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Assessing the delay to detection and the size of the outbreak at the time of detection of incursions of foot and mouth disease in Australia

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ABSTRACT

The time delay to detection of an outbreak of an emergency animal disease directly affects the size of the outbreak at detection and the likelihood that the disease can be eradicated. This time delay is a direct function of the efficacy of the surveillance system in the country involved. Australia has recently completed a comprehensive review of its general surveillance system examining regional variation in both the behaviour of modelled outbreaks of foot and mouth disease and the likelihood that each outbreak will be detected and reported to government veterinary services. The size of the outbreak and the time delay from introduction to the point where 95% confidence of detection was reached showed significant ($p < 0.05$) regional variation with the more remote northern areas experiencing smaller outbreaks that are less likely to spread and less likely to be reported to government services than outbreaks in the more developed southern areas of Australia. Outbreaks in the more densely populated areas may take up to 43 days until a 95% confidence of detection is achieved and at that time, the outbreak may involve up to 53 farms.

1. Introduction

Australia's economy relies heavily on the export of agricultural produce. In 2012–13, the gross value of farm production was $47.9 billion with exports of livestock and livestock products worth $14.9 billion (ABARES, 2013a). In the current world trade environment, the capacity to demonstrate freedom from disease is a crucial component in maintaining an export trade in livestock products (OIE, 2014a)

Australia has a favourable animal health status, being free of many of the diseases of concern in other parts of the world (OIE, 2014b), and is recognised as having a competent surveillance capability and capacity. In recent years, this system has allowed rapid detection of outbreaks of equine influenza, highly pathogenic avian influenza and velogenic Newcastle disease that has allowed for their successful eradication (Garner et al., 2011; Turner, 2011). Globally, the threat of animal disease incursions is increasing due to increased movements of humans and increased trade in live animals and animal products. There is growing recognition by Australia's national and jurisdictional governments and agricultural industries (Langstaff, 2008) that Australia needs to strengthen its surveillance arrangements to be able to mitigate these increasing biosecurity threats whilst continuing to facilitate and enhance trade. In the face of static or declining public sector resources there is a need to understand better the current biosecurity threats to ensure that the funds are invested in quarantine and surveillance programmes that target those threats. The general surveillance system can be defined as recognition and reporting of suspect clinical signs by a producer, inspector, veterinarian or other person observing animals, and the effectiveness of this system is of particular relevance to timely detection of exotic and emerging animal diseases.

In Australia, surveillance for diseases of livestock is the responsibility of the eight states and territory governments (Australian Capital Territory; New South Wales; Northern Territory; Queensland; South Australia; Tasmania; Victoria; Western Australia). Australia's Animal Health Committee (comprised of the Australian Chief Veterinary Officer (CVO) and the eight state/territory CVOs) established the general surveillance epidemiology working group (GSEWG) to review the way in which general surveillance is conducted in Australia, to find ways of allocating limited surveillance resources on the basis of risk and make recommendations for future

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surveillance programs. The first tasks of this GSEWG were to map the risk posed by livestock diseases not present in Australia (exotic diseases) and new livestock diseases that might emerge within Australia (emerging diseases), and to investigate the distribution of general surveillance 'effort' around the country. They found a good correlation between general surveillance effort and risk of exotic and emerging diseases. This work mapped and compared relative risk and relative surveillance effort, making no attempt to quantify either the relative risk or the efficacy of the surveillance effort (East et al., 2013).

The second task of the GSEWG was to identify options to promote early detection of exotic and emerging diseases for each region of Australia, and to quantify the potential effectiveness of these options. Evaluation of different options for enhancement of disease detection by the general surveillance system required development of a tool to quantify the efficacy of the general surveillance process in different parts of Australia. The General Surveillance Assessment Tool (GSAT) previously described by Martin et al. (2015) provided region-specific estimates for the probability that an instance of an exotic or emerging disease on a single farm will result in notification of the CVO and the expected time delay until that report occurs, should it occur. The time elapsed until the report of infection was received (should that farm choose to report) showed little variation except that the northern regions of Australia, characterised by larger and remote farms where cattle are inspected infrequently, recorded longer time periods until notification (Martin et al., 2015). The GSAT however cannot, in isolation, predict the time delay until the point that the CVO can be 95% confident of receiving a report of a disease outbreak or the size of the outbreak at that time because the GSAT calculates the probability of reporting and the time delay to reporting for a single farm and it does not know the rate at which the disease spreads and therefore the rate at which additional farms become infected. In this current paper, we combine the use of the GSAT with disease simulation modelling to estimate both the time delay to 95% confidence of reporting of an outbreak of foot and mouth disease (FMD) and the size of the outbreak at the time of notification. FMD was selected as the case study because it represents the most serious threat to Australia's livestock industries (Matthews, 2011) with a recent report estimating the cost of a multi-state outbreak over a 10 year time frame at around AUD$52 billion (Buetre et al., 2013).

2. Materials and methods

2.1. General surveillance assessment tool

The general surveillance assessment tool (GSAT) is a stochastic spreadsheet model that calculates the cumulative probability of detection, diagnosis and reporting of disease on a single infected farm. Briefly, the GSAT combines probabilities for each of ten identified steps in the process of general surveillance from the occurrence of clinical signs in the infected animals, through to the notification of the CVO to estimate the probability that FMD on the farm would be detected (single farm sensitivity). The GSAT calculates the probability of detection for each of 14 different farm types to account for differences in the expression of clinical signs by different species of animals and the impact of differences in management practices on steps such as the owner's opportunity to inspect their animals e.g. dairy inspected twice daily compared to sheep inspected weekly. It utilises the output of an intra-herd disease spread model to determine the duration and prevalence of infection on the different types of farm. The 14 different probabilities are combined to give a weighted average that accounts for the proportion of each farm type within the livestock production area being assessed. The GSAT also combines the probability of on-farm reporting with reporting at saleyards, abattoirs and export depots to account for the potential reporting of disease by different observers at different stages of the production chain.

The outputs of the GSAT are:

1. The probability that disease on a single farm will be reported to the CVO.
2. the average time elapsed from incursion of the disease up to notification of the CVO (time to detection) should that single farm result in a report to the CVO.
3. the average number of farms that would need to be infected before the CVO could be 95% confident of detecting at least one infected farm.

The GSAT was applied separately to each of twelve regions of Australia, demarcated by dominant livestock production practices. A different panel of experts familiar with a particular livestock production region was assembled for each region to provide estimates of probabilities relevant to the detection of FMD, for each of the fourteen farm types and all species susceptible to the disease. The development, parameterisation and application of the GSAT have been described previously (Martin et al., 2015). The probability that a single infected farm would result in a report to the CVO, the time delay to that report occurring (should that farm choose to report) and the number of farms that need to be infected to be 95% confident of a report to the CVO occurring are reproduced from Martin et al. (2015) in Table 1 for convenience of the reader.

2.2. Model for disease spread

Disease modelling was used to quantify the relationship between the number of infected farms and time from initial incursion for different parts of Australia. Used in conjunction with the results from the GSAT this enabled us to determine the likely size of an outbreak at the time it is reported to the authorities under the current surveillance system. These findings would provide benchmarks against which any proposed changes to the general surveillance system could be assessed.

The Australian Department of Agriculture's regional FMD model *AusSpread* was used for these studies. This model is a stochastic spatial simulation model designed to study spread and control of FMD in livestock populations. The development and structure of this model has been described previously (Garner and Beckett, 2005; Beckett and Garner, 2007). In brief, disease spread between farms is simulated in daily time steps. Interactions between farms, including those with different animal species or production types, are incorporated into the model, capturing the role that such interactions might play in the epidemiology of an outbreak of FMD. The attributes and spatial locations of individual farms, saleyards, weather stations, local government areas and various other features of the regional environment, are incorporated into the model. The number and type of animals (species) present on a farm will influence the risk of infection occurring and for infected farms the infectious pressure that they exert. Seasonal conditions will affect probability of FMD transmission through effects on virus survival outside the host and on movement and marketing behaviours. Seven different farm types are identified—specialist beef, dairy, sheep, pig, mixed beef-sheep, smallholders and feedlots.

The model allows for the spread of disease through a number of 'pathways':

1. Direct contact: spread between farms by movement of animals.
2. Local spread: spread to farms in close proximity to an infected farm (<3 km) when the actual means of spread is not known (Gibbens et al., 2001). It may be associated with local aerosol spread across fences, movement of stock, vehicles or people,