New England Foot and Mouth Disease Tabletop Exercise

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October 2, 2008

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Analysis and Summary Information for Background Outbreak Scenario and the
Multiscale Epidemiologic/Economic Simulation and Analysis (MESA) Decision
Support System

Provided by the Lawrence Livermore National Laboratory Foreign Animal Disease
Analysis Team

September 30, 2008

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Overview of the Multiscale Epidemiologic/Economic Simulation and Analysis (MESA) Decision Support System

The Multiscale Epidemiologic/Economic Simulation and Analysis (MESA) Decision Support System (DSS) is the product of investments that began in FY05 by the Department of Homeland Security (DHS) Science and Technology Directorate and continue today with joint funding by both DHS and the US Department of Agriculture (USDA). The DSS consists of a coupled epidemiologic/economic model, a standalone graphical user interface (GUI) that supports both model setup and post-analysis, and a Scenario Bank archive to store all content related to foreign animal disease (FAD) studies (Figure 1).

Figure 1 MESA Decision Support System Architecture
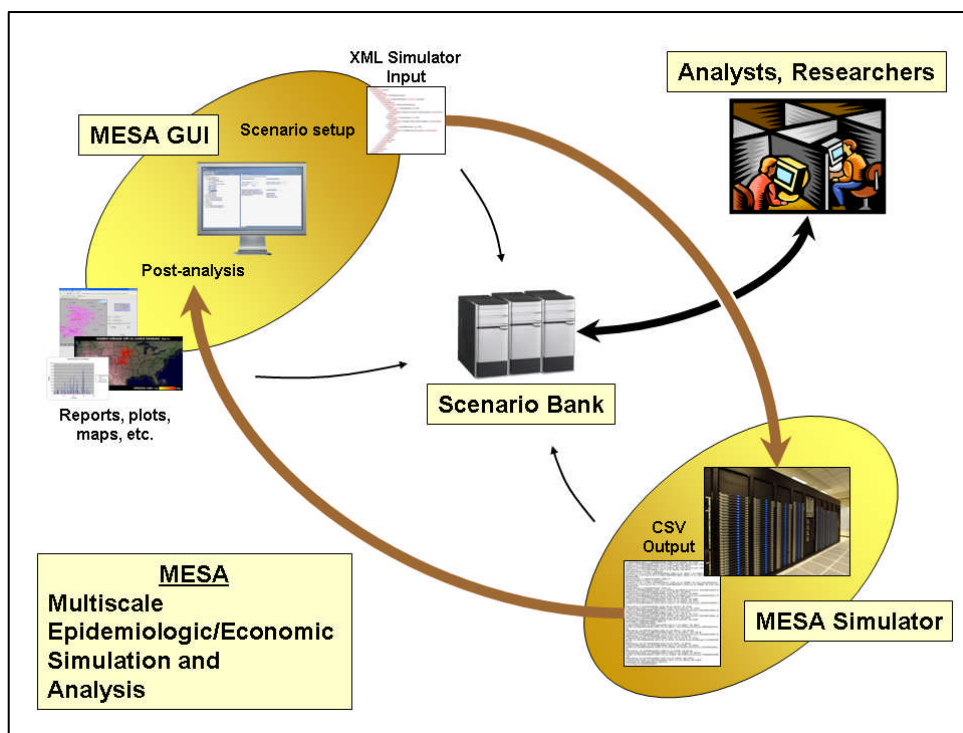
The MESA epi model is an object-oriented, agent-based, stochastic, spatio-temporal simulator that parametrically models FAD outbreaks and response strategies from initial disease introduction to conclusion over local, regional, and national scales. Through its output database, the epi model couples to an economic model that calculates farm-level impacts from animal infections, responsive control strategies and loss of trade. The MESA architecture contains a variety of internal models that implement the major components of the epi simulation, including disease introduction, intra-herd spread, inter-herd spread (direct and indirect), detection, and various control strategies (movement restrictions, culling, vaccination) in a highly configurable and extensible fashion.

MESA will produce both overall and daily summary statistics for the outbreak, epidemic curves, and costs associated with the outbreak. This information can be used to

reconstruct and analyze the course of the outbreak. Geographical information produced by MESA can be used to produce maps and movies as visual aids to understand the distribution characteristics of a simulated outbreak.

The MESA foot-and-mouth disease baseline parameters, response and control measures used for the purposes of this exercise are summarized as follows. Please contact the Lawrence Livermore National Laboratory, foreign animal disease analysis team for additional details regarding the parameters or modeling assumptions.

- Initial Quarantine. At the time an infected premises (IP) is suspected (based on the percentage of the herd with clinical signs), it is quarantined. The efficacy of the quarantine is not 100%, but the efficacy varies by premises type. In general, quarantines are more effective for larger "commercial" premises (avg ~92-95% effective) and are less effective for backyard premises (avg ~84% effective). The high risk indirect contacts (e.g. veterinarians and hoof trimmers) are reduced by ~80% for commercial premises and ~65% for backyards and the low risk indirect contacts (e.g. milking equipment service providers or feed trucks) are reduced by ~70% for commercial premises and ~50% for backyards.

- Confirmation time. There is a time delay between initial identification of the suspected premises (detection) and the actual confirmation of that premises as being infected. This represents the time associated with a diagnostic visit, then collecting, submitting and testing diagnostic samples. The minimum confirmation time is assumed to be 2 days, the average time is 3 days and the maximum time is 5 days.

- Infected Zone. For all confirmed infected premises, a 10 km radius infected zone is established around any confirmed infected premises. In this zone there are reductions in the direct and indirect contacts for all premises (as would be accomplished via biosecurity and movement restrictions). In general, the direct contacts leaving the premises are reduced by 80-90%. The high risk indirect contacts (e.g. veterinarians and hoof trimmers) are reduced by ~60% for commercial premises and ~50% for backyards and the low risk indirect contacts (e.g. milk equipment service providers or feed trucks) are reduced by ~50% for commercial premises and ~20% for backyards.

- Buffer Surveillance Zone. A buffer surveillance zone (BSZ) is established at the state level. In this zone there are reductions in the direct and indirect contacts for all premises. In general the direct contacts leaving the premises are reduced by 70-80% for commercial premises and 60% for backyards. The high risk indirect contacts (e.g. veterinarians and hoof trimmers) are reduced by ~20% and the low risk indirect contacts (e.g. milk equipment service providers or feed trucks) are reduced by ~20%

- Interstate Movement. Interstate livestock movement leaving any affected state(s) is "stopped" (avg 95% efficacy) once at least one IP is confirmed in a state.

- Sales Yard Closure. Closing of all sales yards within the BSZ occurs at the time of confirmation.

- Tracing. Tracing of all direct and high-risk indirect contacts forward and backward for one generation from known infected premises. Tracing may lead to detection of infected premises before passive clinical detection identifies the infected premises. The time delay to accomplish a trace is a distribution ranging from 2 to 9 days with an average of 4 days. The probability that a premises is successfully traced varies by premises type with

the assumption that larger commercial premises would have better records and be easier to trace from than backyards.

- Depopulation. Slaughter of confirmed infected herds after a species-dependent delay.
- No preemptive depopulation of non-infected herds.
- No vaccination.
- Minimal time to obtain freedom from disease following the last case is three incubation periods (42 days). This is not a relevant issue for the purposes of modeling the scenario for the NE exercise.

Overview of the Scenario Evaluated:

The scenario requested was a foot and mouth disease outbreak originating in a small dairy herd in New Hampshire which was within 10 km of the Maine border. A small dairy herd in Strafford county was selected as the initially infected premises and 4000 realizations were simulated in an effort to identify a small to moderate outbreak affecting as many of the NE states as possible. The summary results below are derived primarily from one realization (#1364) of the scenario. Some slight adjustments to the course and extent of this outbreak were made at the request of the planning team for the purposes of allowing the exercise to meet specific objectives.

Status Report Day end of day 3 –
At the end of day 3 of the outbreak:
FMD has been confirmed on 1 premises in New Hampshire. The index case is a small dairy (68 animals) in Strafford county which is with in 10 km of the border with Maine. At the end of day 3, a second suspected case of FMD is under investigation in New Hampshire (a small dairy in Hillsborough county).

The following tables outline the results through day 3 of the outbreak:

Table 1: Total number of confirmed infected premises and livestock, by production type at the end of day 3.

Production type	No. of confirmed infected premises	Number of livestock
Dairy	1	68

Table 2: Total number of depopulated premises and livestock by production type at the end of day 3.

Production type	Number of premises depopulated	Number of livestock on those premises
Dairy	1	68

Table 3: Total number of premises, by production type, within control zones ending on day 3.

Production type	Number of premises (animals) in infected zone(s) (10)	Number of premises (animals) buffer surveillance zone(s) (state)
Commercial Dairy	1 (292)	176 (28,709)
Commercial Beef	2 (57)	246 (6,386)
Commercial Swine	0	13 (2,043)
Commercial Sheep	2 (82)	71 (5,479)
Commercial Goats	0	32 (949)
NASS Backyards (cattle, swine, sheep and goats)	14 (107)	1,055 (7,386)

Status Report Day end of day 10 –

At the end of day 10 of the outbreak FMD has been confirmed on five premises across four states. This includes disease confirmed on 2 small dairies in NH (Strafford and Hillsborough counties), one small dairy in ME (York county), one beef operation in CT (New London county) and one large dairy in VT (Orange county)

The following tables outline the results through day 10 of the outbreak:

Table 4: Cumulative total number of confirmed infected premises and livestock, by production type at the end of day 10.

Production type	No. of confirmed infected premises	Number of livestock
Dairy	4	868
Beef	1	150

Table 5: Cumulative total number of depopulated premises and livestock by production type at the end of day 10.

Production type	Number of premises depopulated	Number of livestock on those premises
Dairy	3	216

Table 6: Total number of premises, by production type, within control zones ending on day 10.

Production type	Number of premises (animals) in infected zone(s) (10 km)	Number of premises (animals) buffer surveillance zone(s) (state)
New Hampshire		
Commercial Dairy	2 (381)	176 (28,709)
Commercial Beef	11 (315)	246 (6,386)
Commercial Swine	1 (259)	13 (2,043)
Commercial Sheep	3 (111)	71 (5,479)
Commercial Goats	0	32 (949)
NASS Backyards (cattle, swine, sheep and goats)	40 (308)	1,055 (7,386)
Maine		
Commercial Dairy	1 (57)	379 (48,571)
Commercial Beef	5 (108)	606 (24,711)
Commercial Swine	2 (139)	31 (4,670)
Commercial Sheep	2 (82)	128 (7261)
Commercial Goats	0	6 (116)
NASS Backyards (cattle, swine, sheep and goats)	16 (120)	1,578 (10,114)
Vermont		
Commercial Dairy	17 (1,298)	1,343 (181,292)
Commercial Beef	12 (356)	939 (57,988)
Commercial Swine	0	16 (1120)
Commercial Sheep	5 (289)	176 (13,352)

Commercial Goats	0	60 (2,253)
NASS Backyards (cattle, swine, sheep and goats)	14 (103)	1,170 (6,177)
Connecticut		
Commercial Dairy	11 (880)	192 (32,667)
Commercial Beef	19 (337)	371 (12,113)
Commercial Swine	0	2 (420)
Commercial Sheep	1 (120)	47 (3,047)
Commercial Goats	0	15 (362)
NASS Backyards (cattle, swine, sheep and goats)	39 (301)	1,088 (8449)

Status Report Day end of day 20 –
At the end of day 20 of the outbreak FMD has been confirmed on ten premises across five states. This includes disease confirmed on 2 small dairies in NH (Strafford and Hillsborough counties), one small dairy in ME (York county), one beef operation in CT (New London county) five premises in VT (Lg dairy:Orange county, Sm dairy:Orange county, market:Orleans county, Sm dairy:Franklin county and a Sm dairy:Rutland county), and a market in NY (Washington county).

The following tables outline the results through day 20 of the outbreak:

Table 7: Cumulative total number of confirmed infected premises and livestock, by production type at the end of day 20.

Production type	No. of confirmed infected premises	Number of livestock
Dairy	7	1,110
Beef	1	150
Livestock market	2	

Table 8: Cumulative total number of depopulated premises and livestock by production type at the end of day 20.

Production type	Number of premises depopulated	Number of livestock on those premises
Dairy	6	1,038
Beef	1	150

Table 9: Total number of premises, by production type, within control zones ending on day 20.

Production type	Number of premises (animals) in infected zone(s) (10 km)	Number of premises (animals) buffer surveillance zone(s) (state)
New Hampshire		
Commercial Dairy	2 (381)	176 (28,709)
Commercial Beef	11 (315)	246 (6,386)
Commercial Swine	1 (259)	13 (2,043)
Commercial Sheep	3 (111)	71 (5,479)

Commercial Goats	0	32 (949)
NASS Backyards (cattle, swine, sheep and goats)	40 (308)	1,055 (7,386)
Maine		
Commercial Dairy	1 (57)	379 (48,571)
Commercial Beef	5 (108)	606 (24,711)
Commercial Swine	2 (139)	31 (4,670)
Commercial Sheep	2 (82)	128 (7,261)
Commercial Goats	0	6 (116)
NASS Backyards (cattle, swine, sheep and goats)	16 (120)	1,578 (10,114)
Vermont		
Commercial Dairy	43 (4,621)	1,343 (181,292)
Commercial Beef	35 (1,648)	939 (57,988)
Commercial Swine	0	16 (1,120)
Commercial Sheep	7 (412)	176 (13,352)
Commercial Goats	1 (24)	60 (2,253)
NASS Backyards (cattle, swine, sheep and goats)	25 (191)	1,170 (6,177)
Connecticut		
Commercial Dairy	11 (880)	192 (32,667)
Commercial Beef	19 (337)	371 (12,113)
Commercial Swine	0	2 (420)
Commercial Sheep	1 (120)	47 (3,047)
Commercial Goats	0	15 (362)
NASS Backyards (cattle, swine, sheep and goats)	39 (301)	1,088 (8,449)
New York		
Commercial Dairy	26 (4,989)	6,255 (869,760)
Commercial Beef	19 (1,564)	5,504 (296,370)
Commercial Swine	1 (56)	231 (71,192)
Commercial Sheep	6 (573)	701 (66,788)
Commercial Goats	2 (58)	2 (58)
NASS Backyards (cattle, swine, sheep and goats)	28 (208)	6,978 (48,681)

Conclusion of the Outbreak –
The last infected premises is depopulated on day 88. At the conclusion of the outbreak, on day 88, there have been a total of 20 IPs across five states. This includes 15 IPs in VT, 2 IPs in NH, and one each in ME, CT and NY. While the simulation ends with the removal of the last infected premises, in a real outbreak it would take several weeks of continued monitoring and surveillance to have confidence that the outbreak is truly over. In addition, post-outbreak surveillance would need to be designed and conducted to demonstrate that the virus had been successfully eradicated from all animals and the environment and enable application for declaration of freedom from disease from the Office of International Epizootics (OIE).

The following tables outline the results through the end of the outbreak:

Table 10: Cumulative total number of confirmed infected premises and livestock, by production type at the end of the outbreak.

Production type	No. of confirmed infected premises	Number of livestock
Dairy	15	2,610
Beef	3	829
Livestock markets	2	

Table 11: Total number of premises, by production type, within control zones at the end of the outbreak.

Production type	Number of premises (animals) in infected zone(s) (10 km)	Number of premises (animals) buffer surveillance zone(s) (state)
New Hampshire		
Commercial Dairy	2 (381)	176 (28,709)
Commercial Beef	11 (315)	246 (6,386)
Commercial Swine	1 (259)	13 (2,043)
Commercial Sheep	3 (111)	71 (5,479)
Commercial Goats	0	32 (949)
NASS Backyards (cattle, swine, sheep and goats)	40 (308)	1,055 (7,386)
Maine		
Commercial Dairy	1 (57)	379 (48,571)
Commercial Beef	5 (108)	606 (24,711)
Commercial Swine	2 (139)	31 (4,670)
Commercial Sheep	2 (82)	128 (7,261)
Commercial Goats	0	6 (116)
NASS Backyards (cattle, swine, sheep and goats)	16 (120)	1,578 (10,114)
Vermont		
Commercial Dairy	195 (27,020)	1,343 (181,292)
Commercial Beef	125 (9,587)	939 (57,988)
Commercial Swine	0	16 (1,120)
Commercial Sheep	13 (748)	176 (13,352)

Commercial Goats	2 (48)	60 (2,253)
NASS Backyards (cattle, swine, sheep and goats)	78 (571)	1,170 (6,177)
Connecticut		
Commercial Dairy	11 (880)	192 (32,667)
Commercial Beef	19 (337)	371 (12,113)
Commercial Swine	0	2 (420)
Commercial Sheep	1 (120)	47 (3,047)
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NASS Backyards (cattle, swine, sheep and goats)	39 (301)	1,088 (8,449)
New York		
Commercial Dairy	26 (4,989)	6,255 (869,760)
Commercial Beef	19 (1,564)	5,504 (296,370)
Commercial Swine	1 (56)	231 (71,192)
Commercial Sheep	6 (573)	701 (66,788)
Commercial Goats	2 (58)	2 (58)
NASS Backyards (cattle, swine, sheep and goats)	28 (208)	6,978 (48,681)

Scenario Summary Statistics –

A small dairy FMD introduction scenario was modeled for Stafford county. The NH scenario was actualized (run) 4000 times, summary results for 2007 of those runs are provided below.

The mean number of herds infected was 2.4 herds, mean number of animals infected was 285, and the mean duration was 45 days. Enhanced box-whisker plots of the number of herds infected, number of animals infected and the duration of the outbreaks for the 2007 realizations are shown in Figure 1. For a detailed explanation of the enhanced box-whisker plot please see Appendix A.
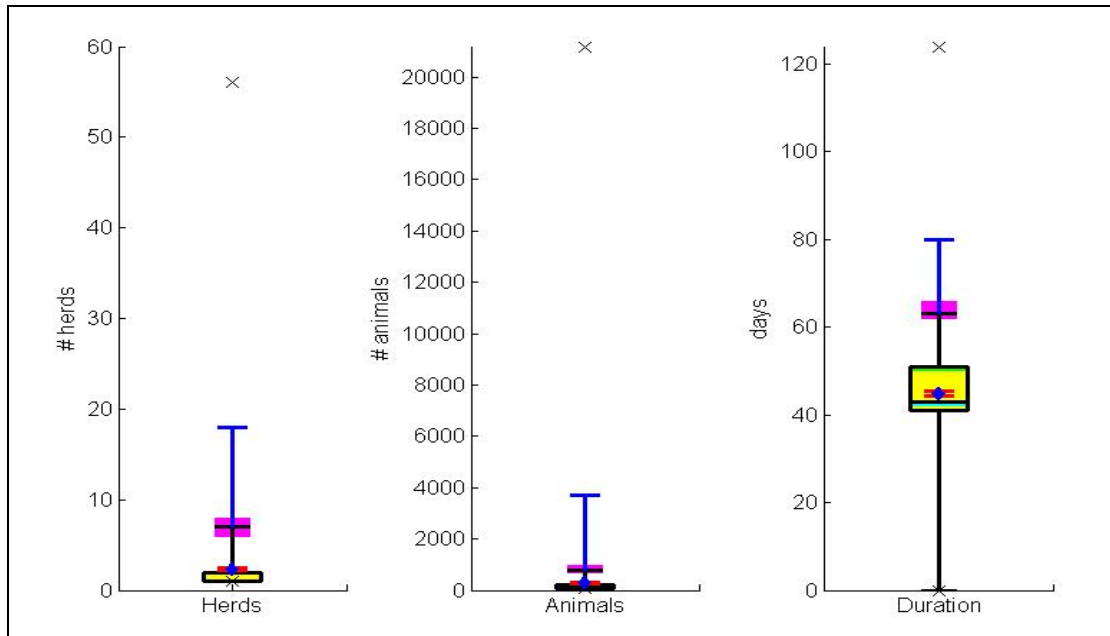

Figure 1: Summary of number herds infected, animals infected and duration of the outbreak.

A histogram of the confirmed infected premises by day of the outbreak, premises type and state is provided in Figure 2.

Figure 2: Infected premises by facility type, state and by day of outbreak

Spread beyond NH state border:

For each of the 2007 simulation runs, the number of states to which the disease spread was tallied.

Total number of runs	Number of times disease spread outside of NH	Percent of time disease spread outside of NH
2007	810	40.36%

Over all the simulations, the disease spread most frequently to Vermont, followed by Massachusetts, New York, Maine, Connecticut and Pennsylvania (Figure 3).
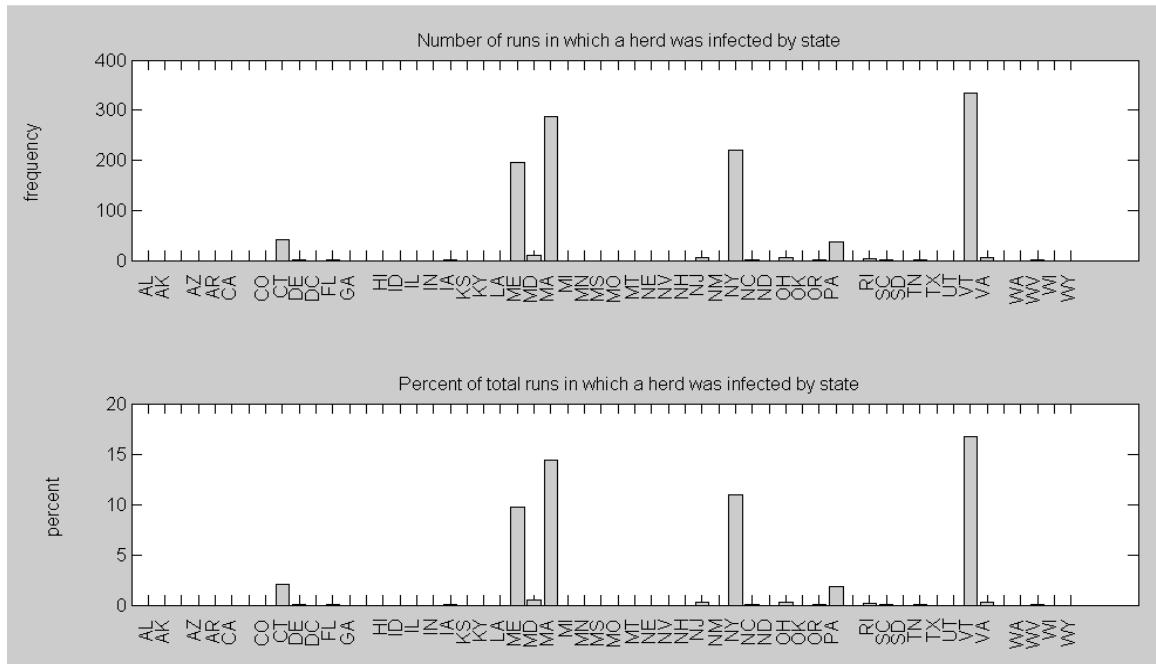

Figure 3: Infected herds by state and by number of simulation runs

It is also of interest to understand how many states other than New Hampshire (the initially infected state) are infected during a realization. It appears that in about 15% of cases or less, 2 or more other states are affected by the disease spread. A spread to 6 other states occurred only once over all the runs (Figure 4).
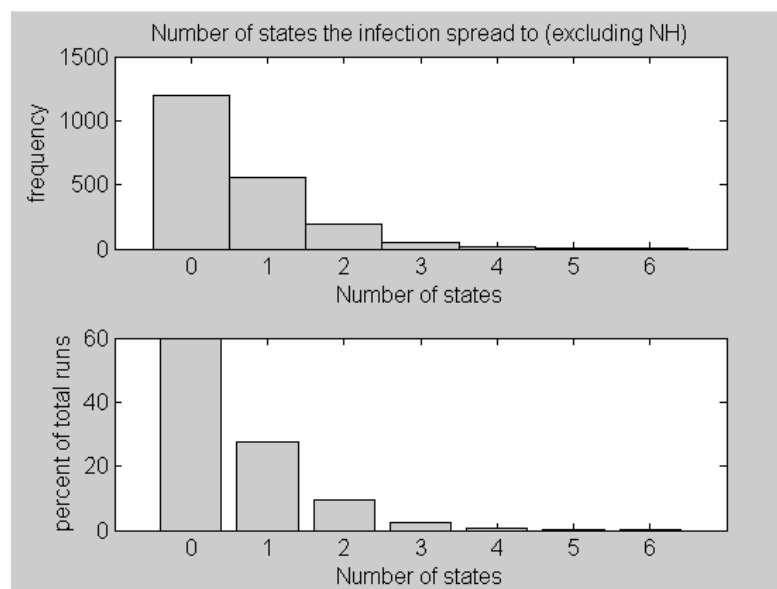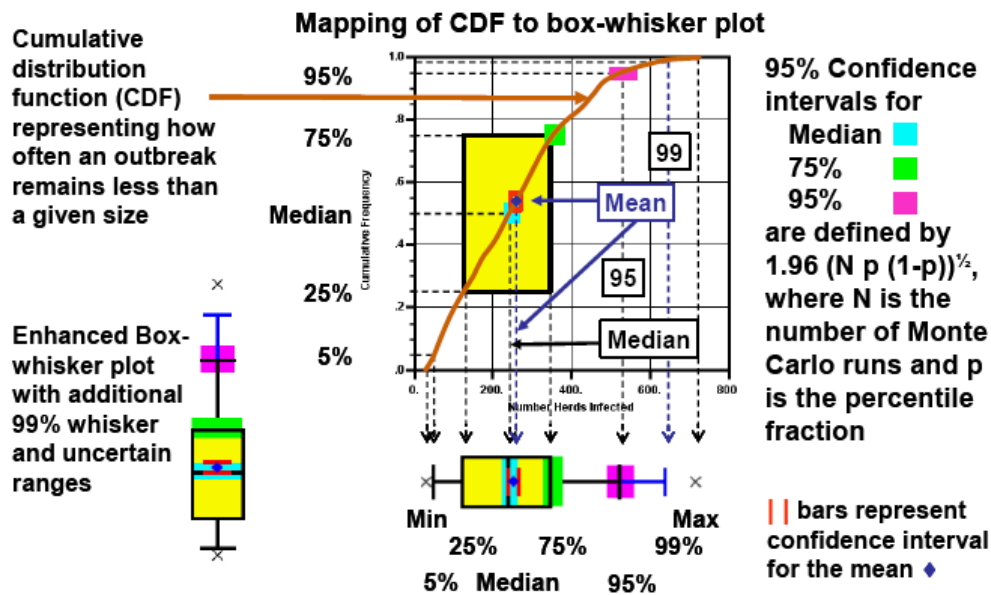

Figure 4: Spread of infection by number of states infected

Appendix A. Explanation of Enhanced Box-Whisker Plot.

Mapping of CDF to box-whisker plot

Cumulative distribution function (CDF) representing how often an outbreak remains less than a given size

Enhanced Box-whisker plot with additional 99% whisker and uncertain ranges

95% Confidence intervals for
Median (cyan)
75% (green)
95% (magenta)
are defined by $1.96 (N p (1-p))^{1/2}$, where N is the number of Monte Carlo runs and p is the percentile fraction

| | bars represent confidence interval for the mean ◆