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# Simulation modelling of a hypothetical introduction of foot-and-mouth disease into Alberta

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ABSTRACT

This study describes the use of simulation modelling to evaluate the predicted benefits of an effective livestock traceability system in responding to a hypothetical introduction of foot-and-mouth disease (FMD) in to the province of Alberta, Canada, and whether or not the implementation of emergency ring vaccination in addition to a standard stamping-out (SO) strategy would lead to smaller and shorter epidemics. Three introduction scenarios were defined, with the primary case in either an intensive beef feedlot operation, an extensive cow–calf operation or in a swine operation. Disease spread was simulated using, three levels of tracing effectiveness, five types of vaccination zone, three different vaccination start times, three lengths of vaccination campaigns, two levels of culling resource and using FMD strains with two different virulence levels. Using standard SO procedures (without vaccination), improving traceability effectiveness from a level whereby only 65% of movements were traced within 5–7 days, to a capability whereby all movements were traced within 1 day, led to a reduction in the number of infected premises (IPs) between 18.7 and 64.5%, an average saving of CAN$29,000,000 in livestock compensation costs alone, and a reduction in the length of epidemics ranging from 1 to 22 days. The implementation of emergency vaccination also led to a reduction in the number of IPs and a shortening of epidemics. The effects were more pronounced when the higher virulence settings were used, with a predicted reduction in IPs of 16.6–68.7% (mean = 48.6%) and epidemics shortened by up to 37 days. Multi-variable analyses showed these effects were highly significant, after accounting for the incursion location, virulence of virus and time of first detection. The results clearly demonstrated the benefits of having effective traceability systems with rapid query and reporting functionality. The results also supported the value of early vaccination as an adjunct to SO in reducing the number of IPs and shortening the length of the epidemics. The most effective vaccination strategy involved a 3 km or larger suppressive vaccination zone around all IPs, begun as soon as practicable after first detection, and which continued until the last IP was detected.



## 1. Introduction

Foot-and-mouth disease (FMD) is a viral infection that primarily affects cloven-hoofed animals including wild ungulates and domestic swine, cattle, sheep, goats and

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deer (Anon, 2012a). The disease, which is caused by an Apthovirus of the genus Picornaviridae, remains endemic in parts of Africa and Asia and there are sporadic outbreaks in South America (Grubman and Baxt, 2004). Although the disease has been eradicated from North America and much of Europe, it continues to be a threat to all livestock intensive regions of the world as demonstrated in the outbreaks in Europe in 2001, Japan in 2010 and South Korea in 2010 and 2011. The last reported case of FMD in Canada was in 1952 (Daggupaty and Sellers, 1990; Sellers and Daggupaty, 1990). FMD is the most feared exotic disease in North America due to its highly contagious nature and the presence of large populations of immunologically naïve livestock.

Worldwide, FMD remains a significant economic threat for any country that relies on the export of live animals and/or animal products to support the economy (see for instance Paarlberg et al., 2002). This is largely due to the trade restrictions that are applied during and following an outbreak until proof of freedom can be re-established (Anon, 2012b). Current 'FMD-free without vaccination' countries, such as the United Kingdom, the United States of America, Australia and New Zealand, would primarily rely on stamping-out (SO) methods to control any incursion of FMD. The key components of this strategy comprise the tracing of all infected animals, containment and destruction of infected animals and animal products, and thorough cleaning and disinfection of contaminated vehicles and premises, augmented by stringent movement controls within the affected province(s) or region(s), and active surveillance to detect infected animals.

Given how quickly FMD can spread, a timely and effective response is vital in order to achieve rapid eradication. Rapid detection and a good surveillance system are essential to ensure that disease response plans are implemented in a timely manner. Delays can lead to massive outbreaks especially in regions where livestock density is high and contact pathways are numerous (Ward et al., 2009; Carpenter et al., 2011). Clearly, accurate and timely information on all livestock movements can aid in the tracing of infected and exposed animals, particularly those movements that occurred during the silent phase of the epidemic and prior to the implementation of movement restrictions. Livestock movement recording systems that operate routinely during 'peacetime' can be of benefit, but are costly to establish and operate. Alberta has implemented such a system (Lamont et al., 2010), but the Canadian Food Inspection Agency (CFIA) is interested in quantifying the potential benefits of such systems.

A number of countries are also investigating the benefits of strategic vaccination as an adjunct to SO (Kahn et al., 2002; Backer et al., 2012a,b). A significant amount of research is being conducted to address the need for alternative methods to limit disease spread, rather than rely on mass culling of apparently healthy animals, which caused significant public disquiet in the UK. Historically, there has been a reluctance to use vaccination, due to the challenges associated with proving disease freedom following the outbreak, and the delays involved (Anon, 2012b), despite the fact that vaccination can assist the control and eradication process (Park et al., 2013). The advent of vaccines that can be included in a Differentiating Infected from Vaccinated Animals (DIVA) programme shows promise (Pasick, 2004). In the event of an outbreak of FMD, Canada would launch a SO programme for infected farms to control and eradicate the disease. Emergency vaccination would be evaluated immediately, and would be used in conjunction with SO if it was deemed to be of benefit in controlling the production and spread of the virus (CFIA, 2012).

This study used a simulation modelling system, InterSpread Plus (ISP), developed in New Zealand (Dubé et al., 2007; Stevenson et al., 2013), to parameterise a model of FMD in Alberta, which was then used to explore both the merits of implementing a full traceability system and the use of emergency vaccination as an adjunct to a SO programme. The study was part of a wider comparative study using the North American Animal Disease Spread Model (NAADSM; Harvey et al., 2007).

## 2. Methods

ISP was parameterised to represent the 2012 livestock production systems in the province of Alberta, which were predominantly feedlots and extensive cow–calf beef cattle units. The livestock population was represented by spatial files representing farm and market locations. The levels of contact between farms of different types were represented by direct (animal) and indirect (non-animal) movement generators that attempted to emulate the different livestock trading patterns and other forms of contact between farms in the province. The main epidemiological components of the model comprised the disease settings; the detection settings, representing various passive and active surveillance programmes; and the standard SO control procedures employed in Canada. The potential role of cloven-hoofed wildlife in a FMD outbreak was ignored for the purposes of this study.

Three different introduction scenarios were defined, with primary infection in a cow–calf beef farm, a beef feedlot or a swine herd.

In order to investigate the impacts of different levels of traceability, three sets of traceability settings were defined and tested using simulations. The potential benefits of using emergency vaccination as an adjunct to the stamping-out strategy were also investigated through simulations.

These sections of the model are described in more detail below.

### 2.1. Farm file

A spatial file representing the point locations of all known livestock producers was prepared, based on data held in the Premises Identification Database (PID) by Alberta Agriculture and Rural Development (AARD) as at 2012. Estimates on the relative completeness of the data held for the different producer types were obtained by expert opinion from the Office of the Chief Provincial Veterinarian (B. Oliver-Lyons, pers. comm.). These estimates varied by species (85–95% completeness) and to ensure a realistic farm level density was used, the author randomly created presumed missing farm points in order to better represent the true farm density. It was assumed that