Information, Modeling, and Analysis – Project 1

Spatial Epidemiologic Modeling of Foot-and-Mouth Disease in the United States

DHS Priority Areas Addressed	☒ Prevention	☐ Detection	☒ Response	☐ Recovery	☐ Education/Risk Communication
Proposal Section Addressed	Sections 5.1.2 and 5.3.2				
Investigators	UCD: Tim Carpenter and Mark Thurmond				

Objectives	Deliverables	Progress Toward Deliverables	Percent Complete
Continue development, verification, and validation of the UCD FMD model	Direct and indirect contact data collected and analyzed	Current data collection for California ended in September 2006 and the data were analyzed to determine distributions that have been entered into the model. All California data have also been geocoded. The national online survey was launched in the fall of 2006 and livestock associations in all states have been contacted for support with mixed levels of interest. Approximately 12 state veterinarians have offered support of varying degrees and national level help has been gained from National Cattlemens Beef Assoc, National Sheep Producers Federation and dairy. Confidential relationships are being created with APHIS in an attempt to gain premises location information for small ruminants, and Monsanto and Cargill are also considering assisting in data collection. A database of national salesyard locations, species types and days of business has been created and work is underway to contact all major US salesyards to verify data as identified by the Livestock Marketing Association. A relationship has been created with NASS allowing direct access to the 2002 agricultural census data. Articles relating to the project have been published in numerous newsletters and magazines across the country along with radio and TV interviews broadcast on RFTV which has an audience of 400,000.	90%
	Computer code rewritten to permit parallel computer processing and evaluating of alternative control strategies and consequence assessment	Changes to the code to allow parallel computing and control strategy evaluation have been completed; however, the code is constantly being revised and extended to permit results that will be helpful in addressing our objectives and those of others.	100%
	FMD graphic user interface enhanced to facilitate user accessibility	The enhanced GUI was written in R-excel as this interfaces better with the simulation model, which is written in R. The completed GUI will run for a user determined state and allows users to determine control strategies and the species/herd type of the index case. In-house testing has been successful and the GUI was shown to state level response specialists at the 2007 National Institute of Animal Agriculture annual meeting in Sacramento and met with favorable reviews. It was a very useful tool for being able to show state level representatives how the simulation model works without them having to have any knowledge of R. In addition to the creation of a GUI work has begun to create a user's manual the first draft of which will be for in-house use but future versions will be written for external use.	100%
Increase the model scope to permit evaluation of FMD spread and its control throughout the US	Statewide FMD model	The California state model was re-parameterized with the distributions calculated from the California survey data analysis.	100%
	Regional FMD model	It was decided that rather than create a rigid regional model, the national model would be configured in such a way that user defined regions can be created for any location in the US. This has been completed	100%

	National FMD model	Changes have been made to the model allowing it to run on a national level and outbreaks can now be simulated on a national level. Early in 2007 meetings occurred with USDA Fort Collins, LLNL and Quebec to discuss model comparisons. Preparation for this meeting resulted in several important changes in the model as did the discussions themselves. Code changes include: a total revamping of graphical procedures, major changes in the kernel epi routines, e.g. allowing for shipment sizes >1, keeping track of epi state distributions throughout shipments, creation of a mass-balance algorithm, i.e. a cow arriving at a salesyard leaves as a cow.	100%

Presentations:
Invited Presentation – "Predictions of Carcass Disposal Capacity for a Foot-and-Mouth Disease Outbreak in California", Imperial County, CA, August 2, 2006.

Invited Presentation and Workshop Participant – "Modeling Implications of Decisions Affecting FMD Control and Eradication", FMD Summit, National Cattlemen's Beef Association, Washington, DC, October 10-11, 2006.

Invited Keynote Speaker – "Application of GIS to Animal Health Problems", Reunión Nacional de Investigación Pecuaria, Vera Cruz, Mexico, Nov. 6-10, 2006

Presentation – "Distillation of Simulation Scenario Results", Council of Research Workers on Animal Diseases (CRWAD), Chicago, IL, Dec. 4-5, 2006.

Invited Presentation – Foreign Animal Disease Modeling, University of California, Davis; UC Davis Goat Day Meeting, January 20, 2007, 150 attendees.

Organizer – National FMD Model Comparison Workshop: Organizer, United States Department of Agriculture, Canadian Department of Agriculture, Lawrence Livermore National Laboratory, UC Davis, Davis, CA, February 26-28, 2007, 12 attendees.

Participant – DHS Annual University Network Summit on Research and Education: Participant, Department of Homeland Security Scientists, US University Researchers, Washington, DC, March 14 - 16, 2007, 250 attendees.

Participant – Criticality Study Workshop: Participant, DHS and National Center University Researchers, Kansas City, MO, April 3 - 4, 2007, 15 attendees.

Invited Presentation and Workshop Participant – "Multicenter comparison of modelling tools for the evaluation of foot and mouth disease vaccination strategies in Denmark", Foreign Animal Disease Modeling Meeting, Arlington, VA, August 22, 2007.

Invited Presentation – National Institute of Animal Agriculture ID Expo, Kansas City, MO, August 27 – 30, 2007, 400 attendees.

Publications:
1. Marshall, ES, TE Carpenter and MC Thurmond, A survey of miniature swine owners to describe potential for disease transmission, 2007 J Am Vet Med Assoc. 230:702-707.
2. Kobayashi M, TE Carpenter, BF Dickey, and RE Howitt. A dynamic optimal disease control model for foot-and-mouth disease. I. Model description, Preventive Veterinary Medicine 29:257-273.
3. Kobayashi M, TE Carpenter, BF Dickey**,** and RE Howitt. A dynamic optimal disease control model for foot-and-mouth disease. II. Model results and policy implications, Preventive Veterinary Medicine 79:274-286.
4. Thunes, C and TE Carpenter, Biosecurity practices and travel history of individuals exhibiting livestock at the 2005 California State Fair. J Am Vet Med Assoc. 231:581-585.
5. Carpenter, TE, LE Christiansen, et al., The potential impact of an introduction of foot-and-mouth disease into the California State Fair. JAVMA, In Press.
6. Dickey, BF, TE Carpenter and SM Bartell, Parsimony in spatial simulation modeling of livestock disease. I. The role of contact parameters (submitted Preventive Veterinary Medicine)

Highlight for Research Briefs

Model modifications:

- The model is running at a national level and further changes made this year allow it to do so efficiently and without major increase in computing power. No major computing problems have been experienced.
- Changes have been made to the model, making it a more realistic interpretation of real world activities in the livestock industry.

Model validation:

- Model validation was conducted through the National FMD Model Comparison Workshop attended by researchers from LLNL, Quebec and USDA Fort Collins. The DADS model was found to cause disease to spread at an unrealistically fast rate. As a result of these findings mistakes in the code were identified and fixed.
- The comparison models did not model individual animals within a facility, and instead attribute a disease state to an entire facility. It was determined that this is not as accurate a depiction of reality as that captured by our DADS model that does model individual animals within herds.

Outreach:

- Nine presentations were given during this period, two for producers, two at scientific meetings, and five for regulatory officials and industry associations.
- Five papers were published: three in the Journal of the American Veterinary Medical Association, two in Preventive Veterinary Medicine, in addition to 1 submitted, using data from this project.

Interpretive Summary

There are 2 objectives in this project: (1) continued development of the UCD/FMD model and (2) model expansion.

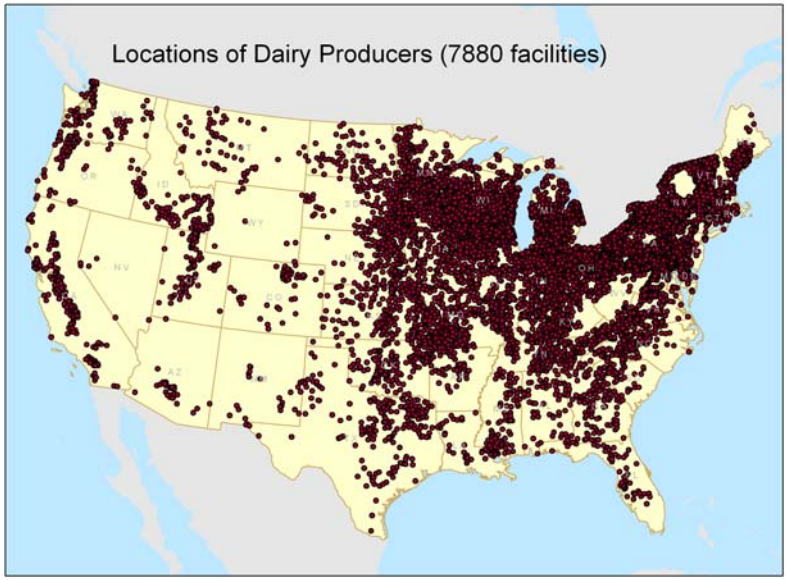
The third year of this project involved three activities: (1) data collection and analysis on a national level, (2) continued computer code writing, and (3) development of a national model.

We have collected direct and indirect contact data for the livestock industries across the US and collection is ongoing. We have set-up strong relationships with national level organizations and industry groups who are keen to help provide data for the project. Work continues in the analysis of this data.

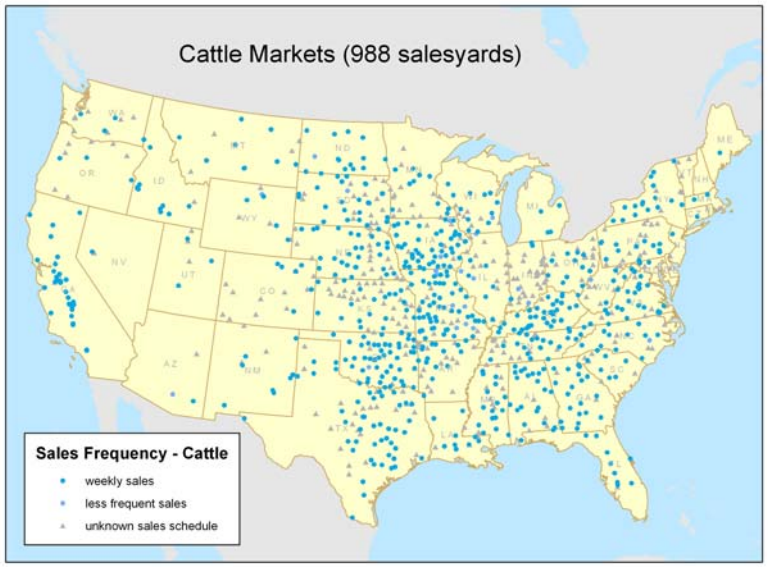
Results and Interpretations

As per the Year 2 report the national level survey was launched online. As was forecast, response rates were lower (1200 completed surveys) but the quality of completed surveys was higher. Unfortunately the response rate was significantly lower than anticipated and has left certain areas of the US and/or certain species types under-represented. Specialist statistical help has been employed in order to ascertain the best approach for analyzing this data and how best to extrapolate the data collected to those areas/facility types that are lacking data. Currently the model is parameterized with data collected for California.

Accurate location data for approximately 80% of the US dairies have been acquired through a confidential partnership with Monsanto. These have been geocoded for use in the simulation model.

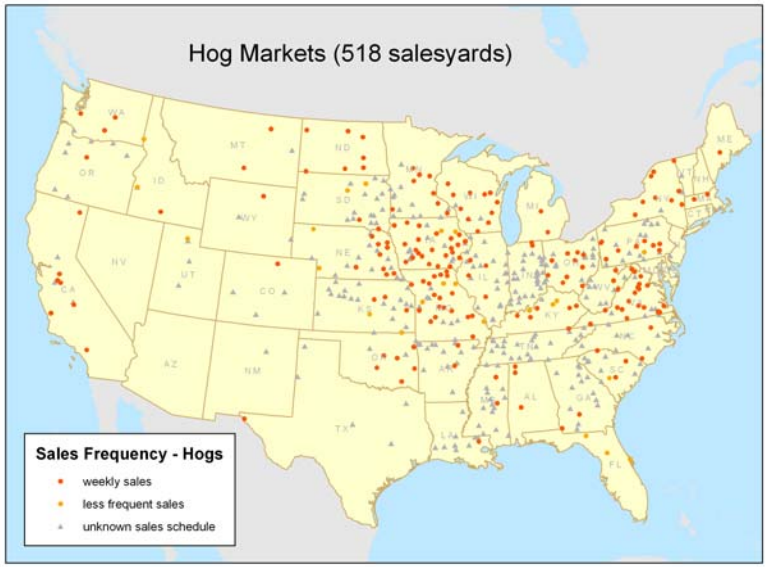


Starting with the APHIS list of approved markets, a database of US salesyards has been created and geocoded. This database includes information about types of species sold, days of business, length of time animals are at the salesyard that is being verified through personal contact. Distributions of US livestock markets are shown in the following maps.

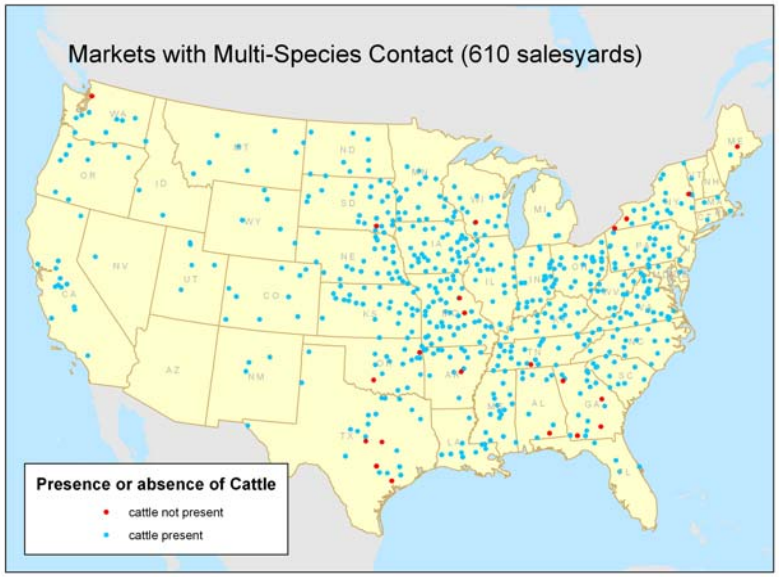


Edited: 10 Aug 2007

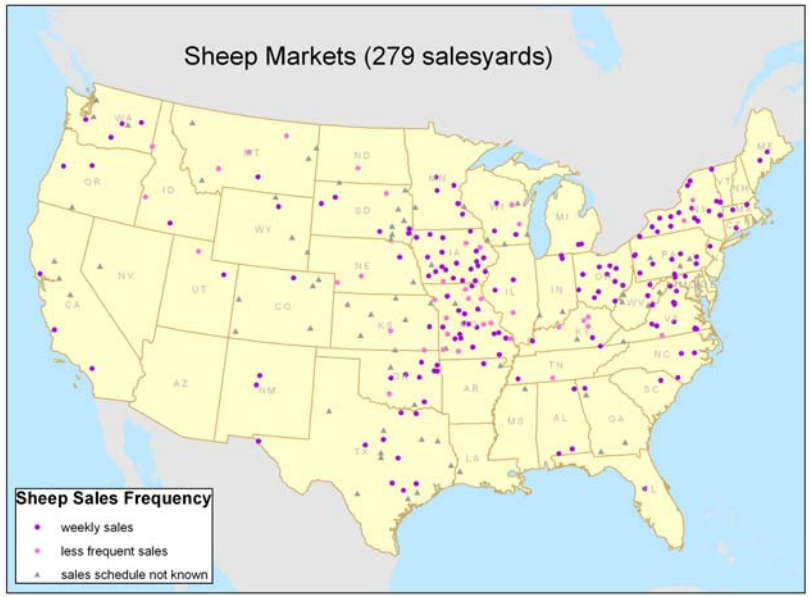
Edited: 10 Aug 2007



Edited: 10 Aug 2007



Edited: 10 Aug 2007



The spatial, epidemic simulation model by way of the GUI, was shown to regulatory officials from several states at the NIAA annual meetings. It was possible to demonstrate alternative control and eradication strategies for outbreaks in California. Feedback was positive. Since these meetings, the GUI has been expanded so any state in the US can be selected as the source state for the outbreak.

We are constantly examining the model to determine the need to have accurate data, which reflect the location and management of livestock in the US. Over the past year several errors and inconsistencies in coding where identified and work is either underway to make corrections or corrections are complete. These errors include; inconsistencies in how the model selects distances for disease transmission contacts due to errors in the distance function which has been re-written, no between species disease transmission at sales yards for which new code has been written, individual animals changing species while at a sales yard corrected by addition of a mass balance algorithm, direct contact transmission between feedlots yet to be corrected, animal shipment sizes fixed at 1 animal per shipment which has been changed so that the number of animals in a shipment can be varied. Other improvements to the model include a total revamping of graphical procedures, major changes in the kernel epi routines, options allowing selection between different distance distributions, triangular and Weibull with user defined parameters, number of outgoing direct contacts from infected premises are sampled from a Poisson distribution where the Poisson parameter can be specified by the user, individual animals can make the transition from clinical to immune and back to susceptible where the duration of the clinical and immune state can be specified as a temporal transition distribution, depopulation of infected premises can be disabled by the user, re-infection of already infected herds can occur through direct contact, individual animals selected for shipment are sampled from the originating herd and added to the receiving herd, the current epi state (i.e. susceptible, latent, subclinical, clinical, immune) of shipped animals and the

duration for which they remain in this state is kept track of during shipment, and a posthoc analysis function has been created that checks whether the changes in number of individuals per disease state and herd add up with the number of shipped animals and the number of animals making transitions between different disease states.

Model validation occurred early in 2007 with researchers from Quebec, USDA Fort Collins and LLNL. The following scenarios were compared; use of very restrictive contact parameters to create a "ring" of infections around the index case, as previous but runs longer so that secondary rings appear, with direct contact that eventually infects the whole population, addition of detection & movement restrictions, addition of a small amount of vaccination, addition of more vaccination, inclusion of a small amount of ring depopulation, use of larger rings. Some issues with speed of disease spread within the DADS model were identified and have subsequently been fixed. Validations also confirmed that the DADS model's ability to model individual animals within a facility (intra-herd) was superior as compared to the other comparison models which apply a disease status to a facility but not to the individuals within that facility.

Technology Transition

Contact parameters calculated from California survey responses have been shared with LLNL.

Status of Funding

We are currently on budget for year three and may finish the year slightly under budget. Funding has been secured for continuation of a limited number of areas of this projects scope; however, is it not at a high enough level to maintain the current staffing levels for another 12 month period. As of this time, FAZD will not be providing funding to continue model development, verification, validation or to permit relevant scenario analyses, such as exploring vaccination alternatives. Funding is being solicited from alternative sources and alternative partners.