Preventive Veterinary Medicine 131 (2016) 20–30

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Use of Bayesian Belief Network techniques to explore the interaction of biosecurity practices on the probability of porcine disease occurrence in Canada

Ruth Cox*, Crawford W. Revie, Daniel Hurnik, Javier Sanchez

Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada

ARTICLE INFO

Article history:
Received 2 October 2015
Received in revised form 14 March 2016
Accepted 28 June 2016

Keywords:
Bayesian Belief Network
Disease probability
Swine farm
Biosecurity

ABSTRACT

Identification and quantification of pathogen threats need to be a priority for the Canadian swine industry so that resources can be focused where they will be most effective. Here we create a tool based on a Bayesian Belief Network (BBN) to model the interaction between biosecurity practices and the probability of occurrence of four different diseases on Canadian swine farms. The benefits of using this novel approach, in comparison to other methods, is that it enables us to explore both the complex interaction and the relative importance of biosecurity practices on the probability of disease occurrence.

In order to build the BBN we used two datasets. The first dataset detailed biosecurity practices employed on 218 commercial swine farms across Canada in 2010. The second dataset detailed animal health status and disease occurrence on 90 of those farms between 2010 and 2012. We used expert judgement to identify 15 biosecurity practices that were considered the most important in mitigating disease occurrence on farms. These included: proximity to other livestock holdings, the health status of purchased stock, manure disposal methods, as well as the procedures for admitting vehicles and staff. Four diseases were included in the BBN: Porcine reproductive and respiratory syndrome (PRRS), (a prevalent endemic aerosol pathogen), Swine influenza (SI) (a viral respiratory aerosol pathogen), Mycoplasma pneumonia (MP) (an endemic respiratory disease spread by close contact and aerosol) and Swine dysentery (SD) (an enteric disease which is re-emerging in North America).

This model indicated that the probability of disease occurrence was influenced by a number of manageable biosecurity practices. Increased probability of PRRS and of MP were associated with spilt feed (feed that did not fall directly in a feeding trough), not being disposed of immediately and with manure being brought onto the farm premises and spread on land adjacent to the pigs. Increased probabilities of SI and SD were associated with the farm allowing access to visiting vehicles without cleaning or disinfection. SD was also more likely to occur when the health status of purchased stock was not known. Finally, we discuss how such a model can be used by the Canadian swine industry to quantify disease risks and to determine practices that may reduce the probability of disease occurrence.

1. Introduction

Effective biosecurity strategies need to determine the means by which a pathogen can be introduced and transmitted in order to identify major or minor pathogen threats, so that prevention measures can be placed where they will be most effective. In Canada, not enough money, time, and effort have been invested in identifying and quantifying transmission risks for important swine pathogens (Desrosiers, 2011). Lack of understanding of potential threats has resulted in unsuccessful control efforts and in losses that can jeopardize both individual businesses and the swine industry. Outbreaks of Swine influenza virus and Porcine Circovirus, for example, have contributed to the considerable reduction in the number of swine farms in Canada (Brisson, 2014), while more recently, the emergence of Porcine Epidemic Diarrhea (PED) has had considerable economic impact (Paarlberg, 2014) In the past, Porcine reproductive and respiratory syndrome (PRRS), was the most costly pig disease for more than two decades, (costing the US swine industry $560 million per year) (Neumann et al., 2005), yet it took 20 years to identify that airborne transmission was an important means of spread (Desrosiers, 2011).

* Corresponding author.
E-mail address: rucox@upei.ca (R. Cox).

http://dx.doi.org/10.1016/j.prevetmed.2016.06.015

Here we create a tool, known as a Bayesian Belief Network (BBN), which can be used to identify and quantify the probability of disease occurrence in Canadian swine farms. A BBN is a probabilistic graphical model which represents a network of nodes connected by directed links that represent a probability function (Jensen, 2001). BBN models allow users to make informed decisions about a range of possible outcomes using information based on prior evidence (Fenton and Neil, 2013). BBNs have previously been used in the veterinary domain, for example, to aid disease diagnosis (McKendrick et al., 2000; Seidel et al., 2003; Otto and Kristensen, 2004) and to assess associations between biosecurity practices and disease outbreak (Firestone et al., 2014). These studies focused on one specific disease, and BBNs have not, to our knowledge, been used to assess the relative impact of biosecurity practices simultaneously on a group of diseases.

BBNs are ideally suited to the statistical analyses of data from complex epidemiological systems (McCormick et al., 2013). We chose to design a BBN in this context for two reasons. First BBNs provide a method of consolidating evidence in a consistent and mathematically robust manner. Unlike more traditional methods of data analysis, they can incorporate a large number of predictors and a number of interactions (Fenton and Neil, 2013). They can therefore be used to investigate causal relations between events, weigh the consequences of actions and identify unintended side effects. Here we highlight the utility of a BBN, in particular how one might be used to assess on-farm scenarios and to determine the trade-offs that must be made during decision making on any farm operation. Second, an innovative feature of BBNs is that they do not require precise probabilities to calculate the outcome and can provide good results even when only approximate probabilities are available (Ben-Gal, 2007). This is an advantage to the swine industry where precise prior information about emerging disease events is often not available and because stakeholder opinions (e.g. producers, veterinarians and allied industry personnel) can vary widely (Marvin et al., 2010).

Our objectives are to demonstrate the utility of the BBN for evaluating the effectiveness of biosecurity practices on disease occurrence, and for evaluating how biosecurity scenarios could reduce probability of disease. We discuss the limitations of the approach, based on the amount of data available, and we comment on how future data collection could be focused to allow more complete analysis and model development.

2. Method

In order to build a BBN we used data that detailed (1) the biosecurity practices used on farms across Canada and (2) the occurrence of disease on these farms. These data were collected in two different ways as described below.

2.1. Farm features and biosecurity data

In spring 2010 a detailed biosecurity survey was conducted by the Canadian Swine Health Board (CSHB) to acquire knowledge about the management and biosecurity practices in the Canadian swine industry. The survey was conducted at 218 commercial farms that were situated in 5 regions of Canada – British Columbia (BC), the Prairies, Ontario, Quebec and the Maritimes (Table 1). Similar surveys were also conducted at approximately 100 breeder farms and approximately 40 boar stud farms. The surveys were completed by trained assessors who were Canadian Quality Assurance (CQA™) validators, the majority of whom are practicing veterinarians. All assessors attended one of two training session to ensure that all questions were asked and recorded in a consistent manner.

The assessor collected the information using a questionnaire containing 145 questions, each with approximately five or six categories. Full results of the survey were reported internally to the Canadian Swine industry (Canadian Swine Health Board, 2010). Specific findings of the survey will not be reported here; rather we will describe how we used the data for BBN construction.

Each survey question was weighted by ten swine industry experts who were members of the Canadian Association of Swine Veterinarians (CASV). The criteria were weighted according to how important the farm feature or biosecurity practice is for the prevention of any and all disease. Each question was given a weight of between 1 and 10 (10 = most important) by each expert. The mean weight was calculated and agreed upon by the experts. Thus the expert elicitation followed a Delphi style approach, where weights were assigned and later agreed upon as a group (O'Hagan et al., 2006). This process occurred at the time of the biosecurity survey (before our work began) and we therefore had no input about the method of expert elicitation. Any question that scored a mean weight of more than 6 was included in our analysis. This gave a total of 14 questions (Table S1), which represent 14 biosecurity practices that were incorporated into the BBN.

2.2. Disease data

2.2.1. Selection of diseases

Following discussion with experts at UPEI and CSHB, six diseases were selected as 'test' diseases for the BBN. They were selected because they were of particular concern to the Canadian swine industry.

Porcine Reproductive and Respiratory Syndrome (*PRRS virus*) (PRRS) – a prevalent endemic disease transmitted via aerosol.

Swine Influenza (*Swine influenza virus*) (SI) – a viral respiratory aerosol pathogen.

Mycoplasma pneumonia (*Mycoplasma hyopneumoniae*) (MP) – an endemic respiratory disease transmitted by close contact and aerosol.

Swine dysentery (*Brachyspira hyodysenteriae* or novel strains) (SD) – an enteric disease which is re-emerging in Canada.

Transmissible Gastro-Entiritis (*Transmissible Gastro-Entiritis Virus*) (TGE) – a highly infectious coronavirus.

Pleuropneumonia (*Actinobacillus Pleuropneumonia*) (APP) – a respiratory bacterial disease that is spread by aerosol or direct contact.

2.3. Collection of disease data

A questionnaire was designed to collect information about the occurrence of the six diseases on the farms that had taken part in the biosecurity survey in 2010 (Fig. S1). The questionnaire was administered via email as a Microsoft Word 2007 document and online via the Fluidsurveys website in 2013 (Fluidsurveys, 2013). The questionnaire presented the list of six diseases and asked three questions: (1) what is the identification number of the farm? (2) what was the health status of the farm in 2010 at the time when the biosecurity survey was conducted? (3) were there any disease outbreaks on the farm between January 2010 and December 2011? The questionnaire was emailed by CSHB researchers to all veterinarians (n = 40) who completed the biosecurity survey for the 218 farms. The veterinarians were invited to complete the survey for each farm within 2 weeks. One reminder email was sent to non-responders after 2–3 weeks. Vets were instructed that they would receive a payment of $100 for participation. Farm identification and precise location of the farm was only known by the veteri-