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Assessing the efficacy of general surveillance for detection of incursions of livestock diseases in Australia

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A B S T R A C T

Australia, as a relatively isolated country with a high level of agricultural production, depends on, and has the opportunity to maintain, freedom from a range of important diseases of livestock. Occasional incursions of such diseases are generally detected by 'passive', general surveillance (GS). In current surveillance planning, a risk-based approach has been taken to optimising allocation of resources to surveillance needs, and having mapped the relative risk of introduction and establishment of diseases of concern, a means of mapping the efficacy of GS for their detection was required, as was a means of assessing the likely efficacy of options for improving GS efficacy if needed. This paper presents the structure and application of a tool for estimating the efficacy of Australia's GS, using the example of foot and mouth disease (FMD). The GS assessment tool (GSAT) is a stochastic spreadsheet model of the detection, diagnosis and reporting of disease on a single infected farm. It utilises the output of an intraherd disease spread model to determine the duration and prevalence of infection on different types of farm. It was applied separately to each of twelve regions of Australia, demarcated by dominant livestock production practices. Each region supplied estimates of probabilities relevant to the detection of FMD, for each of fourteen farm types and all species susceptible to the disease. Outputs of the GSAT were the average probability that FMD on the farm would be detected (single farm sensitivity), the average time elapsed from incursion of the disease to the chief veterinary officer (CVO) being notified (time to detection), and the number of average properties that would need to be infected before the CVO could be 95% confident of detecting at least one. The median single farm sensitivity for FMD varied among regions from 0.23 to 0.52, the median time to detection from 20 to 33 days, and the number of properties infected for 95% confidence of detecting at least one from 4 to 12. The GSAT has proved a valuable tool in planning surveillance for detection of exotic livestock disease in Australia, and it provides a practical example of the use of probabilistic modelling to answer important questions in the face of imperfect information.

1. Introduction

Australia's economy relies heavily on the export of agricultural produce (ABARES, 2013). 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 capacity. In recent years, outbreaks of equine influenza and highly pathogenic avian influenza have been detected and successfully eradicated (Garner et al., 2011; Turner, 2011) and emerging infections such as Hendra virus, Australian bat lyssavirus, and Bungowannah virus have been detected and subsequently described (Black et al., 2008). In Australia there is growing recognition by governments and livestock industries (Langstaff, 2008) of the need to strengthen surveillance arrangements to be able to mitigate disease risks whilst continuing to facilitate and enhance trade. In the face of static or declining public sector resources we need to ensure that

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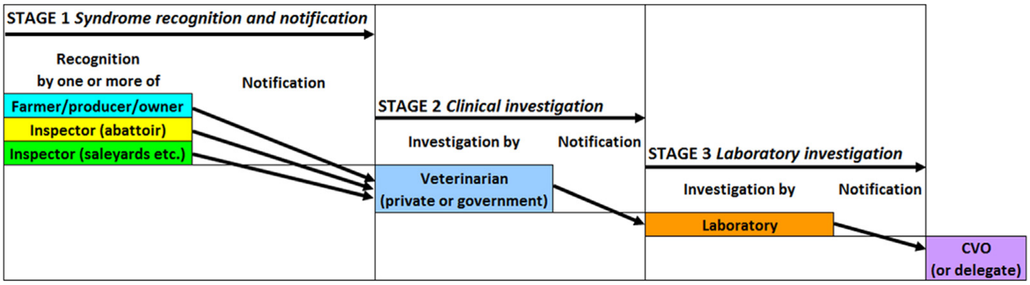

Fig. 1. Diagram representing final model implemented in the general surveillance assessment tool, showing players and their possible roles.

quarantine and surveillance programmes are both effective and efficient. The effectiveness of the general surveillance (GS) 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 governments of its eight constituent states and territories (hereinafter referred to as jurisdictions). One response to the increasing demands and diminishing resources has been the development of risk-based surveillance programs (Stärk et al., 2006; Alban et al., 2008), and in line with this approach Australia's Animal Health Committee established the GS 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 surveillance programs. East et al. (2013) reported on the first tasks of this GSEWG; namely 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 GS 'effort' around the country. They found a good correlation between GS 'effort' and risk of exotic and emerging diseases. This work mapped and compared relative risk and relative GS effort, making no attempt to quantify either the risk or the efficacy of GS. In Australia, GS is relied upon for detection of most outbreaks of livestock disease. In order 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, we developed a means of quantifying the efficacy of the GS process, with and without proposed enhancements – the GS assessment tool, or GSAT. This paper describes the GSAT and its application to foot and mouth disease (FMD).

2. Methods

2.1. General surveillance definitions and assumptions

General surveillance is the process whereby disease in livestock is noticed by someone who, directly or indirectly, then informs, or seeks assistance from, a veterinarian or other person with animal health knowledge, who in turn investigates the problem and instigates a laboratory investigation, the outcome of which is a diagnosis. In the case of a notifiable exotic disease, the jurisdictional CVO and the Australian CVO will then be notified. Clearly this process is not perfectly sensitive, so not all disease occurrences are identified in this way. The efficacy of general surveillance is most directly measured as its sensitivity – the probability that an outbreak of an exotic or emerging disease will come to the attention of the CVO, given that it has occurred. In the absence of such diseases from the population, GS sensitivity cannot be measured directly, so a modelling approach must be used. The development of such a model requires breaking down the process of disease detection by GS into its constituent steps, estimating the probability of each of these steps taking place, then appropriate combination of the step probabilities to give the overall probability of detection of the disease event (Martin et al., 2007; Martin, 2008; Hadorn and Stärk, 2008; Hadorn et al., 2008; Frössling et al., 2009; Knight-Jones et al., 2010).

The purpose of the GSAT is to estimate the sensitivity of the GS process, and thence the likely extent and duration of an outbreak of disease when the CVO learns of it. The GS system is, by definition, not focussed on any specific disease (Hoinville, 2013), and its sensitivity will vary with the disease, since clinical signs (CS) vary enormously, affecting their impact on farmers and others who are in a position to notice them.

2.2. Names of variables

In the variable names used in this paper, P in the name refers to the producer (farmer); IA to an inspector at an abattoir; IS to an inspector at a saleyard or export depot; CS to clinical signs; Ave to an average; V to a veterinarian (private or government). Variable names are shown in italics.

2.3. Model structure

Our model represents the GS process for a single infected farm. Its output is the average single-farm sensitivity (*SFSe*) of the GS process. *SFSe* may vary with the type of farm, the species of animal(s), the disease under consideration, and the area in which the farm is located. We developed lists of farm types, host species, diseases, and regions of Australia, and then developed a model which could estimate *SFSe* for each combination of these sources of variation. The model then requires inputs from the user which cover numerous other potential sources of variation in *SFSe*. In addition to estimating *SFSe*, the GSAT also estimates the time elapsed (in days) between the initial introduction of disease onto the farm and the CVO learning of its presence (time to detection; *TtD*). The GSAT incorporates uncertainty associated with estimates of model parameters by specifying them as random variables (with Pert distributions except where stated otherwise) and using Monte Carlo simulation to generate uncertainty distributions for model outputs.

2.3.1. Stages, steps and players

In identifying the steps contributing to the disease detection process in the GSAT we developed a reasonably comprehensive conceptual model involving interactions among twelve 'players' (categories of people participating in the process; e.g. farmer; government veterinarian; laboratory veterinarian). At each of four stages in the GS process, each of these 12 players could potentially interact with each of the other 11 players, as specified by a 12 × 12 matrix of probabilities. While this provided a computationally straightforward model, the task of estimating values for each cell of each probability matrix was daunting, and certainly not consistent with the user-friendly tool we required. We therefore simplified the model by removing pathways with very low