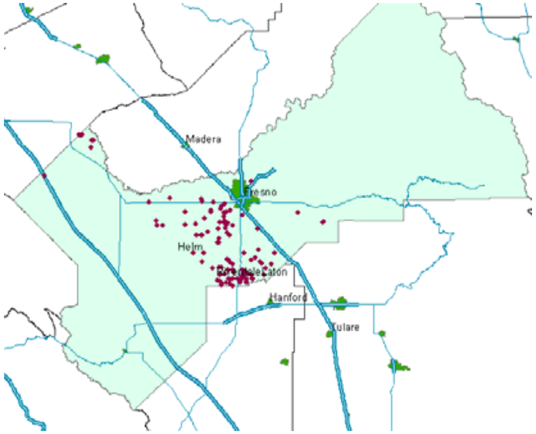










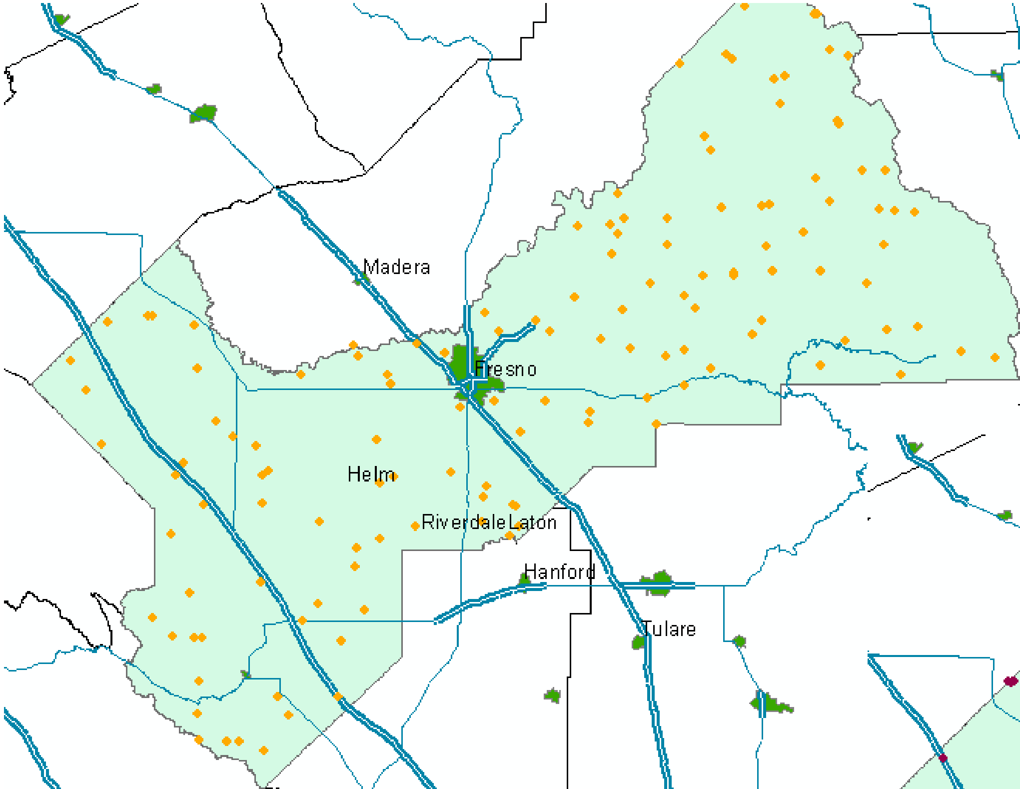


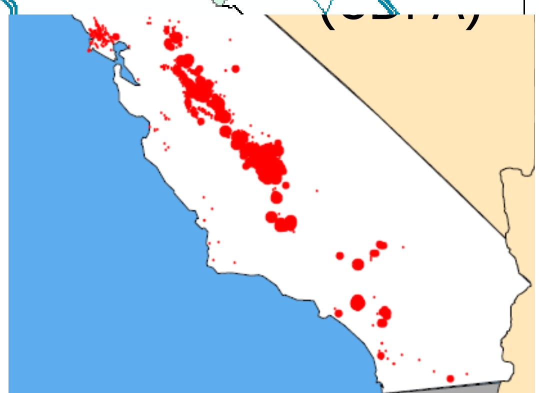
Geolocation Data: CA Dairies

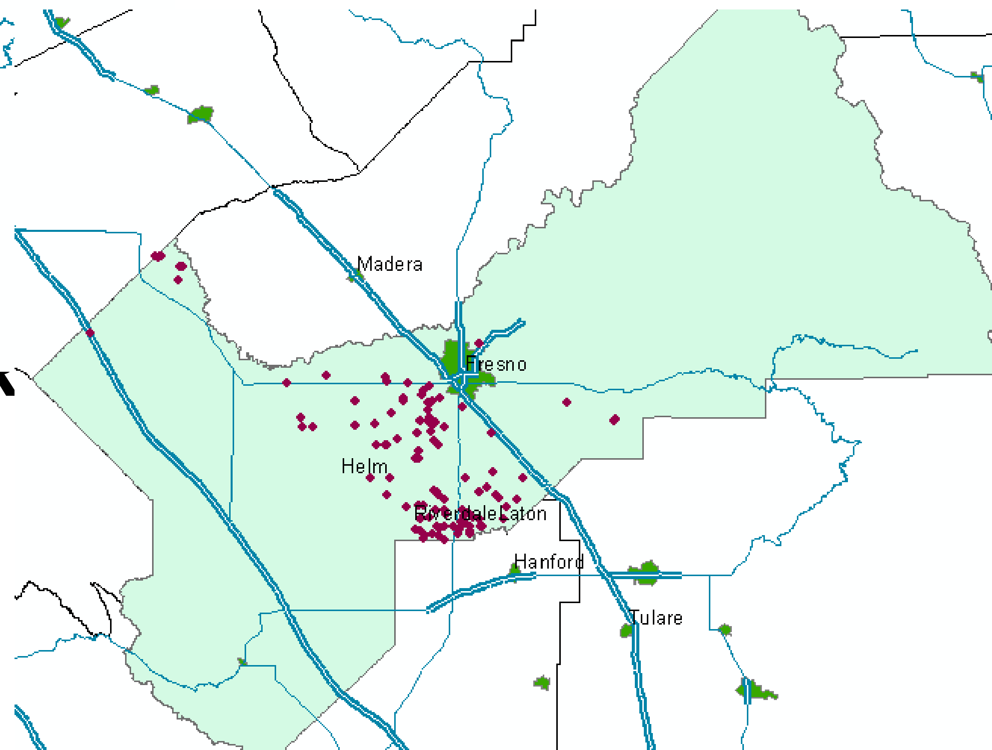
/s. true locations

disperse

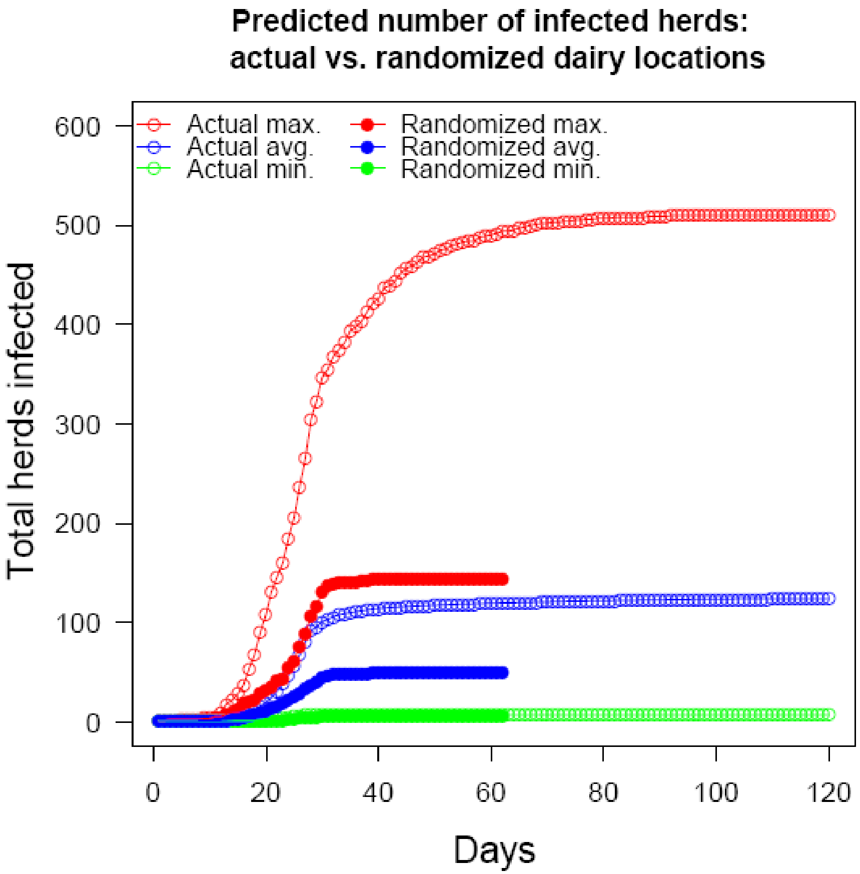
stimates (25%) dairies





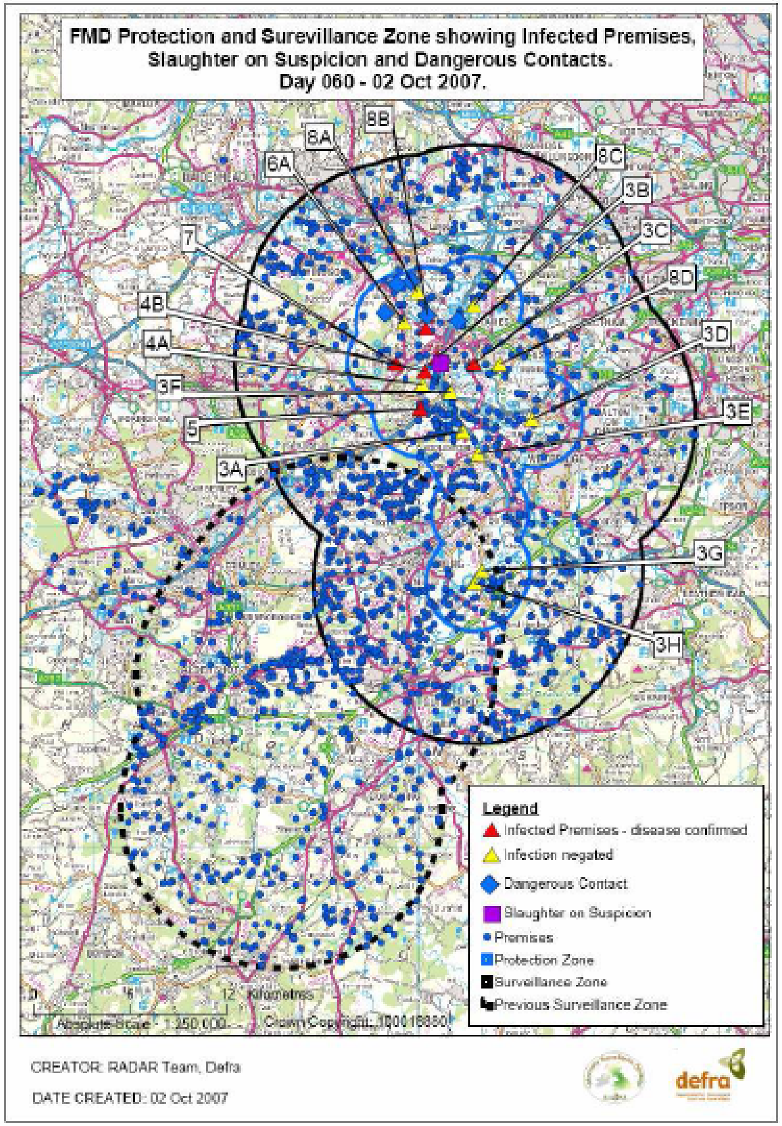


Simulation Results: Random vs. Actual Locations



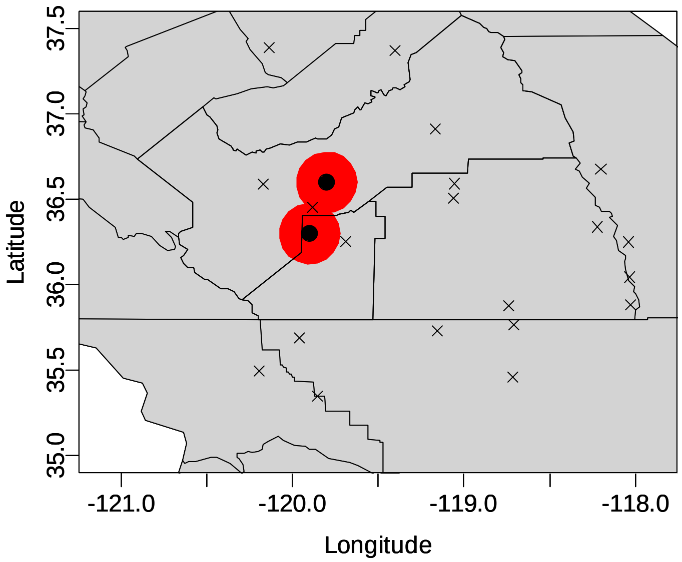
- **NASS vs. true data sims.**
  - **Min. similar but early end**
  - **Mean 60% underestimate**
  - **Max. 75% underestimate**
- **Implications**
  - **Underestimates epidemic impact and duration**
  - **Potentially misdirects resources**
  - **No info. > misinformation?**

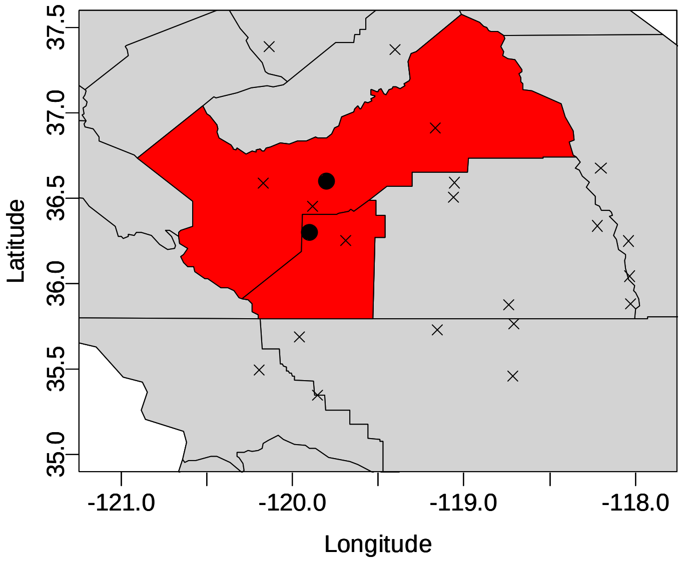
Circular Controls in UK 2007



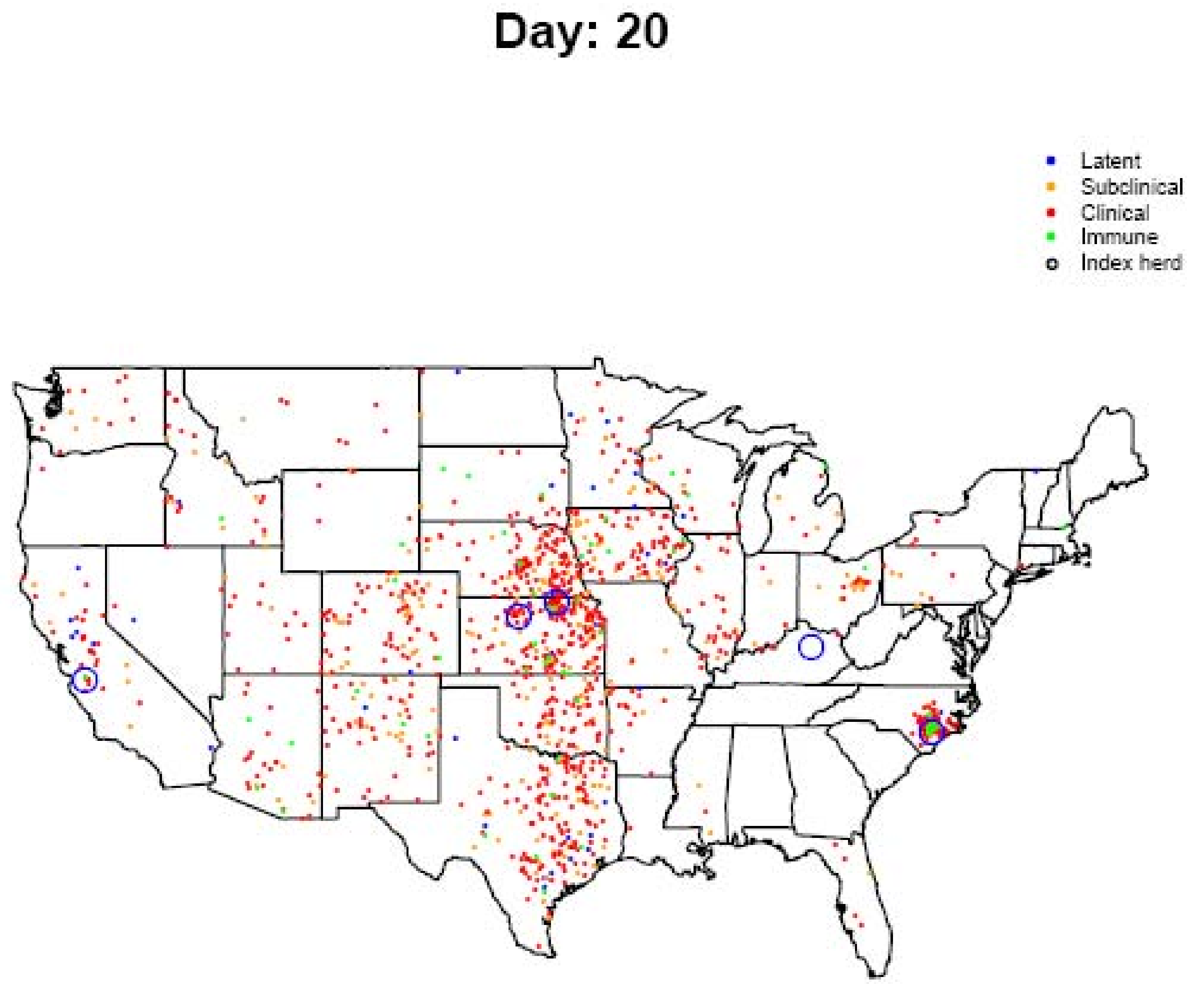
- Premises statuses updated daily
- “Target” constantly changing
- Resource allocation efficiency?
- Disease control impact?

Circular vs. Areal Surveillance



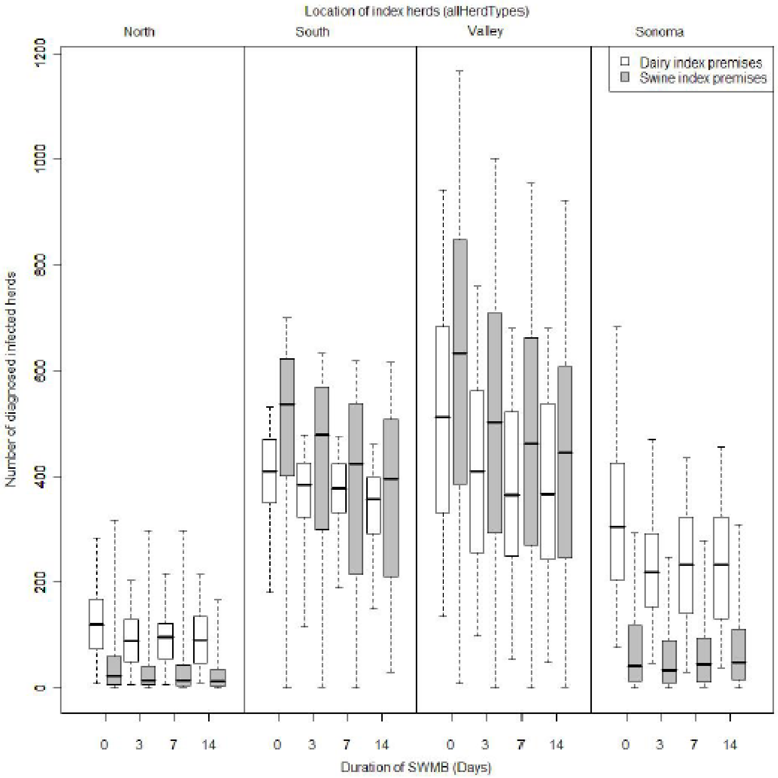


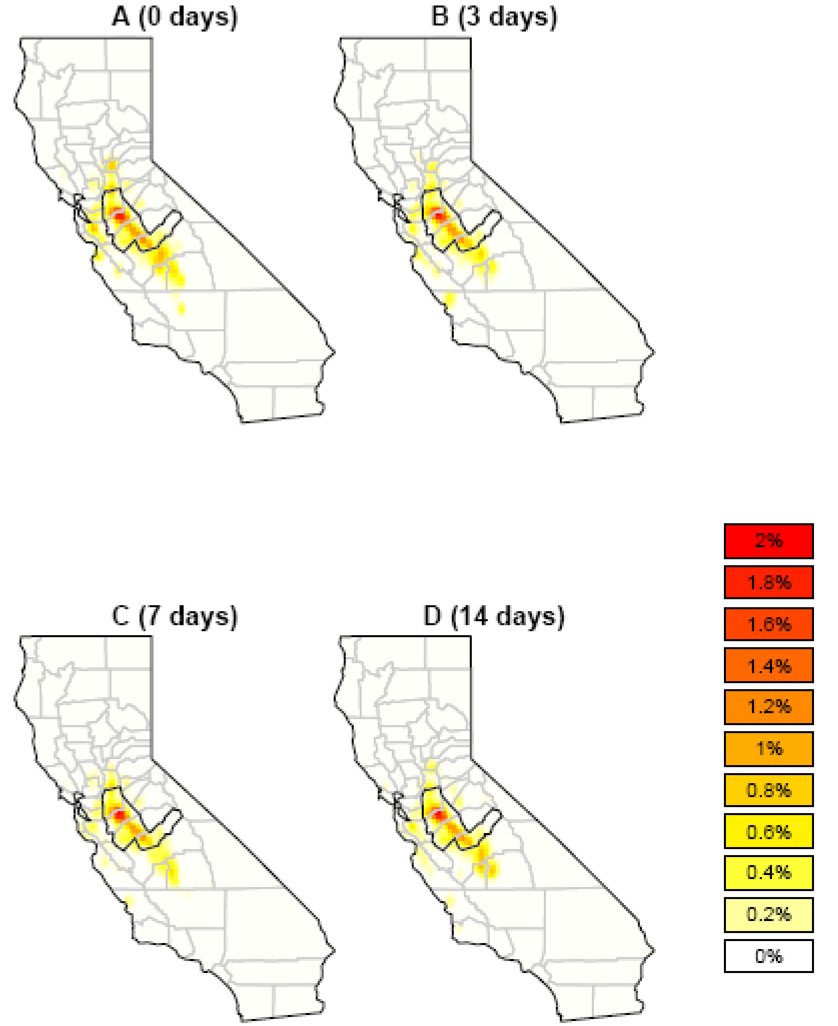
- **Regional control benefits**
  - **10% decrease in IPs**
  - **10% decrease in epidemic duration**
  - **40% increase affected premises**
  - **80% decrease in surveillance zone definition**
- **Additional applications**
  - **Vaccination/culling**
  - **Movement**
  - **Expansion to states or regions vs. counties**



Intentional Introduction: 5 herds, 4 states

Importance of Stochastic and Spatial Components: Wild Pigs





Spatial Model Conclusions

- Spatial models enhance visualization of an epidemic
- They may more accurately reflect spatial relationships, e.g. LAS, controls and spread
- Computationally, they make life very difficult

Stochastic, Spatially Explicit Model Conclusions

- Need for data
  - Spatial
  - Contact (DC, IDC)
- Need for complexity (stoch., spatial)
- Importance of model precision/predictability
- Need to consider model use during an epidemic with latent variable information

Dairy Council of California
Healthy Eating Made Easier

National Pork Producers Council

FARM BUREAU FEDERATION

Western United Dairymen

Washington Cattlemen's Association

TAD

Professional Dairy Heifer Growers Association

Colorado Livestock Association

USDA

cdfa

National Hog Farmer

Hoof Trimmers Association Inc

Oregon Meat Goat Producers

BEEF USA

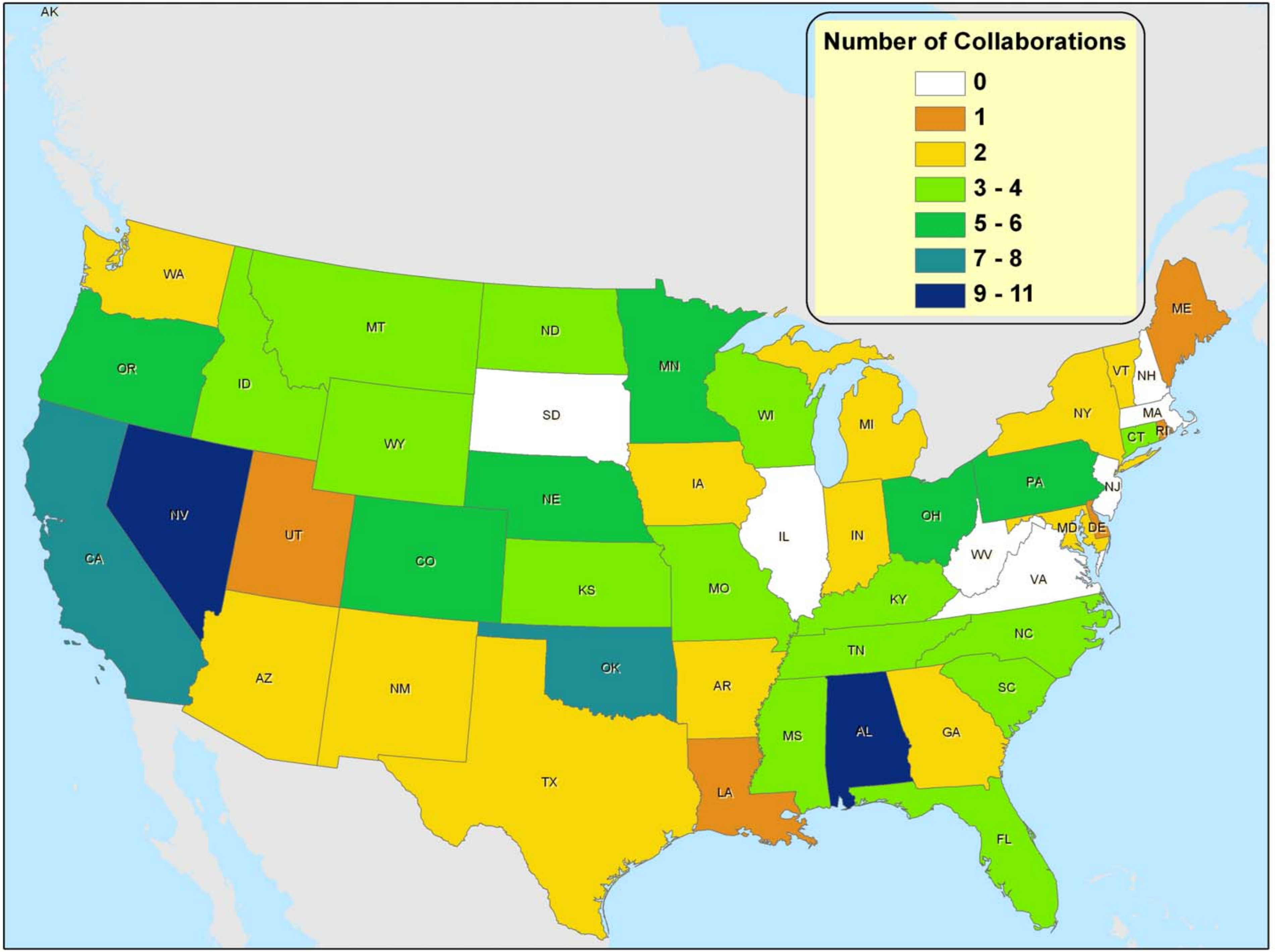
United Dairymen of Idaho

REAL

CCA

California Dairy Campaign

LMA
Livestock Marketing Association


AK
Number of Collaborations
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5 - 6
7 - 8
9 - 11
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OR
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AZ
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CO
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MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
VT
NH
ME
MA
RI
CT
NJ
DE
MD

Funding

Collaboration – CADMS, CDFA, Texas A&M, WUD, CDC, PDHGA, CWGA, CCA, ARPAS, VMTRC, USDA, CDFG, ARE (UCD), LLNL, DK, UK, NZ

Questions?