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The value of animal movement tracing: A case study simulating the spread and control of foot-and-mouth disease in California

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ABSTRACT

The purpose of this study was to estimate the benefits of an electronic animal tracing system and an improved paper-based system in terms of the potential spread of foot-and-mouth disease (FMD) if introduced in California. A spatial, stochastic simulation model and data for California were used to simulate FMD outbreaks originating from a dairy herd as the index case (IC). Descriptive statistics of the simulated FMD outbreak extent and duration were examined to determine the benefit of an electronic system or paper-based tracing systems of varying efficacies. According to the simulations, an electronic tracing system would reduce the median number of infected premises (IPs) by 8–81%, depending on size of the IC herd compared with the results expected from identifying IPs based on clinical signs alone. The benefit also varied by IP herd type, e.g. ≥50% for sheep farms, goat farms and calf and heifer raising operations and ≤20% for swine and beef premises. The electronic system simulated a decrease in the median duration from at least 200 d to 42 d, if the IC were a small dairy and from 110 d to 45 d if the IC were a large dairy. The impact of an introduction of FMD in California could be reduced substantially even without an electronic system, if paper-based tracing were more efficient; however, these benefits are far less than those that could be realized from an electronic animal identification system. Results show that substantial benefits, in terms of fewer IPs and infected animals and reduced epidemic duration, may be realized as a result of an efficient electronic animal identification system, compared with a paper-based animal tracing system; however, until then, an improvement in the current system, especially regarding the ability to trace movements the day prior to a premises being diagnosed with FMD, may be highly beneficial.

1. Introduction

Experience shows that early detection and response to a disease outbreak will increase the effectiveness of the emergency response and reduce the social, economic and environmental costs associated with the outbreak (Murray and McCutcheon, 1999; Howard and Donnelly, 2000; Ferguson et al., 2001; Carpenter et al., 2011). In addition, domestic and wild animal movements are important in the spread of disease (Fevre et al., 2006). After the detection of any transboundary disease, animal health officials need to quickly identify which animals are involved, where infected animals are located, and what other animals might have been exposed to the disease. Typically, an outbreak investigation concludes when the disease is traced back to its source and forward to potential new infections (Caporale et al., 2001; Elbers et al., 2001). For

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these reasons, many countries have animal identification systems that allow a quick, efficient and effective response in the face of a disease threat. Some countries, e.g. Australia, Canada, Japan, New Zealand, Switzerland, and the UK have implemented systems, with near 100% compliance, that facilitate animal tracing by gathering information relating to livestock identification and movement (SFAO, 2004; MAF, 2006; Defra, 2007; Murphy et al., 2008; Sugiura and Onodera, 2008; NLIS, 2012). To be successful, the implementation of a national animal identification system needs to balance cost, reliability/durability, feasibility, data transfer speed, and user confidentiality (APHIS, 2007a). Prior to 2004, the US had several federally mandated program for the surveillance and control of infectious diseases. These included the Cooperative State/Federal Brucellosis Eradication Program for cattle, the Pseudorabies Eradication Program for swine, and the National Scrapie Eradication Program for sheep and goats. These disease surveillance, control and eradication program have had considerable success in reducing animal diseases in the US (APHIS, 2007a). Additionally, 15 states require documentation of movements of branded animals; however, due to producer confidentiality issues, in the US there is currently no national animal movement database. Furthermore, these separate state systems do not share compatible data entry or integrated technology, which hinders their ability to efficiently track infected animals. According to the US Department of Agriculture (USDA), it is possible with these current systems that an animal may be identified multiple times and yet still not be fully traceable (APHIS, 2007a). Additionally, their success in reducing disease has resulted in reduced participation in these programs so that the traceability infrastructure in the US is less effective than it was in the past (APHIS, 2007a). The USDA has determined that their emergency response capabilities can be improved if data within these systems were standardized and more livestock premises and animals were registered. A new goal of trace-back of data within a 48-h window has been proposed as being optimal for efficient and effective disease containment (APHIS, 2007b). Specifically, the plan states, "... within this timeframe, animal health officials must have the data required to trace a disease back to its source and limit potential harm to animal agriculture, such as loss of producer income. The sooner reliable data are available, the sooner affected animals can be located, and appropriate response measures can be established and disease spread halted..." (APHIS, 2007b). From this desire, the National Animal Identification System (NAIS) was developed as an initial pilot project by 2004; however, it was officially stopped in early 2010 (USDA, 2010). During its implementation, NAIS was comprised of three components: premises registration, animal identification and animal tracing. This voluntary program was further implemented nationally and as of July 2009, 524,962 (36.5%) of an estimated total of 1,438,280 premises were registered. There were several databases in which producers could register their animals and their movements; however, participation in these portions of NAIS was low with only just over 5 million of radio-frequency identification (RFID) tags distributed to producers. In February, 2010, the US Secretary of Agriculture announced a new framework for animal disease traceability, which means that USDA's efforts will include only interstate animal movements and be administered by States and Tribal Nations (USDA, 2010), which has a potentially negative impact on the ability to trace animal movements in a timely fashion.

Simulation models are useful tools for evaluating potential disease spread and the impact of alternative disease control and eradication strategies. Specifically, the Davis Animal Disease Simulation (DADS) model has been used previously to evaluate the application of circular vs. non-circular control strategies against foot-and-mouth disease (FMD), estimate the benefit of vaccination vs. preemptive slaughter in controlling FMD (Bates et al., 2003a,b), predict the spread of FMD virus (FMDV) from a State Fair (Carpenter et al., 2007), assess alternative movement control strategies if FMDV were transmitted from wild pigs to commercial livestock premises (Pineda-Krch et al., 2010), and estimate the economic impact to the US if there were an outbreak of FMD in California (Carpenter et al., 2011).

The objectives of this study were to simulate FMD outbreaks in a population of approximately 22,000 FMD-susceptible livestock herds in California and compare the results assuming either an electronic tracing system, a paper-based tracing system of variable efficacy, or no tracing system was used.

2. Materials and methods

2.1. Simulation modeling of FMD spread and control

For this study, the DADS model, a spatial, stochastic, individual-animal-based model, was used to simulate the spread and control of FMD in California. The model uses information collected from previous studies, including the daily probability of animal movements, indirect contacts, and local area spread, as well as actual or approximate locations of FMD-susceptible premises. The model simulates disease spread via direct contact, indirect contact, or local area spread. For the study presented here, the feature of traceability of animal movements was added to the DADS model. This involved the addition of the ability to keep track of infected animal movements from FMD-infected herds and of a new user-specified model parameter, which determines the percentage of herds that participate in electronic animal tracing. In the model, any animal shipment between two participating herds is now traced, if the shipping herd is infected, whether it results in disease transmission or not. A shipment between a pair of non-infected herds or involving at least one non-participating herd is not traced by the model. With an electronic animal tracing system, it was assumed that all IPs linked with the diagnosed herd through a network of traced shipments become diagnosed the day after the initially diagnosed herd and the number of traced herds was not limited by manpower constraints.

2.2. DADS model simulations

Two sets of simulations were run assuming either 0% or 100% of the herds participated in an electronic tracing system. With 100% participation, all herds that were infected through animal shipments from the first diagnosed herd